ACCURATE THERMAL SENSING WITH MODERN CMOS INTEGRATED CIRCUITS

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ABSTRACT

Digital control systems can be found performing a wide range of duties throughout modern society. These systems demand accurate, low cost interfaces to physical parameters of interest, one of the most common being temperature. A ‘smart’ sensor takes advantage of modern integrated circuit technology to create a sensor and analog-to-digital converter on the same silicon chip. Smart temperature sensors are widely available offering simple digital interfaces, high reliability, low power consumption and low cost. The primary weakness of these devices is the low inherent accuracy of on-chip thermal sensors.

This thesis presents a smart thermal sensor design that improves upon current technology by employing a modern 0.13μm CMOS process and circuit-level techniques to reduce sensor size and power consumption while increasing digital converter resolution. Data is presented that shows uncalibrated sensor accuracy can be increased by using correlated device characteristics to compensate for random inter-device variation. The research findings guide the construction of future smart thermal sensors with uncalibrated accuracy levels exceeding that of any currently available design.

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DECLARATION

The author declares that this is his own work except where due acknowledgement has been given. It is being submitted for the PhD in Engineering to Massey University, New Zealand.

This thesis describes the research carried out by the author at the School of Engineering, Massey University, New Zealand from February 2005 to January 2010, supervised by Dr. Rezaul Hasan and Dr. Tom Moir.

Candidate's signature:

Robert Patrick Fisk 10th March 2010

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DEFINITIONS AND ABBREVIATIONS

ΔΣ	Delta-Sigma
A-D	Analog-to-Digital
AC	Alternating Current
ADC	A-D Converter
CDS	Correlated Double Sampling
CIFB	Cascade of Integrators, FeedBack
CIFF	Cascade of Integrators, FeedForward
CM	Common-Mode
CMC	CM Control
CMOS	Complementary MOS
CSV	Comma-Separated Values
CTAT	Constant To Absolute Temperature
D-A	Digital-to-Analog
DAC	D-A Converter
DC	Direct Current
DEM	Dynamic Element Matching
DMM	Digital Multimeter
DRC	Design Rule Check
DSO	Digital Storage Oscilloscope
DUT	Device Under Test
ENOB	Effective Number Of Bits
ESD	Electrostatic Discharge
FIR	Finite Impulse Response
IC	Integrated Circuit
IIR	Infinite Impulse Response
I/O	Input / Output
MIM	Metal-Insulator-Metal
MOS	Metal Oxide Semiconductor
NC	No Connection

NTF	Noise Transfer Function
OSR	Oversampling Ratio
PDK	Process Development Kit
PID	Proportional, Integral, Differential
PTAT	Proportional To Absolute Temperature
Recursion	See ‘Recursion’
RTD	Resistance Temperature Detector
SC	Switched Capacitor
STF	Signal Transfer Function
ZIF	Zero Insertion Force