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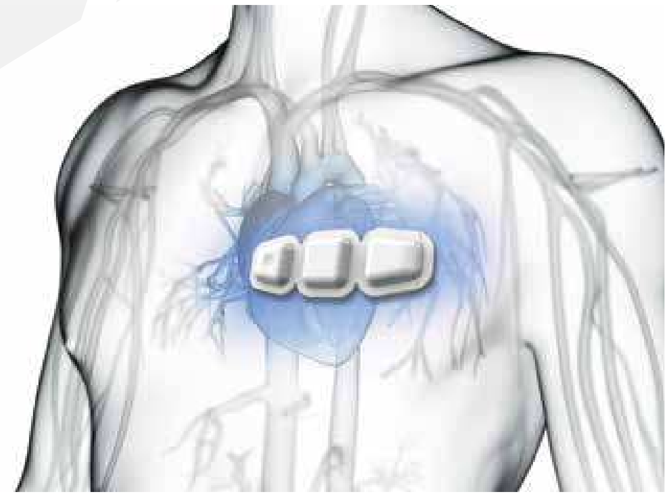
complex problems inspired solutions



Medical Device Heart Monitor

• August 2013 - April 2015

Objectives

• Add ECG analysis, plus detection and logging of interesting cardiac events, to an existing ECG recorder
• Optimize firmware to extend battery life from 24 hours to 7 days

Approach

• Applied analysis and testing to characterize device energy use and identify targets for energy optimization
• Optimized the firmware implementation to reduce energy use while maintaining algorithm performance

Results

• The finished system exceeded lifetime requirements, and received FDA approval to go to market
• Low power, long-term Electrocardiogram (ECG) recording and analysis tested against the ANSI/AAMI EC57 standard

"Making a device wearable almost inevitably means that the device must be battery-powered, which makes managing the energy budget of the device a key concern."

A Complete Product Development Partner

- Brainstorming and Concept Generation
- Feasibility Studies and System Architecture
- Detailed Product Design
- Prototyping
- Design for Manufacturing (DFM)
- Verification Testing
- Manufacturing Assembly and Test Equipment
- Sustaining Engineering

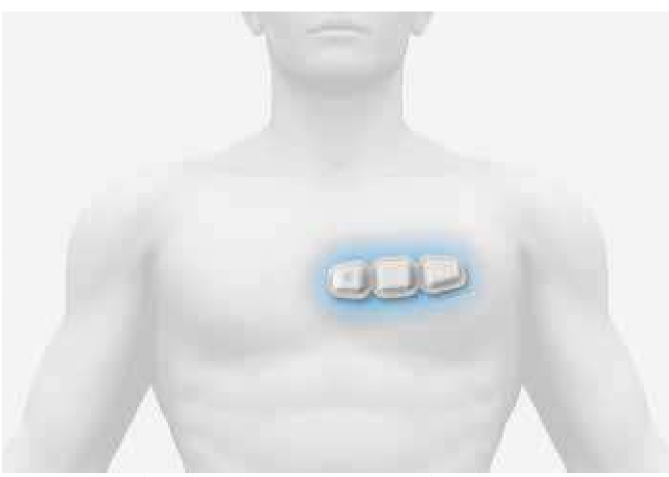
Summary

Wearable medical devices are a growing market segment in the medical device industry. A device that the patient can wear as they go about their daily life enables gathering data that is simply not available during a brief visit to a clinic or doctor's office. However, making a device wearable almost inevitably means that the device must be battery-powered, which makes managing the energy budget of the device a key concern.

Complex Problems

Syncroness was tasked with modifying the design for an existing wearable ECG data recorder to extend its battery life from 24 hours to 7 days, while at the same time adding the capability to perform real-time analysis on the ECG waveform to detect various kinds of interesting cardiac events. The constraints on the project were such that there was little opportunity for changing the hardware design or batteries. As a consequence, any additional battery life had to come from optimization of the firmware to reduce the amount of time that the microcontroller is awake and consuming power, and to minimize the frequency or duration of operations that have a high energy cost.

Battery life had to come from optimization of the firmware



Inspired Solutions

The Syncroness team began by conducting an analysis to understand which parts of the firmware were execution-time and energy consumption hotspots, along with preliminary testing of the device to characterize its power consumption profile. The analysis and testing quickly revealed that, although the new detection algorithms had initially been a concern, they were not a major contributor to power consumption since their high computational cost was offset by their relatively infrequent execution. The analysis and testing showed that acquiring and processing individual ECG samples, despite being a small amount of code, was the single largest contributor to power consumption due to its frequent execution. The next largest contributor to power consumption was writing ECG data to Flash, both due to the amount of time that operation kept the microcontroller awake during a write and the frequency with which writes occurred.

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Syncroness software engineers tackled the task of reducing power consumption by applying a variety of different optimization techniques. To achieve large gains, we worked with the customer to migrate towards ECG processing algorithms that could operate at a lower sample rate, reducing the frequency with which the processing algorithms were executed and reducing the frequency of writing ECG data to Flash. These steps achieved a substantial reduction in average current consumption, but not enough to meet the target battery life. To save additional energy, and reach our battery life goal, we applied targeted optimizations to further reduce the computational cost of ECG processing and Flash writes, such as:

- Simplifying the state-machine logic to reduce the number of operations performed in the ECG data sampling mode
- Modifying the way Flash writes were managed to allow the microcontroller to sleep during lengthy write operations
- Reorganizing ECG processing logic to avoid unnecessary branching
- Resizing integer variables to represent the full range of required values while minimizing the number of instructions required to manipulate those values
- Unrolling loops to reduce loop-management overhead
- Converting the digital filters used during ECG processing into more efficient realizations
- Trading space for speed to simplify computations at the cost of slightly higher RAM usage

Throughout the optimization process we performed regular testing against the ANSI/AAMI EC57 standard for Testing and Reporting Performance Results of Cardiac Rhythm and ST Segment Measurement Algorithms to confirm that we were maintaining the performance of the ECG detection and processing algorithms. We also measured on actual hardware the difference in power consumption created by each proposed optimization to ensure that the changes we were making had their intended effect. The end result of these optimization efforts was an extension of the device lifetime from 24 hours to 7 days without changing the battery capacity and without compromising device performance.

About Syncroness

For more than 18 years, Syncroness has provided inspired solutions to highly complex business and technical problems. The company has a strong portfolio of clients in the medical device, aerospace, and industrial equipment industries. By providing a full complement of engineering services aligned to the entire product lifecycle, Syncroness enables companies to accelerate product development and drive more predictability and productivity into their businesses. Working with Syncroness, companies gain the critical insights necessary to develop products that make a difference and create a better world.

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