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Design and simulation of Eighth-order Active-R Band pass filter for UHF Radio Frequency Identification system using Biquadratic Topology

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Abstract:

In this paper an Eighth-order Active-R Band pass filter using Biquadrtic topology at variable centre frequencies and fixed quality factor Q of 30 was Designed and simulated using MULTISIM work bench (version 11.0). the simulated response characteristics show that, the filter gives the highest Mid band gain of 33.452dB at f_0*=40KHz and the least Mid band gain of -8.820dB at* f_0*=640KHz which is in agreement with filter theory. The bandwidth and Gain roll-off are also in perfect agreement with filter theory. Therefore the filter meets design specifications, performs well and therefore can be used in the receiver of an RFID system in the UHF region.. A shift in the centre frequency was observed but not out of range as it recorded 0.7% deviation from the actual centre frequency which is negligible. The filter therefore performed well and meets its specification.*

Keywords: filter**,** active, UHF, Biquad, Eigth-order

1.0 Introduction

Radio Frequency Identification (RFID) system is a wireless communication system that is used to identify tagged objects, people or animals (Zin, M.M.M, Zaw, M.A, Zaw, M.N, 2009). The area of applications for RFID is increasing rapidly. Applications include supply chain management, access control to building security systems, animal identification, public transportation, healthcare, open-air events, air-port baggage, excess parcel logistics and so on (Zin, M.M.M *et al*., 2009).

RFID system uses radio frequency to automatically identify products. The RFID system conditions two parts, Reader and Tag (Jin, L, Chang, T.O, 2006). The different transmission frequencies are classified into four basics ranges, LF (low frequency e.g 867MHz or 915MHz) and micro wave (e.g 2.4GHz). For LF and HF RFID, the read range is usually less than 60cm. for micro wave RFID, because of the sensitivity to the environment, the maxim reader range is about 1m. for UHF RFID the read range cab generally reach to 5m (Jin *et al*., 2006). Also the RFID system can be classified into Active RFID (Tag with battery) and passive UHF RFID. This passive RFID, reader should send out electromagnetic waves first to work-up the Tag, and then transmit the modulated wave to command Tag. The tag transmits its Identification (ID) to the reader and the reader consults an external database with receives ID to recognize the object (i.e The reader transmits continuous waves (CW)), while Tag backscatters the information.

There are many protocols about UHF RFID, in this paper, we base our standard on EPC class 1 Generation 2 UHF RFID. The signals defined in the EPC standard for UHF use either the FMO or the Miller coding. These involve modulating a subcarrier by means of inverting its phase. A subcarrier has frequencies called backscatter link frequency (BLF) (Carlos, F.C., 2009). Depending on the coding, the symbols have different length. The EPC standard for UHF determines that the BLF that the Tag use is freely chosen by the reader in the range from 40KHz and transmitted to the tag at the beginning of the communication. The length of the symbol also varies according to the selected BLF.

The development of capacitor-less filter (R-filter) network has eliminated these bulky components (thereby reducing cost of production) and has also enhanced the stability of the filters. The building block of the R-filter is the internally compensated operational amplifiers (Op-Amps) [4] [5]. In addition to frequency stabilization by the R-filter network, it also has the potential advantages of miniaturization, ease of design and high frequency performance [6]-[8]. Active R-filters have been reported to be suitable for medium-Q high frequency applications [9]. The major disadvantages 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 [10]. These disadvantages have been overcome by applying the active-R technique to current-feedback Op-Amps [10].

The most common filter responses are the Butterworth, Tschebyscheff, and Bessel types. Among these responses, Butterworth type is used to get a maximally-flat response. Also, it exhibits a nearly flat pass band with no ripple. The roll-off is smooth and monotonic, with a low-pass or high pass roll off 20dB/dec for every pole.Thus, a fourth order Butterworth band-pass filter would have an attenuation rate of 40 dB/dec and -40dB/dec. [Miss Zin, 2009].

This paper an Eight-order Active-R Band pass filter using a Biquadratic topology at different centre frequencies (i.e BLF 40KHz, 107KHz, 160KHz, 156KHz, 320KHz, 465KHz and 640KHz) that can be used for ultra-high frequency (UHF) Radio Frequency Identification (RFID) system and at a constant quality factor of Q 30. This simulation will be done using MULTISIM work bench (version 11.0).

2.0 Methodology

The architecture that was used to implement the Eighth-order Active-R Band pass filter is the Biquadratic topology. This topology was realized by cascading Second-order band pass filter of figure 1 (stage 1 with two Operational Amplifiers). All operational amplifiers are of the A6259 type with ¼ watt resistors with 5% tolerance.

2.1 Theoretical Consideration

2.1.1 Design Specification

The architecture that has been used to implement the Eight-order Band pass filter is the Biquadratic topology because of its advantages of interms of mid-frequency stability, high-Q factor, independent gain and Q values, high-roll-off and second-order Band pass filter is shown in fig. 1. Table 1 illustrates specifications for the desired band pass filter. By using the following filter parameters, the required filter can be designed and simulated with MULTISIM work bench version 11.0

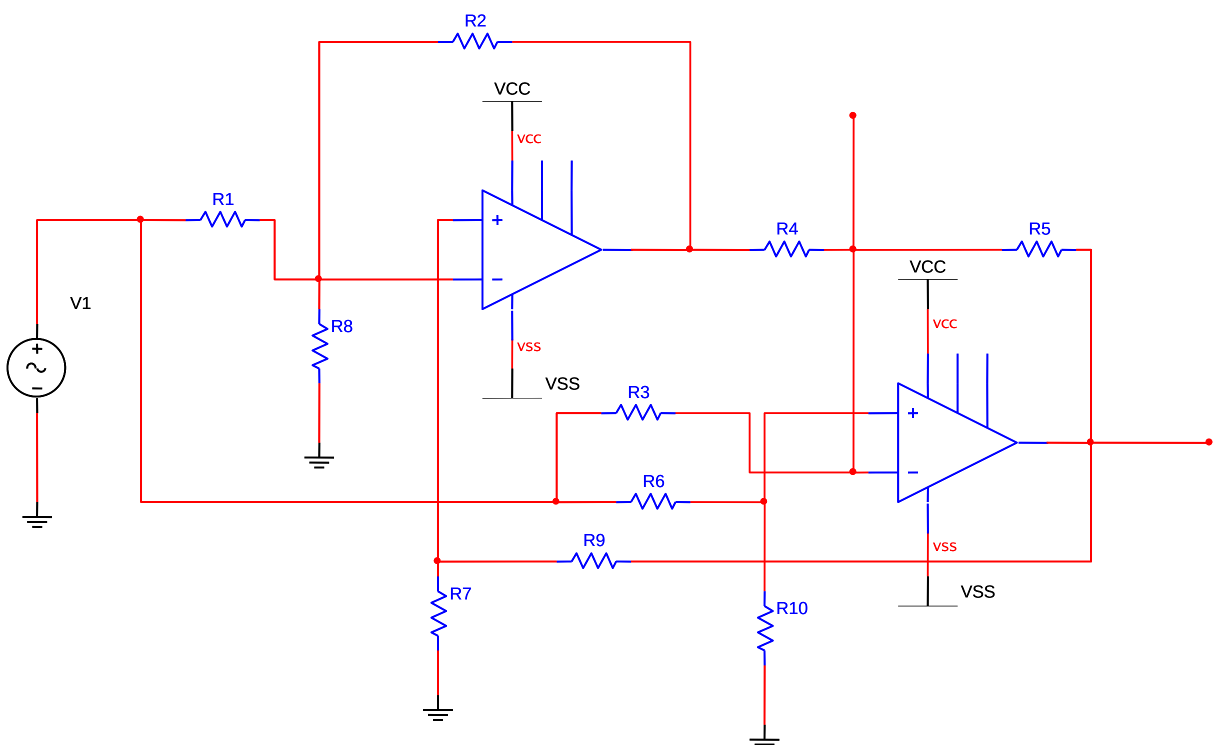


Fig.1. Second-order Active Biquadratic Filter

2.1.2 Design Implementation

Fig. 1 shows the second-order Band pass R-filter used in this work to design eight-order Band pass configuration presented by Hyong, K.K, Ra, J.B. (1977) has a voltage transfer function;

$$\frac{V_2}{V_1} = \frac{(\alpha-\beta)s+(\gamma-\delta)}{s^2+(\omega_1+\omega_2)s+(1+K)\omega_1\omega_2} \qquad 1$$

The band-pass function is obtained with $\gamma = \delta$, giving the transfer function from equation 1 to be

$$\frac{V_2}{V_1} = \frac{(\alpha-\beta)s}{s^2+(\omega_1+\omega_2)s+(1+K)\omega_1\omega_2} \qquad 2$$

Where; S=Jω 3

and the transmission parameters of the filter are given as;

$$\alpha = \frac{R_{6b}}{R_{6a}+R_{6b}}\left(1+\frac{R_5}{R_4}+\frac{R_5}{R_3}\right)\omega_2 \qquad 4$$

$$\beta = \frac{R_5}{R_3}\omega_2 \qquad 5$$

$$2\omega_1 = \frac{\omega_Q}{\omega_p} = 2\omega_2 \qquad 6$$

$$\omega_p = \text{pole frequency} = \sqrt{(1+k)\omega_1\omega_2} \qquad 7$$

$$Q_p = \text{pole quality} = \frac{\sqrt{(1+k)\omega_1\omega_2}}{\omega_1+\omega_2} \qquad 8$$

$$\omega_1 = frquency\ of\ first\ op-amp$$

$$\omega_2 = frquency\ of\ second\ op-amp$$

The alternator, k of the filter is given as;

$$k = \left(1+\frac{R_2}{R_{1a}//R_{1b}}\right)\frac{R_5}{R_4}\frac{R_{7b}}{R_{7a}+R_{7b}} \qquad 9$$

The Gain (G) of the filter is;

$$Gain\ (G) = \frac{\alpha-\beta}{\omega_1+\omega_2} \qquad 10$$

For convenience, he assumed $\omega_1 = \omega_2$ in the equation

$$\omega_1 = GB_1 / \left(1 + \frac{R_2}{R_{1a}//R_{1b}}\right) \qquad 11$$

$$\omega_2 = GB_2 / \left(1 + \frac{R_5}{R_4} + \frac{R_5}{R_3}\right) \qquad 12$$

And then identify equation 6 together with equation 11 for ω_1 yields;

$$1 + \frac{R_2}{R_{1a}//R_{1b}} = \frac{2\omega_Q}{\omega_p} = 2GB_2 \qquad 13$$

where the values of the resistors are determined by ratios. Similarly, using equation 12 for equation 6 for ω_2, then substituting

$$1 + \frac{R_5}{R_4} + \frac{R_5}{R_3} = 2\frac{Q_p}{\omega_p} = GB_2 \qquad 14$$

and using $\omega_p^2 = (1+k)\omega_1\omega_2$, we express resistance ratios as;

$$\frac{R_2}{R_{1a}//R_{1b}} = \frac{2\omega_Q}{\omega_p} GB_2 - 1 \qquad 15$$

$$\frac{R_5}{R_3} = \eta \frac{2\omega_Q}{\omega_p} GB_2 \qquad 16$$

$$\frac{R_5}{R_4} = (1-\eta)\frac{2\omega_Q}{\omega_p} GB_2 - 1 \qquad 17$$

and

$$\frac{R_{7b}}{R_{7a}+R_{7b}} = \frac{2Q_p \frac{\omega_p}{GB_1}\left(1 - \frac{1}{Q_p^2}\right)}{(1-\eta)\frac{2Q_2}{\omega_p} GB_2 - 1} \qquad 18$$

Using $\gamma = \frac{R_2 R_5}{R_{1a} R_4}\omega_1\omega_2$, $\delta = (\beta - \alpha)\omega_1$ together with equation 4 and 5, we have;

$$\frac{R_{6a}}{R_{6b}} = \frac{1 + 2\frac{R_5}{R_3} + \frac{R_5}{R_4}\left(1 + \frac{R_2}{R_{1a}}\right)}{\frac{R_5}{R_4}\frac{R_2}{R_{1a}} - \frac{R_5}{R_3}} \qquad 19$$

$$R_{1a} \geq \frac{R_2 R_3}{R_4} \qquad 20$$

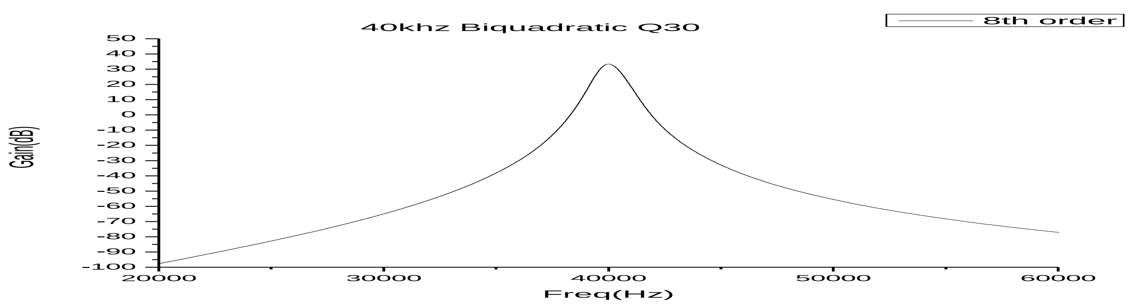
where $0 < \eta < 1$ 21

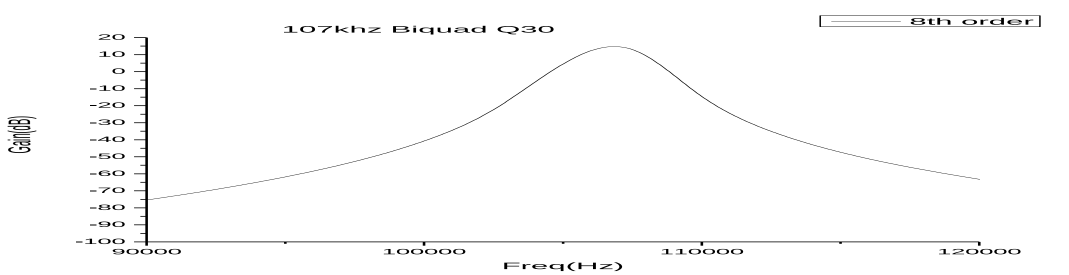
Given the pole parameters and the Gain Bandwidth product of the operational amplifiers GB_1 and GB_2 we determine the resistance ratios from the equations above for a chosen η. For $4Q^2 >> 1$, it can be seen from equation 18 that the since tuning of the pole frequency (ω_p) is attainable by R_{7b}/R_{7a}, while the pole frequency (Q_p) is tuned by R_4.

We first consider the design of a Second-order band pass R filter (stage 1) with centre frequency (f_0)=40KHz and Q=30 and $GB_1=GB_2=10\times10^6$Hz. Choosing R_{1a}=1.0MΩ, R_2=40KΩ, from equation 15, we calculate R_{1b}=18.94Ω . From equation 16, we choose η=0.1 and the values of R_5=40KΩ, R_3=189.33Ω . From equation 17,

Similar calculations for the component values for different centre frequencies f_0=107KHz, 160 KHz, 256 KHz, 320 KHz, 465 KHz, and 640 KHz at constant Q=30 using equation 16 to 19 and presented in table 1. To realize an Eight-order configuration, the Second-order filter was cascaded as shown in fig. 2 and implemented using MULTISIM work bench (version 11.0) software.

3.0 Results and Discussion





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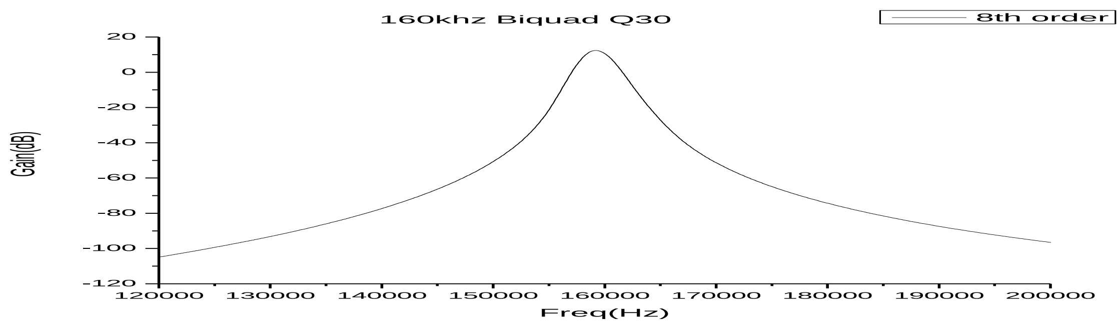

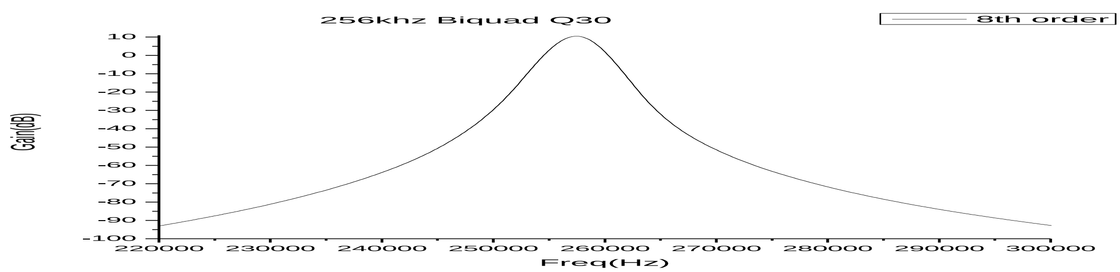

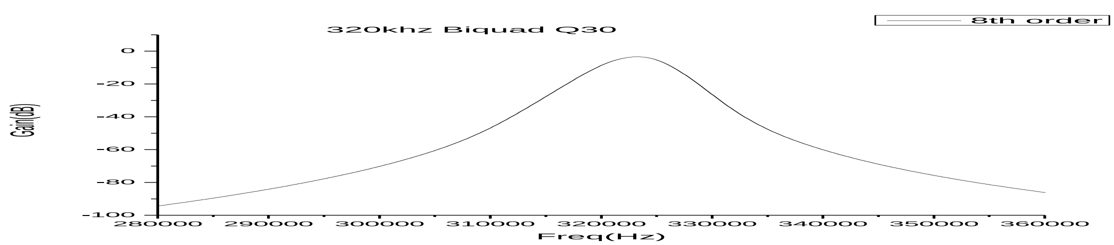

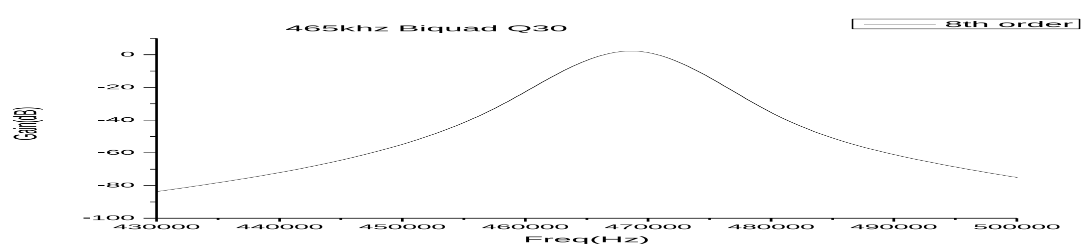

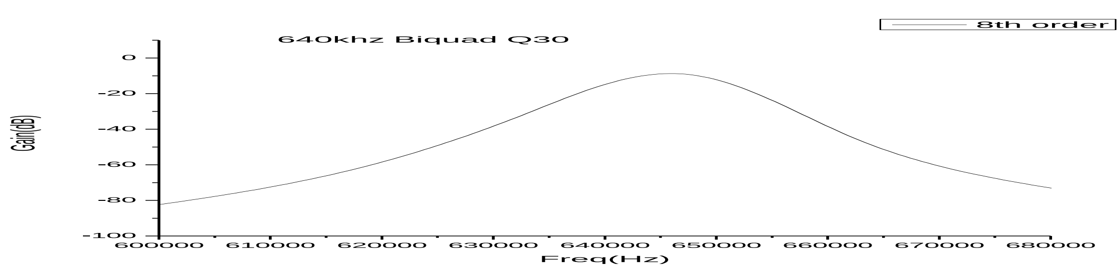

FIG 3:Magnitude Plot of Active-R Filter using Biquad Topology at Varying f_0=40khz,107khz,160khz,256khz,320khz,465khz,and 640khz respectively at constant Q=30.

Fig. 3 shows the magnitude frequency plot obtained from the output of the Eighth-order band pass filter with Q=30. The plot shows that at 40kHz, the filter has a mid band gain of 33.452dB and roll-off of -163.055dB/decade. The bandwidth is 640Hz (0.640Hz). from the result of the roll-off presented in Table 1, the roll-off of the filter looks like the ideal filter roll-off of an Eight-order filter (40ndB/decade) where n is 8. Also at f_0=107KHz, the mid band Gain is 14.691dB=160dB/decade. The mid band Gain of the filter decreases from a centre frequency f_0=40KHz (33.452dB) to f_0=320KHz (-3.673dB). It then increases at f_0=465KHz (0.062dB) and

Table 1:Results of the Midband Gain, Bandwidth and Roll-off of Active-R Bandpass Filter

F_0(Hz)	Mid Band Gain (dB)	-3dB Gain (dB)	F_H (Hz)	F_L (Hz)	BW (Hz)	Roll-off
40k	33.452	30.452	40.329k	39.689k	0.640k	-163.055
107k	14.691	11.691	107.672k	105.833k	1.839k	-193.00
160k	12.277	9.277	160.515k	157.957k	2.558k	-203.432
256k	10.792	7.792	258.916k	256.144k	2.772k	-213.243
320k	-3.673	-6.673	325.136k	320.658k	4.478k	-218.243
465k	2.062	-0.938	471.297k	465.886k	5.411k	-225.380
640k	-8.820	-11.820	650.040k	641.724k	8.316k	-230.932

then drops to -8.820dB at f_0=640KHz. Aside the increase from the f_0=320KHz to fo=465KHz, the Mid Band Gain of the filter is supposed to be decreasing with increasing centre frequency as theory holds (Adan, A.Q; Shinde, G.N., 2014; Shinde, G.N., Kadam, A.B., Kurumbhatte, S.B., Patil, P.B., 2002; Chavan, U.N., Shinde, G.N., 2013; Shinde, G.N., Bhagat, S.R., 2010; Shinde, G.N., Patil, P.B., Mirkute, P.R., 2003). The Gain roll-off of the filter from f_0=40KHz (-163.055dB/decade) to f_0=640Hz (-230.932dB/decade) satisfies that of an Eight-order since the filter is a double-pole that has roll-off of 40dB/decade and an Eight-order roll-off is 160dB/decade (Adan *et al*., 2013). The filter satisfies the Gain roll-off with over shoot as presented in Table 2.

The bandwidth of the filter is observed to be increasing as centre frequency increases from f_0=40KHz to 640Hz to f_0=640KHz with 8.316KHz satisfying filter theory that says that increase in centre frequency of a filter brings about an increase in the bandwidth of the filter (Shinde, G.N *et al*., 2002; Adan *et al*., 2013; Chavan *et al*., 2003; Shinde *et al*., 2013; Shinde, G.N., Muladhar, D.D., 2010; Shinde *et al*., 2003). All the results are presented in Table 2.

4.0 Conclusion

The Eight-order Active-R Band pass filter using Biquadratic topology has been designed, simulated and studied for different centre frequencies at constant quality factor of 30. The filter gives the highest Mid band gain of 33.452dB at f_0=40KHz and the least Mid bnad gain of -8.820dB at f_0=640KHz which is in agreement with filter theory. The bandwidth and Gain roll-off are also in perfect agreement with filter theory. Therefore the filter meets design specifications, performs well and therefore can be used in the receiver of an RFID system in the UHF region.

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