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Design and Implementation of Current Feedback Amplifier for High Gain and High Bandwidth using Inverter based Current Conveyor

P. Mohan Kumar*, Vandana Sahu and T. Shakeel

School of Electronics and Electrical Engineering, Lovely Professional University, Phagwara - 144411, Punjab, India; mohan.15771@lpu.co.in, sahuvandana923@gmail.com, shakeel.16368@lpu.co.in

Abstract

A new current feedback amplifier is proposed which is suitable for high gain and constant bandwidth applications. This new topology is employing a inverter based positive current conveyor followed by an amplifier to achieve high gain and a constant bandwidth. The inverter based current conveyor has no on –chip capacitors so it will reduce the cost of chip fabrication The proposed Design is simulated in 180nm technology in cadence kit.

Keywords: Current/Voltage Feedback Amplifier, Gain and Bandwidth, Inverter

1. Introduction

Current feedback amplifiers are the most widely used for applications which require constant gain bandwidth and excellent slew-rate capabilities. Because of their advantages came through inherency and the properties expressed in high speed, the CFA's are used in several applications as an alternative to the conventional voltage operational amplifiers. The current feedback amplifiers in its basic closed-loop configuration, uses the current as the feedback signal which is rather considered as an error. Unlike the voltage feedback amplifier the response of a CFA depends on the current provided which in turn produces the voltage as a corresponding output. The most important limitation in most of the voltage feedback topologies till date is the persistence of constant gain bandwidth which is absent in the current feedback amplifier topologies

Current feedback amplifiers are meant to be designed to work for wider bandwidth at lower closed loop gain. A real operational amplifier's bandwidth is limited by Gain- Bandwidth product (GB), which is defined as the frequency where the gain of an operational amplifier becomes unity. In case of CFA the Bandwidth is primarily the function of the values of the feedback resistor and the values of compensation capacitors instead of the constant gain bandwidth product[3]. Unlike Voltage feedback amplifier topologies the current feedback amplifier topologies eliminates the constant gain bandwidth[1,2]. Bandwidth is an important criteria while designing any analog circuitry as it can be the sole determinant of the circuit output but in case of amplifiers it can be more crucial as it can totally change the design of the circuit as well as the frequency response.

2. Circuit Description

The block diagram of proposed current feedback amplifier is shown in Figure 1. It consist of inverter based low voltage current conveyor and an amplifier which increases the overall gain of amplifier. The purpose behind using an inverter based second generation current conveyor circuit is to solve the problem of loading effect and high voltage supply because it has one high and one low impedance port.

* Author for correspondence

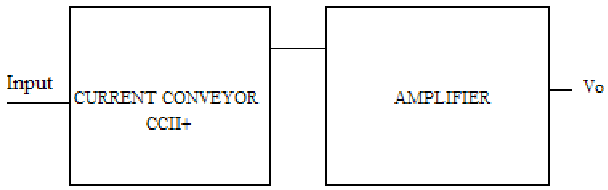

Figure 1. Block diagram of current feedback amplifier.

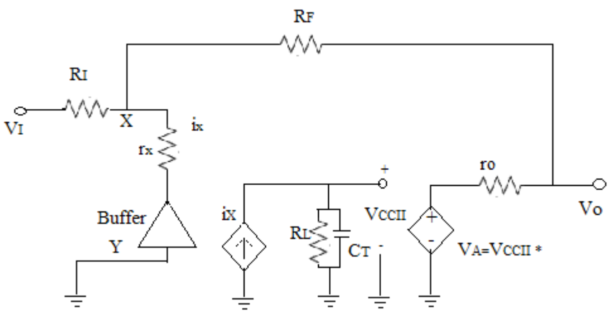

Figure 2. Current conveyor second generation.

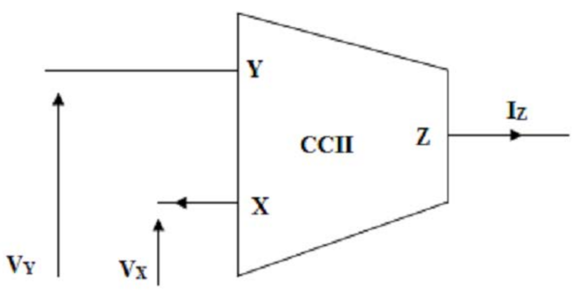

Figure 3. Small signal AC equivalent circuit of CFA.

3. Circuit Analysis

For an ideal amplifier the relationship between its terminal voltages and current can be defined by the matrix (1). The current flow at node Y is zero and this port is used as voltage input port and whatever the voltage appear at Y port the same will be appear at X port.

$$\begin{bmatrix} I_Y \\ V_X \\ I_z \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 \\ 1 & 0 & 0 \\ 0 & \pm 1 & 0 \end{bmatrix} \begin{bmatrix} V_Y \\ I_X \\ V_Z \end{bmatrix} \quad (1)$$

The current at X node is equal to the current at Z node i.e. Ix = Iz, so the port X can be used as voltage output or as a current input port.

An unconventional operational amplifier is used here to improve the gain of current feedback amplifier. To verify the functionality of the proposed amplifier we designed inverting current feedback amplifier and a non-inverting current feedback amplifier. The closed loop gain of both kind of amplifier can be stated as:

$$Av = -\frac{Rf}{Rg} \quad (2)$$

$$Av = 1 + \frac{Rf}{Rg} \quad (3)$$

The small signal equivalent circuit of the designed CFA circuit is represented in Figure 3. The total closed loop Gain (G(s)) of the designed CFA in inverting configuration can be calculated by applying concept of KVL and KCL and it will be:

$$\frac{[G(s) = \frac{Vo}{Vi} = (r]_X r_{OUT} - R_F Z_N)}{R_{IN}(r_X + r_{OUT} + R_F + Z_N)} \quad (4)$$

Where

$$Z_N = A_O \times (R_L \; ll \; (1/(SC_T)) \quad (5)$$

Then r_f and r_{OUT} are very small by comparing to r_w and Z_N(open loop trans-impedance of the CFA) so both of r_w and r_{OUT} can be neglected, and the overall closed loop gain will be given by the following equation:

$$G = \frac{Vo}{Vi} = -\left(\frac{R_F}{R_I}\right) \times \frac{Z_N}{R_F + Z_N} \quad (6)$$

This equation here is more accurate than in[8] as the r_{OUT} is true low output impedance even in low frequency range (output impedance of the buffer).

$$A(s) = \frac{A_O \times \omega_C}{S + \omega_C} \quad (7)$$

From equations 2 and 4 into 3, the total closed loop gain (G(s)) will be:

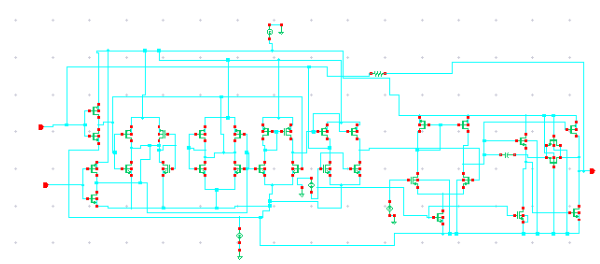

Figure 4. Schematic of current feedback amplifier for high gain and high bandwidth using inverter based current conveyor.

$$G(s) = -\frac{R_F}{R_I} \times \frac{A_O \omega_C R_L}{SR_F + A_O \omega_C R_L} \quad (8)$$

Then, the BW ω_O of the proposed CFA circuit is:

$$\omega_O = A_O \omega_C \frac{R_L}{R_F} \quad (9)$$

Equation 6 states that the bandwidth of the circuit is not depending on the closed loop gain of the CFA circuit.

4. Simulation Result

The circuit is designed and simulated by using 180 nm kit in cadence. Total power supply used is 0.9 Volt. Value of feedback resistor R_F was kept constant i.e. 1kΩ. W/L ratio of PMOS is kept 2.5 times the value of NMOS and then the value of R_G Rg had been varied. The gain of an amplifier from equation (2) is inversely proportional to the R_G so as we increase the value of R_G the gain decreases. At the non-inverting terminal we applied the supply voltage of 0.9 V.

4.1 Gain Plots Inverting current feedback amplifier

- By taking values of Rg and the feedback resistance Rf equal to 500Ω and 1k Ω respectively, the gain found to be 26dB at a bandwidth of 80 Mhz approximately.

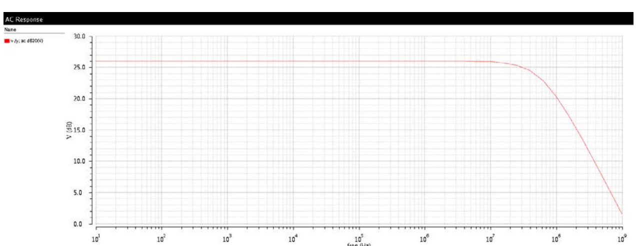

Figure 5. Gain plot at Rg value of 500 ohm.

- By taking values of Rg and the feedback resistance Rf equal to 750Ω and 1k Ω respectively. The gain found to be 18.5 dB at a bandwidth of 80 Mhz.

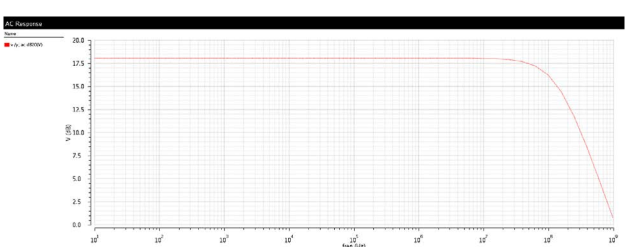

Figure 6. Gain plot at Rg value of 1 kohm.

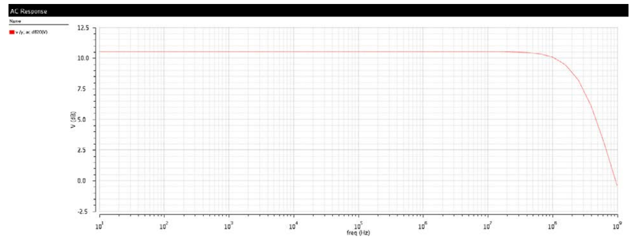

Figure 7. Gain plot at Rg value of 750 ohm.

- By taking values of Rg and the feedback resistance Rf equal to 1kΩ and 1k Ω respectively. The gain found to be 10.5 dB at a bandwidth of 80 Mhz approximately.

4.2 Non- Inverting Current Feedback Amplifier

- By taking values of Rg and the feedback resistance Rf equal to 500 Ω and 1 k Ω respectively, the gain found to be 26 dB at a bandwidth of 80 Mhz approximately.

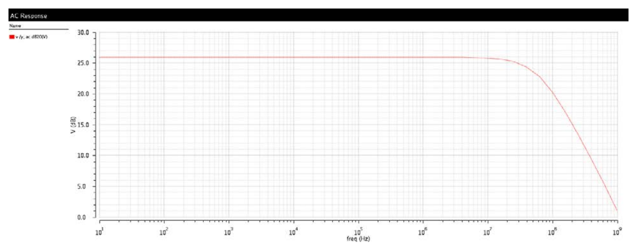

Figure 8. Gain plot at Rg value of 500 ohm.

- By taking values of Rg and the feedback resistance Rf equal to 750 Ω and 1 k Ω respectively, the gain found to be 20 dB at a bandwidth of 80 Mhz approximately.

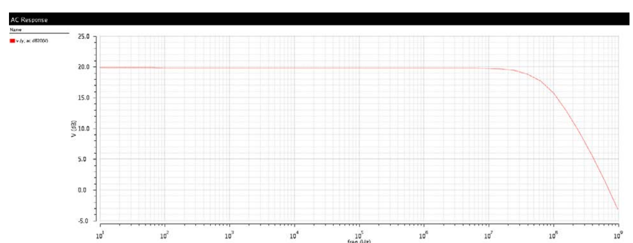

Figure 9. Gain plot at Rg value of 1k ohm.

- By taking values of Rg and the feedback resistance Rf equal to 1k Ω, the gain found to be 13 dB at a bandwidth of 80 Mhz approximately.

In the above plots we have seen the gain has been improved a lot. Earlier the values of gain at Rg 500 Ω 750

Ω and 1 kΩ were 9.5 dB, 7.3 dB and 6.0 dB respectively but now it has been increased to 26 dB, 20 dB and 13 dB respectively.

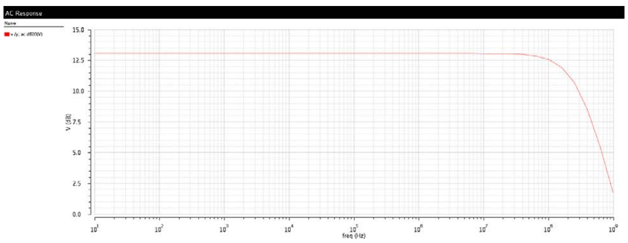

Figure 10. Gain plot at Rg value of 750 ohm.

The slew rate defines the rate of change of voltage per unit of time. The slew rate observed in the presented CFA is nearly about 52 micro Volts per second.

5. Conclusion

Current feedback amplifier are the most widely used electronic devices in linear as well as no-linear contexts because of its high gain bandwidth, high slew rate which makes it suitable for high frequency applications. Unlike Voltage feedback amplifiers their counterpart CFAs are ideally suited for the environment where moderate accuracy is required. With the several advancements and by using different topology in the Current feedback amplifier architecture we can highly improve its accuracy, speed, voltage requirements, CMRR etc.

Some of the basic techniques of current feedback amplifier has been simulated in 180 nm technology and parameters such as high bandwidth is obtained, but high slew rate can be obtained by modifying the circuit with less no of transistors and these circuits can be done at low power by implementing the techniques at lower technology or by changing the topology.

6. References

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