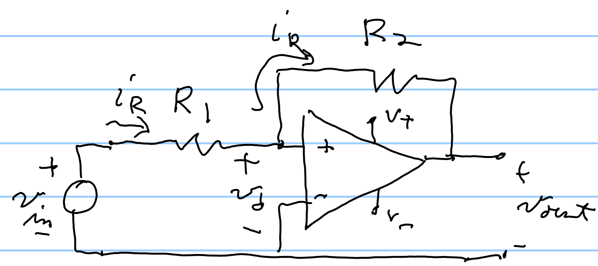
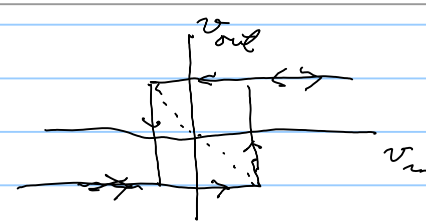
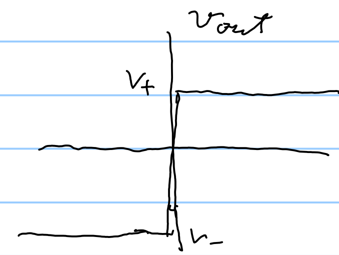
ENEE 610
11/14/17

Note Title 11/14/2017

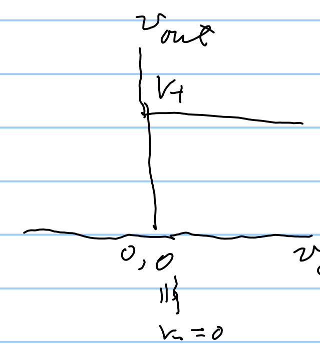
# Binary hysteresis



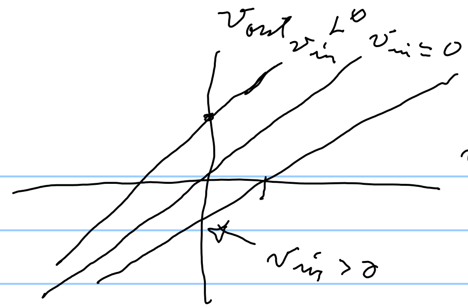

$\Rightarrow$



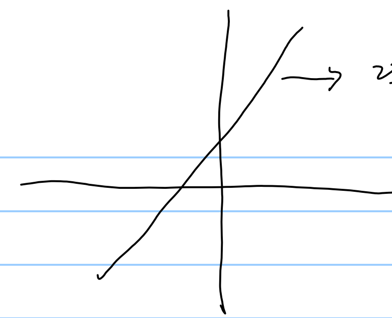

$$v_{out} = V_+ 1(v_d)$$

$i_{in_{+,-}}$ of op amp $= 0$, $\quad i_R = G_1(v_{in} - v_d) = G_2(v_d - v_{out}) \Rightarrow G_1 v_{in} - (G_1+G_2)v_d = -G_2 v_{out}$

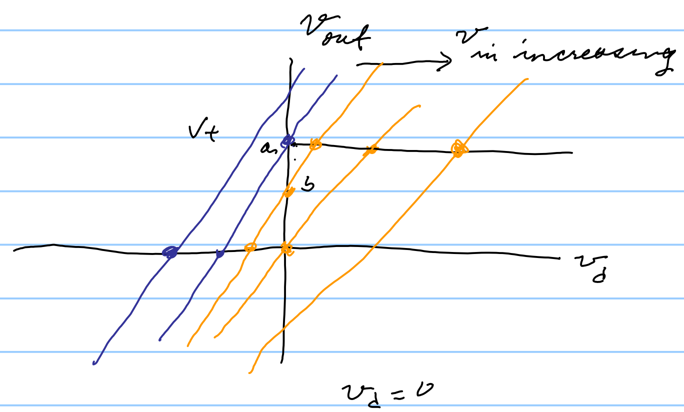
$$v_{out} = \frac{1}{G_2}\left[(G_1+G_2)v_d - G_1 v_{in}\right] = \left(\frac{G_1}{G_2}+1\right)v_d - \frac{G_1}{G_2}v_{in}$$

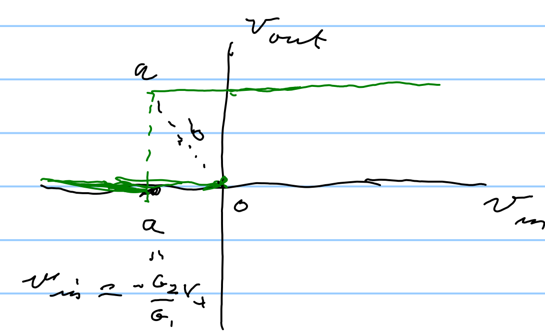



$\leftarrow$ slope $= \left(1 + \frac{G_1}{G_2}\right) = \left(1 + \frac{R_2}{R_1}\right)$



$\rightarrow v_{in}$ increases



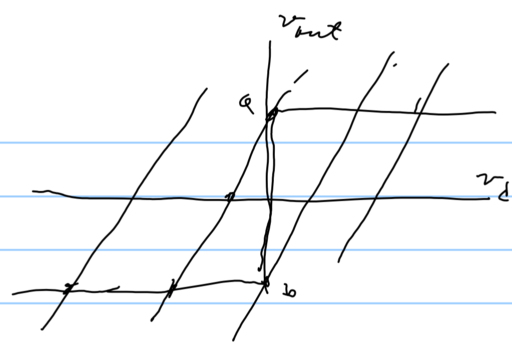



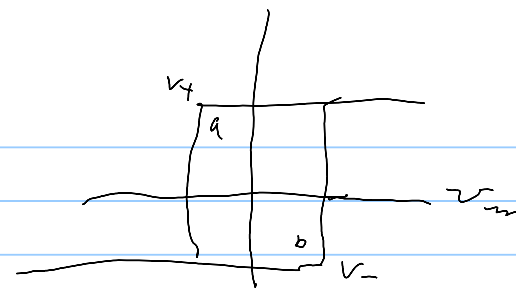

jump point a: $v_{out}\Big| = V_+ = -\frac{G_1}{G_2} v_{in_a} \Rightarrow v_{in_a} = -\frac{G_2}{G_1} V_+$

$v_{out} = \left(1 + \frac{G_1}{G_2}\right) v_d - \frac{G_1}{G_2} v_{in}$

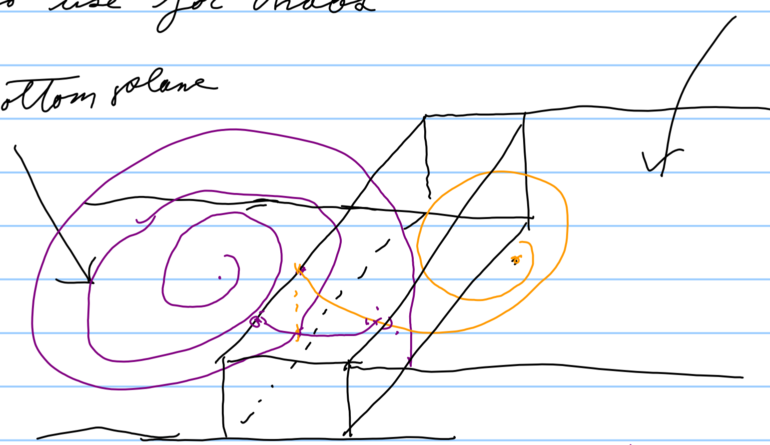
$v_{out} = V_+ \mathcal{S}(v_d)$

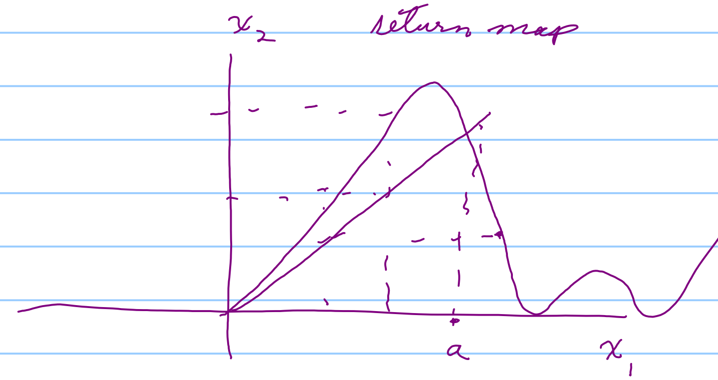
If $V_- \neq 0$




How to use for chaos



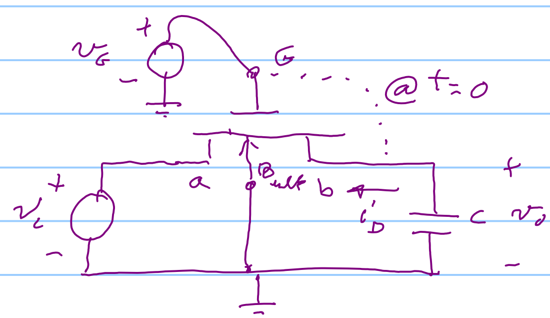




"if get a period 3 return map then get "chaos" as defined by Prof. Yorke

$\Rightarrow \liminf_{t\to\infty} v_{out} \neq \limsup_{t\to\infty} v_{out}$

if set initial conditions in period 3 position of return map

can make the unstable oscillators with the same capacitors.




assume $v_o = V_{DD} > 0$

@ $t = 0$ let $v_G = V_{DD}$, $v_i(t) = 0$, $t > 0$

$b$ = drain @ $t = 0$, $a$ = source
$= D$ $\quad\quad = S$

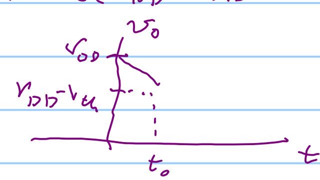
$v_{DS} = V_{DD}$, $v_{GS} = V_{DD}$, $\underbrace{v_{GS}}_{V_{DD}} - V_{th} < v_{DS}(t) = v_o(t)$

$\Downarrow$

Transistor is saturation

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

$-C\frac{dv_o}{dt} = k(V_{DD} - V_{th})^2$




$$v_o = -\frac{1}{C}\int_0^t k(V_{DD} - V_{th})^2 d\tau + V_{DD}$$
$$= -\frac{1}{C}k(V_{DD} - V_{th})]\,t + V_{DD}$$

for $t > t_0$ then $\underset{v_o(t)}{\overset{V_{DS}(t)}{\shortparallel}} < V_{DD} - V_{th} = v_{GS} \Rightarrow$ transistor is ohmic, triode

$$i_D = k\left(2(v_{GS} - V_{th})v_{DS} - v_{DS}^2\right) \approx -C\frac{dv_o}{dt} = k\left(2(V_{DD} - V_{th})v_o - v_o^2\right)$$

$$\frac{dv_o}{2(V_{DD} - V_{th})v_o - v_o^2} = -\frac{dt}{C/k} \Rightarrow \int_{v_o(t_0)}^{v_o(t)} \frac{dv_o}{v_o(d - v_o)} = \int_{t_0}^{t} \frac{-d\tau}{C} = -\frac{k}{C}(t - t_0), \quad d = 2(V_{DD} - V_{th})$$

$$\frac{1}{v_o(d - v_o)} = \frac{-1}{v_o(v_o - d)} = \frac{1/d}{v_o} + \frac{-1/d}{v_o - d} = \frac{(1/d)(v_o - d)}{v_o(v_o - d)} + \frac{(-1/d)v_o}{v_o(v_o - d)} = \frac{-1}{v_o(v_o - d)}$$

$$\int_{v(t_0)}^{v(t)} \left[(+1/d)\frac{dv_o}{v_o} + \frac{(-1/d)}{v_o - d}\, d(v_o - d)\right] = \frac{1}{d}\ln v_o \Big|_{v_o = v(t_0)}^{v_o = v(t)} + \left(-\frac{1}{d}\right)\ln(v_o - d)\Big|_{v_o(t_0) - d}^{v_o(t) - d} = -\frac{k}{C}(t - t_0)$$

$$\frac{-dk}{C}(t - t_0) = \ln\left(\frac{v(t)}{v(t_0)}\right) - \ln\left(\frac{v(t) - d}{v(t_0) - d}\right) = \ln\left(\frac{v(t)}{v(t) - d} \times \left(\frac{v(t_0) - d}{v(t_0)}\right)\right) \quad t > t_0$$

$$e^{-\frac{dk}{\dot{c}}(t-t_0)} = \frac{v_0(t)}{v_0(t)-d} \cdot \frac{v(t_0)-d}{v(t_0)} \qquad @\ t=t_0 \Rightarrow e^0 = 1$$

can solve for $v_0(t)$, $t > t_0$ as $t \to \infty$, $v_0(t) \to d$