Microcontroller Power Consumption Measurement Based on PSoC

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Abstract — Microcontrollers are often used as central processing elements in embedded systems. Because of different sleep and performance modes that microcontrollers support, their power consumption may have high dynamic range, over 100 dB. In this paper, a data acquisition (DAQ) system for measuring and analyzing power consumption of microcontrollers is presented. DAQ system consists of current measurement circuit using potentiostat technique, DAQ device based on system on chip PSoC SLP and Python PC program for the analysis, storage and visualization of measured data. Both Successive Approximation Register (SAR) and Delta-Sigma (DS) ADCs contained in the PSoC SLP are used for measuring voltage drop across the shunt resistor. SAR ADC samples data at 10 times higher rate than DS ADC, so input range of DS ADC can be adjusted based on data measured by SAR ADC, thus enabling the extension of current measuring range by 28%. Implemented DAQ device is connected with computer through USB port and tested with developed Python PC program.

Keywords — DAQ, Microcontrollers, Power consumption, PSoC.

I. INTRODUCTION

POWER management is an actual topic for both stationary and mobile electronic systems [1], [2]. In stationary systems it can be used to reduce generated heat and environmental impact as well as to reduce the electricity bills. In addition, the increased power dissipation increases the probability of device failure, and leads to an increase in prices due to the introduction of a system for cooling and packaging. In wide range of portable electronic devices for computing, communication, biomedical and many other applications, power consumption represents extremely important issue. Reducing power consumption when devices are battery powered allows the use of light batteries and longer device operation between the charging cycles. Many design methodologies are implemented to achieve energy-efficient electronic system [3]-[7]. For power management to be effective, power consumption of power managed system

needs to be accurately measured [8].

Power consumption of an embedded system depends on operating voltage and current. In order to measure and visualize voltage and current in real-time, oscilloscopes and data acquisition (DAQ) systems can be used. Oscilloscopes have high precision and allow real-time visualization and analysis of measured data. DAQ systems consist of sensor, DAQ device connected to a computer and PC software for data acquisition, visualization and analysis running on that computer [9].

When measuring power consumption of an embedded system, voltage is kept at a certain operating value (for the system to be functional) and current consumption is measured. If current is sampled at predefined time intervals, average energy and power consumption data can be obtained.

In this paper new DAQ system for measuring microcontroller power consumption is presented. This paper is organized in the following way: the section *Measurement principles* provides concepts and details of measuring current with high dynamic range, since microcontroller current consumption exhibits similar behavior. The section *System implementation* focuses on presenting three integral parts of the proposed solution: Programmable System on Chip (PSoC SLP), Data acquisition device and Python PC program. Experimental results are presented in section *Results and Discussion.* Finally, the conclusions are given in the last section.

II. MEASUREMENT PRINCIPLES

Current measurement using shunt is widely used technique [10]. However, problem with shunt is the burden voltage effect [11], which affects operating voltage of the system whose power consumption is being measured. That is especially noticeable if current rapidly changes in time as a result of system activity and if dynamic range of changes is several orders of magnitude.

Several shunt-based current measurement techniques exist which solve the problem with burden voltage [12]-[14]. One solution to the problem of burden voltage is to use current mirror (Fig. 1a).

As can be seen from Fig. 1a, current flowing through system whose power consumption is measured is mirrored and shunt is placed in the mirrored branch. Thus the operating voltage remains constant, but accuracy of measurement is affected by the transistors and matching of those transistors. Also, power consumption of the whole system is increased and calibration is required.

Another possibility is to use the potentiostat technique

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professionals practitioners academicians and researchers interested in the applications of biotechnology *Mechatronics and Applied Mechanics II* Ching Kuo Wang,Jing Guo,2013-02-13 Selected peer reviewed papers from the 2nd International Conference on Mechatronics and Applied Mechanics ICMAM 2012 December 6 7 2012 Honkong December 8 9 2012 Taipei TinyML for Edge Intelligence in IoT and LPWAN Networks Bharat S Chaudhari,Sheetal N Ghorpade,Marco Zennaro,Rytis Paškauskas,2024-05-29 Recently Tiny Machine Learning TinyML has gained incredible importance due to its capabilities of creating lightweight machine learning ML frameworks aiming at low latency lower energy consumption lower bandwidth requirement improved data security and privacy and other performance necessities As billions of battery operated embedded IoT and low power wide area networks LPWAN nodes with very low on board memory and computational capabilities are getting connected to the Internet each year there is a critical need to have a special computational framework like TinyML TinyML for Edge Intelligence in IoT and LPWAN Networks presents the evolution developments and advances in TinyML as applied to IoT and LPWANs It starts by providing the foundations of IoT LPWANs low power embedded systems and hardware the role of artificial intelligence and machine learning in communication networks in general and cloud edge intelligence It then presents the concepts methods algorithms and tools of TinyML Practical applications of the use of TinyML are given from health and industrial fields which provide practical guidance on the design of applications and the selection of appropriate technologies TinyML for Edge Intelligence in IoT and LPWAN Networks is highly suitable for academic researchers and professional system engineers architects designers testers deployment engineers seeking to design ultra lower power and time critical applications It would also help in designing the networks for emerging and future applications for resource constrained nodes This book provides one stop solutions for emerging TinyML for IoT and LPWAN applications The principles and methods of TinyML are explained with a focus on how it can be used for IoT LPWANs and 5G applications Applications from the healthcare and industrial sectors are presented Guidance on the design of applications and the selection of appropriate technologies is provided *Medical Instrument Design and Development* Claudio Becchetti,Alessandro Neri,2013-05-20 This book explains all of the stages involved in developingmedical devices from concept to medical approval including systemengineering bioinstrumentation design signal processing electronics software and ICT with Cloud and e Healthdevelopment Medical Instrument Design and Development offers a comprehensivetheoretical background with extensive use of diagrams graphics andtables around 400 throughout the book The book explains how thetheory is translated into industrial medical products using amarket sold Electrocardiograph disclosed in its design by the GammaCardio Soft manufacturer The sequence of the chapters reflects the product developmentlifecycle Each chapter is focused on a specific University courseand is divided into two sections theory and implementation Thetheory sections explain the main concepts and principles whichremain valid across technological evolutions of medicalinstrumentation The Implementation sections show how the theory istranslated into a medical product

The Electrocardiograph ECG or EKG is used as an example as it is a suitable device toexplore to fully understand medical instrumentation since it issufficiently simple but encompasses all the main areas involved indeveloping medical electronic equipment Key Features Introduces a system level approach to product design Covers topics such as bioinstrumentation signal processing information theory electronics software firmware telemedicine e Health and medical device certification Explains how to use theory to implement a market product usingECG as an example Examines the design and applications of main medicalinstruments Details the additional know how required for productimplementation business context system design projectmanagement intellectual property rights product life cycle etc Includes an accompanying website with the design of thecertified ECG product ahref http www gammacardiosoft it bookwww gammacardiosoft it book a Discloses the details of a marketed ECG Product from GammaCardio Soft compliant with the ANSI standard AAMI EC 11under open licenses GNU GPL Creative Common This book is written for biomedical engineering courses upper level undergraduate and graduate students and for engineersinterested in medical instrumentation device design with acomprehensive and interdisciplinary system perspective **Introduction to Mixed-Signal, Embedded Design** Alex Doboli,Edward H. Currie,2010-12-17 This textbook is written for junior senior undergraduate and first year graduate students in the electrical and computer engineering departments Using PSoC mixed signal array design the authors define the characteristics of embedd design embedded mixed signal architectures and top down design Optimized implementations of these designs are included to illustrate the theory Exercises are provided at the end of each chapter for practice Topics covered include the hardware and software used to implement analog and digital interfaces various filter structures amplifiers and other signal conditioning circuits pulse width modulators timers and data structures for handling multiple similar peripheral devices The practical exercises contained in the companion laboratory manual which was co authored by Cypress Staff Applications Engineer Dave Van Ess are also based on PSoC PSoC s integrated microcontroller highly configurable analog digital peripherals and a full set of development tools make it an ideal learning tool for developing mixed signal embedded design skills **Newark Electronics** ,2009 *ICCCE 2020* Amit Kumar,Stefan Mozar,2020-10-11 This book is a collection of research papers and articles presented at the 3rd International Conference on Communications and Cyber Physical Engineering ICCCE 2020 held on 1 2 February 2020 at CMR Engineering College Hyderabad Telangana India Discussing the latest developments in voice and data communication engineering cyber physical systems network science communication software image and multimedia processing research and applications as well as communication technologies and other related technologies it includes contributions from both academia and industry This book is a valuable resource for scientists research scholars and PG students working to formulate their research ideas and find the future directions in these areas Further it may serve as a reference work to understand the latest engineering and technologies used by practicing engineers in the field of communication engineering **CMBEBIH 2017** Almir Badnjevic,2017-03-14 This volume presents the

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