Chapter 5
Contemporary Low Power Design Approaches

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ABSTRACT
This chapter describes three contemporary low power design approaches: a resistor-less bandgap reference circuit, a hybrid voltage level shifter with a diode connected NMOS and a modified dynamic comparator, each design with the objective to demonstrate the feasibility of contemporary approaches in achieving lower power VLSI design. All three designs are simulated in 0.18 µm CMOS technology using industrial simulation tool and the results are based on performance parameters defined in the chapter.

INTRODUCTION
Today’s power-conscious climate has elevated low power design approaches even at contemporary level, infiltrating every aspect of building blocks in VLSI system especially with the shrinking circuit board sizes in portable and wearable electronics and the much talked-about Internet of Things devices which require wireless and energy-storage-based design. The growing market of portable, battery-powered devices demand circuits design and VLSI system with ultra-low power dissipation. As the integration, size and complexity of the chips continue to increase; the difficulty in providing adequate cooling might either add significant cost or limit the functionality of the computing system in those integrated circuits.

OVERVIEW FOR BANDGAP REFERENCE CIRCUIT (BGR), VOLTAGE LEVEL SHIFTER (VLS) AND DYNAMIC COMPARATOR
In today’s new deep submicron CMOS technology especially in the System on Chip (SoC) products, the CMOS technology scaling and demand for high efficiency low power devices is higher than ever. One fundamental approach to low power design is low power supply: when the power supply is low, the total power consumption would be lowered subsequently. How about a circuit which needs to operate at certain

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temperature condition? What happen if the temperature is higher than the selected testing temperature? Would the power consumption of the circuit increases? In order to overcome all these obstacles, a self-biased low power CMOS bandgap reference (BGR) circuit is designed. This is a circuit which uses two temperature-control techniques to provide flexibility and functionality.

How about speed in low power design? Having high speed in low power design would be considered as luxury in circuit design. In the second part of the chapter, a hybrid voltage level shifter (VLS) using the contemporary approach of a diode connected NMOS would be introduced. In this part, there would be some equations introduced in order to aid in achieving an optimized VLS.

The final approach uses a modified dynamic comparator which has been designed from a modified latch utilizing a NMOS transistor. The \( t_{latch} \) of the comparator shows improvement of approximately 23\% compared to conventional comparator. This modified version of latch type voltage sense amplifier comparator uses a contemporary approach and it is able to dissipate only 118 pW at 1.5 V power supply with 200 MHz frequency as reported by Iffa S. and L. Lee (2014). Detailed simulation results are included to give an insight onto the actual architecture.

**BANDGAP REFERENCE CIRCUIT (BGR)**

Electronic devices require steady and constant power supply in order to function smoothly, without flaws. With growth in demand for more portable electronic devices, more and more circuits and systems would require low power, small area and low cost features. Bandgap reference is one of the essential units in analog circuit systems. It provides a constant voltage supply regardless of fluctuations or changes in temperature and power supply. Brokaw Paul (1981) invented the first BGR circuit which has a temperature compensated band-gap reference of the type employing two transistors operating at different current densities to develop a positive TC (Temperature Coefficient) current. As CMOS technology developing rapidly and bringing us into the era of high integration and ultra-low power consumption, the need for lower than the conventional bandgap voltage reference was created. Hence, it is critical to design low power consumption bandgap reference circuits which work under low voltage supply and yet compatible with other modern circuit blocks. There are a number of researchers or authors such as Bo Wanget al. (2015), Klimach H. et al. (2013) and Yat-Hei Lam et al. (2010). They have contributed new solutions based on the concept of using a fraction of the original bandgap voltage level.

Here in this chapter, a self-biased low power CMOS bandgap reference is introduced, working at 0.8V power supply and 0 to 100\(^\circ\)C temperature range. Advanced startup circuit was adopted in the voltage reference to improve circuit precision and stability. The proposed BGR circuits are designed in 0.18 \( \mu \)m CMOS technology. A first proposed BGR with a resistor load (Figure 1) is introduced with minimum of 13 transistors and 3 passive resistors while second proposed BGR (Figure 2) would not have any resistor. Xin Ming and authors (2010) mentioned that using resistor increases a chip area size and causes variation on the resistor sheet from substrate. The resistor would be replaced by a transistor which acts as an active resistor. A typical BGR circuit consisted of three building blocks: self-biased differential amplifier, start-up circuit and bandgap core circuit.

A voltage reference is an essential sub-electronic circuit present in many Systems on Chip (SoC) product such as mobile electronics product, Analog-to-Digital (A/D) and Digital-to-Analog (D/A) converters. However, the heat dissipation issues raised from the circuit operation would create huge