ECE 445

Fall 2017

Mock Design Review

Recovery-Monitoring Knee Brace

Team #40

Locker D10

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1. Diagrams & Physical Design

1.1 Diagram

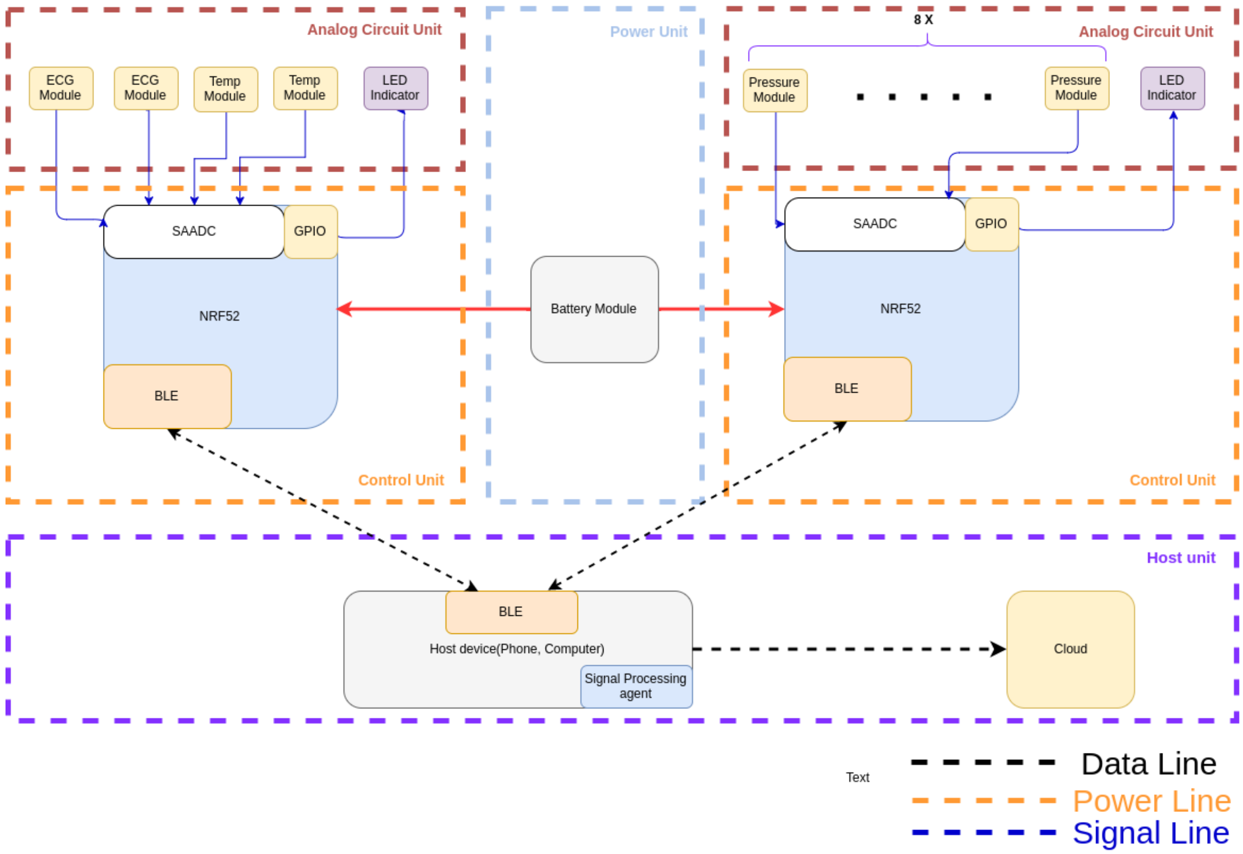


Figure1: Diagram of Overall Design.

1.2 Physical Design

Our device is using a Knee brace that is commonly used for Knee injured patients. The basic frame is lightweight metal and has multiple straps that goes around patient's knee. There are three straps on each side of brace with angle control dial on a middle. Figure 2 shows specific sensor location on the front side of knee brace. T is for temperature and located on each side knee to measure the current temperature of the knee. In addition to those sensors, another temperature located on the upper side of knee brace to compare the body temperature and knee temperature. Pressure sensors' location is underneath the straps to measure optimal pressure for proper put on. Power module is going to be on the side of the Knee brace as located on the figure 4. PCB board will be back located on back of the knee brace.

Figures 2,3,4: Front/Back/Right Sides of Knee Brace and Sensor Locations

2. Design Unit

2.1Control 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.

2.1.1 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.

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.

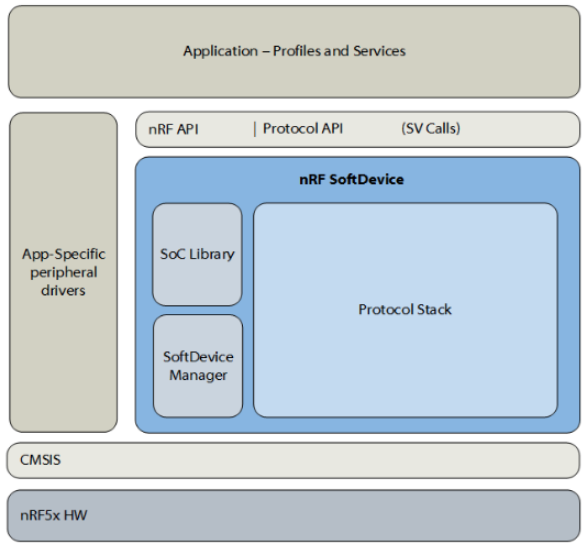


Figure 5: Software Structure Diagram

2.2 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. To capture a better bio signal from a sensor after we implemented each bio sensor, we used instrumentation amplifier such as INA333 and OPA 2333 which consists with two INA333. It has low offset voltage, low drift and low noise. It is important to capture a precise value and it is good enough to provide a precision accuracy on our Circuit.

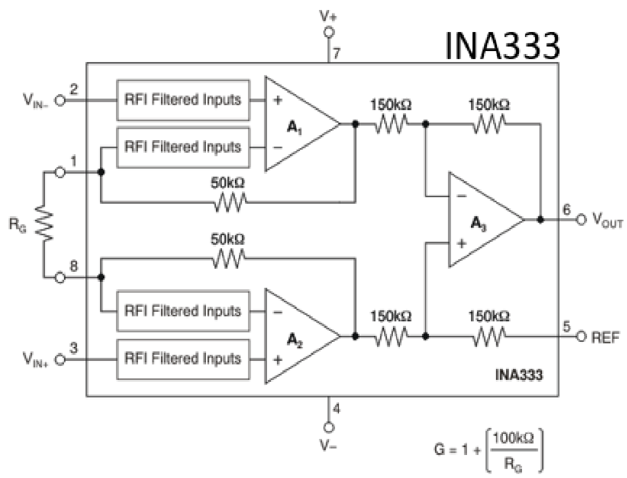


Figure 6: Schematic of INA333[2]

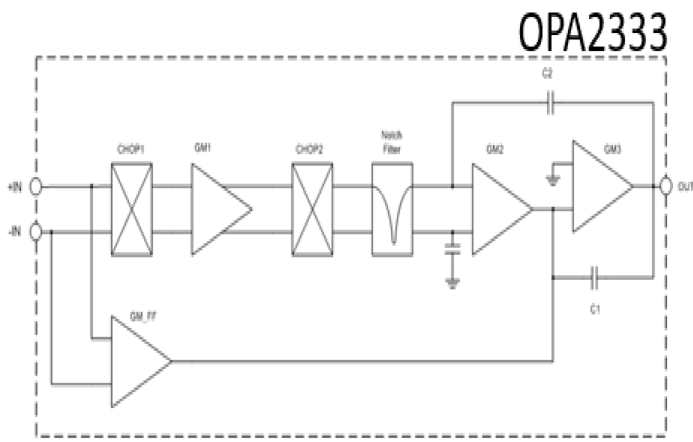


Figure 7: Schematic of OPA2333[3]

2.2.1 Temperature Sensor and its Circuit

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. Since it is really important to capture a precise temperature difference of ±2° Celsius, Metal resistance Temperature Detector is a optimal choice. RTD is able to measure temperature range between -200 to 850°Celsius and it has sensitivity of 3850 ppm per Celsius. RTD (M-Series 222) from Heraeus Sensor Technology USA is the one that we are going to use under the circuit call Wheatstone Bridge Circuit which is proper for thermistor. As we said on the introduction of Analog circuit unit, we also going to use INP333 if we require an amplification.

Requirements	Validation
- It has to be sensitive enough to capture the difference of ±2° Celsius. - v_{out}< 3.3v Since NRF52 has a voltage minimum in a input and out pin.	- Using Voltmeter to measure a v_{out} on a circuit in a various condition and see how it does change. - Using a number that we get through the experiment, find out that the sensor actually gives us a accurate values. Following equation provided in a calculation part.

Schematic

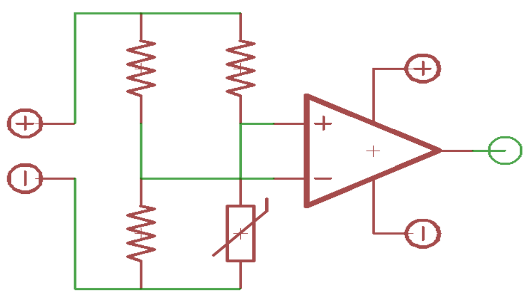


Figure 8: Schematic of Temperature Sensor (Wheatstone Bridge Circuit)

Calculation

$$\mathrm{TCR} = 3850\ \mathrm{ppm/K}$$

$$\mathrm{TCR} = \frac{R_2 - R_1}{R_1(T_2 - T_1)} 10^{-6}$$

$$R_1 = room\ temperature\ (\Omega)$$

$$R_2 = operating\ temperature\ (\Omega)$$

$$T_1 = room\ temperature\ (\mathrm{K})$$

$$T_2 = operating\ temperature\ (\mathrm{K})$$

$$R_T = R_O[1 + AT + BT^2]$$

$$R_T = resistance\ at\ the\ measured\ temperature$$

$$R_O = resistance\ in\ \Omega\ at\ t = 0℃$$

$$A = 3.9083 \times 10^{-3}\ /℃$$

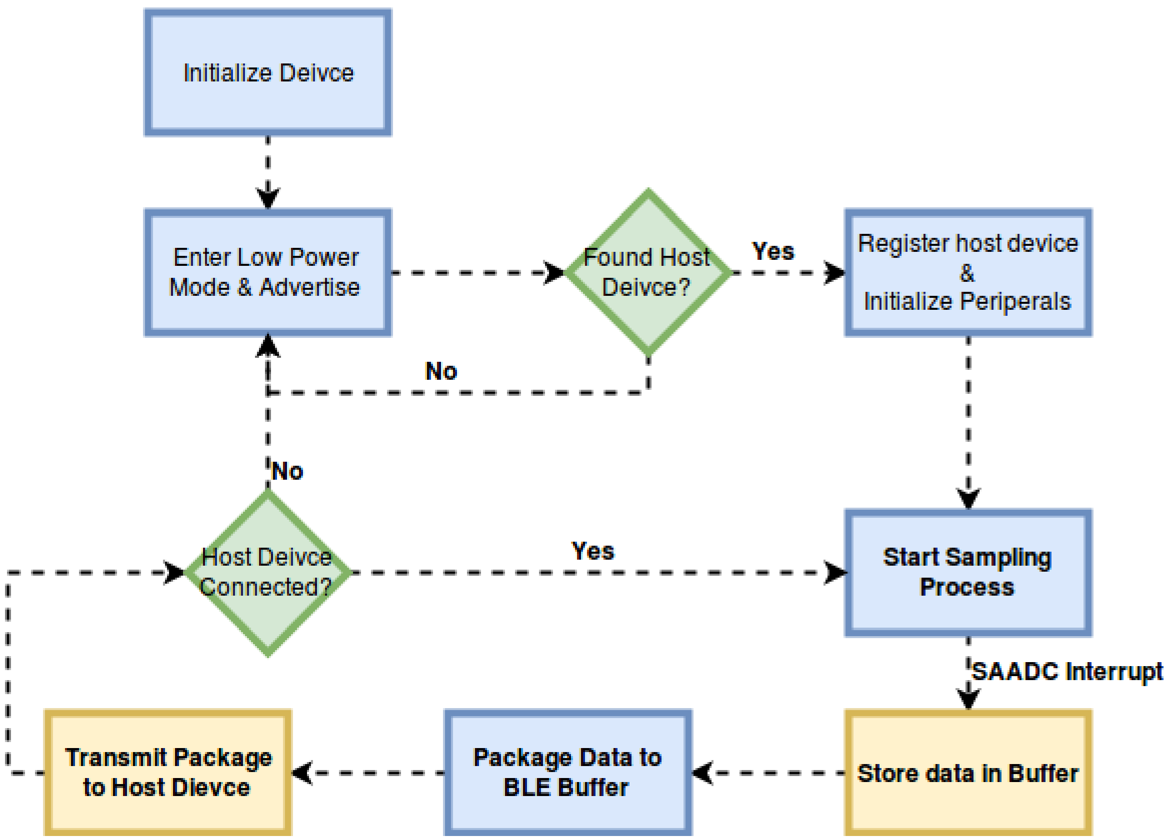
$$\mathrm{B} = 5.7750 \times 10^{-7}\ /℃^2$$

3. Software

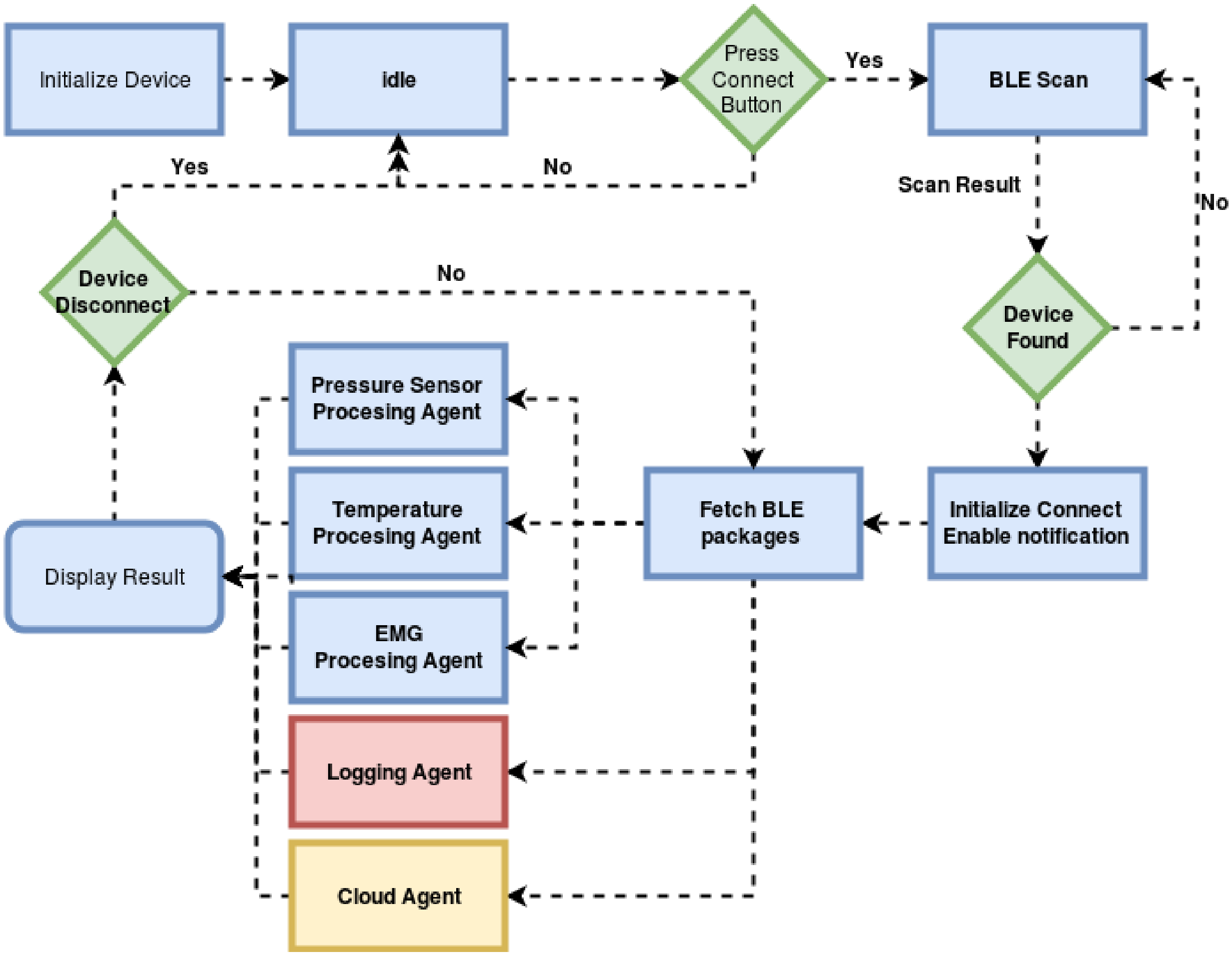
We will design a two node system that consist of a Host and a device. For the device node, the goal is to put the device in lower power mode(sleep) as much as possible to allow long operation. In order to achieve this goal, we are going to utilize the interrupt based adc. Also, It will use the Bluetooth Low Energy soft device provided by the vendor to send burst of BLE packages to the host device. The host device has multiple tasks it needs to take on when data from the device comes in. We will have multiple agent with different tasks to run concurrently to achieve the necessary real-time tasks.

3.1 Flowchart

3.1 Flowchart – Device



3.1 Flowchart – Host



4. Safety statements

Considering the scope of our project and the IEEE Code of Ethics, we wish to make a few statements regarding the standards.

[1] To accept responsibility in making decisions consistent with the safety, health, and welfare of the public, and to disclose promptly factors that might endanger the public or the environment;

As 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.

[5] To improve the understanding of technology; its appropriate application, and potential consequences;

Our knee braces serves to make comfortable the lives of the injured, and is founded on the notion of helping. But we must be careful not to overlook important medical standards that our device may miss out upon.

[6] To maintain and improve our technical competence and to undertake technological tasks for others only if qualified by training or experience, or after full disclosure of pertinent limitations;

During the final stages of our project, we will need to solder the components onto our printed circuit board. Only students qualified and who have passed the lab safety trainings should be eligible in performing tasks that involve the use of potentially harmful lab equipment.

[7] to seek, accept, and offer honest criticism of technical work, to acknowledge and correct errors, and to credit properly the contributions of others;

In order to seek improvement and success in constructing our knee brace, we must be open to criticism and embrace the public opinion.

4. References

[1] interlinkelectronics. (2017). *Pressure Sensor FSR400 Series Datasheet*. [online] Available at: http://www.interlinkelectronics.com/datasheets/Datasheet_FSR.pdf [Accessed 3 Oct. 2017].

[2] Texas Instrument. (2017). *INA333 Data Sheet*. [online] Available at: http://www.ti.com/lit/ds/sbos445c/sbos445c.pdf [Accessed 3 Oct. 2017].