Penn Engineering

SUNFEST

Pediatric In-Shoe Physical Activity Dynamometer

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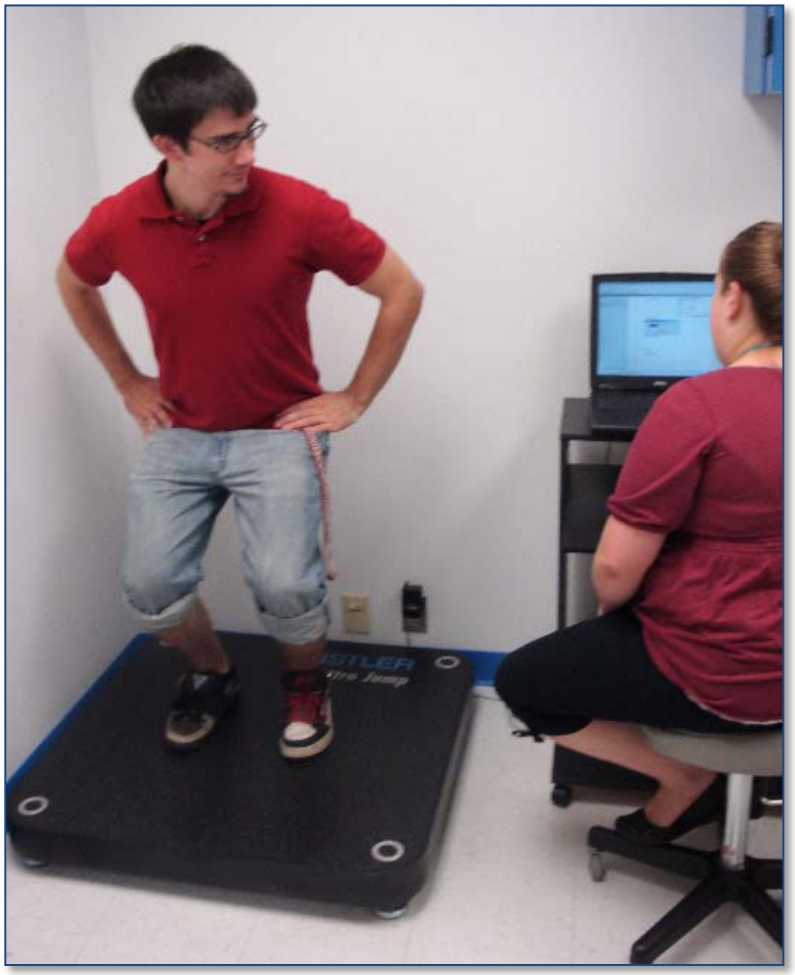
Research Motivation

- Developing strong bones early in life reduces the risk of osteoporosis in the future. [1]
- According to the Mechanostat model, bone size and mass are impacted by the forces developed by muscles on bone during growth. [2-5]
- A device to measure forces on bones, specifically in the legs, would be useful for research.
- Device may also be used for research on:
  - Obesity
  - Childhood developmental disorders

Force Measurement Methods

- Observation and Reporting of Activity
- Accelerometer
- Force Plate
- Physical Activity Dynamometer (PAD)
  - Wired
  - Self-Contained (the Foot-PAD project)



Foot-PAD: Previous Work

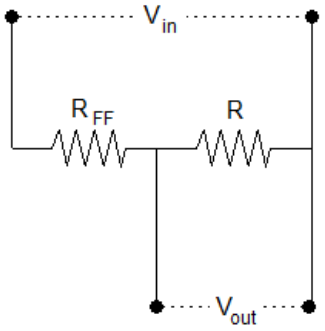
- 2004 – Foot-PAD project initiated
- 2005-2008 – Piezoelectric (PVDF) sensors tested in shoe, circuit board initial design laid out
- 2009 – Piezoelectret sensors used
- 2010 – Piezoresistive sensors first used, new software developed

Project Goals

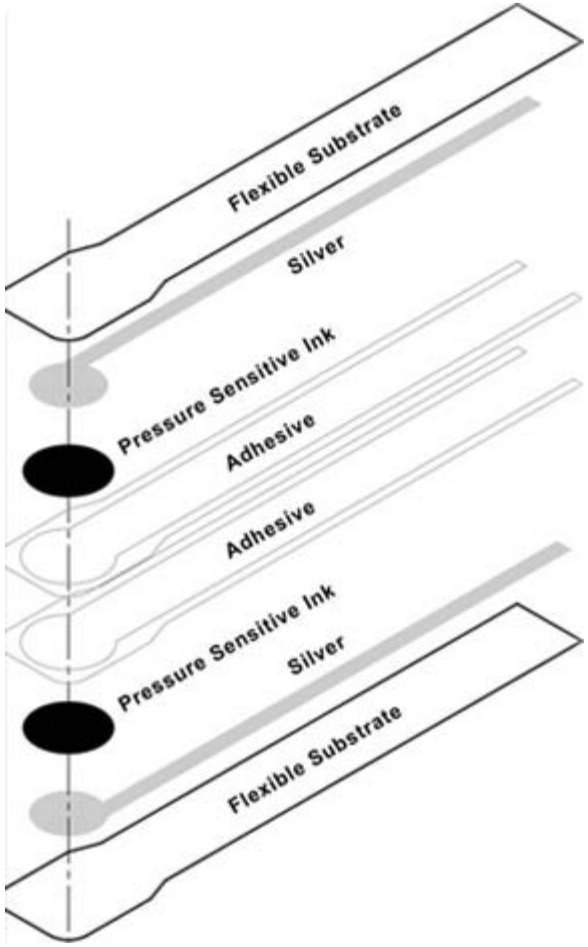
- **Eliminate obtrusiveness**
  - Reduce size of circuit board to less than 2 square inches
  - Use surface-mounted components
  - Conceal the entire device within a shoe
- **Reduce inaccuracy**
  - Avoid sensors that depend heavily on temperature
  - Measure forces in the direction of application
  - Perform calibrations to demonstrate data fit

FlexiForce Sensor

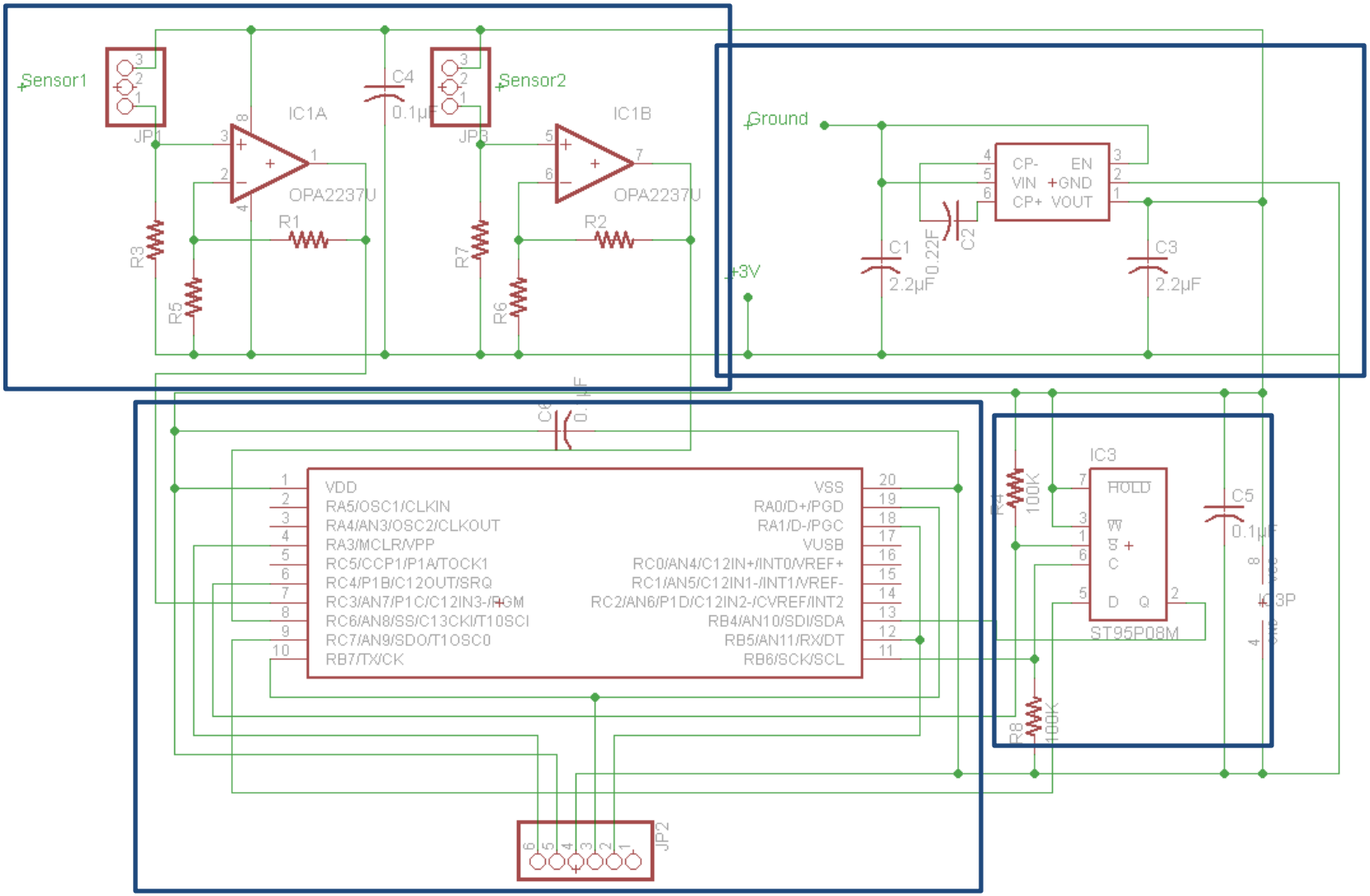
- Chosen for use in device
  - Low susceptibility to gradual temperature changes [6]
  - Designed to measure vertically applied forces
- Change in resistance quantized by voltage divider



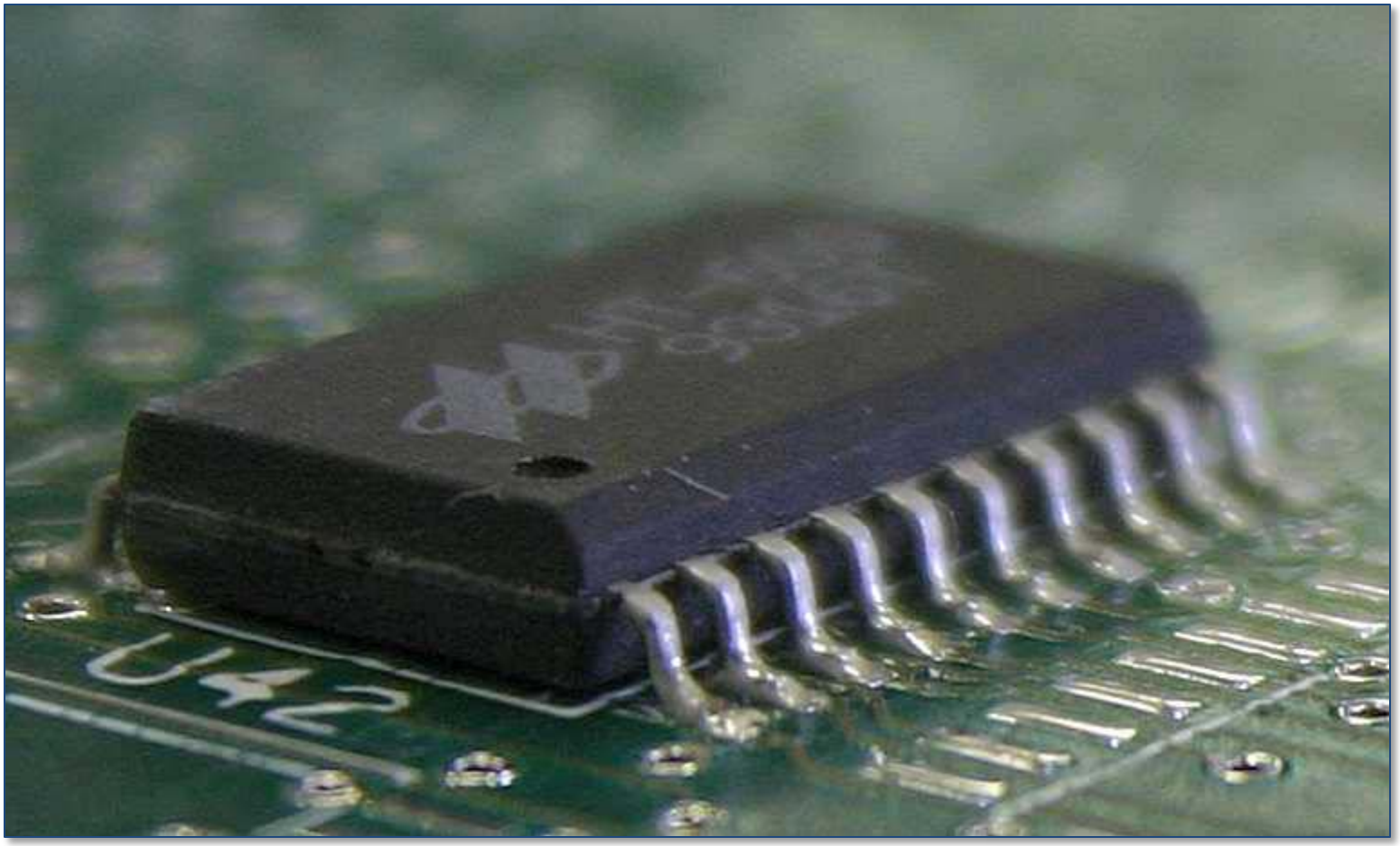
$$V_{out} = V_{in}\left(\frac{R}{R + R_{FF}}\right)$$



Circuit Design

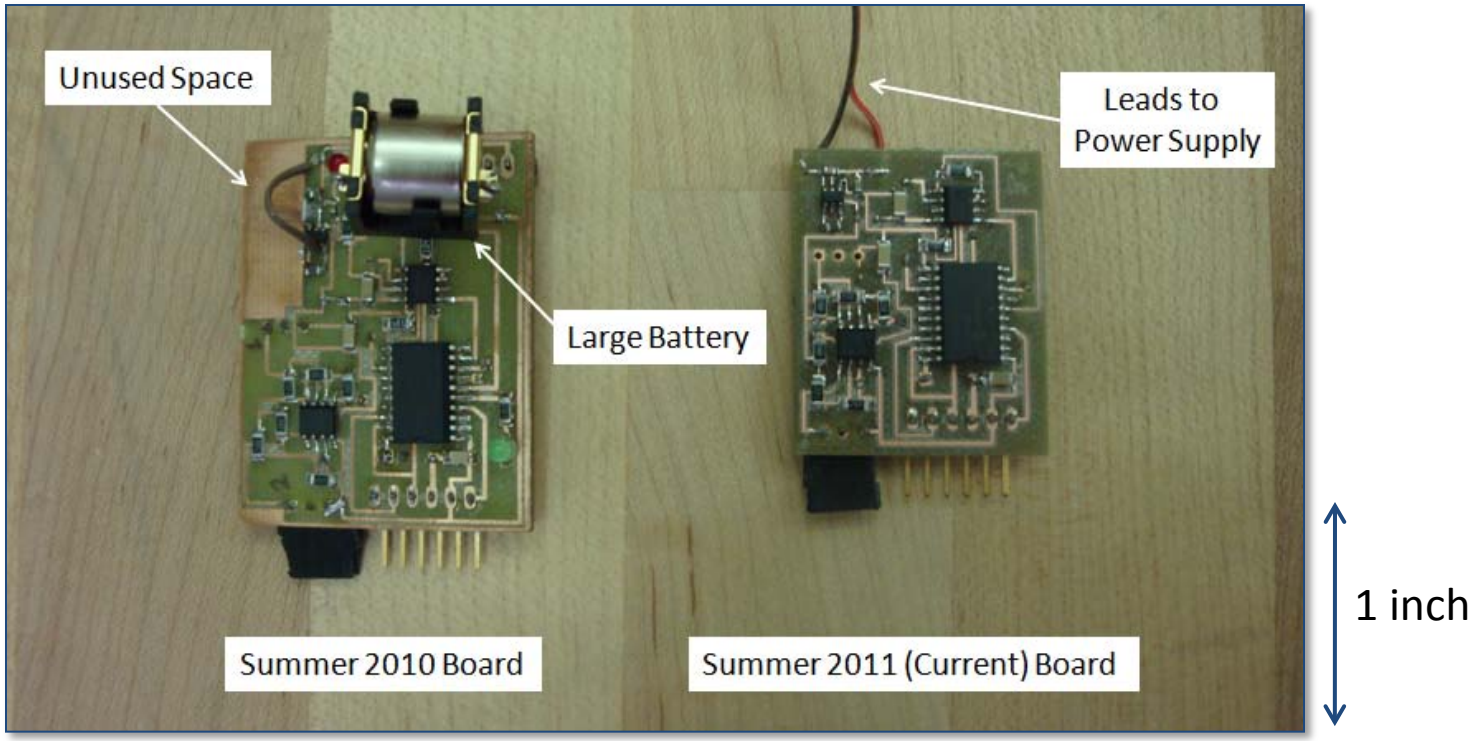


Circuit Board Construction



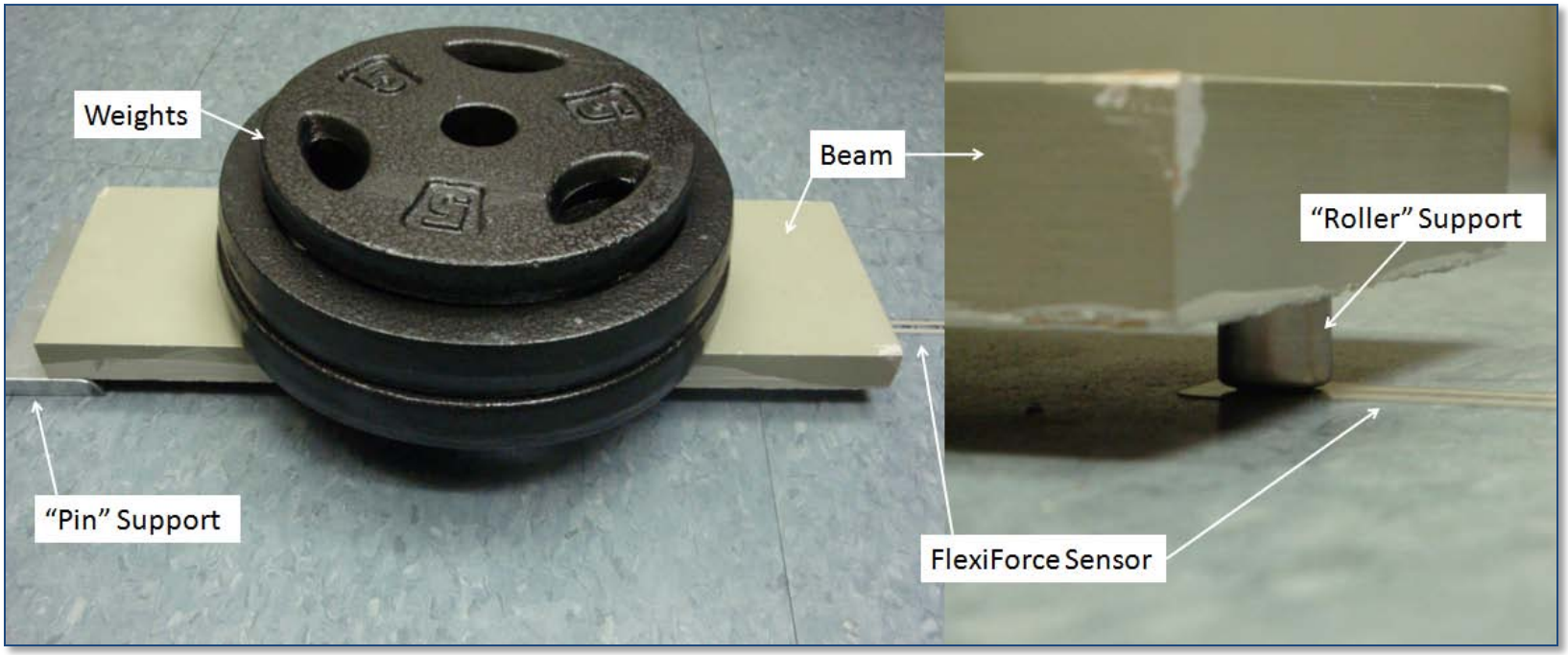
Board Comparison

- Modifications decreased the total chip area by 40% down to 1.88 square inches.
- The chip height was decreased by over 100% by removal of the battery.

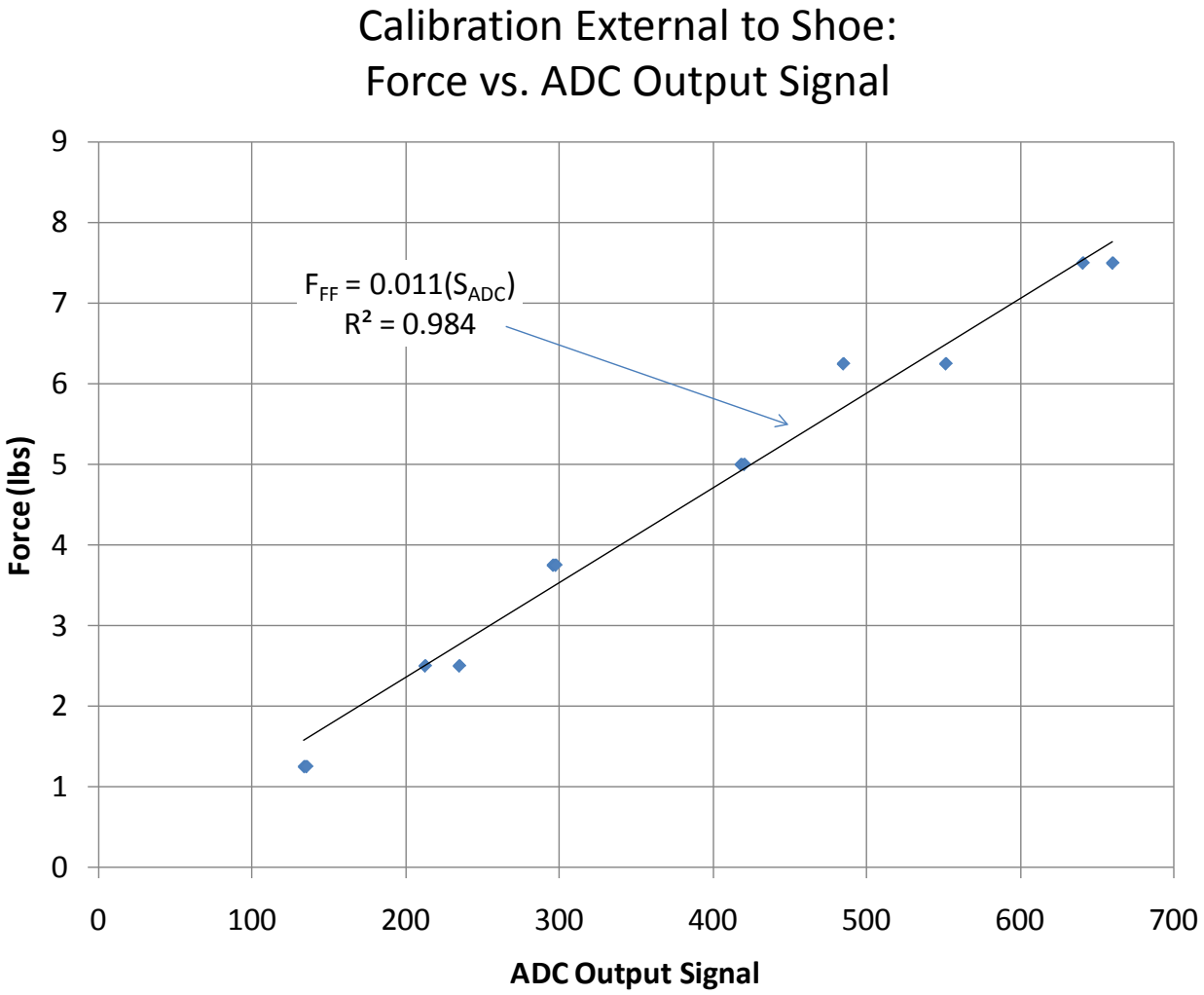


Testing without Shoe

- Initial testing was conducted to determine the device functionality before installation in the shoe.
- For calibration, the known forces were applied with a device based on beam theory.

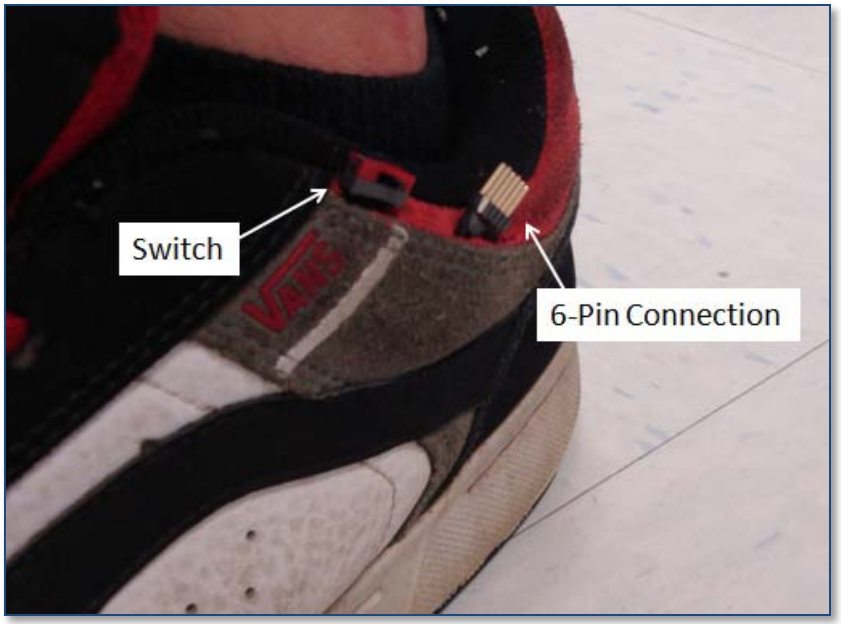


Calibration Curve

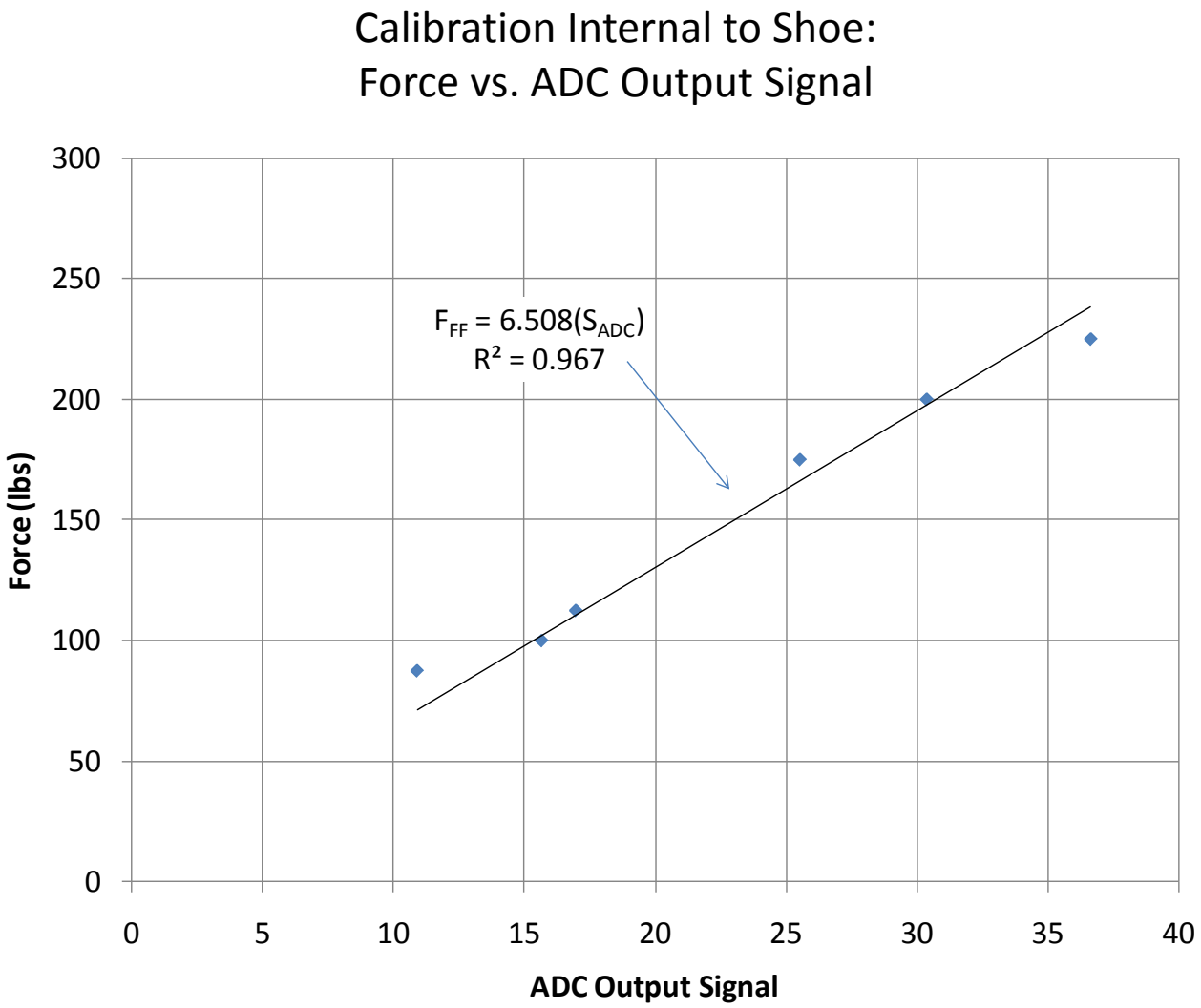


Installation into Shoe

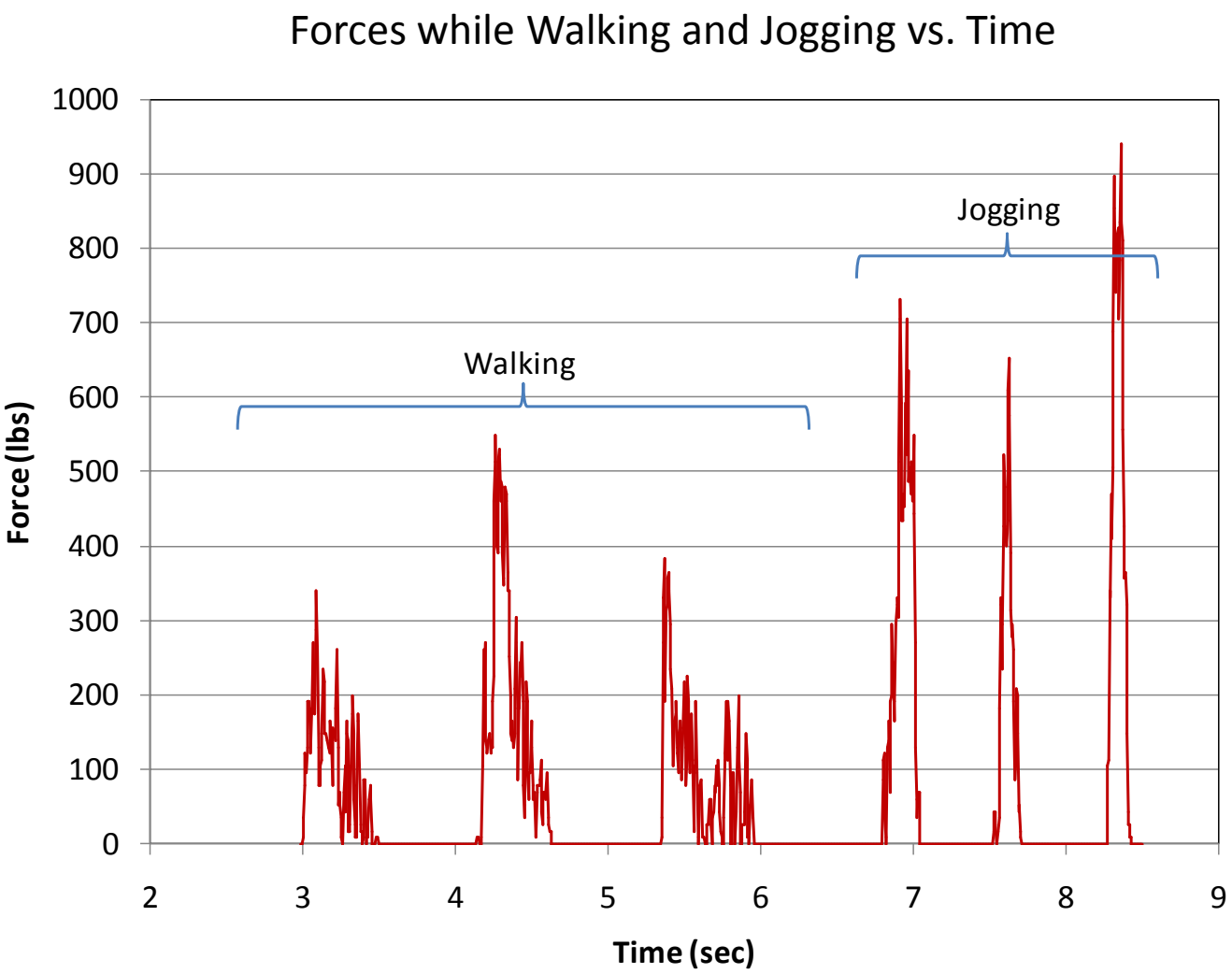
- The circuit board, sensor, power supply, switch, and a 6-pin extension cord were all inserted into a shoe for testing.
- The platform shoe used was a Vans skateboarding-style shoe.
  - Removable insole
  - Padded walls and tongue
- Only the switch and 6-pin connection were visible.



In-Shoe Calibration



In-Shoe Test Data



Conclusions

- The strong correlation between the actual forces and ADC output during calibration suggests that there will be little inaccuracy in any subsequent measurements.
- Concealing the sensor completely within a shoe has been successfully addressed.

The Foot PAD device, in progress since 2004, has finally overcome its main problems and been produced in a usable form.

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