FTFN BASED FILTERS DESIGNING AND ANALYSIS

A DISSERTATION

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE AWARD OF THE DEGREE
OF

MASTER OF TECHNOLOGY
IN
CONTROL AND INSTRUMENTATION

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2019

M. Tech (Control and Instrumentation) HEM PRABHA 2019

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I, Hem Prabha, Roll No. 2K17/C&I/06 student of M.Tech. (Control and Instrumentation), hereby declare that the project Dissertation titled "FTFN based filters designing and analysis " which is submitted by me to the Department of Electrical Engineering Department, Delhi Technological University, Delhi in partial fulfillment of the requirement for the award of the degree of Master of Technology, is original and not copied from any source without proper citation. This work has not previously formed the basis for the award of any Degree, Diploma Associate ship, Fellowship or other similar title or recognition.

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I, Hem Prabha, Roll No. 2k17/C&I/06 student of M. Tech. (Control &Instrumentation), hereby declare that the dissertation/project titled "FTFN based filters designing and analysis " under the supervision of Associate Prof. Ram Bhagat of Electrical Engineering Department Delhi Technological University in partial fulfillment of the requirement for the award of the degree of Master of Technology has not been submitted elsewhere for the award of any Degree.

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ACKNOWLEDGEMENT

I would like to express my gratitude towards all the people who have contributed their precious time and effort to help me without whom it would not have been possible for me to understand and complete the project.

I would like to thank Associate prof. Ram Bhagat, DTU Delhi, Department of Electrical Engineering, my Project guide, for supporting, motivating and encouraging me throughout the period of this work was carried out. His readiness for consultation at all times, his educative comments, his concern and assistance even with practical things have been invaluable.

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ABSTRACT

This thesis deals with the designing of filters using FTFN.As we know, there are many approaches to realize filters, we have adopted the device replacement method where the active device is replaced by FTFN.As FTFN has not been designed yet, therefore it is we realize it only by other devices like conveyors ,op amp & OTAs. We have realized FTFN using CFOAs(AD844) and further we are using this FTFN in designing of filters like bandpass, low pass & high pass filters. In designing of these second order filters, minimum number of components are used i.e. two capacitors and two resistors in different configurations to get the output .Two configurations of circuits has been designed where configuration 1 is an example of MISO system consisting of three inputs and one outputs whereas in configuration 2 ,we are using only one input to get the output to realize different filters.

CONTENTS

LIST OF FIGURES

LIST OF ACRONYMS

FTFN	Four terminal floating nullor
CCII-	Current conveyor second generation

CHAPTER 1

1.1 INTRODUCTION:

This section focuses on a filter designing to select or reject a particular frequency range.Voltage mode and current mode filters are getting popularity as it has an excellent feature in terms of low power consumption ,less circuitry ,less complexity ,larger bandwidth and wide dynamic range and linearity .

In past years ,many new active building blocks have been introduced which has brought revolution in terms of using less number of components used and also all the other parameters what a designer should take care of to have a performance of good quality.But still there are need of realizing new active building blocks to meet the requirements and specification what a designer is looking for while designing filters and also the advantages in terms of all the features listed above ,are also being considered .

1.2 FILTERS AND SIGNALS

In circuits, a filter is a circuit that changes any signal's amplitude and/or phase characteristics with respect to its frequency. A filter adds any new frequencies to the signal and will not alter the signal's component ranges, but will alter the amplitude of some frequency components and/or the phase relationships of those components In electronics, filters are usually used to connect signals within a specific frequency range and to dismiss all signals not within that frequency range. These filter kinds have a gain depending on the signal frequency. For instance, there is a circumstance where another unwanted signal with frequency f_1 has been polluted with a specific signal that is needed with frequency f_1 If the polluted signal at frequency f_2 passes through a circuit with very low gain compared to frequency f_1, the unwanted signal will be removed and the desired signal will remain. In this simple example, we are not concerned at any frequency about the gain of the filter, rather than at frequencies f_1 and f_2 . If f_2 is removed correctly compared to f_1, it can be regarded acceptable to operate the filter. However, it is possible to mention a filter gain at various distinct frequencies or for a frequency band. Filters are well-defined by their frequency signals, it makes sense that filters also have the greatest useful logical and graphical properties in the frequency domain .In particular, gain vs. frequency and phase vs. frequency curves are used to show filter features and are defined in the frequency domain as the most frequently used tools. In terms of its transfer function or network function, a filter's frequency-domain efficiency is described .This transfer function is the ratio of the Laplace transforms of its output signal and input signal. The transfer function H(s) of any filter can be written as:

$$H(s) = \frac{V_{OUT}(s)}{V_{IN}(s)}$$

where $V_{IN}(s)$ is the input signal voltage and $V_{OUT}(s)$ is the and output signal voltage and s being the complex frequncy variable. Transfer function defines the reaction of any filter to random input signal, but scientists are generally worried about its outcome on ongoing sinusoidal waves. The most important is the magnitude of the transfer function expressed as a frequency function, which shows the outcome of the filter at various frequencies on amplitudes of sine wave signals. By understanding the magnitude (or gain) of the transfer function at each frequency, we can decide how okay the filter can distinguish between signals at different frequencies.

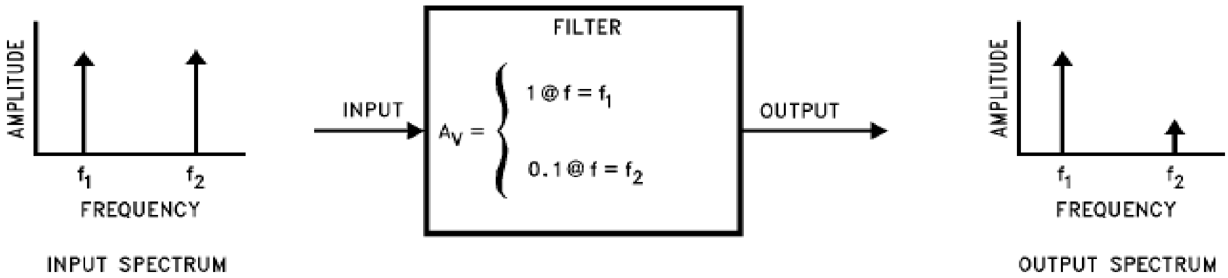


Fig. 1.1 Filter use to decrease the outcome of an unwanted signal at frequency f_2, though keeping wanted signal at frequency f_1

The transfer function magnitude vs freq. is known as the amplitude response or at times, specially in audio uses, the frequency response. In the same way, phase response of a filter describes the quantity of phase shift produced in sine wave as a function of frequency. As a variation in phase of any signal represents a variation in time, the phase features of a filter become particularly significant when working with the complex signals where time relations between signal components at diverse frequencies are serious. On replacing variable s with jω (j is equal to $\sqrt{-1}$ and ω is the frequency in radians (2πf)), we can determine the filter's result on the magnitude and phase of the input signal.

1.3 THE BASIC TYPES OF FILTERS

1.3.1 BANDPASS FILTER

Five common filter types are available, i.e. bandpass filter, notch filter, low-pass filter, high-pass filter, and all-pass filter. The quantity of probable bandpass response properties is infinite, but they all have the same basic form. Some examples of an amplitude responses for the bandpass filter are shown in Fig. 2. The curve in Fig.2(a) is called as an "ideal" response of the bandpass filter with fixed passband gain, zero gain after the passband, and a sudden boundary between the two passbands. This response characteristic is practically impossible to design, but it can be made by actual filters to variable degrees of correctness. Curves 2(a) to 2(f) are some bandpass response samples that estimate the ideal curve with variable degrees of accuracy. While some of the bandpass responses are having smooth curves, others in their passbands have ripple gaining differences. Some of them also have ripple in their stopbands. Stopband is defined as the frequency series in which unwanted signals are stopped. Bandpass filters always have two stop bands, one over the passband and the other under the passband.

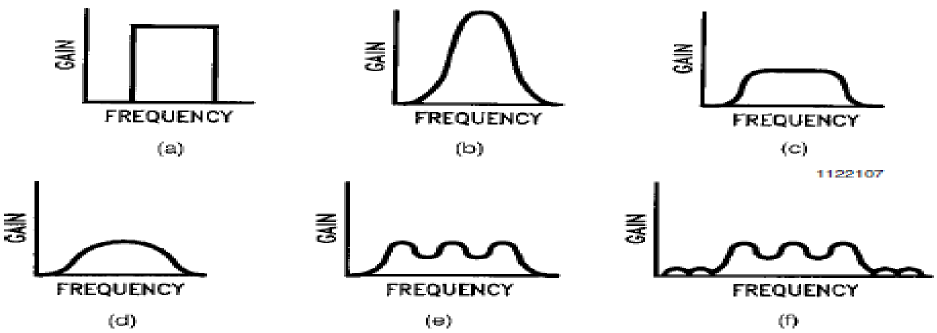


Fig. 1.2 Some examples of bandpass amplitude response curves

1.3.2 BAND REJECT FILTER

A filter having completely the opposite response of the bandpass filter is the notch or band reject filter. Band reject filters are useful in removing an undesired frequency from a signal, without touching other frequencies. Example of this band reject filter can be with an audio sequencer that is polluted by a 60 Hz power-line hum. A band reject filter having a cut off frequency of 60 Hz will remove the hum without affecting the audio signals.

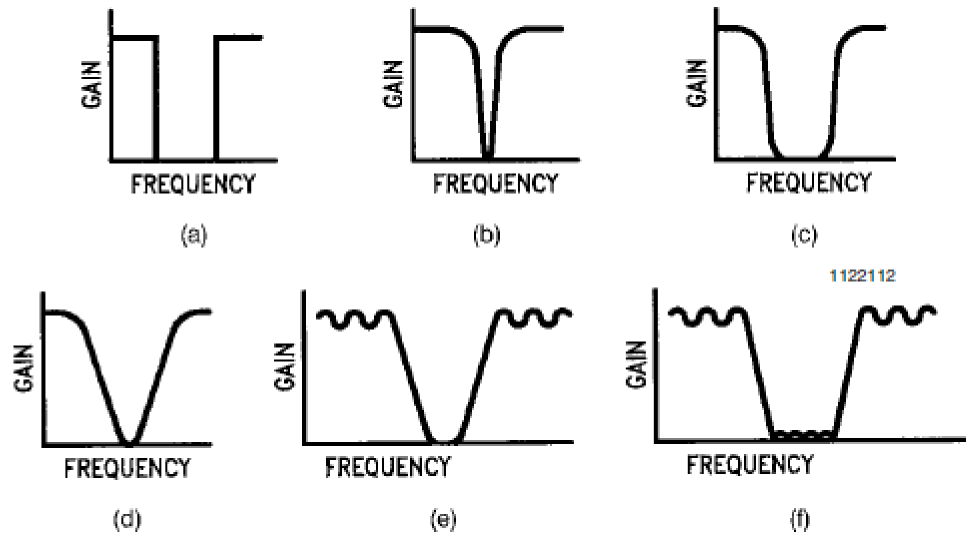


fig.1.3 Some examples of band reject filter response curves

1.3.3 LOW PASS FILTER

Another filter type is a low-pass filter. A low-pass filter permits low frequency signals to pass, and rejects signals of frequencies higher than the filter's crossover frequency. Low- pass filters are useful in rejecting the components of high frequency from the signal. Example can be seen in a light-sensing tool having a photodiode. If the level of light is low, the photodiode output will be very slight thus letting it to be partly covered by the sensor noise and amplifier, whose spectrum can be extended to high frequencies. A low-pass filter placed at the amplifier output having cutoff frequency lets the wanted signal frequencies to pass while removing the complete noise.

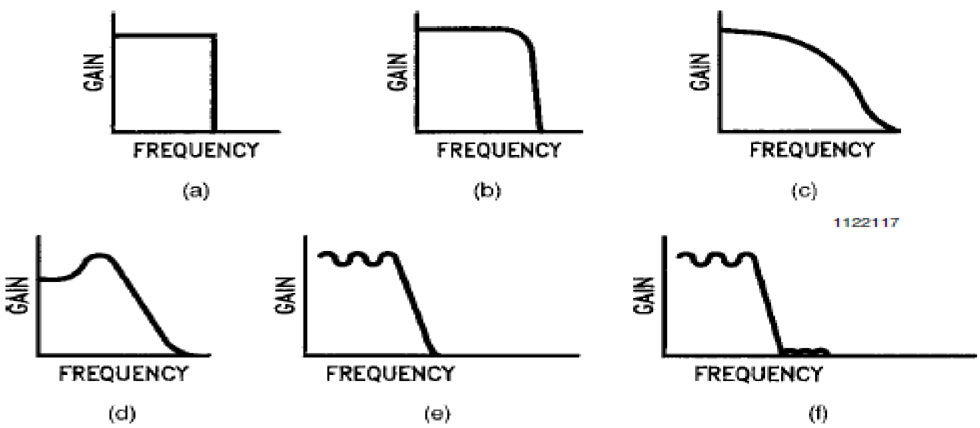


Fig.1.4 Some examples of Low-Pass Filter Response Curves

1.3.4 HIGH PASS FILTER:

The reverse of the low-pass filter is high-pass filter, which discards signals below its crossover frequency. High-pass find applications in needing the blocking of signals of low- frequency. One of the application is high reliability loudspeakers. Music comprises substantial energy in range from about 100 Hz to 2 kHz, but drivers of high-frequency gets damaged if audio signals of low frequency and insufficient energy appears at their input terminals. A high-pass among the broadband signal and tweeter input terminals can stop program material of low frequency from arriving at the tweeter. In combination with a low- pass for the low-frequency driver, the high-pass is portion of what is identified as a “crossover network”.

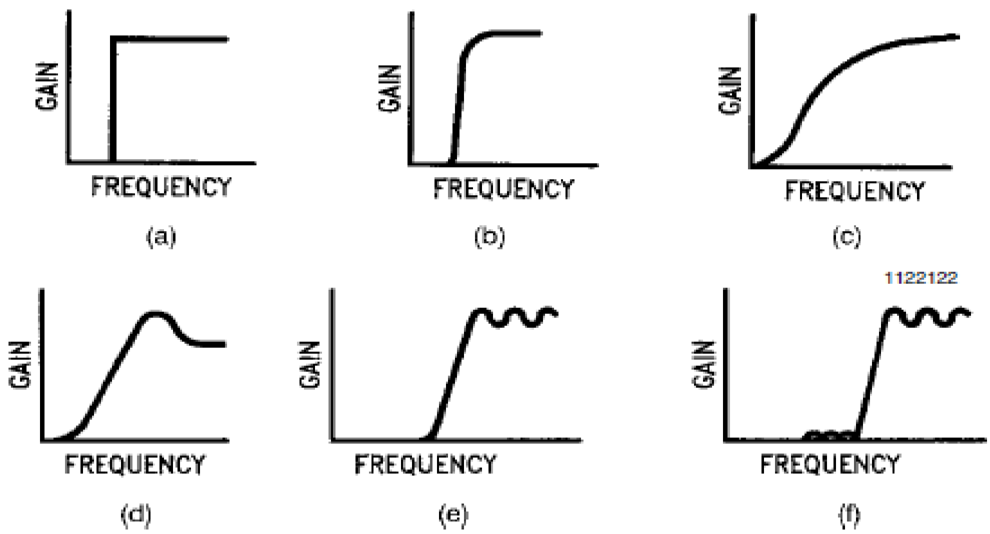


fig.1.5 Some examples of high-pass filter response curves

1.3.5 ALL PASS FILTER

The fifth response kind has zero effect on the amplitude of the signal at different frequencies. Its main purpose is to alter the phase of its signal without touching the amplitude. This filter is called a phase shift or an all-pass filter. The result of a phase shift is illustrated in Fig1.6.

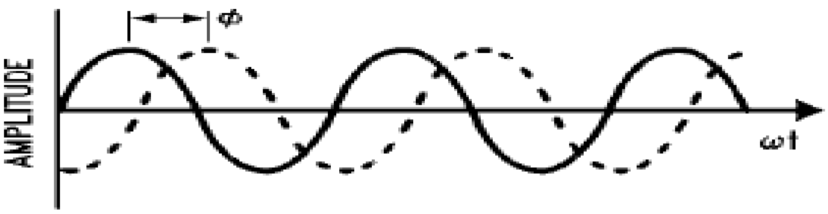


Fig.1.6 Two sine waves with phase difference θ.

Two sine waves, one in dashed lines and the other one is solid line, are revealed. The curves are alike but their peaks as well as their zero crossings of dashed curve befall at later periods than the solid curve. Thus, it can be said that the dashed curve has undertaken a delay time w.r.t the solid curve.

1.4 ORGANIZATION OF THESIS

The thesis is organized as follows

Chapter 1 present the overall introduction regarding the project and the offers overall summary regarding a number of the active building blocks and the basic filters .This additionally consists of the objectives of the thesis and organization of the thesis work.

Chapter 2 presents the literature review that is on the previous work of the research scholars in the relevant field. FTFN is utilized in this thesis for realizing different kind of filters. This chapter additionally introduces works outlined to this point.

Chapter 3 presents FTFN and its realization is discussed .

Chapter 4 presents FTFN based filters designing and analysis.

Chapter 5 presents FTFN results and discussion.

Chapter 6 presents conclusion and future work with FTFN.

CHAPTER 2

LITERATURE REVIEW

NISAR AHMAD SHAH AND MOHMAD AMIN MALIK[1] presented a novel voltage/current-mode universal filter configuration using one each of FTFN and CFA. Advantages like versatility to synthesize all the standard filtering functions in both CM and VM from the same topology, lowoutput impedance in case of voltage-mode configuration which permits easy cascading,low active and passive sensitivity figures has been observed.

MUHAMMAD TAHER ABUELMA'ATTI AND HUSAIN ABDULLAH AL-ZAHER [2]presented current mode sinusoidal oscillator**.** The proposed circuits use single four-terminal floating nullor and,at most, eight passive elements. Two of the oscillator circuits use grounded capacitors and enjoy the independent grounded-element control of the frequency of oscillation and the condition of oscillation.

CHUN-LI HOU, ROKIE YEAN AND CHIEN-KUO CHANG[3] presented sinusoidal oscillators using single FTFN.Six different types of oscillators has been represented in this paper with all the grounded or virtually grounded capacitors .Four of the oscillators enjoy independent oscillation and frequency control .

D.R. BHASKAR[4] presented single resistance controlled sinusoidal oscillator using single FTFN. The proposed structure offers very good frequency stability ,use of two grounded capacitors, low passive and active sensitivities and oscillation control through a grounded resistor.

M.T. ABUELMA'ATTI[5] presented cascadable current mode filters using single FTFN. A new configuration for realising cascadable second orderlowpass, highpass, bandpass, notch and allpass cunent mode filters has been presented. The proposed realisations use asingle FTFN and have low active and passive sensitivities. While the notch and allpass realisations require six passive elements, the lowpass, highpass and bandpass realisations require only five passive elements.

HUIREM TARUNKUMAR, ASHISH RANJAN, NONGLEN MEITEI PHEIROIJAM [6]presented fourth order bandpass and allpass filter using Four Terminal Floating Nullor (FTFN) where the selection of input sections provides the output filter function. The proposed filter uses single FTFN with four resistors and four capacitors and does not required component matching. The filter circuit is simulated using commercially available AD844 and CMOS technology with 0.35 µm based FTFN design.

WORAPONG TANGSRIRAT, SUMALEE UNHAVANICH ,TEERASILAPA DUMAWIPATA AND WANLOP SURAKAMPONTORN[7] presented a circuit configuration for the realization of a four-terminal floating nullor with electronically tunable current gain. It mainly consists of an opamp in input together with two complementary current mirrors with controlled gain and two standard improved Wilson current mirrors. The validity of the performance of the scheme is verified through PSPICE simulation results.

UGUR CAM ,OGUZHAN CICEKOGLU, ALI TOKER AND HAKAN KUNTMAN [8]presented current mode high output impedance multifunction filters employing minimum no.of FTFNs. All circuits employ two capacitors and three resistors.The proposed topologies simultaneously realize three basic filtering functions using minimum number of FTFNs and provide high output impedances that enable easy cascading in current mode.

NISAR AHMAD SHAH AND MOHMAD AMIN MALIK[9] presented FTFN based voltage mode filter The circuit employs only one FTFN, two capacitors, two resistors and one voltage follower which are absolute minimum requirement for this class of filter.In this,they used negative ftfn whose current directions are different from the positive FTFN.

SHEN-IUAN LIU[10] presented a new single-resistance-controlled sinusoidal oscillator using two four-terminal floating nullors (FTFNs) . The proposed oscillator having good frequency stability, single-element-controlled ability and low passive and active sensitivities has been designed. Only grounded capacitors have been used in this oscillator and its oscillation frequency independently controlled by a grounded resistor.

OGUZHAN CICEKOGU[11] presented multifunction filters using three current conveyors. A new current conveyor based filter topology with ten different realisation possibilities, using only positive type second generation current conveyors and only grounded passive components. For all possibilities, no element matching conditions are imposed. The filters permit orthogonal adjustment of quality factor Q and resonant angular frequency . All circuits exhibit high input impedance thus enabling easy cascadability. The passive sensitivities are shown to be low.

WORAPONG TANGSRIRAT[12] presented a circuit having two inputs and two outputs employing only four dual-output current-controlled conveyors (DO-CCCIIs) and two grounded capacitors to design a presented a current-tunable current-mode multifunction filter. By suitably connecting the input and output , the proposed circuit can give lowpass, bandpass, highpass, bandstop and allpass current responses. The filter is provided with an independent electronic control of the natural frequency and the quality factor (Q) through changing the bias currents of the DO-CCCIIs.The characteristics of the proposed circuit are simulated using PSPICE to confirm the theory.

A. AWAD AND A. M. SOLIMAN[13] presented the voltage mirror and the current mirror , two pathological elements to represent active devices featuring voltage or current reversing properties. The properties of these ideal elements are presented and it is demonstrated that they form a complete set analogous to that formed by the nullator and the norator.

D.G. HAIGH, F.Q. TAN AND C. PAPAVASSILIOU[14] presented how some basic building blocks for active-RC circuit design, such as amplifiers, impedance converters and simulated inductance circuits, may be synthesized in a systematic way by expansion of their port admittance matrices. The circuit topology emerges from the synthesis procedure, allowing all possible implementations to be identified and explored. Nullors representing ideal op-amps and transistors are represented within the nodal admittance matrix of a synthesized circuit by linked infinity parameters. In nodal admittance matrices describing ideal circuits synthesized, the replacement of linked infinity parameters by finite parameters provides a seamless transition to non-ideal analysis and practical circuit design.

Hung-Yu Wang Sheng-Hsiung Chang Yuan-Long Jeang Chun-Yueh Huang[15] presented The rearrangement of mirror elements has been presented. By virtue of the proposed approach, new topologies realizing the same transfer function as the initial circuit can be obtained. Moreover, we may derive the circuits with improved properties than the original circuit. A practical example has been given to demonstrate the feasibility.

Ahmed M. Soliman[16] presented a new generation method of the grounded capacitor Wien oscillator circuits using current conveyors (CCII) or inverting current conveyors (ICCII) or combination of both of them. The nodal admittance matrix (NAM) of the single Op Amp Wien oscillator is taken as the starting point in the new approach of systematic synthesis of equivalent oscillators. The synthesis procedure is based on the generalized systematic synthesis framework using NAM expansion. The resulting derived 32oscillators include many novel oscillators, using current conveyors or inverting current conveyors or both. Comparison between the generated oscillators based on the effect of parasitic elements on the oscillator performance is discussed.

Kapil Dev Sharma, Kirat Pal, Costas Psychalinos [17] presented A new first order all-pass filter topology realized using current controlled current conveyors (CCCIIs) is introduced in this paper. Offered benefits are the high-impedance of the input node, the absence of external resistors because of the usage of CCCIIs with positive and negative intrinsic resistances, the presence of only grounded capacitors, and the capability of electronic adjustment of the phase shift through single bias current. The correct operation of the introduced topology is conformed through simulation results, while its behavior is evaluated through comparison results.

JOHAN H. HUIJSING AND JACOB DE KORTE [18] presented The element consists of a differential input stage, a symmetrical level shift stage, and a differential output stage. In the latter stage the collectors of a long-tailed transistor pair function as a pair of connected vessels for the output currents at high common-mode output impedance. This gives the output port its floating character. The element is capable of conveying a potential from one input terminal to the other input terminal and a current from one output terminal to the other output terminal at an accurate unity gain. The total inaccuracy of these operations is in the order of 2 X 10-4 at signal voltage levels of 1 V and 1 mA. The element has a bandwidth of 25MHz and can handle maximum signal values of 10 V and 1 mA. The availability y of such universal active elements makes it possible to minimize the number of active elements and passive precision elements in implementations of analog system functions.

Mohd Amin Malik [19] presented A new configuration realizing current/voltage-mode (CM/VM) universal filter using two four terminal floating nullors (FTFN) and four passive components is presented. The current-mode configuration has single input and three outputs and realises simultaneously lowpass (LP), bandpass (BP) and highpass (HP) responses from which allpass (AP) and notch functions can also be implemented. The voltage-mode filter has three inputs and two outputs and can be configured to realise all the five filtering functions. The circuit in current-mode uses grounded capacitors which are ideal for monolithic integration. Besides using a bare minimum number of passive components, the topology enjoys low active and passive sensitivity figures. Experimental and PSPICE simulation results are also included.

Recai Kilic [20] presented realization of the autonomous Chua circuit using FTFN is presented. In this realization, a new version of the autonomous Chua circuit has been considered using FTFN-based active circuit topologies both the nonlinear resistor, namely Chua's diode and inductor element. The presented modifications provide an alternative solution to the integration problem of the chaotic circuits using CMOS VLSI technologies. The performance of the proposed inductor less Chua circuit is demonstrated with PSpice simulations.

Ashish Ranjan and Sajal K. Paul [22] presented multi-input single-output (MISO) second-order active-C voltage mode (VM) universal filter using two second-generation current-controlled current conveyors (CCCIIs) and two equal-valued capacitors. The proposed circuit realizes low pass, band pass, high pass, all pass, and notch responses from the same topology. The filter uses-minimum number of passive components and no resistor which is suitable for IC Design. The filter enjoys low-sensitivity performance and exhibits electronic and orthogonal tunability of pole frequency ($\omega 0$) and quality factor ($Q0$) via bias current of CCCIIs. PSPICE simulation results confirm the theory.

CHAPTER 3

3.1 INTRODUCTION

With increasing opportunities, the present mode strategy of developing analog integrated is becoming increasingly essential. The almost real supplementary transistors are being created ,opening the way for effective present mode systems to be designed.The presen t mode processinghas potential benefits over the voltage mode such as wider bandwidth, alm ost autonomous of the gain of the closed loop.Wider dynamic range with a very high slew rate, lower power consumption and simpler circuitry.

As a result several old current mode techniques are being reinstated and a new generation of current mode building blocks and systems are being developed aiming to overcome the conventional op-amps limitations, which one of them will replace the op-amps is clear at present. Among these, however, the FTFN seems to be very promising, and extremely powerful device combining both voltage mode and current mode capabilities. In fact, most of the devices proposed in both the academics and industry an be configured using the FTFN. For example, the minus type second generation current conveyor CCII- which proved to be very promising device is only a special case of FTFN. This implies that the most versatile and flexible active device has to be a practical implementation of FTFN.

The FTFN, described as the elemental active device or the ideal amplifier, was first implicitly introduced in 1954 by Tellengen. It was demonstrated that any active circuit can be realized using only such element and passive components. This universal active network element was called Nullor in 1964 by Carlin. It comprises an input Nullator (V_1=0, I_1=0) and norator at the output port with arbitrary (V_2 & I_2). It is known as nullor shorting and norator nullor pair.Also, since the four terminals of the nullor are isolated from ground(floating) and to be distinguished from the three terminal nuller of which is associated with a grounded terminal, this nullor is commontly referred to as four terminal floating nullor.

3.2 FTFN

The fourth floating nullor terminal is a four-terminal active block (X, Y, Z, W). The four-terminal-floating-null (FTFN) is a conceptual nullor generalization with all four terminals floating with the ground terminal being taken as an external. This concept is similar to the operational floating amplifier introduced. This implementation is based on the identification that a CCII is a three terminal nullor using the identity of nullor; two CCII can be linked properly to represent an FTFN. By the way, if CCII-is replaced by CCII+, the modified circuit still has an FTFN and can now be realized with two AD844 ICs. FTFN was identified in the literature as a universal construction block..

3.3 THE FTFN REALIZATIONS

Since its introduction in the sixties the FTFN remain the theoretical element used only in circuit theory books. Recently, however after the improvement of complementary transistor fabrication and the current mode circuit evolution, the FTFN implementation has become feasible. Thus, it is moving from being a theoretical element to that wide range of possible application.

At present the FTFN is not yet commercially available, however several techniques of realising the FTFN utilising the available devices have been suggested. There are possible candidate for the implementation of the FTFN as a discrete element.

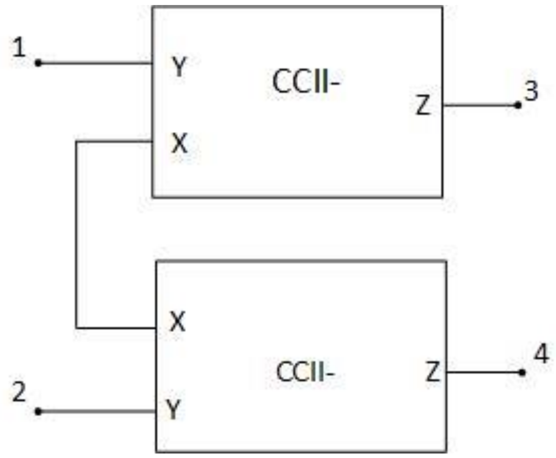


Fig. 3.1 Structure of FTFN using CCII-

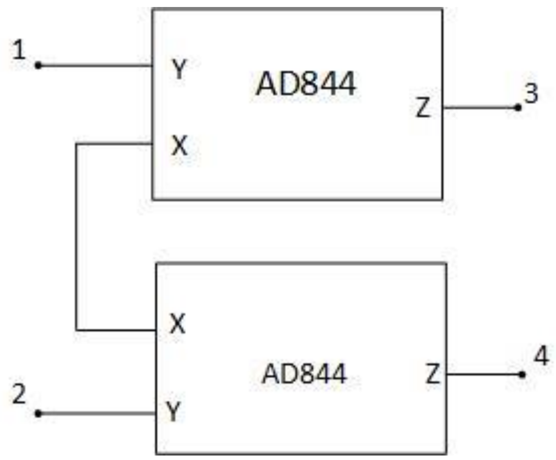


Fig. 3.2. Structure of FTFN using AD844

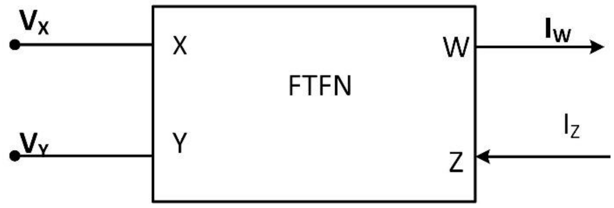


Fig.3.3.Structure of FTFN

CIRCUIT DESCRIPTION:

The fourth terminal floating nullor is an active block with four terminals (X,Y,Z,W).Its circuit symbol and its realisation using AD844 ICs are shown in figure. The port relations can be classified as

$I_X= I_Y= 0$, $V_X=V_Y$ and $I_Z= \pm I_W$.

From the above port relations, it is evident that the input impedence of port X and port Y are infinite while output impedence of ports Z and W are arbitrary. There are two types of FTFN that can be realized

1) Positive FTFN

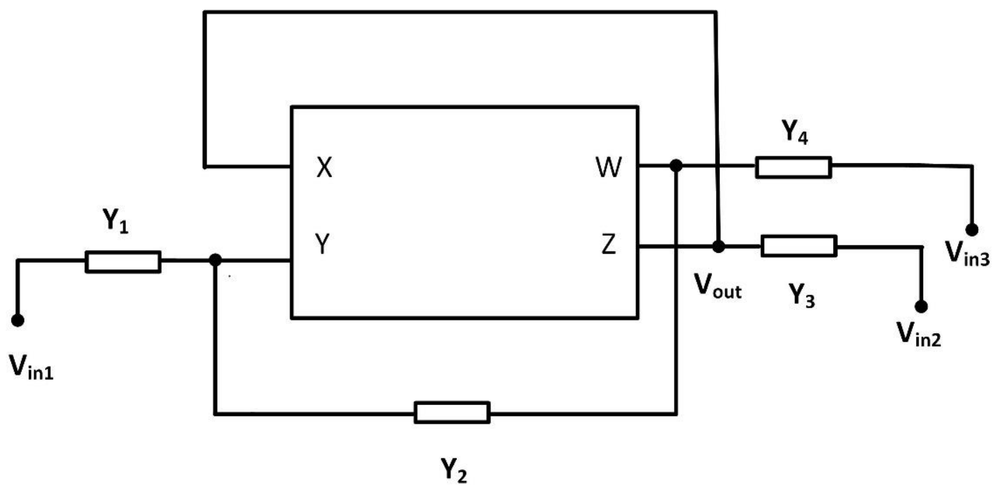
2) Negative FTFN

These both FTFNs are different from each other only by the directions of currents at the w and z terminals.

CHAPTER 4
REALIZATION OF FILTERS USING FTFN

A filter is a circuit that changes any signal's amplitude and/or phase characteristics with respect to its frequency. A filter adds any new frequencies to the signal and will not alter the signal's component ranges, but will alter the amplitude of some frequency components and/or the phase relationships of those components In electronics, filters are usually used to connect signals within a specific frequency range and to dismiss all signals not within that frequency range.
In this thesis we have designed three types of filters;
High pass filter is a electronic filter that passes signals with a frequency higher than a certain cut off frequency and attenuates signals with frequencies lower than the cut off frequencies.
Low pass filter is a electronic filter that passes signals with a frequency lower than a certain cut off frequency and attenuates signals with frequencies higher than the cut off frequencies.
Band pass filter that passes frequencies with in a certain range and rejects frequencies outside that range

4.1 FTFN BASED FILTER CONFIGURATION 1



Fig(4.1).Second order filter prototype using FTFN

Transfer function for the above circuit is given as follows:
At node 1

$$(V_{OUT} - V_{IN})y_1 + (V_{OUT} - V_1)y_2 = 0 \tag{4.1}$$

At node 2

$$(V_1 - V_{OUT})y_2 + (V_1 - V_{IN1})y_4 - I_W = 0 \tag{4.2}$$

At node 3

$$(V_{OUT} - V_{IN2})y_3 + I_Z = 0 \tag{4.3}$$

From eqn (4.2) & (4.3)

$$(V_1 - V_{OUT})y_2 + (V_1 - V_{IN1})y_4 = (V_{IN2} - V_{OUT})y_3 \tag{4.4}$$

From eqn (4.1) & (4.4)

$$V_{OUT}(y_1y_2 + y_1y_4 + y_2y_4 + y_2y_3) = (y_1y_2 + y_1y_4)V_{IN} + (y_2y_3)V_{IN1} + (y_2y_4)V_{IN2} \tag{4.5}$$

$$V_{OUT} = \frac{(y_1y_2 + y_1y_4)V_{IN1} + (y_2y_3)V_{IN2} + (y_2y_4)V_{IN3}}{(y_1y_2 + y_1y_4 + y_2y_3 + y_2y_4)} \tag{4.6}$$

Now take,

$$y_1 = G_1$$
$$y_2 = sC_2 \tag{4.7}$$
$$y_3 = sC_3$$
$$y_4 = G_4$$

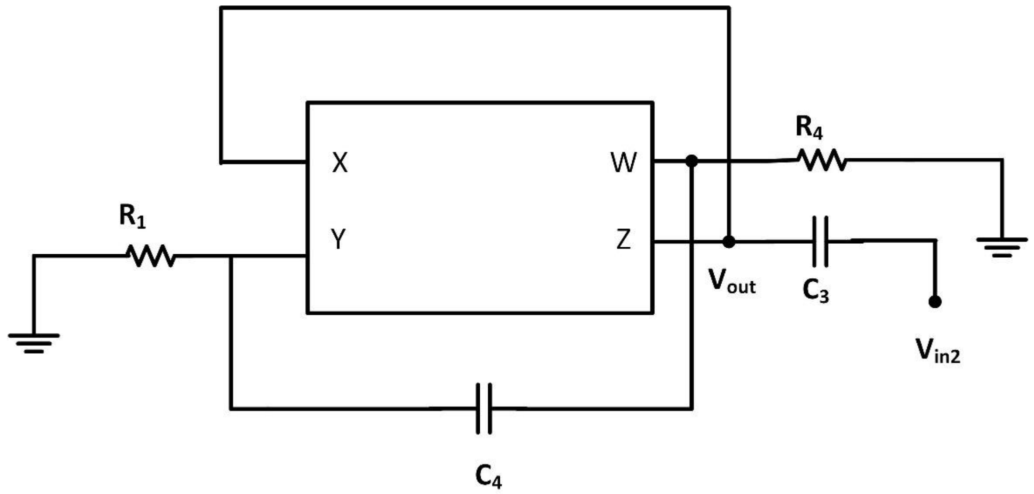
$$V_{OUT} = \frac{(G_1sC_2 + G_1G_4)V_{IN1} + (sC_2G_4)V_{IN3} + (sC_2sC_3)V_{IN2}}{(G_1sC_2 + G_1G_4 + sC_2G_4 + sC_2sC_3)} \tag{4.8}$$

OR

$$V_{OUT} = \frac{(R_4sC_2 + 1)V_{IN} + (s^2C_2C_3R_1R_4)V_{IN2} + (sC_2R_1)V_{IN3}}{(s^2C_2C_3R_1R_4 + sC_2(R_1 + R_4) + 1)} \tag{4.9}$$

CASE – 1

FOR HIGH PASS FILTER



Fig(4.2).Second order high pass filter using FTFN

If we take, $y_1 = G_1$, $y_2 = sC_2$, $y_3 = sC_3$, $y_4 = G_4$, $V_{IN} = 0$ & $V_{IN3} = 0$, then transfer function will become

$$V_{OUT} = \frac{(\, s^2 C_2 C_3 R_1 R_4) V_{IN2}}{(s^2 C_2 C_3 R_1 R_4 + sC_2(R_1 + R_4) + 1)} \tag{4.10}$$

Transfer function of high pass filter is given by

$$\frac{V_O}{V_{IN}} = \frac{s^2\, H}{s^2 + \ (\omega_O/Q)\, s + \ \omega_O^2} \tag{4.11}$$

By comparing eqn (4.10) & (4.11),we will get the filter parameters as

FREQUENCY

$$\omega_O = \frac{1}{\sqrt{C_2 C_3 R_1 R_4}} \tag{4.12}$$

$$f = \frac{1}{2\pi\sqrt{C_2 C_3 R_1 R_4}}$$

QUALITY FACTOR (Q)

$$Q = \sqrt{\frac{C_3 R_1 R_4}{C_2}} * \frac{1}{(R_1+R_4)} \tag{4.13}$$

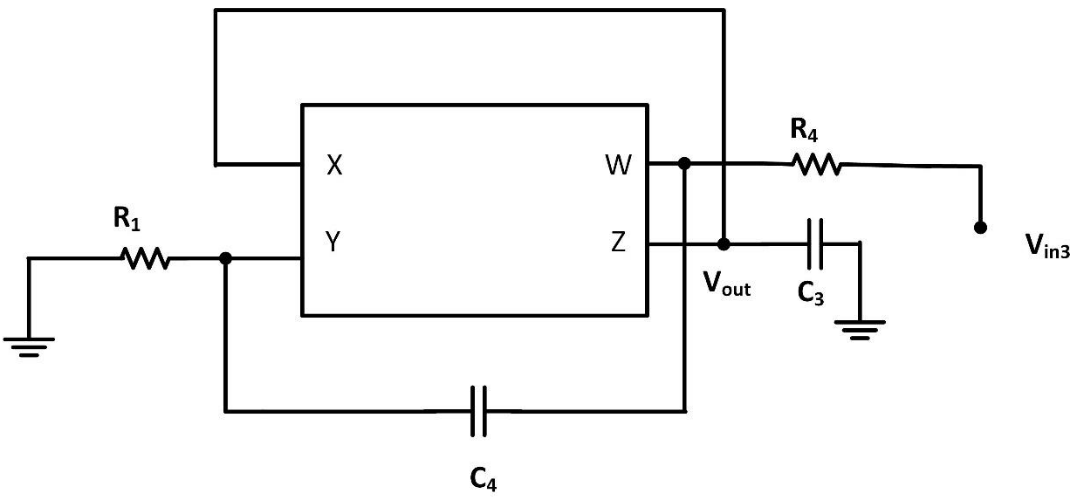
GAIN

$$H = \frac{(C_2 C_3 R_1 R_4)}{(C_2 C_3 R_1 R_4)} \tag{4.14}$$

H = 1

CASE – 2

FOR BAND PASS FILTER



Fig(4.3).Second order bandpass filter using FTFN

If we take, $y_1 = G_1$, $y_2 = sC_2$, $y_3 = sC_3$, $y_4 = G_4$, $V_{IN} = 0$, $V_{IN2} = 0$ then transfer function will become

$$\frac{V_{OUT}(s)}{V_{IN3}(s)} = \frac{(\ sC_2 R_1)}{(s^2 C_2 C_3 R_1 R_4 + sC_2(R_1 + R_4) + 1)}$$

(4.15)

As transfer function of band pass filter is given by

$$\frac{V_O(s)}{V_{IN}(s)} = \frac{s\ \frac{\omega_O}{Q} H}{s^2 +\ (\omega_O/Q)s + \omega_O^2}$$

(4.16)

By comparing eqn (4.15) & (4.16) ,we will get the filter parameters as

FREQUENCY

$$W_O = \frac{1}{\sqrt{C_2 C_3 R_1 R_4}}$$

(4.17)

$$f = \frac{1}{2\pi\sqrt{C_2 C_3 R_1 R_4}}$$

QUALITY FACTOR (Q)

$$Q = \sqrt{\frac{C_3 R_1 R_4}{C_2}} * \frac{1}{(R_1+R_4)} \qquad (4.18)$$

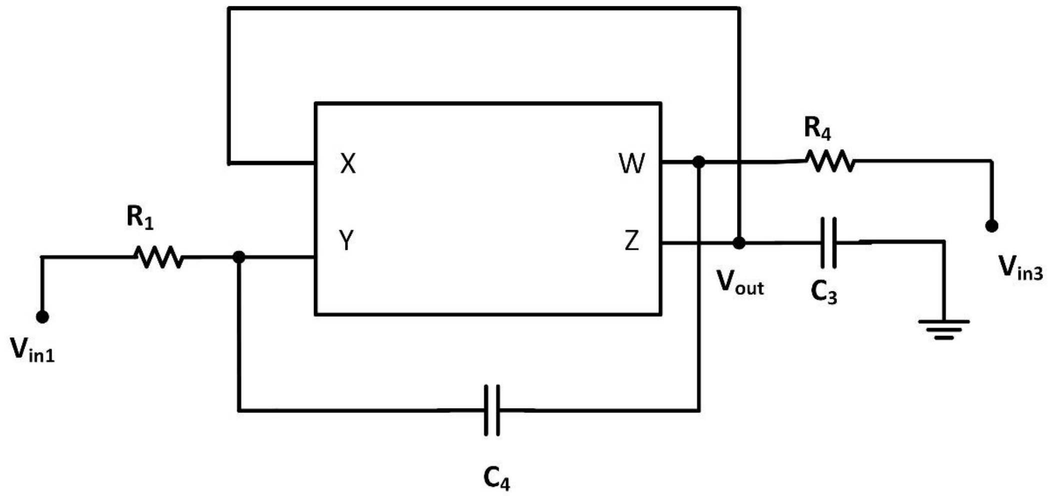
GAIN

$$H = \sqrt{\frac{C_2 R_1}{2 C_3 R_4}}$$

(4.19)

CASE – 3

FOR LOW PASS FILTER



Fig(4.4).Second order filter lowpass filter using FTFN

If we take, $y_1 = G_1$, $y_2 = sC_2$, $y_3 = sC_3$, $y_4 = G_4$, $V_{IN2} = 0$ & $V_{IN3} = -V_{IN}$ then transfer function will become

$$\frac{V_{OUT}(s)}{V_{IN}(s)} = \frac{(1)}{(s^2C_2C_3R_1R_4 + sC_2(R_1 + R_4) + 1)} \tag{4.20}$$

As transfer function of low pass filter is given by

$$\frac{V_O(s)}{V_{IN}(s)} = \frac{H\ \omega_O^2}{s^2 + \ (\omega_O/Q)\ s + \omega_O^2} \tag{4.21}$$

By comparing eqn. (4.20) & (4.21) ,we will get the filter parameters as

FREQUENCY

$$\omega_O = \frac{1}{\sqrt{C_2 C_3 R_1 R_4}}$$

$$f = \frac{1}{2\pi\sqrt{C_2 C_3 R_1 R_4}}$$

(4.22)

QUALITY FACTOR (Q)

$$Q = \sqrt{\frac{C_3 R_1 R_4}{C_2}} * \frac{1}{(R_1 + R_4)} \quad (4.23)$$

GAIN

$$H = \frac{C_2 C_3 R_1 R_4}{C_2 C_3 R_1 R_4}$$

(4.24)

4.2 NON IDEAL ANALYSIS

Because of parasitic effects in it, each analog block is deviated from its perfect features. Four Terminal Floating Nullor (FTFN) also displays nonideal behaviour, which is why the device's output deviates from the optimal. FTFN's non ideal port relations are

$I_X = I_Y = 0$, $V_X = \beta V_Y$ and $I_Z = \alpha I_W$.

At node 1

$$(V_{OUT} - V_{IN})y_1 + (V_{OUT} - V_1)y_2 = 0 \quad (4.25)$$

At node 2

$$(V_1 - V_{OUT})y_2 + (V_1 - V_{IN1})y_4 - I_W = 0 \quad (4.26)$$

At node 3

$$(\beta\, V_{OUT} - V_{IN2})y_3 + I_Z = 0 \quad (4.27)$$

From eqn (4.26) & (4.27)

$$\alpha[(V_1 - V_{OUT})y_2 + (V_1 - V_{IN1})y_4] = (V_{IN2} - \beta V_{OUT})y_3 \quad (4.28)$$

From eqn (4.25) & (4.28)

$$V_{OUT}\, \alpha(y_1 y_2 + y_1 y_4 + y_2 y_4) + V_{OUT}\, \beta y_2 y_3) = (y_1 y_2 + y_1 y_4)V_{IN1}\alpha + (\, y_2 y_3)V_{IN2} + (\, y_2 y_4)V_{IN3}\alpha \quad (4.29)$$

$$V_{OUT} = \frac{(y_1 y_2 + y_1 y_4)\alpha V_{IN1} + (\, y_2 y_3)V_{IN2} + (\, y_2 y_4)\alpha V_{IN3}}{(\alpha y_1 y_2 + \alpha y_1 y_4 + \beta y_2 y_3 + \alpha y_2 y_4)}$$

Now take, (4.30)

$y_1 = G_1$

$y_2 = sC_2$

$y_3 = sC_3$

$y_4 = G_4$

$$V_{OUT} = \frac{(G_1 sC_2 + G_1 G_4)\alpha V_{IN1} + \alpha(\, sC_2 G_4)V_{IN3} + (\, sC_2 sC_3)V_{IN2}}{\alpha(G_1 sC_2 + G_1 G_4 + sC_2 G_4) + \beta sC_2 sC_3)}$$

OR (4.31)

$$V_{OUT} = \frac{(R_4 sC_2 + 1)\alpha V_{IN1} + (\, s^2 C_2 C_3 R_1 R_4)V_{IN2} + (\, sC_2 R_1)\alpha V_{IN3}}{(s^2 C_2 C_3 R_1 R_4 \beta + \alpha s C_2 (R_1 + R_4) + \alpha .1)}$$

(4.32)

$$\omega_{non-ideal} = \frac{\sqrt{\alpha}}{\sqrt{\beta C_2 C_3 R_1 R_4}}$$

So, (4.33)

$$\omega_{non-ideal} = \sqrt{\frac{\alpha}{\beta}}\,\omega_{ideal}$$

(4.34)

$$Q_{non-ideal} = \sqrt{\frac{C_3 R_1 R_4 \beta}{\alpha C_2}} * \frac{1}{(R_1 + R_4)} \tag{4.35}$$

So,

$$Q_{non-ideal} = \sqrt{\frac{\beta}{\alpha}}\,Q_{ideal} \tag{4.36}$$

Where $\alpha = \beta \ll 1$

$$S_{\alpha}^{W_{non-ideal}} = \frac{1}{2}$$

$$S_{\beta}^{W_{non-ideal}} = -\frac{1}{2}$$

4.2.1 CASE – 1

FOR HIGH PASS FILTER

If we take, $y_1 = G_1$, $y_2 = sC_2$, $y_3 = sC_3$, $y_4 = G_4$, $V_{IN} = 0$, $V_{IN3} = 0$, $I_X = I_Y = 0$, $V_X = \beta V_Y$ and $I_Z = \alpha I_W$,then transfer function will become

$$\frac{V_{OUT}}{V_{IN2}} = \frac{(s^2 C_2 C_3 R_1 R_4)}{(s^2 C_2 C_3 R_1 R_4 \beta + \alpha s C_2 (R_1 + R_4) + \alpha.1)} \tag{4.37}$$

As transfer function of high pass filter is given by

$$\frac{V_O}{V_{IN}} = \frac{s^2\ H}{s^2 + \ (\omega_O/Q)\ s + \ \omega_O^2} \tag{4.38}$$

By comparing eqn (4.37) & (4.38),we will get the filter parameters as

FREQUENCY

$$\omega_{non-ideal} = \frac{\sqrt{\alpha}}{\sqrt{\beta C_2 C_3 R_1 R_4}} \tag{4.39}$$

$$f_{non-ideal} = \frac{\sqrt{\alpha}}{2\pi\sqrt{\beta C_2 C_3 R_1 R_4}}$$

QUALITY FACTOR (Q)

$$Q_{non-ideal} = \sqrt{\frac{C_3 R_1 R_4 \beta}{\alpha C_2}} * \frac{1}{(R_1+R_4)} \tag{4.40}$$

GAIN

H = $\frac{(C_2C_3R_1R_4)}{(\beta C_2C_3R_1R_4)}$ (4.41)

H = $\frac{1}{\beta}$

4.2.2 CASE – 2

FOR BAND PASS FILTER

If we take, $y_1 = G_1$, $y_2 = sC_2$, $y_3 = sC_3$, $y_4 = G_4$, $V_{IN} = 0$, $V_{IN2} = 0$, $I_X = I_Y = 0$, $V_X = \beta V_Y$ and $I_Z = \alpha I_W$ then transfer function will become

$$\frac{V_{OUT}}{V_{IN3}} = \frac{(sC_2R_1)\alpha}{(s^2C_2C_3R_1R_4\beta + \alpha sC_2(R_1 + R_4) + \alpha.1)}$$

(4.42)

As transfer function of band pass filter is given by

$$\frac{V_O}{V_{IN}} = \frac{s\ \frac{\omega_O}{Q} H}{s^2 + \ (\omega_O/Q)s + \omega_O^2}$$

(4.43)

By comparing eqn (4.42) & (4.43) ,we will get the filter parameters as

FREQUENCY

$$\omega_{non-ideal} = \frac{\sqrt{\alpha}}{\sqrt{\beta C_2C_3R_1R_4}}$$

$$f_{non-ideal} = \frac{\sqrt{\alpha}}{2\pi\sqrt{\beta C_2C_3R_1R_4}}$$

(4.44)

QUALITY FACTOR (Q)

$$Q_{non-ideal} = \sqrt{\frac{C_3R_1R_4\beta}{\alpha C_2}} * \frac{1}{(R_1+R_4)} \tag{4.45}$$

GAIN

$$H = \sqrt{\frac{C_2R_1\alpha}{2C_3R_4\beta}} \tag{4.46}$$

4.2.3 CASE – 3

FOR LOW PASS FILTER

If we take, $y_1 = G_1$, $y_2 = sC_2$, $y_3 = sC_3$, $y_4 = G_4$, $V_{IN2} = 0$, $V_{IN3} = -V_{IN}$, $I_X = I_Y = 0$, $V_X = \beta V_Y$ and $I_Z = \alpha I_W$ then transfer function will become

$$\frac{V_{OUT}}{V_{IN1}} = \frac{(1)\alpha}{(s^2C_2C_3R_1R_4\beta + \alpha sC_2(R_1 + R_4) + \alpha.1)} \tag{4.47}$$

As transfer function of low pass filter is given by

$$\frac{V_O}{V_{IN}} = \frac{H\ \omega_O^2}{s^2 + \ (\omega_O/Q)\ s + \omega_O^2} \tag{4.48}$$

By comparing eqn. (4.47) & (4.48) ,we will get the filter parameters as

FREQUENCY

$$\omega_{non-ideal} = \frac{\sqrt{\alpha}}{\sqrt{\beta C_2C_3R_1R_4}} \tag{4.49}$$

$$f_{non-ideal} = \frac{\sqrt{\alpha}}{2\pi\sqrt{\beta C_2C_3R_1R_4}}$$

QUALITY FACTOR (Q)

$$Q_{non-ideal} = \sqrt{\frac{C_3 R_1 R_4 \beta}{\alpha C_2}} * \frac{1}{(R_1 + R_4)} \tag{4.50}$$

GAIN

$$H = \frac{\alpha C_2 C_3 R_1 R_4}{\beta C_2 C_3 R_1 R_4} \tag{4.51}$$

4.3 SENSITIVITY ANALYSIS

Senstivity is may be defined as change in one quantity w.r.t change in another quantity .

$$S_x^y = \frac{lim}{\Delta x \to 0} \left\{ \frac{\frac{\Delta y}{y}}{\frac{\Delta x}{x}} \right\} = \frac{x}{y} \frac{\partial y}{\partial x}$$

Where x is the varying component and y is filter characterstics that is evaluated as x is changing.

$$S_{R_1}^{\omega o} = S_{R_4}^{\omega o} = S_{C_2}^{\omega o} = S_{C_3}^{\omega o} = S_{\beta}^{\omega o} = -\frac{1}{2}$$

$$S_{\alpha}^{\omega o} = \frac{1}{2}$$

$$S_{R_1}^{Q} = S_{R_4}^{Q} = 0$$

$$S_{C_3}^{Q} = S_{\beta}^{Q} = \frac{1}{2}$$

$$S_{C_2}^{Q} = S_{\alpha}^{Q} = -\frac{1}{2}$$

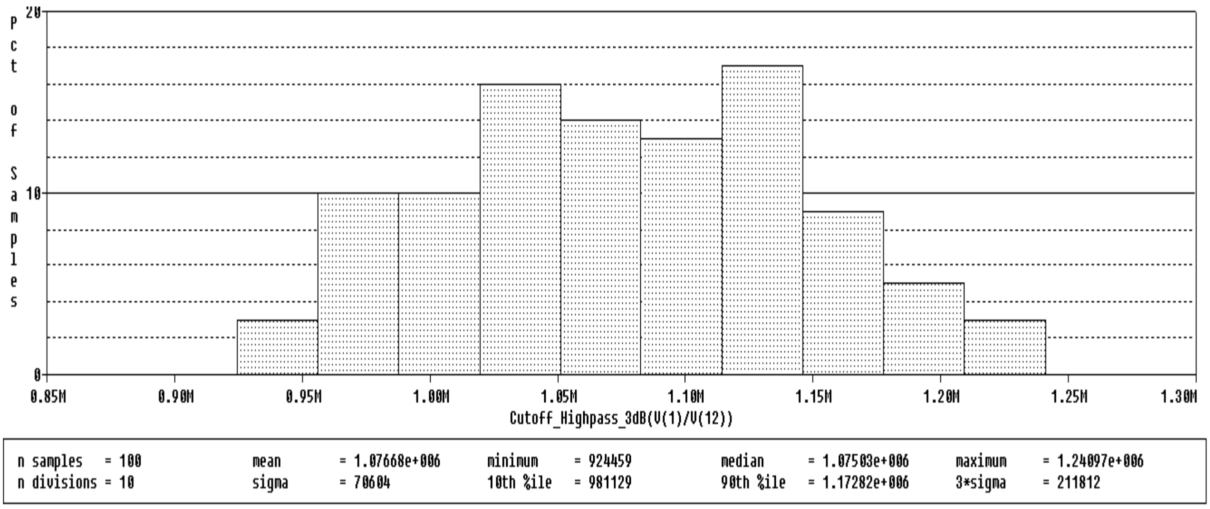


Fig.4.5. Senstivity analysis of high pass filter(config.1) by monte carlo

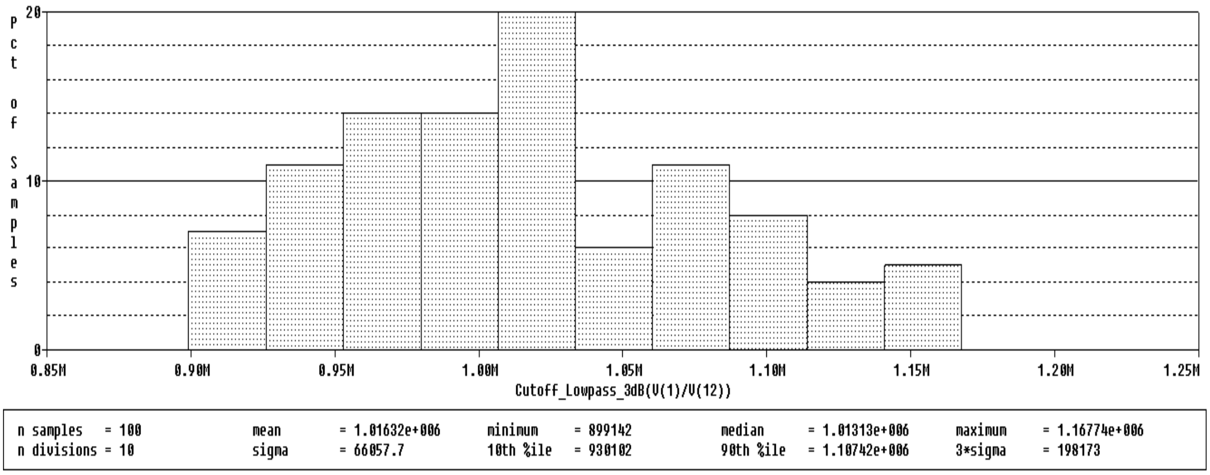


Fig.4.6. Senstivity analysis of low pass filter (config.1) by monte carlo

4.4 SIMULATION RESULTS

By keeping the values of the parameters as R_1 =2K , C_2 =100pF, C_3 =50pF ,R_4 =2K , $V_{IN} = 0$ & $V_{IN3} = 0$ at cutoff frequency of 1.125MHz with quality factor of 0.7 and gain of 1db we will get the Frequency response of high pass filter as

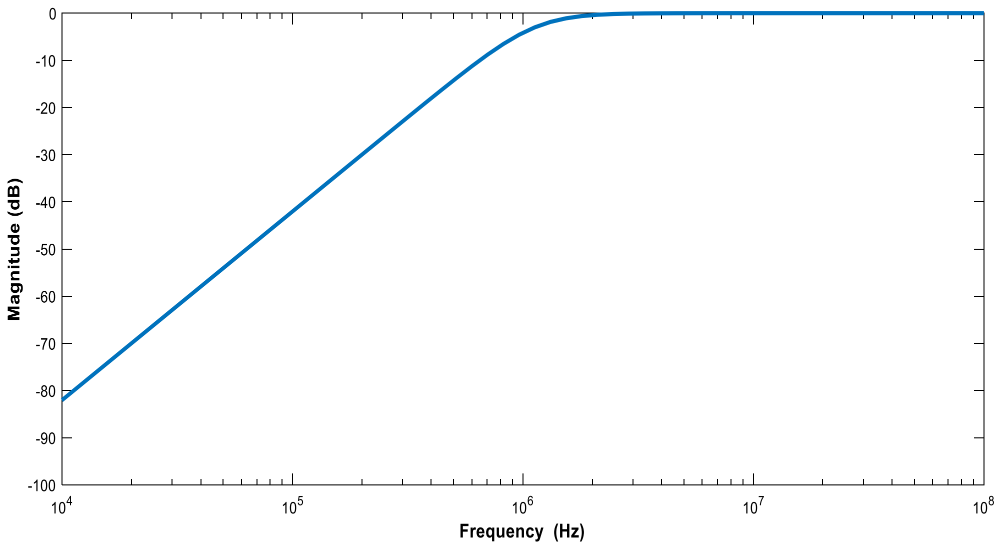


Fig.4.7. Frequency response of high pass filter (config.1)

By keeping the values of the parameters as R_1 =2K , C_2 =100pF, C_3 =50pF ,R_4 =2K , $V_{IN} = 0$ & $V_{IN2} = 0$, at cutoff frequency of 1.125MHz with quality factor of 0.7 and gain of -4bd we will get the frequency response of band pass filter as

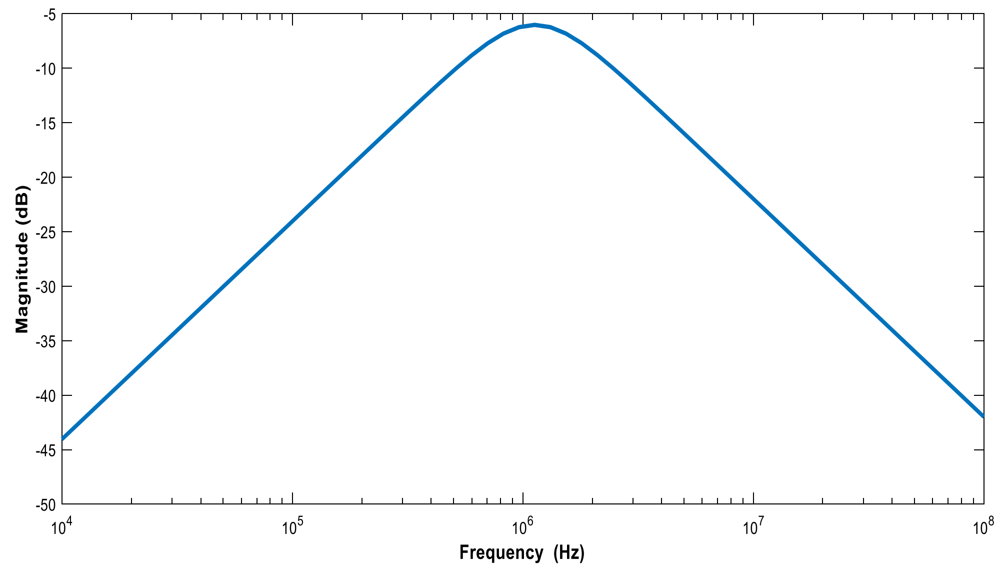


Fig.4.8. Frequency response of band pass filter (config.1)

By keeping the values of the parameters as R_1 =2K , C_2 =100pF, C_3 =50pF ,R_4 =2K , $V_{IN2} = 0$ $V_{IN3} = -V_{IN}$, at cutoff frequency of 1.125MHz with quality factor of 0.7 and gain of 1db we will get the Frequency response of low pass filter as

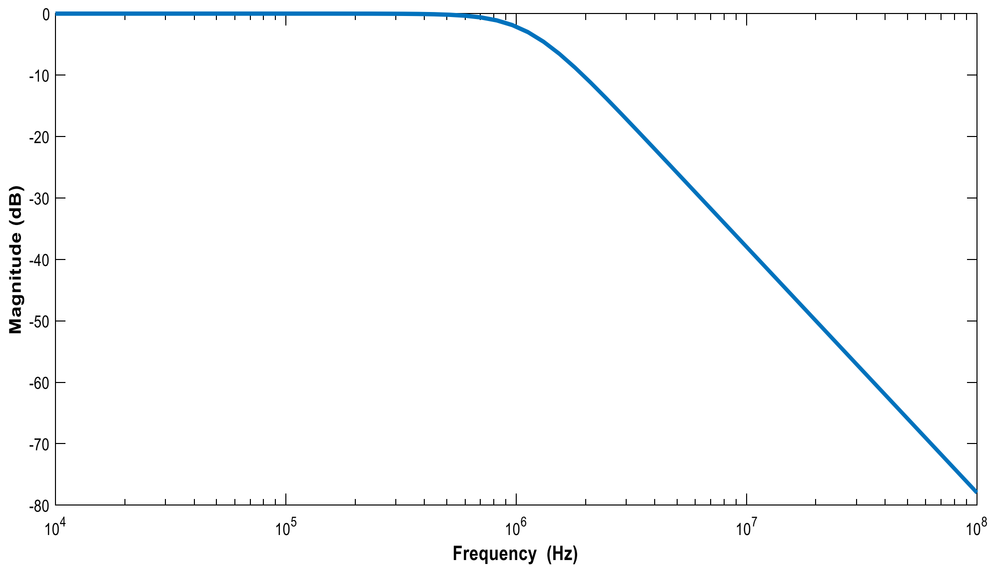
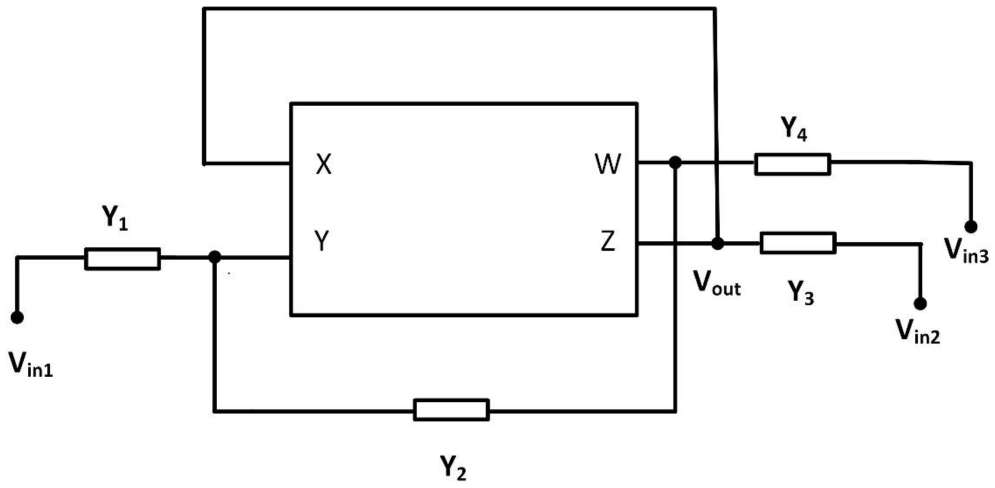


Fig.4.9. Frequency response of low pass filter (config.1)

4.5. FTFN BASED FILTER CONFIGURATION 2



Figure(4.10) Second order filter prototype using FTFN

Transfer function for the given circuit is as follows;

At node 1

$$(V_{OUT} - V_{IN})y_1 + (V_{OUT} - V_1)y_2 = 0 \quad (4.37)$$

At node 2

$$(V_1 - V_{OUT})y_2 + (V_1 - V_{IN1})y_4 - I_W = 0 \quad (4.38)$$

At node 3

$$(V_{OUT} - V_{IN2})y_3 + I_Z = 0 \quad (4.39)$$

From eqn (4.38) & (4.39)

$$(V_1 - V_{OUT})y_2 + (V_1 - V_{IN1})y_4 = (V_{IN2} - V_{OUT})y_3 \quad (4.40)$$

From eqn (4.37) & (4.40)

$$V_{OUT}(y_1y_2 + y_1y_4 + y_2y_4 + y_2y_3) = (y_1y_2 + y_1y_4)V_{IN}+(\ y_2y_3)V_{IN1}+(\ y_2y_4)V_{IN2} \quad (4.41)$$

$$V_{OUT} = \frac{(y_1y_2 + y_1y_4)V_{IN1} + (\ y_2y_3)V_{IN2} + (\ y_2y_4)V_{IN3}}{(y_1y_2 + y_1y_4 + y_2y_3 + y_2y_4)}$$

(4.42)

$y_1 = sC_1$

$y_2 = G_2$

$y_3 = G_3$

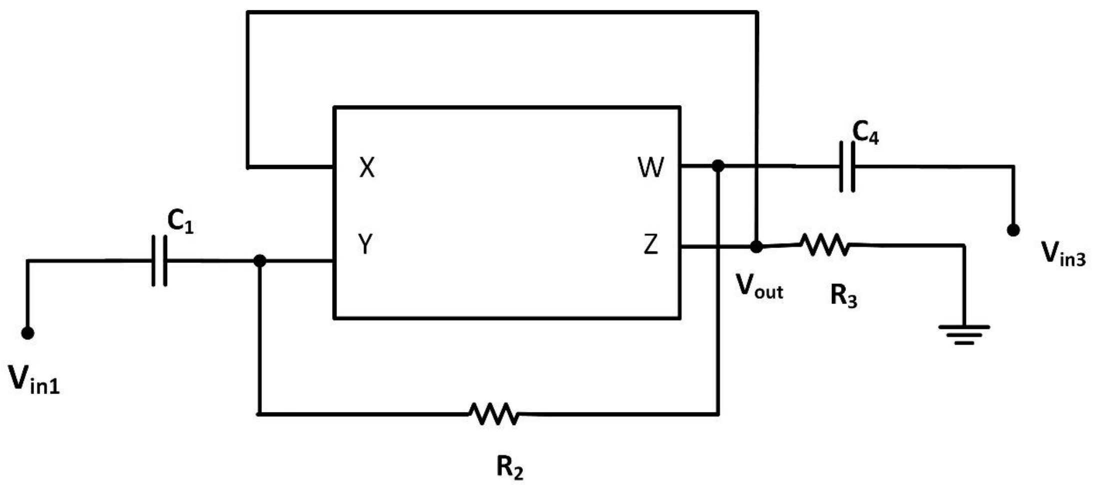
$y_4 = sC_4$

$$V_{OUT}(s) = \frac{(R_3 sC_1 + s^2 C_1 C_4 R_2 R_3)V_{IN}(\mathrm{s}) + (1)V_{IN2}(\mathrm{s}) + (\ sC_4 R_3)V_{IN3}(s)}{(s^2 C_1 C_4 R_2 R_3 + s(C_1 R_3 + C_4 R_3) + 1)}$$

(4.43)

CASE – 1

FOR HIGH PASS FILTER



Fig(4.11).Second order high pass filter using FTFN

If we take, $y_1 = sC_1$,$y_2 = G_2$,$y_3 = G_3$,$y_4 = sC_4$,$V_{IN2} = 0$ & $V_{IN3} = -V_{IN}$ then transfer function will become

$$\frac{V_{OUT}}{V_{IN}} = \frac{(s^2 C_1 C_4 R_2 R_3)}{(s^2 C_1 C_4 R_2 R_3 + s(C_1 R_3 + C_4 R_3) + 1)}$$

(4.44)

Transfer function of high pass filter is given by

$$\frac{V_O}{V_{IN}} = \frac{s^2\ H}{s^2 + \ (\omega_O/Q)\ s + \omega_O^2} \tag{4.45}$$

By comparing eqn (4.44) & (4.45), we will get the filter parameters as

FREQUENCY,

$$\omega_O = \frac{1}{\sqrt{C_1 C_4 R_2 R_3}}$$

$$f = \frac{1}{2\pi\sqrt{C_1 C_4 R_2 R_3}} \tag{4.46}$$

QUALITY FACTOR

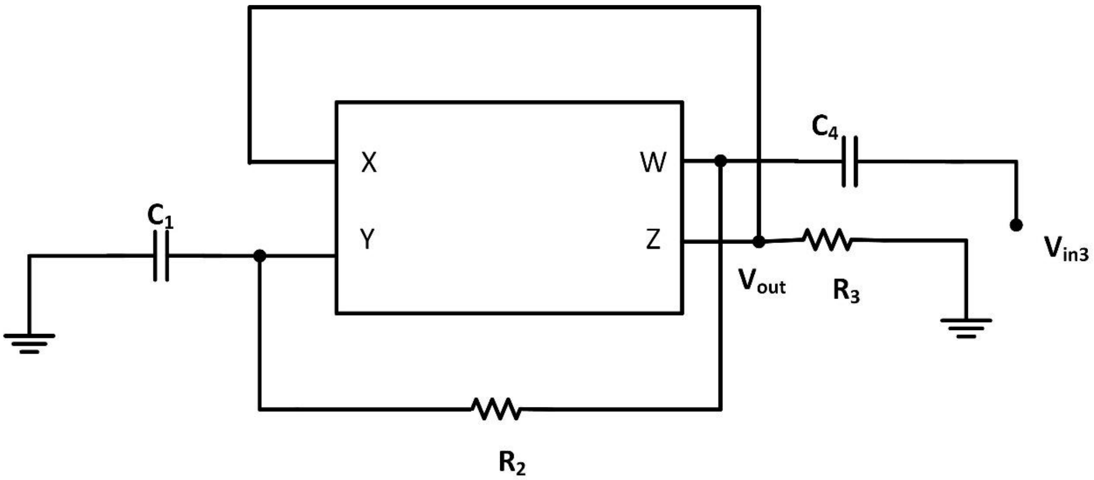
$$Q = \sqrt{\frac{C_1 R_2 C_4}{R_3}} * \frac{1}{(C_1 + C_4)} \tag{4.47}$$

GAIN CALCULATION

$$H = \frac{(C_1 C_4 R_2 R_3)}{(C_1 C_4 R_2 R_3)} \tag{4.48}$$

CASE – 2

FOR BAND PASS FILTER



Fig(4.12).Second order bandpass filter using FTFN

If we take, $y_1 = sC_1$,$y_2 = G_2$,$y_3 = G_3$,$y_4 = sC_4$,$V_{IN1} = 0$ & $V_{IN2} = 0$ then transfer function will become

$$\frac{V_{OUT}(s)}{V_{IN3}(s)} = \frac{(\ sC_4R_3)}{(s^2C_1C_4R_2R_3 + s(C_1R_3 + C_4R_3) + 1)} \tag{4.49}$$

Transfer function of band pass filter is given by

$$\frac{V_O(s)}{V_{IN}(s)} = \frac{s\ \frac{\omega_O}{Q} H}{s^2 + \ \ (\omega_O/Q)s + \omega_O^2} \tag{4.50}$$

By comparing eqns (4.49) ,(4.50) ,we will get the filter parameters as

FREQUENCY

$$\omega_O = \frac{1}{\sqrt{C_1C_4R_2R_3}}$$

$$f = \frac{1}{2\pi\sqrt{C_1C_4R_2R_3}} \tag{4.51}$$

QUALITY FACTOR

$$Q = \sqrt{\frac{C_1 R_2 C_4}{R_3}} * \frac{1}{(C_1 + C_4)} \tag{4.52}$$

GAIN

$$H = \sqrt{\frac{C_4 R_3}{2 C_1 R_2}} \tag{4.53}$$

4.6 NON IDEAL ANALYSIS

FTFN's non ideal port relations are

$I_X = I_Y = 0$, $V_X = \beta V_Y$ and $I_Z = \alpha I_W$.

At node 1

$$(V_{OUT} - V_{IN})y_1 + (V_{OUT} - V_1)y_2 = 0 \tag{4.54}$$

At node 2

$$(V_1 - V_{OUT})y_2 + (V_1 - V_{IN1})y_4 - I_W = 0 \tag{4.55}$$

At node 3

$$(\beta\, V_{OUT} - V_{IN2})y_3 + I_Z = 0 \tag{4.56}$$

From eqn (4.55) & (4.56)

$$\alpha[(V_1 - V_{OUT})y_2 + (V_1 - V_{IN1})y_4] = (V_{IN2} - \beta V_{OUT})y_3 \tag{4.57}$$

From eqn (4.54) & (4.57)

$$V_{OUT}\, \alpha(y_1 y_2 + y_1 y_4 + y_2 y_4) + V_{OUT}\, \beta y_2 y_3) = (y_1 y_2 + y_1 y_4)V_{IN1}\alpha + (\, y_2 y_3)V_{IN2} + (\, y_2 y_4)V_{IN3}\alpha$$

$$V_{OUT} = \frac{(y_1 y_2 + y_1 y_4)\alpha V_{IN1} + (\, y_2 y_3)V_{IN2} + (\, y_2 y_4)\alpha V_{IN3}}{(\alpha y_1 y_2 + \alpha y_1 y_4 + \beta y_2 y_3 + \alpha y_2 y_4)} \tag{4.58}$$

$y_1 = sC_1$

$y_2 = G_2$

$y_3 = G_3$

$y_4 = sC_4$

$$V_{OUT} = \frac{(R_3 sC_1 + s^2 C_1 C_4 R_2 R_3)\alpha V_{IN} + (1)V_{IN2} + (\, sC_4 R_3)\alpha V_{IN3}}{\alpha(s^2 C_1 C_4 R_2 R_3 + s(C_1 R_3 + C_4 R_3) + 1.\beta)} \tag{4.59}$$

$$\omega_{non-ideal} = \frac{\sqrt{\beta}}{\sqrt{\alpha C_1 C_4 R_2 R_3}}$$

(4.60)

So,

$$\omega_{non-ideal} = \sqrt{\frac{\beta}{\alpha}}\,\omega_{ideal}$$

(4.61)

$$Q_{non-ideal} = \sqrt{\frac{C_1 R_2 c_4 \beta}{\alpha R_3}} * \frac{1}{(C_1+C_4)}$$

(4.62)

So,

$$Q_{non-ideal} = \sqrt{\frac{\beta}{\alpha}}\,Q_{ideal}$$

(4.63)

Where $\alpha = \beta \ll 1$

$$S_{\alpha}^{W_O} = -\frac{1}{2}$$

$$S_{\beta}^{W_O} = \frac{1}{2}$$

Case 1

FOR HIGH PASS FILTER

If we take, $y_1 = sC_1$,$y_2 = G_2$,$y_3 = G_3$,$y_4 = sC_4$,$V_{IN2} = 0$ & $V_{IN3} = -V_{IN}$ then transfer function will become

$$\frac{V_{OUT}(s)}{V_{IN}(s)} = \frac{(s^2 C_1 C_4 R_2 R_3)\alpha V_{IN}}{\alpha(s^2 C_1 C_4 R_2 R_3 + s(C_1 R_3 + C_4 R_3) + 1.\beta)} \quad (4.64)$$

As transfer function of high pass filter is given by

$$\frac{V_O(s)}{V_{IN}(s)} = \frac{s^2\ H}{s^2 + \ (\omega_O/Q)\ s + \ \omega_O^2}$$

(4.65)

By comparing eqn (4.64) & (4.65),we will get the filter parameters as

FREQUENCY

$$\omega_{non-ideal} = \frac{\sqrt{\beta}}{\sqrt{\alpha C_1 C_4 R_2 R_3}}$$

(4.66)

QUALITY FACTOR

$$Q_{non-ideal} = \sqrt{\frac{C_1 R_2 C_4 \beta}{\alpha R_3}} * \frac{1}{(C_1+C_4)}$$

(4.67)

GAIN

$$H = \frac{(C_1 C_4 R_2 R_3)}{(C_1 C_4 R_2 R_3)}$$ (4.68)

Case 2

BANDPASS FILTER

If we take, $y_1 = sC_1$,$y_2 = G_2$,$y_3 = G_3$,$y_4 = sC_4$,$V_{IN1} = 0$ & $V_{IN2} = 0$ then transfer function will become

$$\frac{V_{OUT}(s)}{V_{IN3}(s)} = \frac{(\ sC_4 R_3)\alpha}{\alpha(s^2 C_1 C_4 R_2 R_3 + s(C_1 R_3 + C_4 R_3) + 1.\beta)}$$

(4.69)

Transfer function of band pass filter is given by

$$\frac{V_O(s)}{V_{IN}(s)} = \frac{s\ \frac{\omega_O}{Q} H}{s^2 + \ (\omega_O/Q)s + \omega_O^2}$$

(4.70)

By comparing eqns (4.69) ,(4.70) ,we will get the filter parameters as

FREQUENCY

$$\omega_{non-ideal} = \frac{\sqrt{\beta}}{\sqrt{\alpha C_1 C_4 R_2 R_3}}$$

(4.71)

QUALITY FACTOR

$$Q_{non-ideal} = \sqrt{\frac{C_1 R_2 c_4 \beta}{\alpha R_3}} * \frac{1}{(C_1 + C_4)}$$

(4.72)

GAIN

$$H = \sqrt{\frac{C_4 R_3 \alpha}{2 C_1 R_2 \beta}} \qquad (4.73)$$

4.7 SENSITIVITY ANALYSIS

Senstivity is may be defined as change in one quantity w.r.t change in another quantity .

$$S_x^y = \frac{lim}{\Delta x \to 0}\left\{\frac{\frac{\Delta y}{y}}{\frac{\Delta x}{x}}\right\} = \frac{x}{y}\ \frac{\partial y}{\partial x}$$

Where x is the varying component and y is filter characterstics that is evaluated as x is changing.

$$S_{C_1}^{\omega o} = S_{C_4}^{\omega o} = S_{R_2}^{\omega o} = S_{R_3}^{\omega o} = S_{\alpha}^{\omega o} = -\frac{1}{2}$$

$$S_{\beta}^{\omega o} = \frac{1}{2}$$

$$S_{C_1}^{Q} = S_{C_4}^{Q} = 0$$

$$S_{R_3}^{Q} = S_{\alpha}^{Q} = \frac{1}{2}$$

$$S_{R_2}^{Q} = S_{\beta}^{Q} = -\frac{1}{2}$$

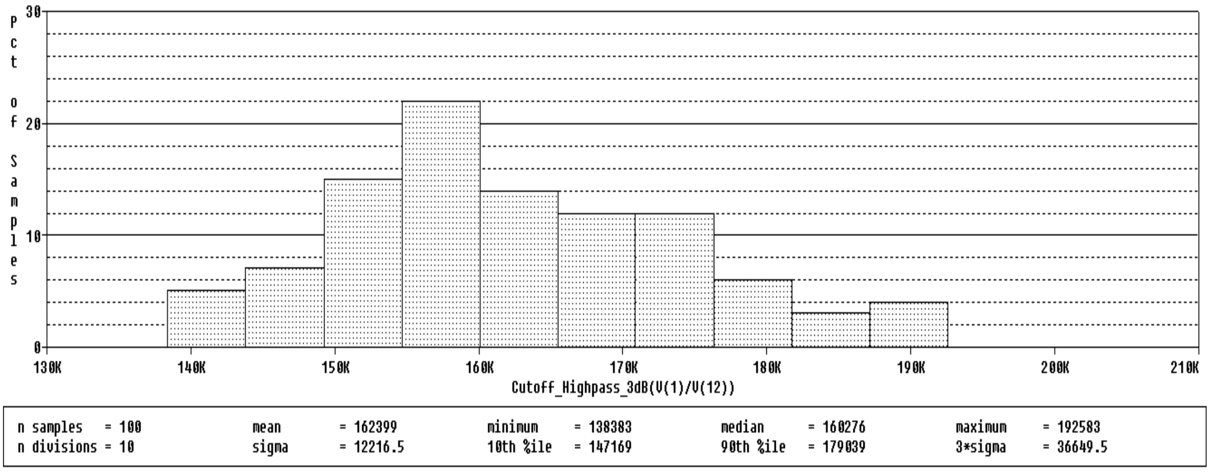


Fig.4.13. Senstivity analysis of high pass filter(config.2) by monte carlo

4.8 SIMULATION RESULTS

By keeping the values of the parameters as C_1 =1nF ,R_2 =1414.21 , R_3 =707.10 ,C_4 =1nF , $V_{IN2} = 0$ & $V_{IN3} = -V_{IN}$, at cutoff frequency of 1.125MHz with quality factor of 0.7 and gain of 1db we will get the Frequency response of high pass filter as

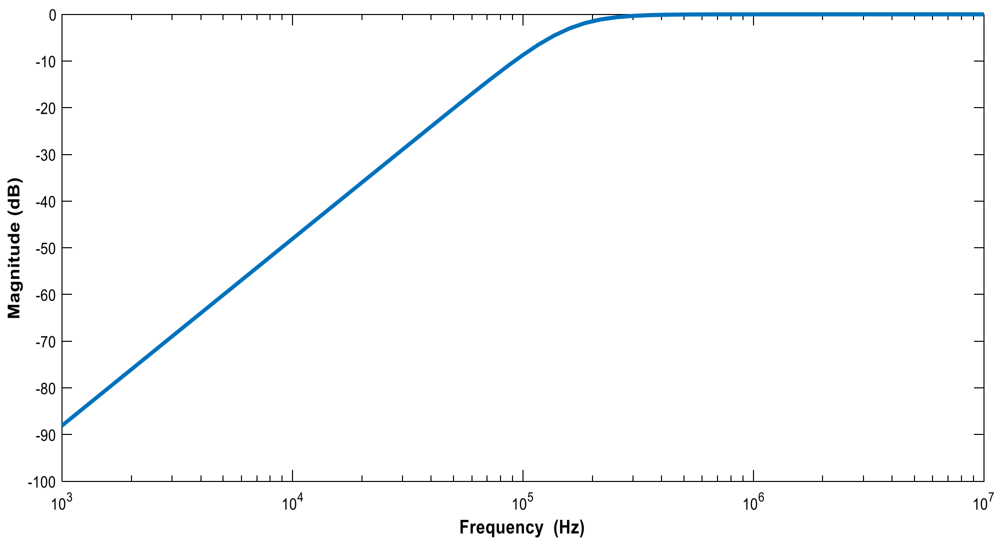


Fig.4.14. Frequency response of high pass filter (config.2)

By keeping the values of the parameters as C_1 =1nF ,R_2 =1414.21, R_3 =707.10 , C_4 =1nF, $V_{IN1} = 0$ & $V_{IN2} = 0$, at cutoff frequency of 1.125MHz with quality factor of 0.7 and gain of -4 db, we will get the Frequency response of high pass filter as

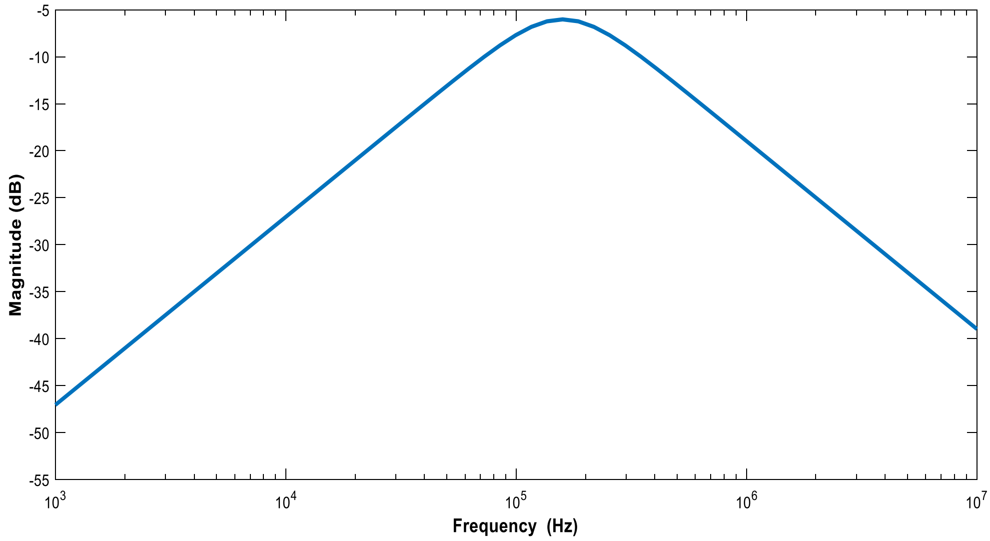


Fig.4.15. Frequency response of band pass filter (config. 2)

CHAPTER 5
CONCLUSION AND FUTURE SCOPE

5.1 CONCLUSION

In this thesis, the FTFN and its applications were discussed The uses of FTFN in designing active filters was investigated.

In this chapter, the thesis work is summarized and some conclusions and comments regarding this work are drawn. Then, recommendations and suggestions for future work will be presented.

The different possible realizations of the FTFN based on the currently available active devices have been discussed indicating their associated advantages and disadvantages The two-CCII+ based FTFN realization was selected to implement and test the proposed circuits practically.

The FTFN wide range of applications was investigated paying more attention to those demonstrating the flexibility and versatility of the FTFN over the Op Amp and the current - conveyor .In this thesis, the use of FTFN in designing universal active filters has been enriched by proposing several active filters. The FTFN current mode based filters are associated with high impedence output currents suitable for cascading. Also, some of filters based on the FTFN use only grounded passive elements which is appropriate for integration

5.2 FUTURE SCOPE

Since nothing is perfect and the science and engineering is continually improving, this work can be improved and further extended in many directions:

1. Designing and implementing of fully integrated FTFN is highly recommended as the FTFN proved to be a very versatile and flexible active device Also, it will be very' useful if an additional output current and voltage buffer are added in the integration to approach the dream of universal element
2. Designing universal filter circuits which can offer some advantages over the proposed filters in terms of reducing the passive and active components as well as the matching cancellation requirements for realizing the filters
3. Introducing the FTFN into the design of function generators.
4. For further designing of higher order filters.

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