Application Report
SLOA093 – December 2001

Filter Design in Thirty Seconds

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ABSTRACT

Need a filter—fast? No theory, very little math—just working filter designs, and in a hurry? This is the right document.

Contents

Figures

1 Introduction

This document is intended for designers that do not have the time to check filter theory in old college textbooks—and try to translate transfer equations into something that can be put into production. This is like looking at the back of the textbook for the answer. Speaking of the back of the book—Appendix B contains a brief introduction to the filter circuits given here, and the limitations of this *quickie* approach to design.

To design a filter, four things must be known in advance:

- The power supplies available: positive / negative—or only positive (single supply)
- The frequencies that need to be passed, and those that need to be rejected.
- A transition frequency, the point at which the filter starts to work—or—a center frequency around which the filter is symmetrical.
- An initial capacitor value—pick one somewhere from 100 pF for high frequencies to 0.1 µF for low frequencies. If the resulting resistor values are too large or too small, pick another capacitor value.

Ready? Let's design the filter. Pick the filter type from one of the following 6 options that represents the frequencies to be passed (shaded area):

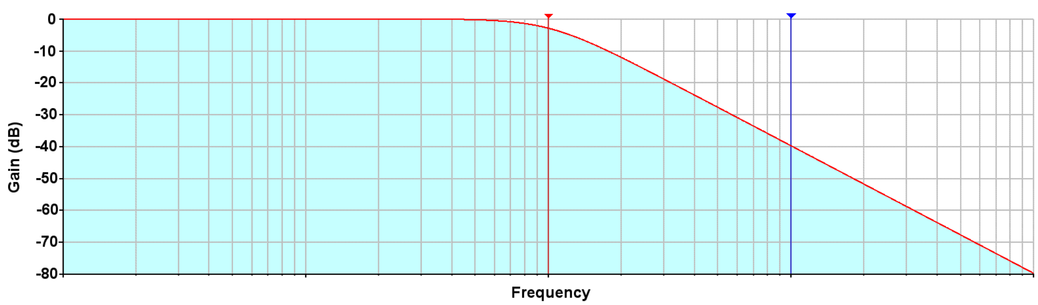

Figure 1. Low Pass Filter—Go to Section 2

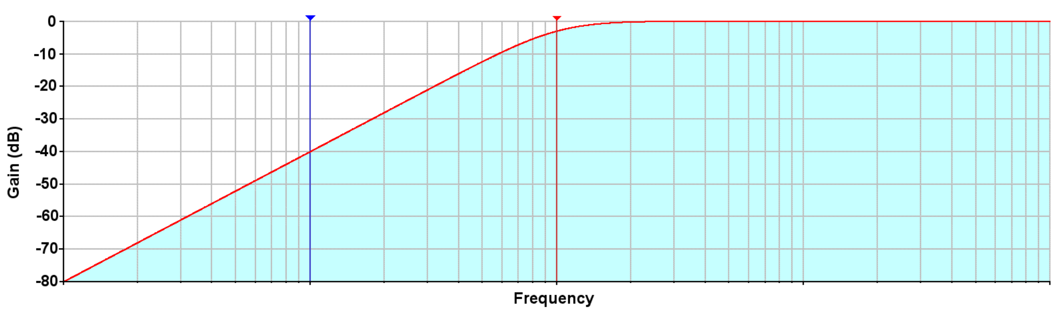

Figure 2. High Pass Filter—Go to Section 3

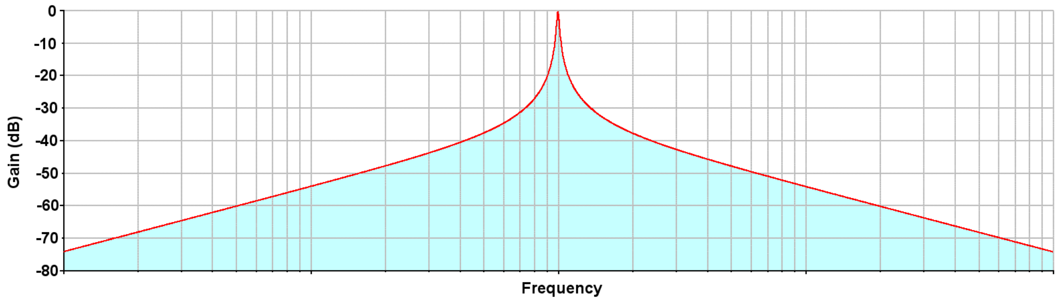

Figure 3. Narrow (Single Frequency) Band Pass—Go to Section 4

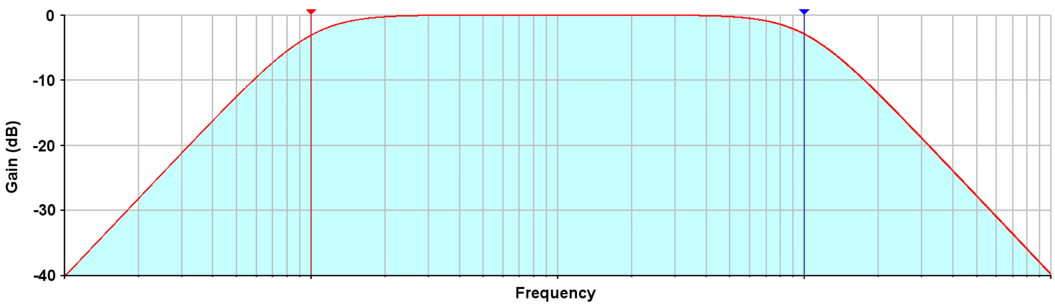

Figure 4. Wide Band Pass —Go to Section 5

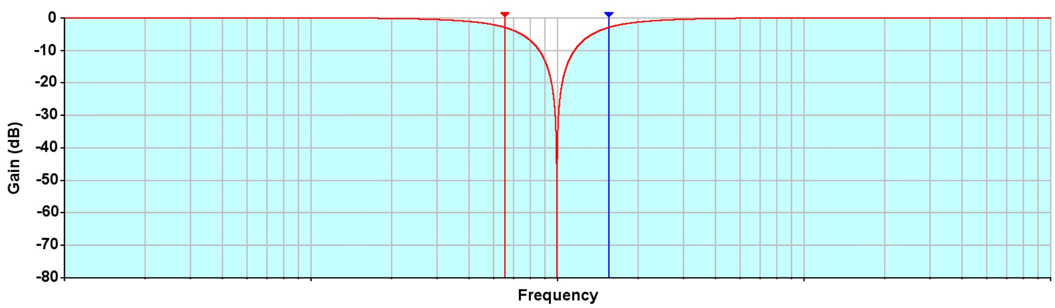

Figure 5. Notch Filter—Single Frequency Rejection

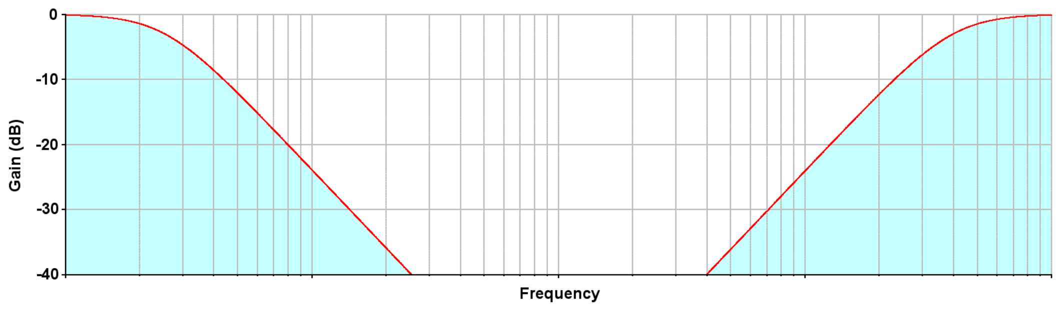

Figure 6. Band Reject Filter

2 Low Pass Filter

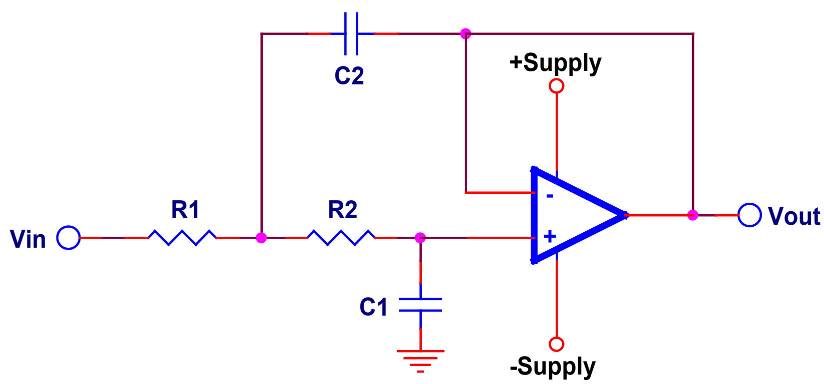

Figure 7. Low Pass Filter for ± Supplies

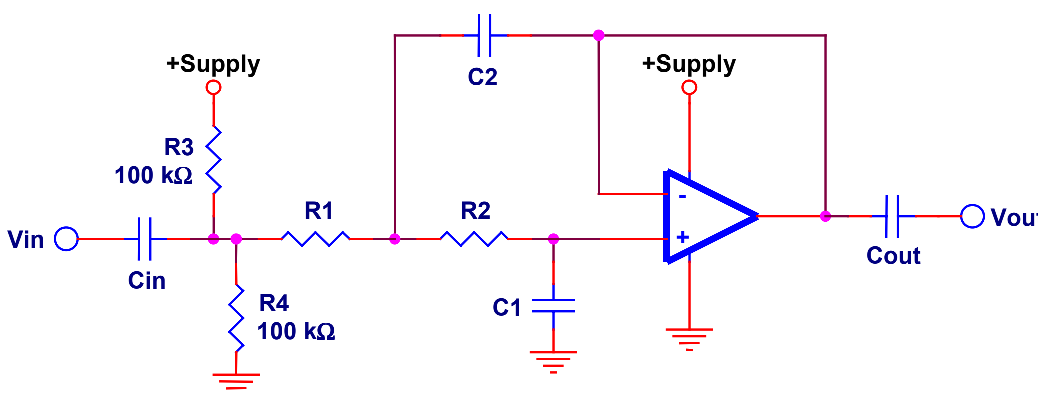

Figure 8. Low Pass Filter for a Single Supply

Design Procedure:

- Pick C1: ___________
- Calculate C2 = C1 * 2: ___________

- Calculate R1 and R2 = $\frac{1}{2\sqrt{2} * \pi * C1 * \text{Frequency}}$: ___________ (pick a standard value from Appendix A).

For the single supply case only:

- Calculate Cin = Cout = 100 to 1000 times C1 (not critical): ___________

DONE

3 High Pass Filter

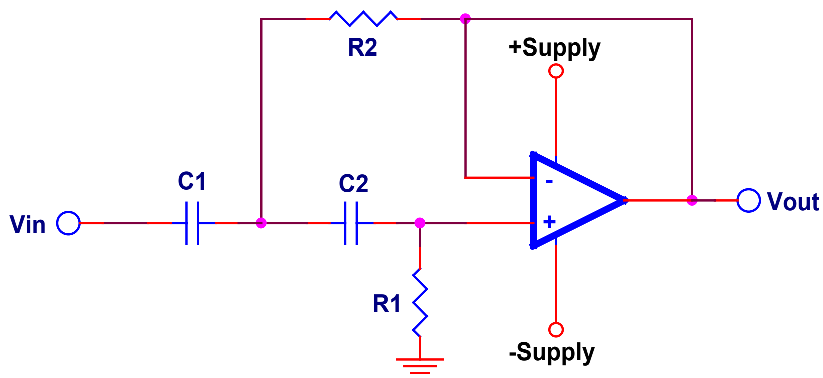

Figure 9. High Pass Filter for ± Supplies

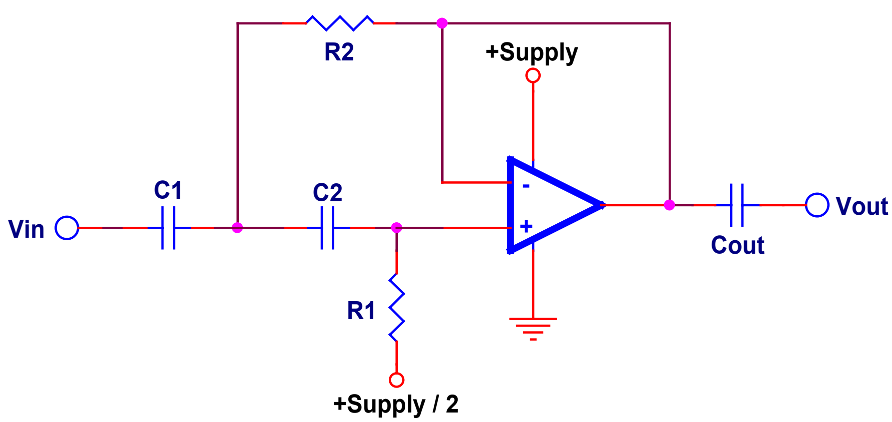

Figure 10. High Pass Filter for a Single Supply

Design Procedure:

- Pick C1 = C2: ___________
- Calculate R1: $\frac{1}{\sqrt{2} * \pi * C1 * \text{Frequency}}$: ___________ (pick a standard value from Appendix A).

- Calculate R2: $\dfrac{1}{2\sqrt{2} * \pi * C1 * \text{Frequency}}$: ___________ (pick a standard value from Appendix A).

For the single supply case only:

- Calculate Cout = 100 to 1000 times C1 (not critical): ___________

DONE

4 Narrow (Single Frequency) Band Pass Filter

NOTE: These circuits include a gain of 10 (20 dB) at the center frequency.

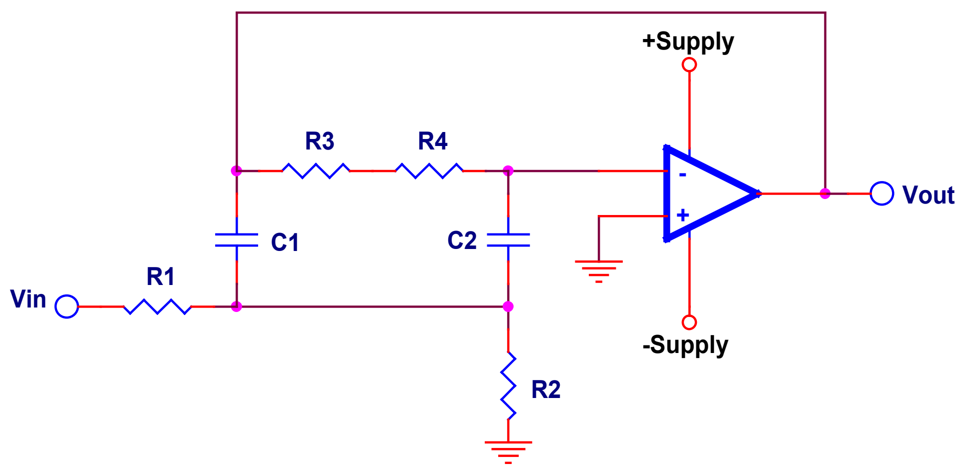

Figure 11. Narrow Band Pass Filter for ± Supplies

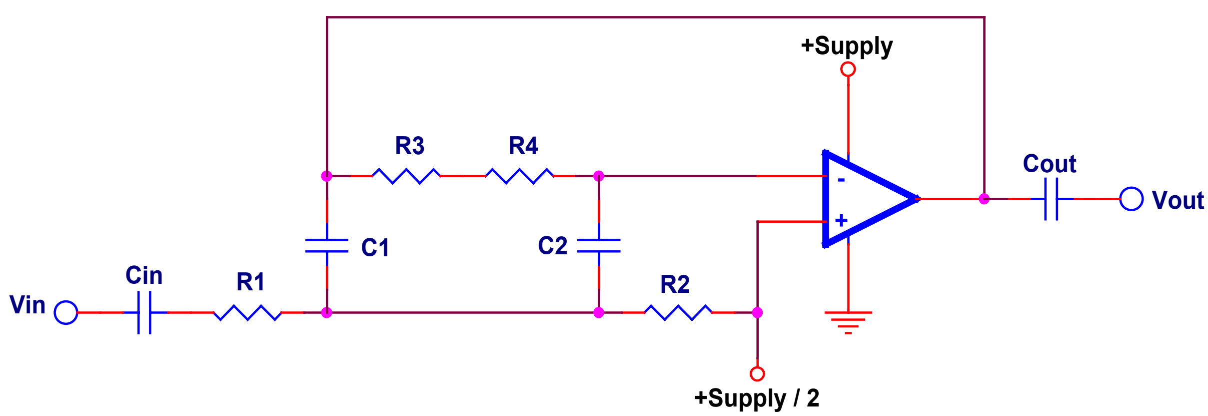

Figure 12. Narrow Band Pass Filter for a Single Supply

Design Procedure:

- Pick C1 = C2: ___________

- Calculate R1 = R4: $\frac{1}{2 * \pi * C1 * Frequency}$: ___________ (pick a standard value from Appendix A).
- Calculate R3 = 19 * R1
- Calculate R2 = $\frac{R1}{19}$

For the single supply case only:

- Calculate Cin = Cout = 100 to 1000 times C1 (not critical): ___________

DONE

5 Wide Band Pass Filter

NOTE: The start and ending frequencies of the band should be at least five times different.

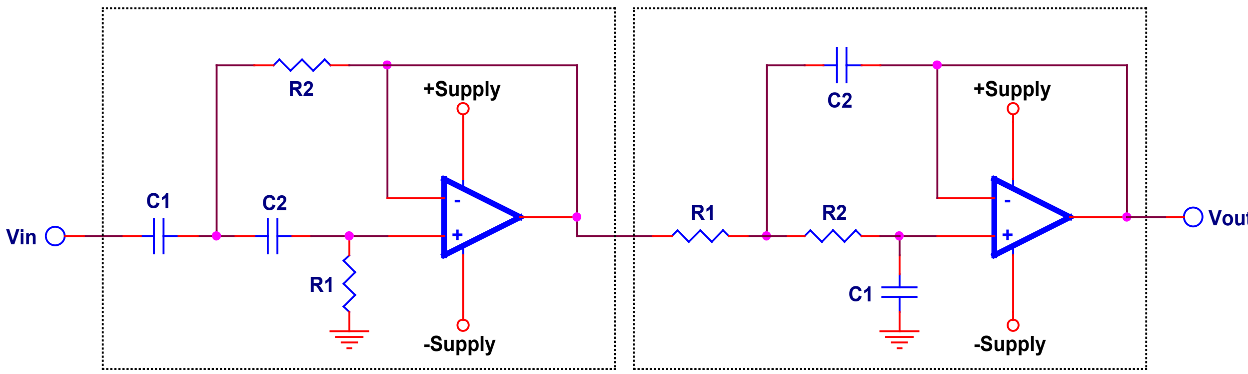

Figure 13. Wide Band Pass Filter for ± Supplies

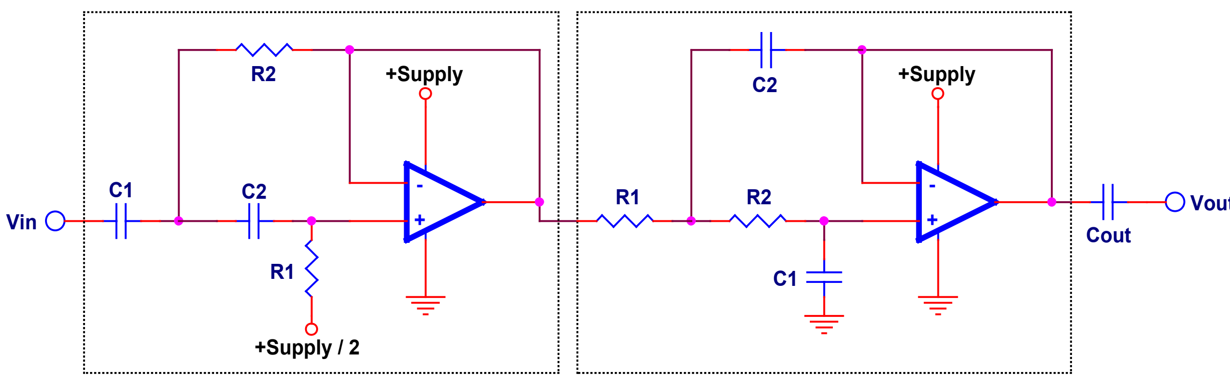

Figure 14. Wide Band Pass Filter for a Single Supply

Design Procedure:

- Go to Section 3, and design a high pass filter for the low end of the band.

- Go to Section 2, and design a low pass filter for the high end of the band.
- For the single supply case only:
- Calculate Cin = Cout = 100 to 1000 times C1 in the low pass filter section (not critical):

  ____

DONE

6 Notch (Single Frequency Rejection) Filter

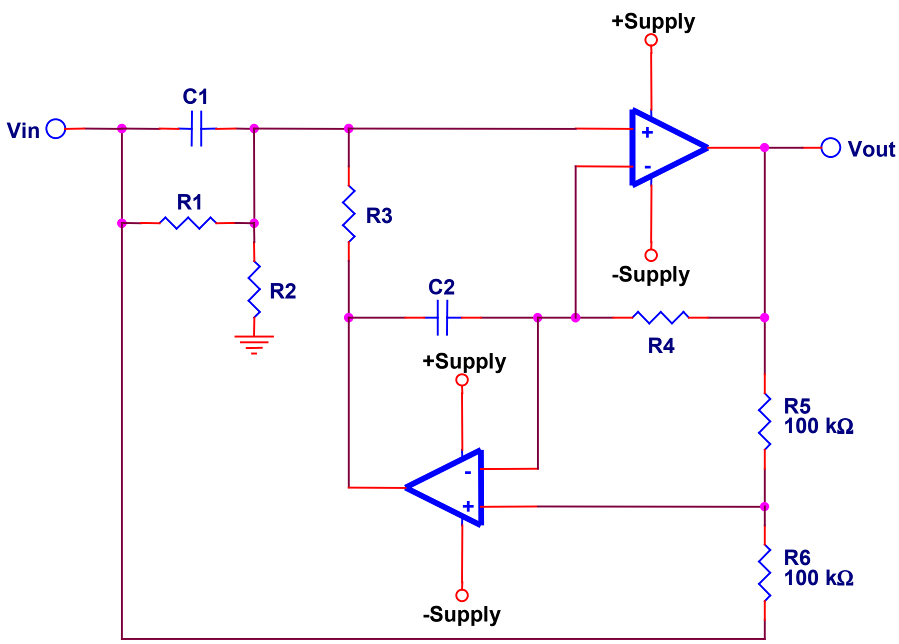

Figure 15. Narrow Band Pass Filter for ± Supplies

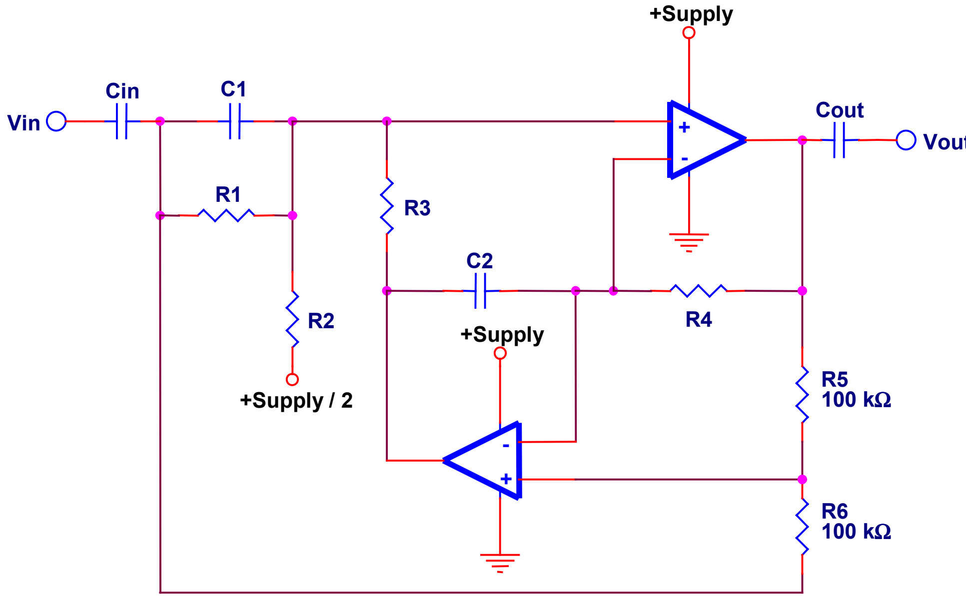

Figure 16. Narrow Band Pass Filter for a Single Supply

Design Procedure:

- Pick C1 = C2: ___________
- Calculate R3 = R4: $\frac{1}{2 * \pi * C1 * \text{Frequency}}$: ____________ (pick a standard value from Appendix A).
- Calculate R1 = R2 = 20 * R3
- For the single supply case only:
- Calculate Cin = Cout = 100 to 1000 times C1 (not critical): ___________

DONE

7 Band Reject Filter

NOTE: The start and ending frequencies of the band to be rejected should be at least fifty times different.

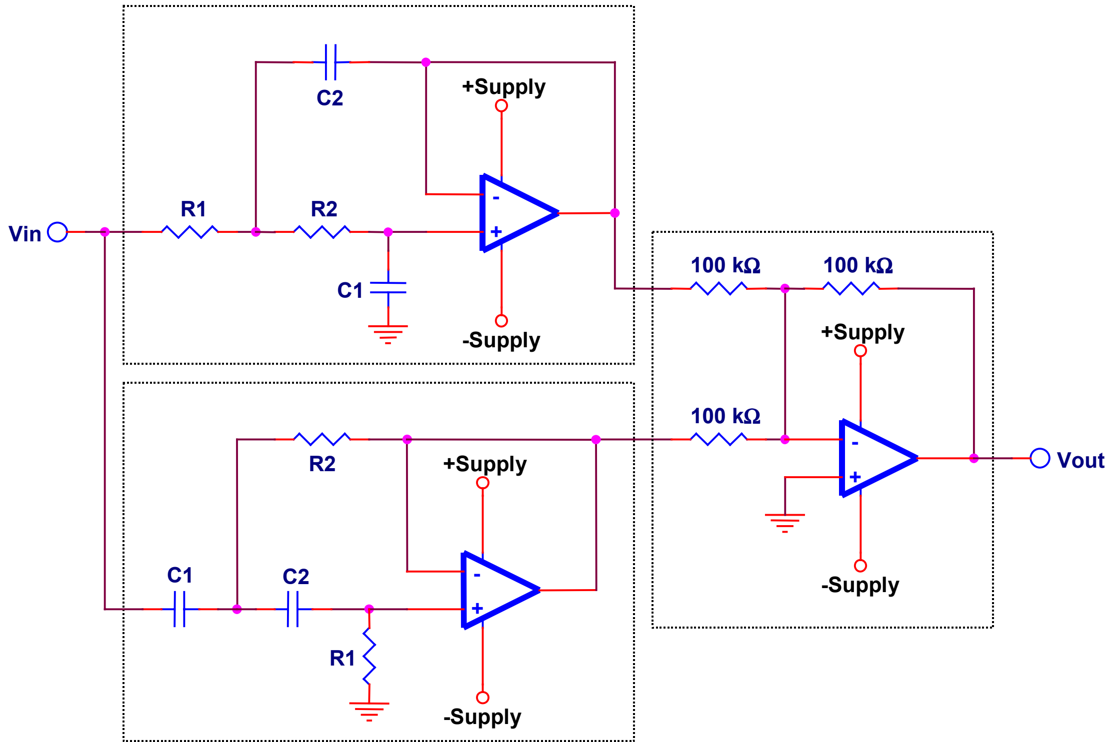

Figure 17. Band Reject Filter for ± Supplies

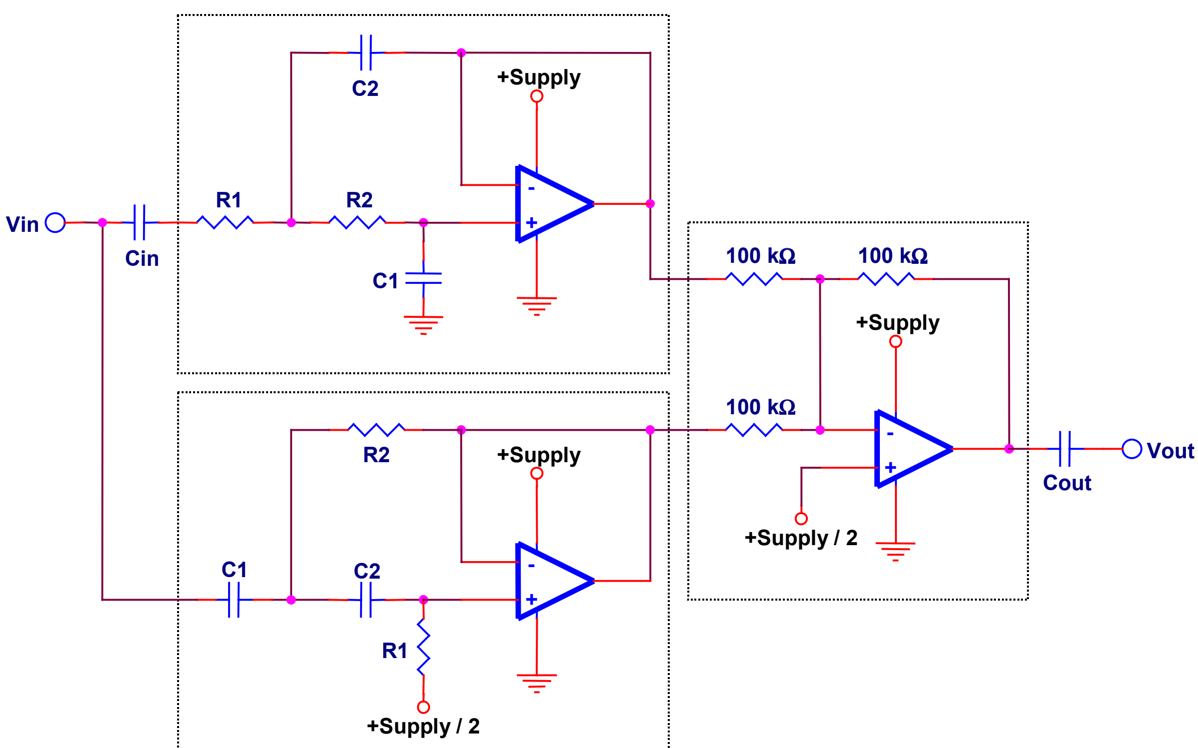

Figure 18. Band Reject Filter for a Single Supply

Design Procedure:

- Go to Section 3, and design a high pass filter for the low end of the upper band.
- Go to Section 2, and design a low pass filter for the high end of the lower band.
- For the single supply case only:
- Calculate Cin = Cout = 100 to 1000 times C1 in the low pass filter section (not critical): ___________

DONE

Appendix A—Standard Resistor and Capacitor Values

E-12 Resistor / Capacitor Values

1.0, 1.2, 1.5, 1.8, 2.2, 2.7, 3.3, 3.9, 4.7, 5.6, 6.8, and 8.2; multiplied by the decade value.

E-24 Resistor / Capacitor Values

1.0, 1.1, 1.2, 1.3, 1.5, 1.6, 1.8, 2.0, 2.2, 2.4, 2.7, 3.0, 3.3, 3.6, 3.9, 4.3, 4.7, 5.1, 5.6, 6.2, 6.8, 7.5, 8.2, and 9.1; multiplied by the decade value.

E-96 Resistor Values

1.00, 1.02, 1.05, 1.07, 1.10, 1.13, 1.15, 1.18, 1.21, 1.24, 1.27, 1.30, 1.33, 1.37, 1.40, 1.43, 1.47, 1.50, 1.54, 1.58, 1.62, 1.65, 1.69, 1.74, 1.78, 1.82, 1.87, 1.91, 1.96, 2.00, 2.05, 2.10, 2.15, 2.21, 2.26, 2.32, 2.37, 2.43, 2.49, 2.55, 2.61, 2.67, 2.74, 2.80, 2.87, 2.94, 3.01, 3.09, 3.16, 3,24, 3.32, 3.40, 3,48, 3.57, 3.65, 3.74, 3.83, 3.92, 4.02, 4.12, 4.22, 4,32, 4.42, 4,53, 4.64, 4.75, 4.87, 4.99, 5.11, 5.23, 5.36, 5.49, 5.62, 5.76, 5.90, 6.04, 6.19, 6.34, 6.49, 6.65, 6.81, 6.98, 7.15, 7.32, 7.50, 7.68, 7.87, 8.06, 8.25, 8.45, 8.66, 8.87, 9.09, 9.31, 9.53, 9.76; multiplied by the decade value.

Appendix B—Filter Notes (for the More Technically Minded)

Low Pass Filter

The filter selected is a unity gain Sallen-Key filter, with a Butterworth response characteristic. Numerous articles and books describe this topology.

High Pass Filter

The filter selected is a unity gain Sallen-Key filter, with a Butterworth response characteristic. Numerous articles and books describe this topology.

Narrow Band Pass Filter

The filter selected is a modified Deliyannis filter. The Q is set at 10, which also locks the gain at 10, as the two are related by the expression:

$$\frac{R3 + R4}{2 \cdot R1} = Q = Gain$$

A higher Q was not selected, because the op amp gain bandwidth product can be easily reached, even with a gain of 20 dB. At least 40 dB of headroom should be allowed above the center frequency peak. The op amp slew rate should also be sufficient to allow the waveform at the center frequency to swing to the amplitude required.

Wide Band Pass Filter

This is nothing more than cascaded Sallen-Key high pass and low pass filters. The high pass comes first, so energy from it that stretches to infinite frequency will be low passed.

Notch Filter

This is the Fliege Filter topology, set to a Q of 10. The Q can be adjusted independently from the center frequency by changing R1 and R2. Q is related to the center frequency set resistor by the following:

$$R1 = R2 = 2 * Q * R3$$

The Fliege filter topology has a fixed gain of 1.

The only real possibility of a problem is the common mode range of the bottom amplifier in the single supply case.

Band Reject Filter

This is nothing more than summed Sallen-Key high pass and low pass filters. They cannot be cascaded, because their responses do not overlap as in the wide band pass filter case.

IMPORTANT NOTICE

Mailing Address:

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