Adaptive Amplifier System for Sensor Network Applications

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Abstract. This paper presents an adaptive amplifier that is part of a sensor node in a wireless sensor network. The system presents a target gain that has to be maintained despite the presence of faults while its bandwidth must be as large as possible, without direct human intervention. The system is composed by a software-based built-in self-test scheme implemented in the node that checks all the available gains in the amplifiers, a reconfigurable amplifier and by a genetic algorithm (GA) for reconfiguring the node resources that runs in a host computer. We adopt for the node implementation a PSoC device from Cypress. The performance evaluation of the scheme presented is made by adopting two different types of fault-models in the amplifier gains. The fault simulation results show that GA finds the target gain with low error, maintains the bandwidth above the minimum tolerable bandwidth and presents a run time lower than an exhaustive search method.

Keywords: Evolvable hardware, software-based built-in self-test, genetic algorithm, adaptive amplifier system, wireless sensor networks.

1 Introduction

Wireless sensor networks are implemented with a usually large number of sensor nodes. These nodes have the ability to communicate each other by means of wireless transmission. Usually, a host computer collects data from the sensors and performs different actions depending on the particular purpose of the system. A broad range of applications have been proposed for this kind of systems such as industrial sensor networks, environmental monitoring, home automation, medical and health care among others [1].

In the above-mentioned applications, the nodes can operate under the action of a number of agents that potentially could degrade the system performance. If the application is critical, the system can require characteristics of safe operation, adaptation to a changing environment or ability for compensating degradations in its own circuitry. For achieving this purpose, two related characteristics are necessary: fault detection and self-adaptation to a changing environment.

A typical wireless sensor node comprises sensor processing and communication units. In this context, microcontrollers are god candidates for implementing part of a node because they offer some benefits. These include low cost and power consumption, ability to perform data processing tasks in the node and usually, powerful communication interfaces. In addition, modern microcontrollers (μCs) offer a wide pool of configurable digital and analog sections that enhance the chip ability for adapting to a broad range of applications.

The programmable analog sections in μCs offer an alternative to traditional fault tolerant schemes because the reconfigurable nature of these devices enables runtime correction [2]. Additionally, although reconfiguration not always guarantees that a complete functionality can be restored, it allows maintaining the system operation with slight degradation [3].

Particularly, evolvable hardware (EHW) is a methodology that combines reconfigurable hardware with evolutionary algorithms with the aim of adapting a system to changing environments or providing fault recovery. In this methodology, the designer establishes performance goals and a GA searches the possible hardware configurations for reaching them [2], [3]. Relevant work in the area of fault tolerance and fault recovery of electronic circuits can be found in [4-7].

EHW usually require a test strategy for detecting the presence of hardware faults in order to establish that it is necessary a reconfiguration. Regarding the test of configurable analog circuits, in [8], [9], is presented an on-line testing strategy for continuous-time field programmable analog arrays (FPAAs). In [10-12], techniques such as oscillation-based test and transient analysis method have been successfully applied to FPAAs for testing interconnection resources and basic building blocks.

In this paper, we present an adaptive amplifier that is part of a sensor node in a wireless sensor network. The system presents a target gain that has to be maintained despite the presence of faults while its bandwidth must be as large as possible, without direct human intervention. We employ for implementing the GA a host computer, which is commonly used in sensor networks. The system is composed by a software-based built-in self-test (SW-BIST) scheme (implemented in the node) that checks all the available gains in the amplifiers, a reconfigurable amplifier and by a GA for reconfiguring the node resources that runs in a host computer. We adopt for the node implementation a PSoC device from Cypress.

2 System Description

PSoC device is a programmable system-on-chip platform with an on-chip processor core [13]. It includes configurable blocks of analog circuits, programmable interconnect and configurable IO in a low-cost chip. Analog functions in the device are organized as groups of general-purpose analog blocks that can be configured into user-determined functions. The control for these blocks is register-based and can be programmed through design tools or reprogrammed by the user at run-time. Some of the available configurations for the analog arrays are up to 14 bits analog to digital