Cyclops Healthcare Network

Smart Active Footbed for Wound Prevention and Management

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EPSRC Engineering and Physical Sciences Research Council
cyclops
IISE Institute for Innovation in Sustainable Engineering
UNIVERSITY of DERBY

Project Outline:

1.) Evaluate the performance of ‘smart’ materials appropriate for use as an active footbed

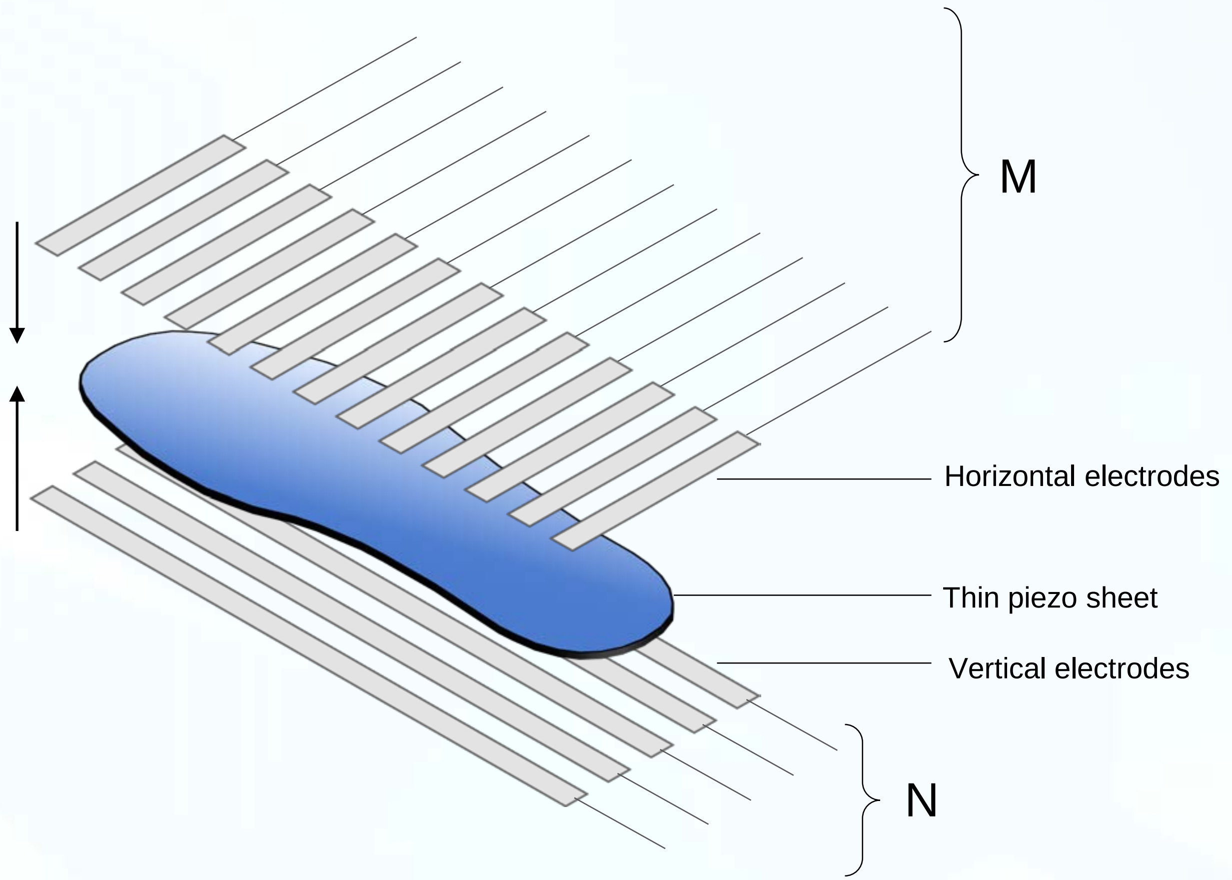
2.) Establish an appropriate combination of sensors and data processing for monitoring foot health

3.) Develop a closed loop control system comprised of smart foot sensing, processing and materials to prototype a footbed capable of autonomously detecting foot ulcers and altering itself to alleviate pressure in affected areas.

A system of two perpendicular sets of electrodes sandwiching a piezoresistor reduces the number of connections required compared to a typical array system.

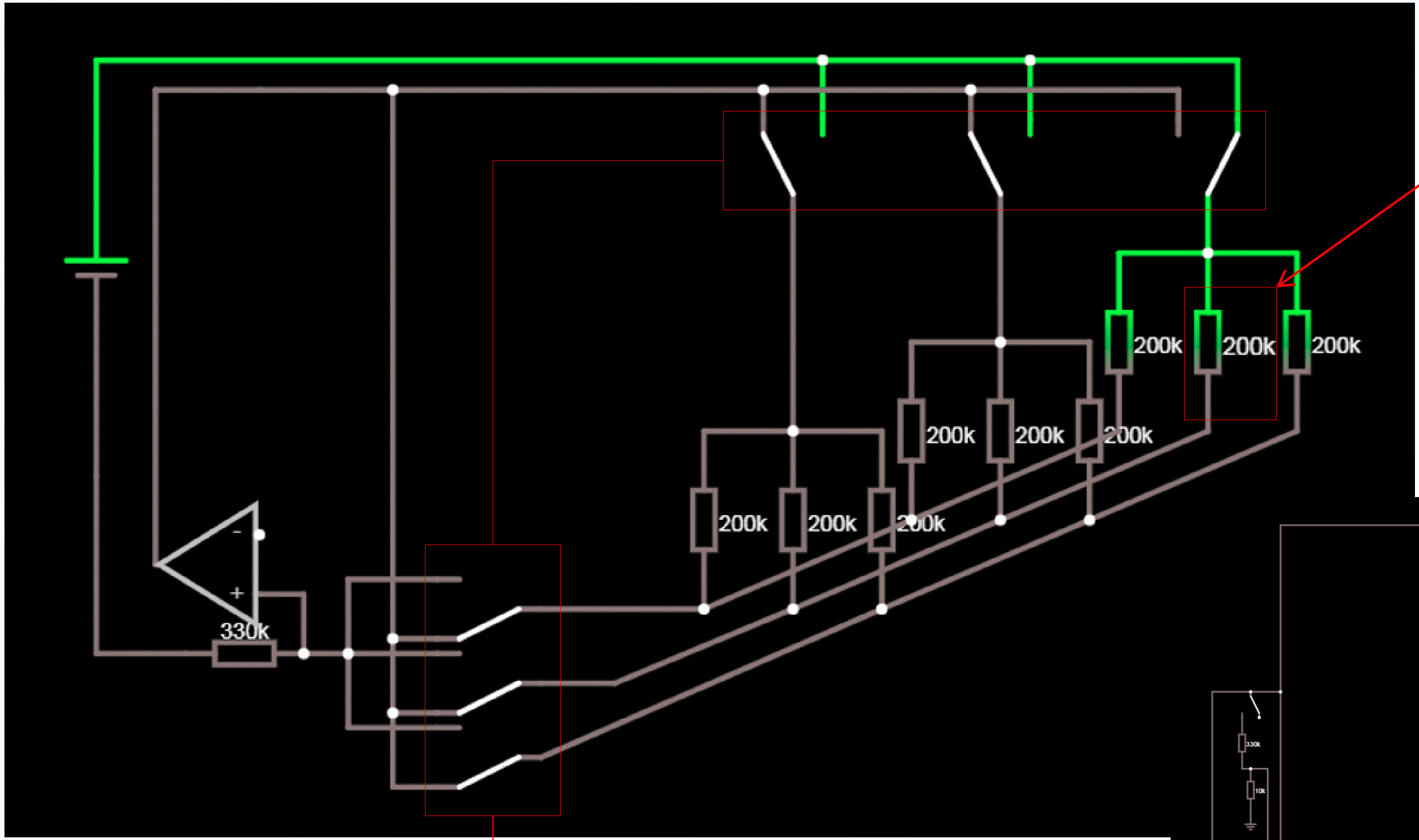
This matrix of M x N sensors requires only M + N connections, at the cost of introducing crosstalk between elements.

Crosstalk is eliminated through a simple voltage-feedback circuit.



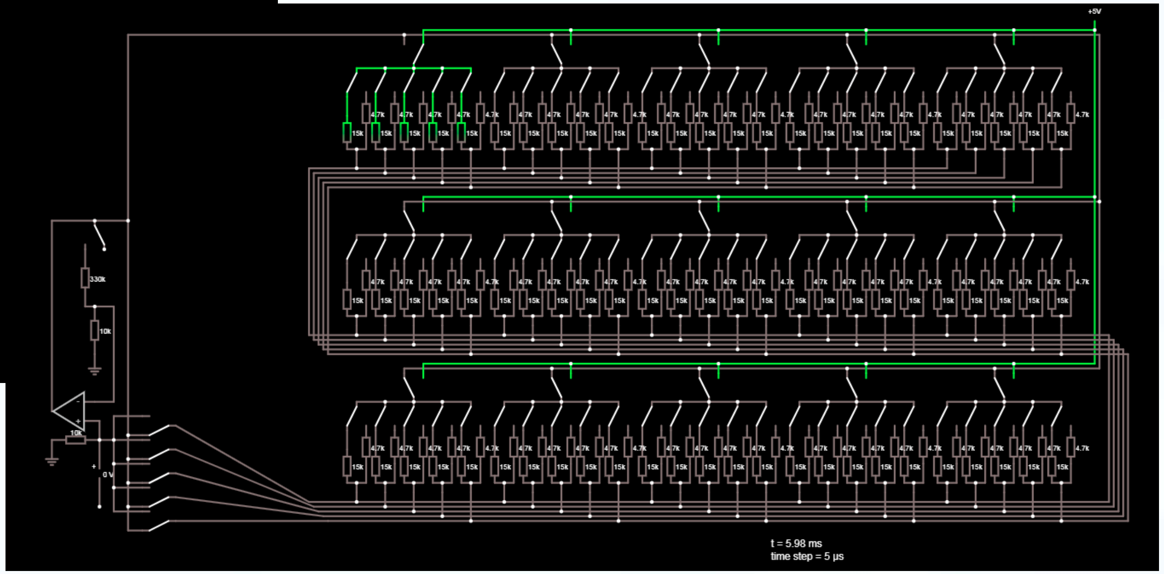
Circuitry

Example of noise-cancelling voltage-feedback circuit used on a 3x3 matrix array:



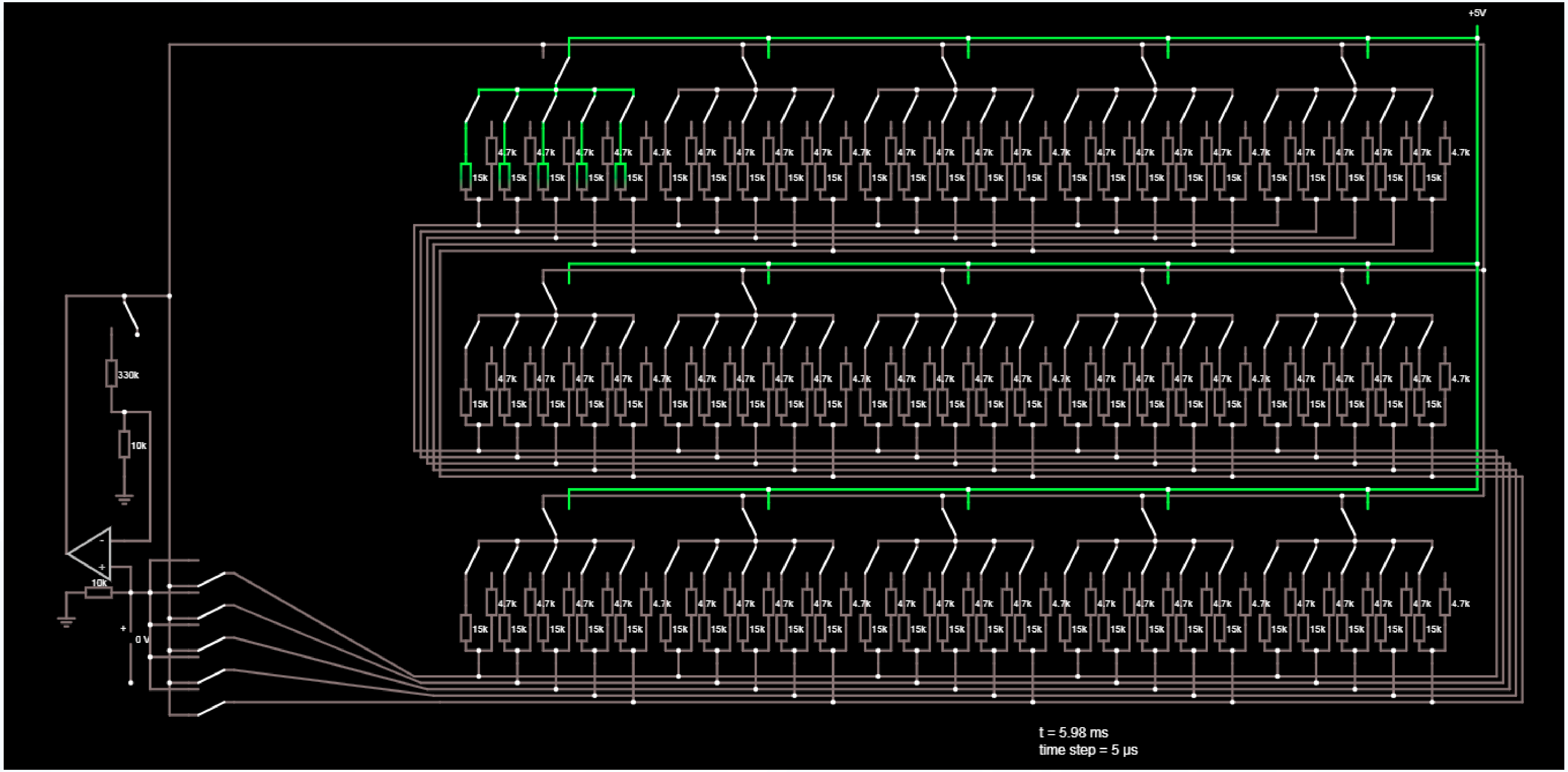
Particular array sensor element (sensel) being measured

This circuit was expanded to a 15 x 5 sensel array to maximise measurement resolution:

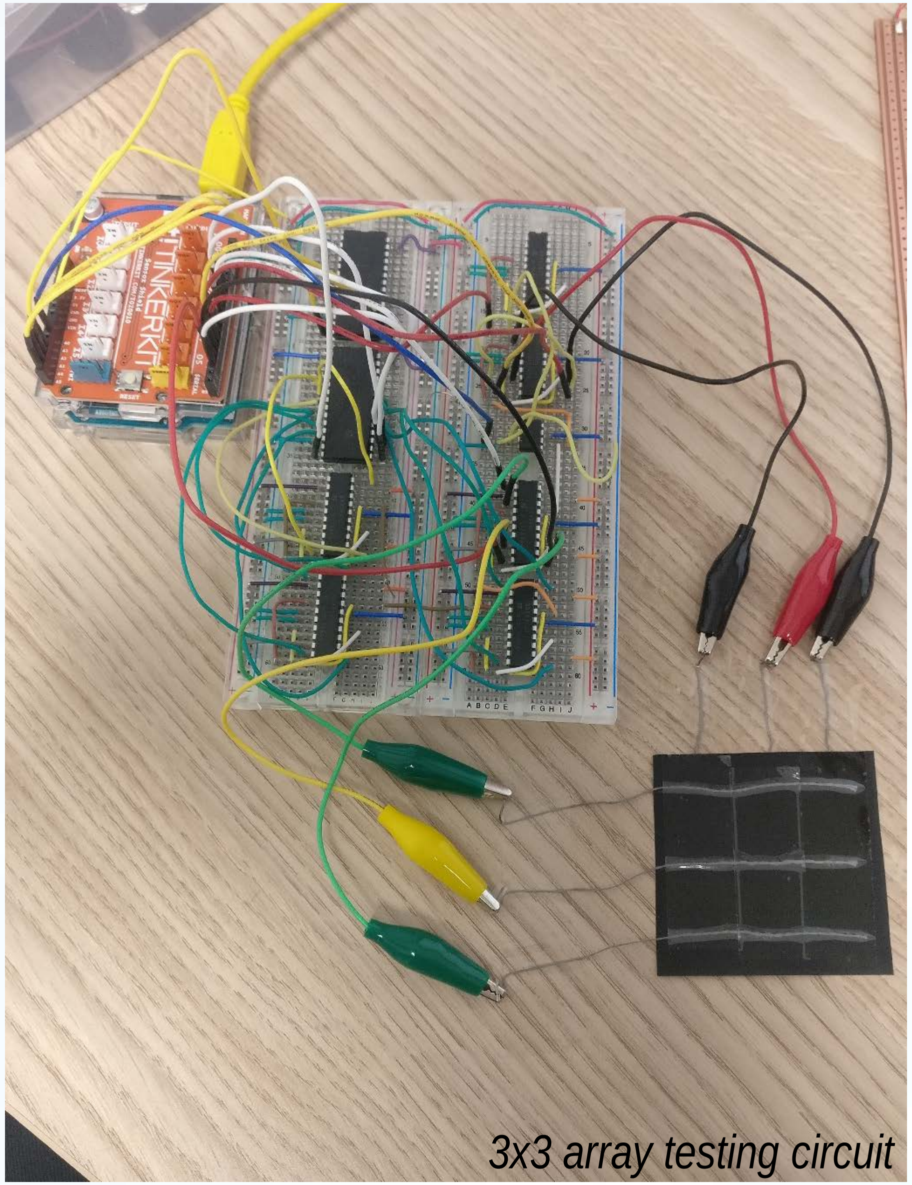


These switches control the row and column activations that select each sensel.

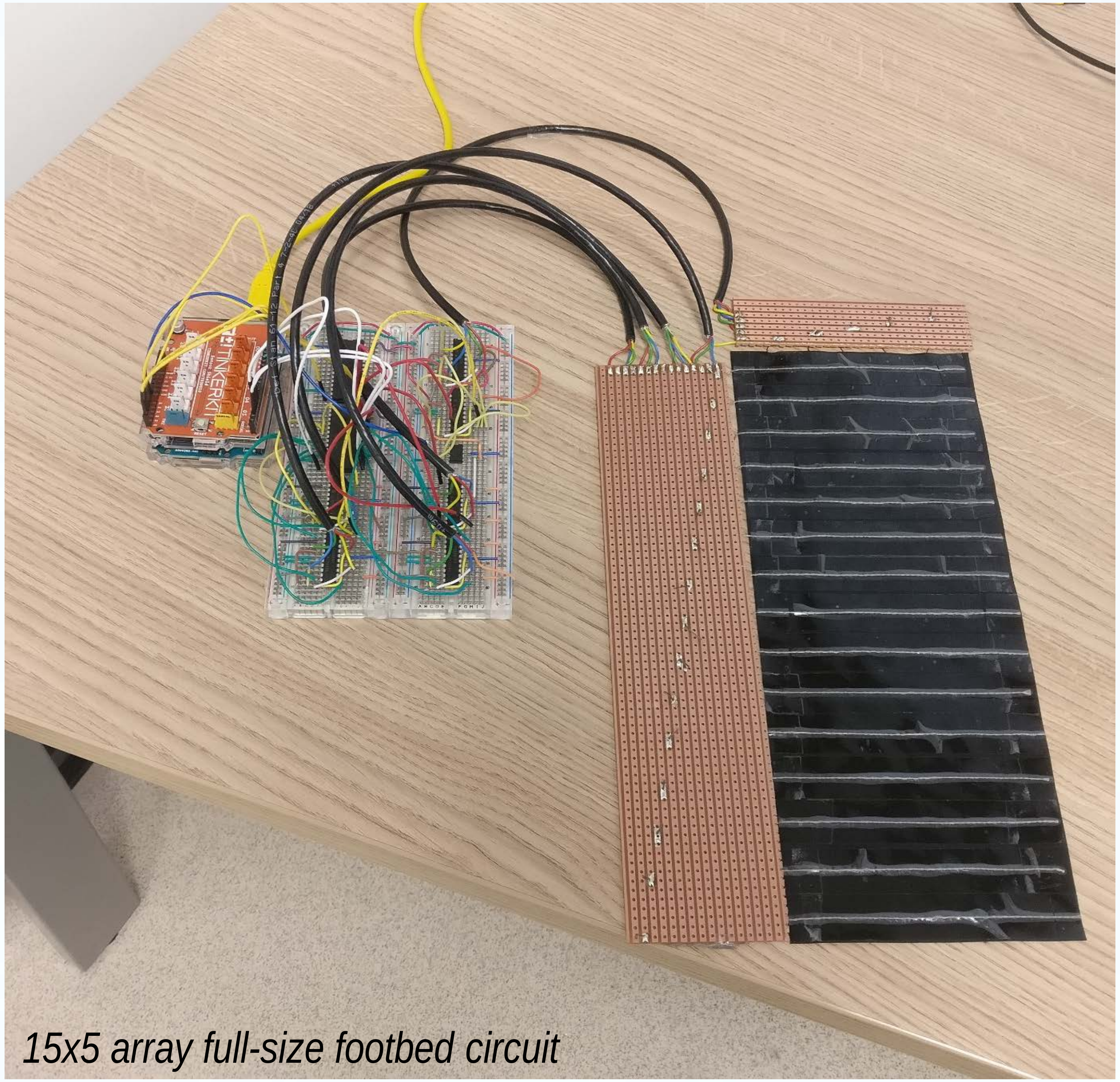
Same circuit, expanded to the full-size 15 x 5 array used in the final prototype:



Despite greatly reduced wiring requirements, it is still a necessity to multiplex microprocessor outputs to achieve the 20 I/O connections needed.



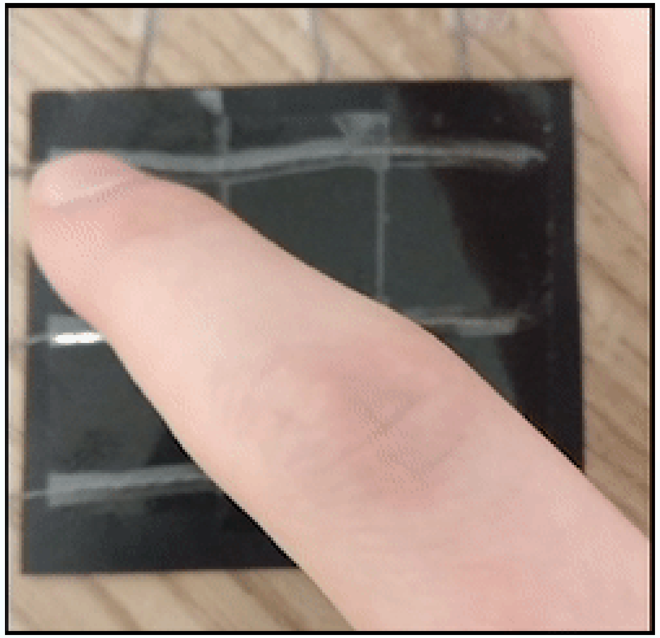
3x3 array testing circuit

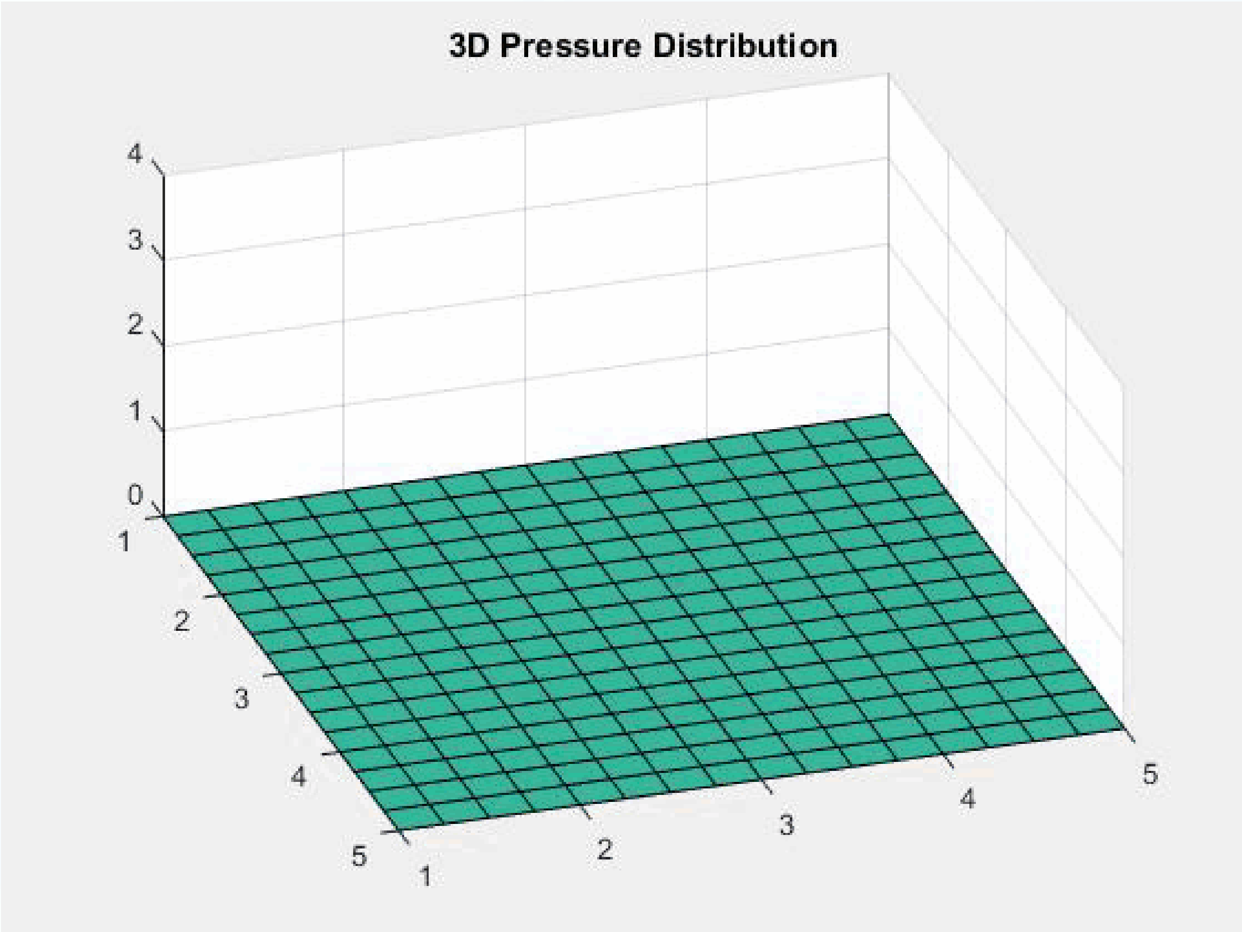


15x5 array full-size footbed circuit

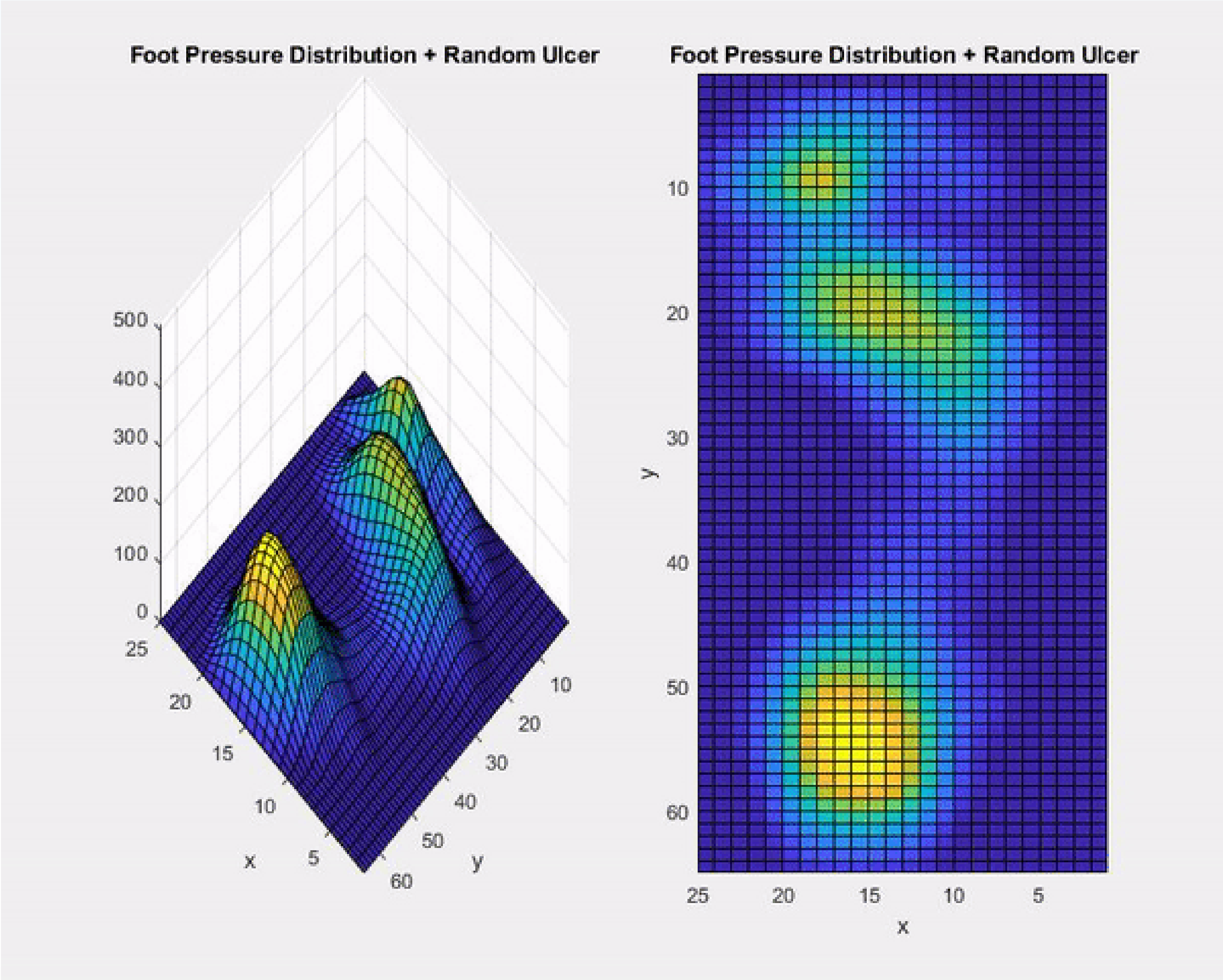
Processing

Sensor data is pre-processed by an Arduino Uno before being sent for full processing in MATLAB. Data is then interpolated to produce a representative pressure distribution.





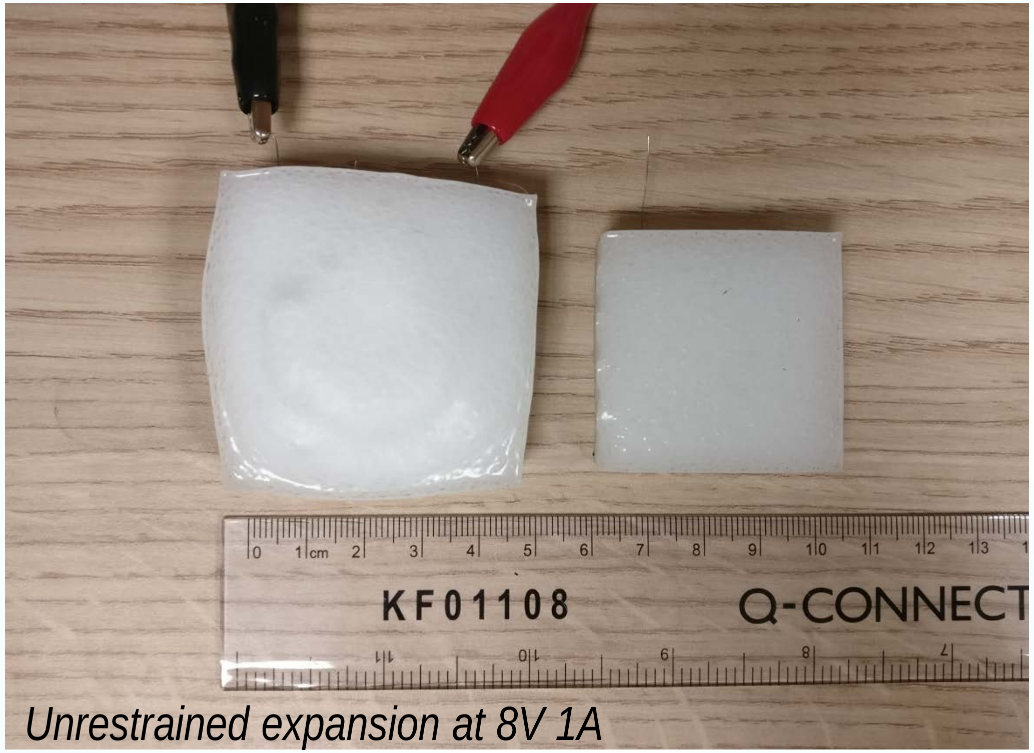
Measuring foot pressure distributions also allows us to simulate ulcer development in likely areas:



Ultimately, an ideal topographical model of an insole can be generated.
This model will then serve as a digital template for the smart material to attempt to imitate.

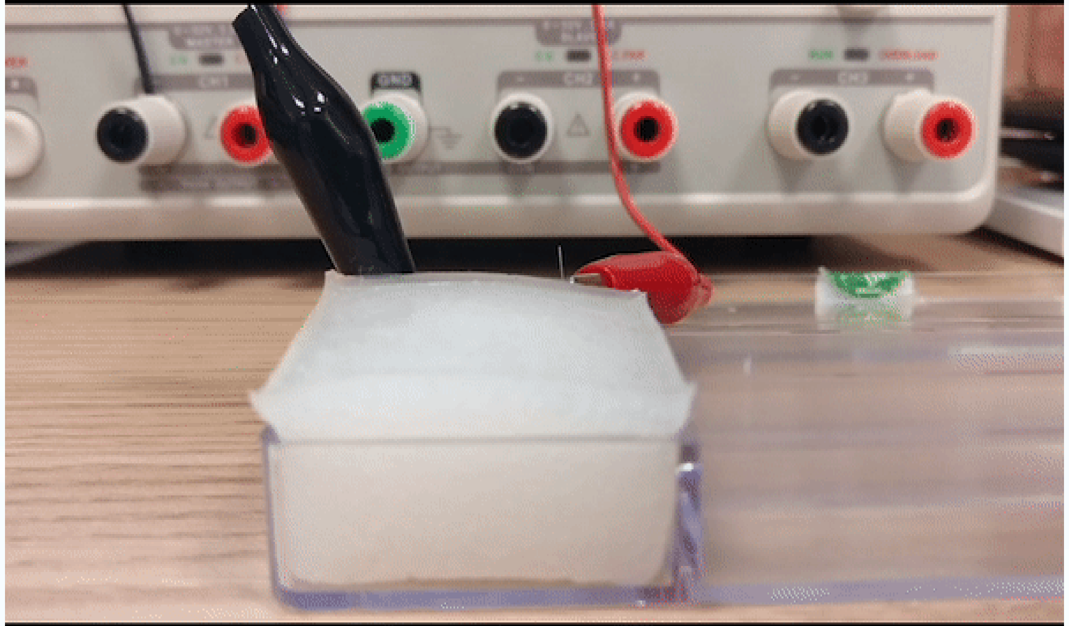
Smart Material

- With an optimal design and ideal wire placement within the silicone elastomer (Ecoflex 00-50) cured with 20% ethyl alcohol material, strains of up to 900% are possible. However, in the footbed design where only one dimension of expansion is allowed, strains typically range from 50-100%.



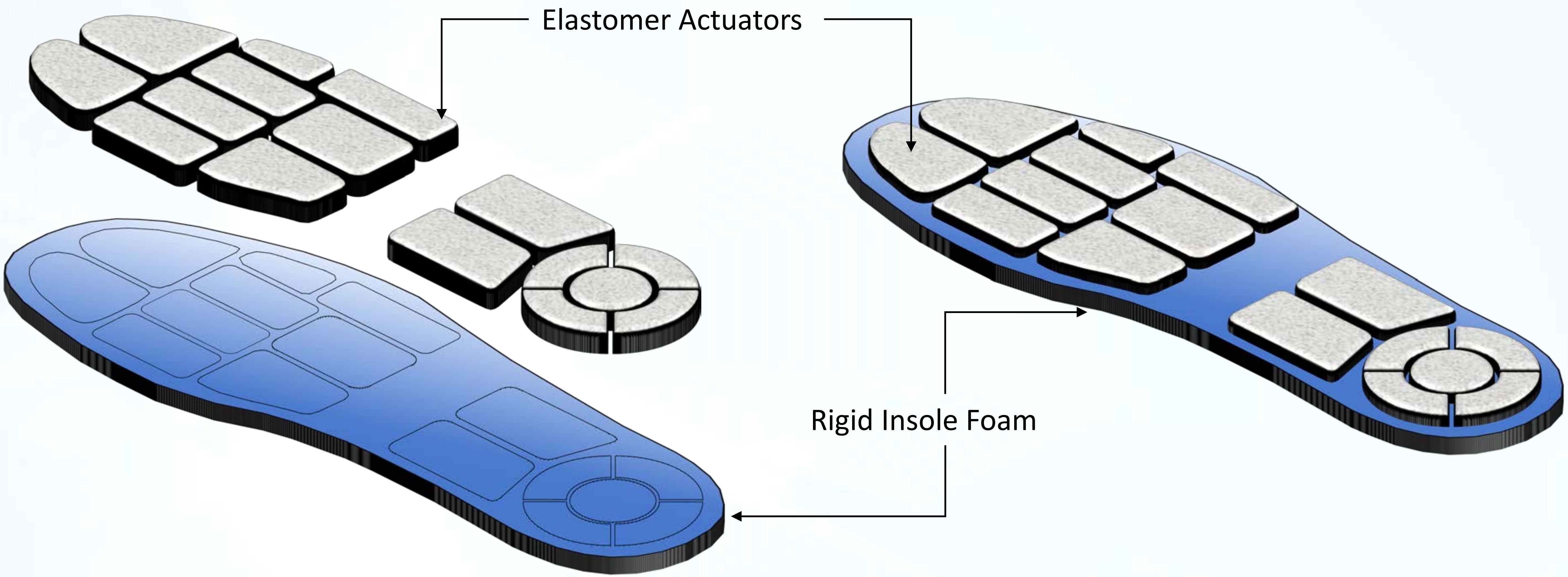
Unrestrained expansion at 8V 1A

32x Speed over 4 min



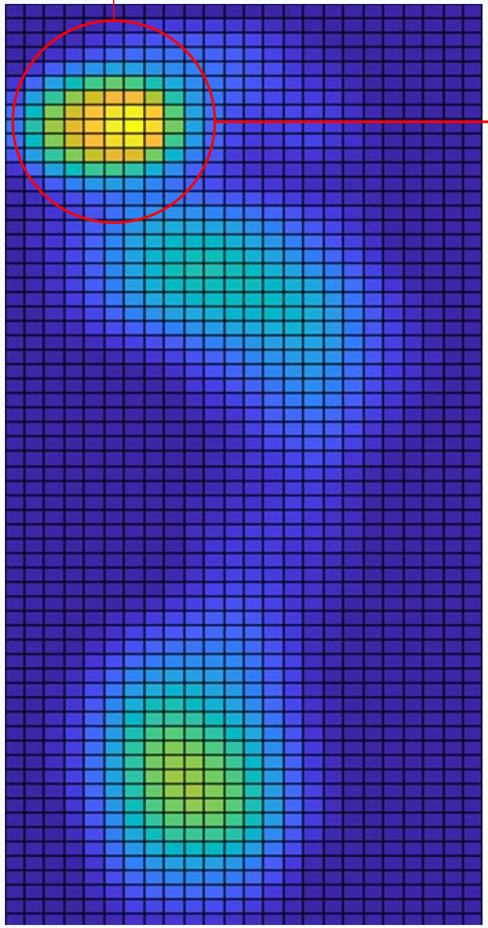
Restrained expansion at 8V 1A

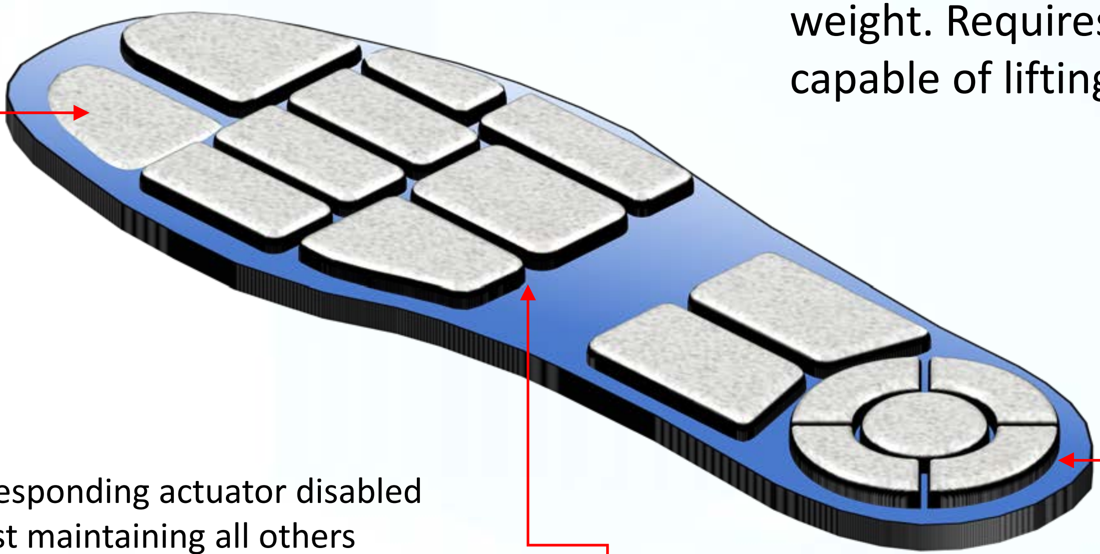
Smart Material: Footbed Design



Smart Material: Footbed Design

Ulcer development on first toe

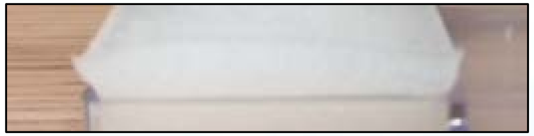




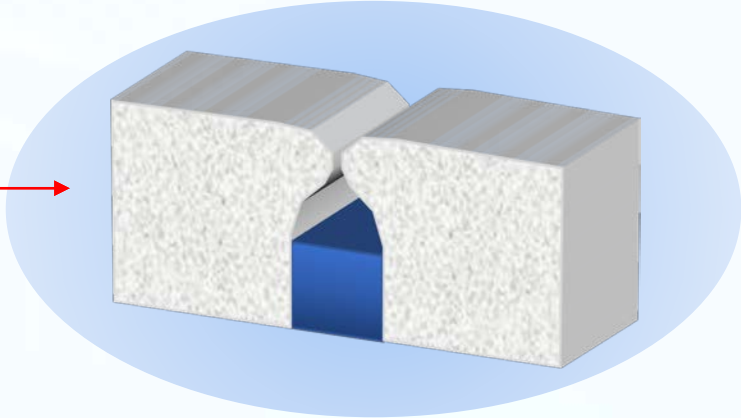
- Elastomer lifting ability exceeds 1000x own weight. Requires approx. 80g of material to be capable of lifting an 80kg human.

Adaptive radial heel design

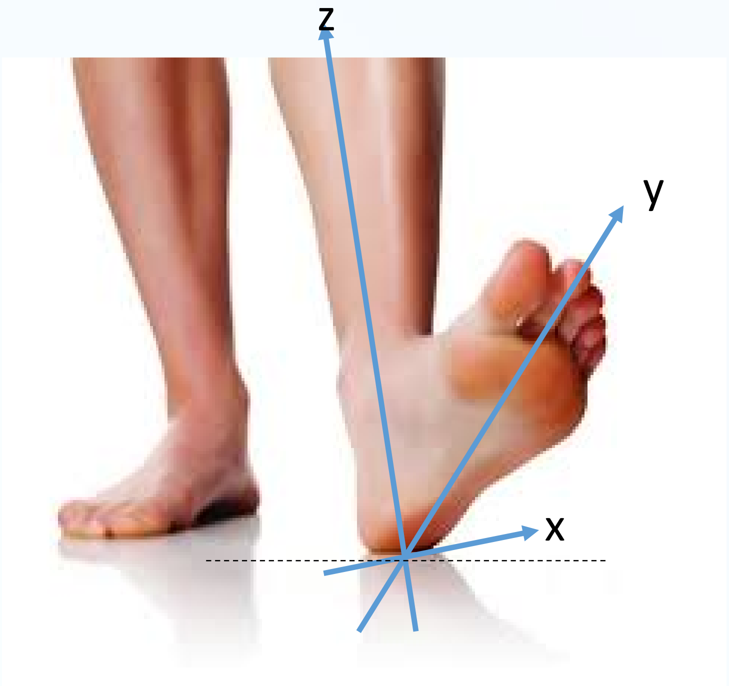
Corresponding actuator disabled whilst maintaining all others



Sufficient spacing allows for expansion overhang



Simple 1-D Foot Model & Plantar Pressure Reconstruction



- Simple biomechanical model of human foot describing the main elements that induce plantar pressure
- Assumes uniform elastic medium to describe soft tissue behaviour
- 3 sensors (heel, metatarsus and phalanges) are sufficient to reconstruct real time data for a 'healthy' foot while standing/walking.
- 6 sensors required for diabetic foot (WIP)
- Distribution of plantar pressure is linked to forces applied at the ankle such that link between posture and plantar pressure