Typical Applications

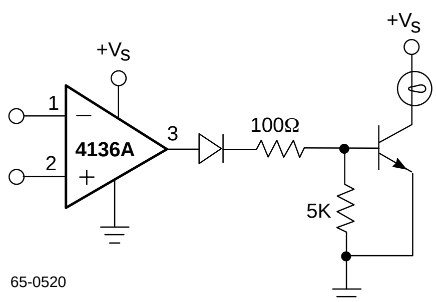


Figure 21. Lamp Driver

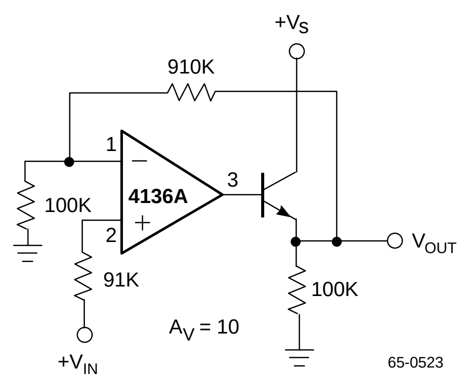


Figure 22. Power Amplifier

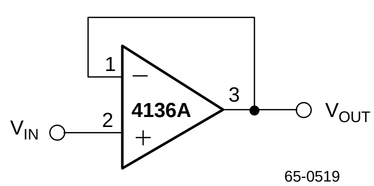


Figure 23. Voltage Follower

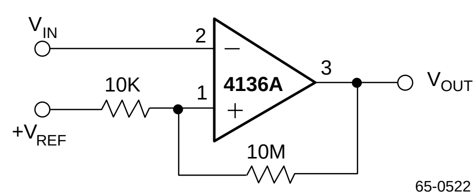


Figure 24. Comparator with Hysteresis

Typical Applications (continued)

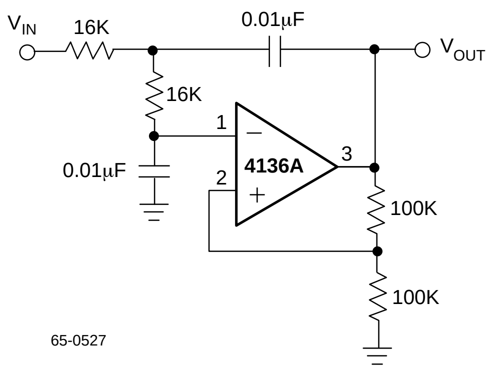


Figure 25. DC Coupled 1kHz Lowpass Active Filter

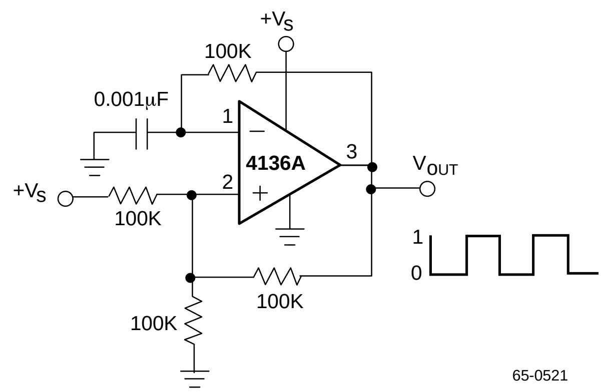


Figure 26. Squarewave Oscillator

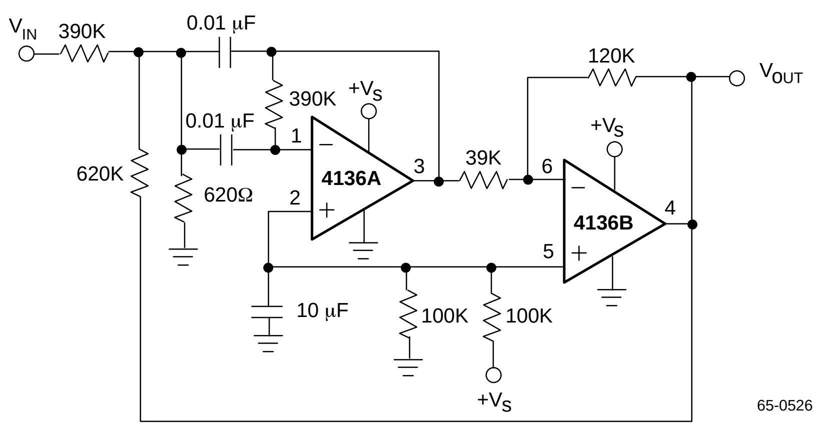


Figure 27. 1kHz Bandpass Active Filter

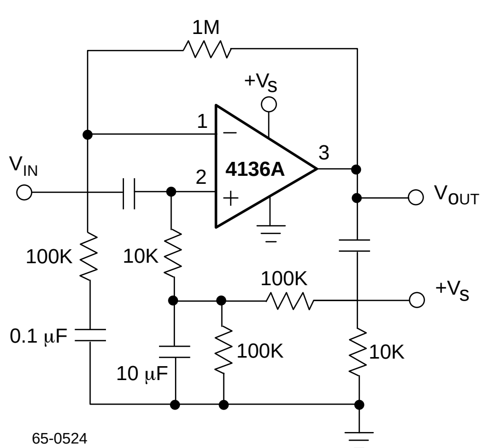


Figure 28. AC Coupled Non-Inverting Amplifier

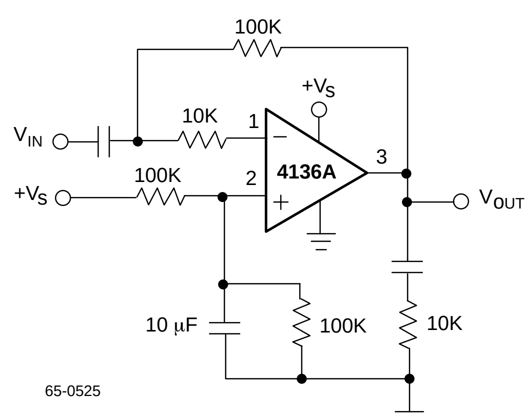
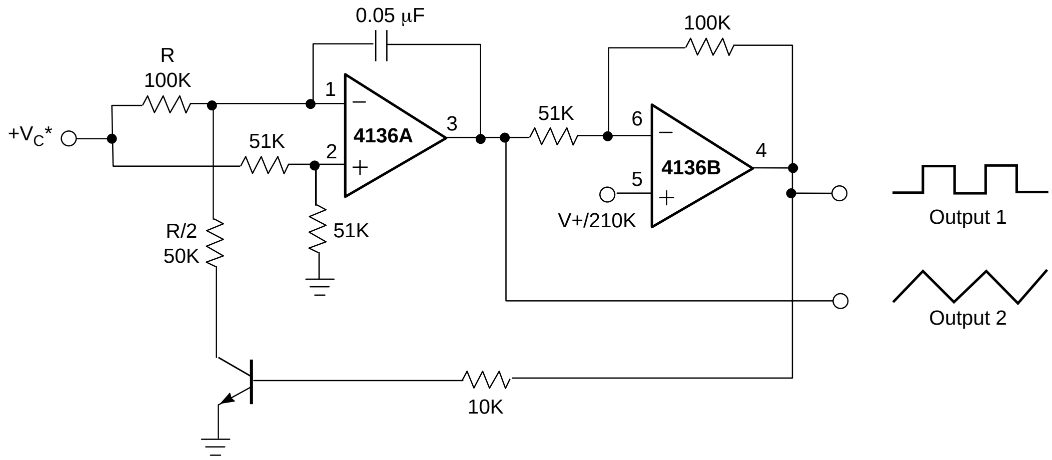


Figure 29. AC Coupled Inverting Amplifier

Typical Applications (continued)



* Wide control voltage range: 0V < V_C < 2(+V_S-1.5V)

Figure 30. Voltage Control Oscillator (VCO)

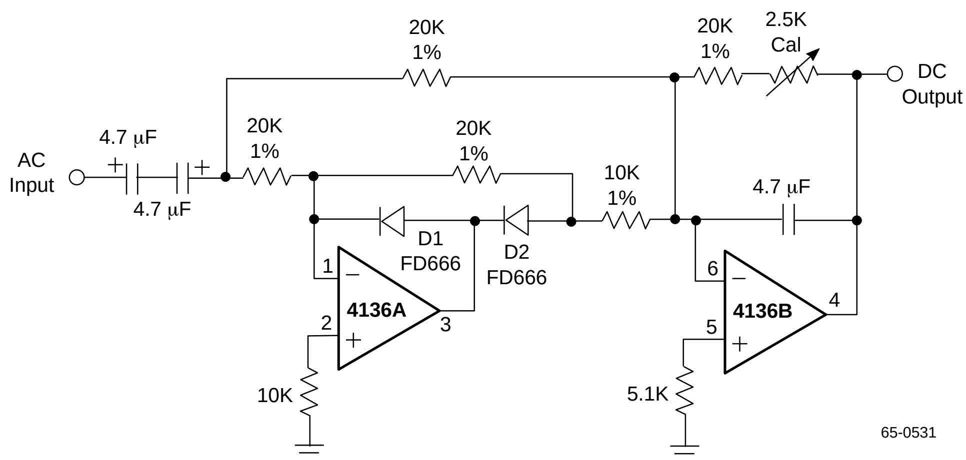


Figure 31. Full-Wave Rectifier and Averaging Filter

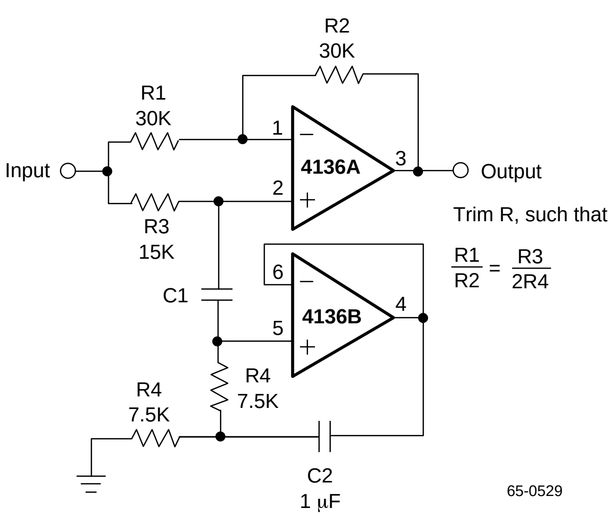


Figure 32. Notch Filter Using the RC4136 as a Gyrator

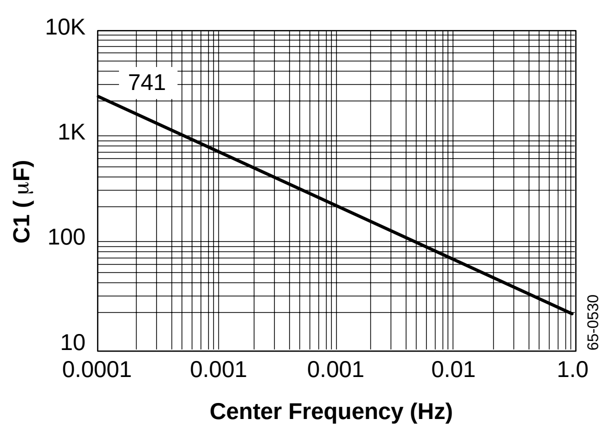


Figure 33. Notch Frequency vs. C1

Typical Applications (continued)

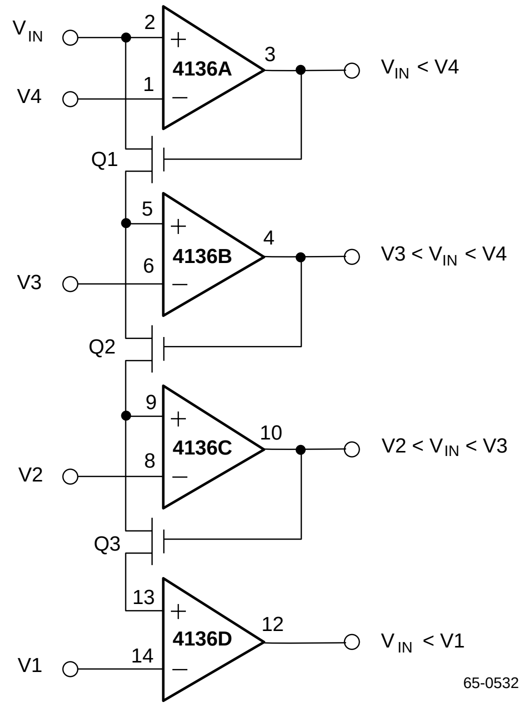
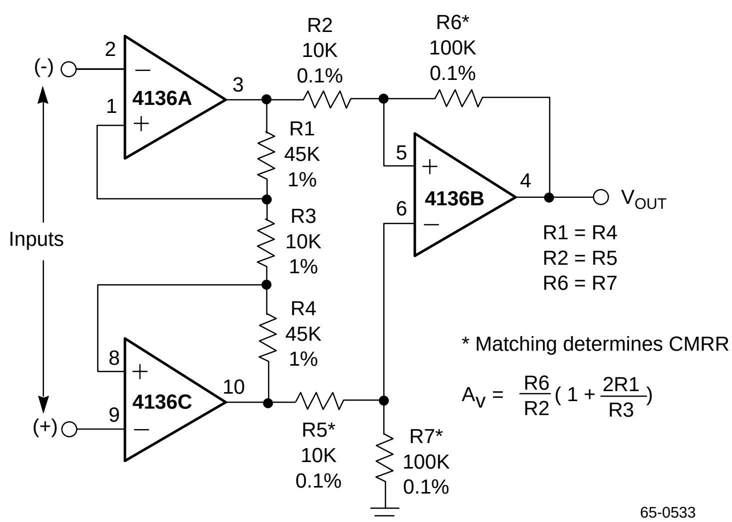


Figure 34. Multiple Aperture Window Discriminator



$$A_V = \frac{R6}{R2}\left(1 + \frac{2R1}{R3}\right)$$

Figure 35. Differential Input Instrumentation Amplifier with High Common Mode Rejection

Typical Applications (continued)

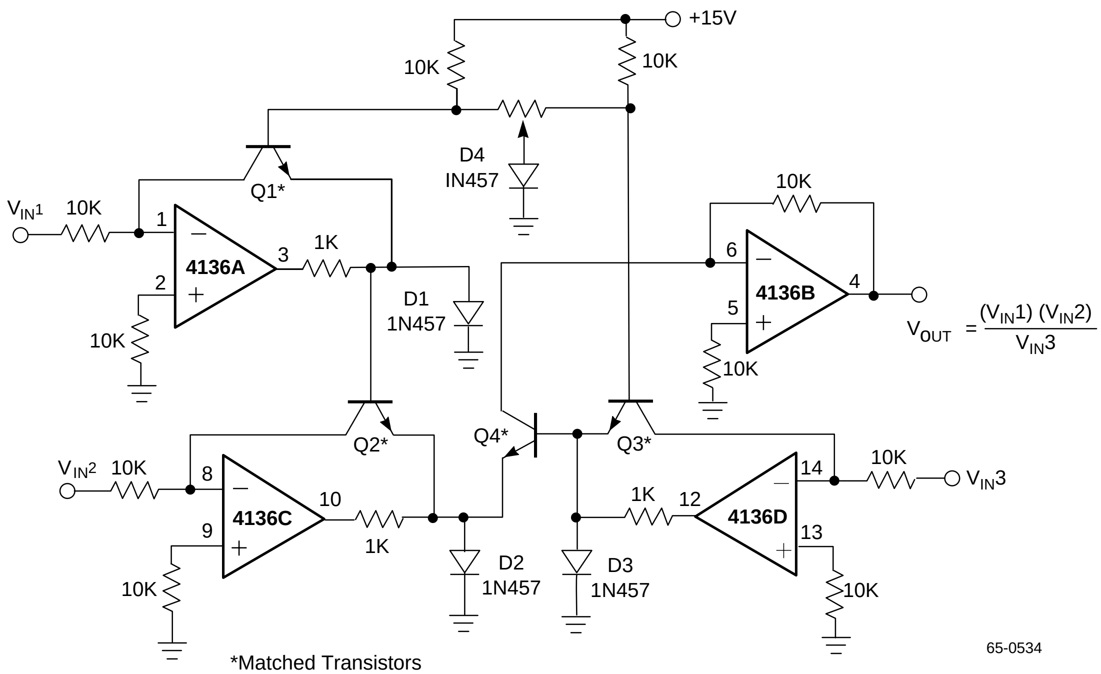


Figure 36. Analog Multiplier/Divider

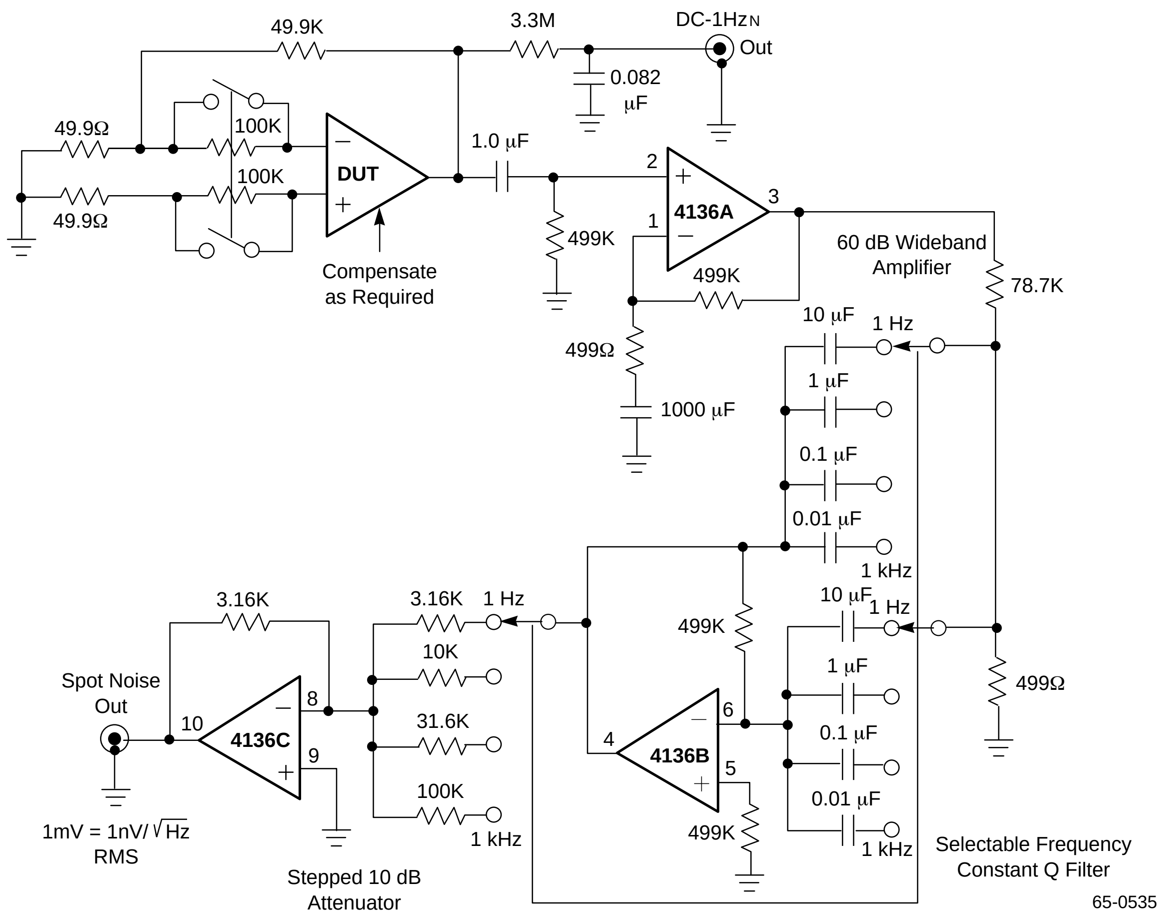
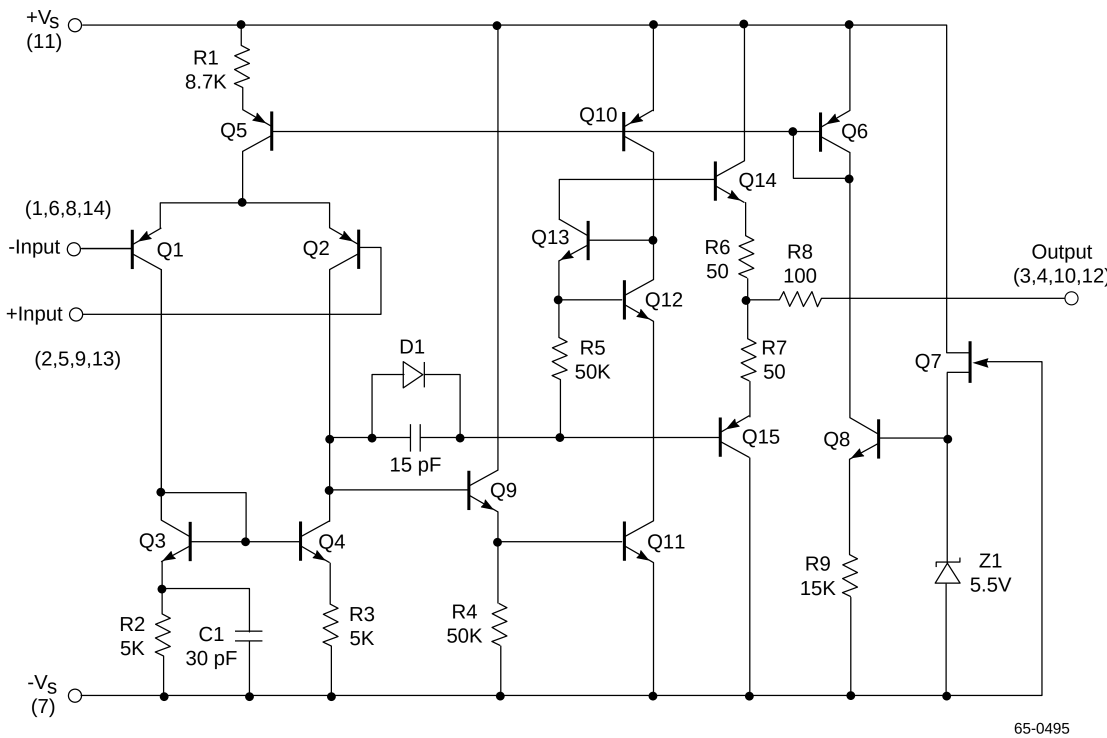


Figure 37. Spot Noise Measurement Test Circuit

Simplified Schematic Diagram



Applications Discussion

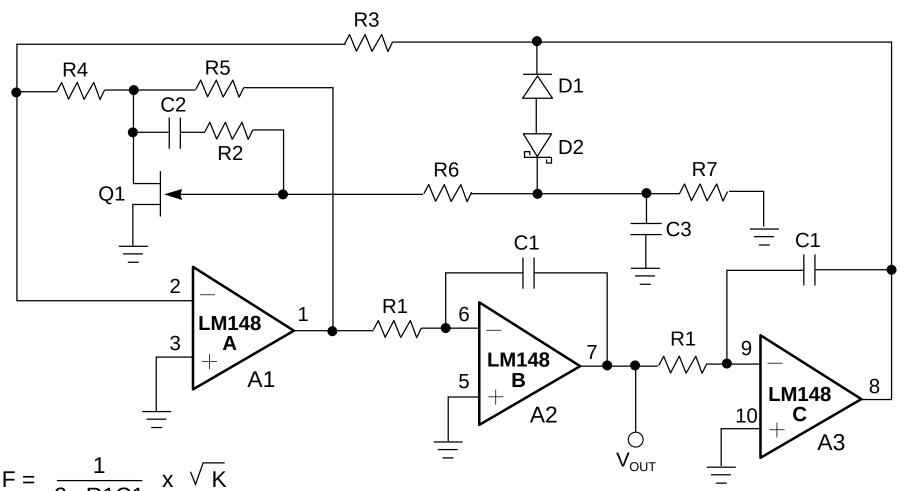
The LM148 low power quad operational amplifier exhibits performance comparable to the popular 741. Substitution can therefore be made with no change in circuit behavior.

The input characteristics of these devices allow differential voltages which exceed the supplies. Output phase will be correct as long as one of the inputs is within the operating common mode range. If both exceed the negative limit, the output will latch positive. Current limiting resistors should be used on the inputs in case voltages become excessive.

When capacitive loading becomes much greater than 100pF, a resistor should be placed between the output and feedback connection in order to reduce phase shift.

The LM148 is short circuit protected to ground and supplies continuously when only one of the four amplifiers is shorted. If multiple shorts occur simultaneously, the unit can be destroyed due to excessive power dissipation.

To assure stability and to minimize pickup, feedback resistors should be placed close to the input to maximize the feedback pole frequency (a function of input to ground capacitance). A good rule of thumb is that the feedback pole frequency should be 6 times the operating -3.0B frequency. If less, a lead capacitor should be placed between the output and input.



$$F = \frac{1}{2\pi R1C1} \times \sqrt{K}$$

$$K = \frac{R4R5}{R3}\left(\frac{1}{R_{DS}} + \frac{1}{R4} + \frac{1}{R5}\right)$$

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$$R_{DS} \cong \frac{R_{ON}}{\left(1 - \frac{V_{GS}}{V_P}\right)^{1/2}}$$

F_{MAX} = 5.0 KHz, THD$\leq$ 0.03%

R1 = 100K pot., C1 = 0.0047µF, C2 = 0.01µF, C3 = 0.1µF, R2 = R6 = R7 = 1M, R3 = 5.1K, R4 = 12Ω.

R5 = 240Ω, Q1 = NS5102, D1 = 1N914, D2 = 3.6V avalanche diode (ex. LM103), V_S = ±15V

A simpler version with some distortion degradation at high frequencies can be made by using A1 as a simple inverting amplifier, and by putting back to back zeners in feedback loop of A3.

Figure 21. One Decade Low Distortion Sinewave Generator

Applications Discussion (continued)

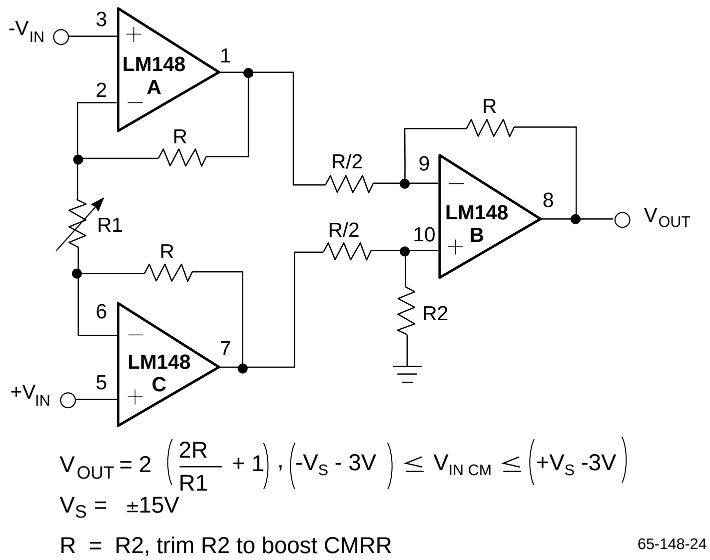


Figure 22. Low Cost Instrumentation Amplifier

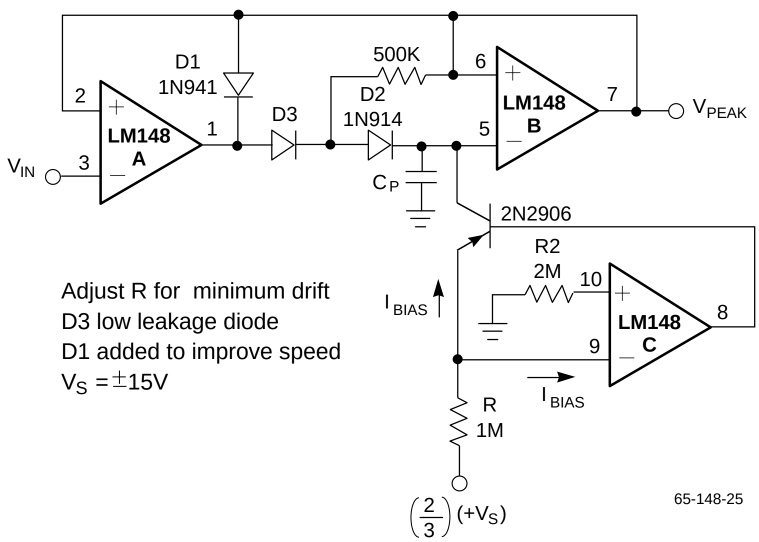
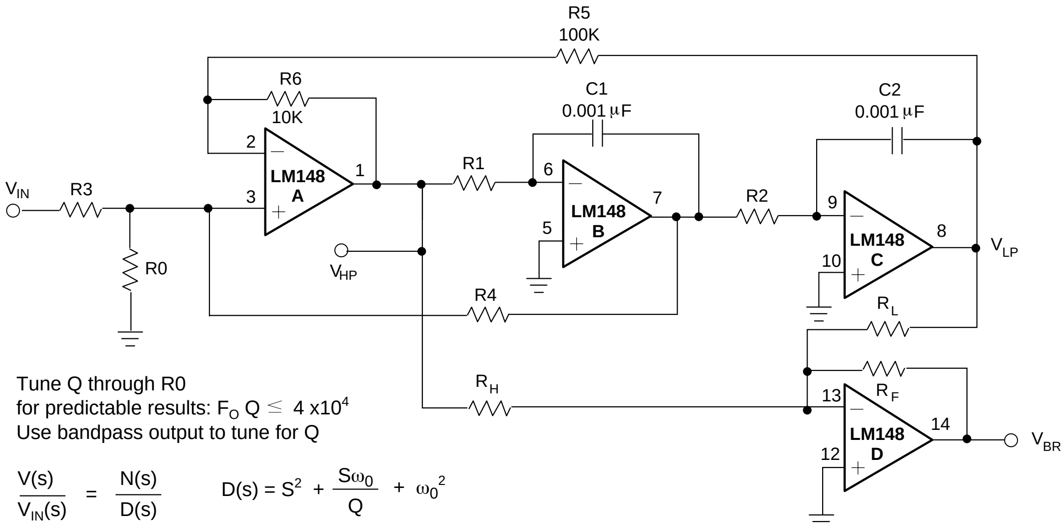


Figure 23. Low Voltage Peak Detector with Bias Current Compensation

Applications Discussion (continued)



Tune Q through R0
for predictable results: $F_O\,Q \leq 4 \times 10^4$
Use bandpass output to tune for Q

$$\frac{V(s)}{V_{IN}(s)} = \frac{N(s)}{D(s)} \qquad D(s) = S^2 + \frac{S\omega_0}{Q} + \omega_0^2$$

$$N_{HP(S)} = S^2 H_{OHP},\; N_{BP(S)} = \frac{-S\omega_0 H_{OBP}}{Q} \qquad N_{LP} = \omega_0^2 H_{OLP}$$

$$F_O = \frac{1}{2\pi}\sqrt{\frac{R6}{R5}}\sqrt{\frac{1}{t1t2}}\;, \qquad t1 = R1C1,\; Q = \left(\frac{1 + R4\,|\,R3 + R4\,|\,R0}{1 + R6\,|\,R5}\right)\left(\frac{R6}{R5}\;\frac{t1}{t2}\right)^{1/2}$$

$$F_{NOTCH} = \frac{1}{2\pi}\left(\frac{R_H}{R_L\, t1\, t2}\right)^{1/2},\; H_{OHP} = \frac{1 + R6\,|\,R5}{1 + R3\,|\,R0 + R3\,|\,R4},\; H_{OBP} = \frac{1 + R4\,|\,R3 + R4\,|\,R0}{1 + R3\,|\,R0 + R3\,|\,R4}$$

$$H_{OLP} = \frac{1 + R5\,|\,R6}{1 + R3\,|\,R0 + R3\,|\,R4}$$

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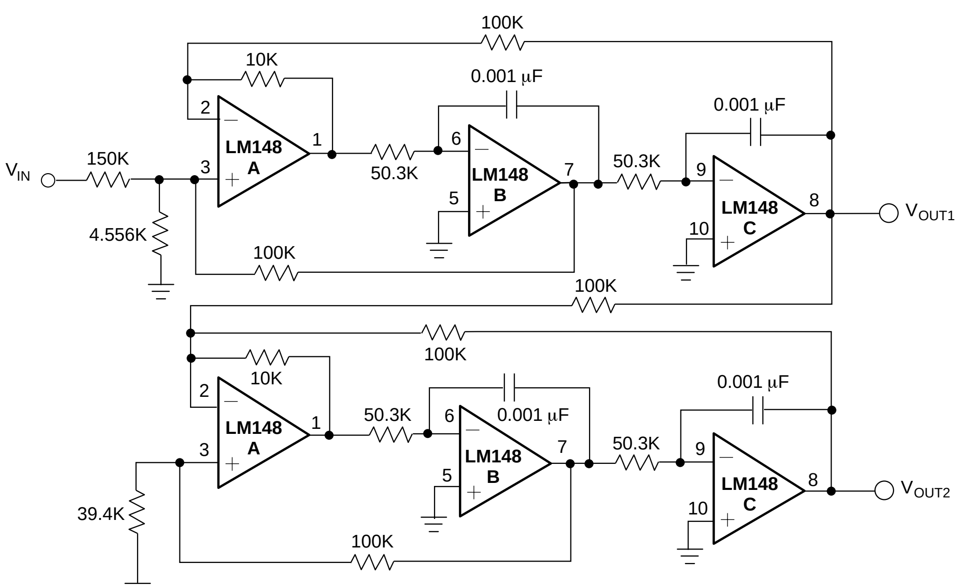
Figure 24. Universal State-Space Filter



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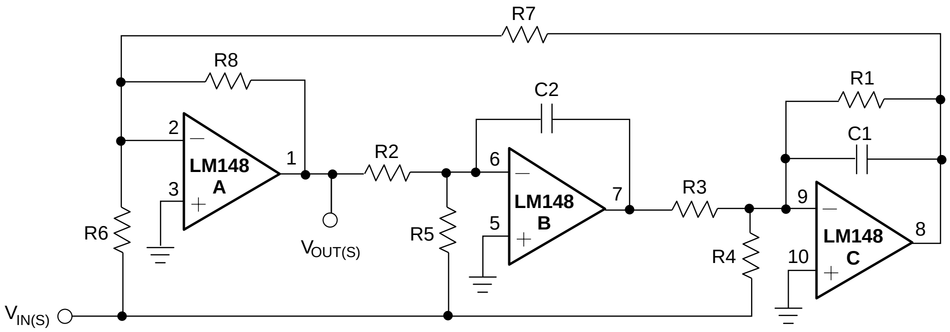
Use general equations, and tune each section separately.
Q_{1st} Section = 0.541, Q_{2nd} Section = 1.306.
The response should have 0 dB peaking.

Figure 25. 1 KHz 4-Pole Butterworth Filter

Applications Discussion (continued)



$$Q = \sqrt{\frac{R8}{R7}}\left(\frac{R1C1}{\sqrt{R3C2R2C1}}\right),\ F_O = \frac{1}{2\pi}\sqrt{\frac{R8}{R7}}\left(\frac{1}{\sqrt{R2R3C1C2}}\right),\ F_{NOTCH} = \frac{1}{2\pi}\sqrt{\frac{R6}{R3R5R7C1C2}}$$

Necessary condition for notch : $\frac{1}{R6} = \frac{R1}{R4R7}$

Examples: F_{NOTCH} = 3 kHz, Q = 5, R1 = 270K, R2 = R3 = 20K, R4 = 27K, R5 = 20K, R6 = R8 = 10K, R7 = 100K.
C1 = C2 = 0.001 μF.
Better noise performance than the state-space approach.

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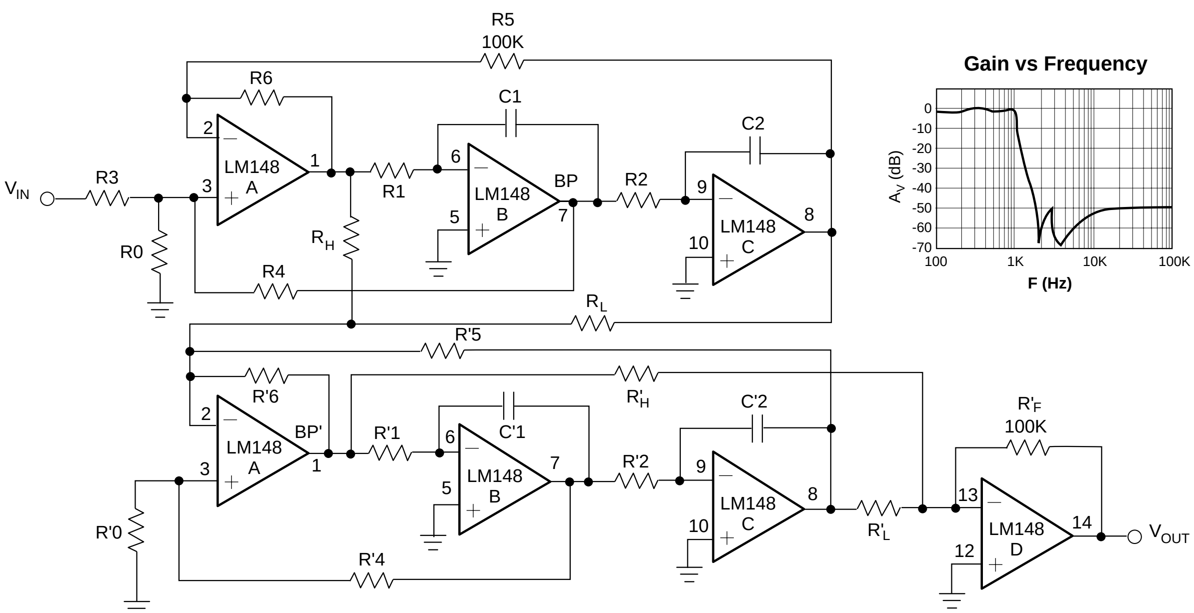
Figure 26. 3 Amplifier Bi-Quad Notch Filter



F_C = 1 kHz, F_S = 2 kHz, F_P = 0.543. F_Z = 2.14, Q = 0.841, F'_P = 0.987, F'_Z = 4.92.
Q' = 4.403 normalized to ripple BW.

$$F_P = \frac{1}{2\pi}\sqrt{\frac{R6}{R5}}\left(\frac{1}{t}\right),\ F_Z = \frac{1}{2\pi}\sqrt{\frac{R_H}{R_L}}\left(\frac{1}{t}\right),\ Q = \frac{1 + R4/R3 + R4/R0}{1 + R6/R5} \times \sqrt{\frac{R6}{R5}},\ Q' = \sqrt{\frac{R'6}{R'5}} \times \frac{1 + R'4/R'0}{1 + R'6/R'5 + R'6/R_P}$$

$$R_P = \frac{R_H R_L}{R_H + R_L}$$

Use the B'P outputs to tune Q, Q', tune the 2 sections separately.
R1 = R2 = 92.6K, R3 = R4 = R5 = 100K, R6 = 10K, R0 = 107.8K, R_L = 100K, R_H = 155.1K,
R'1 = R'2 = 50.9K, R'4 = R'5 = 100K, R'6 = 10K, R'0 = 5.78K, R'_L = 100K, R'_H = 248.12K, R'_F = 100K.

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All capacitors are 0.001μF.

Figure 27. 4th Order 1 KHz Elliptic Filter (4 Poles, 4 Zeros)