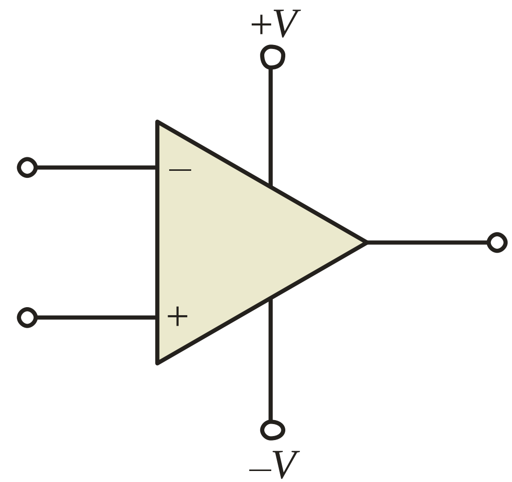
Lecture 10: Operational Amplifiers (1)

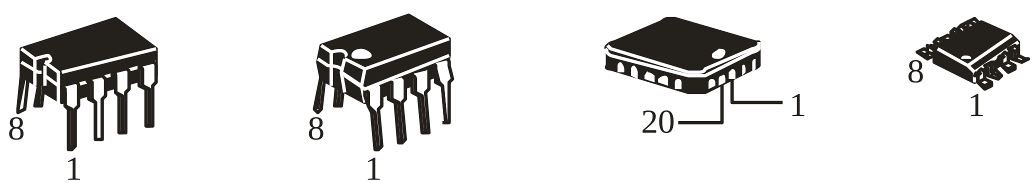
Ideal OpAmp, Practical OpAmp, Parameters of a Practical OpAmp, Examples

What is an OpAmp?

Operational amplifiers (op-amps) are very high gain dc coupled amplifiers with differential inputs. One of the inputs is called the inverting input (-); the other is called the noninverting input. Usually there is a single output.

Most op-amps operate from plus and minus supply voltages, which may or may not be shown on the schematic symbol.





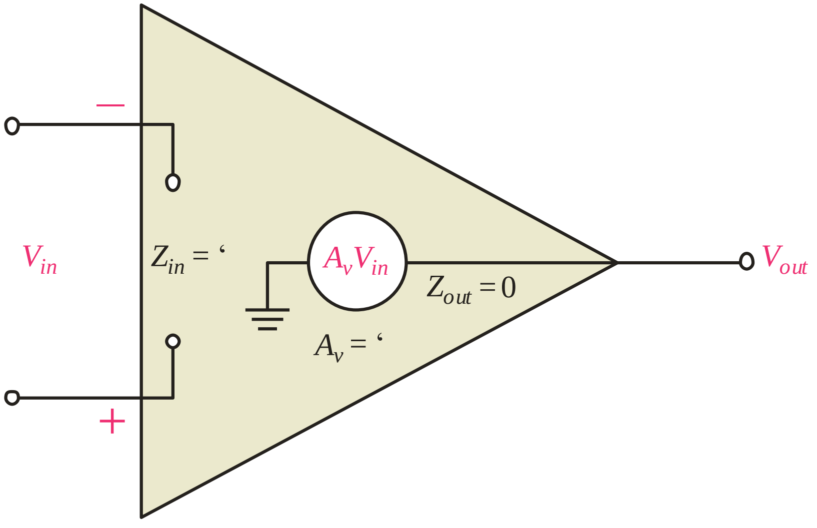
DIP DIP SMT SMT

The Ideal OpAmp

The ideal op-amp has characteristics that simplify analysis of op-amp circuits. Ideally, op-amps have *infinite voltage gain*, *infinite bandwidth*, and *infinite input impedance*. In addition, the ideal op-amp has *zero output impedance*.

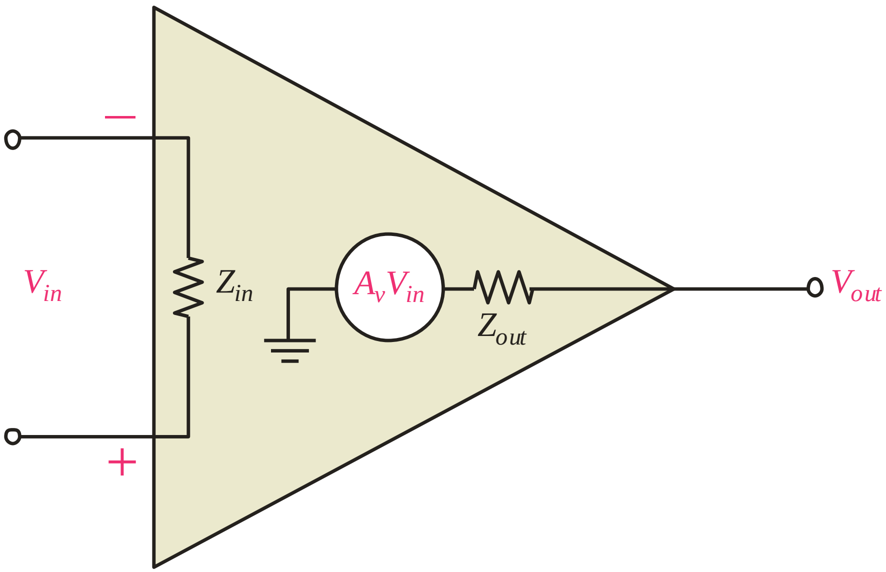
As a result, the two input terminals of the OpAmp have the same voltage and no current flows into the OpAmp input terminal

This model usually gives reasonably accurate results



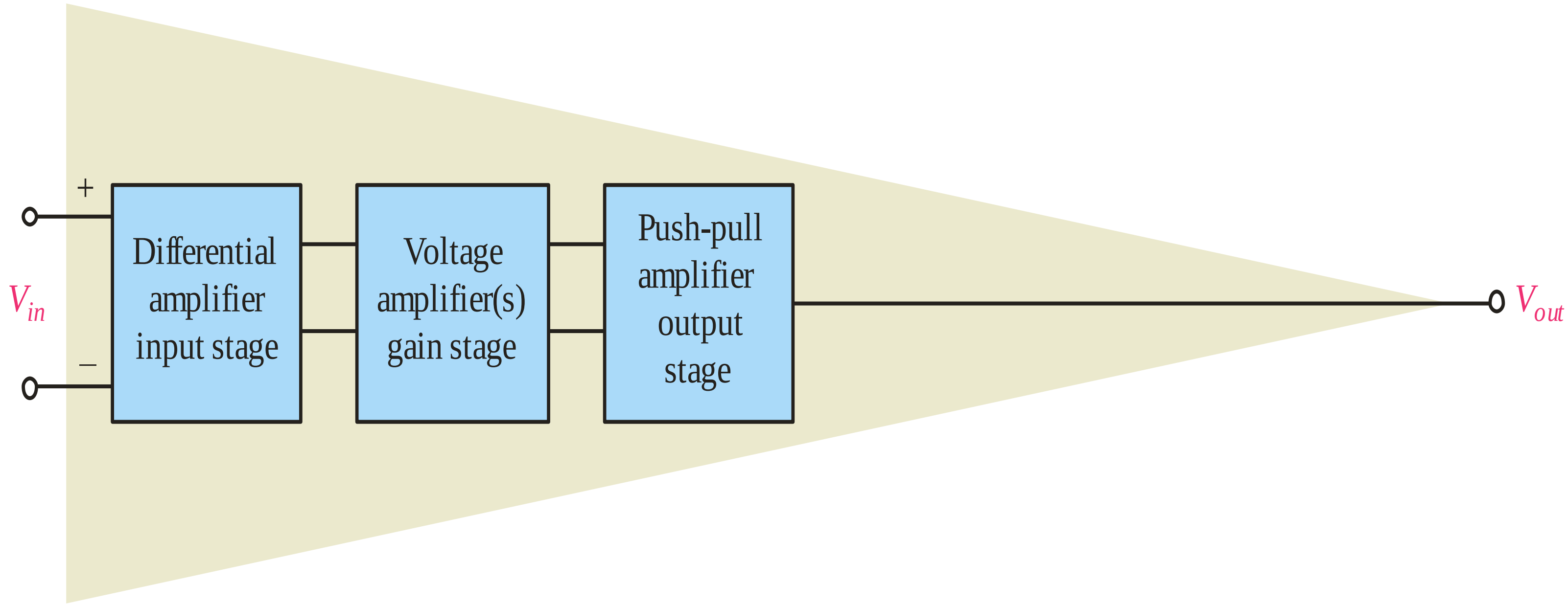
Practical OpAmp

Practical op-amps have characteristics that often can be treated as ideal for certain situations, but can never actually attain ideal characteristics. In addition to finite gain, bandwidth, and input impedance, they have other limitations.



Complicates circuit analysis significantly!

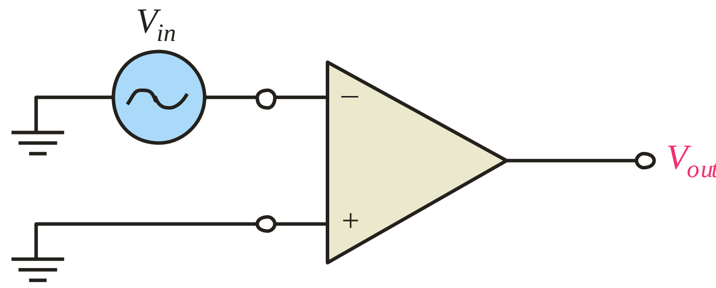
Practical OpAmp (Cont'd)

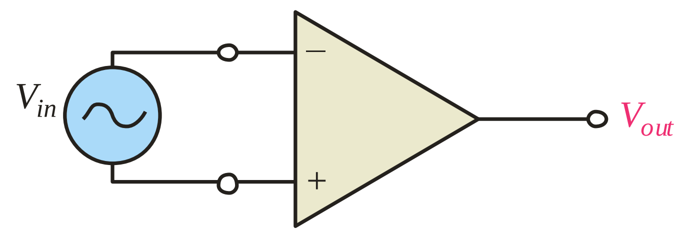


Many parameters have to be taken into account for accurate modeling of the OpAmp response

Differential Mode Vs. Common Mode

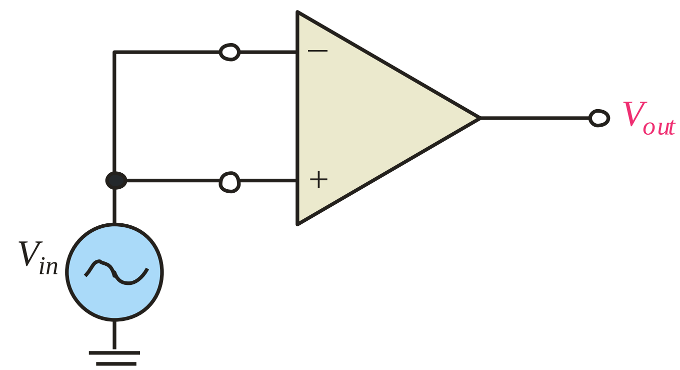
Differential-mode signals are applied either as single-ended (one side on ground) or double-ended (opposite phases on the inputs).





$$V_{out1}=A_{ol}(V_{+}-V_{-})$$

Common-mode signals are applied to both sides with the same phase on both terminals



$$V_{out2}=A_{cm}(V_{+}+V_{-})$$

Common Mode Rejection Ratio (CMMR)

The ability of an amplifier to amplify differential signals and reject common-mode signals is called the **common-mode rejection ratio (CMRR)**.

$$\mathbf{CMRR} = \frac{A_{ol}}{A_{cm}}$$

where A_{ol} is the open-loop differential-gain and A_{cm} is the common-mode gain.

CMRR can also be expressed in decibels as $\mathbf{CMRR} = 20\log\left(\frac{A_{ol}}{A_{cm}}\right)$

Example

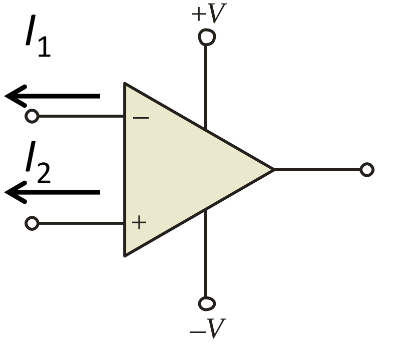
Practical Parameters

$V_{O(p\text{-}p)}$: The **maximum output voltage swing** is determined by the op-amp and the power supply voltages

V_{OS}: The **input offset voltage** is the differential dc voltage required between the inputs to force the output to zero volts

I_{BIAS}: The **input bias current** is the average of the two dc currents required to bias the differential amplifier

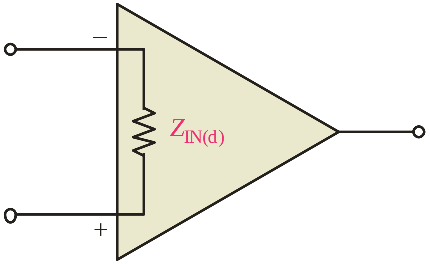
$$I_{BIAS} = \frac{I_1 + I_2}{2}$$



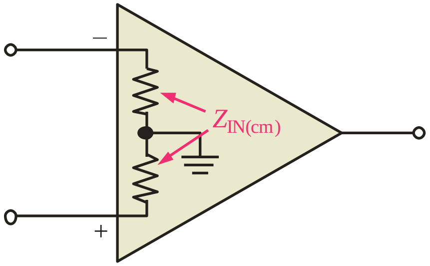
I_{OS}: The **input offset current** is the difference between the two dc bias currents $I_{OS} = |I_1 - I_2|$

Practical Parameters (Cont'd)

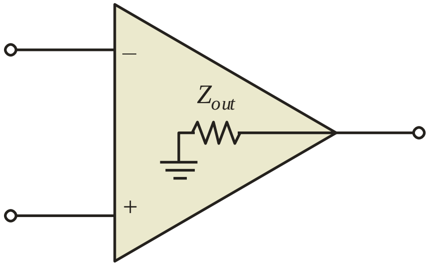
$Z_{IN(d)}$: The **differential input impedance** is the total resistance between the inputs



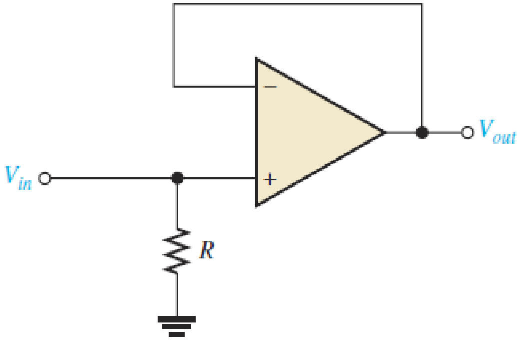
$Z_{IN(cm)}$: The **common-mode input impedance** is the resistance between each input and ground

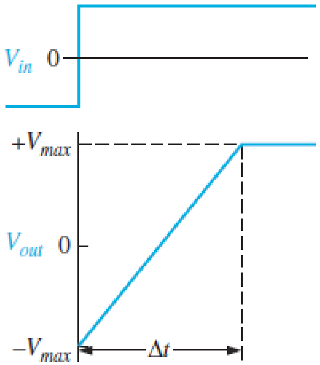


Z_{out}: The **output impedance** is the resistance viewed from the output of the circuit.



Practical Parameters (Cont'd)





Slew rate: The **slew rate** is the maximum rate of change of the output voltage in response to a step input voltage

$$\text{Slew Rate} = \frac{\Delta V_{out}}{\Delta t}$$

Frequency Response and Noise!