Analysis of Class-A Voltage Follower

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Abstract
This paper describes about different types of voltage followers. Each follower has its own advantages and limitations. The voltage follower can be characterized with current mirror source current or it can be used as a ideal current source. Voltage Follower is one of the most important analog circuits required in many analog integrated circuits. Input impedance of op amp is very high, giving effective isolation of the output from the signal source.

Keywords: Voltage Follower, Op-Amp, Buffer, Transconductance

I. INTRODUCTION

This A voltage follower (also known as a unity gain amplifier, a buffer amplifier, and an isolation amplifier) is an operational amplifier circuit having a voltage gain of one. This means that the operational amplifier provides no signal amplification. The reason why it is called a voltage follower is because the output voltage follows the input voltage directly, means that the output voltage is the same as the input voltage. For example, if 10 V enters the operational amplifier as an input, output will be 10V. A voltage follower acts as a buffer, providing no amplification or attenuation of the signal.

II. PURPOSE OF VOLTAGE FOLLOWER

A voltage buffer amplifier is used to transfer a voltage from a first circuit, having a high output impedance level, to a second circuit with a low input impedance level. The interposed buffer amplifier prevents the second circuit from loading the first circuit unacceptably and interfering with its desired operation. In the ideal voltage buffer in the diagram, the input resistance is infinite, the output resistance zero (impedance of an ideal voltage source is zero). Other properties of the ideal buffer are: perfect linearity, regardless of signal amplitudes; and instant output response, regardless of the speed of the input signal. One may ask then what is the purpose of a voltage follower? Since it displays the same computer signals input, what is its purpose in a circuit? This will now be explained.

Operational amplifier circuit is a circuit having very high input impedance. Due to this high input impedance of voltage follower are used. This will in Fig.1. above. When a circuit has very high input impedance, very little current is drawn from the circuit. If you know Ohm's law, you know that the current, I = V / R. Thus, the higher the resistance, the less current is drawn from a power source. Thus, the power of the circuit is not affected when the current is input to a high impedance load. The above circuit is a circuit in which a power source feeds a low-impedance load.

Voltage followers are important to buffer or isolate a low impedance load from a voltage source. This means that instead of connecting a relatively low value of the load resistor across the power source, the operational amplifier can be used to eliminate any charge that may occur. Thus, the power source will not load down. The circuit acts as a source of great tension with near zero internal impedance because it uses almost no power, still full voltage outputs.
III. VOLTAGE FOLLOWER AS A CURRENT BUFFER

Typically, a current buffer amplifier is used for transferring a current from a first circuit, having a level of high output impedance, to a second circuit to a low level of input impedance. The buffer amplifier interposed prevents the second charging circuit of the first current circuit and unacceptably interfere with the desired operation. In the ideal current buffer in the diagram, the output impedance is zero and the infinite input impedance. Again, other properties of the ideal buffer are: perfect linearity whatever signal amplitudes; and an instantaneous response output, regardless of the speed of the input signal.

Voltage Follower must satisfy certain requirements.
These are:
- High input impedance,
- Low output impedance,
- High bandwidth,
- Low power dissipation,
- Linearity and Unity voltage gain,
- High current gain and power gain, etc.

IV. TOPOLOGIES OF VOLTAGE FOLLOWER

A. Basic Voltage Follower:

The simple design voltage follower is the basis source follower or source voltage follower. It is a common drain amplifier circuit with a voltage gain of unity. The output the source terminal follows the input applied to the door. Therefore it is called as a source follower. The diagram in circuit is shown in Fig.3. [6]

It is designed with the ideal source of PMOS and current. We can use current mirror also in place the power source. Source follower can also be designed with the resistance connected between the source and supply. But it does not provide a constant amount of current flowing through the source terminal of the PMOS. This results in non-linearity in the exit and we cannot get a voltage gain of unity always. [2] it also has a high output impedance. Thus, the resistive configuration is not used. We can use PMOS and NMOS as an expense. But the implemented with current mirror gives good results [1].

The most important parameters related to the voltage follower design in any technology are the voltage gain and output impedance. For this circuit, the output impedance and the voltage gain is given by (1) and (2).

\[
R_o = \frac{1}{\frac{g_m g_{mb}}{g_m}} \\
A_v = \frac{g_m}{g_m + g_{mb}}
\]
Here, $g_m$ indicates the transconductance. The index denotes the transconductance with body effect. The value of output impedance can be reduced by increasing the body effect [1]. But, it reduces the voltage gain.

Transconductance and output impedance are inversely bonded to each other. Considering (3) and (4), we can say that to increase transconductance and reduce production impedance, drain current $I_D$ must be increased. However, this leads to large ratio $W/L$. This is not acceptable in submicron technologies, since the main objective is to reduce the transistor size. In addition, the power dissipation increases with an increase in the $W/L$ [6].

$$g_m = \sqrt{2I_D \beta}$$  \hspace{1cm} (3)

$$\beta = \frac{W}{L} \mu C_{ox}$$  \hspace{1cm} (4)

**B. Flipped Voltage Follower**

It is essentially a cascade amplifier with negative feedback where the gate terminal of $M_1$ is used as an input terminal and its source as the output terminal. It is characterized by a very low output impedance due to the feedback provided by $M_2$, high low supply requirement close to a transistor threshold voltage $V_{TH}$, low static power dissipation and high gain bandwidth. The flipped (inverted) voltage follower name is based on the fact that FVF is applied on the drain side than on the side of the source. Variation of the output current is absorbed by transistor $M_2$ which is current sensing transistor, while the current remains constant $M_1$, because of this source voltage of the gate of $M_1$ is constant and remains low distortion even at high frequency. A practical limitation of the FVF cell is that it gives very small input and output signal swing [15].

![Flipped Voltage Follower](image)

It has high input impedance. Because of the low output impedance, there is a large supply capacity [5]. The damping capacity of FVF is limited by the bias current source. For analysis of the FVF output impedance analysis in the open loop gain can be used. There are two MOSFETs are used in the topology.

There transconductance are $g_{m1}$ and $g_{m2}$ respectively. The output impedance of FVF can be given by (5).

$$R_0 = \frac{1}{g_{m1}g_{m2}R_{o1}}$$  \hspace{1cm} (5)

Minimum supply voltage required for flipped voltage follower is $V_{TH} + 2V_{DSAT}$. The voltage follower output level is reversed decreased $V_{GS} - 2V_{DSAT}$ [5]. It limits the output swing in deep submicron technology. This is the main disadvantage of this topology.

Table-1 shows the comparison between two voltage followers.

<table>
<thead>
<tr>
<th>Topology</th>
<th>Output Impedance</th>
<th>Output Voltage Swing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic Source Follower</td>
<td>$1/g_m$</td>
<td>VDD-VGS-VDSAT</td>
</tr>
<tr>
<td>Flipped Voltage Follower</td>
<td>$1/g_{m1}g_{m2}R_{o1}$</td>
<td>VGS-2VDSAT</td>
</tr>
</tbody>
</table>

**V. CONCLUSION**

The simplest design is basic source follower. But, it has many limitations for deep-sub micron design. Flipped voltage follower achieves low output impedance. But, it suffers from non-linearity due to feedback path. Basic source follower and flipped voltage follower possess non-linear distortion. Other designs like super source follower, bulk-driven voltage follower, and class-AB based voltage followers have also been designed to overcome non-linearity problem. But, selection of voltage follower is dependent on application and requirements since, all designs have certain advantages and limitations.
REFERENCES