91

AIN SHAMS UNIVERSITY
FACULTY OF ENGINEERING

TRANSISTOR OSCILLATOR PERFORMANCE

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CONTENTS

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Page

APPENDIX

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where

$$A_1 = \left[\frac{L_2'}{R_2} + L_2' g_{\ell_1}\right] \quad , \quad A_2 = \left[1 + \frac{g_o' L_2'}{R_2 C_1} + \frac{g_o' g_{\ell_1} L_2'}{C_1}\right]$$

$$A_3 = \left[\frac{g_o'}{C_1} + \frac{L_2'}{L_1' R_2 C_1} + \frac{L_2' g_{\ell_1}}{L_1' C_1} - \frac{K_2 g_{f_1}}{C_1}\right]$$

$$\omega_o^2 = \frac{1}{C_1 L_1} \quad , \quad B_1 = L_2' g_{\ell_2} \qquad \ldots \quad (A.12)$$

$$B_2 = \frac{g_o' g_{\ell_2} L_2'}{C_1} \quad , \quad B_3 = \left[\frac{L_2' g_{\ell_2}}{L_1' C_1} - \frac{K_2 g_{f_2}}{C_1}\right]$$

$$E_1 = L_2' g_{\ell_3} \quad , \quad E_2 = \frac{g_o' g_{\ell_3} L_2'}{C_1} \quad , \quad E_3 = \left[\frac{L_2' g_{\ell_3}}{L_1' C_1} - \frac{K_2 g_{f_3}}{C_1}\right]$$

Again, to improve the stability, we made the coupling between L_1 and L_2 tight, then, from (A.3), we have,

$$L_1' = L_2' = 0 \qquad \ldots \quad (A.13)$$

Then, from (A.12), we have,

$$A_1 = B_1 = B_2 = E_1 = E_2 = 0 \quad , \quad A_2 = 1$$

$$A_3 = \left[\frac{g_o'}{C_1} + \frac{L_2}{L_1 R_2 C_1} + \frac{L_2 g_{\ell_1}}{L_1 C_1} - \frac{K_2 g_{f_1}}{C_1}\right] \quad , \quad B_3 = \left[\frac{L_2}{L_1} \cdot \frac{g_{\ell_2}}{C_1} - \frac{K_2 g_{f_2}}{C_1}\right] \quad , \quad E_3 = \left[\frac{L_2}{L_1} \cdot \frac{g_{\ell_3}}{C_1} - \frac{K_2 g_{f_3}}{C_1}\right]. \qquad \ldots \quad (A.14)$$

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From (A.14), and (2.53), (2.54), we have,

$$\epsilon = \frac{1}{3} a^2 B_3^2 =$$

$$= \frac{1}{3} \frac{a^2}{C_1^2} \left[\frac{L_2}{L_1} g_{\ell_2} - K_2 g_{f_2} \right]^2 \qquad \ldots \qquad (A.15)$$

$$a^2 = \frac{4}{3} \cdot \frac{A_3}{-E_3} = -\frac{4}{3} \left[\frac{g_o' + \frac{L_2}{L_1 R_2} + \frac{L_2}{L_1} g_{\ell_1} - k_2 g_{f_1}}{\frac{L_2}{L_1} g_{\ell_3} - K_2 g_{f_3}} \right] \qquad \ldots \qquad (A.16)$$

To minimize ϵ in (A.15), we can adjuste the value $\frac{L_2}{L_1 K_2}$ around g_{f_2} / g_{ℓ_2}, taking into account the amplitude requirments in (A.16), such that,

$$K_2 g_{f_1} > g_o' + \frac{L_2}{L_1} \left(g_{\ell_1} + \frac{1}{R_2} \right) \quad \& \quad \frac{L_2}{L_1} g_{\ell_3} > K_2 g_{f_3}$$

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. Hartley Oscillator :

From Fig. (A.2), one can write,

$$i = -g_1 v - \frac{1}{L_1'}\int (v + k_2 v_e)\, dt - \frac{C\, d(v - v_e)}{dt} \quad \ldots \quad (A.17)$$

$$i_p = -g_2 v_e - \frac{1}{L_2'}\int (k_1 v + v_e)\, dt + C\frac{d(v - v_e)}{dt} \quad \ldots \quad (A.18)$$

here,

$$\left.\begin{array}{ll} g_1 = \frac{1}{R_1}, & g_2 = \frac{1}{R_2} \\ L_1' = \left(L_1 - \frac{M^2}{L_2}\right), & L_2' = \left(L_2 - \frac{M^2}{L_1}\right) \\ k_1 = \frac{M}{L_1}, & k_2 = \frac{M}{L_2} \end{array}\right\} \quad \ldots \quad (A.19)$$

As, in (2.9) and (2.10),

$$\left.\begin{array}{l} = g_f v_e + g_o v = g_{f_1} v_e + g_{f_2} v_e^2 + g_{f_3} v_e^3 + g_o v \\ p = g_i v_e + g_r v = g_{i_1} v_e + g_{i_2} v_e^2 + g_{i_3} v_e^3 + g_r v \end{array}\right\} \quad \ldots \quad (A.20)$$

From (A.17), (A.20) and (A.18), (A.20) give

$$v_e + \frac{1}{L_1'}\int (k_2 v_e)\, dt - C\frac{dv_e}{dt} = -(g_o + g_1)\, v$$

$$- \frac{1}{L_1'}\int v\, dt - C\frac{dv}{dt} \quad \ldots \quad (A.21)$$

and

$$g_i + g_2)\, v_e + \frac{1}{L_2'}\int v_e\, dt + C\frac{dv_e}{dt} = -g_r v$$

$$- \frac{1}{L_2'}\int k_1 v\, dt + C\frac{dv}{dt} \quad \ldots \quad (A.22)$$

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3. **Colpitt's Oscillator :**

From, Fig. (A.3), we have

$$i = -v(g_i + g_L) - C_1 \frac{dv}{dt} - \frac{1}{L}\int v\,dt + g_L v_e + \frac{1}{L}\int v_e\,dt \quad \ldots \quad (A.28)$$

$$i_p = -v_e(g_2 + g_L) - C_2 \frac{dv_e}{dt} - \frac{1}{L}\int v_e\,dt + g_L v + \frac{1}{L}\int v\,dt \quad \ldots \quad (A.29)$$

where $\left[g_1 = \frac{1}{R_1} \; , \; g_2 = \frac{1}{R_2} \; , \; g_L = \frac{1}{R_L} \right]$ ... (A.30)

From (A.20), (A.28) and (A.20), (A.29), we have,

$$(g_f - g_L) v_e - \frac{1}{L}\int v_e\,dt = -(g_o + g_r + g_1) v - (g_L - g_r) v - C_1 \frac{dv}{dt} - \frac{1}{L}\int v\,dt \quad \ldots \quad (A.31)$$

and

$$(g_i + g_2 + g_L) v_e + C_2 \frac{dv_e}{dt} + \frac{1}{L}\int v_e\,dt = (g_L - g_r) v + \frac{1}{L}\int v\,dt \quad \ldots \quad (A.32)$$

$\left[(A.31) + (A.32) \right]$ give,

$$\left[g_f + g_i + g_2 \right] v_e + C_2 \frac{dv_e}{dt} = -(g_o + g_r + g_1) v - C_1 \frac{dv}{dt} \quad \ldots \quad (A.33)$$

From (A.33), (A.31), by assuming,

$(g_L - g_r) \ll (g_o + g_r + g_1)$ (this justified by assuming R_L is high). gives :

$$\frac{1}{L}\int v\,dt = (g_i + g_2 + g_L) v_e + C_2 \frac{dv_e}{dt} + \frac{1}{L}\int v_e\,dt \quad \ldots \quad (A.34)$$

Substituting by (A.34) in (A.33), we have,

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$$(D^3 + A_1 D^2 + \omega_o^2 D + A_2)\, v_c + (B_1 D^2 + B_2 D + B_3)\, v_c^2 + (E_1 D^2 + E_2 D + E_3)\, v_c^3 = 0 \qquad \ldots \qquad (A.45)$$

where,

$$\left.\begin{aligned}
A_1 &= \left(\frac{K_1}{C_1} + \frac{g'_{l_1}}{C_2}\right), \qquad A_2 = \left(\frac{g'_{f_1} + K_1}{L C_1 C_2}\right) \\
\omega_o^2 &= \left(\frac{1}{LC} + \frac{K_1 g'_{l_1}}{C_1 C_2}\right), \qquad C = \left(\frac{C_1 C_2}{C_1 + C_2}\right) \\
B_1 &= \frac{g_{l_2}}{C_2}, \qquad B_2 = \frac{K_1 g_{l_2}}{C_1 C_2}, \qquad B_3 = \frac{g'_{f_2}}{L C_1 C_2} \\
E_1 &= \frac{g_{l_3}}{C_2}, \qquad E_2 = \frac{K_1 g_{l_3}}{C_1 C_2}, \qquad E_3 = \frac{g'_{f_3}}{L C_1 C_2} \\
K_1 &= g_o + g_r + g_1, \qquad g'_{f_1} = g_{f_1} + g_{l_1} + g_2 \\
g'_{f_2} &= g_{f_2} + g_{l_2}, \qquad g'_{f_3} = g_{f_3} + g_{l_3} \\
g'_{l_1} &= g_{l_1} + g + g_L
\end{aligned}\right\} \qquad (A.50)$$

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4. <u>The average angular frequency (ω_{av}):</u>

From equation (3.45), we have, using (3.24, 41)

$$\frac{1}{N_1}\sum_{N=1}^{N_1} \omega_o - \frac{\epsilon_{1N}}{2\omega_o} + \frac{\alpha_{1N}'}{4\omega_o}\left[\frac{2k_{1N}e^{\alpha_{1N}'(t_1+N\tau)} - k_{1N}^2 e^{2\alpha_{1N}'(t_1+N\tau)}}{\left[1+k_{1N}e^{\alpha_{1N}'(t_1+N\tau)}\right]^2}\right]$$

$$\frac{1}{N_1}\sum_{N=1}^{N_1} \omega_o - \frac{\epsilon_{1N}}{2\omega_o} + \frac{\alpha_{1N}'}{4\omega_o}\left[\frac{2k_{2N}e^{\alpha_{1N}'(t_2-(N-1)\tau)} - k_{2N}^2 e^{2\alpha_{1N}'(t_2-(N-1)\tau)}}{\left[1+k_{2N}e^{\alpha_{1N}'(t_2-(N-1)\tau)}\right]^2}\right]$$

$$\omega_o - \frac{2}{N_1}\frac{(\epsilon_{11}+\cdots+\epsilon_{1N})}{2\omega_o} + \frac{1}{N_1}\left\{\frac{\alpha_{11}'^2}{4\omega_o}\left[\frac{2k_{11}e^{\alpha_{11}'(t_1+\tau)} - k_{11}^2 e^{2\alpha_{11}'(t_1+\tau)}}{\left[1+k_{11}e^{\alpha_{11}'(t_1+\tau)}\right]^2}\right]\right.$$

$$\frac{\alpha_{11}'^2}{\omega_o}\left[\frac{2k_{11}e^{(\alpha_{11}'t_1+2\alpha_{av_1}\delta t)} - k_{11}^2 e^{2(\alpha_{11}'t_1+2\alpha_{av_1}\delta t)}}{\left[1+k_{11}e^{(\alpha_{11}'t_1+2\alpha_{av_1}\delta t)}\right]^2}\right]$$

$$\frac{\alpha_{12}'^2}{\omega_o}\left[\frac{2b_1k_{11}e^{\alpha_{11}'t_1+(\alpha_{11}'+\alpha_{12}')\tau} - k_{11}^2 b_1^2 e^{2\alpha_{11}'t_1+2(\alpha_{11}'+\alpha_{12}')\tau}}{\left[1+b_1k_{11}e^{\alpha_{11}'t_1+(\alpha_{11}'+\alpha_{12}')\tau}\right]^2}\right]$$

$$\frac{\alpha_{2}'^2}{\omega_o}\left[\frac{2b_1k_{11}e^{\alpha_{11}'t_1+2\alpha_{av_1}\delta t-\alpha_{11}'\tau} - b_1^2k_{11}^2 e^{2(\alpha_{11}'t_1+2\alpha_{av_1}\delta t-\alpha_{11}'\tau)}}{\left[1+b_1k_{11}e^{(\alpha_{11}'t_1+2\alpha_{av_1}\delta t-\alpha_{11}'\tau)}\right]^2}\right]$$

$$\frac{\alpha_{1N}'^2}{\omega_o}\left[\frac{2(b_1\cdots b_{N-1})k_{11}e^{\alpha_{11}'t_1+(\alpha_{11}'\cdots\alpha_{1N}')\tau} - (b_1\cdots b_{N-1})^2k_{11}^2e^{2\alpha_{11}'t_1+2(\alpha_{11}'\cdots\alpha_{1N}')\tau}}{\left[1+(b_1\cdots b_{(N-1)})^2k_{11}e^{\alpha_{11}'t_1+(\alpha_{11}'+\alpha_{12}'\cdots\alpha_{1N}')\tau}\right]^2}\right]$$

$$\frac{\alpha_{1N}'^2}{\omega_o}\left[2(b_1\cdots b_{(N-1)})k_{11}e^{\alpha_{11}'t_1+2\alpha_{av_1}\delta t-(\alpha_{11}'\cdots\alpha_{1(N-1)}')\tau} - \right.$$

$$\left.(b_1\cdots b_{(N-1)})^2k_{11}^2e^{\alpha_{11}'t_1+2\alpha_{av_1}\delta t-(\alpha_{11}'\cdots\alpha_{1(N-1)}')\tau}\right] \Big/$$

$$\left.\left(1+(b_1\cdots b_{N-1})k_{11}e^{\alpha_{11}'t_1+2\alpha_{av_1}\delta t-(\alpha_{11}'\cdots\alpha_{1(N-1)}')\tau}\right)^2\right\} \qquad \cdots (A-37)$$

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Let $\tau \to 0$ and using $e^{x} \simeq 1 + x$ for small values of x,

we have

$$\frac{1}{N_1}\left[\sum + \sum\right] = 2\omega_0 - \frac{2\,\epsilon_{1av}}{2\omega_0} +$$

$$+ \frac{2}{N_1}\left\{ \frac{\alpha_{11}'^2}{4\omega_0}\left[\frac{2K_{11}\,e^{(\alpha_{11}' t_1 + \alpha_{av_1}\delta t)} - K_{11}^2\,e^{(2\alpha_{11}' t_1 + 2\alpha_{av_1}\delta t)}}{\left[1 + K_{11}\,e^{\alpha_{11}' t_1 + \alpha_{av_1}\delta t}\right]^2}\right]\right.$$

$$+ \frac{\alpha_{12}'^2}{4\omega_0}\left[\frac{2b_1K_{11}\,e^{(\alpha_{11}' t_1 + \alpha_{av_1}\delta t)} - b_1^2K_{11}^2\,e^{(2\alpha_{11}' t_1 + 2\alpha_{av_1}\delta t)}}{\left[1 + b_1K_{11}\,e^{\alpha_{11}' t_1 + \alpha_{av_1}\delta t}\right]^2}\right]$$

$$\vdots$$

$$\left. + \frac{\alpha_{1N}'^2}{4\omega_0}\left[\frac{2(b_1 - b_{N-1})K_{11}\,e^{(\alpha_{11}' t_1 + \alpha_{av_1}\delta t)} - (b_1 \cdots b_{N-1})^2K_{11}^2\,e^{(2\alpha_{11}' t_1 + 2\alpha_{av_1}\delta t)}}{\left[1 + (b_1 \cdots b_{N-1})K_{11}\,e^{(\alpha_{11}' t_1 + \alpha_{av_1}\delta t)}\right]^2}\right]\right\} \quad \ldots \quad (A.38)$$

as from (3.24)

$$b_1 = \frac{\gamma_{11}'}{\gamma_{12}'} \quad \& \quad b_1 b_2 = \frac{\gamma_{11}'}{\gamma_{13}'} \quad \& \quad \text{---} \quad \& \quad b_1 \cdots b_{(N-1)} = \frac{\gamma_{11}'}{\gamma_{1N}'}$$

$$\therefore \frac{1}{N_1}\left(\sum + \sum\right) = 2\omega_0 - \frac{2\,\epsilon_{1av}}{2\omega_0} + 2\lambda_1 \quad \ldots \quad (3.46)$$

where ϵ_{1av} & λ_1 as in equation (3.46')

Similarly, using (3.24, 38, 41), we have

$$\frac{1}{2}\left[\sum + \sum\right] = 2\omega_0 - \frac{2\,\epsilon_{2av}}{2\omega_0} + \frac{1}{N_2}\sum_{N=1}^{N_2}\frac{\alpha_{3N}'^2}{4\omega_0}\left[\vphantom{\frac{1}{1}}\right.$$

$$\left.\frac{2\gamma_{11}'\gamma_{3N}'\,K_{31}\,e^{(\alpha_{11}' t_2 + \alpha_{av_2}\rho)} - \gamma_{11}'^2 K_{31}\,e^{(2\alpha_{11}' t_2 + 2\alpha_{av_2}\rho)}}{\left[\gamma_{3N}' + \gamma_{11}' K_{31}\,e^{(\alpha_{11}' t_2 + \alpha_{av_2}\rho)}\right]^2}\right] \quad \ldots \quad (A.39)$$

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From (24, 38, 44), we have

$$k_{11}\, e^{(q_n' t_2 + q_{av_2} y)} = K_{11}\, e^{(q_n' t_1 + q_{av_1} t)} \qquad \ldots \qquad (3.40)$$

$$\therefore \frac{1}{N_2}\left[\sum + \sum\right] = 2\omega_0 - \frac{2\,\epsilon_{2av}}{7\,\omega_0} + 2\lambda_2$$

where ϵ_{2av} & λ_2 as in equation (3.47')

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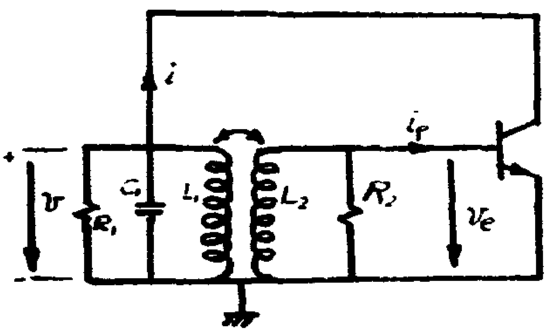

Fig. A-1

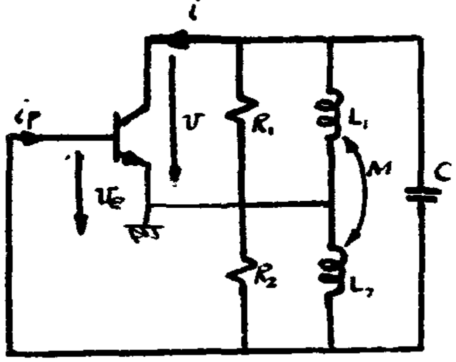

Fig. A- 2

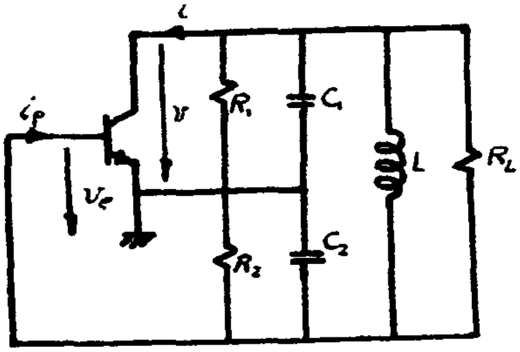

Fig A-3

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