Demo Abstract: Building Battery-free Devices with Riotee*

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ABSTRACT

Battery-free devices eliminate the need for batteries, which are expensive, environmentally harmful, and require frequent replacement, thus reducing waste and making devices more cost-effective. We introduce Riotee, the next-generation platform for the battery-free Internet of Things. The platform comprises a base module, a debug probe that allows to conveniently update the firmware on the base module, and a number of expansion boards that extend the capabilities of the platform without the need to design a custom printed circuit board (PCB). We provide a brief overview of Riotee, and describe a demo setup that showcases the key functionality and how to get started with the platform in less than three minutes.

CCS CONCEPTS

• **Computer systems organisation → Sensor networks**; **Sensors and actuators**; **Embedded software**.

KEYWORDS

battery-free, intermittent computing, transient computing, energy harvesting, intermittent networking

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1 INTRODUCTION

New programming abstractions [4] and solutions for peripheral state retention [5] and networking [2] are pushing the boundaries of what battery-free devices can accomplish. Most works use development boards without harvesting capabilities or design custom battery-free hardware tailored to the specific requirements of the project. The few existing general-purpose platforms [1, 3] are well suited for prototyping, but sacrifice small size for versatility and are difficult to setup for beginners.

With Riotee we set out to establish a common and well documented battery-free platform for both prototyping and real-world deployments. The Riotee Board (Figure 1) and a selection of stacking boards make it easy to build battery-free prototypes. The open-source software that comes with the platform can be installed with a few mouse clicks and supports intermittent computing and basic networking. After prototyping, the same module that sits on the Riotee board can be soldered onto a custom PCB together with sensors and peripherals to build a small production-ready device.

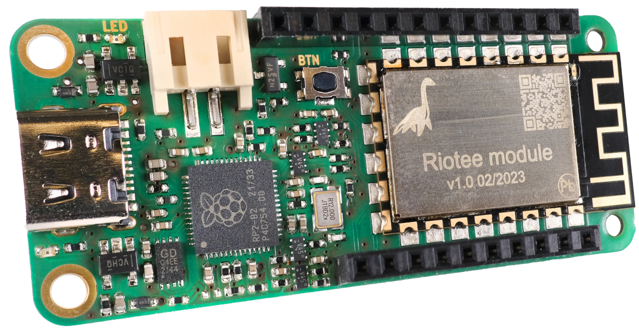

Figure 1: The Riotee Board is a self-contained development board for battery-free devices. It allows to conveniently program the nRF52833 and the MSP430FR5962 onboard the Riotee Module from the Arduino IDE.

2 HARDWARE

Riotee Module. Figure 2 illustrates the block diagram of the Riotee Module. A boost charger with maximum power point tracking transfers energy from an attached harvester to the on-board capacitor. Two comparators monitor the capacitor voltage against two software-defined voltage thresholds and notify the software of an impeding power failure. The module has two fully programmable microcontrollers that are connected via a 4-wire SPI bus and share access to all other components of the system: The Nordic Semiconductor nRF52833 has a 64 MHz Cortex-M4 CPU with a floating point unit and a low-power 2.4 GHz wireless radio. The TI MSP430FR5962 has 128 kB of non-volatile FRAM for retaining application state across power failures. Application and networking code can run on the powerful nRF52 and retain application state across power failures using the MSP430 as non-volatile co-processor. Alternatively, application code can run on the MSP430 and use the nRF52 as wireless co-processor. When idling with timekeeping and capacitor voltage monitoring enabled, the Riotee module draws 4 µA. In the deepest sleep mode, the current draw ranges below 0.1 µA.

Riotee Probe. The power from a harvester is often insufficient for programming the device, and the leakage through the programming pins can interfere with battery-free operation. The Riotee Probe is a programming dongle that connects to the Riotee Module through a number of analog switches. During programming, the switches

*https://riotee.nessie-circuits.de

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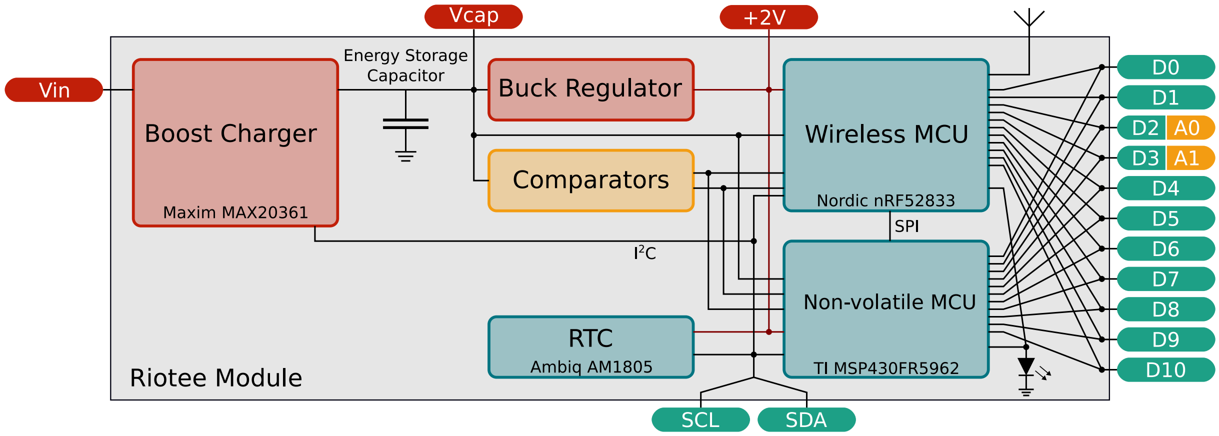

Figure 2: The Riotee module integrates energy harvesting, energy storage, power management, non-volatile memory, a powerful Cortex-M4 processor, and a 2.4 GHz BLE-compatible radio into a tiny module with the footprint of a stamp.

are closed and the module is supplied with a constant voltage. After programming all connections between the probe and the target are cut, and the device continues to operate from harvested energy.

Riotee Board. The Riotee Board combines a Riotee Module, the Riotee Probe's circuitry, a push button, and an LED on a single PCB.

Expansion Shields. In addition, we provide several shields that plug into the expansion headers of the Riotee Board. The Solar Shield adds four small solar panels, the Capacitor Shield extends the on-board capacitance, and the Sensor Shield adds a microphone, a temperature sensor, a humidity sensor, and an accelerometer.

3 BATTERY-FREE RUNTIME

Our open-source runtime executes user code as a FreeRTOS task on the nRF52. When the comparator on the Riotee Module indicates low capacitor voltage, a high-priority system task preempts the user task. During this context switch, the FreeRTOS kernel automatically stores all registers on the user stack. The system task copies the user stack and all global and static variables to the MSP430's non-volatile memory over the SPI bus, and puts the system into a low-power sleep mode. When the capacitor voltage rises above a turn-on threshold, the user task is resumed and execution continues. Even after power supply interruptions, the application state is restored from non-volatile memory as soon as energy is available again.

4 DEMO SETUP

Figure 3 shows the demo setup, a video is available at https://tinyurl.com/33d4w5nv. It consists of a Riotee Solar Shield, a Riotee Board, a laptop, and a smartphone. We showcase how to get started with Riotee in less than three minutes. This includes installing the toolchain and runtime in the Arduino IDE, and uploading a sketch to the Riotee board. Next, we demonstrate a battery-free application that counts the number of charging cycles and repeatedly transmits the current counter value using the nRF52's Bluetooth Low Energy (BLE) radio to the smartphone. An app on the smartphone displays the last received counter value. We cover the solar panels until the on-board capacitor discharges and a power failure occurs. After uncovering the panels, the device automatically restores the application state from non-volatile memory. On the smartphone, visitors of the demo can observe the counter incrementing from the last value before the power failure.

Figure 3: The demo shows how to get started with Riotee and its key functionality, video at https://tinyurl.com/33d4w5nv.

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