FAST-RESPONSE (SETTLING) LOW-PASS FILTER

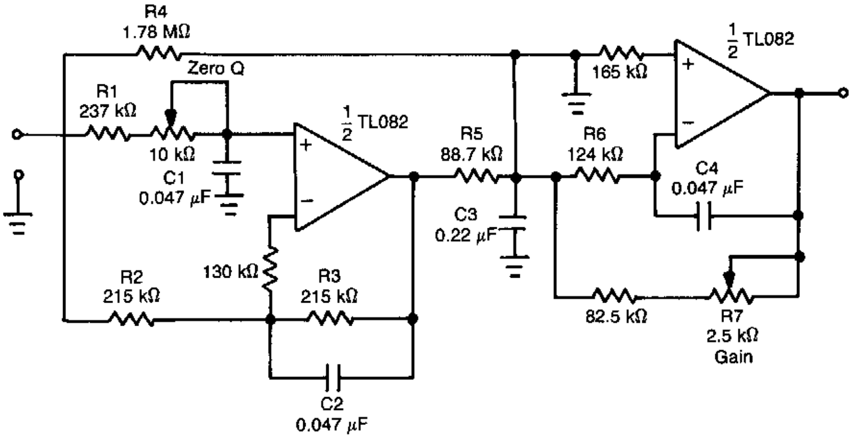


Fig. 30-1(a)

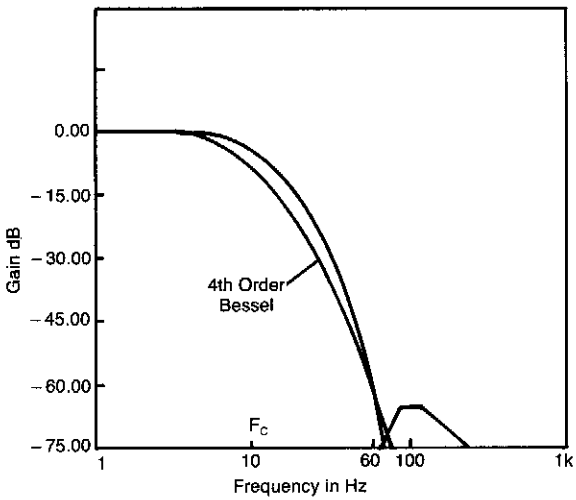


Fig. 30-1(b)

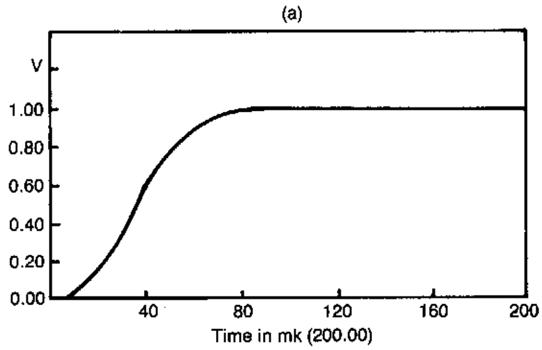


Fig. 30-1(c)

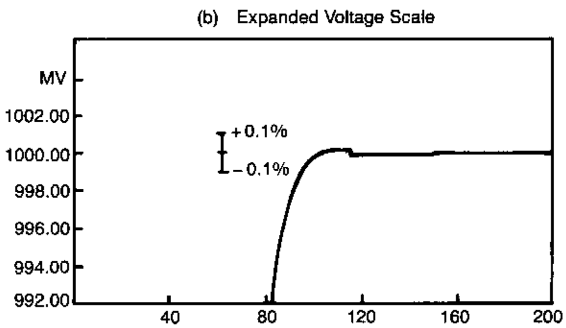


Fig. 30-1(d)

By introducing an extra transmission zero to the stopband of a low-pass filter, a sharp roll-off characteristic can be obtained. The filter design example of Fig. 30-1(a) shows that the time-domain performance of the low-pass section can also be improved. Figure 30-1(b) shows the attenuation characteristic of the proposed circuit. Position of the transmission zero is determined by the passive components around the first op amp. It was chosen to obtain 60 dB of rejection at 60 Hz.

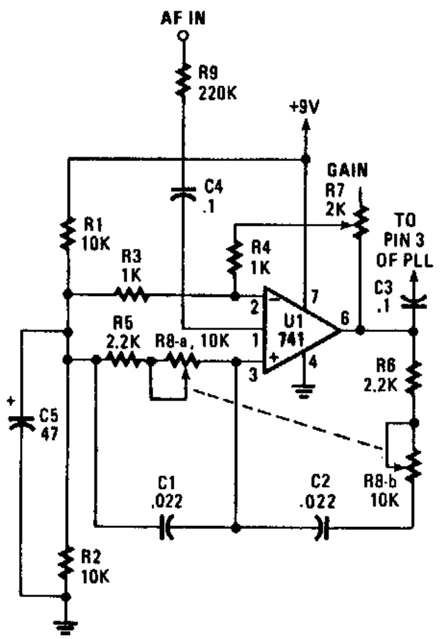
A suitable fourth-order Bessel filter has the frequency response, as shown by the dashed line. Its response to a step input is characterized by settling time to 0.1% of $1.8 \div F_C = 180$ ms.

Figure 30-1(c) and 30-1(d) represent the step response for the filter of Fig. 30-1(a) in both normal and expanded voltage scales. As you can see, settling time to 0.1% is below 100 ms; overshoot and ringing stay below 0.03%.

This quite significant speed and accuracy improvement can be a major factor, particularly for low-frequency applications. Averaging filter for low-frequency linear or true rms ac-to-dc converters is an example. Some anti-aliasing applications can also be considered.

For best results, resistance ratios $R_4 \div R_5 = 20$, $R_6 \div R_5 = 1.4$, and capacitance ratios $C_3 \div C_2 = C_3 \div C_4 = 4.7$ should be kept up for any selected F_C.

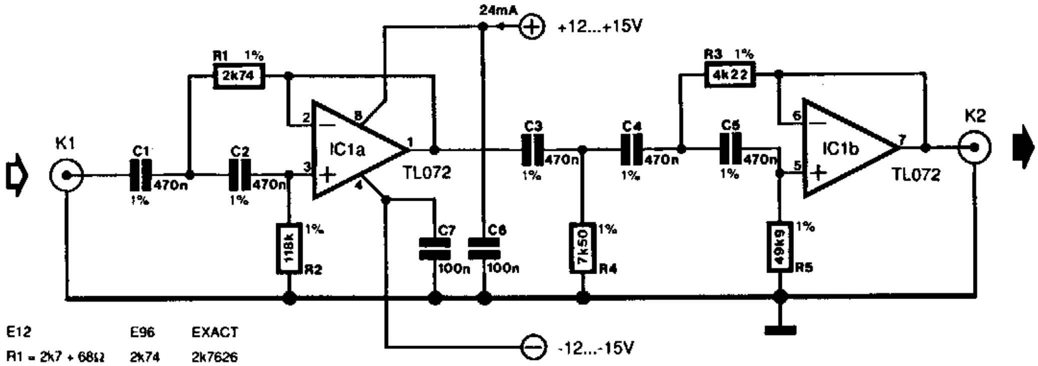
TUNABLE AUDIO FILTER



POPULAR ELECTRONICS *Fig. 30-2*

This circuit uses a Wien Bridge and variable negative feedback. R7 controls the gain and R8A and R8B controls the tuned frequency.

TURNTABLE RUMBLE FILTER



E12	E96	EXACT
R1 = 2k7 + 68Ω	2k74	2k7626
R2 = 120k	118k	119k05
R3 = 3k9 + 330Ω	4k22	4k2314
R4 = 6k8 + 680Ω	7k50	7k4648
R5 = 47k + 2k2	49k9	49k475

ELEKTOR ELECTRONICS *Fig. 30-3*

Many record players unfortunately exhibit two undesired side effects: rumble (noise caused by the motor and the turntable) and other low-frequency spurious signals. The active high-pass Chebyshev filter presented here was designed to suppress those noises. The filter has a 0.1-dB ripple characteristic and a cut-off point of 18 Hz.

The choice of a Chebyshev filter might not seem optimum for audio purposes, but because of its 0.1-dB ripple in the pass band it behaves very much like a Butterworth type. Its advantage is that the response has steeper skirts (which are calculated curves). Frequencies below 10 Hz are attenuated by more than 35 dB. The phase behavior in the pass band shows a gradual shift so that its effect on the reproduced sound is inaudible.

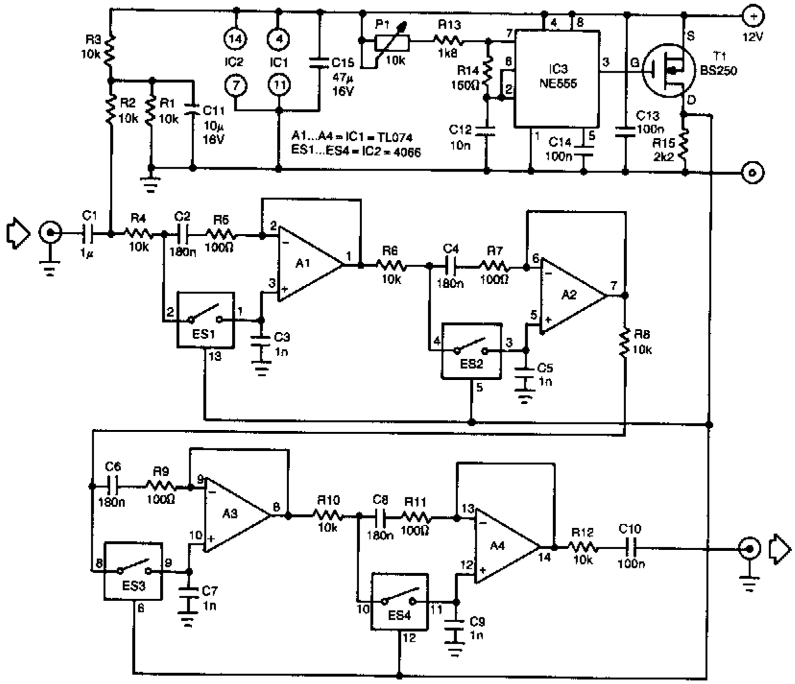
If the filter is used in a stereo installation, the characteristics of both filters must be identical or nearly so. Phase differences between channels can be heard—perhaps not so much at lower frequencies, but certainly in the mid ranges. To ensure identity and also to obtain the desired characteristics, capacitors C1 through C5 must be selected carefully. It does not matter much whether their value is 467 or 473 pF; this difference only causes a slight shift of the cut-off point. However, they must be identical within that 1% tolerance. For symmetry of channels, the capacitors can be paired and then used in either channel at the corresponding position.

The diagram shows theoretical values for the resistors: their practical values are given in the table. The prototype was constructed with 5% metal-film types from the E12 series and these were used without sorting. Their tolerance was perfectly acceptable in practice.

The current drawn by the circuit is purely that through the op amp and it amounts to about 4 mA. The high cut-off point is also determined by the op amp and it lies at about 3 MHz.

The only problem that cannot be foreseen is a possible coupling capacitor in the signal source. That component will be in series with C1 and this might adversely affect the frequency response. However, if its value is greater than 47 μF, it will have little if any effect; if it is below that value, it is best removed; C1 will assume its function.

TUNABLE BANDPASS FILTER



ELEKTOR ELECTRONICS

Fig. 30-4

One of the difficulties in the design of higher-order tunable bandpass filters is achieving correct tracking of the variable resistors in the RC networks. The use of switched capacitor networks can obviate that difficulty, as is shown in this filter.

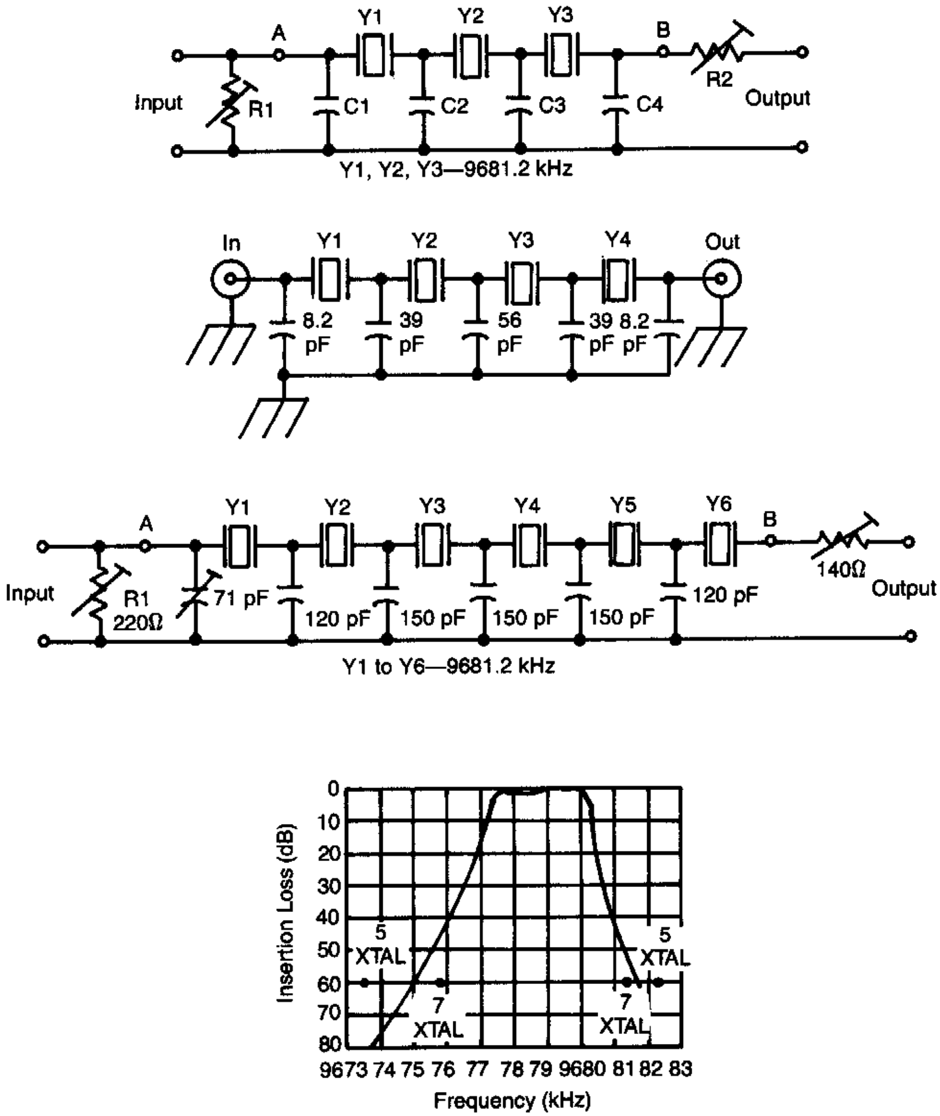
The filter can be divided roughly into two stages: an oscillator that controls the electronic switches and the four phase-shift networks that provide the filtering proper. The oscillator, based on a 555, generates a pulsating signal whose frequency is adjustable over a wide range: the duty factor varies from 1:10 to 100:1.

Electronic switches ES1 through ES4 form the variable resistors whose value is dependent on the frequency of the digital signal. The operation of these switches is fairly simple. When they are closed, their resistance is about 60 Ω; when they are open, it is virtually infinitely high. If a switch is closed for, say, 25% of the time, its average resistance is therefore 240 Ω. Varying the open:closed ratio of each switch varies the equivalent average resistance. The switching rate of the switches must be much greater than the highest audio frequency to prevent audible interference between the audio and the clock signals.

The input signal causes a given direct voltage across C1, so the op amp can be operated in a quasisymmetric manner, in spite of the single supply voltage. The direct voltage is removed from the output signal by capacitor C10.

The fourth-order filter in the diagram can be used over the entire audio range and it has an amplification of about 40, although this depends to some extent on the clock frequency. The bandwidth depends mainly on the set frequency. The circuit draws a current of not more than 15 mA.

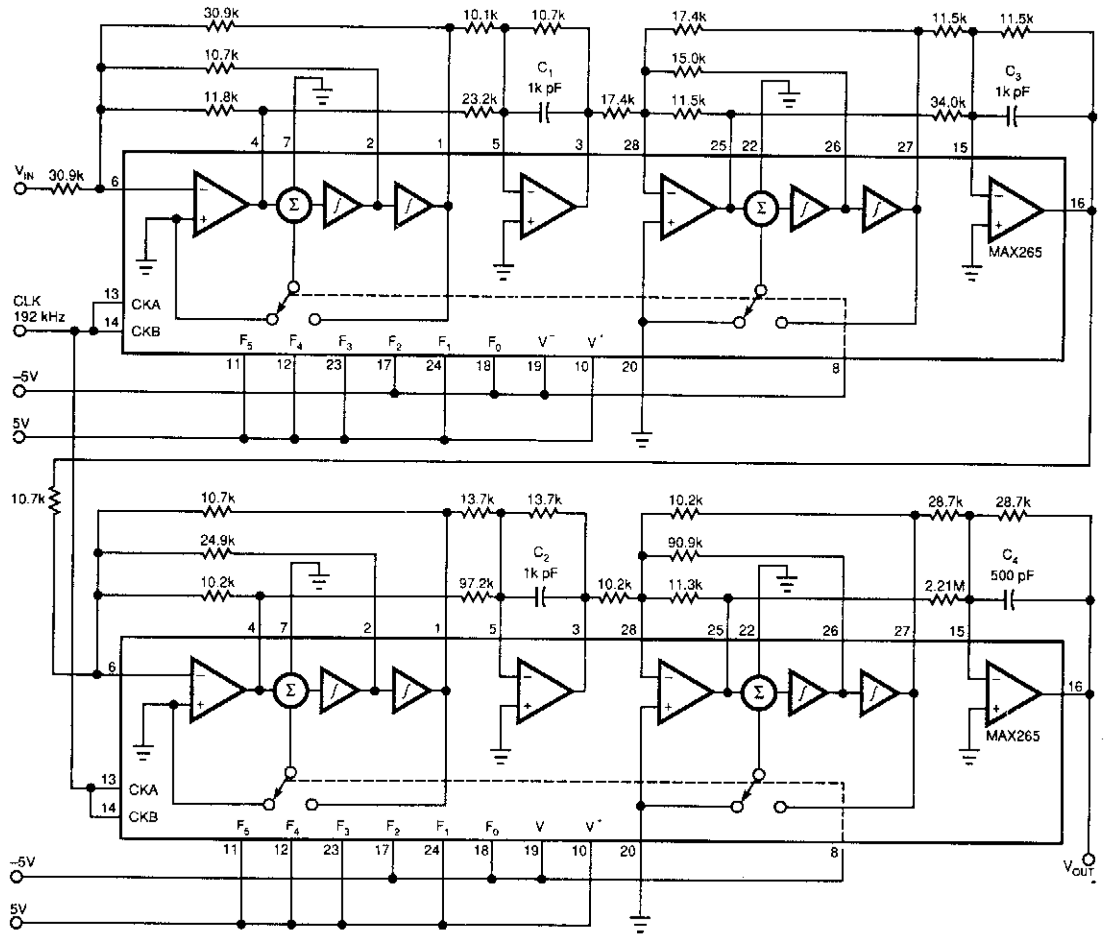
LOW-COST CRYSTAL FILTERS



ARRL HANDBOOK *Fig. 30-5*

Low-cost CB crystals can be used for these 9-MHz crystal ladder filters. Notice that the 27-MHz crystals (3rd overtone) are used on their fundamental frequencies.

ANTIALIASING AND SYNC-COMPENSATION FILTER



EDN

Fig. 30-6

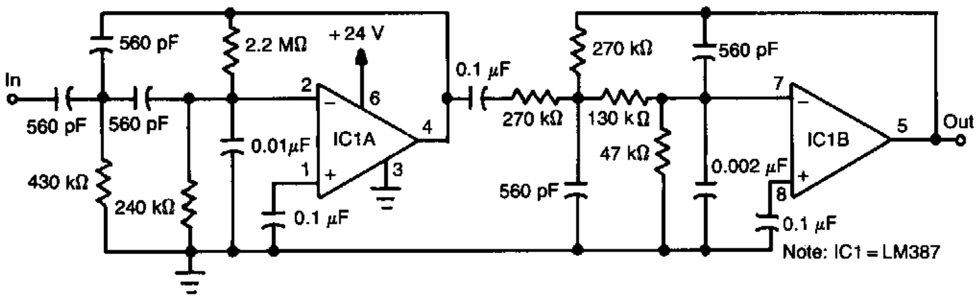
Two dual-biquad filter chips and some external components form a multipurpose filter to reconstruct D/A converter signals. Connected to a converter's output, the filter provides antialiasing, reduces the D/A converter's quantization noise, and compensates for $\sin(\pi x) \div (\pi x)$—the "sync" function (attenuation).

The circuit incorporates an inverse-sync function that operates to one-third of the converter's sample rate. Beyond one-third, the filter's response shifts to a stopband filter, which provides −70 dB attenuation. This attenuation conforms to the converter's inherent signal-to-noise ratio and quantization error.

To prevent aliasing, the stopband edge must be no higher than the Nyquist frequency ($f_{sn} \div 2$). To achieve 70-dB stopband rejection with this eighth-order filter requires a transition ratio ($f_{\text{STOPBAND}} \div f_{\text{PASSBAND}}$) of 1.5, which sets the passband's upper limit at $f_s \div 3$.

Notice also that you can apply a simple divide-by-64 circuit to the 192-kHz clock frequency to set the necessary 3× ratio between the converter's sample rate and the filter's 1-kHz corner frequency. The V^+, V^-, and the F_0 through F_5 connections program each filter chip for an f_{CLK}/f_0 ratio of 191.64.

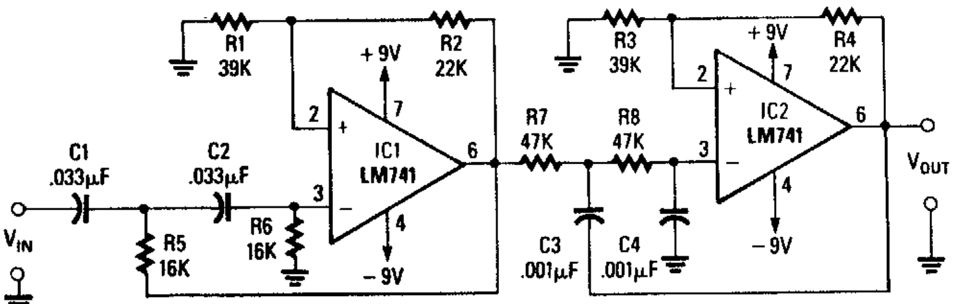
TWO-SECTION 300-3 000 Hz SPEECH FILTER



RADIO-ELECTRONICS **_Fig. 30-7_**

An LM387 dual low-noise amplifier is used in an active filter. Both sections are used to produce second-order HP and LP filters, respectively.

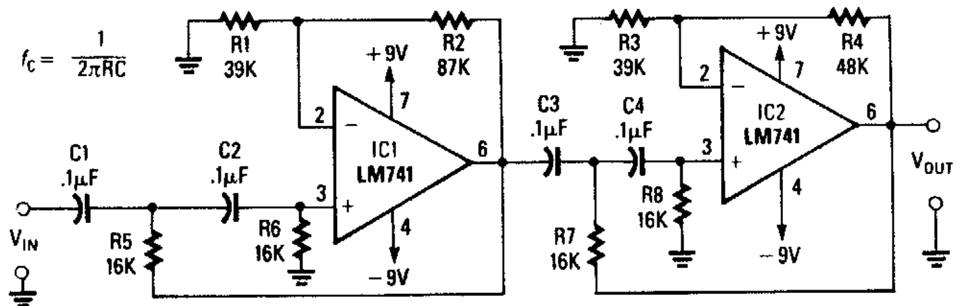
300-to-3 400 Hz SECOND-ORDER SPEECH FILTER



RADIO-ELECTRONICS **_Fig. 30-8_**

Using two op amps, this filter is designed for second-order response. It has a bandpass of 300 to 3 400 Hz, for applications in speech or telephone work.

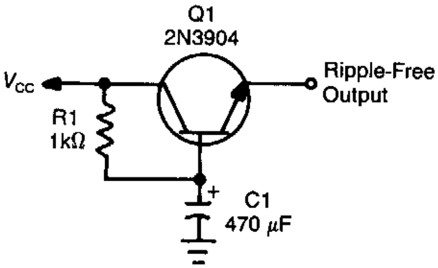
FOURTH-ORDER 100-Hz HIGH-PASS FILTER



RADIO-ELECTRONICS **_Fig. 30-9_**

This filter, using two sections of LM741, can be scaled in frequency, if desired.

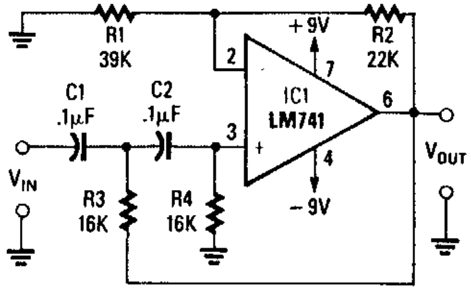
SIMPLE RIPPLE SUPPRESSOR



WELS' THINK TANK *Fig. 30-10*

This circuit, at times called a *capacitance multiplier*, is useful for suppression of power-supply ripple. C1 provides filtering that is equal to a capacitor of $(B+1)\ C_1$, where $B=$ dc current gain of Q1 (typically > 50).

SECOND-ORDER 100-Hz HIGH-PASS FILTER

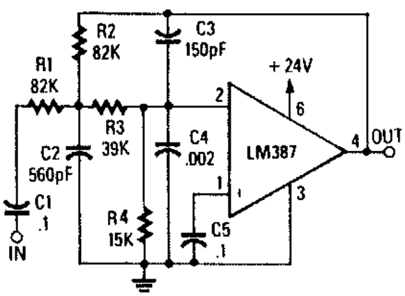


$$f_C = \frac{1}{2\pi RC}$$

RADIO-ELECTRONICS *Fig. 30-11*

This second-order filter can be scaled to change the cutoff frequencies.

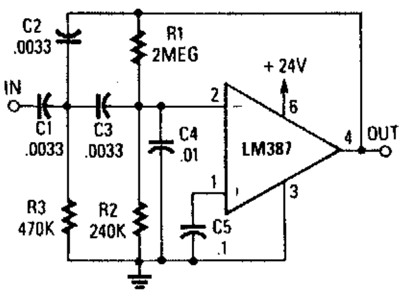
SCRATCH FILTER



RADIO-ELECTRONICS *Fig. 30-12*

Designed to produce 12-dB/octave roll-off above the 10-kHz cutoff frequency, this LP active filter will help reduce needle scratch on records. It uses an LM387 low-noise amplifier IC.

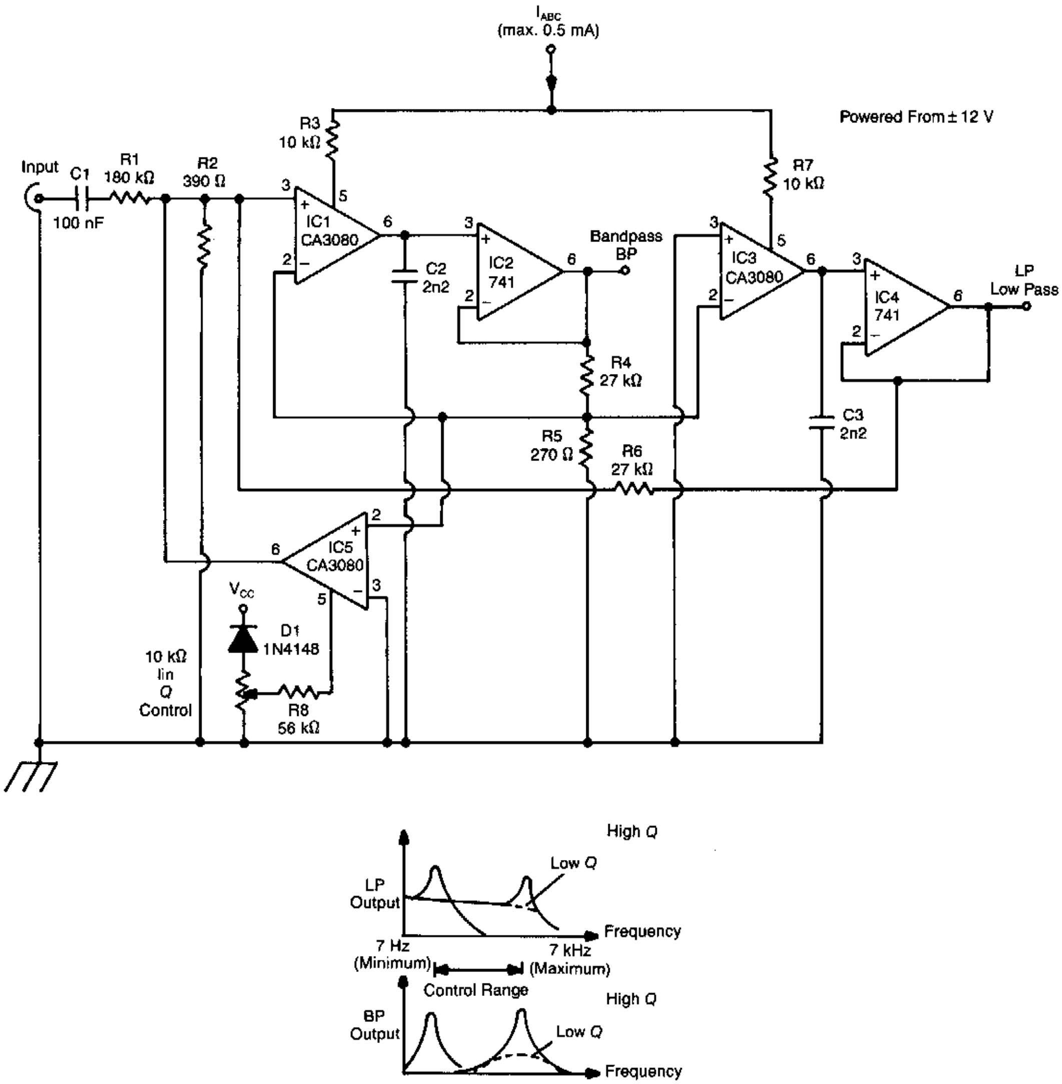
SIMPLE RUMBLE FILTER



RADIO-ELECTRONICS *Fig. 30-13*

This circuit is a two-section active HP filter using an LM387, with a cutoff below 50 Hz at 12-dB per octave. It will help reduce rumble as a result of turntable defects in record systems.

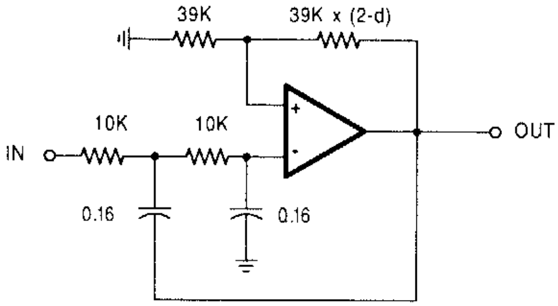
1 000:1 TUNING VOLTAGE-CONTROLLED FILTER



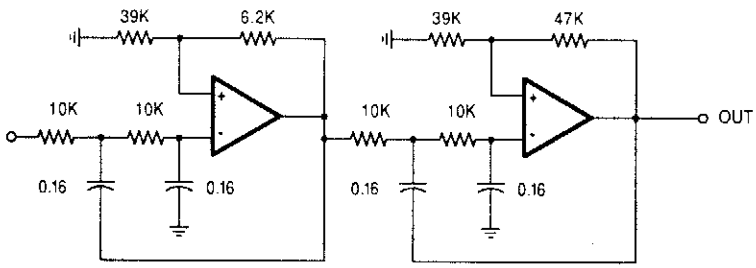
ELECTRONICS TODAY INTERNATIONAL ***Fig. 30-14***

A standard dual integrator filter can be constructed using a few CA3080s. By varying IABC, the resonant frequency can be swept over a 1 000:1 range. At IC1, three are current-controlled integrators. At IC2, four are voltage followers that serve to buffer the high-impedance outputs of the integrators. A third CA3080 (IC5) is used to control the Q factor of the filter. The resonant frequency of the filter is linearly proportional to I_{ABC}. Hence, this unit is very useful in producing electronic music. Two outputs are produced: a low-pass and a bandpass response.

TWO SALLEN-KEY LOW-PASS ACTIVE FILTERS



(A) SIMPLE SECOND ORDER SALLEN-KEY SECTION



(B) FOURTH ORDER BUTTERWORTH LOW PASS AUDIO FILTER

RADIO-ELECTRONICS ***Fig. 30-15***

These filters are designed for 10-kΩ impedance level and 1-kHz cutoff frequency, but the components can be scaled as required for other impedances and cutoff frequencies.