STUDY AND IMPLEMENTATION OF CONTINUOUS TIME APPLICATIONS OF VOLTAGE CONVEYER-II

A DISSERTATION

SUBMITTED IN THE PARTIAL FULFILLMENT OF THE REQUIREMENTFOR THE AWARD OF THE DEGREE

OF

MASTER OF TECHNOLOGY

In

VLSI DESIGN & EMBEDDED SYSTEMS

Submitted by:

RAM DUTT (2K21/VLS/15)

Under the Supervision of:

DR. RAJESHWARI PANDEY

DEPARTMENT OF OF ELECTRONICS AND

COMMUNICATIONENGINEERING

DELHI TECHNOLOGICAL UNIVERSITY

(Formerly Delhi College of Engineering)

Bawana Road, Delhi-110042

MAY, 2023

DEPARTMENT OF OF ELECTRONICS AND COMMUNICATION ENGINEERING

DELHI TECHNOLOGICAL UNIVERSITY

(Formerly Delhi College of Engineering)

Bawana Road, Delhi-110042

MAY, 2023

CANDIDATE'S DECLARATION

I, RAM DUTT, student of M.Tech (VLSI Design and Embedded Systems), hereby declare that the project Dissertation titled "STUDY AND IMPLEMENTATION OF CONTINUOUS TIME APPLICATIONS OF VOLTAGE CONVEYER-II" which is submitted by me to the Department of Electronics and Communication Engineering, Delhi Technological University, Delhi in partial fulfilment of the requirement for the award of the degree of Master of Technology, is original and not copied from any sourcewithout proper citation. This work has not previously formed the basis for the award of any Degree, DiplomaAssociateship, Fellowship or other similar title or recognition.

Date: __/05/2023 **RAM DUTT**

Place: New Delhi

DEPARTMENT OF OF ELECTRONICS AND COMMUNICATION ENGINEERING

DELHI TECHNOLOGICAL UNIVERSITY

(Formerly Delhi College of Engineering)

Bawana Road, Delhi-110042

MAY, 2023

CERTIFICATE

This is to certify that the work contained in the project titled "**Study and implementation of continuous time applications of voltage conveyer-II",** submitted by **Ram Dutt, Roll no. 2K21/VLS/15,** in the partial fulfillment of the requirement for the award of Master of Technologyin VLSI & Embedded Systems to the Electronics & Communication Engineering Department, Delhi Technological University, Delhi, is a bona fide work of the students carried out under my supervision.

Date: __/05/2023

Place: Delhi

Prof. Rajeshwari Pandey
(Supervisor)

Prof. O.P. Verma
(Head of Department)

Abstract

This abstract provides an overview of the second generation of voltage conveyors (VCs) and their applications. second generation voltage conveyor is also known as VCII, is a fundamental building block in analog signal processing circuits. Voltage conveyors are widely used in various applications such as analog filters, oscillators, amplifiers, and analog-to-digital converters. The second generation of VCs introduces significant improvements in performance, power efficiency, and integration capabilities compared to the previous generation.

The second-generation voltage conveyor is a versatile and efficient circuit element that allows for the transmission of voltage signals with high linearity and low distortion. It offers enhanced voltage and current transfer characteristics, enabling more precise and accurate signal processing. Furthermore, the second-generation VCs feature reduced power consumption, making them suitable for low-power and portable applications.

Overall, the second generation of voltage conveyors represents a significant advancement in analog signal processing circuits. Their improved performance, power efficiency, integration capabilities, and robustness make them a valuable component for a wide range of applications in the field of analog electronics. Future developments in this area are expected to further enhance the capabilities of voltage conveyors, opening up new possibilities for analog circuit design and signal processing.

The properties of VCII can be used to implement applications like current follower, voltage follower, voltage to current converter, current to voltage converter, voltage differentiator, voltage integrator, etc. The work done during this project helps in realizing analog circuits based on second generation voltage conveyer circuit. The analog circuits which have been implemented using VCII in this project are voltage buffer, current buffer, current to voltage converter, voltage to current converter, voltage differentiator, voltage integrator and Inverting type Voltage amplifier.

These circuits were designed using CMOS technology with a 180nm process. Mathematical calculations have been used to critically analyse each circuit's operation, and SPICE simulations have been used to confirm the functionality of circuit.

ACKNOWLEDGEMENT

The successful completion of this project would not have been possible without the guidance and supportive mentorship of Prof. Rajeshwari Pandey. The constant motivation and support of my mentor was the major driving force behind all the hard work put into the completion of this work, brainstorming of ideas, all the learnings acquired during this project and successful implementation of all the ideas

A special thanks to my cohorts and peers for always helping with my queries during this project. Despite the odds, they have always motivated and inspired to work hard.

I would like to thank my family members for all the support and guidance, to cope up with all the hardships and adversities, and keeping consistent focus for successful completion of this project.

RAM DUTT
Roll no: 2K21/VLS/15
M.TECH. (VLSI Design and Embedded System)
Department of Electronics and Communication Engineering

Table of Contents

LIST OF FIGURES

LIST OF TABLES

NOMENCLATURE

Abbreviations

NMOS	channel Metal oxide semiconductor
PMOS	channel Metal oxide semiconductor
CMOS	Complementary Metal oxide semiconductor
VCII	Second generation voltage conveyer
mW	Milli Watts
nW	Nano Watts
pJ	Pico Joules
V	Volts
F	Farads
nm	Nano meters
V to I	Voltage to current
I to V	Current to voltage
G	Transconductance gain
R	Impedance gain
α	Intrinsic voltage gain
β	Intrinsic current gain
AC	Alternating current
dB	Decibels
Vin	Input voltage
Vout	Output voltage

Chapter 1

Introduction to Analog Signal processing

1.1 Introduction

Analog signal processing refers to the manipulation and analysis of continuous signals in their original analog form. It is a field of study and practice that deals with various techniques and methods used to modify, enhance, and extract information from analog signals. These signals are characterized by their continuous variation over time, typically represented by a continuous voltage or current waveform.

In analog signal processing, the signals are processed using electronic circuits and devices that operate on the physical properties of the signals. These circuits can perform operations such as amplification, filtering, modulation, demodulation, mixing, and signal conditioning. The goal is to modify the analog signal in a way that enables desired functionalities or improves the quality of the signal for further processing or transmission.

Analog signal processing finds applications in a wide range of fields, including telecommunications, audio and video processing, instrumentation, control systems, and many other areas. For example, in telecommunications, analog signal processing techniques are used to transmit, receive, and manipulate voice and video signals. In audio processing, analog circuits are employed to amplify and shape audio signals for playback or recording purposes.

Key components and techniques commonly used in analog signal processing include operational amplifiers (op-amps), filters (such as low-pass, high-pass, bandpass, and notch filters), oscillators, mixers, and modulation techniques like amplitude modulation (AM) and frequency modulation (FM). These components and techniques enable the manipulation of analog signals to achieve desired outcomes, such as noise reduction, frequency shaping, signal conditioning, and modulation/demodulation for communication purposes.

1.2 Different Analog signal processing blocks

Analog active blocks refer to electronic circuits or components that are designed to perform specific functions in analog signal processing. These blocks are typically implemented using active electronic components such as transistors to manipulate analog signals. Here are some commonly used analog active blocks:

1. **Amplifiers:** Amplifiers are used to increase the amplitude of an input signal. Op-amps are frequently used as building blocks for amplifiers due to their high gain and versatile characteristics.
2. **Filters:** Filters are circuits that selectively pass or reject specific frequencies from an input signal. Active filters employ active components like op-amps to achieve precise filtering characteristics.
3. **Oscillators:** Oscillators generate continuous waveforms at specific frequencies. Active oscillators typically use a combination of resistors, capacitors, and active devices like transistors or op-amps to create the desired oscillation.
4. **Voltage regulators:** Voltage regulators maintain a stable output voltage regardless of variations in the input voltage or load conditions. Active voltage regulators use feedback mechanisms and active devices to provide a regulated output.
5. **Comparators:** Comparators compare two input voltages and produce a digital output indicating which voltage is greater. They are commonly used in applications such as threshold detection, level shifting, or signal conditioning.
6. **Phase-locked loops (PLLs):** PLLs are circuits used to synchronize the phase and frequency of an output signal to that of an input signal. Active components, including op-amps and voltage-controlled oscillators (VCOs), are integral to the operation of PLLs.
7. **Analog-to-Digital Converters (ADCs) and Digital-to-Analog Converters (DACs):** ADCs and DACs are used to convert analog signals to digital and vice versa. These converters often employ active components to achieve accurate and precise conversions.

1.3 How voltage conveyor is different from operational amplifiers

These are just a few examples of analog active blocks. There are numerous other types of circuits and components used in analog signal processing, each designed to perform specific functions based on the requirements of the application.

The voltage conveyor (VC) and operational amplifier (op-amp) are two analog building blocks used in electronic circuits, but they have distinct differences in terms of their functionality and internal structure.

1.3.1 Operational Amplifier (Op-Amp):

An op-amp is a widely used integrated circuit (IC) component that amplifies the difference between its two input terminals and provides a high-gain output signal. It typically has two inputs (inverting and non-inverting) and a single output. Op-amps are primarily used for amplification, filtering, signal conditioning, and mathematical operations like addition, subtraction, and integration.

Op-amps have a differential input stage that provides high input impedance, a gain stage that amplifies the difference between the inputs, and an output stage that provides a high-output current. Op-amps are designed to have high gain, high input impedance, low output impedance, and wide bandwidth.

1.3.2 Voltage Conveyor (VC):

The voltage conveyor is a specialized active circuit block that is specifically designed to transfer voltage signals between different parts of a circuit. Unlike op-amps, voltage conveyors are not primarily used for amplification. They have multiple input and output terminals, typically labeled X, Y, Z.

The voltage conveyor can transfer a current signal from the Y terminal to the X terminal, and simultaneously transfer a voltage signal from the X terminal to the Z terminal. This means it can perform voltage transfer operation and current transfer operation. It essentially acts as a "conveyor belt" for voltage signals.

Voltage conveyors are commonly used in applications such as analog signal processing, active filters, analog computing, and mixed-mode circuits. They can be advantageous in circuits where signal transfer or manipulation requires specific voltage relationships or when additional control over signal paths is necessary [5].

In summary, while both op-amps and voltage conveyors are active circuit components used in analog circuits, they have different functions and characteristics. Op-amps are versatile amplifiers with high gain and are used for various signal processing tasks, while voltage conveyors specialize in voltage signal transfer between different parts of a circuit.

1.4 Motivation

The use of second generation voltage conveyers (VCII) to accomplish various analog applications is being considered. Applications include voltage and current buffers as well as analog filters, current to voltage and current to current converters, etc. The research opportunities for second-generation voltage conveyers have inspired researchers to investigate alternative uses for the device's design [5].

In this project, several applications have been investigated, and the characteristics and performance metrics related to each application have been examined and analysed. Additionally, other VCII designs have been researched.

Chapter 2
Circuit of VCII

This chapter has examined a second-generation voltage conveyer (VCII) circuit as well as several design limitations and characteristics. The circuit's schematic design was carried out using the tool LT-Spice. The second-generation voltage conveyer circuit's operation has also been covered, and the function of each of the circuit's constituent parts has been described.

2.1 Second generation voltage conveyors (VCII)

The voltage conveyor (VC) is a fundamental building block in analog circuit design, widely used in various applications such as amplifiers, filters, and signal processing circuits. The second generation of voltage conveyors has emerged as an advanced and versatile circuit element, offering enhanced performance and extended functionality compared to its predecessors [5].

Unlike the first-generation voltage conveyor, the second-generation version incorporates several improvements, including increased bandwidth, reduced power consumption, improved linearity, and enhanced dynamic range [10].

The second-generation voltage conveyor maintains the basic operating principles of its predecessor, which involve the transmission of voltage signals from input to output terminals while providing high impedance at the input and low impedance at the output. However, it introduces additional features, such as increased voltage swing capability, extended frequency response, and improved noise performance [3].

Furthermore, the second-generation voltage conveyor offers enhanced controllability, allowing the adjustment of various circuit parameters to meet specific application requirements. It can operate in different modes, including voltage mode (VM), current mode (CM), and transimpedance mode (TM), enabling versatile signal processing capabilities. This versatility makes it suitable for a wide range of applications, including analog signal conditioning, filtering, and mixed-signal systems [6].

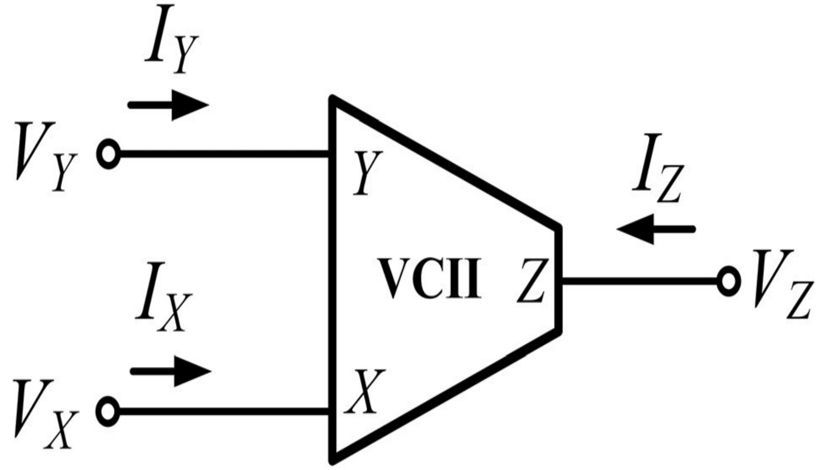

Fig. 2.1: Basic block of second-generation voltage conveyer [7]

2.2 Mathematics of voltage conveyer second-generation (VCII)

A Second-generation voltage conveyer is a three-port block. The block's three ports/terminals are the X, Y, and Z terminals. In accordance with (1.1), the output at each of the three ports—X, Y, and Z ports is described in relation to the parasitic component values inside the device, the values of voltage, and the values of current [8]. The computation of output signals at the X, Y, and Z ports may be done at low frequencies using equation (1.1). A voltage buffer between X and Z terminals and a current buffer between Y and X terminals make up a VCII block, as can be shown in Fig 1.1.

$$\begin{bmatrix} Ix \\ Vy \\ Vz \end{bmatrix} = \begin{bmatrix} \left(\frac{1}{Rx}\right) + sCx & \pm\beta & 0 \\ 0 & Ry + sLy & 0 \\ |\alpha & 0 & Rx + sLz \end{bmatrix} \begin{bmatrix} Vx \\ Iy \\ Iz \end{bmatrix} \qquad (1.1)$$

The voltage conveyer active block's functionality is shown in (1.1). According on how the conveyer is operating, the input current that is delivered to the Y terminal of the VCII block is transferred to the X terminal. Between the X and Y terminals, there is a current buffer network that facilitates this current transmission. The output voltage created at the low impedance Z terminal will then be created by the voltage created at the x terminal. Between the X and Z terminals of VCII, a voltage buffer connection is used to generate this voltage [5].

2.3 Circuits of VCII+ and VCII-

Circuit diagram of VCII+ and VCII- have been illustrated in Fig 2.2 and Fig. 2.3. The schematic has been designed on LT Spice using 180-nm CMOS technology and supply voltage of 0.90 V. The aspect ratio of all the PMOS transistors and NMOS transistorsin the VCII+ circuit, are (40.5 µm/0.54 µm) and (13.5 µm/0.54 µm) respectively [7].

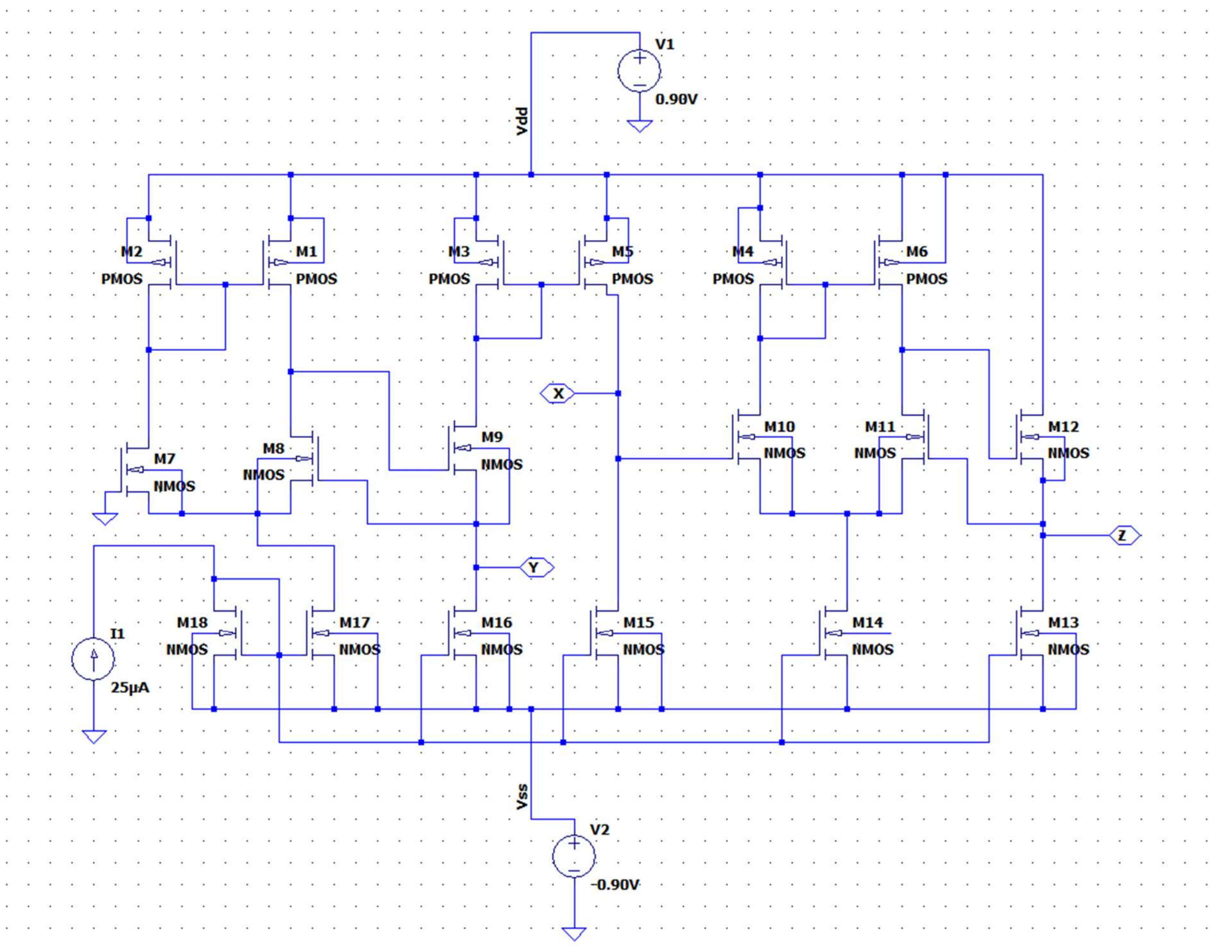

Fig 2.2: Circuit diagram of VCII+

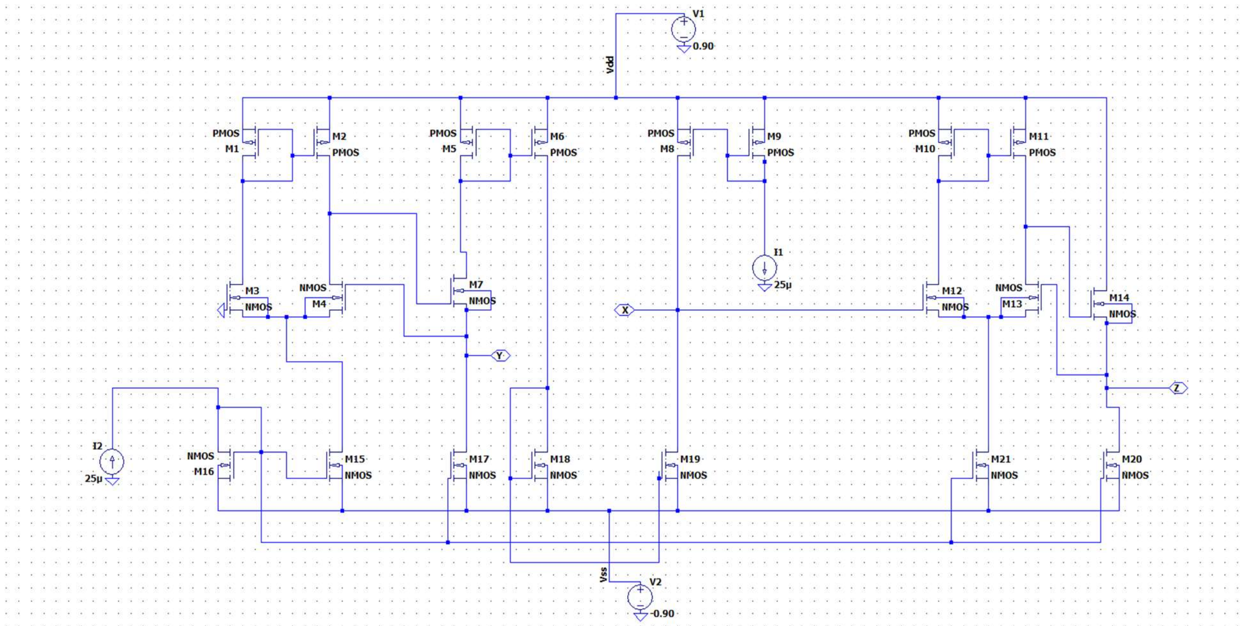

Fig. 2.3. Circuit diagram of VCII-

2.4 Explanation and role of different components

The circuit is fed with a constant current using the separate current sources shown in the above schematics in Figs. 2.2 and 2.3. Two fundamental circuits make up a VCII circuit arrangement. A single voltage buffer connection is created between the circuit's X and Z terminals. In the circuit, a current buffer connection is created between the Y and X terminals [7].

As shown in Fig. 2.2, the implementation of VCII involves a series connection between the current buffer, which is made up of MOS transistors M1, M2, M3, M5, M7, M8, and M9, and the voltage buffer, which is made up of MOS transistors M4, M6, M10, M11, and M12. The current buffer network, which is made up of MOS transistors M1, M2, M7, and M8, is set up with a separate negative feedback in order to produce low impedance at the Y terminal. According to Fig. 2.2, a straight forward current mirror formed by MOS transistors M3 and M5 enables input current provided at the Y terminal to be transferred to the X terminal in accordance with conveyer action [8].

The MOS transistors M4, M6, M10, M11, and M12 form and build a voltage buffer network. The voltage generated at the X terminal can be transmitted to the Z terminal thanks to the voltage conveyer operation. The negative feedback loop built between MOS transistors M10, M4, and M6 makes use of the low impedance produced at the Z terminal. Finally, the biassing is done using MOS transistors M13 to M18 [8].

2.5 Symbol of VCII block

To generate a symbol for the voltage conveyer circuit mentioned above, i used LT SPICE's create symbol option. VCII block is the name provided to the instance of this block that will be utilised in the development of numerous applications. Three bidirectional nodes—the x, y, and z nodes—make up the block. In circuits created with VCII blocks, these nodes serve as input and output nodes. A steady supply voltage of 0.90 V is used.

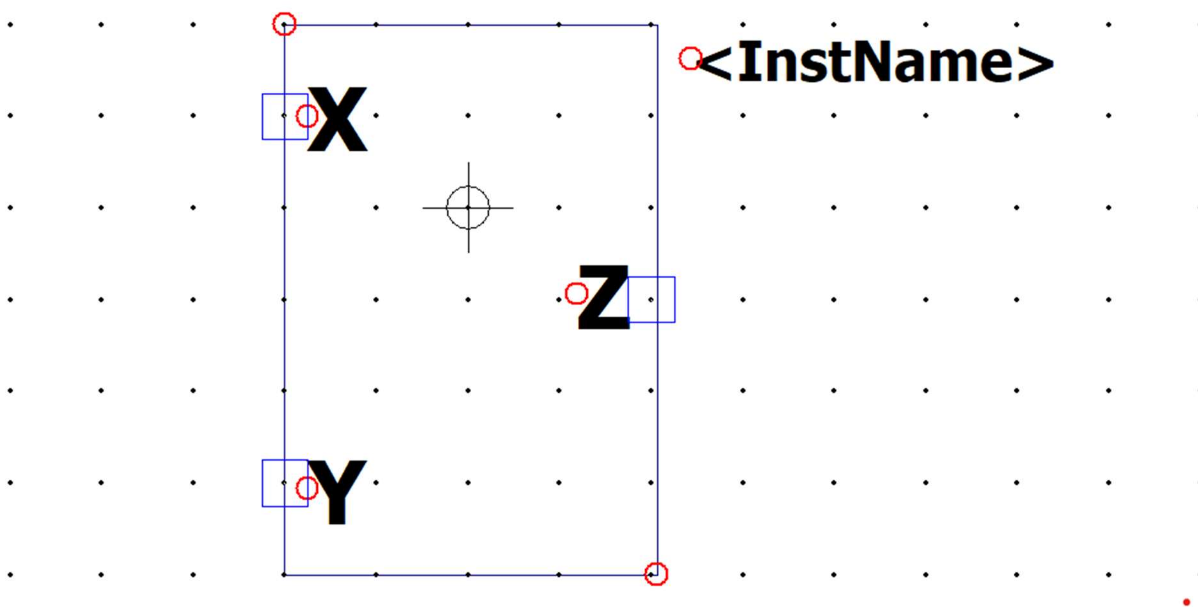

Fig 2.4: Symbol for VCII block

2.6 Applications of voltage conveyer circuit (VCII)

2.6.1 Voltage to current converter

A typically ideal V to I converter employs high output impedance characteristics. The circuit diagram of Vto I converter implemented by using VCII is illustrated in Fig.2.5

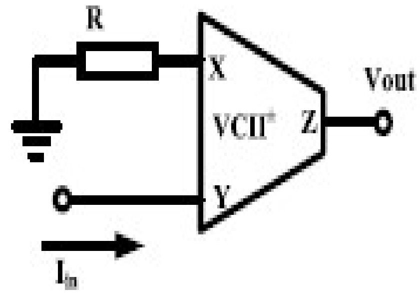

Fig. 2.5: Voltage to current converter [5]

2.6.2 Current to voltage converter

A typically ideal I to V converter employs low output impedance characteristics. The circuit diagram ofI to V converter implemented by using VCII is illustrated in Fig.2.6

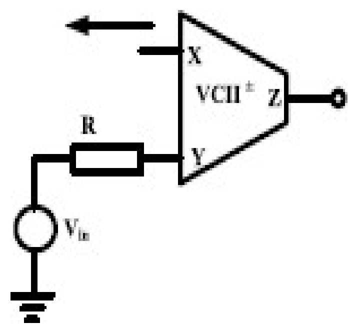

Fig. 2.6: Current to voltage converter [5]

2.6.3 Voltage Buffer

The voltage buffer circuit is implemented using the unity voltage gain of second generation voltage conveyer.The circuit diagram of the VCII based voltage buffer is given in Fig 2.7.

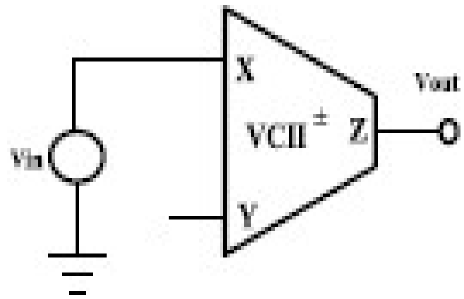

Fig. 2.7: Voltage buffer [5]

2.6.4 Current buffer

The unity current gain of the second generation voltage conveyer enables the implementation of a currentbuffer using VCII. The circuit diagram of the current buffer circuit is given in Fig 2.8.

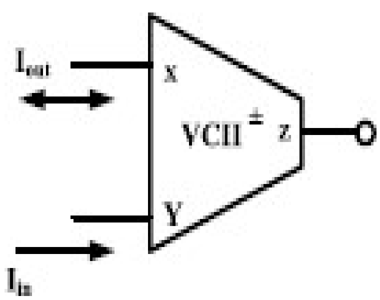

Fig.2.8: Current buffer [5]

2.6.5 Voltage Differentiator

The circuit diagram for implementation of a voltage differentiator circuit using VCII is given in Fig. 2.9.The output response and the gain bandwidth curve is plotted to analyze it's performance.

$$\frac{V_{out}}{V_{in}} = \alpha\, \beta\, S\, C\, R$$

The values of resistance and capacitance determine the mid band gain and the output level of the circuit.

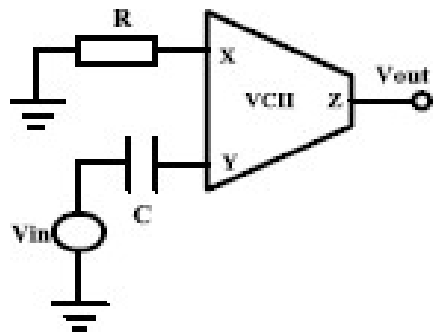

Fig. 2.9: Voltage differentiator [5]

2.6.6 Voltage Integrator

The circuit diagram for implementation of a voltage integrator circuit using VCII is given in Fig 2.10. The output response and the gain bandwidth curve is plotted to analyze it's performance.

$$\frac{V_{out}}{V_{in}} = \alpha\, \beta /(S\ C\ R)$$

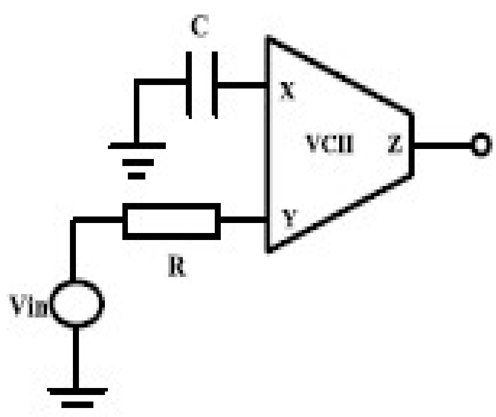

Fig. 2.10: Voltage integrator [5]

The mid band gain and the output level of the circuit is dependent on the values of passive components present in the circuit. The operations of these circuits have been discussed and validated in chapter 3.

2.6.7 Inverting type voltage amplifier:

The output of a voltage amplifier is an amplified copy of the applied input voltages. As seen in fig. 2.11 below, voltage conveyor can be utilised to create a voltage amplifier. In inverting type voltage amplifiers, the output is inverted of the input provided and amplified with some finite gain value. Two resistors are used at both x and y terminals and input is provided to the y terminal and output is taken from the z terminal as shown in the fig. 2.11 [6].

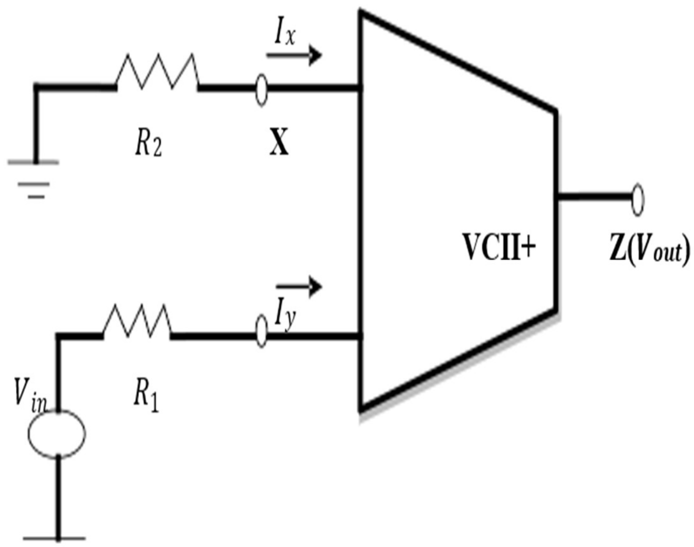

Fig. 2.11: Inverting voltage amplifiers [6]

$Vy = 0$ (Always GND); $Ix = - \beta.IY$; $V_2 = \alpha . Vx$

$Iy = Vin / R1$ ----------------(1)

$Vx = Ix . R_2$

$Vx = (\beta. Iy). R_2$; due to current Buffer

$Vx = (-\beta. Vin/ R1) R_2$; from Eqt^n 1

$Vx = - R2/R1 . B. Vin$ ------------(2)

Now, $Vz = \alpha . Vx$

$Vz= \alpha . (-R2/R1. B. Vin)$; from Eqt^n 2

$Vz=$ $Vout / Vin = -R2/R1. \alpha. B$

Av = Voltage gain of Amplifier

$Av = Vout/Vin = -R2/R1. \alpha. B$

Chapter 3

VCII based Analog circuits

This chapter discusses and implements a number of applications for the second generation voltage conveyer (VCII) utilising the 180-nm CMOS technology in the schematic simulation tool LT Spice. The supply voltage is 0.90 V, which is constant. Each circuit's performance metrics have undergone a thorough and careful analysis. The second generation voltage conveyer circuit utilised in the circuit implementation is drawn from Chapter 2's Fig. 2.2.
Voltage buffer, Current buffer, Voltage differentiator, and Voltage integrator are the applications that have been implemented and explained in this chapter. All circuits' functional viability has been confirmed utilising step response and transient response with sinusoidal waveform input signal.

3.1 Voltage to current converter (V to I converter)

Circuit Diagram is given in Fig 3.1. The voltage conveyer block used in the circuit is the circuit taken from Fig 2.2 in chapter 2. The aspect ratio of all the PMOS transistors and NMOS transistorsin the VCII+ circuit, are (40.5 μm/0.54 μm) and (13.5 μm/0.54 μm) respectively. The supply voltage given to the circuit is 0.90 V. To plot the sinusoidal response, a sine waveform having frequency 1 kHz and amplitude of 20 mV peak to peak is given as input to the circuit. To plot thestep response, a step waveform of 20 mV is given as input to the circuit.

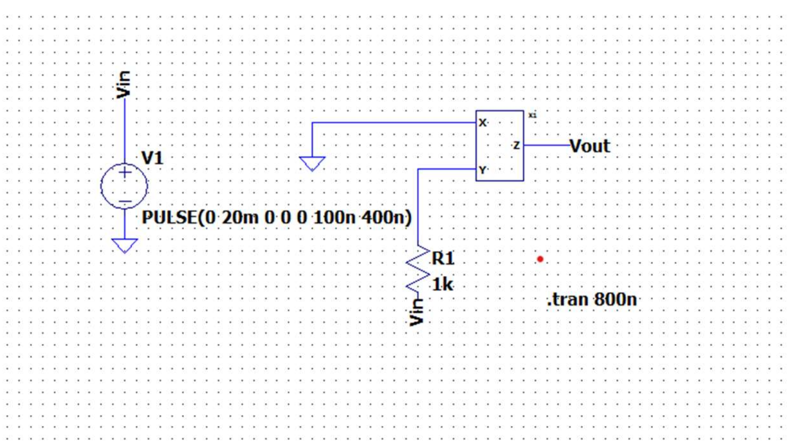

Fig. 3.1: Voltage to current converter

The input voltage is provided to terminal Y of the VCII block and output current is taken from the nodalcurrent of X node of VCII block.

Transient or the sinusoidal response of the V to I circuit can be observed in Fig. 3.2.

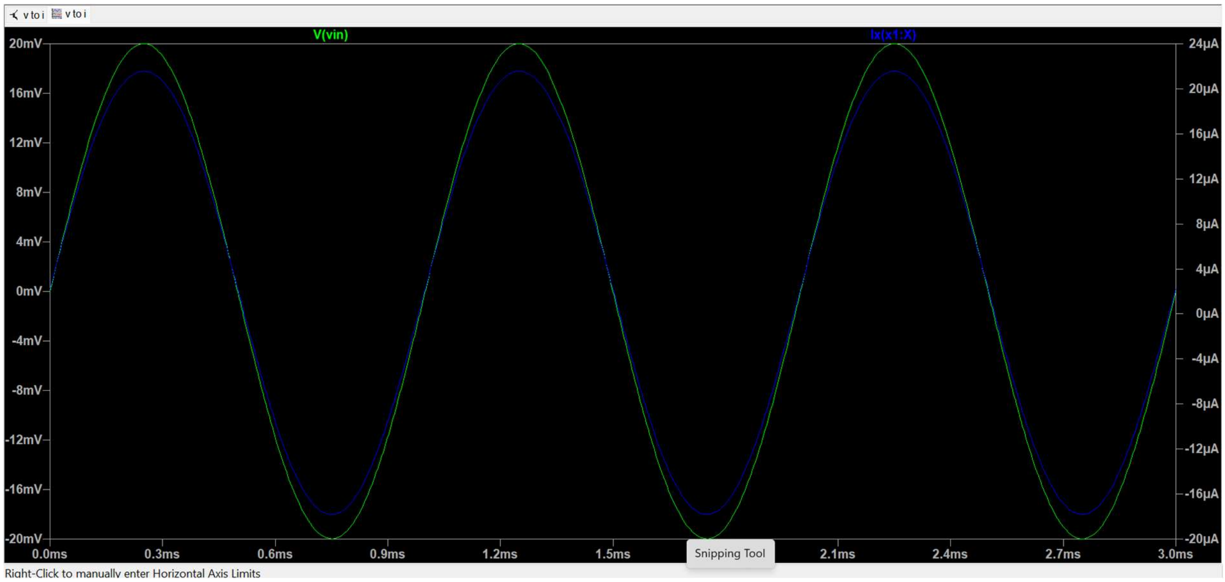

Fig. 3.2: Sinusoidal response of V to I circuit

The step response of the V to I circuit can be observed in Fig. 3.3.

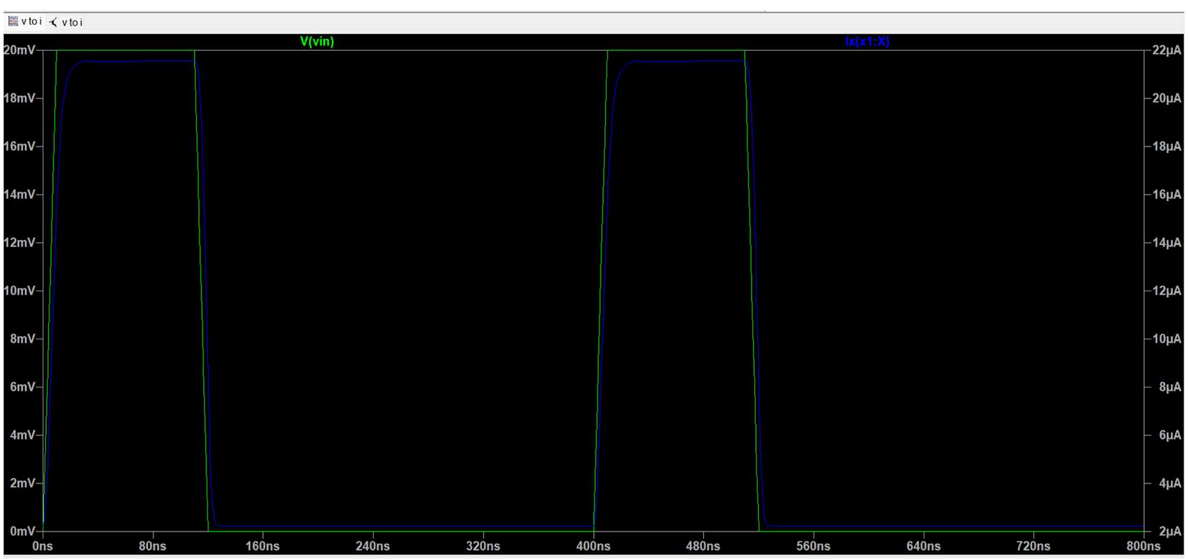

Fig. 3.3: Step response of V to I converter

Calculation of the transconductance gain of V to I converter from the above step response.The transconductance gain of the circuit is calculated as:

Transconductance gain(G)= Ix(x1:x)/V(Vin) G = 21.5488uA/20mV

=1.0774 mS.

3.2 Current to voltage converter (I to V converter)

Circuit Diagram is given in Fig 3.4. The voltage conveyer block used in the circuit is the circuit taken from Fig 2.2 in chapter 2. The aspect ratio of all the PMOS transistors and NMOS transistorsin the VCII+ circuit, are (40.5 µm/0.54 µm) and (13.5 µm/0.54 µm) respectively. The supply voltage given to the circuit is ±0.90 V. To plot the sinusoidal response, a sine waveform having frequency of 1 KHz and amplitude of 20 µA peak to peak is given as input to the circuit. To plot the step response, a step waveform of 10 µA is given as input to the circuit.

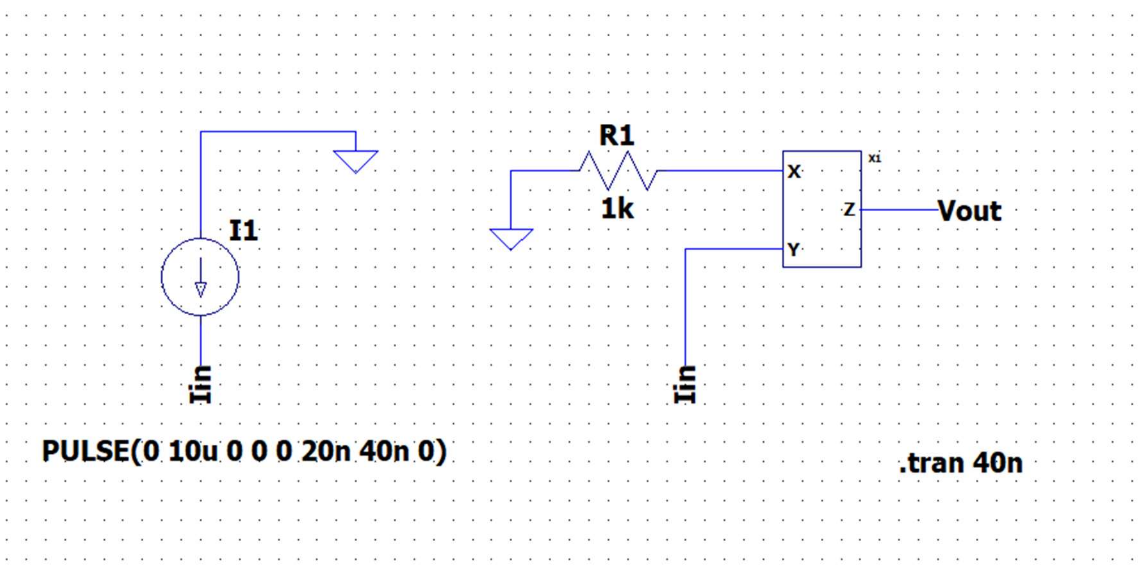

Fig. 3.4: I to V converter

The input current is provided to terminal Y of the VCII block and output voltage is taken from Z node of VCII block. The voltage conveyer action enables the current at y terminal to be reflected on the x terminal of the circuit. The corresponding voltage which is produced at the X terminal is transferred to the z terminalof the circuit. Transient or the sinusoidal response of the I to V circuit can be observed in Fig. 3.5

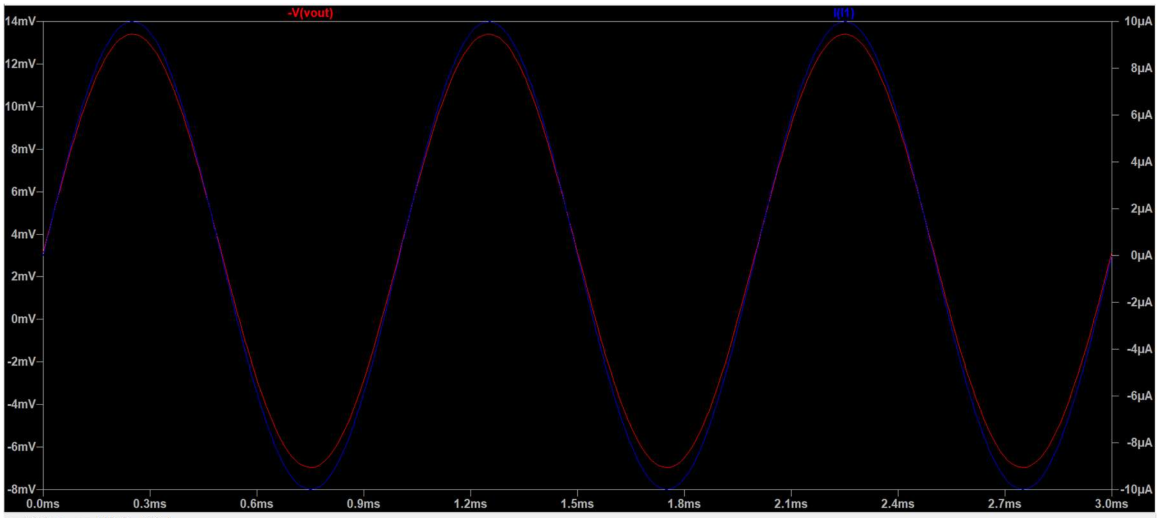

Fig. 3.5: Sinusoidal response of I to V circuit

The step response of the I to V circuit can be observed in Fig. 3.6.

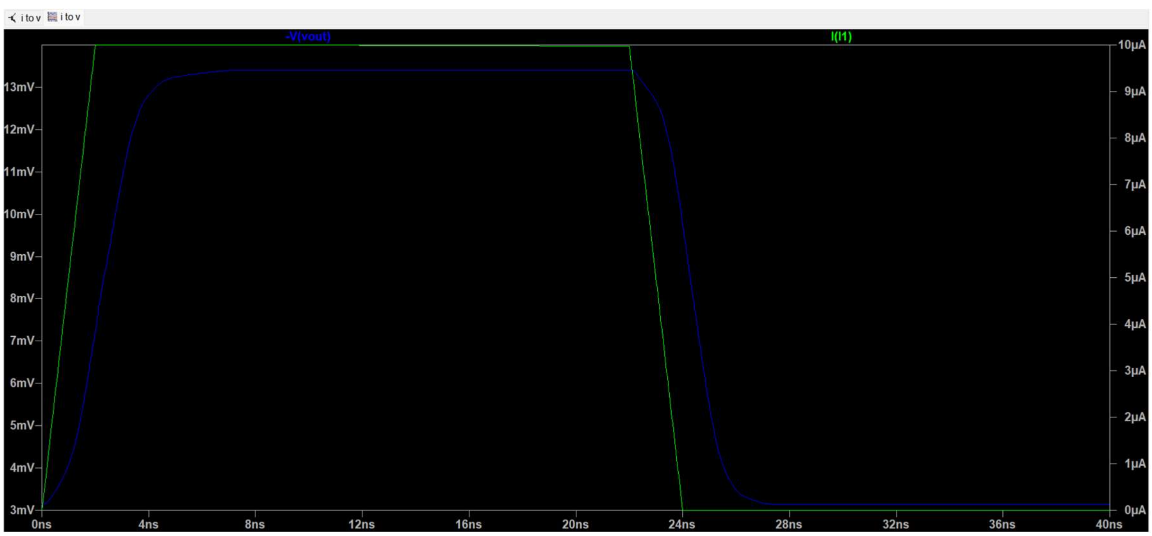

Fig. 3.6: Step response of I to V converter

Calculation of the impedance gain of I to V converter from the above step response.

Impedance gain(R) = V(Vout)/Ix(x1:Y)

R = 13.40mV/10uA = 1.34 kohms .

3.3 Voltage Buffer

Circuit Diagram of the voltage buffer circuit implemented by using VCII is given in Fig. 3.7. The voltage conveyer block used in the circuit is the circuit taken from Fig. 2.2 in chapter 2. The aspectratio of all the PMOS transistors and NMOS transistors in the VCII+ circuit, are (40.5 µm/0.54 µm) and (13.5 µm/0.54 µm) respectively. The supply voltage given to the circuit is ±0.90 V. To plot the sinusoidal response, a sine waveform having frequency of 1 kHz and amplitude of 200 mVpeak to peak is given as input to the circuit. To plot the frequency response, the gain is plotted as a function of frequency using logarithmic scale.

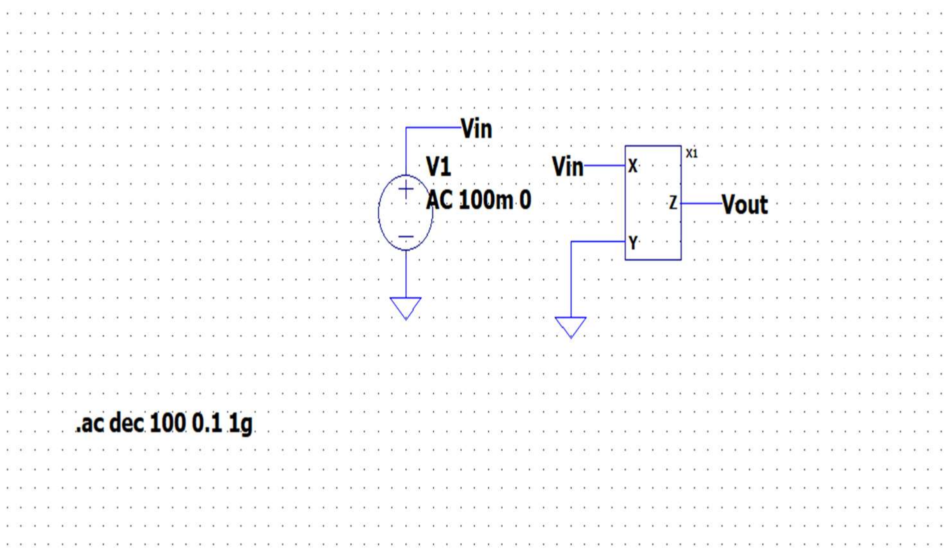

Fig. 3.7: Voltage Buffer circuit

The input voltage is provided to terminal X of the VCII block and output voltage is taken from the Z node of VCII block. The functionality of the voltage conveyer circuit enables the voltage at the x node to reflect at z node. The corresponding current at the x terminal will be transferred to the y terminal according to the voltage conveyer action.

The step response of the V to I circuit can be observed in Fig. 3.8.

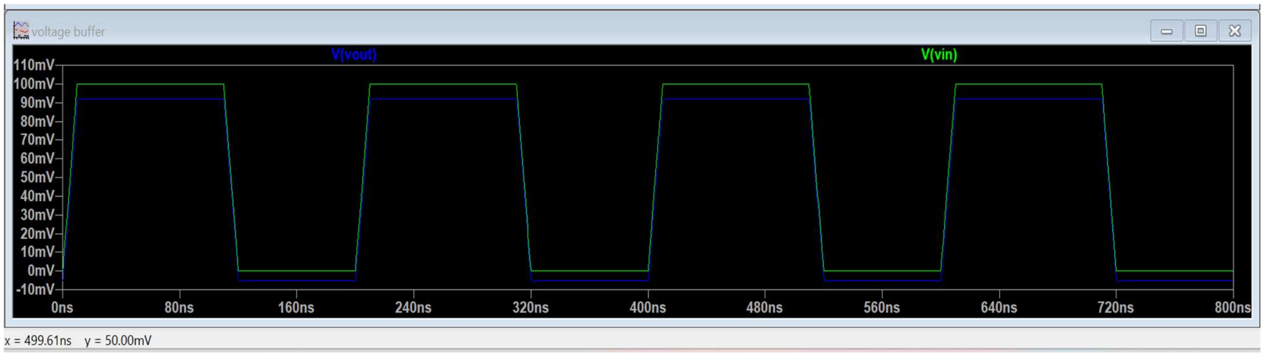

Fig. 3.8: Step response of Voltage buffer circuit

The frequency response of the Voltage buffer circuit can be observed in Fig. 3.9.

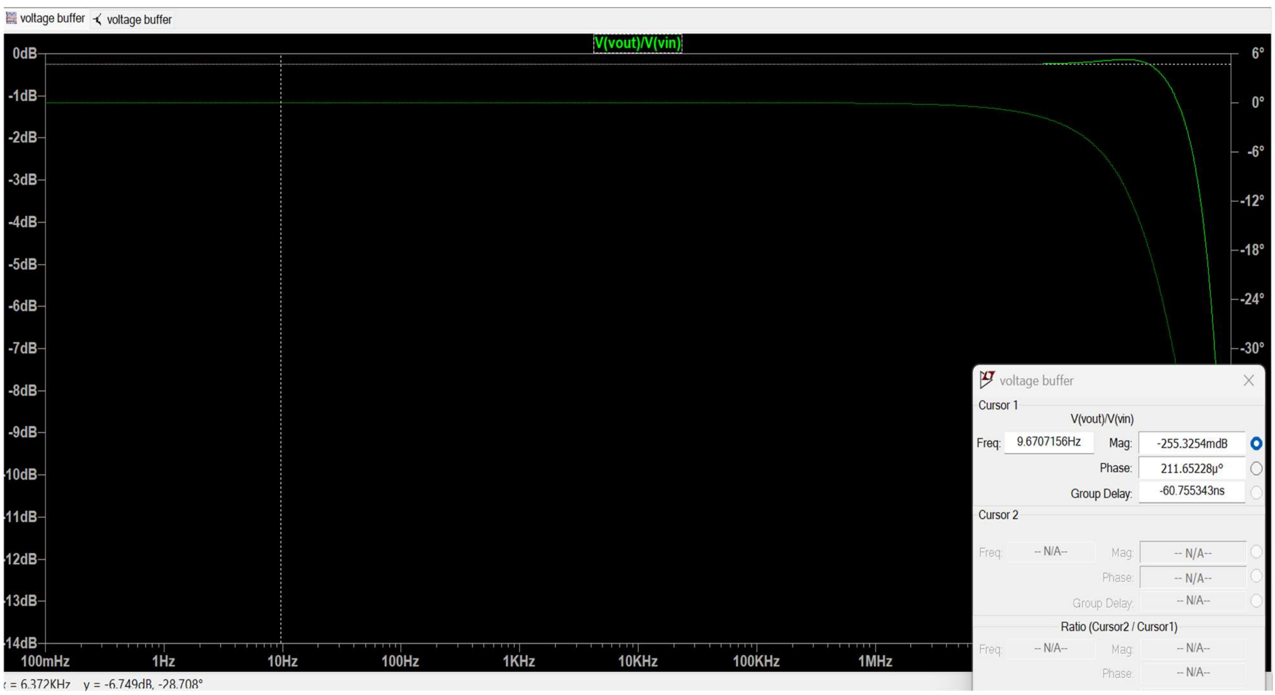

Fig. 3.9: Frequency response of Voltage buffer

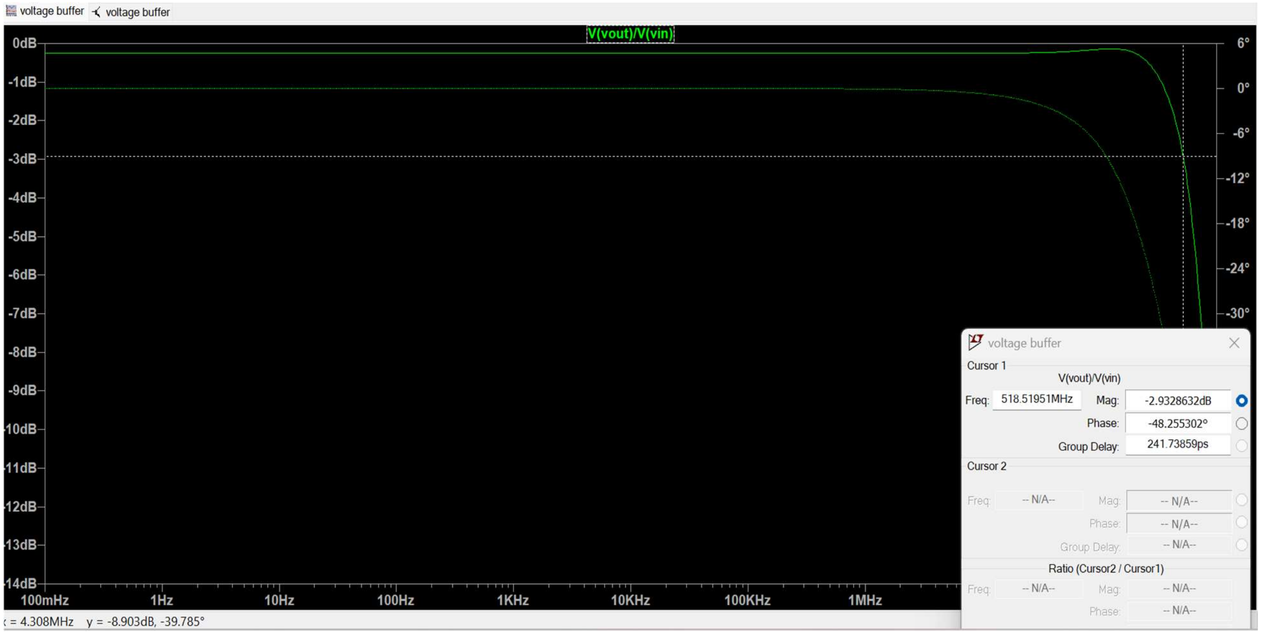

Fig. 3.10: -3 dB Bandwidth of Voltage buffer frequency response

Calculation of the intrinsic voltage gain of voltage buffer circuit and the -3 dB bandwidth fromthe above frequency response.

Intrinsic voltage gain(α) = Vout/Vin = -255.32 mdB = 0.971033.

-3 dB bandwidth = 518.51 MHz.

3.4 Current Buffer

Circuit Diagram of the current buffer circuit implemented by using VCII is given in Fig 3.11. Thevoltage conveyer block used in the circuit is the circuit taken from Fig 2.2 in chapter 2. The aspect ratio of all the PMOS transistors and NMOS transistors in the VCII+ circuit, are (40.5 µm/0.54 µm) and (13.5 µm/0.54 µm) respectively. The supply voltage given to the circuit is ±0.90 V. To plot the sinusoidal response, a sine waveform having frequency of 1 KHz and amplitude of 20 µApeak to peak is given as input to the circuit. To plot the frequency response, the gain is plotted as a function of frequency using logarithmic scale.

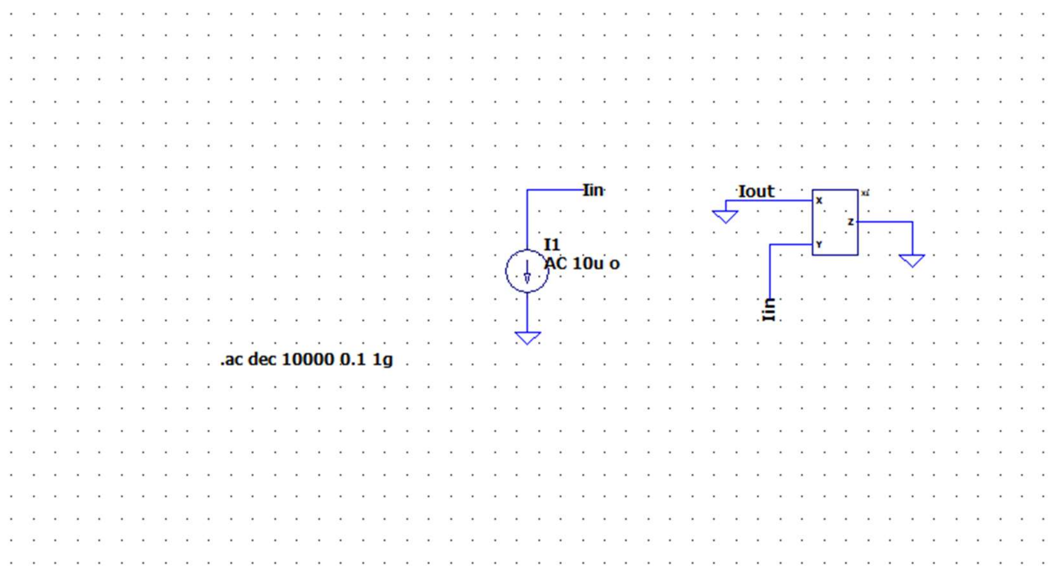

Fig. 3.11: Current Buffer circuit

The input current is provided to terminal Y of the VCII block and output current is taken from the nodalcurrent of X node of VCII block.

the step response of the V to I circuit can be observed in Fig. 3.12.

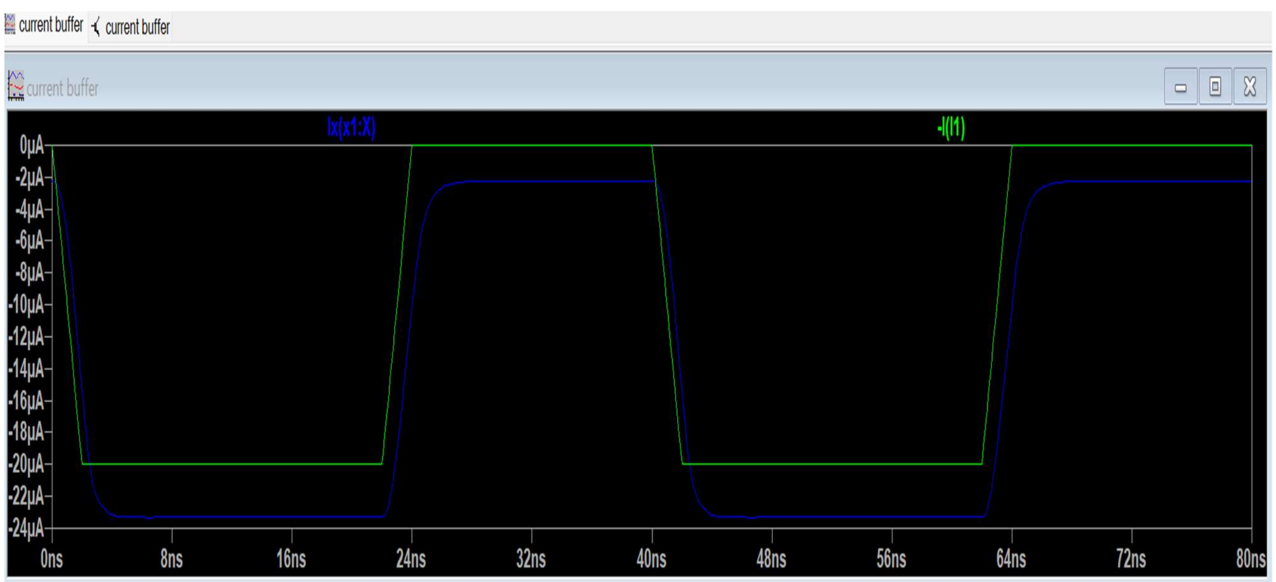

Fig. 3.12: Step response of current buffer circuit

The frequency response of the Voltage buffer circuit can be observed in Fig 3.13.

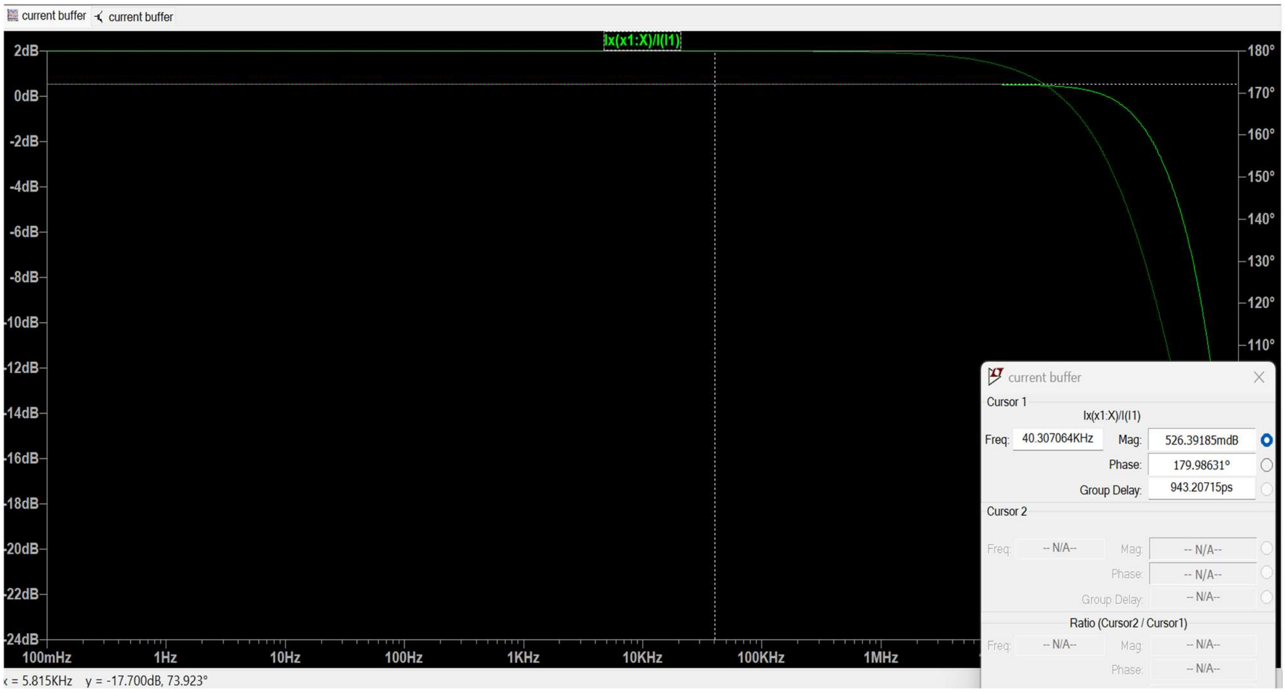

Fig. 3.13: Frequency response of Current buffer

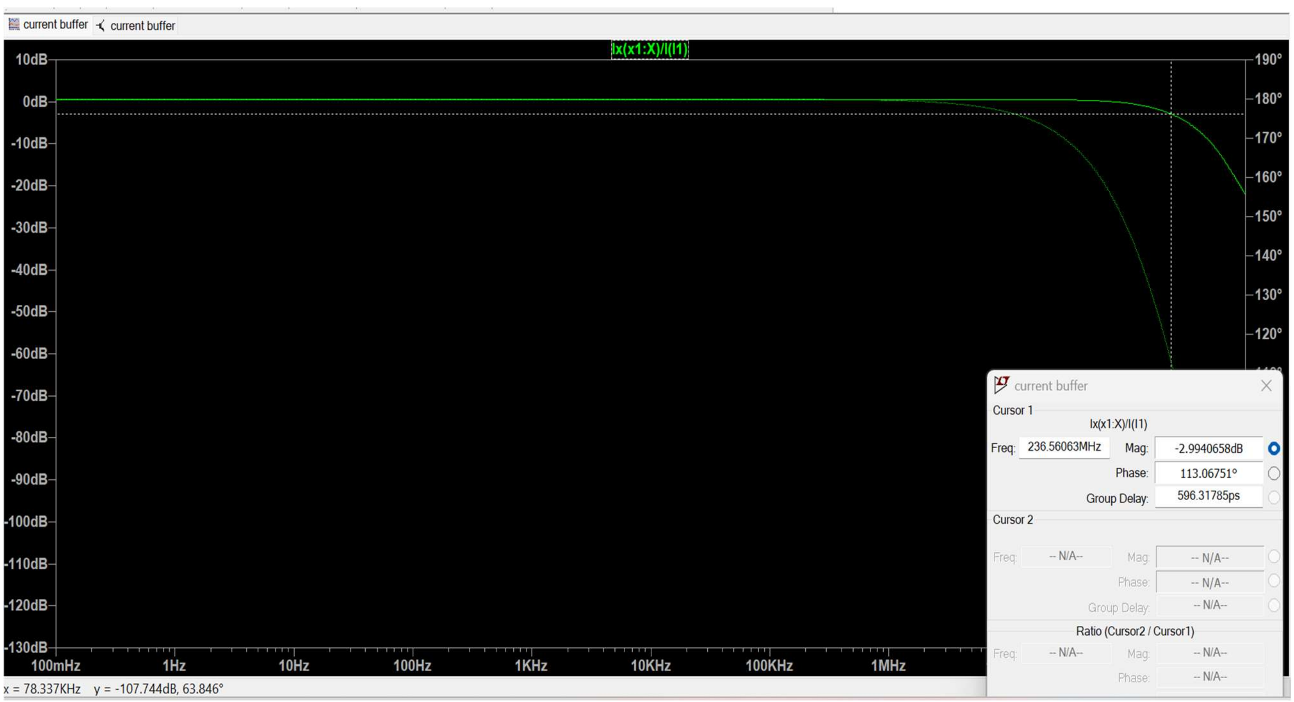

Fig. 3.14: -3 dB Bandwidth of Current buffer frequency response

Calculation of the intrinsic voltage gain of voltage buffer circuit and the -3 dB bandwidth fromthe above frequency response.

Intrinsic current gain(β) = Iout/Iin = 526.391 mdB = 1.0624.

-3 dB bandwidth = 239.56 MHz.

3.5 Summarized results

The intrinsic parameters calculated from the above applications can be summarized in the table 3.1.

Parameters	Values
Impedance gain	1.34 kΩ
Transconductance gain	1.0774 mS
Intrinsic voltage gain (-3 dB Bandwidth)	0.9710(527.11 MHz)
Intrinsic current gain (-3 dB Bandwidth)	1.0624(237.72 MHz)

Table 3.1: Intrinsic parameters calculation

Chapter 4

Voltage Differentiator, Voltage Integrator and Voltage amplifier using VCII

Voltage buffer, current buffer, and other uses of VCII covered in the previous chapter and all are linear analogue circuits developed using second-generation voltage conveyer blocks. Voltage Differentiator and Voltage Integrator are two additional devices that can be used with VCII to build analog circuits in the linear domain.

4.1 voltage differentiator

An electrical circuit known as a voltage differentiator differentiates a input voltage signal. It generates an output voltage that is proportionate to the input voltage's rate of change (derivative) over time. Differentiation in mathematics indicates the slope or instantaneous rate of change of a function [6].

The operational amplifier (OPAMP) and voltage controlled integrated inverter (VCII) are active blocks that are used to create the voltage differentiator circuit. It is significant to remember that voltage differentiation generates high-frequency noise amplification and may result in circuit instability. This is as a result of the differentiation procedure amplifying the input signal's high-frequency components [10].

Voltage differentiators can be used for edge detection, frequency analysis, waveform shaping, and signal processing. The consequences of noise amplification and possible circuit instability must be taken into consideration while designing and implementing voltage differentiators, though [5].

In this chapter, voltage differentiator circuit based on second generation voltage conveyer (VCII) have been discussed and implemented using schematic simulation tool LT Spice with 180-*n*m CMOS technology. The circuit of VCII block is the same as illustrated in Fig. 2.2, chapter 2. The supply voltage is a constant 0.90 V.

The functionality of differentiator circuit has also been validated using input waveformsin form of pulsed waveform. The input waveform to the differentiator circuit is a pulsed waveform having time period of 6 us, rise time and fall time of 1 us and 1 us respectively and amplitude of 800 mV peak to peak.

Circuit diagram of VCII based voltage differentiator circuit is given in Fig. 4.1.

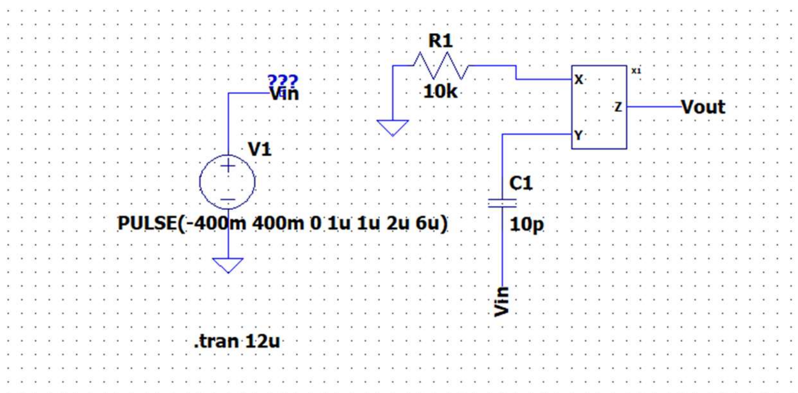

Fig. 4.1: Voltage differentiator circuit

The output waveform of the VCII based voltage differentiator circuit is given in Fig. 4.2.

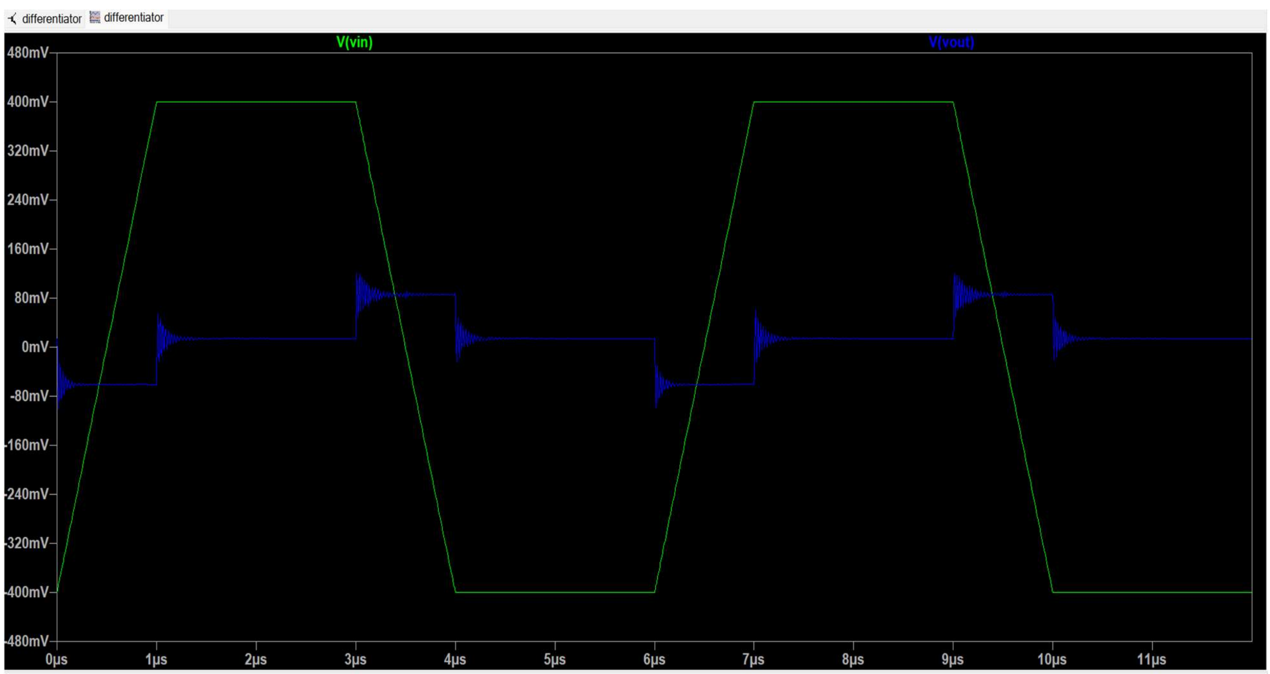

Fig. 4.2: Output waveform of voltage differentiator

The sinusoidal response of the VCII based voltage differentiator circuit is given in Fig. 4.3 and 4.4.

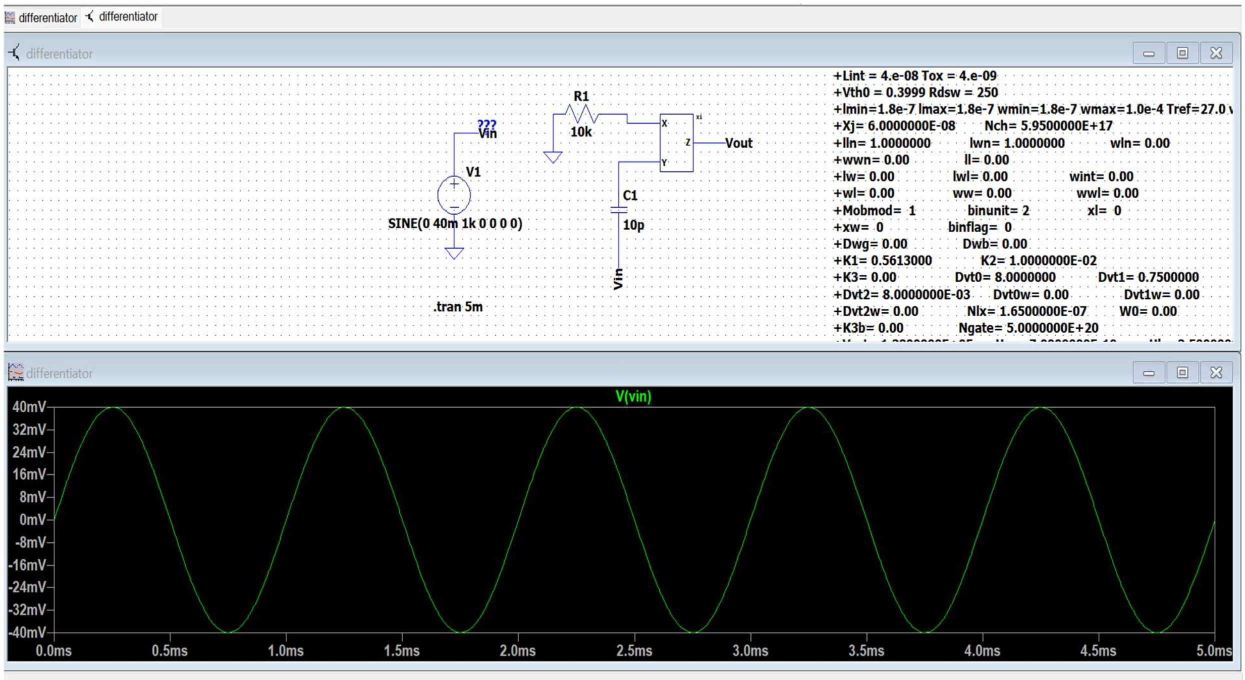

Fig. 4.3: Sinusoidal Response of voltage differentiator

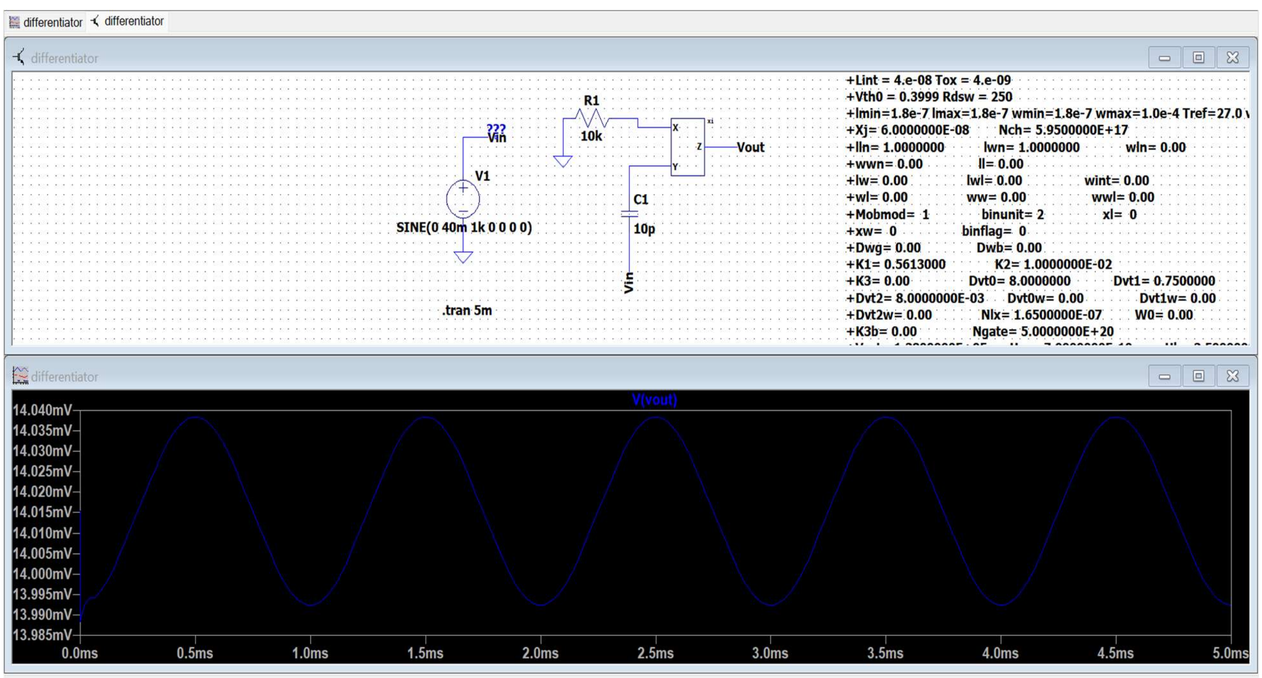

Fig. 4.4: Sinusoidal Response of voltage differentiator

The frequency response of the voltage differentiator circuit is given in Fig. 4.5.

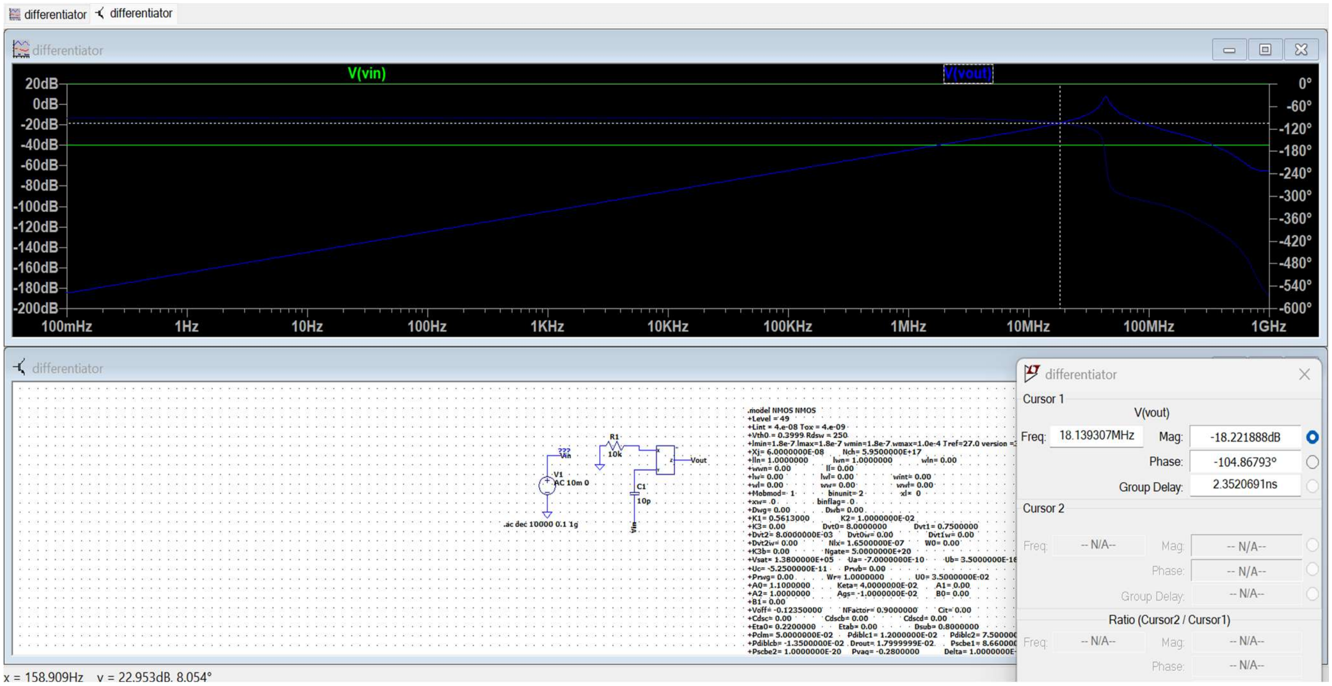

Fig. 4.5: Frequency response of voltage differentiator

Mid band voltage gain = -18.22 dB

Cutoff frequency = 18.13 MHz

4.2 Voltage integrator

A voltage integrator is a type of electrical circuit that integrates a voltage signal input. The output voltage is a function of the input voltage's integral (accumulated sum) with respect to time. It is significant to highlight that because of the accumulation of errors and the finite performance of real-world components, voltage integration might result in output voltage drifting over time. Many techniques can be used to minimize the drift in order to solve this problem.[6]

Voltage integrators are used in control systems, waveform synthesis, frequency analysis, and analog signal processing. They are frequently employed in circuits that need to integrate signals over time or carry out integration-related mathematical computations.[5]

To achieve the desired integration behavior, stability, noise performance, and the selection of suitable time constants should be considered while developing and implementing voltage integrators.

In this chapter, voltage differentiator circuit based on second generation voltage conveyer (VCII) have been discussed and implemented using schematic simulation tool LT Spice with 180-*n*m CMOS technology. The circuit of VCII block is the same as illustrated in Fig. 2.1, chapter 2. The supplyvoltage is a constant 0.90 V.

The functionality of integrator circuit has also been validated using input waveformsin form of pulsed waveform. The input waveform to integrator circuit is a pulsed waveform having time period of 100 ns, with zero rise timeand fall time and amplitude of 1000 mV peak to peak. Circuit diagram of the voltage integrator circuit implemented using VCII is given in Fig. 4.5.

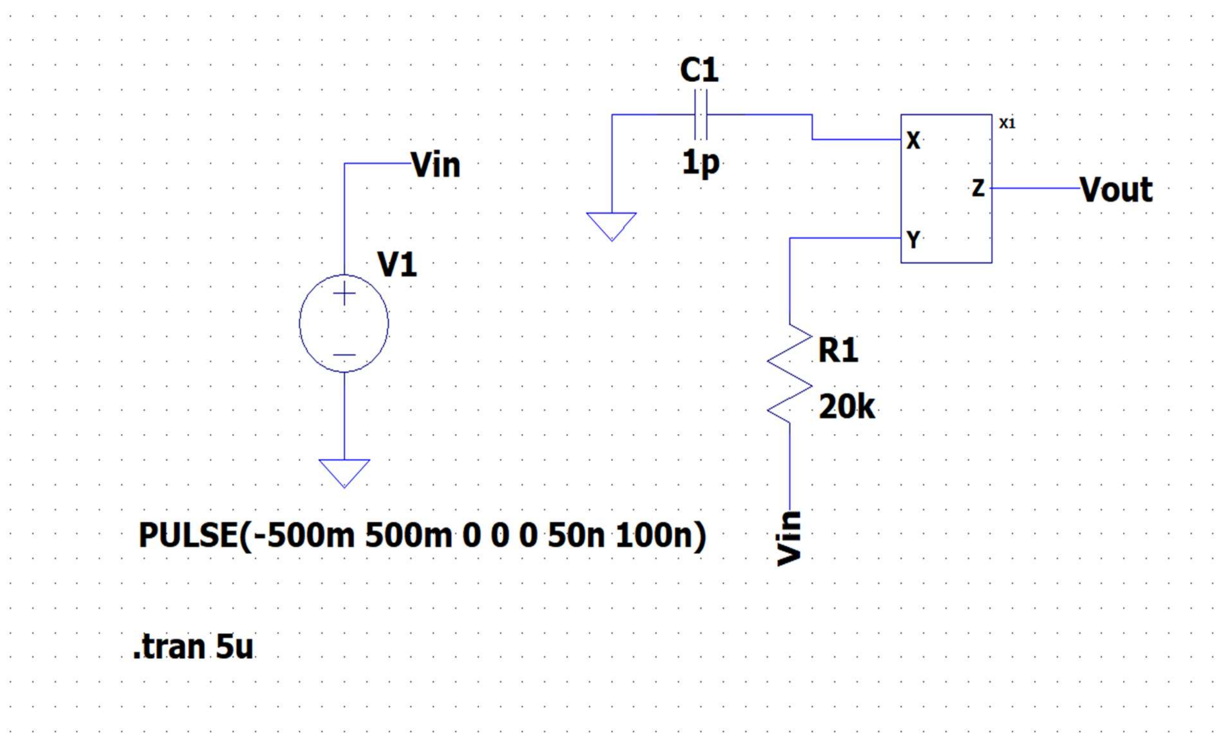

Fig. 4.6: Voltage integrator circuit

The output waveform of the voltage integrator is given in Fig. 4.6.

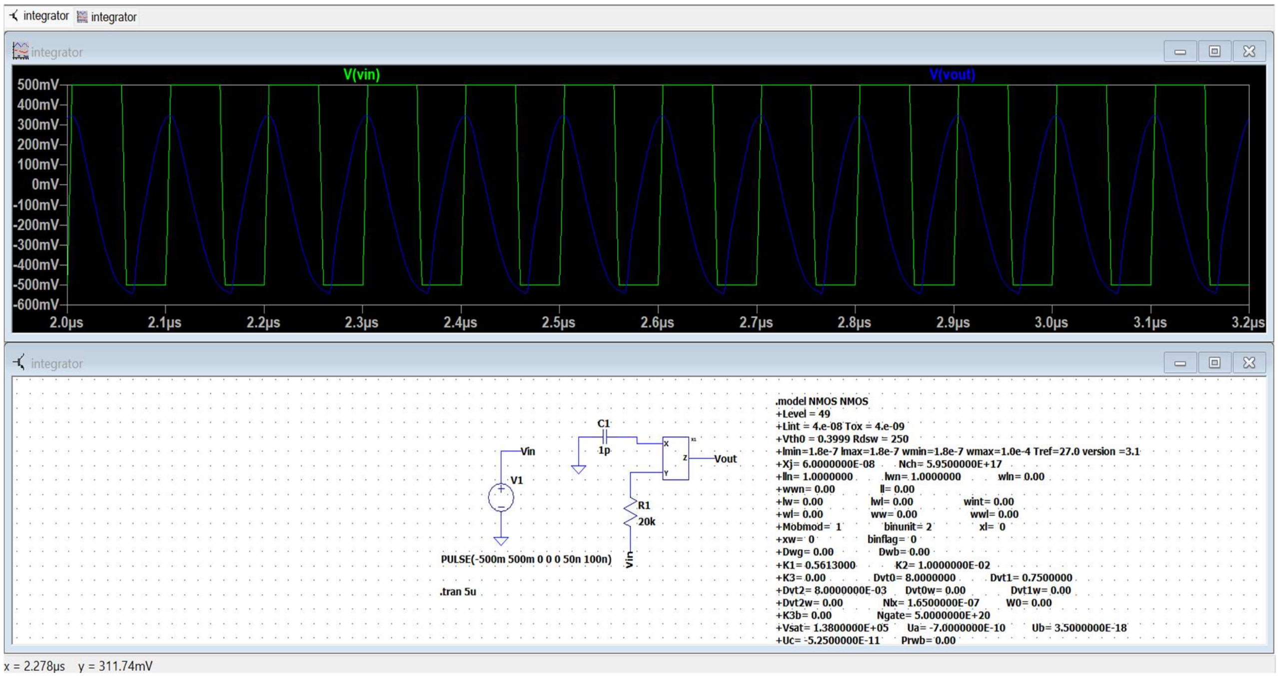

Fig. 4.7: Output waveform of voltage integrator

Sinusoidal response of the voltage integrator is given in Fig. 4.7 and 4.8.

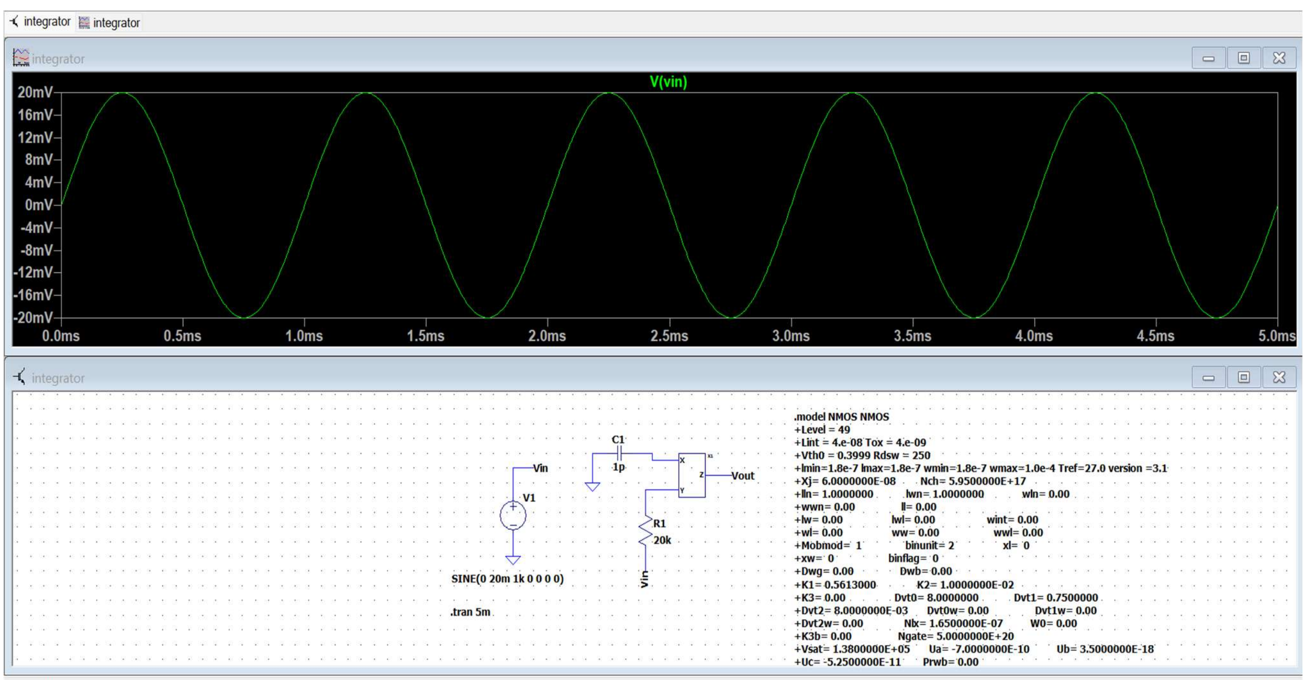

Fig. 4.8: sinusoidal response of voltage integrator

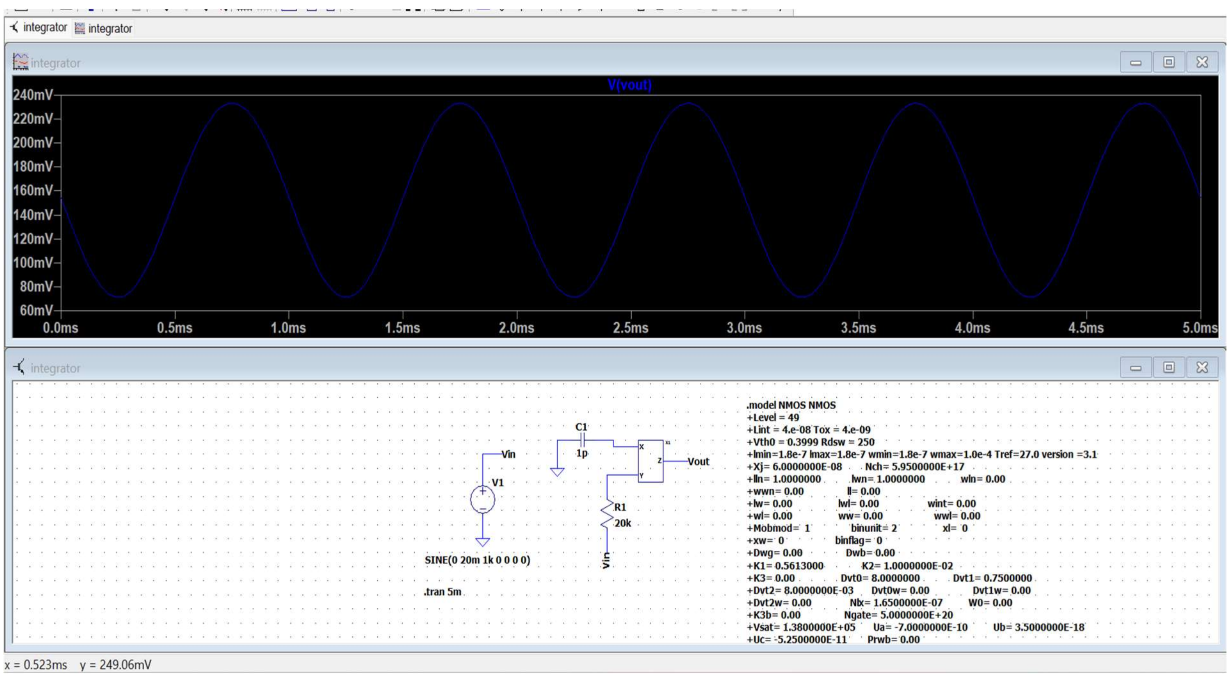

Fig. 4.9: sinusoidal response of voltage integrator

The frequency response of the voltage integrator circuit is given in Fig. 4.9.

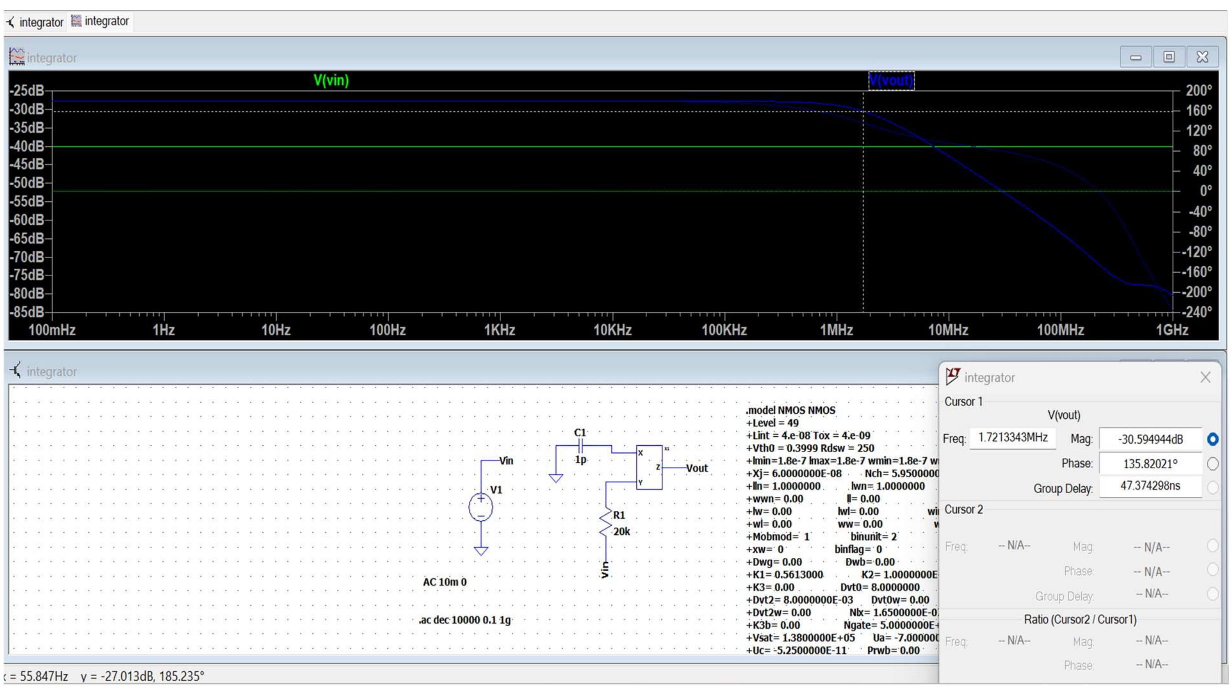

Fig. 4.10: Frequency response of voltage integrator

Mid band voltage gain = -30.59 dB.

Cut off frequency = 1.721 MHz

4.3 Voltage amplifier (Inverting type):

Second-generation voltage conveyors with the ability to accurately transport voltage signals across various components of a circuit can be used to create inverting voltage amplifiers. Voltage conveyor second generation have increased performance characteristics and are sometimes referred to as voltage conveyor amplifiers (VCAs) [6]. Using second-generation voltage conveyors to implement inverting voltage amplifiers can have benefits including increased linearity, high input and output impedances, broad bandwidth, and low distortion. They are excellent for applications requiring precise signal amplification in analogue signal processing, instrumentation, and audio systems because of these qualities [6].

In this chapter, inverting voltage amplifier circuit based on second generation voltage conveyer (VCII) have been discussed and implemented using schematic simulation tool LT Spice with 180-*n*m CMOS technology. The circuit of VCII block is the same as illustrated in Fig. 2.2, chapter 2. The supplyvoltage is a constant 0.90 V.

The functionality of inverting voltage amplifier circuit has also been validated using input waveform of pulsed waveform. The input waveform to inverting voltage amplifier circuit is a pulsed waveform having time period of 10 ms, with 1 ms rise time and 1 ms fall time and amplitude of 5 mV, value of R1 and R2 is 10 K-ohm and 5K-ohm respectively. For Sinusoidal response input is provided of 1 KHz frequency with 40 mv amplitude peak to peak.

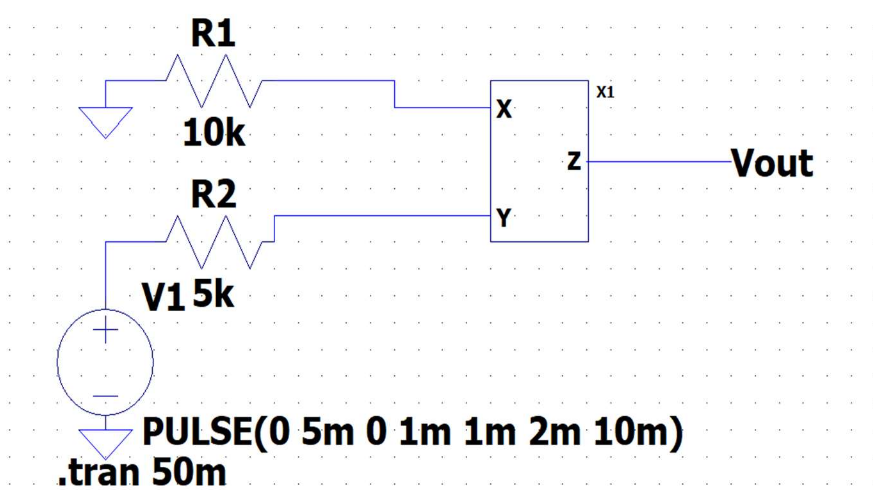

Fig. 4.11: inverting voltage amplifier circuit

Sinusoidal response of the voltage amplifier is given in Fig. 4.12

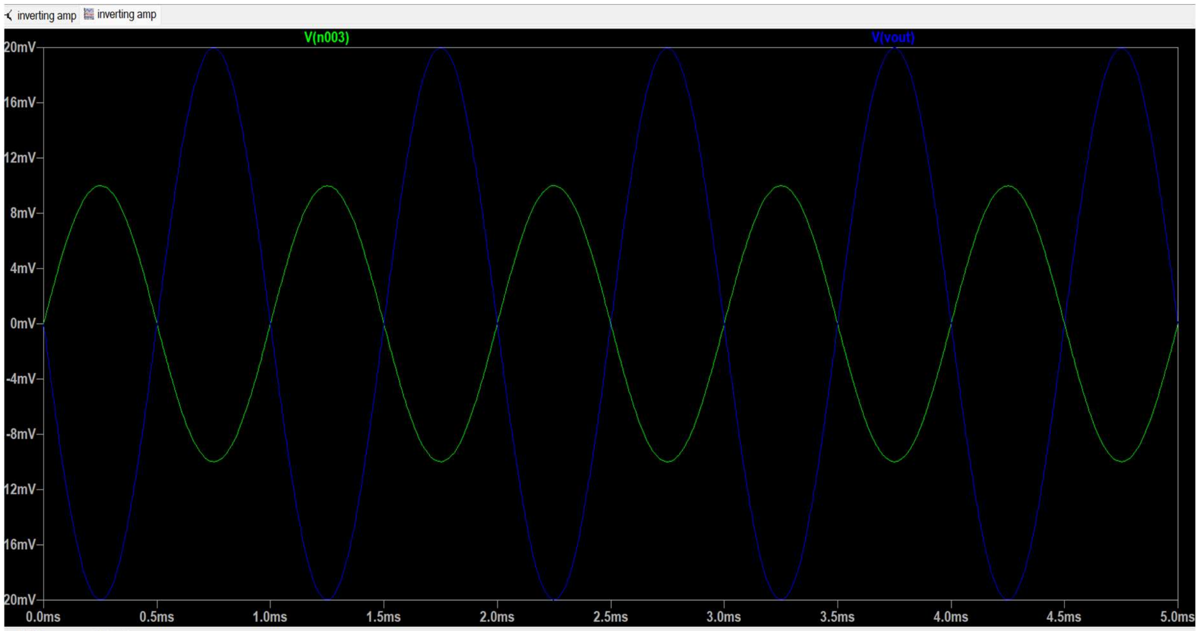

Fig. 4.12: inverting voltage amplifier sinusoidal response

Step response of the voltage amplifier is given in Fig. 4.13

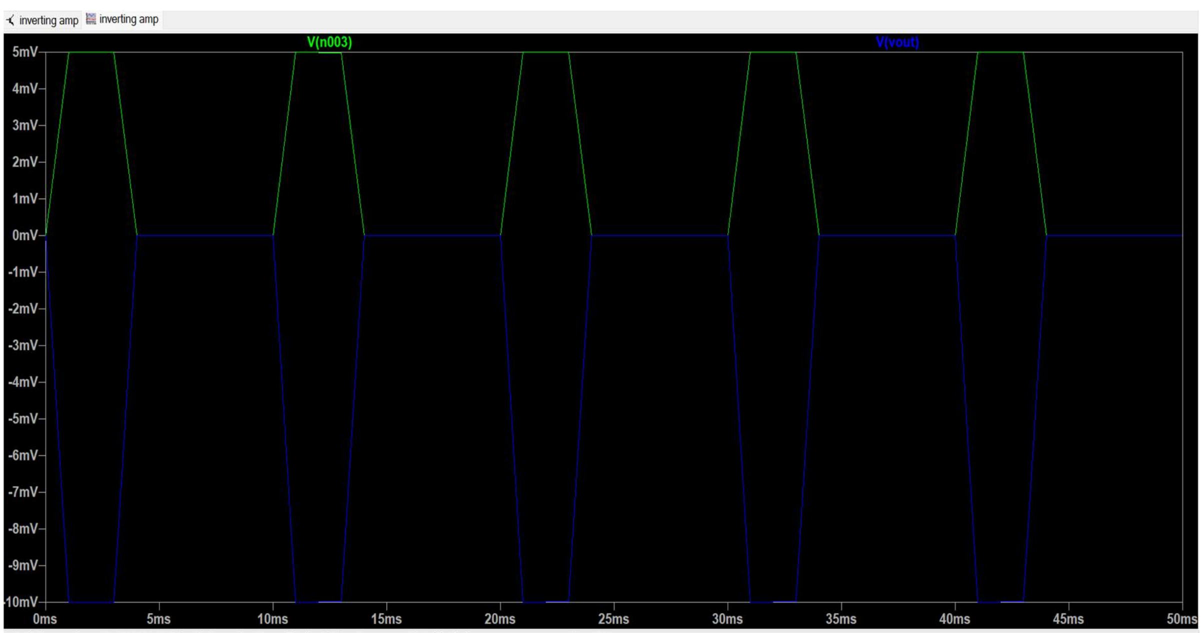

Fig. 4.13: inverting voltage amplifier step response

Voltage gain (A_v) =10/2= 5

Chapter 5
Results

The implementation of VCII has been done in the LT-spice tool. To model VCII circuits 180-nm CMOS technology is used. The supply voltage is given 0.90 V, which is constant. Each circuit's performance metrics have undergone a thorough and careful analysis.

Continuous time applications of VCII like V to I converter, I to V converter, Voltage buffer, Current buffer, Voltage differentiator, Voltage integrator and inverting voltage amplifier have been implemented and explained. All circuit's functional viability has been confirmed using step response and transient response with sinusoidal waveform input signal. Characteristics of the block is given in table below.

Parameters	**Values**
Impedance gain	1.34 kΩ
Transconductance gain	1.0774 mS
Intrinsic voltage gain (-3 dB Bandwidth)	0.9710(527.11 MHz)
Intrinsic current gain (-3 dB Bandwidth)	1.0624(237.72 MHz)

Chapter 6
Conclusion and Future Scope

In conclusion, voltage conveyors are specialized active circuit blocks created to transport voltage signals correctly and effectively between various components in a circuit. Because of their benefits, including high accuracy, broad bandwidth, and low distortion, they are essential parts of many analogue signal processing applications.

Beyond the conventional capabilities of operational amplifiers (op-amps), voltage conveyors provide special possibilities. They feature numerous input and output terminals (X, Y, Z,) which enables complicated signal routing and processing, and they can transfer voltage signals in both directions.

Voltage conveyors can be used to accomplish several circuit operations, including amplification, filtering, integration, differentiation, mixing, and more. High-performance analog systems can be designed using these adaptable building components.

Voltage conveyors are important components in modern analog circuit design because they give engineers more flexibility and accuracy for processing and manipulating signals. The creation of high-performance analog systems for a variety of uses, such as audio processing, communications, instrumentation, and control systems, is facilitated by their distinctive properties.

The second-generation voltage conveyer's attributes and design implementations were thoroughly examined in this project work. The fundamental applications connected to the VCII circuit have also been investigated, with each application's performance being carefully examined and contrasted. Numerous applications, including voltage buffer, current buffers, V to I converters, voltage differentiators, etc., have been put into use and their performances have been evaluated. The performance of the constructed circuits has been thoroughly examined utilising features of the software simulation tool, and each circuit's characteristics have been plotted to confirm its viability for operation.

References

[1] A. Fabre, O. Saaid, F. Wiest, and C. Boucheron, "High frequency applications based on a new current controlled conveyer," *IEEE Transactions on Circuits and Systems I: Fundamental Theory and Applications*, vol. 43, no. 2, pp. 82-91, 1996.

[2] C. K. Smith and A. Sedra, "The current conveyer - New building block," *Proceedings of the IEEE*, vol. 56, no. 8, pp. 1368-1369, 1968.

[3] C. K. Smith and A. Sedra, "A second-generation current conveyor and its applications," *IEEE Transactions on Circuit Theory*, vol. 17, no. 1, pp. 132-134, 1970.

[4] E. Yuce and S. Minaei, "New CCII-based versatile structure for realizing PID controller and instrumentation amplifier," *Microeloctronics Journal*, vol. 41, no. 5, pp. 311-316, 2010.

[5] L. Safari, G. Barlie, and V. Stornelli, "An Overview on the Second-Generation Voltage Conveyor: Features, Design and Applications," *IEEE Transactions on Circuit Theory II: Express Briefs*, vol. 66, no. 4, pp. 547-551, 2019.

[6] A. S. Sedra and K. C. Smith, "Microelectronics Circuits", 4th Ed. Oxford University Press, pp. 1002-1005, 1998.

[7] A. Anand and R. Pandey, "A Novel Dual Output Schmitt Trigger Using Second Generation Voltage Controlled Conveyer," 2022 2nd International Conference on Intelligent Technologies (CONIT), Hubli, India, 2022, pp. 1-5, doi: 10.1109/CONIT55038.2022.9848259.

[8] A. Anand and R. Pandey, "Second Generation Voltage Conveyer based Comparator and its application as Pulse Width Modulator," 2022 2nd Asian Conference on Innovation in Technology (ASIANCON), Ravet, India, 2022, pp. 1-5, doi: 10.1109/ASIANCON55314.2022.9908730.

[9] K. Pitaksuttayaprot, S. Ritnathikul and W. Jaikla, "Voltage-Mode Biquad Multifunction Filter Using VCIIs," 2022 International Symposium on Intelligent Signal Processing and Communication Systems (ISPACS), Penang, Malaysia, 2022, pp. 1-4, doi: 10.1109/ISPACS57703.2022.10082805.

[10] L. Safari, G. Barile, V. Stornelli, G. Ferri and A. Leoni, "New Current Mode Wheatstone Bridge Topologies with Intrinsic Linearity," 2018 14th Conference on Ph.D. Research in Microelectronics and Electronics (PRIME), Prague, Czech Republic, 2018, pp. 9-12, doi:

10.1109/PRIME.2018.8430363.

[11] A. Fabre, O. Saaid, F. Wiest, and C. Boucheron, "High frequency high Q BiCMOS current mode bandpass filter and mobile communication applications," *IEEE Journal of Solid-State Circuits*, vol. 33, no. 4, pp. 614-625, 1998.

[12] Filanovsky, I.M., 2001, August. Current conveyor, voltage conveyor, gyrator. In Proceedings of the 44th IEEE 2001 Midwest Symposium on Circuits and Systems. MWSCAS 2001 (Cat. No. 01CH37257) (Vol. 1, pp. 314-317). IEEE.

[13] Pathak, S.D., Luitel, A., Singh, S. and Pandey, R., 2021, May. Second Generation Voltage Conveyor II based Shadow Filter. In 2021 2nd International Conference for Emerging Technology (INCET) (pp. 1-5). IEEE.

[14] J.M. Martinez-Heredia, A. Torralba, "Enhanced source-degenerated CMOS differential transconductor", Microelectronics Journal, vol. 42, pp.396–402, 2011. [9] L. Safari, S. J. Azhari, "A novel wide band super transistor based voltage feedback current amplifier", Int. J. Electron. Commun. (AEUE), vol. 67 pp.624– 631, 2013.