Practical Precision Analog and Mixed Signal Circuits and Hardware Security

**Abstract**

The semiconductor industry supports a wide range of sectors, including computer systems, mobile devices, communication systems, medical equipment, military, and many more. As technology advances, integrated circuits are becoming more complex and powerful, enabling new applications and improving existing ones. However, this also poses challenges in manufacturing, testing, and reliability, as even minor defects or errors can have significant consequences.

This dissertation will address practical, precision, and low-cost solutions for some of the major bottlenecks in design and test solutions in the analog and mixed-signal circuits domain and analog solutions for hardware security. First, the accuracy of high-precision analog and mixed-signal circuits, like data converters, depends on the accuracy and temperature dependence of the reference voltage. The widely used circuit solution for building a highly stable and precise voltage reference is the bandgap voltage reference, whose output is proportional to the bandgap voltage of silicon. Practical circuit solutions to reduce the temperature coefficient of the bandgap reference below 1ppm/C over a temperature range of  165C are described in this work. There is a need for diodes with different values of temperature exponent term of the saturation current of the diodes or the substrate pnp transistors in designing high-precision references. One solution uses diffusion diodes with different temperature exponent terms in a single substrate pnp device. The other solution is changing the I-V characteristics of a two-terminal device to make it fundamentally different, which can have a higher or lower temperature dependence than the unaltered traditional diode.

Next, the test cost of trimming or calibration of high-precision temperature dependant analog and mixed-signal circuits using conventional techniques is very high. The challenge for practical and low test cost solutions for trimming or calibration of analog circuits such as references, operational amplifiers, and temperature sensors using multitemperature measurements for high precision performance exists in the industry. A new strategy uses an on-chip constant power microheater, which can be placed at temperature-critical parts of the die and utilized during the calibration or trimming to reduce the test cost and improve relative temperature accuracy.

Furthermore, after production, there has been a growing challenge in the semiconductor industry to maintain legitimate parts in the supply chain owing to the diverse and multitudinous consumers. A cost-effective counterfeit countermeasure solution is proposed to combat the financial barrier for commercial off-the-shelf (COTS) manufacturers to include authentication circuits. A Physically Unclonable Function (PUF) circuit that requires no die area, no additional pins, and no readout circuitry that does not degrade the performance of the primary circuit and with an improved number of bits per transistor offers a low-cost and practical solution