Synthesis of 8th order Active-Band pass filter for UHF Radio Frequency Identification System using MFB Topology

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***Abstract*: This paper presents the design and simulation of eight order Active Band pass filter for UHF Radio Frequency Identification System (RFID) using the multiple Feedback Topology and the gain magnitude response is simulated using MULTISIM work bench version 11.0. the result shows that the filter has a mid-band frequency that decreases from f_0=40KHz (106.505dB) to f_0=256KHz (87.908dB) and increases again from f_0=320KHz (88.449dB) to 640KHz (95.085dB), while the Bandwidth increased from 0.959KHz to 21.537KHz (ff_0=40KHz to f_0=320KHz) and then decreases from 25.376KHz to 25.162KHz (f_0=465KHz to f_0=640KHz). The roll-off rate behaves like a single filter with values approaching -60dB/decade instead of a double stage filter. These however conform with the specifications of EPC class one Generation 2 Standard for UHF domain RFID which offer new opportunities to develop RFID systems for better performance. Therefore the filter can be used for RFID systems.**

***Key words:* Eighth-Order, Active-Band Pass, filter, Ultra High Frequency (UHF) RFID, Multiple Feedback.**

I. INTRODUCTION

In the reader, the front-end system needs RC filter and Active Band pass filter and an Active low-pass filter to reject the undesired signal (Zin, and Zaw, 2009). Filters are essential components in the many electrical systems.

In the state-of-the-art RF receivers, high performance filters are required to remove undesired signals at different stages of the receiving process, such as noise from incoming signals the antenna receives undesired signals at the image frequency, and harmonics after the mixing operation (Zin *et al*., 2009).

In the UHF RFID system, Active filters are used because of the following advantages (Sridevi, 2001;Löwenborg, 1999);

1. The transfer function with inductive characteristics can be achieved by particular circuit design, resistors can be used instead of inductors.
2. The high input impendence and low output impendence of the operational amplifier means that the filter circuit is excellent in isolation characteristics and suitable for cascade.
3. Active components provides amplification, therefore active filters have high gains.

The active filter without the capacitor is called and Active-R filter and has received much attention due to its potential advantages in terms of miniaturization, ease of design and high frequency performance [Srinivasan, (1992); Shinde, Patil, and Mirkute, (2003)]. Also Active-R filter offer substantially low sensitivity characteristics as compared to R-C structure (Soderstand and Mitra, 1971).

Active-R filters give greater stop band attenuation and sharper roll-off at the edge of the pass band. Also in terms of functionality the Active-R filter is better than the Active-RC (Igwe, Amah, and Atsuwe, 2014).

In the paper, active band-pass filter is designed and simulated. An active band-pass filter is used for the RFID system to reject all signals outside the (40-640) kHz signals and to amplify the low antenna signal.

The most common filter responses are the butterworth, chebysshew and Basel types. Among these responses, butterworth type is used to get a miximally-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 of 20dB/dec for every pole (Zin *et al*., 2009). Thus an Eight-order Butterworth band pass filter would have an attenuation rate of -160dB/dec and 160dB/dec.

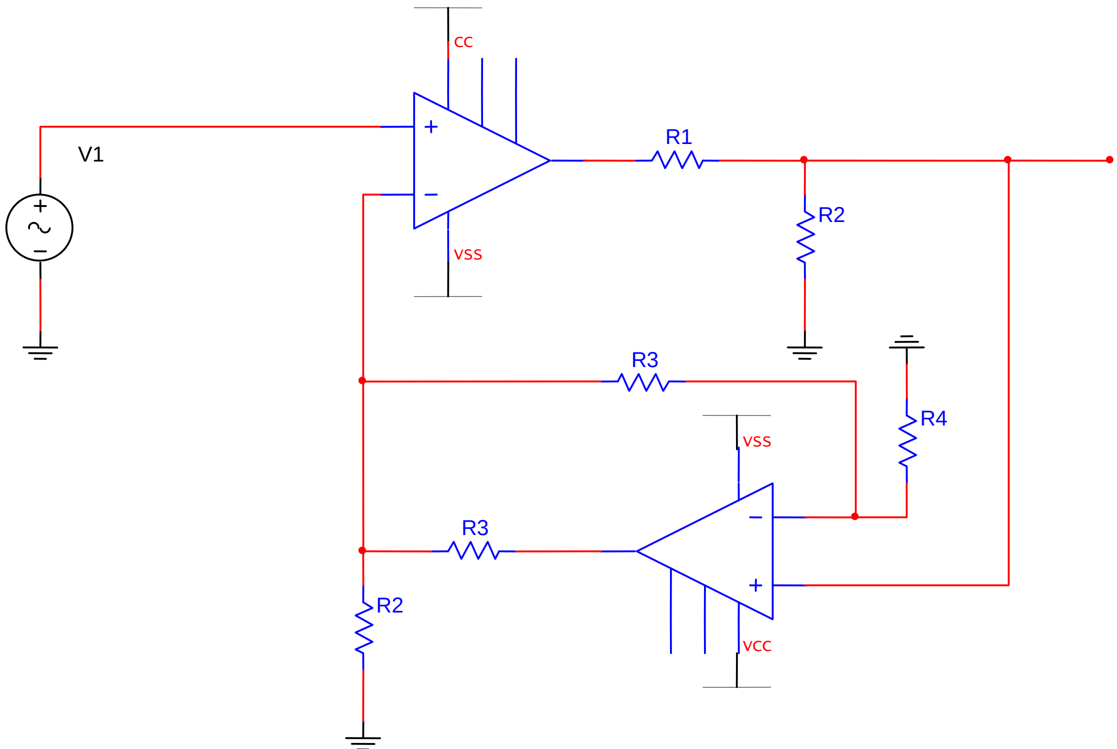


Fig 1 second order Active-R filter using MFB topology

II. METHODOLOGY

The Eighth-order Active-R filter can be realized through the cascading of four Second-order filter stages presented in figure1 above. The values of the different resistances are given from the equations;

$$\frac{V_o}{V_i} = \frac{(S+GB_i k_2/Q)GB_i k_2}{S^2+SGB_i k_2/Q+GB_i^2 K_2^2} \quad 1$$

$$R_4 = \frac{k_1 \times R_3}{(1-k_1)} \quad 2$$

$$R_2 = \frac{k_2 \times R_1}{(1-k_2)} \quad 3$$

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

$$k_1 = \frac{1}{Q} \quad 4$$

$$k_2 = \frac{2\times\pi\times f}{\frac{A_o}{T}} \quad 5$$

The value of 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 1.

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.

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. Therefore the Eighth-order Active-R MFB filter which is here developed is shown in fig. below;

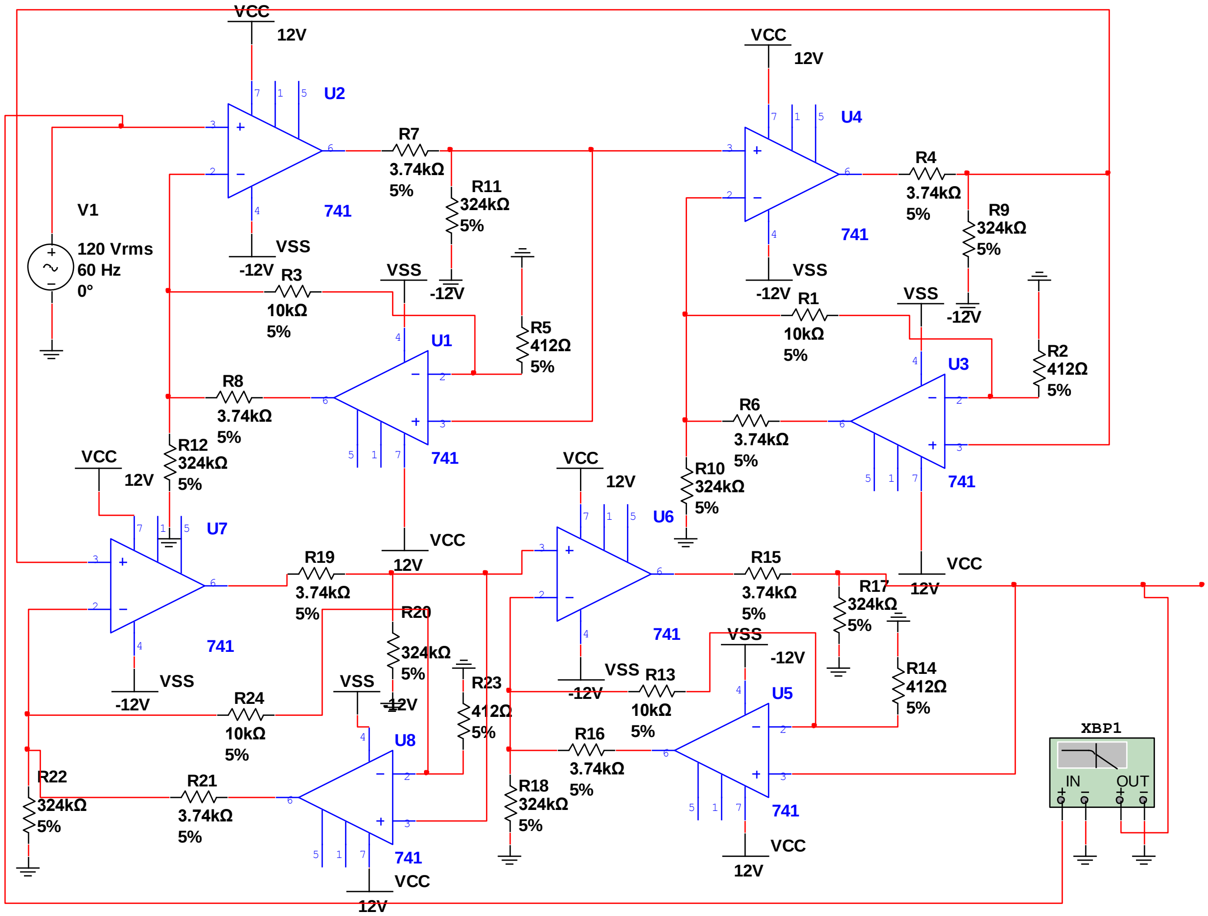
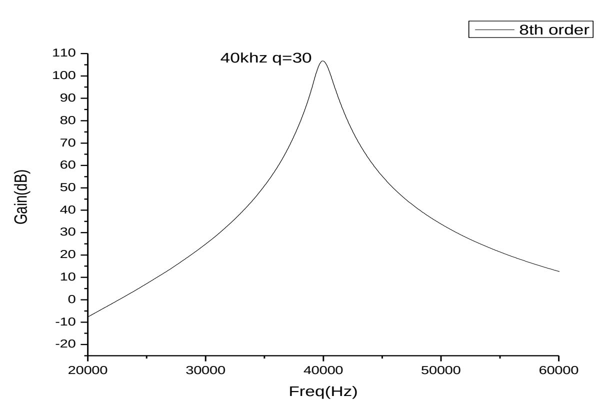


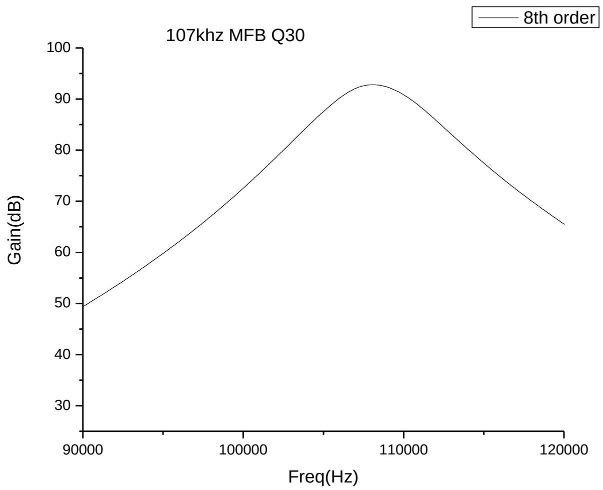
Figure2. Eight-order Active-R Band pass filter using MULTIPLE FEEDBACK Topology

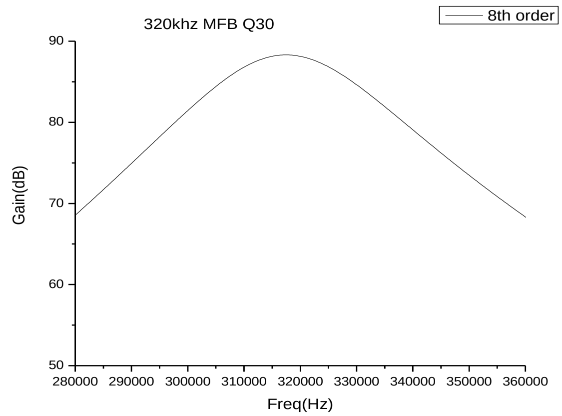
III. RESULTS AND DISCUSSION

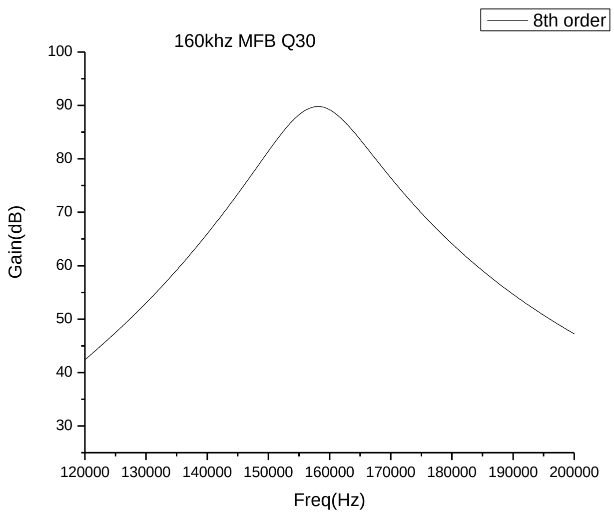
Fig. 3 shows the magnitude frequency plot obtained from the output of the Eight-order band pass filter with Q=30. The plot shows that at 40KHz, the filter has a mid-band gain of 33.452dB and roll-off of -163.055dB/decade. The bandwidth is 640Hz (0.640KHZ). from the result of the roll-off presented in 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=107 KHz, the mid band Gain is 14.691dB=160dB/decade. The mid band Gain of the filter decreases from a centre frequency f_0=40 KHz (33.452dB) to f_0=320 KHz (-3.673dB). It then increases at f_0=465KHz (0.062dB) and then drops to -8.820dB at f_0=640KHz. Aside the increase from the f_0=320KHz to f_0=465KHz, the Mid Band Gain of the filter is supposed to be decreasing with increasing centre frequency as theory holds (Adan, and Shinde, 2014; Shinde, Kadam, Kurumbhatte, and Patil, 2002; Chavan and Shinde, 2013; Shinde, and Bhagat, 2010; Shinde, Patil, and Mirkute, 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 1.

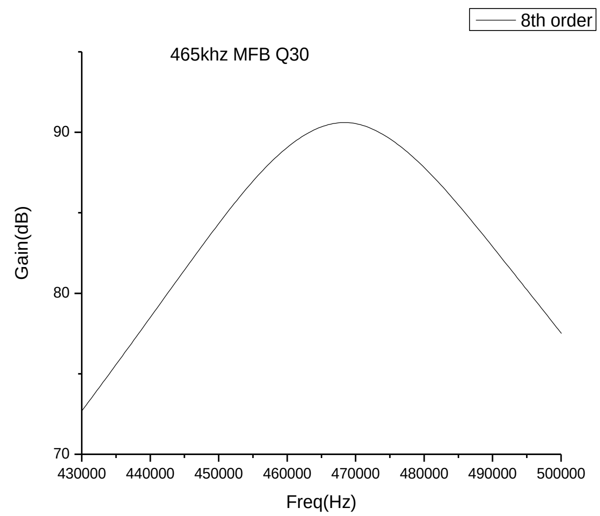
The bandwidth of the filter is observed to be increasing as centre frequency increases from f_0=40KHz to 640KHz to f_0=640KHz with 8.316KHz satisfying filter theory that says that increase in centre frequency of a filter brings about an increase in the bandwidth of the filter (Shinde, *et al.*, 2002; Adan *et al.*, 2013; Chavan *et al.*, 2003; Shinde *et al.*, 2013; Shinde, and Muladhar, 2010; Shinde *et al.*, 2003). All the results are presented in Table 1.

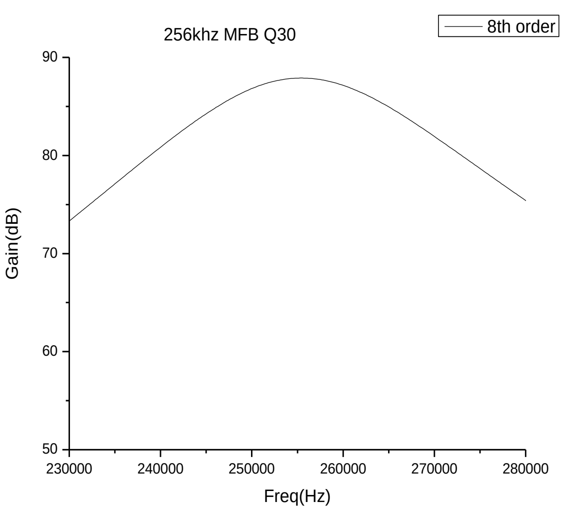












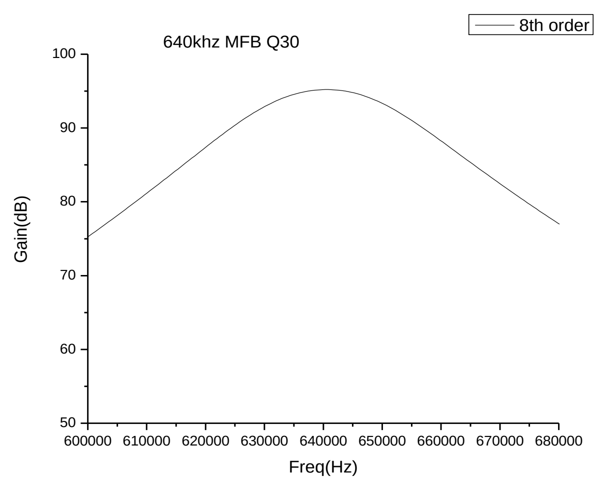


FIG 3 Magnitude Plot of Active-R MFB Filter for Varrying Fo=40khz,107khz,160khz,256khz,320khz,465khz and 640khz at constant Q=30.

IV. 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 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.

Table 1: MFB for Q 30

F_0(Hz)	Mid Band Gain (dB)	-3dB Gain (dB)	F_H (Hz)	F_L (Hz)	BW (Hz)	Roll-off (dB)
40k	106.505	103.505	40.453	39.494	0.959k	-73.953
107k	92.627	89.627	101.618	105.740	4.878k	-193.000
160k	89.896	86.896	162.506	153.763	8.743k	-56.191
256k	87.908	84.908	265.495k	245.771k	19.724k	-48.087
320k	88.449	85.449	328.512k	306.975k	21.537k	-50.846
465k	90.497	87.497	481.373k	455.997k	25.376k	-58.296
640k	95.085	93.085	653.416k	628.254k	25.162k	-66.868

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