EE 230
Lecture 20

Nonlinear Circuits

Nonlinear Op Amp Applications

Review from Last Time:

Methods of Analysis of Nonlinear Circuits

KCL and KVL apply to both linear and nonlinear circuits

Superposition, voltage divider and current divider equations, Thevenin and Norton equivalence apply only to linear circuits!

Some other analysis techniques that have been developed may apply only to linear circuits as well

Review from Last Time:

Methods of Analysis of Nonlinear Circuits

Will consider three different analysis requirements and techniques for some particularly common classes of nonlinear circuits

1. Circuits with continuously differential devices

   Interested in obtaining transfer characteristics of these circuits or outputs for given input signals

2. Circuits with piecewise continuous devices

   interested in obtaining transfer characteristics of these circuits or outputs for a given input signals

3. Circuits with small-signal inputs that vary around some operating point

   Interested in obtaining relationship between small-signal inputs and the corresponding small-signal outputs. Will assume these circuits operate linearly in some suitably small region around the operating point

Other types of nonlinearities may exist and other types of analysis may be required but we will not attempt to categorize these scenarios in this course

3. Circuits with small-signal inputs that vary around some operating point

Interested in obtaining relationship between small-signal inputs and the corresponding small-signal outputs. Will assume these circuits operate linearly in some suitably small region around the operating point

Analysis Strategy:

Determine the operating point (using method 1 or 2 discussed above after all small signal independent inputs are set to 0)

Develop small signal (linear) model for all devices in the region of interest (around the operating point or "Q-point")

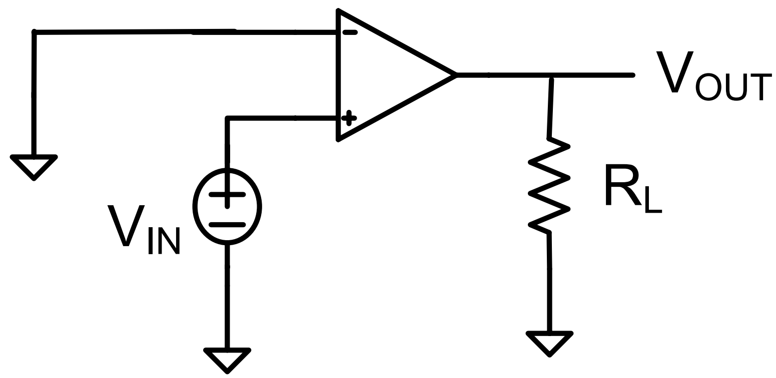
Create small signal equivalent circuit by replacing all devices with small-signal equivalent

Solve the resultant small-signal (linear) circuit

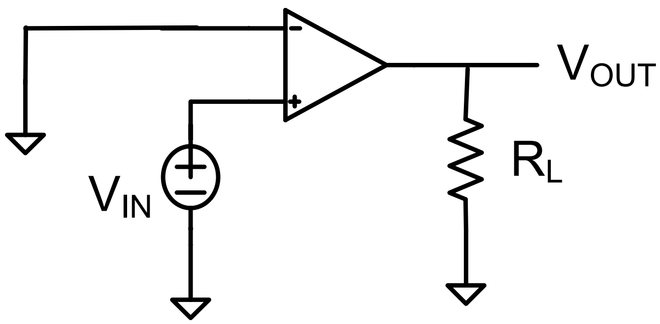
Can use KCL, DVL, and other linear analysis tools such as superposition, voltage and current divider equations, Thevenin and Norton equivalence

Determine boundary of region where small signal analysis is valid

Op Amp Is Almost Never Used as an Open Loop High Gain Amplifier !!

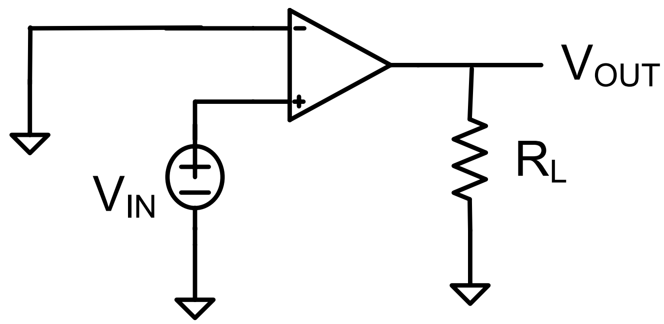


Op Amp Is Almost Never Used as an Open Loop High Gain Amplifier !!

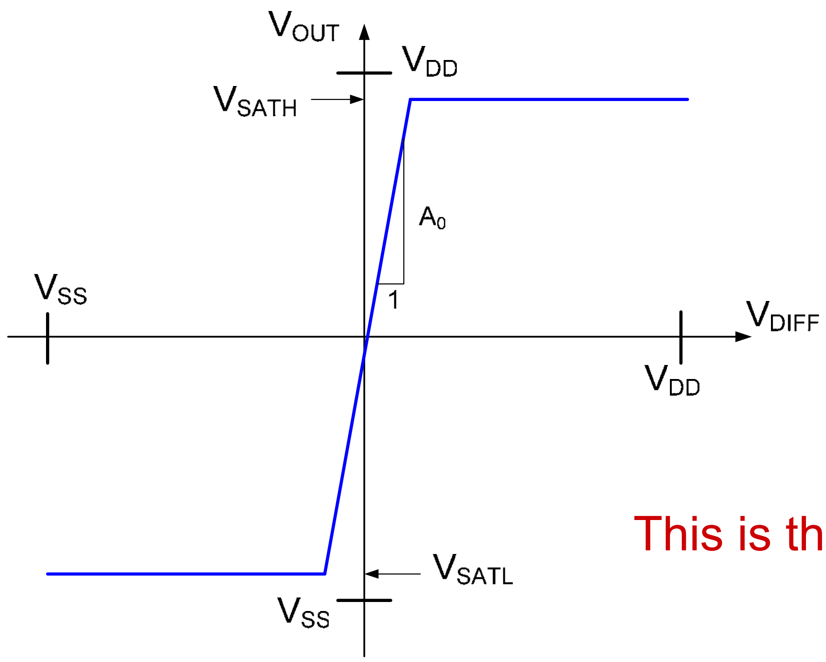


But what will happen if an engineer attempts to use this circuit as an amplifier?

Op Amp Is Almost Never Used as an Open Loop High Gain Amplifier !!

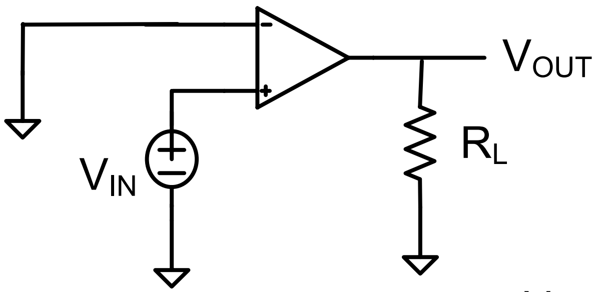


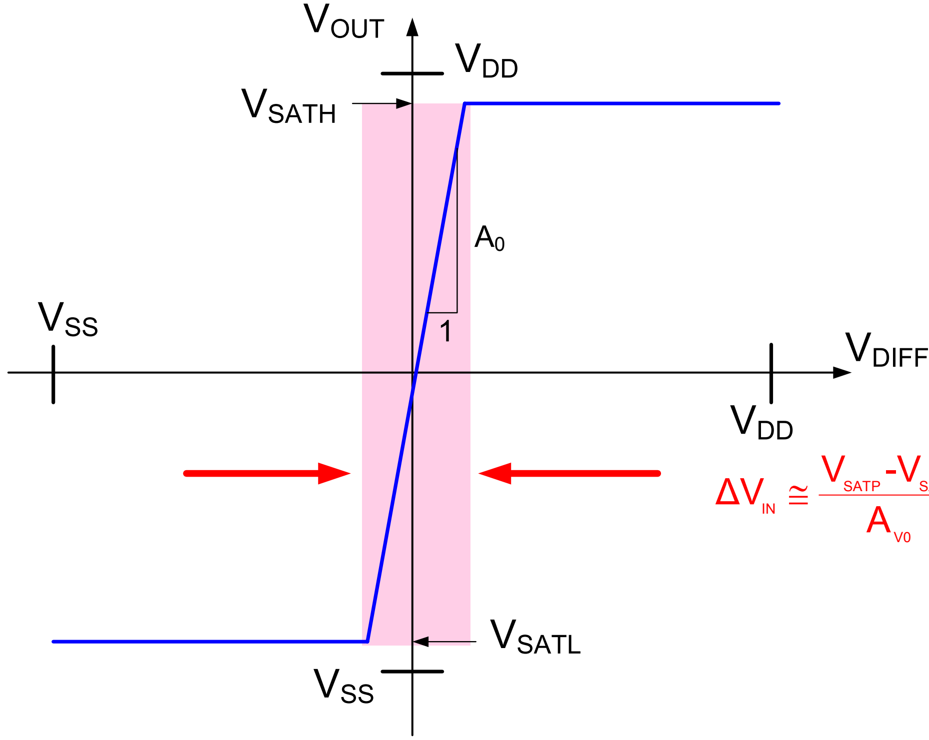
But what will happen if an engineer attempts to use this circuit as an amplifier?



This is the I/O characteristics of this circuit !

Op Amp Is Almost Never Used as an Open Loop High Gain Amplifier !!

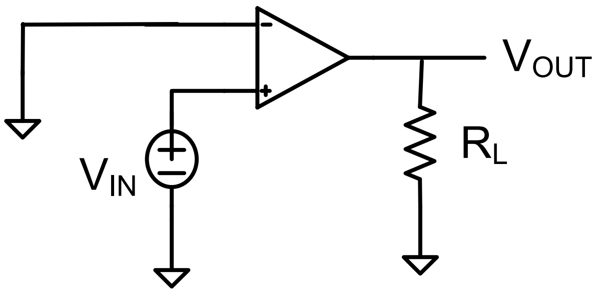


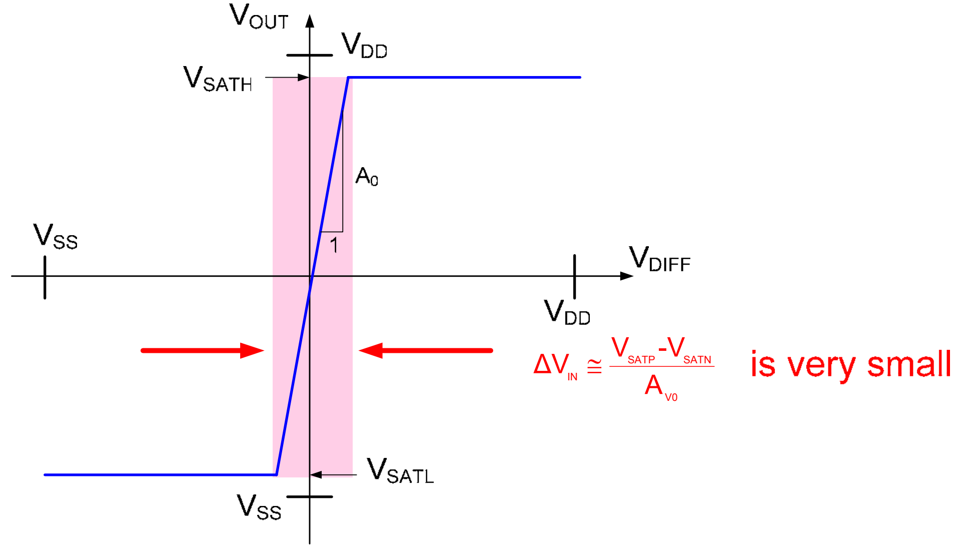


$\Delta V_{IN} \cong \frac{V_{SATP} - V_{SATN}}{A_{V0}}$ is very small

This is the I/O characteristics of this circuit !

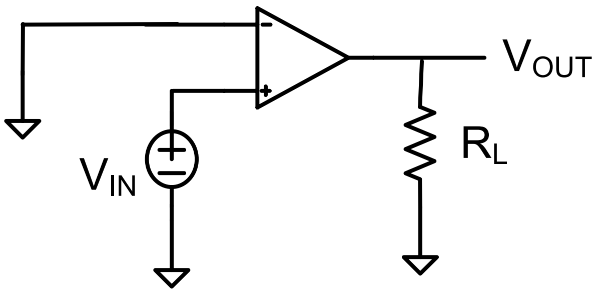
Op Amp Is Almost Never Used as an Open Loop High Gain Amplifier !!





$$V_{OUT} \cong \begin{cases} V_{SATH} & V_{IN} < 0 \\ V_{SATL} & V_{IN} > 0 \end{cases}$$

Op Amp Is Almost Never Used as an Open Loop High Gain Amplifier !!

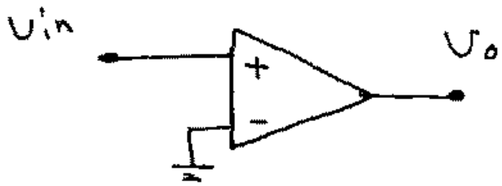


$$V_{OUT} \cong \begin{cases} V_{SATH} & V_{IN} < 0 \\ V_{SATL} & V_{IN} > 0 \end{cases}$$

This circuit serves as a comparator !

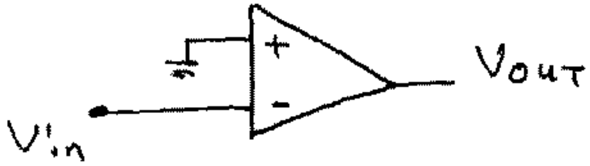
This circuit serves as a 1-bit analog to digital converter (ADC)

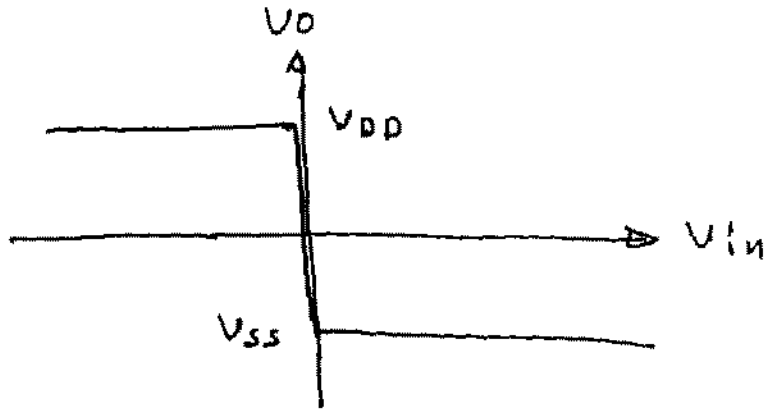
Comparator

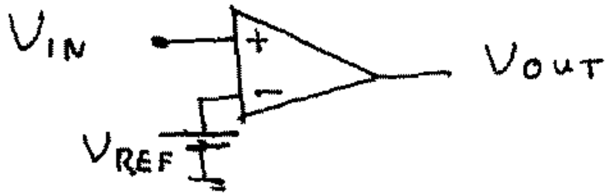


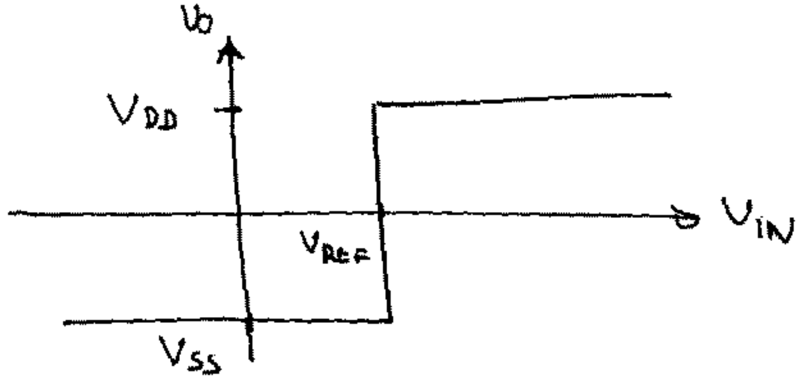
$$V_o = \begin{cases} V_{DD} & V_{IN} > 0 \\ V_{SS} & V_{OUT} < 0 \end{cases}$$

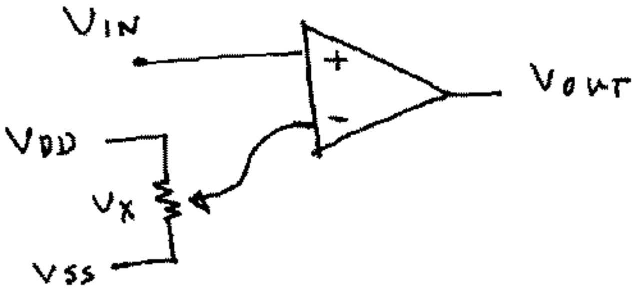
- will convert sine wave to square wave
- widely used in control systems
- Serves as an Analog to Digital Converter (resolution limited)
- May like other output polarity or different trip points





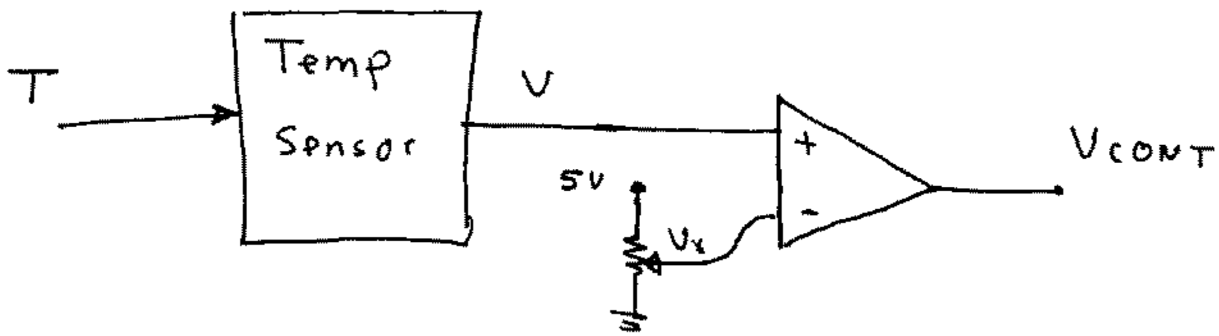






$$V_{OUT} = \begin{cases} V_{DD} & V_{IN} > V_X \\ V_{SS} & V_{IN} < V_X \end{cases}$$

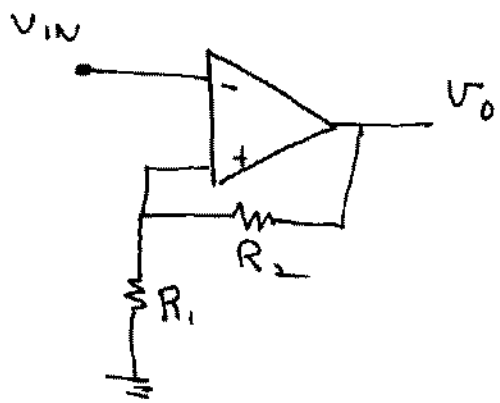
Comparator Application



$$V_{CONT} = \begin{cases} V_{DD} & V > V_x \\ V_{SS} & V < V_x \end{cases}$$

- could be used to control air conditioner (if V increases with T) (AC "on" when V_{CONT} high)
- could be used to control heater (if polarity reversed) (Heater "on" when V_{CONT} high)
- Very fine "resolution"
- would not be acceptable in some applications

Consider:



Unstable Circuit

Define $\theta = \dfrac{R_1}{R_1 + R_2}$

How does this circuit perform?