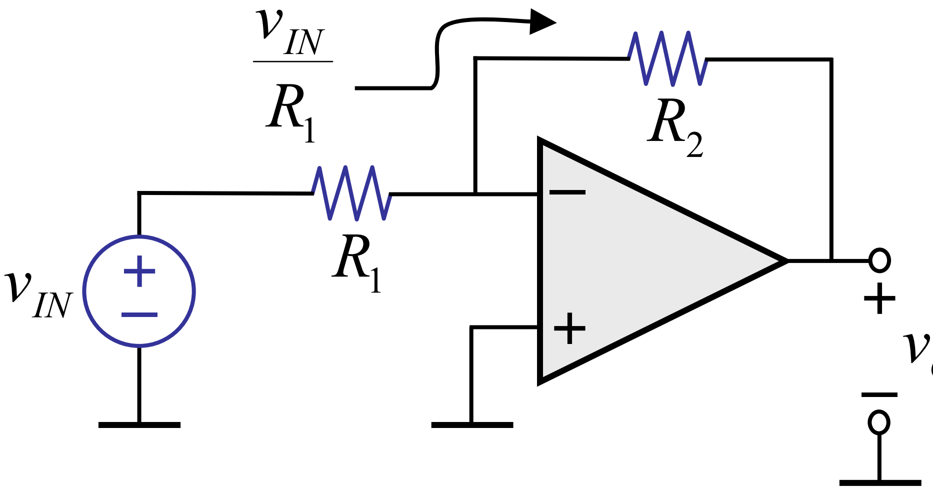
Op Amps Positive Feedback

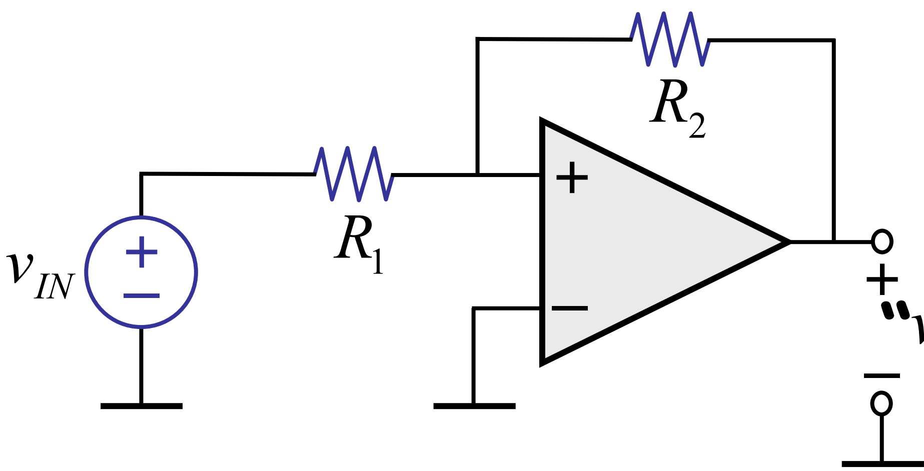
Negative vs Positive Feedback

Consider this circuit — *negative feedback*



$$v_{OUT} = -\frac{R_2}{R_1} v_{IN}$$

and this — *positive feedback*



see analysis on next page

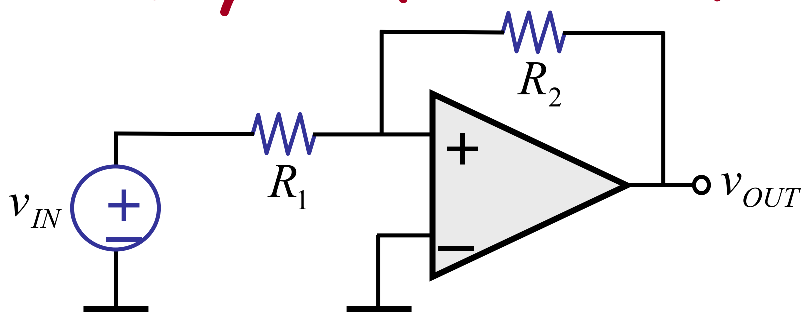
$$\text{"}v_{OUT} = -\frac{R_2}{R_1} v_{IN}\text{"}$$

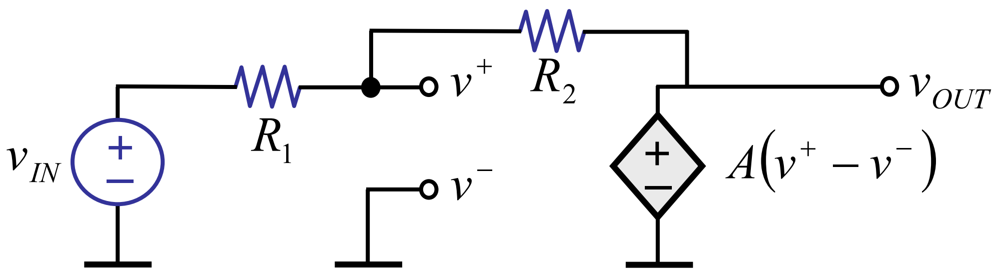
What's the difference?

Consider what happens when there is a pertubation…
Positive feedback drives op amp into saturation:

$$v_{OUT} \rightarrow \pm V_S$$

Static Analysis of Positive Feedback Ckt





$$v_{OUT} = A(v^+ - v^-)$$

$$= Av^+$$

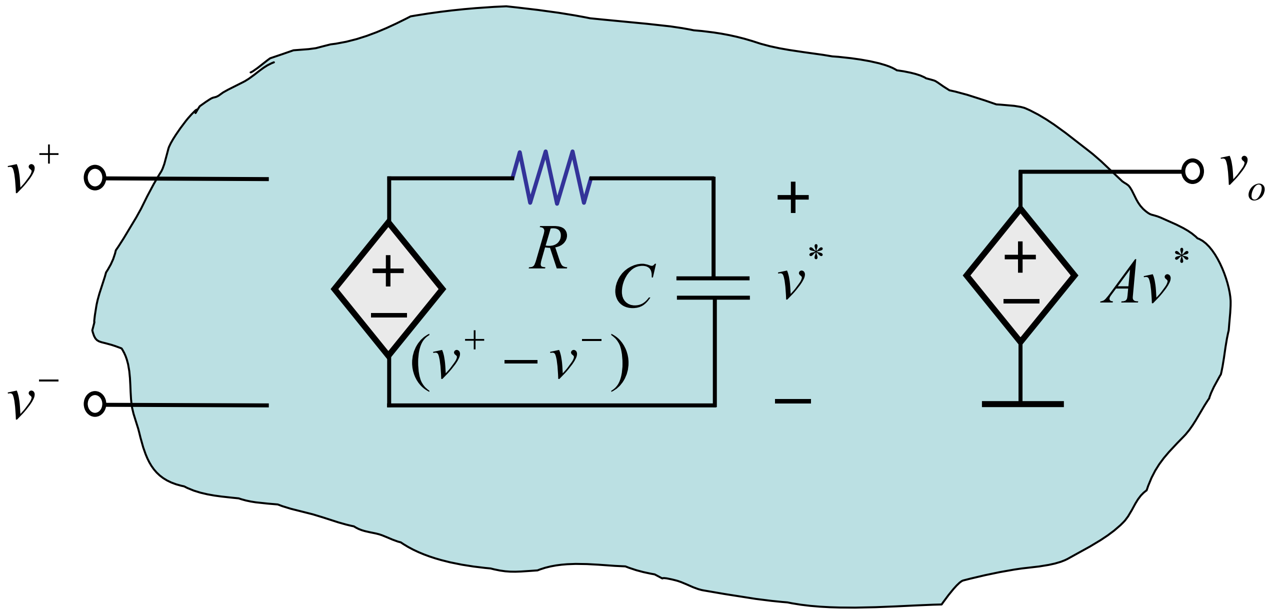
$$= A\left[\frac{v_{OUT} - v_{IN}}{R_1 + R_2} \cdot R_1 + v_{IN}\right]$$

$$= \frac{AR_1}{R_1 + R_2} v_{OUT} - \frac{AR_1 v_{IN}}{R_1 + R_2} + Av_{IN}$$

$$v_{OUT}\left[\cancel{1} - \frac{AR_1}{R_1 + R_2}\right] = v_{IN} A\left[1 - \frac{R_1}{R_1 + R_2}\right]$$

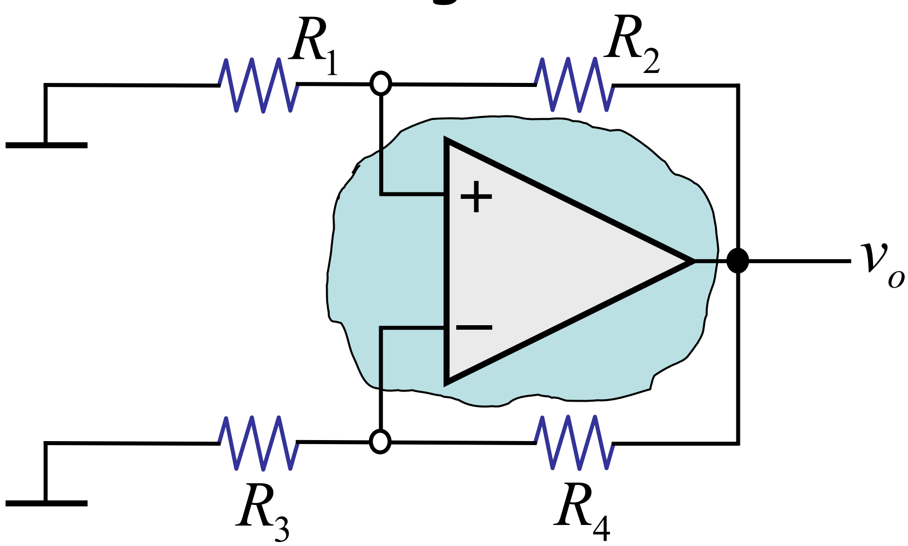
$$v_{OUT} = \left[\frac{1 - \frac{R_1}{R_1 + R_2}}{-\frac{\cancel{A}R_1}{R_1 + R_2}}\right] \cdot \cancel{A} v_{IN} = -\frac{R_2}{R_1} v_{IN}$$

Representing dynamics of op amp…

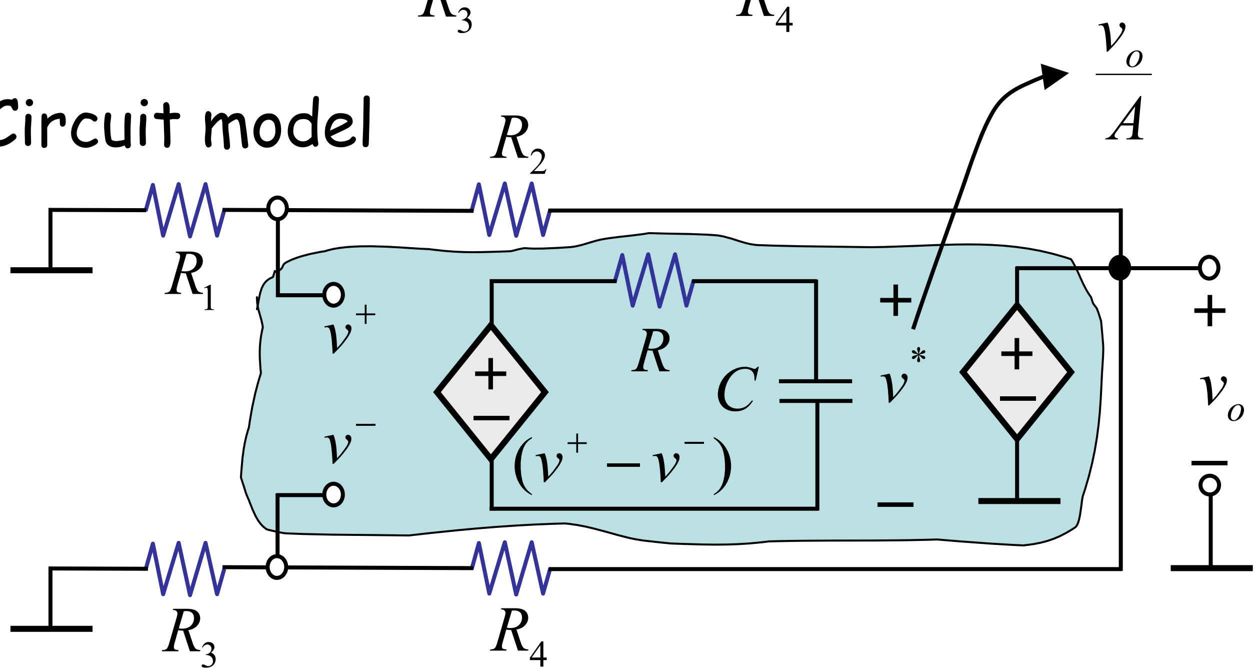


Representing dynamics of op amp…

Consider this circuit and let's analyze its dynamics to build insight.



Circuit model



Let's develop equation representing time behavior of v_o.

Dynamics of op amp…

$$v_o = Av^* \quad \text{or} \quad v^* = \frac{v_o}{A}$$

$$RC\frac{dv^*}{dt} + v^* = v^+ - v^-$$

$$\frac{RC}{A}\frac{dv_o}{dt} + \frac{v_o}{A} = v^+ - v^-$$

$$= (\overset{+}{\gamma} - \bar{\gamma})\ v_o$$

$$v^+ = \frac{v_o R_1}{R_1 + R_2} = \overset{+}{\gamma}\ v_o$$

$$v^- = \frac{v_o R_3}{R_3 + R_4} = \bar{\gamma}\ v_o$$

neglect

or $$\frac{dv_o}{dt} + \left[\frac{1}{RC} + \frac{A}{RC}(\bar{\gamma} - \overset{+}{\gamma})\right]v_o = 0$$

$$\frac{dv_o}{dt} + \underbrace{\frac{A}{RC}(\bar{\gamma} - \overset{+}{\gamma})}_{\text{time}^{-1}}\, v_o = 0$$

or $$\frac{dv_o}{dt} + \frac{v_o}{T} = 0 \quad where \ T = \frac{RC}{A(\bar{\gamma} - \overset{+}{\gamma})}$$

$$v_o(0) = 0$$

Consider a small disturbance to v_o (noise).

if $\bar{\gamma} > \overset{+}{\gamma}$ $\quad T$ *is positive*

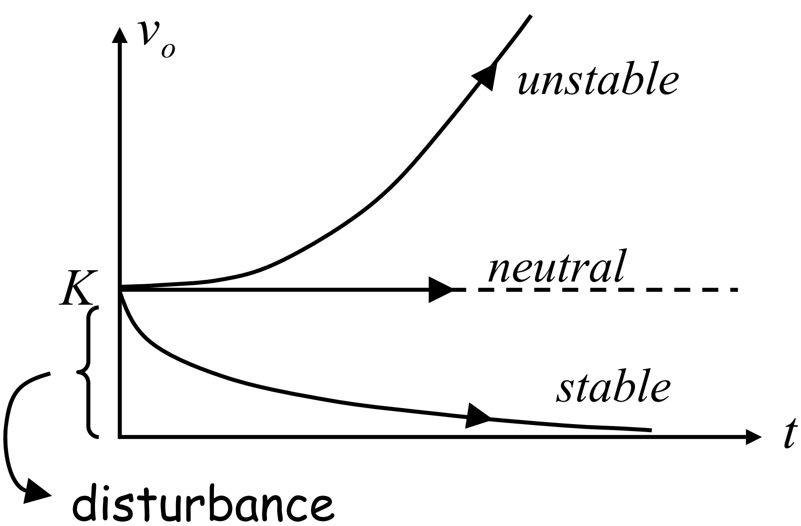
$$v_o = K e^{-\frac{t}{T}} \qquad \textit{stable}$$

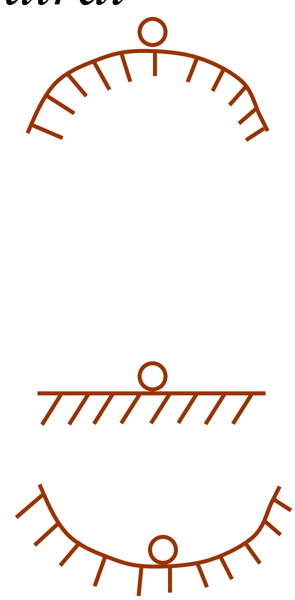
if $\overset{+}{\gamma} > \bar{\gamma}$ $\quad T$ *is negative*

$$v_o = K e^{\frac{t}{|T|}} \qquad \textit{unstable}$$

if $\overset{+}{\gamma} = \bar{\gamma}$ $\quad T$ *is very large*

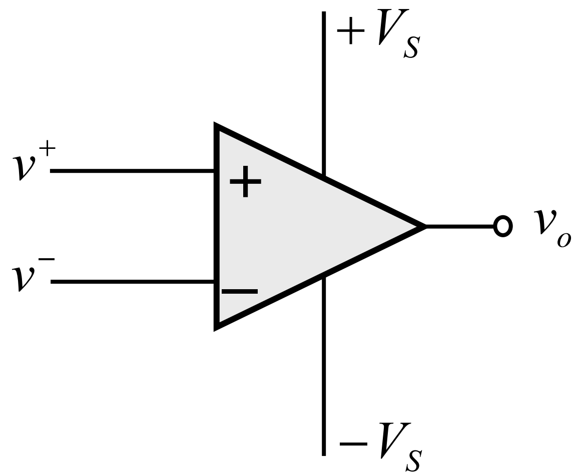
$$v_o = K \qquad \textit{neutral}$$

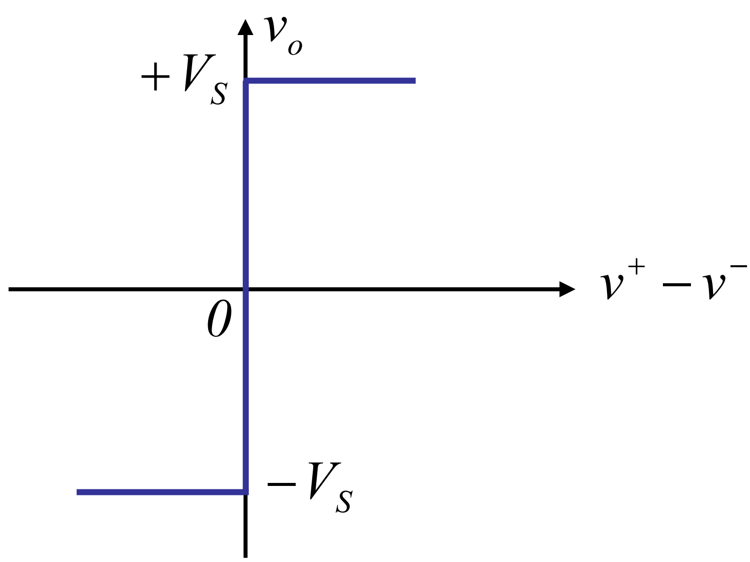


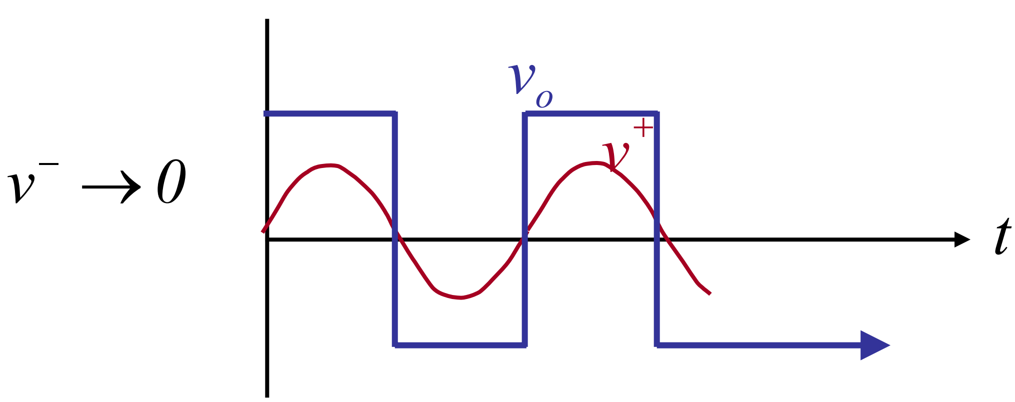


Now, let's build some useful circuits with positive feedback.

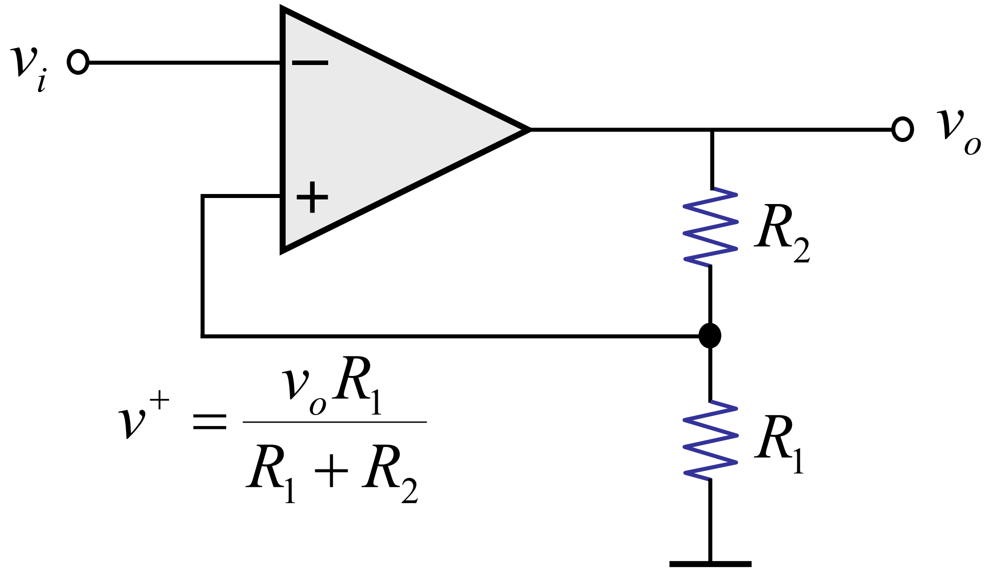
One use for instability: Build on the basic op amp as a comparator

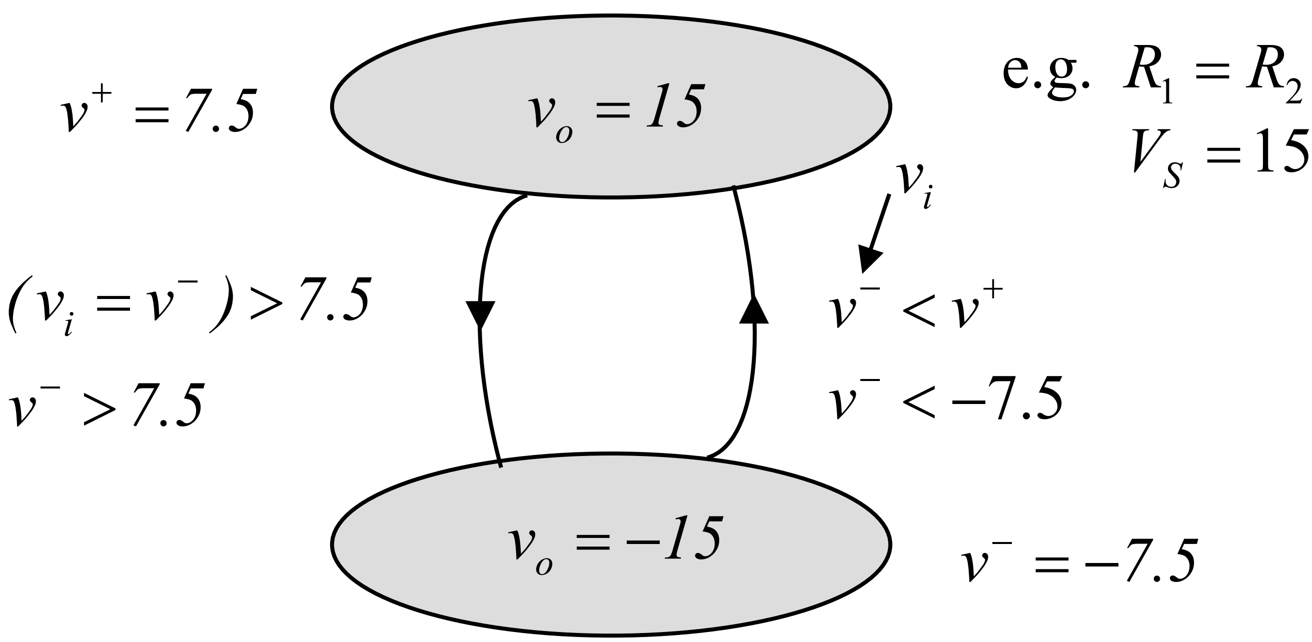




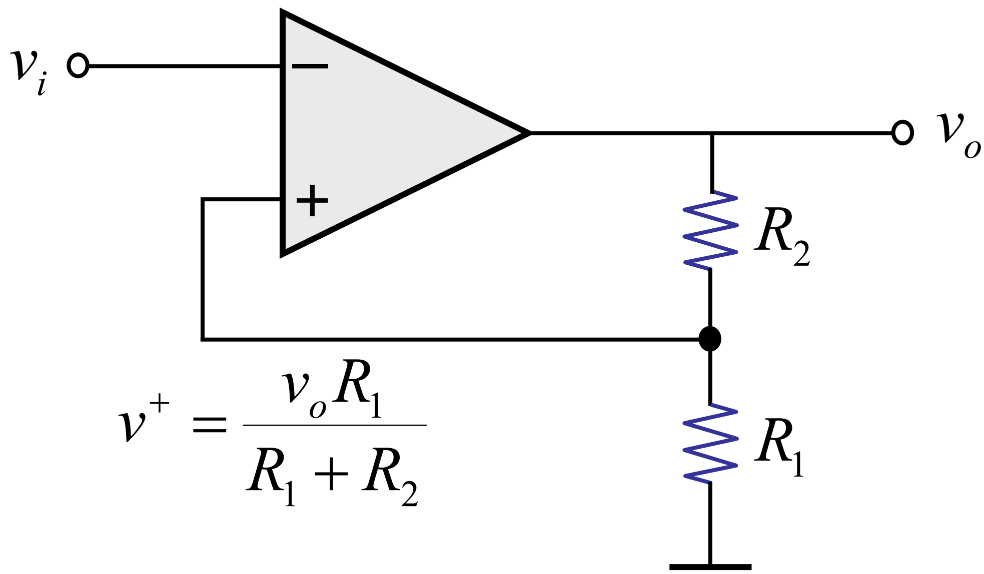


Now, use positive feedback

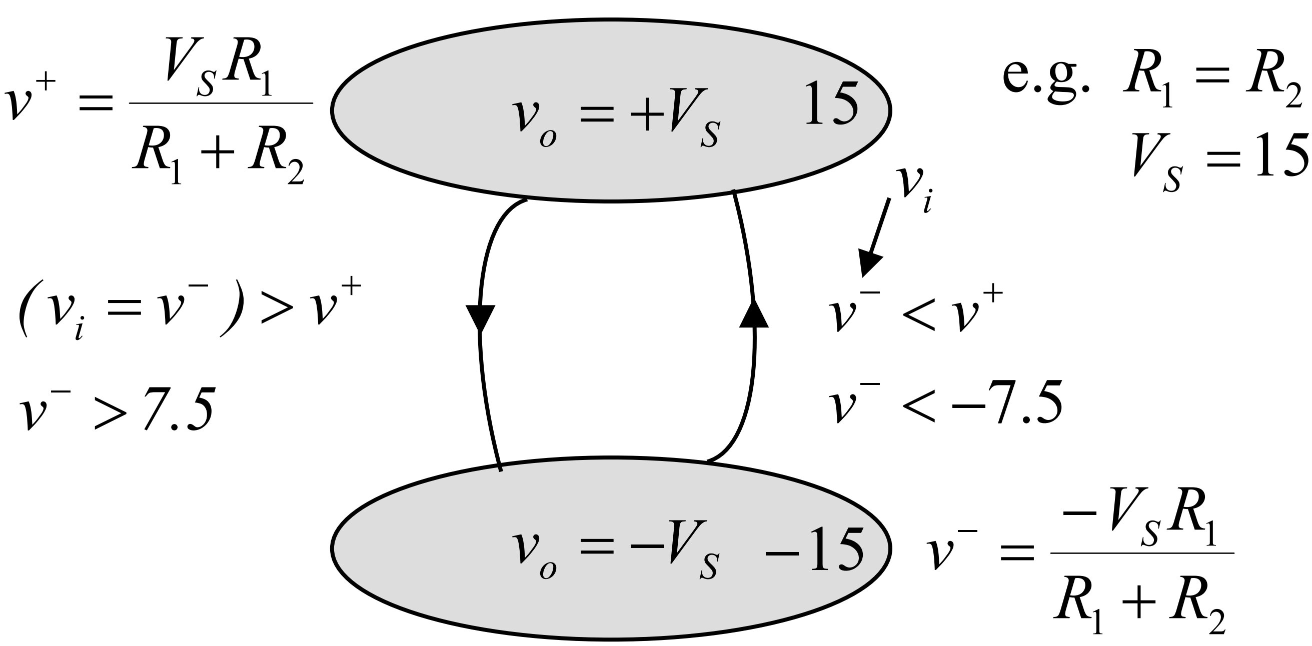


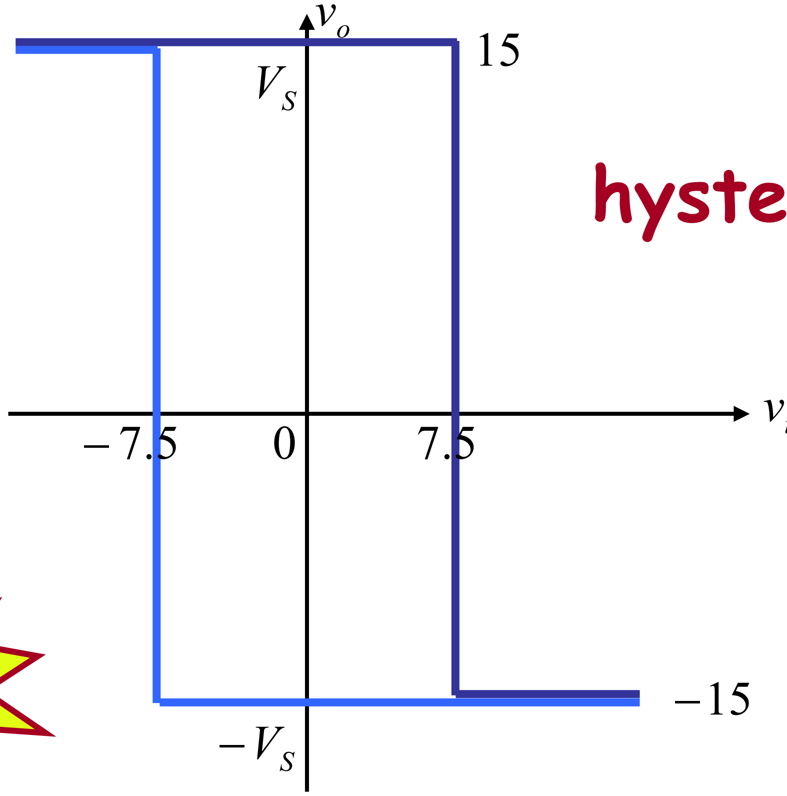


Now, use positive feedback



$$v^+ = \frac{v_o R_1}{R_1 + R_2}$$

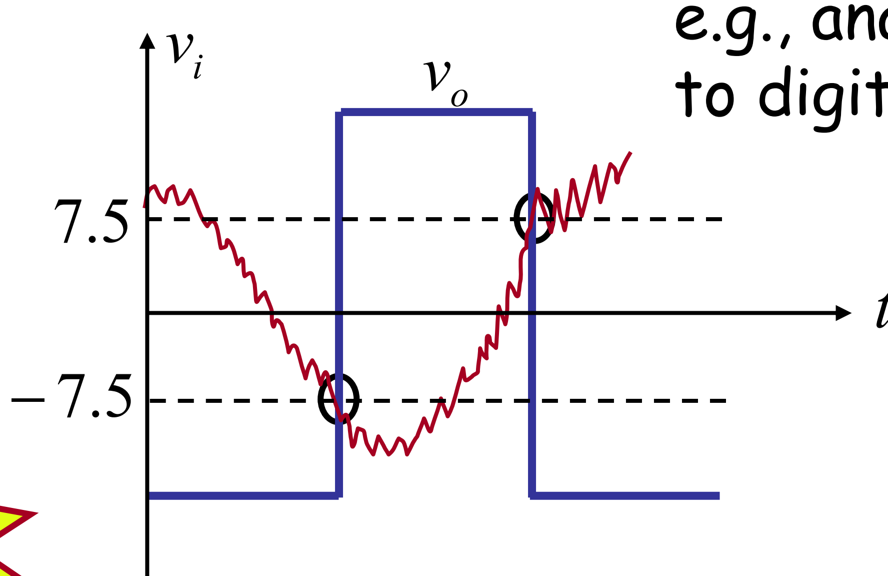




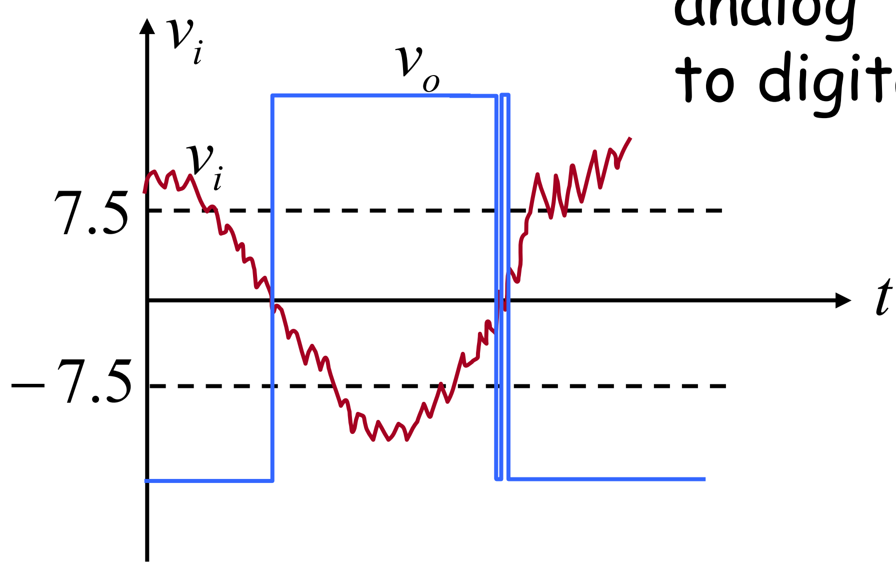
hysteresis

Why is hysteresis useful?

e.g., analog to digital

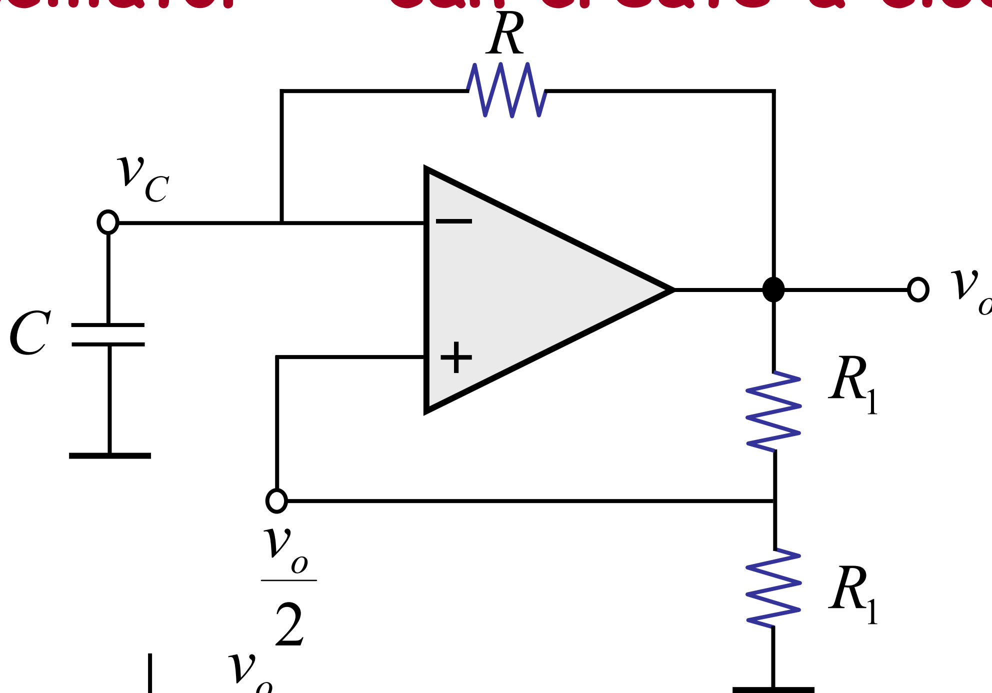


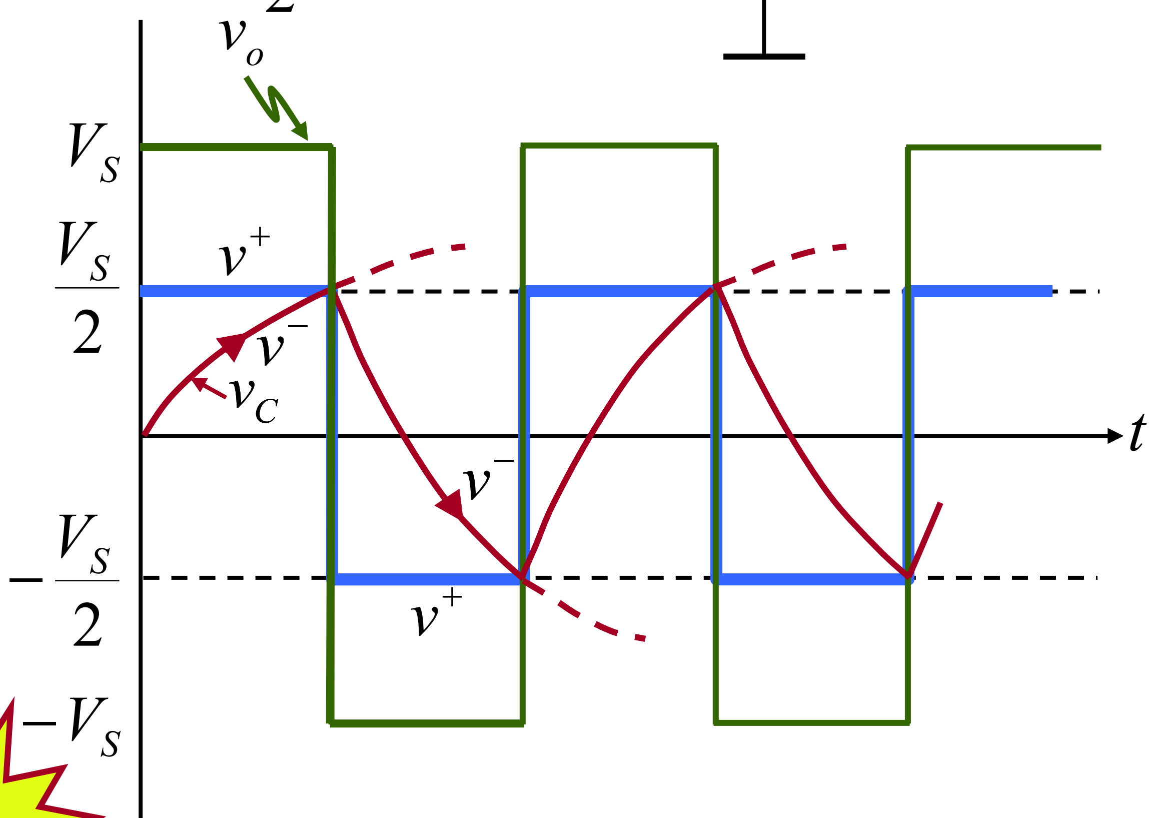
Without hysteresis

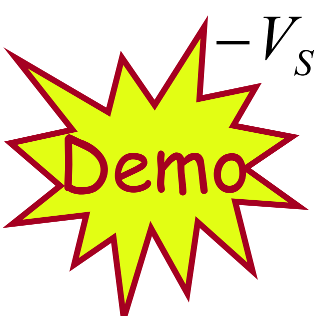


analog
to digital

Oscillator — can create a clock





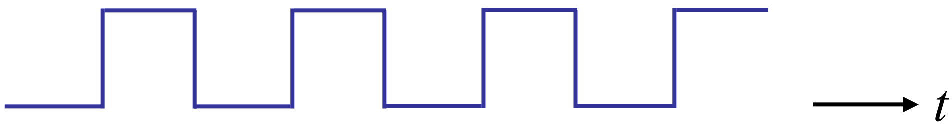


Assume $v_o = V_S$ at $t = 0$

$v_C = 0$

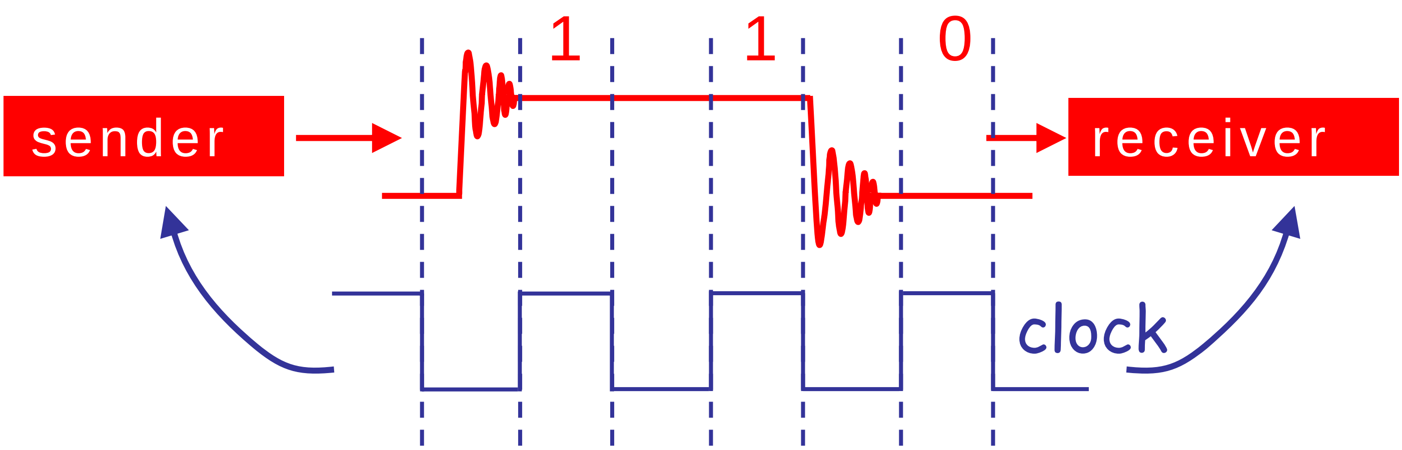
Clocks in Digital Systems

- We built an oscillator using an op amp.



can use as a clock

- Why do we use a clock in a digital system?
  (See page 735 of A & L)



ⓐ 1,1,0?

ⓑ When is the signal valid?

common timebase -- when to "look" at a signal
(e.g. whenever the clock is high)

→ Discretization of time
one bit of information associated with
an interval of time (cycle)