Earlobe Heart and Sleep Monitor

Project Description

Paul Cyr

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Introduction

The Earlobe Heart and Sleep Monitor is a system that logs data based on the user's sleeping patterns. This is an ideal device for those who are suspicious that they either snore or toss and turn too much during the night, preventing them from getting a good night's sleep. The microcontroller with circuitry and a battery pack strap around the bicep and has wires that connect to the patient's ear. From there it monitors heart rate and listens for snoring and detects restlessness. If a heart rate goes outside an acceptable range, it will log what time the event occurred. If you start snoring or tossing around, it will log what time it began. The Earlobe Heart and Sleep monitor is a convenient way for doctors to do a quick and cost efficient evaluation of a patient's sleeping patterns.

Electrical Specifications

- Project Specifications

	Heart Rate module	Microphone module	Accelerometer
Accuracy	± 5 BPM	± 5 dB	±2.64 %
Resolution	16 bit	16 bit	14 bit
Range	0 – 230 BPM	100-1000 Hz frequency response	± 8 g
Communication protocol			I2C

The heart rate will be accurate within ± 5 beats per minute, which is consistent with other heart rate devices on the market, with an exception for EKGs. When a threshold decibel level is exceed, the time that the snoring began will be recorded for the doctor to view. All of the data collected by the Earlobe Heart and Sleep Monitor will be stored on the device and may be viewed by the doctor using an A to B mini USB 2.0 connection to a computer. Since this is a medical device it will be held to FDA standards for quality regulation under Title 21 §820.

- Power Requirements

This device at the absolute minimum only has to operate for 10 hours to ensure it fully monitors the patients sleep for a night. However, this will not be an issue because it will come with a 6.4V rechargeable LiFePO4 battery and charger.

	Voltage	Worst Case Dissipated Power	Lifespan
LiFePO4 battery	6.4 V	251 mW	18 hr

- <u>Environmental Requirements</u>

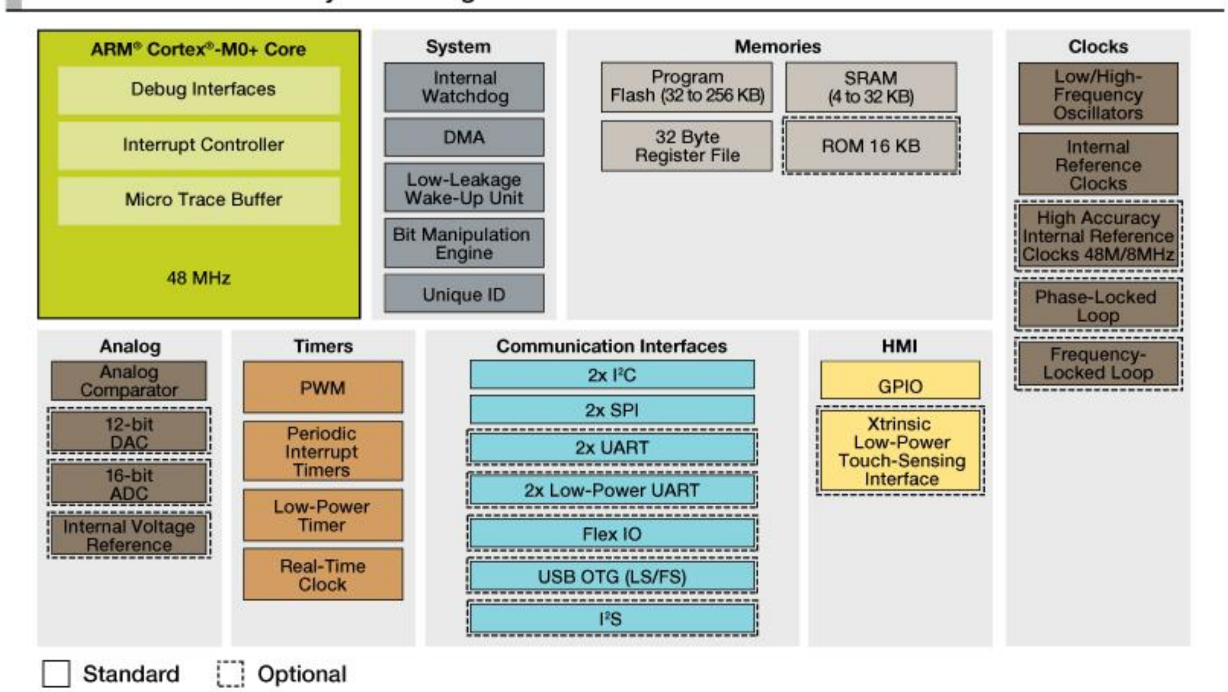
  This device will be worn by patients at night during their sleep, so it should be subject to a small variance in temperature and vibration while in use. The temperature and humidity limitations are determined by the most sensitive parts.

Min operating temp	Max operating temp	Vibration	Humidity	
0 °C	85 °C	N/A	Time	Condition
			168 hr	≤30 °C/60% RH

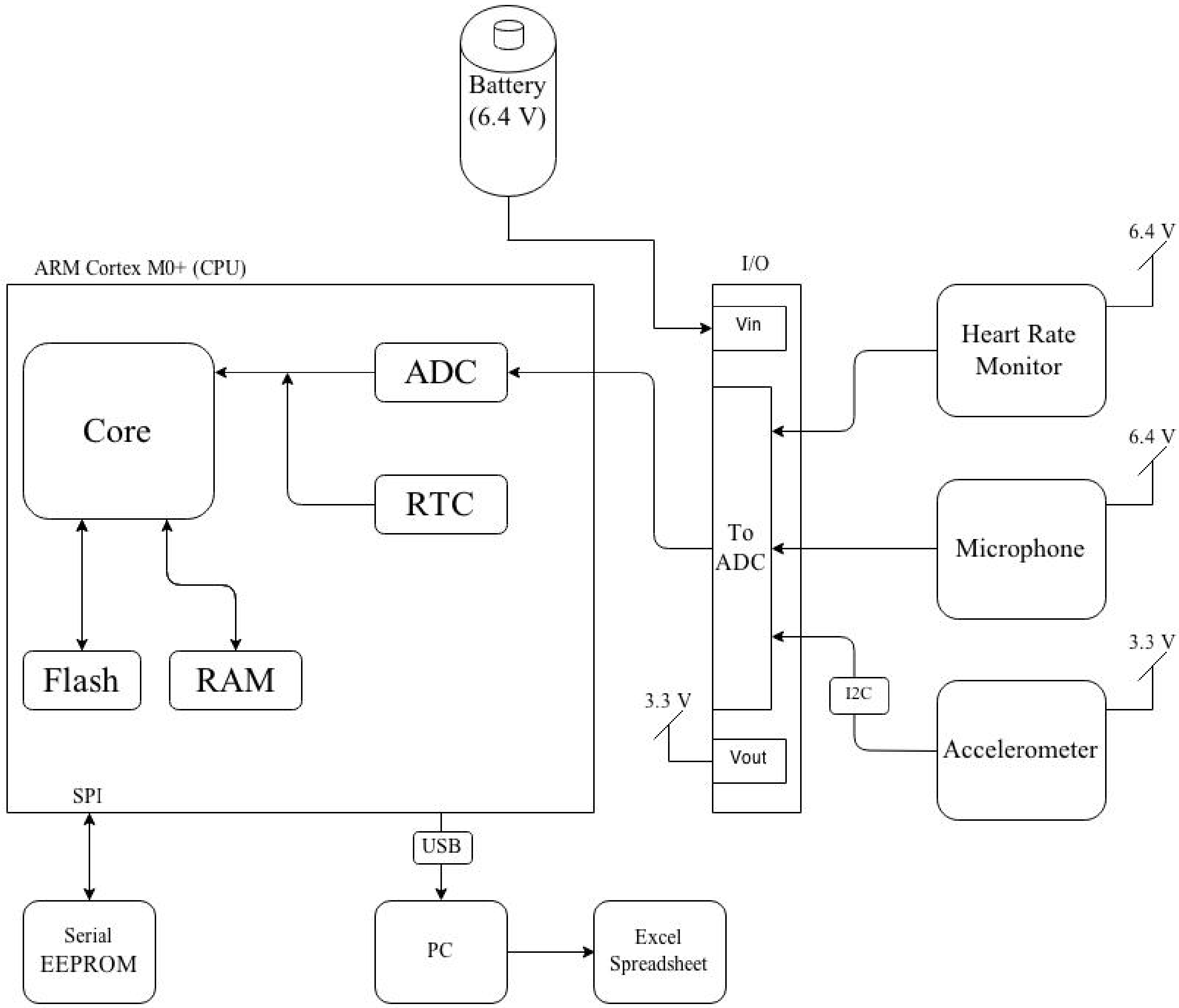
System Description and Specifications

This project will be conducted with the Kinetis KL2x ultra low power MCU family. The ideal microcontroller is low power, can handle multiple sensors using I/O and has plenty of ROM for storing data. The KL2x was the family of MCU I chose because it supports low power and has an on board accelerometer, Real Time Clock (RTC) timer, and supports a wide range on battery voltages for power. The 6.4V rechargeable battery will be charged by a proprietary charger and it will not drain any power from the board. The FRDM-KL25Z only has boot up ROM, so I will be using serial EEPROM for saving data. The doctor will get the data off of the controller through the USB port, so it will comply with USB 2.0 specifications.

Kinetis KL2x MCU Family Block Diagram



- System Level Block Diagram

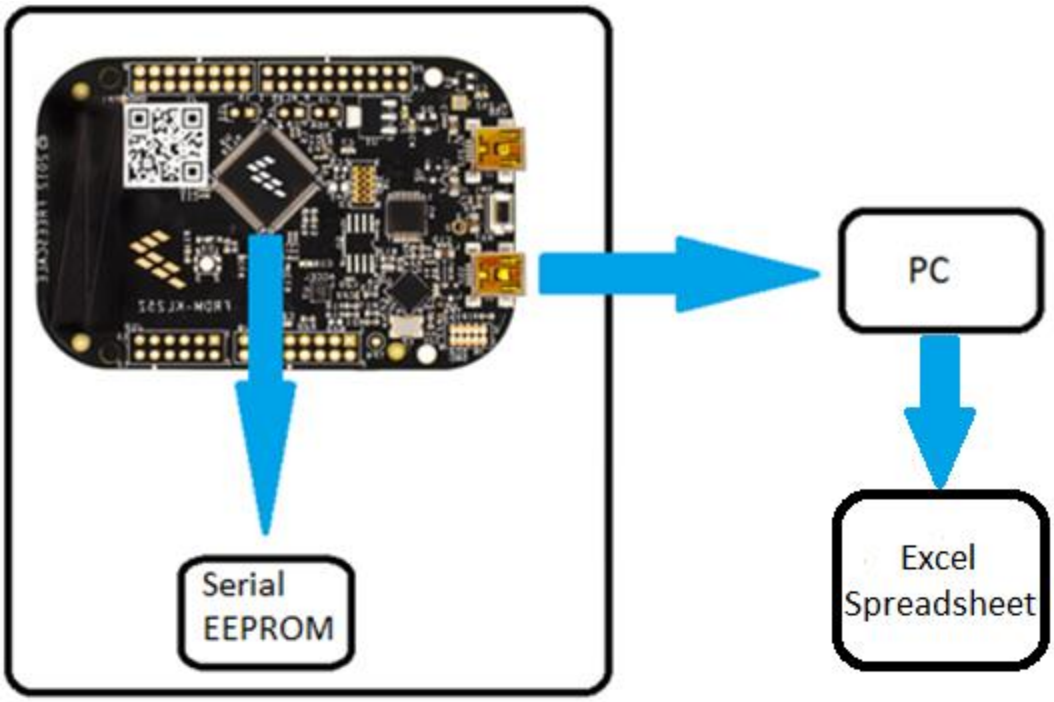


- Software Requirements
  The ARM processor will be programmed using C coding language with a µC/OS kernel. The first major algorithm will take the amplified and filtered signal from the photoplethysmograph and convert it to a heart rate. The second major algorithm will take the input sound levels and convert it to decibels. The final major algorithm will be setting up the accelerometer to present meaningful data from all three axes.

- PCB size limitations
  The Earlobe Heart and Sleep Monitor must be comfortable strapped to the patient's arm, so there are tight size requirements that must be met. The arm module that has the microcontroller and circuitry must not exceed the dimensions 6" x 2.5" x 1". If these dimensions are not met it will not be practical to place it on the users arm.

User Interface Requirements

This device will not have any formal user interface for the patient. It will be important for the doctor to be able to access the data collected by the monitor, but this will all be done by connecting the microcontroller into a computer. Data will be collected and stored on serial EEPROM where it can be easily opened as a Microsoft Excel spreadsheet.



Development Plan

- <u>Prioritized list of features</u>

➢ <u>High Priority</u>

- Obtains patient's heart rate via photoplethysmograph that attaches to the earlobe.
- Uses an electret microphone to capture decibel levels of snores.
- Has serial EEPROM to have 1 kB of saved data.
- Uses a Real Time Clock to time stamp saved data.

➢ <u>Not a Part of This Course</u>

- Employs a digital three axis accelerometer to detect motion indicative of restlessness.
- Has a cell phone vibrator that wakes the patient after abnormal heart rhythms are recorded.

- <u>Weekly Schedule</u>

Week of	Task to be completed	Course requirements
Winter Quarter		
1/5 – 1/11	Order all parts.	
1/12 – 1/18	Begin design on earlobe photoplethysmograph.	
1/19 – 1/25	Continue photopleth design.	
1/26 – 2/1		
2/2 – 2/8		
2/9 – 2/15	FRDM-KL25Z should arrive. Continue photopleth design.	
2/16 – 2/22	Design microphone amplification circuit. Set up EEPROM chip.	
2/23 – 3/1	Continue mic circuit design.	
3/2 – 3/8	Begin working on RTC and ADC.	
3/9 – 3/15	Continue RTC, ADC and circuit designs.	
3/16 – 3/22		
Spring Quarter		
3/30 – 4/5	Program.	
4/6 – 4/12		
4/13 – 4/19	Build clip to hold LEDs and mic on ear. Continue programming.	
4/20 – 4/26		
4/27 – 5/3		
5/4 – 5/10		Hardware review
5/11 – 5/17		
5/18 – 5/24	Prepare for presentations.	
5/25 – 5/31		Code review
6/1 – 6/7		Final presentation

- <u>Development Hardware and Software</u>
  Throughout the development of my senior project I will be using laboratory hardware and software development tools. For the programming aspect, I plan on using the Kinetis Design Studio environment since it has replaced Code Warrior on our lab computers. While no extra lab space is required, I will be using a lot of the equipment in the labs such as function generators, oscilloscopes, power supplies and meters.

- <u>Description of Demonstration</u>
  For demonstration I will put the microcontroller and electrical circuitry inside of a polycarbonate or ABS project box. This box will mount on to the arm via an elastic or Velcro strap. The earpiece containing the IR LED, receiver and electret microphone

will be placed inside of a clip that has a screw for limiting how clamped it becomes. The microphone's values shall not be saved unless it hears something louder than a silent room for an extended period of time. For the sake of demonstration this may be around 60 dB to compensate for a loud room. Similarly, the photopleth's data will not be saved unless an irregular heart beat is detected. To simulate this I can use an artificial heart beat function on a function generator.

Preliminary Parts List

Part	Price	Lead Time	Power Dissipation
FRDM-KL25Z microcontroller	**$12.95**	**4 weeks**	**251 mW**
LFP-6.4V0.8Ah-18500 battery	**$14.50**	**5 days**	
P9949-ND electret microphone	**$0.95**	**Already acquired**	**8.91 mW**
IR LED/ receiver	**$3.99**	**Immediate in store**	**231 mW**
25AA010A serial EEPROM	**$0.42**	**4 days**	**27.5 mW**
Resistors (x13)	**$1.06**	**Immediate in store**	**8.91 mW**
Capacitors (x3)	**$0.78**	**Immediate in store**	
Quad Op-amp	**$2.30**	**4 weeks**	**376 μW**