International Journal of Academic Multidisciplinary Research (IJAMR)
ISSN: 2643-9670
Vol. 6 Issue 8, August - 2022, Pages: 74-82

Performance Evaluation of Active-RC Bandpass Filter Using Composite Operational Amplifier (CNOA) and a Modified Universal Active-R Filter For UHF RFID Applications.

[1]Atsuwe, B.A. Ph.D and [2]Mom, J. Ph.D

[1]Department of science education: E-mail: atsuwe.bernard@uam.edu.ng
[2]Department of Electrical/Electronics Engineering; E-Mail: joe.mom@uam.edu.ng
[1,2]Joseph Sarwuan Tarka University, Makurdi, Benue state, Nigeria

***Abstract**: This paper presents the comparison of the performance of the Active-RC filter using composite operational amplifier and a modified Active-R bandpass filters for the implementation in the ultra-high frequency (UHF) radio frequency identification (RFID) applications. From the results, the active-RC bandpass filter using composite op-amp performed incredibly well than the active-R bandpass filter in terms of filter parameters of Midband gain, extended bandwidth and roll-off rate. While the active-R bandpass filter, had advantage in terms of the shift in the centre frequency. Both filters can be used for implementation in the UHF RFID applications. This is because the frequencies from fo=40kHz to fo=640kHz are accommodated in the EPC class 1 generation 2 protocol for RFID implementation which allows a deviation of ±22% of the frequency. It is thereby recommended that cre be taken in the selection of components if a desired result is to be achieved.*

Keywords: Performance, CNOA, Active-R, Filter, UHF, RFID, Evaluation

1. INTRODUCTION

Advanced integrated circuit technology based on very cheap CMOS technology enables the radio frequency identification (RFID) to be more and more popular. RFID can be applied for various industries or organizations, such as toll road, parking area access, intermodal freight container identification, pallet tracking, railroad and truck (rolling stock) tracking, animal identification, work-in-progress tracking, matching passengers with their bags at airports, and so on (Rao,K.V.S. et al., 2005; Tuttle, J.R. 1997).

Especially, ultra high frequency (UHF) RFID systems have much longer reading range of 3 to 10 m, compared to the low frequency (LF) of either 125 or 134 kHz or high frequency (HF) of 13.56 MHz.

Radio Frequency Identification is a technology which uses electromagnetic fields to identify and track tags and it can be attached to any object. It basically has two components RFID reader and tags. High frequency RFID can track tags within a distance of 1 to 12 inches. The RFID Reader is used to transmit and receives the signal and the tag which is attached to an object. An RFID Reader requires an active band-pass filter which is used to reject the frequency outside the 10-15 MHz frequency range. RFID tags operate in three frequency ranges: (LF, 30 - 500 kHz) High frequency (HF, 10 – 15 MHz) Ultra high frequency (UHF, 850 - 950MHz, 2.4 - 2.5 GHz, 5.8GHz) (Vigneh, et al. 2015).

In earlier research many types of designs were proposed based on filter design for RFID (Zin, et.al.2009: Shalab, R.& Vahid, S. 2012: Teryima, et.al. 2014: Abdul, H. 2014). In 2009 (Zin,et al. 2009), Active band-Pass Filter for Low Frequency RFID was proposed for (10-20 KHz) frequency. In 2012 (Shahab, R & Vahid, S. 2012), Integrate Band-pass Filter was designed for 13.56 MHz RFID Reader. In 2014 (Teryima, et al. 2014), An Active RC Band-Pass Filter was designed. The filter is designed from given specifications of the filter, center frequency of 15 kHz and roll-off rate of -20dB/decade. The filter was designed from given specification of the filter center frequency of 15 kHz and roll off fate of -2odb/decade. In 2014(Abdul Hussein Adul Z. 2014), the 4th order active band pass filter using multiple feedback and sallen key topologies was designed and fabricated for RFID system reader to reject all signals outside the band of (10-20kHz). Also in 2017 (VijayL.K & swati, S. 2017), A CFOA based active bandpass filter for high frequency band (10-15MHz) using AD844 IC was proposed. In the paper, the author(s) are designing CFOA based active band pass filter on high frequency (10-15 MHz) using AD844 IC. CFOA has gain- bandwidth independence, higher slew rate and consequently higher frequency range of operation. Instead of other op-amp IC, in this paper we have used AD844 as it provides: better ac performance, high linearity, and an exceptionally clean pulse response. It has a very fast large signal response and very high slew rate (2,000 V/μ s). Again, in 2018 (Atsuwe,B.A. 2018). An active –R band pass filter of 8th order for UHF RFID system using Biquadratic topology was also proposed.Also in 2021, an eitht order active-R filter for UHF RFID application using the Multiple Feedback topology was proposed(Atsuwe, et al. 2021).

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 uses is freely chosen by the reader in the range from 40 kHz to 640 kHz 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) (Hioashumura, M. 1992; Huelsman, L.P. 1971). 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 (Hyong, K.K & Ra, J.B. 1977; Mohan, N& Patil, R. L. ; Shinde, G.N., & Patil,P.B. 2002). Active R-filters have been reported to be suitable for medium-Q high frequency applications (Shinde, G.N & Mulaskar, D.D. 2010). The major disadvantages of the active R-filters were the temperature dependence of the filter centre frequency. In the same instance, the CNOA filters also have been known to have ease of design,

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), and the limited dynamic range due to Op-Amp slew rate limitations. These disadvantages have been overcome by applying the active-R technique to current-feedback Op-Amps (Sun zhi-Xhao, 1983).

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. [Zin, 2009 in Atsuwe, et al, 2021]. A composite op amp, as its name implies, is an op amp topology obtained from the combination of at least two other op amps. Generally, the composite op amp offers an improvement over single or conventional op amp performance in terms of extended useful bandwidth, low sensitivity to component and op amp mismatch, and wide dynamic range. (Michael, W.B. and Mikhael, S. 1987). The work by Kollmorgen, & Gary S. 1986 ; Stout, D. F., and Kaufman, M. 1976 provides detailed discussions regarding the generation of composite op amp topologies. Of the 136 possible composite configurations using two op amps (C20A's), four were found to offer superior performance in the areas previously discussed. A composite op. amp offers an improvement over single or conventional op. amp. Performance in terms of extended useful bandwidth, low sensitivity to component and op. amp mismatch and wide dynamic range which can be substantially utilized in the design of filters for the UHF RFID range.

2. DESIGN EQUATIONS OF ACTIVE-RC BANDPASS FILTER USING COMPOSITE OP. AMP

A biquadratic active filter which uses the functional building blocks is designed and tested. It uses two inverting integrators and a differential finite – gain amplifier which are constructed using the composite operational amplifier (ADA 4870 ARRZ).

The transfer function of the filter is given by:

$$\frac{V_{out}}{V_{in}} = \frac{\frac{R_2(R_3+R_4)}{R_3(R_1+R_2)} \times \left(\frac{1}{RC}\right)}{\frac{R_3}{R_{4RC}} + \left[\frac{R_1(R_3+R_4)}{R_4(R_1+R_2)} \times \frac{1}{2\pi f_C RC}\right] + \left(\frac{1}{2\pi f_C RC}\right)^2} \ldots\ldots(1)$$

The band pass is a very narrow, high Quality factor (Q). Therefore the normalised second order transfer function will be given as;

$$\frac{V_{out}}{V_{in}} = \frac{A_O\left(\frac{f}{f_O}\right)}{\left[1 + 2\aleph\frac{f}{f_o} + \left(\frac{f}{f_o}\right)^2\right]} \ldots\ldots\ldots\ldots\ldots\ldots\ldots..(2)$$

Where ℵ is the damping factor, if we make both the integrators input resistors and feedback capacitors the same, then the state variable corner frequency (f_c), can be easily tuned without affecting the overall Q. likewise the value of Q can be varied without altering the corner frequency. Then the corner frequency is given as:

$$2\pi f_c = \sqrt{\frac{R_3}{R_4(RC)^2}} \ldots\ldots\ldots\ldots\ldots..(3)$$

$$f_C = \sqrt{\frac{R_3}{R_4(2\pi RC)^2}} \ldots\ldots\ldots\ldots\ldots.(4)$$

Also, if we make feedback resistors $R_3 and\ R_4$ the same values, then the centre frequency of each filter output from the state variable filter simply becomes.

$$f_{c(HP)} = f_c(BP) = f_{c(Lp)} = \frac{1}{2\pi RC} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(5)$$

Then tuning the state variable corner frequency is accomplished simply by varying either the tuning resistor, R or the capacitor C.

For a bandpass filter.

$$Q = \frac{fc}{bandwidth(BW)} \ldots\ldots\ldots\ldots\ldots\ldots.(6)$$

$$Q = \frac{f_c}{BW} = \frac{1}{2\aleph} = \frac{R_1(R_3+R_4)}{R_4(R_1+R_2)}\sqrt{\frac{R_3}{R_4}\times\frac{RC}{RC}}$$

If the resistors $R_3\ and\ R_4$ are equal and both integrators, components R and C are equal, then the final square root expression would reduce to $\sqrt{1}$ or simply 1.

2.1 SIMULATION OF ACTIVE-RC BANDPASS FILTER USING COMPOSITE OP. AMP

The UHF, RFID backscatter frequency range for (860-960) MHz is (40-640) KHz. Therefore the design is done to cover the backscatter frequency range. The quality factor Q is chosen to be 30. If we let capacitor value C=InF, then we use equation 5 to determine the value of the resistor R to be
3.9kΩ for f_o=40kHz and then we assume the feedback resistors R_3 and R_4 to be the same and equal to 10kΩ. Again, if we assume a suitable value of the input resistor $R_1$of say 1kΩ, then we found the value of R2 from equation 7 to be 6.67kΩ. The process was repeated for Different values of centre frequencies of f_o = 107kHz, 160kHz, 256kHz, 320kHz and 640kHz.The calculated resistor values along with the preferred values are presented in Table 1. The filter was then simulated using NI Multism Version 14.2 simulation software and results read, recorded and presented on Table 2. The simulated magnitude response curves for the band pass filters are presented in Figs 2 to 8. Below

Fig 1: Second Order Bandpass Filter using Composite Operational Amplifier

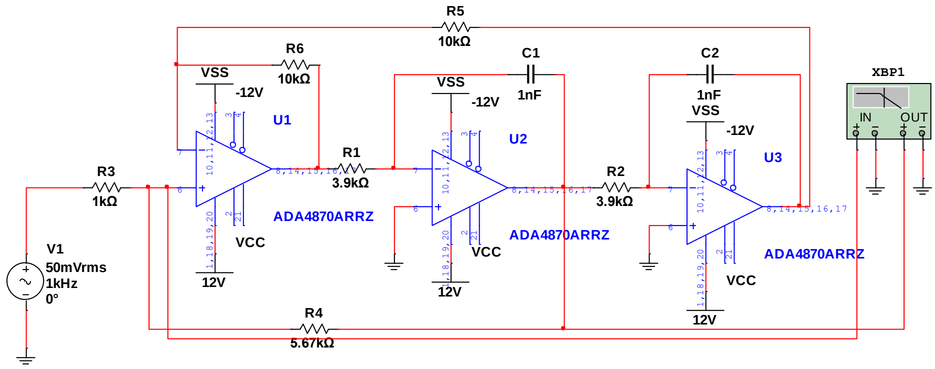

Table 1: Resistor values for calculated and preferred values

s/n	FLF (MHz)	BLF (KHz)	Capacitor Value (nF)	Calculated resistor values						Preferred Resistor Values.				
				R(kΩ)	R1(kΩ)	R2(kΩ)	R3(KΩ)	R4 (K.Ω)		R.(Ω)	R1(kΩ)	R2(kΩ)	R3(kΩ)	R4(kΩ)
1	860.00	40.00	1.00	3.90k	1.00	6.67	10.00	10.00		3.90k	1.00	6.67	10.00	10.00
2	880.00	107.00	1.00	1.49k	1.00	6.67	10.00	10.00		1.50k	1.00	6.67	8.66	8.66
3	900.00	160.00	1.00	994.59	1.00	6.67	10.00	10.00		1.00k	1.00	6.67	10.00	10.00
4	910.00	256.00	1.00	621.62	1.00	6.67	10.00	10.00		620.00	1.00	6.67	10.00	10.00
5	920.00	320.00	1.00	442.04	1.00	6.67	10.00	10.00		500.00	1.00	6.67	10.00	10.00
6	930.00	465.00	1.00	342.22	1.00	6.67	10.00	10.00		249.00	1.00	6.67	10.00	10.00
7	940.00	860.00	1.00	248.65	1.00	6.67	10.00	10.00		249.00	1.00	6.67	8.87	8.87

3. DESIGN EQUATIONS OF A MODIFIED UNIVERSAL ACTIVE-R BANDPASS FILTER

The design considered for this research is the work done by Ahmed, M., & Mahmoud, F. (1977) with a little modification. This was chosen because, its an active -R filter that realizes inverting bandpass and low pass transfer characteristics of any arbitrary gain at two different output terminals, at a third output terminal, a general biquadratic transfer characteristics was obtained, namely a non-minimum phase, a generalizes notch or a high pass transfer function. This architecture was particularly chosen since from available literature, it has not been found to be implemented in the UHF RFID systems.

A Circuit diagram for the second order Universal Active –R filter which was slightly modified is presented in Figure 1.

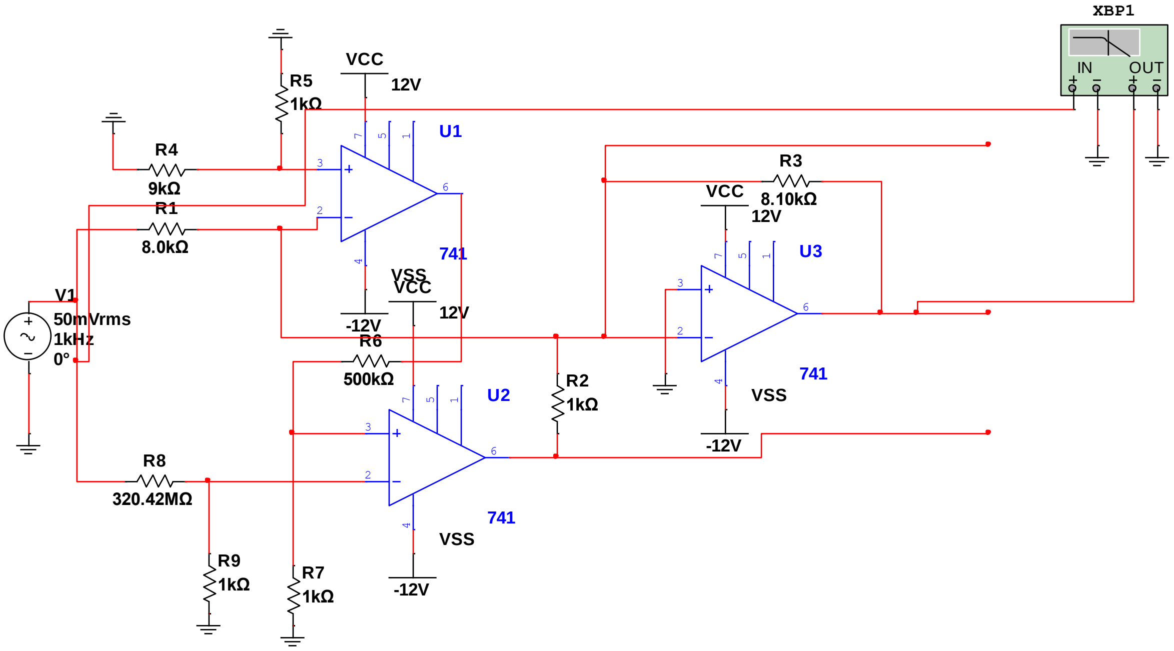

Fig. 2: A Modified Second Order Universal Active-R Filter

$$Ai = \frac{GBi}{s}(i = 1,23, \dots ..)\ (1)$$

Where the GB is the gain bandwidth product of the operational amplifier, the transfer function at different output terminals can be calculated by direct analysis as:

$$Ti(S) = \frac{V_2}{V_1} = K\frac{S^2 - S\left(\frac{W_z}{Q_z}\right) + W_z^2}{s^2 + s\left(\frac{W_p}{Q_p}\right) + {W_p}^2} \dots \dots \dots \dots .(2)$$

Where S=complex pole conjugate, W_z=frequency at zeros and Q_z=quality factor at zeros, W_p=pole frequency and Q_p= quality factor at pole.

Where the gain factor K=a/b ------ (3)

For a band pass realization, when

$\frac{V_2}{V_1}$ Represents a high pass filter ($i.e\ P = 0, n = 0$), then we consider the transfer function.

$$T_{2(S)} = \frac{V_3}{V_1} = \frac{-H_1.S}{S^2+S\left(\frac{W_P}{Qp}\right)+W_p^2} \dots \dots \dots \dots \dots (4)$$

Which represents a band pass filter where

$$H_1 = K.GB_2 \dots\dots\dots\dots (5)$$

The mid band pass is given by:

$$|G_O| = \frac{a}{b-a-1} = \frac{R_3}{R_1} \dots \dots \dots \dots .(6)$$

This can take any arbitrary value.

4.1 DESIGN EQUATIONS OF THE MODIFIED FILTER

For a band-pass filter design for a given centre frequency (fp), pole quality factor (Qp) and mid-band gain (|Go|), the resistor values can be calculated using the equations shown below.

$$\frac{R_3}{R_1} = |G_O| \dots\dots\dots\dots\dots\dots (7)$$

$$\frac{R_1}{R_2} = \frac{D-1}{|G_O|} - 1 \dots\dots\dots\dots (8)$$

$$\frac{R_6}{R_7} = \frac{f_{c2} \times f_{c2}}{{F_P}^2} . \left(1 - \frac{1+|G_o|}{D}\right) - 1 \dots\dots\dots (9)$$

$$\frac{R_3}{R_2} = D(1-K) - 1 \dots\dots\dots\dots\dots\dots\dots (10)$$

$$\frac{R_1}{R_2} = \frac{1}{K}\left(1 - K - \frac{1}{D}\right) \dots\dots\dots\dots.. (11)$$

$$\frac{R_6}{R_7} = \frac{F_{C_{i.}\ F_{C2}}}{{F_P}^2}\left(1 - K - \frac{1}{D}\right) - 1 \dots\dots\dots\dots\dots (12)$$

$$\frac{R_4}{R_5} = \frac{1}{K}\left[\frac{F_P}{F_Z}\right]^2 - 1 \dots\dots\dots\dots\dots . (13)$$

$$\frac{R_8}{R_9} = \frac{F_{C_2}}{F_2} . \frac{F_P}{K} . \left(1 - K - \frac{1}{D}\right) - 1 \dots\dots\dots . (14)$$

Where:

$$D = Q_{p \times} \frac{f_{c2}}{f_p} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (15)$$

$$F_{C_i} = \frac{GB}{2\pi}(i = 1,2,3 \dots\dots) \dots\dots\dots\dots\dots\dots\dots\dots.. (16)$$

Where a & b are the band pass coefficient, D is the damping factor and fci, fz, are the frequency of the op. amp.

In this design, it is proposed that a second order Active- R band pass filter for UHF RFID systems using the universal active-R filter circuit be considered. The filter is to reject all signals backscattered by the tag in the UHF region (40 kHz – 640kHz) for RFID systems, therefore the parameters used are K=0.1 a=1, b=10, Q_p=30, GB=5.0x10^6Hz and f_p=40kHz, 107kHz, 160kHz, 256kHz, 320kHz, 465kHz, and 640kHz.

The resistor values were then calculated using equations 7 to 16 as shown below.

K=0.1, a=1, b=10, Q_p=30, f_p=40x10^3Hz GB=50x10^6Hz $_3$

$$D = Qp - \frac{fc_3}{fp}$$

$$fci = \frac{GBi}{2\pi}(i = 1,2,3 \dots\dots)$$

$$fc_{3=\frac{5.0x10^6}{2\pi}=\frac{5.0x10^6}{2x3.142}=795798.1856}$$

$$D = 30 - \frac{795798.1856}{40X10^3}$$

$$= 30 - 19.895$$

$$= 10.105$$

$$\frac{R3}{R2} = D(1-K) - 1$$

$$= 10.105(1 - 0.1) - 1$$

= 10.105 (0.9) – 1

=9.0945 – 1

$$\frac{R3}{R2} = 8.0945 =\rightarrow R3 = 8.0945R_2$$

$$let\ R_2 = 1k\Omega = R_3 = 8.0945X1X10^3 = 8.0945K\Omega$$

$$\frac{R_1}{R_2} = \frac{1}{K}(1 - K - \frac{1}{D})$$

$$= \frac{1}{0.1}(1 - 0.1 - \frac{1}{10.105})$$

$$= \frac{1}{0.1}(1 - 0.1 - 0.099)$$

$$= \frac{1}{0.1}(0.801)$$

$$\frac{R_1}{R_2} = 8.01 \; but \; R_2 = 1\text{K}\Omega = R_1 = 8.0X \; 1K\Omega$$

$$= 8.0K\Omega$$

$$\frac{R_4}{R_5} = \frac{1}{K}\left[\frac{F_P}{f_z}\right]^2 - 1$$

$$= \frac{1}{0.1}\left[\frac{40000}{40000}\right]^2 - 1$$

$$= 9 = R_4 = 9R_5 Let \; R_5 = 1K\Omega$$

$$= R_4 = 9K\Omega$$

$$\frac{R_6}{R_7} = \frac{F_{C_{i.}} f_{c_2}}{{f_p}^2}\left(1 - k - \frac{1}{d}\right) - 1$$

$$= \frac{795798.1856.795798.1856}{40000^2}.\left(1.0.1 - \frac{1}{10.105}\right) - 1$$

$$\frac{R_6}{R_7} = \frac{6.33X10^{11}}{1600000000}.\left(1 - 0.1 - \frac{1}{10 - 105}\right) - 1$$

$$= 395.625.(1 - 0.1 - 0.09896) - 1$$

$$= 395.625.(0.80104) - 1$$

$$= 316.91145 - 1$$

$$\frac{R_6}{R_7} = 315.91 = R_6 = 315091R_7$$

$$Let \; R_7 = 1K\Omega$$

$$then \; R_6 = 315091K\Omega$$

$$\frac{R_8}{R_9} = \frac{F_{C_2}}{F_Z}.\frac{Q_Z}{K}.\left(1 - K - \frac{1}{D}\right) - 1$$

$$= 1.\frac{40X10^3}{0.1}.\left(1 - 0.1 - \frac{1}{10.10}\right) - 1$$

$$= 1.400000.(0.80104) - 1$$

$$= 320416 - 1 = 320415$$

$$\frac{R_8}{R_9} = 320415 = R_8 = 320415R_9$$

$$let \; R_9 = 1K\Omega$$

Then R_8= 320415X1KΩ

$$= 320415000$$

$$\approx 320.42M\Omega$$

$$R_1 = 8.0K\Omega, R_2 = 1K\Omega, R_3 = 8.10\text{K}\Omega, R_4 = 9\text{K}\Omega, R_5 = 1\text{K}\Omega, R_6 = 315.91\text{K}\Omega, R_7 = 1\text{K}\Omega, R_8 = 320.42\text{M}\Omega, R_9 = 1\text{K}\Omega. R_6 = 500\text{k}\Omega.$$

The resistor values were first calculated using a centre frequency fp = 40 kHz as presented above and then repeated for the other values of centre frequencies fp with the Qp, a, b, K, and GB remaining the same. The calculated resistor values and preferred values are presented on Table 2.

Table 2: Calculated Resistor Values (Active-R filter)

S/n	**FLF (MHZ)**	**BLF (KHZ)**	**Calculated Resistor Values**									**Preferred Resister Values**			
			R1 (kΩ)	R2 (kΩ)	R3 (kΩ)	R4 (kΩ)	R5 (kΩ)	R6 (Ω)	R7 (kΩ)	R8 **Ω**	R9 (kΩ)	R1 (kΩ)	R3 (kΩ)	R6 (**Ω**)	R8 (**Ω**)
1	860.00	40.00	8.00	1.00	8.10	9.00	1.00	315.91k	1.00	320.42	1.00	8.00	8.20	490..61	490.61 K
2	880.00	107.00	8.56	1.00	19.31	9.00	1.00	46.43K	1.00	915.00M	1.00	8.50	19.10	72.62	1.00T
3	900.00	160.00	8.60	1.00	21.53	9.00	1.00	20.27K	1.00	1.38T	1.00	8.66	21.50	30.12K	1.00T
4	910.00	256.00	8.63	1.00	23.20	9.00	1.00	7.34K	1.00	2.20T	1.00	8.66	23.20	12.13K	2.00T
5	920.00	320.00	8.64	1.00	24.10	9.00	1.00	3.22K	1.00	3.11T	1.00	8.66	24.00	7.32K	3.11T
6	930.00	465.00	8.59	1.00	24.46	9.00	1.00	1.52K	1.00	4.00T	1.00	8.59	24.46	3.00K	4.00T
7	940.00	640.00	8.65	1.00	24.90	9.00	1.00	337.00	1.00	5.54T	1.00	8.66	24.88	1.02K	5.00T

5.RESULT AND DISCUSSION

We have designed a second order Active-band pass filter using the composite operational amplifier and a slightly modified universal Active-R Bandpass filters at ultra-high frequency to reject frequencies outside the band and pass frequencies within the backscatter frequency (i.e. 40 KHz-640 KHz) band.

The calculated and preferred resistor values used in the design of both filters is shown on Tables 1 and 2 respectively. The Magnitude frequency response curves are shown in Figs 3and 4 below, while the results of the output Magnitude response are shown on Table 3 and 4 for the composite Op amp and universal active bandpass filters respectively.

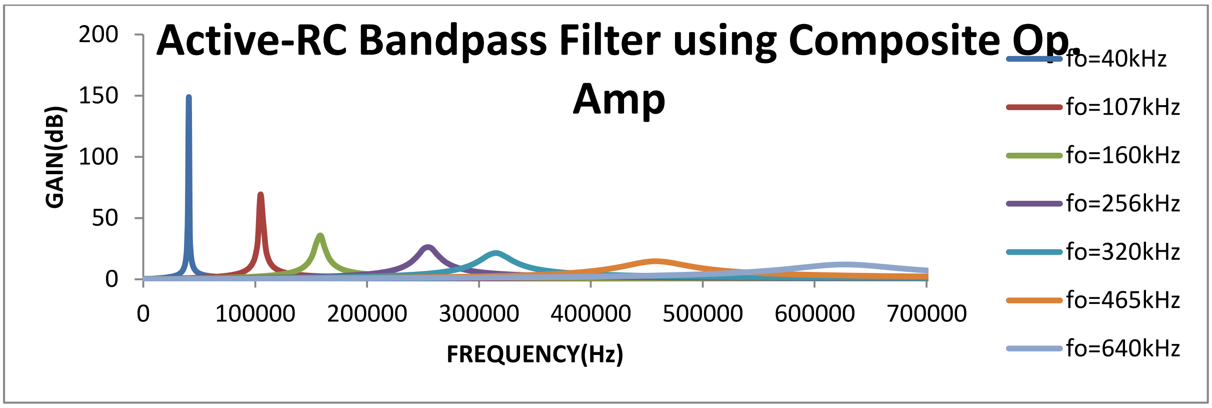

Fig. 2. Magnitude Response Curve for an Active-RC Bandpass filter using Composite Operational Amplifier.

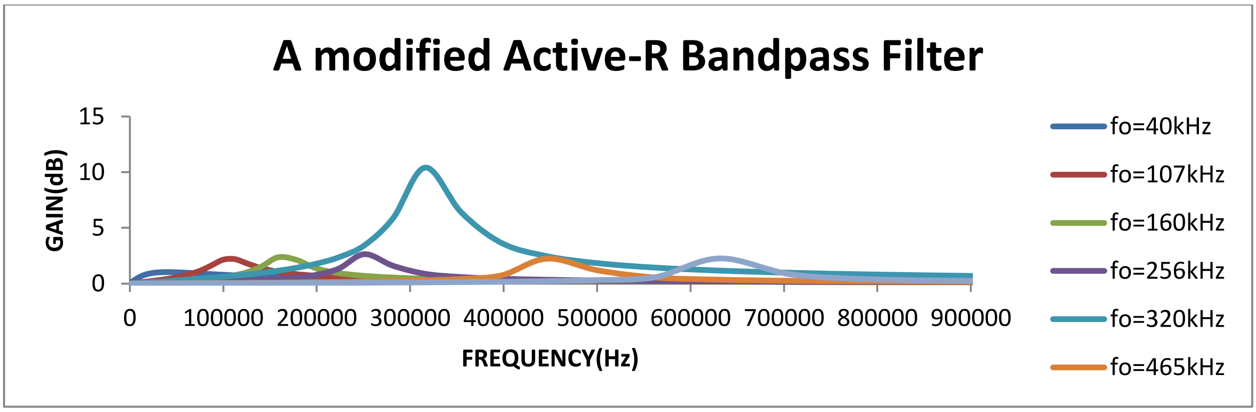

Figure.3. Magnitude Response curve for A Modified Universal Active-R Bandpass Filter

Table 3: Variation of functional properties (centre frequencies, mid-band gain, Bandwidth and Roll-off rate) of the designed Active-RC Bandpass filter using Composite Op. Amp.

S/N	**FLF (MHz)**	**BLF (kHz)**	**Centre freq (fo) (kHz)**	**Shifted Centre for (%)**	**Midband Gain (dB)**	**-3dB Gain (dB)**	**Upper cut-off Freq. (F_H)(kHz)**	**Lower cut-off Freq. (F_L)(kHz)**	**Bandwidth BW(F_H-F_L) (Hz)**	**Roll-off Rate dB/DECADE**
1	860.00	40.00	40.74	-1.85	148.89	145.89	41.69	40.74	950.00	-21.64
2	880.00	107.00	104.71	2.14	69.09	66.09	107.15	102.33	4.82k	-20.29
3	900.00	160.00	158.49	0.94	35.68	32.68	162.18	154.88	7.30k	-20.08
4	910.00	256.00	257.04	-0.41	25.58	22.58	263.03	245.47	17.56k	-20.10
5	920.00	320.00	316.23	1.18	21.33	18.33	323.59	296.03	27.56k	-20.10
6	930.00	465.00	457.09	1.73	14.66	11.66	478.63	436.52	42.11k	-20.66

7	940.00	640.00	630.96	1.41	11.98	8.98	676.08	575.44	100.64k	-20.84

Table 4: Variation of Functional Properties (centre frequencies (f_o), Midband gain, Bandwidth and Roll-Off Rate) of the designed Slightly Modified Universal Active-R Bandpass Filter

S/n	**FLF (MHZ)**	**BLF (kHZ)**	**Shifted centre frequency(kHz)**	**% shifted centre frequency**	**Mid band gain (dB)**	**-3db (dB)**	**Upper cut off frequency F_H (kHz)**	**Lower cut off frequency F_L (kHz)**	**Bandwidth Bld (F_H-F_L) (kHz)**	**Roll-off rate dB/decade.**
1	860.00	40.00	39.75	0.63	0.21	-2.79	119.91	13.56	106.35	-20.94
2	880.00	107.00	111.51	-4.21	6.82	3.82	132.75	85.85	46.90	-20.02
3	900.00	160.00	160.34	-0.21	7.35	4.35	188.13	144.84	43.29	-20.17
4	910.00	256.00	251.56	1.73	8.37	5.37	274.46	237.35	37.11	-20.62
5	920.00	320.00	318.92	0.34	8.25	5.25	341.29	298.01	43.28	-20.78
6	930.00	465.00	447.61	3.74	6.89	3.89	479.00	425.41	53.59	-22.02
7	940.00	640.00	632.00	1.25	6.12	3.12	661.02	606.02	54.31	-24.61

6.COMPARISON OF THE DESIGNED FILTERS PERFORMANCE

From Table 3, the result shows that the centre frequencies of the filters are all shifted. This shift, for all the centre frequencies are within a range of ±0.41% to ±2.14%, while Table 4, presents result from plots which shows that all the centre frequencies (Fp) from 40kHz to 640kHz are also shifted with a value of 39.75kHz to 632.00kHz respectively with a percentage shift of 0.63% to 1.73%. This result shows that in terms of shifting of the centre frequencies, the composite filter has the highest percentage than the universal Active-R filter; Even though, both filters are well accommodated in the EPC class1 Generation 2 Protocol for UHF RFID deployment, which specifies that deviations should not be outside ± 22%. The modified universal Active R bandpass filter performed better than the Active-RC bandpass filter using composite op. amp. This shift could be attributed to the value of resistors used since the calculated values of the resistors are not readily available.

Again, Table 3 shows the Midband gain of the filter decreased from a value of f_o = 40kHz at 148.89dB to 11.98dB at 640kHz. While Table 4 is observed to record low gain which increased gradually as the centre frequency increases from 40kHz to 256kHz with a value of 0.21dB to 8.35dB and then decreased from 320kHz to 640kHz with a value of 8.25dB to 6.12dB. The result obtained by the Active-RC bandpass filter using composite op amp conforms to filter theory from the behavior of the Midband gain while that of the modified universal active-R filter does not behave in conformation to filter theory which states that, as the centre frequency increases, the midband gain should be decreasing (Atsuwe, B.A., 2018; Atsuwe, et.al. 2021).Also, the Active-RC bandpass filter using composite op. amp recorded the highest gain of 148.89dB at fo=40kHz, while the modified universal Active-R bandpass filter which recorded its highest gain of 8.37dB at fo=256kHz.

This result also shows that the former performed better than the latter in terms of gain.

Furthermore, was observed from table 3 that, the roll-off rate of the Active-RC bandpass filter using composite op. amp from f_o= 40kHz approaches 21.64dB/decade all the way to 20.84 dB/decade at fo=640kHz, Showing a single pole, second order filter which is used for the design of this filter. The roll off rate for all the centre frequencies also approaches a single pole, second order filter as shown on Table 3. While Table 4 shows the roll-off rate of the modified universal Active-R filter which also approaches a single pole, second –order filter with a value of -20.94dB/decade at f_p=40kHz, -20.02dB/decade at f_p=107kHz, -20.17dB/decade at f_p=160kHz, -20.62dB/decade at f_p=256kHz, f_p=320kHz , -22.02dB/decade at f_p=465kHz and -24.61dB/decade at f_p=640kHz. The result confirms the type of op. amp used for the research.Both filters perform well in this respect.

The bandwidth of the filter increases from a centre frequency of f_o = 40kHz at 950Hz to f_o = 640kHz at 100.64kHz, showing an extended bandwidth of the filter in Table 3, which is one of the advantages of the composite operational amplifier. This also confirms filter theory that as centre frequency of filters increase, bandwidth also increase (Atsuwe, B.A.2018; Atsuwe, B,et al. 2021) unlike the modified universal Active-R bandpass filter in Table 4, that shows a decrease in the bandwidth of the filter from a value of 106.35 kHz at $f_p = 40kHz$ to a value of 37.11 kHz at f_p=256 kHz and then increases to 43.28 kHz at f_p=320 kHz to 54.31 kHz at f_p=640 kHz. The observed behaviour is irregular and only works from f_p=320 kHz to f_p=640 kHz. This behaviour could be attributed also to parasitic effects of the circuit which could be corrected with careful selection of circuit components.

The designed Active-RC bandpass filter using composite op. amp again performed better than the modified universal Active-R bandpass filter in terms of Bandwidth selection.

7.CONCLUSION

The second-order Active-RC bandpass filter using composite operational amplifier and a modified Active-R Bandpass filter has been designed, simulated and presented. From the output results shown on Tables 3 and 4, the former filter was found to conform to all the desired parameters of decreased mid band gain, increase bandwidth and roll-off rate that approached a single pole, second order filter, while the latter filter only performed well in terms of frequency shifting. Consequently, it can be concluded that the Active-RC bandpass filter using composite op.amp performed better, but both filters can be used in the UHF RFID application if care is taken in the selection of components and proper specification coupled with the right manipulative skills in filter design.

8.RECOMMENDATIONS

The filters designed and presented above all work in the UHF RFID range, but the centre frequencies were observed to be shifted. Therefore, it is recommended that components used shold be carefully selected to avoid shifting, also higher order of these filters should be implemented for analysis and operation in the lower frequency range (i.e LF, HF, e.t.c.)

9.Acknowledgements

I would like to sincerely appreciate my lovely and kind hearted wife Mrs. Aember Atsuwe for her understanding and support in the period of this research. It would not have been possible to carry it out without you. To my Beloved mother Mrs. Esther Kasevhemba Atsuwe for always availing me her quiet residence to do the write up when the lab work was over. Also to Emmanuella, Zita, Bernard and Melvin, you guys were supper awesome. Thank you

Also, I wish to state clearly that this research was self -sponsored, and that there is no clash of interest by anyone or anywhere.

References

K. V. S. Rao, P. V. Nikitin, and S. F. Lam, “Antenna design for UHF RFID tags: A review and a practical application”, *IEEE Trans. Antennas Propag.*, vol. 53, pp. 3870–3876, 2005.

J. R. Tuttle, “Traditional and emerging technologies and applications in the radio frequency identification (RFID) industry”, *Proc. IEEE RFIC Symp.*, pp. 5–8 1997.

Miss Zin Ma Ma Myo, Dr.Zaw Min Aung, Dr.Zaw Min Naing, “Design and Implementation of Active Band-Pass Filter for Low Frequency RFID (Radio Frequency Identification) System "Proceedings of the International Multi Conference of Engineers and Computer Scientists 2009 Vol I IMECS 2009, March 18 - 20, 2009, Hong Kong

Shahab Rooznow, Vahid Sohani, “Integrate Band-pass Filter Design for 13.56MHz RFID Reader”, Journal of Applied Sciences Research, 8(2): 1018-1025, 2012 ISSN 1819-544X This is a refereed journal and all articles are professionally screened and reviewed

Teryima D. Kureve, Johnson A. Mise, Benard A. Atsuwe," Implementation Of An Active RC Band-Pass Filter At Varying Quality Factors Using Matlab", International Journal Of Scientific & Technology Research Volume 3, Issue 5, May 2014 , ISSN: 2277-8616.

Abdul Hussein Adul Zehra Abd, “Design and simulation of 4th order active band- pass filter using multiple feedback and Sallenkey topologies "Journal of Babylon University/Engineering Sciences/ No.(2)/ Vol.(22): 2014.

Atsuwe, B. A. (2018). Design and simulation of eigth order Active-R Bandpass filter for UHF Radio Frequency Identification System using Biquadratic Topology. International journal of Research, 5(15), 1360-1368.

Atsuwe, B, Amah, A. & Igwe, G (2021). Synthesis of 8th order Active Bandpass filter for UHF Radio Frequency Identification systems using MFB Topology. International journal of Research & Scientific Innovation, vol. (viii) issue iii, p1-5.

Carlos, F.C (2009). Development of Receiver Algorithm for Radio Frequency Identification (RFID). Inst. of comm. and RF engineering Viena.

Hioashumura, M (1992). Active-R realization of current mode high pass filter. Int.J.Electron, 73:1279-1283.

Huelsman, L.P (1971). Equal valued capacitor Active-RC network realization of a 3rd order low pass Butterworth characteristics. Electron lette 7:291-293.

Hyong, K.K., Ra, J.B (1977). An Active-Biquadratic Building Block without External Capacitors. IEEE Transactions on Circuits and systems 24(12):689-694.

Mohan, N., Patil, R.L. (). Ripple pass function and their Active-R realization: Indian. J. Pure Appl. Phys. 30:749-750.

Shinde, G.N, Patil, P.B (2002). Study of Active-R Second order Active-R filter using feedback at non-inverting terminals Bull.Pure.Appl.Sci. 21:23-31.

Shinde, G.N., Mulaskar, D.D (2010). Electronically Tunable Current Mode Second order High Pass Filter with Variable Central Frequency (F0). (Progress in Electromagnetic Research Symposium Processing’s). -26Xian. Chin

W.B. Mikhael and s. Michael; composite operational amplifiers; Generation and finite gain appreciations IEEE trans circuits and systems CAS-34, n-5, pp449-459, May 1987.

Sun Zhi-Xiao (1983). Active-R filter: a new biquadratic with four terminals. Int.J.Electron.54:523-530.

Ahmed, M.S., and Mahmoud,F.((1977). A Universal Active-R Filter. Electronic Engineering Cairo University , Giza, Cairo, Egypt.

Kollomorgen, Gary, S. Generation of Programmable Composite Operational Amplifiers with CMOS Integrated Circuit, Mather’s Thesis, Naval Postgraduate School, Monterey, California, December, 1986.

Stout, D.F & Kaufman, F. Handbook of Operational Amplifier Circuit Design, McGraw Hill Inc. 1976.