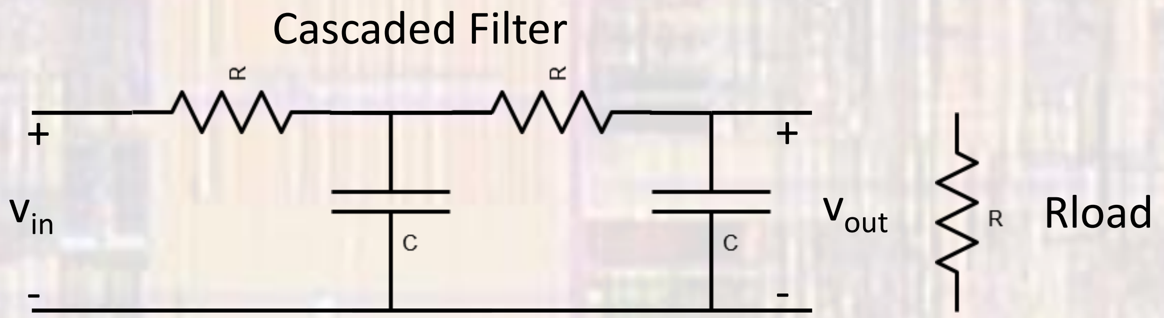
RC Active Filters
1st Order

Last updated 4/28/22

RC Active Filters

- Passive filter concerns
  - Each stage loads the previous stage
  - Best case gain is 1 (0dB)
  - Any non-infinite output load will change the filter output



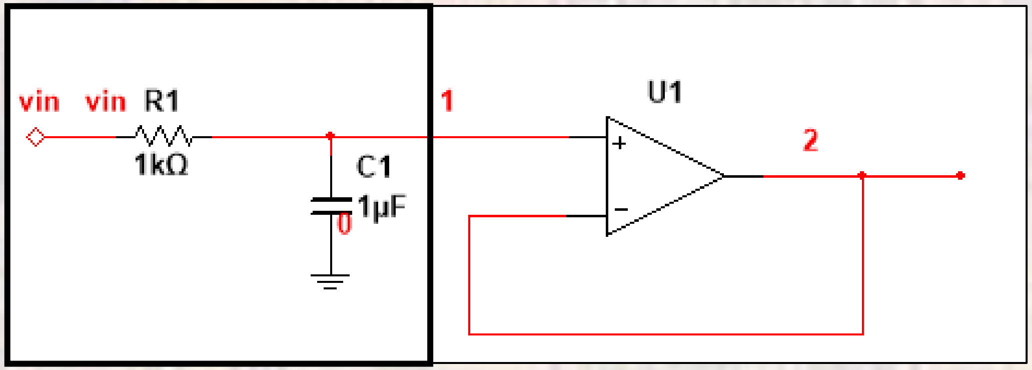
RC Active Filters

- Why RC
  - It is much easier and cheaper to build integrated circuit capacitors and resistors than inductors

RC Active Filters

- Just buffer the passive filter – Low Pass
  - Non-inverting
  - Load insensitive
  - Can be cascaded
  - Unity Gain

Passive Filter

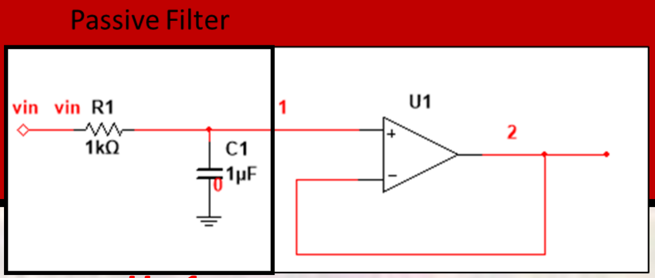


$$f_C = \frac{1}{2\pi RC}$$

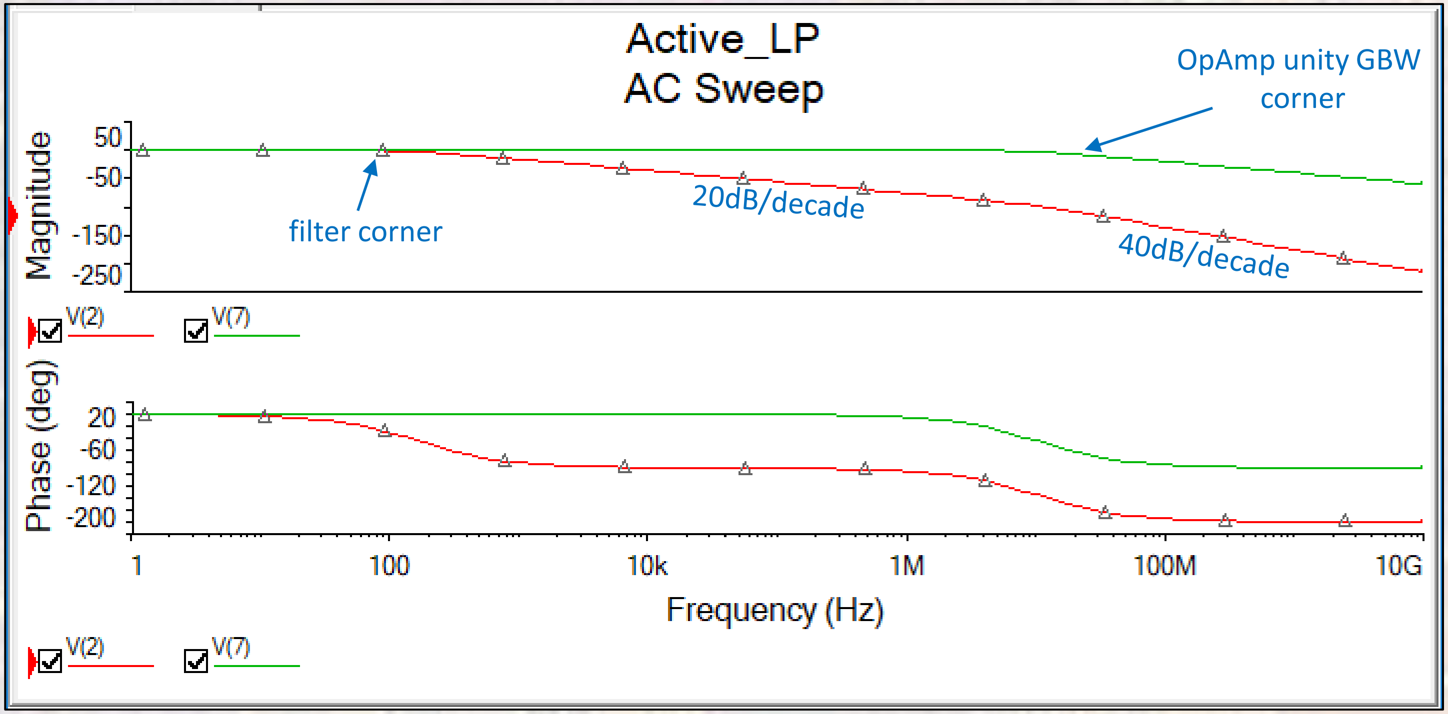
$$A = 1$$

$$A_v = \frac{A}{\sqrt{1 + \left(\frac{f}{f_C}\right)^2}}$$

RC Active Filters



- Just buffer the passive filter – Caveat # 1
  - The OpAmp has an internal Lowpass characteristic (GBWP)
    - Can be good or bad depending on the situation



RC Active Filters

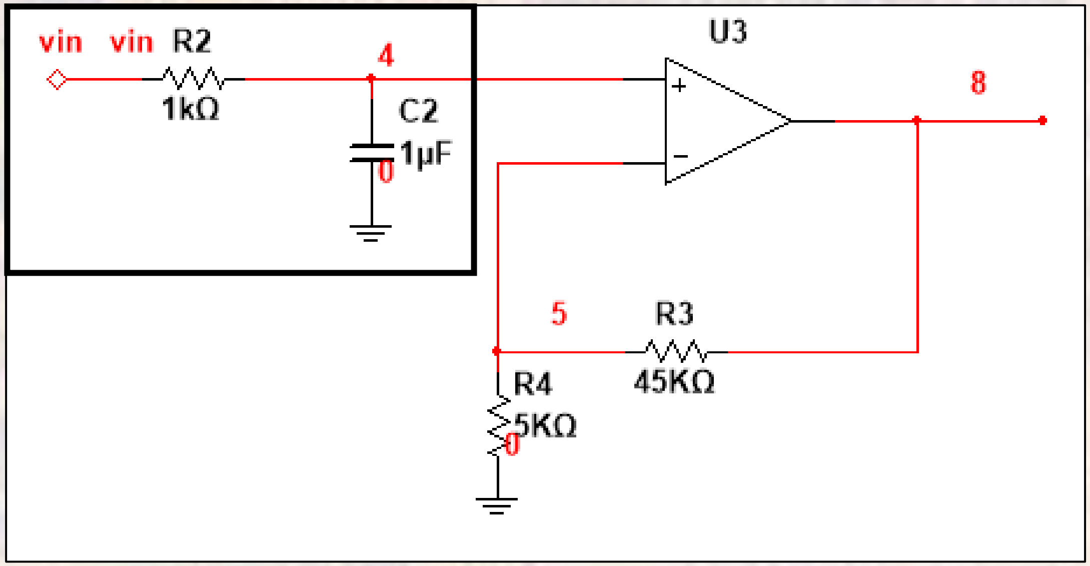
- Buffer the passive filter with gain – Low Pass
  - Non-inverting
  - Load insensitive
  - Can be cascaded
  - Selectable Gain

$$f_C = \frac{1}{2\pi RC}$$

$$A = 1 + \frac{R_F}{R_I}$$

$$A_v = \frac{A}{\sqrt{1 + \left(\frac{f}{f_C}\right)^2}}$$

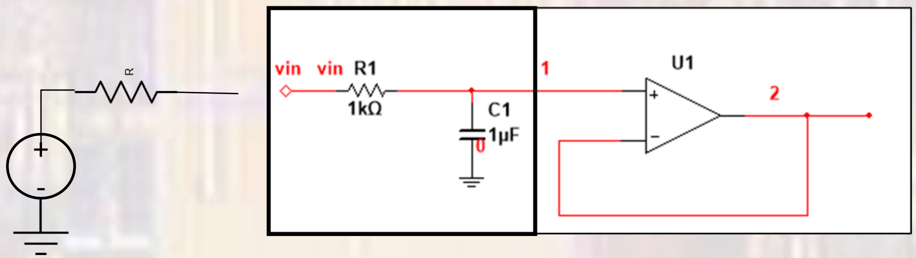
Passive Filter



RC Active Filters

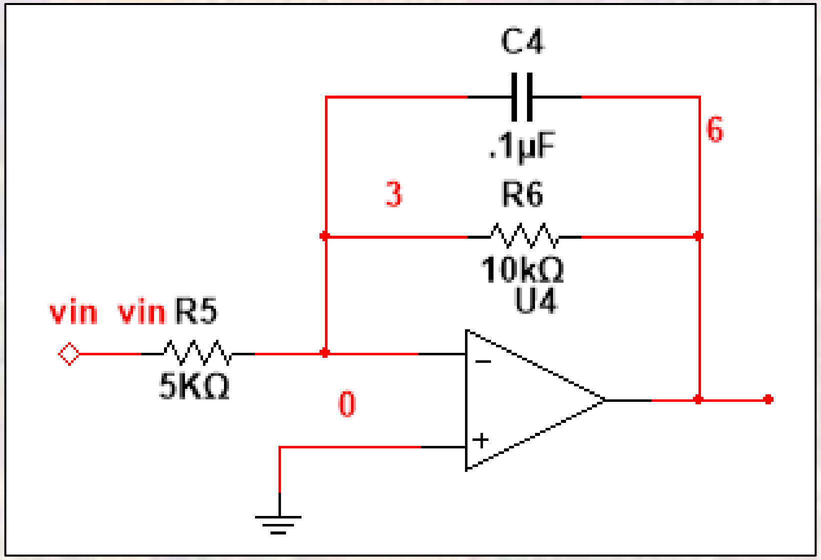
- Buffer the passive filter – Caveat # 2
  - The filter has a relatively small input impedance
    - Loads the driver
    - Driver output impedance may affect the filter

Passive Filter



RC Active Filters

- Buffer the passive filter – Low Pass
  - Remove the reactive element from the input
  - Inverting
  - Selectable Gain



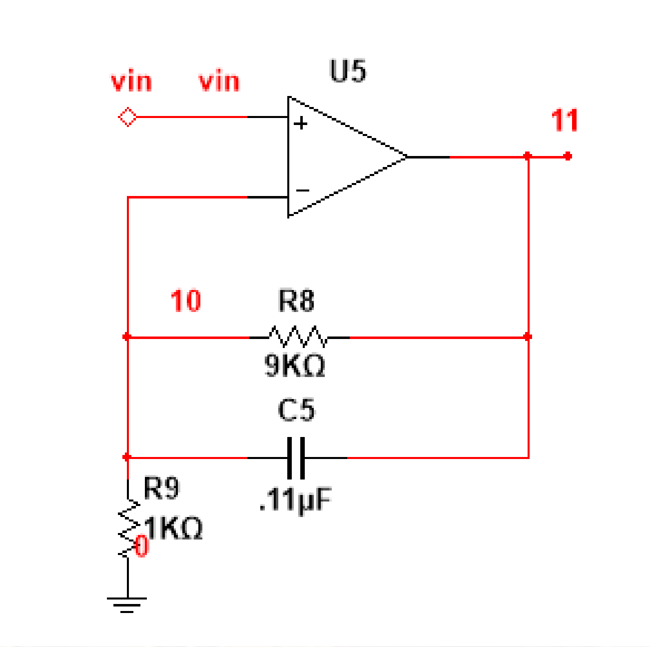
$$f_C = \frac{1}{2\pi R_F C}$$

$$A = -\frac{R_F}{R_I}$$

$$A_v = \frac{A}{\sqrt{1 + \left(\frac{f}{f_C}\right)^2}}$$

RC Active Filters

- Buffer the passive filter – Low Pass
  - Remove the reactive element from the input
  - Non-inverting
  - Selectable gain
  - High frequencies → unity gain



$$f_C = \frac{1}{2\pi R_F C}$$

$$A = 1 + \frac{R_F}{R_I}$$

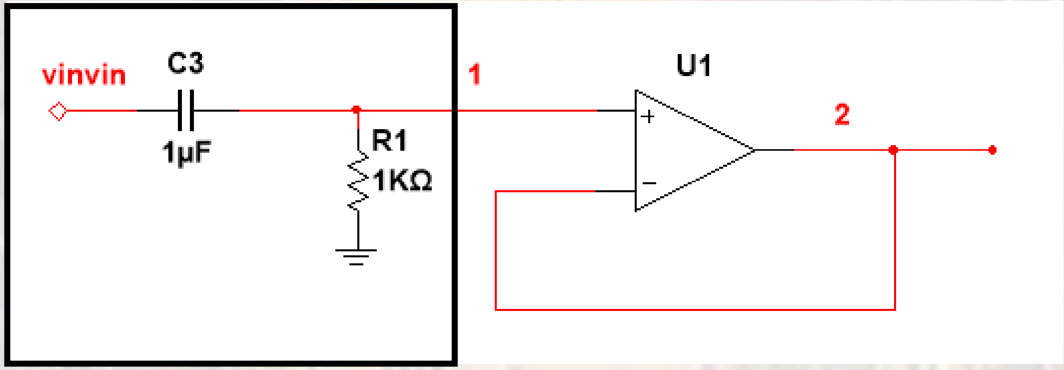
$$A_v{}^* = \frac{A}{\sqrt{1 + \left(\frac{f}{f_C}\right)^2}}$$

$$* \; A_{v\,min} = 1 = 0dB$$

RC Active Filters

- First order – High Pass
  - Non-inverting
  - Unity Gain

Passive Filter



$$f_C = \frac{1}{2\pi RC}$$

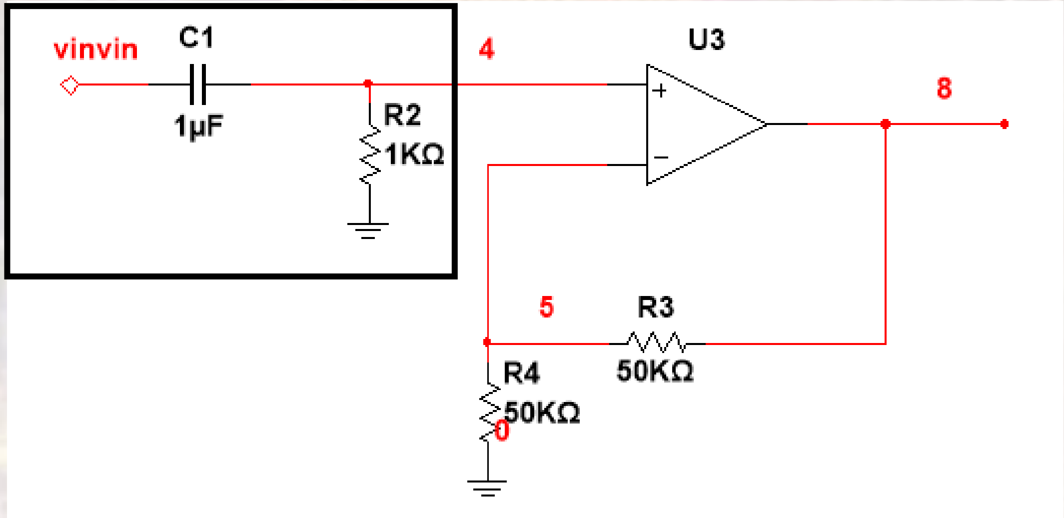
$$A = 1$$

$$A_v = \frac{A\left(\frac{f}{f_C}\right)}{\sqrt{1 + \left(\frac{f}{f_C}\right)^2}}$$

RC Active Filters

- First order – High Pass
  - Non-inverting
  - Selectable Gain

Passive Filter



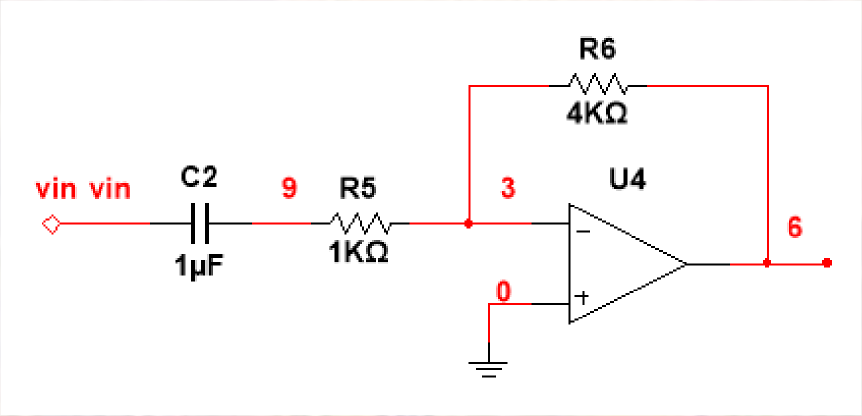
$$f_C = \frac{1}{2\pi RC}$$

$$A = 1 + \frac{R_F}{R_I}$$

$$A_v = \frac{A\left(\frac{f}{f_C}\right)}{\sqrt{1 + \left(\frac{f}{f_C}\right)^2}}$$

RC Active Filters

- First order – High Pass
  - Inverting
  - Selectable Gain



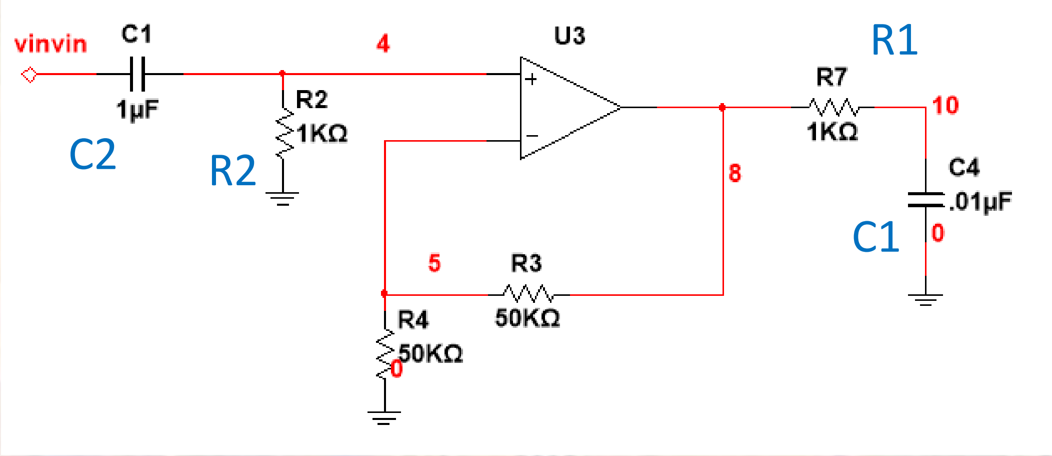
$$f_C = \frac{1}{2\pi RC}$$

$$A = -\frac{R_F}{R_I}$$

$$A_v = \frac{A\left(\frac{f}{f_C}\right)}{\sqrt{1 + \left(\frac{f}{f_C}\right)^2}}$$

RC Active Filters

- First order – Band Pass
  - Non-inverting
  - Selectable Gain
  - Wide passband



$$f_{CL} = \frac{1}{2\pi R2C2}$$

$$f_{CU} = \frac{1}{2\pi R1C1}$$

$$A = 1 + \frac{R_F}{R_I}$$

$$A_v = \frac{A\left(\frac{f}{f_{CH}}\right)}{\sqrt{1 + \left(\frac{f}{f_{CH}}\right)^2}} \frac{1}{\sqrt{1 + \left(\frac{f}{f_{CL}}\right)^2}}$$

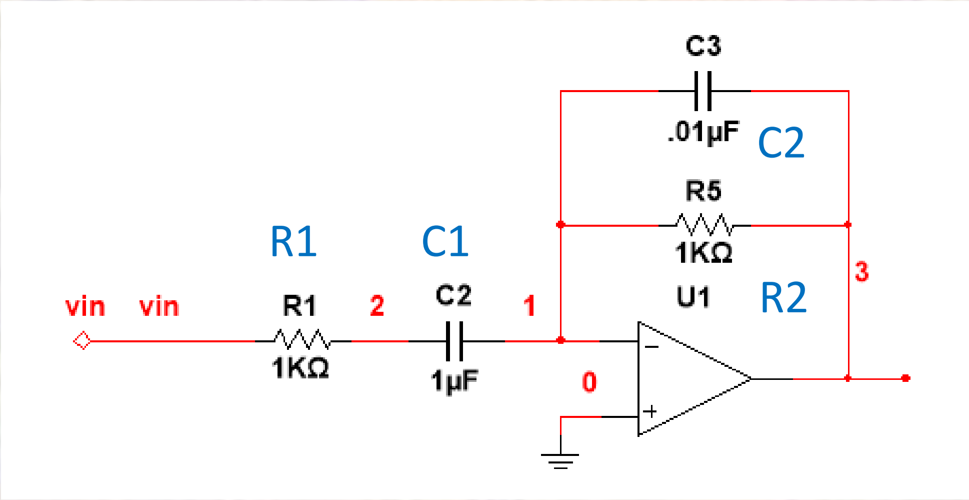
RC Active Filters

- First order – Band Pass
  - Inverting
  - Selectable Gain
  - Narrower passbands possible

$$f_{CL} = \frac{1}{2\pi R1C1}$$

$$f_{CU} = \frac{1}{2\pi R2C2}$$

$$A = -\frac{R_F}{R_I}$$



$$A_v{}^* = \frac{A\left(\frac{f}{f_{CH}}\right)}{\sqrt{1+\left(\frac{f}{f_{CH}}\right)^2}} \frac{1}{\sqrt{1+\left(\frac{f}{f_{CL}}\right)^2}}$$

* At high frequencies, the OpAmp internal capacitance limits the rolloff

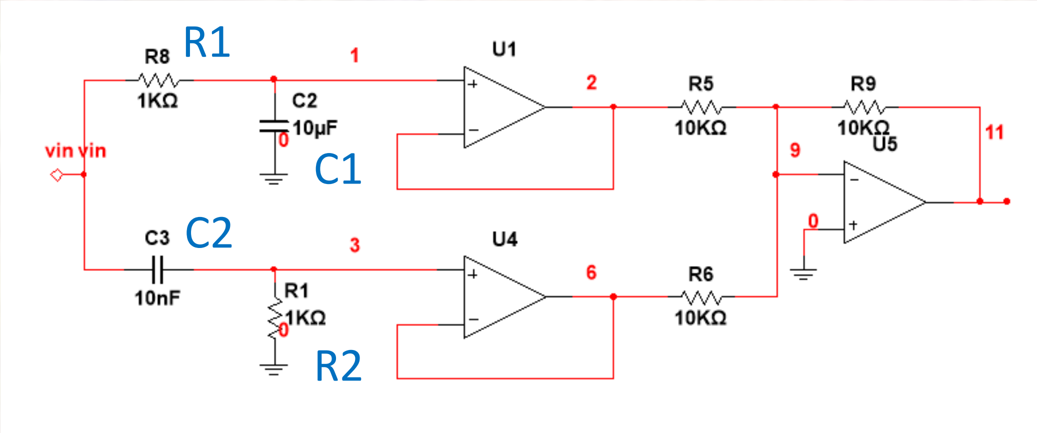
RC Active Filters

- First order – Band Stop
  - Non-inverting
  - Selectable Gain

$$f_{CL} = \frac{1}{2\pi R1C1}$$

$$f_{CU} = \frac{1}{2\pi R2C2}$$

$$A = -\frac{R_F}{R_I}$$



$$A_v^{\,*} = \frac{A\left(\frac{f}{f_{CH}}\right)}{\sqrt{1+\left(\frac{f}{f_{CH}}\right)^2}} \frac{1}{\sqrt{1+\left(\frac{f}{f_{CL}}\right)^2}}$$

* At high frequencies, the OpAmp internal capacitance limits the rolloff