

International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering

ISO 3297:2007 Certified

Vol. 5, Issue 6, June 2017

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

Jasbir Kaur<sup>1</sup>, Neha Shukla<sup>2</sup>

Assistant Professor, P.E.C University of Technology, Chandigarh, India<sup>1</sup>

P.G Scholar, P.E.C University of Technology, Chandigarh, India<sup>2</sup>

**Abstract:** Folded cascode configuration is a very fascinating unit to any Analog VIsi 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



## International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering ISO 3297:2007 Certified

Vol. 5, Issue 6, June 2017

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.



# International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering

ISO 3297:2007 Certified

Vol. 5, Issue 6, June 2017

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



# International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering

ISO 3297:2007 Certified

Vol. 5, Issue 6, June 2017

### 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.

Image: State in the second	0		-,	•							
Eile Lools Yiev Options Constants Help In Context Results DB: /root/simulation/cascod/spectre/schematic/psf accos accosh asin asinh atan atarh cos cosh sin sinh tan tarh in log10 agrt x+2 y++x app plot erplot vt vf vdc vs op var vn sp vswr he zm t if ido is opt me vn2 zp ye gd data 36.94E6 Function Panel 11 10 10 11 10 10 10 10 10 10	<u>9</u> N					Virtuos	50 (R) Vi	sualization & An	alysis XI	L calcula	itor
In Context Results IB: /root/simulation/cascod/spectre/schematic/psf I accose accosh asin asinh atan atarh cos cosh sin sinh tan tarh I /root/simulation/cascod/spectre/schematic/psf I accose accosh asin asinh atan atarh cos cosh sin sinh tan tarh I /r 0 / 10 / 10 / 10 / 10 / 10 / 10 / 10	Eile Iool	s <u>V</u> iew Option:	s <u>C</u> onstant	ts <u>H</u> elp							
<ul> <li>In Context Results DB: /root/simulation/cascod/spectre/schematic/psf</li> <li>acos acosh asin asinh atan atanh cos cosh sin sinh tan tanh</li> <li>1/x 10*+x abs dB10 dB20 exp int in log10 sqnt x**2 y**x</li> <li>app plot erplat</li> <li>iii</li> <li>if i ido</li> <li>is opt np</li> <li>np</li> <li>np</li> <li>np</li> <li>np</li> <li>is opt np</li> <li>np</li> <li>np</li></ul>											
I acos acosh asin asinh atan atanh cos cosh sin sinh tan tanh I 1/x 10**x abs dB10 dB20 exp int in log10 sant x**2 y**x I app plot erplot U U U U U U U U U U U U U U U U U U U	In Co	ntext Results I	B: /root	/simulation/	cascod/spectro	e/schematic/p	sf				
<pre>ii 1/x 10**x abs dB10 dB20 exp int in log10 sqrt x**2 y**x ii app plot erplot</pre>	II acos a	cosh asin a	asinh at	an atanh	cos cosh	sin sinh	tan	tanh			
i app       plot       erplot       ii         iiiiiiiiiiiiiiiiiiiiiiiiiiiiiiiiiiii	∥ 1/x 10	**× abs dB:	10 dB20	exp int	ln log10	sqrt ×**	•2 y**x				
vt       vf       vd       vs       op       var       vn       sp       vsur       hp       za         it       if       idc       is       opt       np       vn2       zp       yp       gd       data         96,94E6	∥app pl	ot erplot									
Image:	Ovt O	vf Ovdc		op O var	O vn O	sp O vswr	Ohp O	ZR			
96.94E6	IO It IO	11   0 100		opt U Np	10 vn2 10	zp Uyp	U ga U	data			
Image:											
Image:											
Image:											
Image:											
Image:											
Image:											
Image:											
Function Panel Function	- 🎝 🗈	Pop B	a   🖩 🕷 🔰	8 <b>**</b>	ме <b><i>f</i></b>	5 C					
All Constant of the set of the se	Function H	anel									
1/x atanh cross evmQpsk gainBwProd harmonic itime overshoot pir real settlingTi 1/*x average d2a exp gainBwProd harmonicFreq kf pavg pwhoise riseTime in PN bif dB10 eyeDiagram getAsciikave histo In peak provide the power restains and add clip dBn flip gmin ih log10 period_jitter pros rn settlingTi abs_jitter compression deriv freq_gp imag labift phaseDeg padbb rshift spectrumMe acosh compute dftb frequency gpc_gain integ nc_freq phaseDegUnurapped pstdev ill spet asin convolve dnl ga groupDelay intersect nc_gain phaseNoise pv s22 stddev atan cosh evmQRM gac_gain gunx ipnVRI nfmin phaseRadUnurapped psfilter sample tan	A11		<b>Q</b>								
1/x atanh cross evmQpsk gainBWFrod harmonic filme overshoot pir real settling[1 10**x atanh cross evmQpsk gainBWFrod harmonicFreq kf pavg pwNoise riseTime sin PN bif dB10 eyeDiagram getAsciikkave histo in peak pn rms sinh Rn bandwidth dB20 fallTime gmax ifreq loadpull peakToPeak pno rms sinh s2d clip dBm flip gmin ih log10 period_jitter prms rm spectraPo abs					- 8 6 1						
PN bif dB10 eyéDiagram getAscilWave histo in peak por rms sinh Rn bandwidth dB20 fallTime gmax ifreq loadpull peakToPeak pou rmsNoiseslexRate a2d clip dBn flip gmin ih log10 period_jitter prms rn spectralPo abs	1/× 10**×	atanh average	cross d2a	evnQpsk exp	gainBwProd gainMargin	harmonic harmonicFreq	itine kf	overshoot pavg	pir pmNoise	real riseTime	settlingTi sin
An bandwidth db20 failline gmax ifreq ibaqbilipeak oreak, pour manoise siewate abd clip dBn flip gmin ih logiD period_jitter prns m spectralPo abs_ditter.compression deriv freq gp inag lahift phaseDeg peddb rahift spectrum acosh compossionVRI dft freq_ditter gpc_freq int mag phaseDegUnurapped petddev sli spe acosh conjugate dftub frequency gpc_gain integ nc_freq phaseMargin pvi sl2 sqrt asinh convolve dhl ga groupDelay intersect nc_gain phaseNoise pvr s21 sab atan cosh evmQAM gac_gain gunx ipnVRI nfmin phaseRadUnurapped pzfilter sample tan	PN	b1f	dB10	eyeDiagram	getAsciiWave	histo	In	peak.	pn	ras	sinh
abs compare delay fourEval gracg linteg lab phase peda root spectrum abs_jitter compression/WEI dft freq_jitter gro_freq ins hag labift phaseDeg pedda rabift spectrum acosh compression/WEI dft freq_jitter gro_freq int mag phaseDegInurapped petddev s11 spe acosh conjugate dftbb frequency gro_gsin integ nc_freq phaseMargin pvi s12 sqrt asin convolve dnl ga groupDelay intersect nc_gain phaseNoise pvi s21 sqb asinh cos dutyCycle gac_freq gt ipn nf phaseRadUnurapped pzfilter sample tan atam cosh evmQMM gac_gain gunx ipnVRI nfmin phaseRadUnurapped pzfilter sample tan	a2d	clip	dBn	flip	gmax gmin	ih	log10	peak lomeak period_jitter	pou pras	rnsNo1se rn	spectralPo
abs_jitter compression deriv freq gp inag lshift phaseDeg peddo rshift spectrumMe acos compressionVRI dft freq_jitter gpc_freq int mag phaseDegUnurapped pstddev sll spe acosh conjugate dftbb frequency gpc_gain integ nc_freq phaseMargin pvi sl2 sqrt asin convolve dhl ga groupDelay intersect nc_gain phaseMolise pvr s21 sab asinh cos dutyGuel gac_freq gt ipn nf phaseRad pyzbode s22 stddev atan cosh evmQRM gac_gain gumx ipnVRI nfmin phaseRadUnurapped pzfilter sample tan	abs	compare	delay	fourEval	gmsg	iinteg	lsb	phase	psd	root	spectrum
acos compressionWildrt frequitter geo_freq int mag phaseBegUnurapped pstodev sil spn acosh conjugate dftbb frequency geo_gain integ no_freq phaseMargin pvi sil sqrt asin convolve dhl ga groupDelay interset nc_gain phaseNoise pvr sil ssb asinh cos dutuGuelgaco_freq gt ipn nf phaseRad pzbode siz stdev atan cosh evmQAM gac_gain gunx ipnVRI nfmin phaseRadUnurapped pzfilter sample tan	abs_jitter	compression	deriv	freq	gp _	inag	lshift	phaseDeg	psdbb	rshift	spectrumMe
alosi convolve di col rrequency groupDelay intersect nc_gai phaseNoise pvr s21 sab asin convolve dnl ga groupDelay intersect nc_gai phaseNoise pvr s21 sab asinh cos dutyCyclegac_freq gt ipn nf phaseRad pzbode s22 stddev atan cosh evmQRM gac_gain gumx ipnVRI nfmin phaseRadUnurapped pzfilter sample tan	acos	compressionVRI	dfit dfithh	freq_jitter	gpc_freq	inter	hag ho frec	phaseDegUnwrapped	pstddev	s11	spn
asinh cos dutyCyclegac_freq gt ipn nf phaseRad pzbode s22 stddev atan cosh evmQAM gac_gain gumx ipnVRI nfmin phaseRadUnurapped pzfilter sample tan	asin	convolve	dnl	(a	grouplelau	intersect	nc_rreq	phaseNoise	PV1 PV1	s21	ssb
atan cosh evmQAM gac_gain gumx ipnYRI nfmin phaseRadUnurapped pzfilter sample tan	asinh	COS	dutyCycle	gac_freq	gt	ipn	nf	phaseRad	pzbode	s22	stddev
	atan	cosh	evaQAM	gac_gain	gunx	ipnVRI	nfmin	phaseRadUnurapped	pzfilter	sample	tan

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.



# International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering

ISO 3297:2007 Certified

Vol. 5, Issue 6, June 2017

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 Configuration

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.



### International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering ISO 3297:2007 Certified

Vol. 5, Issue 6, June 2017



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



## International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering ISO 3297:2007 Certified

Vol. 5, Issue 6, June 2017



Figure 11: DC analysis of Folded Cascode Operational Amplifier

TABLE I COMPARISION BETWEEN	VARIOUS PARAMETERS

S.	After A.C & D.C Analysis			Reference Paper			
No	Parameters	Conventional	Folded	Design of Folded Cascode			
		Opamp	Cascode	<b>Operational Amplifier in High</b>			
			Opamp	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

### ACKNOWLEDGMENT

Working on this research paper was a source of immense knowledge to us. We would like to thank God, our parents for their love and support.

## REFERENCES

- J. Mahattanaku, Design Procedure for Two-Stage CMOS OperationalAmplifiers Employing Current Buffer, IEEE Transactions on Circuits and SystemsII: Express Briefs, Vol. 52, pp.766-770, November 2005
- [2] Ayush Gupta, Aditya Bhansali, Swati Bhargava, Shruti Jain Configuration of Operational Amplifier using CMOS



# International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering

ISO 3297:2007 Certified

Vol. 5, Issue 6, June 2017

- [3] S. Zhang, C. Zhu, J. K. O. Sin, and P. K. T. Mok, "A novel ultrathin elevated channel low-temperature poly-Si TFT," IEEE Electron Device Lett., vol. 20, pp. 569–571, Nov. 1999.
- [4] D. Nageshwarrao, K.Suresh Kumar, Y.Rajasree Rao,G.Jyothi, Implementation and simulation of CMOS two stage operational amplifier, International Journal of Advances in Engineering Technology, Vol. 5, pp.162-167, Jan. 2013
- [5] A.-J. Annema, B. Nauta, R. van Langevelde, and H. Tuinhout, Analog circuits in ultra-deep-submicron cmos, IEEE J. Solid-State Circuits, vol.Vol. 40, January 2005
- [6] E. Sackinger and W. Guggenbuhl, A high-swing high-impedance mos cascode circuit, IEEE J. Solid-State Circuits, vol. 25, pp. 289298, Feb.1990
- [7] J. Lloyd and H.-S. Lee, A cmos op amp with fully-differential gainenhancement,IEEE, 1994
- [8] T. Burger and Q. Huang, On the optimum design of regulated cascode operational transconductance amplifiers, ISLPED, 1998.
- [9] NPTEL lecture on Analog Vlsi design (IIT Bombay)by Prof. A.N Chandorkar
- [10] T. Burger and Q. Huang, A 100 db, 480 mhz ota in 0.7 m cmos for sampled-data applications, Custom Integrated Circuits Conference, 1996.
- [11] Benjamin Lutgen, 2009," Design of a folded cascode operational amplifier in high voltage CMOS technology".

#### BIOGRAPHIES



**JASBIR KAUR** She is an Assistant Professor at P.E.C University of Technology, Chandigarh. She has more than 20 publications. She is pursuing her PhD in VLSI Design at P.E.C University of Technology.



**NEHA SHUKLA** She is P.G Scholar at P.E.C University of Technology Chandigarh. She has also published her paper in ICAMT-2016 (Elsevier indexed) & ICMTES-2017 (Scopus Indexed).