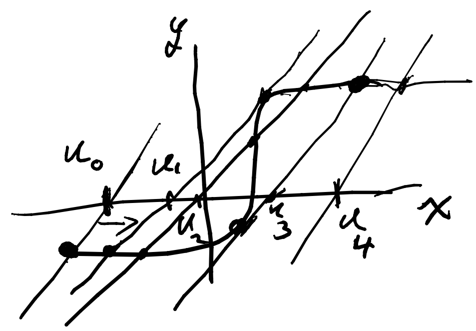
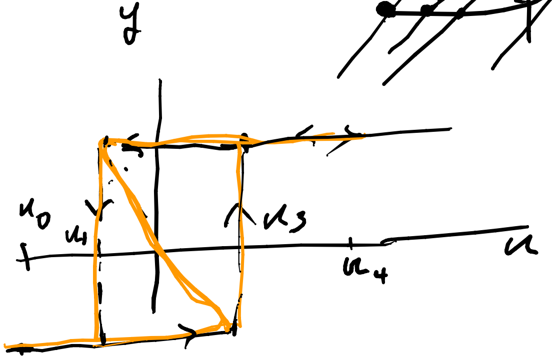
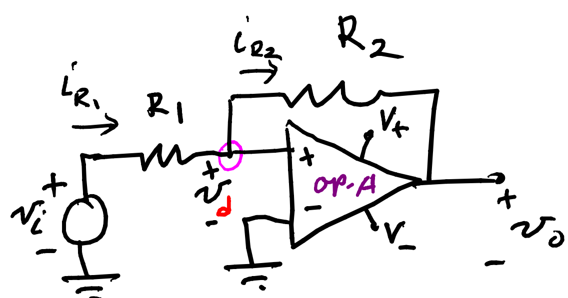
Hysteresis

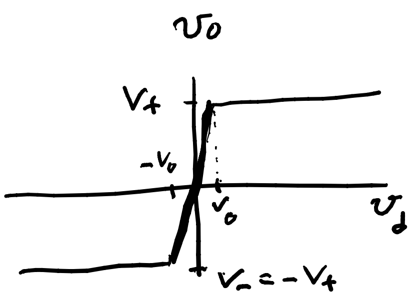
EE 610
10/27/08





actual circuit for



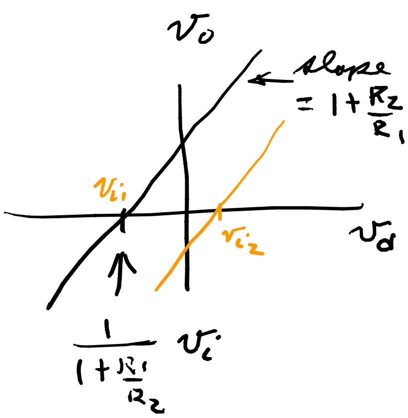


device curve

$i_{R_1} = i_{R_2}$ as no current into input lead of the op-amp

$$i_{R_1} = \frac{1}{R_1}(v_i - v_d) = i_{R_2} = \frac{1}{R_2}(v_d - v_o)$$

$$\frac{R_2}{R_1}(v_i - v_d) = v_d - v_o$$



$$v_o = v_d + \frac{R_2}{R_1} v_d - \frac{R_2}{R_1} v_i$$

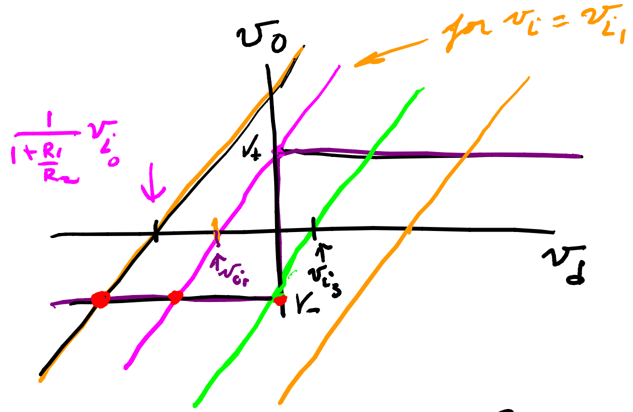
$$= \left(1 + \frac{R_2}{R_1}\right) v_d - \frac{R_2}{R_1} v_i$$

$y = \left(1 + \frac{R_2}{R_1}\right) x + y_0$

$\frac{dy}{dx} = 1 + \frac{R_2}{R_1}$

when $v_o = 0$ intersect at

$$v_d = \frac{R_2/R_1}{1 + R_2/R_1}, \quad v_i = \frac{1}{1 + \frac{R_1}{R_2}} v_i$$



1) $v_o = (1+\frac{R_2}{R_1})v_d - \frac{R_2}{R_1}v_{i_1}$

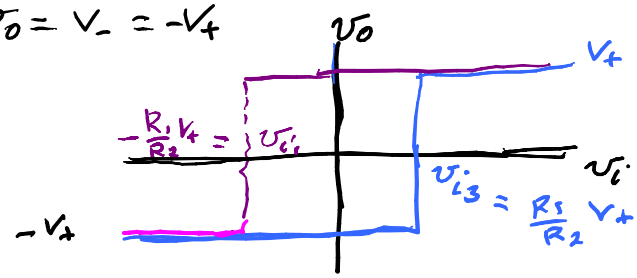
2) $v_o = V_+$ for v_{i_1} intersect

here $v_d = 0$ for v_{i_1}

$$V_+ = 0 - \frac{R_2}{R_1}v_{i_1} \Rightarrow v_{i_1} = -\frac{R_1}{R_2}V_+$$

1') $v_o = (1+\frac{R_2}{R_1})v_d - \frac{R_2}{R_1}v_{i_3} = V_- = -V_+$ & $v_d = 0$ $\Big\}$ $v_{i_3} = -\frac{R_1}{R_2}V_- = +\frac{R_1}{R_2}V_+$

2') $v_o = V_- = -V_+$

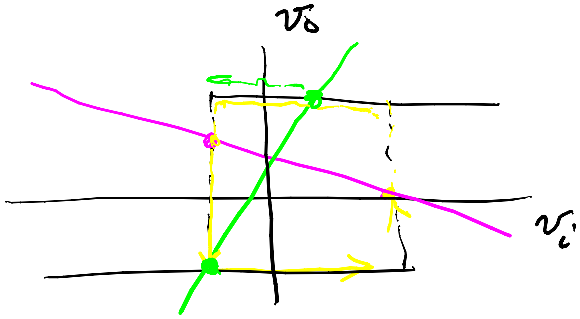


hysteresis width $= v_{i_3} - v_{i_1} = 2\frac{R_1}{R_2}V_+$

For a more practical one there is a non ∞ slope at the origin for v_o/v_d of the op-amp

To get more than 1 intersect need the slope of the load line, $\left(\frac{1}{1+\frac{R_2}{R_1}}\right)$, less than the device slope.

We need slope of load line = device slope for a jump point



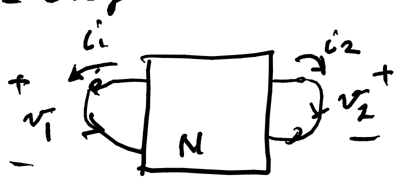
This makes a nice oscillator

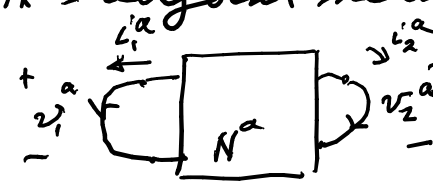
or memory

p.406 = adjoint   allows to take the derivative by solving circuit equations

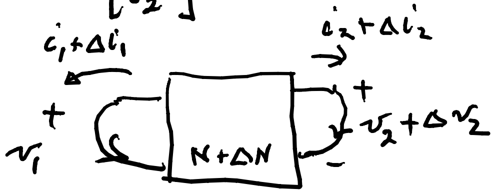
Here will get $Y^a_{b\times b} = Y^T_{b\times b}$ where these b's don't include input & output branches

N = original network, N^a = adjoint network; same graph





1) $[v_1\ \ v_2]\begin{bmatrix} i_1^a \\ i_2^a \end{bmatrix} + v_b^T i_b^a = 0$ $[v_1^a\ v_2^a]\begin{bmatrix} i_1 \\ i_2 \end{bmatrix} + v_b^{aT} i_b = 0$ (2



(same graph)

3) $[v_1\ \ v_2+\Delta v_2]\begin{bmatrix} i_1^a \\ i_2^a \end{bmatrix} + (v_b+\Delta v_b)^T i_b^a = 0$

4) $[v_1^a,\ v_2^a]\begin{bmatrix} i_1+\Delta i_1 \\ i_2+\Delta i_2 \end{bmatrix} + v_b^{aT}(i_b+\Delta i_b) = 0$

if the output is open-circuit v_2, & input voltage source v_1

$\Downarrow$

$i_2 = 0 \Rightarrow \Delta i_2 = 0$

assume have admittance matrices $Y = Y_{b\times b}$, $Y^a = Y^a_{b\times b}$

& have a change in Y, ΔY.

1)−3): $[0+\Delta v_2\cdot i_2^a] + v_b^T i_b^a - [v_b+\Delta v_b]^T\cdot i_b^a = 0$

$$\Rightarrow \Delta v_2\cdot i_2^a - (\Delta v_b)^T\cdot i_b^a = \Delta v_2\cdot i_2^a - \Delta v_b^T\cdot Y^a v_b^a = 0 \qquad (5$$

2)−4): $[\cancel{v_1^a i_1} - \cancel{v_1^a i_1} - v_1^a\Delta i_1 - \underbrace{v_2^a i_2}_{0} - \underbrace{v_2^a\Delta i_2}_{0}] + \cancel{v_b^{aT} i_b} - v_b^{aT}(\cancel{i_b}+\Delta i_b) = 0$

$$\Rightarrow -v_1^a\Delta i_1 - v_b^{aT}\Delta i_b = 0$$

but $i_b = Y_{b\times b}\cdot v_b \Rightarrow \Delta i_b = \Delta Y\cdot v_b + Y\cdot\Delta v_b$

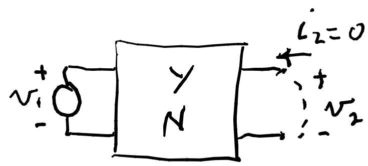
$$-v_1^a\Delta i_1 - v_b^{aT}\Delta Y\cdot v_b - v_b^{aT} Y\cdot\Delta v_b = 0 \qquad (6$$

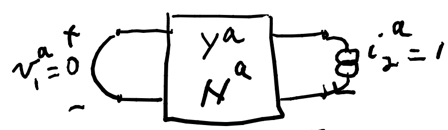
6)−5) $\Rightarrow -v_1^a\Delta i_1 - v_b^{aT}\Delta Y\cdot v_b - v_b^{aT} Y\Delta v_b - \Delta v_2\cdot i_2^a + \Delta v_b^T Y^a v_b^a = 0$ $\Rightarrow$ gives $Y^a = Y^T$

set $v_1^a = 0$ (a short) $\Rightarrow \Delta v_2\cdot i_2^a = v_b^{aT}\cdot\Delta Y\cdot v_b$

$\therefore$ set $i_2^a = 1 \Rightarrow \boxed{\Delta v_2 = v_b^{aT}\Delta Y v_b}$

$\Rightarrow$





$Y^a = Y^T$