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تصميم مرشح حزمة ذو نمط فولتية من الدرجة السادسة من نوع (elliptic) باستخدام مضخم نوع ZC-CFTA

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الملخص:

إن هذا البحث يتناول مفهوم التركيب الجديد للعنصر الفعال المسمى (Z Copy Current Follower Transconductance Amplifier). في هذه الدراسة تم تصميم مرشح حزمة يعمل (ZC -CFTA) بالإعتماد على (elliptic) ذو نمط فولتية من الدرجة السادسة من نوع ضمن تردد عالٍ بحدود ٣٠ ميغا هرتز. كما أن العنصر الفعال يحتوي على محاثات مؤرضة و عائمة بوجود متسعة واحدة. حيث أن الـ (ZC -CFTA) الذي هو من نوع الـ (ABB) تم تشكيلها مع عنصر غير فعال ألا وهي مرشح الحزمة ذو نمط الفولتية من الدرجة السادسة. نتائج محاكاة برنامج (LT - SPICE) باستخدام وحدة المعالجة (CMOS) مايكرو ٠,١٨ نوع متر تظهر أن المرشح المصمم يمكنه العمل بفولتية ٠,٩ فولت ومن محاسنه أنه يمنح قابلية الكسب العالي و إمكانية تشكيله بحجم صغير.

كلمات دالة: مكبر نوع ZC-CFTA, مرشح حزمة نمط فولتية من الدرجة السادسة من نوع (elliptic), مرشح حزمة , وحدة البناء الفعالة

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Design of Voltage Mode 6th Order Elliptic Band-pass Filter Using Z-Copy Current Follower Transconductance Amplifier (*ZC-CFTA*)

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Abstract

This paper describes the realization of the new configuration of an active element namely, Z Copy Current Follower Transconductance Amplifier (ZC-CFTA). In this study, the elliptic 6th order voltage-mode (VM) Band-pass filter was configured based on the ZC-CFTA, which operates at a high frequency of about 30 MHz. The active element also contains floated and grounded inductance with one capacitor. The ZC-CFTA which is an ABB (Active Building Block) is configured with a passive element that is the 6th order elliptic Band Pass Filter. The results LT-SPICE software simulation using 0.18µm CMOS processing parameter show that the designed filter could be operated at a supply voltage of 0.9V and it offers the advantages of a small size and high gain.

Keywords: Z copy current follower transconductance amplifier (ZC-CFTA); Elliptic 6th order voltage-mode;

Band-pass filter; active building block (ABB's).

1. Introduction

Recently, analog filter circuits are continuously developed for not only reducing die areas but also increasing their performance, for example, high-frequency response, electronically tunable and uses less active devices. In IC processing, it is well known that the use of active devices is better than passive devices as well as electronically tunable capability. The realization of Elliptic ladder band-pass filters (BPF) based on active devices by using RLC doubly terminated Elliptic ladder band-pass filter prototype [1,2]. Voltage-mode (VM) Elliptic ladder band-pass filter based on ZC-CFTAs are presented in [3]. But it suffers from a large number of passive devices and cannot operate in high frequency.In the current differencing transconductance amplifier (CDTA) has been introduced in 2003 [1]. It has been considered to be a versatile active building block for current-mode signal processing. The input circuitry of the CDTA consists of the current differencing unit (CDU), which is followed by the operational transconductance amplifier (OTA) [2]. Some of the earlier reported circuits in [1, 3, 5], do not fully use the potential of the CDTAs since one of the input terminals p or n is not used. Thus, it may cause some noise injection into the monolithic circuit. This drawback of CDU-based analog building blocks (ABBs) was previously discussed regarding another such ABB so-called current differencing buffered amplifier (CDBA) [6,7]. Therefore, to avoid this problem, the CDTA has been simplified by replacing the CDU by a simple current follower (CF) and the appropriate element called current follower transconductance amplifier (CFTA) has been presented in 2008 [8]. This active element was used in linear circuit applications in [8,9]. To increase the universality of the conventional CDTA, the "Z-current copy" technique with advantage presented in was presented[11]. Subsequently, the Z-copy CFTA (ZC-CFTA) was introduced in [10], which has recently received considerable attention in [4]. In general, previously published CFTA/ZC-CFTA papers [8-10] mainly report new filters or oscillators excepting [11,3] where novel grounded/floating inductance simulators are described using active filters [2].The main aim of this paper is to combine both active filter Z copy current follower transconductance amplifier ZC-CFTA equivalent of six-order VM elliptic BPF which is simply passive filter, by replacing passive components with their active equivalents filter by providing an alternate realization of grounded/floating inductance simulator employing ZC-CFTAs LTSPICE software simulation results are included to verify the workability of the designed circuit.

2. Theories And Principle

2.1 Circuit Description of ZC-CFTA

A circuit configuration of (ZC-CFTA), which is a schematic symbol and behavioral model is shown in Figure 1 consists of an input current (IP) which are transferred by the current follower to Z terminal (IZ = IP)). A copy of IZ current may also be conveyed to the Z-copy terminal (ZC). The voltage drop at the terminal Z is transformed into currents ix+ and ix- at the terminals x+ and x- respectively using transconductance gm of improved floating current sources (IFCS), which is electronically controllable by an external bias current. There is also ZC terminal, which copies the Z terminal current indirect direction. Relations between the individual terminals of ZC-CFTA can be described by the following set of the equation:

$$V_f = 0,\ i_z = i_{zc} = i_f,\ \ i_{x+} = g_m V_z, i_{x-} = -g_m V_z \qquad (1)$$

and the characterization of the transconductance can be calculated as:

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$$g_m = \sqrt{I_B \mu_O C_{OX}(\frac{W}{L})} \quad (2)$$

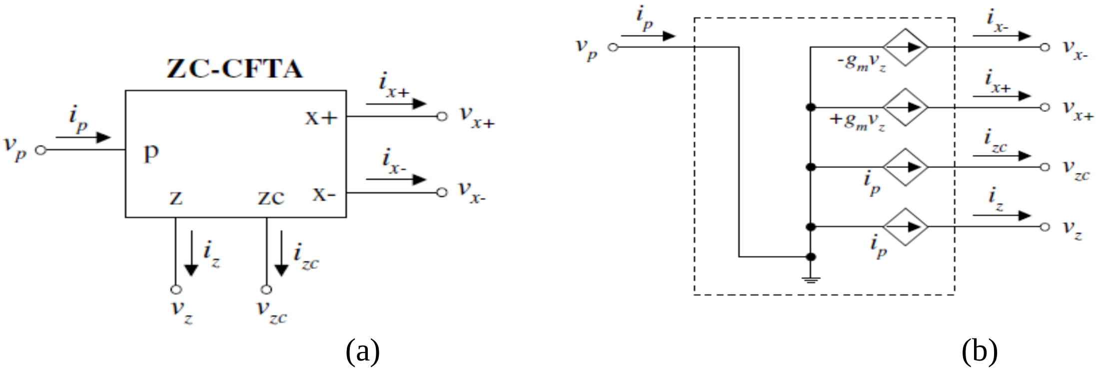


Figure 1. (a) Circuit symbol (b) behavioral model of ZC-CFTA.

Where I_B controls the transconductance g_m, μ_0 is a free electron mobility of channel, C_{ox} is the gate oxide capacitance per unit area as a function of W/L which is the aspect ratios of the identical MOSFETs. The CMOS implementation of the ZC-CFTA based on the IFCS structure presented in [9], is shown in Figure 2. Assuming that all MOS transistors operate in the saturation region and the M $_{21, 27}$ and M $_{20, 26}$ are precisely matched.

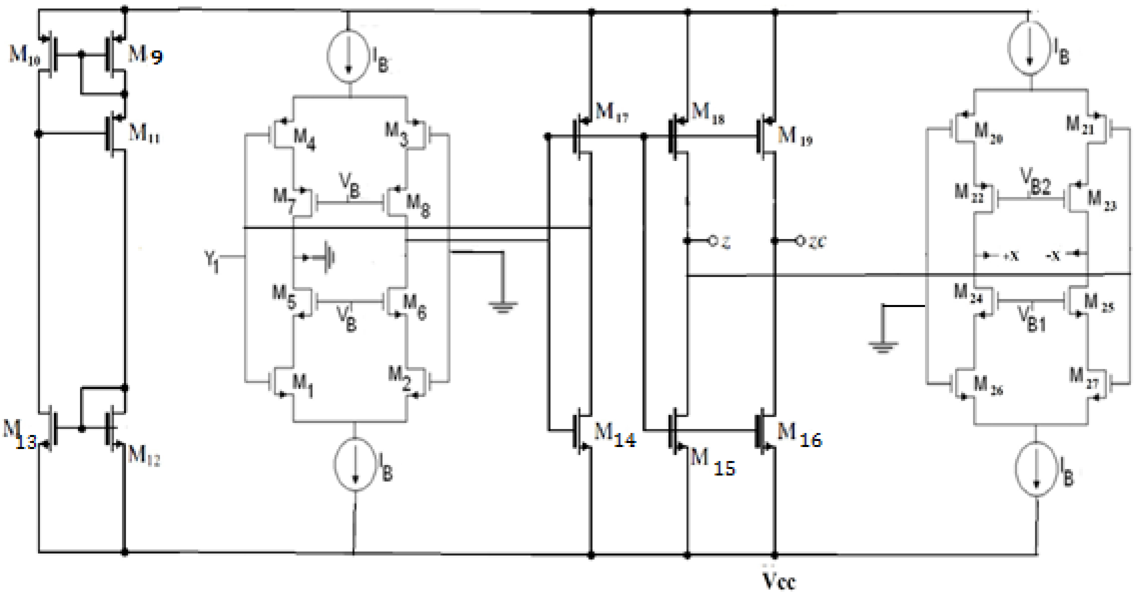
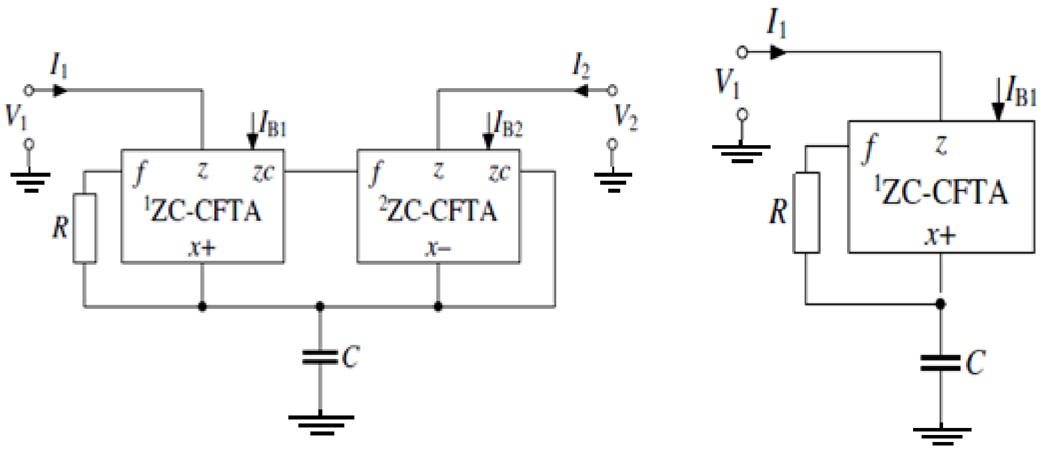


Figure 2. CMOS implementation of ZC-CFTA

2.2 Floating and grounded inductor based on ZC-CFTA

A floating and grounded inductors which employ of Z-copy current follower transconductance amplifier (ZC-CFTA) in Figure 3. Since ZC-VDTA is composed of transconductance amplifier structures, the floating, and grounded inductors can be simulated respectively by two active elements with one capacitor and only one active element are with one capacitor. Assuming gm1 = gm2 = gm (i.e. transconductances are perfectly matched), with an equivalent value of $\mathbf{Leq = c / g_{m1} . g_{m2}}$. It is clearly seen that the positive inductance value Leq can be adjusted electronically by I_B. In addition, there should be also noted that inductance simulator is composed of the grounded capacitor. Thus, the circuit is attractive for integration.



(a) (b)

Figure. 3. (a) Floating inductance (b) grounded inductance

3. Elliptic 6th - order ladder BPF synthesis

The 6th order band-pass filter is realized from ZC-CFTAs and inductors. Applying network transform [11] into single terminated RLC Elliptic ladder low-pass filter prototype shown in Figure 4 to achieves an Elliptic ladder band-pass filter prototype.

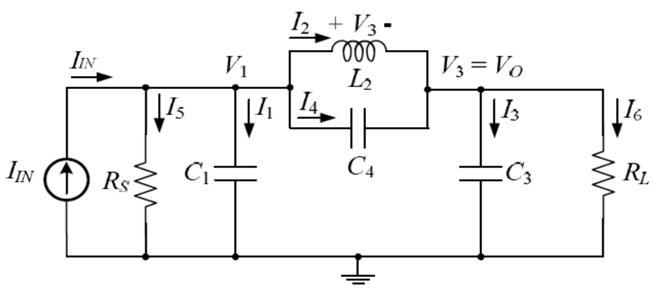


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Figure 4. RLC Elliptic ladder low-pass filter prototype

Using Table 1 to transforms C and L in Figure 4 to achieve the Elliptic ladder band-pass filter prototype shown in Figure 5.

Table 1. RLC network transform

LP prototype	Denormalized BP
L_{LP} (inductor)	L_{LP} (inductor) in series with $\frac{1}{L_{LP}\omega_r^2}$ (capacitor)
C_{LP} (capacitor)	$\frac{1}{C_{LP}\omega_r^2}$ (inductor) in parallel with C_{LP} (capacitor)
R_{LP} (resistor)	R_{LP} (resistor)

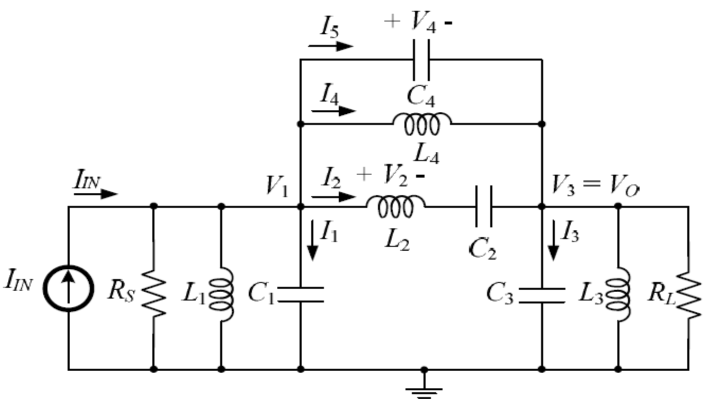

Figure 5. RLC Elliptic ladder band-pass filter prototype

Considering current and voltage of the 6th order ladder band-pass filter in Figure 5 by using KCL, their relationships can be written as.

$$I_1 = I_{IN} - I_2 - I_4 - I_5 - {}^{V_1}/_{SL_1} - {}^{V_1}/_{R_S} \qquad (3)$$

$$I_2 = \frac{V_2}{SL_2} \qquad (4)$$

$$I_3 = I_2 - I_4 - I_5 - {}^{V_3}/_{SL_3} - {}^{V_3}/_{R_L} \qquad (5)$$

$$I_4 = \frac{V_4}{SL_4} \qquad (6)$$

$$V_1 = \frac{I_{IN} - I_2 - I_4 - I_5 - {}^{V_1}/_{SL_1} - {}^{V_1}/_{R_S}}{S(C1+C2)} + V_3 \frac{C_4}{C_1 + C_4} \qquad (7)$$

$$V_2 = V_1 - V_3 - {}^{I_2}/_{SL_2} \qquad (8)$$

$$V_3 = \frac{I_2 - I_4 - I_5 - {}^{V_3}/_{SL_3} - {}^{V_3}/_{R_L}}{S(C3+C4)} + V_1 \frac{C_4}{C_3 + C_4} \quad (9)$$

$$V_4 = V_1 - V_3 = V_2 + {}^{I_2}/_{SC_2} \quad (10)$$

From equations (3-10), we can move C4 to the below (C1+C4), (C3+C4) which is connected to dependent sources, hence the prototype can be redrawn as in Figure 6

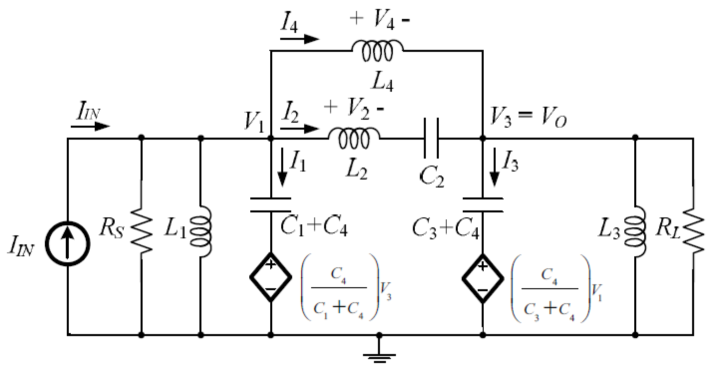

Figure 6. Transformed RLC Elliptic ladder Band-pass filter

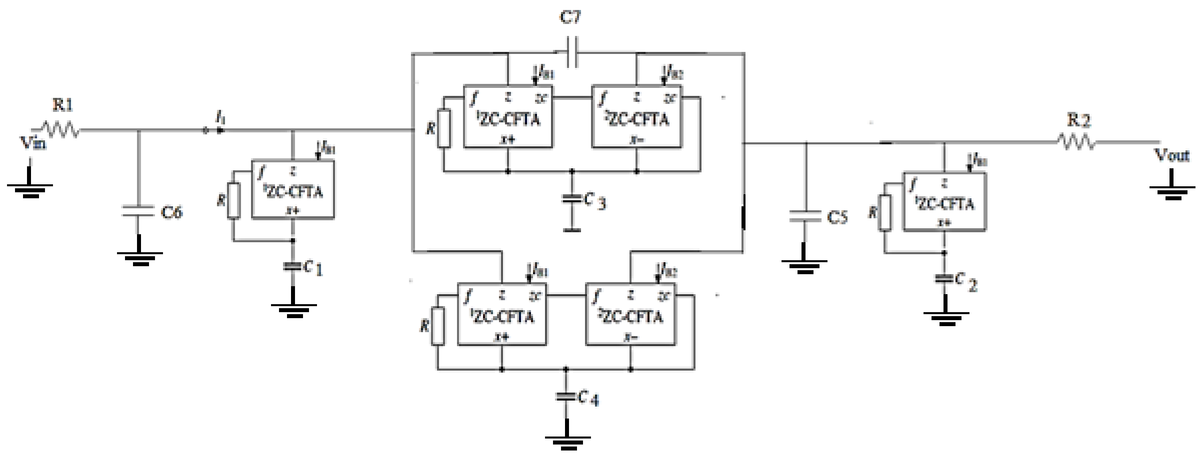

Figure 7. Elliptic 6th order ladder band-pass filter

The resulted Elliptic 6th order ladder band-pass filter can be realized as shown in Figure 7. It contains 4 passive capacitors, 2 resistances, 2 actives grounded inductors and 2 active floating inductors.

Table 2. Aspect ratio (W/L) of transistor in ZC-CFTA

Transistor	W(µm)	L(µm)
M12,M13,M14,M15,M16	18	0.18
M9,M10,M11,M17,M18,M19	72	0.18
M1,M2,M26,M27	18	0.18
M3,M4,M20,M21	72	0.18

M5,M6,M24,M25	27	0.18
M7,M8,M22,M23	90	0.18

4. Simulation Results

To prove the theoretical validity of the filter designed in Figure 7, this filter was simulated with LTP-SPICE program. The ZC-CFTAs are simulated using the CMOS implementation given in Figure 2 based on the 0.18 µm Taiwan Semiconductor Manufacturing Company (TSMC) process parameters. The aspect ratios of the MOS transistors are presented in Table 2. The supply voltages are +V = −V = 0.9 V, and all the biasing currents (I_B) which are realized by the simple current mirror

circuits are set to 300 µA. In order to realize the filter responses with a natural frequency of $\mathbf{f_o = w_o/2\pi \cong 29.7}$ MHz and a quality factor of Q = 1, the following setting for the presented filter of Figure7 has selected the transconductance (g_m) which is equal to 1.85 A/V ($I_{B1} = I_{B2}$ =300 µA). The ideal and simulated responses of the impedance of the designed floating and grounded are shown in Figure 8. The inductor simulator is realized with the following active parameters and passive element values:

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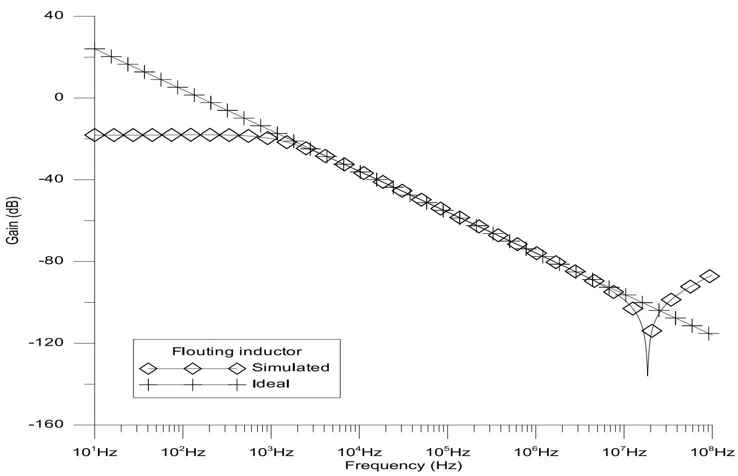
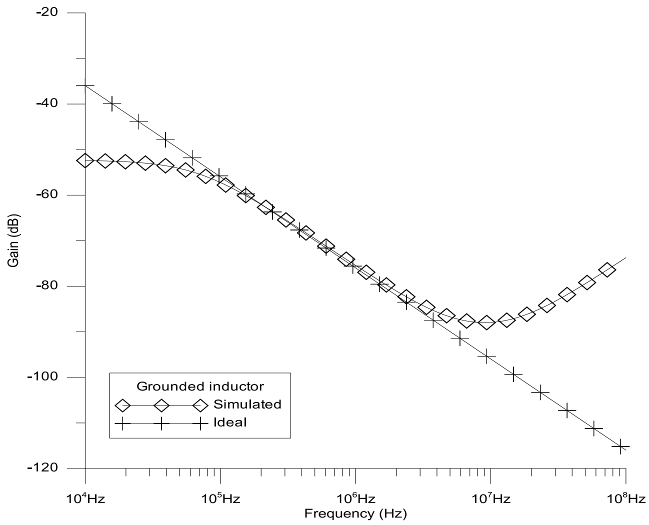
CL = 5.76 nF to obtain L = 1 mH and R = 4KΩ for floating and grounded respectively. Simulated DC transfer characteristics are shown in Figure 9 where it is shown that linear range of ZC-CFTA is from -18 µA to 30 µA.

Figure 10 shows the comparison of magnitude response of the designed 6th order Elliptic ladder band-pass filter in Figure 7 by setting C1=0.1 pF, C2= 0.1 pF, C3= 14 pF, C4=33 pF C5=225pF, C6=225pF and C7=12.5pF and prototype in Figure 6 by setting C1= 225nF, C2= 12.5pF, C3= 225nF, L1=125nH L2=2.251µH, L3=125nH, L4=2.251µH and RS=RL=10Ω, respectively. It can be seen that there is a slight error in a magnitude response of high- pass, but the pass-band is close to the prototype. Total harmonic distortion (THD) analysis has been carried out on BP Filter at **f_o = 29.7** MHz MHz at various sinusoidal peak input currents and results for the same are shown in Figure 11.



(a)



(b)

Figure 8. Ideal and simulated magnitude responses of the (a) floating (b) grounded inductor

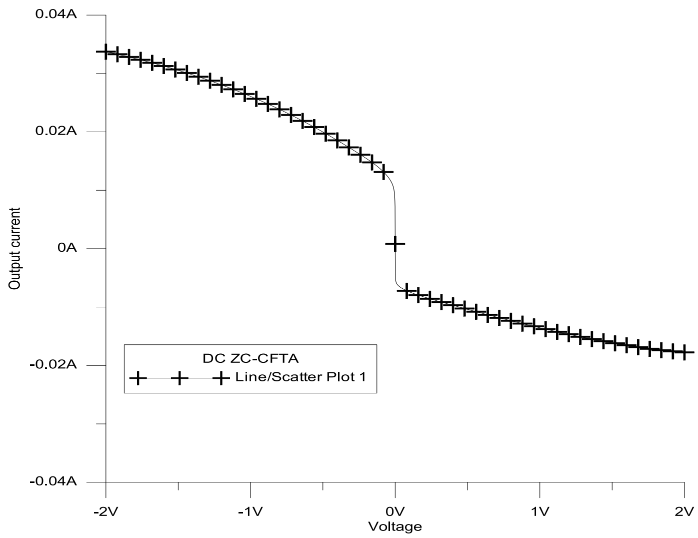


Figure 9. Simulated DC transfer Characteristics of ZC-CFTA.

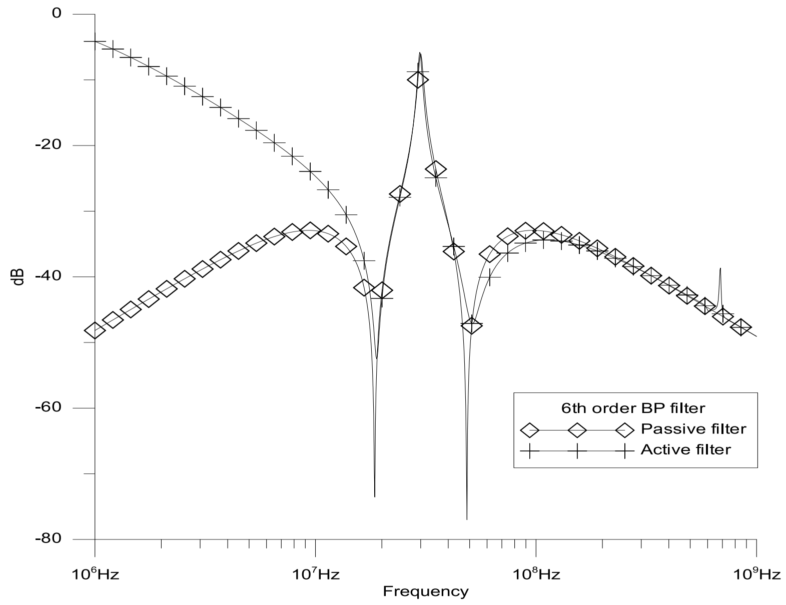


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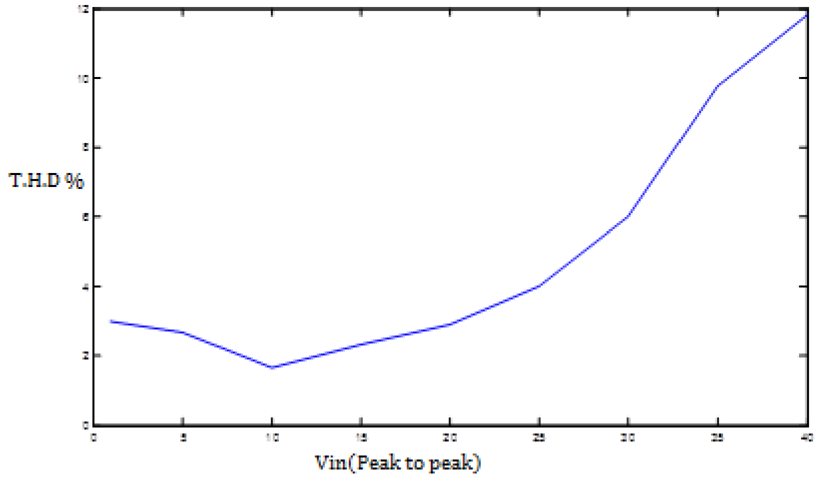
Figure 10. Magnitude responses of purpose Elliptic 6th order ladder band-pass

The filter in Figure 7 compared with the prototype in Figure 6



Figu11. THD variations of the output waveform of the BP filter.

5. Conclusion

This paper presents ZC-CFTA-based electronically tunable Elliptic 6th order voltage-mode ladder band-pass filter realized by transforming an RLC Elliptic ladder low-pass filter prototype. The designed filter contains 4 passive capacitors, 2 resistances, 2 active grounded inductors and 2 active floating inductors. The frequency response can be electronically tuned 29.7 MHz by adjusting I_B which is equal to 300 μA. The designed circuit utilizes just least number of active filter and is sanctioned in nature which settles on its perfect decision for coordinated circuit usage. The filter has low incremental active and passive affectability figures. The PSPICE re-enactment results are appeared and discussed to concentrate all parts of the circuit which guarantee wide utility of the circuit in battery controlled, versatile electronic contraptions and gadgets for wireless communication systems, instrumentation systems, etc.

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