Lecture 14: October 17, 2001

Op-Amp Circuits and Comprators

A) Cascade Op-Amps

B) Integration/Differentiation Op-Amps

C) I vs. V of Op-Amps – Source Limits

D) Comparator Circuits

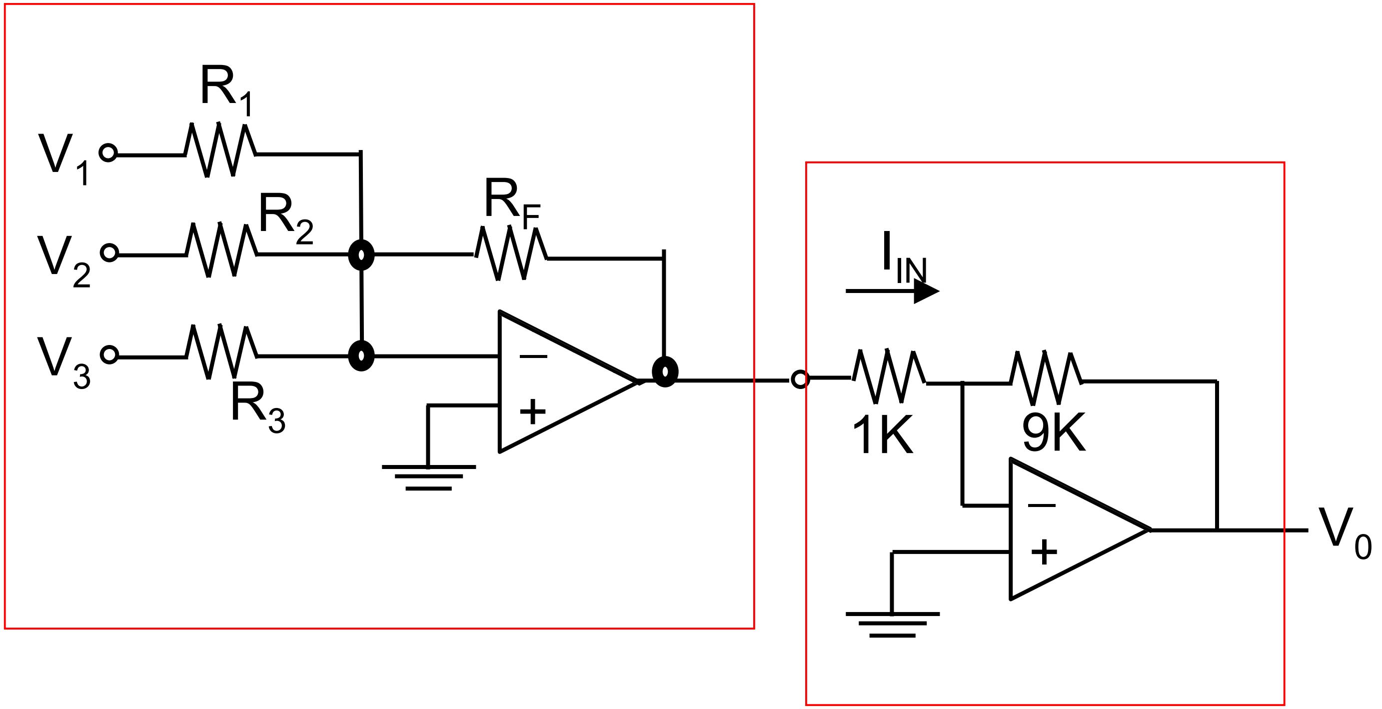
E) D to A Converters

The following slides were derived from those prepared by Professor Oldham For EE 40 in Fall 01

Reading:

Schwarz and Oldham 4.3-4.4 (light on non-ideal) and comparator viewgraphs

CASCADE OP-AMP CIRCUITS



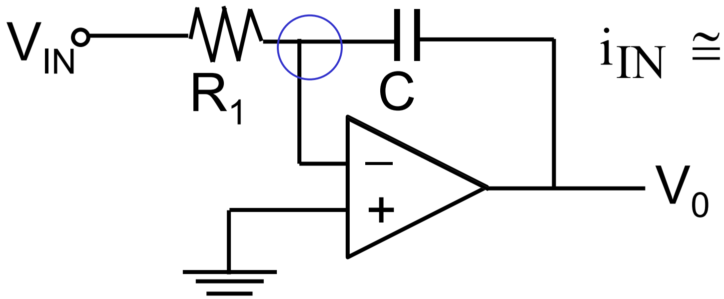
How do you get started on finding V_O?

Hint: Identify Stages

Hint: I_{IN} does not affect V_{O1}

See the further examples of op-amp circuits in the reader

INTEGRATING OP-AMP



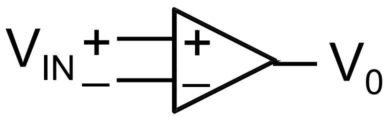
$i_{IN} \cong 0$ and $V_{(-)} \cong V_{+} = 0$

How do you get started on finding V_O?

Hint: $i_{IN} \cong 0$ and $V_{(-)} \cong V_{+} = 0$

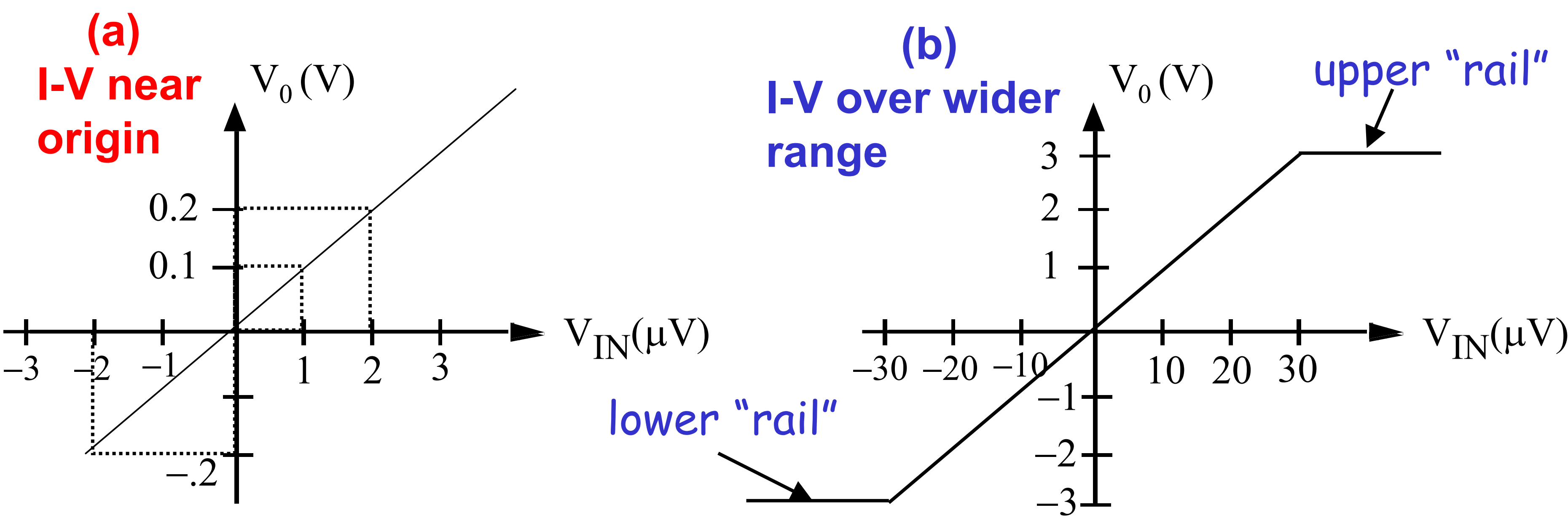
Hint: KCL at V_- node with $I_{IN-} = 0$

OP-AMP I-V CHARACTERISTICS WITH RAILS



- Circuit model (ideal op-amp) gives the essential linear part
- But V_0 cannot rise above some physical voltage related to the positive power supply V_{CC} (" upper rail") $V_0 < V_{+RAIL}$
- And V_0 cannot go below most negative power supply, V_{EE} i.e., limited by lower "rail" $V_0 > V_{-RAIL}$

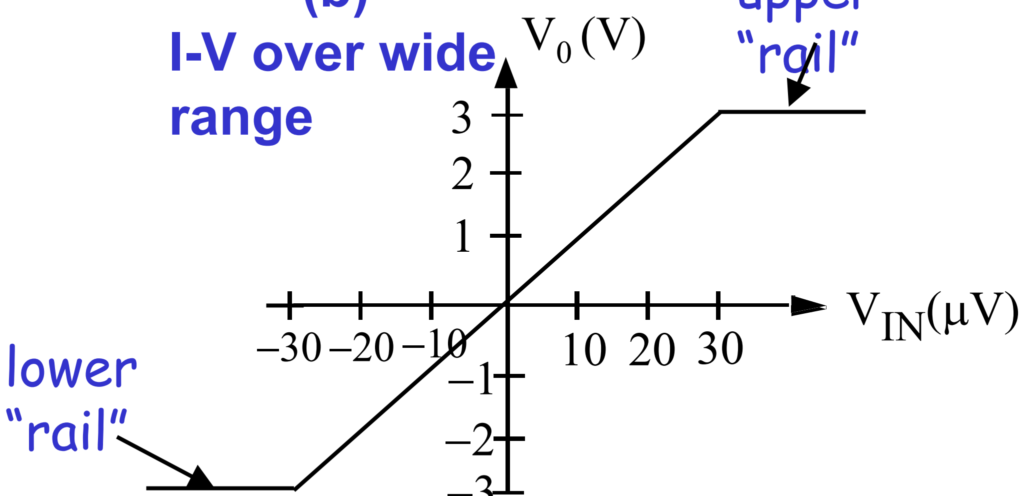
Example: Amplifier with gain of 10^5, with max V_0 of 3V and min V_0 of −3V.



OP-AMP I-V CHARACTERISTICS WITH RAILS (cont.)

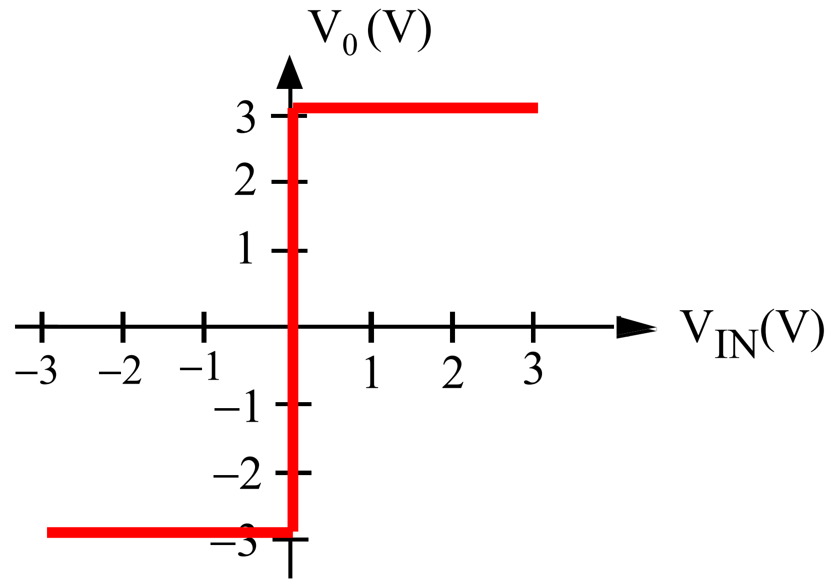
Example: Amplifier with gain of 10^5, with upper rail of 3V and lower rail of −3V. We plot the V_0 vs V_{IN} characteristics on two different scales

(b) I-V over wide range



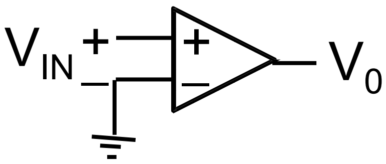
(c)

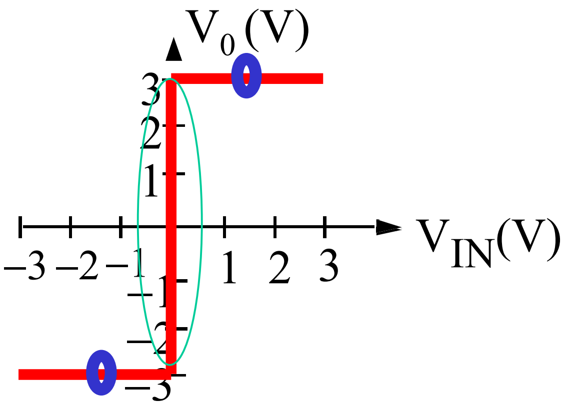
Same V_0 vs V_{IN} over even wider range



SIMPLE A/D CONVERTER

I-V with equal X and Y axes



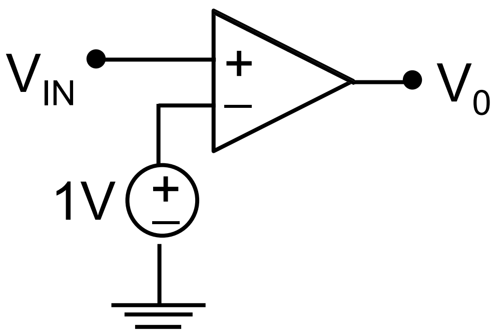


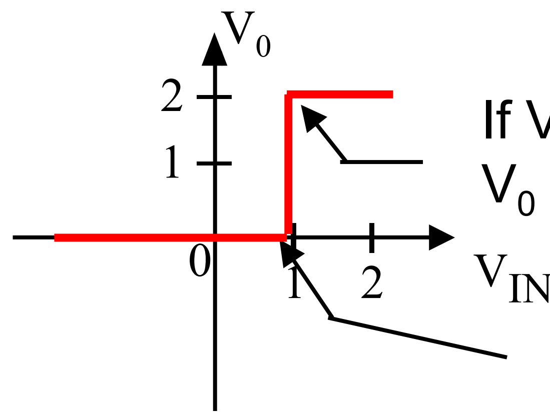
Note:

- (a) displays linear amplifier behavior ($|V_{IN}| < 30\ \mu V$) and stops at rails
- (b) shows comparator decision function (1 bit A/D converter centered at $V_{IN} = 0$) where lower rail = logic “0” and upper rail = logic “1”

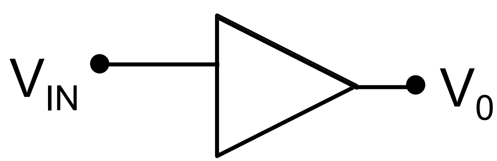
OP-AMP USE AS COMPARATOR (A/D) MODE

Simple comparator with threshold at 1V. Design lower rail at 0V and upper rail at 2V (logic "1"). A = large (e.g. 10^2 to10^5)



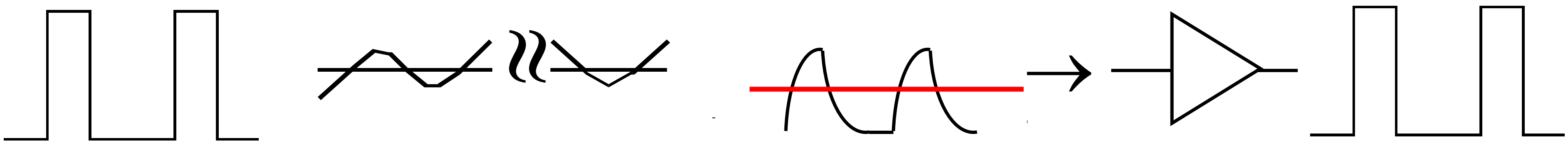


NOTE: The actual diagram of a comparator would not show an amplifier with "offset" power supply as above. It would be a simple triangle, perhaps with the threshold level (here 1V) specified.



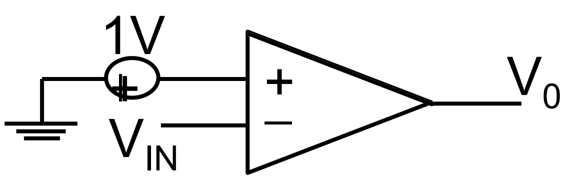
Comparator

ONE-BIT A/D CONVERSION
REQUIRED IN DIGITAL SYSTEMS



As we saw, we set comparator threshold at a suitable value (e.g., halfway between rails) and comparator output goes to +rail if $V_{IN} > V_{THRESHOLD}$ and to –rail if $V_{IN} < V_{THRESHOLD}$.

What would this circuit do?



The inverse pulse shaped function is generated by applying the input voltage to V- and setting V+ to the threshold voltage.

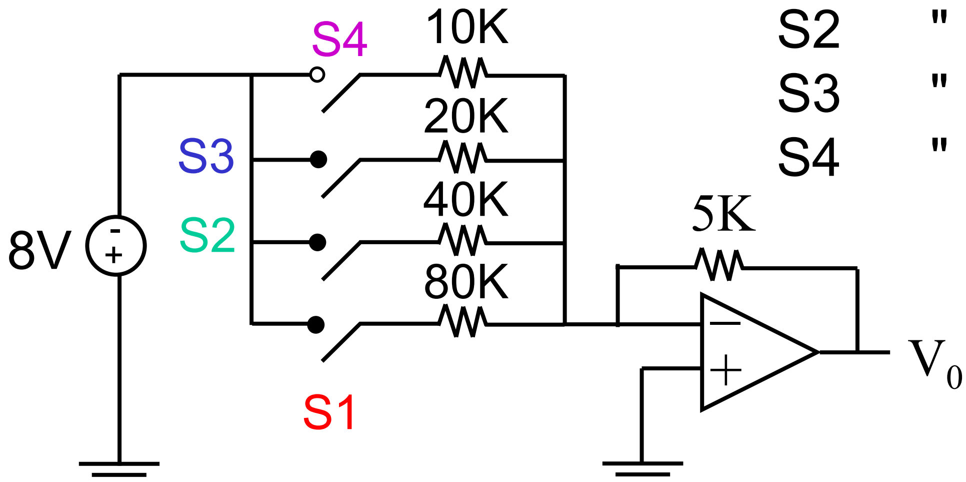
D/A CONVERSION

Version Date 10/16/01

Example: Digital representation of sound to analog (so you can hear it!) → D/A conversion

The summing junction op-amp provides a simple means of D/A conversion via **weighted-adder D/A converter**

S1 closed if LSB =1
S2 " if next bit = 1
S3 " if " " = 1
S4 " if MSB = 1



4-Bit D/A

Another way (not shown) is to sum **charges** instead of current with capacitor networks

Binary number	Analog output (volts)
0 0 0 0	0
0 0 0 1	.5
0 0 1 0	1
0 0 1 1	1.5
0 1 0 0	2
0 1 0 1	2.5
0 1 1 0	3
0 1 1 1	3.5
1 0 0 0	4
1 0 0 1	4.5
1 0 1 0	5
1 0 1 1	5.5
1 1 0 0	6
1 1 0 1	6.5
1 1 1 0	7
1 1 1 1	7.5

↑ MSB ↑ LSB

CHARACTERISTIC OF A 4-BIT DAC