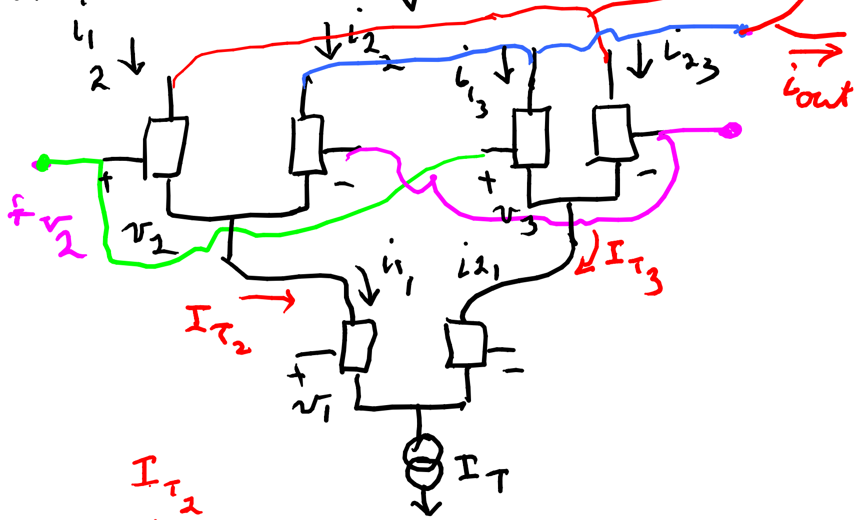
EE 303

10/09/12

Note Title 10/9/2012

Transmission gate pulse response

multiple: p. 1160, Fig. 14.12



any diff pair

$i_1 = I_T f(v)$

$i_2 = (I_T - i_1)$ by KCL

$$i_{1_2} = \underbrace{i_{1_1}}_{I_{T_2}} f(v_2), \quad i_{2_2} = i_{1_1} - i_{1_2} = I_T f(v_1) - I_T f(v_1) \cdot f(v_2)$$

$$= I_T f(v_1) f(v_2) \qquad = I_T f(v_1)(1 - f(v_2))$$

$$i_{1_3} = i_{2_1} f(v_3) \qquad i_{2_3} = i_{2_1} - i_{1_3} = \underbrace{i_{2_1}}_{I_{T_3}} - i_{2_1} f(v_3)$$

$$= (I_T - i_{1_1}) \cdot f(v_3) \qquad = i_{2_1}(1 - f(v_3))$$

$$= I_T (1 - f(v_1)) f(v_3) \qquad = I_T (1 - f(v_1))(1 - f(v_3))$$

$$\underbrace{(i_{1_2} - i_{2_2})}_{\text{normal } i_{out_2}} - \underbrace{(i_{1_3} - i_{2_3})}_{i_{out_3}} = (i_{1_2} + i_{2_3}) - (i_{2_2} + i_{1_3})$$

$$i_{1_2} + i_{2_3} = I_T f(v_1) f(v_2) + I_T (1 - f(v_1))(1 - f(v_3))$$

$$i_{2_2} + i_{1_3} = I_T f(v_1)(1 - f(v_2)) + I_T (1 - f(v_1)) f(v_3)$$

difference $= I_T \{ f(v_1) \cdot f(v_2) + 1 - f(v_1) - f(v_2) + f(v_1) f(v_3)$

$$-\left[f(v_1) - f(v_1)f(v_2) + f(v_3) - f(v_1)f(v_3)\right]\Big\}$$

set $v_3 = v_2$

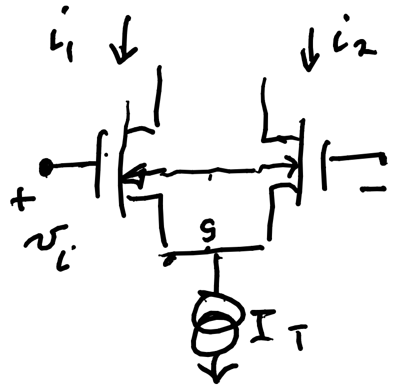
$$I_{out} = (i_{1_2}+i_{2_3}) - (i_{2_2}+i_{1_3}) = I_2\left[2f(v_1)-1\right]\left[2f(v_2)-1\right]$$

but $i_1 = \dfrac{I_T}{1+e^{-v/V_T}} \Rightarrow f(v) = \dfrac{1}{1+e^{-v/V_T}} \Rightarrow 2f(v)-1 = \tanh\left(\frac{v}{2V_T}\right)$

$$i_o = I_T \tanh\left(\frac{v_1}{2V_T}\right)\cdot\tanh\left(\frac{v_2}{2V_T}\right) \approx I_T\cdot\frac{v_1}{2V_T}\cdot\frac{v_2}{2V_T}$$ for small v_1 & v_2

∴ this connection gives a multiplier (analog) for small signals = Gilbert multiplier

($f(v) = \tanh v/2V_T$ for BJT)



here assume in saturation for MOS

$$i_D = k(v_{GS}-V_{th})^2$$

$$i_1 = k(v_+ - v_S - V_{th})^2 \quad \text{— 1)}$$

$$i_2 = k(v_- - v_S - V_{th})^2 \quad \text{2)}$$

$$i_1 + i_2 = I_T \quad \text{3)}$$

and from 1) & 2)

$$v_+ - v_S - V_{th} = \sqrt{i_1/k}$$

$$v_- - v_S - V_{th} = \sqrt{i_2/k}$$

$$v_{id} = v_i = v_+ - v_- = \sqrt{i_1/k} - \sqrt{i_2/k}$$

square $v_i^2 = \dfrac{i_1}{k} + \dfrac{i_2}{k} - \dfrac{2}{k}\sqrt{i_1 i_2}$

$$\Rightarrow -\sqrt{i_1 i_2} = \frac{k}{2}v_i^2 - \frac{(i_1+i_2)}{2} = \frac{k}{2}v_i^2 - \frac{I_T}{2}$$

$$i_1 i_2 = \left(\frac{k}{2}v_i^2 - \frac{I_T}{2}\right)^2$$

$$i_2 = I_T - i_1 \Rightarrow i_1 I_T - i_1^2 = \left(\frac{k}{2}v_i^2 - \frac{I_T}{2}\right)^2$$

$$i_1^2 - I_T i_1 + \left(\frac{k}{2}v_i^2 - \frac{I_T}{2}\right)^2 = 0$$

$$i_1 = \frac{I_T}{2} \pm \frac{1}{2}\sqrt{I_T^2 - 4\left(\frac{k}{2}v_i^2 - \frac{I_T}{2}\right)^2} = \frac{1}{2}\left\{I_T \pm \sqrt{4\cdot 2\,\frac{k}{2}v_i^2\,\frac{I_T}{2} - k^2 v_i^4}\right\}$$