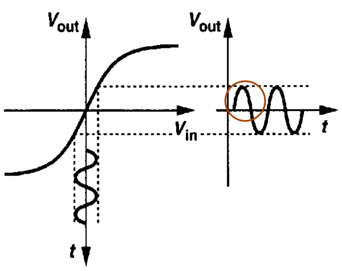
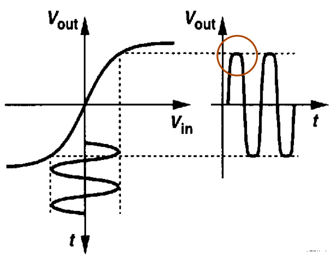
回去詳讀推導

Non-Linearity Analysis

G&M – Chap 3.5.2



Small input amplitude



Large input amplitude

The nonlinearity of a circuit can be characterized by applying a sinusoid at the input and measuring the harmonic content at the output.

Non-Linearity Analysis

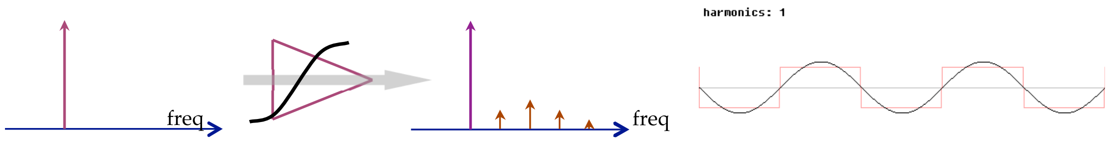
$$y(t) = \alpha_0 + \alpha_1 A \cos\omega t + \alpha_2 A^2 \cos^2\omega t + \alpha_3 A^3 \cos^3\omega t \cdots$$

$$= \alpha_0 + \alpha_1 A \cos\omega t + \frac{\alpha_2 A^2}{2}(1 + \cos 2\omega t) + \frac{\alpha_3 A^3}{4}(3\cos\omega t + \cos 3\omega t) \cdots$$

$$= b_0 + b_1 \cos\omega t + b_2 \cos 2\omega t + b_3 \cos 3\omega t \cdots\cdots$$

where $b_0 = a_0 + \frac{\alpha_2 A^2}{2} + \cdots\cdots,\quad b_2 = \frac{\alpha_2 A^2}{2} + \cdots,$

$b_1 = a_1 A + \frac{3\,a_3 A^3}{4} + \cdots\cdot,\quad b_3 = \frac{\alpha_3 A^3}{4} + \cdots,$



Non-Linearity Analysis

The second-order hormonic distortion

$$HD_2 = \left|\frac{b_2}{b_1}\right| \cong \frac{\alpha_2 A^2}{2} \Big/ \left(\alpha_1 A + \frac{3}{4}\alpha_3 A^3\right)$$

The third-order harmonic distortion

$$HD_3 = \left|\frac{b_3}{b_1}\right| \cong \frac{1}{4}\alpha_3 A^3 \Big/ \left(\alpha_1 A + \frac{3}{4}\alpha_3 A^3\right)$$

$$\mathrm{THD} = \frac{\sum \text{harmonic powers}}{\text{fundamental frequency power}} = \frac{P_2 + P_3 + P_4 + \cdots + P_n}{P_1}$$

$$THD = \sqrt{(b_2^2 + b_3^2 + b_4^2 \cdots\cdots)} \Big/ b_1$$

$$\simeq \sqrt{\left(\frac{\alpha_2 A^2}{2}\right)^2 + \left(\frac{\alpha_3 A^3}{4}\right)^2} \Big/ \left(\alpha_1 A + \frac{3}{4}\alpha_3 A^3\right)$$

算到 Third order即可~

SCP Non-linearity Analysis

The differential current of source-coupled pair

$$I_{d1} - I_{d2} = \frac{1}{2}\mu C_{ox}\left(\frac{W}{L}\right) V_{id} \sqrt{\frac{4 I_{ss}}{\mu C_{ox}\left(\frac{W}{L}\right)} - V_{id}^2}$$

$$= \frac{1}{2}\mu C_{ox}\left(\frac{W}{L}\right) V_{id} \sqrt{4(V_{GS}-V_t)^2 - V_{id}^2}$$

$$= \mu C_{ox}\left(\frac{W}{L}\right) V_{id} (V_{GS}-V_t) \sqrt{1 - \left[\frac{V_{id}}{2(V_{GS}-V_t)}\right]^2}$$

when $V_{id} = A\cos\omega t$ if $V_{id} \ll V_{GS}-V_t$.

$$I_{d1} - I_{d2} \cong \mu C_{ox}\left(\frac{W}{L}\right) V_{id} (V_{GS}-V_t) \left[1 - \frac{V_{id}^2}{8(V_{GS}-V_t)^2}\right]$$

$$= \mu C_{ox}\left(\frac{W}{L}\right)(V_{GS}-V_t)\left[A\cos\omega t - \frac{A^3\cos^3\omega t}{8(V_{GS}-V_t)^2}\right]$$

SCP Non-linearity Analysis

$$\cos^3 \omega t = \frac{3}{4}\cos\omega t + \frac{1}{4}\cos 3\omega t$$

$$I_{d1} - I_{d2} \cong g_m \left[\left(A - \frac{3A^3}{32(V_{GS}-V_t)^2} \right)\cos\omega t - \frac{A^3}{32(V_{GS}-V_t)^2}\cos 3\omega t \right]$$

$$\text{if } A \gg \frac{3A^3}{32(V_{GS}-V_t)^2}$$

Second Order Distortion $HD_2 = 0$

Third Order Distortion $HD_3 = \frac{A^2}{32(V_{GS}-V_t)^2}$

For rule of thumbs : -60dB distortion, $A < 0.2\ V_{ov}$
-40dB distortion, $A < 0.5\ V_{ov}$