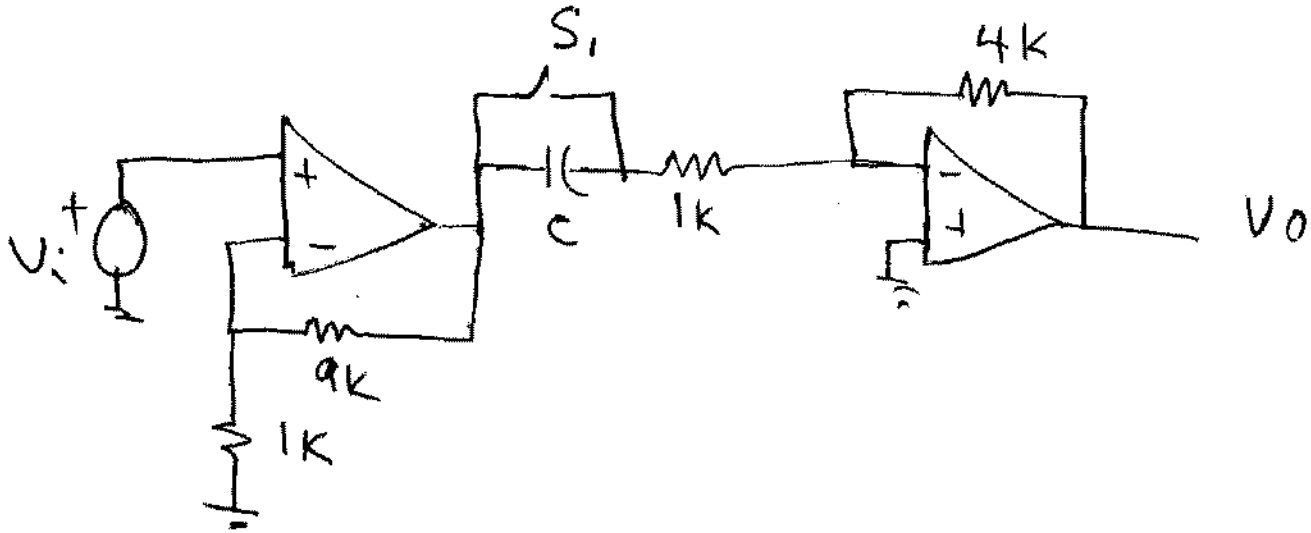
# EE 230

## Lecture 18

## Nonlinear Op Amp Applications

- But first will consider nonlinear circuit properties and analysis

# Quiz



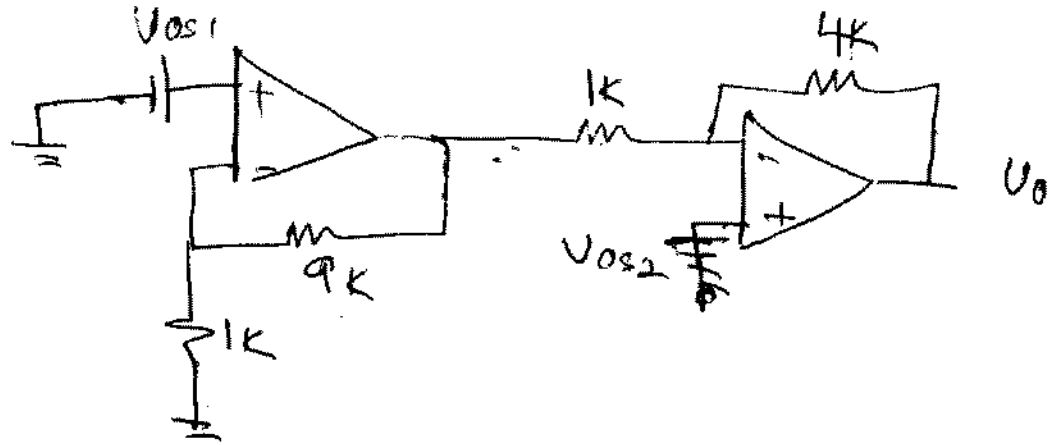

Determine the worst case output offset if $V_{os}$ for the first op amp is 3 mV and for the second op amp is 2 mV for $S_1$ open and $S_1$ closed. Assume C is very large

Solution:

$V_{os2} = 2mV$

$V_{os1} = 3mV$

Assume $S_1$ closed.

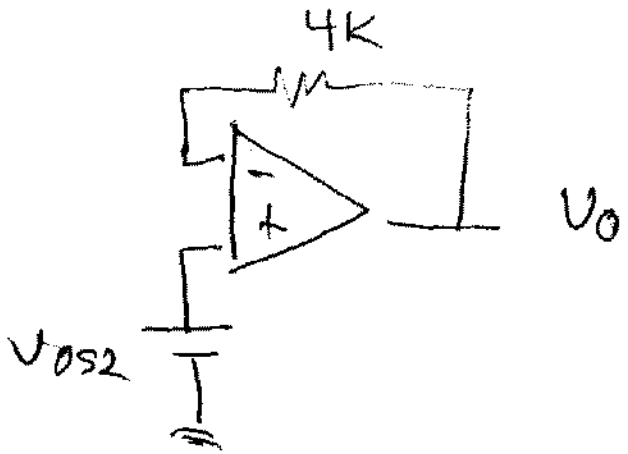



$$V_{oos} = 5V_{os2} + (10V_{os1})(-4)$$

$$= 5V_{os2} - 40V_{os1}$$

$$V_{oos_{wc}} = |5 \cdot 2mV - 40(-3mV)| = 130mV$$

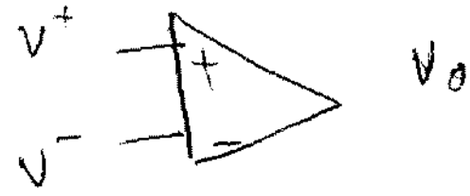
Assme $S_1$ open




$$V_{oos} = V_{os2}$$

$$V_{oos_{wc}} = 2mV$$

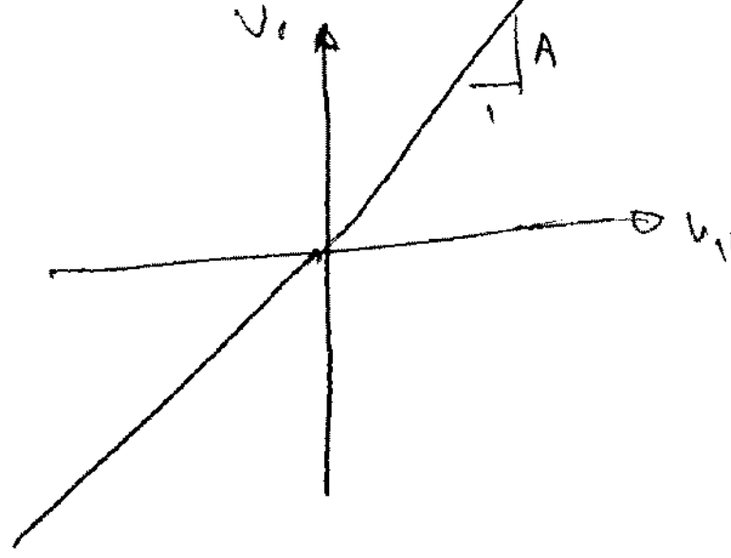
# Nonlinear Devices



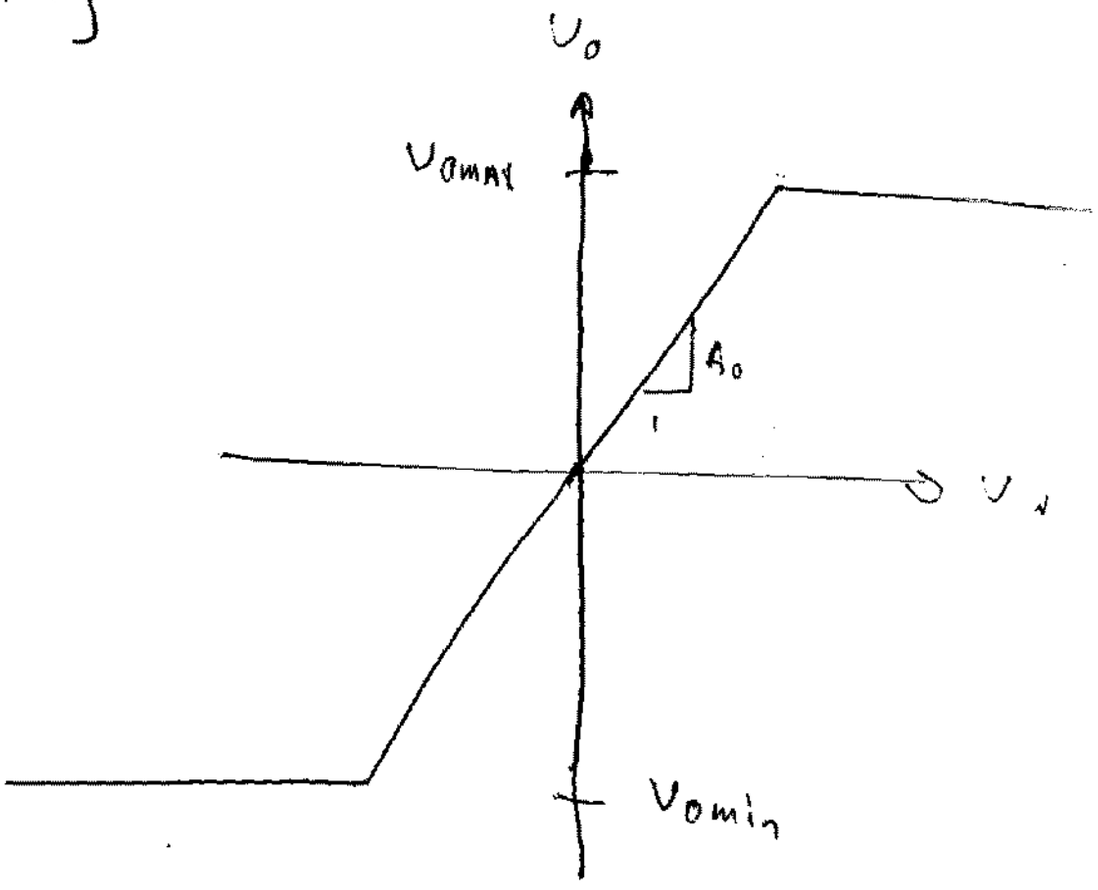

Have assumed (except when considering $V_{omax}$, $I_{omax}$, SR) op amp.

$$V_o = A(v^+ - v^-)$$

at dc



Actually




$V_{OMAX} \simeq V_{DD}$

$V_{OMIN} \simeq V_{SS}$

$$v_o \overset{v_{os}=0}{=} \begin{cases} V_{OMIN} & v_i < \frac{V_{OMIN}}{A_0} \\ A_0 v_i & \frac{V_{OMIN}}{A_0} < v_i < \frac{V_{OMAX}}{A_0} \\ V_{OMAX} & v_i > \frac{V_{OMAX}}{A_0} \end{cases}$$

Observe: OA is highly nonlinear

Observe

1) This nonlinear transfer characteristic has been defined piecewise where in each segment operation is linear (provided segment boundry is not crossed)

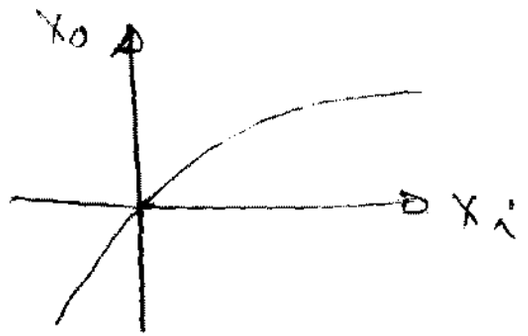
2) Continuity at transitions but discontinuity in derivatives at transitions

3) All operation of OA circuits up to this time were restricted to the linear region.

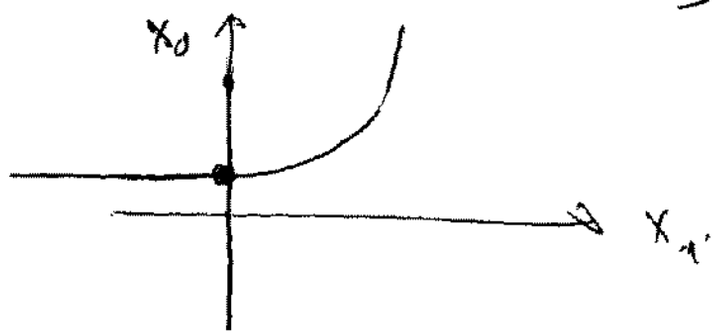
Types of nonlinearities

a) Piecewise transfer characteristics

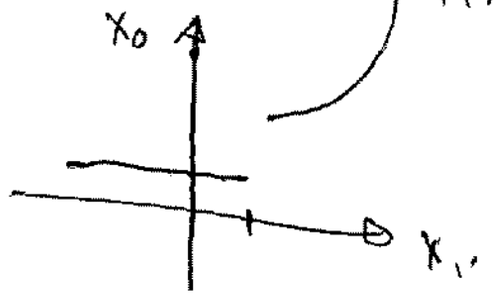
b) Continuously differentiable nonlinearities



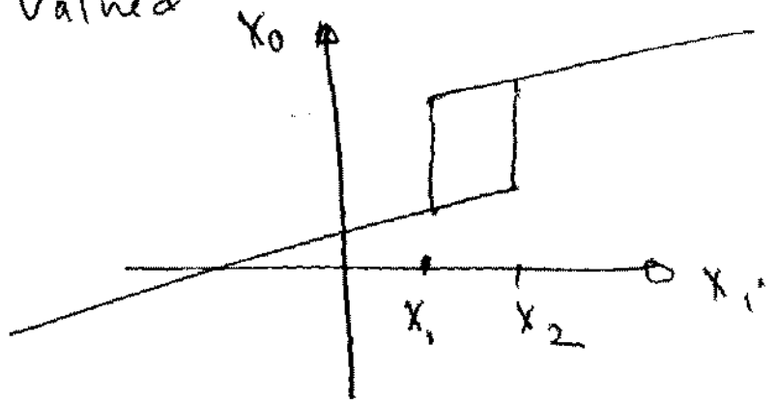

c) Piecewise and continuously differentiable




d) Discontinuous transfer characteristics



e) Multi-Valued




f) many other types of nonlinearities that could exist

- Nonlinear analysis is often more difficult than linear analysis
- Nonlinear analysis is often much easier than linear analysis
- Some very useful circuits are based upon nonlinear devices
  - almost all logic circuits
  - ADCs & DACs
  - :
- Nonlinear devices, at lowest level,
  - MOSFETs
  - BJTs
  - Diodes
- Often a large number of nonlinear devices are combined to form a linear (or nearly linear) device

Nonlinear analysis is often more difficult than linear analysis because a large number of devices and circuits that are not linear are lumped into the category "nonlinear" circuits but there are many different types of nonlinearities and each may require special considerations for analysis, design, and understanding