Wearable system for applied force sensing during telemedicine operations

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BACKGROUND

Telemedicine
- Telemedicine enables medically remote areas to have access to healthcare services, helps in overcoming socio economic barriers to treatment, reduces workload on the healthcare system, and improves patient-therapist communication

Telepresence technologies
- Telepresence technologies facilitate more effective and safer healthcare service delivery and can be achieved through multimedia sensory feedback that involves haptic or tactile, sound, vision or olfactory.

Tactile modality
- Tactile modality, particularly, has found wider use in the field of medicine and minimally invasive robotic surgery. Integrating tactile feedback in robotic surgery would expand the role of robotics in clinical tests and examinations requiring palpation.

OBJECTIVE

Contributions of this research include:
- Specifying a reproducible design method of the modular wearable pressure sensor array.
- Suggesting a closed loop two-way communication system where the produced design and its future iterations can be implemented.

Main objective: To design a modular wearable pressure sensor array for monitoring a human end effector's palm contact forces on the patient

DESIGN METHODOLOGY

Component selection for Sensor Reading of applied force values
- The selection process primarily focused on compatibility of the pressure sensors with a fabric while achieving the primary function 1 (flexibility of the sensor, lightweightness, force sensitivity, and less number of components for data acquisition.) using a force sensitive resistor (FSR)
- To deduce the force the end effector applies on the patient, the applied force values needs determined in real time.

Building the control circuit consisting of a buffer, microcontroller, multiplexer and a wireless communication module.
- A voltage divider circuit was designed [figure 1, 2] for real-time resistance reading
- XIAO RP2040 microcontroller from Seeed Studio was used for portability and wearability
- To ensure that the microcontroller can accurately read the Vin values without drawing substantial current from the voltage divider circuit, an input buffer stage was introduced before the Vin reaches the microcontroller.
- A wireless communication module, HC-12 long-range wireless module was used for up to a range of 1000 Meters.

DESIGN METHODOLOGY

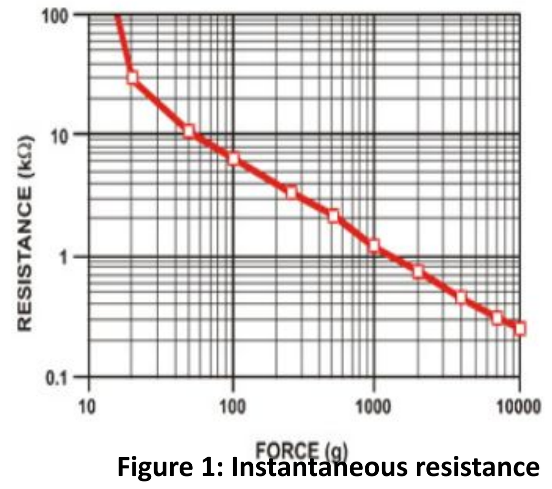

Figure 1: Instantaneous resistance versus applied force curve of the FSR (Model 402).

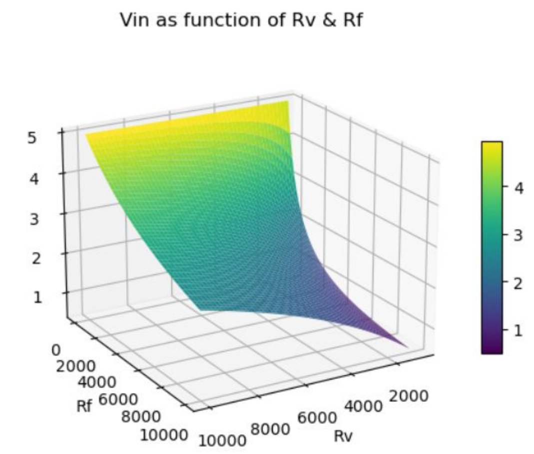

Figure 2 : Vin as a function of the two resistances in the voltage divider circuit.

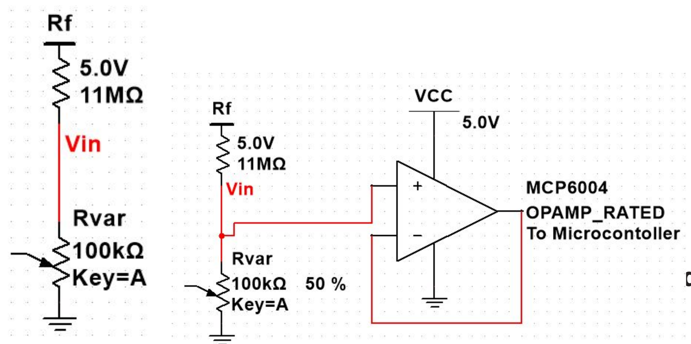

Figure 3 : Left: Voltage divider circuit for calculating realtime resistance of the FSR and hence deducing the applied contact force. Right: Voltage divider circuit connected to the OpAmp buffer prestage to the input into the microcontroller.

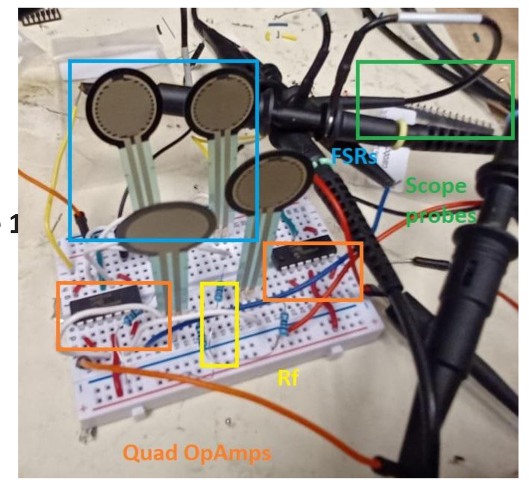

Figure 4 : Experimental setup for testing the unity gain buffer

RESULTS

- Experiment 1: Testing the buffer circuit to ensure the unity gain buffer worked correctly once with a square wave input and other tests were done by touching the FSR units
- The unity gain buffer showed no attenuation or amplification hence met expectations.
- The Oscilloscope readings of the FSR behavior matched the theoretical expectations deduced from Kirchoff's laws and the component datasheet

Figure 5 : Oscilloscope reading of the buffer output and original signal input (blue:original input signal, other colors: buffered output).

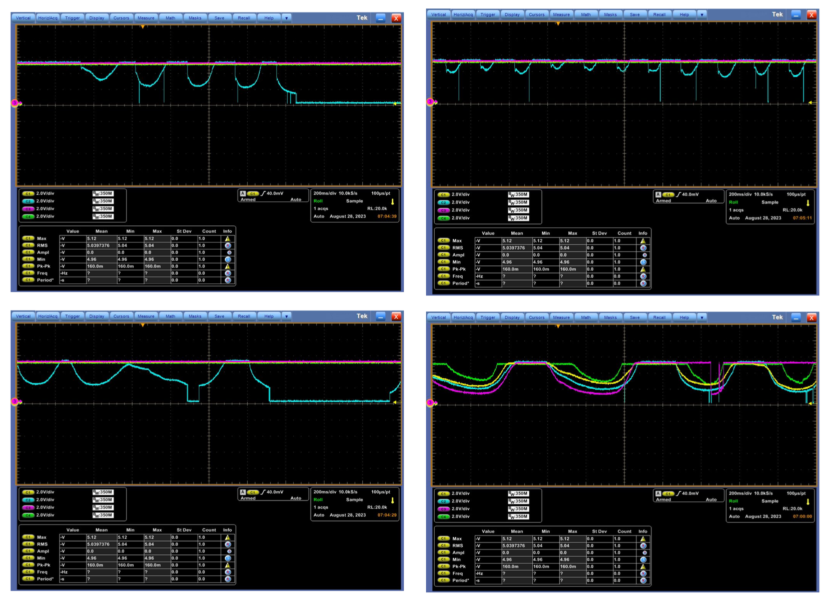

Figure 6 : Oscilloscope readings of the FSR response to touch stimulus from the human hand.

RESULTS

Experiment 2: Building & testing the control circuit

To build the system incrementally in modules and test the same. Modular design involved detachable and reconfigurable FSRs, detachable voltage divider bar and detachable control unit.

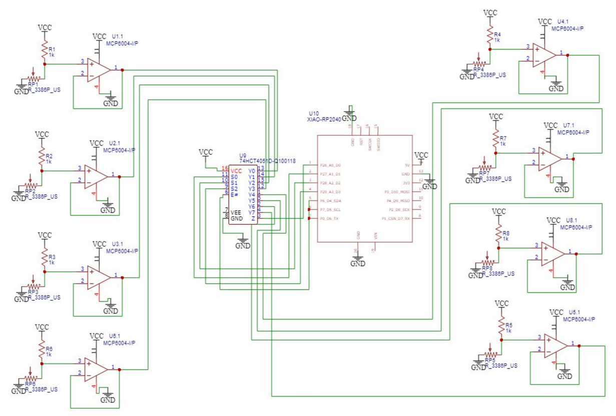

Figure 7: Circuit diagram of the wearable device showing buffers, multiplexer and the microcontroller.

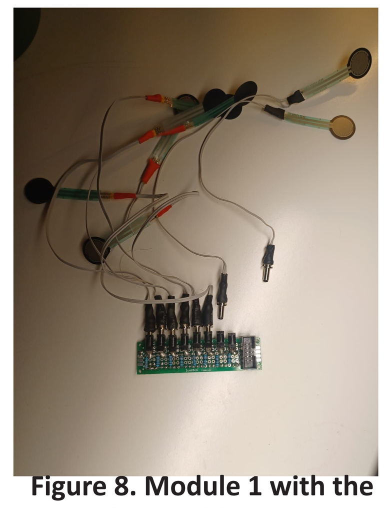

Figure 8. Module 1 with the detachable FSRs

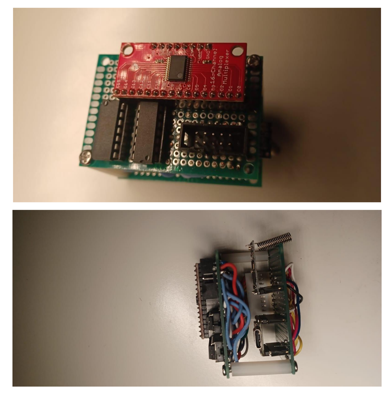

Figure 9. Module 2 Top and side view of the control circuit

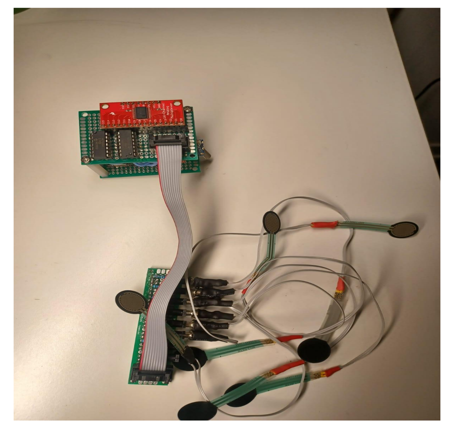

Figure 10. Fully connected module 1 and module 2

Figure 11. The entire system embedded into a glove

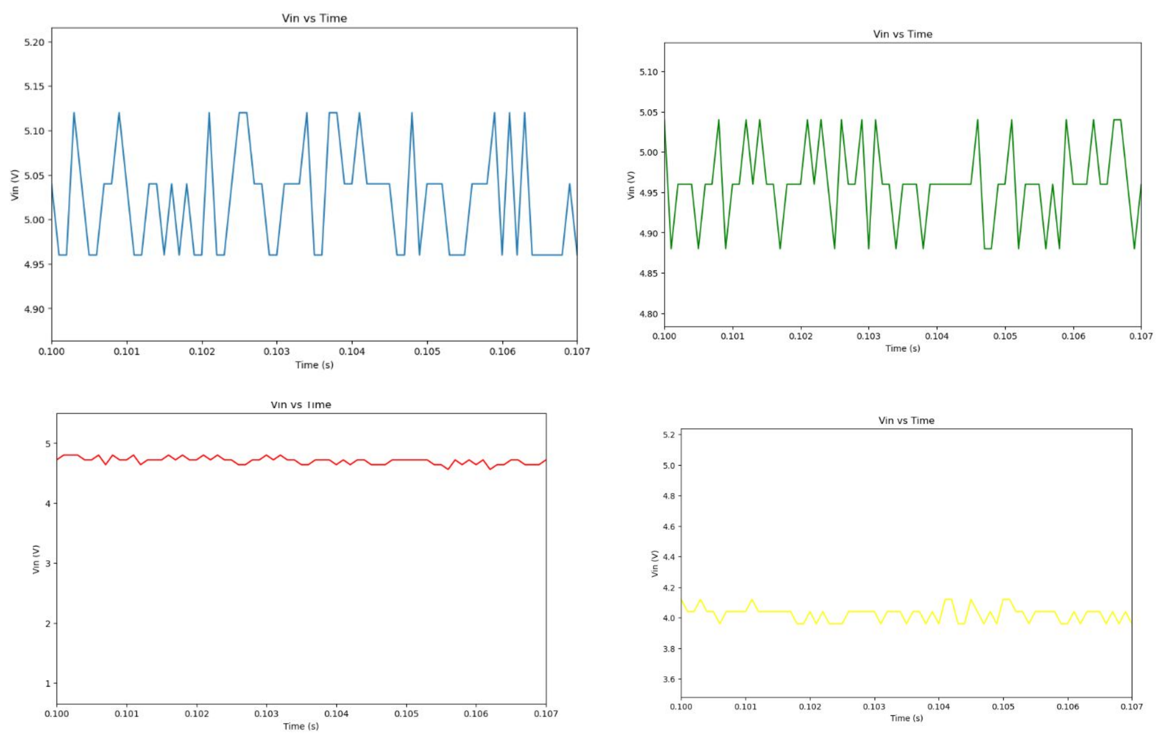

Figure 12. Signal acquired by the receiving unit from four of the FSRs on the gloves. A difference in the pulse pattern is observed across the four plots.

CONCLUSIONS

- The observed FSR stimulus data demonstrates that the system is working.
- Further improvements have to made on increasing the fidelity of the circuit by using a Printed Circuit Board for connecting the components, implementing better polling and encoding algorithms and schemes, and using flexible connectors for reconfigrability.
- A haptic gloves need to developed for rendering the applied force data on the remote manipulator's side.