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Design and Simulation of Eighth-Order Active-R Band Pass Filter Using Multiple Feedback Topology

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ABSTRACT

In this paper, an active Eight-order R band pass filter is designed and simulated at centre frequency f_0 of 284KHz and quality factor Q of 30. The filter is designed from given specifications of the filter. The architecture that will be used is the multiple feedback and the gain magnitude response is simulated using MULTISIM work bench version 11.0. The simulation shows that the bandwidth of the filter at stage 3 was most selected with Bandwidth of 7.65KHz and the roll-off of the filter with values approaching -60dB/decade instead of an Eight-order which is -160dB/decade and there was a shift in the centre frequency of the filter, which is only a slight shift. The filter had a high mid-band gain that increased with each stage 1 (40.14dB) to stage 4 (87.50dB).

Keywords: R-Filter; Quality Factor; Multi-Sim; Band-Pass; Multiple.

1.0 Introduction

Active-R filters with only resistors and operational amplifiers are Active-R filters (Shinde, G.N., Chavan, U.N., 2013). They are easy to design and have extension of response towards high frequencies. The operational amplifier shows the high frequency roll-off (Shinde, G.N., Patil, P.B., Mirkute, P.R., 2002, Soderstrand, M.A., 1976) due to parasitic capacitances.

Active-R circuits contain only op-amps and resistors, so that they are suitable for high frequency operation and integration with the bipolar monolithic technology (Srinivasan, S, 1976; Masami, H, 1992).

The need to have monolithic high-performance analog filter motivated circuit designers to investigate alternatives to conventional Active-RC filters (Shinde et al., 2013). A practical Alternative appeared in the form of Active-R filters.

The Active-R filter has received much attention due to its potential advantages in terms of miniaturization, ease of design and high frequency performance (Shinde, G.N, Patil, P.B., Mirkute, P.R., 2003; Srinivasans, S., 1992). It has also been pointed out in the literature that Active-R networks offer substantially low sensitivity characteristics as

compared to Active-RC structures (Soderstrand, M.A, Mitra, S.K, 1971).

The major disadvantage of the Active-R filters were the temperature dependence of the filter centre frequency and the limited dynamic range due to op-amp slew rate limitations (Toumazoa, C., payne, A., Pookaiyandom, S., 1995).

But these disadvantages have been overcome by applying the Active-R technique to current-feedback op.amp (Toumazoa et al., 1995).

The patterns of pass bands and stop bands give rise to most common filters as low pass, high pass, band pass and Band stop (Kalsi, 2002). Band pass filter is a type of device or electronic circuitry that allows only specific signals or frequencies to pass through it but rejects or distinguishes the unwanted signals or frequencies (Mestura, B., Omar, M.B.R, Mohammad, T.I, 2013). The top application of band pass filter can be found in Radio Frequency world where the frequency range from ultra high.

This paper processes realization and design made for Eight-order Active-R filter using the multiple feedback topology. This filter circuit gives high maximum pass band design and studied for a quality factor (Q) of 30 and centre frequency of 284KHz.

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2.0 Methodology

The Eight order Active-R filter can be realized through the cascading of four second-order filter stages presented in figure 1. Therefore the eight-order Active-R MFB filter which is here developed is shown in figure.

The values of the different resistances are given from the equations.

$$R_4 = \frac{k_1 \times R_3}{(1 - k_1)} \quad \dots (1)$$

$$R_2 = \frac{k_2 \times R_1}{(1 - k_2)} \quad \dots (2)$$

Since k_1 and k_2 are attenuators, their values are given as

$$k_1 = \frac{1}{Q} \quad \dots (3)$$

$$k_2 = \frac{2 \times \pi \times f}{\frac{A_o}{T}} \quad \dots (4)$$

The value of $\frac{A_o}{T}$ is taken as 10×10^6 which is the gain bandwidth product of the amplifier. The gain of the filter can be determined by using equation .

Thus the role of attenuator k_2 is that it controls the open loop gain of operational amplifiers used in the circuit. Thus adjustment of k_2 results in control of centre frequency of the band pass filter. The resistances R_2 's can be varied using FET replaced resistances, thus giving single control of two attenuators k_2 . The quality factor Q is independently adjusted using element k_1 , which is adjustable through resistance R_4 .

The circuit performance was studied with different values of $Q=30$ with constant $f_0=284\text{kHz}$. The Table 1 shows resistor values of Q for the active R-band pass filter.

3.0 Results and Discussion

Fig. 2 shows the magnitude versus frequency response plot obtained from the output of the four cascading sections (stages 1, 2, 3 and 4) of the Eight-order Active-R Band pass filter with $Q=30$. The plot shows a gradual increase in the Mid-band gain and

roll-off of the Active-R filter network obtained from the output of the first cascading section (stage 1) to the fourth section (stage 4). The bandwidth was however found to be increase from the first section (stage 1) to the second section (stage 2) and then decrease in the third section (stage 3) and then finally increasing in the fourth section (stage 4) from the result of the roll-off presented in Table 2. It seems each cascading section is providing a single pole roll-off $\approx 20\text{dB/decade}$. According to Jacob, J.M., 2003, the roll-off (ΔL_n) of n identical first order sections in cascade is given by;

$$\Delta L_n = n\Delta L_1 = 20n \frac{\text{dB}}{\text{decade}} \text{ or } 6n \text{ dB/octave}$$

Fig 1: Second Order Active-R Filter Using MFB Topology

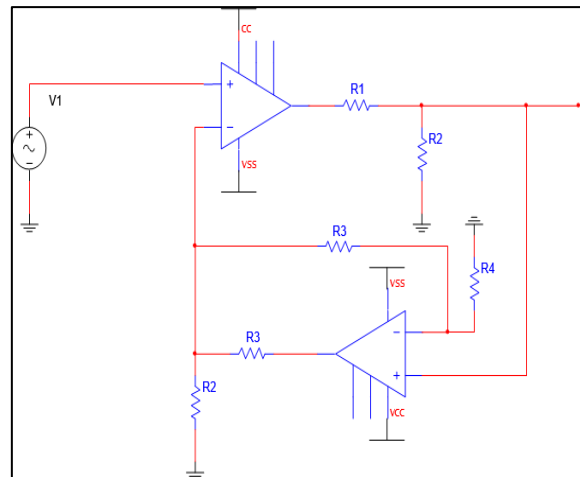
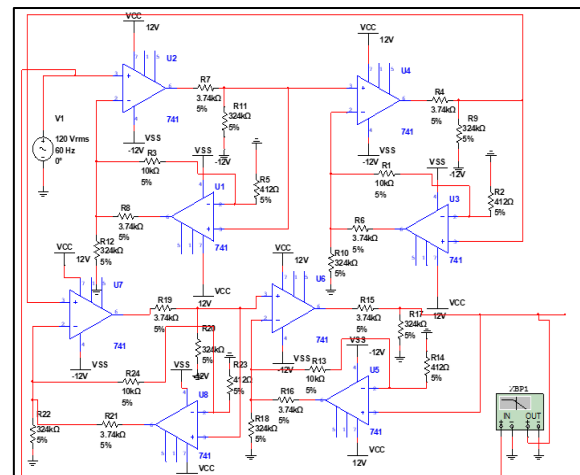


Fig 2: Eight-Order Active-R Band Pass Filter Using Multiple Feedback Topology



Thus for the four cascading stages (fig. 2), $n=4$ and the result in Table 2 Shows consistency with the above argument. This observation is contrary to the report by Shinde *et al.*, 2003, that each section is a two pole network.

A modification of the filter to provide higher roll-off without the addition of a single component is possible as observed from a preliminary work carried out by (Amah, A.N., Ahemen, I., Atsuwe, B.A., 2014). There is a relative shift in the centre frequency of the multiple feedback topology which are not available in the market.

Table 1: Resistor Values for Eight-Order Active-R Filter Network Using Multiple Feedback Topology At $F_0=284\text{kHz}$ And $Q=30$.

S/N	Quality Factor (Q)	Designed Resistor Values (Ω)				Experimental Resistor Values (Ω)			
		R1	R2	R3	R4	R1	R2	R3	R4
1	30	100.00k	21.72k	10.00k	344.83k	100.00k	21.72k	10.00k	412.00k

Table 2: Active-R Band Pass MFB Filter Section Response Characteristics

S/N	Stage	Bandwidth (Hz)	MidBand Gain (dB)	Roll-off (dB/decade)
1	1	11.20k	40.14	-11.07
2	2	38.06k	44.03	-22.56
3	3	7.65k	80.91	-34.05
4	4	22.58k	87.50	-45.53

4.0 Conclusions

We have successfully designed the Eight-order Active-R band pass filter using Multiple feedback topology and found that in addition to the advantages of miniaturization, ease of design and high frequency performance, the filter provides better selectivity at stage 3, greater stop band attenuation and steeper cut-off at the edge of the pass band. Aside this there was relatively shift from the centre frequency and low roll-off rate records for the fourth cascaded selections indicating a third order configuration rather than the proposed Eight-order.

Nevertheless these can be modified to provide higher roll-off and non-shifting of the centre frequency when desired. However, MFB particularly is very sensitive to variation in attenuation resistor, but not to the other component variations and very precise resistors and capacitors when applied are needed to make narrow bandpass filter with MFB topology (Elliot, 2000) this may account for the behavior of the filter.

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