Chapter 1

Introduction

As feature size of MOS technology continues to shrink, power density becomes a critical issue for transistor scaling. With power density reaching hundreds of watts per centimeter square, temperature has significant impacts on threshold voltage, carrier mobility, resistivity, reliability and even package.

In recent years, researchers have proposed a number of Dynamic Thermal Management (DTM) techniques for assuring thermal safety at run time [2]. Amit et al. [13] presented a methodology for thermal management using a hybrid of hardware techniques and software techniques. On the other hand, In order to maintain performance under modern process technologies in multi-core systems using thermal management, Rajarshi et al. [12] proposed a frequency selection algorithm to assist DTM for multi-core systems. Furthermore, some researchers observed the interdependency between leakage energy and chip temperature in real time system. Lin et al. [14] presented a temperature-aware leakage minimization algorithm that can adjust run/sleep mode in the real time system while considering each task's urgency. However, the basis of these works is accurate temperature detection during run time.

The key step to the success of DTM techniques is to accurately detect the temperature in the selected hot spots, so as to determine the executions of dynamic voltage scaling, frequency scaling, or energy aware process scheduling, etc. In the previous work, *absolute* temperature sensor was used. Subsequently, researches on allocation and placement of temperature sensor were proposed based on the model of *absolute* temperature sensor [1,2].

In deep submicron technologies, process variations present difficulty in manufacturing and in design. They will result in performance degradation, power increase, functional failure, all amounting to yield loss. Moreover, process variations will cause inaccurate *absolute* temperature sensing. For example, in [2], the un-calibrated accuracy of temperature sensors is about ± 12°C over the manufacturing process corners for *absolute* temperature measurements. To solve this inaccuracy problem, research work using external calibration was proposed in [7]. However, calibration requires to be performed from lot to lot and even from die to die. It is time and cost consuming. Furthermore, Negative-Bias Temperature Instability (NBTI), caused by temperature fluctuation and switching activity of circuitry in advanced technologies, fluctuates threshold voltage [8,9]. Fluctuation of threshold voltage results in unstable performance of temperature sensor. It, in turn, results in inaccurate absolute temperature measurement.

In this thesis, we propose a *relative* temperature sensor which as corollary minimizes the temperature errors caused by process variations and temperature fluctuation behavior. Furthermore, a sensor placement algorithm taking into consideration the characteristics of our *relative* temperature sensors is proposed. With these techniques, accurate temperature data are captured without external temperature calibration.

The rest of the thesis is organized as follows. We give an overview of previous work in Chapter 2. Chapter 3 discusses the motivation of this work. Chapter 4 proposes architecture of our *relative* temperature sensor. Chapter 5 formulates the problem of placing *relative* temperature sensors and proposes an algorithm to solve it. Chapter 6 shows the experimental results. Conclusions are put forth in Chapter 7.