Design and Implementation of Active Band-Pass Filter for Low Frequency RFID (Radio Frequency Identification) System

Miss Zin Ma Ma Myo, Dr.Zaw Min Aung, Dr.Zaw Min Naing

***Abstract*—In this paper, an active fourth order band-pass filter for RFID reader is designed and simulated. An active band-pass filter is required for the front-end system because all signals outside the (10-20) kHz time-varying signal backscattered by the tag need to be rejected. The filter is constructed from some given specifications, one of which is, that the filter needs to have a Butterworth response. The architecture that will be used is the Sallen-Key. The values for the passive components are calculated, and the circuits are then simulated with Circit Maker to reach the final conclusion which will describe the results of the simulations compared to MATLAB simulation results.**

***Keywords*—Band-pass filter, Butterworth response, Circuit Maker, MATLAB, RFID (Radio Frequency Identification), Sallen-Key.**

I. INTRODUCTION

Radio frequency identification (RFID) system is a wireless communication system that is used to identify tagged objects, people or animals. The area of applications for RFID is increasing rapidly. Applications incude 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.

RFID system consists of readers and a large number of tags. A tag has an identification number (ID) and a reader recognizes an object through consecutive communications with the tag attached to it. The reader sends out a signal which supplies power and instructions to a tag. The tag transmits its ID to the reader and the reader consults an external database with received ID to recognize the object. In this paper, RFID system is considered with 125 kHz, FSK modulation scheme.

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In the reader, the front-end system needs a RC filter, an active band-pass filter and an active low-pass filter to reject the undesired signals.

Filters are essential components in many electrical systems. In 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. All analog filters fall in one of two categories: passive or active. In this low frequency RFID system, active filters are used because of the following advantages:

-active filter can generate a gain larger than one.

-higher order filters can easily be cascaded since each Op-amp can be second order

-filters are smaller in size as long as no inductors are used, which makes it very useful as integrated circuits.

In this paper, an 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 (10-20) kHz signals and to amplify the low antenna signal. These are because the ID signals from the tag are 12.5 kHz and 15.65 kHz and signal power is very low.

The most common filter responses are the Butterworth, Chebyshev, 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 -40dB/dec and 40 dB/dec.

In the second section of this paper, the band-pass filter design will be determined with its specifications. And then implementation of 4^{th} order Butterworth band-pass filter design will be carried out in order to meet the design specifications. The third and final part of this paper, the comparison of the Circuit Maker simulation result and MATLAB simulation result will be discussed.

II. DESIGN CONSIDERATION

The architecture that has been used to implement the fourth order band-pass filter is Sallen-Key Topology. This was chosen because of its simplicity compared to other known architectures such as multipe feedback and state variable, where the latter is for precision perfomance. Butterworth filter response is used to get the maximum flat gain. The Active - RC Butterworth filters have a range of advantages when used for lower order of the filter: have excellent linearity, have low power dissipation and are easy to design and analyze. The filter response is insensitive to parasitic, and it has large Dynamic range.

A circuit diagram for second order Sallen-Key band-pass filter is shown in Fig.1.

Table.1 illustrates the specifications for the desired band-pass filter. By using the following filter parameters, the required filter can be designed and simulated with circuit maker and MATLAB.

III. DESIGN IMPLEMENTATION

The transfer function for the fourth order band-pass filter is: where

$$A(s) = \frac{\frac{A_{mi}}{Q_i}\alpha.s}{\left[1+\frac{\alpha.s}{Q_i}+(\alpha.s)^2\right]}\cdot\frac{\frac{A_{mi}}{Q_i}\alpha.s}{\left[1+\frac{1}{Q_i}\left(\frac{s}{\alpha}\right)+\left(\frac{s}{\alpha}\right)^2\right]} \quad (1)$$

- A_{mi} is the gain at the mid frequency, f_{mi}, of each filter
- Q_i is the pole quality of each filter
- α and 1/α are the factors by which the mid frequencies of the individual filters, f_{m1} and f_{m2}, are derived from the mid frequency, f_m, of the overall band-pass. Factor α needs to be determined through successive approximation, using the following equation.

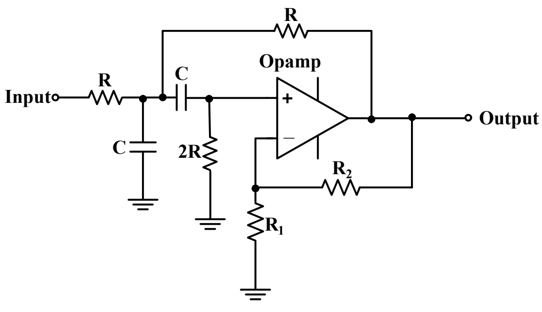

Fig.1. General architecture of a second order Sallen-Key filter

TABLE I. Band-pass Filter Specifications

Center frequency	15 kHz	
Pass band Frequency	10 kHz	20 kHz
Pass band Ripple	0.1dB	
Stop band Attenuation	60dB	
V_{p-p}	100µV	

$$\alpha^2+\left[\frac{\alpha\cdot\Delta\Omega\cdot a_1}{b_1\left(1+\alpha^2\right)}\right]^2+\frac{1}{\alpha^2}-2-\frac{\left(\Delta\Omega\right)^2}{b_1}=0 \quad (2)$$

where normalized bandwidth $\Delta\Omega=1/Q_{BP}$, (Q_{BP} is the overall quality of the filter), with a_1 and b_1 being the second-order low-pass coefficients of the desired filter type.

For Butterworth filter type,

- a_1=1.4142 and
- b_1=1

Fourth-order Butterworth Band-Pass filter with the following parameters:

Passband frequencies = (10-20) kHz

Mid – frequency of the overall filter , f_m = 15 kHz

Let overall gain at mid-frequency, A_m = 2

Bandwidth, BW = f_H-f_L = 10 kHz

$$Q_{BP} = \frac{f_m}{BW} = 1.5$$

By using equation (2),

α = 1.2711 is obtained.

After α has been determined, all quantities of the partial filters can be calculated as follows:

The mid frequency of filter 1 is:

$$f_{m1} = \frac{f_m}{\alpha} = 11.8 \text{ kHz}$$

The mid frequency of filter 2 is:

$$f_{m2} = f_m \cdot \alpha = 19.067 \text{ kHz}$$

The individual pole quality, Q_i, is the same for both filters:

$$Q_i = Q_{BP}\cdot\frac{\left(1+\alpha^2\right)b_1}{\alpha\cdot a_1} = 2.1827$$

The individual gain (A_{mi}) at the partial mid- frequencies, f_{m1} and f_{m2}, is the same for both filters:

$$A_{mi} = \frac{Q_i}{Q_{BP}}\cdot\sqrt{\frac{A_m}{b_1}} = 2.0579$$

For Sallen-Key achitecture, the required parameters can be calculated by the following equations:

mid-frequency: $f_{mi} = \frac{1}{2\pi RC}$

inner gain: $G = 1+\frac{R_2}{R_1}$

gain at f_m: $A_{mi} = \frac{G}{3-G}$

filter quality: $Q_i = \frac{1}{3-G}$

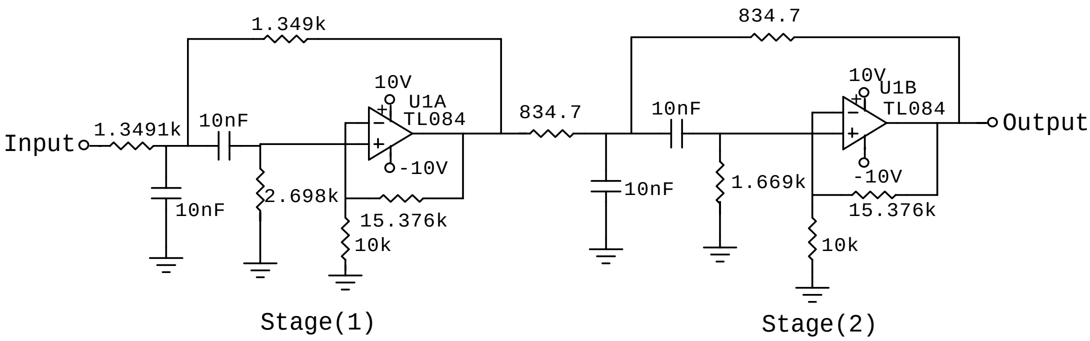

Fig.2. Schematic scheme of 4th order Butterworth Band-pass filter

To design the individual second-order band-pass filters, specifies C = 10 nF, the resistor values for both partial filters are calculated as mentioned below:

Filter 1:

$R = 1.3491\ k\Omega$

Let $R_1 = 10k\Omega$

$R_2 = 15.376\ k\Omega$

Filter2:

$R = 834.7\ \Omega$

Let $R_1 = 10k\Omega$

$R_2 = 15.376\ k\Omega$

The 4th order Butterworth band-pass filter is constructed from two non-identical 2nd-order sections shown in Fig.2.

The transfer function of that circuit is

$$H(s) = \frac{0.8889s^2}{s^4 + 0.9427s^3 + 3.4413s^2 + 0.9428s + 1}$$

By using the transfer function, the frequency response of the filter can be plotted using MATLAB to verify the design.

IV. SIMULATION RESULTS

The results of circuit maker simulation for the fourth order Active-RC Butterworth band-pass filter are shown in Fig.3. Fourth order Active - RC Butterworth filter design has passband frequencies 10 kHz and 20 kHz, passband gain of about 49 dBV and roll-off rates of -40dB/dec and 40dB/dec.

Also, Fig.4 illustrates the frequency response of the filter using MATLAB simulation method. It can be seen that the simulated response looks good and also looks familiar with the simulated response in MATLAB, and thereby decided to be implemented in the real world.

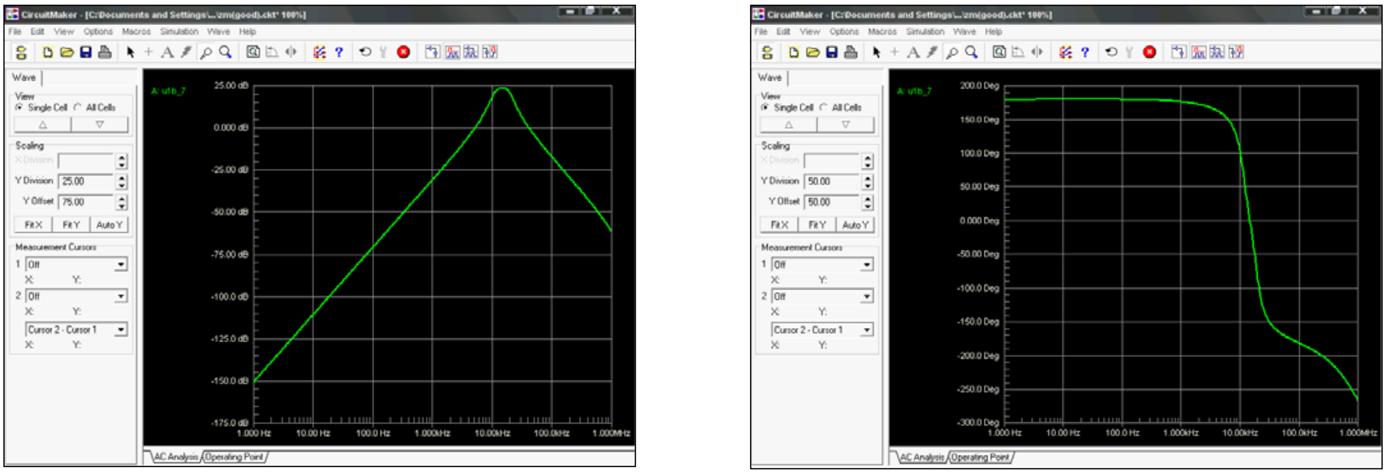

Fig.3. Simulated filter responses in circuit maker of fourth order Butterworth Band-pass filter; the left plot shows the filter magnitude response in dB and the right plot shows the phase function in degrees.

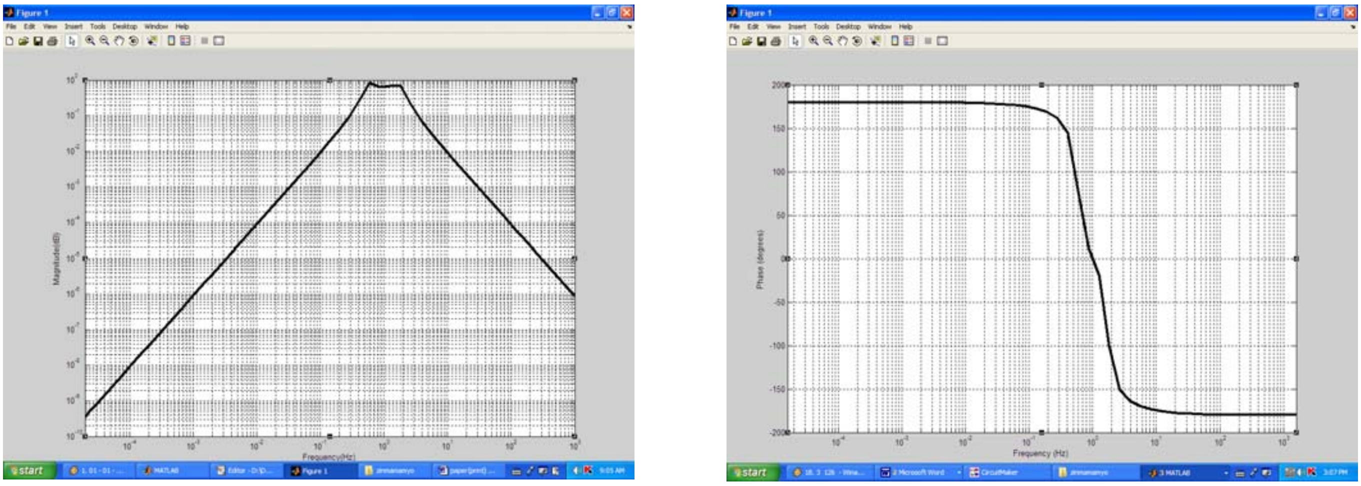

Fig.4. Simulated filter responses of fourth order Butterworth Band-pass filter by using MATLAB; the left plot shows the filter magnitude response in dB and the right plot shows the phase function in degrees.

V. CONCLUSION

Band-pass filter design and simulation for RFID system is presented in this paper. These circuits are composed of two Op-amps, ten resistors, and four capacitors. The amplifiers are based on the TL084 circuits as the gain element since this circuit is good for this RFID application. As the simulated results satisfy the system requirements, these circuit structures are suitable for RFID application. If more-accurate frequency response is required, more stages should be used.

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