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Analysis of Two Stage Folded Cascode Operational Amplifier in 90nm Technology

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Abstract: Folded cascode configuration is a very fascinating unit to any Analog Vlsi researcher as it has advantage of high gain, lesser power dissipation and High Bandwidth. This paper describes about the parametric analysis of folded cascode opamp at low power supply requirements, input voltage and using 90nm technology. At the end, the results which are obtained are compared with the conventional two stage opamp with the same specifications and same technology (90nm).

Keywords: CMRR, dB, NMOS, PMOS, opamp, folded cascade.

I. INTRODUCTION

Operational amplifiers are playing prominent role in many electronics applications. These amplifiers are important as these are very high gain amplifiers. Basically, an ideal opamp characteristics becomes the driving force behind more and more improvements in practical opamps. Folded cascode is one of the effort in the field of enhancing the performance of practical opamp so that the characteristics of ideal opmap can be achieved.
This paper is divided into four sections. First section describes about basics of conventional two stage opamp in detail. The second section describes about Folded Cascode configuration along with difference between normal cascode and folded cascade .The third gives the detailed observations and results which are obtained from simulations in cadence. The results are then compared with the conventional opamp with various parameters. Finally in last section this paper gives the conclusion

II. BASIC APPROACH TOWARDS FOLDED CASCODE OPERATIONAL AMPLIFIER

A. The Conventional Two Stage Operational Amplifier
Basic two stage opamp is basically combination of two stages
1. Differntial stage
2. High gain stage

In nutshell, it can be said that the two stage opmap is a high gain direct coupled amplifier. Verstality of opamp is observed when lots of applications are encountered like oscillators, filters, also in regulated power supply. The only requirement is that accurate type of feedback has to be selected
1. Positive feedback for Oscillators
2. Neagative Feedback for Amplification Following figure 1 is showing the two stage opamp.

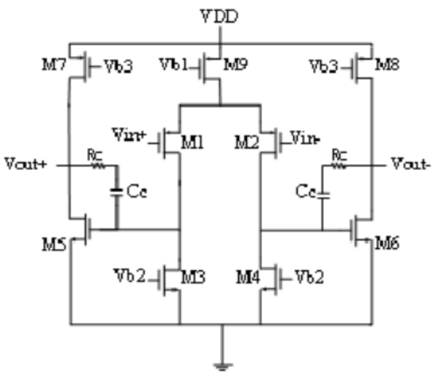

Figure 1: Two Stage CMOS Operational Amplifier

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B. Cascode Configurations
There are two types of cascode configurations:
1. Telescopic
2. Folded Cascode
Telescopic cascode configuration is very useful for neural recording applications .In this MOS transistors are stacked such that gain is improved and to increase overall output impedance .Practically , NMOS transistors are usually preferred over PMOS so as to achieve high unity gain bandwidth and high transconductance and these can be obtained by using NMOS transistors. But if noise suppression and improved phase margin is required then PMOS is the best option. Telescopic amplifier is best described by figure 2.

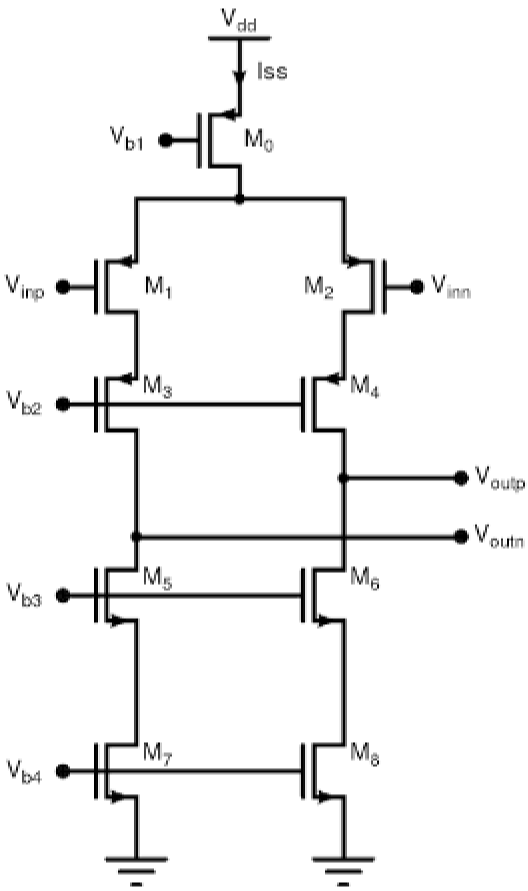

Figure 2: Telescopic CMOS Operational Amplifier

C. Introduction to Folded Cascode Configuration
Before analyzing the folded cascode , there is a need to see the term ’cascode’ means. The Cascode Stage is nothing but the combination of Common Source and Common Gate Stage.
These Kind of configurations is used to achieve:
1. Boosted Gain opamp
2. High Transconductance , As this stage increases the output imapedance to a great extent .The Cascode Configuration can be studided in two parts
1. Normal Cascode
2. Folded Cascode

Normal Cascode: Normal cascode is a combination of CS-CG stage in series configuration. The main requirement is the both the transistors must be same either p channel or n channel It is shown in figure . Advantages of Normal Cascode The biggest advantage of normal cascode is that it can increase gain 2-3 folds depends upone the number of stages which are cascoded. The second big advantage of folded cascode opamp is these are very good with layouts.
In refernce to fig 3 , there is only one pair , it can be extended to n times depending upone the need of gain which is required.

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The various disadvantages of Normal Cascode are

1. The power supply requirement is very high
2. The GBW product is not constant, as the gain increases with this configuration , the bandwidth decreases as a result of which the GBW is not constant.

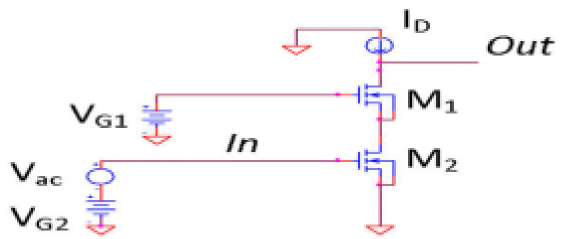

Figure 3 : Normal Cascode Configuration

Folded cascode configuration is an extention of normal cascode configuration. The main difference is that this configuration consists of two transistors either n channel and p channel or both n channel transistors in a way that both transistors must face each other .It will be more clear from figure 4 that this folded cascode as it is clear from figure 4 that both the transistors MP1 MP2 are placed opposite to each other. Similarly it is extended one more time with MP3 MP4.

Advantages of Folded Cascode

1. The biggest advantage of folded cascode is that the power supply requirement is low.
2. The GBW is constant upto an extent.

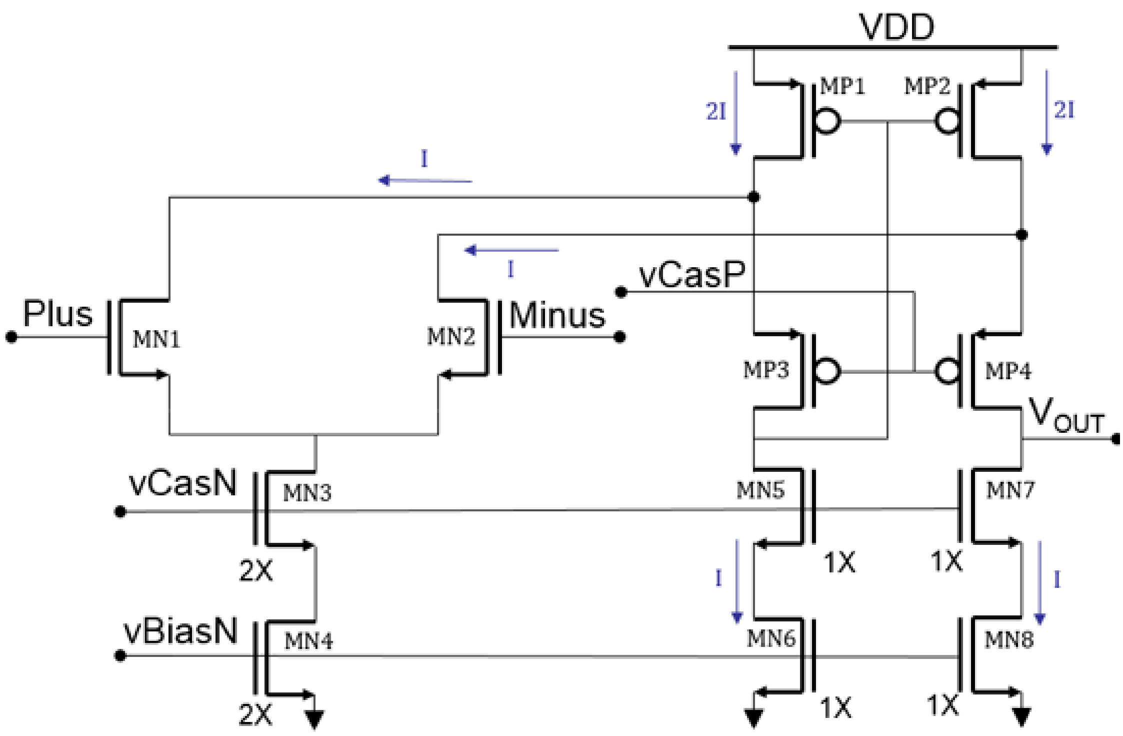

Figure 4 : Folded Cascode Configuration.

D. Design Methodology for Two stage Opamp Folded Cascode opamp

1) Selection of W/L Ratio

Out of all the factors W/L ratio is one of the most important parameter in designing any analog device. So in 90nm technology , W/L for NMOS for PMOS is 1.2.

2) Selection of Power Supply

The power supply is 1.8 V

3) Selection of Input Signal

The input signal should be given between 1 to 1.2 V

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III. VARIOUS ANALYSIS OF FOLDED CASCODE TWO STAGE OPAMP

1) Bandwidth: The gain and frequency are inveresly proportional to each other. The bandwidth is observed by using AC analysis . It also defines the speed of the circuit.The BW of folded cascode is 96.94 MHz.

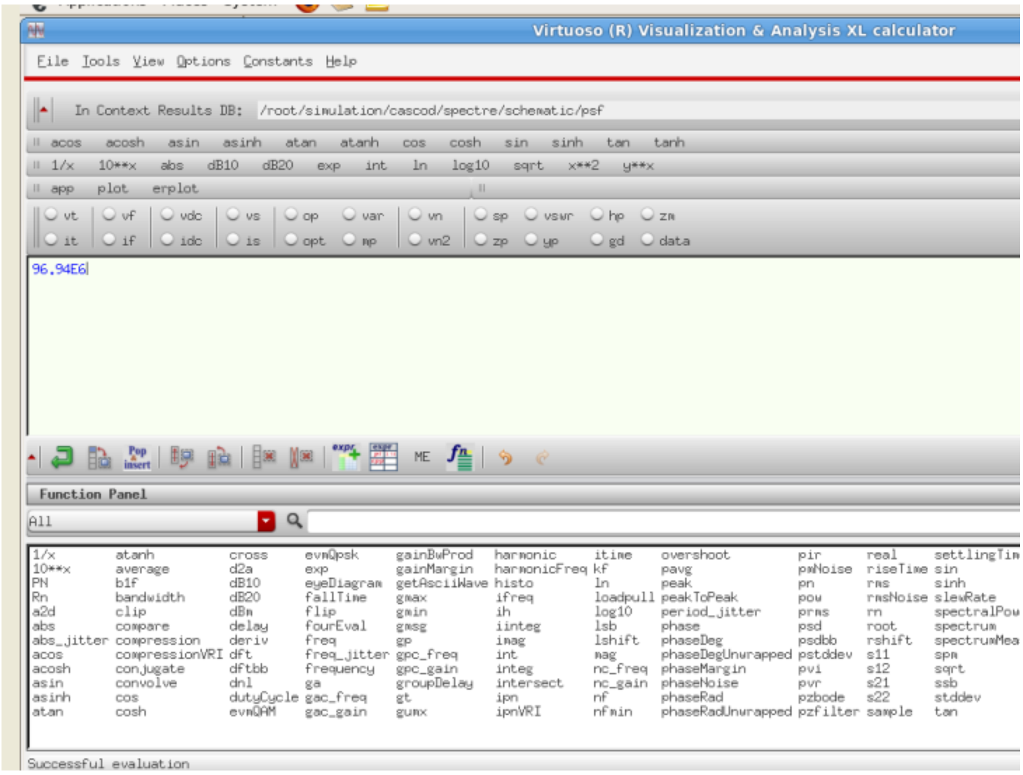

Figure 5 . Bandwidth of Folded Cascode Operational Amplifier

2) Phase Margin: As it is already discussed that , folded cascode configuration gives very high gain and If the phase margin of opamp is grater than 60(in degrees) , it is acceptable for analog applications. This is analysed using AC analysis Methodology.

It is shown in figure 6 : The observed gain is 80dB and phase margin = 71(in degrees).

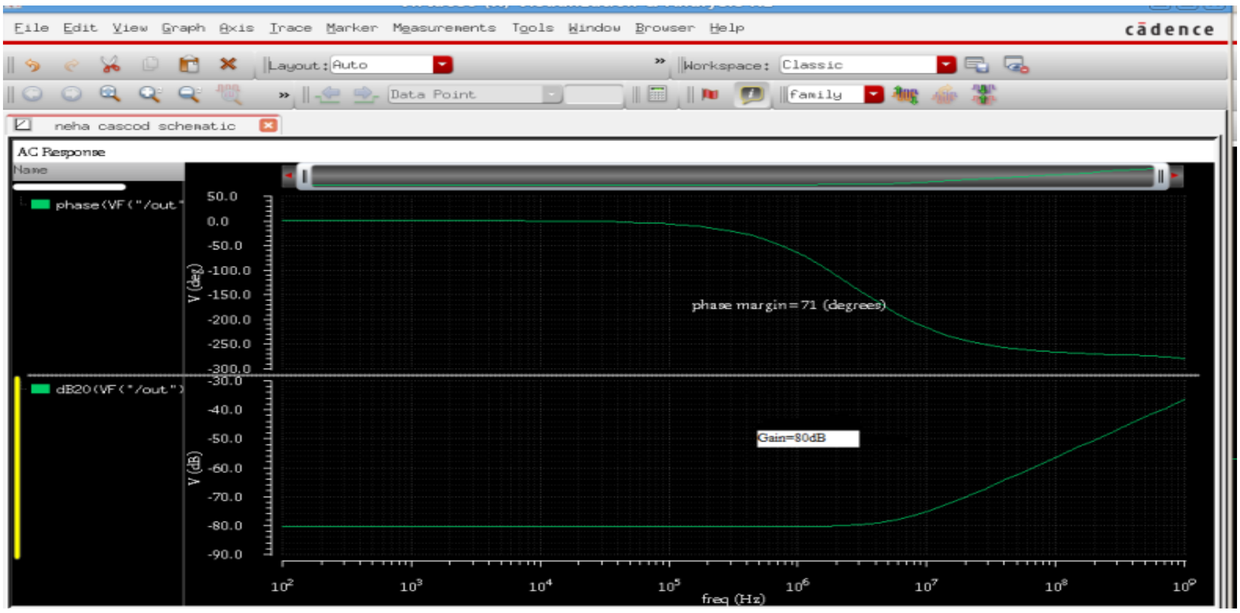

Figure 6: Gain & Phase of Folded Cascode Configuration.

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3) Slew Rate: The slew rate is basically defined as the the rate of change of output voltage with respect to time. It is analyzed by using transient analysis. The slew rate of folded cascode is shown in fig 7.

Figure 7: Slew Rate of Folded Cascode Configuartion

The slew rate of two stage opamp in 90nm technology is shown in figure 8

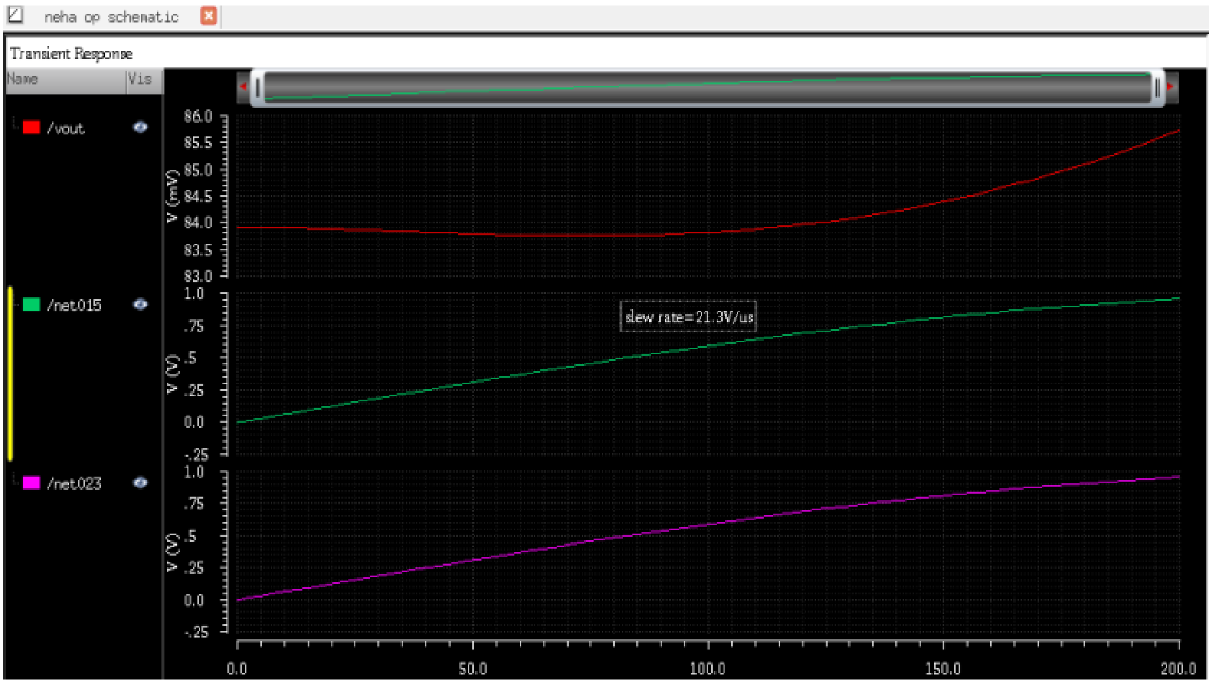

Figure 8: Slew Rate of Two Stage Operational Amplifiers

4) Power Dissipation: The power dissipation should be as low as possible for a good circuit. The power dissipation of folded cascode is shown below in figure 9 the power dissipation of conventional two stage opamp is shown in figure 10.

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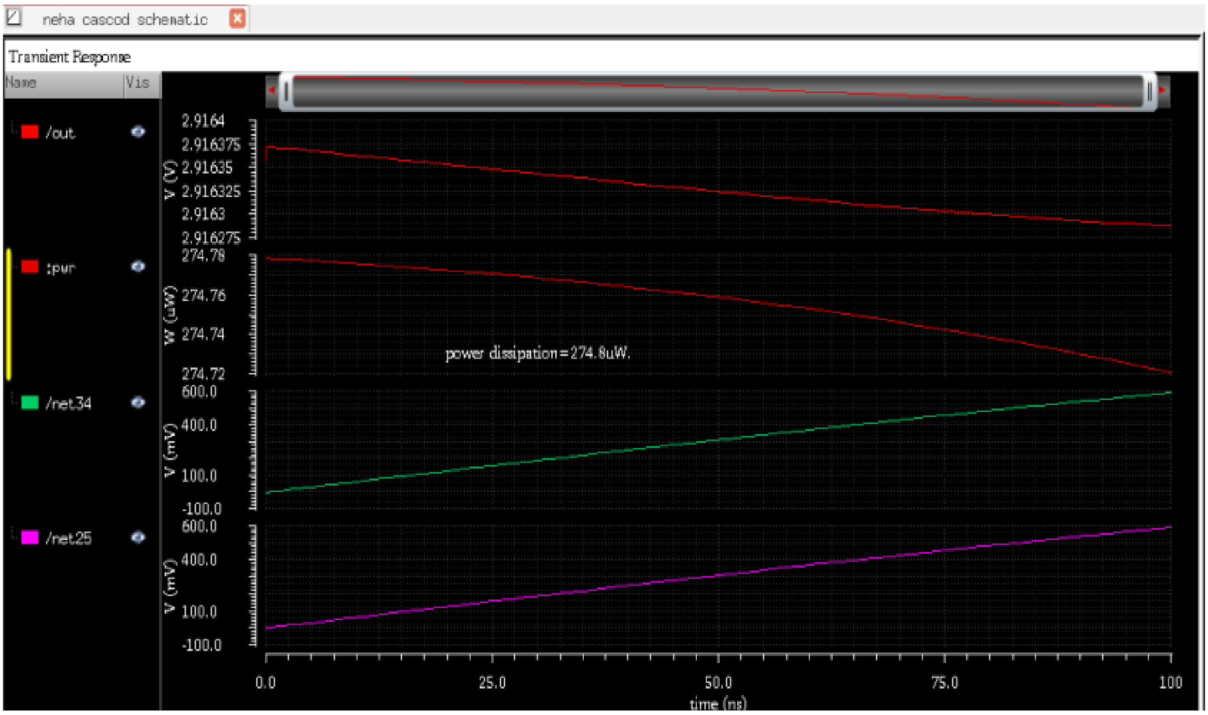

Figure 9: Power Dissipation of Folded Cascode Operational Amplifier.

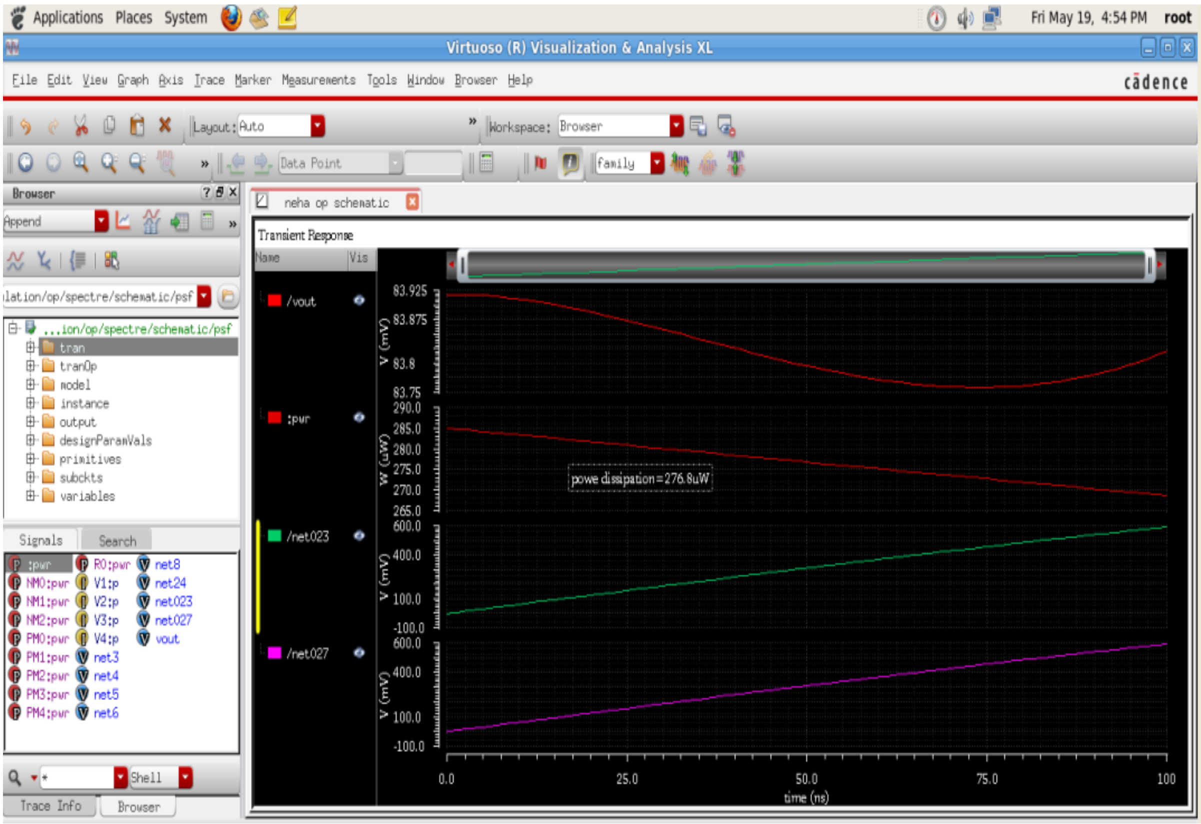

Figure 10 : Power Dissipation of Two Stage Operational Amplifier.

E. DC Analysis of Folded Cascode opamp

With DC analysis, any operating point of transistors involved in the circuit cab be observed and these operating parameters can be varied as per the requirement. DC analysis is shown in figure 11

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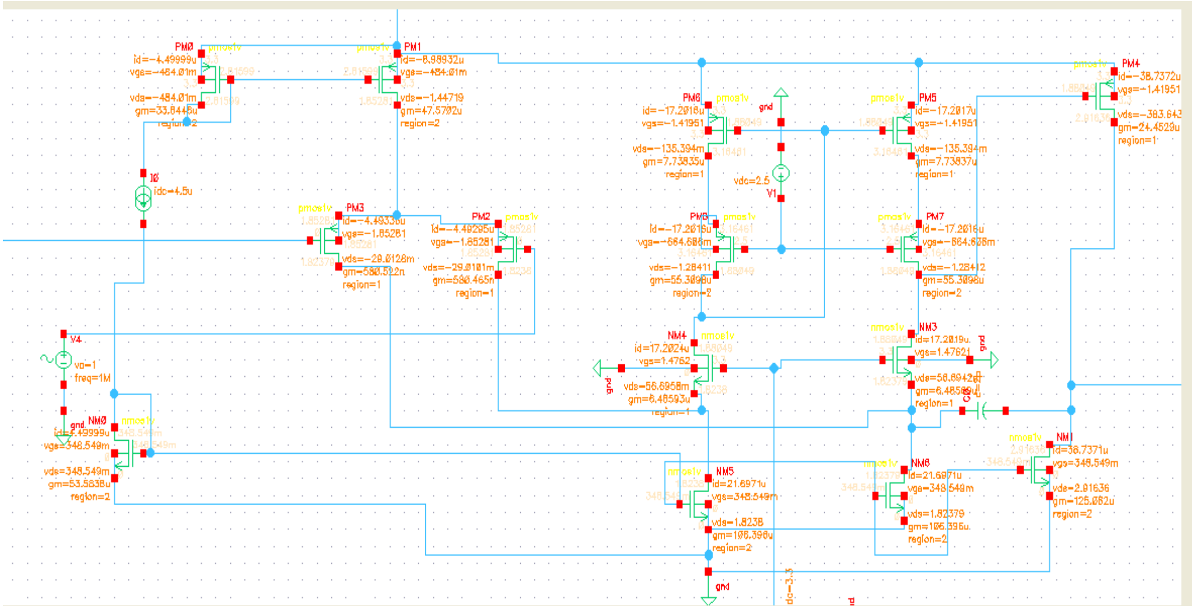

Figure 11: DC analysis of Folded Cascode Operational Amplifier

TABLE I COMPARISION BETWEEN VARIOUS PARAMETERS

S. No	**After A.C & D.C Analysis**			**Reference Paper**
	Parameters	**Conventional Opamp**	**Folded Cascode Opamp**	**Design of Folded Cascode Operational Amplifier in High Voltage CMOS Technology [10]**
1	Power Supply(V)	1.8	1.8	20
2	Power Dissipation(μW)	276.8	274.8	0.02212
3	Phase Margin(in degrees)	125	71	52.09
4	Bandwidth(MHz)	0.09042	96.94	17.80
5	Capacitance(pF)	30	2	10
6	Gain(dB)	22.14	80	84.52
7	Slew Rate9(V/μs)	21.3	17.8	25.69
8	CMRR(dB)	Approx80	160	97.95
9	Input signal Voltage(V)	1	1	-
10	Frequency of input signal(MHz)	1	1	-

IV. CONCLUSION

The results obtained for folded cascode opamp and conventional opam in 90nm are:
1. Power dissipation is improved from 276.8uW to 274.8uW
2. Gain is improved from 22 dB to 80dB
3. Slew rate is also improved 21.3 V/us to 17.8 V/us.
4. CMRR is also improved from 80 dB to 160 dB.
Hence, Folded Cascode opamp can be used where the higher gain is required

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BIOGRAPHIES

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