บทที่ 3

วิธีการดำเนินการวิจัย

2

CFTA

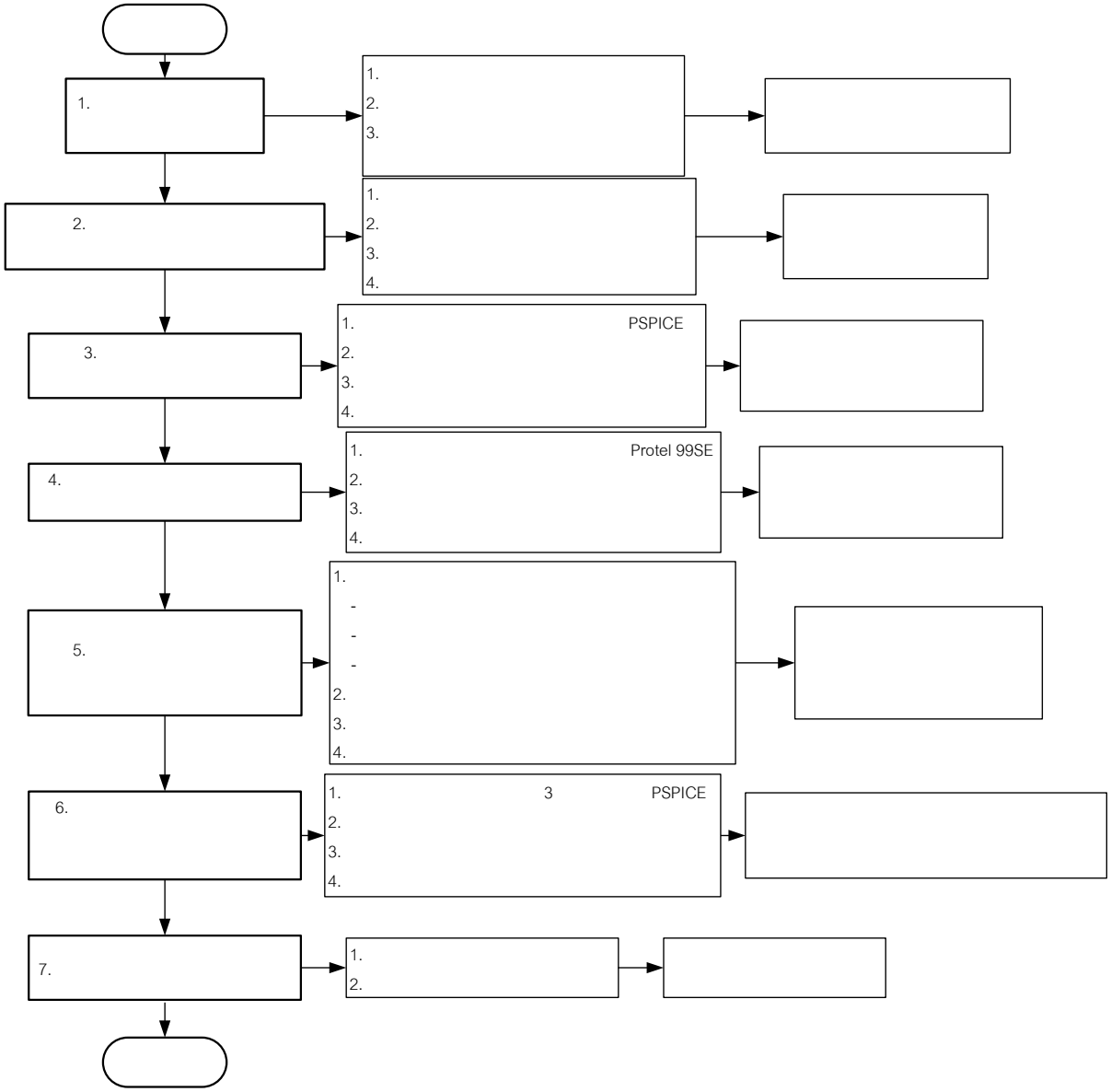
3.1

3.1

2

PSpice

4 5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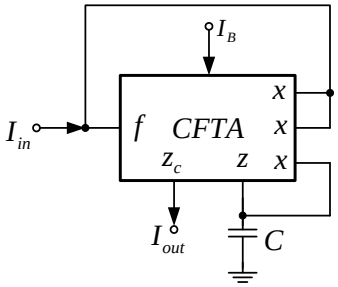
3.1

3.1 การออกแบบและพัฒนาวงจรกรองผ่านทุกความถี่ลำดับหนึ่งโหมดกระแส

CFTA 3.1

CFTA 1 1 I_B

CFTA



3.2

3.2 CFTA 2

z

$$V_z = \frac{I_z + I_x}{sC} \qquad (3.1)$$

$I_x = g_m V_z$ (3.1)

$$V_z = \frac{I_z}{sC - \beta g_m} \qquad (3.2)$$

3.2 f

$$I_f = I_{in} + 2I_x \tag{3.3}$$

$I_x = g_m V_z$ (3.3)

$$I_f = I_{in} + 2g_m V_z \tag{3.4}$$

(3.2) (3.4)

$$I_f = I_{in} + 2g_m \left(\frac{I_z}{sC - g_m} \right) \tag{3.5}$$

$I_z = -I_f$ (3.5)

$$I_z = I_{in} \left(\frac{g_m - sC}{g_m + sC} \right) \tag{3.6}$$

$I_{Out} = I_{zc} = I_z$ (3.6)

$$\frac{I_{Out}}{I_{in}} = \left(\frac{g_m - sC}{g_m + sC} \right) \tag{3.7}$$

$s = j\omega$ (3.7)

$$\left| T(j\omega) \right| = \left| \frac{I_{Out}(s)}{I_{in}(s)} \right| = 1 \tag{3.8}$$

$$\angle T(j\omega) = \varphi(\omega) = -2\tan^{-1}\left(\frac{2\pi fC}{g_m}\right) \quad (3.9)$$

(3.9) 0

-180

$g_m = \sqrt{kI_B}$

I_B

3.2 การวิเคราะห์วงจรในกรณีไม่เป็นอุดมคติ

CFTA

$$I_z = \alpha I_f . I_{zc} = \gamma I_z . I_x = \beta g_m V_z \quad (3.10)$$

α, β γ

1 CFTA

3.2 CFTA (3.17)

z

$$V_z = \frac{I_z + I_x}{sC} \quad (3.11)$$

$I_x = \beta g_m V_z$ (3.11)

$$V_z = \frac{I_z}{sC - \beta g_m} \quad (3.12)$$

3.1 f

$$I_f = I_{in} + 2I_x \tag{3.13}$$

$I_x = \beta g_m V_z$ (3.13)

$$I_f = I_{in} + 2\beta g_m V_z \tag{3.14}$$

(3.12) (3.14)

$$I_f = I_{in} + 2\beta g_m \left(\frac{I_z}{sC - \beta g_m} \right) \tag{3.15}$$

$I_z = -\alpha I_f$ (3.15)

$$I_z = \left(\frac{\alpha\beta g_m - \alpha sC}{2\alpha\beta g_m - \beta g_m + sC} \right) I_{in} \tag{3.16}$$

$I_{Out} = I_{zc} = \gamma I_z$ (3.16)

$$\frac{I_{Out}}{I_{in}} = \gamma\alpha \left(\frac{\beta g_m - sC}{2\alpha\beta g_m - \beta g_m + sC} \right) \tag{3.17}$$

$s = j\omega$ (3.17)

$$\left|T(\omega)\right| = \alpha\gamma\sqrt{\frac{\beta^2 + \left(\omega C / g_m\right)^2}{\beta^2\left(2\alpha - 1\right)^2 + \left(\omega C / g_m\right)^2}} \tag{3.18}$$

$$\angle T(j\omega) = -\tan^{-1}\left(\omega C / \beta g_m\right) - \tan^{-1}\left\{\omega C / \left[\beta\left(2\alpha - 1\right) g_m\right]\right\} \tag{3.19}$$

(3.18)-(3.19)

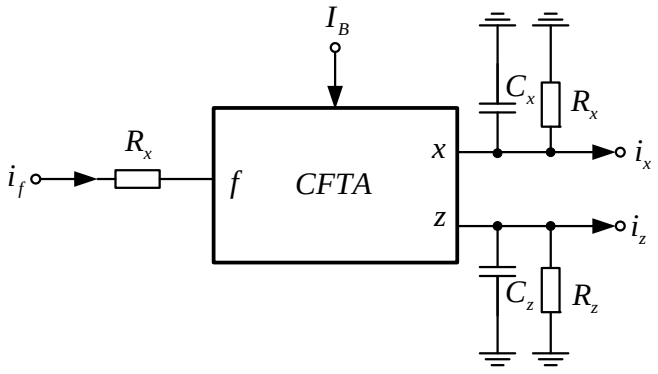
CFTA

CFTA 3.3

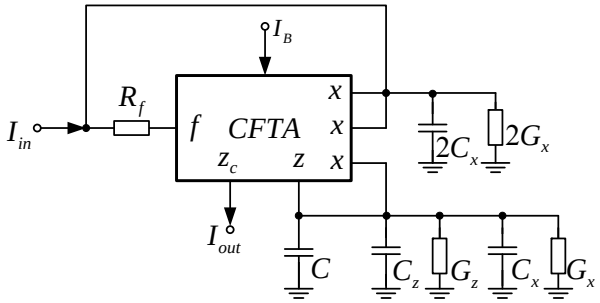
3.2

3.4 $G_z = 1/R_z$ $G_x = 1/R_x$

$$Y_1 = s\left(C + C_z + C_x\right) + G_z + G_x \tag{3.20}$$



3.3 CFTA



3.4

$$Y_2 = 2sC_x + 2G_x \tag{3.21}$$

z

$$V_z = \frac{I_z + I_x}{Y_1} \tag{3.22}$$

$I_x = g_m V_z$ (3.22)

$$V_z = \frac{I_z}{Y_1 - g_m} \tag{3.23}$$

3.4 f

$$I_f = \left(\frac{1}{1 + Y_2 R_f}\right)\left(I_{in} + 2I_x\right) \tag{3.24}$$

$I_x = g_m V_z$ (3.24)

$$I_f = \left(\frac{1}{1+Y_2R_f}\right)\left(I_{in} + 2g_m V_z\right) \tag{3.25}$$

(3.2) (3.4)

$$I_f = \left(\frac{1}{1+Y_2R_f}\right)\left[I_{in} + 2g_m\left(\frac{I_z}{Y_1 - g_m}\right)\right] \tag{3.26}$$

$I_z = -I_f$ (3.26)

$$I_z = -\left(\frac{1}{1+Y_2R_f}\right)\left[\frac{Y_1 - g_m}{\left(Y_1 - g_m\right)\left(1+Y_2R_f\right) + 2g_m}\right] I_{in} \tag{3.27}$$

(3.27) R_f

CFTA R_f

R_f (3.27)

$$I_z = -\left[\frac{Y_1 - g_m}{\left(Y_1 - g_m\right) + 2g_m}\right] I_{in} \tag{3.28}$$

$I_{Out} = I_{zc} = I_z$ (3.28)

$$\frac{I_{Out}}{I_{in}} = -\left[\frac{Y_1 - g_m}{\left(Y_1 - g_m\right) + 2g_m}\right] \tag{3.29}$$

(3.20) (3.29)

$$\frac{I_{Out}}{I_{in}} = \frac{g_m - s(C + C_z + C_x) + G_z + G_x}{g_m + s(C + C_z + C_x) + G_z + G_x} \quad (3.30)$$

$s = j\omega$ (3.30)

$$|T(j\omega)| = \left|\frac{I_{Out}(s)}{I_{in}(s)}\right| = 1 \quad (3.31)$$

$$\angle T(j\omega) = -2\tan^{-1}\left[\omega(C + C_z + C_x)/(g_m + G_z + G_x)\right] \quad (3.32)$$

(3.32) C_z C_x R_z R_x

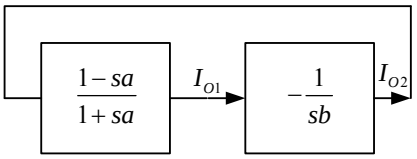
C_z C_x R_z R_x C C_z C_x g_m $1/R_z$ $1/R_x$

3.3 การออกแบบและพัฒนาวงจรประยุกต์ใช้งาน

3.3.1 วงจรกำเนิดสัญญาณซายน์แบบควอเดรเจอร์

2

(Lossless integrator) 3.5



3.5

3.5 (Characteristic equation)

$$s^2ab + s(b-a) + 1 = 0 \tag{3.33}$$

(3.33) (Oscillation condition: OC)
(Oscillation frequency: OF)

$$OC: \quad b = a \tag{3.34}$$

$$OF: \quad \omega_{osc} = \sqrt{\frac{1}{ab}} \tag{3.35}$$

$\omega_{osc} = 2\pi f_{osc}$ (3.35)

$$OF: \quad f_{osc} = \frac{1}{2\pi}\sqrt{\frac{1}{ab}} \tag{3.36}$$

(3.34) (3.36) a
b (I_{O1} I_{O2})

3.5 (Current transfer function) I_{O2} I_{O1}

$$\frac{I_{O2}(s)}{I_{O1}(s)} = -\frac{1}{sb} \qquad (3.37)$$

$$s = j\omega_{osc} \qquad (3.37)$$

$$\frac{I_{O2}(j\omega)}{I_{O1}(j\omega)} = \frac{1}{\omega b} e^{90^\circ} \qquad (3.38)$$

I_{O2} I_{O1} 90°

CFTA

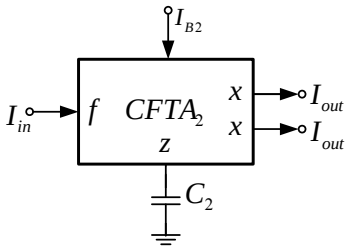
3.5

3.2 3.6

CFTA 1 1

I_{Out}

3.6 CFTA 2



3.6

$$\frac{I_{Out}}{I_{in}} = -\frac{g_{m2}}{sC_2} \tag{3.39}$$

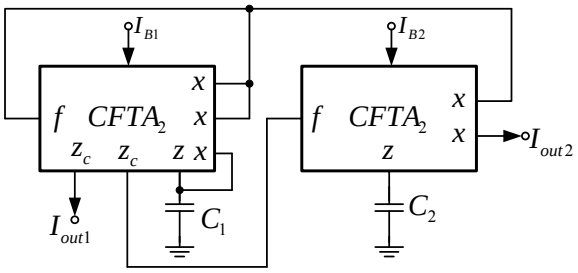
3.7 CFTA 2

2 I_{B1} I_{B2} CFTA

I_{Out1} z_c CFTA I_{O2} x

CFTA 3.7

$$s^2 + \left(\frac{g_{m1}}{C_1} - \frac{g_{m2}}{C_2}\right)s + \frac{g_{m1}g_{m2}}{C_1C_2} = 0 \tag{3.40}$$



3.7

(Real part)

$$\omega_{osc} = \sqrt{\frac{g_{m1}g_{m2}}{C_1C_2}} \tag{3.41}$$

(Imaginary part)

$$\frac{C_2}{C_1} = \frac{g_{m2}}{g_{m1}} \tag{3.42}$$

$g_{mi} = \sqrt{kI_{Bi}}$

$$\omega_{osc} = \sqrt{\frac{k\left(I_{B1}I_{B2}\right)^{1/2}}{C_1C_2}} \tag{3.43}$$

$$\frac{C_2}{C_1} = \sqrt{\frac{I_{B2}}{I_{B1}}} \tag{3.44}$$

(3.43) (3.44)

I_{B1} I_{B2} (3.43) $\omega_{osc} = 2\pi f_{osc}$

$$f_{osc} = \frac{1}{2\pi}\sqrt{\frac{k\left(I_{B1}I_{B2}\right)^{1/2}}{C_1C_2}} \tag{3.45}$$

3.7 I_{O1} I_{O2}

$$\frac{I_{O2}(s)}{I_{O1}(s)} = -\frac{g_{m2}}{sC_2} \tag{3.46}$$

(3.46)

$$\frac{I_{O2}(j\omega)}{I_{O1}(j\omega)} = \frac{g_{m2}}{\omega C_2}e^{90^\circ} \tag{3.47}$$

I_{O1} I_{O2}

$$\phi = -90° \tag{3.48}$$

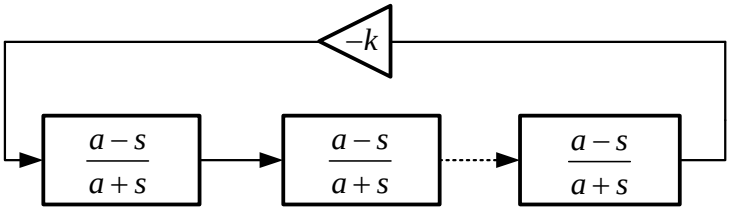
3.3.2 วงจรกำเนิดสัญญาณซายน์แบบหลายเฟส

3.8

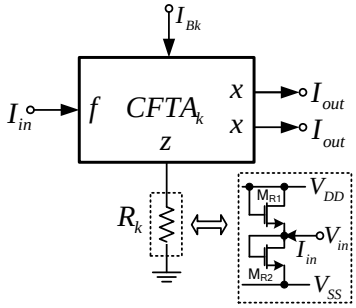
n 3.2 n

CFTA

3.9 3



3.8 n



3.9 CFTA

3.9

$$I_{Out} = -kI_{in} \tag{3.49}$$

$$k = g_{mk} R_k \tag{3.50}$$

3.8 (System loop gain)

$$L(s) = -k\left(\frac{a-s}{a+s}\right)^n \tag{3.51}$$

$$\omega_{osc} = 2\pi f_{osc}$$

$$L(j\omega_{osc}) = -k\left(\frac{a-j\omega_{osc}}{a+j\omega_{osc}}\right)^n = 1 \tag{3.52}$$

$$\left|L(j\omega_{osc})\right| = 1 \tag{3.53}$$

$$k = 1 \tag{3.54}$$

$$\angle L\left(j\omega_{osc}\right) = 2n\tan^{-1}\left(\frac{\omega_{osc}}{a}\right) \tag{3.55}$$

(3.55) π

$$\pi = 2n\tan^{-1}\left(\frac{\omega_{osc}}{a}\right) \tag{3.56}$$

(3.56)

$$\omega_{osc} = a\tan\left(\frac{\pi}{2n}\right) \tag{3.57}$$

(3.41) (3.44)

K a

3.2 3.9

3.8 3.10

$$\frac{I_{Out}(s)}{I_{in}(s)} = \left(\frac{g_m - sC}{g_m + sC}\right)$$

$k = g_{mk}R_k$

$$OC: \quad g_{mk}R_k = 1 \tag{3.58}$$

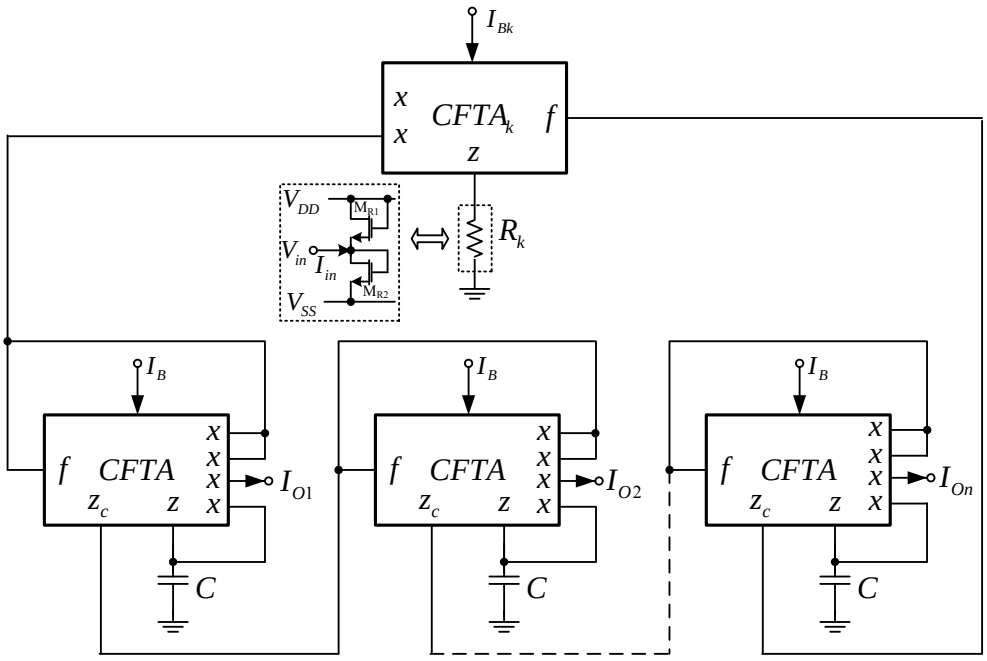
$$OF: \quad \omega_{osc} = \frac{g_m}{C}\tan^{-1}\left(\frac{\pi}{2n}\right) \tag{3.59}$$

$g_{mi} = \sqrt{kI_{Bi}}$

$$OC: \quad R_K\sqrt{kI_{Bk}} = 1 \tag{3.60}$$

$$OF: \qquad \omega_{osc} = \frac{\sqrt{kI_B}}{C}\tan^{-1}\left(\frac{\pi}{2n}\right) \tag{3.61}$$

(3.60) (3.61)

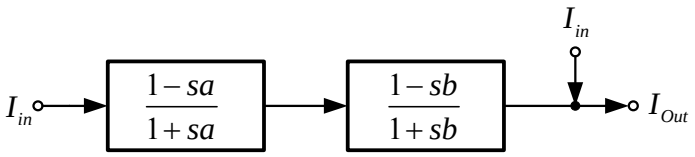


3.10 n

3.3.3 วงจรกำจัดแถบความถี่อันดับสอง

3.11

2



3.11

$$\frac{I_{Out}}{I_{in}} = \frac{2\left(s^2 + \frac{1}{ab}\right)}{s^2 + s\left(\frac{1}{a} + \frac{1}{b}\right) + \frac{1}{ab}} \tag{3.62}$$

(3.62)

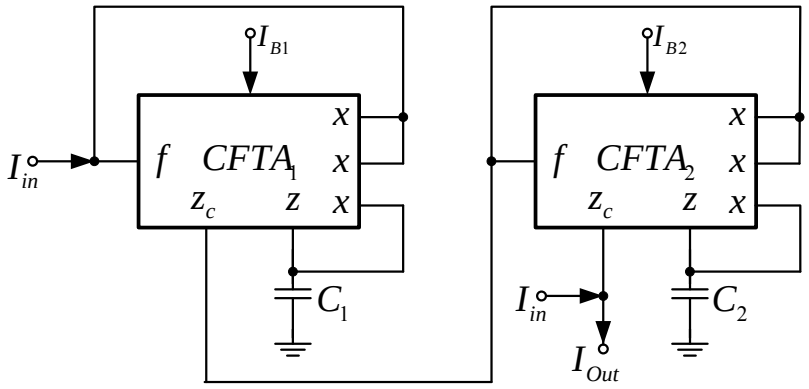
$$\omega_0 = \sqrt{\frac{1}{ab}} \tag{3.63}$$

$$Q_0 = \frac{\sqrt{ab}}{a+b} \tag{3.64}$$

3.2 3.11

3.12

$\frac{I_{Out}(s)}{I_{in}(s)} = \left(\frac{g_{m1} - sC_1}{g_{m1} + sC_1}\right)$ $\frac{I_{Out}(s)}{I_{in}(s)} = \left(\frac{g_{m2} - sC_2}{g_{m2} + sC_2}\right)$



3.12

$$\frac{I_{Out}}{I_{in}} = \frac{2\left(s^2 + \frac{g_{m1}g_{m2}}{C_1C_2}\right)}{s^2 + s\left(\frac{g_{m1}}{C_1} + \frac{g_{m2}}{C_2}\right) + \frac{g_{m1}g_{m2}}{C_1C_2}} \tag{3.65}$$

(3.65)

$$\omega_0 = \sqrt{\frac{g_{m1}g_{m2}}{C_1C_2}} \tag{3.66}$$

$$Q_0 = \frac{\sqrt{g_{m1}g_{m2}C_1C_2}}{g_{m1}C_2 + g_{m2}C_1} \tag{3.67}$$

$g_{mi} = \sqrt{kI_{Bi}}$ (3.66) (3.67)

3.5 สรุป

CFTA

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- CFTA 1

4