# Microcontroller Power Consumption Measurement Based on PSoC

Strahinja P. Janković, *Student Member, IEEE*, Vujo R. Drndarević, *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 5LP 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 5LP 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

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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 5LP), 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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**Robert Ashby**

**Microcontroller Power Consumption Measurement Based On Psoc:**

**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 reinforcemet federated adversarial transfer natural language recommendation systems *World Congress on Medical Physics and Biomedical Engineering September 7 - 12, 2009 Munich, Germany* Olaf Dössel,Wolfgang C. Schlegel,2010-01-04 Present Your Research to the World The World Congress 2009 on Medical Physics and Biomedical Engineering the triennial scientific meeting of the IUPESM is the world s leading forum for presenting the results of current scientific work in health related physics and technologies to an international audience With more than 2 800 presentations it will be the biggest conference in the fields of Medical Physics and Biomedical Engineering in 2009 Medical physics biomedical engineering and bioengineering have been driving forces of innovation and progress in medicine and healthcare over the past two decades As new key technologies arise with significant potential to open new options in diagnostics and therapeutics it is a multidisciplinary task to evaluate their benefit for medicine and healthcare with respect to the quality of performance and therapeutic output Covering key aspects such as information and communication technologies micro and nanosystems optics and biotechnology the congress will serve as an inter and multidisciplinary platform that brings together people from basic research R D industry and medical application to discuss these issues As a major event for science medicine and technology the congress provides a comprehensive overview and in depth first hand information on new developments advanced technologies and current and future applications With this Final Program we would like to give you an overview of the dimension of the congress and invite you to join us in Munich Olaf D ssel Congress President Wolfgang C *EDN* ,2008 Biotechnology: Concepts, Methodologies, Tools, and Applications Management Association, Information Resources,2019-06-07 Biotechnology can be defined as the manipulation of biological process systems and organisms in the production of various products With applications in a number of fields such as biomedical chemical mechanical and civil engineering research on the development of biologically inspired materials is essential to further advancement Biotechnology Concepts Methodologies Tools and Applications is a vital reference source for the latest research findings on the application of biotechnology in medicine engineering agriculture food production and other areas It also examines the economic impacts of biotechnology use Highlighting a range of topics such as pharmacogenomics biomedical engineering and bioinformatics this multi volume book is ideally designed for engineers pharmacists medical

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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        **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 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 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     Proceedings of the Multi-Conference 2011 Himanshu B. Soni,Apurva Shah,2011-06-06 The International Conference on Signals Systems and Automation ICSSA 2011 aims to spread awareness in the research and academic community regarding cutting edge technological advancements revolutionizing the world The main emphasis of this conference is on dissemination of information experience and research results on the current topics of interest through in depth discussions and participation of researchers from all over the world The objective is to provide a platform to scientists research scholars and industrialists for interacting and exchanging ideas in a number of research areas This will facilitate communication among researchers in different fields of Electronics and Communication Engineering The International Conference on Intelligent System and Data Processing ICISD 2011 is organized to address various issues that will foster the creation of intelligent solutions in the future The primary goal of the conference is to bring together worldwide leading researchers developers practitioners and educators interested in advancing the state of the art in computational intelligence and data processing for exchanging knowledge that encompasses a broad range of disciplines among various distinct communities Another goal is to promote scientific information interchange between researchers developers engineers students and practitioners working in India and abroad     **Electronic Design** ,2002     EDN, Electrical Design News ,2003     *APEC 2002* ,2002     **F & S Index United States Annual** ,2007     *Microcontroller Based Power Consumption Monitoring System* Muhammad Khairin Mohd Taib,2017     Designer's Guide to the Cypress PSoC Robert Ashby,2005-09-08 This it 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 ll 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

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