Low-Power Current-Sensing Circuit for Boost Converter

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***Abstract*—This paper presents an improved current-sensing circuit for boost converter. The proposed circuit replaces n-channel switching transistors with p-channel switching transistors to eliminate glitch current. The proposed circuit therefore consumes less current when the control voltage V_{GN} changes from V_{DD} to GND. The proposed current-sensing circuit has been designed using standard TSMC 0.18 µm 1P6M CMOS technology. In a simulation, the circuit achieved a high sensing accuracy of 96.38% at a 484 mA inductor current. Additionally, a boost converter using the proposed current-sensing circuit can regulate a 1.2 V supply to 1.8 V at a 50 mA load current.**

I. INTRODUCTION

Demand for battery-powered personal electronics, such as smartphones and cameras, has increased considerably in recent years. The batteries in these devices require a boost converter [1]-[3] to boost a low input voltage to a sufficient high voltage, but the boost converter's current-sensing circuit [1] often causes a glitch current and inaccurate senses voltage when the control voltage V_{GN} changes from V_{DD} to GND. This is problematic because boost converters must have an accurate current-sensing circuit. Current-sensing circuits [1], [4]-[6] have been developed and implemented to accurately sense the inductor current and limit the peak-inductor current; however, the current-sensing circuit proposed in this paper is an improvement over existing circuits and completely resolves the problem. With the proposed circuit, by changing the control voltage V_{GN} changes from V_{DD} to GND, a small current of 12.5 µA is achieved.

II. OPERATING ANALYSIS OF AN EXISTING CURRENT-SENSING CIRCUIT [1]

Leung et al. proposed an accurate current-sensing circuit for a boost converter based on an error-amplifier voltage mirror [1]. Their current-sensing circuit [1] is composed of an error amplifier, current mirror M_{R1} and M_{R2}, a power transistor M_{N1}, switching transistors M_{N2} and M_{S1} – M_{S3}, and a bias transistor M_1, as shown in Fig. 1. The circuit operation is divided into two periods: an energy storage period and an energy release period. In the energy storage period, the switching transistors M_{N2} and M_{S1} are turned on and M_{S2} and M_{S3} are turned off by setting V_{GN} to a high value. The ratio of M_{N1} to M_{N2} is K; therefore, their drain current ratio is K. A sensing voltage V_{SEN} is described in

$$\left(\frac{W}{L}\right)_{M_{N1}} \Big/ \left(\frac{W}{L}\right)_{M_{N2}} = K \tag{1}$$

$$V_{SEN} = I_{SEN} \times R_{SEN} = \frac{I_L}{K} \times R_{SEN} \tag{2}$$

To mirror the current of the power transistor M_{N1} accurately, an error amplifier is used to enforce equal voltage at nodes V_A and V_B; the drain voltage of M_{S2} and M_{S3} are approximately the same. Fig. 2 shows that the sensing accuracy is higher than 96% at V_{IN} = 1.2 V and I_L = 484mA. In the energy release period, transistors M_{N1}, M_{N2} and M_{S1} are turned off and the switching transistors M_{S2} and M_{S3} are turned on because the control voltage V_{GN} is low. The sensing current I_{SEN} equals I_{bias} during this period. The sensing voltage $V_{SEN} = I_{bias}R_{SEN}$ nears zero because the bias current I_{bias} is 1.83µA. A glitch current of 83 µA occurs when the control voltage V_{GN} changes from V_{DD} to GND, causing an inaccurate sensing voltage 642 mV, as shown in Fig. 2.

III. PROPOSED CURRENT-SENSING CIRCUIT

The proposed current-sensing circuit uses p-channel switching transistors M_{SP1} and M_{SP2} to replace the n-channel switching transistors M_{S2} and M_{S3} and thus eliminate the glitch current (Fig. 3). In the energy storage period, a high sensing accuracy of 96.38 % is achieved at V_{IN} = 1.2 V and I_L = 484 mA, as shown in Fig. 4. A small current of 12.5 µA flows into transistor M_{SP1} when the control voltage V_{GN} changes from V_{DD} to GND. This improved result is mainly attributable to two design factors. First, the mobility μ_p of a p-channel transistor is less than the mobility μ_n of an n-channel transistor. Second, the overdrive voltage (0.3 – 0.5 V) of the transistor M_{SP1} is less than the overdrive voltage (0.7 V) of the transistor M_{S3}. The simulation verified that a glitch current is effectively eliminated by using p-channel switching transistors. Compared with existing current-sensing circuits, the proposed current-sensing circuit consumes less current, and saves an inverter chain.

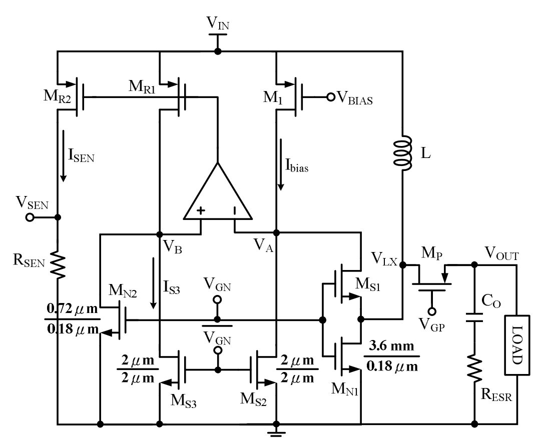

Fig. 1. Schematic of the existing current-sensing circuit [1].

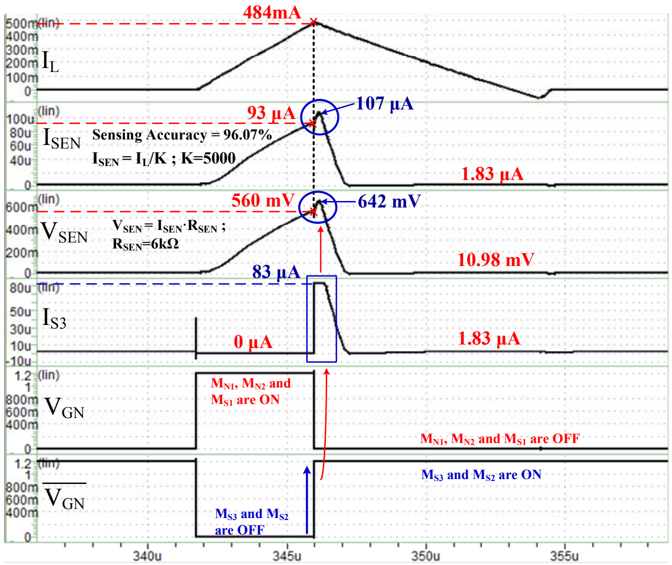

Fig. 2. Simulation result of the existing current-sensing circuit.

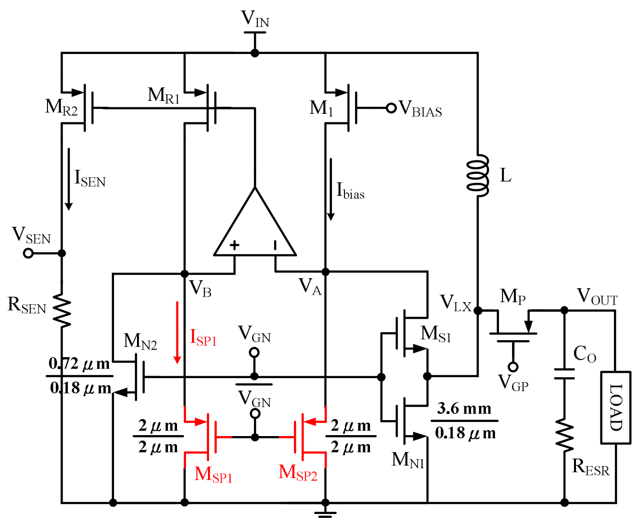

Fig. 3. Proposed current-sensing circuit.

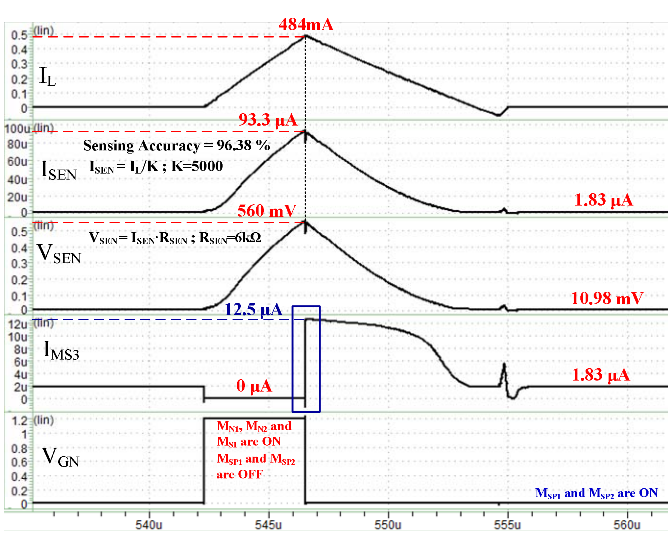

Fig. 4. Simulation result of the proposed current-sensing circuit.

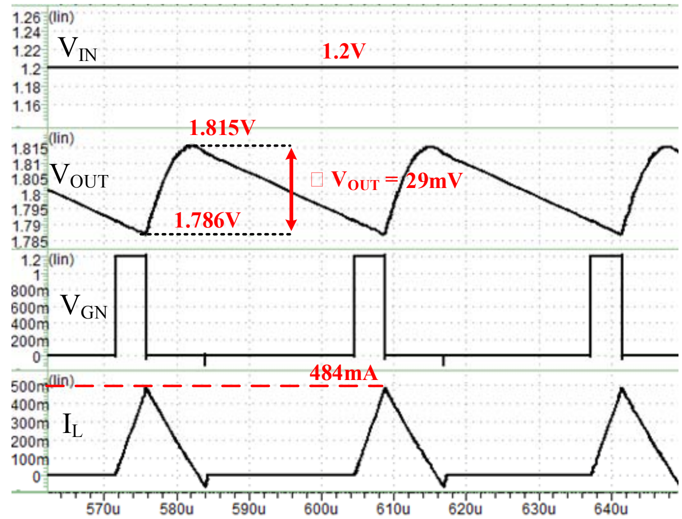

Fig. 5. Simulation result of the proposed boost converter under a 50 mA load.

IV. Conclusion

The proposed low-power current-sensing circuit was designed using the TSMC 0.18 μm CMOS 1P6M technology and was simulated in HSPICE. The simulation of the proposed current-sensing circuit verified that the glitch current is effectively eliminated when the control voltage V_{GN} changes from V_{DD} to GND. A 96.38% sensing accuracy is achieved at a peak-inductor current of 484 mA. The proposed boost converter with the current-sensing circuit can boost a 1.2 V supply to 1.8 V at a 50 mA load current and has the stable operation with an output ripple voltage of 29 mV.

Acknowledgment

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