Performance Improvement Strategies of Analog & Mixed Circuits

Saumya Srivastava, Tripti Sharma

Abstract*: In modern days technology becomes very advanced and it moves from analog to digital domain. Everything depends on one and zero frame. In any case, the foundation of any computerized circuit is constantly simple and without simple can't envision this world. ADCs play an intermediate role between analog and digital circuits. Analog and mixed circuits are basic piece of any gadget and there are bunches of works in analog domain for researcher. This paper is extremely helpful for understanding the extent of analog and mixed circuits, also give description about various smart techniques which help to improve the performance of the device. Presently gadgets turn out to be little because of scaling and circuits works on nano-scale process so area become comparably very small but on the penalty of power dissipation which is important term for consideration. This paper additionally talked about different way to deal with decrease control supply. It is thoroughly legitimizes the way that Analog is exceptionally amazing area for researcher.

***Index Terms*: Analog & Mixed signal, Bulk driven, Floating gate, Slew Rate, DTMOS, DC gain**

I. INTRODUCTION

Analog and mixed signal are basics of any device, although today technologies moves to digital side but spine of any device is analog. Analog circuits are very complex for analysis and there are lots of good challenges for new researcher. Analog domain always based on continuous signal but digital is in 0 and 1 form [1] Due to continuous nature it is difficult to work in this domain. Digital area mainly concerned about speed, how fast gadgets perform the task. In analog domain speed is considered in the form of bandwidth so analog circuit requires high bandwidth to make device faster. Noise is main issue in analog domain for high accuracy [2]. There are lots of EDA (Electronic design automation) tools are available like HSPICE, ELDOSPICE, PSPICE, TANNER, Mentor Graphics and CADENCE VIRTUOSO which helpful to enhance the performance of analog circuit based design simulation. Power supply reduction is exceptionally urgent issue in modern days. Performance parameters of analog circuits are Slew-rate, DC gain, Unity gain bandwidth and common mode rejection ratio. These factors plays important role to improve the device performance. Analog domain has many opportunities to generate new building block and improve overall performance of the device. Researcher can also work on reducing chip area of the device and try to make compact device. There are various technologies are available which are very helpful to reduce chip size, Power consumption. Bulk driven, DTMOS, FVF(Flipped voltage follower) and

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and recycling techniques help to improve the gadgets performance. Operational amplifier is basic building block of analog circuits.

II. TECHNIQUES TO REDUCE SUPPLY VOLTAGE & POWER SUPPLY

A. Bulk Driven MOSFET

Bulk driven technique is an ideal way to minimize the threshold voltage and low threshold voltage is extremely valuable to reduce the power. In this technique bulk acts like gate terminal and it operates as a depletion type JFET [6]. Input signal is applied to the bulk terminal and amount of current is controlled by bulk. Device will be on small positive voltage and it will enhance ICMR. Fig-1 shows bulk driven MOSFET here bulk used as a gate terminal, it shows simple PMOS current mirror by using both gate driven and bulk driven. In gate driven current mirror's output current follows its input more closely than bulk driven MOSFET current mirror design [6].

Table-I presents a proper comparison value of different essential parameters of analog design for different SUB-1V amplifiers with bulk driven techniques.

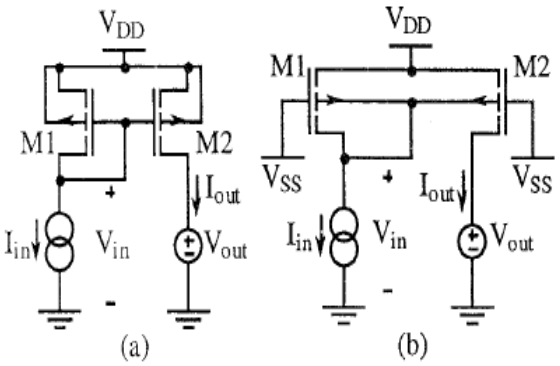

Fig-1: (a) PMOS gate driven current mirror (b) PMOS bulk driven current mirror [6]

B. Floating Gate MOSFET

Floating gate technology is based on capacitor instead of resistor based technique. In this Floating gate technique multiple inputs are deposited above the floating gate. Floating gate method is very useful to design CMOS transconductors. FGMOS is very convenience for scaling purpose and level shifting of input voltages due to capacitor divider at input stage [8]. It is beneficial for low threshold voltage and high output impedance. Due to low threshold voltage essential term power consumption is also low. FGMOS technique multiple inputs are very useful for tenability. Drawback of this technique is low bandwidth and it affects the speed of the device. Fig-2 shows how FGMOS transistors allow the implementation of compact programmable current mirrors.

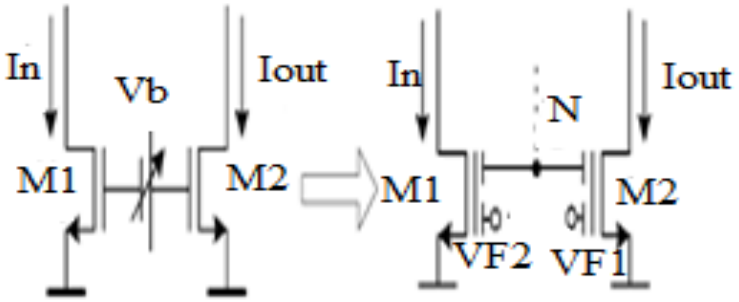

Fig-2: FGMOS Programmable current mirror [8]

Table-I Comparison between other SUB-1V amplifiers with bulk driven [7]

Works	Tech (µm)	C_L (pF)	UGBW (MH_Z)	Gain (db)	PM (deg)	SR+/- (V/µs)	Area (mm^2)	Supply (V)	Power (µW)	FOM
1998	2	22	1.3	48.8	57	0.7/1.6	1.51	1	287	10
2000	1.2	15	1.9	87	61	0.8/1	0.81	1	410	13.7
2001	0.5	-	2	62-69	57	0.5	-	1	40	50
2002	2.5	-	5.6	79	62	-	0.5	0.9	0.45	13.4
2003	0.25	18	1.2	52	60	0.2	0.006	0.8	8	218
2005 (Bulk)	0.18	20	2.5	52	-	2.89	0.026	0.5	110	22.7
2005 (Gate)	0.18	20	10	62	-	2	0.017	0.5	75	133.4
2009	0.35	2.5	540	62	52	-	-	0.9	9.1	12.3
2012	0.35	15	11.67	88.3	66.1	2.53/1.37	0.157	1	197	88.9

C. Quasi-Floating Gate MOSFET

Quasi-Floating gate is similar to Floating gate MOSFET but except that gate weakly connected to one of the supply rail via a very high value resistor. Advantage of QFGMOS over FGMOS is that it reduces the charge accumulation problem.

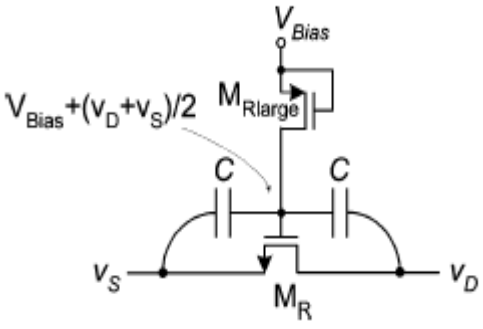

Fig-3: Triode transistor with enhanced linearity using QFG Technique [8]

Fig-3 express that how QFGMOS technique improve the linearity term when MOS operates in triode region. Here two input QFGMOS transistor in triode region act as active resistor [8].

D. Dynamic Threshold MOS (DTMOS)

In this technique both gate and body terminal are tied together. DTMOS concept is used when gate and body voltages are raised then it helps to minimize the threshold voltage of the device. Threshold voltage helps to reduce the power consumption [9]. DTMOS plays excellent role for increasing current drive and trans-conductance value. Disadvantage of this DTMOS concept is large junction capacitance, due to large capacitive value area of the device enhanced.

E. MOSFET Operating in Sub-threshold/ Weak inversion Region

In past more focus was on strong inversion region but weak inversion is also important for low power CMOS analog circuit design [10] It is very useful in controlling threshold voltage and reducing power consumption. Advantage of this technique is that it helps to enhance g_m/I_d value which is new trending technique as compare to current square law method. Due to week inversion trans-conductance value increased and helps to improve amplification of MOSFET. Drawback of week inversion is that it is not beneficial for very high frequencies applications

III. CIRCUIT PERFORMANCE

IMPROVEMENT TECHNIQUES

Circuit performance of analog and mixed circuits depends upon its essential parameters like DC gain, slew rate and bandwidth. These techniques are helpful to enhance the performance of analog circuits. These are as follows:

A. Flipped Voltage Follower

Flipped voltage follower is a cascade amplifier with negative feedback circuit. This circuit has high current sinking capability due to low output impedance [11]. This technique is very helpful for low static power dissipation, low distortion and unity voltage gain. High slew rate, ICMR and large voltage swing are useful for enhancing device performance. Voltage buffer circuit is able to sink large amount of current from load but loop hole of this circuit is that its sourcing capabilities is limited whereas source follower circuit has input current held constant value and it is independent of output current. This is also called voltage follower with shunt feedback.

B. Differential Flip Voltage Followers (DFVF)

Differential flip voltage follower is built by the help of FVF after adding one more MOS.[11] In DFVF maximum output current can be very high than quiescent current. In this technique output can be available as both current as well as voltage form. Fig-4(a) is called as FVF Pseudo differential pair. It is enhance version of DFVF by adding extra one transistor. Fig-4(b) shows DC output current vs. differential voltage graph. Main difference between DFVF and FVFDP is that output current is large in case of DFVF when the differential output voltage should be positive and in case of FVFDP differential voltage should be negative.

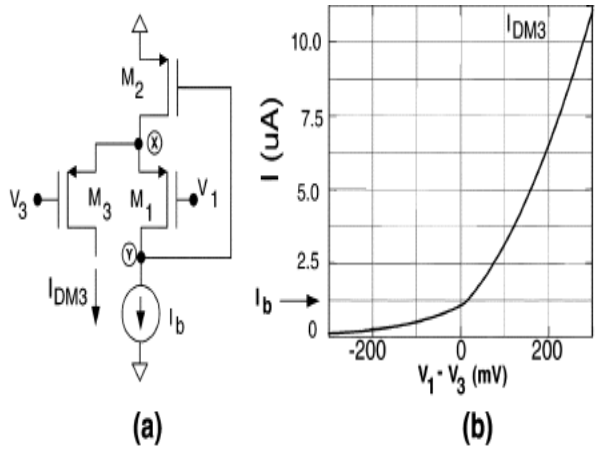

Fig-4: (a) FVFDP (b) DC transfer characteristic [11]

C. Fully Differential Flip Voltage Follower (FDFVF)

Fully differential voltage follower technique is using two DFVF to find the behavior of fully differential circuit. This circuit similar to DFVF very high output current can occur as compare to quiescent current and advantage of this circuit is that it can work on low supply voltage.

D. Supper Source Follower (SSF)

FVF technique is very useful for performance aspects of analog circuit but there few drawback of this circuit like small voltage swing, limited input voltage range. To reduce the loop hole of previous circuit Source follower circuit comes into picture. It is very useful as voltage buffer and level shifter [12]. SSF circuit has negative feedback which is very good for making device stable. Better current efficiency, less distortion, very high linearity and no restrictions on input ranges are positive side of super source follower circuit. SSF express when input voltage is constant output voltage increases.

E. Self Cascode(SC) Structure

Self cascode is two transistor based structure and it is very beneficial to provide higher output impedance and consumes very less area [13]. It has very high cut-off frequency due to shorter physical length. Fig-5 shows gain boosted self cascode amplifier stage and the gain of simple amplifier can be increased by amplifier circuit by increasing the cascoding effect of transistor M_2 [13].

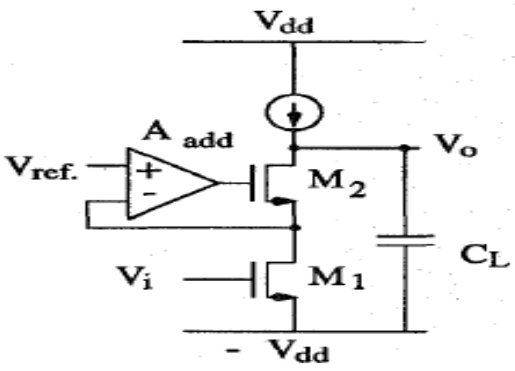

Fig-5: Gain boosted cascode amplifier stage [13]

F. Feedback Circuits

Feedback means some portion of output is return to input of the circuit [14]. In Fig-6 shows Common mode feedback circuit. CMFB is used to control the stability of the device and make device more stable. Recycling and reusing technique is similar to feedback technique but here same circuit or device is used for additional task [15].

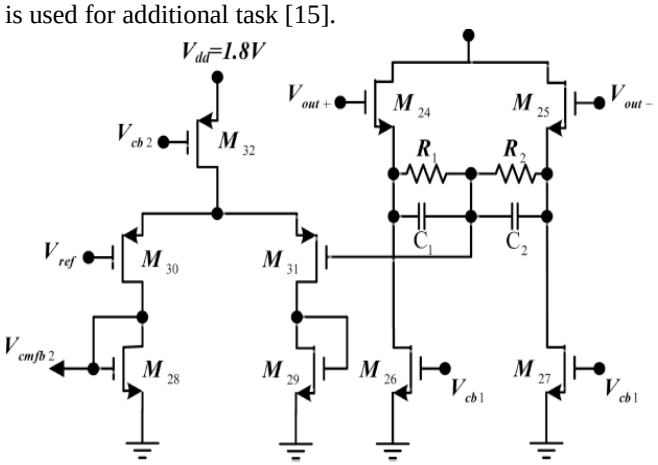

Fig-6: Common mode Feedback circuit [14]

G. Folded Cascode Amplifier

Folded cascode is very essential circuit for high gain and high output resistance. When folded cascode is used in place of self cascode then power dissipation is

minimized [16]. It is mostly used in analog circuits. Fig-7 shows conventional folded cascode circuit which helps to reduce the power consumption. In two- stage operational amplifier first stage differential amplifier is replaced by folded cascode circuit for high amplification purpose.

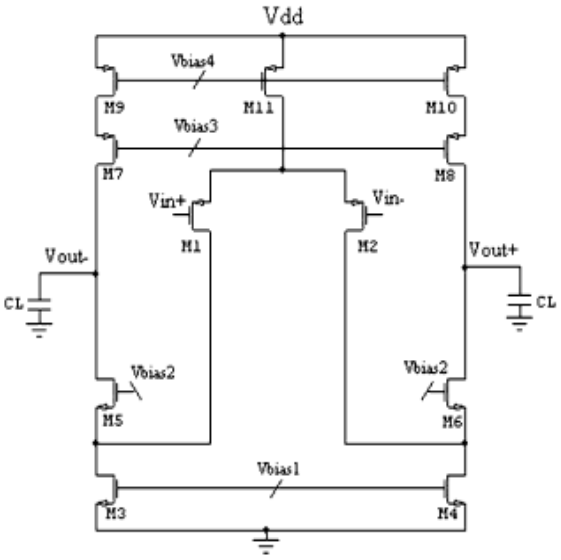

Fig-7: Conventional Folded cascode [16]

H. Resistance Compensation Technique & Current Enhancer Technique

Current enhancer or current booster technique is helpful for current enhancement purpose and current is increased by the help of external transistor which is connected parallel side to regulate the circuit [17]. Resistance compensation technique is a method in which, compensate the resistance value inside the circuit accordingly and increase the performance of the circuit [18]. Fig-8 shows state diagram of RC-PLBC which helps PLL (Phase locked loop) circuit for frequency tracking, Phase tracking and phase locked purpose [18].

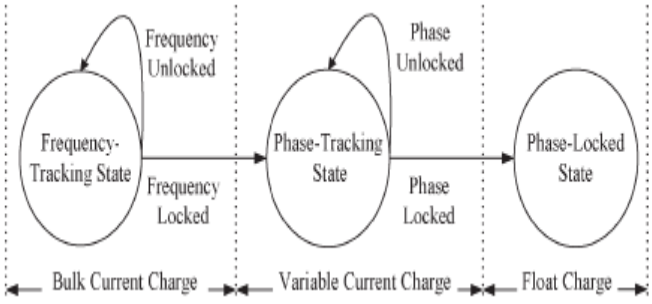

Fig-8: Equivalent state diagram of RC-PLBSC [18]

IV. VARIOUS BUILDING BLOCKS OF ANALOG CIRCUITS

These are the basic building blocks of analog and mixed circuits and exceptionally basic in structuring any analog circuit based device. **Operational-amplifier** is a basic building block of any analog device and it is a three terminal gadget and performs all mathematical operation and device formation. **OTA** is operational transconductance amplifier. It is very versatile and dominating block in analog domain [19]. All the circuit which is based on signal processing concept is designed by OTA.

MI-OTA basically OTA design with multiple input terminals and it converts all input signals to a single output current [18] Transconductance value is increased and it will help for amplification purpose. **CC** stands for current conveyors and it is an alternative of op-amp in analog circuit. It gives high gain over large bandwidth and useful for high gain bandwidth product, speed of the device enhanced when GBW is large [1]-[5]. **VDTA** is voltage difference transconductance amplifier provides differential input voltage and it multiplied to transconductance results provide high current at output terminal. VDTA is designed by the help of two OTA in cascade form. VDTA is beneficial in terms of low power, high input impedance, high transconductance and high bandwidth. **CDTA** stands for current differencing Transconductance amplifier and it combines the merit of both the circuit CC and OTA [19]. High slew rate, absence of parasitic capacitance and simple design are advantage of CDTA circuit.

V. CONCLUSION

Analog circuit is most important part of the all gadgets. This paper focused to describe various power supply reduction method and performance improvement strategies. This will help to improve the performance of continuous signals. Floating gate, DTCMOS, recycling technique and feedback circuits are excellent technique for designers to achieve high slew rate, high gain and high bandwidth to make device performance excellent. There are bunches of good work remain for new comers in analog domain. EDA tools are also available in the market which helps to reduce the complexity of analog circuit during research.

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