

A New Analog Switch CMOS Charge Pump Circuit without Body Effect

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Abstract: The charge – pump circuit which is used to generate higher voltage than the available supply voltage has wide applications such as the flash memory of EEPROM. Because the demand for high voltage comes from physical mechanism such as the oxide tunneling, the required pumped voltage cannot be scaled as the power supply voltage is scaled. Therefore, an efficient charge – pump circuit that can achieve high voltage from the available low supply voltage is essential. A new Analog Switch p-well CMOS charge pump circuit without the MOS device body effect is processed. By improve the structure of the circuit’s transistors to reduce the threshold voltage shift of the devices, the threshold voltage of the device is kept constant. So, the circuit electrical characteristics are higher output voltage within a shorter time than the conventional charge pump. The propose analog switch CMOS charge pump shows compatible performance of the ideal diode or Dickson charge pump.

Keywords: MOSFET Circuit, Body Effect, Charge Pump

1. INTRODUCTION

The need for voltage elevators has increased with the apparition of circuitis operating from single battery cell. But their principle does not allow a high level of efficiency in standard CMOS technologies. The growing portable equipment has made a strong demand for low voltage operation in EEPROMs. Although a minimum power supply voltage of 2.1V has been achieved in previously reported, further improvements in an on chip high voltage generator circuit are indispensable to obtain a power supply voltage below 2 V. This article discusses the theoretical low-voltage limit of the conventional high-voltage generator, Dickson’s charge pump circuit, and describes the design of a charge pump circuit applicable of power supply as low as 1 V by using the CMOS circuit without body effect of the device.

2. CONVENTIONAL CHARGE PUMP CIRCUIT

The conventional Dicson charge pump circuit shown in figure 1 the voltage gained at jth stage V_{m(j)} is given by

$$V_m(j) = \frac{CV_{CC}}{(C + C_p)} - V_t(V_{bs}(j)) \tag{1}$$

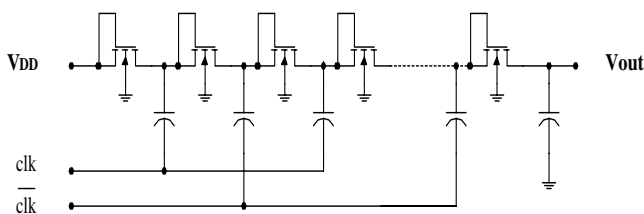


Fig. 1. Conventional Dickson’s charge pump circuit

where C and C_p are clock coupling capacitance and parasitic capacitance at the input node (C_{gs} of the devices) of each unit stage, respectively, V_{CC} is the clock amplitude equal to the power supply voltage, and V_t (V_{bs(j)}) represents the threshold

voltage of the jth nMOS transistor with a substrate bias of V_{bs(j)}. Equation (1) indicates that as the output voltage of each stage increases, V_{m(j)} decreases due to the body effect. When the threshold voltage of the last stage’s transistor becomes equal to the CV_{CC}/(C+C_p), the output voltage is not increased by the addition of subsequent stages. As C is much larger than C_p in typical conditions, the maximum output voltage V_{MAX} obtained by a conventional charge pump is given by

$$V_{MAX} = \left(\frac{V_{CC} - V_{t0}}{\gamma} + \sqrt{2\phi_F} \right)^2 - 2\phi_F \tag{2}$$

where V_{t0} is the zero-bias threshold voltage, γ is the body effect coefficient, and φ_F is the substrate’s Femi potential.

3. PROPOSED CHARGE PUMP CIRCUIT

To generate a sufficient programming voltage with such a small power supply voltage, we propose a charge pump circuit, in which the voltage gained at each stage is not degraded by the body effect of the device

The proposed charge pumps shown by the schematic in the figure 2. Two auxiliary MOSFET of each side are introduced to control the body bias. The source side auxiliary MOSFET shares the source and the gate with the charge- transfer MOSFET and the drain side auxiliary MOSFET shares the drain with the charge-transfer MOSFET. For each charge-transfer block, two auxiliary MOSFET’s and one charge-transfer MOSFET share the body, which is separated from the body of other block. For the positive Pumping, the proposed circuit is composed of only pMOSFET’s so that it can be made compact with little possibility of the latchup. When the charge-transfer MOSFET is ON, the source side auxiliary MOSFET always turns on. Then the source and the body of the charge-transfer MOSFET are connected through the source side auxiliary MOSFET, so that no reverse bias exists between the source and the body of the charge-transfer MOSFET preventing threshold voltage increase. When the charge-transfer MOSFET is OFF, the drain side auxiliary MOSFET turns on so that the drain and the body of the charge-transfer

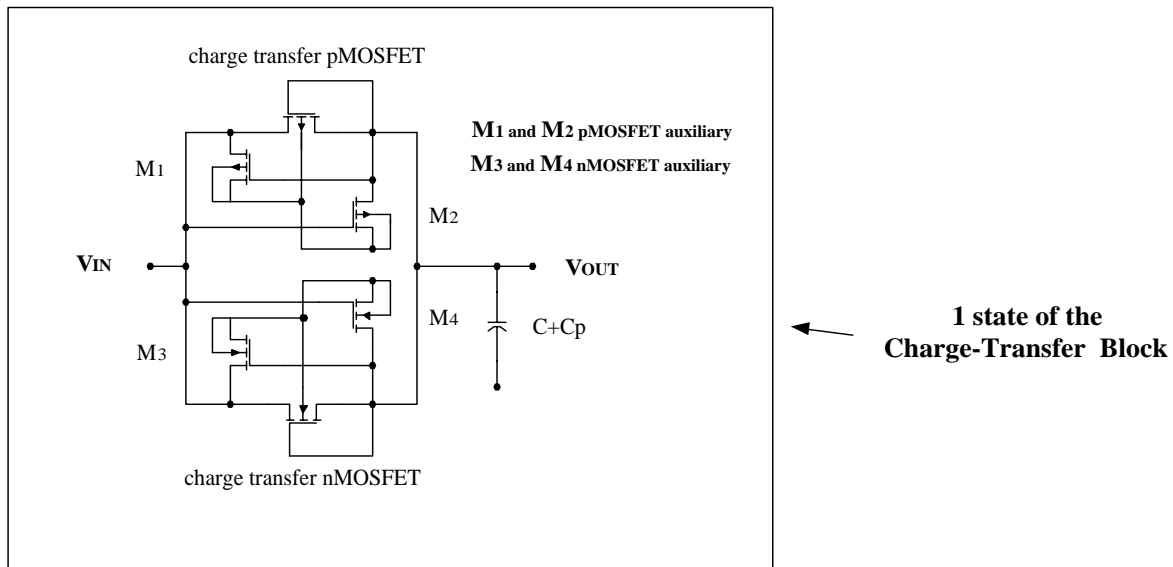


Figure 2. One block of the propose charge pump

MOSFET are connected to prevent the body from floating. When the clk is low and the \overline{clk} is high, the j^{th} charge-transfer MOSFET is ON and charges are transferred through it. At this moment, the source side auxiliary MOSFET of the j^{th} charge-transfer MOSFET turn on so that the source and the body of the j^{th} charge-transfer MOSFET are connected. In this way, regardless of the pumped voltage, the threshold voltage of the j^{th} charge-transfer MOSFET stays with V_{to} (the threshold voltage at zero back bias) during the charge transfer state. In this clock state, the $(j-1)^{th}$ charge-transfer MOSFET is OFF and the drain side auxiliary MOSFET. When the clk is high and the \overline{clk} is low, the proposed pump operates in the same manner as the previous state.

To verify the circuit concept, SPICE program is used for all of the simulation. The 3 state of each charge pump (Dickson and the propose charge pump) have 5pF load capacitor and the clk voltage is 5 V . The output voltage of each charge pump have shown in figure 3

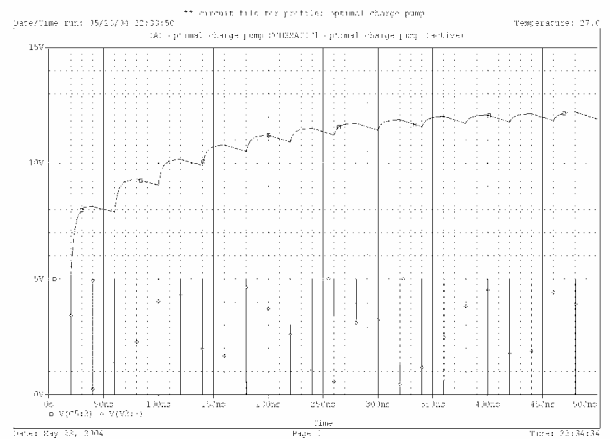


Figure 3(B) 3 state Propose Charge Pump

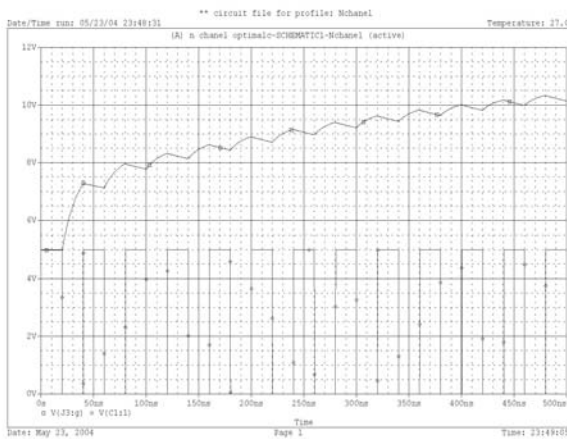


Figure 3(A) 3 state Dickson Charge Pump

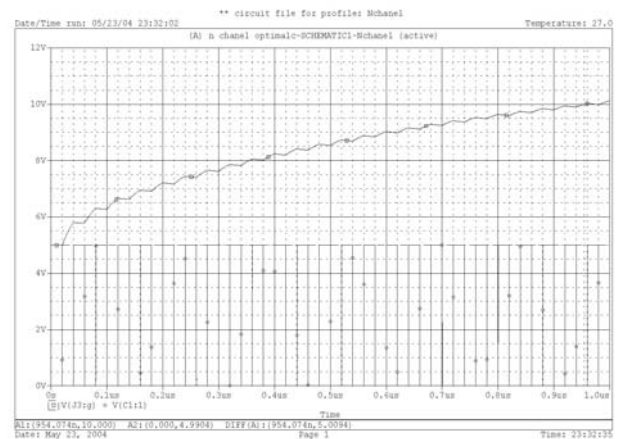


Figure 3(C) 5 state Dickson Charge Pump

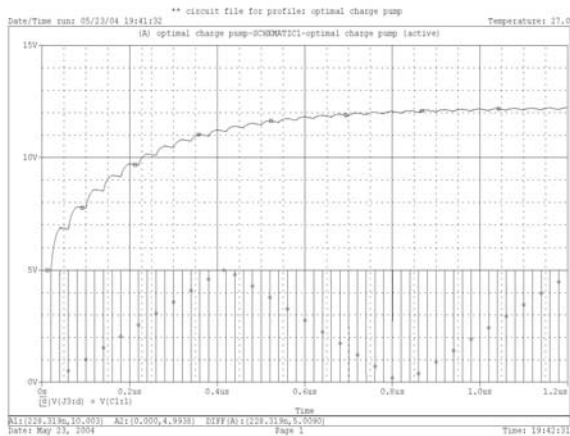


Figure 3(D) 5 state Propose Charge Pump

The output voltage of the propose charge pump with 3 state and 5 state have even higher output voltage than the conventional Dickson charge pump.

4. CONCLUSION

A new charge pump has been present by controlling the body voltage of the charge-transfer device. It has been shown that much higher output voltage than the Dickson charge pump is obtained by the newly proposed charge pump with variable body voltage. With two auxiliary MOSFET's of each side, the body voltage is adjusted to remove the threshold voltage increase. By the SPICE simulation, it has been shown that the proposed charge pump successfully follows the performance of the ideal diode charge pump.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the contribution of Dr. Warakorn Kaseamsuwan . The best lecturer in analog IC design of the department.

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