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Lecture 12: October 10, 2001

Dependent Sources and Ideal Op Amps

A) Dependent Source Concept
B) Four Basic Dependent Source Types
C) Use in Amplifier Models
D) Feedback and Ideal Op-Amp Model
E) Examples of Op-Amp Circuits

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

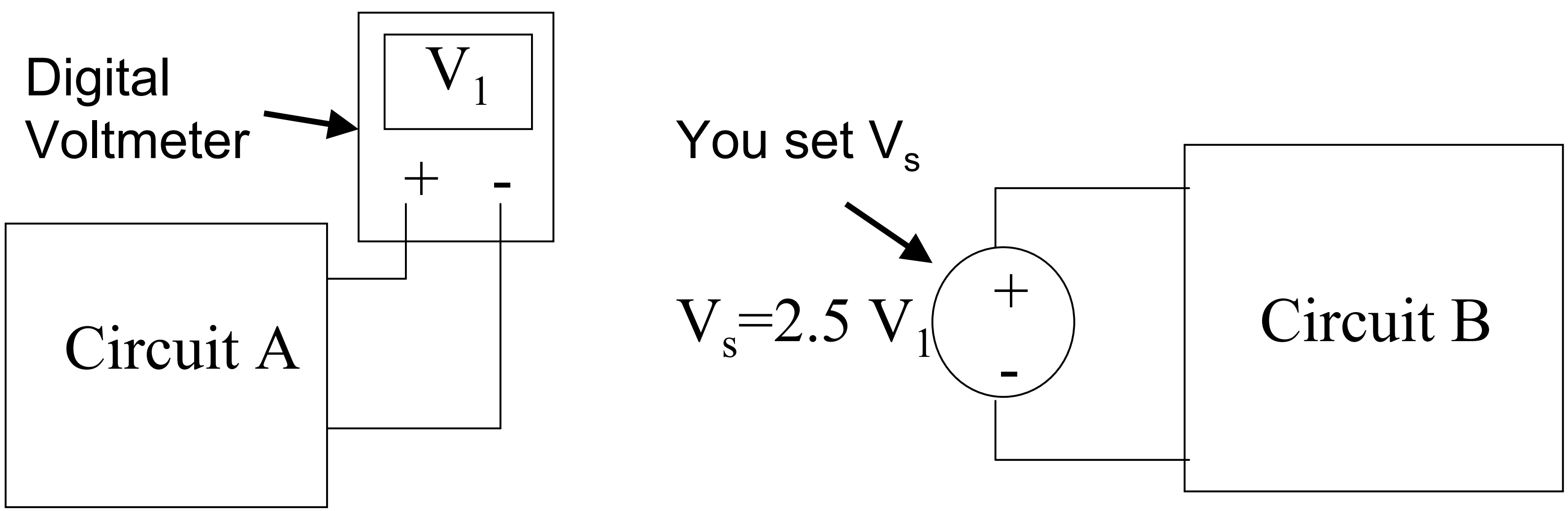
Reading:

Schwarz and Oldham 4.1 and 4.3 with ideal Op-Amp analysis only

Dependent Voltage and Current Sources

A linear dependent source is a voltage or current source that depends linearly on some other circuit current or voltage.

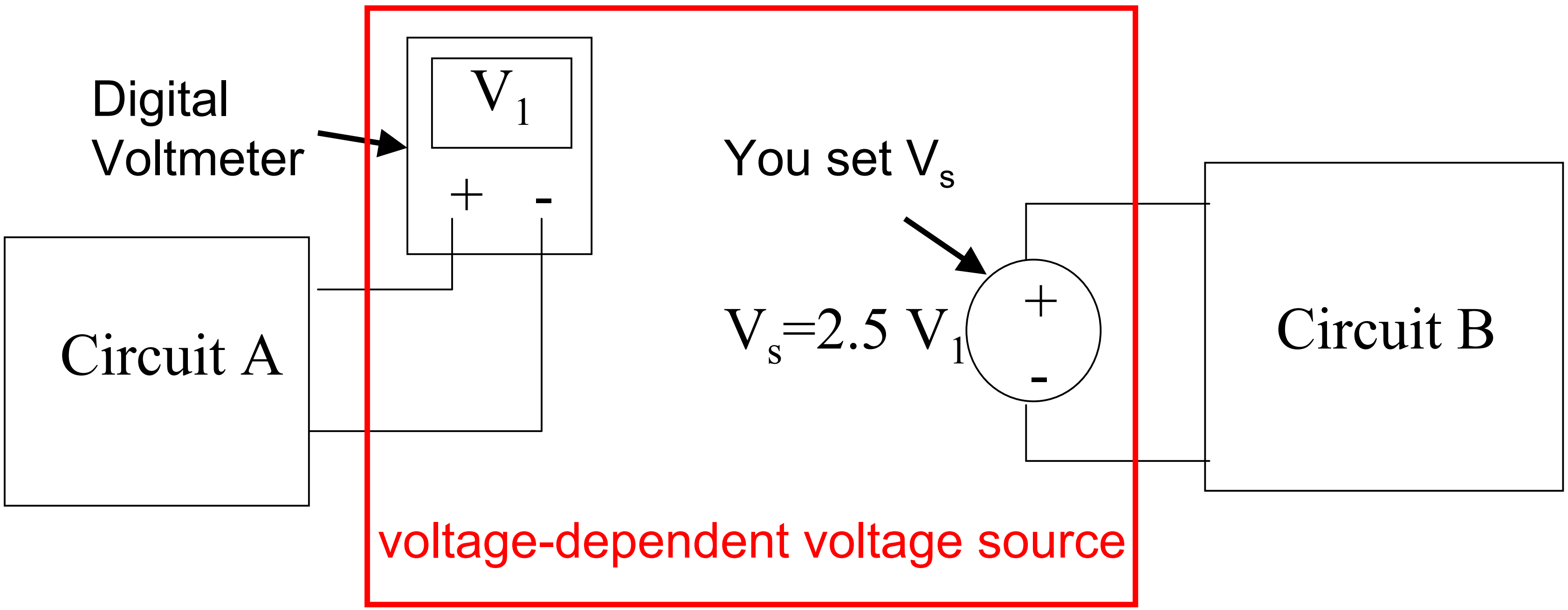
Example: you watch a certain voltmeter V_1 and manually adjust a voltage source V_s to be 2.5 times this value.



Dependent Voltage Source Example

The voltage V_s source depends linearly on V_1 (because you set it to 2.5 times V_1, no matter what V_1 is.

If you and the voltmeter are placed inside a box, the box functions as a voltage-dependent voltage source.



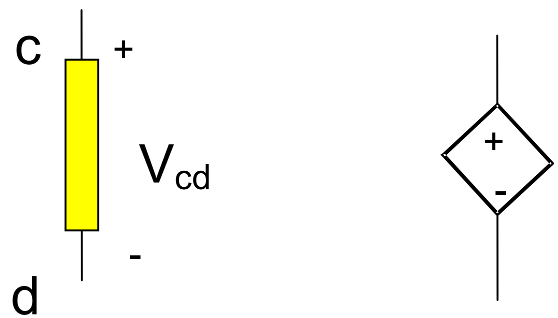
Note that the red box has two wires in (to read the input voltage) and two wires out (to deliver the output voltage).

Dependent Voltage and Current Sources

• A linear dependent source is a voltage or current source that depends linearly on some other circuit current or voltage.

• We can have voltage or current sources depending on voltages or currents elsewhere in the circuit.

Here the voltage V is proportional to the voltage across the element c-d .



$V = A_v \times V_{cd}$

A diamond-shaped symbol is used for dependent sources, just as a reminder that it's a dependent source.

Circuit analysis is performed just as with independent sources.

The 4 Basic Linear Dependent Sources

Constant of proportionality

Parameter being sensed

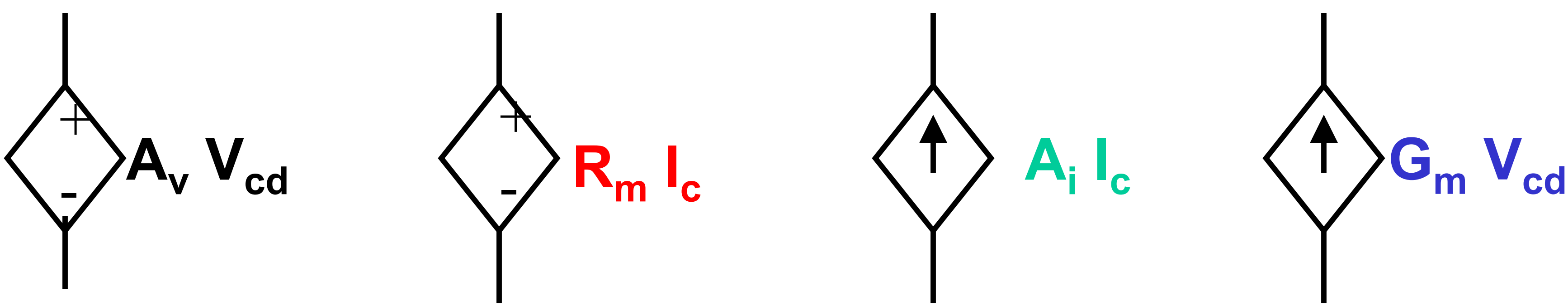
Output

Voltage-controlled voltage source … $V = A_v \; V_{cd}$

Current-controlled voltage source … $V = R_m \; I_c$

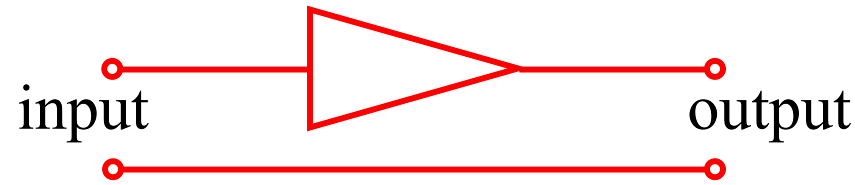
Current-controlled current source … $I = A_i \; I_c$

Voltage-controlled current source … $I = G_m \; V_{cd}$

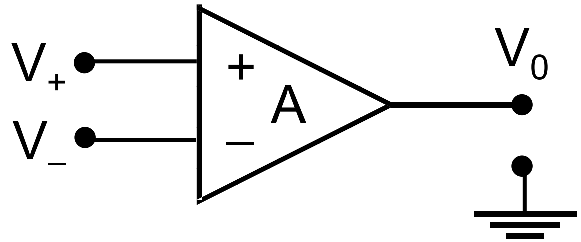


WHY DEPENDENT SOURCES?
EXAMPLE: MODEL FOR AN AMPLIFIER

AMPLIFIER SYMBOL



Differential Amplifier



$$V_0 = A(V_+ - V_-)$$

V_0 depends only on input $(V_+ - V_-)$

EXAMPLE: A =20 Then if input $(V_+ - V_-)$ = 10mV; V_o = 200mV.

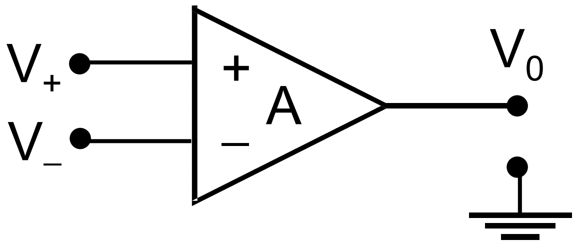
An actual amplifier has dozens (to hundreds) of devices (transistors) in it. But the dependent source allows us to model it with a very simple element.

EXAMPLE OF THE USE OF DEPENDENT SOURCE IN THE MODEL FOR AN AMPLIFIER

AMPLIFIER SYMBOL

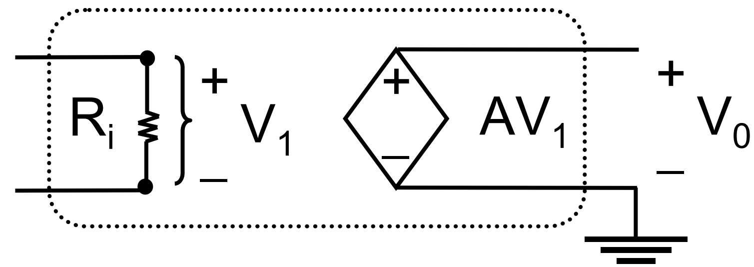
Differential Amplifier

$$V_0 = A(V_+ - V_-)$$



AMPLIFIER MODEL

Circuit Model *in linear region*

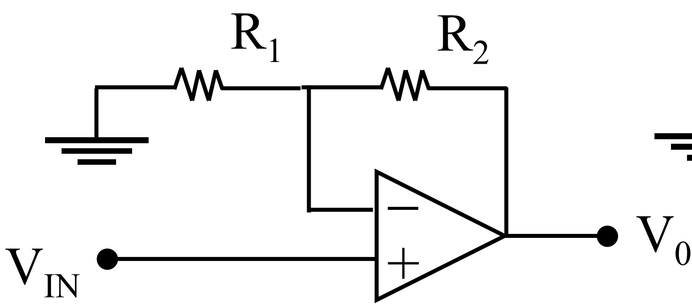


V_0 depends only on input $(V_+ - V_-)$

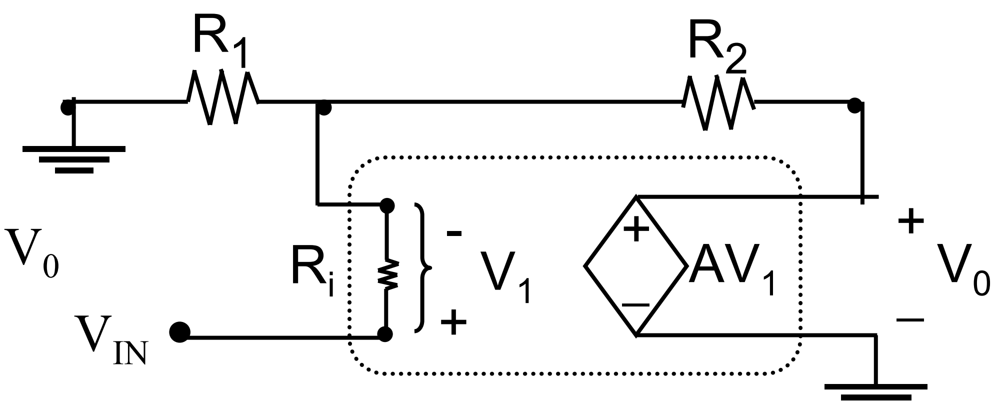
See the utility of this: this Model when used correctly mimics the behavior of an amplifier but omits the complication of the many many transistors and other components.

OP-AMP AND USE OF FEEDBACK

A very high-gain differential amplifier can function in an extremely linear fashion as an operational amplifier by using negative feedback.



EXAMPLE



Circuit Model

Negative feedback ⇒ ***Stabilizes*** the output

We can show that that for $A \to \infty$ and $R_i \to \infty$,

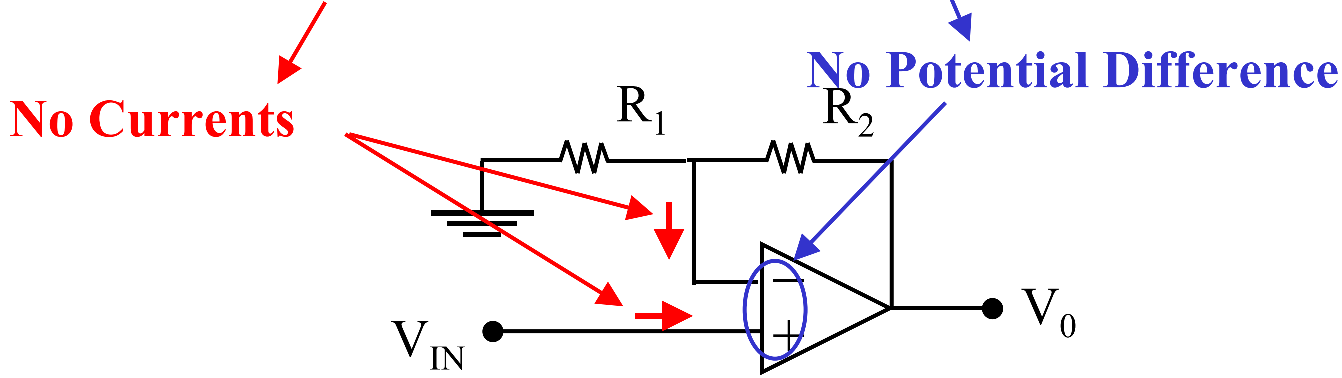
$$V_0 \cong V_{IN} \cdot \frac{R_1 + R_2}{R_1}$$

Stable, finite, and independent of the properties of the OP AMP !

IDEAL OP-AMPS ANALYSIS TECHNIQUE

Assumption 1: The potential between the op-amp input terminals, $v_{(+)} - v_{(-)}$, equals zero.

Assumption 2: The currents flowing into the op-amp's two input terminals both equal zero.



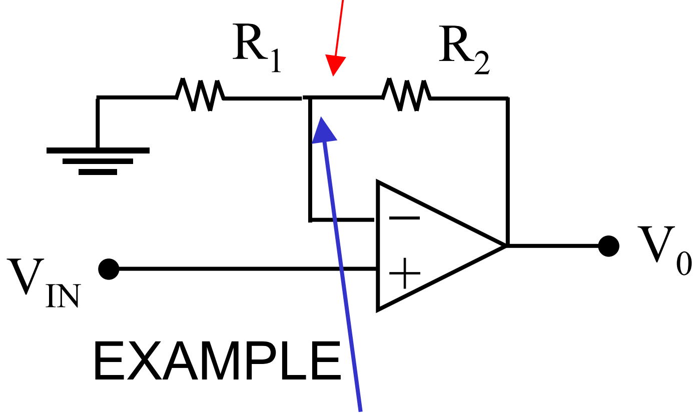
EXAMPLE

IDEAL OP-AMPS ANALYSIS EXAMPLE #1

Assumption 1: The potential between the op-amp input terminals, $v_{(+)} - v_{(-)}$, equals zero.

Assumption 2: The currents flowing into the op-amp's two input terminals both equal zero.

KCL with currents in only two branches



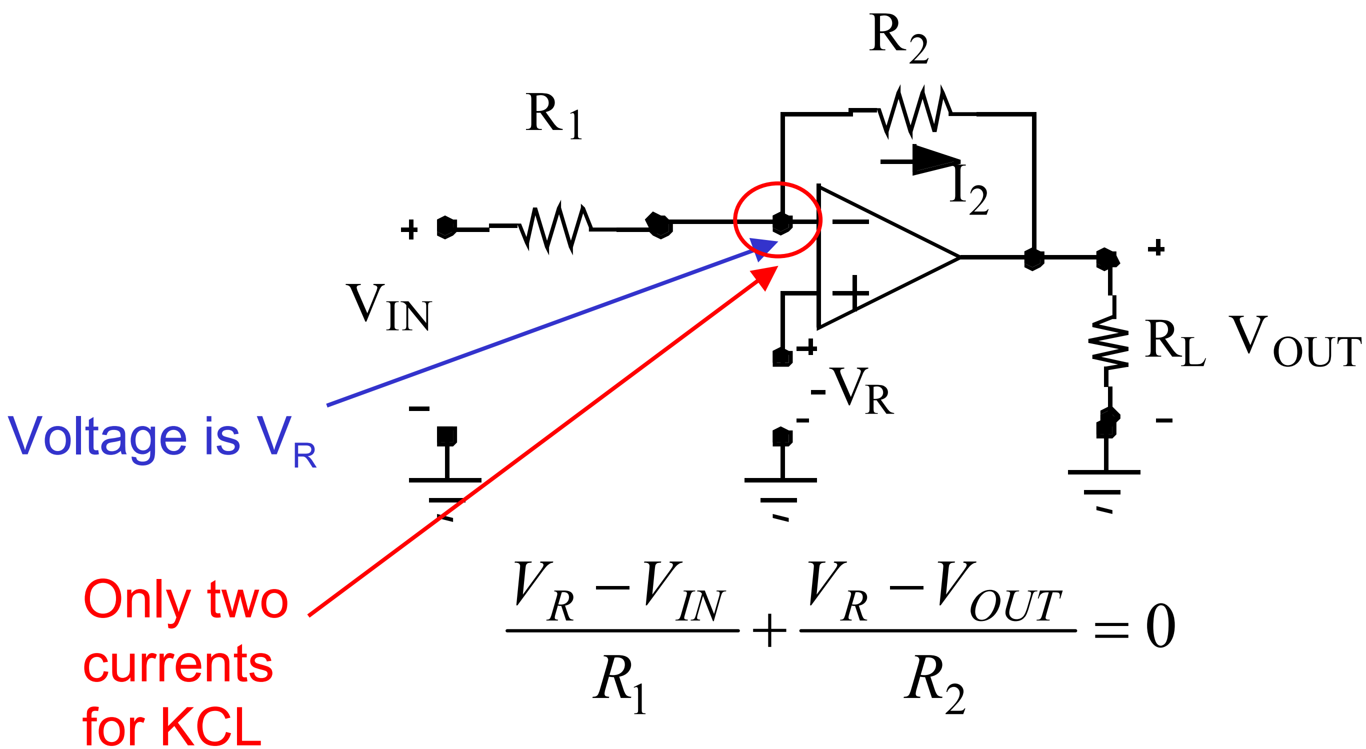
V_{IN} appears here

$$\frac{v_{in}}{R_1} + \frac{v_{in} - v_{out}}{R_2} = 0$$

$$v_{out} = \frac{R_1 + R_2}{R_1} v_{in}$$

Non-inverting Amplifier

IDEAL OP-AMPS ANALYSIS EXAMPLE #2



$$\frac{V_R - V_{IN}}{R_1} + \frac{V_R - V_{OUT}}{R_2} = 0$$

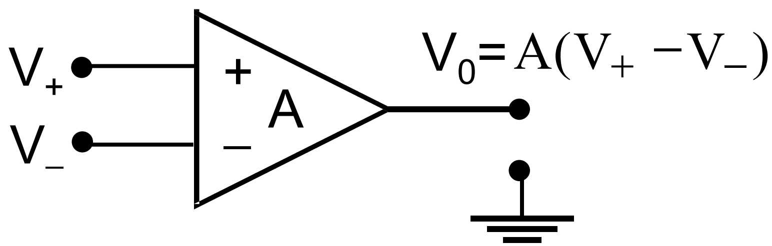
$$V_{OUT} = V_R - \frac{R_2}{R_1}\left(V_{in} - V_R\right)$$

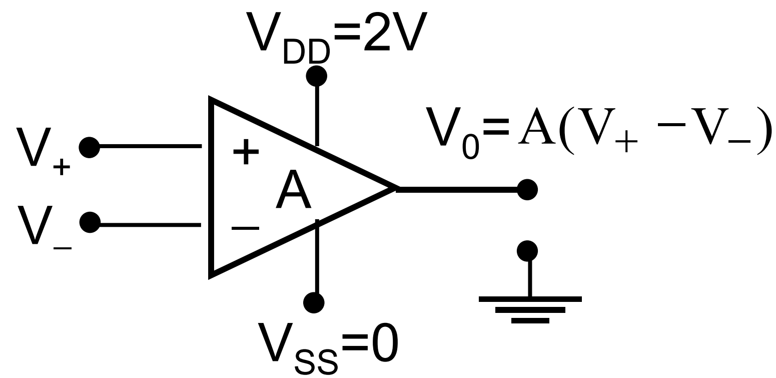
Inverting Amplifier with reference voltage

THE RAILS

The output voltage of an amplifier is of course limited by whatever voltages are supplied (the "power supplies"). Sometimes we show them explicitly on the amplifier diagram, but often they are left off.

Differential Amplifier





If the supplies are 2V and 0V, the output cannot swing beyond these values. (You should try this experiment in the lab.) So in this case we have upper rail = 2V, lower rail = 0V.

The rails cannot be larger than the supply voltages. For simplicity we will use the supply voltages as the rails.