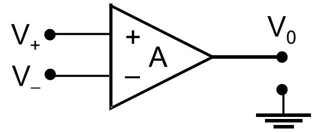
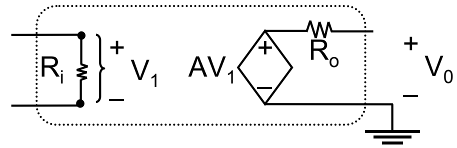
DIFFERENTIAL AMPLIFIER

Differential Amplifier



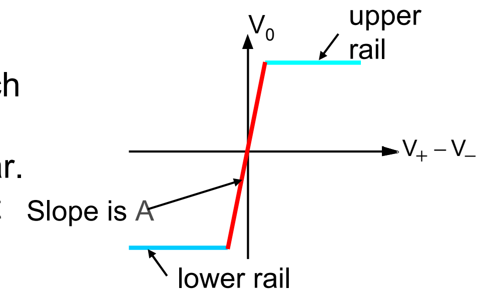
$V_0 = A(V_+ - V_-)$

Circuit Model *in linear region*



"Differential" $\Rightarrow V_0$ depends only on difference $(V_+ - V_-)$

The output cannot be larger than the supply voltages, which are not shown. It will limit or "clip" if we attempt to go too far. We call the limits of the output the "**rails**".

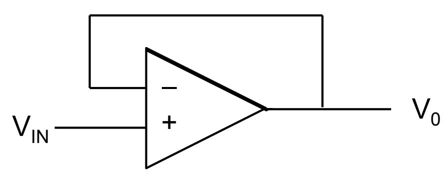


Can add negative feedback to perform an "operation" on input voltages (addition, integration, etc.): **operational amplifier**

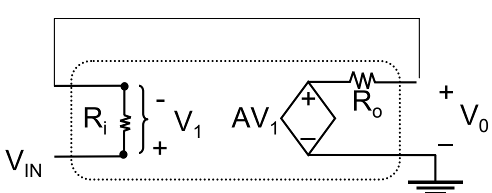
AMPLIFIER ANALYSIS USING CIRCUIT MODEL

To analyze an amplifier circuit, you can replace the amplifier with the circuit model, then make sure the output is within "rails".

Example: Voltage Follower



Circuit Model *in linear region*



$$\frac{V_o - AV_1}{R_o} = \frac{V_1}{R_i}$$

$$V_1 = V_{IN} - V_o$$

$$\boxed{V_o = \frac{AR_i + R_o}{(A+1)R_i + R_o} V_{IN}}$$

ANALYZING OPERATIONAL AMPLIFIER CIRCUITS: "IDEAL" ASSUMPTIONS

For easier, approximate analysis of op-amp circuits:

Rule 1: Assume $A = \infty$
Since V_o finite (limited by rails), Vp-Vn = 0

Rule 2: Assume $R_i = \infty$
No current flows into or out of input (+ and -) terminals

Rule 3: Assume $R_o = 0\ \Omega$

But current **can** come out of/into amplifier output!

EECS 40 Spring 2003 Lecture 9 Copyright Regents of the University of California S. Ross and W. G. Oldham

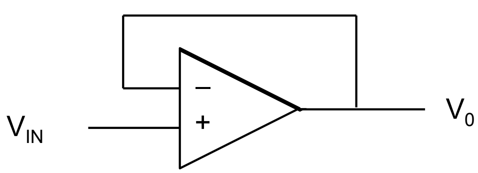
EECS 40 Spring 2003 Lecture 9 Copyright Regents of the University of California S. Ross and W. G. Oldham

OPERATIONAL AMPLIFIER: HOW DOES IT DO THAT?

Remember: current can flow out of/into op-amp output

How? Op-amp is actually connected to positive and negative voltage supplies which **set rails** and **deliver power to output load** (via this output current)

Utility of Voltage-Follower:
If input voltage source cannot provide much power (current), use voltage follower at output to drive a high power load



EECS 40 Spring 2003 Lecture 9 Copyright Regents of the University of California S. Ross and W. G. Oldham

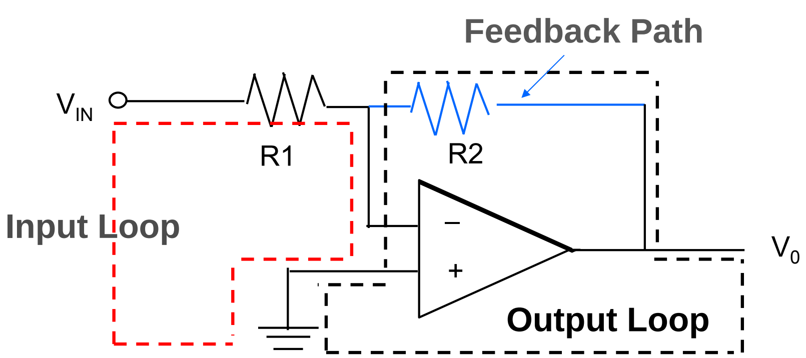
ANALYZING AN OP-AMP: TIPS

Step 1: KVL around input loop (involves V_{in} and op-amp inputs)
Use Rule 1: Vp-Vn = 0

Step 2: Find the current in the feedback path
Use Rule 2: No current into/out of op-amp inputs

Step 3: KVL around output loop (involves V_o and feedback path)
Remember current can flow in/out op-amp output

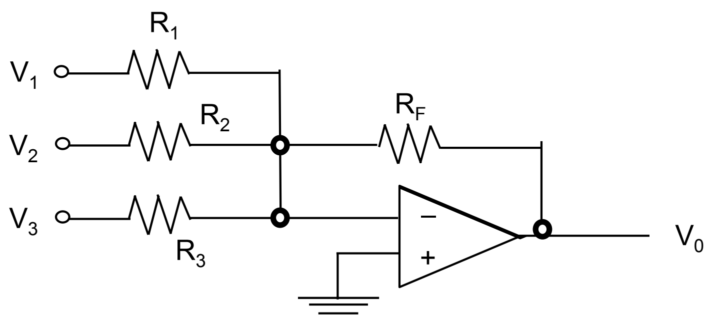
EXAMPLE: INVERTING AMPLIFIER



$$V_o = -\frac{R_2}{R_1} V_{IN}$$

ANOTHER EXAMPLE

INVERTING SUMMING AMPLIFIER



$$V_0 = -\frac{R_F}{R_1}V_1 - \frac{R_F}{R_2}V_2 - \frac{R_F}{R_3}V_3$$

EECS 40 Spring 2003 Lecture 9 Copyright Regents of the University of California S. Ross and W. G. Oldham

EECS 40 Spring 2003 Lecture 9 Copyright Regents of the University of California S. Ross and W. G. Oldham

IMPORTANT POINTS

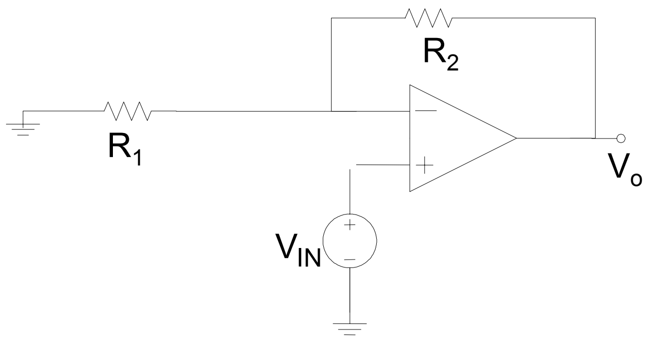
- The amplifier output voltage does not depend on the “load” (what is attached to the output).
- The “form” of the output voltage (the signs of the scaling factors on the input voltages, for example) depends on the amplifier circuit layout.

  To change the values (magnitudes) of scaling factors, adjust resistor values.
- Input voltages which are attached to the + (non-inverting) amplifier terminal get positive scaling factors.

  Inputs attached to the – (inverting) terminal get negative scaling factors.
- You can use these last two principles to design amplifiers which perform a particular function on the input voltages.

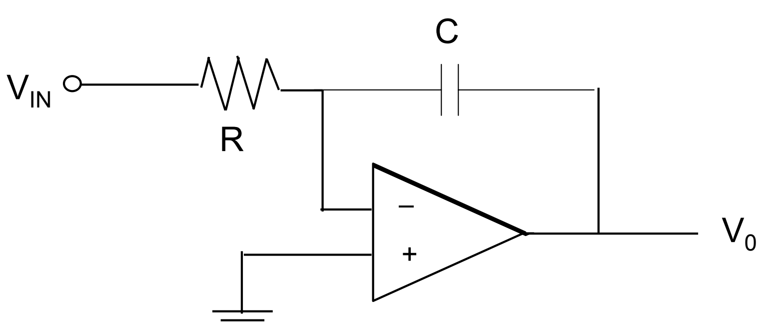
EECS 40 Spring 2003 Lecture 9 Copyright Regents of the University of California S. Ross and W. G. Oldham

NON-INVERTING AMPLIFIER



$$V_O = \left(1 + \frac{R_2}{R_1}\right) V_{IN}$$

INTEGRATING AMPLIFIER



$$V_O(t) = -\frac{1}{RC}\int_0^t V_{IN}(T)dT + V_C(0)$$