Temperature-independent Current Reference with Tunable Temperature Coefficient DAC

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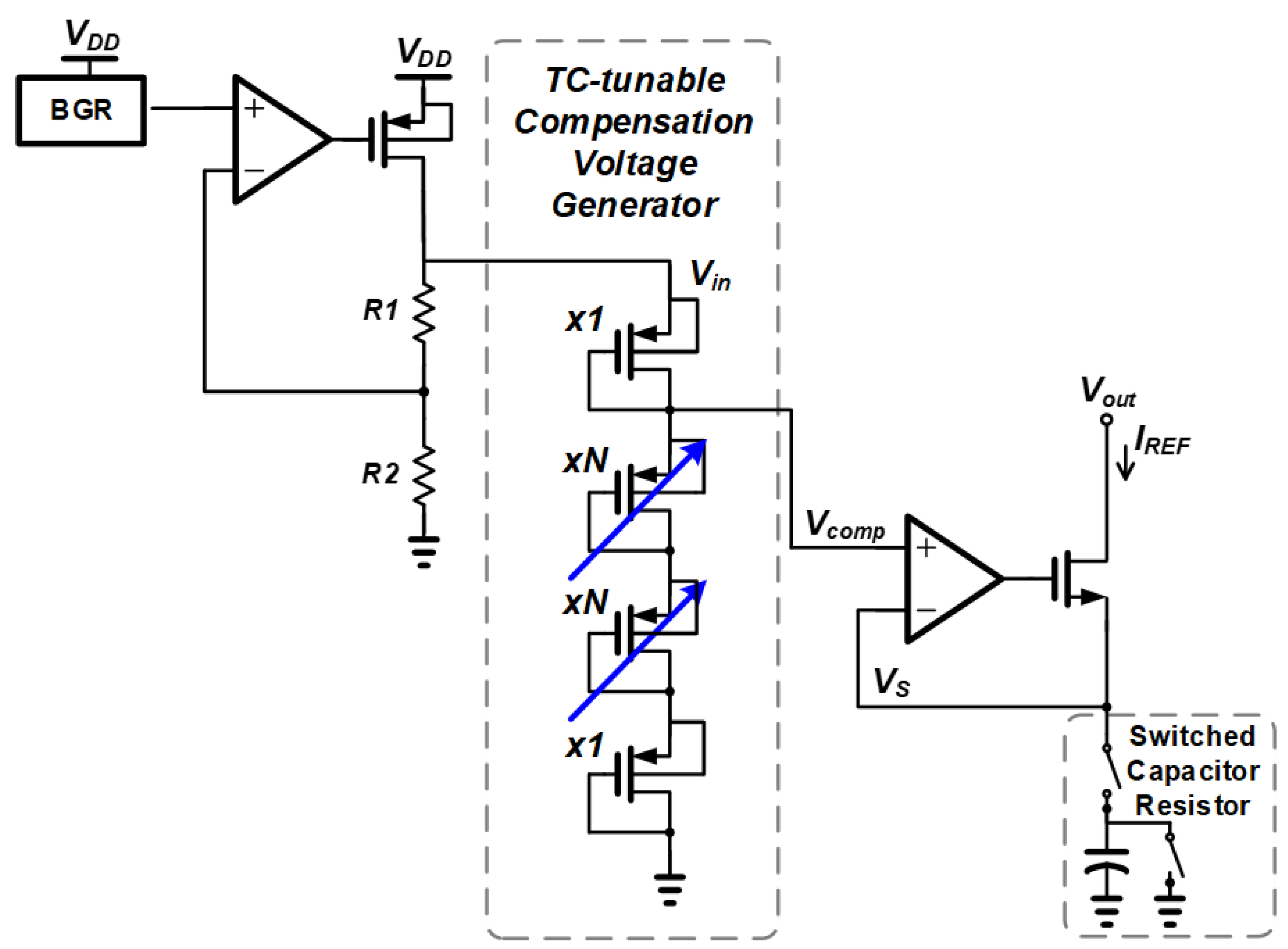
Introduction

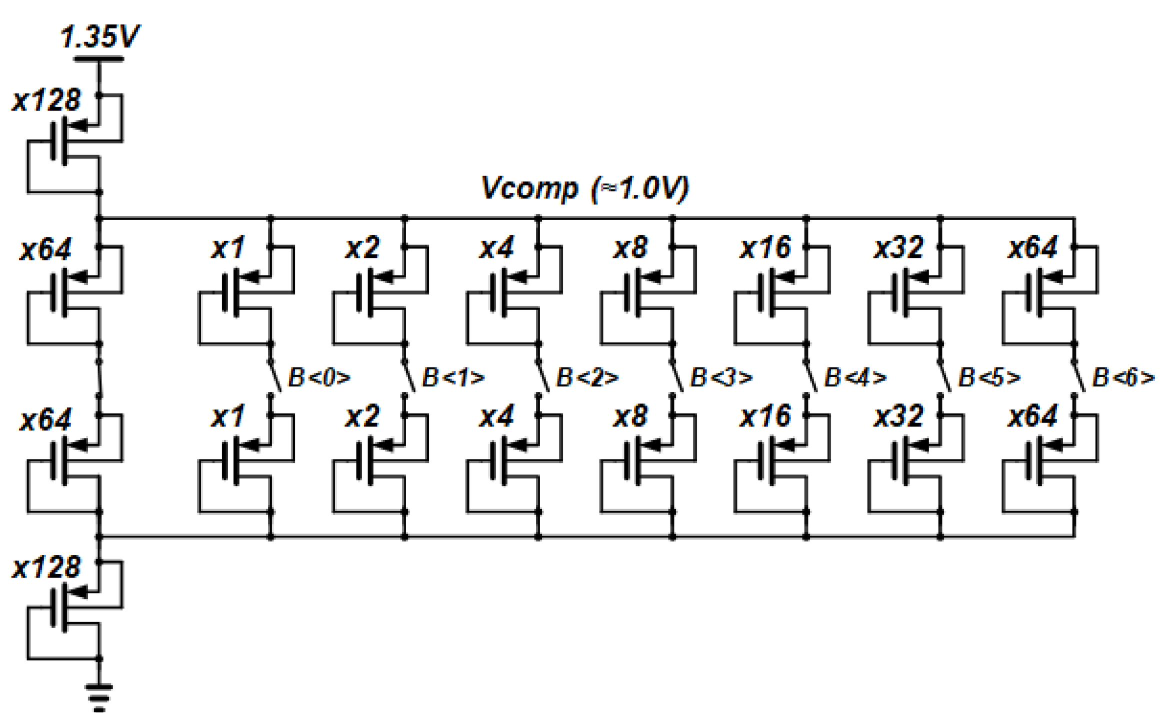
As automobiles integrate more features and focus on safety increases, especially in autonomous vehicles, the demand for highly accurate sensor technology that remains reliable despite environmental changes is becoming increasingly important. While sensor accuracy is influenced by various factors, it fundamentally depends on a reference value, meaning the performance of the sensor is closely tied to the accuracy of the circuit providing this reference. These circuits include reference voltage sources, reference current sources, and reference frequency generators, with the sensor output indicating how much the input has deviated from these reference values. Despite the significant role this field plays, reference current sources have historically been more limited in circuit design options compared to reference voltage sources, which are commonly used in analog-to-digital converters (ADCs), or reference frequency generators, which serve frequency synthesizers. Reference current sources, however, offer versatility in applications like current biasing and current-based DACs. Recognizing the importance of developing a reference current source that functions independently of environmental conditions, we proposed such a system. Among environmental factors, temperature fluctuations are known to particularly impact reference current sources. This is because generating current involves converting voltage into current, and the physical properties of the components used in this process (such as MOSFETs and resistors) are highly sensitive to temperature changes. Consequently, if a reference current source without temperature compensation is used in sensor applications, the output may vary with ambient temperature changes, even if the actual input remains constant. Thus, it is critical to employ a temperature-compensated reference current source. The proposed architecture is an expansion of the process, voltage and temperature (PVT) insensitive current reference proposed in [1].

Overall Architecture

Implementation of TC-compensated Current Reference



TC-Tunable Compensation Voltage Generator



TC-DAC for post-cancellation of the residue temperature coefficient in the reference current after fabrication.

Analysis on Temperature-Coefficient

$$V_{comp} = \frac{1}{2}\left(\frac{3V_{in}}{2} + \frac{mkT_0\ln(N)}{q} + \Delta V_{TH}\right) + \frac{1}{2}\frac{mk}{q}ln(N)\Delta T$$

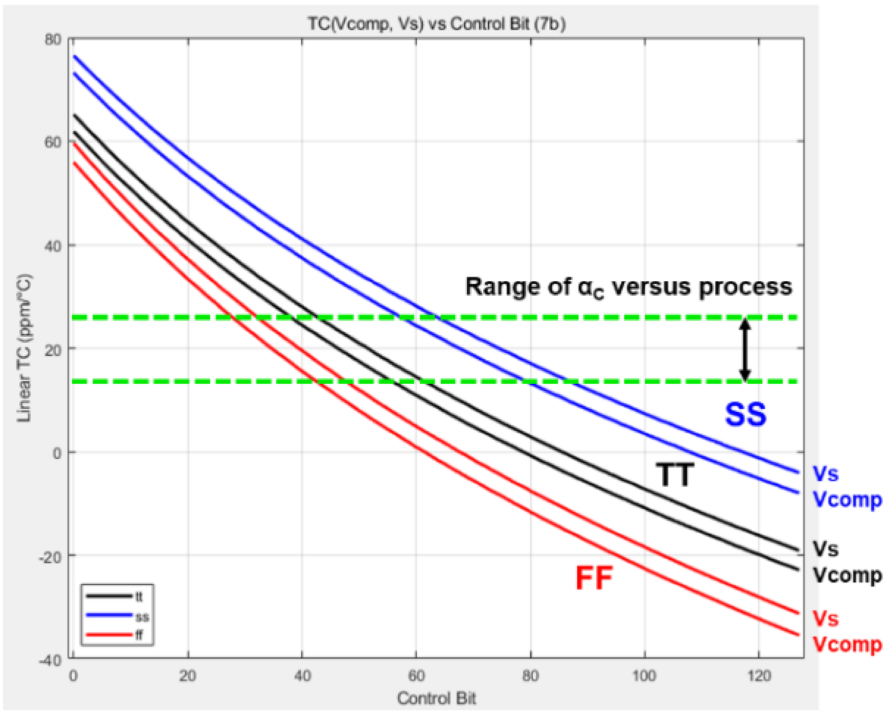
$$I_{ref} = V_{comp} \cdot C \cdot f_{XO}$$

$$\therefore\ I_{REF} = f_{XO} \cdot C_o(1 + \alpha_C \cdot \Delta T) \times V_{comp0}(1 + \alpha_{comp}(N) \cdot \Delta T)$$

- If $\alpha_C = \alpha_{comp}(N)$, the first temperature coefficient can be canceled.

Chip Photo, Measurement Results

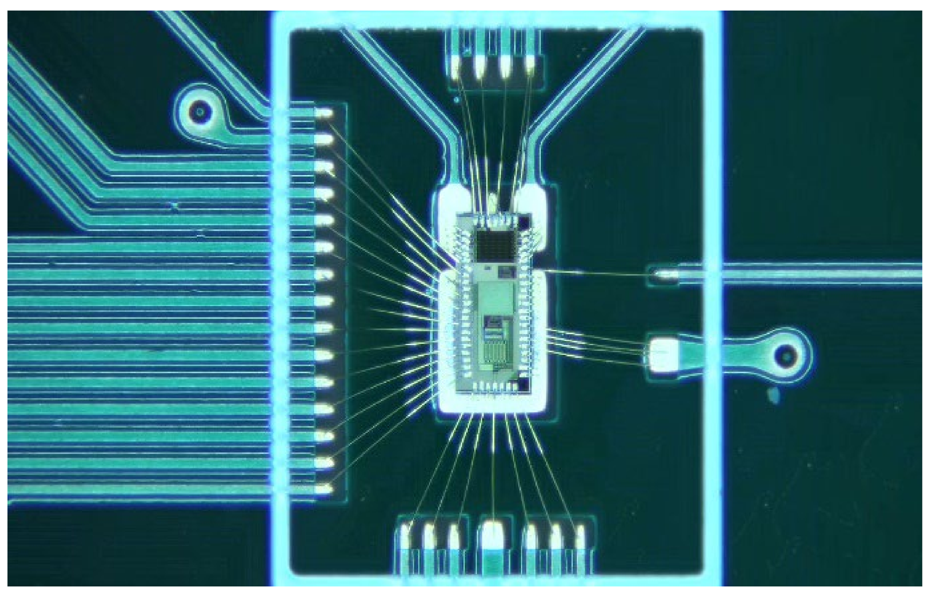
Verification of TC Controllability through simulation



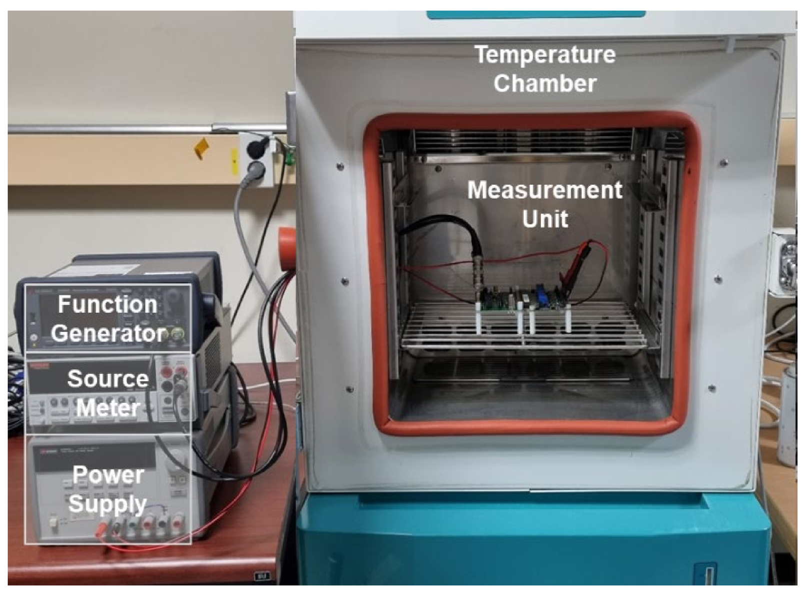
Verified through simulations that the DAC can still compensate for the capacitor's TC even in the presence of process variations.

Implemented with TSMC 180nm Technology(HM-2401)

- Effective area: $0.453mm^2$

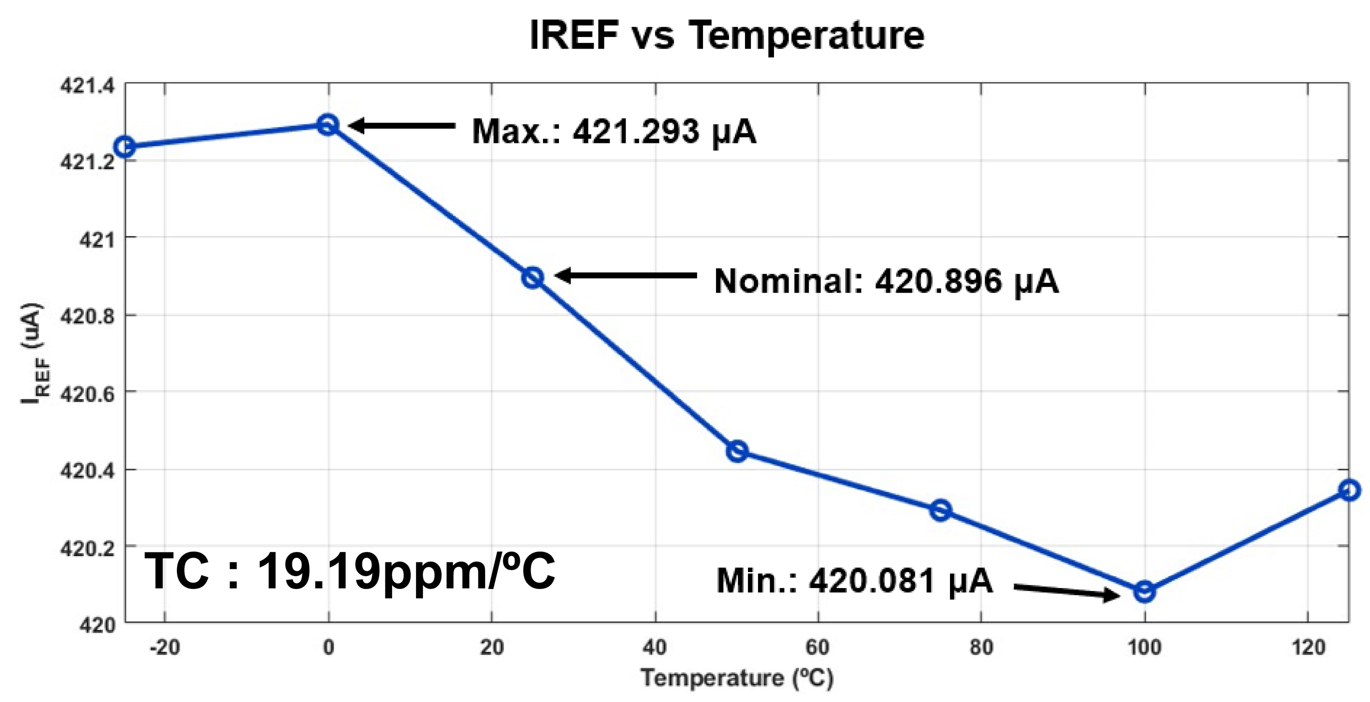


Chip Photo



Measurement Set-up

Reference Current over temperature variation



Acknowledgement and Reference

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[1] Lee, J., & Cho, S. (2012). A 1.4-μW 24.9-ppm/° C current reference with process-insensitive temperature compensation in 0.18-μm CMOS. IEEE Journal of Solid-State Circuits, 47(10), 2527-2533.