海纳百川，有容乃大

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通信电子线路

——习题答案

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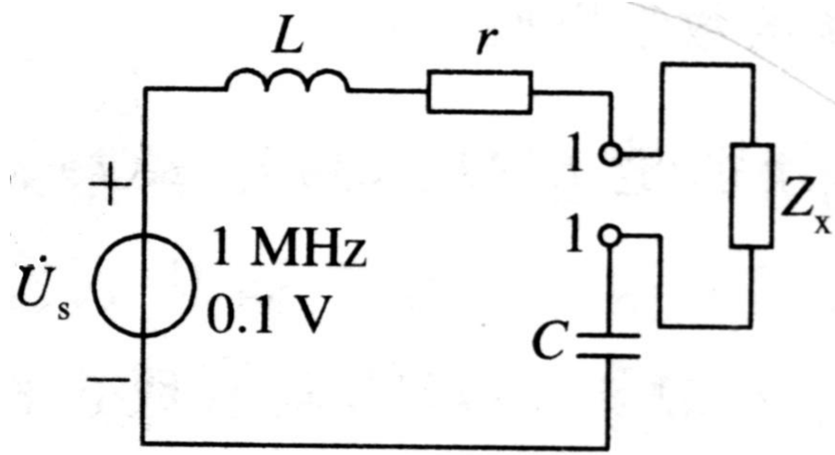
第 1 章

1.1 解：



（1）1—1端短接时，谐振，电感

$$L=\frac{1}{\omega_0^2 C}=\frac{1}{(2\pi\times10^6)^2\times100\times10^{-12}}=253\mu\mathrm{H}$$

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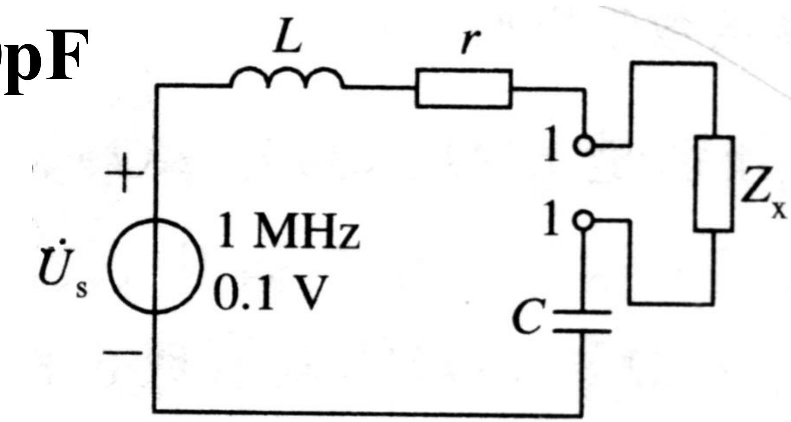
（2）1—1端开路时，因为

$$\frac{1}{\omega_0 \dfrac{C_x C}{C_x + C}} = \omega_0 L \Rightarrow C_X = 200\mathrm{pF}$$

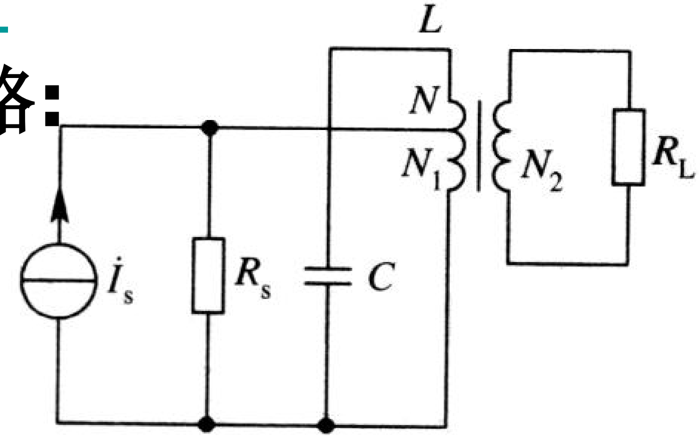


因为

$$Q_0 = \frac{1}{\omega_0 C r} \Rightarrow r = \frac{1}{\omega_0 C Q_0} = 15.9\Omega$$

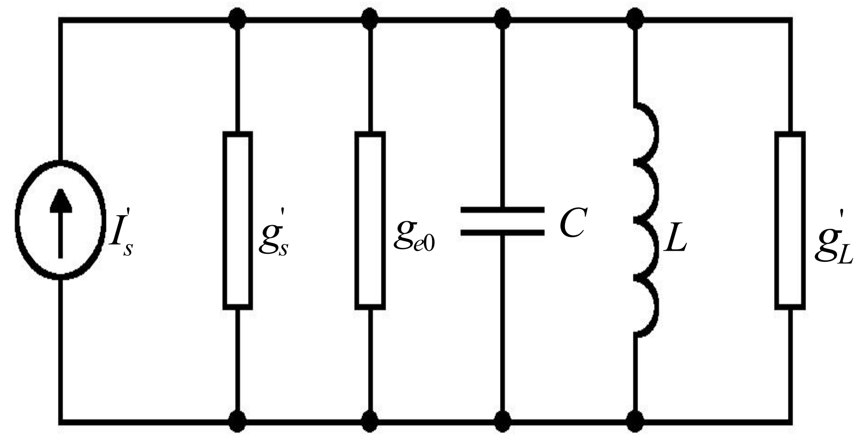
$$Q_e = \frac{1}{\omega_0 (r + r_x) \dfrac{C_x C}{C_x + C}} \Rightarrow r_x = r = 15.9\Omega$$

1.2 解：原电路如图示等效电路：



$$\because L=\frac{1}{\omega_0^2 C}=586\mu\text{H},$$

$$n_1=\frac{N_1}{N}=\frac{1}{4} \qquad n_2=\frac{N_2}{N}=\frac{1}{16}$$



$$g_{e0}=\frac{1}{\omega_0 L Q_0}$$

$$g_\Sigma=g_s'+g_{e0}+g_L'$$

$$=n_1^2 g_s+g_{e0}+n_2^2 g_L \qquad \therefore g_\Sigma=13.65\mu$$

$$Q_e=\frac{1}{g_\Sigma\omega_0 L}=43 \qquad BW_{0.7}=\frac{f_0}{Q_e}=10.8$$

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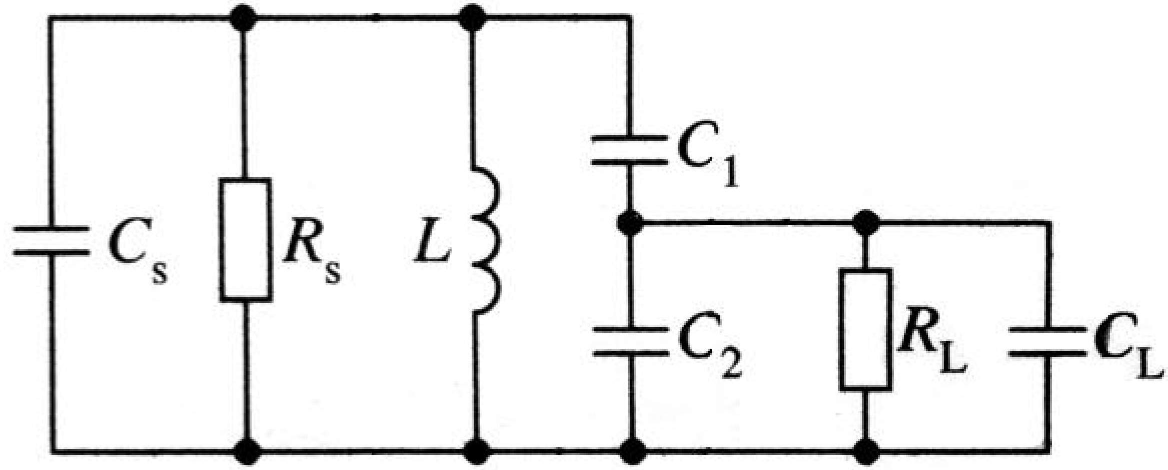
1.3 解：

$$C_2' = C_2 + C_L = 40\text{pF}$$



$$\therefore C_\Sigma = C_s + \frac{C_1 C_2'}{C_1 + C_2'} = 18.3\text{pF}$$

$$\because n = \frac{C_1}{C_1 + C_2'} = \frac{1}{3}$$

$$\therefore 谐振频率 f_0 = \frac{1}{2\pi\sqrt{LC_\Sigma}} = 41.6\text{MHz}$$

$$\therefore g_\Sigma = n^2 g_L + g_{e0} + g_s = 170.1\mu\text{S} \Rightarrow R_\Sigma = \frac{1}{g_\Sigma} = 5.88\text{k}\Omega$$

$$Q_e = \frac{1}{g_\Sigma \omega_0 \text{L}} = 28.1 \qquad BW_{0.7} = \frac{f_0}{Q_e} = 1.48\text{MHz}$$

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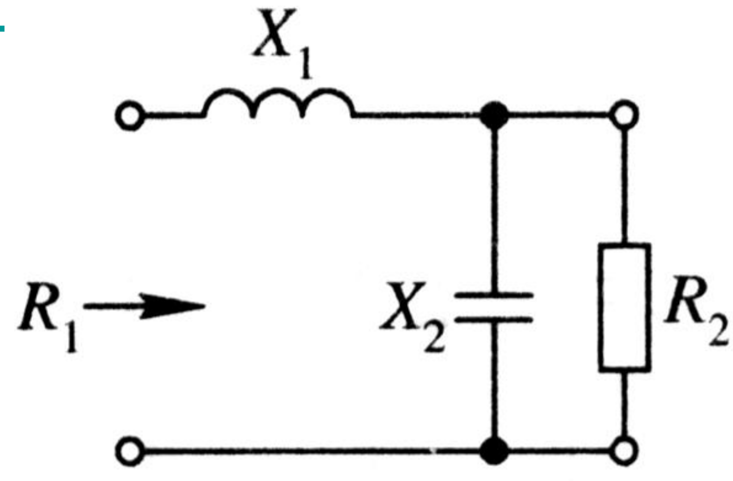
1.4 解:



$$\because |X_2| = R_2\sqrt{\frac{R_1}{R_2 - R_1}} = \frac{100}{\sqrt{6}}$$

$$|X_1| = |X_s| = \sqrt{R_1(R_2 - R_1)} = 10\sqrt{6}$$

$$\therefore L = \frac{|X_1|}{\omega_0} = 0.195\mu\text{H},$$

$$C = \frac{1}{\omega_0 |X_2|} = 195\text{pF}$$

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1.5 解:设计π型匹配网络如题1.5图所示,其中 L_1C_1是增大网络,L_2C_2是减小网络.

$$Q_2 = \sqrt{\frac{R_L - R_e}{R_e}},$$

$$R_e = \frac{1}{1 + Q_2{}^2} R_L$$

$$\therefore \frac{1}{\omega_0 C_2} = \frac{R_L}{Q_2} = R_L \sqrt{\frac{R_e}{R_L - R_e}},$$

$$\omega_0 L_2 = Q_2 R_e = \sqrt{R_e(R_L - R_e)}$$

$$\therefore C_2 = \frac{Q_2}{\omega_0 R_L}, L_2 = \frac{Q_2 R_e}{\omega_0}$$

令 $Q_1 = \sqrt{\dfrac{R_1 - R_e}{R_e}}$

则有 $\omega_0 L_1 = Q_1 R_e = \sqrt{R_e(R_1 - R_e)}$,

$$\frac{1}{\omega_0 C_1} = \frac{R_1}{Q_1} = R_1 \sqrt{\frac{R_e}{R_1 - R_e}}$$

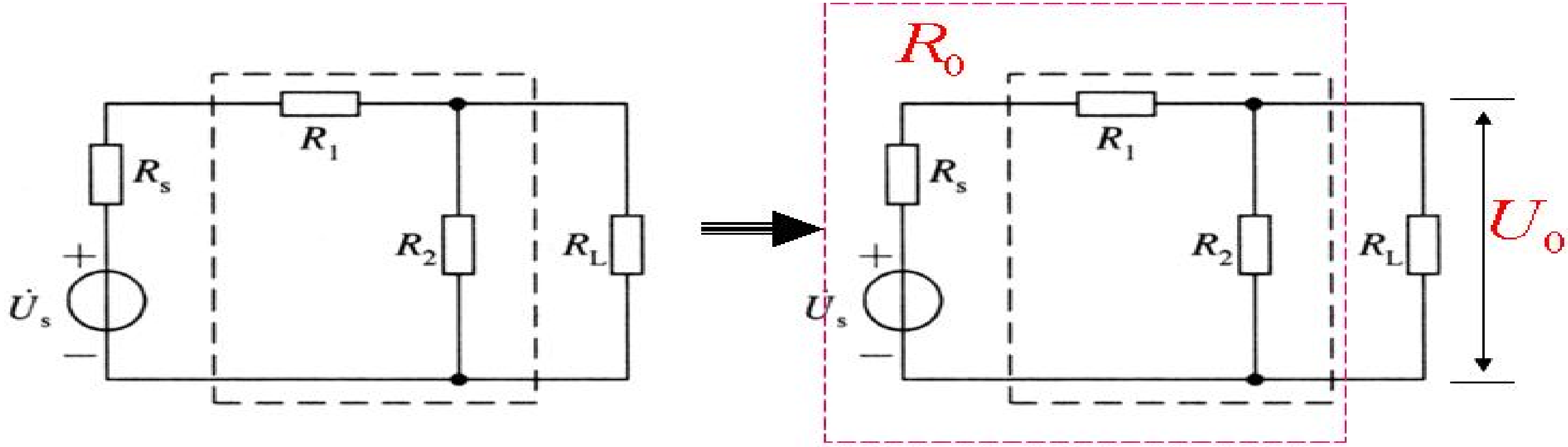
$$\therefore L_1 = \frac{Q_1 R_e}{\omega_0}, C_1 = \frac{Q_1}{\omega_0 R_1}, L = L_1 + L_2,$$

$$\because Q_2^2 = \frac{(1+Q_1^2)R_L}{R_1} - 1 > 0,$$

$$\therefore Q_1^2 > \frac{R_1}{R_L} - 1$$

上式就是此π型网络必须满足的条件, $\boldsymbol{R_1}$可以大于$\boldsymbol{R_L}$,也可以小于$\boldsymbol{R_L}$。

1.6 解: 先求额定功率增益



$$\because G_{PA}=\frac{P_{AO}}{P_{Ai}}=\frac{R_2R_S}{(R_1+R_S)(R_1+R_2+R_S)}$$

$$\therefore \text{可求得噪声系数}\quad NF=\frac{1}{\mathrm{G}_{\mathrm{PA}}}=1+\frac{R_1}{R_S}+\frac{(R_1+R_S)^2}{R_2R_S}$$

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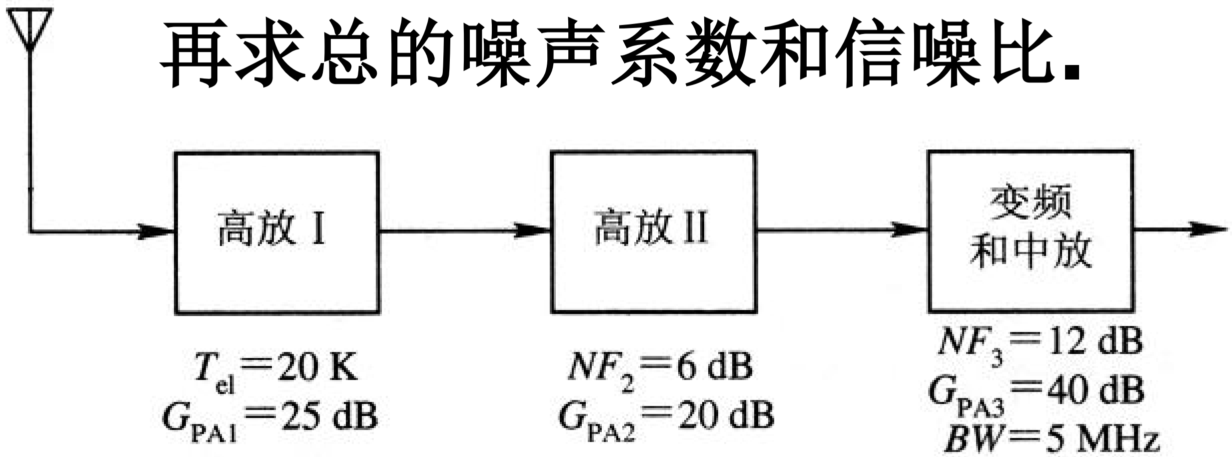
1.7 解:由各部分的关系我们可以知道, 总的噪声系数

$$NF = NF_1 + \frac{NF_2 - 1}{G_{PA1}} + \frac{NF_3 - 1}{G_{PA1} \cdot G_{PA2}},$$

而且因为 $NF_1 = \dfrac{1}{G_{PA1}}$

从而可求得$NF = 20$

1.8 解：我们可以分别求得各部分参数，再求总的噪声系数和信噪比.



$$NF_1 = 1 + \frac{T_{e1}}{T_0} = 1.07, G_{PA1} = 25\text{dB} = 316.2$$

$$NF_2 = 6\text{dB} = 3.98, G_{PA2} = 20\text{dB} = 100;$$

$$NF_3 = 12\text{dB} = 15.85, G_{PA3} = 40\text{dB} = 10000$$

$$\therefore NF = NF_1 + \frac{NF_2 - 1}{G_{PA1}} + \frac{NF_3 - 1}{G_{PA1} \cdot G_{PA2}} = 1.08$$

$$\therefore SNR_{in} = NF \cdot SNR_{out} = 108$$

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1.9 解: 按照题意,我们直接可以得到

$$E_A = \sqrt{4k \cdot T_0 \cdot R_A \cdot BW \cdot D \cdot NF} = 0.436\mu\text{V}$$

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第2章

2.1 解：根据公式:

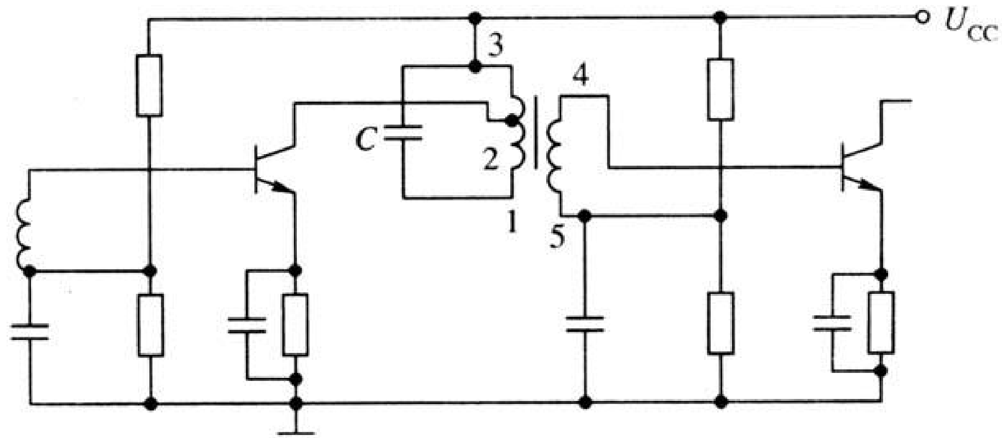
$$g_{ie}=2.8\text{mS},\quad C_{ie}=\frac{3.5}{2\pi f_0}\times10^{-3}=18.6\text{pF},$$

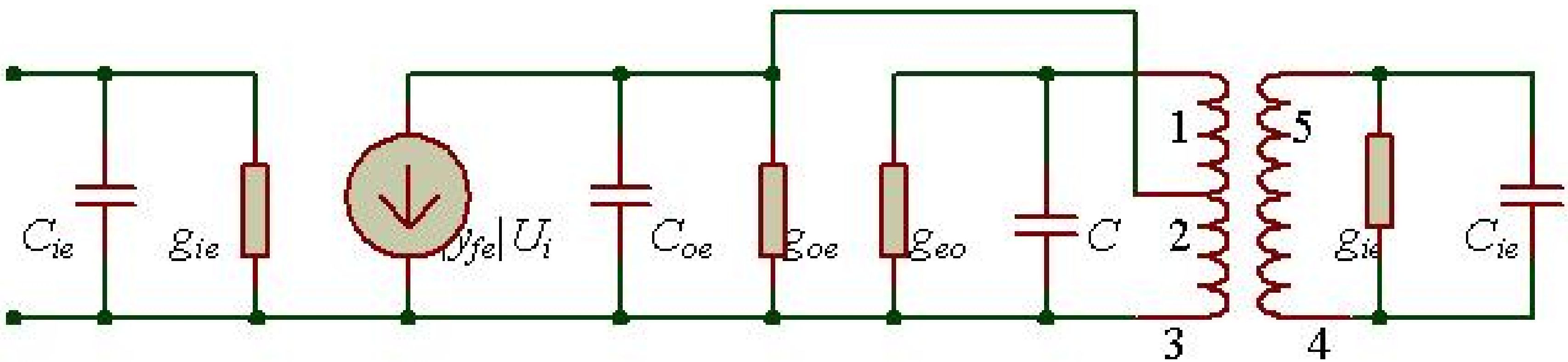
$$C_{oe}=\frac{2\times10^{-3}}{2\pi\times30\times10^{6}}=10.6\text{pF}$$

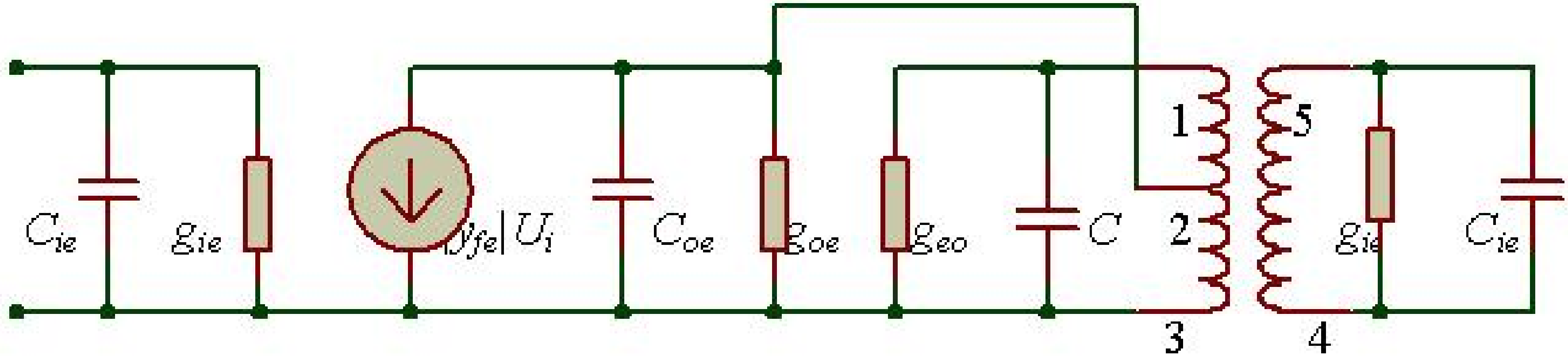
$$g_{\text{oe}}=0.2\text{mS},\quad |y_{\text{fe}}|=45\text{mS},\quad \varphi_{\text{fe}}=-36.9^{\circ},$$

$$|y_{\text{re}}|=0.31\text{mS},\quad \varphi_{re}=-104.9^{\circ}$$

2.2 解：要正确理解各参数之间的关系。







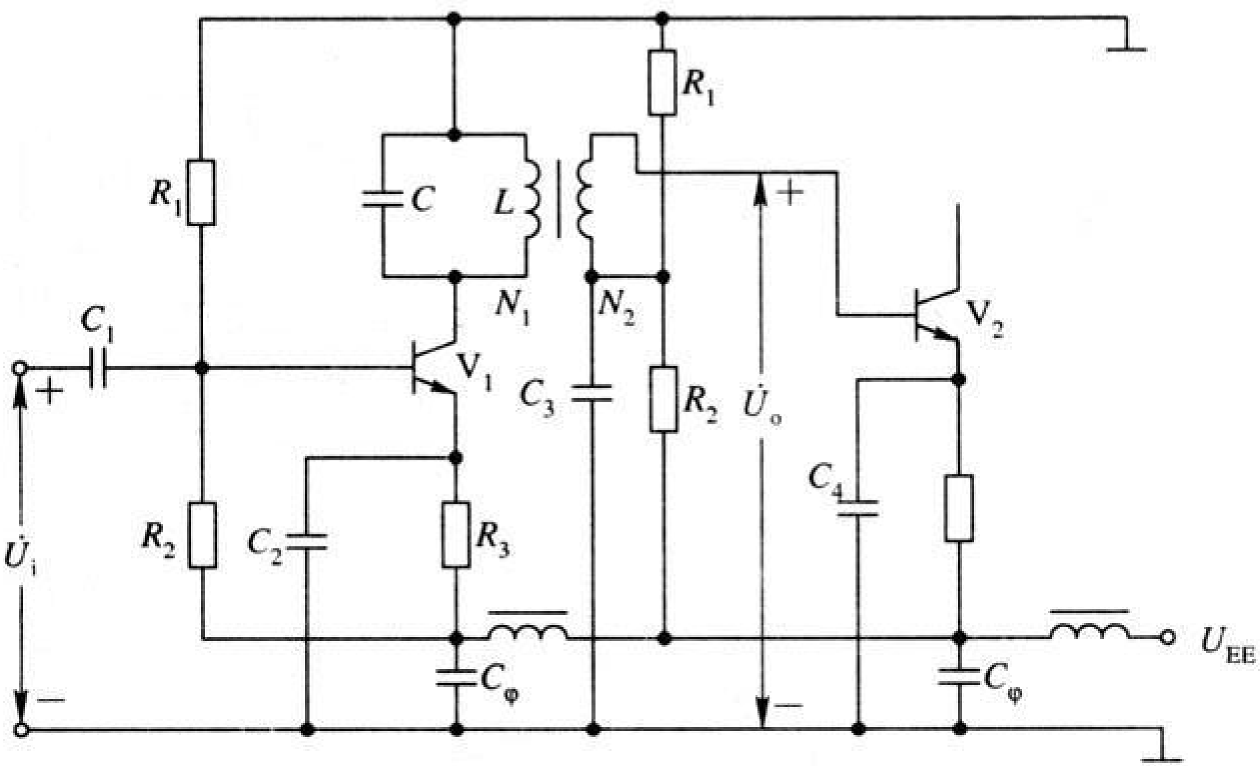
$$\because n_1 = \frac{N_{2\sim3}}{N_{1\sim3}} = 0.25,\quad n_2 = \frac{N_{4\sim5}}{N_{1\sim3}} = 0.25 \qquad \therefore g_{e0} = \frac{1}{Q_0\omega_0 L_{1\sim3}} = 37\mu\mathrm{S}$$

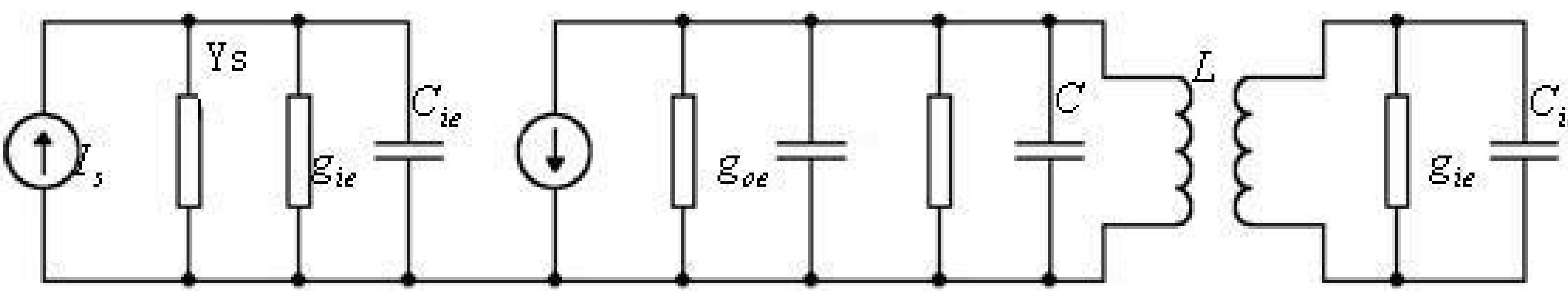
$$\therefore\ g_\Sigma = n_1^2 g_{oe} + n_2^2 g_{ie} + g_{e0} = 228.5\mu\mathrm{S}$$

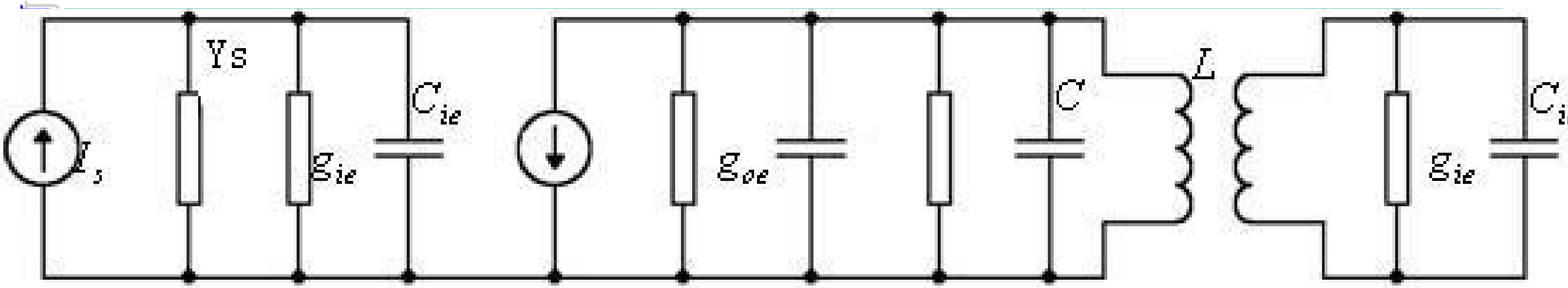
$$\therefore Q_e = \frac{1}{\omega_0 L g_\Sigma} = 16.3,\quad BW_{0.7} = \frac{f_0}{Q_e} = 0.66\mathrm{MHz}$$

$$A_{u0} = \frac{n_1 n_2 \left|y_{fe}\right|}{g_\Sigma} = 12.3$$

2.3 解（1）高频等效电路图如下:





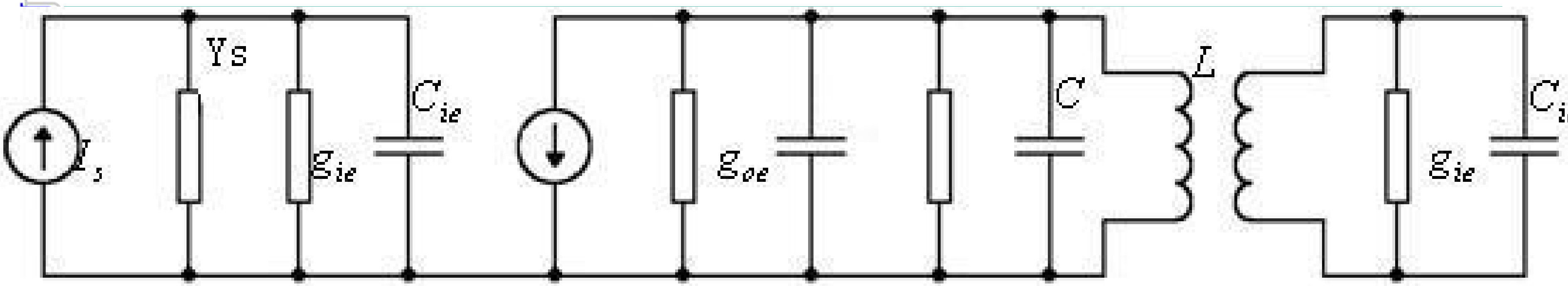


$$(2)\ \because g_{e0}=\frac{1}{Q_0\omega_0 L}=35\mu\mathrm{S}$$

$$\therefore g_{\Sigma}=g_{e0}+g_{oe}+n_2^2 g_{ie}=410\mu\mathrm{S}$$

$$(3)\quad C_{\Sigma}=C+C_{oe}+n_2^2 C_{ie} \qquad \boldsymbol{n}_2=\frac{\boldsymbol{N}_2}{\boldsymbol{N}_1}=\frac{1}{4}$$

$$(\mathbf{4})\ A_{u0}=\frac{\boldsymbol{n}_1\boldsymbol{n}_2\left|\boldsymbol{y}_{fe}\right|}{\boldsymbol{g}_{\Sigma}}=27.4 \qquad \boldsymbol{n}_1=1$$



$$(5)\quad Q_e' = \frac{f_0}{BW_{0.7}'} = \frac{30\times10^6}{10\times10^6} = 3,$$

$$g_\Sigma' = \frac{1}{Q_e'\omega_0 L} = 1180\mu S$$

$$\because g_p = g_\Sigma' - g_\Sigma = 1180 - 410 = 770\mu S$$

$\therefore$ 两端并联电阻

$$R_p = \frac{1}{g_p} = 1.3\text{k}\Omega$$

2.4 解：总通频带

$$BW=\sqrt{2^{\frac{1}{3}}-1}\,\frac{f_0}{Q_e}=5.93\text{kHz}\qquad (Q_e=40)$$

允许最大

$$Q_e=\sqrt{2^{\frac{1}{3}}-1}\,\frac{f_0}{BW'}=23.7\qquad (BW'=10\text{kHz})$$

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2.5 解：

$$A_{u2}=10^2=100 \qquad \therefore BW_2=BW\sqrt{2^{\frac{1}{2}}-1}=2.57\text{MHz}$$

$$BW^{'}=\frac{BW_2^{'}}{\sqrt{2^{\frac{1}{2}}-1}}=6.22\text{MHz}$$

又 $G\cdot BW=4\times10^7$ （增益带宽积）

$$\therefore A_u^{'}=\frac{4\times10^7}{BW^{'}}=6.4,$$

总增益 $A_{u2}^{'}=A_u^{'\,2}=6.4^2=41$

2.6 解：（提示:此题可以参照教材图2.2.1画出晶体管共基极Y参数等效电路,然后再画出放大器等效电路.）

∴根据条件可以求得:

$$C_{\Sigma} = C + C_{ob} = 28\text{pF}, \qquad g_{eo} = \frac{\omega_o C_{\Sigma}}{Q_0} \approx 0.088mS$$

$$g_{\Sigma} = g_{eo} + g_{ob} + n^2 g_L = 288\mu\text{S}$$

$$\therefore A_{u0} = \frac{n\left|y_{fb}\right|}{g_{\Sigma}} = 17.4$$

$$\therefore BW = \frac{f_0}{Q_e} = \frac{g_{\Sigma}}{2\pi C_{\Sigma}} = 1.64\text{MHz}$$

(注：是共基极Y参数)

第3章

3.1 解(1)

$$\eta_c = \frac{P_o}{P_D} = \frac{P_o}{U_{CC} I_{c0}} \Rightarrow I_{c0} = \frac{P_o}{U_{CC}\eta_c} = 0.347\mathbf{A}$$

$$P_C = P_D - P_o = 3.328$$

(2) $$\eta_C = \frac{P_o}{U_{CC} I_{c0}} \Rightarrow I_{co} = \frac{P_o}{U_{CC}\eta_C} = 0.26\mathbf{A}$$

$$P_C = P_D - P_o = 1.24\mathbf{W}$$

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3.2 解: $P_o = \frac{1}{2} I_{c1m}^2 R_\Sigma \Rightarrow I_{c1m} = \sqrt{\frac{2P_o}{R_\Sigma}} = \sqrt{\frac{10}{53}}$

$$\because I_{c1m} = I_{cm}\alpha_1(90^\circ) \Rightarrow I_{cm} = \frac{I_{c1m}}{\alpha_1(90^\circ)} = 2\sqrt{\frac{10}{53}}$$

$$\alpha_0(90^\circ) = \frac{\sin(\frac{\pi}{2}) - \frac{\pi}{2}\cos(\frac{\pi}{2})}{\pi(1-\cos\frac{\pi}{2})} = \frac{1}{\pi}$$

$$I_{c0} = I_{cm}\alpha_0(90^\circ) = \frac{2}{\pi}\sqrt{\frac{10}{53}}$$

$$\therefore P_D = U_{CC} I_{c0} = 6.64 \qquad \eta_c = \frac{P_o}{P_D} = 75.34\%$$

$$\because U_{cm} = I_{c1m} R_\Sigma \approx 23 \qquad \therefore \xi = \frac{U_{CM}}{U_{CC}} \approx 0.96$$

3.3解: $\because \eta = \frac{1}{2}\frac{I_{c1m}U_{cm}}{I_{c0}U_{CC}} = \frac{1}{2}\frac{\alpha_1(\theta)}{\alpha_0(\theta)} \times \frac{U_{cm}}{U_{CC}}$

又三种情况下,均相同

$$\therefore \eta_{180^\circ} : \eta_{90^\circ} : \eta_{60^\circ} = \frac{\alpha_1(180^\circ)}{\alpha_0(180^\circ)} : \frac{\alpha_1(90^\circ)}{\alpha_0(90^\circ)} : \frac{\alpha_1(60^\circ)}{\alpha_0(60^\circ)}$$

$$= g_1(180^\circ) : g_1(90^\circ) : g_1(60^\circ) = 1:1.57:1.8$$

$$\because P_O = \frac{1}{2} I_{cm}\alpha_1(\theta) U_{cm}$$

又三种情况下,均相同,

$$\therefore P_O(180^\circ) : P_O(90^\circ) : P_O(60^\circ) = \alpha_1(180^\circ) : \alpha_1(90^\circ) : \alpha_1(60^\circ)$$

$$= 0.5:0.5:0.391 = 1:1:0.782$$

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3.4 解:

$$P_D = U_{CC} I_{c0} = U_{CC} \times \alpha_0\left(70^\circ\right) I_{cm} = 13.36\text{W}$$

$$\because I_{c1m} = \alpha_1\left(70^\circ\right) I_{cm} = 0.96\text{A}$$

$$U_{cm} = U_{CC} - \frac{I_{cm}}{g_{cr}} = 21.25\text{V}$$

$$\therefore P_O = \frac{1}{2} I_{c1m} U_{cm} = 10.19\text{W}$$

$$P_C = P_D - P_O = 3.17\text{W}$$

$$\eta_c = \frac{P_O}{P_D} = 76\% \qquad R_\Sigma = \frac{2P_O}{I_{c1m}^2} = 22\Omega$$

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3.5 解：（注：P_{00}是原输出功率）

(1) 可改变

$R_{\Sigma} \downarrow \rightarrow$ 负载线斜率 $\uparrow \rightarrow U_{cm} \downarrow, I_{c1m} \uparrow, P_{O} \uparrow, P_{01} > P_{00}$

(2) 可改变 $\boldsymbol{U_{CC}} \uparrow \rightarrow \boldsymbol{U_{cm}} \uparrow, \boldsymbol{I_{c1m}} \uparrow, \boldsymbol{P_{O}} \uparrow, \boldsymbol{P}_{02} > \boldsymbol{P}_{00}$

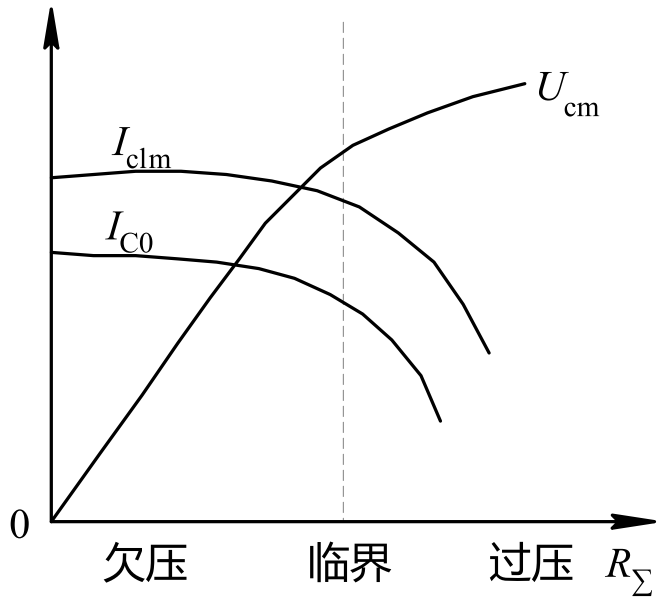
(3) 可改变 $U_{BB} \downarrow \rightarrow$负载线平行下移 $\rightarrow P_{o}$ 略下降，$P_{03} < P_{00}$

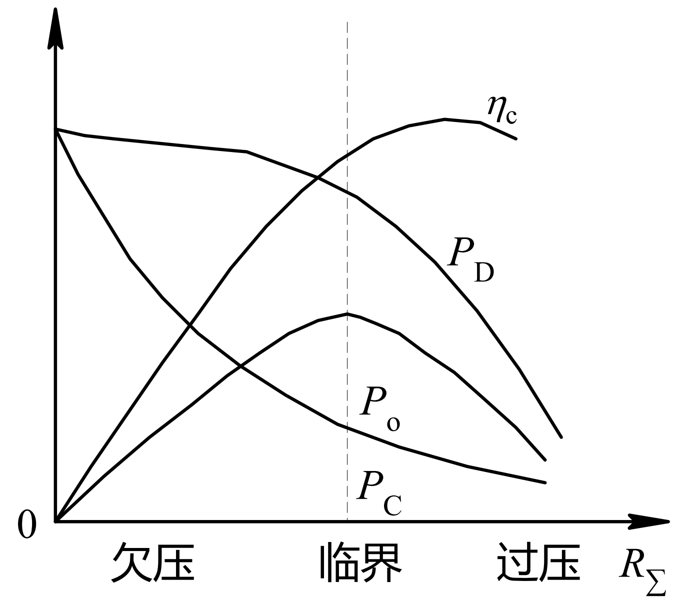
(4) 可改变 $U_{bm} \downarrow \rightarrow$ 负载线不变 $\rightarrow P_{O}$ 略下降，

$P_{04} < P_{00}$

3.6 解: P_O低而I_{C0}略高,则η_c小，故工作在欠压状态.

可以使 $R_\Sigma\uparrow \rightarrow \dfrac{1}{R_\Sigma}\downarrow$, 则 $P_O\uparrow$.





3.7 解:前者工作在欠压区,后者工作在过压区(R_Σ相同)

若要增大前者功率,应该使或 $U_{bm}\uparrow$或$U_{BB}\uparrow$

3.8 解:因为$\xi=\dfrac{U_{cm}}{U_{cc}}$,如果$U_{cm}$和$U_{CC}$不变,则$\xi$也不变.

$\because u_{BE\max}$不变,所以I_{cm}不变,所以仍然工作在临界状态..

$\because \eta_c=\dfrac{1}{2}\xi g_1(\theta),\therefore \eta_c$随$g_1(\theta)$的增大而增大,即$\theta\downarrow, I_{c1m}\downarrow$.

$\therefore P_o=\dfrac{1}{2}I_{c1m}U_{cm}$也减小了.

原因在于U_{BB}减小，U_{bm}增大,但保持

u_{BEmax}不变,即I_{cm}不变.

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3.9 解：由教材中图3.2.4可知

$$\alpha_1(60^\circ)=0.391,\alpha_0(60^\circ)=0.218$$

$$\therefore I_{c1m}=\sqrt{\frac{2P_0}{R_\Sigma}}=0.2\text{A},\qquad I_{cm}=\frac{I_{c1m}}{\alpha_1(60^\circ)}=0.512\text{A}$$

$$U_{cm}=I_{c1m}R_\Sigma=10\text{V},\qquad \eta_c=\frac{P_O}{P_D}=\frac{\alpha_1(\theta)\cdot U_{cm}}{2\alpha_0(\theta)\cdot U_{cc}}=37.3\%$$

因为**0.512A**时对应的临界电压： $\dfrac{\boldsymbol{I_{cm}}}{\boldsymbol{g_{cr}}}=1.28\mathbf{V}$

$$\boldsymbol{U_{CC}-U_{cm}}=14\mathbf{V}>\frac{\boldsymbol{I_{cm}}}{\boldsymbol{g_{cr}}}=1.28\mathbf{V}$$

所以工作在欠压状态。

3.10 解: 错误之处主要有三处:

(1)　V_1,V_2管基极偏置与集电极偏置均不对。

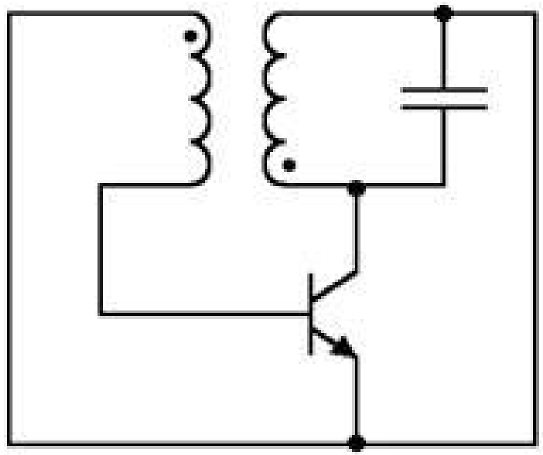
(2)　两管均没有匹配电路。

(3)　带阻网络应该去掉。

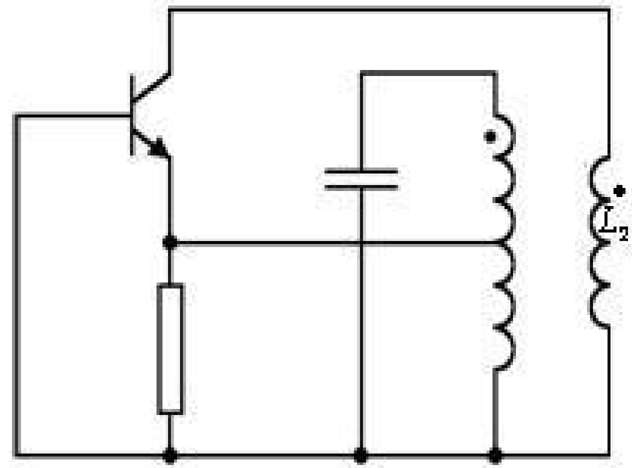
（提示：可以参考教材中例3.4电路进行修改）

第4章

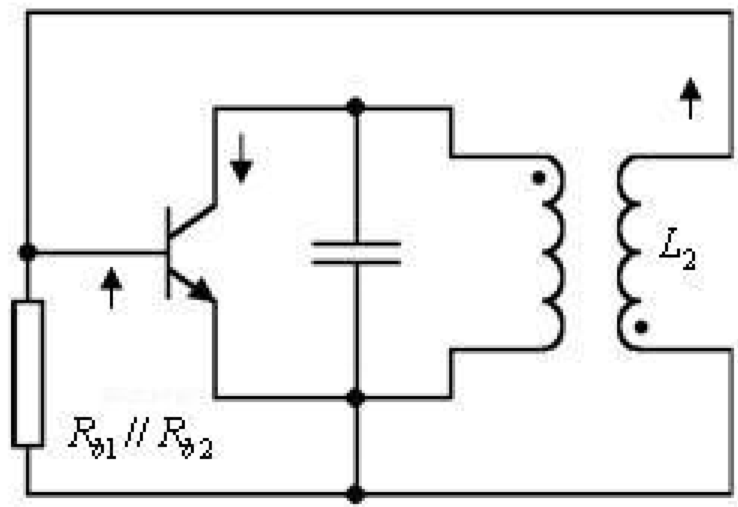
4.1 解：等效电路如图所示。



（a）



（b）



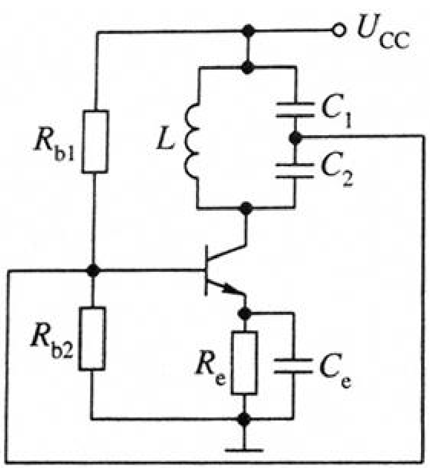
(c)

4.2 解：（a）不能，不能满足三点式法则。

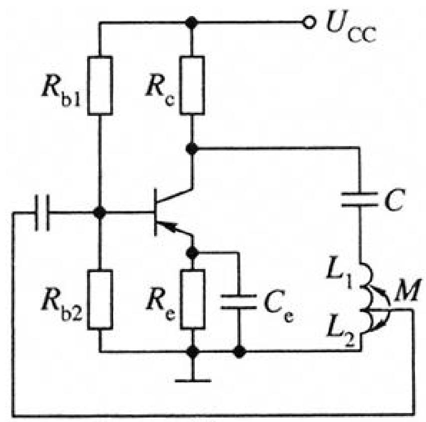
（b）不能，同上。（c）能，满足三点式法则。

（d）能，两级反相放大。（e）不能。

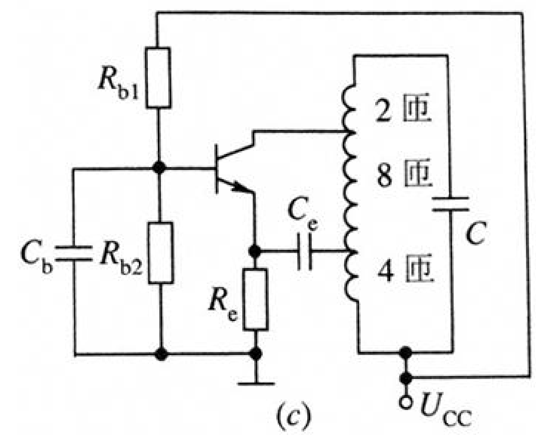
若第二级负载C_2改为电阻则有可能产生振荡。



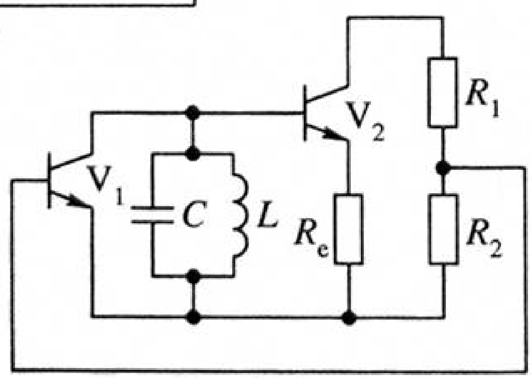
(a)



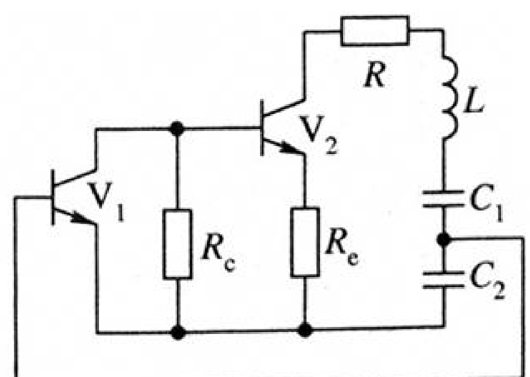
(b)



(c)



(d)



(e)

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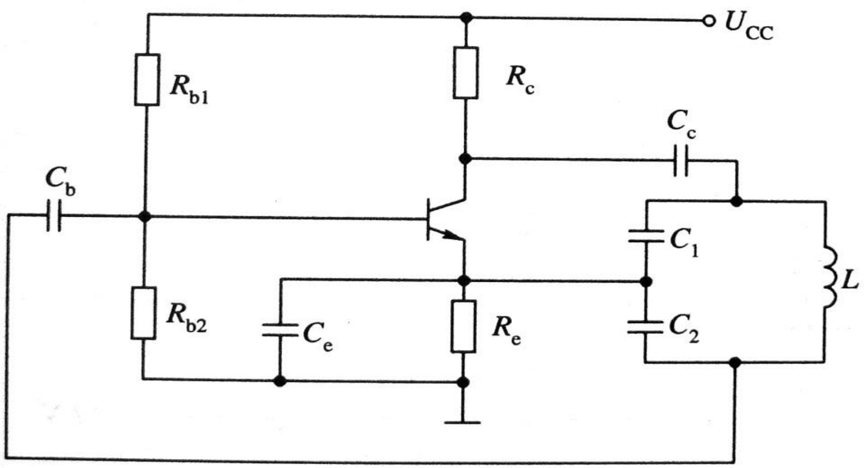
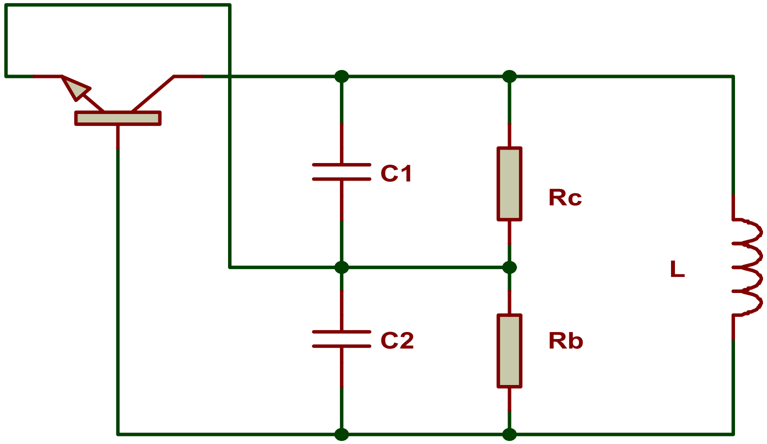
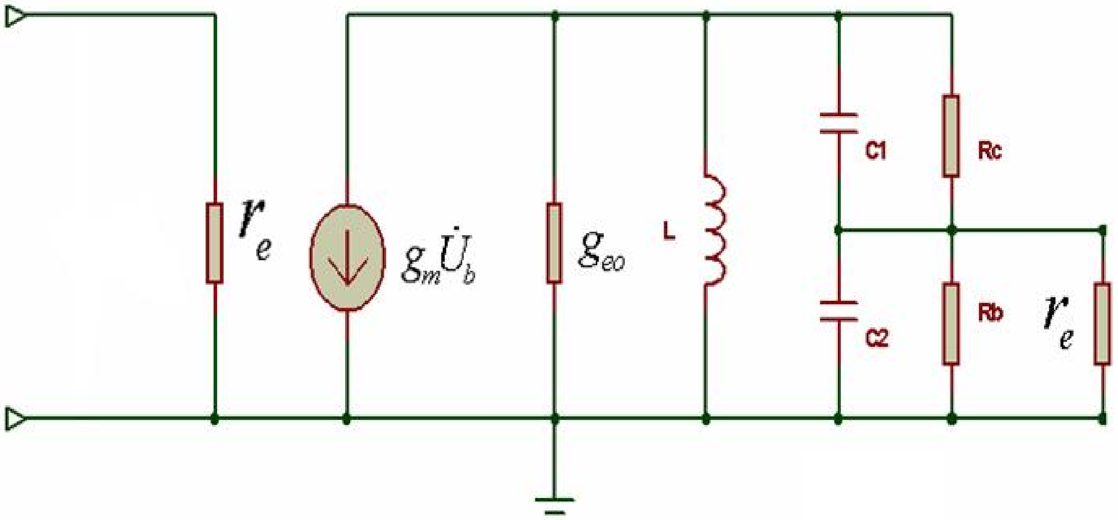
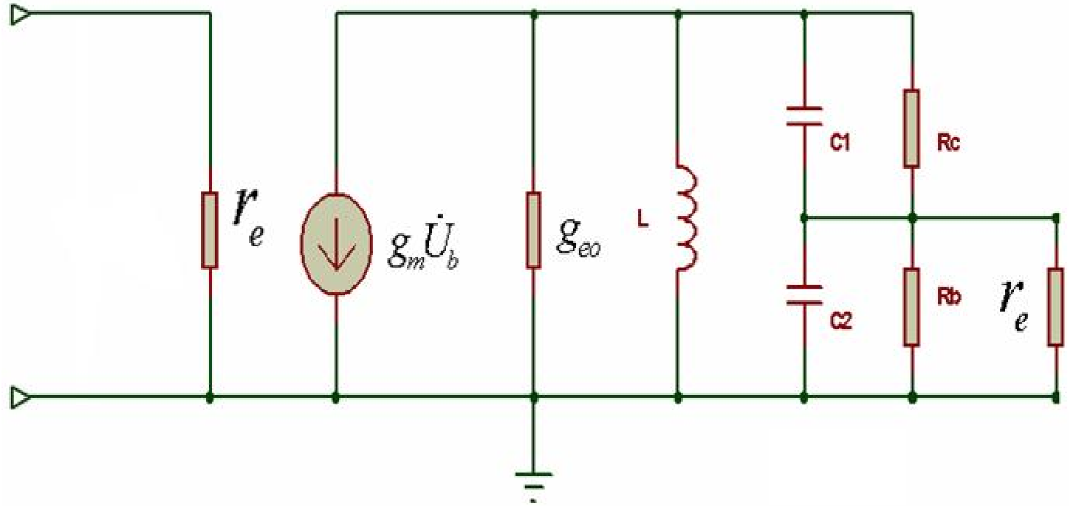
4.3 解：（1）可将此电路用共基电路等效





(a)



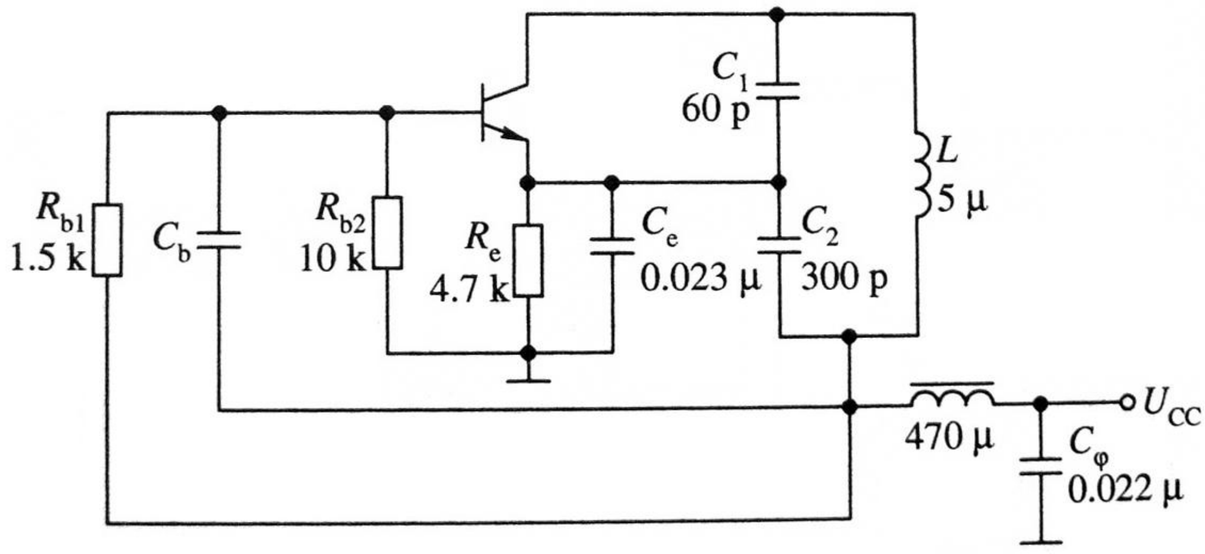


$$\therefore f_0=\frac{1}{2\pi\sqrt{\frac{C_1C_2}{C_1+C_2}L}}\approx 2.6\text{MHz}$$

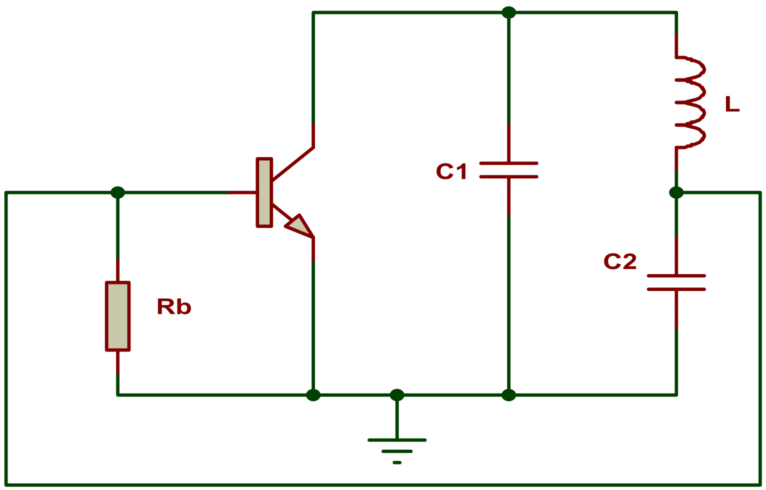
$$\because F=\frac{C_1}{C_1+C_2}=\frac{100\times10^{-12}}{100\times10^{-12}+300\times10^{-12}}=\frac{1}{4}$$

∴共基极电路最小电压增益 $A_{u\min}=\dfrac{1}{F}=4$

4.4 解：

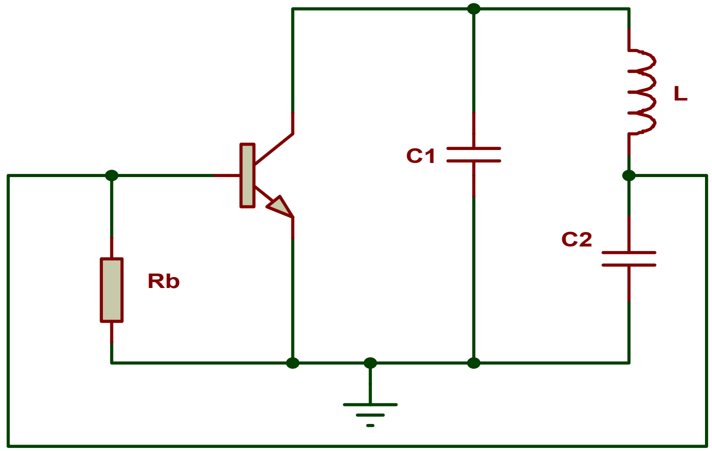


（1）振荡器的共射交流等效电路：

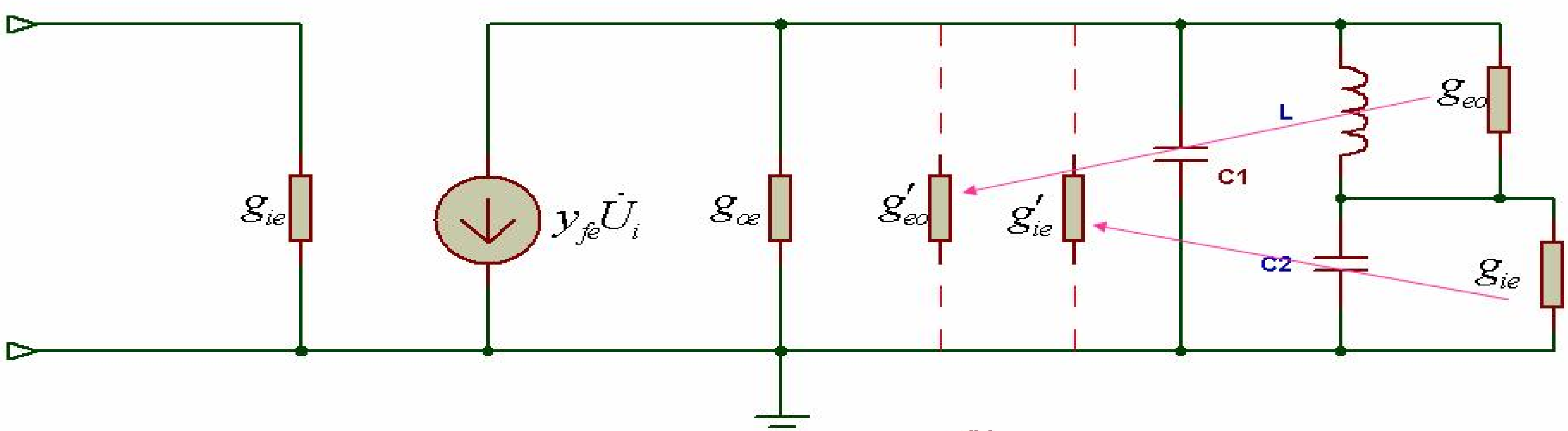


(a)

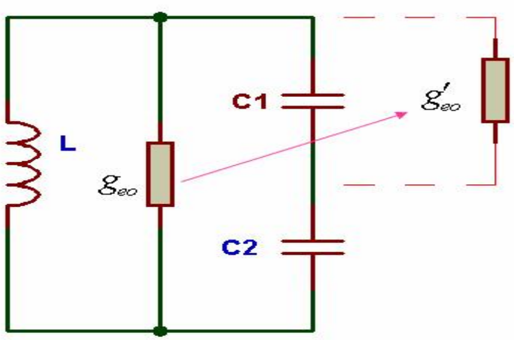
4.4

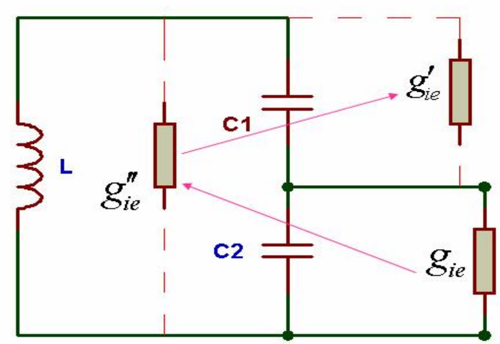

L
C1
C2
Rb

(a)


g_{ie}
$y_{fe}\dot{U}_i$
g_{oe}
g'_{eo}
g'_{ie}
L
C1
g_{eo}
C2
g_{ie}

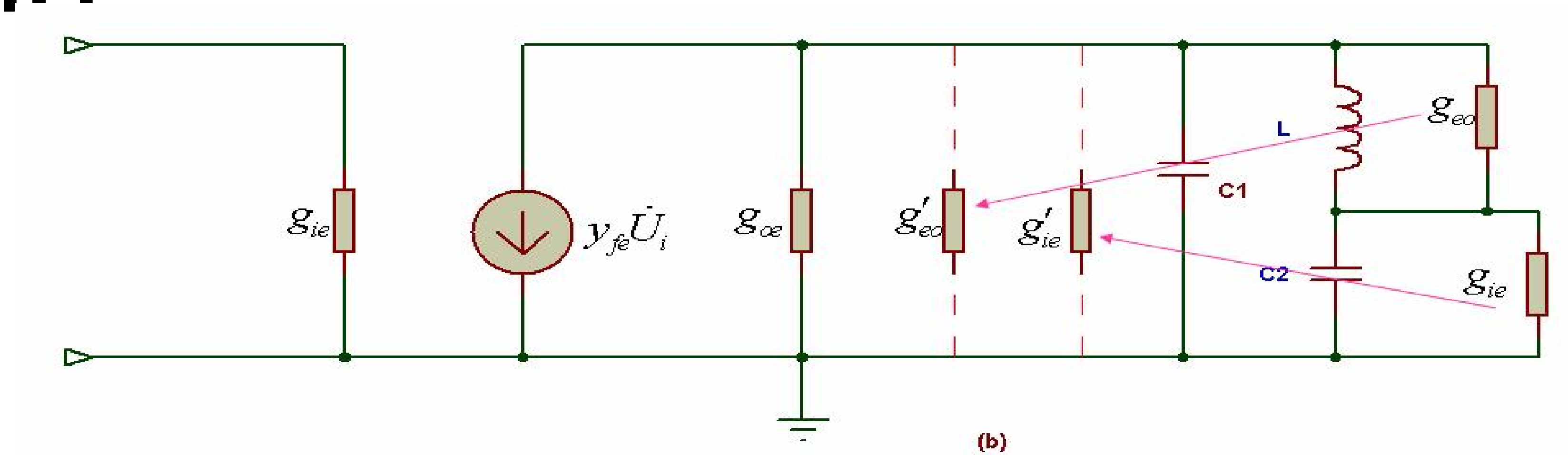
(b)


C1
L
g_{eo}
g'_{eo}
C2


g'_{ie}
C1
L
g''_{ie}
C2
g_{ie}

SCU

4.4



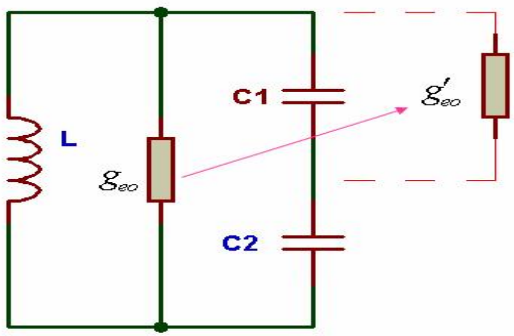
（2）振荡频率和反馈系数：

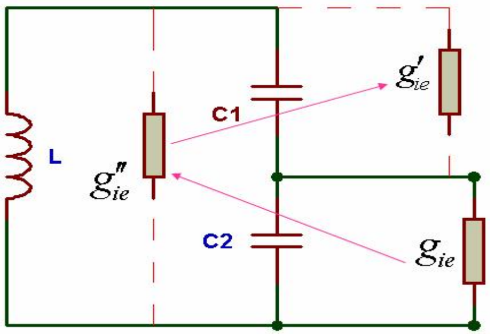
$$f_0 = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\pi\sqrt{L\dfrac{C_1C_2}{C_1+C_2}}} = 10MHz$$

$$F = \frac{U_{C2}}{U_{c1}} = \frac{IX_{C2}}{IX_{C1}} = \frac{C_1}{C_2} = \frac{1}{5}$$

SCU

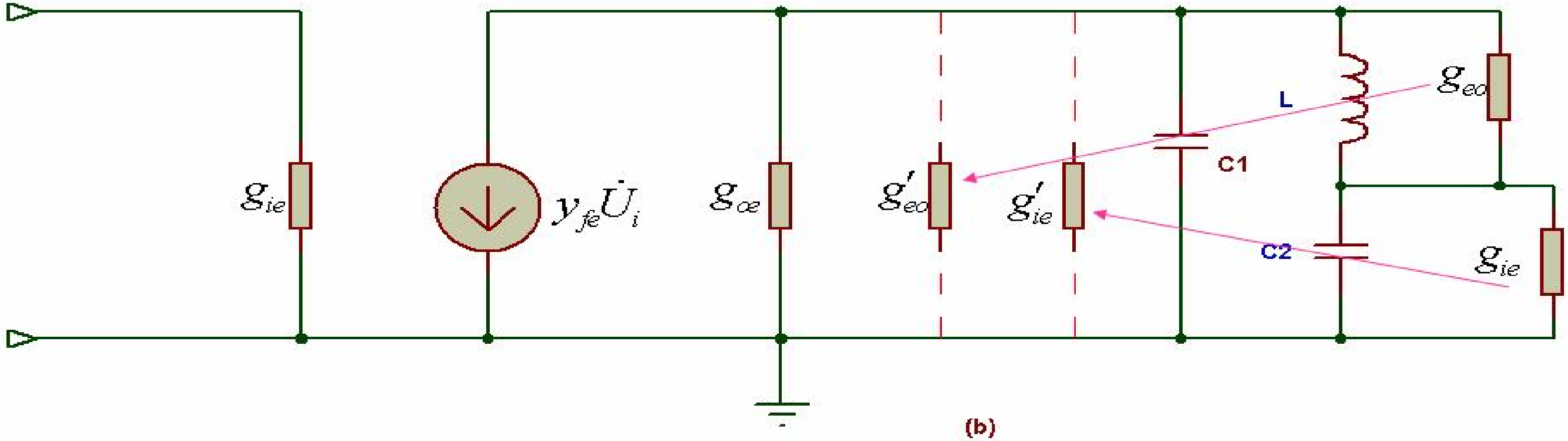
4.4





$$g_{eo} = n^2 g'_{eo} = \left(\frac{C_2}{C_1 + C_2}\right)^2 g'_{eo} \Rightarrow g'_{eo} = \left(\frac{C_1 + C_2}{C_2}\right)^2 g_{eo} = \left(\frac{C_1 + C_2}{C_2}\right)^2 \frac{1}{Q_o \omega_0 L}$$

$$\left.\begin{aligned} g''_{ie} &= \left(\frac{C_1}{C_1 + C_2}\right)^2 g_{ie} \\ g''_{ie} &= \left(\frac{C_2}{C_1 + C_2}\right)^2 g'_{ie} \end{aligned}\right\} \Rightarrow g'_{ie} = \left(\frac{C_1}{C_2}\right)^2 g_{ie}$$



$$\dot{T}=\frac{\dot{U}_f}{\dot{U}_i}=\frac{\dot{U}_{C2}}{\dot{U}_i}=\frac{\dot{F}\dot{U}_{C1}}{\dot{U}_i}=\frac{\dot{F}\left|y_{fe}\right|\dot{U}_i/g_{\Sigma}}{\dot{U}_i}=\frac{\dot{F}\left|y_{fe}\right|}{g_{\Sigma}}$$

$$\dot{T}\geq 1$$

$$\left|y_{fe}\right|\geq\frac{g_{\Sigma}}{\dot{F}}=\frac{1}{\dot{F}}\left(g_{oe}+g'_{eo}+g'_{ie}\right)$$

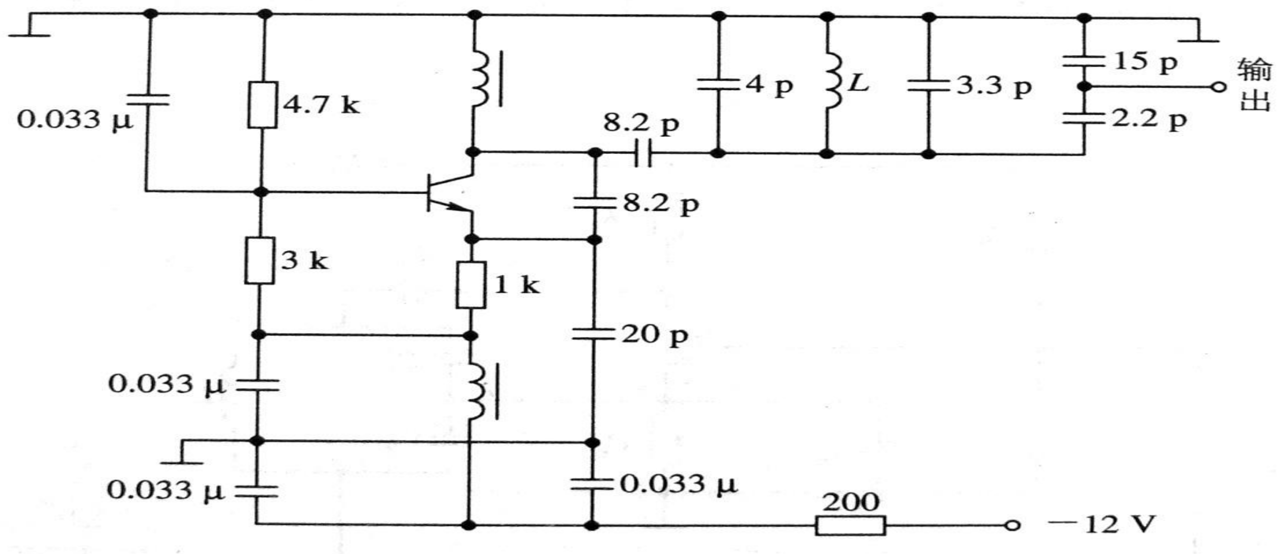
$$=\frac{1}{\dot{F}}\left[g_{oe}+\left(\frac{C_1+C_2}{C_2}\right)^2\frac{1}{Q_o\omega_0 L}+\left(\frac{C_1}{C_2}\right)^2 g_{ie}\right]$$

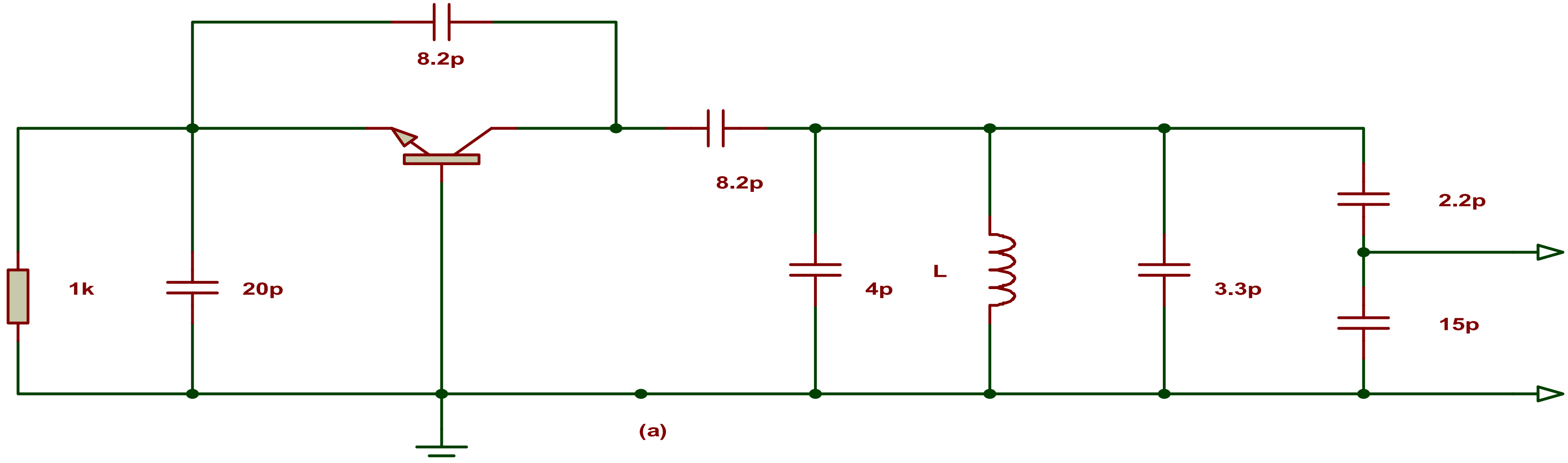
$$=0.73mS$$

由题目条件$|y_{fe}|$=20.6mS知此电路可以起振

SCU

4.5解：如图所示：

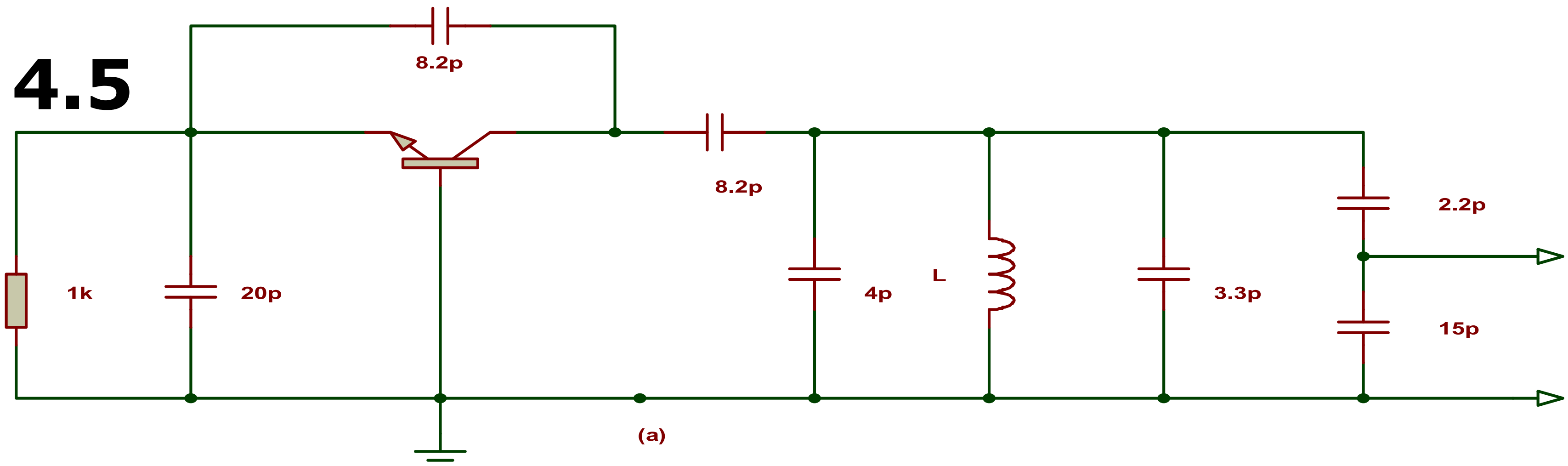


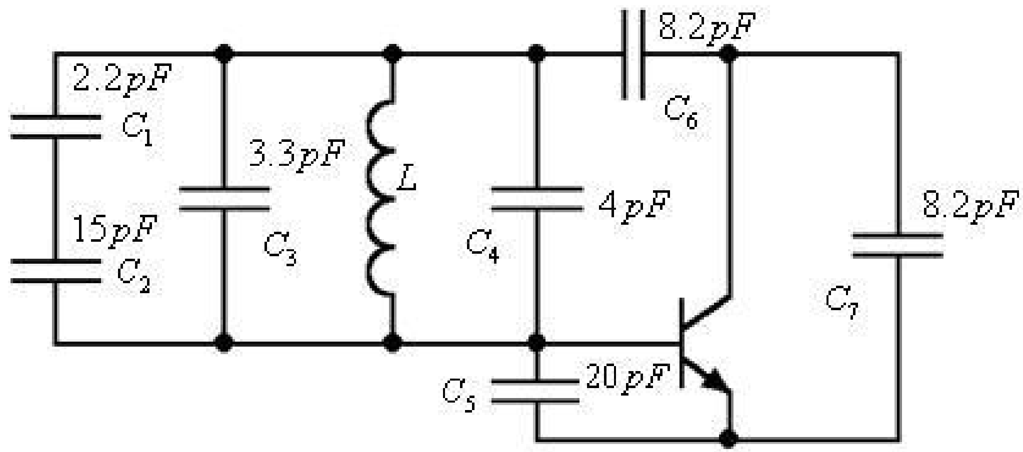


(a)

SCU

4.5



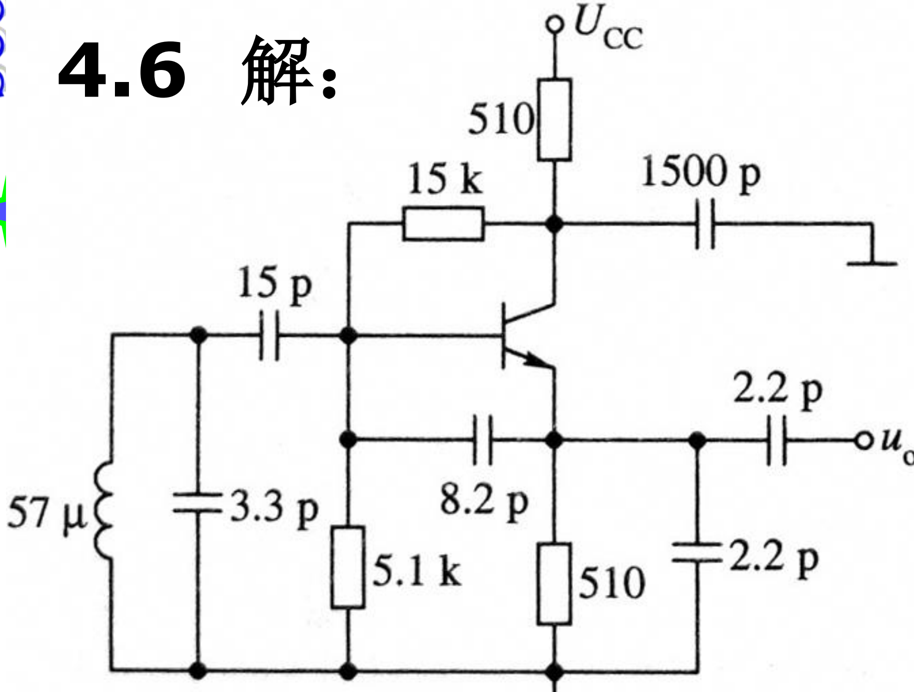


$$C_{\Sigma}=\left(C_1\text{串}C_2\right)+C_3+C_4+(C_5\text{串}C_6\text{串}C_7)=12.6\text{pF}$$

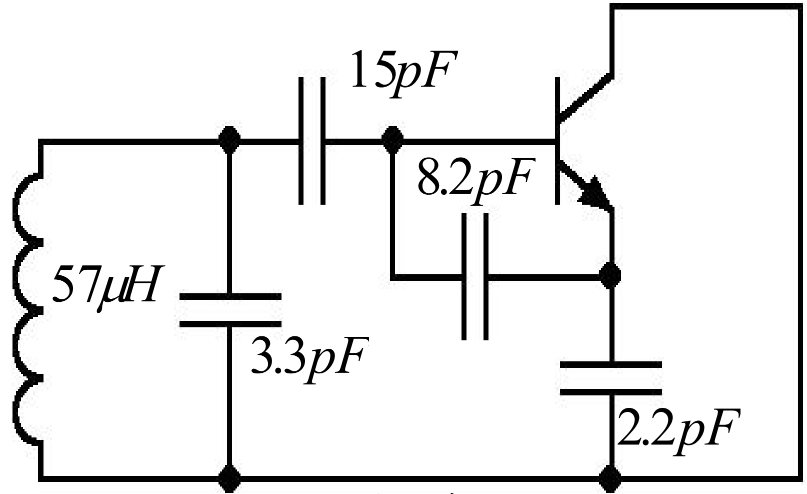
$$\therefore\ L=\frac{1}{\omega^2{}_0C}=0.8\mu\text{H}$$

SCU

4.6 解：



(a)

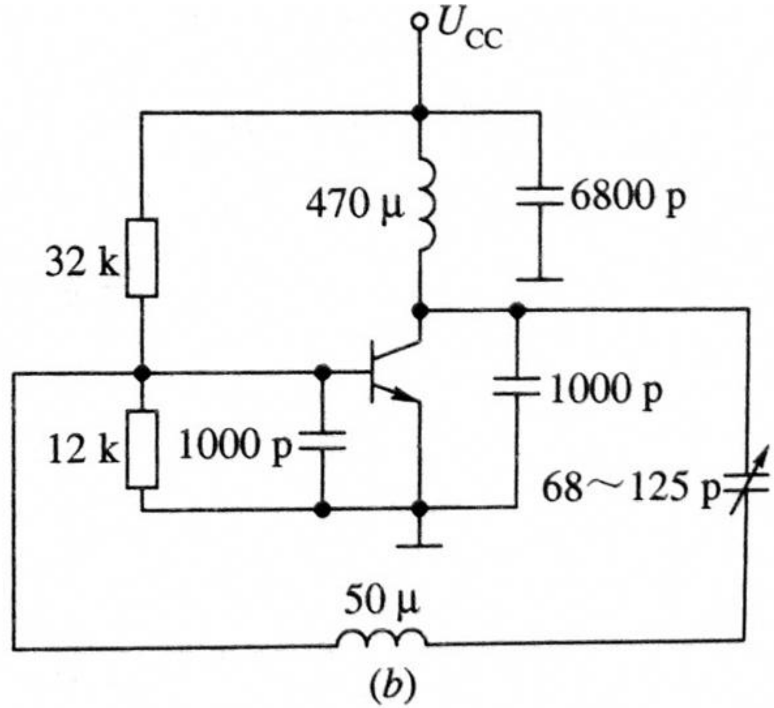


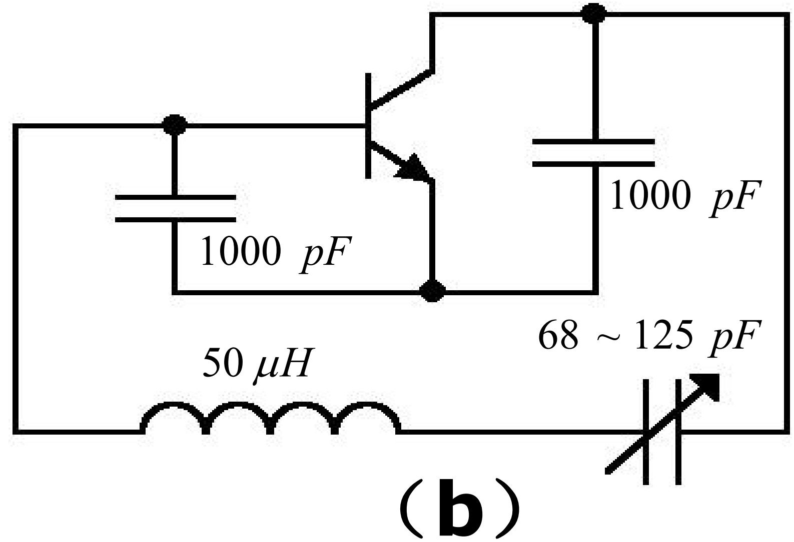
（a）

电容三点式：

$$C=\frac{1}{\frac{1}{8.2}+\frac{1}{2.2}+\frac{1}{15}}+3.3=4.85p$$

$$f_0=\frac{1}{2\pi\sqrt{LC}}=9.58MHz$$





电容三点式:

$$C_{\min} \approx \frac{1}{\frac{1}{1000}+\frac{1}{1000}+\frac{1}{68}} = 60p$$

$$C_{\max} \approx \frac{1}{\frac{1}{1000}+\frac{1}{1000}+\frac{1}{125}} = 100p$$

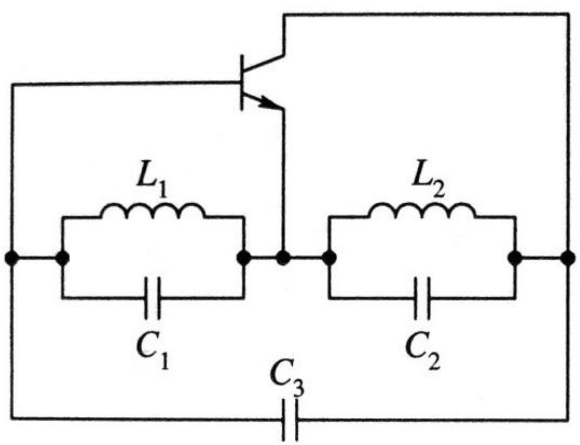
$$f_0 = \frac{1}{2\pi\sqrt{LC}} = 2.91 \sim 2.25MHz$$

SCU

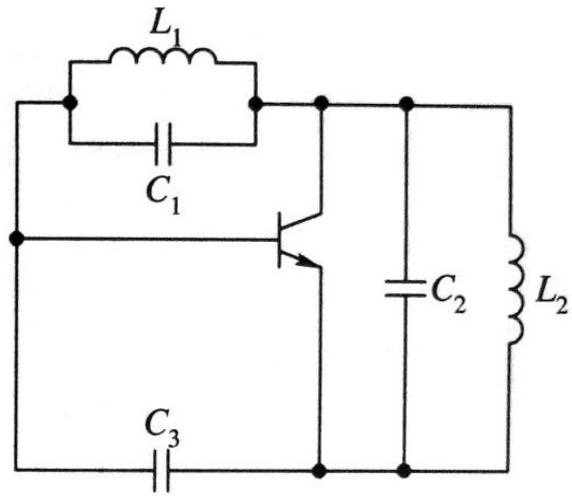
4.7 解：（a）电感三点式，$f_0 < f_1 \le f_2$

或者$f_0 < f_2 < f_1$

（b）电容三点式，$f_2 < f_0 < f_1$



(a)



(b)

SCU

4.8解：

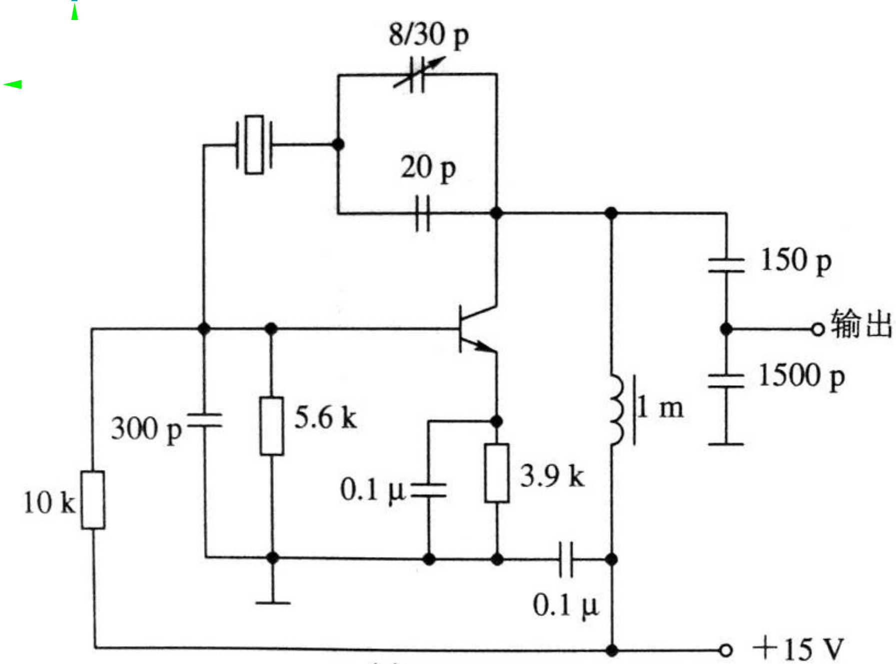
$$(1)\quad f_s=\frac{1}{2\pi\sqrt{L_qC_q}}=\frac{1}{2\pi\sqrt{19.5\times2.1\times10^{-16}}}$$

$$\approx 2.49\times10^{6}\,\mathrm{Hz}=2.49\mathrm{MHz}$$

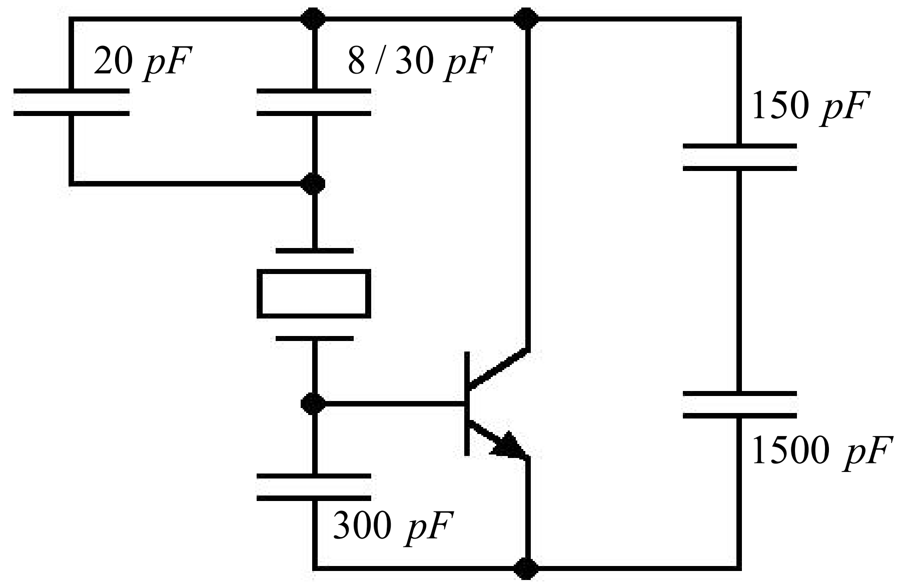
$$(2)\,f_p=f_s\sqrt{1+\frac{C_q}{C_o}}=f_s\sqrt{1+\frac{2.1\times10^{-4}}{5}}\approx1.000021f_s$$

$$(3)\quad Q_q=\frac{1}{r_q}\sqrt{\frac{L_q}{C_q}}=\frac{1}{110}\sqrt{\frac{19.5}{2.1\times10^{-16}}}\approx2.77\times10^{6}$$

4.9 解：（a）图晶体起电感作用，电容三点式



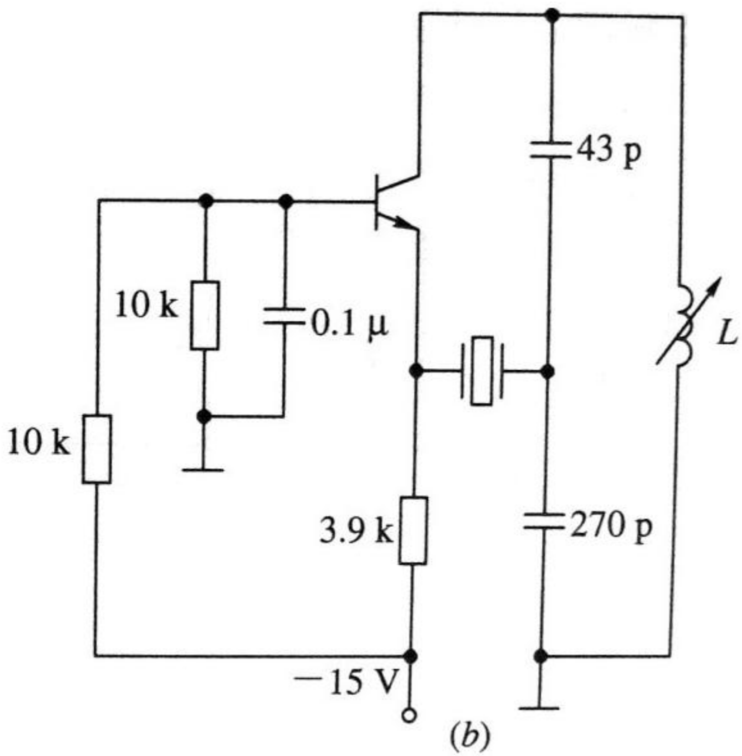
(a)

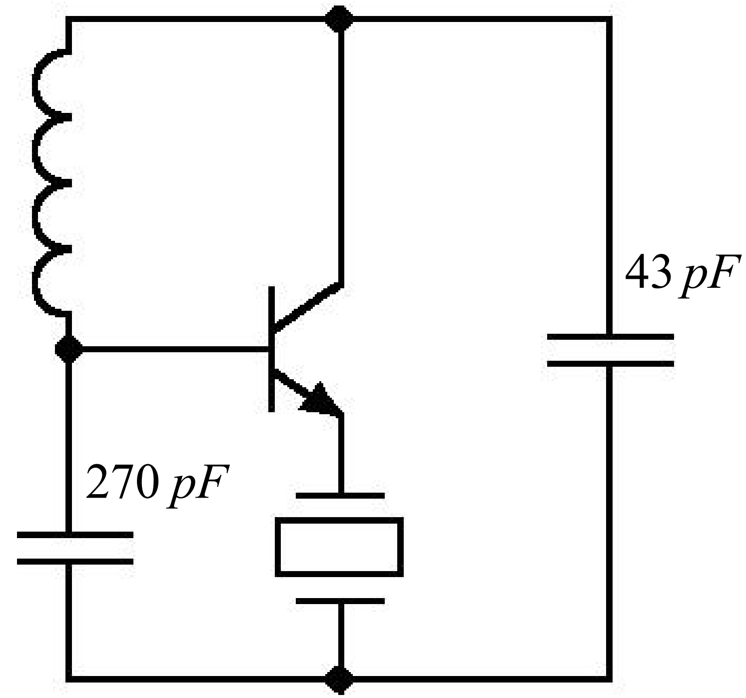


$$C_1 = 150\text{pF}串1500\text{pF} \approx 136\text{pF}, C_2 = 300\text{pF}$$

$$F = \frac{C_1}{C_1 + C_2} = \frac{136}{463} \approx 0.31$$

4.9 (b)图晶体工作在串联谐振频率f_S上

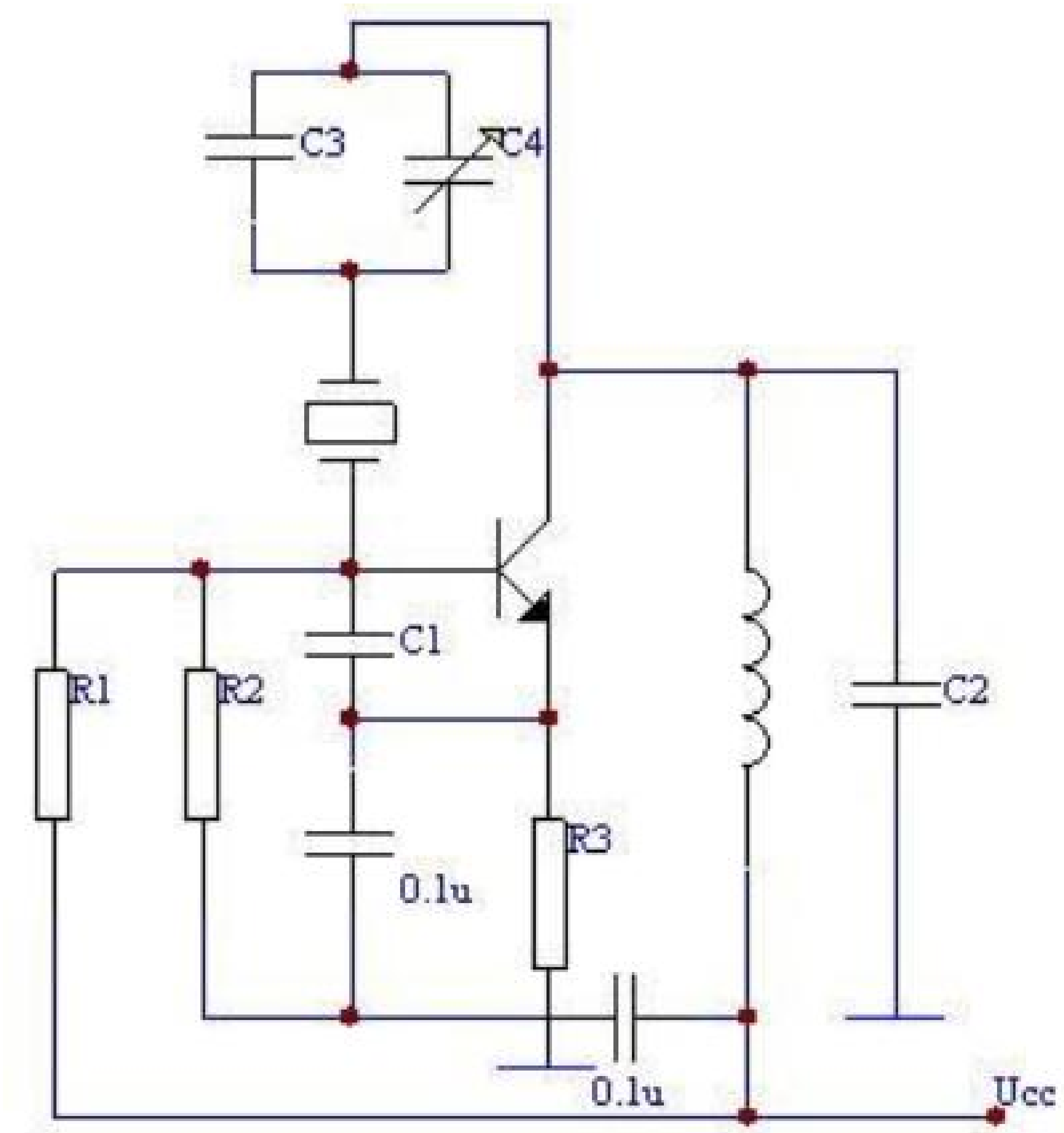




$$F = \frac{C_1}{C_1 + C_2} = \frac{43}{313} \approx 0.14$$

SCU

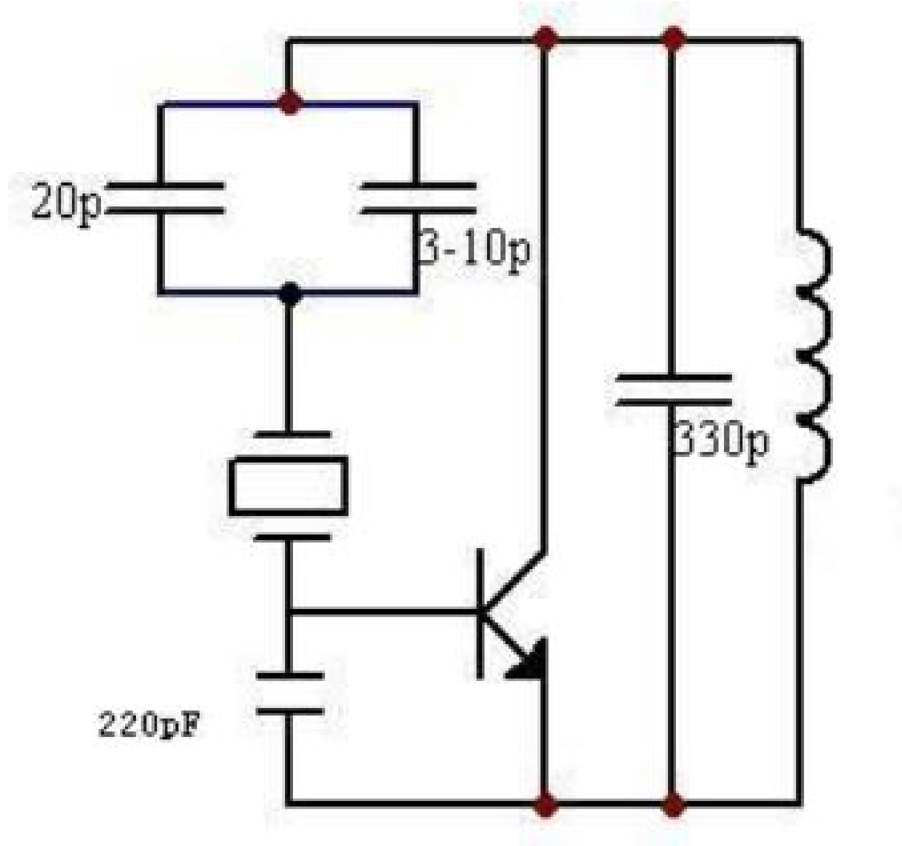
4.10 解：下面给出其中一种解答



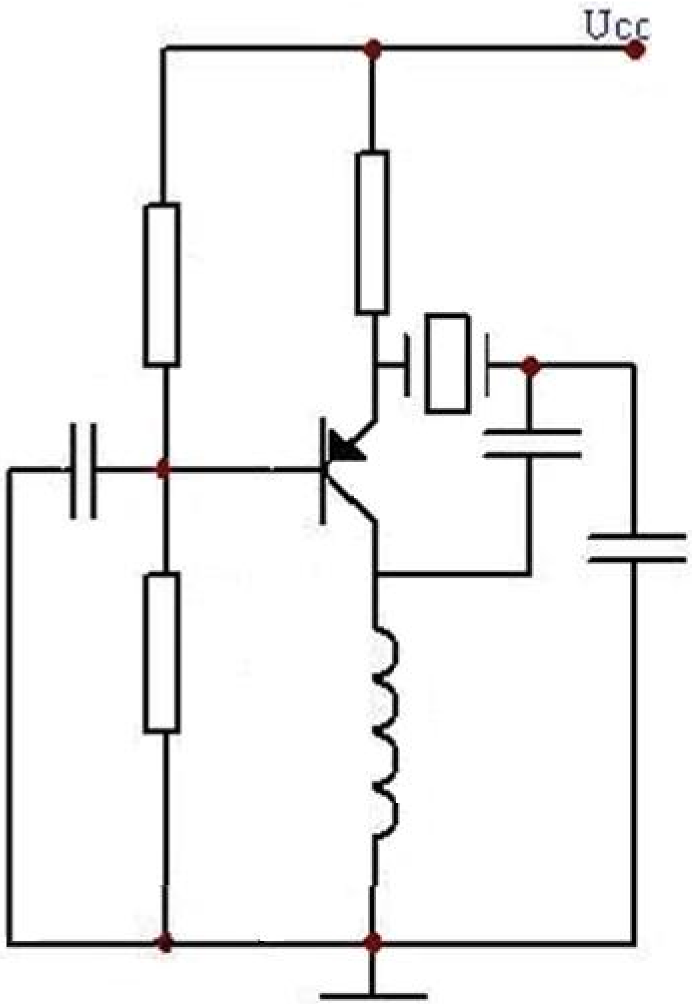
SCU

4. 11解：（1）高频等效电路如题图4. 11所示。

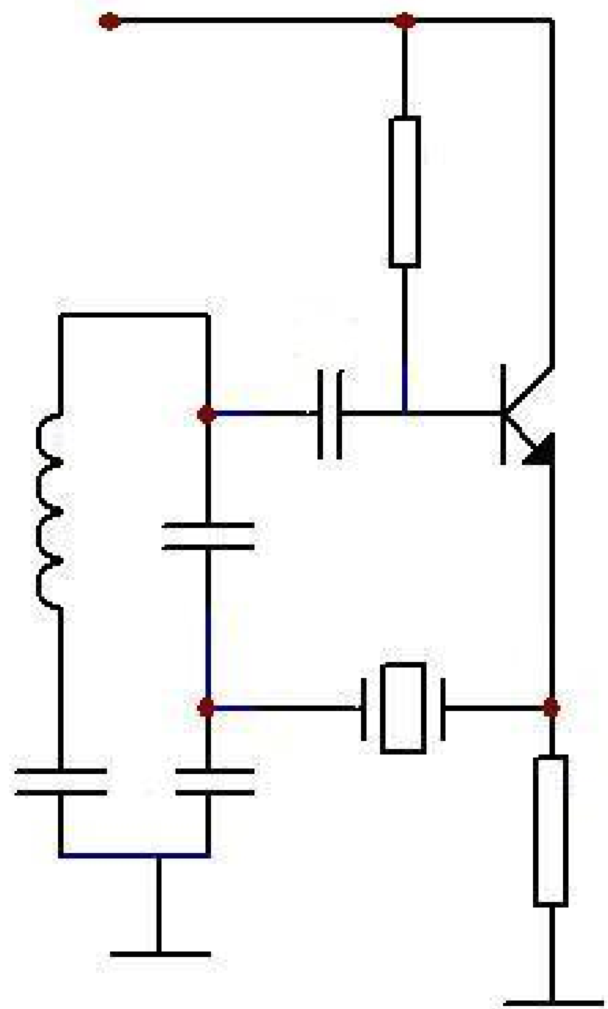
（2）LC回路在振荡频率处相当于一个电容，呈容性，整个电路满足组成法则，为电容三点式电路。



4.12 解： 如题4.12图所示.



（a）



（b）

SCU

第 5 章

5.1 解：

$$i=a_0+a_1u+a_2u^2+a_3u^3+a_4u^4$$

$$=a_0+a_1(U_{\mathrm{m1}}\cos\omega_1t+U_{\mathrm{m2}}\cos\omega_2t)+a_2(U_{\mathrm{m1}}^2\cos^2\omega_1t$$
$$+2U_{\mathrm{m1}}U_{\mathrm{m2}}\cos\omega_1t\cdot\cos\omega_2t+U_{\mathrm{m2}}^2\cos^2\omega_2t)+a_3(U_{\mathrm{m1}}^3$$
$$\cos^3\omega_1t+3U_{\mathrm{m1}}^2U_{\mathrm{m2}}\cos^2\omega_1t\cdot\cos\omega_2t+3U_{\mathrm{m1}}U_{\mathrm{m2}}^2\cos$$
$$\omega_1t\cdot\cos^2\omega_2t+U_{\mathrm{m2}}^3\cos^3\omega_2t)+a_4(U_{\mathrm{m1}}^2\cos^2\omega_1t+$$
$$2U_{\mathrm{m1}}U_{\mathrm{m2}}\cos\omega_1t\cdot\cos\omega_2t+U_{\mathrm{m2}}^2\cos^2\omega_2t)^2$$

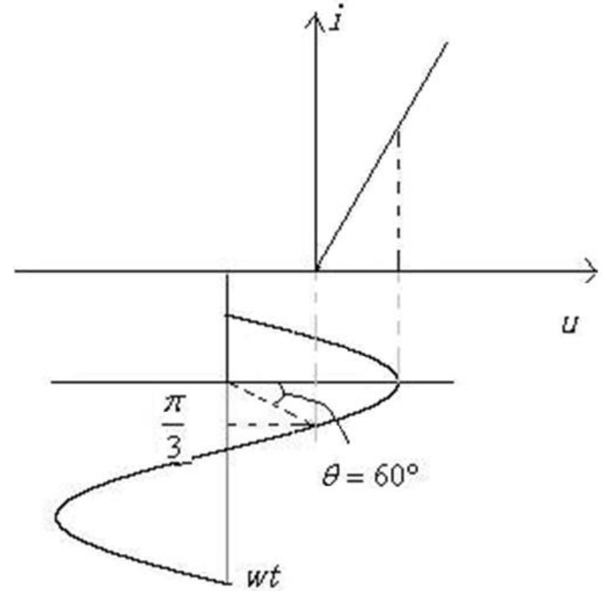
所以***i***中的组合频率分量有：

$$\omega_0=\left|p\omega_1\pm q\omega_2\right| \qquad p\,,\ q=0\,,1,2\,,3\,,4$$

其中分量是 $\omega_1\pm\omega_2$ 由第三项、第五项产生的。

5.2 解：如图所示，当 $u>0$时：

$$i = g_D u = g_D(U_Q + U_{m1}\cos\omega_1 t + U_{m2}\cos\omega_2 t)$$



在线性时变条件下：

$$g(t) = \left.\frac{df(u)}{du}\right|_{u=U_Q+u_1} = g_D\big|_{u=-\frac{1}{2}U_{m1}+U_{m1}\cos\omega_1 t}$$

$$= g_0 + 2g_1\cos\omega_1 t + \cdots + 2g_n\cos n\omega_1 t + \cdots$$

其中： $g_0 = \frac{1}{\pi}\int_0^{\frac{\pi}{3}} g_D d\omega_1 t = \frac{1}{3}g_D$

$$g_n = \frac{1}{\pi}\int_0^{\frac{\pi}{3}} g_D \cos n\omega_1 t \cdot d\omega_1 t = \frac{g_D}{\pi}\cdot\frac{1}{n}\sin\frac{n\pi}{3}$$

$$\therefore g(t) = \frac{g_D}{3} + \frac{2g_D}{\pi}\sum_{n=1}^{\infty}\frac{1}{n}\sin(\frac{n\pi}{3})\cos n\omega_1 t$$

i中的组合分量有：直流，$n\omega_1, \left|\pm n\omega_1 \pm \omega_2\right|$

（n＝0，1，2，3，…….），．．．

SCU

5.3 解：①当 $U_Q=0$ 时，可用单向开关函数表示

$$\because g(t)=g_D K_1(\omega_1 t), I_0(t)=g_D u_1 K_1(\omega_1 t)$$

$$\therefore i=I_0(t)+g(t)u_2=g_D K_1(\omega_1 t)(u_1+u_2)$$

$$=g_D(u_1+u_2)(\frac{1}{2}+\frac{2}{\pi}\cos\omega_1 t-\frac{2}{3\pi}\cos 3\omega_1 t+\cdots)$$

由上式可知，可实现：调幅，混频，倍频，乘积检波

组合频率分量有：直流,

$$\omega_1,\omega_2,2\omega_1,\omega_1\pm\omega_2,4\omega_1,3\omega_1\pm\omega_2,\cdots\cdots$$

②当$U_Q = U_{m1}$时，$g_0 = \frac{1}{\pi}\int_0^\pi g_D d\omega_1 t = g_D$

$$g_n = \frac{1}{\pi}\int_0^\pi g_D \cos n\omega_1 t \cdot d\omega_1 t = \frac{g_D}{\pi}\cdot\frac{1}{n}\sin n\omega_1 t\Big|_0^\pi = 0$$

$$\therefore g(t) = g_D$$

$$\because I_0(t) = f(u)\Big|_{u=U_Q+u_1} = g_D(U_{m1} + U_{m1}\cos\omega_1 t)$$

$$= g_D U_{m1}(1+\cos\omega_1 t)$$

$$\therefore i = I_0(t) + g(t)u_2 = g_D U_{m1}(1+\cos\omega_1 t) + g_D u_2$$

频率分量有：直流， ω_1 和 ω_2 。

此时不能实现任何频谱搬移。

SCU

5.4 解：依题意得：

$$i_c = I_{es}\Bigg\{1+\frac{1}{U_T}(U_{BB}+U_m\cos\omega_c t)$$

$$+\frac{1}{2U_T^2}\left[U_{BB}^2+2U_{BB}U_m\cos\omega_c t+\frac{U_m^2(1+\cos 2\omega_c t)}{2}\right]$$

$$+\frac{1}{6U_T^3}\left[\begin{array}{l}U_{BB}^3+3U_{BB}^2U_m\cos\omega_c t+3U_{BB}U_m^2\cdot\dfrac{1+\cos 2\omega_c t}{2}\\ +U_m^3\dfrac{\cos\omega_c t+(\cos 3\omega_c t+\cos\omega_c t)/2}{2}\end{array}\right]$$

$$+\frac{1}{24U_T^4}\left[U_{BB}^2+2U_{BB}U_m\cos\omega_c t+\frac{U_m^2(1+\cos 2\omega_c t)}{2}\right]^2\Bigg\}$$

SCU

$$= I_{es}\{1 + \frac{1}{U_T}U_{BB} + \frac{U_{BB}^2}{2U_T^2} + \frac{U_m^2}{4U_T^2} + \frac{U_{BB}^3}{6U_T^3}$$

$$+ \frac{U_{BB}U_m^2}{4U_T^4} + \frac{U_m}{U_T}\cos\omega_c t + \frac{U_{BB}U_m}{U_T^2}\cos\omega_c t$$

$$+ \frac{U_{BB}^2U_m}{2U_T^3}\cos\omega_c t + \frac{U_m^3}{12U_T^3}\cos\omega_c t + \frac{U_m^3}{24U_T^3}\cos\omega_c t$$

$$+ \frac{U_m^2}{4U_T^2}\cos 2\omega_c t + \frac{U_{BB}U_m^2}{4U_T^3}\cos 2\omega_c t$$

$$+\frac{U_{BB}^4}{24U_T^4}+\frac{4U_{BB}^3U_m}{24U_T^4}\cos\omega_c t+\frac{U_{BB}^2U_m^2}{8U_T^4}+\frac{3U_{BB}^2U_m^2}{24U_T^4}\cos 2\omega_c t+\frac{2U_{BB}U_m^3}{24U_T^4}\cos\omega_c t$$

$$+\frac{U_{BB}U_m^3}{24U_T^4}\cos 3\omega_c t+\frac{U_m^4}{96U_T^4}+\frac{U_m^4}{48U_T^4}\cos 2\omega_c t+\frac{U_m^4}{192U_T^4}+\frac{U_m^4}{192U_T^4}\cos 4\omega_c t\}$$

$\therefore$ 基波分量为：$\dfrac{I_{es}U_m}{24U_T^4}(24U_T^3+24U_T^2U_{BB}+12U_T^2U_{BB}^2$

$+3U_m^2U_T+3U_m^2U_{BB}+4U_{BB}^3)$

二次谐波为：$\dfrac{I_{es}U_m^2}{48U_T^4}(12U_T^2+12U_TU_{BB}+6U_{BB}^2+U_m^2)$

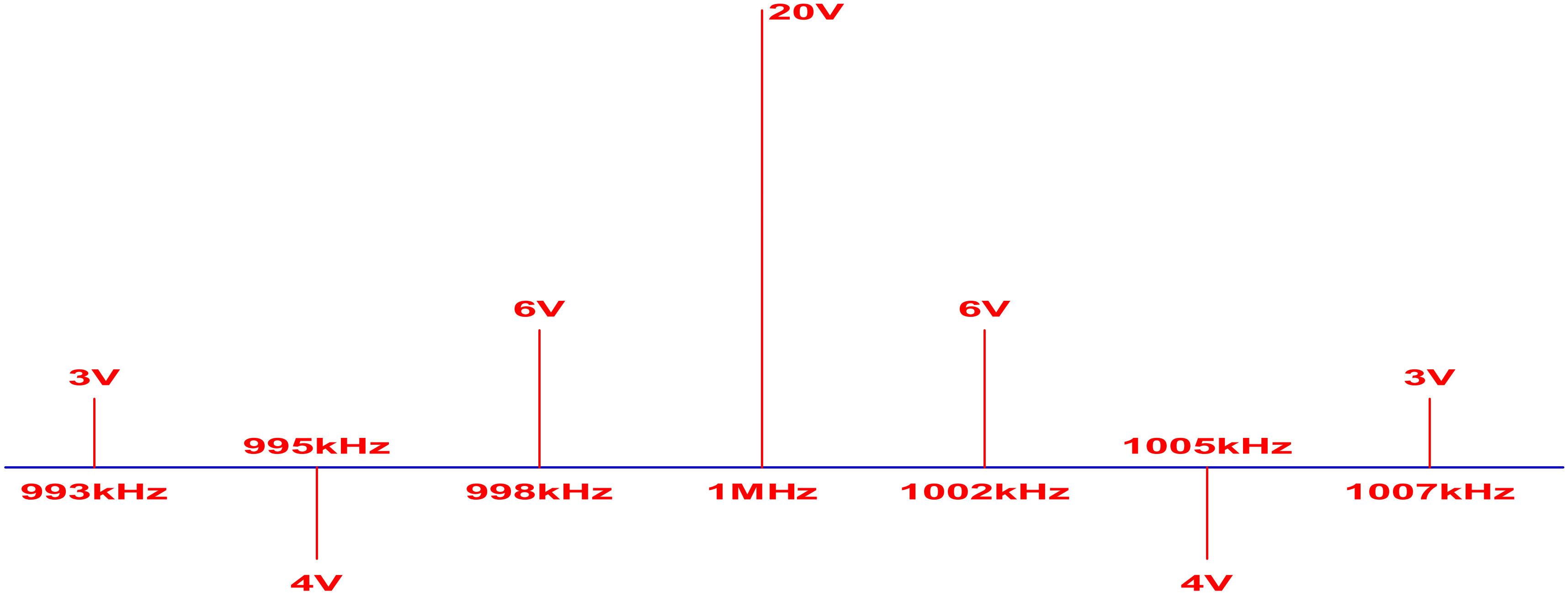
三次谐波为：$\dfrac{I_{es}U_m^3U_{BB}}{24U_T^4}$，四次谐波为：$\dfrac{I_{es}U_m^4}{192U_T^4}$

第 6 章

6.1 解：（1）频率分量

1002 kHz，998 kHz	振幅	**6V，6V**
1005 kHz，995 kHz		**4V，4V**
1007 kHz，993 kHz		**3V，3V**
1000 kHz		**20V**

（2）频谱图如图所示，BW = 2 x 7k = 14k



SCU

（3）设在R=1Ω上的功率情况为：

$$载波功率=\frac{20^2}{2}=200\text{W},$$

$$边带功率=(\frac{6^2}{2}+\frac{4^2}{2}+\frac{3^2}{2})\times 2=61\text{W}$$

$$总功率=200+61=261\text{W}$$

$$功率利用率=\frac{61}{261}\approx 0.23\approx 23\%$$

SCU

6.2 解：载波振幅

$$U_{cm}=\frac{U_{\max}+U_{\min}}{2}=\frac{12+4}{2}=8\text{V}$$

边频振幅各为

$$\frac{M_a U_{cm}}{2}=\frac{0.5\times 8}{2}=2\text{V}$$

调幅指数

$$M_a=\frac{U_{\max}-U_{\min}}{U_{\max}+U_{\min}}=\frac{12-4}{12+4}=0.5$$

6.3 解：边带功率：$P_{SB}=\frac{1}{2}M_a^2P_C=4W$

总输出平均功率：$P_{av}=P_{SB}+P_C=54W$

$$\left(P_D+P_\Omega\right)\times 50\%=P_{av}\Rightarrow P_D+P_\Omega=108W$$

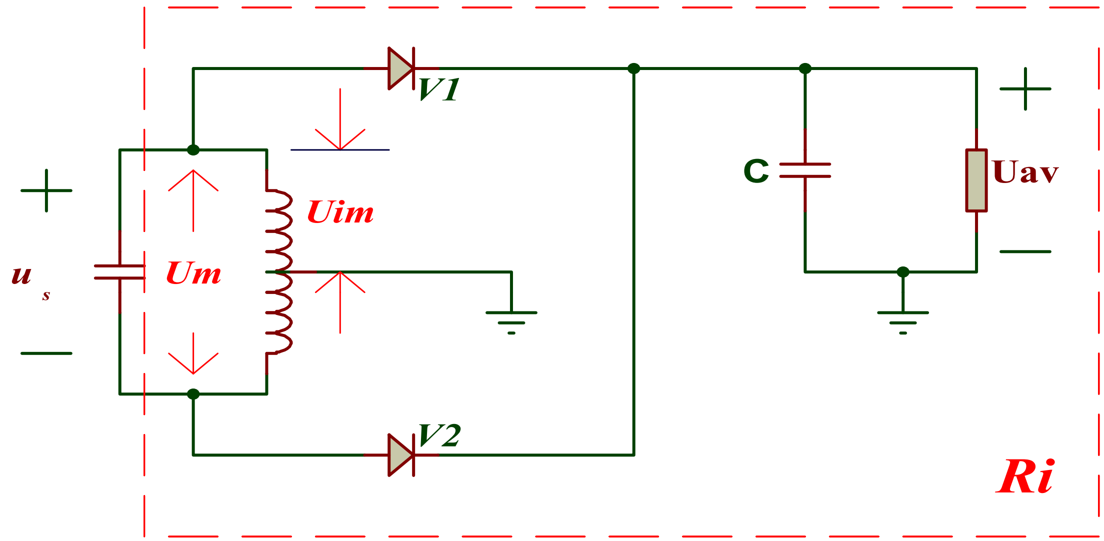
调制信号产生的交流功率：

$$P_\Omega=P_D\cdot\frac{Ma^2}{2}=8\mathrm{W}$$

直流电源提供的平均功率：

$$P_D=100\mathrm{W}$$

6.4解：



$$u_s = U_m \cos\omega_c t$$

当 $u_s = U_m$ 时 和 $u_s = -U_m$ 时，

所以两管分别导通，且每管输入均为

$$\frac{U_m}{2}\cos\omega_c t$$

SCU

① $\because U_{AV} \approx \frac{1}{2} U_m, \quad \therefore \eta_d = \frac{U_{AV}}{U_m} = \frac{1}{2}$

② $\because i \approx I_{AV}(1 + 2\cos\omega_c t + 2\cos 2\omega_c t + \cdots)$

$$\therefore I_{1m} = 2I_{AV}$$

∵正、负半周均有电流流向负载 $R_L C$

∴负载平均电流即为：

$$\boldsymbol{I'_{AV} = 2I_{AV} = I_{1m}}$$

$$\therefore \boldsymbol{R_i = \frac{U_m}{I_{1m}} = \frac{2U_{AV}}{I'_{AV}} = 2R_L} \qquad \boldsymbol{(R_L = \frac{U_{AV}}{I'_{AV}})}$$

SCU

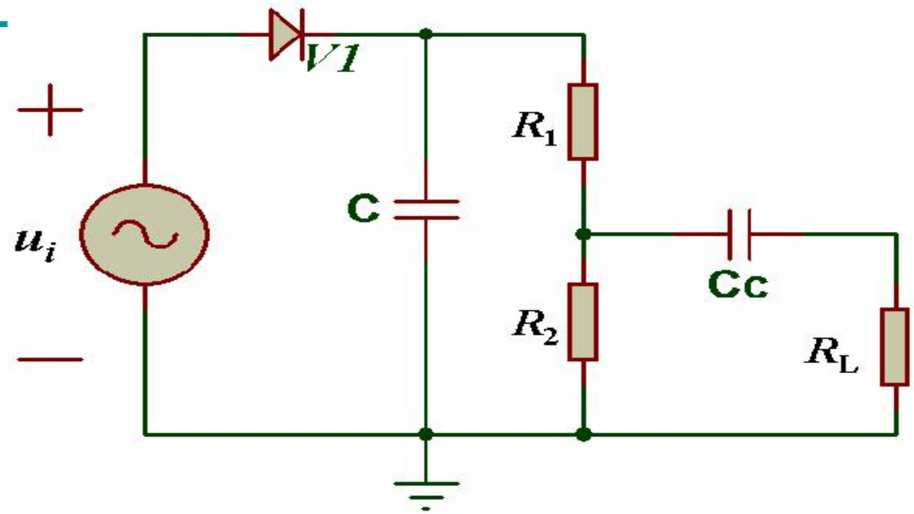
6.5 解：（1）当 $u_r \neq 0$ 时，$\boldsymbol{u_r}$则应是大信号。对于（***a***）图，在正半周时，**V_1、V_2**导通，由于叠加在其上的 $\frac{1}{2}u_s$ 与 $-\frac{1}{2}u_s$ 反相，因此**u_o**为直流，不能同步检波。对于（***b***）图。两检波器输出迭加，故能同步检波。

（2）当 $u_r = 0$ 时，u_s 应是大信号。

对于（**a**）图，两个检波器输出相同，叠加后电流加倍，故能检波。对于（**b**）图，$u_{01}=u_{02}$，$u_0=0$，故不能检波。

SCU

6.6 解：



$$\omega_c = 2\pi f_c = 2\pi \times 4.7 \times 10^6 = 2.952 \times 10^7$$

要避免惰性失真，必须满足

$$\frac{5 \sim 10}{\omega_c} \le RC \le \frac{\sqrt{1-M_a^2}}{M_a \Omega_{\max}},$$

即

$$\frac{5 \sim 10}{R\omega_c} \le C \le \frac{\sqrt{1-M_a^2}}{M_a \Omega_{\max} R}$$

SCU

$$\because R = R_1 + R_2 = 5\mathrm{k\Omega}$$

$$\therefore (5 \sim 10) \times 6.8 \times 10^{-12} \le C \le 4.78 \times 10^{-9} \quad (\mathrm{F})$$

要避免底部切割失真，必须满足

$$M_{a\max} \le \frac{R'}{R} = \frac{R_1 + \dfrac{R_2 R_L}{R_2 + R_L}}{R}$$

即

$$R_L \ge \frac{R_2 (M_{a\max} R - R_1)}{R(1 - M_{a\max})} = 12\mathrm{k\Omega}$$

SCU

6.7 解：（1）当接触点在中心位置时，直流电阻

$$R = 0.51 + 2.35 = 2.86\text{k}\Omega$$

交流电阻 $R' = 0.51 + 2.35 // 1 = 1.21\text{k}\Omega$

所以不产生底部切割失真的条件是

$$M_a < \frac{1.21}{2.86} = 0.42$$

由于实际调制度为**0.3**，因此不会产生底部切割失真。

（2）当接触点在最高位置时，

$$R = 0.51 + 4.7 = 5.21\text{k}\Omega$$

$$R' = 0.51 + 4.7 // 1 = 1.33\text{k}\Omega$$

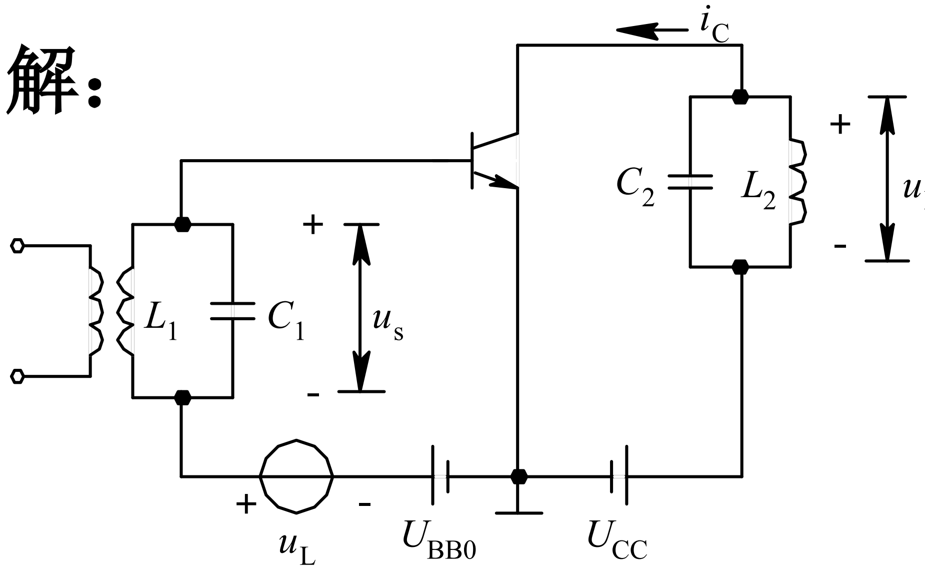
所以不产生底部切割失真的条件是

$$M_a < \frac{1.33}{5.21} = 0.26$$

所以会产生底部切割失真。

SCU

6.8 解：



$$g(t)=\frac{\partial f(u_{BE})}{\partial u_{BE}}\bigg|_{u_{BE}=U_{BB}(t)}=\frac{1}{U_T}I_{es}e^{\frac{U_{BB}(t)}{U_T}}$$

$$\therefore g_c=\frac{1}{2}g_1=\frac{1}{2\pi}\int_{-\pi}^{\pi}\frac{1}{U_T}I_{es}e^{\frac{U_{BB}(t)}{U_T}}\cos\omega_L t d\omega_L t$$

$$=\frac{I_{es}}{U_T}e^{\frac{U_{BB0}}{U_T}}\cdot\frac{1}{2\pi}\int_{-\pi}^{\pi}e^{\frac{U_L}{U_T}}\cos\omega_L t d\omega_L t$$

其中$e^{\frac{u_L}{U_T}}\approx 1+\frac{u_L}{U_T}+\frac{1}{2}\left(\frac{u_L}{U_T}\right)^2+\frac{1}{6}\left(\frac{u_L}{U_T}\right)^3$

SCU

代入后积分，有

$$\int_{-\pi}^{\pi} \cos\omega_L t d\omega_L t = 0$$

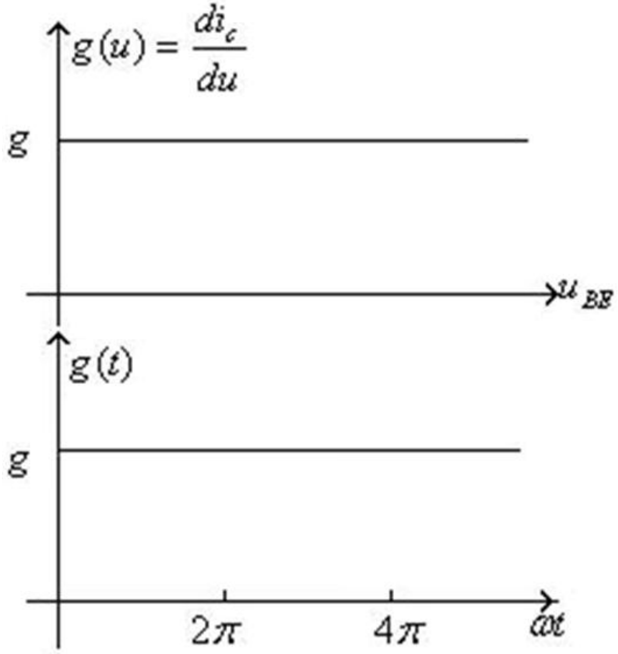
$$\int_{-\pi}^{\pi} \cos^2 \omega_L t d\omega_L t = \pi$$

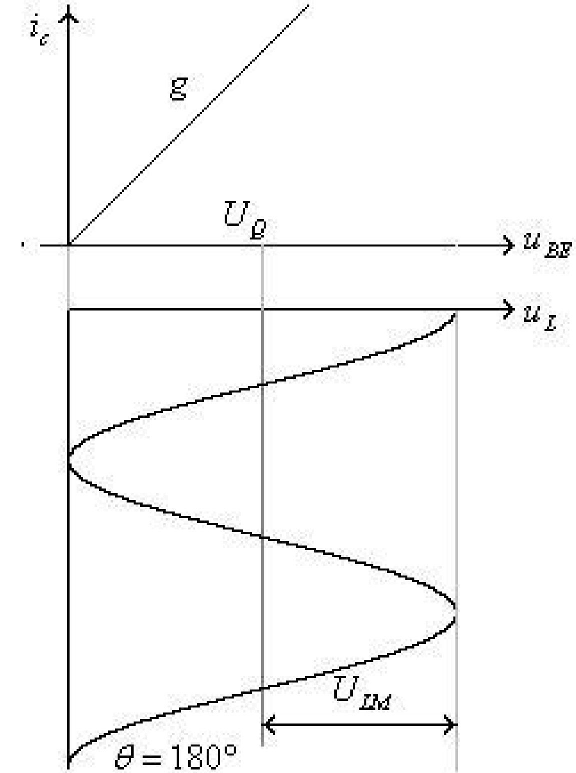
$$\int_{-\pi}^{\pi} \cos^3 \omega_L t d\omega_L t = 0$$

$$\int_{-\pi}^{\pi} \cos^4 \omega_L t d\omega_L t = \frac{3}{4}\pi$$

所以 $g_c = \frac{I_{es} U_{LM}}{2U_T^2} e^{\frac{U_{BB0}}{U_T}} (1 + \frac{U_{LM}^2}{8U_T^2})$

6.9 解：（1）



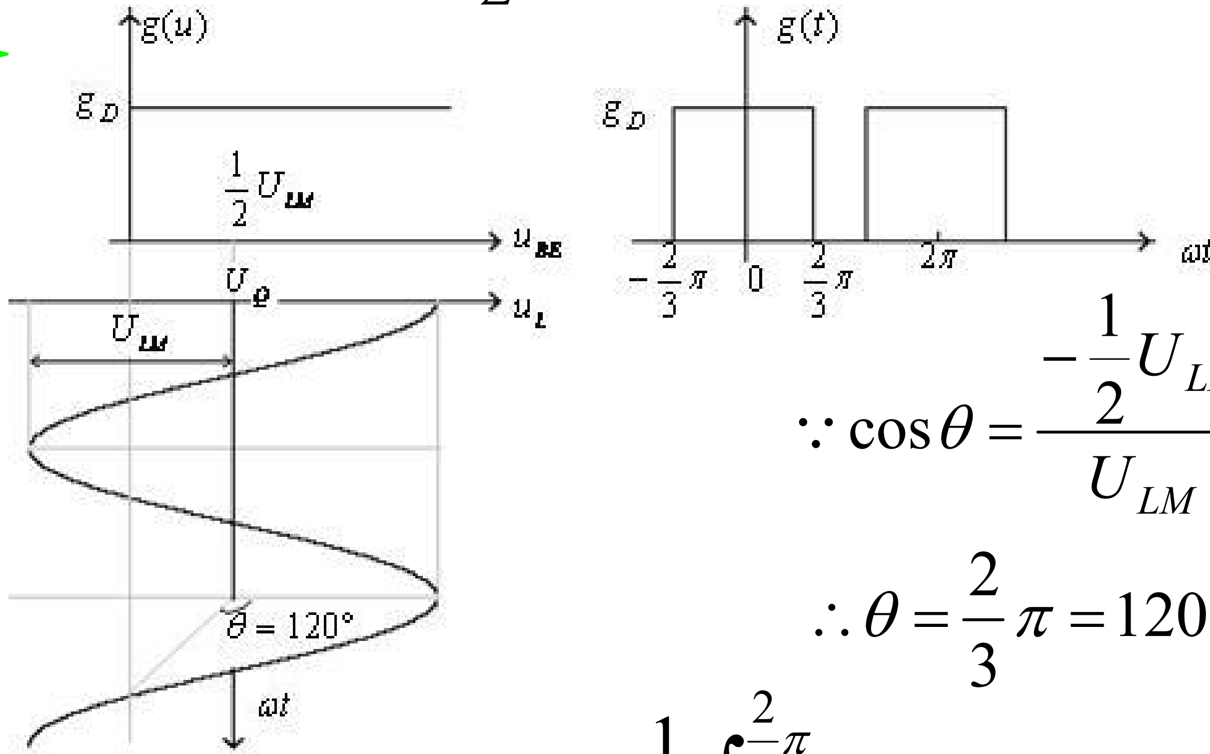


（1）当 $U_Q=U_{LM}$ 时，$g(t)$波形如图所示

$$g_c=\frac{1}{\pi}\int_0^{\pi}g_D\cos\omega_L t d\omega_L t=0$$

SCU

（2）当 $U_Q=\frac{1}{2}U_{LM}$ 时，$g(t)$ 波形如图所示



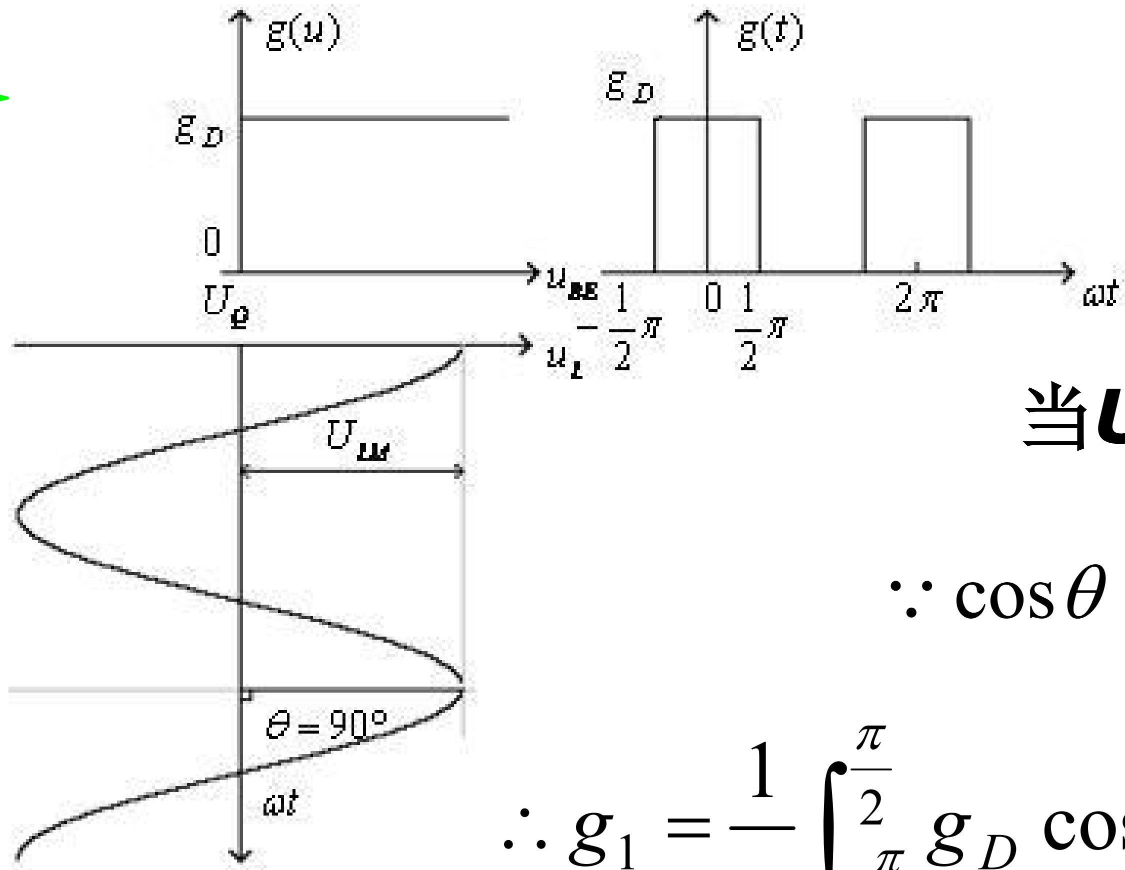
$$\because \cos\theta=\frac{-\frac{1}{2}U_{LM}}{U_{LM}}=-\frac{1}{2}$$

$$\therefore \theta=\frac{2}{3}\pi=120^{\circ}$$

$$\therefore g_1=\frac{1}{\pi}\int_{-\frac{2}{3}\pi}^{\frac{2}{3}\pi}g_D\cos\omega t\,d\omega t=\frac{\sqrt{3}}{\pi}g_D$$

$$\therefore g_c=\frac{1}{2}g_1=\frac{\sqrt{3}}{2\pi}g_D$$

（3） *g(t)*波形如图所示。



当U_Q=0时，

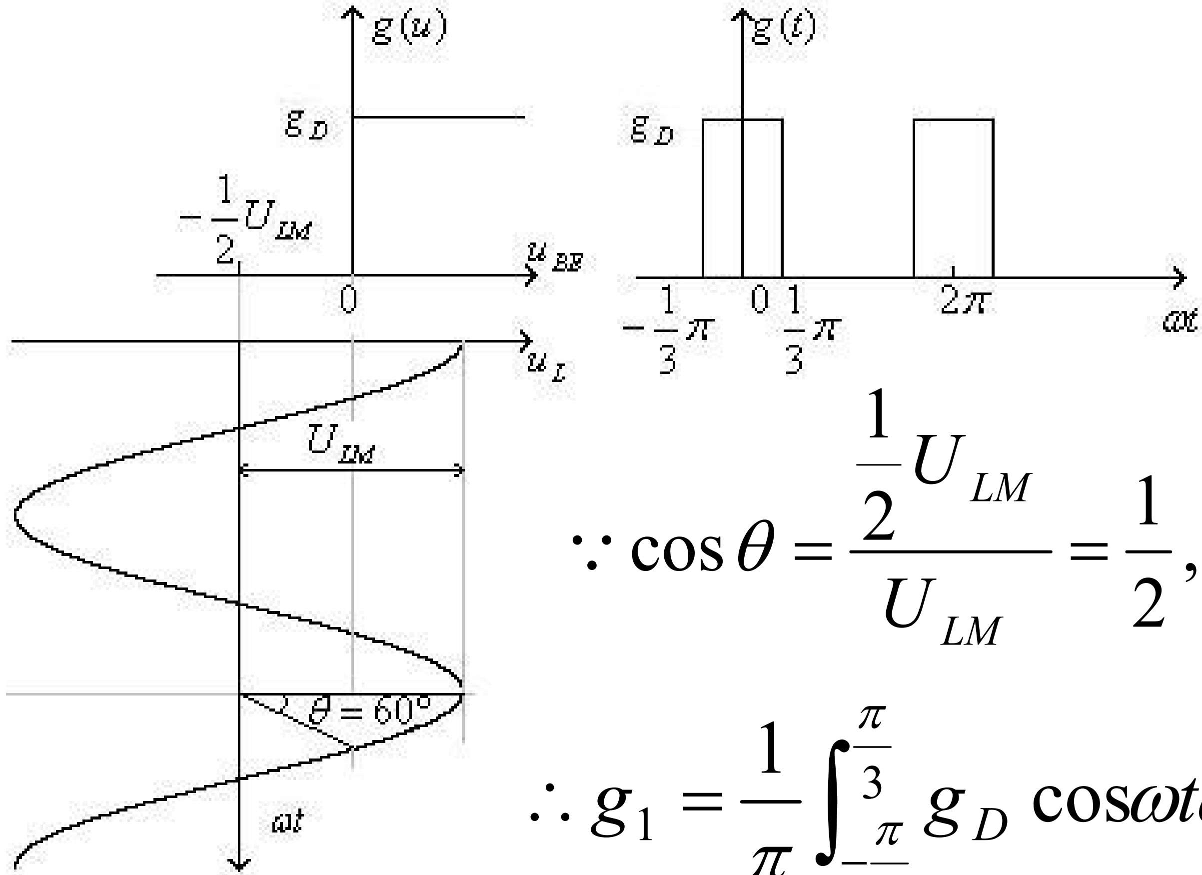
$$\because \cos\theta = 0, \therefore \theta = \frac{\pi}{2}$$

$$\therefore g_1 = \frac{1}{\pi}\int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} g_D \cos\omega t d\omega t = \frac{2g_D}{\pi}$$

$$\therefore g_c = \frac{1}{2}g_1 = \frac{g_D}{\pi}$$

SCU

（4）当 $U_Q=-\frac{1}{2}U_{LM}$ 时,*g(t)*波形如图所示。



$$\because \cos\theta=\frac{\frac{1}{2}U_{LM}}{U_{LM}}=\frac{1}{2},\therefore \theta=\frac{\pi}{3}$$

$$\therefore g_1=\frac{1}{\pi}\int_{-\frac{\pi}{3}}^{\frac{\pi}{3}} g_D\cos\omega t\, d\omega t=\frac{\sqrt{3}}{\pi}g_D$$

$$\therefore g_c=\frac{1}{2}g_1=\frac{\sqrt{3}}{2\pi}g_D$$

6.10解：（a）正半周两回路导通，次级感应电流互相抵消，负半周两回路截止。不能实现调幅。

(b)正负半周两回路分别导通，在次级的感应电流分别为：

$$i_1 = (u_c + u_\Omega) g K_1(\omega_c t), i_2 = -(u_c + u_\Omega) g K_1(\omega_c t - \pi)$$

$$\therefore i = i_1 + i_2 = (u_c + u_\Omega) g K_2(\omega_c t)$$

其频率分量为 $p\omega_c \pm q\Omega$ 。

（当时 $q=0$， $p=0,2,4,\cdots$ ；当 $q=1$时， $p=1,3,5,\cdots$）

所以可以实现双边带调幅 。

（c）图正半周与负半周分别导通

$$i_1=(u_c+u_\Omega)gK_1(\omega_c t),$$

$$i_2=-(u_c-u_\Omega)gK_1(\omega_c t-\pi)$$

$$\therefore \boldsymbol{i}=\boldsymbol{i}_1-\boldsymbol{i}_2=\boldsymbol{g}\boldsymbol{u}_c+\boldsymbol{u}_\Omega\boldsymbol{K}_2\left(\boldsymbol{\omega t}\right)$$

其频率分量为：

$$\omega_c\,,\omega_c\pm\Omega\,,3\omega_c\pm\Omega\,,5\omega_c\pm\Omega\cdots$$

所以不能实现双边带调幅，但可作普通调幅。

（d）图正半周两回路导通，负半周两回路截止。

正半周时：

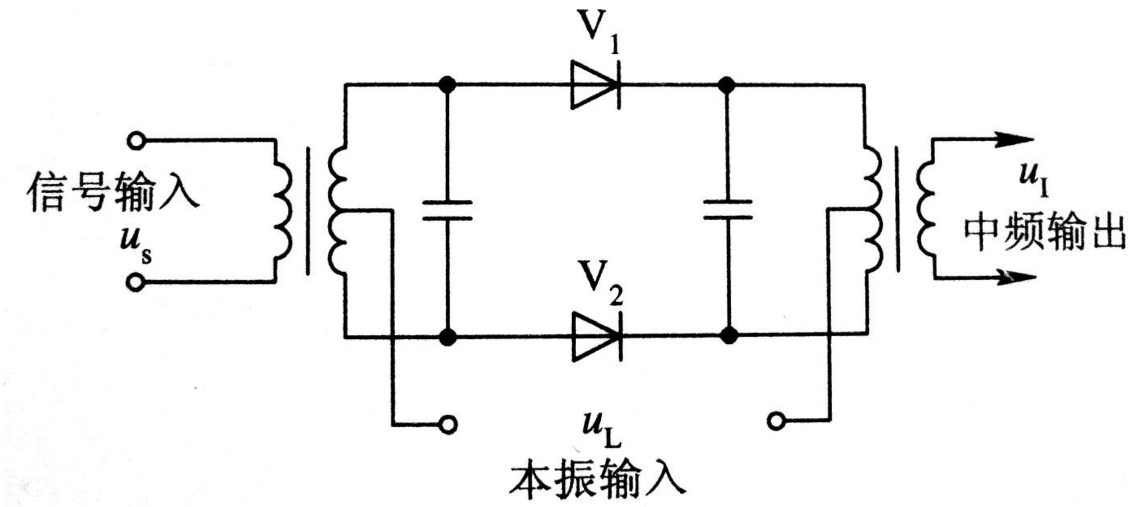
$$i_1 = (u_c + u_\Omega) g K_1(\omega_c t)$$

$$i_2 = (u_c - u_\Omega) g K_1(\omega_c t)$$

所以 $i = i_1 + i_2 = 2u_c g K_1(\omega_c t)$

所以不能实现调幅。因为仅有载波及其谐波分量。

6.11 解：



$$u_L = U_{Lm} \cos \omega_L t$$

$$u_s = U_{sm} \cos \omega_s t$$

则：

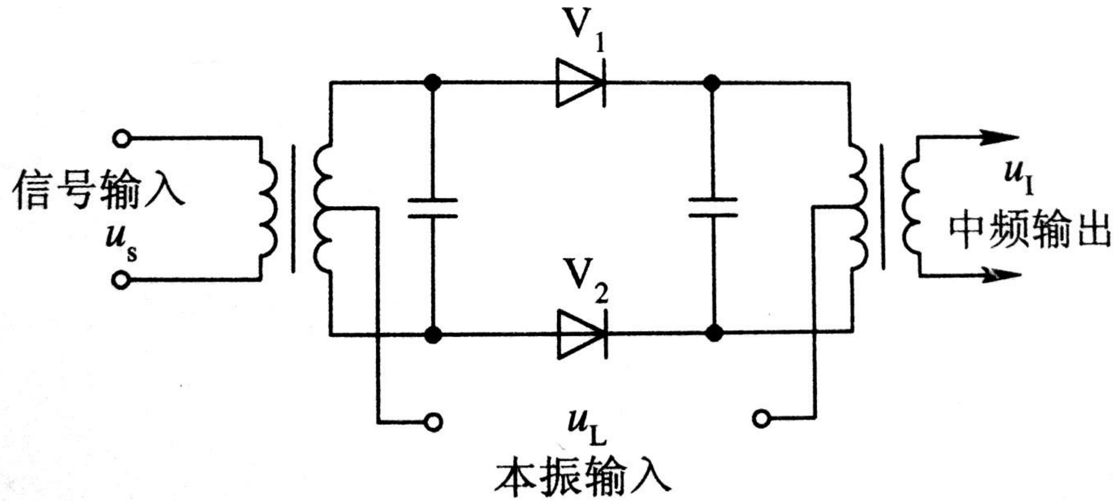
$$i_1 = g_D(u_S + u_L)K_1(\omega_L t)$$

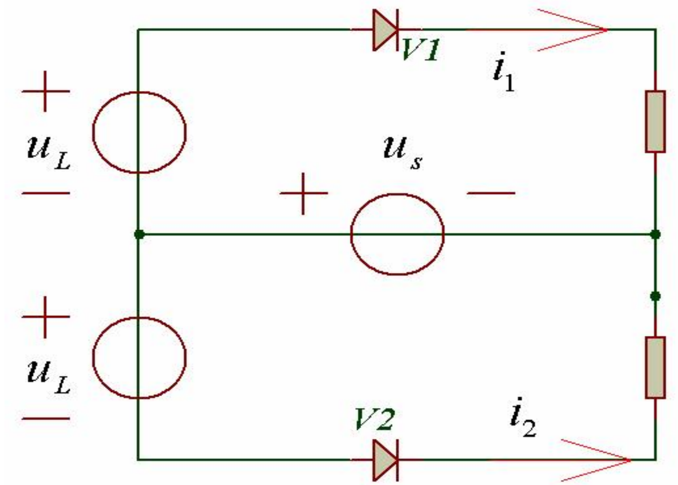
$$i_2 = g_D(-u_S + u_L)K_1(\omega_L t)$$

$$i = i_1 - i_2 = 2g_D u_S K_1(\omega_L t)$$

SCU

当将输入信号u_s与本振u_L互换位置后有：





$$i_1 = g_D(u_S + u_L)K_1(\omega_L t)$$

$$i_2 = g_D(u_S - u_L)K_1(\omega_L t - \pi)$$

$$i = i_1 - i_2 = g_D u_S\left[K_1(\omega_L t) - K_1(\omega_L t - \pi)\right]$$

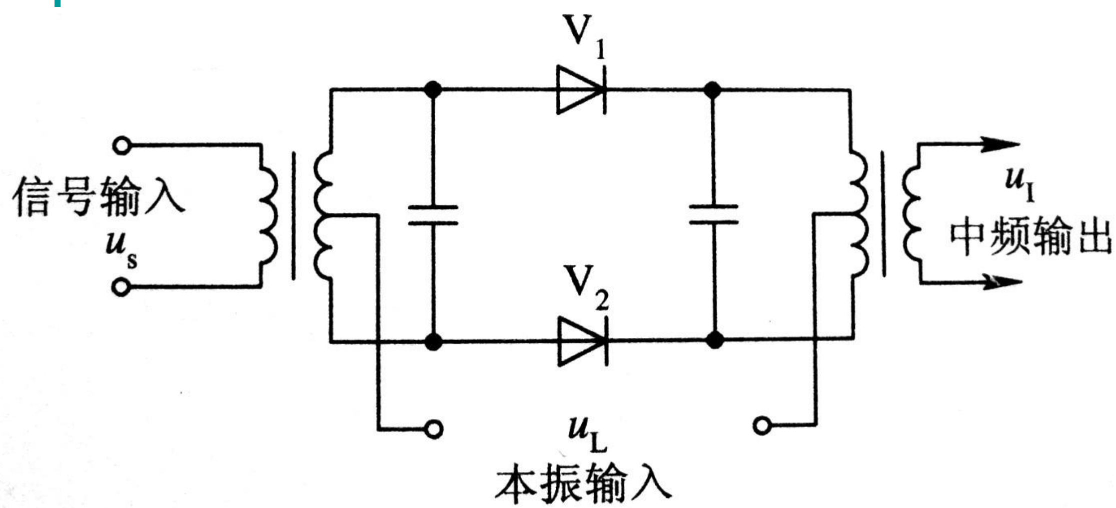
$$+ g_D u_L\left[K_1(\omega_L t) + K_1(\omega_L t - \pi)\right]$$

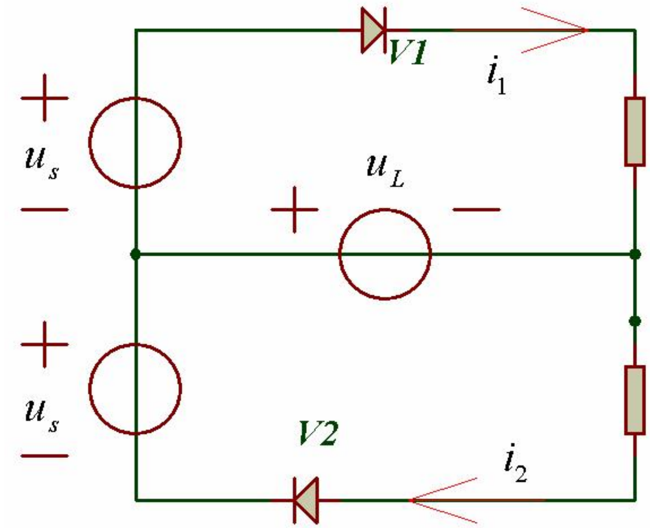
$$= g_D u_S K_2(\omega_L t) + g_D u_L$$

表达式可看出此调制为普通调幅（**AM**）

SCU

若将V_2正负极对调后：





$$i_1 = g_D(u_S + u_L)K_1(\omega_L t)$$

$$i_2 = g_D(u_S - u_L)K_1(\omega_L t - \pi)$$

$$i = i_1 + i_2 = g_D u_S\left[K_1(\omega_L t) + K_1(\omega_L t - \pi)\right]$$

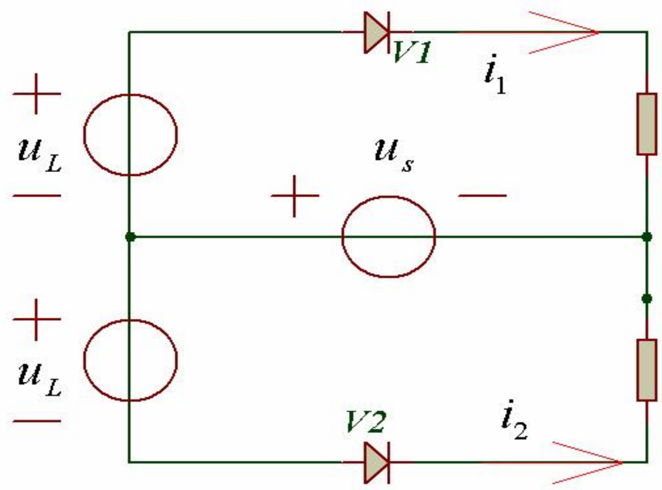
$$+ g_D u_L\left[K_1(\omega_L t) - K_1(\omega_L t - \pi)\right]$$

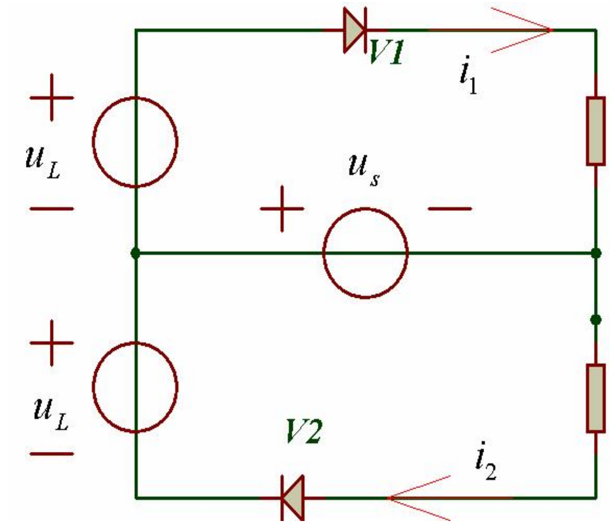
$$= g_D u_L K_2(\omega_L t) + g_D u_S$$

上面表达式可看出此电路不能产生调制信号

SCU

若将V_2正负极对调后：





$$i_1 = g_D(u_S + u_L)K_1(\omega_L t)$$

$$i_2 = g_D(-u_S + u_L)K_1(\omega_L t)$$

$$i = i_1 + i_2 = 2g_D u_L K_1(\omega_L t)$$

上面表达式可看出此电路不能产生调制信号

SCU

6.12 解：（1）是干扰哨声。

根据 $|pf_L \pm qf_c| = f_I \pm F$

其中，$f_c = 931kHz, f_I = 465kHz, F = 1kHz$

即由p=1, q=2的组合分量产生。

（2）由于接收干扰频率为1480kHz，且 $f_c = 550\text{kHz}$,

$f_I = 465\text{kHz},\ f_L = 1015\text{kHz}$ ，因此可知是镜频干扰。

（3）由于接收干扰频率为740kHz，

$$f_c = 1480\mathbf{kHz}, f_I = 465\mathbf{kHz}, f_L = 1945\mathbf{kHz},$$

可知这是寄生通道干扰，而且是p=1, r=2时产生的。

6.13 解： 能够产生寄生通道干扰的单个外来干扰频率f_{n1}需满足

$$pf_L - rf_{n1} = f_I, \quad -pf_L + rf_{n1} = f_I \qquad f_L - f_c = f_I$$

由题意可知，f_{n1}**=700kHz,** f_I**=465kHz** （因为此处**700kHz**电台是作为外来干扰源在其它接收频段内产生寄生通道干扰。）当p**=1,**r**=2**时:

$$f_c = 2f_{n1} = 2\times 700 = 1400\mathbf{kHz}$$

当p**=1,**r**=3**时： $f_c = 1170kHz$

当p**=2,**r**=3**时： $f_c = 817.5kHz$

当p**=2,**r**=4**时： $f_c = 1167.5kHz$

所以，在 **1400 kHz**、**1170 kHz**两处能接收到**700 kHz**干扰源产生的寄生通道干扰，即听到这个电台的播音，当然播音强度较弱。

6.14 解：镜频范围4135～5205，

不会产生镜频干扰。

$$f_{L1} = 2335\text{kHz} \sim 3405\text{kHz},$$

$$f_{L2} = 2265\text{kHz}$$

SCU

6.15 解：

$$n_g = \frac{m_i}{m_0} = \frac{10000}{1/0.8} = 8000 = 78\text{dB}$$

6.16 解：

$$\because \boldsymbol{u}_c = \boldsymbol{k}_1\boldsymbol{\eta}_d\boldsymbol{U}_y - \boldsymbol{U}_R = \boldsymbol{k}_1\boldsymbol{u}_y - \boldsymbol{U}_R$$

$$u_y = \left[A_g\left(u_c\right)\right]^3 u_x$$

$$\therefore \boldsymbol{u}_y = \left[\frac{20}{1+2\boldsymbol{u}_c}\right]^3 \boldsymbol{u}_x = \left[\frac{20}{1+2\left(\boldsymbol{k}_1\boldsymbol{u}_y - \boldsymbol{U}_R\right)}\right]^3 \boldsymbol{u}_X$$

SCU

6.16 解：

$$\because \boldsymbol{u_c = k_1 \eta_d U_y - U_R = k_1 u_y - U_R}$$

$$u_y = \left[A_g\left(u_c\right)\right]^3 u_x$$

$$\therefore \boldsymbol{u_y} = \left[\frac{20}{1+2\boldsymbol{u_c}}\right]^3 \boldsymbol{u_x} = \left[\frac{20}{1+2\left(\boldsymbol{k_1 u_y - U_R}\right)}\right]^3 \boldsymbol{u_X}$$

① 在上式中代入 $\boldsymbol{U_{y\min} = 1\text{V}, U_{x\min} = 125\mu\text{V}}$,

可以求得： $k_1 = U_R$

② $\because \boldsymbol{U_{y\max} = 3V, U_{x\min} = 0.25V}$

$$\therefore \boldsymbol{U_R \approx 1.94\text{V}}$$

第7章

7.1 解： （注意角频率积分得到相位）

$$\because u_{\Omega}(t)=1.5\cos 2\pi\times 10^{3}t+0.5\cos 2\pi\times 2\times 10^{3}t$$

$$u_c(t)=5\cos 2\pi\times 10^{8}t\mathrm{V},\Delta f/1\mathrm{V}=4\mathrm{kHz/V}，\ \Delta\phi/\mathrm{V}=0.2\mathrm{rad/V}$$

$$\therefore k_f=2\pi\times 4\times 10^{3}\mathrm{rad/s\cdot V},\ \ k_p=0.2\mathrm{rad/V}$$

$$\therefore u_{\mathrm{FM}}(t)=5\cos(2\pi\times 10^{8}t+6\sin 2\pi\times 10^{3}t+\sin 2\pi\times 2\times 10^{3}t)\mathrm{V}$$

$$\therefore u_{\mathrm{PM}}(t)=5\cos(2\pi\times 10^{8}t+0.3\cos 2\pi\times 10^{3}t+0.1\cos 2\pi\times 2\times 10^{3}t)\mathrm{V}$$

SCU

7.2 解：

$$u(t)=10\cos(2\pi\times10^{8}t+\cos4\pi\times10^{3}t)\mathrm{V}$$

若*u*(*t*)是FM信号或者PM信号，均有

$$f_c=100\mathrm{MHz}，\ F=2\mathrm{kHz},\mathrm{M}=1\mathrm{rad},\Delta\mathrm{f}_\mathrm{m}=2\mathrm{kHz}$$

SCU

7.3 解：（1）振幅不变，*F*加大一倍，则 Δf_{m} **不变，BW略增加**

$$因为\Delta f_m = \frac{k_f U_{\Omega m}}{2\pi}，所以\Delta f_{\mathrm{m}} \propto U_{\Omega\mathrm{m}}与\mathbf{F}无关$$

$$因为BW = 2(\Delta f_m + F),所以BW与F有关。$$

（2）*F*不变, $U_{\Omega m}$ **增加一倍，则** Δf_m **增加一倍,*BW*也增加, 原因同（1）。**

（3） $U_{\Omega m}$ **与 *F*都加大一倍，则** Δf_m **增大一倍,*BW*也增大一倍,原因同（1）。**

SCU

7.4 解：

	频谱结构	带宽
AM	若 F 大小改变，则谱线数目不变。因为谱线数目仅与 F 的数目有关，与其大小无关。	若 F 增大，BW 也增大。因为 $BW=2F$，谱线间距增加。
FM	若 F 增大，则 M_f 减小，旁频数也就减少。因为 $M_f=\dfrac{k_f U_{\Omega m}}{2\pi F}$	若 F 增大，BW 略有增大。因 $BW\approx 2(M_F+1)F=\dfrac{k_f U_{\Omega m}}{\pi}+2F$
PM	因 $M_p=k_p U_{\Omega m}$，故 M_p 与 F 无关。只要 M_p 不变，则频谱线数目也不变。	若 F 增大，则 BW 增大，因 $BW=2(M_p+1)F$

7.5 解：（1）FM：

$$\Delta f_m = M_f F = 1.5\text{kHz}, BW = 2(M_f + 1)F = 4\text{kHz}$$

PM：

$$\Delta f_m = M_p F = 1.5\text{kHz}, BW = 2(M_p + 1)F = 4\text{kHz}$$

SCU

（2）FM：

$$\because \Delta f_m = k_f U_{\Omega m}, \text{又} k_f，U_{\Omega m} \text{不变}, \therefore \Delta f_m \text{不变，仍为} 1.5\text{kHz}$$

$$M_f = \frac{\Delta f_m}{F} = 1.5\text{rad}, BW = 2(1.5+1)\times 1 = 5\text{kHz}$$

PM：

$$\because M_P = k_p U_{\Omega m}, \text{又} k_p，U_{\Omega m} \text{不变}, \therefore M_p \text{不变，仍为} 3\text{rad}$$

$$\Delta f_m = M_p F = 3\text{kHz}, BW = 2\times 4\times 1 = 8\text{kHz}$$

SCU

（3）FM：

$\because \Delta f_m = k_f U_{\Omega m}, U_{\Omega m}$降为一半，$\therefore \Delta f_m$也降为一半，为0.75kHz

$$M_f = \frac{\Delta f_m}{F} = 1.5\mathrm{rad}, BW = 2\times 2.5\times 0.5 = 2.5\mathrm{kHz}$$

PM： 因为$M_P = k_p U_{\Omega m}$=1.5rad,

$$\Delta f_m = M_p F = 1.5\times 0.5 = 0.75\mathrm{kHz}$$

$$BW = 2\times 2.5\times 0.5 = 2.5\mathrm{kHz}$$

SCU

7.6 解：

$$因为BW = 2（M_f + 1）F = 2(\Delta f_m + F)$$

所以$F = 300\text{Hz}, 1\text{kHz}, 3\text{kHz}, 10\text{kHz}$ **时的带宽分别是：**

100.6kHz，102kHz，106kHz，120kHz。

SCU

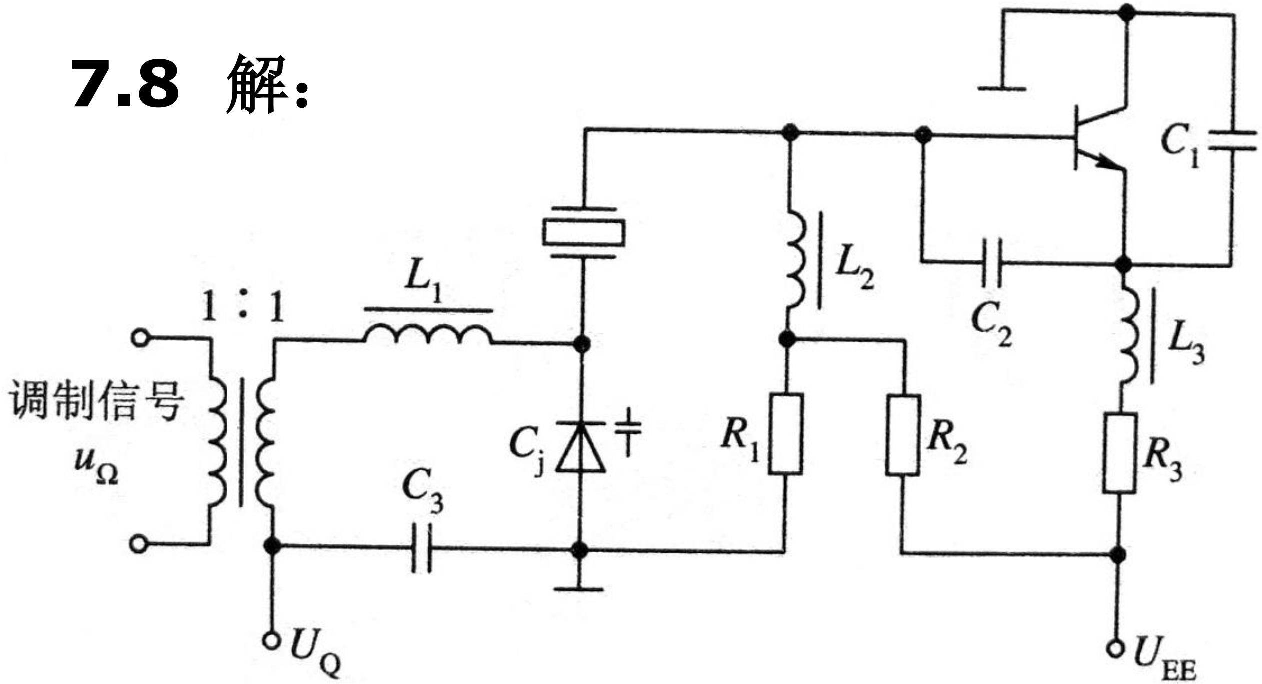
7.7 解：小信号谐振放大器：目的→选频；性能→带宽，矩形系数。

振荡器：目的→选频；性能→频率准确度。

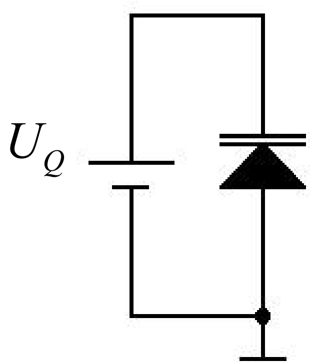
斜率鉴频器：目的→频幅转换；性能→转换线性范围，灵敏度，非线性失真。

相位鉴频器：目的→频相转换；性能→转换线性范围，灵敏度，非线性失真。

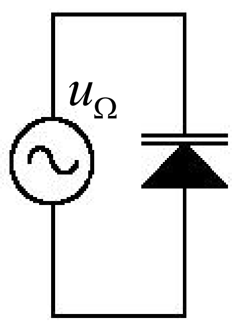
7.8 解：



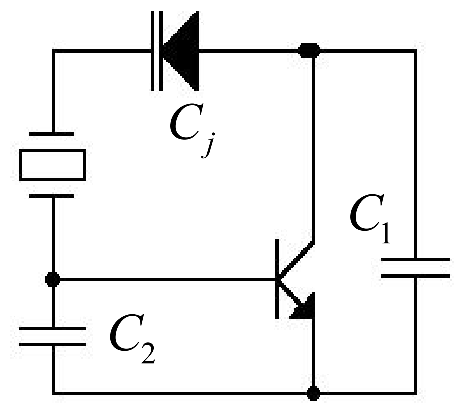
（1）等效电路如题图所示



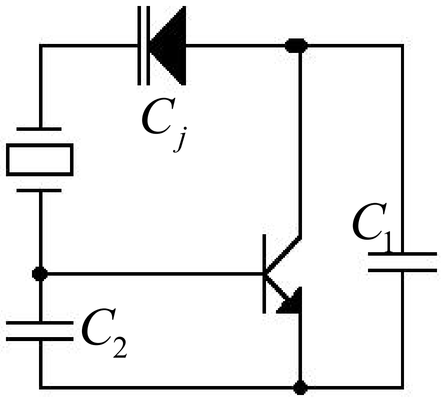
（变容二极管直流通路）

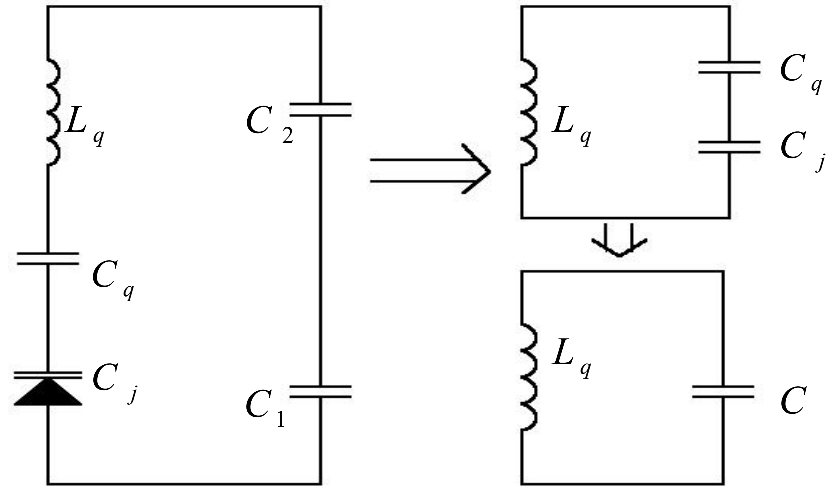


（变容二极管低频通路）



（高频等效电路）





（2） 因为$C_q << C_1$，$C_q << C_2$，所以C_1串C_2串$C_q \approx C_q$

所以

$$\therefore C = C_q\text{串}C_j \approx C_q\text{串}C_{jQ} = \frac{C_q C_{jQ}}{C_q + C_{jQ}} = \frac{C_{jQ}}{1+\dfrac{C_{jQ}}{C_q}}$$

$$= \frac{1}{501} C_{jQ}(\text{利用了}\frac{C_q}{C_{jQ}} = 2\times 10^{-3})$$

$$C=\frac{1}{501}C_{jQ}$$

$$\Delta f_m=\frac{n}{2}mpf_c=\frac{n}{2\times 501}\cdot\frac{U_{\Omega m}}{U_B+U_Q}\cdot f_c$$

$$=\frac{1}{501}\cdot\frac{1.5}{0.6+2}\times 10^7=11.52\text{kHz}$$

注：此题中变容二极管是部分接入，且 $C_j >> C_q$ ，所以接入系数很小，变容二极管对于谐振回路产生的最大频偏也大大减小。

SCU

7.9 解：①振荡器的高频交流等效电路如图所示.

② $\because f_0 = \dfrac{1}{2\pi\sqrt{LC_\Sigma}}$， $\therefore C_\Sigma = \dfrac{1}{L(2\pi f_0)^2} \approx 203\text{pF}$

$$\because C_\Sigma = (350\text{pF}串350\text{pF}) \| (C_{\text{j1}Q}串C_{\text{j2}Q})$$

$$\therefore C_{\text{j1}Q} = C_{\text{j2}Q} \approx 56\text{pF} = C_{jQ}$$

$$\because C_j = 100(U_Q + u_\Omega)^{-\frac{1}{2}}$$

$$\therefore C_{jQ} = 100U_Q^{-\frac{1}{2}} \quad (u_\Omega = 0)$$

$$\therefore U_Q^{-\frac{1}{2}} = \frac{C_{jQ}}{100} = \frac{56}{100} = 0.56$$

$$\therefore U_Q = \frac{1}{0.56^2} = 3.19\text{V}$$

SCU

（3）$\Delta f_m = M_f F = 5\times 10 = 50\text{kHz}$

$$\therefore f_{0\max} = 5.05MHz，\ f_{0\min} = 4.95MHz$$

$$\therefore C_{\Sigma\min} = \frac{1}{L(2\pi\times f_{0\max})^2} = \frac{1}{5\times 10^{-6}\times(2\pi\times 5.05\times 10^6)^2} \approx 199\text{pF}$$

$$\therefore C_{\Sigma\max} = \frac{1}{L\left(2\pi\times f_{0\min}\right)^2} = \frac{1}{5\times 10^{-6}\times\left(2\pi\times 4.95\times 10^6\right)^2} \approx 207pF$$

$$\because C_{\Sigma\min} = (350\text{p串}350\text{p}) + (C_{j\min}\text{串}C_{j\min})$$

$$\because C_{\Sigma\max} = \left(350p\text{串}350p\right) + \left(C_{j\max}\text{串}C_{j\max}\right)$$

$$\therefore C_{j\min} = (199-175)\times 2 = 48\text{pF}$$

$$\therefore C_{j\max} = \left(207-175\right)\times 2 = 64pF$$

$$\because C_{j\min} = 100(U_Q + U_{\Omega m})^{-\frac{1}{2}}$$

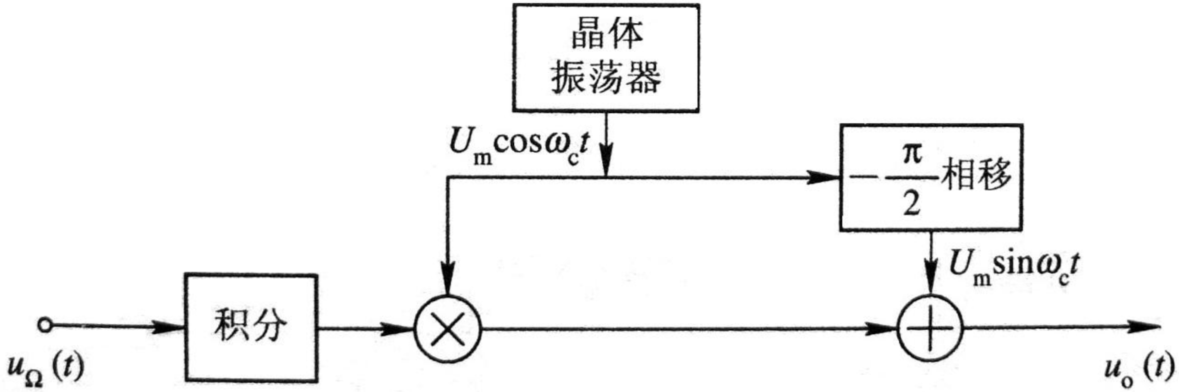
$$\because C_{j\max} = 100\left(U_Q - U_{\Omega m}\right)^{-\frac{1}{2}}$$

$$\therefore U_{\Omega m} = \left(\frac{100}{C_{j\min}}\right)^2 - U_Q = \left(\frac{100}{48}\right)^2 - 3.19 = 1.15\text{V}$$

$$\therefore U_{\Omega m} = U_Q - \left(\frac{100}{C_{j\max}}\right)^2 = 3.19 - \left(\frac{100}{64}\right)^2 \approx 0.75V$$

SCU

7.10 解：设载波 $U_m \sin\omega_c t$ 为，则调相波为



$$u_0 = U_m \sin(\omega_c t + \Delta\varphi) = U_m \sin\omega_c t \cdot \cos\Delta\varphi$$

$$+ U_m \sin\Delta\varphi \cdot \cos\omega_c t \approx U_m \sin\omega_c t + U_m \Delta\varphi \cdot \cos\omega_c t$$

$$(\text{当}|\Delta\varphi| \le \frac{\pi}{6}\text{时})$$

由原题图可知，式中 $\Delta\varphi = \int u_\Omega(t)\mathrm{d}t$

$$\therefore u_0(t) = U_m \cos\omega_c t \int u_\Omega(t)dt + U_m \sin\omega_c t$$

SCU

7.11 解：由原题图可知，$U_Q = 9\text{V}$, 所以

$$m = \frac{U_{\Omega m}}{U_Q + U_B} = \frac{0.1}{9+1} = 0.01$$

所以$M_p = nmQ_e = 2 \times 0.01 \times 20 = 0.4\text{rad}$

所以$\Delta f_m \approx \dfrac{n}{2} m f_0 \approx 0.01 f_0$

或$\Delta f_m \approx M_P F$

SCU

7.12 解：调相器输出调相信号的瞬时相位

$$\varphi(t)=2\pi f_{c1}t+M_p\sin 2\pi Ft$$

瞬时频率

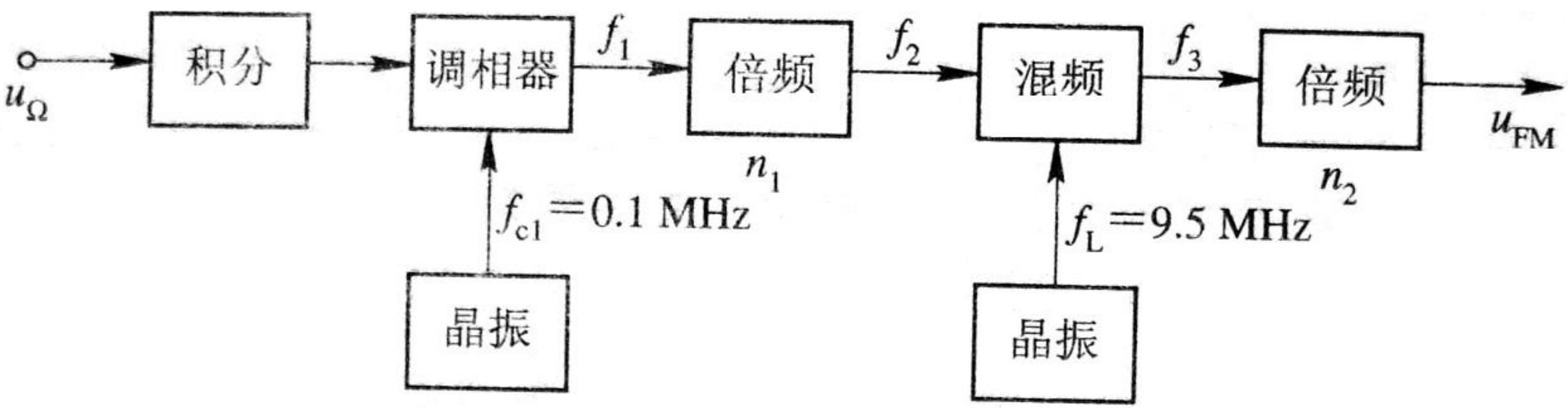
$$f_1(t)=\frac{1}{2\pi}\cdot\frac{d\varphi(t)}{dt}=f_{c1}+M_pF\cos 2\pi Ft$$

所以$f_2(t)=n_1f_1(t)=n_1(f_{c1}+M_pF\cos 2\pi Ft)$

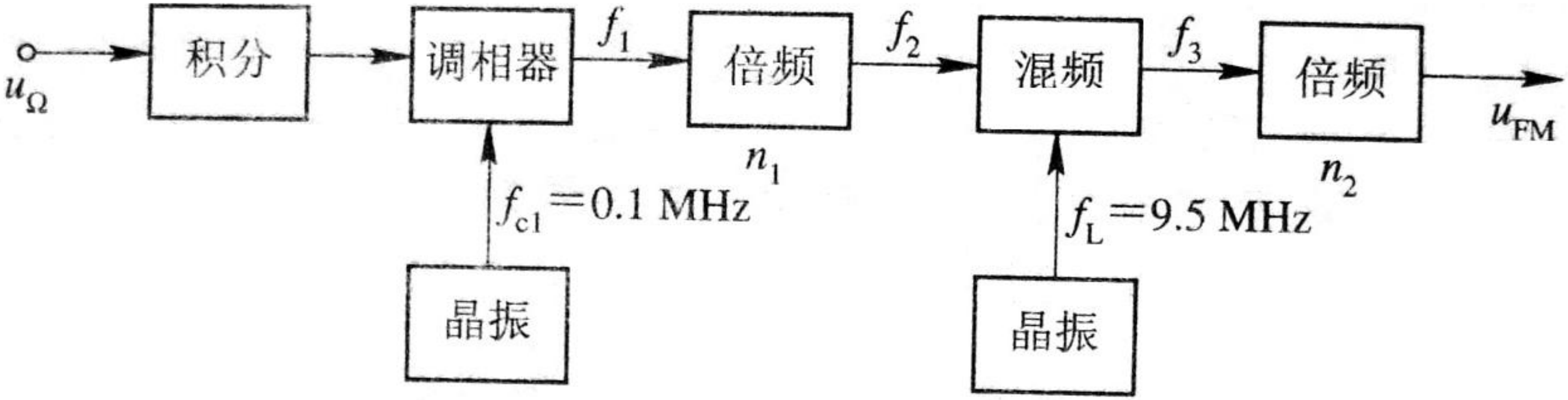
$$f_3(t)=f_L-f_2(t)=f_L-n_1(f_{c1}+M_pF\cos 2\pi Ft)$$

所以，输出u_{FM}的瞬时频率

$$f_0(t)=n_2f_3(t)=n_2f_L-n_1n_2f_{c1}-n_1n_2M_pF\cos 2\pi Ft$$



7.12



$$f_0(t)=n_2 f_3(t)=n_2 f_L-n_1 n_2 f_{c1}-n_1 n_2 M_p F\cos 2\pi Ft$$

因为$\boldsymbol{u}_{\mathbf{FM}}$ $f_c=n_2(f_L-n_1 f_{c1})=100\times 10^6$

最大频偏 $\Delta f_m=n_1 n_2 M_p F=75\times 10^3$

$$\begin{cases} n_2(9.5-0.1n_1)=100 \\ 0.2n_1 n_1\times 100=75\times 10^3 \end{cases} \quad 得\begin{cases} n_1=75 \\ n_2=50 \end{cases}$$

SCU

7.13 解：

$$\because M_f = 4, F = 2\text{kHz} \quad \therefore \Delta f_m = M_f F = 8\text{kHz}$$

$$\Delta f(t) = 8\times10^3 \sin 4\pi\times10^3 t \ \ (\text{Hz})$$

$$\therefore u_0(t) = S_d \Delta f(t) = 0.08 \sin 4\pi\times10^3 t(\text{V})$$

SCU

7.14 解：（a）可以斜率鉴频，因f_{01}与f_{02}分别处于f_s两侧。$F_{01}- f_s= f_s- f_{02}$。不能包络检波，因两个包络检波器输出波形相减后互相抵消，u_0中无交流分量。

（b）图可以斜率鉴频。因$f_{01}= f_{02}$均处于斜率中点。可以包络检波。因$f_{01}= f_{02} =f_s$。此时两个包络检波器输出波形相同，二者相加后作为输出信号。二包络检波器分别在u_s的正、负半周导通。

7.15 解：（**a**）图可行，因为是对中频信号振幅大小进行比较后产生控制电压，此控制电压反映了中频信号振幅的大小，故可以用来调节中放的增益。

（**b**）图不行，因为是对鉴频器输出音频信号振幅大小进行比较后产生控制电压，而鉴频器输出电压是与中频信号中频率的变化成正比，而不是与中频信号的振幅成正比。

SCU

7.16 解：与图7.5.3所示一般调频负反馈电路方框图比较，此电路框图的差别在于一是将AFC环路中鉴频器的中心频率从8.7MHz降为1.3MHz，二是将主通道上的鉴频器移到AFC环路之外。前者可以改善鉴频性能，后者使主通道鉴频器输入端的信号更加稳定。

如果将低通滤波器去掉则不能正常工作，也不能将低通滤波器合并在其他环节里。

SCU

7.17 解：中频的最大角偏移：

$$\Delta\omega_I = \frac{1}{10} M_f \Omega$$

则

$$\Delta\omega_I = \frac{\Delta\omega_c}{1 + k_b k_c} = \frac{M_f \Omega}{10} = \frac{\Delta\omega_c}{10}$$

所以 $k_b k_c = 9$

第 8 章

8.1 解： 由基本环路方程中表达的控制频差定义可知，在线性稳态情况下，有

$$k_c k_b H(s)\varphi_e(\infty)=10\times10^3$$

$$\therefore \varphi_e(\infty)=\frac{10\times10^3}{0.63\times40\times10^3\times1}\approx0.397\text{rad}$$

$$\therefore u_c(\infty)=k_b\varphi_e(\infty)=0.63\times0.397\approx0.25\text{V}$$

又因为固有频差 $=f_{\mathrm{i}}-f_0=10\text{kHz}$

所以$f_{\mathrm{i}}=f_0+10=2510\text{kHz}=2.51\text{MHz}$

SCU

8.2 解：在调幅接收机中可以采用**AGC**电路，起稳定输出信号振幅的作用，应注意不能出现反调制现象；可以采用**AFC**电路，起稳定中频频率的作用；可以采用**APC**电路，起稳定中频频率的作用。在调频接收机中可以采用**AGC**电路，起稳定中频输出信号振幅的作用；可以采用**AFC**电路进行调频负反馈，应注意使其中的低通滤波器的带宽足够宽，以便不失真地让解调后的调制信号通过；可以采用**APC**电路进行锁相鉴频，应注意使环路带宽足够宽，使调制信号顺利通过。

8.3 解：锁定时， $\dfrac{f_y}{n_1 n_2} = f_r$,所以

$$f_y = n_1 n_2 f_r = (653 \sim 793) \times 8 \times 12.5 \times 10^3 = (65.3 \sim 79.3)\mathrm{MHz}$$

所以,频率间隔$\Delta f = n_1 f_r = 100\mathrm{kHz}$,

转换时间$t_s = \dfrac{25}{f_r} = \dfrac{25}{12.5} = 2\mathrm{ms}$

SCU

8.4 解:

$$f_y = f_2 - f_1 = \frac{n_3}{n_2} f_r - \frac{1}{n_1} f_r = (\frac{n_3}{n_2} - \frac{1}{n_1}) f_r$$

SCU

8.5 解：在锁相环中，**VCO**被视为积分器，若低通滤波器的阶数为**1**，则整个锁相环是一个二阶环路，所以锁相环电路的频率特性不等于环路滤波器的频率特性。其中低通滤波器的作用是滤除鉴相器输出中的无用组合频率分量及其他干扰分量。

8.6 解：不能。因为鉴相器的作用是将输入信号和VCO输出信号的相位差转换为电压信号，它有两个输入，而相位鉴频器的作用是利用频相转换网络和鉴相器对调频信号进行解调，它仅有一个输入。

SCU

8.7 解：频率合成器的输出频率范围为11.52～15.456MHz，频率间隔为2kHz，总频率数1969个。

8.8 解：有差别。如果设输入是调制频率为F的单频双边带信号，则：

①乘积鉴相器的输入信号是载频为f_c的调幅波和载波，输出是含有f_c和$2f_c$的高频分量；

②乘法器的输入信号频率是F，输出信号频率是F、$2F$；

③乘积鉴相器之后的低通滤波器的截止频率应大于F；

④乘法器之后的低通滤波器的截止频率应小于F。