

A 1.5V, 100MS/s, 12-bit Current-Mode CMOS Sample-and-Hold Circuit

O. Hashemipour, and S. G. Nabavi

Abstract—A high-linearity and high-speed current-mode sample-and-hold circuit is designed and simulated using a 0.25 μ m CMOS technology. This circuit design is based on low voltage and it utilizes a fully differential circuit. Due to the use of only two switches the switch related noise has been reduced. Signal - dependent -error is completely eliminated by a new zero voltage switching technique. The circuit has a linearity error equal to $\pm 0.05\mu$ a, i.e. 12-bit accuracy with a $\pm 160\mu$ a differential output - input signal frequency of 5MHZ, and sampling frequency of 100 MHZ. Third harmonic is equal to -78 dB.

Keywords—Zero-voltage-technique, MOS-resistor, OTA, Feedback-resistor.

I. INTRODUCTION

SAMPLE and hold (S/H) Circuits are important block in data converter systems, such as the front end of A/d Converters. Up to present time, considerable numbers of circuits were designed for S/H in voltage and current mode. Recently more focus is on current-mode circuits due to high speed and low voltage supply in comparison with voltage-mode (switched-capacitor) circuits.

Unfortunately, charge injection error is the main problem of S/H circuits resulting in accuracy reduction of these circuits and hence the creation of non-linearity distortion.

A number of circuits were designed in order to improve either high-speed or high-accuracy [1, 2, 3, 5]. For example, the circuit in [3] which is shown in Fig. 1, is a high accurate switched-current-memory-cell around 14-bit resolution using zero-voltage technique. In order to remove the signal-dependent-error a constant voltage is set at the sampling switch using a High-gain-opamp and a negative-feedback circuit. This design lacks the speed of operation due to gm considerations; however, it is one of the most accurate SI circuits.

In this work, with the aid of two simple OTA and two MOS-resistors a constant voltage on both sides of switches are generated during sample and hold mode resulting in complete removal of the signal-dependent-error and the offset-error part is also canceled out by using the fully-differential outputs.

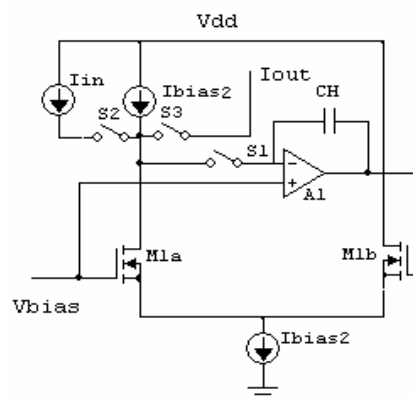


Fig. 1 SI circuit with zero-voltage-technique

II. CIRCUIT OVERVIEW

The circuit block diagram is shown in Fig. 2. It constitutes a differential input stage and three simple OTAs, two Sampling switches and MOS-feedback-resistors. In sampling phase, after closing switches, differential input current between OTA-m in upper part and OTA-A, B is divided in K, and K' ratio respectively. The current at the output nodes will be: $I_{out} = I_{in}$ and $I_{out'} = -I_{in}$. In holding phase the output currents will be equal to input currents. During both phases the two OTAs A and B will hold a constant voltage (V_G) at switches terminals. In order to eliminate the signal dependent error, active feed-back resistors are used for stabilization of V_G .

III. COMPLETE CIRCUIT DESIGN

Fig. 3 shows the designed S/H circuit. It consists of transistors M_{3-5} , M_8, M_m and M_n for differential input stage, transistors M_{1-2}, M_{6-7} , and M_{9-10} for OTA - M, transistors $M_{11}, M_{c11}, M_{13}, M_{c13}, M_f$, and M_{f2} for OTA- A, transistors $M_{12}, M_{c12}, M_{14}, M_{c14}, M_h$ and M_{h2} for OTA -B, transistors M_{S1} and M_{S2} are sampling switches and finally M_{r1} and M_{r2} are MOS-resistors. Common mode feed back circuit is used in order to stabilize the common mode voltage of the fully differential opamp. During sampling mode while

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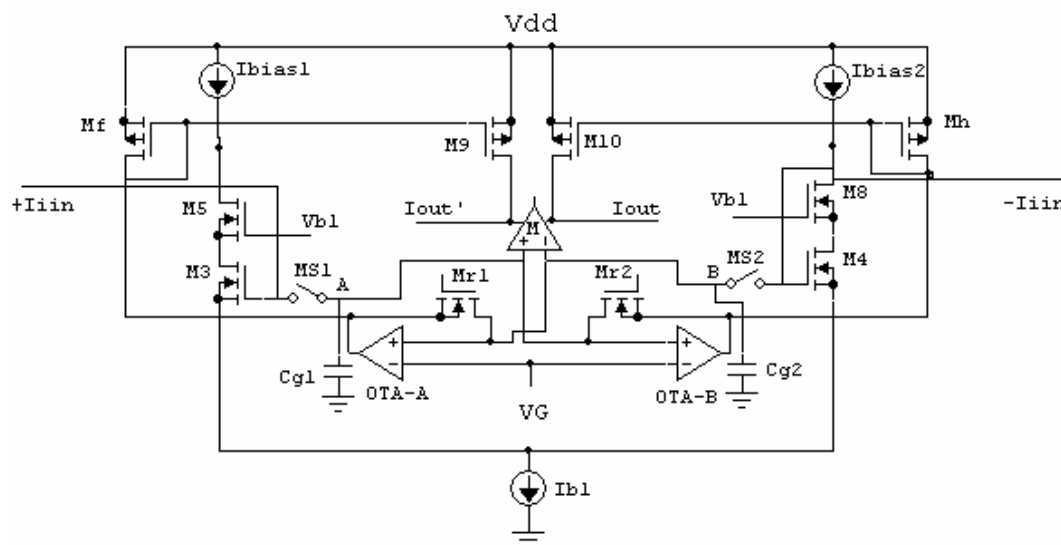


Fig. 2 Block diagram of current-mode S/H

switches M_{S1} and M_{S2} are closed, part of the input differential signal, $\pm K I_{in}$ will be at the outputs of OTA-M and the other part, $\pm K' I_{in}$ after inversion will be at outputs of OTA-A and OTA-B:

$$I_{out} = K' I_{in} + K I_{in} = (K + K') I_{in} \quad (1)$$

$$I_{out'} = -K' I_{in} - K I_{in} = -(K + K') I_{in} \quad (2)$$

For input and output currents to be equal:

$$K + K' = 1 \quad (3)$$

The dimensions of mm and mn are adjusted in order to satisfy (3). In this design the K and k' factors are equal to 2/3 and 1/3 respectively and

$$(W/L)_{m,n} = (W/L)_{f,f2,h,h2,9,10} = 2/3(W/L)_{1,2,3,4}$$

in order to keep the circuit fully balanced.

A. Charge Injection Error Cancellation

Signal-dependent charge-injection arises when the voltage at a switch's sampling terminals varies with the signal level. To avoid signal-dependent-error, the voltage at the terminals of switch must remain at a constant level. In this work, due to fully balanced structure of the different stages during sampling period the voltage at $V_A = V_B = V_G$ is equal to the drain voltages of transistor M_{C11} and M_{C12} . During holding period the above voltages must be kept constant, However, practically open loop gain of the OTAs are not high enough to achieve this, and hence a feedback-resistors network is utilizing using two transistors M_{r1} and M_{r2} in order to provide constant voltage in node A and B. This is due to the fact that in holding mode voltage at input nodes are equal to drain voltage of the transistors M_{C11} , M_{C12} and voltage and

bias voltage V_G , therefore, using large feedback-resistors from drain of M_{C11} and M_{C12} to nodes A and B, the voltage level of these nodes will be equal to V_G . This means nodes A and B are virtual ground and therefore during sample and hold mode the terminal voltages of switches are constant and equal to V_G , thus error is independent of input signal.

B. Speed of Circuit

Time-constant in basic SI circuits is equal to $\tau \approx (C_g/g_m)$.

In order for speed to be increased, g_m must be increased, i.e. increase the bias-current. This of course will result in an increase in both noise and power dissipation. In this work, the speed improvement of the circuit is achieved by using high-speed OTAs and small memory capacitors C_{g1} and C_{g2} . Moreover, diode connected loads are used instead of current sources in order to increase g_m , the time constant is now:

$$\tau \approx C_g / (g_{m3} + g_{mn}) \quad (4)$$

Diode connected loads will also result in a decrease in the input impedance of the circuit, from typical value of $1/g_m$ in basic SI to $1/(g_{m3} + g_{mn})$ in this work. Lower input impedance will result in a decrease in distortion.

IV. SIMULATION RESULTS

The proposed S/H circuit has been designed and simulated using Hspice and the 0.25 μ m CMOS technology and input-signal-frequency of 5MHz in full-scale mode. The full-scale value of the input current is $\pm 80\mu$ a with a sampling frequency of 100MHz. Fig. 4 shows the differential sinusoidal current

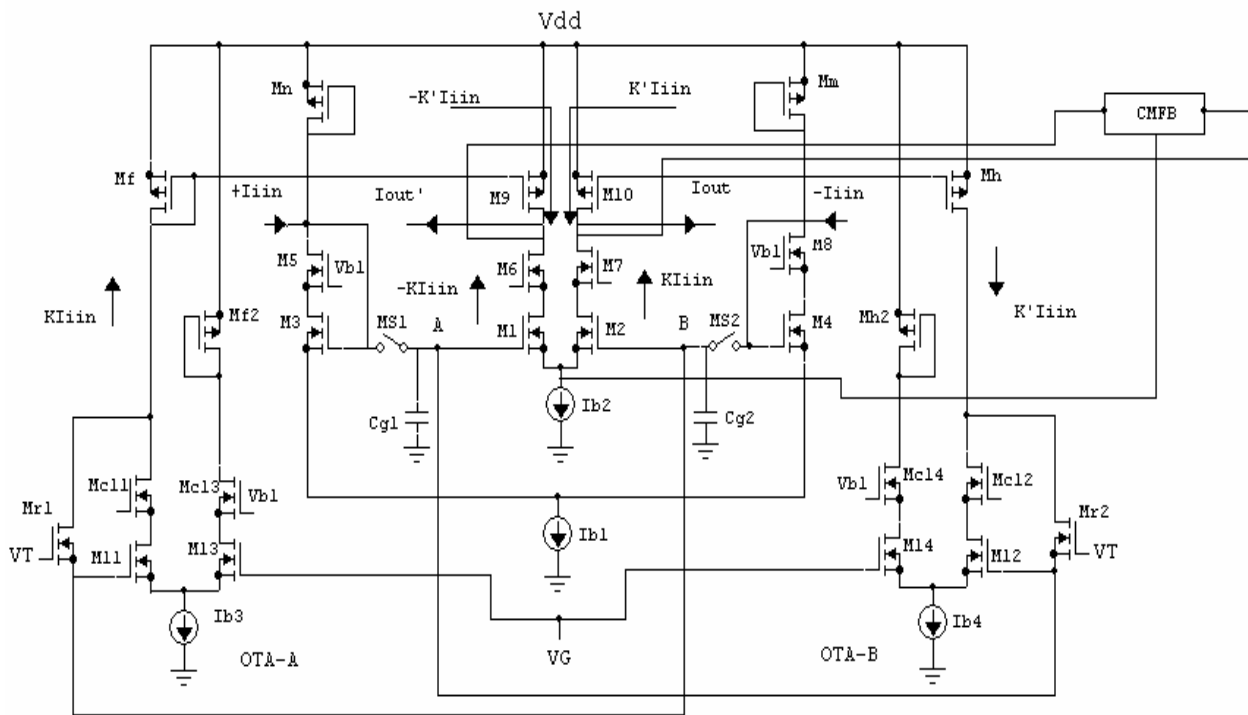


Fig. 3 Complete sample and hold circuit

output. The biasing current is $300\mu\text{A}$ and the hold-capacitors C_{g1} and C_{g2} are 0.26pF . The supply voltage V_{dd} is 1.5V and the power-dissipation of the circuit is 2.5mW . The differential current output is $\pm 160\mu\text{A}$. Simulation results from a triangular input signal with 5MHz frequency and $\pm 80\mu\text{A}$ range, measurements shown in Fig. 5 results in a linearity-error of about $0.05\mu\text{A}$. This much error is equal to 12-Bit resolution for an S/H circuit.

different input frequency range of 1.22MHz to 8.544MHz and the results shows a resolution of 12-Bit under all conditions. Table I shows a summary of the performance of the designed S/H circuit.

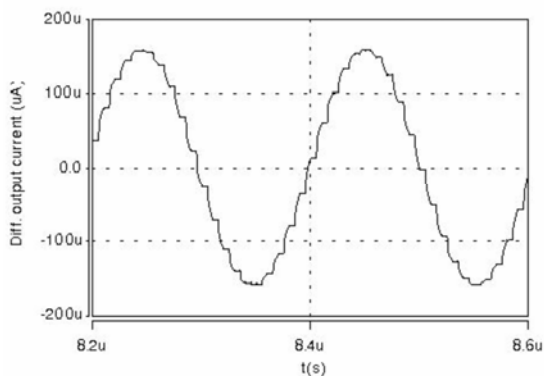


Fig. 4 Differential output current

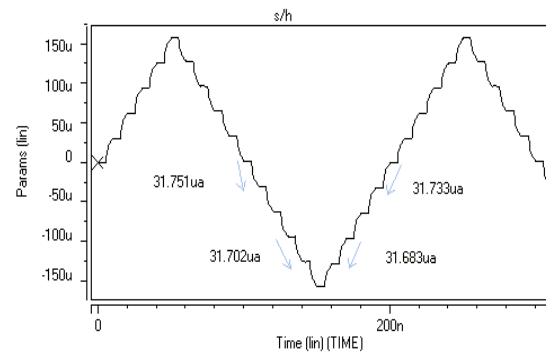


Fig. 5 Triangular output signal for linearity-error Measurement

The total-harmonic-distortion is extracted using PSD output waveform and FFT-method as in [4]. Fig. 6 shows the PSD waveform which results in a 3rd harmonic of less than -78dB . The FFT simulation is performed by using sinusoidal-input signal frequency of 4.88MHz , and a sampling frequency of 100MHz . As shown in Fig. 7 simulation was performed for

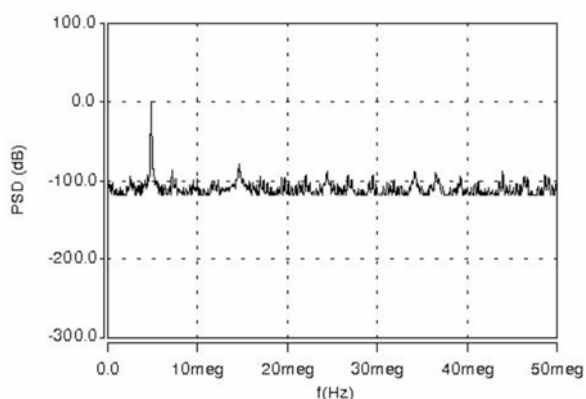


Fig. 6 PSD waveform of sinusoidal response of S/H circuit

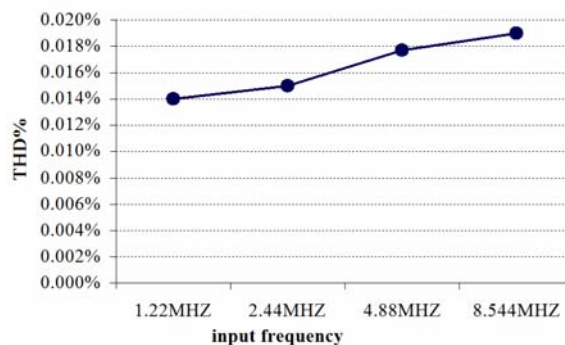


Fig. 7 THD% versus Input-frequency

TABLE I
 SUMMARY OF SIMULATION RESULTS

Technology	0.25um CMOS
Supply voltage	1.5V
Power dissipation	2.5Mw
HD3 @ 100MHz-clock & 4.88MHz input frequency	-78dB
Differential input range	$\pm 80\mu\text{a}$
Differential output @ iout-iout'	$\pm 160\mu\text{a}$
Linearity error	$\pm 0.05\mu\text{a}$
Sampling frequency	100MHz
Input frequency linearity error measurement	5MHz
Resolution	12-Bit
Acquisition time	2ns
3dB bandwidth	178MHz

VII. CONCLUSION

A high-linearity, low-voltage and high-speed current-mode sample-and-hold circuit has been designed. This circuit design is based on low supply voltage at 1.5V and it utilizes a fully differential circuit. Signal - dependent -error is completely eliminated by a new zero voltage switching technique. The circuit has been simulated using a 0.25 μm CMOS technology. The circuit has a linearity error equal to $\pm 0.05\mu\text{a}$, i.e. 12-bit accuracy with a $\pm 160\mu\text{a}$ differential output, input signal frequency of 5MHz, and sampling frequency of 100 MHz. Third harmonic is equal to -78dB. The measured power-dissipation at 1.5V supply-voltage is 2.5mW.

The hold-settling-time and acquisition time are calculated approximately 1.1ns and 2ns.

The presented S/H circuit is suitable for SI systems requiring precise sample-and-hold circuit.

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