Demo Abstract: RocketLogger - Mobile Power Logger for Prototyping IoT Devices

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ABSTRACT

We demonstrate the RocketLogger, a mobile data logger designed for prototyping energy harvesting IoT devices. Novel IoT applications require new dataloggers with a highly increased dynamic range for current measurement to accommodate both ultra-low sleep currents of few nanoamperes as well as wireless communication currents in the range of hundreds of milliamperes. In parallel to ultra-low currents and high dynamic range measurements, novel applications require mobile measurements for easy in-situ characterization or wearable device testing. The RocketLogger is a solution that fulfills these requirements. While being fully mobile, it measures currents from 5 nA up to 500 mA with very fast and seamless range-switching. Using a sample energy harvesting application, we demonstrate its low-current measurement capabilities, fast, seamless auto-ranging and easy-to-use remote user interface.

1. INTRODUCTION

Energy harvesting is seen as a key long-term technology to power the billion devices in the emerging IoT, since batteries alone are too limited, expensive and require too much maintenance. To efficiently integrate energy harvesting techniques, system designers need to address both hardware and software issues, since dimensioning energy buffers depends on both. Measurements are an important tool for prototyping and characterizing these new energy harvesting applications at several steps in the design process. Profiling the used energy harvesting source is necessary for simulating early design. Measurements on first prototypes characterize application performance and energy requirements, and finally, in-situ measurements are required for evaluation and validation of first real-world deployments.

Commonly used low power architectures support several power states to save energy, drawing nanoamperes in sleep state and up to hundreds of milliamperes in active state. Characterizing these systems is challenging, because current measurement devices need to be accurate over a large dynamic range of eight orders of magnitude or more. Moreover, novel energy harvesting applications that rely on devices embedded into the environment, e.g. smart buildings, demand for portable data loggers for in-situ characterization of their energy harvesting sources. Similarly, characterization and evaluation of wearable devices such as smartwatches require portable measurement equipment.

To best of our knowledge, none of today's data logger provides all of these features. While existing solutions focus on a subset of these new requirements, they lack ultra-low current measurement in the nanoampere range [1, 2, 3], do not feature the desired dynamic range from below micro- up to hundreds of milliamperes [2, 4, 5, 6], or do not target portable measurements with remote control [3, 5].

To address the needs of system-level designers, we propose a new data logger design. The RocketLogger not only features a very large dynamic current measurement range of more than 165 dB, but at the same time has a small form factor suitable for mobile measurement and provides remote data acquisition control.

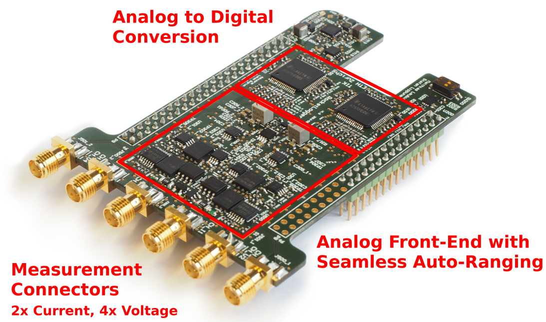

Figure 1: The RocketLogger hardware design with its basic hardware components labeled.

2. ARCHITECTURE

The RocketLogger is based on the BeagleBone Black and consists of two parts: an analog measurement front-end extension including seamless auto-ranging and the software for acquisition management and control. The most relevant performance metrics of the RocketLogger are summarized in Table 1.

Analog Measurement Front-End. Low power techniques have greatly increased the power range between an active device and one in a sleep state, currently up to eight orders of magnitude. No single measurement circuit can

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Table 1: Performance Characteristics of the RocketLogger. Noise was characterized at 1 kSPS sampling rate.

Component	Metric	Range/Value
General	Sampling Rate	1 kSPS to 64 kSPS
Current Channel	Measurement Range	±500 mA
	Total Dynamic Range	165 dB
	Burden Voltage at 500 mA	47 mV
	Noise High Current Range	1.27 µA RMS
	Low Current Range	±2 mA
	Noise Low Current Range	5.42 nA RMS
	Range Switching Time	1.5 µs
Voltage Channel	Measurement Range	±5.5 V
	Noise	7.97 µV RMS
	Input Impedance	> 1 TΩ

accurately and efficiently measure current over this range. A shunt resistor based circuit either results in an intolerable high burden voltage in the high current region or a tiny voltage drop that gets lost in the measurement noise. Feedback ammeter circuits have excellent performance in measuring low current, but they saturate if high currents are out of range and create an uncontrolled burden voltage. Combining two circuits to cover the full measurement range of more than eight orders of magnitude results in the difficult problem of switching these circuits efficiently and seamlessly. To solve this challenge we propose a novel circuit which combines two well-known circuits, the shunt resistor based circuit for high current measurement and the feedback ammeter based circuit for low current measurements [7]. This results in a precision of 5.42 nA for currents of < 2 mA using the feedback ammeter circuit. For higher currents, the shunt resistor circuit measures up to 500 mA with a noise floor of 1.27 µA. By integrating range switching in the analog front-end, the switching time is 1.5 µs, one order of magnitude less than the sampling interval at the maximum sampling rate of 64 kSPS. The burden voltage remains below 47 mV for DC measurements and reaches a maximum of 200 mV for less than 1.5 µs in the extreme measurement of a current step from 0 to 500 mA. In addition to current measurements, the RocketLogger also features four voltage measurement channels with a range of ±5.5 V and a noise floor of less than 10 µV.

Acquisition Management. The software stack of the RocketLogger is responsible for initiating, controlling, and observing the analog-to-digital converters (ADC) and processing their conversion results. To process the large amount of data of up to 10.8 GB per hour in real-time, the low-latency real-time unit of the BeagleBone's CPU is used.

3. DEMONSTRATION

To demonstrate the low current measurement capabilities, a sample energy harvesting node is measured. The setup consists of three parts, as illustrated in Figure 2: (1) a solar panel as source, (2) an Energy Management Unit (EMU) for harvesting and energy management, and (3) a sensor node. The RocketLogger is used to track the power harvested from the solar panel, the sensor node's power consumption, and the capacitance voltage inside the EMU.

Behavior and Measurement. On the energy supply side, the input power harvested by the EMU is measured. This allows recording the real-world power trace for later simulation or new design of a harvesting circuit. While the blinky node remains in deep-sleep, the EMU accumulates energy in a small buffer capacitance. During this phase the node's sleep current of only 20 nA is measured, showing the ultra-low current measurement capabilities of the RocketLogger. Once enough energy for task execution has been accumulated, the node is triggered to wake up. As a result, the node's current consumption jumps to 4 mA. The very fast transition between sleep and active states and the more than five orders of magnitude difference in current consumption in this example show the importance of a fast and seamless auto-ranging as offered by the RocketLogger. After completing task execution, the node goes back to sleep and waits until its next activation. More details about the EMU design is found in [8].

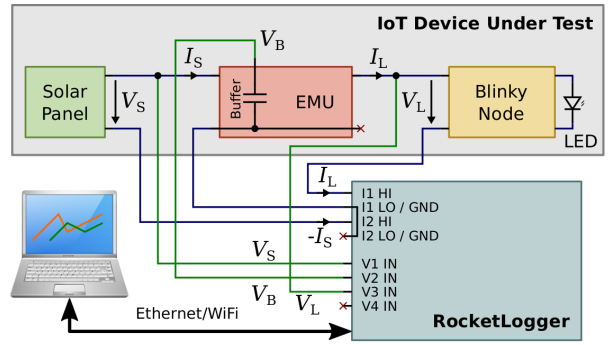

Figure 2: The energy harvesting setup to demonstrate the low-current measurement and range-switching capabilities.

All measurements are displayed using the remote web interface of the RocketLogger. This gives the user the possibility to track the power traces of the harvesting blinky setup in parallel to observing its behavior. This demo showcases the low current measurement capabilities, the fast and seamless auto-ranging and the small size for mobile measurements of the RocketLogger. The combination of precise high-dynamic range measurements, a mobile form factor, and an easy-to use user interface makes the RocketLogger a versatile measurement instrument for prototyping harvesting powered IoT devices.

4. ACKNOWLEDGMENTS

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