ECEN-5833

Low Power Embedded Design Techniques

Project Proposal

*Fitness Performance Tracking Vest*

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# Performance Tracker

We’ll be designing and developing a GPS performance tracker which will measure important performance stats for most sports activities. From a demanding scenic trek to any high intense sports game and provide you an insight of your performance.

It will include the following statistics:

* Current Heart Rate
* Maximum Heart Rate
* Blood Oxygen
* Total Distance
* Altitude, Acceleration
* Max Speed
* No. of Laps/Sprints
* Calories.

# Why this?

Performance tracking devices provide a level of individual performance analysis that far surpasses anything coaches and athletes from previous generations were familiar with. The advantages to early adopters of this technology are enormous. Individuals can keep a track of their fitness and get an in-depth understanding of strengths and weaknesses. This knowledge, put together with the right training can do wonders.

**Managing Workload**

For emerging athletes, consistent and intelligent training is crucial for long-term success, particularly for those aspiring to college-level sports and beyond. Field sports like soccer, football, and baseball demand skill development through year-round, focused training. However, overtraining poses risks to athletes and teams. With performance tracking technology, coaches can now make data-driven decisions to balance intensity and rest, ensuring peak performance on game days.

**Injury Reduction**

Injuries are a significant concern for athletes and teams, especially when they result from preventable factors, such as risky training practices. Performance tracking offers valuable insights into determining suitable training thresholds, preventing overexertion, and managing fatigue and stress during games and practices.

# Block Diagram

A diagram of a computer system

Description automatically generated

Figure 1: High Level Block Diagram

# Microprocessor and Sensor Selection

## EFR32 Blue Gecko

The EFR32 Blue Gecko is a ARM Cortex-M4 based family of wireless system-on-chip (SoC) devices used as an energy-efficient solution for wireless communication and IoT applications.

|  |  |
| --- | --- |
| **Operating Parameters** | **Range** |
| Power Supply Voltage | 1.8V – 3.8V |
| Wireless Connectivity | Bluetooth Low Energy (BLE), Zigbee, Thread |
| Peripherals | GPIO pins, UARTs, SPI, I2C, timers, and analog interfaces |
| Power Modes | active, sleep, deep sleep, and hibernate, (EM0 – EM3) |
| Operating Temperature Range | -40°C to +85°C |

## 

## Heart Rate & Pulse Oximeter Sensor, *MAX30102*

The MAX30102 is used to measure both heart rate and oxygen saturation (SpO2). It works by emitting and detecting infrared light through the skin, measuring variations in light absorption due to blood flow, and using this information to calculate heart rate and SpO2 levels in wearable fitness devices. It plays a crucial role in monitoring the wearer's health and fitness parameters in real-time.

|  |  |
| --- | --- |
| **Operating Parameters** | **Range** |
| Power Supply Voltage | 3.3V – 5V |
| Communication Interface | I2C |
| Capability of heart rate measurement | 30BPM – 200BPM |
| Oxygen Saturation Measurement | 70% - 100% |
| Sampling Rate | 50Hz – 1KHz |
| Operating Temperature Range | -40°C to +85°C |

## Accelerometer, LIS3DH Triple-Axis

The LIS3DH is a triple-axis accelerometer sensor used for motion sensing. Here are the working requirements and specifications of the LIS3DH Triple-Axis module:

|  |  |
| --- | --- |
| **Operating Parameters** | **Range** |
| Power Supply Voltage | 1.71V – 3.6V |
| Communication Interface | I2C/SPI |
| Measurement Axes | Three orthogonal axes: X, Y, and Z |
| Acceleration Range | 70% - 100% |
| Operating Temperature Range | -40°C to +85°C |

## GPS Module, GPS NEO-6M

The GPS NEO-6M module is used for obtaining accurate location and time information. Here are the working requirements and specifications of the NEO-6M GPS module:

|  |  |
| --- | --- |
| **Operating Parameters** | **Range** |
| Power Supply Voltage | 3.3V – 5V |
| Communication Interface | UART |
| Operating Temperature Range | -40°C to +85°C |

# Product Features

* Free and easy to use Vest Mobile Application which enables the user to track the cardinal parameters related to human body (heartbeat rate and blood oxygen levels) and movement (speed, altitude, location) while performing any physical activity.
* Load power management would be implemented though software based on sensory data, such that, components consume as low power as possible.
* The device can run on rechargeable batteries, and it would also support charging over solar energy as a part of energy harvesting.
* If threshold values of heartbeat or oxygen levels are crossed above or below limits, the mobile app will support notifying the user with a warning.

# **Update 1: Week 3**

## **Proposal Feedback Questions**

1. I would like to know how often you plan on sampling your sensors and how often you are going to get GPS positioning?
   * We intend to sample each of the devices to ensure that new data becomes available every 10 seconds, aligning with our initial concept of transmitting data packets at this specific interval.
2. How are you going to implement load power management?
   * If the component under consideration supports low power or sleep mode with some condition/threshold, it will be incorporated for load power management, else the module’s switching will be controlled by the software based on required conditions.
3. Under features, it’s stated load power management will be implemented through software based on sensory data, but is there a low power mode on your GPS module?

* Yes, SAM-M8Q has two low power modes out of which we will be using “Cyclic Tracking” mode which can sample data every 1 – 10 seconds.

1. Does your MAX30102 have a shutdown mode?

* Yes, the MAX30102 sensor does have a shutdown mode. Its shutdown mode allows us to conserve power when the sensor is not actively needed, which is especially important in battery-operated devices.
* In shutdown mode:
* LEDs Turn Off: The MAX30102's LED drivers, which are used for emitting light into the skin to measure pulse and oxygen levels, are turned off. This significantly reduces power consumption as the LEDs are one of the most power-hungry components of the sensor.
* Sensor Functions Pause: The sensor's data acquisition and processing functions are paused. It stops collecting and processing data, which further reduces power consumption.
* Registers Retain Data: The sensor retains its configuration settings and previous data in its registers during shutdown. This means that when you exit shutdown mode and power it up again, you can resume data collection with the same settings.
* To exit shutdown mode and bring the MAX30102 back into active operation, you typically need to write to the sensor's control registers to configure its mode of operation (e.g., heart rate or SpO2 mode) and start data acquisition.

1. How long do you expect your product to run (how long of a workout can it track before you need to charge it)?
   * As per initial estimations and design ideas, we plan to have battery that can keep the device up for at least 5 hours.
2. You mention an LCD in your indicators box, are you planning on implementing an LCD (think about your physical product specifications)?

* The indication segment of the Block Diagram presented potential choices, but our current plan does not involve incorporating an LCD into the device. Instead, the device will feature status LED(s).

1. Also, please elaborate on your ideas for your mobile/web application (high level).

* GUI Development Platform Considerations: Python/MIT App Inventor/Android Studio
* App Features:

Application will display following health, fitness & location parameters:

* + Heart rate
  + Blood Oxygen Level
  + Calories Burnt
  + Distance Covered
  + Location
  + Altitude
  + Motion Speed
  + Total activity time
  + Type of activity
* User will have to set a profile during App initialization.
* User Profile Parameters:
  + Profile name
  + Gender
  + Age
  + Height
  + Weight
* App will be integrated with the fitness tracking vest through wireless communication protocol – Bluetooth.
* Real-time data synchronization between the vest and the app

### **Past Week Progress**

|  |  |  |
| --- | --- | --- |
| **Sr. No.** | **Task** | **Date** |
| 1. | Sensor selection Verification | 09/11/2023 |
| 2. | GPS sensor change based on specifications | 09/12/2023 |
| 3. | Detailed study of sensor datasheets | 09/14/2023 |
| 4. | Sensor working modes | 09/14/2023 |
| 5. | Study and analysis of power consumption of each sensor and microcontroller | 09/15/2023 |
| 6. | Load power management design | 09/16/2023 |
| 7. | Storage element inclusion decision | 09/16/2023 |

### **Plan for Next Week**

|  |  |  |
| --- | --- | --- |
| **Sr. No.** | **Task** | **Planned Date of completion** |
| 1. | Deciding basic process flow algorithm | 09/18/2023 |
| 2. | Study: Basic Converters and Regulators | 09/20/2023 |
| 3. | Study: PMIC and decide suitable one for our application | 09/20/2023 |
| 4. | Components library creation in Altium | 09/22/2023 |
| 5. | Study: App Development | 09/23/2023 |
| 6. | Study: Health Parameters monitoring | 09/24/2023 |

### **Gantt Chart**

Please access the Gantt Chart [here](https://docs.google.com/spreadsheets/d/1KaPb1-7P7Jsq5lPKC4ED-a-X1ax_88Hf/edit?usp=sharing&ouid=111181014121170282160&rtpof=true&sd=true).

### **Support needed for following tasks/decisions**

* Power Consumption Analysis
* Energy Harvesting Specifications
* Review of Process algorithm

## **Why these Sensors?**

### **LIS3DH**

* LIS3DH is a 3-axis accelerometer, measuring acceleration along the X, Y, and Z axes. The primary reasons to use this for our application are following:
  + Known for low power consumption, suitable for battery-powered devices and applications where power efficiency is critical and can help in load power management of our device.
  + Provides good resolution to capture a wide range of accelerations accurately.
  + Supports both I2C and SPI communication interfaces with transaction cycles in the range of microseconds and nanoseconds respectively.

### **MAX30102**

* The selection between the MAX30101 and MAX30102 sensors was deliberated. In cases where exclusive heart rate monitoring suffices, the MAX30101 could be deemed adequate and economically advantageous. Nevertheless, for our application precise SpO2 measurements are necessitated for a broad spectrum of scenarios, the MAX30102 emerges as the favored option owing to its dual-LED configuration and enhanced accuracy.

### **SAM-M8Q**

* Initially, the NEO-6M GPS module was considered, but following thorough research, we opted for the SAM-M8Q GPS module due to its superior features and benefits compared to the former.

|  |  |  |  |
| --- | --- | --- | --- |
| Parameters | SAM-M8Q | NE0-6M | MAX-M10S |
| Integrated Antenna | ✓ | 🗶 | 🗶 |
| Odometer | ✓ | 🗶 | ✓ |
| Tracking Channels | 72 | 50 | 56 |
| Dynamics | ≤4 g | ≤4 g | ≤ 4 g |
| Altitude | 50,000 m | 50,000 m | 80,000 m |
| Velocity | 500 m/s | 500 m/s | 500 m/s |
| VCC Max | 3.6 | 3.6 | 3.6 |

Table 1: GPS module selection based on key specifications

## **Use Case Model**

### **Power Consumption**

The following data regarding current consumption at specific voltage levels as per datasheet was used to determine an estimate of total power usage and which energy modes would the device operate at any instant. All these values are based on specific operating environments from datasheets, and thus the actual consumption based on time periods (power on, stabilizing time, data transfer, sleep/wake) would vary once the measurements are made using the actual sensor and the microcontroller.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  |  | **Current (uA)** | **Voltage** | **Power (uW)** |
| **Interfaces** | MAX30102 (HR and SpO2) |  |  |  |
| HR + SpO2 Mode | 1200 | 5 | 6000 |
| HR Mode | 1200 | 2 | 2400 |
| Standby Mode | 0.7 | 1.7 | 1.19 |
| LIS3DH (Accelerometer) |  |  |  |
| Normal Mode @50 HZ ODR | 11 | 2.5 | 27.5 |
| Normal Mode @1 HZ ODR | 2 | 2.5 | 5 |
| Low Power Mode @50 HZ ODR | 6 | 2.5 | 15 |
| SAM-M8Q (GPS) |  |  |  |
| Continuous Mode | 23000 | 3 | 69000 |
| Cyclic Tracking (@ 1Hz) | 9500 | 3 | 28500 |
| Max Supply Current (@1Hz) | 67000 | 3 | 201000 |

Table 2 2: Power Consumption for Interfacing Devices

For the microcontroller, since it has an onboard Bluetooth module, and the radio would not work beyond EM1 mode, the following current consumption data is available from the datasheet:

|  |  |  |  |
| --- | --- | --- | --- |
| **Energy Modes** | **Typical Current Consumption (uA)** | **Voltage** | **Power (uW)** |
| EM0 | 128 | 3.3 | 422.4 |
| EM1 (all peripherals disabled) | 76 | 3.3 | 250.8 |
| EM1 (with Radio) | 9500 | 3.3 | 31350 |
| EM2 | 2.2 | 3.3 | 7.26 |
| EM3 | 1.5 | 3.3 | 4.95 |
| EM4 | 0.4 | 3.3 | 1.32 |
| EM4 Sleep | 0.08 | 3.3 | 0.264 |

Table 3 3: Power Consumption for Microcontroller

### **Energy Mode Analysis**

According to the initial proposal and brainstorming, we plan to transmit the data packets every 10 seconds to the mobile application over Bluetooth. As per the reference manual of EFR32BG13, the device supports active radio transmission only until EM1 mode. Therefore, based on power consumptions, reference manual data and initial brainstormed sampling rate for data transfers, the device would always be in either **Active Mode, EM0 or EM1 energy modes**. But, with load power management, the current consumption at any instant can be lowered for the time when no new reading of sensory data is required or using sensor’s internal low power feature.

# **Update 2: Week 4**

### **Past Week Progress**

|  |  |  |  |
| --- | --- | --- | --- |
| **Sr. No.** | **Task** | **Planned Date of completion** | **Actual Date of Completion** |
| 1. | Deciding basic process flow algorithm | 09/18/2023 |  |
| 2. | Study: Basic Converters and Regulators | 09/20/2023 |  |
| 3. | Study: PMIC and decide suitable one for our application | 09/20/2023 |  |
| 4. | Components library creation in Altium | 09/22/2023 |  |
| 5. | Study: App Development | 09/23/2023 |  |
| 6. | Study: Health Parameters monitoring | 09/24/2023 |  |

### **Plan for Next Week**

|  |  |  |
| --- | --- | --- |
| **Sr. No.** | **Task** | **Planned Date of completion** |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |

### **Gantt Chart**

Please access the Gantt Chart [here](https://docs.google.com/spreadsheets/d/1KaPb1-7P7Jsq5lPKC4ED-a-X1ax_88Hf/edit?usp=sharing&ouid=111181014121170282160&rtpof=true&sd=true).

### **Support needed for following tasks/decisions**

### **Energy Storage Element and PMU(s)**

Energy Storage element: Battery. Why?

A screenshot of a chart

Description automatically generated

Battery -> Energy Dense, LIBs, in particular, accomplish some of the industry’s highest energy densities at up to 650 watt-hours per liter (Wh/L). On the other hand, supercapacitors exhibit only 15 percent of this energy density, with high-end supercapacitors at 10 Wh/L. This is the main reason why batteries continue to be leveraged in applications that require higher storage capacity, such as electric cars, grid storage, and renewable energy storage. Batteries generally allow for a longer current draw in these high-power applications.

### **Use case and Energy Storage Element selection math**

### **Paragraph summarize activity accomplished in the past week**

### **Paragraph on whether you are on schedule**

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