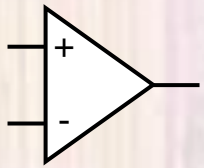
OpAmps

Last updated 4/14/22

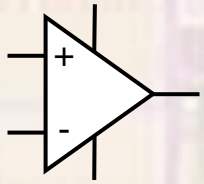
OpAmps

- Operational Amplifier (OpAmp)
  - High Gain difference amplifier

$$V_o = A_{od}\,(V_+ - V_-)$$



Implied power connections

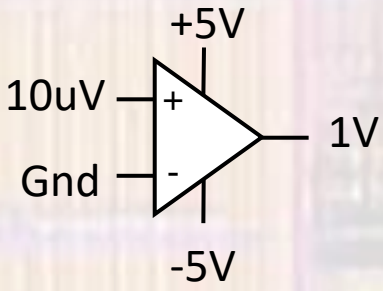


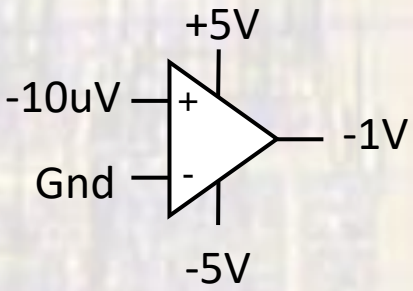
Explicit power connections

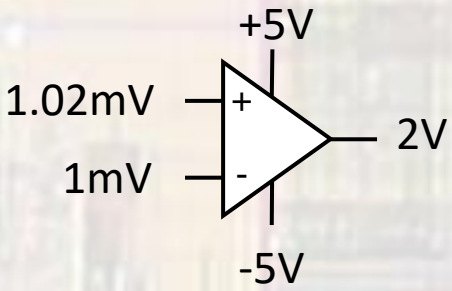
OpAmps

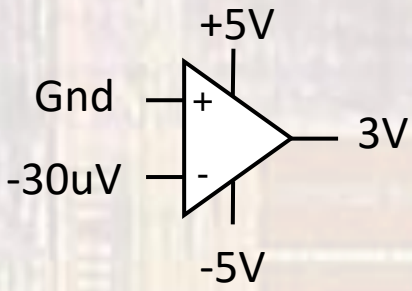
- Ideal OpAmp
  - High Gain difference amplifier

$$V_o = A_{od}(V_+ - V_-) \qquad A_{od} = 100{,}000$$





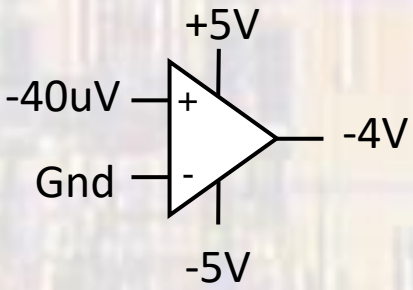


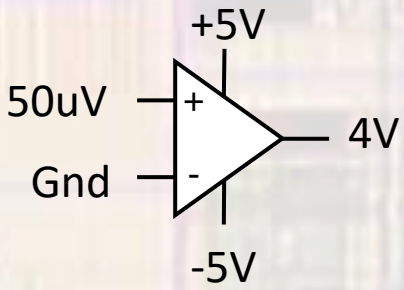


OpAmps

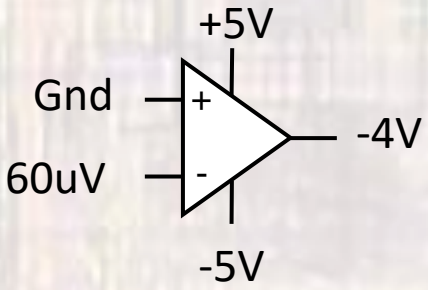
- OpAmp Limitations
  - Output Swing
    - Common opamps can only swing the output to about 1V from the positive or negative voltage rails
    - Rail-to-rail opamps can get to within 10s of mv of the rails

$$A_{od} = 100{,}000$$





Output Saturated
(clipped, limited)

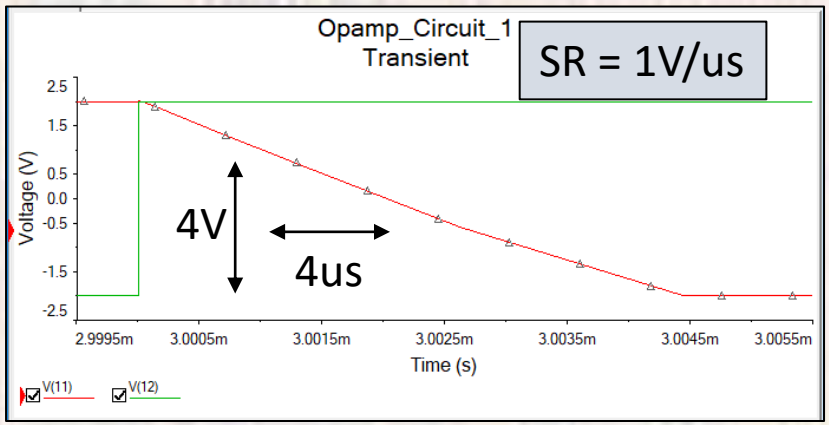


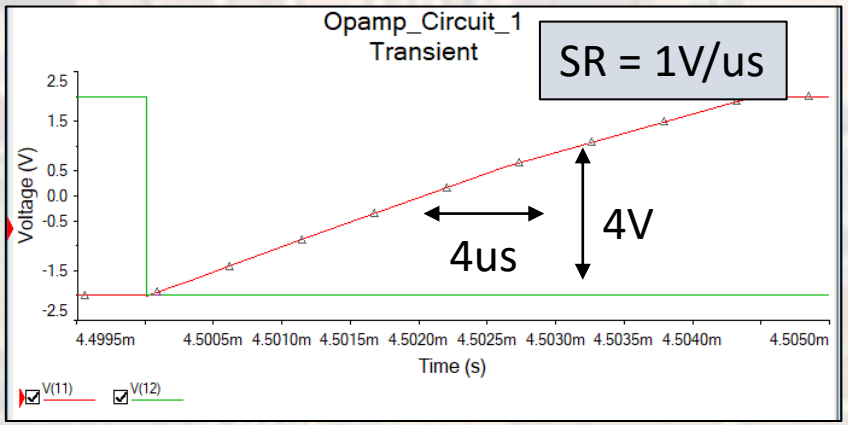
Output Saturated
(clipped, limited)

OpAmps

- OpAmp Limitations
  - Slew Rate
    - Limit on how fast the output can change
    - Limits large signal rise and fall times at the output
      - Typically between 1V/us and 100V/us

$$\left({}^{dV_o}/_{dt}\right)_{max} = SR$$



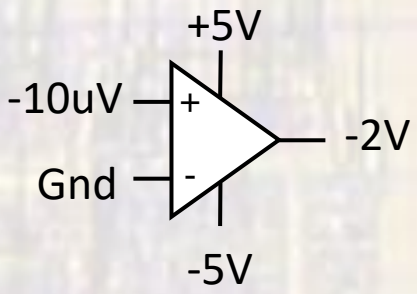


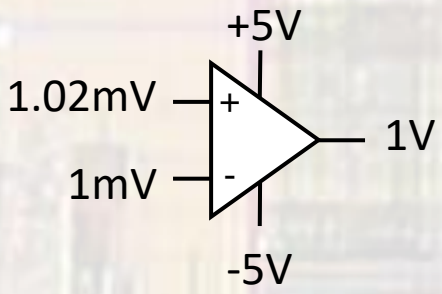
OpAmps

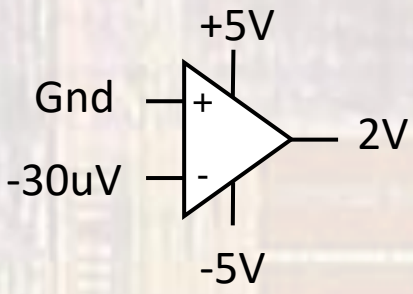
- OpAmp Limitations
  - Input Offset
    - This represents a built-in error between the + and – inputs
      - Bipolar: < 20mV
      - CMOS: < 1mV

$$V_o = A_{od}(V_+ - V_- - V_{offset})$$

A_{od}= 100,000
V_{os} = 10uV







OpAmps

- OpAmp Limitations
  - Input bias current / input bias current offset
    - The required input current to operate the opamp
    - The offset from + to – for the input bias currents
    - Bipolar inputs
      - Bias current, typically < 1uA
      - Offset, typically 20% - 50% of bias current
    - CMOS inputs, typically < 1nA

OpAmps

- OpAmp Limitations
  - Input Impedance
    - The impedance looking into the inputs
    - Bipolar input opamps typically between 1MΩ and 10MΩ
    - CMOS input opamps typically > 10GΩ
  - Output Impedance
    - The impedance looking into the output
    - Typically < 50Ω

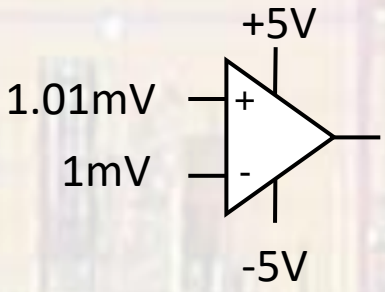
OpAmps

- OpAmp Limitations
  - Common Mode Rejection Ratio (CMMR)
    - This represents the opamps ability to reject signals that are present on both inputs (common)
    - CMRR is the ratio of the common-mode gain to differential-mode gain

$$V_o = A_{od}(V_+ - V_-) + A_{CM}\frac{(V_+ + V_-)}{2}$$

$$CMRR = \frac{A_{od}}{A_{CM}} \qquad CMRR_{dB} = 20\log\frac{A_{od}}{A_{CM}}$$

A_{od} = 100,000
A_{CM} = 80dB (10,000)

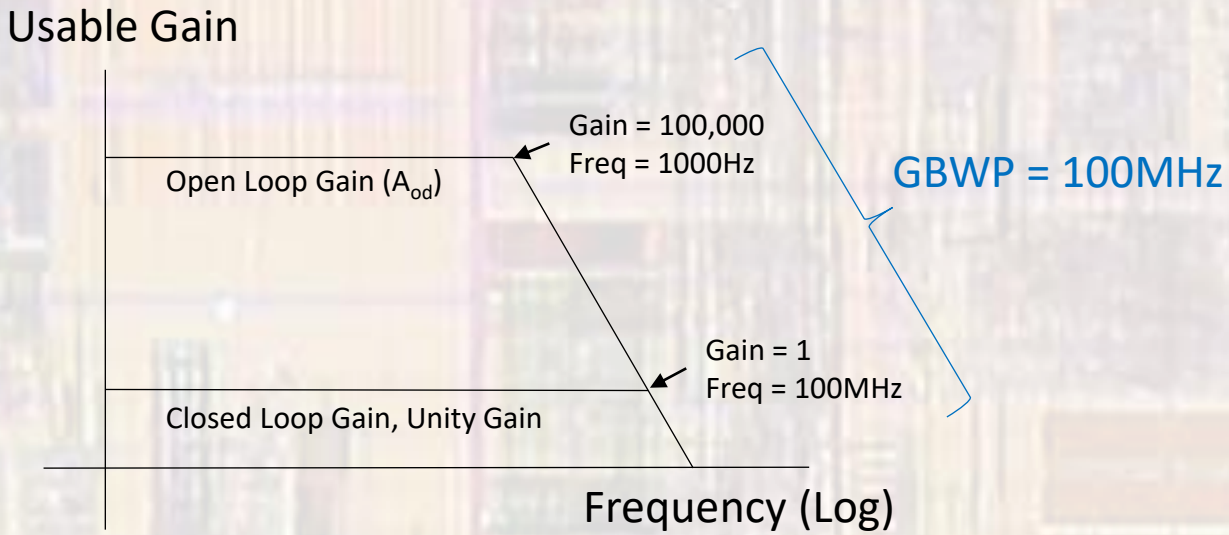


$$1V + \frac{100{,}000}{10{,}000}\frac{(1.01mV + 1mV)}{2}$$

1V + 10.05mV = 1.01V

OpAmps

- OpAmp Limitations
  - Gain Bandwidth Product
    - Product of the Gain at a specific frequency and the frequency
    - For most negative feedback configurations this is constant
    - Sometimes called the Unity Gain Bandwidth



OpAmps

- OpAmp Models