LaACES Student Ballooning Course

# Lecture L02.03

## The Operational Amplifier

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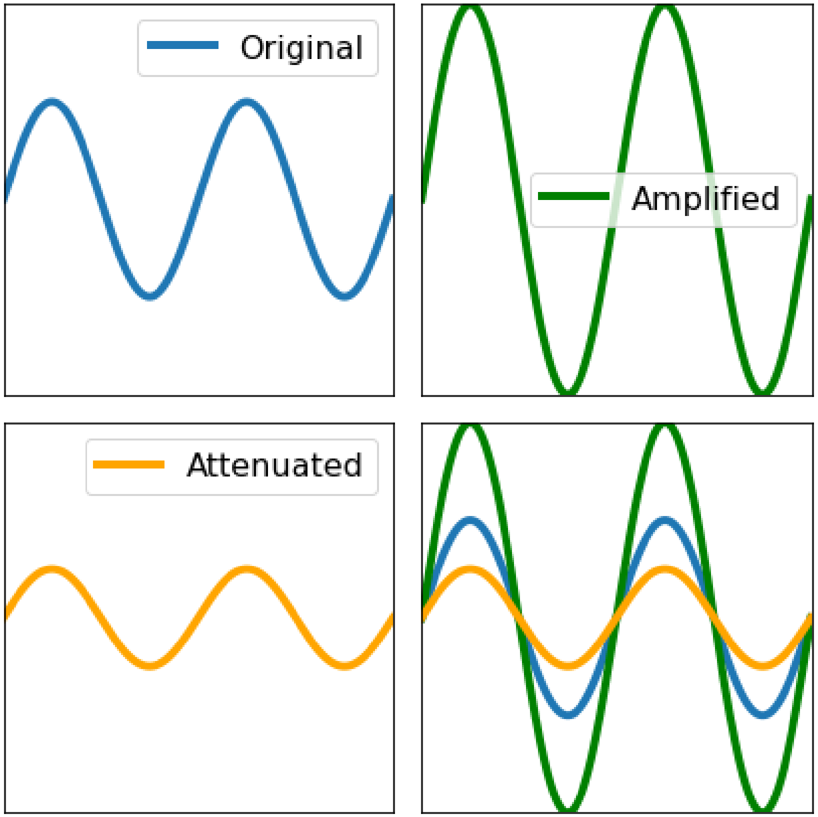
# Amplification and Attenuation



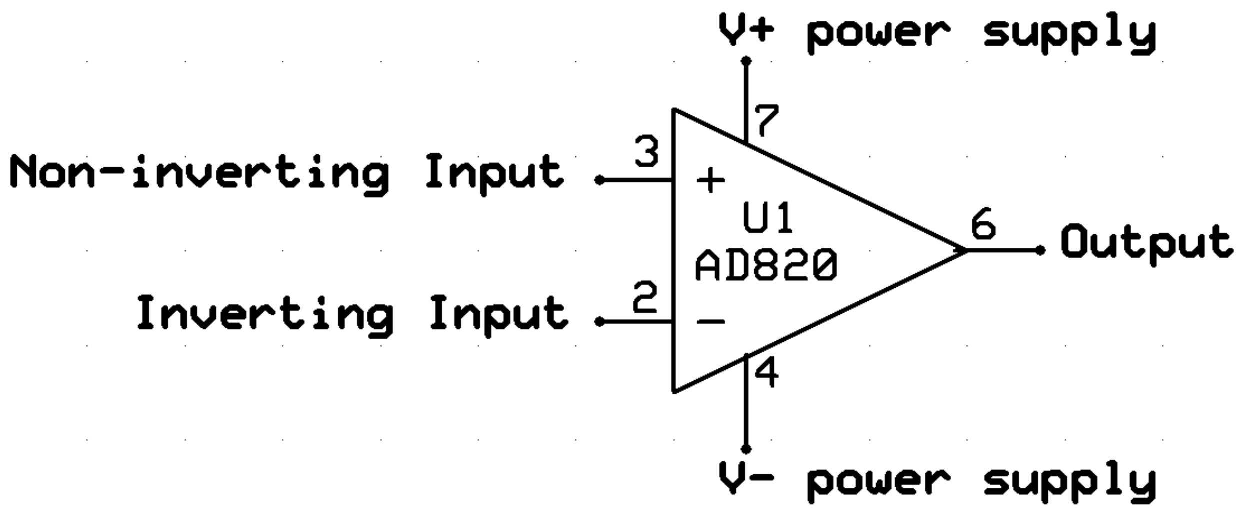

When a signal is too small to be measured correctly, the signal can be amplified. **Amplification** is the process of increasing the amplitude of an electrical signal. (Gain >1)

Sometimes, a signal is strong enough to damage equipment or other devices or exceed the desired thresholds. **Attenuation** is the process of reducing the power of an electrical sensor.(Gain 0-1) Attenuation can occur when a signal is sent over long distances.

# Signal Conditioning Circuit

*Operational Amplifier or "Op amp"*

Amplifying circuits are built using an IC called an op amp.



# Op Amp Connections - Power

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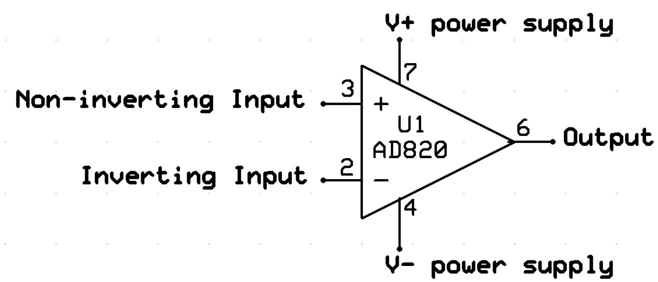
- Vsupply+ (often called Vcc)
  - Maximum output voltage will be slightly lower than this voltage
- Vsupply-
  - Maybe 0V or GND, can often be negative
  - Mininum output voltage will be slightly higher than this voltage
- Current at the output will be drawn via these connections



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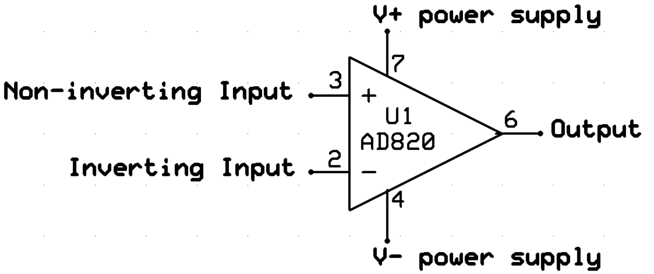
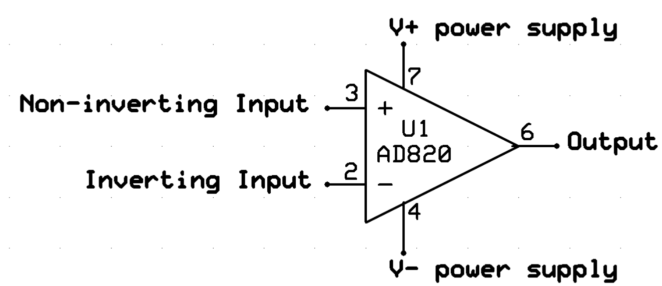
# Op Amp Connections - Inputs

- Vin+ (V+)
  - Non-inverting input
  - Input used when do not want to switch signal to negative
- Vin-
  - Inverting input
  - Used when switching signal sign is desired
  - Also used to for creating an offset or subtracting two signals
- The input signal designated Vin will be connected to one of these pins

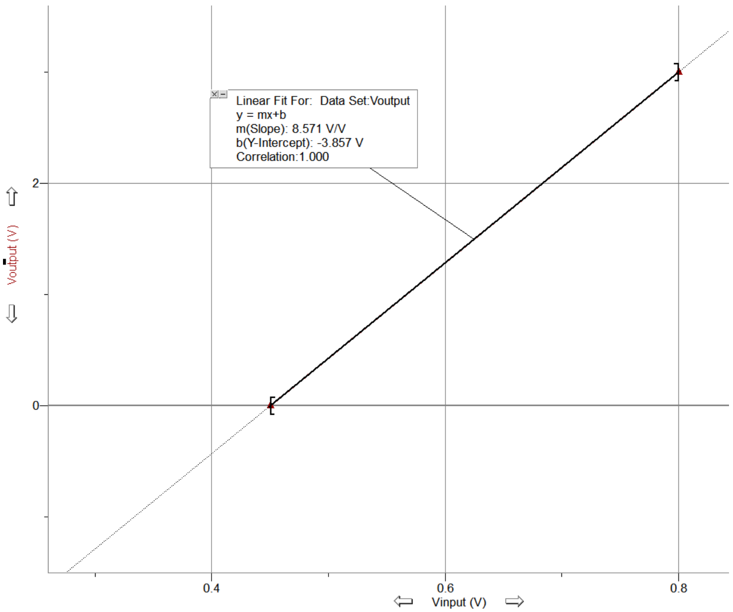


# Op Amp Connections - Output

- Vout
  - The circuit will be designed to change this
  - Will be connected back to one of the inputs to create a feedback loop
  - Op Amp will vary Vout to satisfy the **Golden Rules**
  - Limited between Vs+ and Vs-



# Transfer Function




The equation of between the input and the output of the amplifier is called the **transfer function**.

Usually, the transfer function is linear (at least over range)

The slope is the **gain** and the intercept the **offset**.

In the plot to the left we are amplifying a small (0.450-0.800 V) signal to 0-3V
Gain = 8.571
Offset = -3.857 V

# Op Amp Golden Rules

If Vout is connected to one of the inputs forming a feedback loop, Vout will vary to satisfy the following rules:

I. **The output changes to make the voltage difference between both inputs zero. (V+=V-)**

II. **The inputs draw no current. (I+=I-=0A)**

# Signal Conditioning Circuit

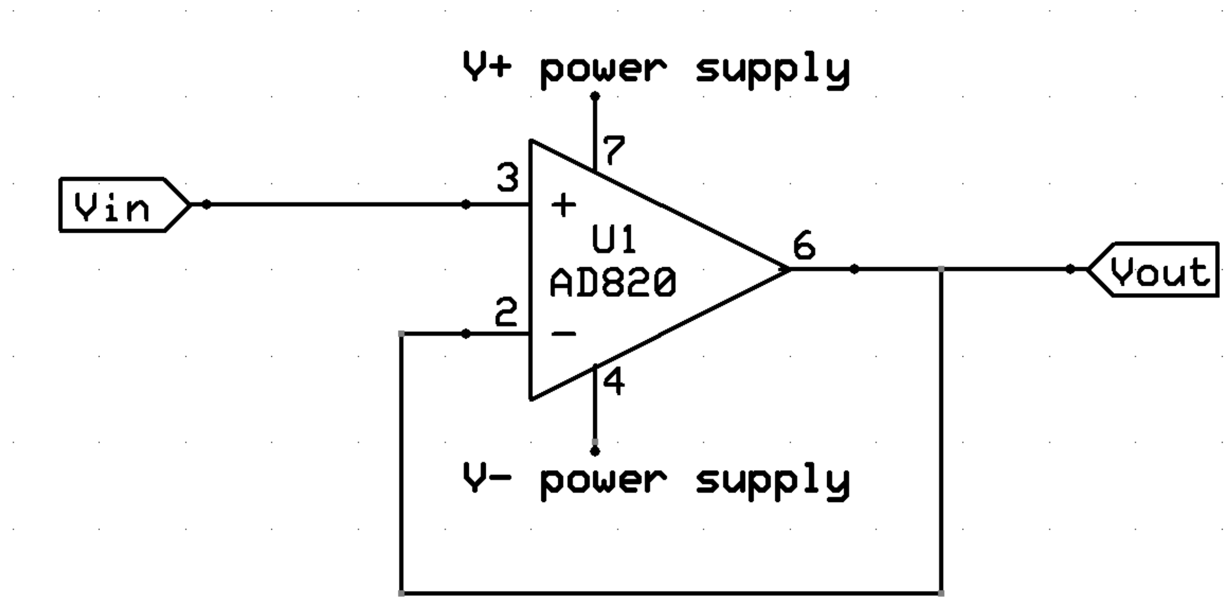
## Example 1: Buffer

No resistors so the equations are simple

Vin=V+

V+=V- (Golden Rule)

V-=Vout      Therefore Vin=Vout

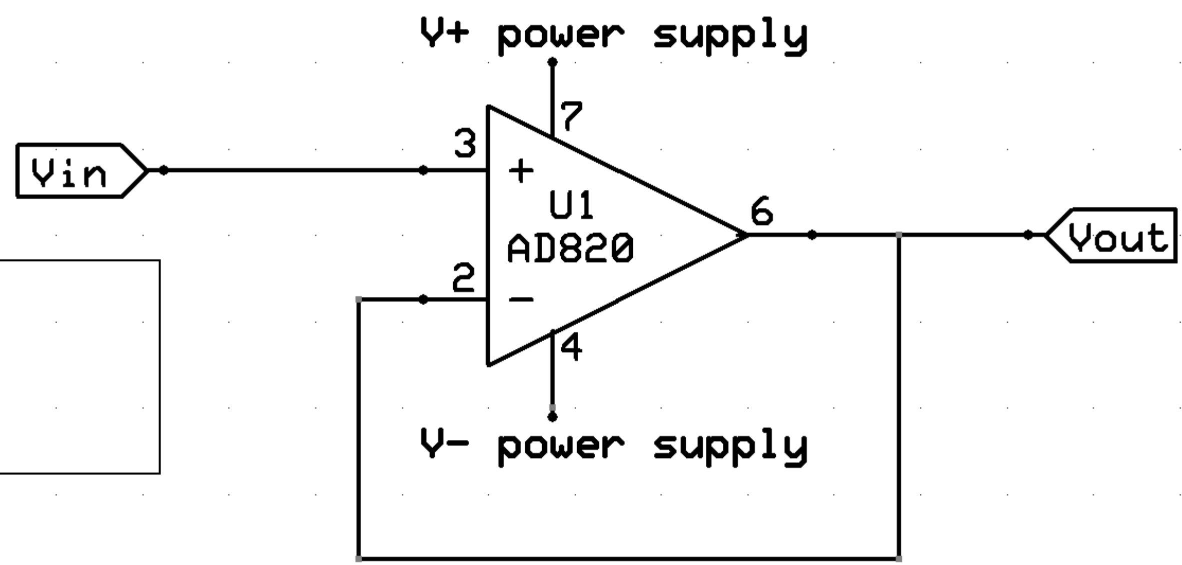


# Signal Conditioning Circuit

## *Buffer usage*

A buffer provides voltage or current isolation between to components to prevent the signal from affecting the performance of a component.

Current on $V_{out}$ comes from the supply, not $V_{in}$.




Gain of Buffer
Vin = Vout
Gain=1

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# Signal Conditioning Circuit

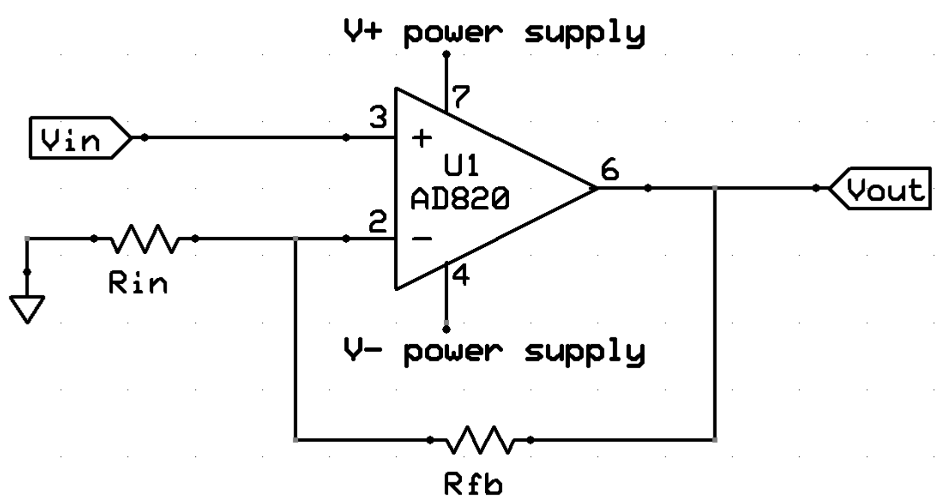
## *Non-Inverting Amplifier Example*

Now we have some resistors and possible current paths so things are more complicated.
Vin=V+=V- (Golden Rule)

Since no current can go into V- we know all the current through Rfb has to go through Rin. Using Ohms Law (I=V/R), we can write that out as:

$$\frac{V_{out} - V_{-}}{R_{fb}} = \frac{V_{-} - 0V}{R_{in}}$$

But since V-=Vin we can Substitute and solve for Vout



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# Signal Conditioning Circuit

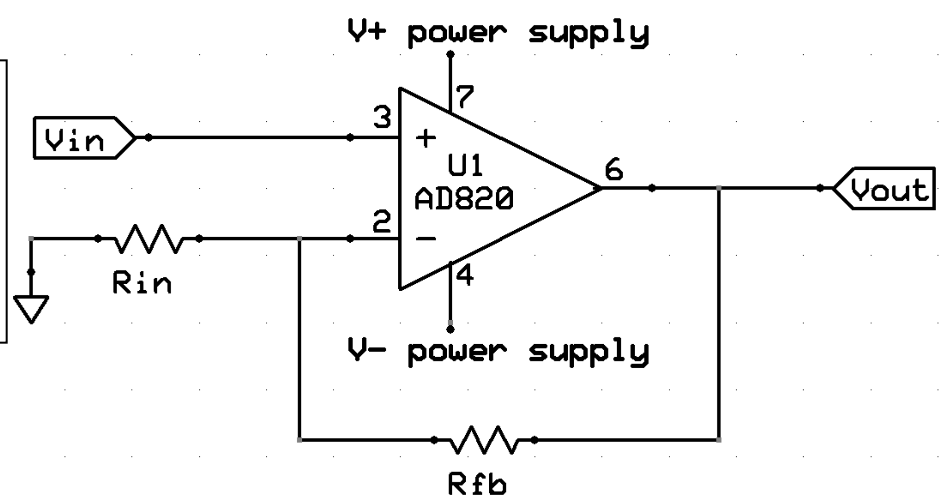
## *Non-Inverting Amplifier Usage*

Non-inverted op amps have Vin connected to the positive terminal. This is commonly used in electronics to amplify DC signal.

$$V_{out} = V_{in}[1 + \frac{R_{fb}}{R_{in}}]$$

$$G = 1 + \frac{R_{fb}}{R_{in}}$$

Gain>0



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# Signal Conditioning Circuit

## *Inverting Amplifier*

Inverted op amps have Vin connected to the negative terminal.

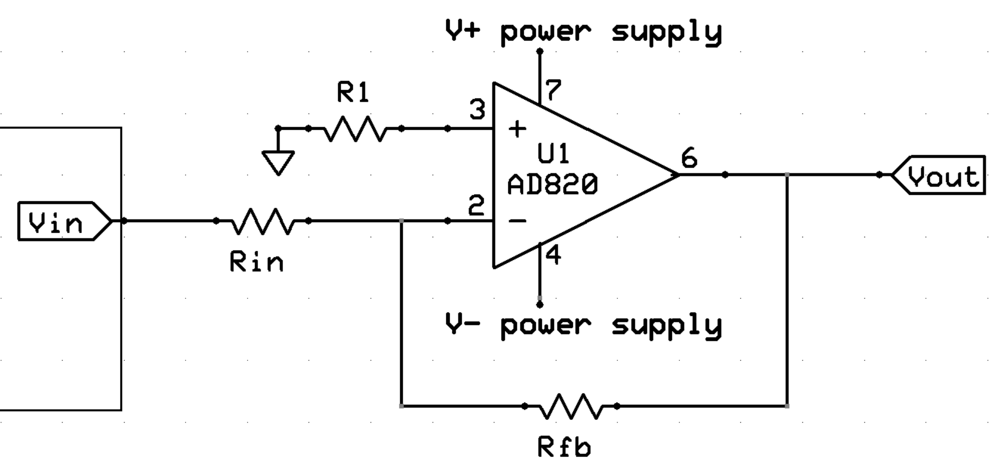
Signal is inverted (flipped).

$$V_{out} = -V_{in}[\frac{R_{fb}}{R_{in}}]$$

Note: the gain is negative so it is important to consider the sign of Vin and if Vs- is negative or zero

$$G = -\frac{R_{fb}}{R_{in}}$$

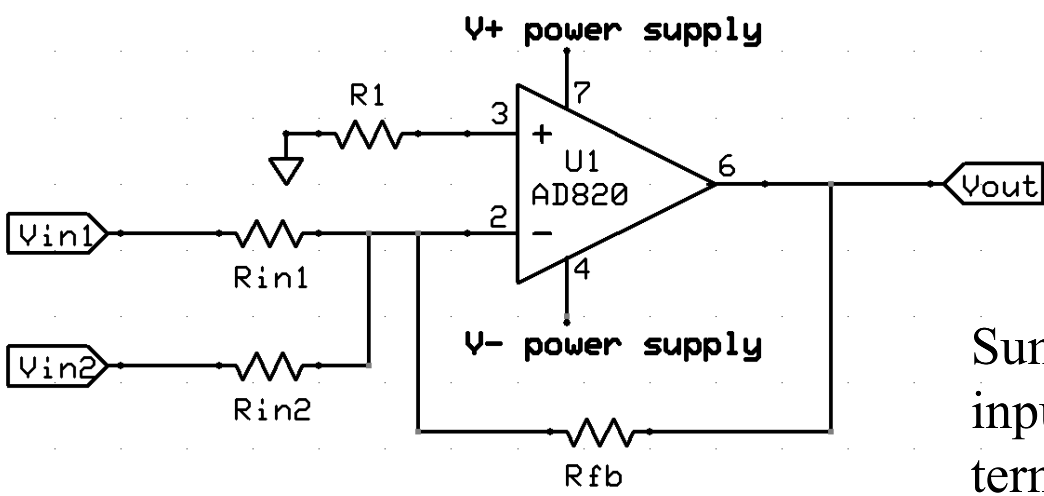
Gain<0



# Signal Conditioning Circuit

## *Summing Amplifier*

$$V_{out} = -[V_{in1}\frac{R_{fb}}{R_{in1}} + V_{in2}\frac{R_{fb}}{R_{in2}}]$$

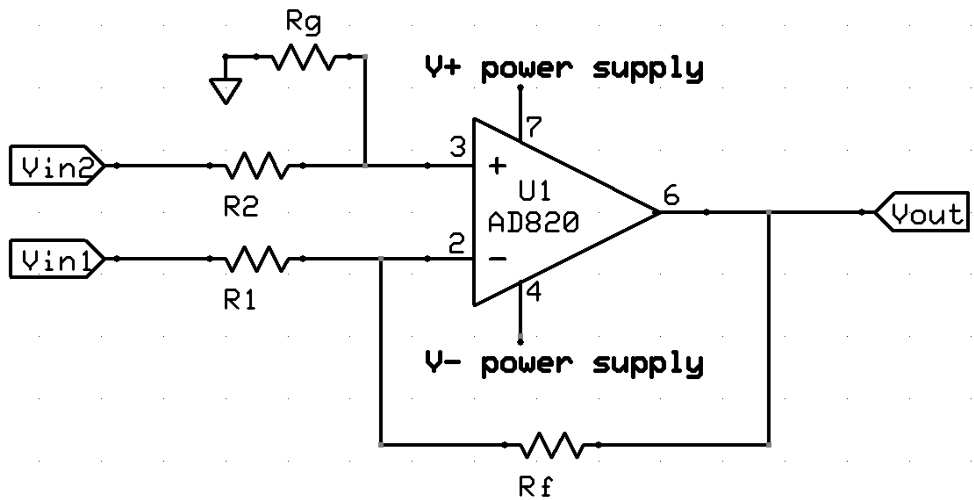



Summing op amps have multiple inputs are connected into a single terminal. Can be inverting (shown here) or noninverting.

# Signal Conditioning Circuit

## *Difference Amplifier*

$$V_{out} = (V_{in2} - V_{in1})\left(\frac{Rf}{R1}\right) \quad \text{if } \frac{Rf}{R1} = \frac{Rg}{R2}$$

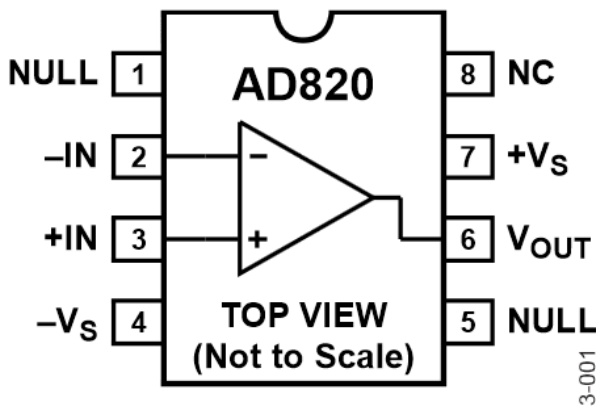


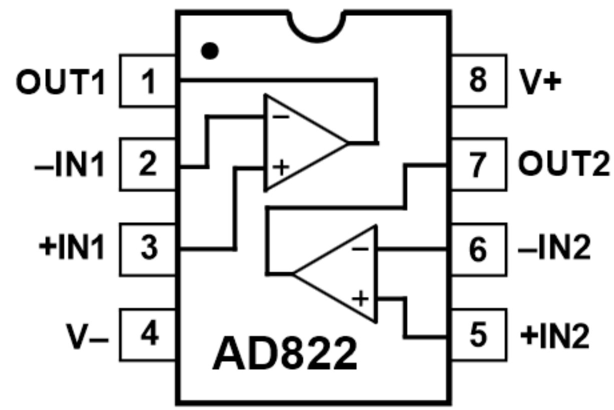

A difference op amp has an input into both the negative and positive terminals.

It amplifies the difference between the two signals.

# Operational Amplifier ICs

Available in Single(1x), Dual(2x), Quad(4x) Packages
May be Bipolar power supply (ex. +/-$V_s$ = +/- 12V)
Single supply operation (ex. +12V, GND)
Variety of voltage and frequency ranges for different chips.

# Other Types of Amplifying Circuits

- A common variation is to add an offset to previous examples, which shifts the entire signal by a constant amount up and down.

- By adding capacitors and or inductors you can make the gain of a circuit depend on a frequency, this allows you to filter undesirable signals (like high frequency RF noise) out
- It is also common to have multiple stages of amplification;  using a buffer to isolate an amplified signal from the rest of the circuit.