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DESIGN HIGHER ORDER ACTIVE RC FILTERS

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Yours Sincerely

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Abstract

This paper presents modeling of Design Of Higher Order Active RC Filters. It focuses on filter types, introduction of High order active RC filter, implementation of high-order filters, Signal Flow Graphs in Filter Analysis and Synthesis and Synthesis of active filter from passive prototype.The criteria that can be used in comparing the various methods of realization of a high-order function are considerd here. The analysis of Multiloop Feedback (MLF) Structure, Active Filters Based on RLC Ladder Filters, Biquadratic (Biquad state variable active filter). Along with this the modeling of 5^{th} order chebyshey filter is designed with SFG.The analysis gives us the required active filter circuit designd.

Introduction

Almost all communication systems use filters. A filter is a device that passes electric signals at certain frequencies or frequency ranges while preventing the passage of others.A filter passes one band of frequencies while rejecting another. A filter can be either passive or active. Passive filters are built with inductors capacitors and resistors in combination to create the filter. Passive filters are used above 1MHz , have no power gain and are relatively difficult to tune.An Active Filter uses amplifiers (usually operational amplifiers) along with resistors and capacitors to do the filtering. Inductors, which can be large and bulky, are not needed. Active filters are useful below 1 MHz have power gain and are relatively easy to tune. Filters of some sort are essential to the operation of most electronic circuits. It is therefore in the interest of anyone involved in electronic circuit design to have the ability to develop filter circuits capable of meeting a given set of specifications. Unfortunately, many in the electronics field are uncomfortable with the subject, whether due to a lack of familiarity with it, or a reluctance to grapple with the mathematics involved in a complex filter design. This Application Note is intended to serve as a very basic introduction to some of the fundamental concepts and terms associated with filters. It will not turn a novice into a filter designer, but it can serve as a starting point for those wishing to learn more about filter design.

High order active RC filter

In most cases, the selectivity provided by a second-order filter is not adequate. Higher-order filter functions have to be realized in order to satisfy the stringent selectivity requirements in telecommunication systems, special instrumentation, and many other applications.

The first is to cascade second-order stages without feedback (cascade filter)or through the application of negative feedback (multiple-loop feedback filters, MLFs).

The second is to use combinations of active (e.g op amps) and passive(resistors and capacitors)components in order to simulate either the inductances or the operation of a high order LC ladder. Yet another approach, the use of just one op amp embedded in an RC network in order to realize the high-order function, although possible, has been dropped for reasons of high sensitivity.

Filter Types Based on there frequency characteristics

1. Low Pass Filter
2. High Pass Filter
3. Band Pass filter
4. Band Stop Filter
5. All pass Filter

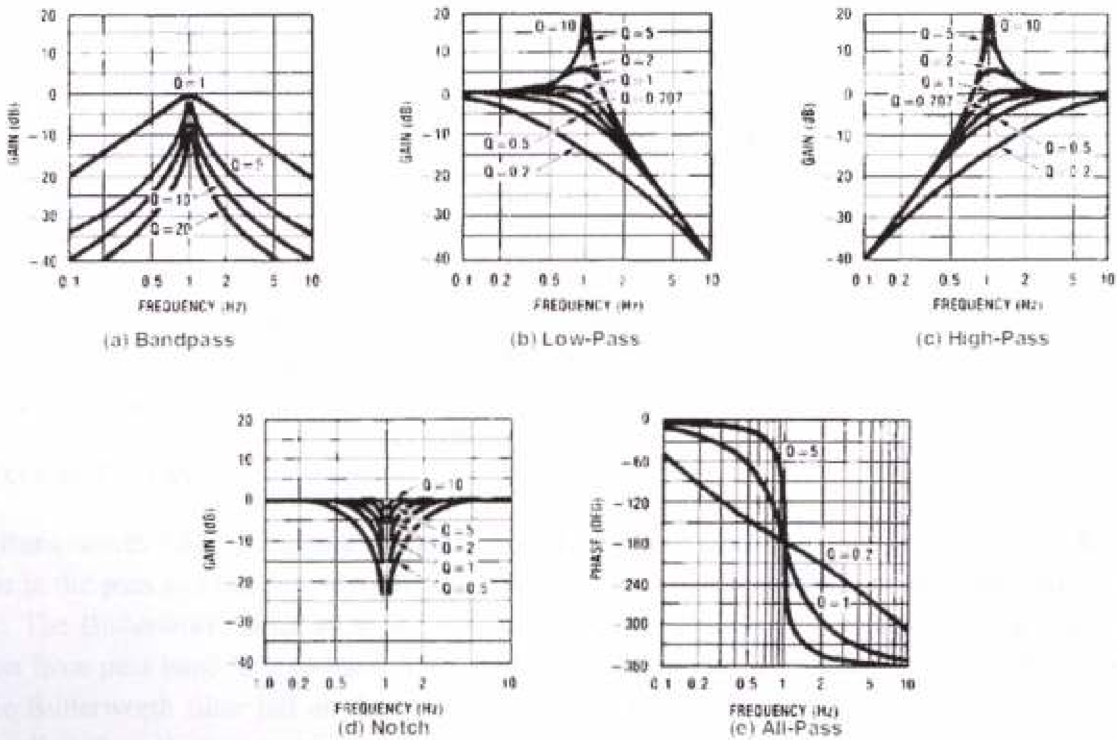


Figure 1. Responses of various 2nd-order filters as a function of Q. Gains and center frequencies are normalized to unity.

Filters Based on Approximations

1. Chebyshev filter
2. Butterworth filter
3. Bessel filter
4. Elliptic filter

Chebyshev filter:

The Chebychev function provides faster roll-off in the transition band than a Butterworth filter would, but at the expense of some variation in the pass-band called ripple. Chebychev stop-band roll-off is monotonic. It avoid Chebychev transfer functions in favor of Elliptic alternatives because section Q's are higher for Chebychev's than with elliptic functions which provide faster roll-off in the transition-band. Another approximation to the ideal filter is the Chebyshev or equal ripple response. As the latter name implies, this sort of filter will have ripple in the pass band amplitude response. The amount of pass band ripple is one of the parameters used in specifying a Chebyshev filter. The Chebyschev characteristic has a steeper roll off near the cutoff frequency when compared to the Butterworth, but at the expense of monotonicity in the pass band and poorer transient response.

Butterworth filter:

The Butterworth filter is the best compromise between attenuation and phase response. It has no ripple in the pass band or the stop band, and because of this is sometimes called a maximally flat filter. The Butterworth filter achieves its flatness at the expense of a relatively wide transition region from pass band to stop band, with average transient characteristics. The normalized poles of the Butterworth filter fall on the unit circle (in the s plane). The pole positions are given by: where K is the pole pair number, and n is the number of poles. The poles are spaced equidistant on the unit circle, which means the angles between the poles are equal. Given the pole locations, $\omega 0$, and α (or Q) can be determined. These values can then be use to determine the component values of the filter. The design tables for passive filters use frequency and impedance normalized filters. They are normalized to a frequency of 1 rad/sec and impedance of 1 Ω. These filters can be denormalized to determine actual component values. This allows the comparison of the frequency domain and/or time domain responses of the various filters on equal footing. The Butterworth filter is normalized for a –3 dB response at $\omega o = 1$. The values of the elements of the Butterworth filter are more practical and less critical than many other filter types. The frequency response, group delay, impulse response, and step response . The pole locations and corresponding ωo and αterms are tabulated .

Bessel filter:

In electronics and signal processing, a Bessel filter is a type of linear_filter with a maximally flatgroup delay (maximally linear phase response). Bessel filters are often used in audio crossover systems. Analog Bessel filters are characterized by almost constant group delay across the entire passband, thus preserving the wave shape of filtered signals in the passband.

The Bessel filter is very similar to the Gaussian filter, and tends towards the same shape as filter order increases. The Bessel filter has been electronics and signal processing, a Bessel filter is a type of linear filter with a maximally flat group delay (maximally linear phase response). Bessel filters are often used in audio crossover systems. Analog Bessel filters are characterized by almost constant group delay across the entire passband, thus preserving the wave shape of filtered signals in the passband.better shaping factor, flatter phase delay, and flattergroup delay than a Gaussian of the same order, though the Gaussian has lower time delay.

Elliptic filter:

The cutoff slope of an elliptic filter is steeper than that of a Butterworth, Chebyshev, or Bessel, but the amplitude response has ripple in both the passband and the stopband and the phase response is very non-linear. However, if the primary concern is to pass frequencies falling within a certain frequency band and reject frequencies outside that band, regardless of phase shifts or ringing, the elliptic response will perform that function with the lowest-order filter. The elliptic function gives a sharp cutoff by adding notches in the stopband. These cause the transfer function to drop to zero at one or more frequencies in the stopband. Ripple is also introduced in the passband . An elliptic filter function can be specified by three parameters(again excluding gain and cutoff frequency): passband ripple, stopband attenuation, and filter order n. Because of the greater complexity of the elliptic filter, determination of coefficients is normally done with the aid of a computer.

Synthesis of active filter from passive prototype

Element substitution

- R : R in active-RC filter
- C : C
- L : Gyrator

Signal flow graph (SFG)

- Emulation/Simulation of Inductors
- Same result as with element substitution
- Useful for optimization (e.g. dynamic range optimization).

Implementing higher filter

Cascaded Biquad

Multiple Feedback

Leap Frog

RLC LADDER

Biquadratic [Biquad]

A close cousin of the state variable filter is the biquad as shown in Figure 8.56. The name of this circuit was first used by J. Tow in 1968 (Reference 11) and later by L. C. Thomas in 1971 (see Reference 12). The name derives from the fact that the transfer function is a quadratic function in both the numerator and the denominator. Hence the transfer function is a biquadratic function. This circuit is a slight rearrangement of the state variable circuit. One significant difference is that there is not a separate high-pass output. The band-pass output inverts the phase. There are two low-pass outputs, one in phase and one out of phase. With the addition of a fourth amplifier section, high-pass, notch (lowpass, standard, and high-pass) and all-pass filters can be realized.

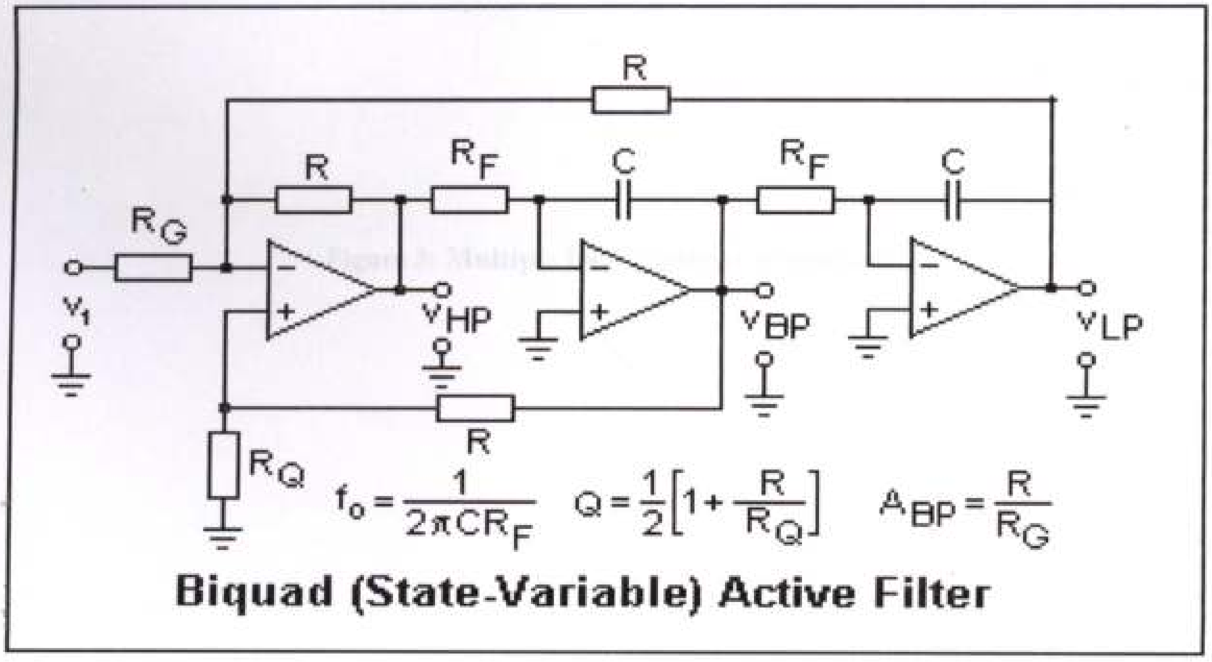


Figure 2: Biquad Active Filter

Multiple loop feedback[MLF] structure

Adding and subtracting are done in special blocks called summing points , gives several examples of summing points. Summing points can have unlimited inputs, can add or subtract, and can have mixed signs yielding addition and subtraction within a single summing point. The terms in a typical control system, and defines the terms in a typical electronic feedback system. Multiloop feedback systems are intimidating, but they can be reduced to a single loop feedback system, as shown in the figure, by writing equations and solving for VOUT/VIN. An easier method for reducing multiloop feedback systems to single loop feedback systems is to follow the rules and use the transforms.

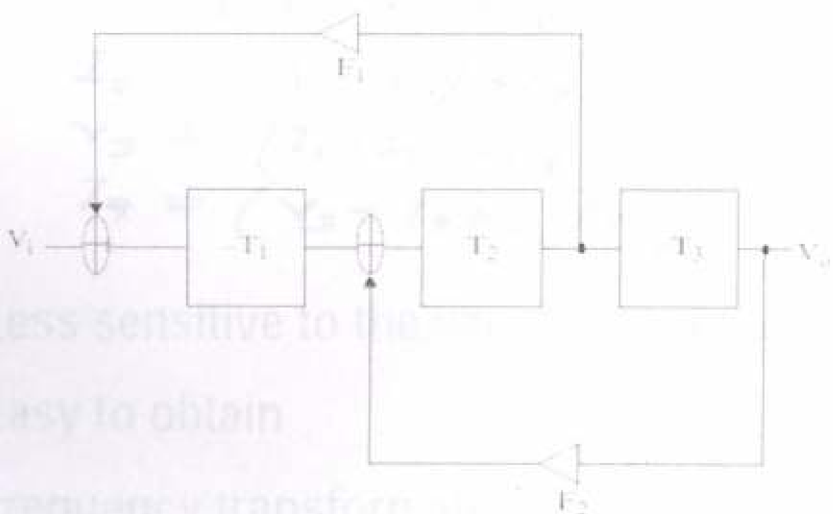
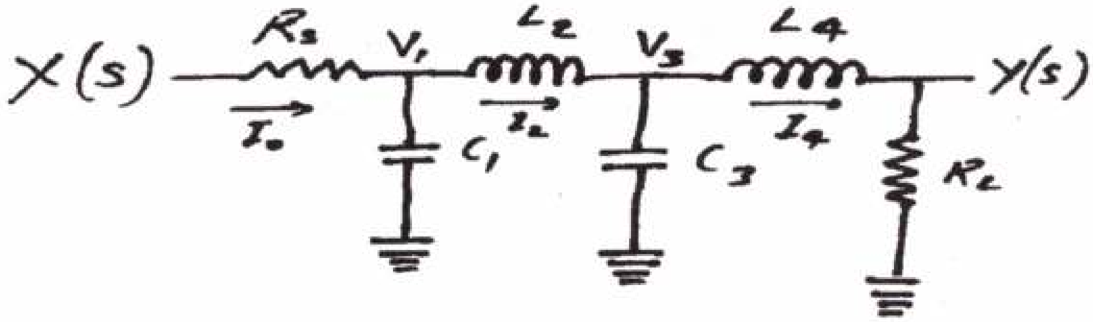


Figure 3: Multiple loop feedback structure

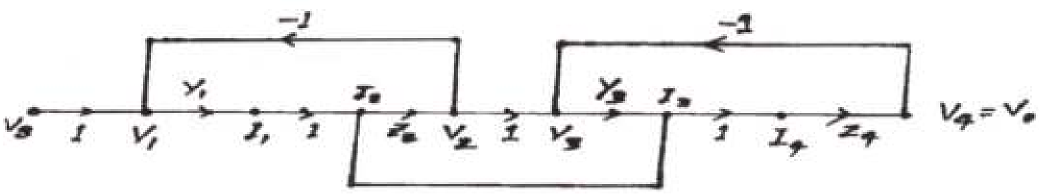
Implementation of high-order filter

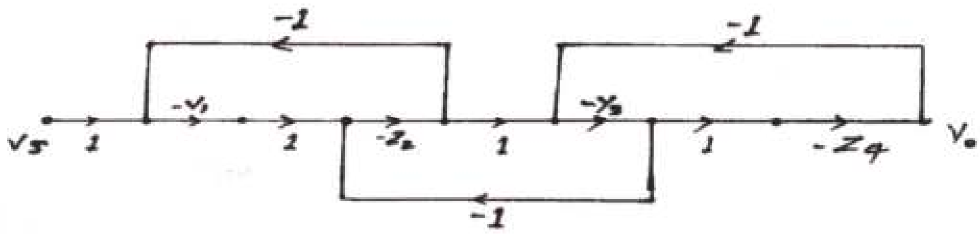


$$I_0 = (X - V_1)/R_s$$
$$V_1 = (I_0 - I_2)/sC_1$$
$$I_2 = (V_1 - V_3)/sL_2$$
$$V_3 = (I_2 - I_4)/sC_3$$
$$I_4 = (V_3 - I_4 R_L)/sL_2$$

- Less sensitive to the variations of component values
- Easy to obtain
- Frequency transformation
- Impedance transformation

Signal Flow Graphs in Filter Analysis and Synthesis





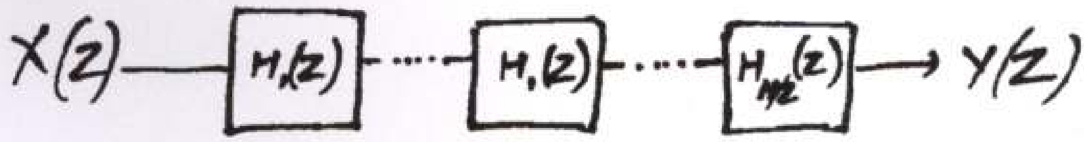
step 1. $V_1 = V_s - V_2 \,,\ V_3 = V_2 - V_4 \,, \cdots V_{2n-1} = V_{2n-2} - V_{2n}$

step 2. $I_2 = I_1 - I_3 \,,\ I_4 = I_3 - I_5 \,, \cdots, I_{2n} = I_{2n-1}$

step 3. $V_2 = Z_2 I_2 \,,\ V_4 = Z_4 I_4 \,, \cdots, V_{2n} = Z_{2n} I_{2n}$

step 4. $I_1 = Y_1 V_1 \,,\ I_3 = Y_3 V_3 \,, \cdots I_{2n-1} = Y_{2n-1} V_{2n-1}$

Implementation of high-order filter



$$H(z) = H_1(z) \cdots H_i(z) \cdots H_{N/2}(z)$$

$$H(z) = \prod_{i=1}^{N/2} H_i(z) = \prod_{i=1}^{N/2} \frac{b_2 z^2 + b_1 z + b_0}{a_2 z^2 + a_1 z + a_0}$$

Easy adjustment of frequency characteristics

Pole/zero pair matching

Biquad permutation issue

Gain distribution issue

Future Work

After getting the resultant output of the given passive circuit, the SFG design is converted to the active RC circuits. Then the designed RC circuit will be further Simulated in multisim to get and check the given input output given signals.

Conclusion

In this paper filter Realization and Synthesis of active filter from passive prototype is done with the help of SFG. We also designed a 5th order Chebyshev filter with SFG . We find the roots of different filter circuits with help of Matlab'9. And further simulation of the circuits will be done in multism.

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