$$E\frac{dx}{dt} = Ax + Bu$$
$$y = Cx$$

Let $\hat{x} = Px$, P = constant nonsingular

$P^{-1}P = 1_b$ = $b \times b$ identity matrix

x = b-vector

$$EP^{-1}\frac{dPx}{dt} = AP^{-1}Px + Bu$$
$$y = CP^{-1}Px$$

can premultiply by a constant matrix, nonsingular,

$$(QEP^{-1})\frac{d\hat{x}}{dt} = QAP^{-1}\hat{x} + QBu$$
$$y = CP^{-1}\hat{x}$$

P & Q are $b \times b$ nonsingular

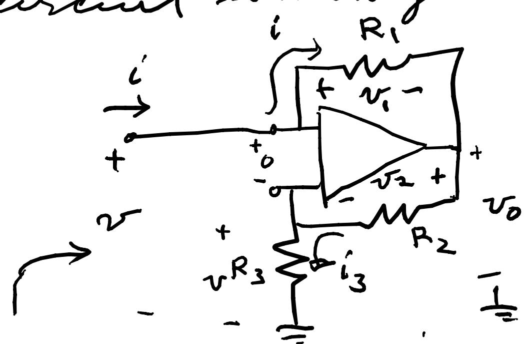
$$\Rightarrow \quad \left.\begin{aligned} \hat{E}\frac{d\hat{x}}{dt} &= \hat{A}\hat{x} + \hat{B}u \\ y &= \hat{C}\hat{x} \end{aligned}\right\} \text{ same input output description (normally } Q=P\text{)}$$

$$T(s) = \hat{C}(s\hat{E}-\hat{A})^{-1}\hat{B} = C(sE-A)^{-1}B$$

this allows many choices for a circuit giving this $T(s)$

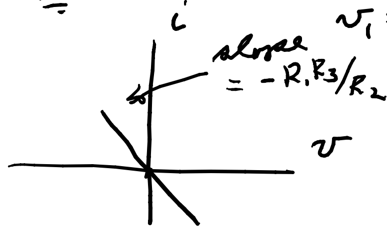
— — — — —

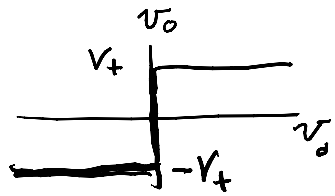
a circuit which gives negative resistance

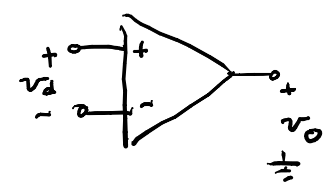


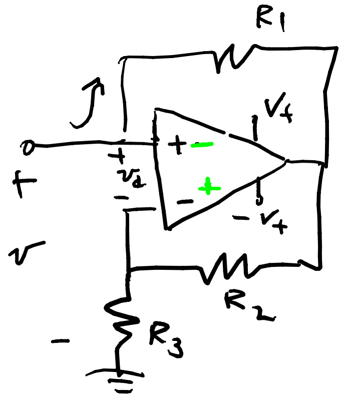
$$v = v_{R_3} = R_3 i_3$$
$$v_2 = R_2 i_3 = \frac{R_2}{R_3} v$$
$$v_2 = -v_1 \Rightarrow v_1 = -\frac{R_2}{R_3} v$$
$$v_1 = R_1 i \Rightarrow i = \frac{1}{R_1} v_1 = -\frac{1}{R_1}\frac{R_2}{R_3} v$$

$$R_{in} = -\frac{R_1 R_3}{R_2}$$



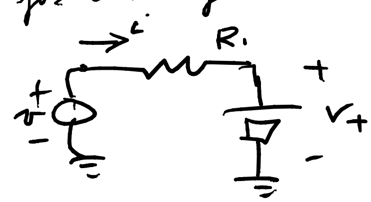




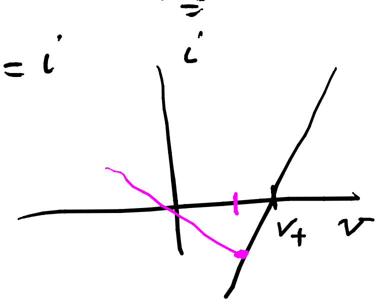


$\Rightarrow v_0 = V_+$

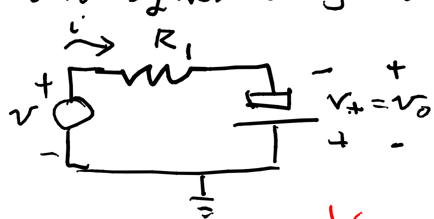
for v large



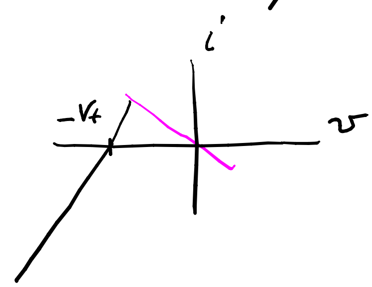
$$\frac{(v - V_+)}{R_1} = i$$

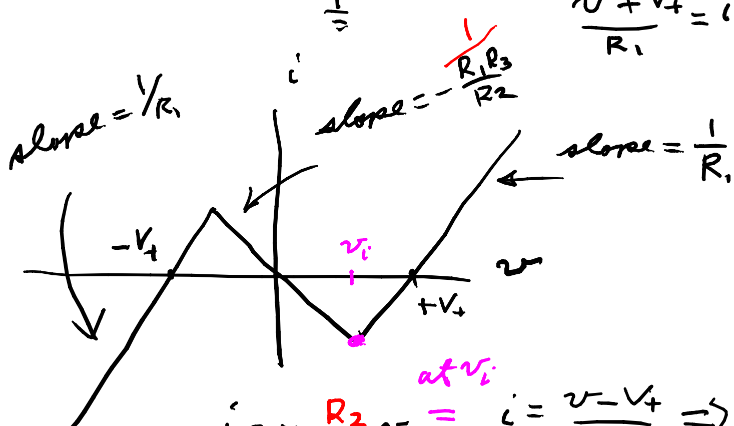


for v very small; $v_0 = -V_+$



$$\frac{v + V_+}{R_1} = i$$



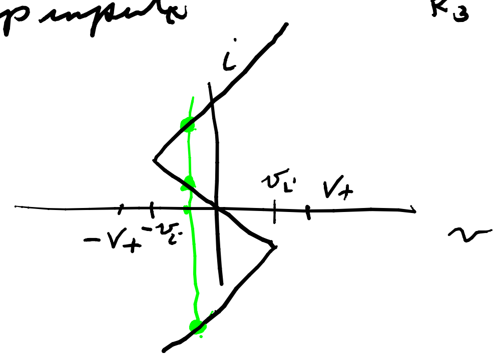


$$i = -\frac{R_2}{R_1R_3}v \overset{\text{at } v_i}{=} i = \frac{v - V_+}{R_1} \Rightarrow -\frac{R_2}{R_3}v_i - v_i = -V_+$$

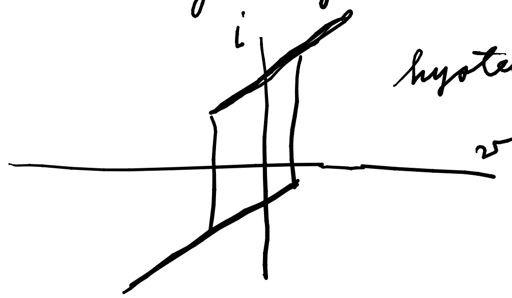
$$v_i = \frac{1}{1 + \frac{R_2}{R_3}} V_+$$

If we reverse the op-amp inputs
we exchange V_+ & $-V_+$

gives



which has 3 values for i given v in the range $-v_i \le v \le v_i$



hysteresis type curve

in Spice a DC run will not converge since there are 3 values at $v = 0$

chapter 8 $\Rightarrow$ positive-real functions
PR