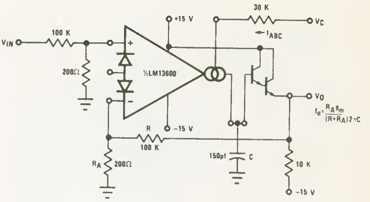


Fig. 22-1. Voltage controlled low-pass filter (NS).

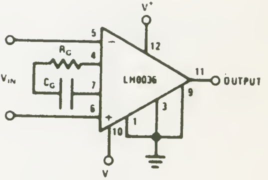


Fig. 22-2. High pass filter (NS).

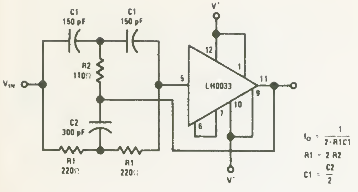


Fig. 22-3. 4.5-MHz notch filter (NS).

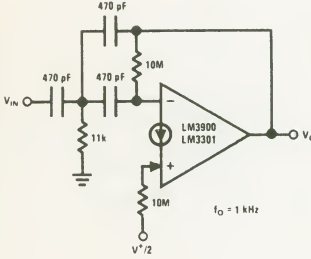


Fig. 22-4. High-pass active filter (NS).

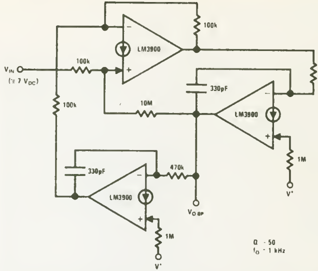


Fig. 22-5. Bi-quad active filter (second degree state-variable network) (NS).

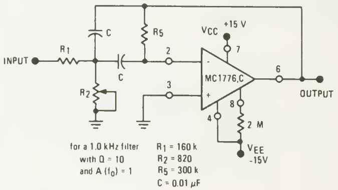
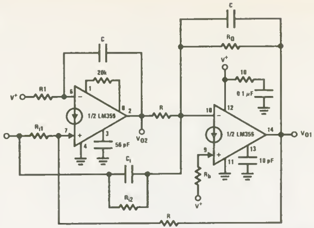


Fig. 22-6. Multiple feedback bandpass 1-kHz filter (M).



DC BIASING EQUATIONS FOR $V_{O1(DC)} \cong V_{O2(DC)} \cong V^+/2$

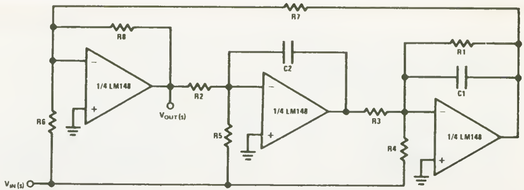
Type I	$\frac{2V_{IN(DC)}}{V^+(R_{i2})} + \frac{1}{R} + \frac{1}{R_Q} = \frac{2}{R_b}$; $R1 = 2R$
Type II	$\frac{1}{R} + \frac{1}{R_Q} = \frac{2}{R_b}$; $R1 = 2R$
Type III	$\frac{1}{R} + \frac{1}{R_Q} = \frac{2}{R_b}$; $\frac{1}{R1} = \frac{V_{IN(DC)}}{V^+(R_{i1})} + \frac{1}{2R}$

- The high speed of the LM359 allows the center frequency Q_o product of the filter to be : $f_o \times Q_o < 5$ MHz
- The above filter(s) maintains performance over wide temperature range
- One half of LM359 acts as a true non-inverting integrator so only 2 amplifiers (instead of 3 or 4) are needed for the biquad filter structure

ANALYSIS AND DESIGN EQUATIONS

Type	V_{O1}	V_{O2}	C_i	R_{i2}	R_{i1}	f_o	Q_o	f_Z (notch)	$H_{o(LP)}$	$H_{o(BP)}$	$H_{o(HP)}$	$H_{o(BR)}$
I	BP	LP	O	R_{i2}	∞	$\frac{1}{2\pi RC}$	R_Q/R	—	R/R_{i2}	R_Q/R_{i2}	—	—
II	HP	BP	C_i	∞	∞	$\frac{1}{2\pi RC}$	R_Q/R	—	—	$R_Q C_i/RC$	C_i/C	—
III	Notch/ BR	—	C_i	∞	R_{i1}	$\frac{1}{2\pi RC}$	R_Q/R	$\frac{1}{2\pi\sqrt{RR_iCC_i}}$	—	—	—	$H_o\big\|_{f\to\infty} = C_i/C$; $H_o\big\|_{f\to 0} = R/R_i$

Fig. 22-7. High-performance 2-amplifier bi-quad filter(s) (NS).

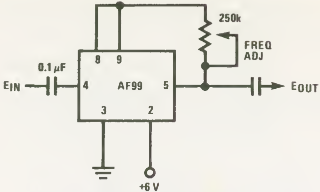


$$Q = \sqrt{\frac{R8}{R7}} \times \frac{R1C1}{\sqrt{R3C2R2C1}}, \quad f_o = \frac{1}{2\pi}\sqrt{\frac{R8}{R7}} \times \frac{1}{\sqrt{R2R3C1C2}}, \quad f_{NOTCH} = \frac{1}{2\pi}\sqrt{\frac{R6}{R3R5R7C1C2}}$$

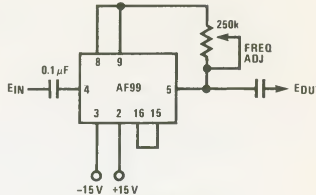
Necessary condition for notch: $\frac{1}{R6} = \frac{R1}{R4R7}$

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

Fig. 22-8. Three-amplifier bi-quad notch filter (NS).



80 Hz TO 130 Hz TUNABLE BANDPASS FILTER
BANDWIDTH = 2.5 Hz, SINGLE SUPPLY



125 Hz TO 270 Hz TUNABLE BANDPASS FILTER
BANDWIDTH = 5 Hz, DUAL SUPPLIES

Fig. 22-9. Bandpass filters (NS).

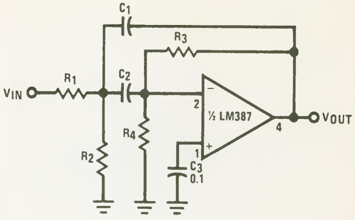


Fig. 22-10. LM387 bandpass active filter (NS).

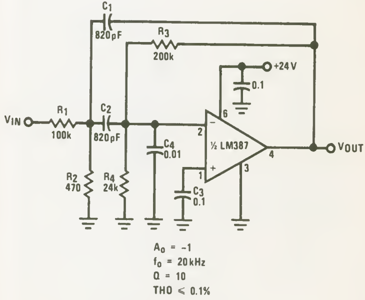
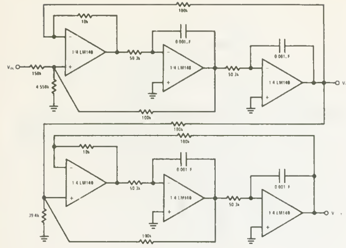
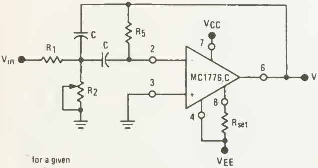


Fig. 22-11. 20 kHz bandpass active filter (NS).



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

Fig. 22-12. A 1 kHz 4 pole butterworth (NS).



for a given
f_0 = center frequency
$A(f_0)$ = Gain at center frequency
Q = quality factor

Choose a value for C, then $R2 = \frac{R1 R5}{4Q^2 R1 - R5}$

$R_5 = \frac{Q}{\pi f_0 C}$

$R1 = \frac{R5}{2A(f_0)}$

To obtain less than 10% error from the operational amplifier

$\frac{Q_0 f_0}{GBW} \leq 0.1$

where f_0 and GBW are expressed in Hz. GBW is available from Figure 6 as a function of Set Current, I_{set}

Fig. 22-13. Multiple feedback bandpass filter (M).