

Microcontroller Power Consumption Measurement Based on PSoC

Strahinja P. Janković, *Student Member, IEEE*, Vujo R. Džundarević, *Member, IEEE*

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 38%. 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

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Corresponding Strahinja P. Janković is Ph.D. candidate at the School of Electrical Engineering, University of Belgrade, Bul. kralja Aleksandra 75, 11120 Belgrade, Serbia (e-mail: jankovic@etf.bg.ac.rs)

Strahinja P. Janković and Vujo R. Džundarević are with the School of Electrical Engineering, University of Belgrade, Bul. kralja Aleksandra 75, 11120 Belgrade, Serbia.

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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Engineering Applications of Neural Networks Lazaros Iliadis, Ilias Maglogiannis, Serafin Alonso, Chrisina Jayne, Elias Pimenidis, 2023-06-06 This book constitutes the refereed proceedings of the 24th International Conference on Engineering Applications of Neural Networks EANN 2023 held in Le n Spain in June 2023 The 41 revised full papers and 8 revised short papers presented were carefully reviewed and selected from 125 submissions The papers are organized in topical sections on artificial intelligence computational methods ethology classification filtering genetic algorithms complex dynamic networks optimization graph neural networks convolutional neural networks spiking neural networks deep learning modeling deep machine learning in engineering LEARNING reinforcement federated adversarial transfer natural language recommendation systems

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Medical Instrument Design and Development Claudio Becchetti,Alessandro Neri,2013-05-20 This book explains all of the stages involved in developing medical devices from concept to medical approval including system engineering bioinstrumentation design signal processing electronics software and ICT with Cloud and e Health development Medical Instrument Design and Development offers a comprehensive theoretical background with extensive use of diagrams graphics and tables around 400 throughout the book The book explains how the theory is translated into industrial medical products using a market sold Electrocardiograph disclosed in its design by the Gamma Cardio Soft manufacturer The sequence of the chapters reflects the product development lifecycle Each chapter is focused on a specific University course and is divided into two sections theory and implementation The theory sections explain the main concepts and principles which remain valid across technological evolutions of medical instrumentation The Implementation sections show how the theory is translated

into a medical product The Electrocardiograph ECG or EKG is used as an example as it is a suitable device to explore to fully understand medical instrumentation since it is sufficiently simple but encompasses all the main areas involved in developing 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 using ECG as an example Examines the design and applications of main medical instruments Details the additional know how required for product implementation business context system design project management intellectual property rights product life cycle etc Includes an accompanying website with the design of the certified ECG product <http://www.gammacardiosoft.it/book> Discloses the details of a marketed ECG Product from GammaCardio Soft compliant with the ANSI standard AAMI EC 11 under open licenses GNU GPL Creative Commons This book is written for biomedical engineering courses upper level undergraduate and graduate students and for engineers interested in medical instrumentation device design with a comprehensive and interdisciplinary system perspective

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 12 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 proceedings of the International Conference on Medical and Biological Engineering held from 16 to 18 March 2017 in Sarajevo Bosnia and Herzegovina Focusing on the theme of Pursuing innovation Shaping the future it highlights the latest advancements in Biomedical Engineering and also presents the latest findings innovative solutions and emerging challenges in this field Topics include Biomedical Signal Processing Biomedical Imaging and Image Processing Biosensors and Bioinstrumentation Bio Micro Nano Technologies Biomaterials Biomechanics Robotics and Minimally Invasive Surgery Cardiovascular Respiratory and Endocrine Systems Engineering Neural and Rehabilitation Engineering Molecular Cellular and Tissue Engineering Bioinformatics and Computational Biology Clinical Engineering and Health Technology Assessment Health Informatics E Health and Telemedicine Biomedical Engineering Education Pharmaceutical Engineering

Introduction to Mixed-Signal, Embedded Design Alex Doholi, 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 embedded 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

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Designer's Guide to the Cypress PSoC Robert Ashby, 2005-09-08 This is the first technical reference book available on the PSoC and it offers the most comprehensive combination of technical data example code and descriptive prose you will find anywhere Embedded design expert Robert Ashby will guide you through the entire PSoC world providing thorough coverage of device feature design programming and development of the software reconfigurable PSoC He shares his best tips tricks and techniques that will help you to utilize the flexible and inexpensive PSoC to its greatest potential with a minimum of heartaches and late nights With its emphasis on designing for adaptability a feature of the utmost importance in today's fast paced and cost pressured design cycles this book will bring you up to speed quickly on everything PSoC from memory management to interconnects You will add brains and capable signal conditioning to a design with one chip giving you

extreme flexibility for a relatively low price Specific application examples highlighting the PSoC s unique capabilities are included throughout the text with the supporting sample source code The first independent technical reference available on the PSoC a product line experiencing explosive growth in the embedded design world Application examples sample code and design tips and techniques will get readers get up to speed quickly Design and Evaluation of Tool Extensions for Power Consumption Measurement in Parallel Systems Timo Minartz,2013

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