Design of CMOS O.T.A using 180 NM Technology for High Frequency Applications

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Abstract

This paper deals with well-defined design criteria of CMOS operational Transconductance amplifiers for high frequency applications. The high frequency OTA can be used as a basic building block in several RF as well as for microwave frequency applications. The performance analysis of conventional O.T.A techniques, using advanced process technology that can break the previous frequency barrier is a key objective of this paper. Operational transconductance amplifier is simulated using cadence 180nm technology Initially D.C analysis is performed to find region of operation of all the transistors , results show that all the transistors are perfectly operating in the saturation region .Theoretical analysis of O.T.A is provided which is very good agreement with measured results. The linearity and intermodulation distortion properties of the O.T.A, which are of particular interest in microwave applications, are experimentally carried out. Using single stage amplifier .For high frequency demonstration purpose we built larger circuit. The comparative analysis of the conventional CMOS based O.T.A and the proposed O.T.A is carried out. A power supply sensitivity simulation at different frequencies are carried out and observed that at low frequencies this O.TA has high power supply rejection ratio of over 86db and at microwave frequencies the PSRR drops to 30 – 40 dB To the impact of high frequencies on-chip shunt capacitors are usually introduced at dc power supply nodes in microwave IC'S shows that significant saving in power , can be obtained without compromising for phase margin and slew rate and little compromise in few characteristics like gain.
Keywords: Figure of Merit, Gain, phase margin, C.M.R.R, P.S.R.R, O.T.A

I. INTRODUCTION

Today operational amplifiers (OPAMPs) are widely used as basic building blocks in implementing a variety of analog applications from amplifiers, summers, integrators, and differentiators to more complicated applications such as filters and oscillators. Using OPAMPs greatly simplifies design, analysis, and implementation for analog applications. OPAMPs work well for low-frequency applications, such as audio and video systems. For higher frequencies, however, OPAMP designs become difficult due to their frequency limit At those high frequencies, operational transconductance amplifiers (OTAs) are deemed to be promising to replace OPAMPS as the building blocks. Theories of using OTAs as the building blocks for analog applications have been well developed with much effort dedicated by analog IC researchers and the continuous scaling-down on commercial semiconductor technologies, the reported OTAs canwork up to several hundred MHz.

II. OTA CONCEPT

An ideal operational transconductance amplifier (OTA) is a voltage-controlled current source with a constant transconductance and infinite input/output impedances, as illustrated in Fig. 1-1. It can be characterized by the following expressions.

$$i_o = g_m v_i \qquad (1\text{-}1a)$$

$$Z_i = \infty \quad , Z_o = \infty \qquad (1\text{-}1b)$$

Where vi and io in (1-1a) denote the input voltage and the output current respectively, and gm is the transconductance with a constant value ideally. Zi and Zo in (1-1b) represent the input and output impedances respectively. For general purposes, (1-1a) and (1-1b) are enough to evaluate an OTA's performance. However, they become inaccurate when a practical OTA at high frequency or with large input signal is concerned. Depending on the input and output configurations, OTAs can be categorized into three types: single input/output, differential-input single-output and differential input/output (fully differential) The above three types of OTAs and their equivalent circuit models are presented in Fig. 1-1. According to their different configurations, (1-1a) can be modified to express the three types of OTAs respectively:

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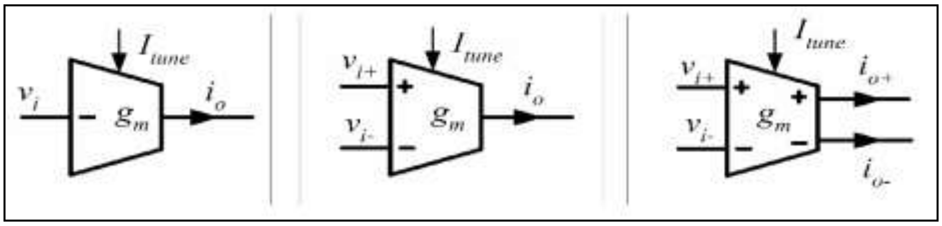

Fig. 1: Three types of OTAs: (a) single-input/output, (b) differential-input single-output, and (c) differential input/output.

According to their different configurations, (1-1a) can be modified to express the three types of OTAs respectively:

$$i_o = -g_m v_i \quad (1\text{-}2a)$$

$$i_o = g_m (v_i+ - v_i-) \quad (1\text{-}2b)$$

$$i_o = i_o+ - i_o- = g_m (v_i+ - v_i-) \quad (1\text{-}2c)$$

In these three types of OTAs, the transconductance gm can be tuned via their DC current bias Itune. The single input/output transconductor shown in Fig. 1-1(a) is the simplest to implement, e.g. a single-NMOS common-source transconductor. The simplicity of this type of OTA makes it interesting for high frequency implementation, while most previous works preferred the differential configurations in Fig. 1-1(b) and Fig. 1-1(c) due to their common-mode rejection and their flexibility to engage feedback configurations

III. CMOS OTA HISTORY

In the early 1990s, RF integrated circuits (RFICs) were dominated by bipolar and GaAs technologies, while CMOS technologies were mainly used for basedband signal applications. As the gate lengths of CMOS devices were scaled down to one micron in the middle of 1990s, CMOS RFICs over GHz became possible Since then, continuous scaling-down of CMOS devices to today's deep sub-micron devices has opened a new era for CMOS RFIC designs, including OTA circuits. Previous OTAs were developed in CMOS technologies due to the unique properties that CMOS can offer: 1) Ease to implement a transconductor – MOSFETs are naturally voltage-controlled current devices; 2) High cutoff frequency – the latest record was beyond 400 GHz ; 3) Wellcommercialized and low-cost processes; 4) Ability to integrate both digital and analog circuits, i.e., system-on-chip (SoC). Currently, CMOS OTAs are developed in threetrends: high frequency, high linearity and low power. High-frequency OTAs will be the focus of this thesis.

IV. MODELING AND ANALYSIS

A. *Design of Conventional CMOS based O.T.A:*

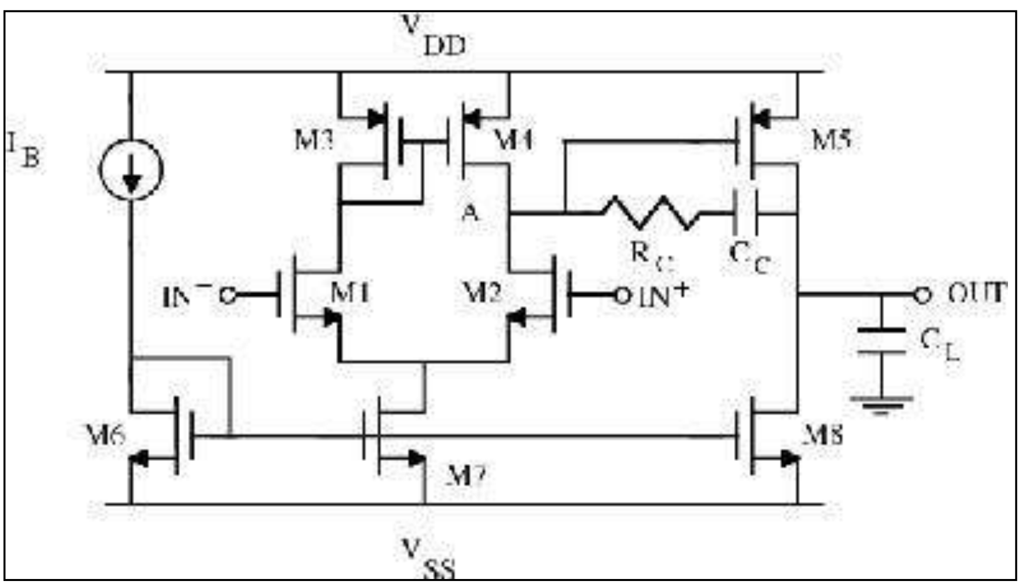

Fig. 2: Simulation result:

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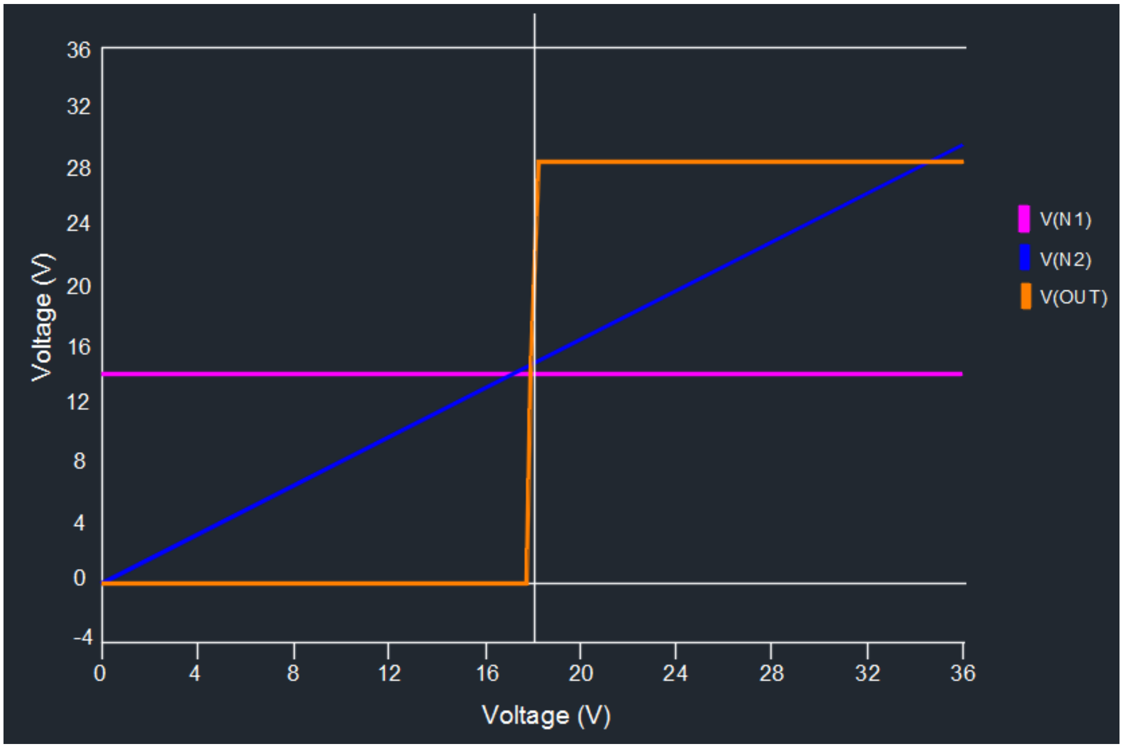

Fig. 3: Dc analysis of CMOS OTA

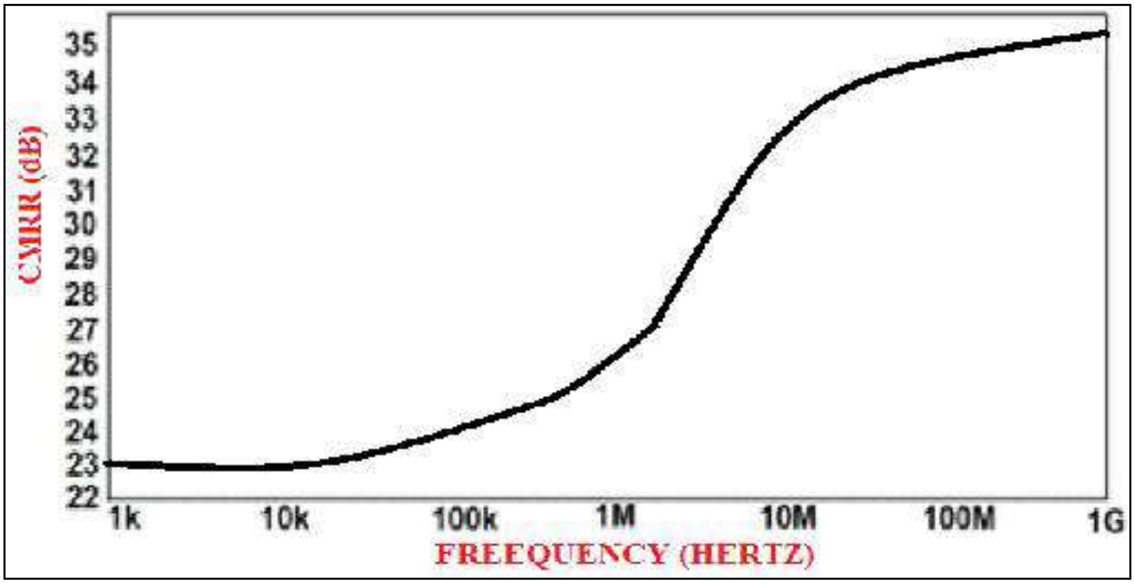

Fig. 4: Input Common mode range of op-amp

B. Design of Proposed Feed Forward Regulated CMOS based O.TA:

Topology which can work at low voltage and higher frequencies is desired. The most important aspect of topology selection is improved Transconductance with better linearity at high frequencies. The feed forward Cascode topology is preferred because it has a perfect balance between complexity and performance [4]. Figure 1 represents a differential input/output topology which has two PMOS Cascode and two NMOS Cascode. The transistors T9-T10 act as DC current source. The circuit arrangement is made in such a way that variation in output voltage is decreased. The topology results in high input output impedance and Transconductance. The performance parameters analyzed for various process technologies include Transconductance Gain (Gm), power consumption, frequency range, supply voltage etc.

It has been observed that Transistor T1, T4, T5 and T8 are in triode Region Whereas Transistor T2, T3, T6 and T7 are in Saturation region. In linear or triode region the MOSFET acts as Variable resistor and in Saturation region MOSFET behaves like a constant current source. The Transistor T9 and T10 also operate in Saturation region in order to provide DC current

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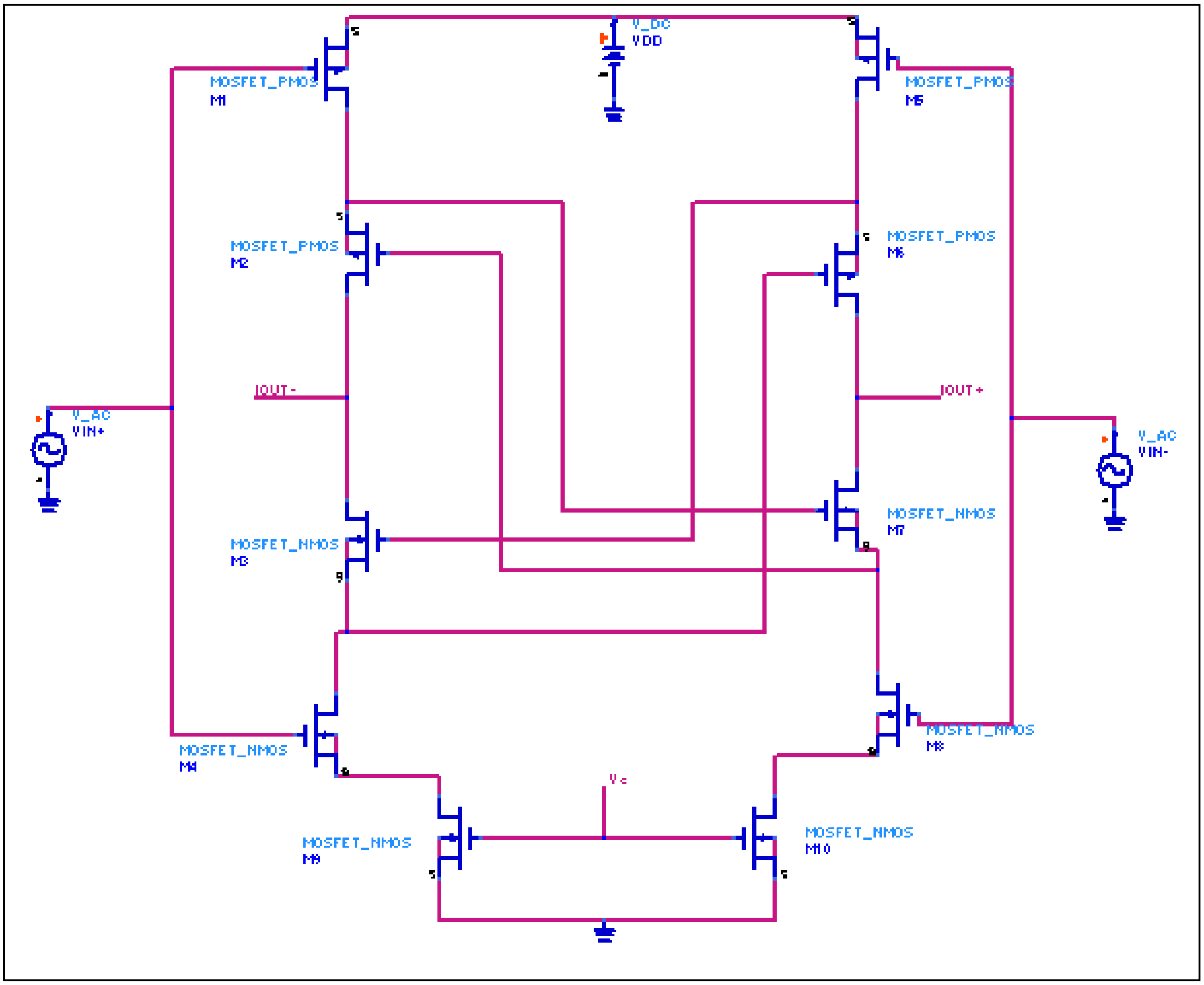

Fig. 5: Feed forward Regulated Cascode OTA

C. SIMULATION Experimental RESULTS of Proposed OTA:

Several circuits were fabricated inorder to characterize the performance of OTA and to demonstrate it's microwave abilities The basic

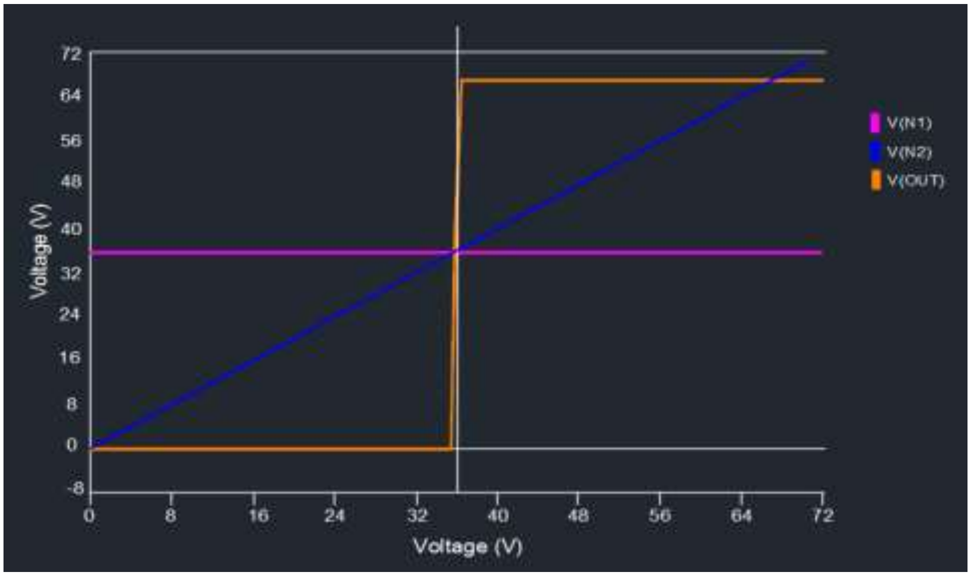

Fig. 6: OTA cell implemented in standard 180 nm CMOS process

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D. D.C Analysis of Proposed OTA

Transconductance and frequency response: Figures 7 and 8 shows the calculated simulated and experimental results for the transconductance and the Input/output parasitic capacitances of the OTA

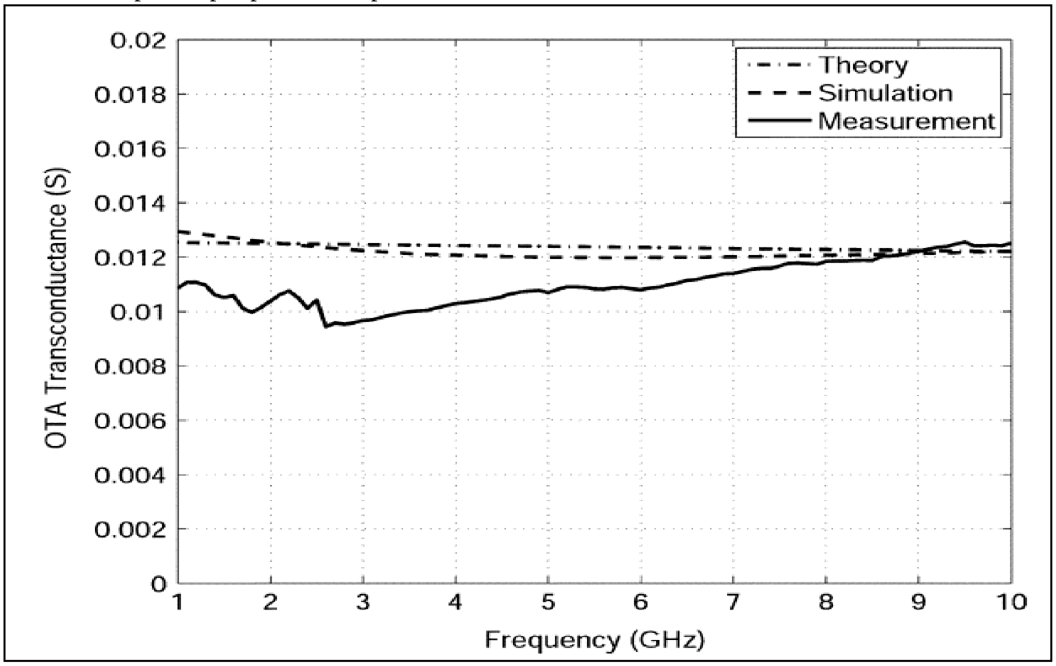

Fig. 7: Proposed OTA's Transconductance

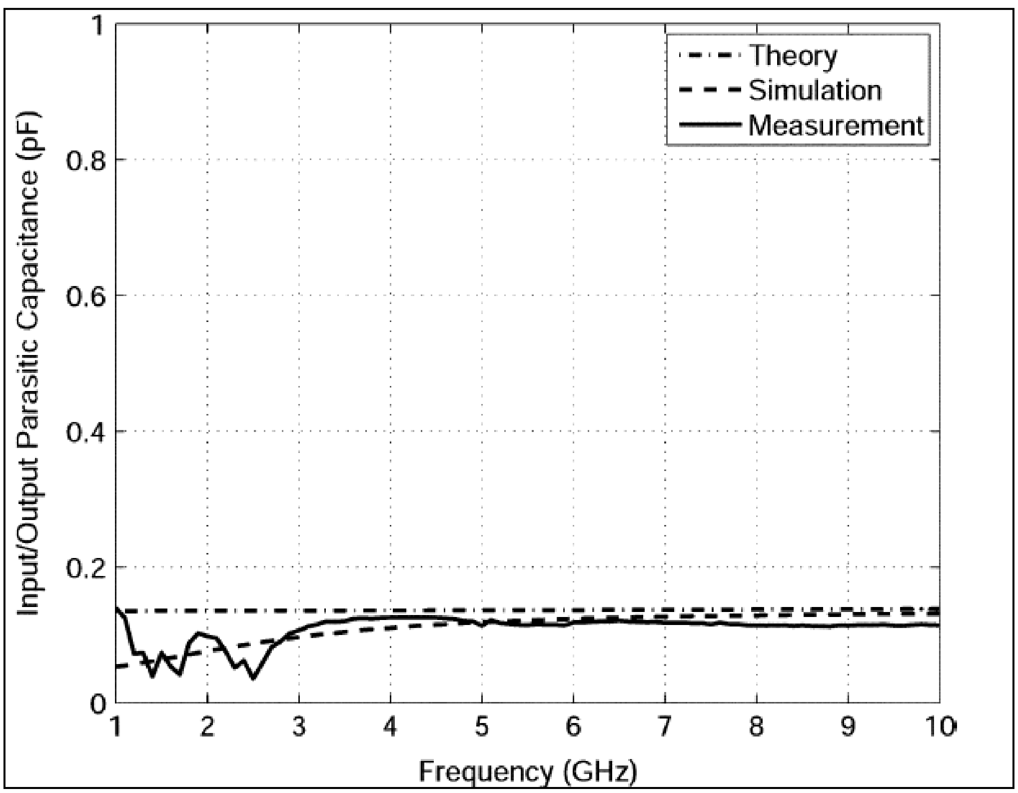

Fig. 8: Input output parasitic capacity of the proposed OTA

V. RESULTS AND DISCUSSION

In this work a comparative study has been done between conventional CMOS based O.T.A and feed forward regulated Cascode O.T.A .and relative performance parameters like D.C gain, Bandwidth, input bias current have been studied Table 1 illustrates comparison between conventional CMOS based O.T.A and proposed CMOS based O.T.A

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Table – 1
Comparisons between this work and the recent works

S.No.	*Design parameters*	*OTA using Feedforward with FDCM technique*	*Conventional amplifier*
1	*Power supply*	*2.5v*	*2.5v*
2	*DC voltage gain*	*68 dB*	*28 dB*
3	*Unity gain freq.*	*10 KHz–1GHz*	*1 KHz – 150 MHz*
4	*Input bias current*	*1 nA – 1 mA*	*1 mA*

Power supply noise can also affect the performance of O.T.A, especially at microwave frequencies .A power supply sensitivity simulation was carried out on the O.T.A at different frequencies and the results are in table below

Table – 2
PSRR from the simulation

PSRR	*10MHz*	*4GHz*
PSRR (+VDD)	*90.4*	*41.5*
PSRR (- FOR VSS)	*86.2*	*36.9*

VI. CONCLUSION

A feedforward-regulated cascode OTA has been proposed, analyzed, and experimentally demonstrated in this paper that can operate at very high speeds. The OTA has a large transconductance, high linearity, and low intermodulation distortion, which makes it very suitable for implementing numerous types of microwave integrated circuits. In OTA design the high frequency, high linearity and low power are the three main concerns but tradeoffs have to be made among these aspects for designing of practical OTA circuits

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