ANALOG CIRCUITS IMPLEMENTATION EMPLOYING VDTA

DISSERTATION

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Submitted by:

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CANDIDATE'S DECLARATION

I, Puneet Pandey, Roll No. 2K21/C&I/04 student of M.Tech (Control & Instrumentation), hereby declare that the thesis titled "**ANALOG CIRCUITS IMPLEMENTATION EMPLOYING VDTA**" which is submitted by me to the Department of Electrical Engineering, 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 Associateship, Fellowship or other similar title or recognition.

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CERTIFICATE

I hereby certify that the thesis titled "ANALOG CIRCUITS IMPLEMENTATION EMPLOYING VDTA" which is submitted by Puneet Pandey, 2K21/C&I/04 [Electrical Engineering Department], Delhi Technological University, Delhi in partial fulfillment of the requirement for the award of the degree of Master of Technology, is a record of the project work carried out by the student under my supervision. To the best of my knowledge this work has not been submitted in part or full for any Degree or Diploma to this University or elsewhere.

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ABSTRACT

This research work aims to realize different types of analog circuit implementation using one of the recently introduced active building blocks i.e., voltage differencing transconductance amplifier (VDTA). Due to its intrinsic qualities such as high input impedance, wide bandwidth, and low sensitivity to parameter fluctuations, VDTAs offer a great foundation for attaining accurate impedance realisation. This work discusses the implementation of positive impedance, negative impedance and inductance simulation using VDTA. Also VDTA can be used significantly for designing filters due to its high frequency operation. A new voltage mode Tow-Thomas biquad filter using optimum number of active and passive elements is proposed in this work. Cutoff frequency, selectivity, and other voltage mode filter parameters can be tuned by modifying the digital parameters of the VDTA, such as transconductance and capacitance values. Designers can develop custom voltage-mode filter circuits that satisfy particular application needs by utilising the capabilities of VDTAs, which enables effective signal processing and frequency shaping. Moreover, the benefits of using VDTAs in integrated circuit implementations, including low power consumption, reduced chip area, and improved noise performance, are discussed.

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ACRONYMS

VDTA	**Voltage differencing transconductance amplifier**
CDTA	**Current differencing transconductance amplifier**
GYRATOR	**Inductance simulator**
TT	**Tow Thomas**
OTA	**Operational transconductance amplifier**

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

The lowering of the voltage supply and the power consumption is a constant requirement that leads to extending the operation duration of the applications in contemporary portable electronics, wireless sensors, biomedical, and energy harvesting applications. Therefore, CMOS designers still need to develop new methods to enhance the performance of analogue circuits running on a 0.9 V supply, which is exceedingly low. The development of microelectronics over the past ten years has led to the development of new active building block circuit principles for quick analogue signal processing, as well as improvements to the qualities of already existing ones such operational transconductance amplifiers (OTA) and current conveyors (CC) [1].

The current differencing transconductance amplifier (CDTA), the current conveyor transconductance amplifier (CCTA), the differential difference current conveyor transconductance amplifier (DDCCTA), and other new analogue active building blocks have been introduced and continue to do so. The voltage differencing transconductance amplifier (VDTA), one of them, is a more recent active component. This element is comparable to the previously disclosed CDTA element, in which the voltage differencer is used in place of the current differencing unit at the front-end [2]. This means that the multiple-output transconductance amplifier, which provides electronic tuning capability through its transconductance gains, and the current source, which is controlled by the difference of two input voltages, make up the VDTA. As a result, the VDTA device is excellent for synthesis of active circuits that can be electronically tuned. Compact structures can be easily achieved in some applications when the VDTA is used as an active element.The VDTA is an alternate option for the implementation of voltage-mode analogue signal processing circuits due to all these benefits.

1.2 VDTA

The voltage differencing transconductance amplifier (VDTA), a more recent electronic active building component, was introduced in 2008 [1]. This device therefore functions as a junction of two separate voltage-controlled current sources. The electronic controllability of the circuit through transconductance gain change is the main feature provided by the VDTA element. The VDTA circuit symbol is shown in Fig. 1.1, where p and n are input terminals and Z, X+, and X- output terminals. All the terminals exhibit high impedance.

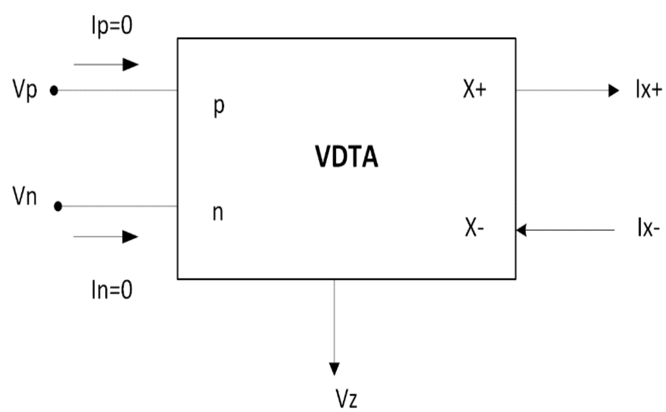

Figure 1.1 VDTA block diagram

Considering ideal VDTA, the terminal relations can be characterized by the following matrix:

$$\begin{bmatrix} I_z \\ I_{x+} \\ I_{x-} \end{bmatrix} = \begin{bmatrix} g_{mf} & -g_{mf} & 0 \\ 0 & 0 & g_{ms} \\ 0 & 0 & -g_{ms} \end{bmatrix} \begin{bmatrix} V_p \\ V_n \\ V_z \end{bmatrix} \qquad (1.1)$$

In above matrix, the parameters g_{mf} and g_{ms} are the first and second stage transconductance gain respectively which are tunable by the external supplied currents of the VDTA. The difference of the input voltages ($V_p - V_n$) is converted into the output current (I_z) with the transconductance gain g_{mf}. Various techniques has been employed to realize VDTA. The VDTA implementation is shown in Fig. 1.2 [4].

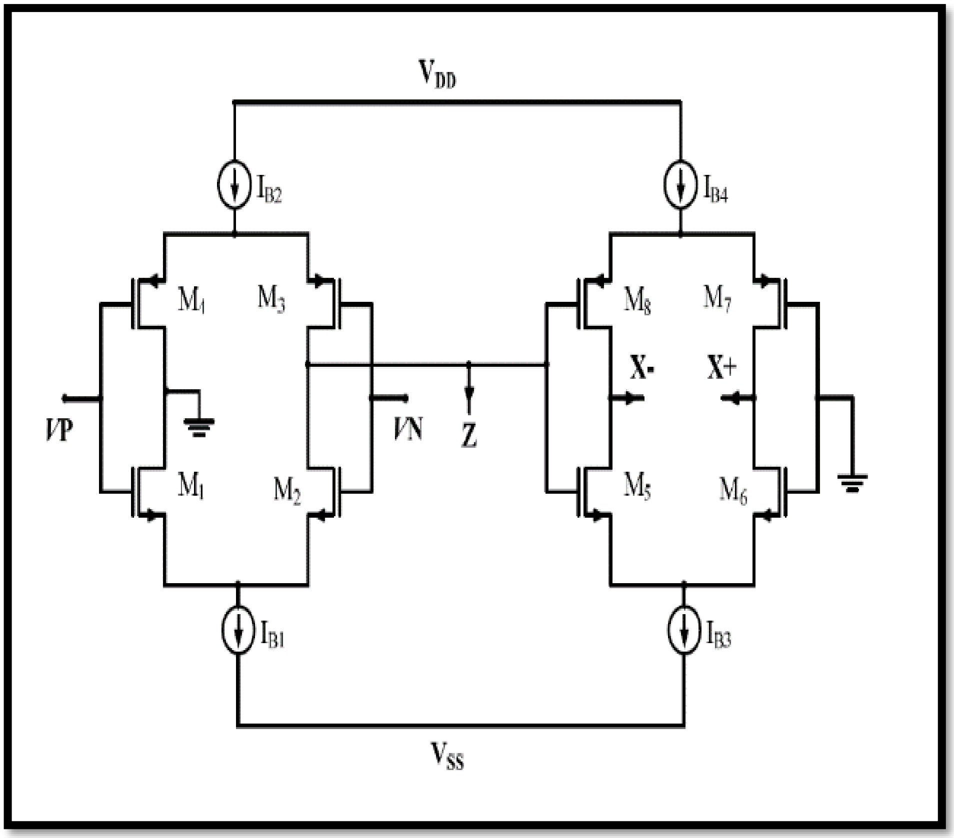

Figure 1.2 VDTA internal architecture

The transconductance parameters derived through this structure are shown as:

$$g_{mf} = \left(\frac{g_1 g_2}{g_1+g_2}\right) + \left(\frac{g_3 g_4}{g_3+g_4}\right) \quad (1.2)$$

$$g_{ms} = \left(\frac{g_5 g_6}{g_5+g_6}\right) + \left(\frac{g_7 g_8}{g_7+g_8}\right) \quad (1.3)$$

where $g_i = \sqrt{\frac{\mu C_{ox} W_i I_{Bi}}{L_i}}$ is the transconductance value, I_{Bi} is the bias current, μ is effective carrier mobility, C_{ox} is the gate-oxide capacitance , $\frac{W_i}{L_i}$ is the effective channel length ratio of the i-th MOS transistor (i = 1,2,….8).

1.3 LITERATURE SURVEY

Modern active element known as the VDTA was initially discussed in [1]. Numerous VDTA-based analogue signal processing/signal generation circuits have recently been proposed by researchers, making it a very valuable and adaptable active building block (ABB) [2]. The VDTA element has been developed as an alternative to the current differencing transconductance amplifier (CDTA) [3], in which the voltage differencing unit is used in place of the current differencing unit at the input stage. In this way, this device connects two separate voltage-controlled current sources. The key characteristic of the VDTA circuit block that allows for direct control of key circuit parameters is electronic controllability with variation in transconductance gain (gm). Due to essential qualities that might affect each other, such as the ability for any parameter to be modified by external voltage or current, many active elements have been proposed and are still being developed.

A straightforward CMOS implementation of VDTA is provided in this work [4]. The differential input voltage (Vp,Vn) is converted to current at terminal Z by the first transconductance gain of the VDTA, and the voltage drop at terminal Z is converted to current at terminals X+ and X- (negative of X+) by the second transconductance gain. Both transconductances can be electronically adjusted by external bias currents [4].

Simulation of impedances and inductances are beneficial in the analysis and designing of analog circuits and systems. Inductance simulation using minimum number of active and passive elements are presented in [5]. There were some limitations in [6] which were overcomed in [7]. Various new circuits were proposed for inductance simulator from [8] through [12]. In the literature, a number of CMOS VDTA circuit designs are published. Two different VDTA architectures are conceivable for usage in designing. It is evident that the ability to linearly tune the transconductance gains of the VDTA has a significant advantage. [13] presents the innovative active circuit for implementing changeable grounded passive elements. Generalised impedance converters were proposed in [14].

The benefit of VDTA over other active blocks is that this new element exhibits two different values of transconductances, making it possible to realise several applications, including oscillator, inductance, and FDNR (frequency dependent negative resistor) simulator, with a single active block using one or two capacitors. [15] The fact that the input and output of this block are voltage and current is very crucial, making it simple to employ in transconductance mode applications. Through the use of a voltage-mode filter application example, the suggested circuit's performance is evaluated [16]-[19]. This architecture can produce the common voltage-mode filter functions by choosing input terminal voltages. There are no external resistors used in the suggested circuit because it uses a small number of passive and active components. Furthermore, no requirement of parameter matching is necessary [20].

VDTA is used to produce the voltage mode all pass filter [21]. Electronically controllable multifunction filter application using single VDTA can also be seen in [22]. Furthermore in the second part of the project, the evaluation of Tow-Thomas biquad filter is discussed [23]. One of the most widely used topologies for filter implementation is the Tow-Tomas (TT) biquad. Utilising a variety of active components, including operational transconductance amplifiers (OTA), current conveyors (CCs), differential voltage current conveyors (DVCC), etc., multiple realisations of TT biquad structure have been developed [23]. Recently, a novel circuit utilising voltage differencing current conveyors (VDCC) was introduced [24]. Different voltage mode filter configuration has been implemented in [25]-[26]. The number of active and passive elements used for implementation of voltage mode Tow-Thomas biquad filter has been varied significantly over the years. The Schmitt trigger circuit using VDTA is discussed in the paper [27]-[28]. The oscillators were also been designed using VDTA [29]. In the recent development the RL/RC immittance simulation is implemented using VDTA [30].

1.4 ORGANISATION OF THESIS

The content of the thesis is organized in five chapters:

- Chapter I INTRODUCTION
- Chapter II IMPEDANCES REALISATION USING VDTA

- Chapter III VDTA-C TOW THOMAS BIQUAD FILTER
- Chapter IV CONCLUSION

Chapter I – Includes the introduction about VDTA basic overview. The literature survey is also presented in this chapter.

Chapter II – This chapter gives brief discussion about the VDTA and its uses in various impedances realization. The gyrator simulation is also presented in this chapter.

Chapter III – This chapter proposed the new voltage mode VDTA-C Tow-Thomas biquad filter presentation. The multifunction filter is also discussed and their transfer function are obtained.

Chapter IV – This includes the conclusion about the research work and future scope further.

CHAPTER 2

IMPEDANCES REALISATION USING VDTA

2.1 IMPEDANCES REALISATION USING VDTA

Positive and negative active resistors that are suitable for on-chip fabrication have recently attracted increasing interest [11]. In order to create filters, oscillators, amplifiers, mixers, artificial neural networks, and control systems, negative-valued adjustable resistors are also becoming an increasingly important component.

2.1.1. Realisation of positive resistor using VDTA

The simulation of passive components like resistors is very much beneficial in the electronics. This reduces the chip area as required by the passive elements is comparatively large and also the power consumption profile is improved. Thus the active realization of positive resistor which have numerous application the electronic field like in filters, inverters etc. is proposed in this chapter. The schematic diagram is shown in the Fig 2.1 for the active realisation of positive resistor.

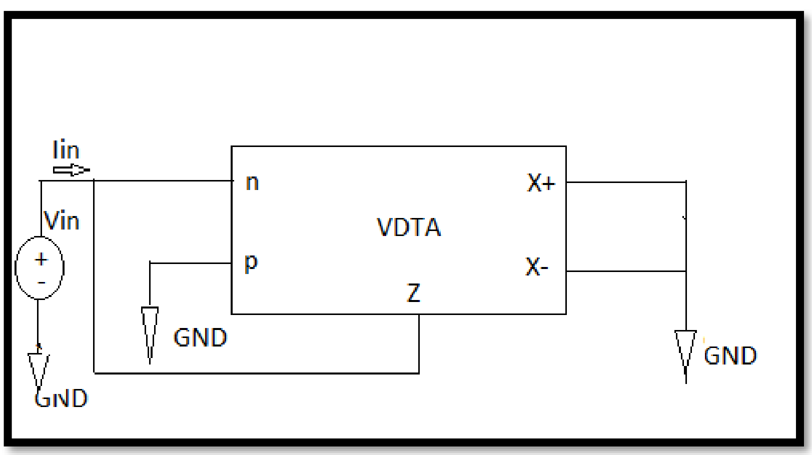

Figure 2.1 Active resistor schematic using VDTA

The resultant impedance is given by

$$Zin = \frac{Vin}{Iin} = \frac{1}{g_{mf}} \tag{2.1}$$

2.1.2. Realisation of negative resistor using VDTA

An electrical component with negative resistance, or one that would cause a voltage drop in the opposite direction of current flow, is referred to as a negative resistor. Negative resistors are a helpful idea in some theoretical and mathematical applications, despite the fact that they don't exist in the real world. Since the invention of the tunnel diode, there have been an increasing number of upgraded circuits incorporating negative resistors. Negative resistors were often selected as negative resistance loads (NRL) in these filter implementations to accommodate for parasitic resistances. Numerous floating and grounded resistance circuits have been created and used in RF bandpass filter applications over the ensuing years [10].

Recently, new methods for using conventional cross-coupled transistor pairs that produce negative resistance have been found. Negative resistance coupling to the main circuit appears to be a problem in the majority of published topologies in the literature, especially for floating negative resistors. The basic circuit characteristics will definitely change as a result of the bias currents of the negative loads and other design elements, necessitating further rectification. This problem has several different manifestations that can be seen. In [14], a standard method for building a negative resistor is illustrated by connecting cross-coupled transistor pairs in a grounded topology. The circuit characteristics of this approach are affected by the recycling of current between the active inductor and the negative resistance load, which is its main disadvantage. The negative resistance load must be isolated from the main circuit due to parasitic input capacitance and biasing problems.

Oscillators and signal generators are theoretically two devices that could use negative resistors. Negative resistors can produce long-lasting oscillations by offering the required positive feedback to compensate for system losses. An oscillator circuit can be made to account for its inherent losses and maintain oscillations by adding a negative resistance element. Different electronic circuit designs for signal creation and frequency generation have investigated this idea. Remote sensing is the field that most frequently uses negative resistance. It might be present on power supplies with greater current ratings since users are more likely to experience voltage drops in load lines at higher currents. Even when the current fluctuates, the power supply can remotely detect the voltage decrease in the load leads.

Negative resistors can also be used in active filters and equalisers, according to theory. In passive filters and equalisers, resistive losses can be made up for by using negative resistance. It is possible to improve frequency responsiveness and account for attenuation at specific frequencies by adding negative resistance elements. When precise frequency shaping is needed for audio applications, this can be quite helpful.

It is significant to emphasise that, as opposed to practical application, the concept of negative resistors is mostly used in theoretical analysis and mathematical modelling. The ideal negative resistor does not exist in real-world electronics, despite certain circuit designs using components that display negative resistance characteristics across a narrow range. Any actual use would therefore be merely speculative or predicated on fictitious events.

The recommended negative resistor in this report is simpler to bias and tune. Additionally, they have less transistors overall, including biasing circuitry. Transistors can be made with the smallest possible dimensions to reduce input parasitic capacitance and power consumption. The implementation also shows the electronic tenability.

The negative resistor schematic is proposed and implemented in the Cadence Virtuoso using gpdk 180nm technology node with single VDTA which is shown in Fig 2.2. The characteristics obtained in the design is similar to the proposed and has been verified through the resultant transfer function.

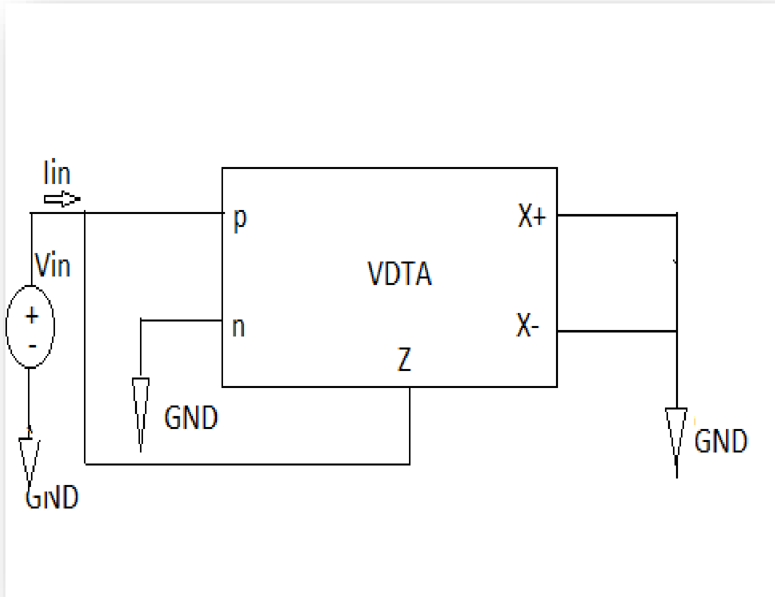

Figure 2.2 Negative resistor schematic

The resultant impedance offered by the circuit is given by

$$\text{Zin} = \frac{\text{Vin}}{\text{Iin}} = -\frac{1}{g_{mf}} \qquad (2.2)$$

2.1.3. Realisation of GYRATOR using VDTA

After the resistor, capacitor, inductor, and ideal transformer, Bernard D. H. Tellegen proposed the gyrator as a possible fifth linear element in 1948. It is a passive, linear, lossless, two-port electrical network component. The gyrator is non-reciprocal, in contrast to the four traditional elements. It is additionally referred to as a positive impedance inverter. The floating inductance is thus obtained which can be tuned with passive elements value. Fig 2.3 depicts the basic gyrator schematic as shown below

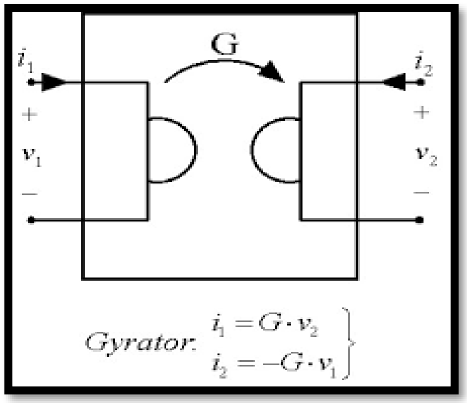

Figure 2.3 Gyrator

The floating inductor simulation using gyrator is given below:

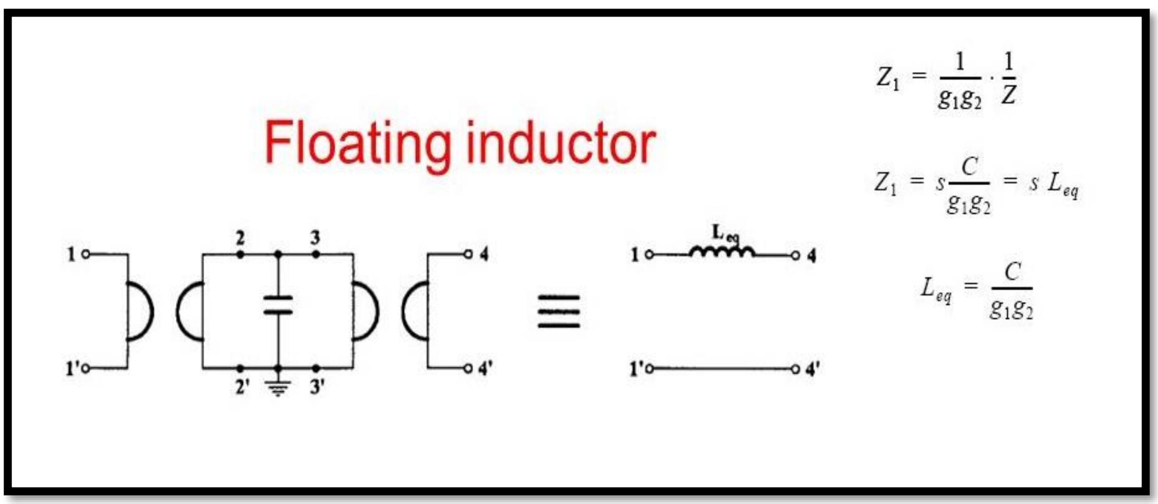

Figure 2.4 Floating Inductor using gyrator

An intriguing research area that has been steadily gaining attention is the development of inductance simulators to be utilised in place of the passive inductor in the analogue signal processing system [14]. Comparing inductance simulators to passive inductors in circuit design also offers a number of benefits, including inductance controllability, a small chip size, a high quality factor, low noise, and low power consumption. Additionally, the method used to create analogue circuits by swapping out passive inductors for inductance simulators is simple to comprehend and put into practise without the use of sophisticated or difficult mathematics [15]. The following circuit is implemented to obtained required inductance values using the active block of VDTA in cadence virtuoso.

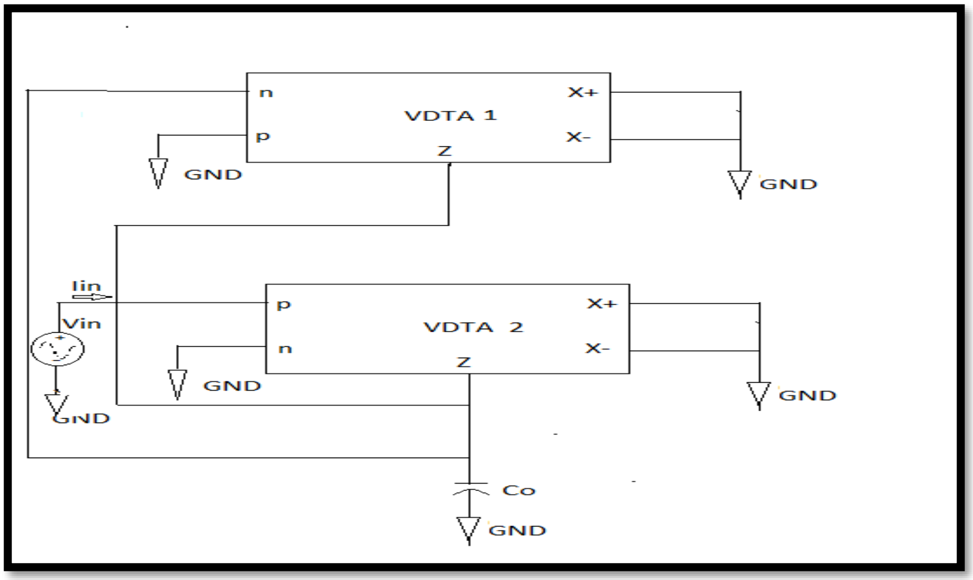

Figure 2.5 GYRATOR using VDTA

The resultant impedance is given by

$$\text{Zin} = \frac{\text{Vin}}{\text{Iin}} = \frac{\text{sCo}}{g_{mf1}g_{mf2}} \tag{2.3}$$

Hence, the equivalent inductance is given by

$$\text{Leq} = \frac{\text{Co}}{g_{mf1}g_{mf2}} \tag{2.4}$$

where, g_{mf1} and g_{mf2} are first stage transconductance gain of both the VDTA.

The circuit in figure 2.5 is simulated in Cadence virtuoso using 180nm technology. The power supply used is 0.9V. The two VDTA blocks and a capacitor were used in the circuit. The power supply is used appropriately as input and the dc and ac analysis is done and simulated result can been seen in the next chapter.

2.2 SIMULATION AND RESULTS

The suggested circuit is simulated in the Cadence Virtuoso environment using the gpdk 180 nm CMOS technology. The implementation of VDTA is done using given MOS transistor aspect ratio in Table 1. The supplied value of biasing currents is 150μA and at the supply voltage V_{dd} = +0.9V and V_{ss} =-0.9V. The cutoff frequency is obtained as 10MHz using the capacitor values as, C1 = C2 = 15pF. The given circuit is subjected to a sinusoidal waveform with an amplitude of 1V and a frequency of 100 KHZ. The results of the perfect simulation demonstrate that this selection results in transconductance values of VDTA as g_{mf} = g_{ms} = 636.5 A/V and the parasitic capacitance at the Z terminal is specified as Cp = 0.17 pF.

Table I

MOS- Transistor Aspect Ratios (W/L) of VDTA

S.No	**Transistors**	**L (μm)**	**W (μm)**
1	M_1 - M_2 - M_5 - M_6	0.36	3.6
2	M_3 - M_4 - M_7 - M_8	0.36	16.64

2.2.1 VDTA characteristics

The dc characteristics of the VDTA element is plotted in the cadence virtuoso. The current Ix+ and Ix- were plotted with the biasing values of biasing current fixed at 150uA. The dc voltage sweep is done the characteristics is plotted as shown:

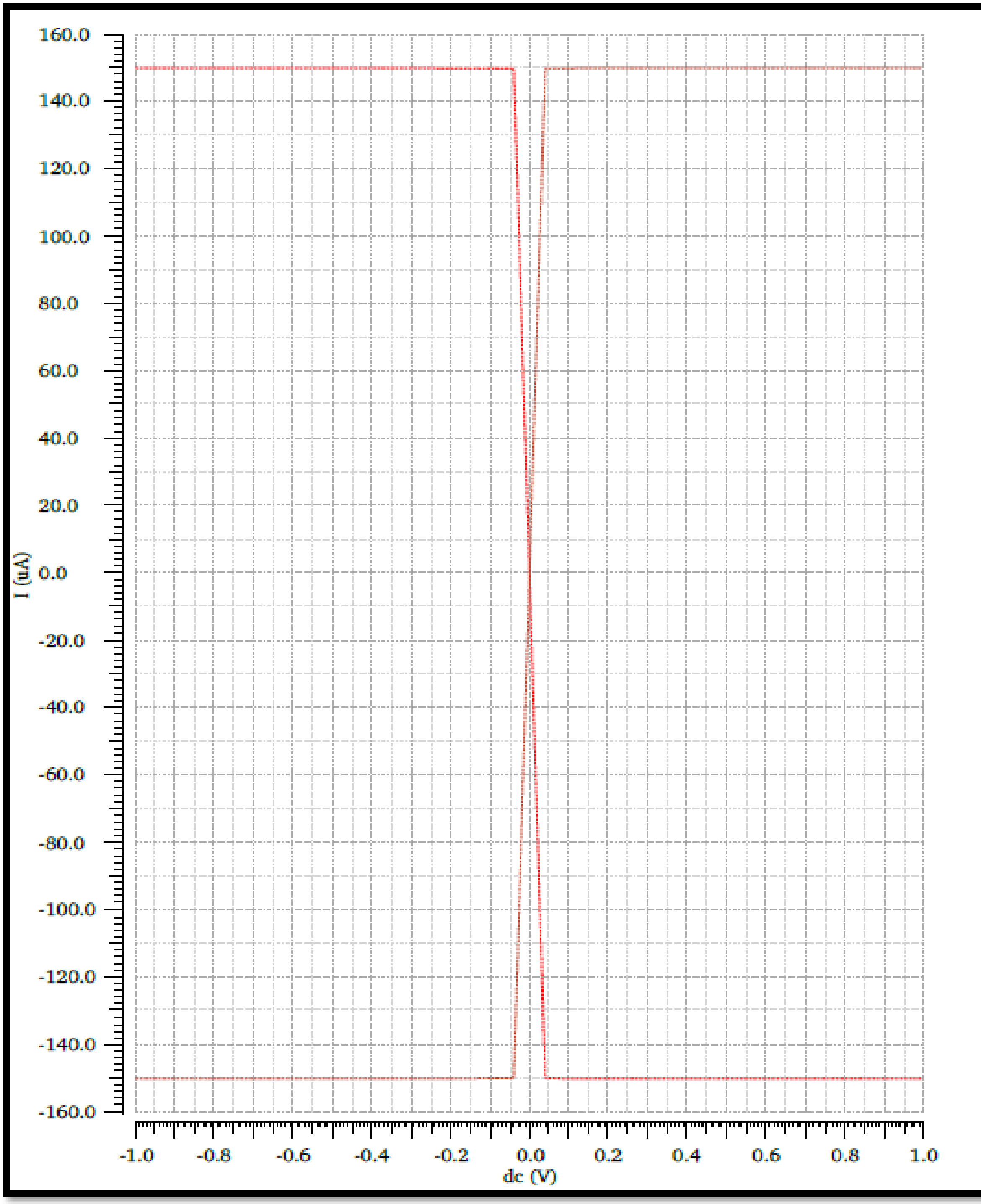

Figure 2.6 DC transfer characteristics of VDTA

2.2.2 VDTA positive resistor simulation

The active realization of resistors is also obtained and the response is shown in the Fig 2.7. The transconductance gain characteristics can be seen in the figure which then saturates to the biasing values of current that is 150uA. Hence the linear operation is limited in the range of 120uA.

The electronic controllability can also be seen in he obtained response.

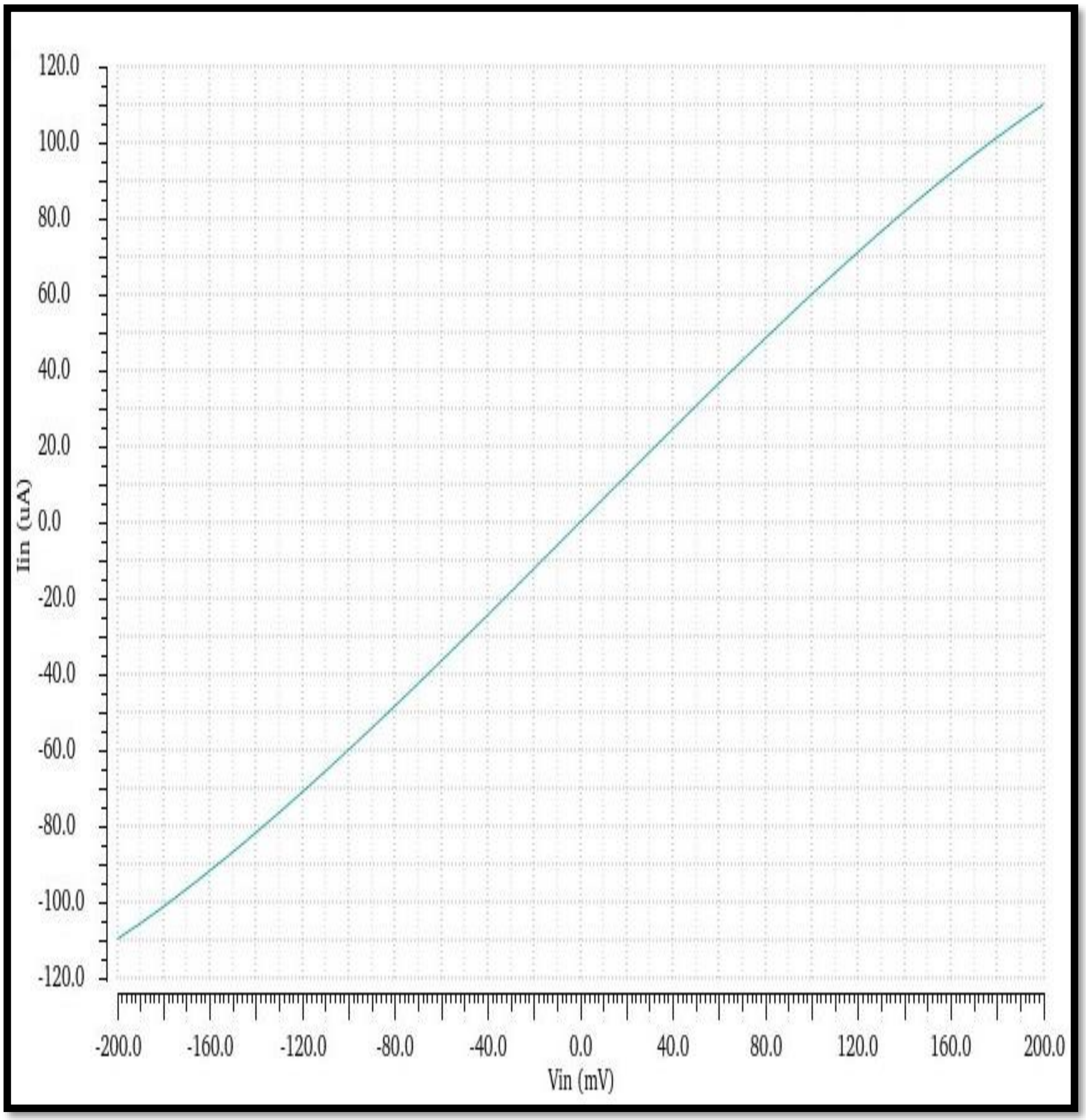

Figure 2.7 VDTA based positive resistor transconductance characteristics

2.2.3 VDTA negative resistor simulation

The negative resistor simulated response is also obtained as seen in the Fig 2.8. The inverse relation between the current and the voltage is clearly seen in the response. Thus there is no power loss in the circuit and the schematic can be used in oscillator for the damped response. To increase the range of operation we can increase the value of biasing currents and thus the linear range of operation is also extended.

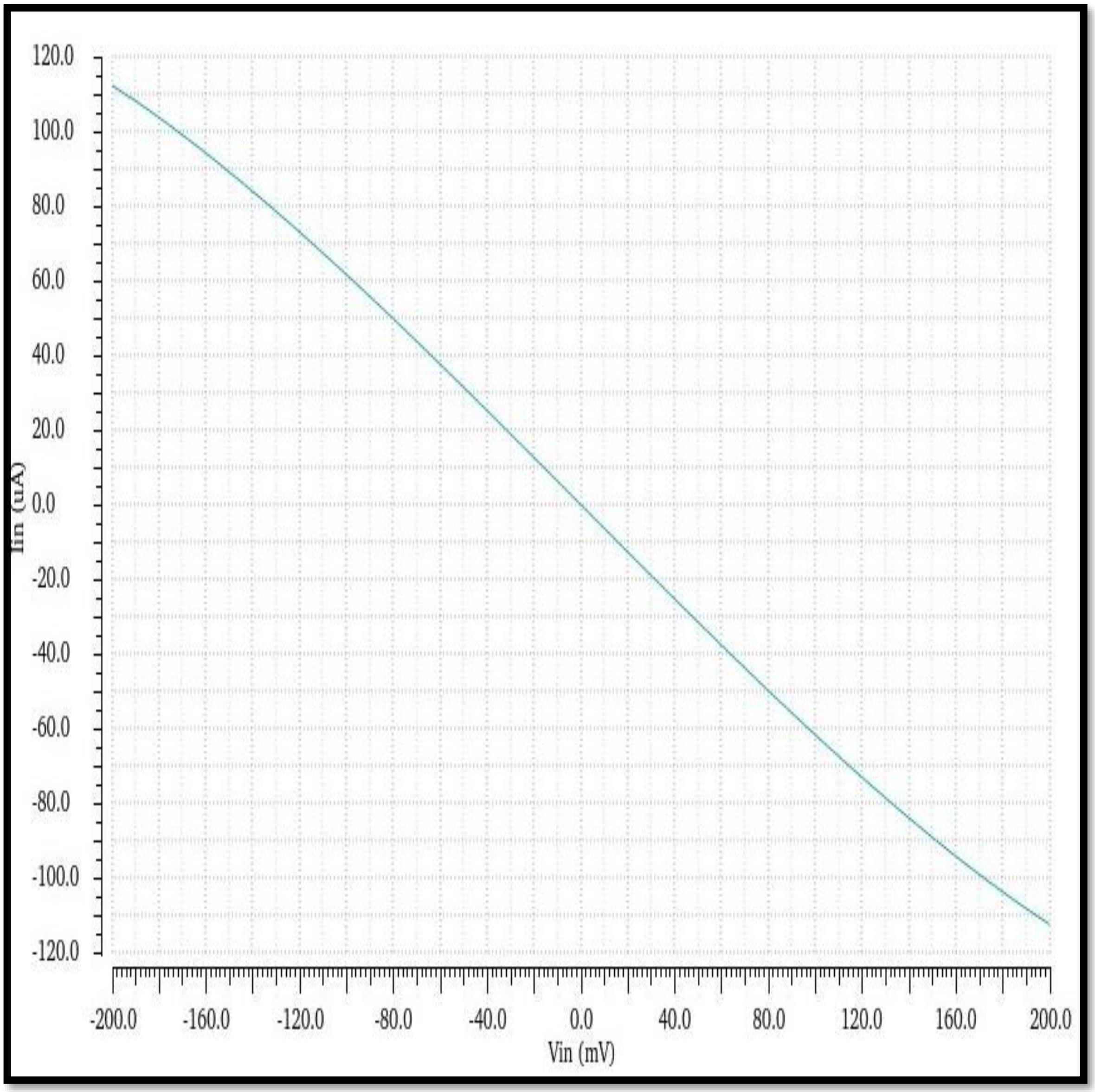

Figure 2.8 VDTA based negative resistor simulated response

2.2.4 VDTA GYRATOR simulation

The inductance simulation and its value has been verified as discussed earlier with the transfer function obtained. Here, the GYRATOR response is obtained as shown below:

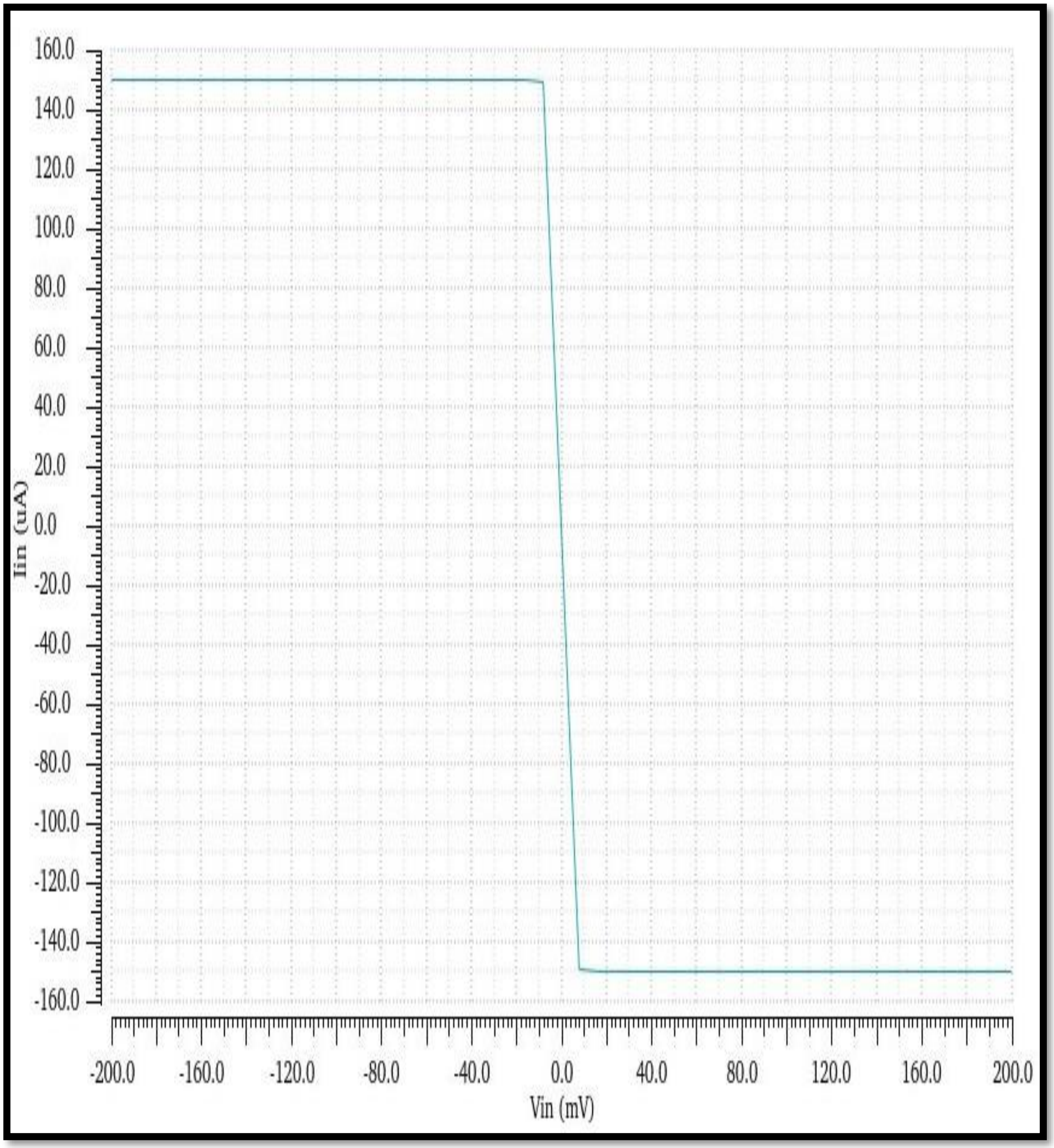

Figure 2.9 VDTA based Gyrator simulated response

CHAPTER 3

VOLTAGE MODE TOW THOMAS BIQUAD FILTER

3.1 VOLTAGE MODE FILTERS

A well-liked analogue circuit for implementing second-order active filters is the Tow-Thomas biquad filter. It bears the names of its creators, George L. Thomas and George H. Tow. Because it operates in the voltage domain, the filter is also known as the voltage-mode biquad filter. A voltage-mode biquad filter is an electronic circuit that utilizes operational amplifiers (op-amps) to implement a biquad filter topology in voltage mode. The biquad filter structure consists of two poles and two zeros, allowing for versatile filtering capabilities, such as low-pass, high-pass, band-pass, and notch filtering.

The filter's input and output signals are in voltage form because the voltage-mode implementation is used. As opposed to current-mode biquad filters, which use signals in current form, this. In applications for analogue signal processing and integrated circuit design, voltage-mode biquad filters are frequently utilised.Op-amps, which amplify and process input signals, are the fundamental building blocks of a voltage-mode biquad filter. A precise control and adjustment of the filter response is possible thanks to the op-amp's high gain and impedance matching. The operational transconductance amplifiers (OTAs) or current conveyors are occasionally used in addition to the standard resistors and capacitors that make up the biquad filter structure.

The transfer function of a voltage-mode biquad filter can be expressed as a ratio of polynomials in the Laplace domain. It is given by:

H(s) = (b0 + b1s + b2s^2) / (a0 + a1s + a2s^2)

Here, the feedforward path is represented by the coefficients b0, b1, and b2, while the feedback path is represented by a0, a1, and a2. You can customise the biquad filter to have the necessary filtering properties by choosing suitable values for these coefficients and the component values.

The versatility, simplicity, and compatibility with voltage-based signal processing systems are benefits of voltage-mode biquad filters. Where exact control of the frequency response is necessary, such as in audio applications, communications, and instrumentation, they are commonly utilised.

Various circuit topologies and design modifications, including Sallen-Key, Multiple Feedback, and State Variable filters, exist for voltage-mode biquad filters. Each has unique qualities and benefits, and the precise implementation specifics might change based on the desired performance needs and design standards. To obtain the desired performance, certain application requirements, component tolerances, and noise factors must be taken into account when constructing or using a voltage-mode biquad filter.

The Tow-Thomas biquad filter's fundamental design consists of three operational amplifiers (op-amps) and a number of passive parts, including resistors and capacitors. Although it can be set up for other filter types, the filter produces two voltage outputs, typically a low-pass output and a band-pass output. In the present work, a voltage mode TT biquad filter is designed using VDTA with an optimal number of active and passive elements. This circuit configuration has high cut-off frequency and independent tunability.

The proposed VDTA-C Tow-Thomas biquad in this thesis utilizes optimal number of active and passive elements. Also there is greater tunability of the filter parameters such as cut-off frequency and gain can be varied independently for LPF.

3.2 VDTA-C TOW THOMAS BIQUAD FILTER

Fig. 3.1 depicts the suggested setup for the multifunctional voltage mode VDTA-C TT biquad filter. One can concurrently acquire the low-pass and band-pass filter responses. It should be noticed that the capacitors are grounded and that no resistors have been utilized in this design.

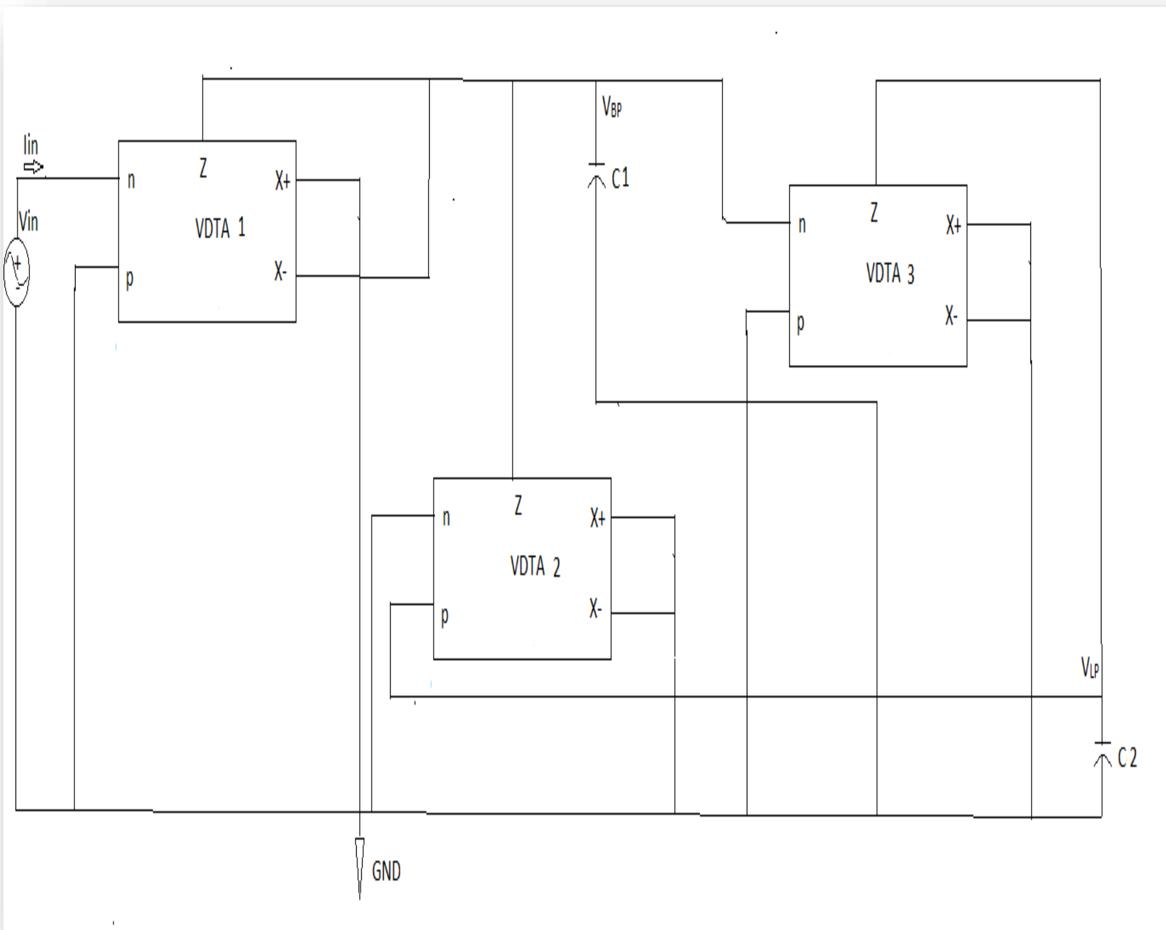

Figure 3.1 Voltage mode VDTA based Tow Thomas Biquad filter

The following output transfer function for a band-pass filter is obtained from the analysis of the suggested circuit configuration:

$$T_{BP}(s) = \frac{V_{BP}}{V_{in}} = \frac{-\left(\frac{g_{mf1}}{C_1}\right)s}{s^2+s\left(\frac{g_{mf3}\,g_{ms1}}{C_1}\right)+\left(\frac{g_{mf3}\,g_{mf2}}{C_1 C_2}\right)} \tag{3.1}$$

In a similar manner, the low pass filter's transfer function is determined as

$$T_{LP}(s) = \frac{V_{LP}}{V_{in}} = \frac{\left(\frac{g_{mf1}\,g_{mf3}}{C_1 C_2}\right)}{s^2+s\left(\frac{g_{mf3}\,g_{ms1}}{C_1}\right)+\left(\frac{g_{mf3}\,g_{mf2}}{C_1 C_2}\right)} \tag{3.2}$$

The quality factor (Q), band width (BW), and pole frequency (0) of the filter are given as

$$\omega_0 = \sqrt{\frac{g_{mf3}\,g_{mf2}}{C_1 C_2}} \tag{3.3}$$

$$BW = \frac{g_{mf3}\,g_{ms1}}{C_1} \tag{3.4}$$

$$Q = \frac{1}{g_{ms1}}\sqrt{\frac{C_1\,g_{mf2}}{C_2 g_{mf3}}} \tag{3.5}$$

The formula for the DC gain for the low pass response is

$$H_{LP} = \frac{g_{mf1}}{g_{mf2}} \tag{3.6}$$

where g_{mf1} and g_{ms1} are first and second stage transconductance gain of VDTA1 and g_{mf2} , g_{mf3} are first stage transconductance gains of VDTA2 and VDTA3 block respectively.

From equations (3.2), (3.3), and (3.6) it can be deduced that for a low pass filter, the pole frequency and DC gain can be changed separately without influencing one another. Similar results were achieved for the pole frequency and center frequency gain of the band-pass filter.

3.3 VDTA-C based Tow Thomas Biquad Filter simulation result

A Low-flow Filter attenuates higher-frequency frequencies while allowing lower-frequency signals to flow through. As frequency rises, the filter response steadily declines. The frequency at which the filter starts to attenuate the signal is known as the cutoff frequency, and it is 10e6 Hz. Significant attenuation is provided by the filter above the cutoff frequency.

A Band-Pass Filter attenuates frequencies outside of its passband while allowing a certain range of frequencies, known as the passband, to pass through. A lower cutoff frequency and an upper cutoff frequency define the passband. The filter responds significantly in the range between these frequencies. The frequency responses of the band-pass and low pass filters are shown in Fig. 3.2.

The suggested circuit is simulated in the Cadence Virtuoso environment using the gpdk 180 nm CMOS technology. The implementation of VDTA is done using given MOS transistor aspect ratio in Table 1. The supplied value of biasing currents is 150μA and at the supply voltage V_{dd} = +0.9V and V_{ss} =-0.9V. The cutoff frequency is obtained as 10MHz using the capacitor values as, C1 = C2 = 15pF. The given circuit is subjected to a sinusoidal waveform with an amplitude of 1V and a frequency of 100 KHZ. The results of the perfect simulation demonstrate that this selection results in transconductance values of VDTA as g_{mf} = g_{ms} = 636.5 A/V and the parasitic capacitance at the Z terminal is specified as Cp = 0.17 pF.

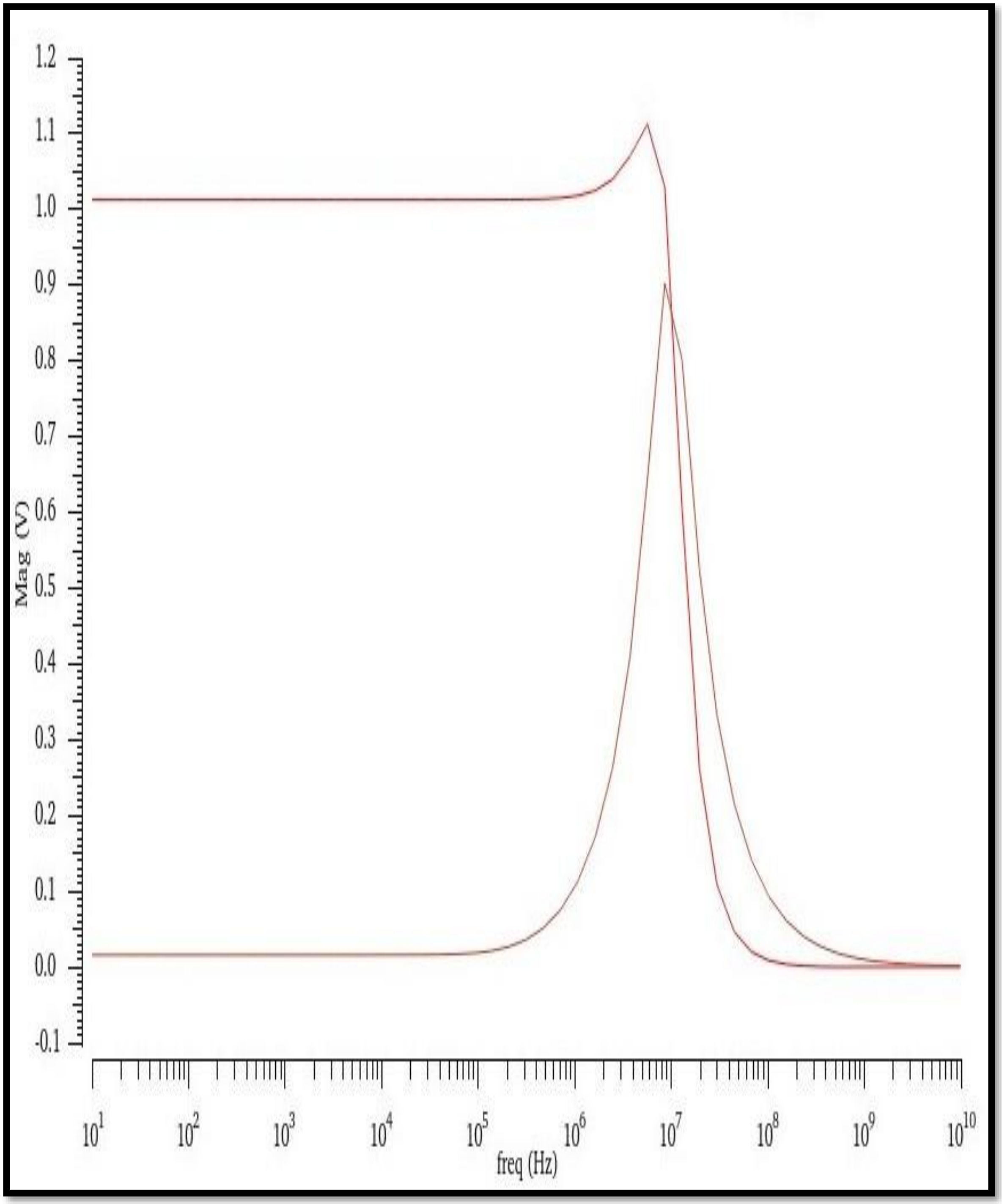

Figure 3.2 Frequency response of TT-Biquad filter

. Fig 3.3 shows the phase response of the band-pass filter, which was likewise produced.

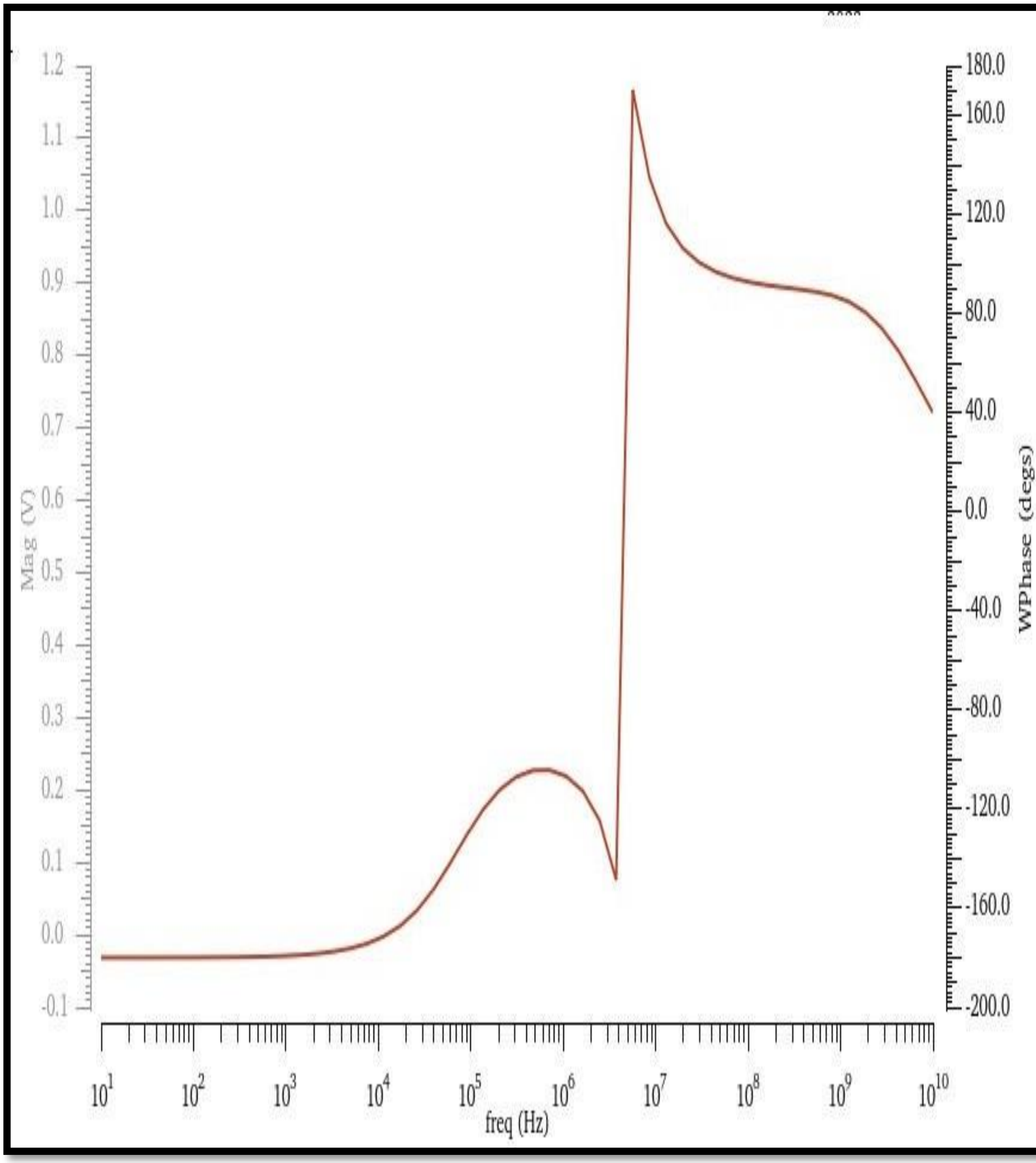

Figure 3.3 Phase response of band pass filter

Since the inverse configuration is obtained, we are having 180 degrees phase change as we can see from the phase response and also from the transient response as seen in Fig 3.4.

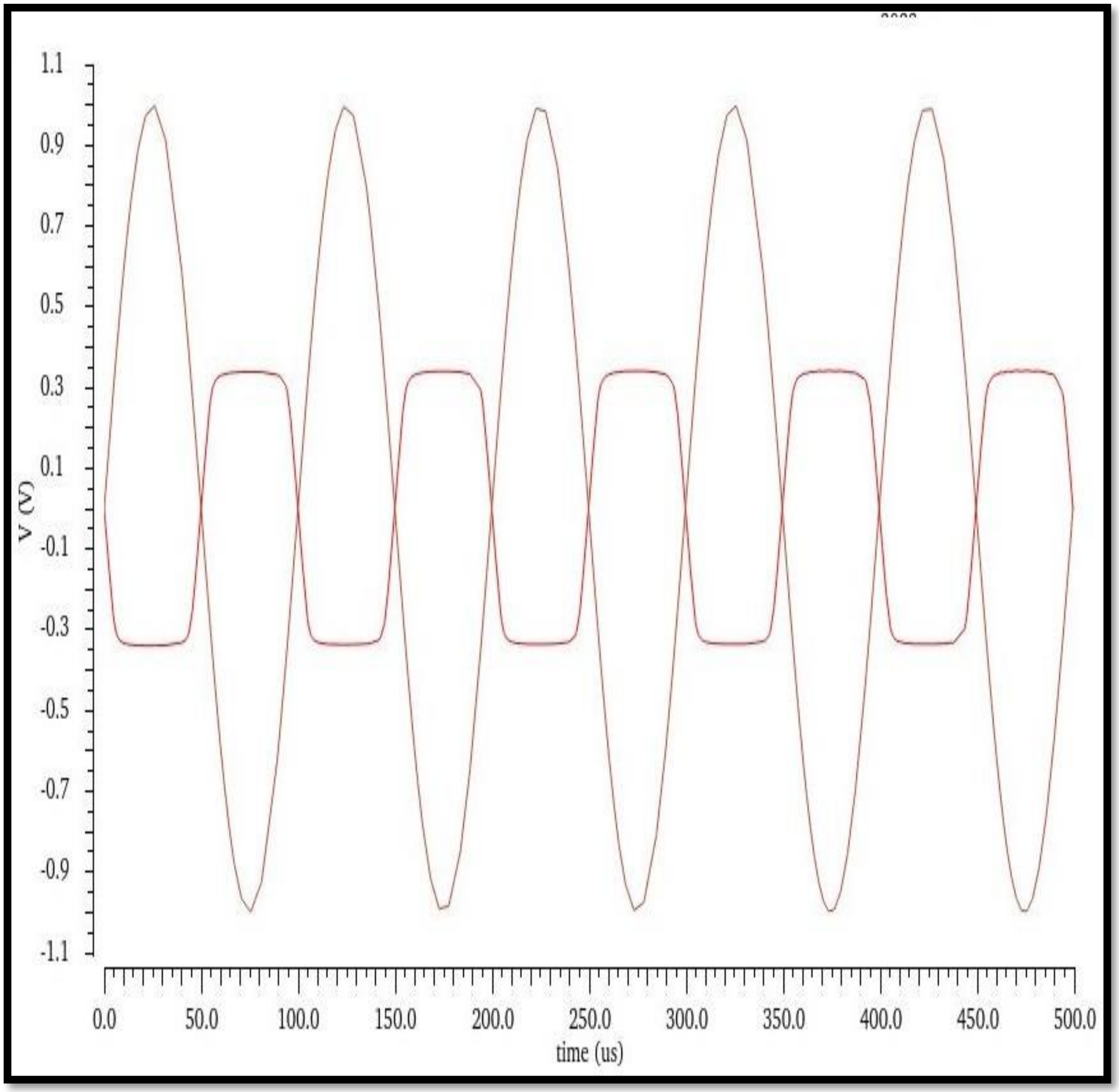

Figure 3.4 Transient response of band pass filter

CHAPTER 4

CONCLUSION & FUTURE SCOPE

4.1 ACTIVE IMPEDANCES REALIZATION USING VDTA

The use of Voltage Differencing Transconductance Amplifiers (VDTAs) for active impedance realisation provides a flexible and effective method for building different kinds of impedance networks and circuits. VDTAs are active building blocks that are suitable for impedance synthesis and transformation because they combine the functions of voltage amplification and transconductance conversion in a single device.

The utilization of VDTAs in active impedance realization brings several advantages:

- Flexibility: Resistors, capacitors, inductors, and their combinations are just a few of the many impedance types that can be realised with VDTAs. Because of their adaptability, complex impedance networks can be designed to meet the needs of particular applications.

- Tunability: Active impedance circuits utilising VDTAs frequently include characteristics that are tuneable, allowing for changes to impedance values or frequency responses. This tunability can be attained by carefully choosing component values or by adding more control components.

- Active gain: VDTAs come with gain by default, enabling signal amplification and compensating for impedance network losses. In cases where impedance matching or signal conditioning are necessary, this function is especially helpful.

- High frequency operation: Because VDTAs can function at high frequencies, they are appropriate for use in RF and analogue signal applications.

- Compactness: By combining several functionalities into a single VDTA device, compact circuit designs are made possible, bringing down the size and complexity of impedance realisation circuits overall.

It's crucial to remember that designing and implementing active impedance circuits employing VDTAs necessitates careful consideration of a number of variables, including biassing, stability, noise, and non-linear effects. Additionally, not all electronic component libraries may have VDTAs readily available, which could make it difficult to design realistic circuits.

Overall, the use of VDTAs to realise active impedance offers a strong method for creating flexible and effective impedance networks, with advantages like flexibility, tunability, active gain, high frequency operation, and compactness. Designers can develop custom impedance circuits to satisfy certain application requirements by effectively utilising the features of VDTAs.

4.2 Voltage Mode Tow-Thomas Biquad Filter

In conclusion, a versatile, accurate, and high-performance method for realising a variety of filter responses in voltage mode is voltage-mode filter realisation utilising VDTAs. Designers can develop custom voltage-mode filter circuits that satisfy particular application needs by utilising the capabilities of VDTAs, which enables effective signal processing and frequency shaping. The proposed VDTA-C Tow-Thomas biquad in this paper utilizes optimal number of active and passive elements. Table II shows the comparision of different configuration of voltage mode TT biquad filter with different count of other active building blocks and passive elements. Noted point is that resistor is not used in this proposed configuration. The independent tunability is also demonstrated and the high frequency performance is required which can be seen in simulation results obtained from Cadence Virtuoso environment.

Table II

Comparision of TT biquad circuit based on number of components used

Active elements	**No. of blocks**	**Resistors**	**Capacitors**	**Gain Control**
OTA	3	6	2	Yes
OTRA	2	4	2	Yes
CCII	3	4	2	Yes
DVCC	3	3	2	No
VDCC	2	5	2	Yes
VDTA (Proposed)	3	0	2	Yes

The use of VDTAs in the realisation of voltage-mode filters has the following benefits:

- Flexibility: A variety of filter responses, including low-pass, high-pass, band-pass, band-stop, and all-pass filters, can be implemented using VDTAs. Due to its adaptability, filters can be created with a variety of frequency characteristics to meet the needs of various applications.

- Accurate control: Filter parameters including the cutoff frequency, bandwidth, and Q-factor can be adjusted with accuracy using VDTAs. The filter response can be precisely customised by choosing the right component values and setting the VDTA circuit.

- High performance: VDTAs have qualities such as great linearity, wide bandwidth, and low distortion that make it possible to realise voltage-mode filters with high performance. They are therefore appropriate for a variety of uses, such as audio processing, telecommunication, and instrumentation.

- Integration with current voltage-based signal processing systems and IC designs is simple for voltage-mode filter circuits utilising VDTAs. The integration of filters into more complex electronic systems is made simpler by this interoperability.

- VDTAs combine voltage amplification and transconductance conversion into a single device, resulting in a reduction in the total number of components in filter designs. This may result in reduced costs, increased dependability, and easier circuit design.

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To whom it may concern:

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Paper ID: 119
Title: VDTA based GYRATOR implementation
Authors: Puneet Pandey, Dr. Garima Mann, Dr. Bhavnesh Jaint
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