Poster Number : 1D-3

A 300 nW, 7 ppm/°C CMOS Voltage Reference Circuit based on Subthreshold MOSFETs

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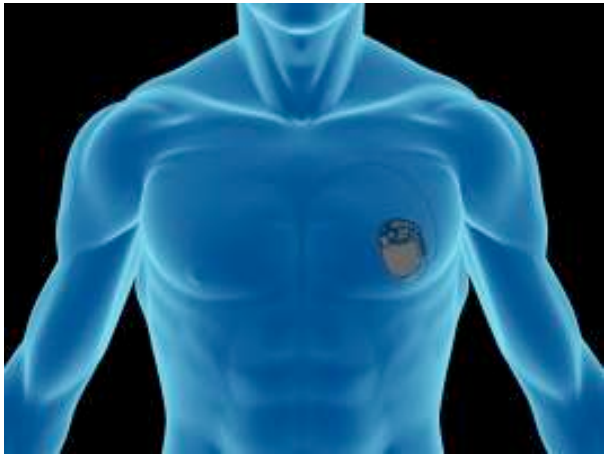
Introduction

Sensor network

RFID

Medical Devices



1. Limited energy source

(button battery)

(solar cell)

2. Long-time operation

Button battery (160 mAh)

↓

(for over 3 years)

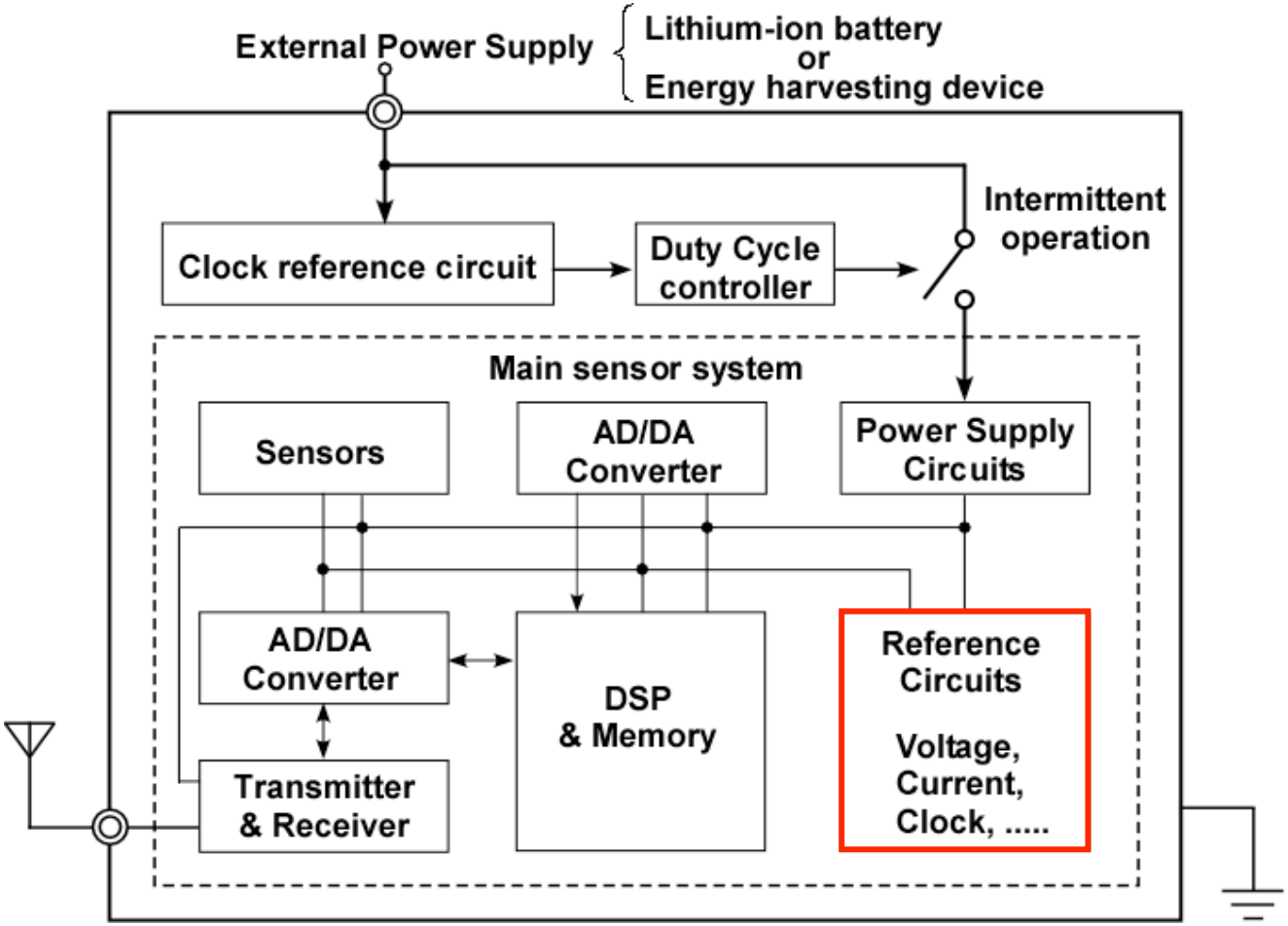
↓

Power < 20 μW

⇩

Ultra-low power LSIs operating in the Subthreshold region

Smart Temperature sensor LSI



All subcircuit : operated in the subthreshold region

⇨ **Ultra-low Power Voltage Reference**

Our previous works

Sensors

- IEEE JSSC, pp. 798-803, 2007.
- IEEE Sensors, pp.186, 2005.
- IEEE VLSI Symp., pp.194 -, 2006.

DC-DC Converter

- IEICE ELEX, pp. 464-468 , 2006.

Voltage Reference

- IEEE ESSCIRC, pp. 398-401, 2008.
- SSDM, pp. 486-487, 2007.
- IEEE ISCAS, pp. 3748-3751, 2007.

Current Reference

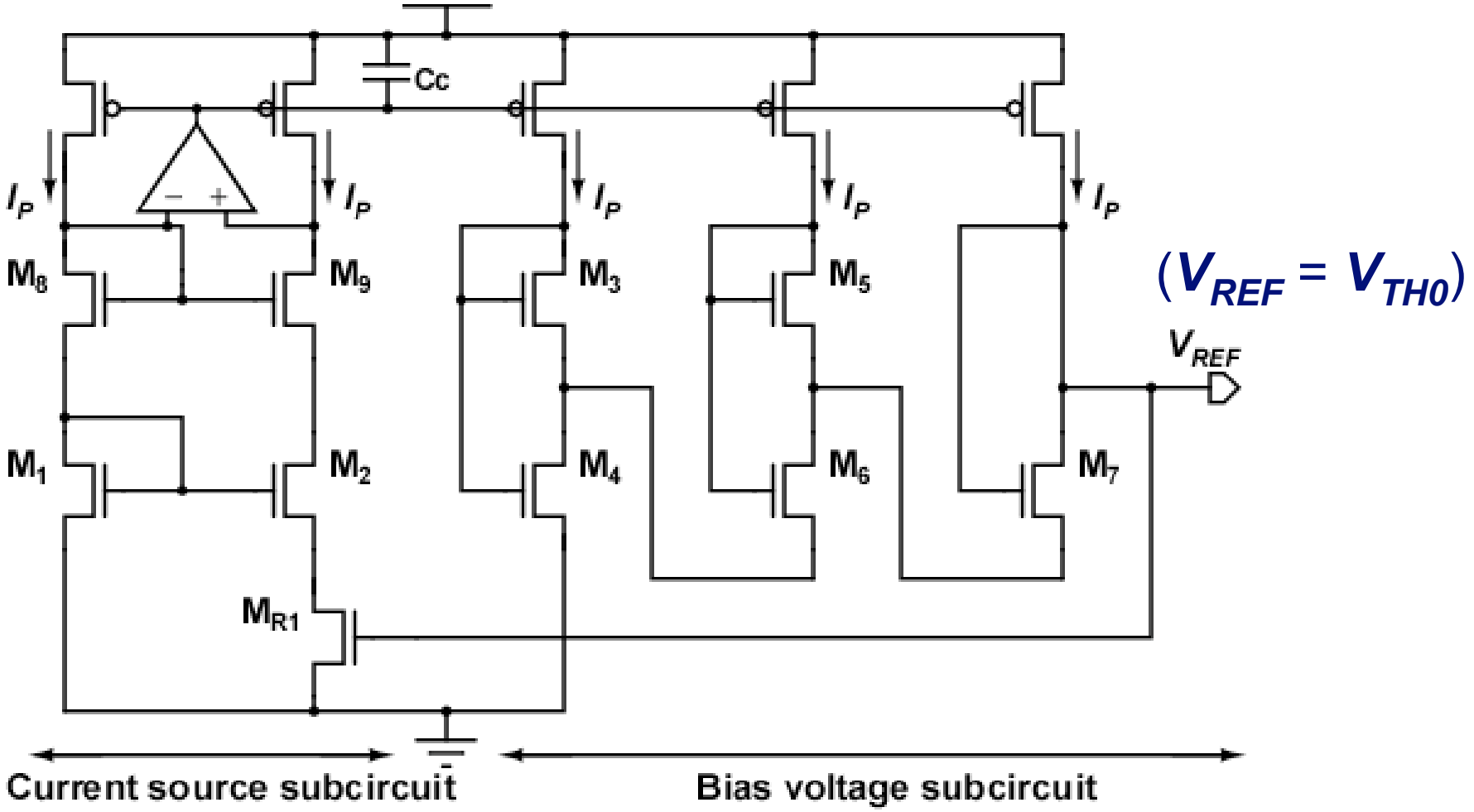
- IEEE Sensors, p.186, 2005.
- SSDM, 2008.
- IEEE ASSCC, 2008.

Digital Circuits

- AVLSIWS, pp. 78-83, 2007.

Voltage Reference Circuit

Threshold Voltage (V_{TH0}) Reference

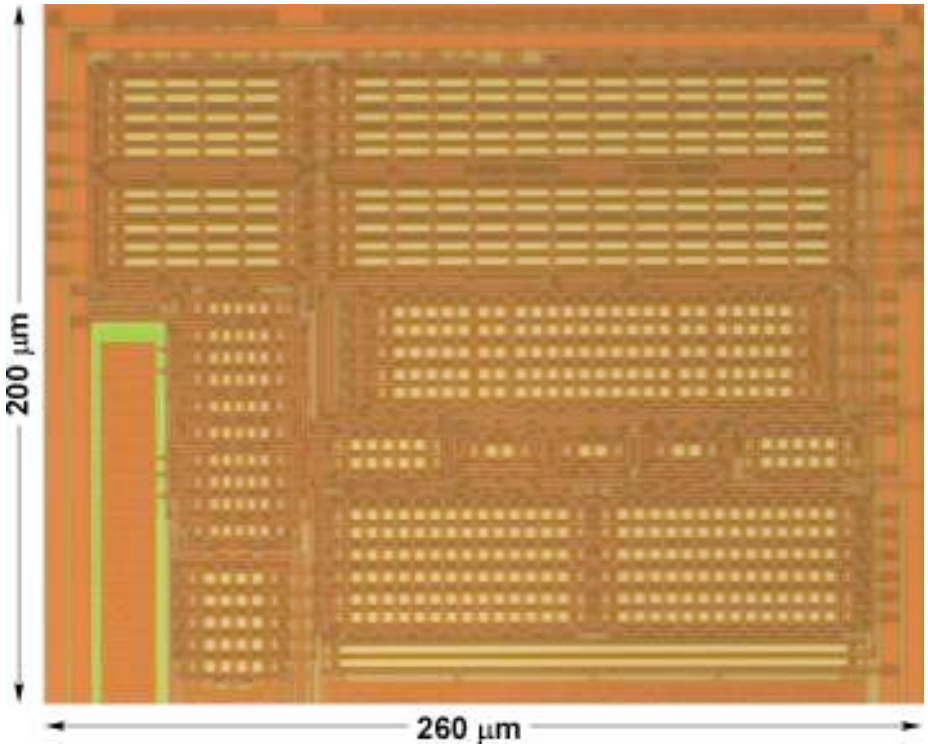


($V_{REF} = V_{TH0}$)

All MOSFETs are operated in the subthreshold region
(Power = 0.3 μW)

Measurement Results

Prototype chip



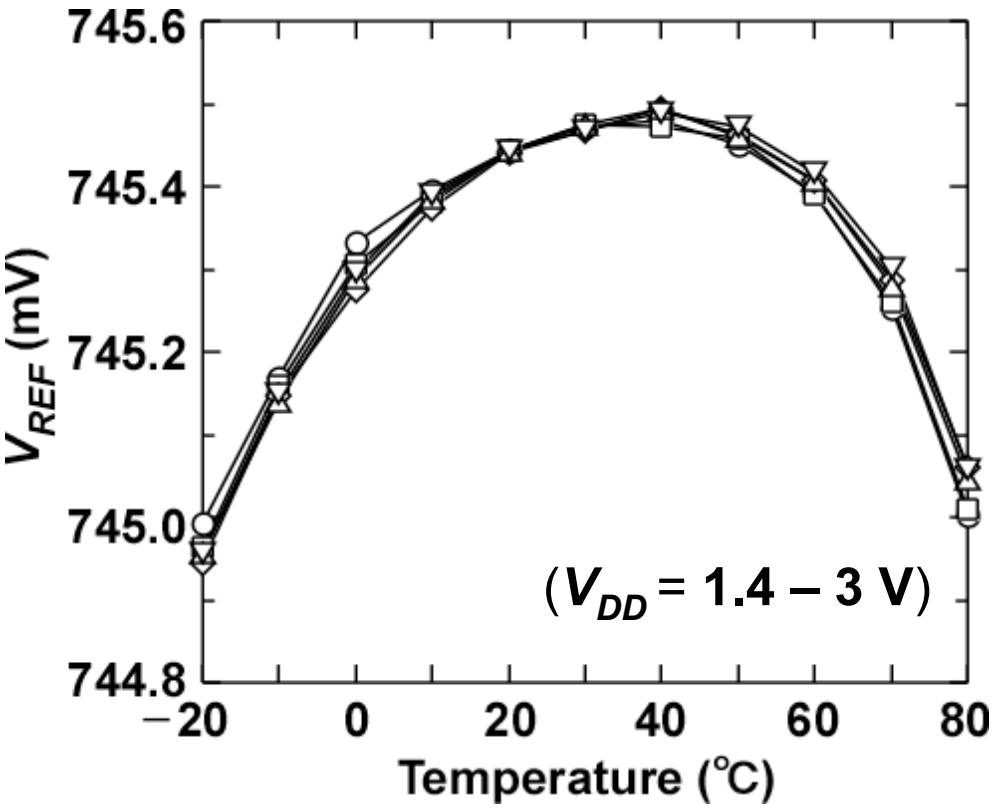
Process: 0.35 μm 2P- 4M CMOS

Area: 0.052 mm²

Temp. range: -20°C – 80°C

Supply voltage: 1.4 – 3.0 V

Temp. characteristics



Temp. coefficient = 7 ppm/°C

Line sensitivity = 20 ppm/V

Performance Summary

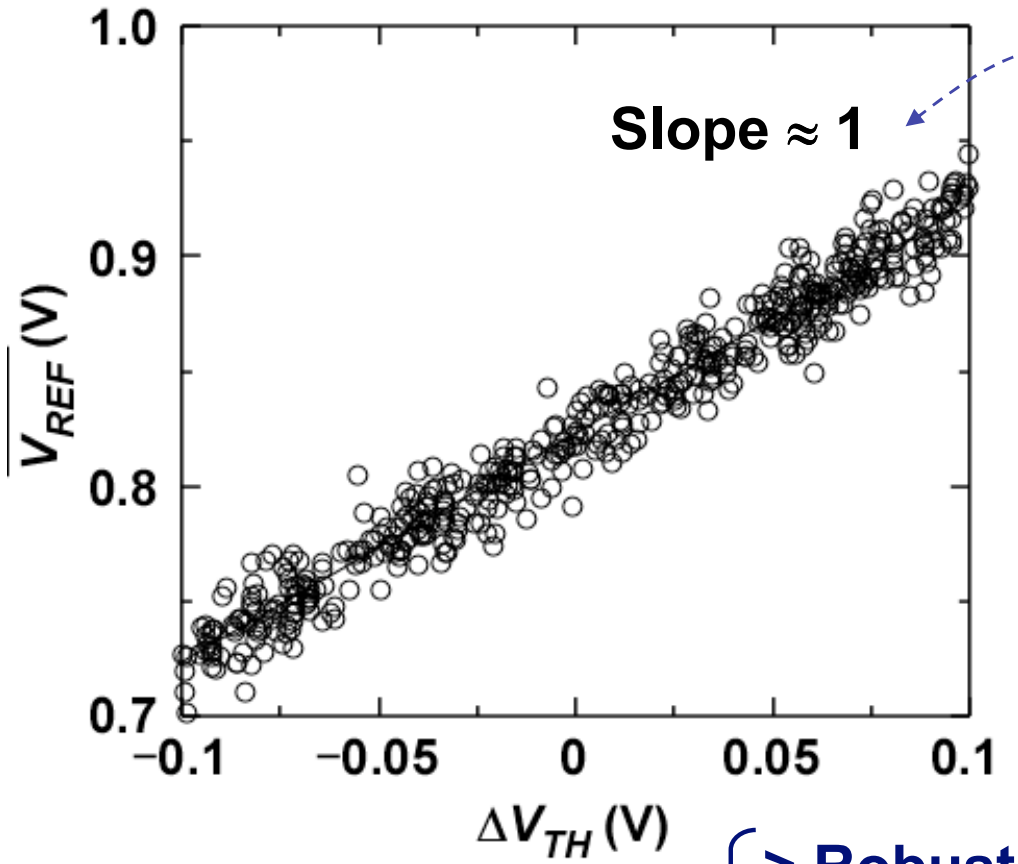
Our performance compared with other reported voltage reference

	This work	De vita JSSC 2008	Leung JSSC 2003	Chen Eleclet 2005	Giustolisi JSSC 2003	Huang CASII 2006
Process	**0.35 μm**	0.35 μm	0.6 μm	0.35 μm	1.2 μm	0.18 μm
Temp. (°C)	**-20 – 80**	0 – 80	0 – 100	0 – 70	-25 – 125	20 – 120
V_{DD}	**1.4 – 3 V**	0.9 – 4 V	1.4 – 3 V	1.4 – 3 V	1.2 V	0.85 – 2.5V
V_{REF}	**745 mV**	670 mV	309.3 mV	579 mV	295 mV	221 mV
Power	**0.3 μW**	0.036 μW	29.1 μW	4.6 μW	4.3 μW	3.3 μW
TC	**7 ppm/°C**	10 ppm/°C	37 ppm/°C	62 ppm/°C	119 ppm/°C	271 ppm/°C
Line	**20 ppm/V**	2700 ppm/V	800 ppm/V	6700 ppm/V	N.A.	9000 ppm/V
Area	**0.052 mm²**	0.045 mm²	0.055 mm²	0.126 mm²	0.23 mm²	0.024 mm²

Best T.C. & Line regulation performances

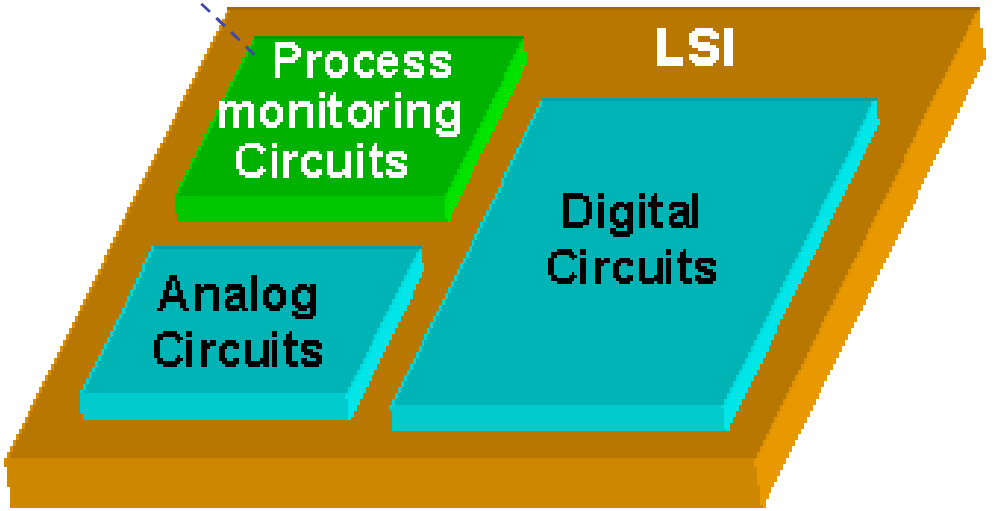
Applications

V_{REF} depends linearly on ΔV_{TH}



Process Compensation System

On-chip monitoring of V_{TH} variations



- > Robust current sources,
- > Slew rate compensation in analog buffers,
- > Frequency compensation in VCOs…