Wireless Applications of a Refactored Prosthesis (W.A.R.P.)

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Introduction

Limbitless Solutions is a non-profit organization founded by Albert Manero in the Spring of 2014 which was created to deliver high quality, inexpensive bionic limbs for use by children in accordance with the ethos, “Nobody should profit from a child in need”. Since its inception the organization has matured and refined the art of creating low cost, 3D printed bionics.

W.A.R.P. is a project commissioned by Limbitless Solutions with the goal of improving their technology by redesigning the hardware and building the software from the ground up. Specifically, by improving existing functionality such as the electromyography sensor (EMG) and implementing innovative ideas into the product. Characteristic features include utilizing a 6-axis inertial measurement unit, digital potentiometer, and solid state relays which can all be controlled and configured wirelessly using Bluetooth Low Energy (BLE).

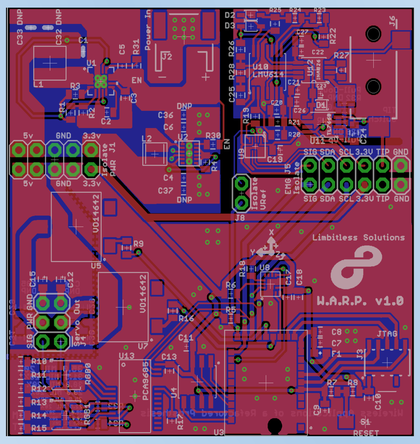
Objectives

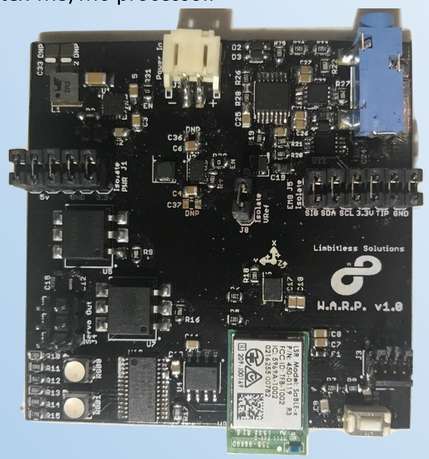
The primary objective of the W.A.R.P. project is to design a printed circuit board which features the Bluetooth capable LSR SaBLE-x module which internally leverages the TI SimpleLink CC2640 ARM Cortex-M3/M0 processors. Furthermore, this device will interface via BLE with a custom mobile application which operates on both Android and IOS. Lastly, the mobile application networks with ephemeral cloud instances in order to provide a channel of communication to transmit data through the internet. The overall objectives are as follows:

- Design and manufacture a compact printed circuit board which can wirelessly communicate with a mobile phone
- Create cross-platform mobile application which can wirelessly interface with both PCB and server-side application
- Configure and deploy a cloud server which interfaces with the mobile application through an exposed RESTful web API
- Wirelessly calibrate the device and transmit sensor data
- Integrated EMG Sensor which employs a digital potentiometer as a method of modifying the gain and reference voltage of the sensor through software.
    - Utilize the reference voltage as an input to an analog comparator which can be used to trigger interrupts rather than polling the sensor.

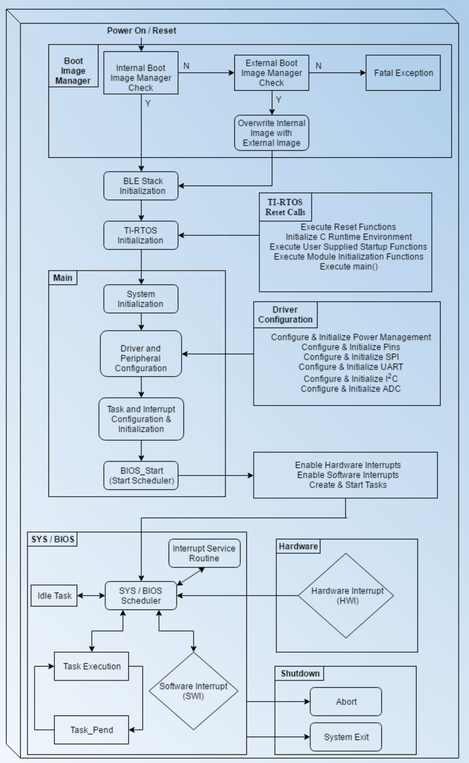
Hardware Design

The schematic for the W.A.R.P. v1.0 PCB was carefully designed and laid out using EAGLE CAD while further simulated using MultiSim and TINA-TI. The board operates using a 2-cell lithium ion battery (7.4v nominal) and was designed to regulate 6.5 – 8.5v down to 3.3v (logic) and 5v (motors). The board fully features 2 voltage regulators, an embedded EMG sensor, digital potentiometer, 2 solid state relays, 2 RGB LEDs, PWM driver, 1 MB external flash memory, 6-axis inertial measurement unit, SaBLE-x ARM Cortex-M3/M0 processor.





Embedded Design



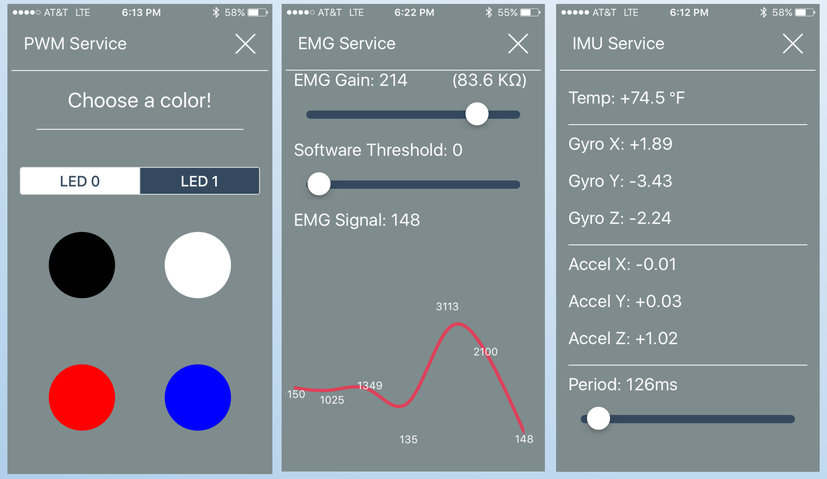
The embedded code which executes on the TI CC2640 uses the TI-BLE Stack which acts as a software interface for the BLE radio. Additionally, the Texas Instruments Real-Time Operating System (TI-RTOS) provides drivers and libraries which can be used to interface with internal peripherals such as I2C, SPI, ADC, and GPIO. TI-RTOS additionally contains the SYS/BIOS Kernel which schedules threads in the system to be executed. W.A.R.P. Embedded utilizes multi-threaded application development tools such as queues, semaphores, and mailboxes. These tools are vital for inter-thread communication and heavily utilized in the development of the embedded software as shown in the provided diagram.

Application Software Design

The mobile application is designed to pair with all W.A.R.P. devices and can identify BLE services by their universally unique identifier. Each service broadcasted by the device exposes read, write, or notify properties which can be accessed wirelessly. W.A.R.P. mobile was developed using React Native which is a library used to create native bindings to both Android and IOS UI elements, thus allowing cross-platform development from a single repository.

The application manages the connected device settings and monitors activity in real-time. W.A.R.P. mobile has the capability of receiving sensor data, including both IMU and EMG in real time and displaying them through the UI. Furthermore, the application is capable of modifying various parameters permitted by the device’s Firmware. In addition, the bright multi-color LEDs mounted on the device can be individually configured through a dedicated modal. Lastly, the EMG hardware and software thresholds can be set using sliders, while the data itself is mapped to a graph in real time for the user to analyze.

The user has the ability to authenticate with the server application and view recently posted images or discussions from other users within the Limbitless community. Additionally, the user may use real-time chat as a method to reach out to system administrators in an attempt to resolve any technical problems. These feature make use of websockets and RESTful services.



Below are the major technologies, frameworks, and languages which power the W.A.R.P. project. The Bluetooth Low Energy stack and Texas Instruments Real-Time Operating System which are programmed using C are fundamental to the embedded programming. React Native is used to make native calls to the BLE interfaces of the mobile devices, Redux is used to manage state in both the web and mobile application using a functional approach, Phoenix has a rich websocket and REST implementation to provide server communication, Elixir is a functional programming language, upon which the Phoenix framework was built.