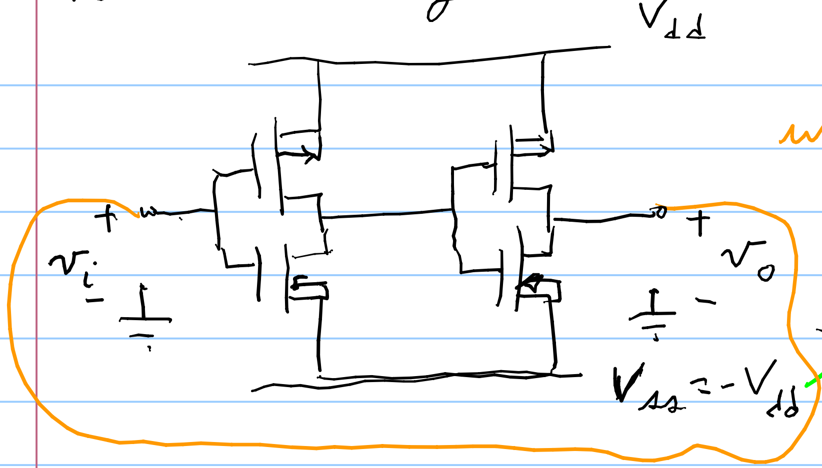
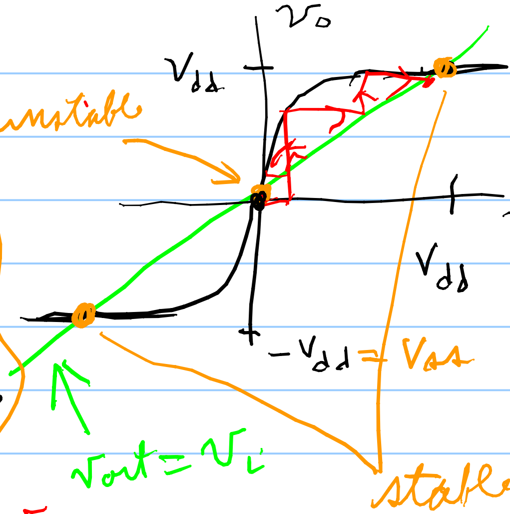
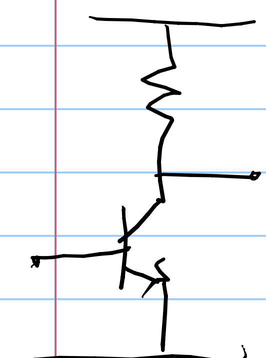
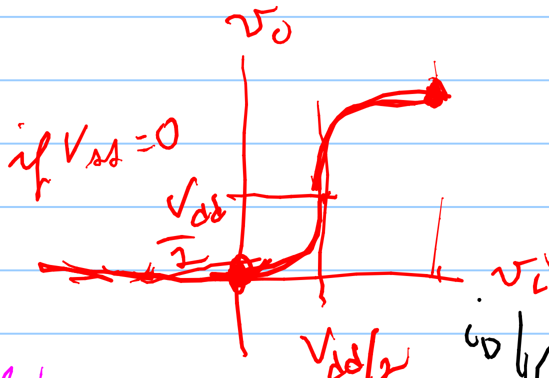
EE302
03/10/05

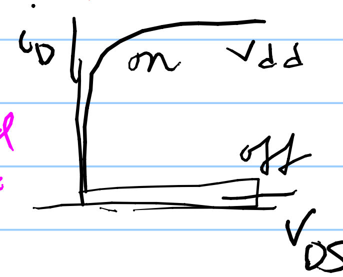
P. 1031 = memory cell

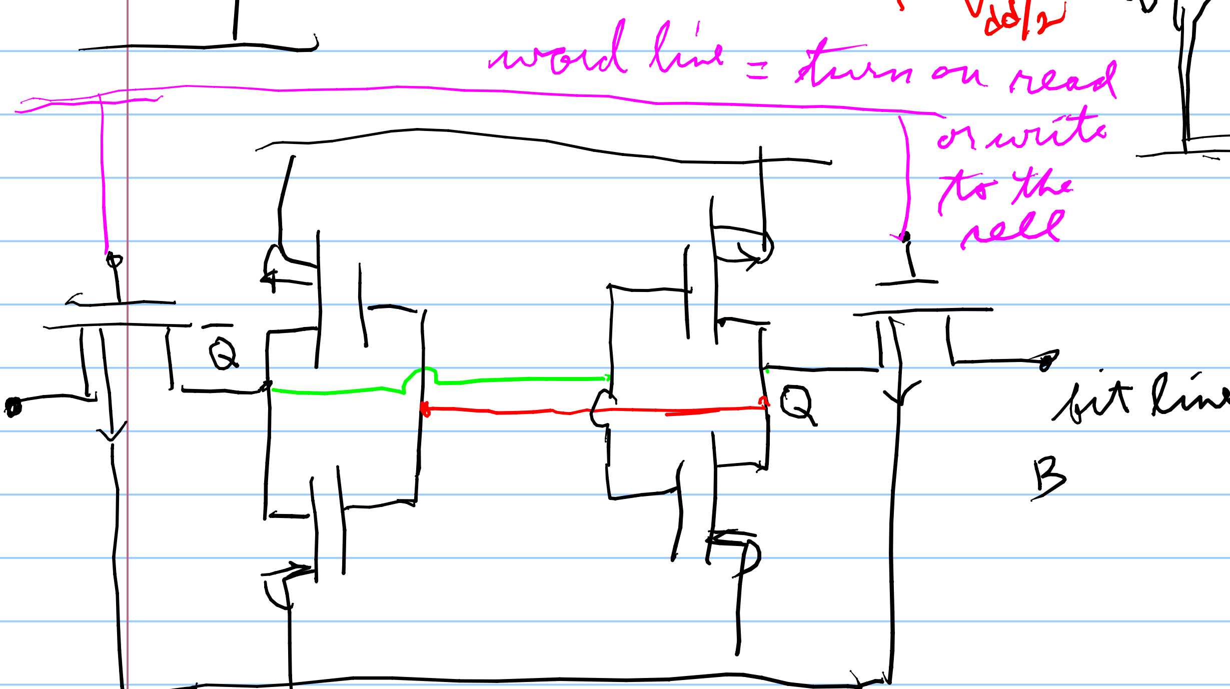


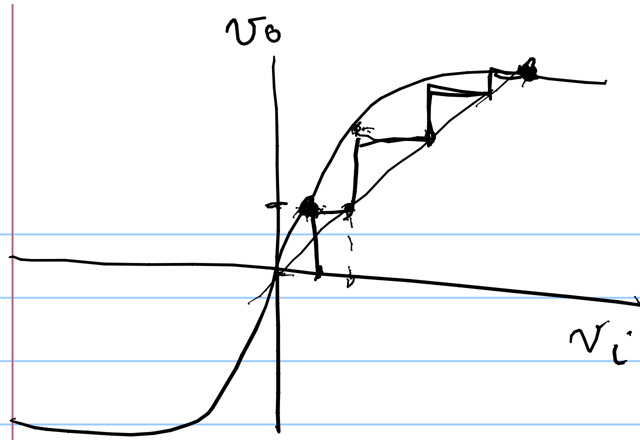




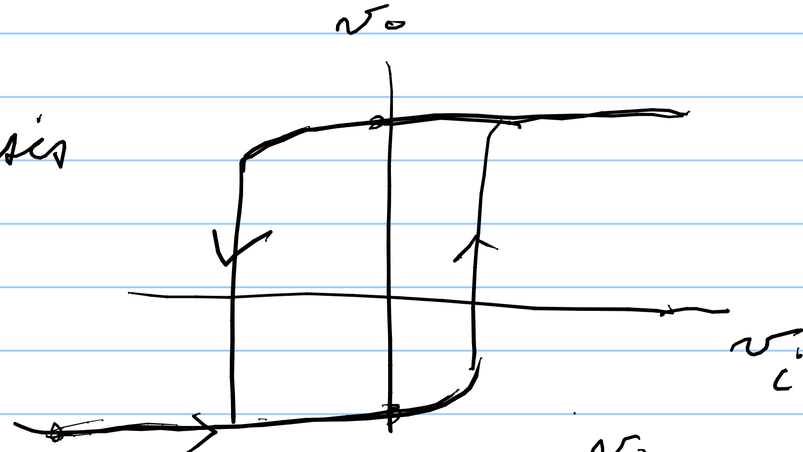


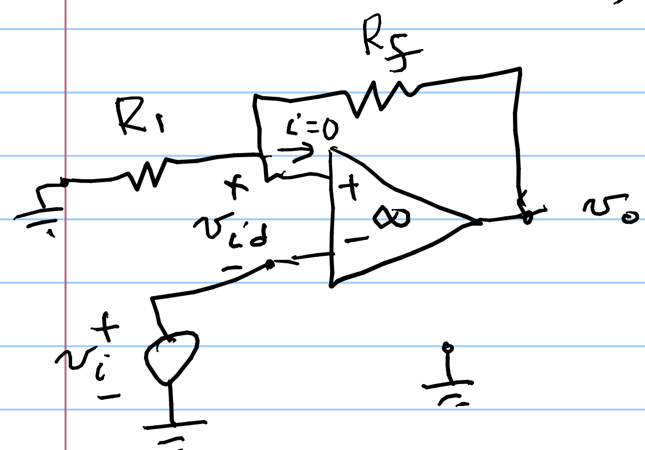


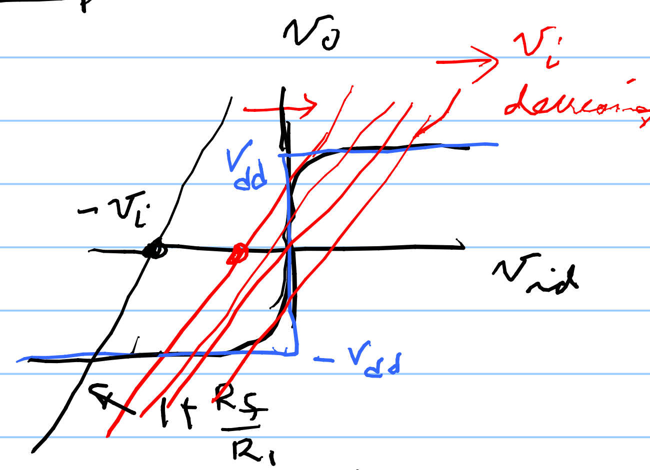




hysteresis







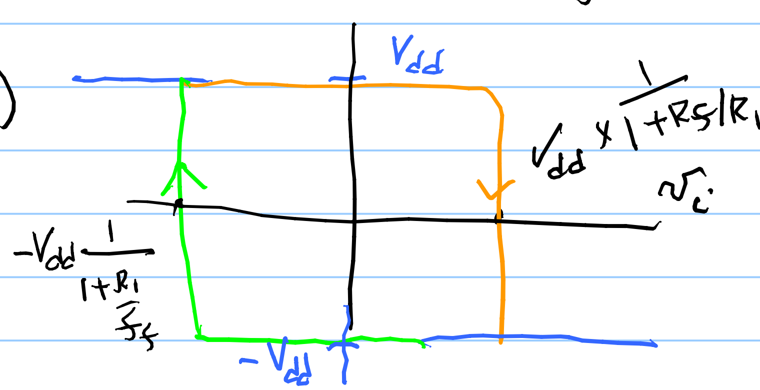
$$v_+ = \frac{R_1}{R_1+R_f} v_o \; ; \quad v_{id} = v_+ - v_i = \frac{R_1}{R_1+R_f} v_o - v_i$$

v_o

$$v_o = \frac{R_1+R_f}{R_1}(v_{id}+v_i)$$

at $v_o = V_{dd}$ & $v_{id} = 0$

$$\Rightarrow v_{i_{jump}} = V_{dd} \times \frac{R_1}{R_1+R_f}$$



$$2\frac{1}{1+\frac{R_f}{R_1}} \times V_{dd} \geq w_{hys}.$$

can control hysteresis width by R_f/R_1

can vary between 0 & $2V_{dd}$ $\quad 0 < w_{hys} < 2V_{dd}$

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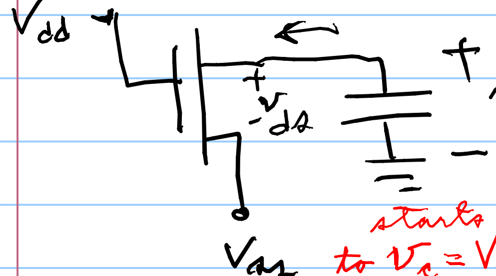
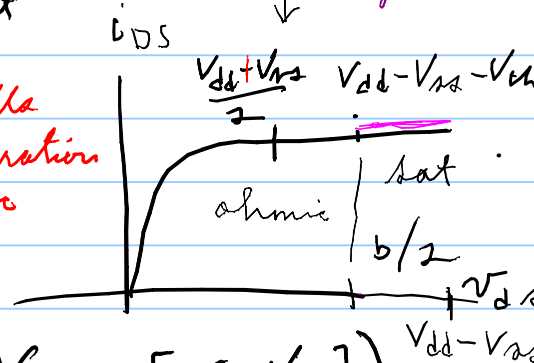
case $\quad i_{DS} = -i_C = -C\frac{dv_C}{dt} = -C\frac{d(v_C - V_{ss})}{dt}$

$$= -C\frac{dx}{dt}$$



starts at $v_C = V_{dd}$, falls to $v_C = V_{dd} - V_{th}$ in saturation then switches to ohmic

switch next stage



in ohmic

$$i_{DS} = \beta\left(2(V_{dd} - V_{ss} - V_{th})(v_C - V_{ss}) - (v_C - V_{ss})^2\right)\left(1 + \lambda[v_C - V_{ss}]\right)$$

let $x = v_C - V_{ss}$ $\quad$ [here start when reach ohmic region i.e. when v_C falls to $V_{dd} - V_{ss} - V_{th} = b/2$]

$$2(V_{dd} - V_{ss} - V_{th}) = b$$

$$\frac{dv_C}{dt} = -\frac{\beta}{C}\left[bx - x^2\right](1 + \lambda x)$$

We desire to find the time t_f to go to $v_{C_f} = \frac{V_{dd}+V_{ss}}{2}$ starting at $t=0$

$$v_C(0) = V_{dd} - V_{th} \equiv v_{ds} = b/2$$

$$\int_0^{t_f} \frac{dv_C}{dt}\,dt = \int_0^{t_f}$$

Thus $x(0) = v_{C_0} - V_{ss} = b/2$

$$x(t_f) = \frac{V_{dd}+V_{ss}}{2} - V_{ss} = \frac{b}{4} + V_{th}$$

$$\left(-\frac{c}{\beta}\,\frac{dx/dt}{(bx-x^2)(1+\lambda x)}\right)dt = \frac{dt}{dt}\cdot dt$$

$$\int_0^{t_f} dt = \frac{-c}{\lambda\beta}\int_{x(0)=b/2}^{x(t_f)=\frac{b}{4}+V_{th}} \frac{dx}{x(b-x)(x+1/\lambda)}$$

$$\frac{1}{x(b-x)(x+1/\lambda)} = \frac{\frac{\lambda}{b}}{x} + \frac{\frac{1}{b}\cdot\frac{1}{b+1/\lambda}}{b-x} + \frac{\frac{1}{-1/\lambda}\cdot\frac{1}{b+1/\lambda}}{x+1/\lambda}$$

$$t_f = \frac{-c}{\lambda\beta}\left\{\frac{\lambda}{b}\cdot\ln x - \frac{1}{b}\cdot\frac{\lambda}{1+\lambda b}\ln(b-x) + \frac{-\lambda^2}{\lambda b+1}\cdot\ln(x+1/\lambda)\right\}\Bigg|_{x=b/2}^{x}$$

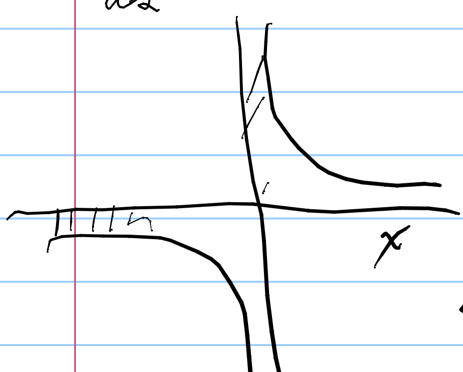
if ignore Early effect $\equiv \lambda = 0$

$$t_f = -\frac{c}{\beta}\left[\frac{1}{b}\ln x - \frac{1}{b}\ln(b-x)\right]\Bigg|_{x=x(0)}^{x=x(t_f)}$$

$$= -\frac{c}{\beta b}\cdot\ln\left(\frac{x}{b-x}\right)\Bigg| = \frac{c}{\beta b}\cdot\ln\left(\frac{b-x}{x}\right)$$

$$= \frac{c}{\beta b}\ln\left(\frac{b}{x}-1\right)\Bigg|_{x(0)}^{x(t_f)}$$

as



$$\int\frac{1}{x}dx = \ln x\ ;\ x>0$$

when $\lambda = 0$

added:

$$x = b/4 + V_{th}$$

$$t_f = \frac{C}{\beta b} \ln\left(\frac{b}{x} - 1\right)\Bigg|_{x=b/2}^{x=b/4+V_{th}} = \frac{\;}{b}\left[\ln\left(\frac{b}{\frac{b}{4}+V_{th}} - 1\right) - \ln\left(\frac{b}{b/2} - 1\right)\right]$$

$$= \frac{C}{\beta b} \ln\left(\frac{3b - 4V_{th}}{b + 4V_{th}}\right) \qquad \beta = \frac{KP}{2}\frac{W}{L}$$

$$b = 2(V_{dd} - V_{ss} - V_{th})$$

previously found the time to go from $v_c = V_{dd}$ to $v_c = V_{dd} - V_{th}$ while in saturation, this was

$$t_{f_s} = \frac{C V_{th}}{\beta (b/2)^2} \qquad \text{from } 03/08/05$$

$\therefore$ the time to trigger a following stage is

$$t_{total} = t_{f_{ohmic}} + t_{f_{sat}} = \frac{C}{\beta b}\left[\frac{4V_{th}}{b} + \ln\left(\frac{3 - [4V_{th}/b]}{1 + [4V_{th}/b]}\right)\right]$$

Example: If $V_{th} = 1$, $V_{dd} = 5$, $V_{ss} = 0$

$$b = 2(5 - 0 - 1) = 8, \quad 4V_{th}/b = 1/2$$

If also $KP = 2 \times 10^{-4}$, $W = L = 10\mu$

$$\beta = \frac{KP}{2}\frac{W}{L} = 10^{-4}$$

If further $C = 10\,pfd$

$$\text{Time to switch} = \frac{10 \times 10^{-12}}{10^{-4} \times 8} \cdot \left[\frac{1}{2} + \underbrace{\ln\left(\frac{3 - 1/2}{1 + 1/2}\right)}_{= \ln(5/3)}\right] \text{ seconds}$$

$$= \frac{10}{8} \times 10^{-6}\left[0.5 + 0.511\right] \approx 1.39\,\mu sec$$