Implementation of a Sixth Order Active Band-pass R-Filter

Igwue,G.A,Amah,A.N,Atsuwe,B.A

Abstract— In this paper, an active band-pass R- filter output response at different values of center frequency using MAPLE programming is carried out. A sixth order active band pass R-filter are constructed at center frequencies of 10 kHz and 100 kHz and quality factors of 2, 5, 7, 8 and 10 and roll off rate of 20dB/decade. The architecture used is the multiple feedbacks. The filter parameters and values for the passive components were calculated, the gain and phase response were then simulated with MAPLE programming. The simulation shows that at high Quality factors, the bandwidth of the filter response reduces considerably while its frequency selectivity increases without a shift in its center frequency. This is an indication that the filter will function well at high frequencies and perform poorly at lower frequencies. This result also shows that the R-filter is most selective at a quality factor of Q=8 and centre frequency of f_o = 100KHz

Index Terms— R-filter, Quality factor, Band pass, MAPLE.

1 INTRODUCTION

A filter is defined as a network which passes a certain portion of a frequency spectrum and blocks the remaining portion of the spectrumThe term “blocking” means that the magnitude response $\left|H(j\omega)\right|$ of the filter is approximately zero for that frequency range. In other words, a filter is a frequency –selective device or system[6]. The active filter without the capacitor is called an active-R filter; and has received much attention due to its potential advantages in terms of miniaturization, ease of design and high frequency performance [15],[11]. It has been also pointed out in the literature that active-R networks offer substantially low sensitivity characteristics as compared to R-C active structures [14]. Although several papers have been published on evaluation of the second order active-R filter, we have not come across any reported circuit regarding direct coupled circuit for realizing third-order active-R filters with feedforward input signals. This gives greater stop-band attenuation and sharper cut-off at the edge of the passband. The band-pass response is characterised by a frequency band between the lower cut off frequency, f_L and upper cut off frequency, f_H such that input signals with frequencies(f) within the band f_L(i-e f_L<f<f_H) less than f and f itself is less than f_H (f_L< f<f_H) emerge unchanged while those signals with frequencies outside the band are attenuated. The difference (f_H - f_L) is called the bandwidth of the filter, and the point of frequency spectrum at which the band is centered is called the centre frequency f_o [9].
Citations

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Filters are usually classified according to filtering range, frequency response in pass band, and circuit component. Classified by filtering range, there are four types of filters: low-pass, high-pass, band-pass, and band-reject filters. According to frequency response in pass band, there are two types: Butterworth and Chebyshev filters. According to circuit component,
they are active and passive filters.

Passive filters are circuits that contain only passive components (resistors, inductors and capacitors) connected in such a way that they will pass certain frequencies while rejecting others. Active filters, which are the only type covered in this paper, employ active
components (transistors or operational amplifiers) plus resistors, inductors and capacitors. Active filters are widely used in modern communication systems, because they have the following advantages[1]:
1. Because the transfer function with inductive characteristic can be achieved by particular
circuit design, resistors can be used instead of inductors.
2. The high input impedance and low output impedance of the operational amplifier means
that the filter circuit is excellent in isolation characteristic and suitable for cascade.
3. Because active components provide amplification, therefore active filters have gain.

2 METHODOLOGY

The circuit configuration for the sixth –order active R- Band pass filter was gotten from the work of [8] which is on the second order active Band pass filter as shown in Fig 1. The resistor values were calculated using equation 1 and 2.

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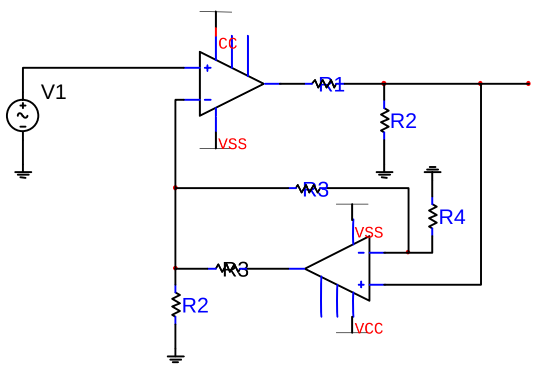

Fig 1: Circuit diagram of a second order active R-band pass filter

The architecture that has been used to implement both the sixth order active R-band-pass filter is the multiple feed-back topology which can be realized through cascading of the second order filter stages. The circuit diagram in Fig. 2 shows the implemented circuit composed of triply cascaded second order active R-band pass filter.

Analysis

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

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

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

$$k_1 = \frac{1}{Q} \tag{3}$$

$$k_2 = \frac{2 \times \pi \times f}{\frac{A_o}{T}} \tag{4}$$

The value of A_o/T is taken as 6.2×10^6 which is the gain bandwidth product of the amplifier. The gain of the filter can be determined according to[8] as;

$$Gain = \frac{A_o K_2}{(1 + sT)} = \frac{A_o}{T} \tag{5}$$

The voltage transfer function $T_f = \frac{V_o}{V_i}$ of the circuit is given by[8] as;

$$\frac{V_o}{V_i} = \frac{\frac{sT}{A_o k_2} + K_1}{\frac{s^2 T^2}{A_o{}^2 k^2{}_2} + \frac{sTK_1}{A_o k_2} + 1} \tag{6}$$

Where K is the attenuator given by equations 3 and 4 above. 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 Field Effect Transistor (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 sixth order active R-band pass filter is obtained by cascading of the second order active R-band pass filter of Fig. 1 and is represented in Fig. 2. Since filter orders determine the gain and selectivity of the filter, there have been attempts to improve on the filter orders hence the need to cascade filters. Fig 1 shows the simplest form of a filter which is called the Second order. If a better functionality of the filter in terms of selectivity is needed, then there will be the need to put two of the second orders together to make the fourth order. Again if a much higher gain is needed, then we increase the order. Consequently the higher the filter order, the higher the gain and the filter selectivity.[16].Furthermore, there has been no known literature for the sixth order Band pass filter, so it was selected. The circuit performance was studied with different values of quality factor (Q = 2, 5, 7, 8 and 10) with constant f_o=10 kHz.

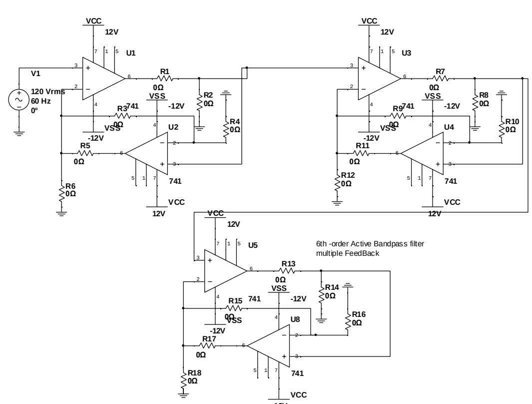

Fig 2: Circuit Diagram of Sixth Order Active-R Band Pass Filter

3 RESULT

For a centre frequency f_o =10kHz, the value of R_1 was chosen to

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be 100kΩ. After the substitution in the same equation 2,R_2 was calculated to be 1.0kΩ.The results for the maximum pass band gain and the bandwidth for the filter at fo=10kHz and fo=100kHz are presented in Tables 1 and 2 respectively,while their respective magnitude responses are shown in Figures 3 and 4.

Table 1.
Maximum PassBand Gain and Bandwidth of the Sixth-Order Active R- BandPass Filter at f_0= 10kHz

Quality factor (Q)	Maximum Pass-Band gain(dB)	-3dB Value (dB)	Lower -3dB Value (Hz)	Upper -3dB Value (Hz)	Bandwidth (Hz)
2	6.71	4.74	7869.33	11498.57	3,629.24
4	12.01	8.49	8234.25	10953.23	2718.98
5	13.60	9.26	8472.59	10953.23	2480.64
7	16.64	11.76	8472.59	10645.12	2172.53
8	17.11	12.10	8472.59	10645.12	2172.53
10	19.00	13.43	8717.82	10345.82	1627.85

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Table 2.
Maximum PassBand Gain and Bandwidth of the Sixth-Order Active R- BandPass Filter at f_0= 100kHz

Quality factor (Q)	Maximum Passband gain(dB)	-3dB Value(dB)	Lower -3dB Value (Hz)	Upper -3dB Value(Hz)	Bandwidth (Hz)
2	6.73	4.76	78940.85	119047.90	40,107.05
4	11.34	8.02	84670.43	112681.70	28011.27
5	12.75	9.01	84670.43	111592.50	26922.07
7	14.65	10.36	84670.43	110681.53	26011.10
8	15.17	10.73	83078.88	108965.12	25886.24
10	16.18	11.44	83078.88	108965.12	25886.24

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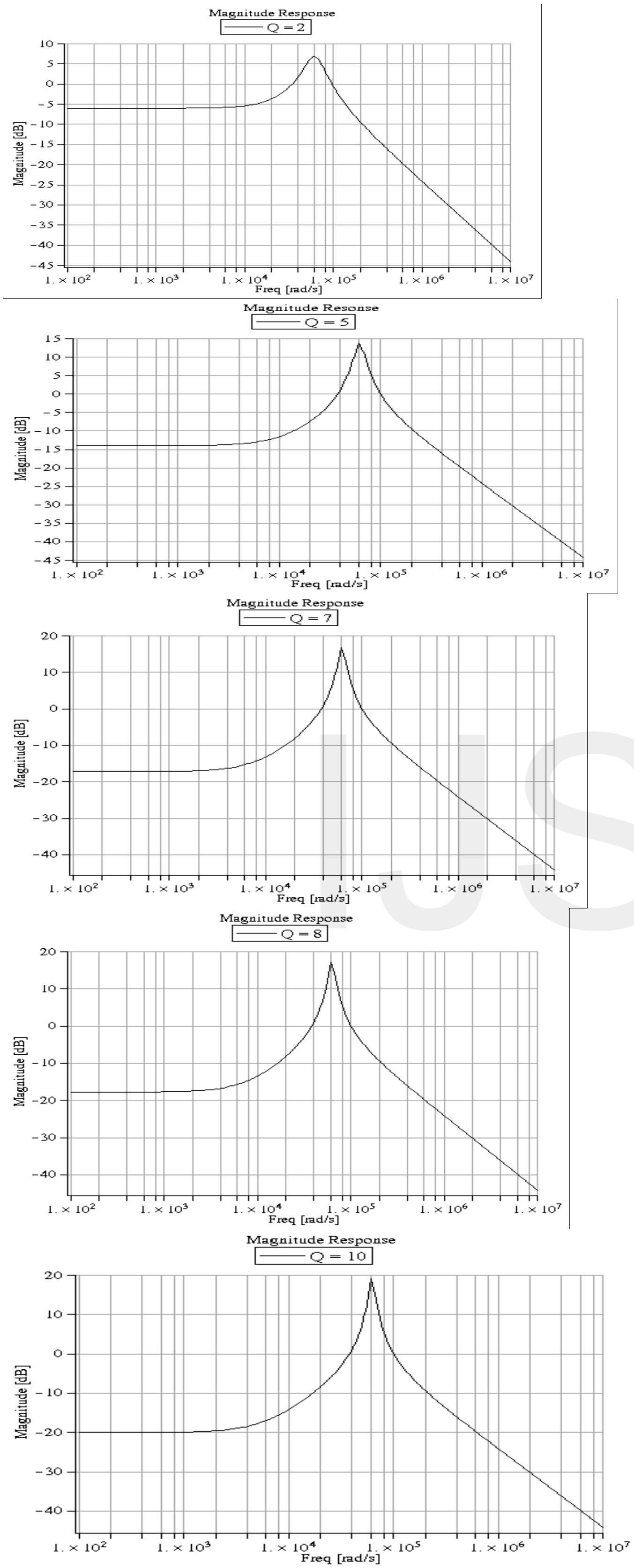

Fig.3: Sixth order active R-band pass filter at centre frequency f_o = 10 kHz and Q= 2, 5, 7, 8, 10 respectively.

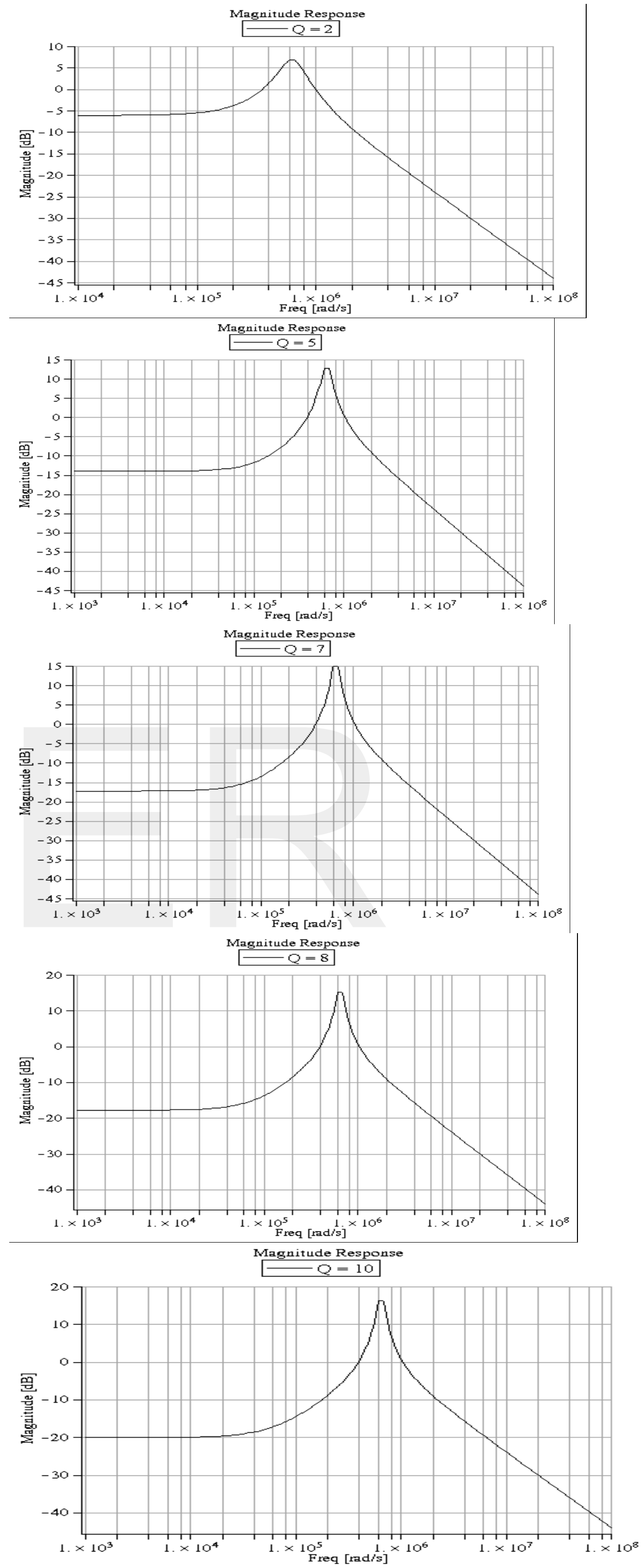

Fig. 4: Sixth order active R- band pass filter at centre frequency f_o = 100 kHz and Q= 2, 5, 7, 8, 10 respectively

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4 DISCUSSION

Table 1 presents results for f_0= 10kHz, the pass band gain increases from a value of 6.71dB at Q=2 to 19.00 dB at Q=10. The bandwidth decreases from a value of 3629.24Hz to 1694.22Hz at Q=8 and Q=10. This implies good behavior of the filter at this centre frequency. Also the filter works and it has high selectivity which is in line with literature. Theory specifies that "increase in Q, leads to increase in the gain (G)" and "increase in Q yields a decrease in the bandwidth". Also the increase in f_o gives a decrease in the bandwidth. Furthermore, at a constant f_o =100kHz, as presented in table 2,the pass band Gain is 6.73dB at Q=2 and increases to 16.18dB at Q=10, while the Bandwidth decreases from 40,107.05 Hz at Q=2 to 25,886.24 Hz at Q=10. This implies consistent behavior of the filter at this centre frequency. Also the filter really works and it has high selectivity which is in line with literature. In summary, the active R-band pass filter is characterized by high gain and narrow bandwidth at both f_o= 10kHz and 100kHz.

6 CONCLUSION

It can be concluded from the above results that even though the constructed filter does not have same values as the simulated results, it still maintains the filter behaviour or characteristics. Therefore the filter performs well at f_0= 10kHz and f_0= 100kHz up to a quality factor of Q=8. It is believed that there can be further improvement in the characteristics if more precise values of resistors and better operational amplifiers were used. This filter can also be used as a narrow band device because the selectivity is high, as well as to obtain high gains.

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