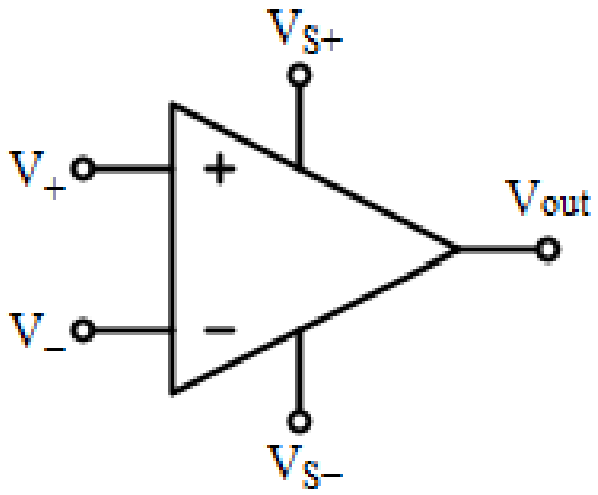
A traditional Op-Amp:

- The ***operational amplifier*** ("***op amp***") is a basic building block used in analog circuits.
  - Its behavior is modeled using a dependent source.
  - When combined with resistors, capacitors, and inductors, it can perform various useful functions:
    - **amplification/scaling** of an input signal
    - **sign changing** (inversion) of an input signal
    - **addition** of multiple input signals
    - **subtraction** of one input signal from another
    - **integration** (over time) of an input signal
    - **differentiation** (with respect to time) of an input signal
    - **analog filtering**
    - **nonlinear functions** like exponential, log, sqrt, etc.

A traditional Op-Amp:



V_+ : non-inverting input
V_- : inverting input
V_{out} : output
V_{s+} : positive power supply
V_{s-} : negative power supply

$$V_{out} = K (V_+ - V_-)$$

- The difference between the two inputs voltages (V_+ and V_-) multiplied by the gain (K, "amplification factor") of the Op-Amp gives you the output voltage

- The output voltage can only be as high as the <u>difference</u> between the power supply (V_{s+} / V_{s-})and ground (0 Volts)

Important Parameters for Op-Amps

- Input Parameters
  - Voltage (Vicm)
  - Offset voltage
  - Bias current
  - Input Impedance
- Output Parameters
  - Short circuit current
  - Voltage Swing
  - Open Loop Gain
  - Slew Rate

Applications of Op-Amps

- Simple Amplifiers
- Summers
- Comparators
- Integrators
- Differentiators
- Active Filters
- Analog to Digital Converters

An Ideal Op-Amp

- Infinite voltage gain
- Infinite input impedance
- Zero output impedance
- Infinite bandwidth
- Zero input offset voltage (i.e., exactly zero out if zero in).

Non-Inverting Op-Amp

- Amplifies the input voltage by a constant
- Closed loop op-amp
- Voltage input connected to non-inverting input
- Voltage output connected to inverting input through a feedback resistor
- Inverting input is also connected to ground
- Non-inverting input is only determined by voltage output

Inverting Op-Amp

- Amplifies and inverts the input voltage
- Closed loop op-amp
- Non-inverting input is determined by *both* voltage input and output
- The polarity of the output voltage is opposite to that of the input voltage
- Voltage input is connected to inverting input
- Voltage output is connected to inverting input through a feedback resistor
- Non-inverting input is grounded

Summing Amplifier

The summing amplifier does exactly as the name suggests by adding up the voltages given to it and producing an output voltage which is the sum of the input voltages scaled by the feedback resistance and input resistance

Comparator

- The comparator is an op-amp circuit that compares two input voltages and produces an output indicating the relationship between them. The inputs can be two signals (such as two sine waves) or a signal and a fixed dc reference voltage.
- Often used as an interface between digital and analog signals.

Integrating Op-Amp

- Integrates the inverted input signal over time
- Closed loop op-amp
- Voltage output is connected to inverting input through a *capacitor*
- The resistor and capacitor form an RC circuit
- Magnitude of the output is determined by length of time voltage is present at input
- The longer the input voltage is present, the greater the output

Filters

- Filters are circuits that are capable of *passing signals within a band* of frequencies while *rejecting or blocking* signals of frequencies *outside this band*. This property of filters is also called "frequency selectivity".
- Filter can be passive or active filter.

Passive filters: The circuits built using RC, RL, or RLC circuits.

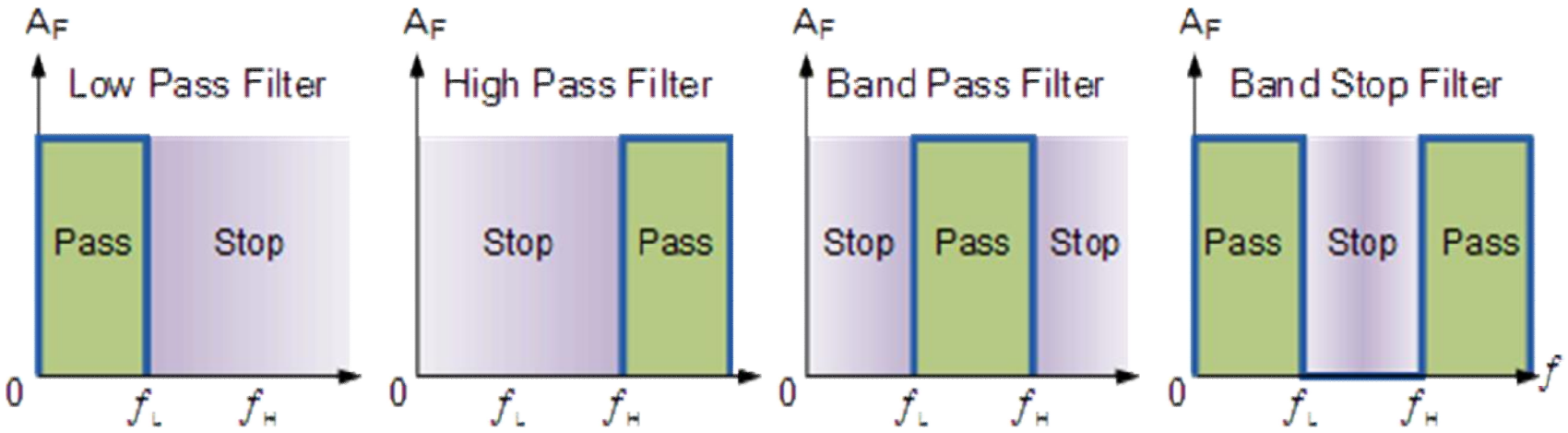
Active filters : The circuits that employ one or more op-amps in the design an addition to resistors and capacitors

Active Filters

- There are 4 basic categories of active filters:

1. **Low-pass filters**
2. **High-pass filters**
3. **Band-pass filters**
4. **Band-reject filters**

- Each of these filters can be built by using op-amp as the active element combined with RC, RL or RLC circuit as the passive elements.


A_F
Low Pass Filter
Pass
Stop
0
f_L
f_H
A_F
High Pass Filter
Stop
Pass
0
f_L
f_H
A_F
Band Pass Filter
Stop
Pass
Stop
0
f_L
f_H
A_F
Band Stop Filter
Pass
Stop
Pass
0
f_L
f_H
f