ECE 445

Fall 2017

Project Proposal

Recovery-Monitoring Knee Brace

Team #40

Locker D10

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1. Introduction

[1.a] Objective

Thanks to modern technology, it is easy to encounter a wide variety of wearable fitness devices such as Fitbit and Apple Watch in the market. Such devices are designed for average consumers who wish to track their lifestyle by counting steps or measuring heartbeats. But it is rare to find a product for the actual patients who require both the real-time monitoring of a wearable device and the hard protection of a brace.

Personally, one of our teammates ruptured his front knee ACL and received reconstruction surgery a few years ago. After ACL surgery, it is common to wear a knee brace for about two to three months for protection from outside impacts, fast recovery, and restriction of movement. For a patient who is situated in rehabilitation after surgery, knee protection is an imperative recovery stage, but is often overlooked. One cannot deny that a brace is also cumbersome to put on in the first place. There should be a viable alternative for such people in need.

[1.b] Background

With that said, our group aims to make a wearable device for people who require a knee brace by adding a health monitoring system onto an existing knee brace. The fundamental purpose is to protect the knee, but by adding a monitoring system we want to provide data and a platform for both doctor and patients so they can easily check the current status/progress of the injury.

A feedback system will notify the wearer when the brace needs to be more tightly bound, and remind via. mobile interface when not worn for extended periods of time. Because the brace should also provide useful information for a professional looking over the patient, heat and EMG sensors placed on the inside of the brace will stream data to a mobile device via. Bluetooth. Marketable aspects include a minimal change in the overall weight of the brace, and the small but sufficiently ample lifespan of the battery we will be using as our power supply.

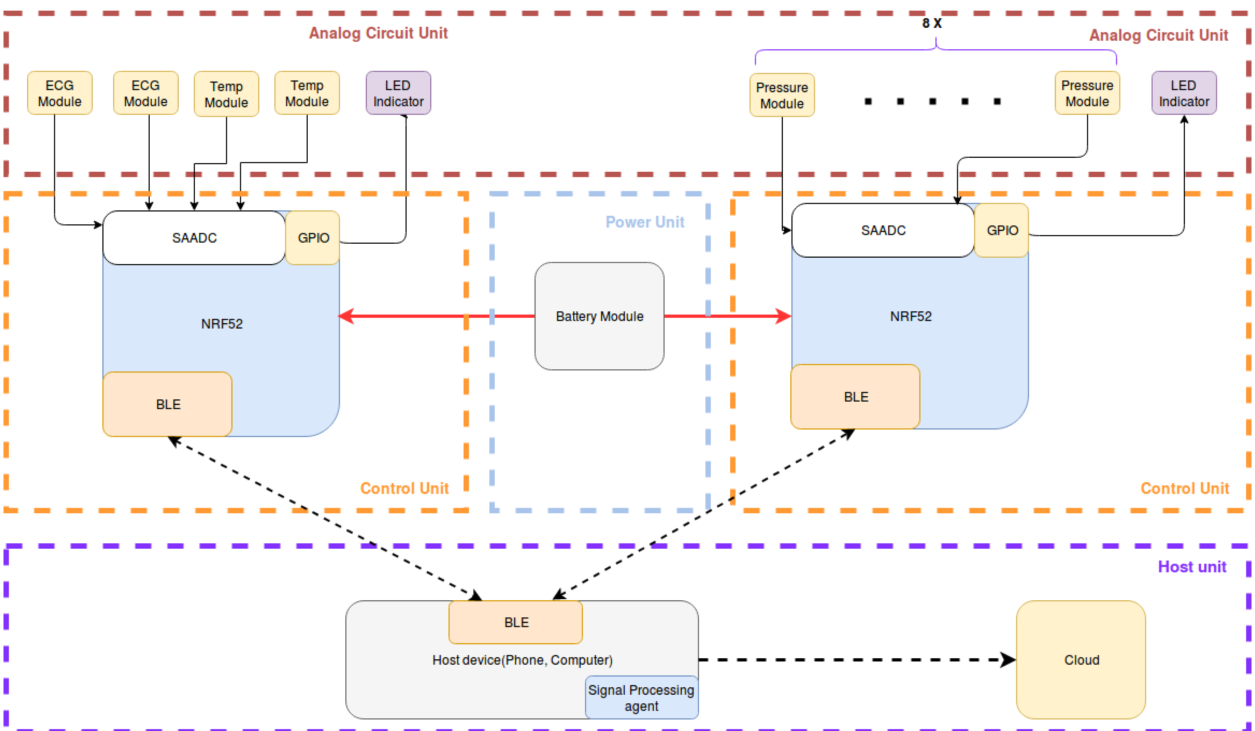
[1.c] High-Level Requirements List

- Brace must be able to stream data continuously for a 48-hour period
- EMG sensors must determine a threshold for too much muscle movement
- Pressure sensors must determine a threshold for a snug fit

2. Design

[2.a] Block Diagram

Our monitoring devices require four logical blocks to operate. In the heart of the operation, we need the **control unit** to orchestrate the analog to digital conversion of the ECG, temperature, and pressure signals while sending the sampled data to the host device in real-time. We will have an **analog circuit unit** that will filter and correctly amplify the analog signal obtained from the sensors. The **Power unit** will deliver regulated power from the battery source to both the control unit and the analog circuit unit. Lastly, we will have the **host unit** that will receive the raw digital data and go through an intensive signal processing process step to deliver a meaningful information to the user. The host unit will also be in charge of spending user data to the cloud periodically for history logs that can be used later for further analysis.



[2.b] Physical Diagram

*See Appendix A

[2.C] Block Requirements & Functional Overview

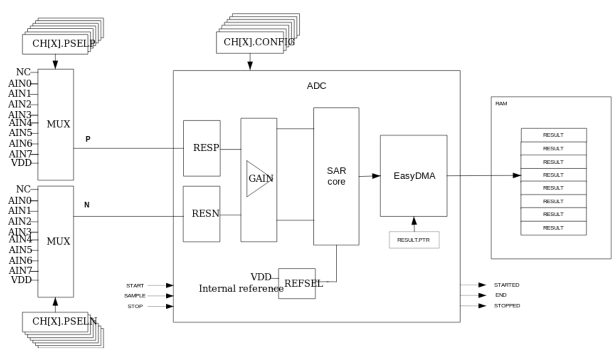
2.C.1 Control Unit

It is going to be the main module of our project device. It has to be a device that can collect all of our bio-signals (pressure, temperature, ECG) from the analog circuit, which means it should have an analog-to-digital converter . Because It is hard to do all the required signal processing on the chip, we need a System-on-Chip (SoC) that has a bluetooth module inside to communicate with the host device. Also, It has to consume low power..

2.C.1.1 nRF52832 SoC

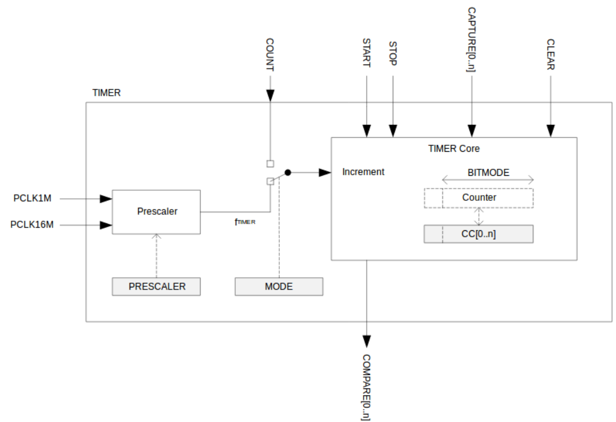
The nRF52 SoC embeds a powerful yet low-power ARM® Cortex®-M4 processor with a 2.4 GHz RF transceiver. With the 2.4 GHz RF transceiver, it has the capability to use standard low-energy wireless protocols such as ANT and BLE. This makes the chip particularly appealing to low-power applications such as ours. The SoC is also packed with such peripherals that will enable us to achieve our goals and though satisfying our requirement as a SoC.

SAADC: The SoC comes with a differential successive approximation register (SAR) analog-to-digital converter. It has eight different channels which means that we can collect up to 8 different signals simultaneously. The sampling rate can be high as 100K samples/second, which is much higher than our target rate of 1000 samples/second for ECG and 10 samples/second for pressure and temperature.

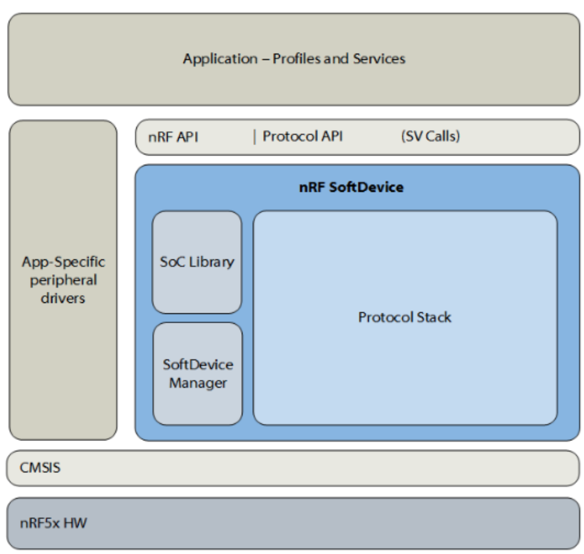


GPIO: The general purpose input/output will be simply used as an indication that will display the status of the device, such as the battery level or connectivity, to a host device. This will be done by connecting LEDs to the GPIO pins and signaling them when necessary. Since we have more than 32 pins on the board, we have plenty of pins to toggle the LEDs.

Timer: The SoC also has a Timer module the runs on the high-frequency clock source which is typically at 16MHz. This extreme high-precision clock will enable us to have a precise interval for the ADC operation and will also schedule periodic jobs for us. This timer will be suitable as it has a resolution of 62.5 ns and a tolerance of less than +- 40 ppm.



Bluetooth: The SoC includes a 2.4 GHz RF transceiver. In order for us to use it, the vendor provides a binary software implementing ble (bluetooth low energy) protocols. This software stack is called ‘softdevice’ and is required in every project involving the use of ble. Our project will work in unison with the softdevice stack to stream the necessary data to the host device. Since this protocol can support up to 20 KBytes/Sec, it satisfies our data rate requirement.



2.C.2 Analog Circuit Unit

The ultimate goal of the analog circuit unit is to implement the multiple sensors that are going to capture bio-signals and send them into our microcontroller. The sensors are located in a different parts of the knee brace and are going to measure the necessary values such as temperature, pressure, and usage of muscle. Since all of the sensors are basically a part of the analog circuit, we are going to use a multimeter and oscilloscope to measure the voltage from our sensor and see if it is properly sending a signal out or not.

2.C.2.1 Temperature Sensor

The overall function of the temperature sensor is to measure the temperature of the knee and compare it with that of another part of the body, and see whether the knee is currently swollen up or not. The general temperature of the knee will be around 30~40°Celsius. It has to be sensitive enough to capture the difference of ±2° Celsius.

2.C.2.2 Pressure Sensor

We are going to place pressure sensors under the strap of the knee brace (Appendix A has a pressure sensor placement). Pressure sensors will monitor if the user has properly worn the knee brace. The degree of tightness of the strap will be measured through pressure sensors, and they will send a analog signal (voltage) into the nRF52. It has to be flexible and sensitive enough to measure a little pressure difference on the strap. The adequate operating force measurement range should be between 0.04lbs to 4.5lbs.

2.C.2.3 EMG Sensor

The purpose of the EMG sensor is to measure the usage of muscle. We are going to implement two electrode-based EMG sensors to indicate the usage of the leg muscle to prevent the user from excessive usage. Figure 1 shows the EMG sensor placement. Two electrodes will come out of the sensor and will be attached to the skin. We will use INA333 for preamplification and different types of filter such as 1st order High Pass filter to capture a better signal.

2.C.2.4 LED Indicator

An LED indicator will be a simple lighting device that indicate the different situations with a corresponding action. We are going to program the actions into our NRF52 and the LED indicator will work as we want. The LED indicator will have a low duty cycle (<%5) in and consume less than 1mA of current draw.

2.C.3 Battery Module

For the Battery module, we are going to use a 9V battery as our main source of power. Our goal is to maintain power availability for as long as possible - the optimal goal would be about two days without having to change a battery. The power circuitry will includes a DC-DC buck converter and the output should be near 3V. The battery module has to be safe enough to use near the human body and must protect our device from a over/under voltage that may cause damage in components.

[2.e] Risk Analysis

The block that poses the greatest risk for successful completion of our project is the Analog circuit unit and post-signal processing from it. Our device needs precise measurements of temperature, pressure, and EMG signals because we have to monitor the user in real-time to provide useful feedback of one's knee. After implementing the circuit, we have to test it in different circumstances and see if we can find out the optimal circuit design and range of measurements that yield the best result.

3. Ethics and Safety

Concerning our project, we do not think there are much ethical concerns, because the knee brace we are modifying is for the sake of alleviating the discomforts of injured people. Aside from the radical case in which the knee brace were to be used as a physical weapon, there are not too many cases in which our product would cause concern to the public.

We will be using a 9V alkaline battery as our power source, which has on average a capacity of 1000mAh. Electrical concerns such as discharge will be at a minimum, and the only mechanical concerns relevant will be of the existing knee brace currently out in the public. Some lab safety concerns we may have are related to soldering when creating our electrical circuit, both on a test breadboard and on the final PCB.

4. Appendix

[4.a] Physical Design Pictures

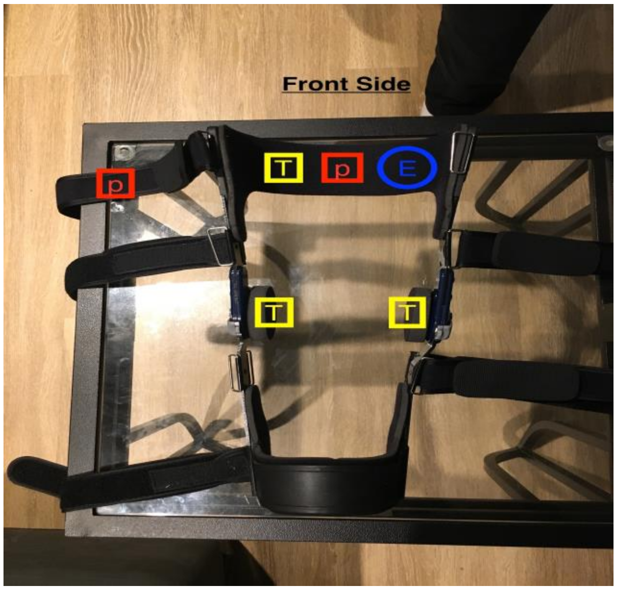


Figure 1: Front Side of Knee Brace and Sensor Location.

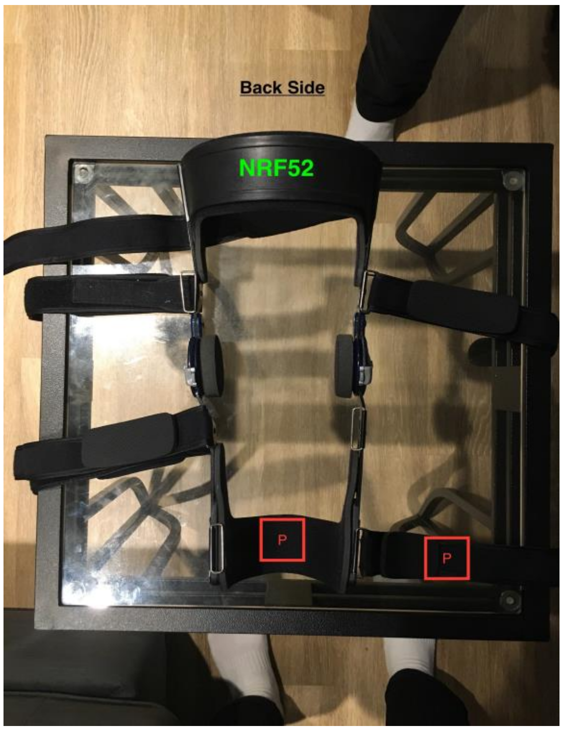


Figure 2: Back Side of the Knee Brace and Sensor Location.

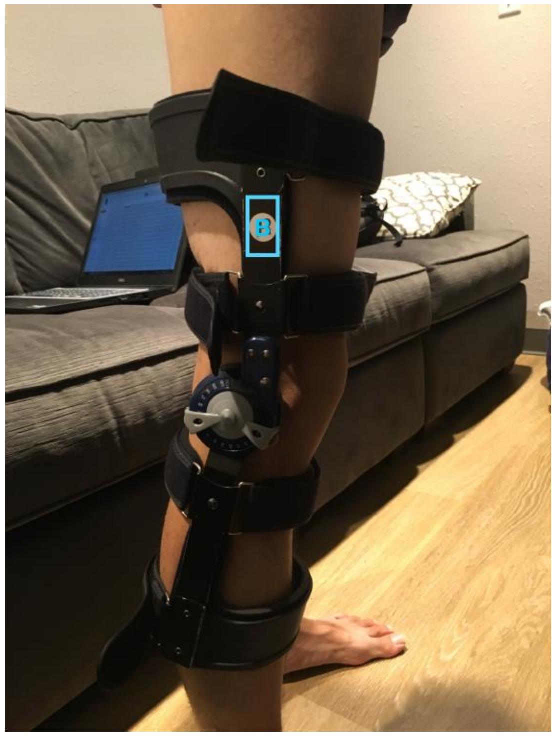


Figure 3: Right Side of the Knee Brace and the Batter Locations.