A RESISTORLESS SWITCHED BANDGAP REFERENCE TOPOLOGY

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Outline

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- Traditional CMOS Bandgap topology
- Device Variability and Mismatch
- Switched-capacitor BGR
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- Monte-Carlo Simulation Results
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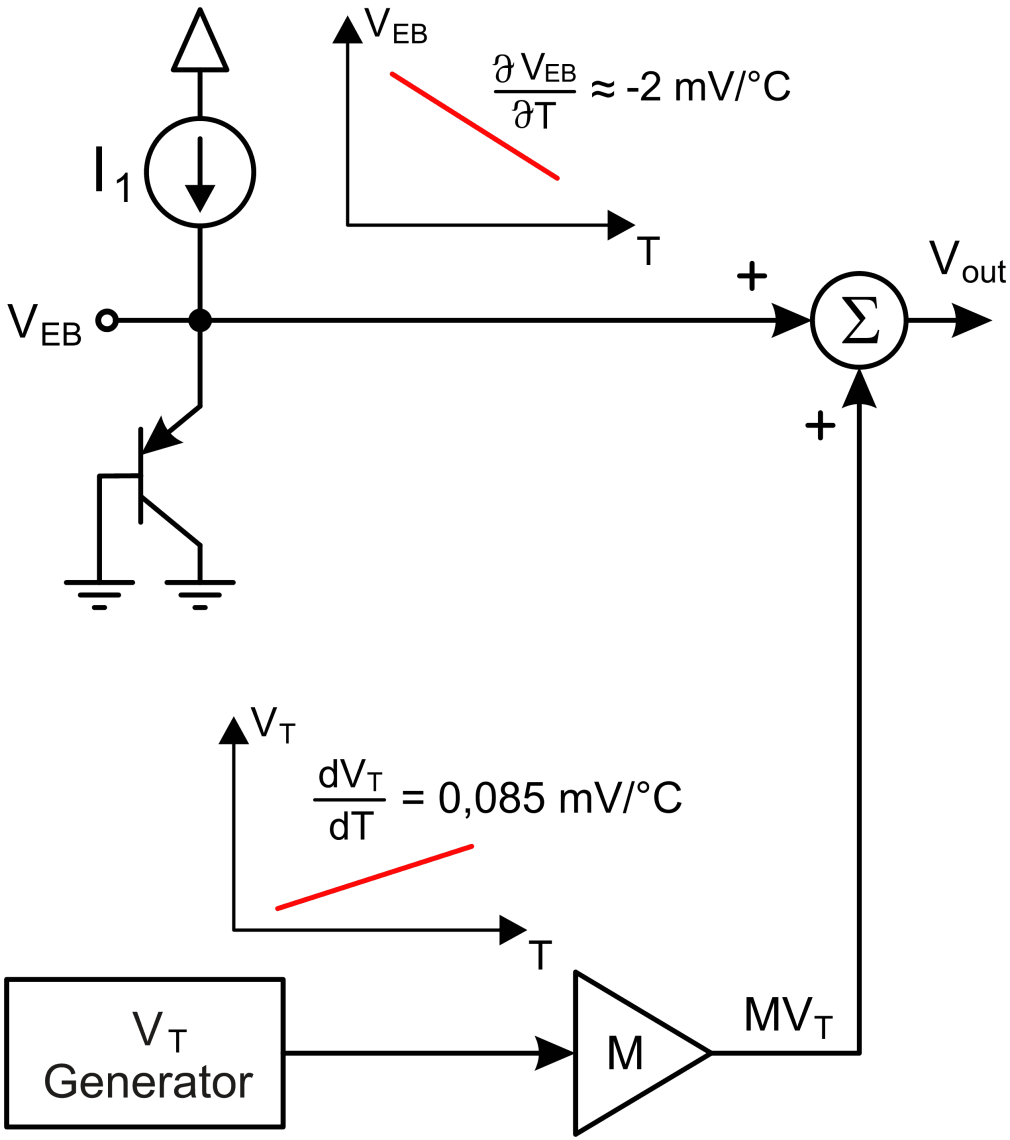
Introduction

- Voltage References are fundamental blocks for analog, mixed-signal, RF and even digital SoCs.
- Most important characteristics:
  - Good thermal stability.
  - Low sensitivity to power-supply variations.
  - Low sensitivity to process fabrication variability effects.
- Traditional Bandgap topologies fulfills the 2 first requirements.

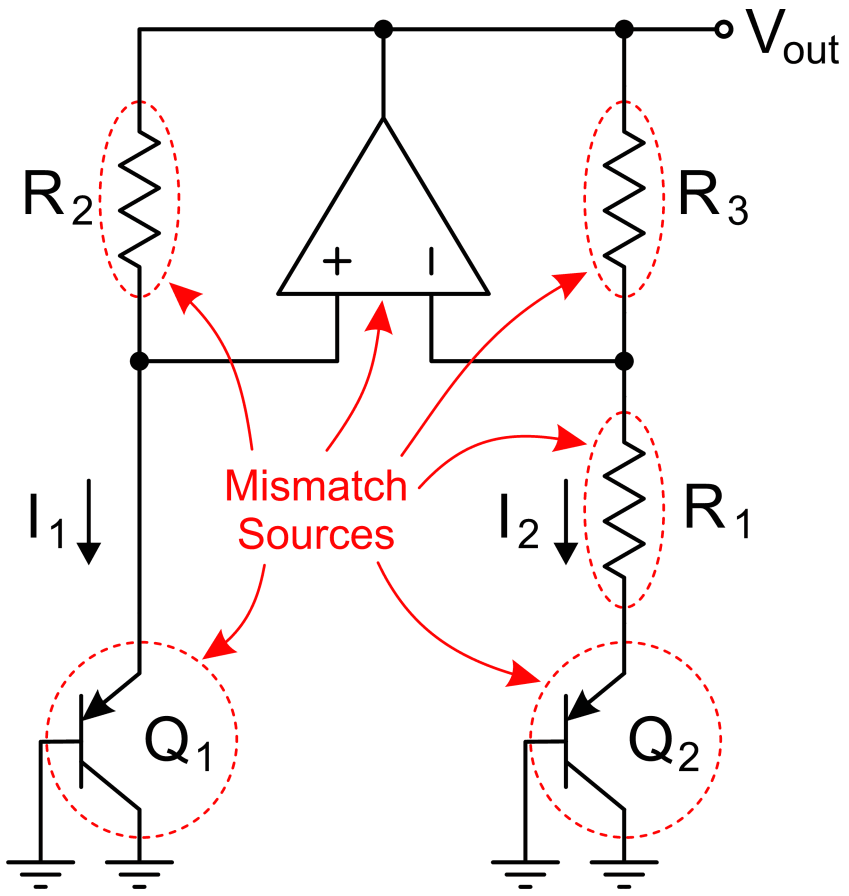
Introduction

General Principle of the Bandgap Reference



Traditional CMOS Bandgap Topology

- PTAT current generated with different transistors
- Thermal counterbalance depends on resistor's ratio
- Thermal stability depends on resistors precision



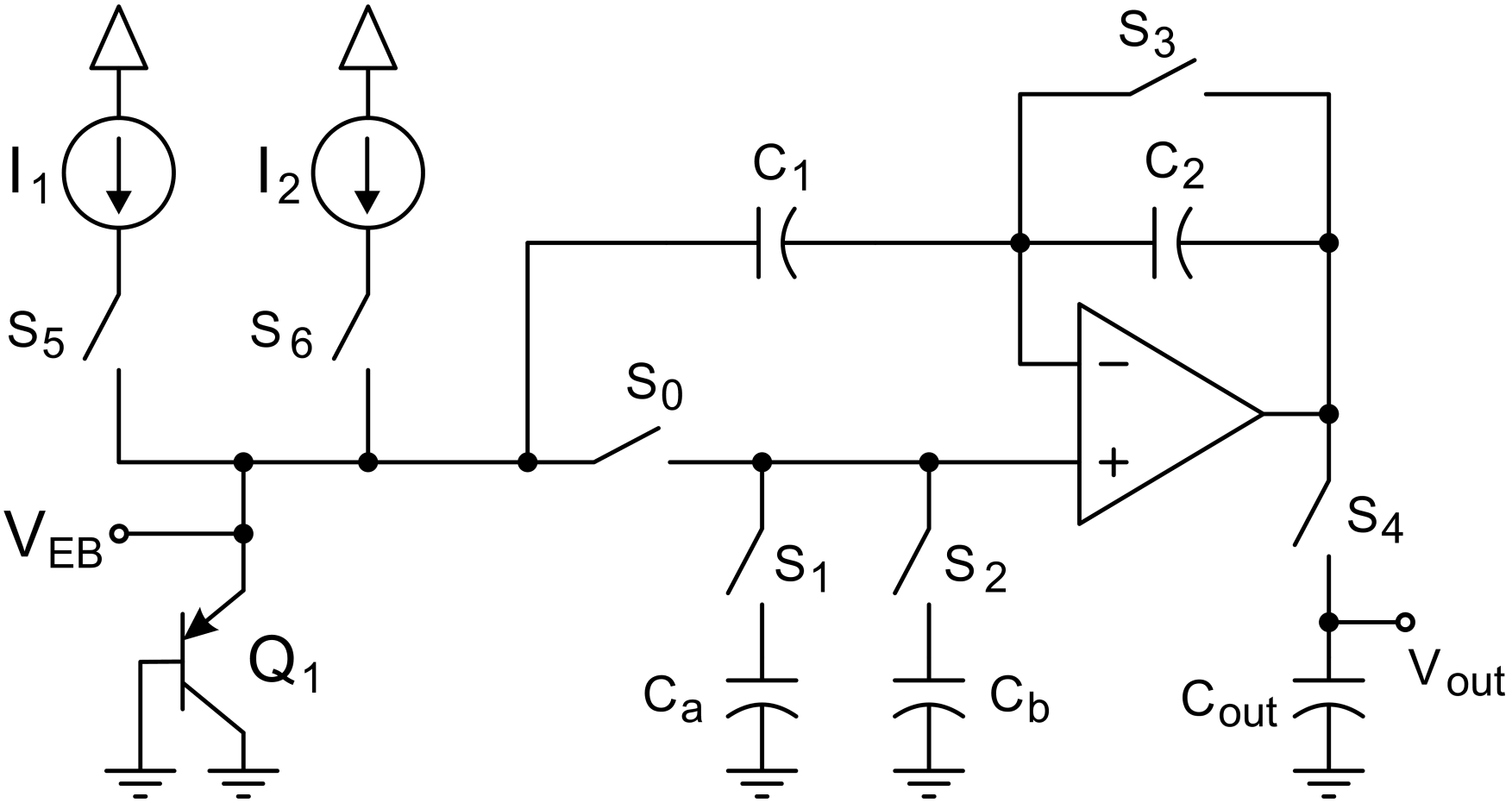
Device Variability and Mismatch

- Thermal stability of traditional topologies relies on matching of both resistors and BJTs
- Resistor precision and matching means large area or expensive CMOS processes
- Capacitors are the best matched devices in CMOS processes

KEY IDEA on this paper:

- Is it possible to make a BGR using only one BJT and relying on capacitors only rather than resistors matching?

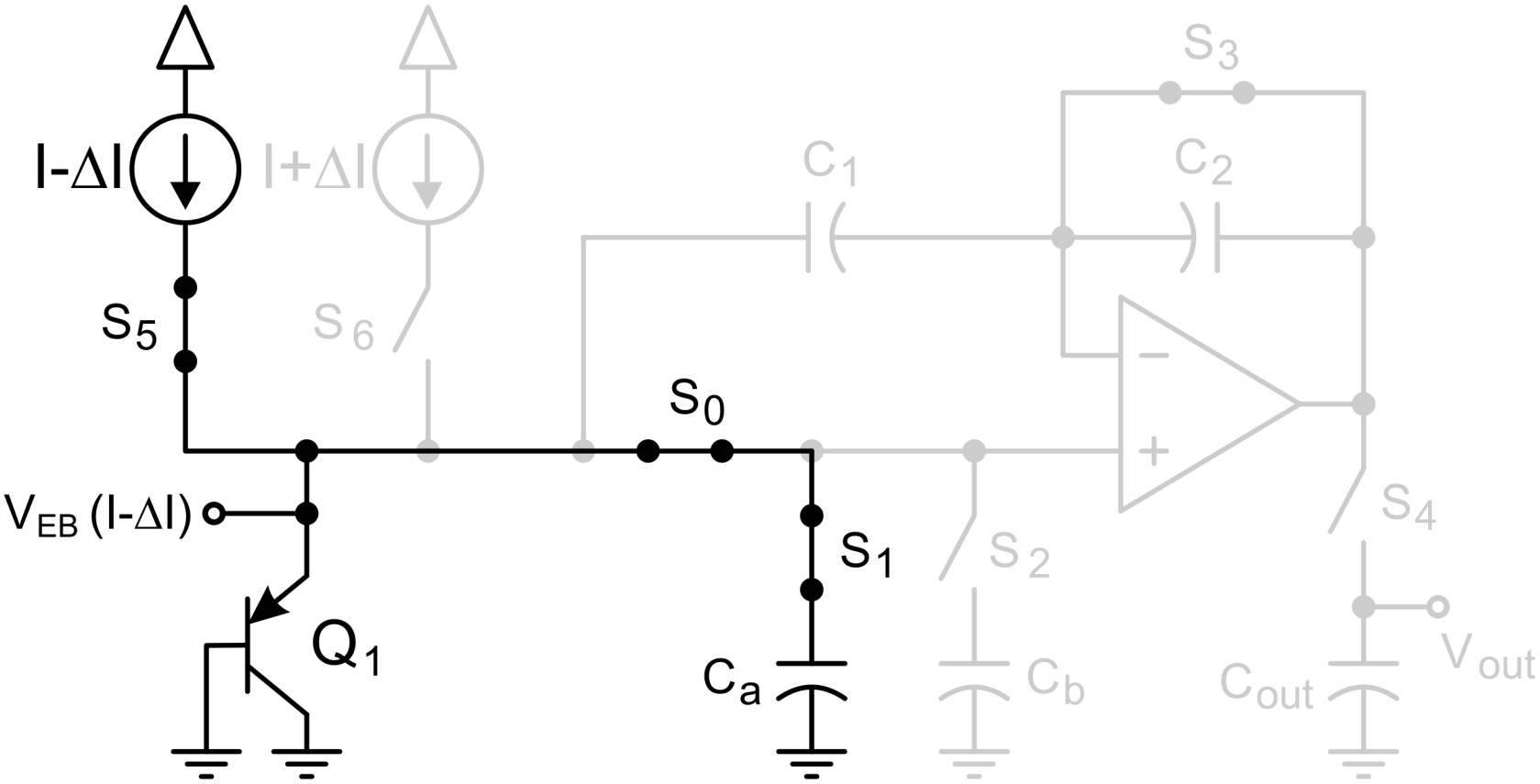
Switched-capacitor BGR



I_1 and I_2 are approximately equal

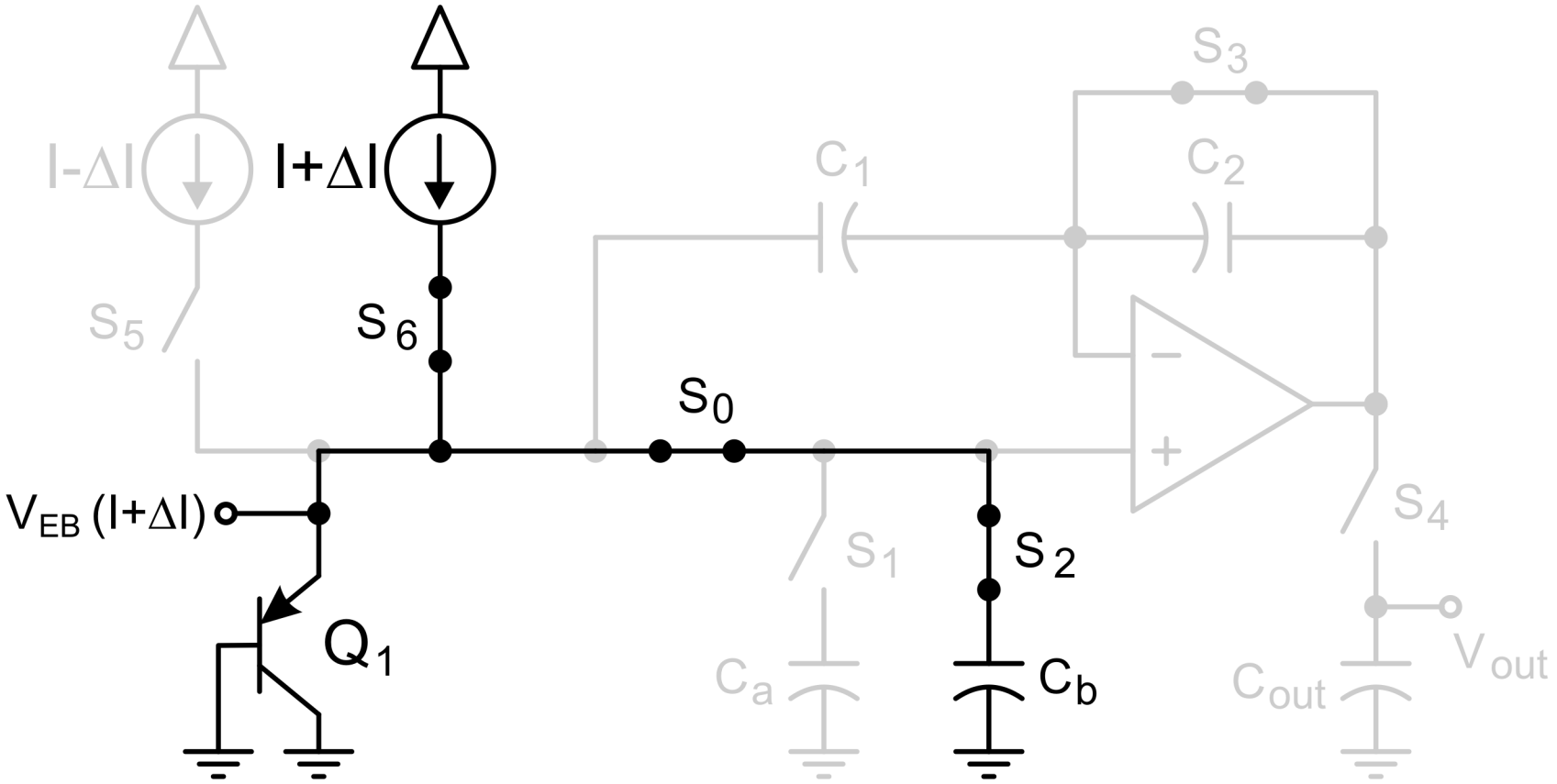
SCBGR - Operation

Phase 1:



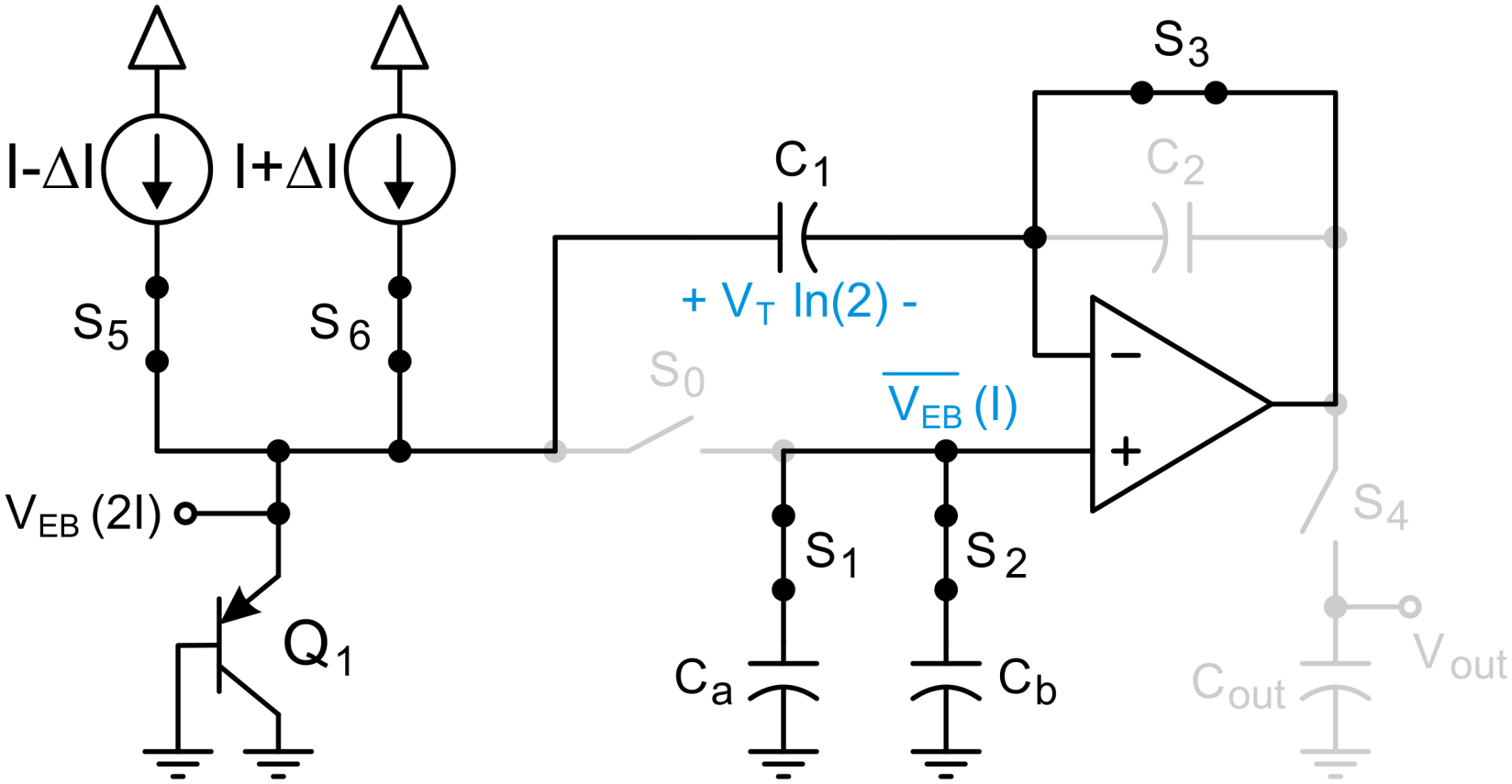
SCBGR - Operation

Phase 2:



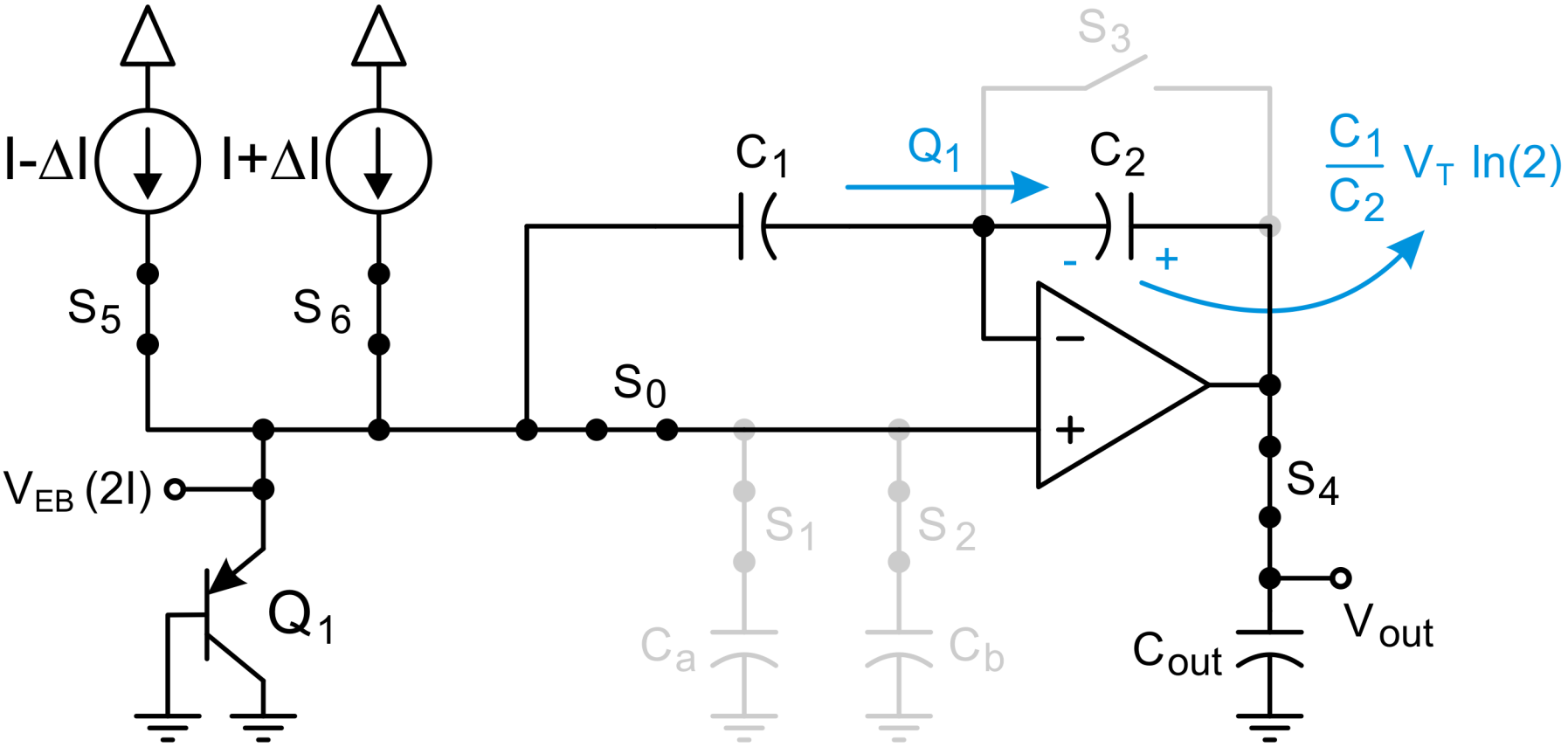
SCBGR - Operation

Phase 3:



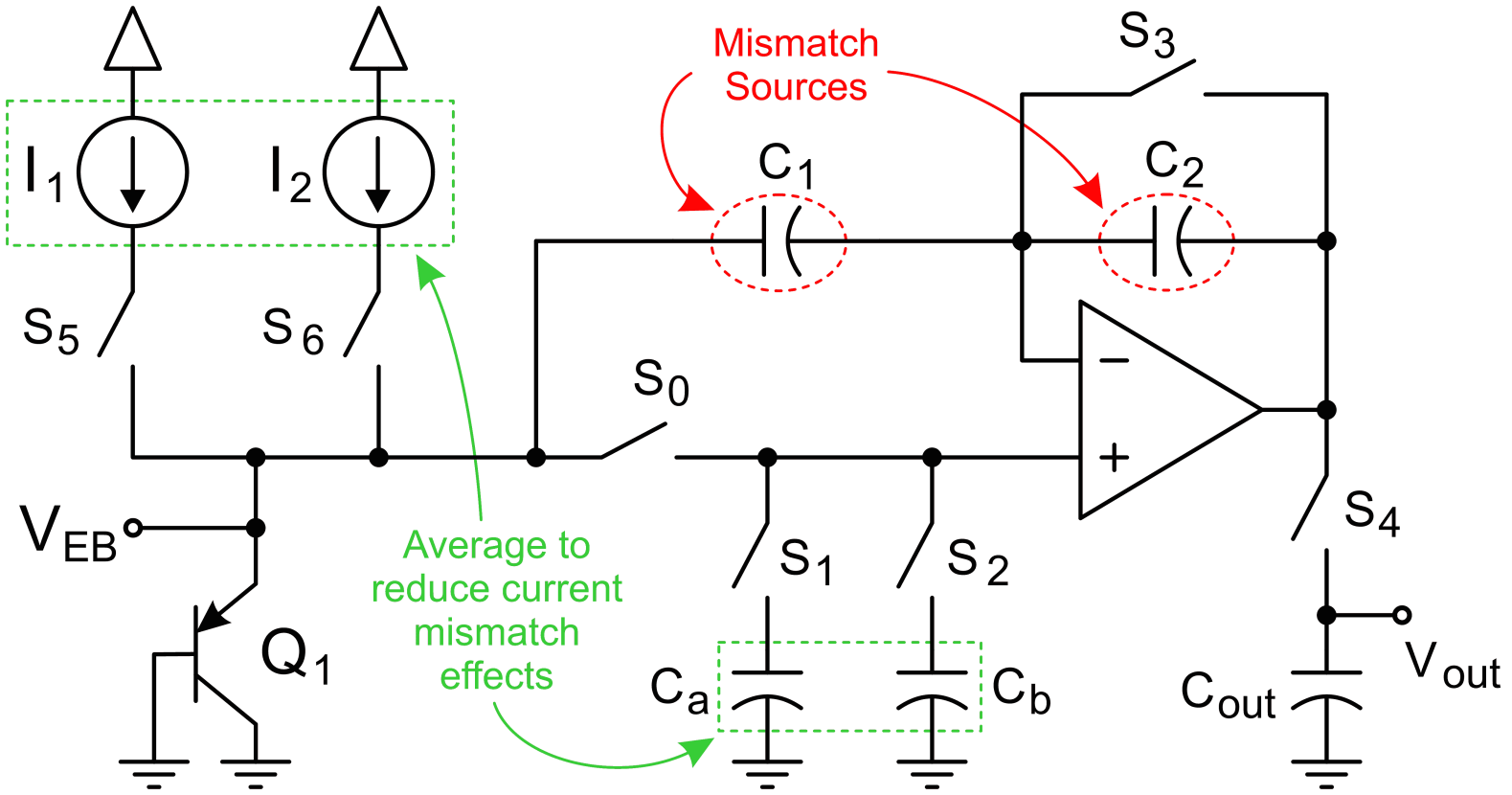
SCBGR - Operation

Phase 4:



SCBGR - Operation

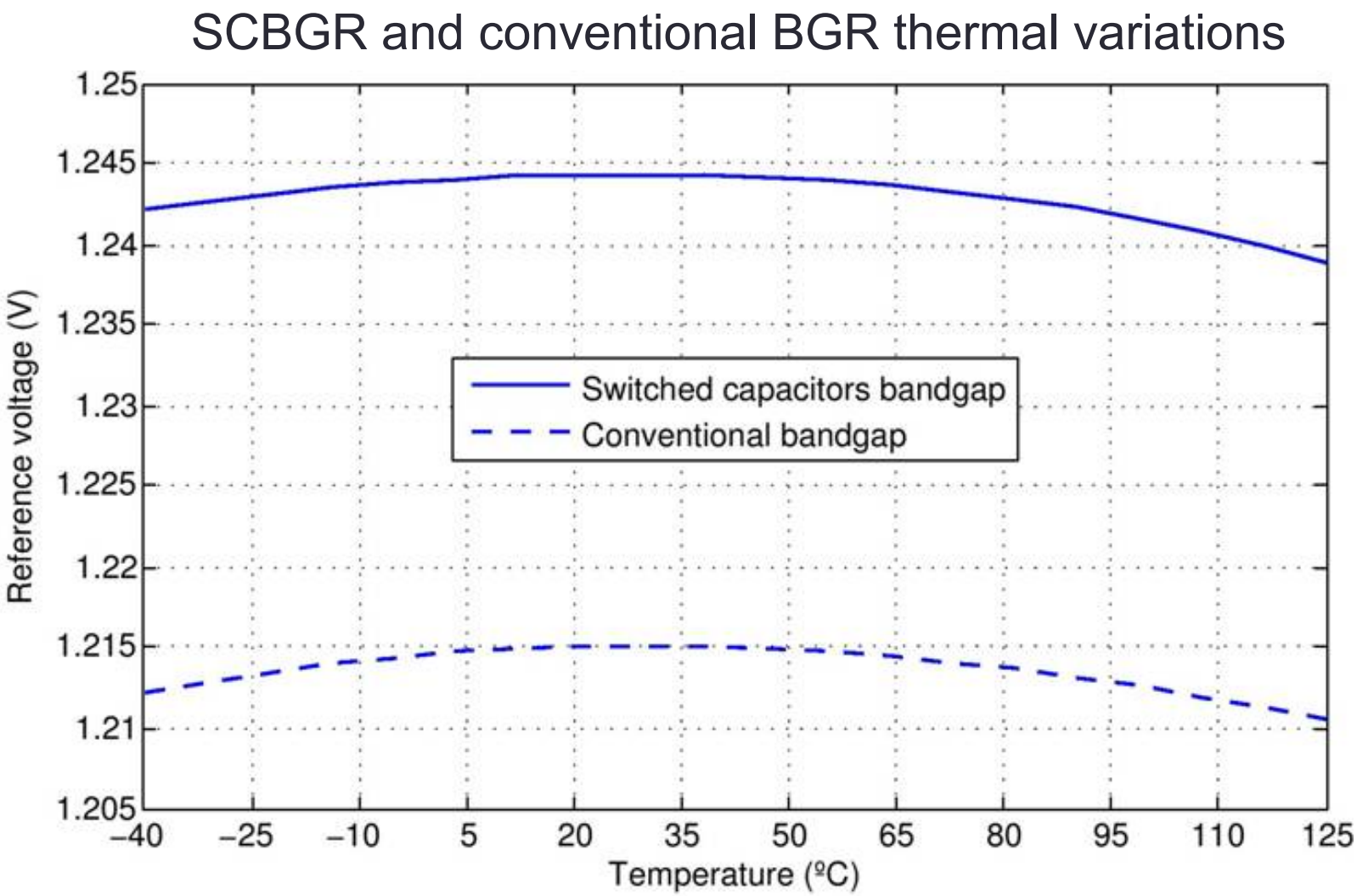
$$V_{out} = V_{EB}(2 \cdot I) + \frac{C_1}{C_2} \cdot V_T \cdot \ln(2)$$



SCBGR - Simulations

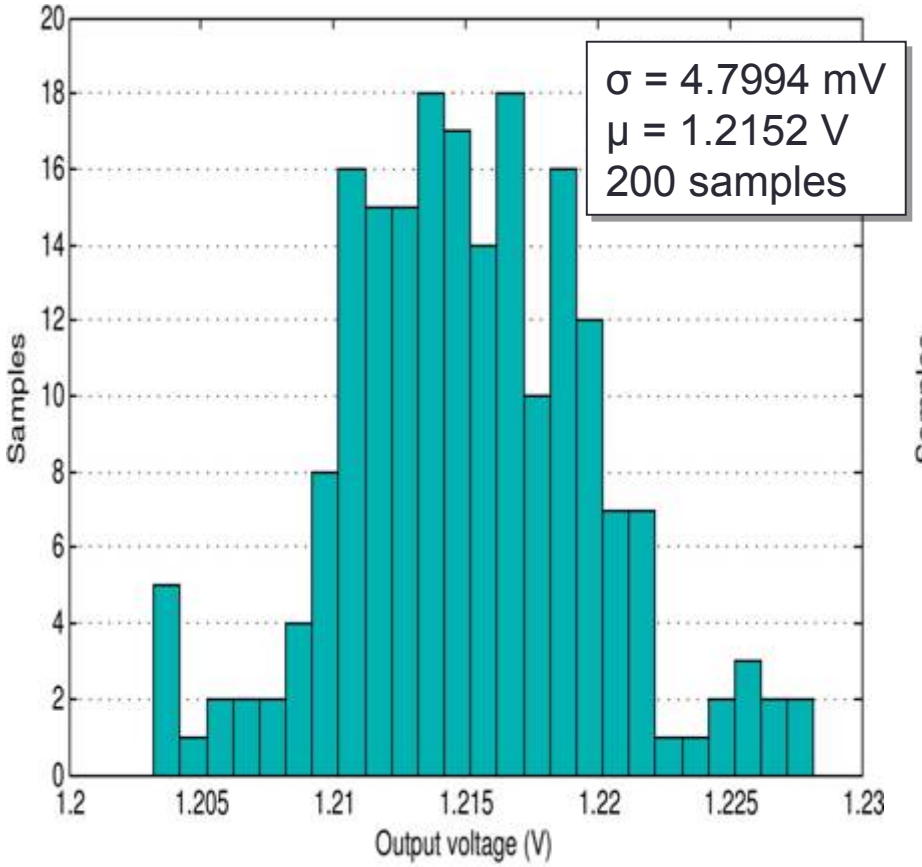
- Simulation with Cadence Virtuoso Spectre and IBM 130nm technology PDK
- Schematic electrical simulations used foundry-supplied parameters for MOSFET model BSIM4.
- Ideal current sources were replaced by MOS current sources, controlled by a low-power only-MOS bias current generator
- Typical BGR topology (in this paper) uses precise resistors available in the process considered.

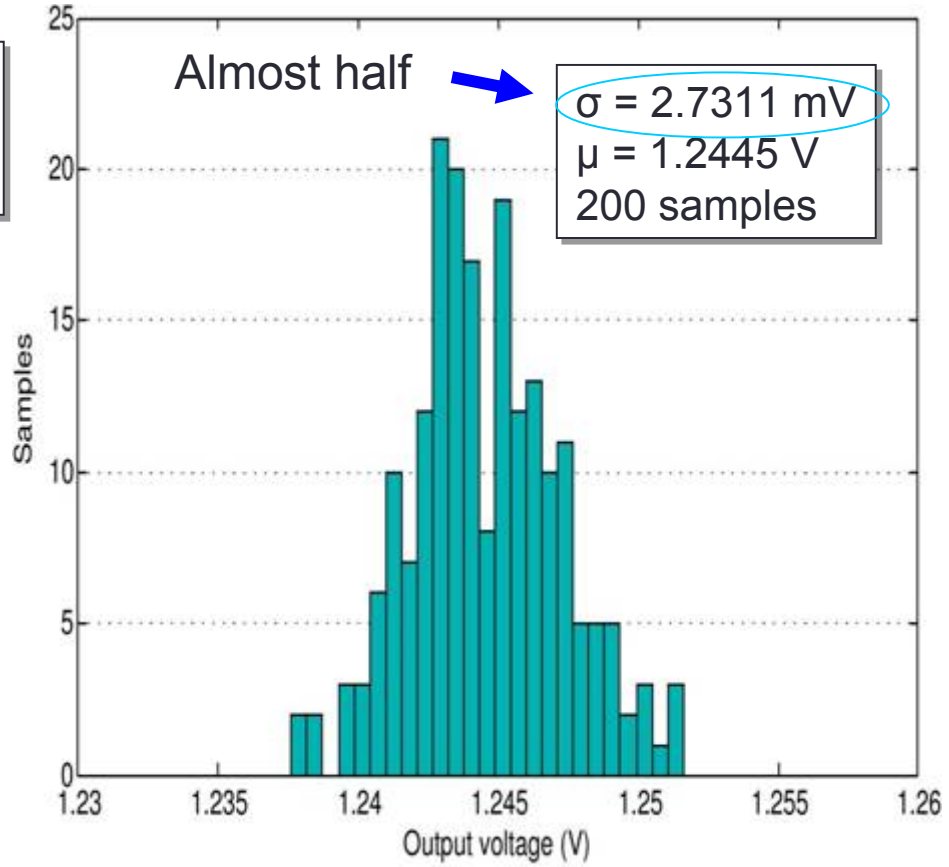
SCBGR - Results



Monte-Carlo Simulation Results

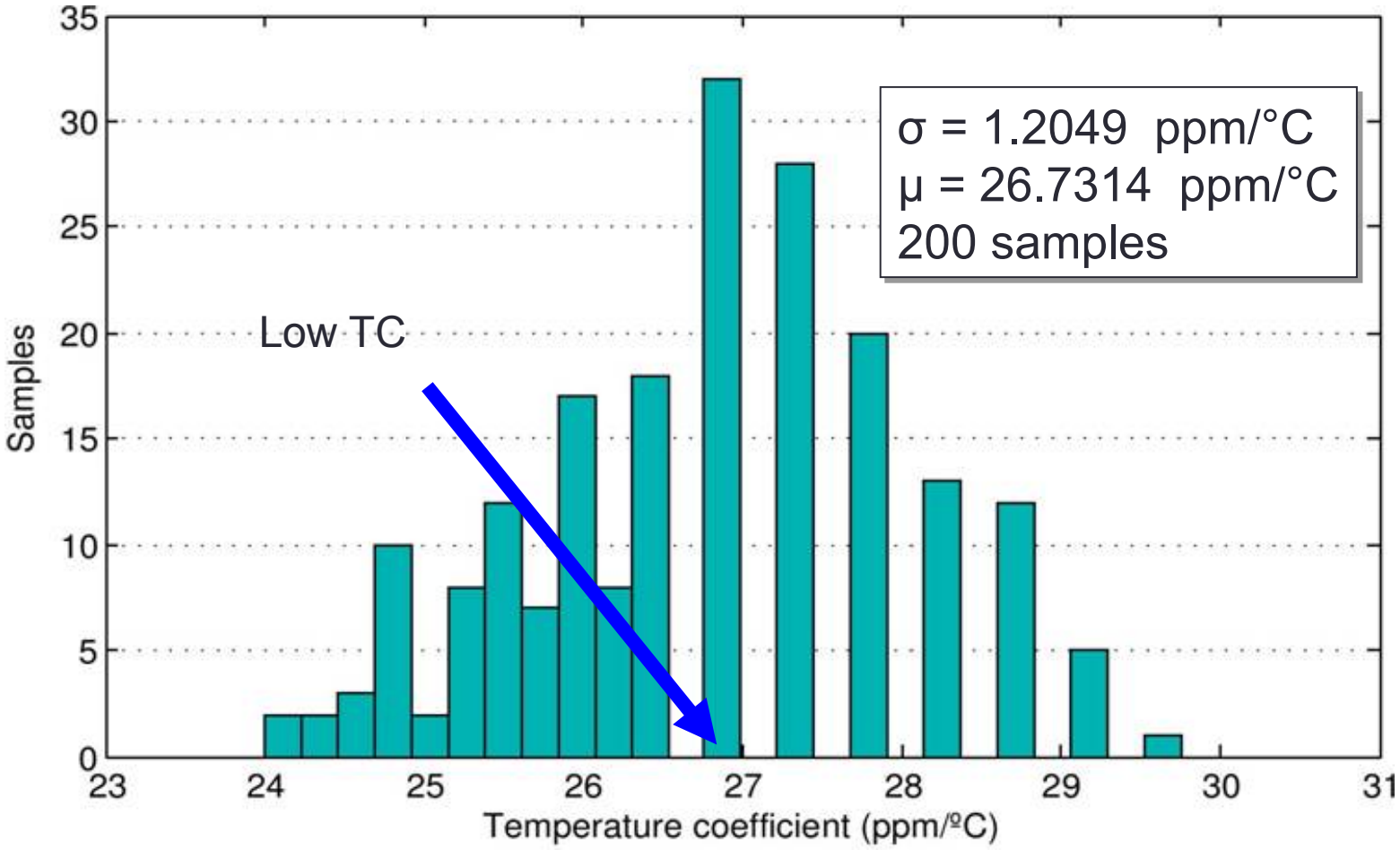
Conventional topology (left) vs SCBGR (right) variability histograms of output voltage





Monte-Carlo Simulation Results

SCBGR temperature coefficient variability histogram



Conclusions

- A new resistorless bandgap reference topology was proposed.
- Lower process impact results from using capacitors instead of resistors and only one BJT.
- Simulations: half the standard-deviation of a typical resistor-based topology, under similar conditions and using precision resistors in the conventional topology.
- An average TC of 26.7 ppm/ºC enables the circuit to be used without calibration in many IC applications.