Analysis, Characterization & Comparison between NMOS Type Basic Source Follower & NMOS Type Flipped Voltage Follower

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Abstract— In this paper, characterization and comparison between NMOS type source follower and NMOS type flipped voltage follower is presented. It is designed using LT spice in 130nm BSIM3 technology at 1.2V supply voltage. Transient, DC and AC analysis carried out for both topologies .Comparison table shows merits and demerits of both the topologies.

Key words: Source Follower, Flipped Voltage Follower

I. INTRODUCTION

A voltage follower produces an output signal that is equal in amplitude to the input signal, means it has current gain but not voltage gain. The voltage follower is a non inverting buffer with unity gain input impedance is very high and output impedance is very low.

Voltage follower is playing as a one unit in many application for example Used for isolation of input and output circuits[1], Used as buffer in electronic logic circuits, Used in bridge circuits through a transducer, Used in sample and hold circuits, Used in active filters.

The essential building block of real-time operational circuits, often called a voltage follower, operates as a buffer. But, the voltage follower demonstrates a variety of limitations, such as an uneven slew rate, distortion that depends on frequency, and an output resistance that is not sufficiently low[2]. To overcome these limitations, a modified version of the voltage follower, called the flipped voltage follower (FVF) cell, was introduced.

The "flipped voltage follower (FVF)" is a sophisticated buffer component that is highly renowned for its utilization in the design of low voltage/low power applications. The utilization of the FVF and its assorted forms in the design of analog and mixed signal circuits has consistently surged over the past few decades[3].

This paper includes five sections as follows. Section II presents basics of NMOS type source follower. Section III presents basics of NMOS type Flipped Voltage Follower (FVF).Section IV presents simulated results. Section V presents conclusion.

II. BASICS OF NMOS TYPE SOURCE FOLLOWER

Source follower is the part of many analog integrated circuits. It is one of the most important analog circuits. Source follower is the two terminal circuit used to transfer the first circuit having a high input impedance level, to the second circuit having a low impedance level. The output voltage of the Source follower tracks or follows the input voltage. Hence, it is called as Source follower. It is also known as the voltage buffer or isolation buffer. It provides the isolation between high impedance level and low impedance level. It has a unity voltage gain (Av = 1). It can provide considerable amount of current gain and power gain. Source followers have high input impedance and low output impedance. They draw a small amount of current from the source and deliver a large current to the load. Thus, they prevent the source from loading effect[1].

They are used primarily for the impedance matching in analog integrated chips and devices. BJTS, MOSFETS, OPAMPS can be used for the design of Voltage follower. In this paper; the design is done with NMOS. We have implemented the designs in 130 nm technology[1]. Voltage follower must satisfy certain requirements. These are[1]:

- Low output impedance.
- High bandwidth
- Low power dissipation
- Linearity and unity voltage gain.
- High input impedance

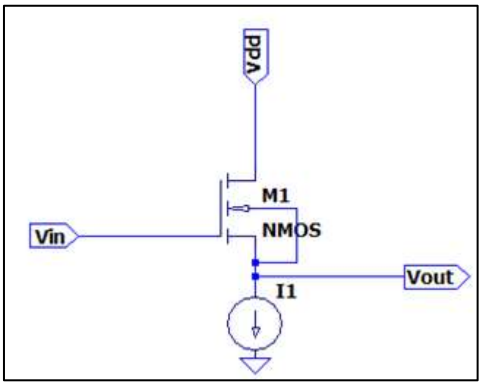

Fig. 1: Circuit Diagram of basic NMOS type source follower

Fig.1 shows schematic of basic source follower made up of one NMOS transistor. In Figure 1, I1 is used for bias M1 (NMOS) transistor which keeps Vgs of M1 ideally constant[3].If the influence of the body effect is not taken into consideration, the output will track the input voltage with a direct current level shift, specifically denoted as Vout equals Vin – Vgs[3]. It has low output impedance in the range of few kΩ which is theoretically Rout=1/gm1[3].Basic source follower suffers from some disadvantages. For example, sometimes output impedance is not sufficiently low[3]. It becomes low enough only when gm is increased or bias current will increased[3]. If W/L ratio of transistor is increased which increased size of the transistor. If value of biasing current is increased which increased power dissipation of the circuit. Sometimes uneven slew rate and distortion over high frequency is also limits operation of the source follower[3].

III. BASICS OF NMOS TYPE FLIPPED VOLTAGE FOLLOWER

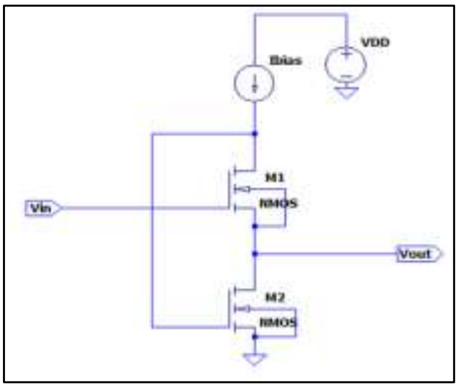

Fig. 2: Circuit Diagram of NMOS type Flipped Voltage Follower (FVF)

Flipped voltage follower is a voltage follower with shunt feedback[1]. The circuit is recognized for its low power and low voltage, while also showcasing a lower impedance when compared to the basic source follower[1]. It is used to defeat some of the constraints of source follower[1]. But, it too has certain disadvantages. Main disadvantage is partial output swing of this topology[1]. The current sensing transistor M2 captures changes in the output current, thereby confirm that the current in M1 remains relatively constant[1]. Therefore, VGS of M1 remain constant if we ignore body effect and channel length modulation effect[1]. Therefore, distortion is decreased at high frequency[1].

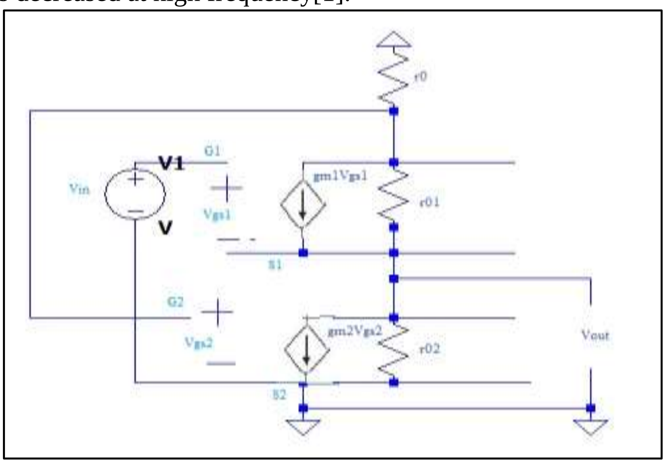

Fig. 3: small signal circuit for Flipped Voltage Follower

Figure 3 shows small signal model of NMOS type flipped voltage follower. Equation for output impedance is Rout=1/gm1gm2ro1[1].From small signal model, small signal voltage gain equation is derived which is shown as below.

$Av=\frac{Vout}{Vin}$

Vout =gm2*Vgs2*ro2

Vgs2=Vg2-Vs2

Vgs2=Vg2 [Vs2=0]

Vg2= gm1*Vgs1*ro1+Vout

So, Vgs2= gm1*Vgs1*ro1+Vout

Vgs2=gm1*(vg1-vs1)*ro1+Vout

Now equation for Vout is

Vout= gm2*ro2*(gm1*Vgs1*ro1+Vout)

= gm2*ro2*gm1*Vgs1*ro1+ gm2*ro2*Vout

Vout(1- gm2*ro2)= gm2*ro2*gm1*Vgs1*ro1

Vout(1- gm2*ro2)= gm2*ro2*gm1*(Vin-Vout)*ro1

$$\frac{Vout}{Vin} = \frac{gm2r02gm1r01}{1 - \mathrm{gm2} * \mathrm{r02} + \mathrm{gm2} * \mathrm{ro2} * \mathrm{gm1} * \mathrm{ro1}}$$

IV. SIMULATED RESULTS

The performance of basic source follower and flipped voltage follower is verified through LT spice simulations using PTM (Predictive Technology Model) 130nm BSIM3 technology file with 1.2V supply voltage. The dimensions of transistors are expressed in Table I and Table II.

Transistor	Width(μm)	Length(μm)
M1(NMOS)	165.044	0.13

Table I. Dimensions of Transistors of Basic Source Follower

Transistor	Width(μm)	Length(μm)
M1(NMOS)	30	0.13
M2(NMOS)	0.044	1

Table Ii. Dimensions of Transistors of Flipped Voltage Follower

Transient, AC and DC analysis is performed for both circuits. Figure 4, 5, 6 and 7 shows results of basic NMOS type source follower.

Figure 4 shows transient analysis for input sine wave of 1.2Vp-p, 1 GHz frequency value. From the waveform, output waveform follows input waveform.

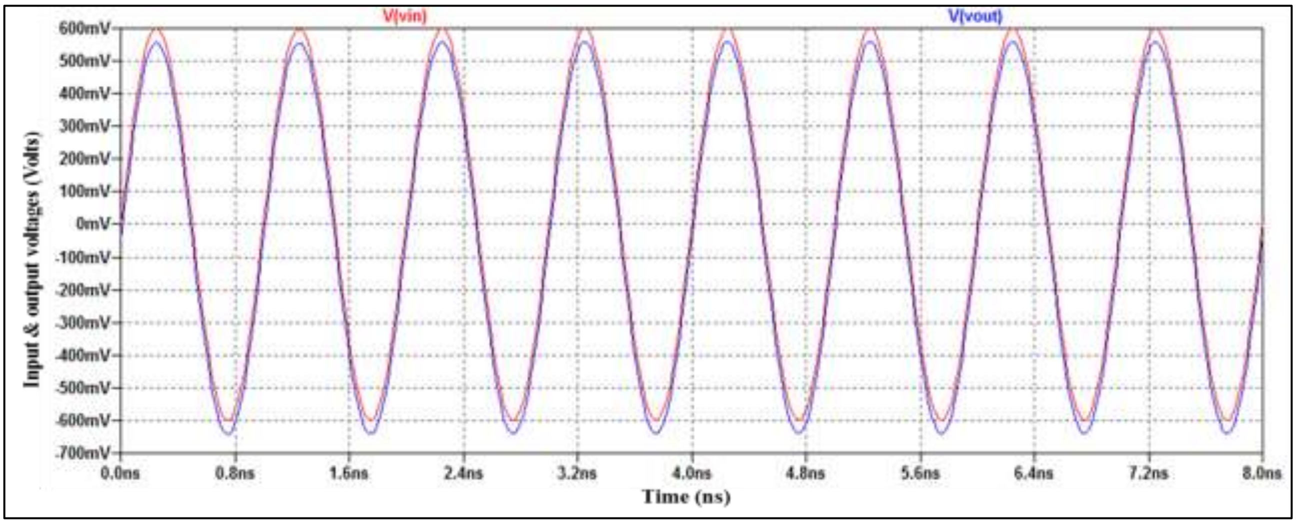

Fig. 4: Transient analysis of basic NMOS type source follower

Figure 5 shows DC analysis waveform to find out linearity range. From the waveform, linearity range is from -1.42V to -1.22V. Figure 6 shows AC analysis waveform to find out -3 db frequency and voltage gain which is 19MHz and 0.965 respectively. Figure 7 shows waveform to find our output impedance of NMOS type basic source follower which value is 240KΩ in this case.

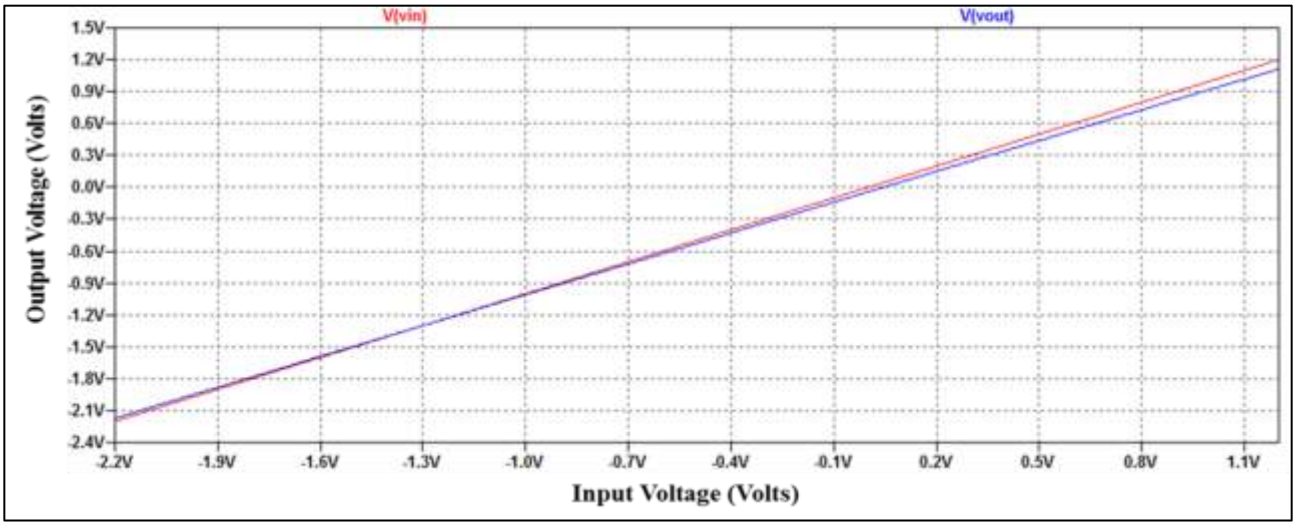

Fig. 5: DC analysis of basic NMOS type source follower

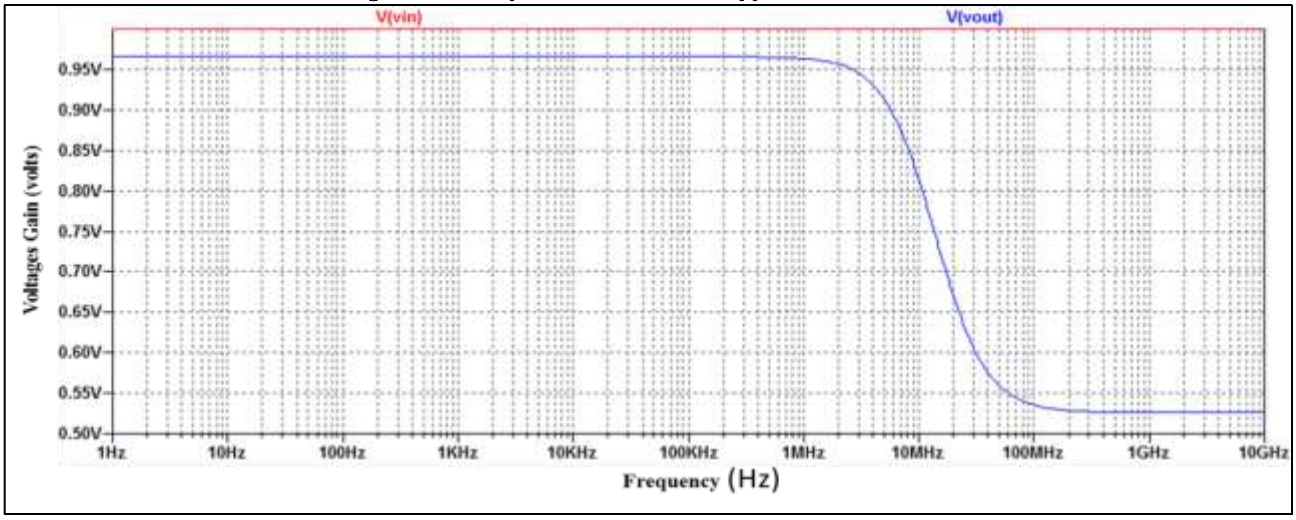

Fig. 6: AC analysis of basic NMOS type source follower

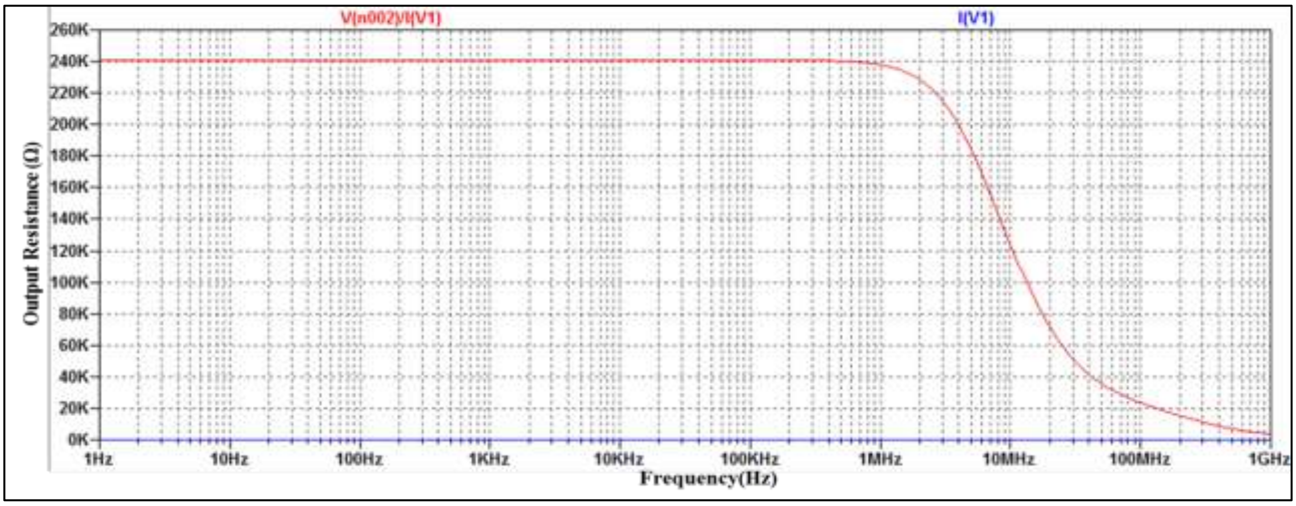

Fig. 7: Output impedance of basic NMOS type source follower

Figure 8,9,10 and 11 shows performance of NMOS type flipped voltage follower circuit. Figure 8 shows transient analysis of NMOS type flipped voltage follower with input sine wave of 1.2Vp-p with 1GHz frequency which is followed by output voltage. Figure 9 shows DC analysis waveform to find linearity which is 0.045V to 0.723V.Linearity range is improved in flipped voltage follower compared to basic source follower. Figure 10 shows AC analysis of NMOS type flipped voltage follower which shows -3 db frequency is 9.83 MHz . Figure 11 shows output impedance which value is 115KΩ.

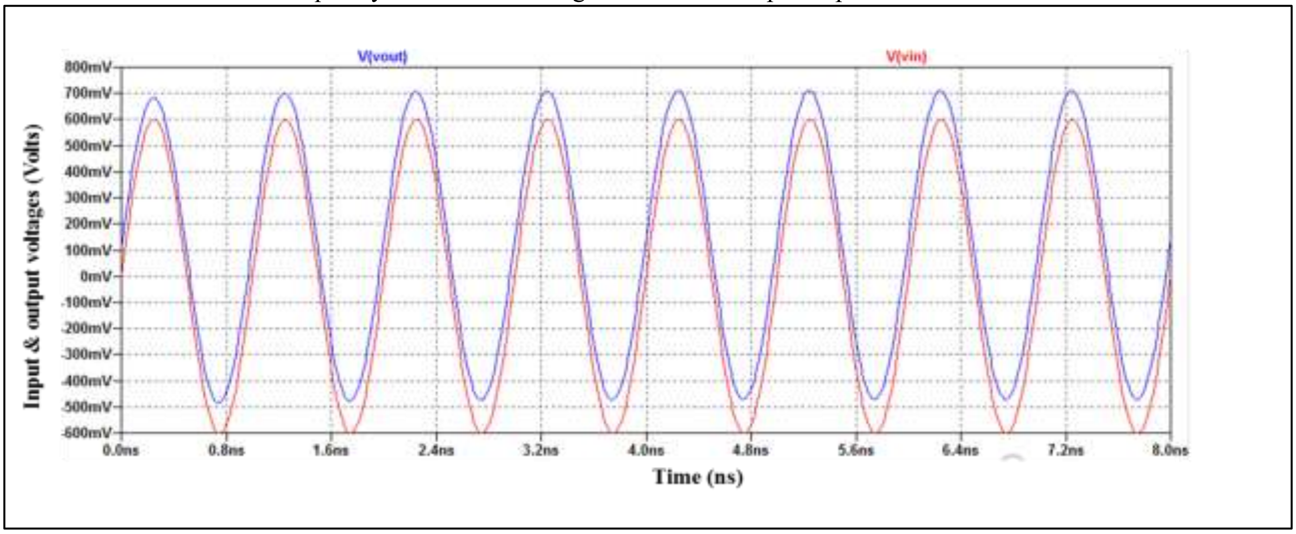

Fig. 8: Transient analysis of NMOS type flipped voltage follower

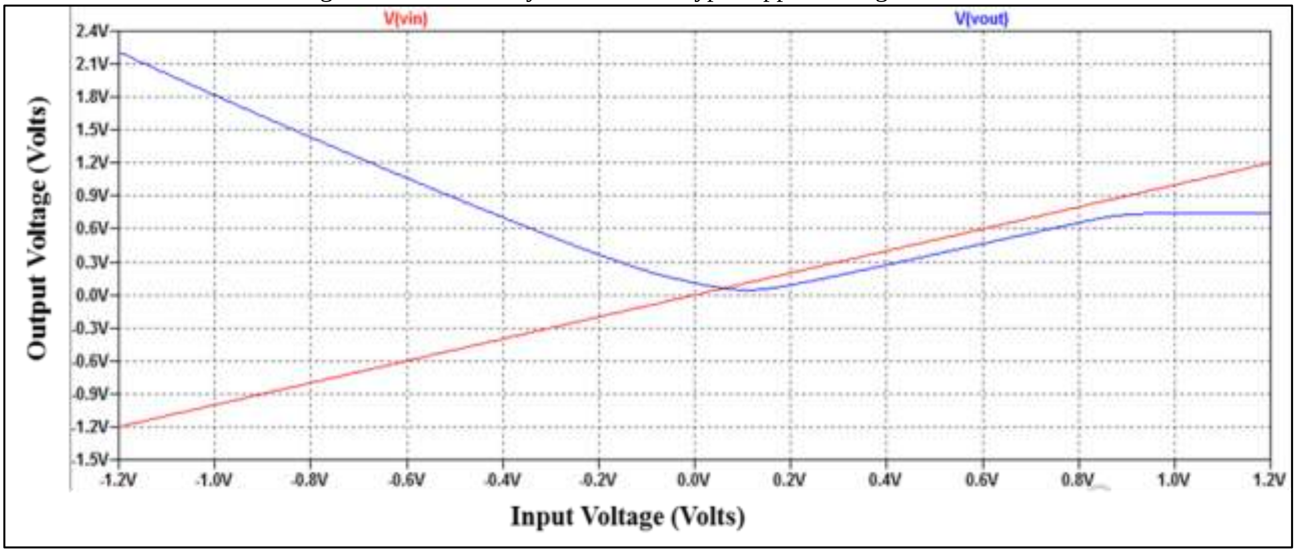

Fig. 9: DC analysis of NMOS type flipped voltage follower

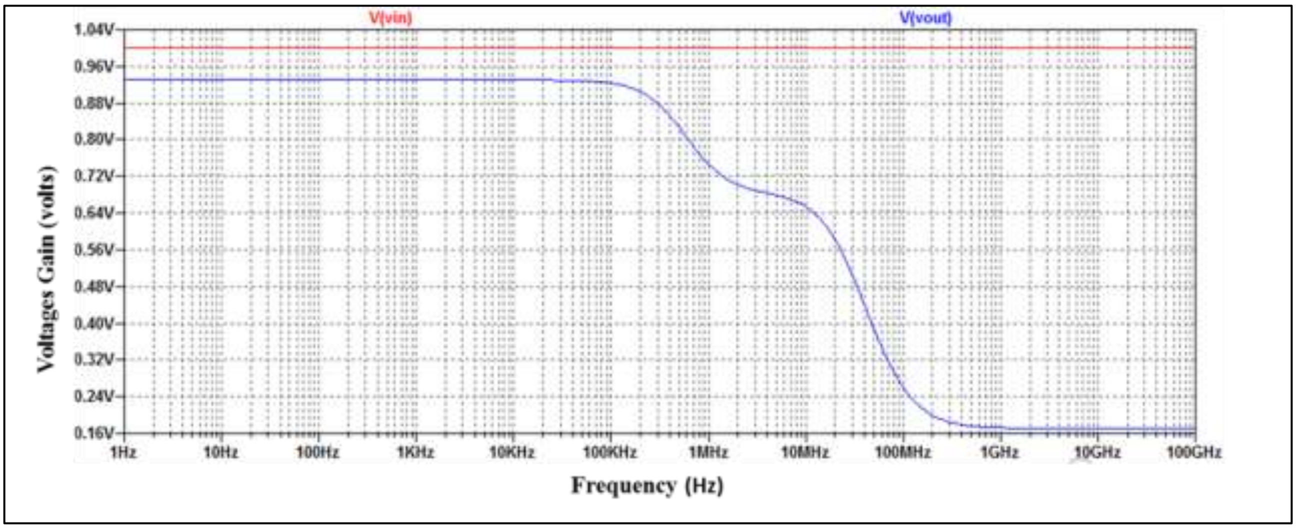

Fig. 10: AC analysis of NMOS type flipped voltage follower

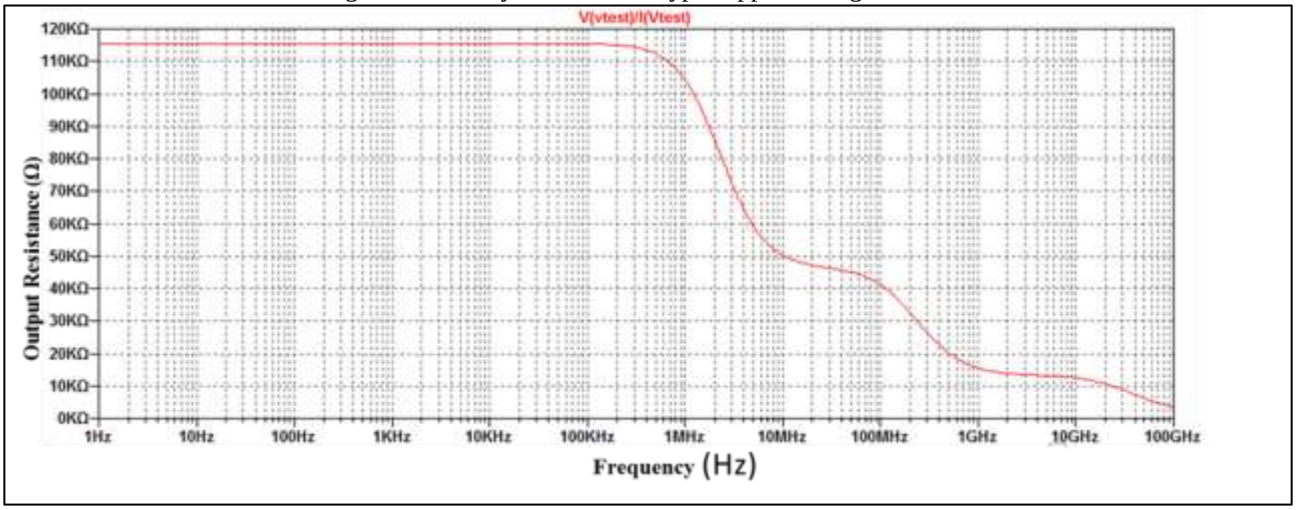

Fig. 11: Output impedance of NMOS type flipped voltage follower

Table III shows comparison between basic NMOS type source follower and NMOS type flipped voltage follower based on simulation results.

Parameters	Simulated Value	
	NMOS type basic source follower	NMOS type flipped voltage follower
Technology	130nm	130nm
Voltage supply	1.2V	1.2V
Bias current	0.5µA	0.5µA
Capacitor	0.1pF	0.1pF
No.of transistor(NMOS)	1	2
Dynamic range	-1.42V to -1.22V	0.045V to 0.723V
Voltage Gain	0.965	0.93
-3 db Bandwidth	19MHz	9.83MHz
Slew Rate	240V/µs	118.7 V/µs
Output Resistance	240KΩ	115KΩ

Table 3: Comparison between NMOS Type Basic Source Follower and NMOS Type Flipped Voltage Follower

V. CONCLUSION

To conclude, dynamic range is far better than basic NMOS type source follower. Output impedance is also low than basic NMOS type source follower because of its shunt feedback configuration. Value of -3 db frequency of both topologies is nearer. Slew rate is high in basic NMOS type source follower compared to flipped voltage follower.

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