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3D Printed Embedded Force Sensors

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MULT 601 | **Team members:** Derek Faltz, Chad Majewski, Andrew Perkins, Faiwei Zhang | **Faculty advisers:** Dr. Hong Zhao & Dr. Weijun Xiao

Introduction

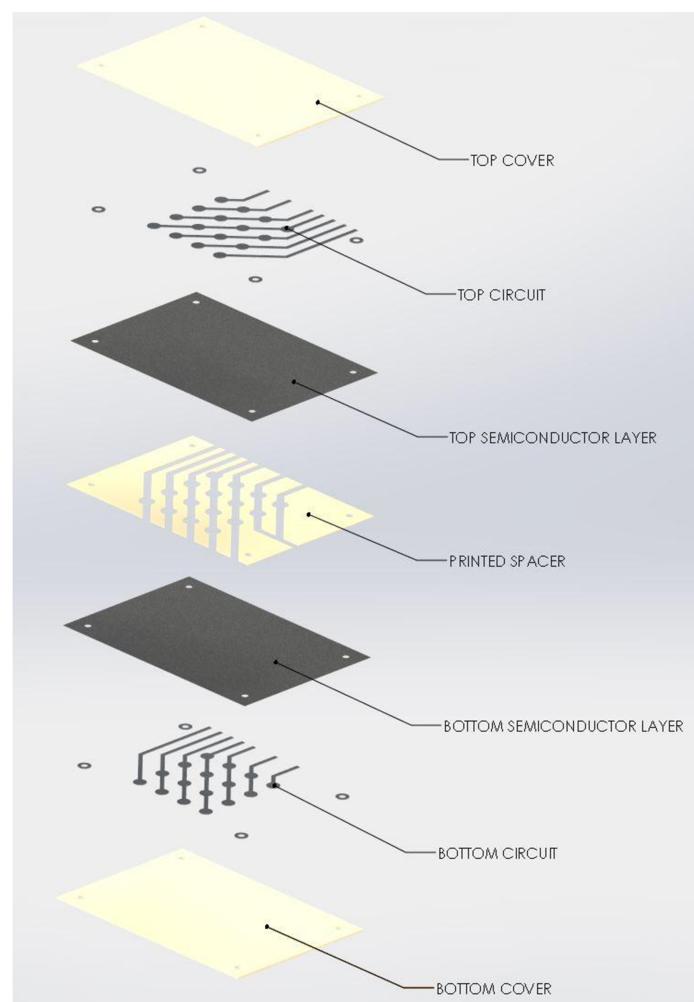
Advances in 3D printing have enabled us to fabricate multi-material based force sensing resistor [FSR] arrays on a single printer. The customizable aspects of additive manufacturing has allowed us to create arrays in a shoe insole which captures and logs the planter pressure data of the user. Analog signals from the pressure sensor arrays are digitized and transmitted wirelessly, via Bluetooth LE 5, to a mobile Android device for real-time feedback. With the capabilities of this insole, physicians and physical therapists are able to gain a quantifiable insight into a patient's progression throughout the rehabilitation process.

3D Printing

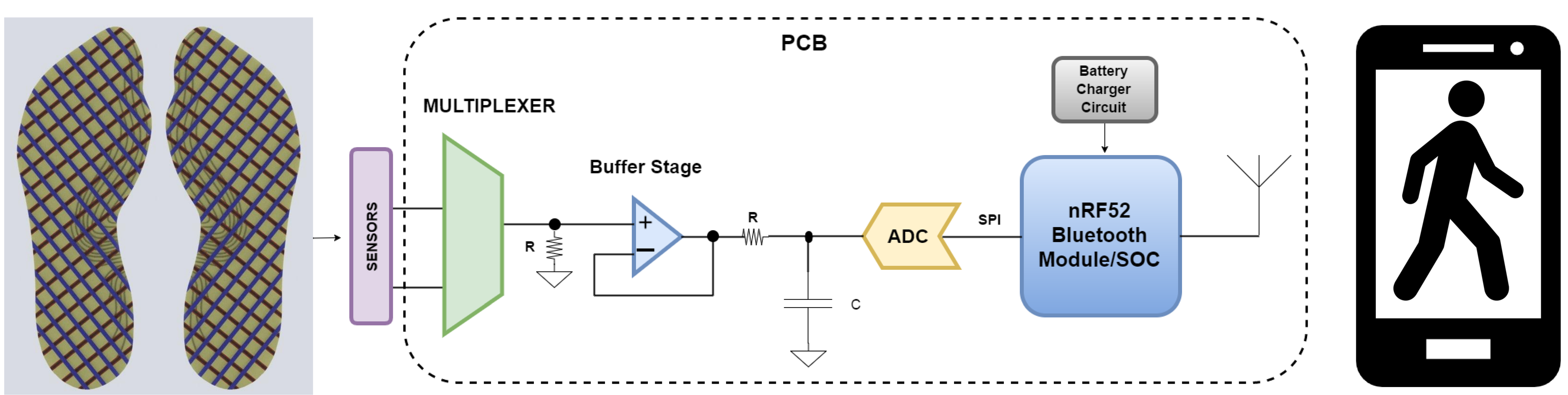
The insole itself is comprised of 3 different materials. The skeletal structure of the circuit uses PLA to laydown a foundation for the silver conductive material. With the use of a dual extrusion printer we are able to print these materials simultaneously. Finally we used a flexible TPU material to create a housing for the circuit that is rugged enough to withstand daily use while having the flexibility to produce sensitive sensor response.

Typical Sensor Array Assembly

The image on the left illustrates the typical component configuration of the force sensing array. On the right, the shoe insole is displayed with wire paths and diagonal sensor traces. The red traces represent the bottom circuit and the blue traces indicate the top circuit of the sensor array. Semi-conductive materials are not shown for clarity.



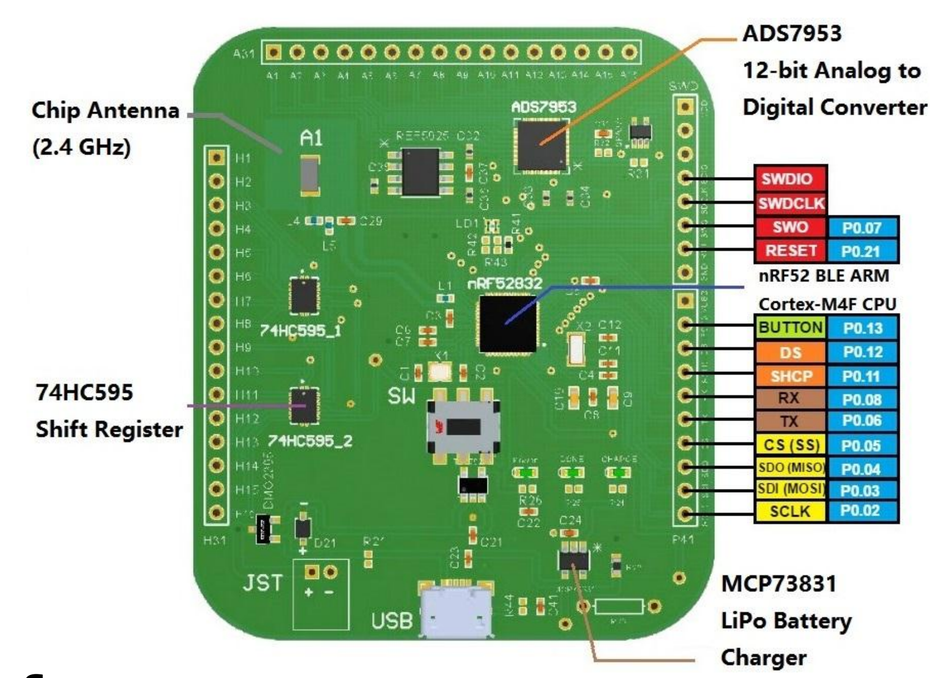
From Sensor Array to Informed User



Hardware

- Nordic nRF52 MCU Bluetooth® Low energy SoC, 32-bit ARM Cortex-M4F CPU
- TI ADS7953 12 bit Analog to Digital Converter with 16 Channels Multiplexer
- NXP 74HC595 8-bit serial-in, parallel-out shift register
- Microchip MCP73831 Lithium-Polymer Battery Charger Management Controller (Single-Cell)
- 3.7V 35mAh Rechargeable Lithium-ion battery

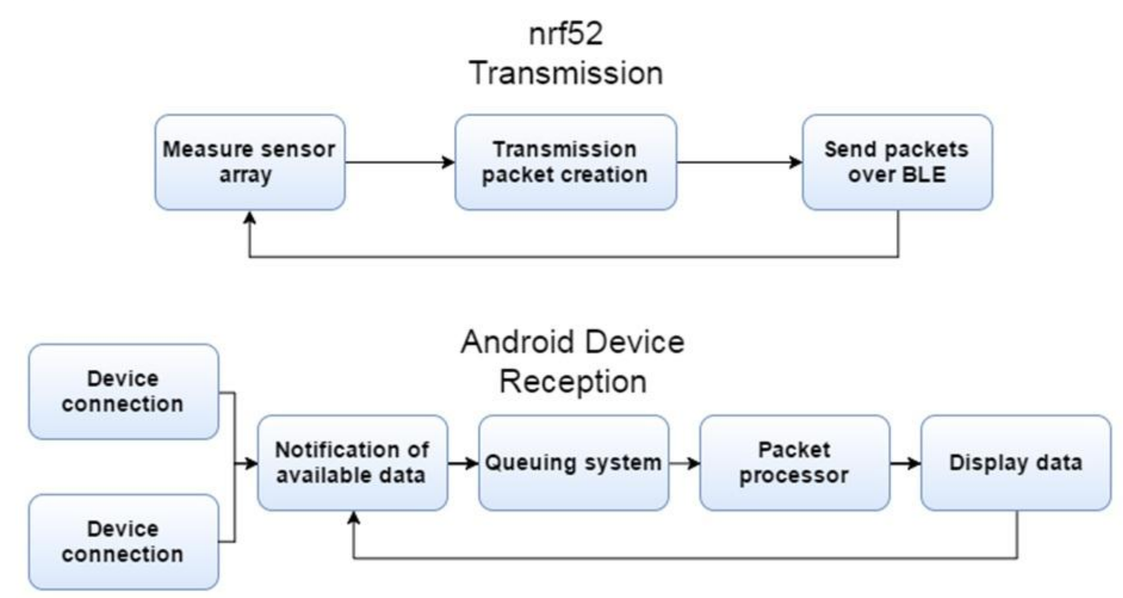
PCB Layout



Software

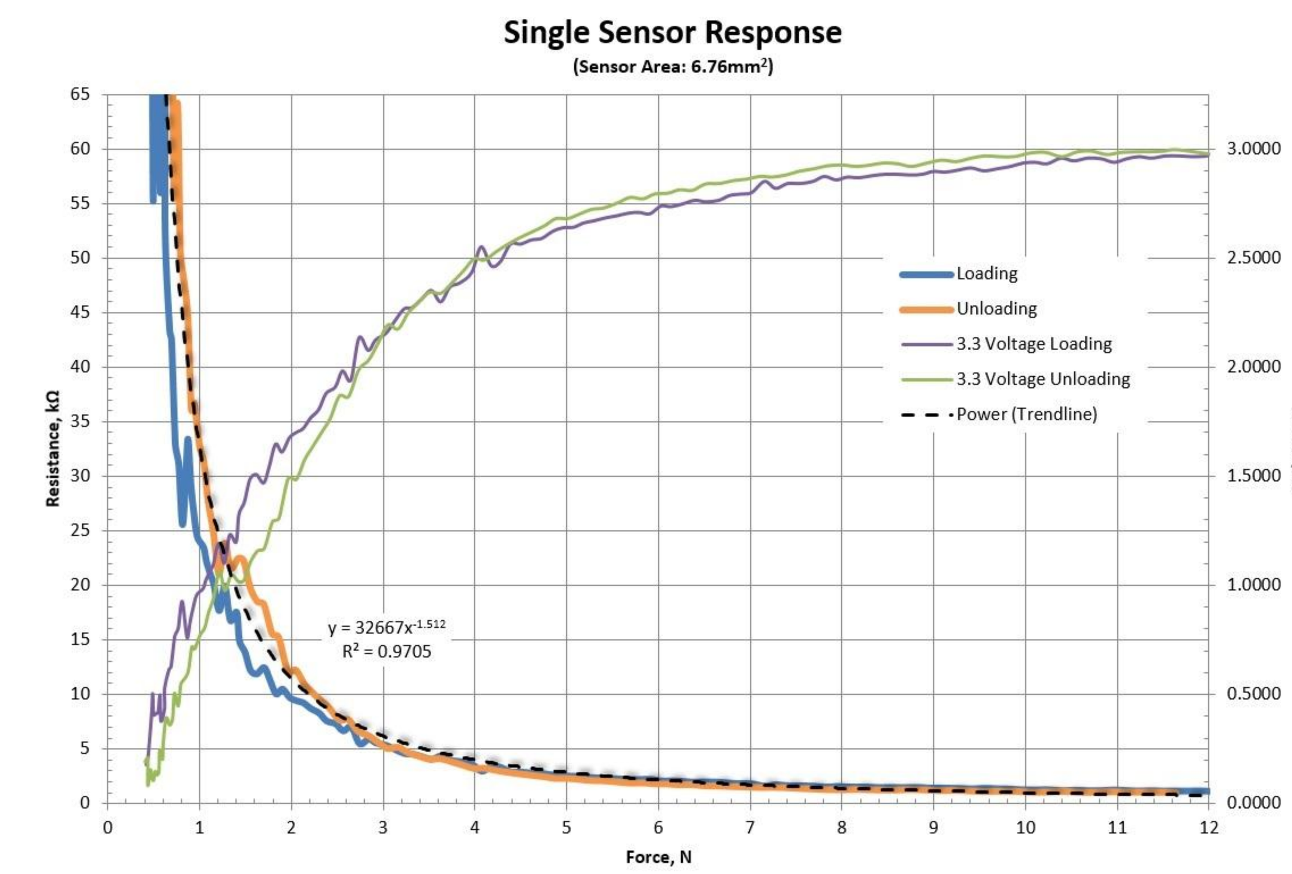
- Utilizes Bluetooth Low Energy 5 to transmit and receive sensor data at real-time data rates
- Historical sensor data storage
- Accurately represents pressure location to user
- Memory based data calculation and processing
- Processing algorithm responds real-time to user's movements

System Data Flow Chart



Sensor Response

Utilizing a traditional compression test to produce an increasing application of force, the electrical resistance produced by the force sensing resistor was recorded and plotted against the instantaneous force being applied. The known force and corresponding resistance of the sensor have been matched with the analog voltage registered by the micro-controller.



Project Outlook

While this project successfully demonstrates the application of embedded force sensors, the possibilities extend far beyond quantitative footwear. The customization made possible through 3D printing provides a nearly limitless number of form factors. From integration into military gear to quantifying a better fit for Prosthesis, fabricating embedded force sensors in this fashion empowers users to gain a higher resolution of response in addition to generating longer-lasting positive outcomes.

Mark A. Sternheimer Senior Design Award

VCU School of Engineering