Frequency Responses and Active Filter Circuits

- Compensation capacitors and parasitic capacitors will influence the frequency response
- Capacitors are also purposely added to create certain functions; e.g. integrators
- The most common use of energy storage elements in opamp circuits is for filtering
- Inductors are not as often used as capacitors because they are much bulkier and more difficult to integrate on an IC
- The order of the filter depends on the number of energy storage elements that are used
Ideal Filters

\[ H(j\omega) = \frac{V_{out}(j\omega)}{V_{in}(j\omega)} \]

\[ V_{in}(j\omega) \quad + \quad H(j\omega) \quad - \quad V_{out}(j\omega) \]

\[ |H(j\omega)| \]

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<th>Pass</th>
<th>Stop</th>
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<td>A</td>
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Ideal Filters

- We know that a first order filter will not look like an ideal model:

- Higher order filters will attempt to have sharper transitions at the cut-off frequencies, but sometimes at the expense of increased ripple.
First-Order Low Pass Filter

• Design for a 3dB cut-off frequency of $3000\pi$ (radians/second), a dc gain of 2, and an input impedance of at least $100k\Omega$
Will the frequency dependence of the open loop gain present a problem for this circuit using a 741 opamp?
First-Order Low Pass Filter

- SPICE results for magnitude using 741 opamp model
First-Order Low Pass Filter

- SPICE results for phase using 741 opamp model
First-Order High Pass Filter

- Calculate a transfer function to approximate the cut-off frequency

![Diagram of a first-order high pass filter](image-url)
First-Order High Pass Filter

- What is the high frequency gain for this circuit?
First-Order High Pass Filter

- SPICE results for magnitude using 741 opamp model
First-Order High Pass Filter

- Note that the low-pass nature of the opamp makes this high-pass filter a band-pass filter when using a 741-type opamp
First-Order High-Pass Filter

- SPICE results for phase using 741 opamp model
- Why the discontinuity?
Band Pass Filter

- Design for a mid-band frequency gain of 5 (volts/volt), and $f_L=500\text{Hz}$ and $f_H=5\text{kHz}$.
Band-Pass Filter
Band Pass Filter

- SPICE results for magnitude using 741 opamp model
Band-Pass Filter

- SPICE results for phase using 741 opamp model
Noninverting Opamp

• Most of the circuits that we’ve seen so far can also be designed in a non-inverting configuration too

![Noninverting Opamp Diagram]
Other Noninverting Configurations

- But sometimes they are a bit trickier to solve
- What is the transfer function of this circuit? How is it best evaluated?
Second-Order Low Pass Filter

- Design for a 3dB cut-off frequency of $3000\pi$ (radians/second), a dc gain of 2, and an input impedance of $100k\Omega$

Suggested configuration and element values from a book
Second-Order Low Pass Filter

- SPICE results for magnitude using 741 opamp model
- Input impedance “magnitude” as a function of frequency
Second-Order Low Pass Filter

- Input impedance “phase” as a function of frequency
Second-Order Low Pass Filter

- SPICE results for magnitude using 741 opamp model
- Fall-off is sharper for higher frequencies, but 3dB point is at 5.6kHz
Second-Order Low Pass Filter

- 3dB cut-off frequency is slightly off from 1.5kHz target
- What parameters do we change to lower it 3dB slightly?
Second-Order Low Pass Filter

- Design for a 3dB cut-off frequency of $3000\pi$ (radians/second), a dc gain of 2, and an input impedance of 100kΩ using values determined by pole analysis.
Second-Order Low Pass Filter

3dB is now at 1.5kHz