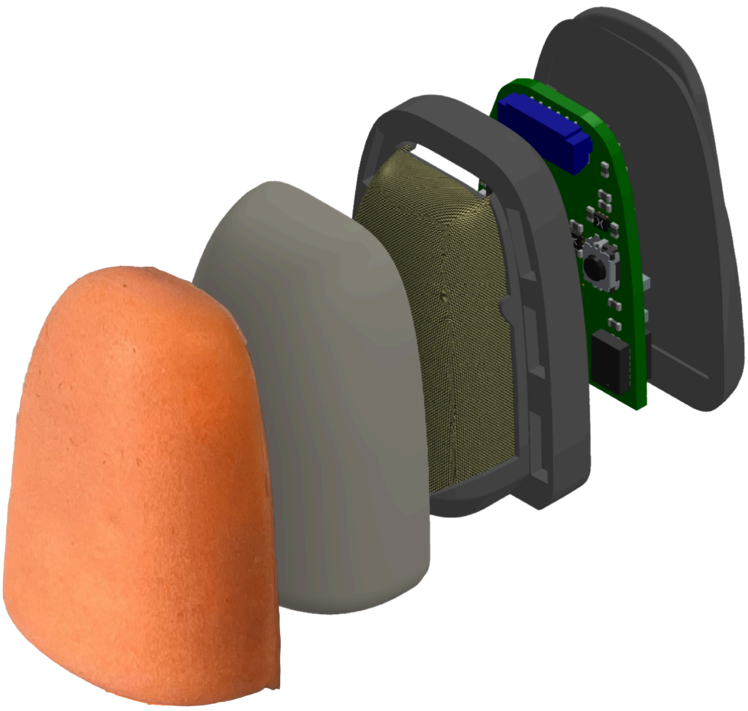
TOUCHLAB

TECHNICAL DATA SHEET

Humanoid Robot Fingertip

Version 2, 2025



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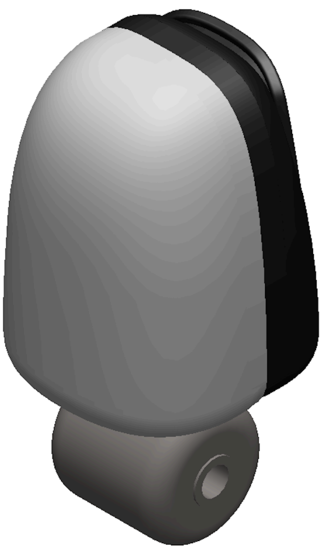
1. Overview

The **Humanoid Robotic Fingertip with Interchangeable Skin Layer and High-Resolution Sensing** is an advanced tactile sensing module. Featuring **16 tactile sensing pixels (taxels)** distributed across the fingertip, it provides **high-resolution force feedback**, enabling precise object interaction.

An **innovative replaceable outer skin layer** eliminates **mechanical crosstalk**, ensuring accurate and independent sensing across the fingertip. The skin layer also enables long-term re-usability as the fingertip can continue operating even after the skin wears out. The fingertip system is optimised for **high sensitivity, low drift, and low hysteresis**, delivering **stable and repeatable** measurements over extended use.

The magnetic attachment system of the outer skin layer allows for quick and secure replacement of the outer layer, offering adaptability for different materials, textures, and sensing applications. The **wide dynamic** range enables detection of both **light and heavy forces**, while an **SPI interface** ensures high-speed digital communication for seamless integration with robotic control systems.



Designed for durability and versatility, this fingertip module is ideal for applications in robotics, prosthetics, industrial automation, and human-robot interaction, where precise tactile sensing and modular customisation are essential.

2. Key Features

- **16 Sensing Elements**: High-resolution tactile sensing elements across the fingertip for precise object interaction.
- **Replaceable Outer Skin Layer**: Enables customisation, material property adjustments, and wear replacement.
- **Pin-and-Magnet Attachment System**: Ensures secure yet easily swappable outer layers.
- **Wide Dynamic Range**: Capable of detecting both light and heavy touch forces.
- **Sensing Range**: 0.1 - 10 N (10kPa - 1073kPa) per sensing element area (taxel - 1.72mm radius: 9.32mm^2 area).
- **Accuracy:** 2% for lower force range, 3% for entire dynamic range.
- **Sampling Frequency:** 315Hz for per 16 taxels, and up to 1kHz+ for lower-taxel regions
- **SPI Output**: Enabling high-speed communication with robotic systems.
- **Compact & Durable**: Optimised for robotic and prosthetic applications, industrial automation, and human-robot interaction.
- **1-to-1 Hardware Mapping with HaptX Gloves:** Optimised for HaptX G1 gloves, for the best experience when using these haptic gloves for teleoperation or teaching robots through with humans-in-the-loop (e.g. imitation learning)
- **Direct Interface with Shadow Robot's Dexterous Hand:** Wiring and SPI communication interface optimised for use and internal routing with the latest Shadow Dexterous Hand

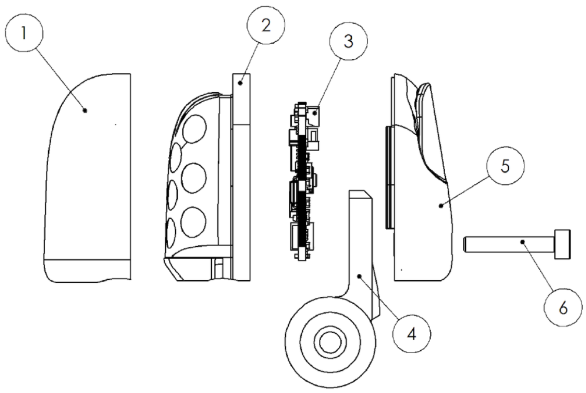
3. Applications

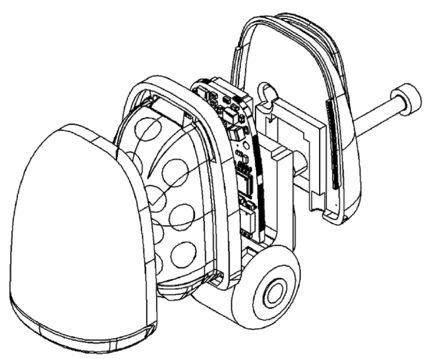
- **Assembly and warehouse fulfilment**: Measure grasp stability and detect object slippage to enhance pick rates and boost warehouse or assembly line productivity.
- **Glove box**: Enable teleoperated robots with touch sensitivity for precise, dexterous tasks in hazardous environments, ensuring safe handling of chemicals, biological, or nuclear materials*.
- **Training humanoid robots**: Train your humanoid robot to perform dexterous real-world tasks. Use the sense of touch to handle scenarios where vision is unreliable or occluded. Create datasets and AI models to advance the next generation of robots for workplaces and households.
- **Material evaluation**: Build a database of materials and object properties, using touch to identify textures, shapes, softness, and more, enabling virtual exploration and allowing customers to feel products before purchase.
- **Robot safety**: Enhance grasp stability and develop robots that regulate grip and force applied during object manipulation, enhancing safety with precise touch and compliant control.

*Primary sensor film layer tested under 300 kGy of Gamma Radiation

4. Specifications

4.1. Mechanical Specifications

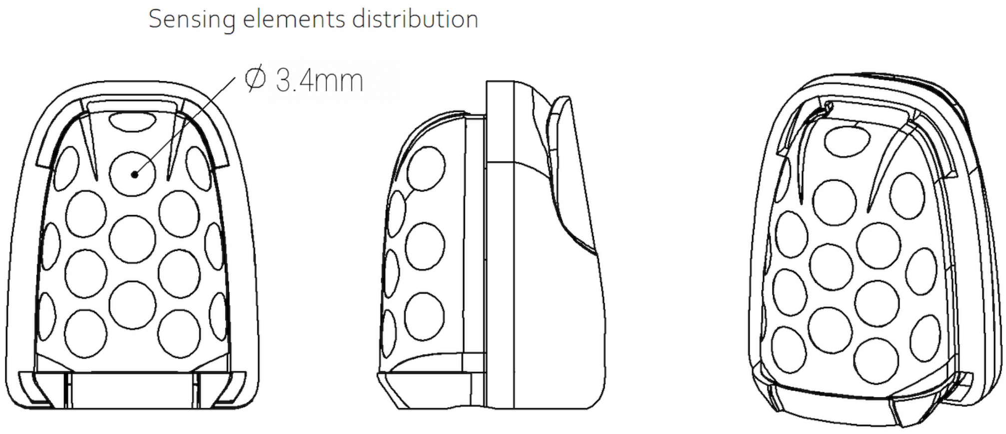


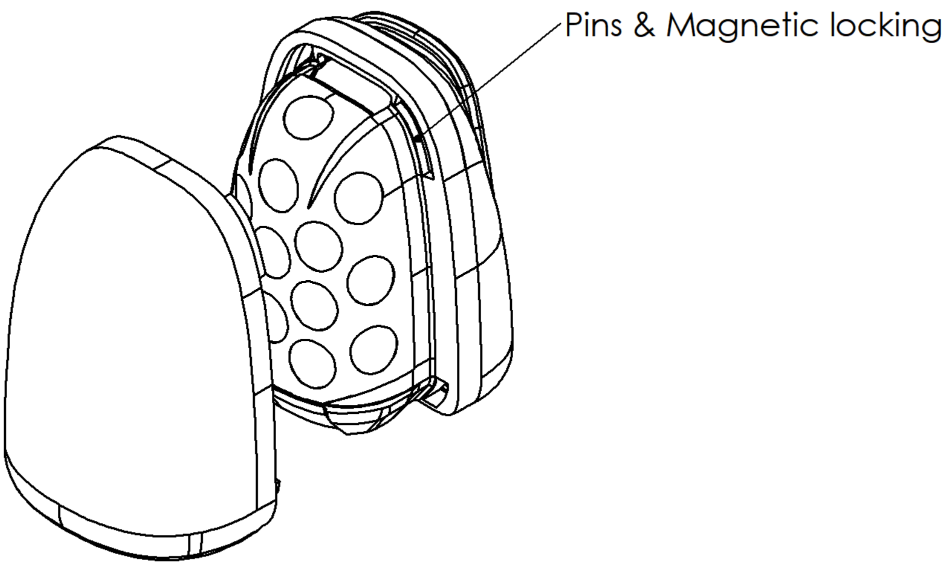


Item №	Part Name	QTY.
1	Replaceable Compliant Outer Skin Layer	1
2	Main fingertip and sensors	1
3	PCB	1
4	Adaptor	1
5	Nail	1
6	ISO 4762 M2 x 10 - 10C	1

Parameter	Value	Notes
Fingertip Dimensions	27.5 x 21x 21.23mm (LxWxD)	Similar to human size fingertip
Base Material	ABS	Structural core

Parameter	Value	Notes
Replaceable Compliant Outer Skin Layer Material	Silicone, PU elastomers	Supports interchangeable transfer layers with varying material properties to suit different applications.
Attachment Mechanism	Magnetic locking mechanism	Secure, quick-swap system
Weight	9 g	Varies with materials used on Transfer Layer
Maximum Load Capacity	40N	
Adaptor	Customisable area	Can be modified to enable attachment to different hands.


Sensing elements distribution
Ø 3.4mm


Pins & Magnetic locking

4.2. Electrical Characteristics

Absolute Maximum Ratings*

PARAMETER	MAX	UNITS	NOTES
Supply Voltage	6.25	V	
SPI_CS# (w.r.t. Ground)	4.39	V	Higher than other SPI pins due to the on-board resistor divider. (Required to allow compatibility with 4V Idle high on CS#)
SPI_CLK, SPI_MISO, SPI_MOSI (w.r.t. Ground)	3.63	V	

⚠ *NOTICE: Stresses above those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. This is a stress rating only and functional operation of the device at those or any other conditions above those indicated in the operational listings of this specification is not implied. Exposure to maximum rating conditions for extended periods may affect device reliability.

IO Characteristics

The following characteristics are defined as applied to the Touchlab fingertip sensor connector pins.

PARAMETER	MIN	TYP	MAX	UNITS	NOTES
Supply Voltage	4	5	6	V	
SPI_CS# - Input low-level voltage	-	0	1.2	V	Higher than other SPI pins due to the on-board resistor divider. (Required to allow compatibility with 4V Idle high on CS#)
SPI_CLK, SPI_MISO, SPI_MOSI - Input low-level voltage	-	0	0.99	V	Dictated by MCU I/O pin characteristics

SPI_CS# - Input high-level voltage	2.8	3.3	-	V	Higher than other SPI pins due to the on-board resistor divider. (Required to allow compatibility with 4V Idle high on CS#)
SPI_CLK, SPI_MISO, SPI_MOSI - Input high-level voltage	2.31	3.3	-	V	Dictated by MCU I/O pin characteristics

4.3. SPI/USB Communications Interface

There are two methods of communicating with a fingertip sensor - SPI and USB.

- **SPI**: Default method used for communicating with external master system in end applications.
  - SPI bus clock: up to 8 MHz.
  - SPI supports parallel peripheral connection (no daisy-chain)
  - SPI controller for connecting up to 5 boards, available to developers.
  - SPI protocol specification available for integrators.
- **USB**: Primarily used for flashing the bootloader onto, and updating the firmware of, the MCU, but can also be used to stream data in development mode.
  - USB 2.0+ supported
  - Data protocol for development mode available for integrators

Packet Structure

In both communications modes, taxel data is sent in the following format:

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
A1	A2	A3	B1	B2	B3	C1	C2	C3	C4	D1	D2	D3	E1	E2	E3	CAL	V

Where:

- [0:15] Values Ax, Bx, Cx, Dx, Ex are taxel readings, mapped to the physical fingerprint in section 4.4. Taxel Mapping.
- [16] CAL is a 'calibration' sample of the readout circuit with no taxels enabled.

- [17] V is a voltage reading from the readout circuit analog supply, which can be used when checking for error cases.

SPI Mode

The communication method must be set during device start-up and operates on an "either/or" basis. By default, the system will use SPI communication.
SPI mode is indicated by fast flashing of the green status LED (100 ms).
Once configured into SPI mode during start-up, the system will remain in SPI mode until the entire system is power cycled. After a power cycle and with no user interaction, the system will default back to SPI communication.

ⓘ The SPI protocol is available to integrators on request.

USB Mode

The system can be configured to use USB communication instead, by holding the push button down while powering up the board.
USB mode is indicated by slow flashing of the green status LED (1 s).
Once configured into USB mode during start-up, the system will remain in USB mode until the entire system is power cycled. After a power cycle and with no user interaction, the system will default back to 4.3. SPI communication.
For integrators:

- **Serial protocol**:
    - Comma separated raw sensor values: “tx1, tx2, … , txN”
    - One value per taxel
    - One line per reading

Incorrect Setting

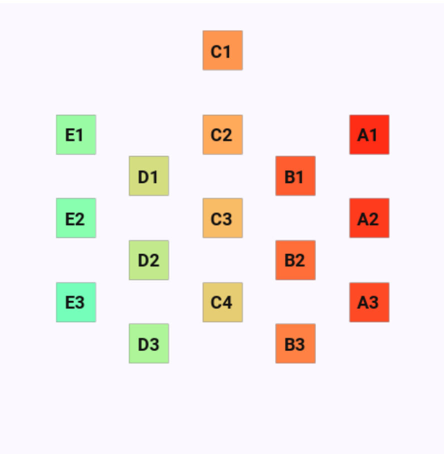
Incorrect setting of the communications mode for a given setup (USB mode when connected to SPI, or SPI mode when configured in USB mode), will not result in damage to the device, but no communications will take place.

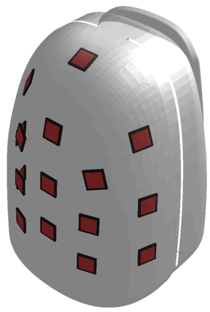
Troubleshooting

If the push button is pressed after the board has powered up, it will still enter USB mode; however, the connected PC may not recognize the device. This occurs because the operating system, having previously detected the board in SPI mode, typically does not continuously check for device readiness, leading to a failure in establishing communication upon mode change.

4.4. Taxel Mapping

Fingertip taxel data is transferred over SPI and USB in the following order: A1, A2, A3, B1, B2, B3, C1, C2, C3, C4, D1, D2, D3, E1, E2, E3. Further details on transmitted data format is discussed in section SPI/USB Communications Interface.



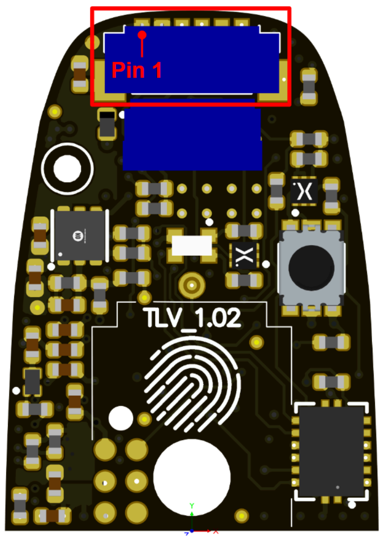


The taxel locations on the fingertip when looking from above

4.5. Interface Connector

The main interface connector to the Fingertip sensor is indicated as shown.

⚠ Although there is sufficient room on the board to connect/disconnect the interface connector, space is tight and care should be taken not to damage nearby components on the board.

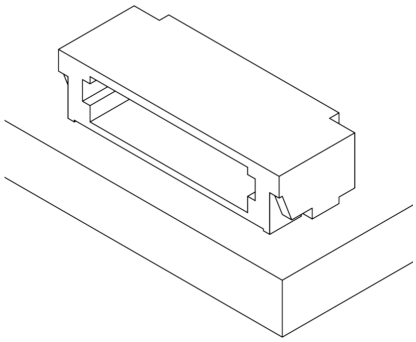


Pinout

PIN	PIN NAME	TYPE	DESCRIPTION
1	Power	Power	Supply voltage with respect to ground. Typically 5V, see electrical characteristics section for details
2	Ground	Power	Ground
3	SPI_CS#	Input	SPI_Chip Select (Active Low, from SPI Master)
4	SPI_CLK	Input	SPI Clock In (from SPI Master)
5	SPI_MOSI *	Input	SPI Data In (to SPI Slave, i.e. Fingertip Sensor)
6	SPI_MISO *	Output	SPI Data Out (from SPI Slave, i.e. Fingertip Sensor)

*SPI_MOSI and SPI_MISO have additional functionality for development purposes only. See in section SPI/USB Communications Interface.

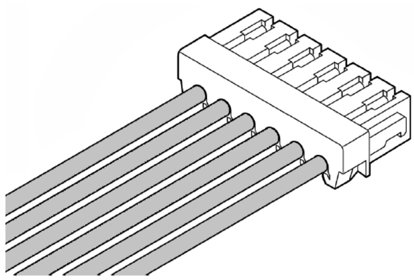
Connector Part Information



Board Header: SM06B-SURS-TF | Product Webpage

This connector is also available as Top Entry:

Board Header (Top Entry): BM06B-SURS-TF | Product Webpage



Mating Socket (AWG#32 (Natural)): 06SUR-32S

Mating Socket (AWG#36 (Lemon Yellow)): 06SUR-36L

⚠ *The JST 'Handling Manual' provides detailed instructions for creating cable assemblies in the SUR connector range. It is essential to follow these guidelines carefully, as failure to do so may lead to unreliable or intermittent connections.*

4.6. Cable Assembly Guide

Fingertip sensor devices interface with a master device via a cable connected to the Interface Connector.

Two options exist for sourcing cables:

1. **Ready-made cable assembly.**
2. **Custom cable assembly.**

Ready-Made Cable Assemblies

Ready-made cable assemblies of different lengths can be purchased from various electronics component distributors, such as Mouser and Digikey.

The customer should be aware that ready-made cable assemblies are available in two versions:

Straight - Pin 1 of connector side A, connects to pin 6 of connector side B.

Reversed - Pin 1 of connector side A, connects to pin 1 of connector side B.

⚠ Touchlab recommends using the 'Reversed' option, to minimise confusion and prevent issues with connector pinouts.

Custom Cable Assemblies

Custom cable assemblies allow the customer to obtain the exact length of cable assembly required for their application.

JST offers a custom cable assembly service, providing an option for low and high volumes, at reasonable costs. This route guarantees high quality harnesses that will perform reliably in your application.

JST provides a 'Handling Manual' which includes important information regarding making harness assemblies utilising the SUR connector range.

⚠The correct tooling must always be used when making cable assemblies, using either JST's automatic insulation displacement (ID) machine, their pneumatic ID press or their hand press.

Failure to use the correct ID tool or the incorrect wire specification can result in unreliable connections, negatively affecting the performance of the fingertip sensor.

⚠Touchlab recommends specifying a 'Reversed' type harness (see above explanation), to minimise confusion and prevent issues with connector pinouts.

4.7. Environmental Operating Range

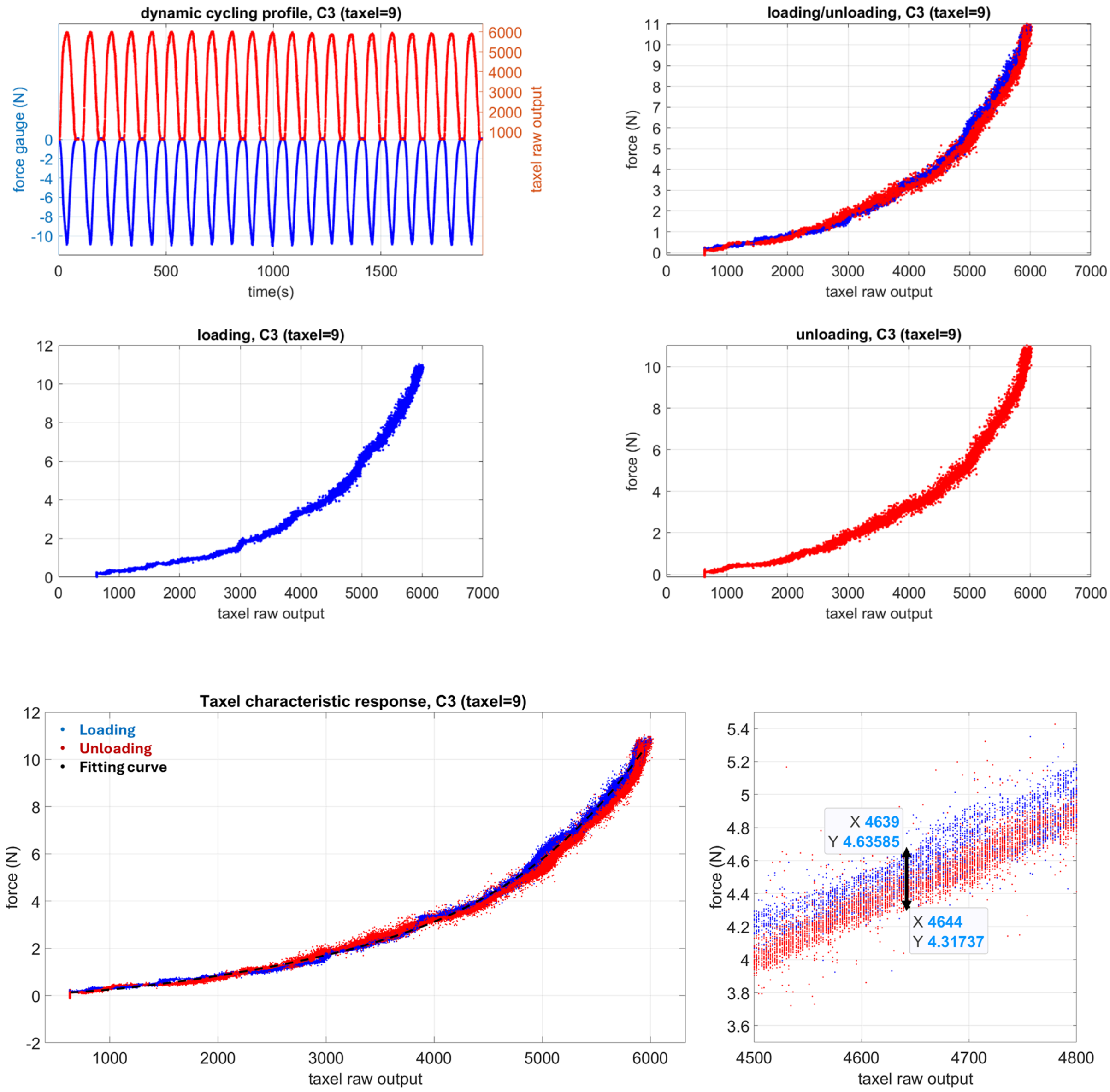
DESCRIPTION	MIN.	TYPE	MAX.	UNITS
Operating Temperature Range	0	25	55	°C
	32	77	131	°F
Operating Humidity Range (Non-Condensing)	0	-	95	%
Storage Temperature Range	0	-	55	°C
	32	-	131	°F
Storage Humidity Range (Non-Condensing)	0	-	95	%

4.8. Typical Performance Characteristics

DESCRIPTION	CONDITIONS	MIN.	TYP.	MAX.	UNITS
Number of tactile pixels (taxels)		-	16	-	-

Sampling Frequency (Full-scan)	All taxels read sequentially	-	315	-	Hz
Sampling Frequency (single element)	Continuous single-taxel sampling	-	5040	-	Hz
Sensing Range	Per taxel area (1.722 mm radius: 9.32 mm² area)	0.1 N (10 kPa)	-	+10 (+1073)	N (kPa)
Resolution	Per taxel area (1.722 mm radius: 9.32 mm² area)		0.1 (10)		N (kPa)
Full Range Accuracy	Per taxel area (1.722 mm radius: 9.32 mm² area)		±3%		%
Static load Drift	Per taxel area (1.722 mm radius: 9.32 mm² area)		0.004 %/sec		Signal drift without compensation over the full range
Overload	Local loading of taxel		>40 (>4300)		N (kPa)
Cross-talk (electrical)	Local loading of taxel		<0.01%		Signal variance (%)
Cross-talk (mechanical)	Local loading of taxel		<0.1%		Signal variance (%)

Characteristic response and behaviour of a typical taxel C3



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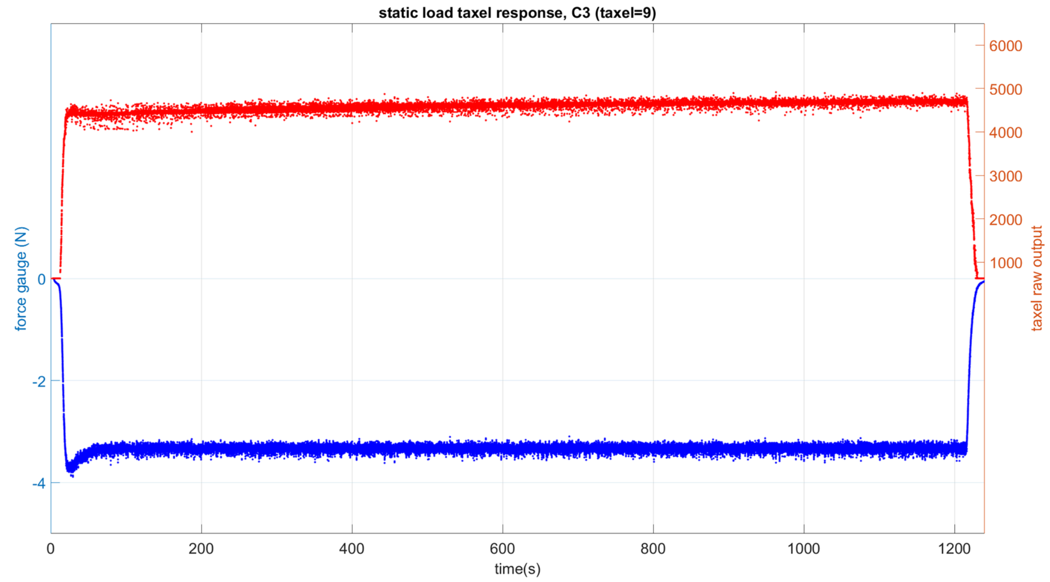
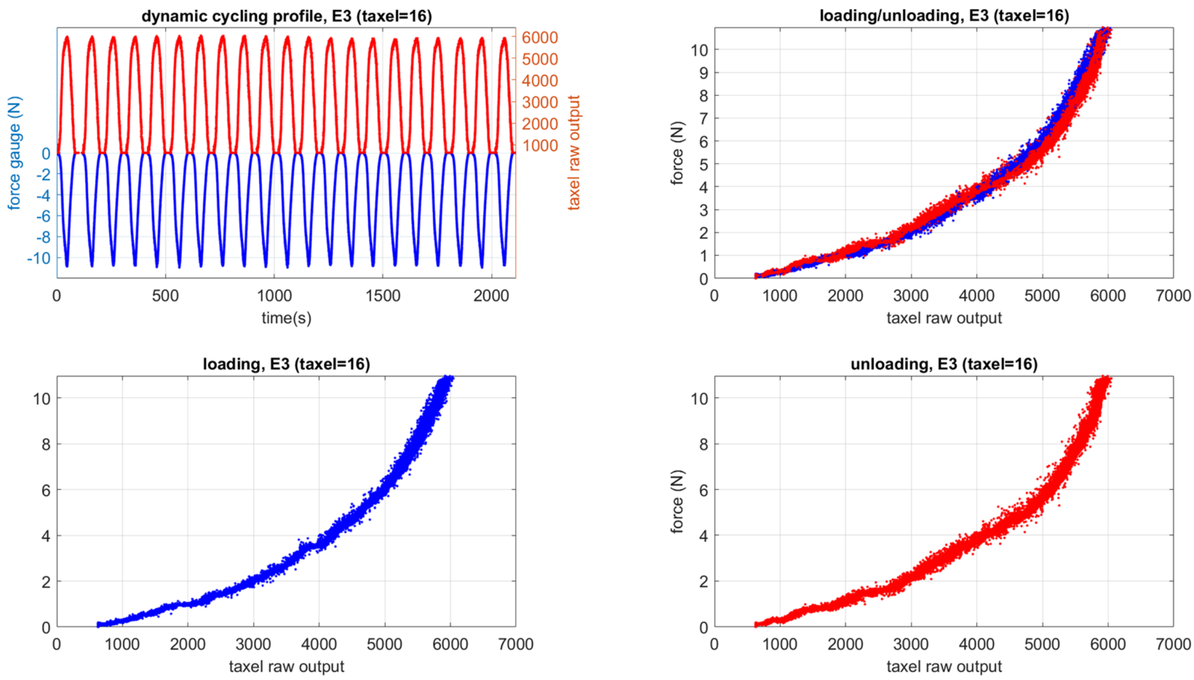
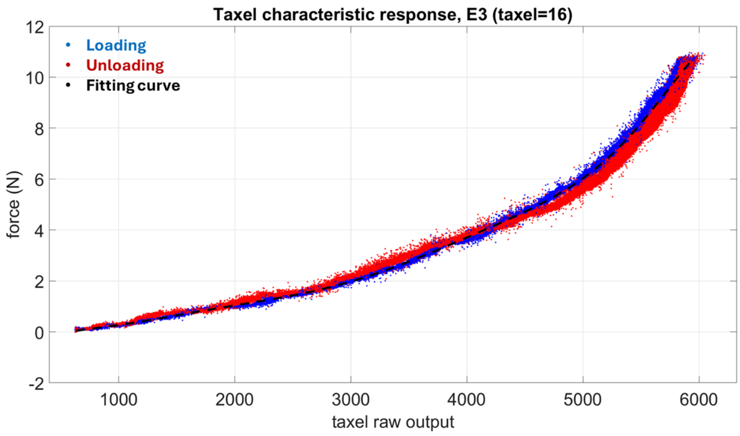
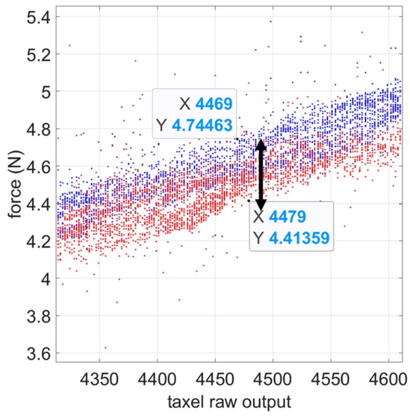
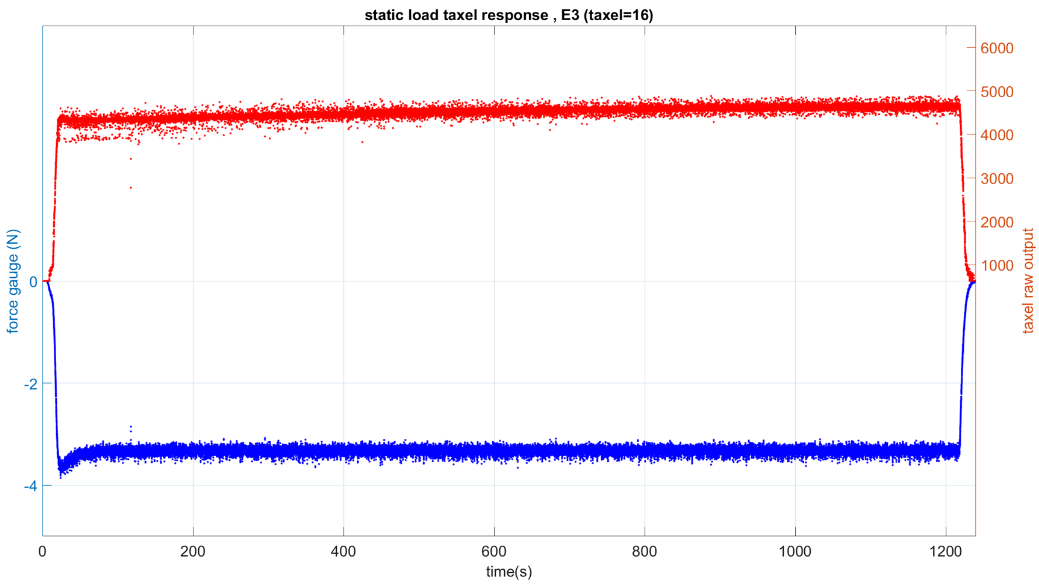


Characteristic response and behaviour of a typical taxel E3

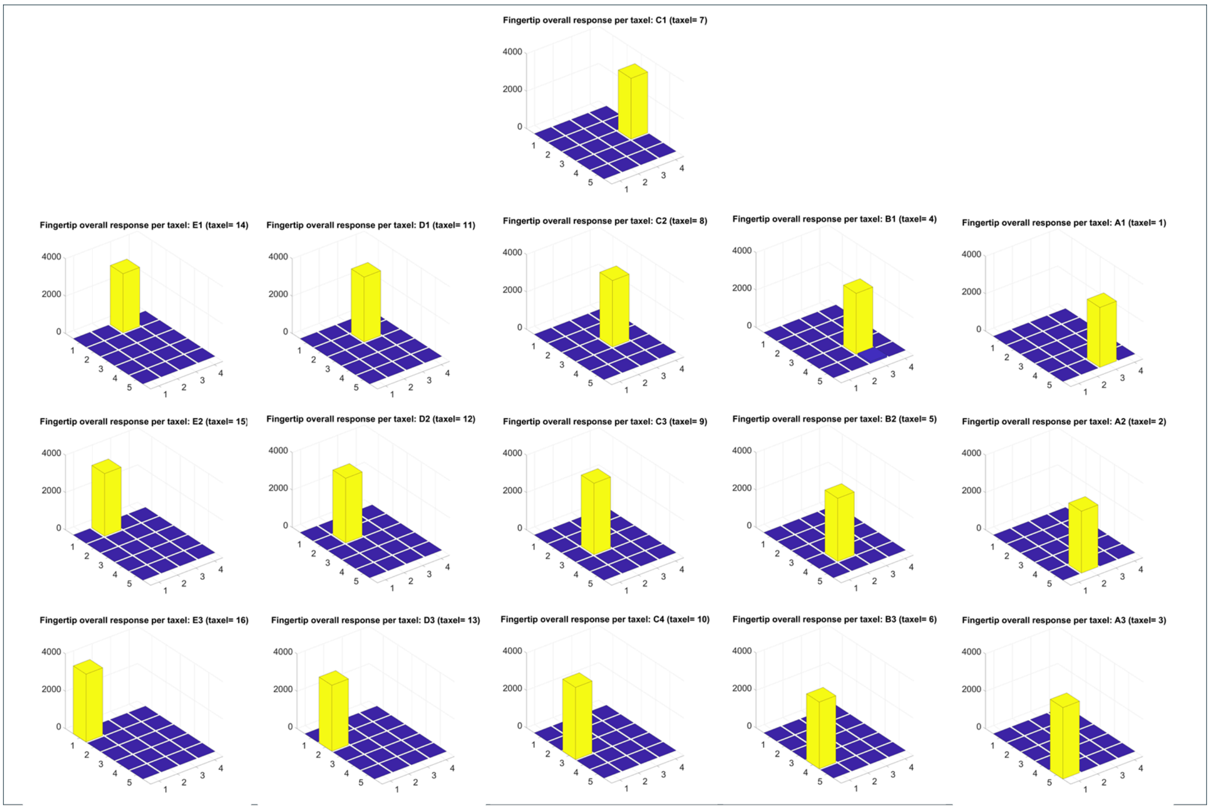



Taxel characteristic response, E3 (taxel=16)
Loading
Unloading
Fitting curve
force (N)
taxel raw output
12
10
8
6
4
2
0
-2
1000
2000
3000
4000
5000
6000


X 4469
Y 4.74463
X 4479
Y 4.41359
force (N)
taxel raw output
5.4
5.2
5
4.8
4.6
4.4
4.2
4
3.8
3.6
4350
4400
4450
4500
4550
4600


static load taxel response , E3 (taxel=16)
force gauge (N)
taxel raw output
time(s)
0
-2
-4
6000
5000
4000
3000
2000
1000
0
200
400
600
800
1000
1200

Mechanical cross-talk of adjacent taxels, when 1 taxel is locally loaded at 5N



5. LED Indicator

An LED indicator positioned underneath the surface of the nail provides user feedback of the operating status of the fingertip sensor. The LED can illuminate red , green , or orange .

The board goes through the following states after powering up:

- Setup - configures all devices and ports
- System check - runs 6 system checks
- Operation - runs the ‘read loop’ and reports values

Setup and System Check

During the setup and system check, the status LED illuminates orange 🟠 .
Pass - If the board successfully completes the system check, the status LED will turn off after 200 ms, and the fingertip will immediately enter operation mode.
Fail - If the fingertip does not pass the system check, it will:

1. Turn off all LEDs ⚫ for 1s
2. Generate a sequence of red LED 🔴 flashes, corresponding to the specific error.

Operation Mode

STATE	LED STATE
SPI Mode, no error state.	🟢 Green LED Fast flashing (100 ms)
USB Mode, no error state.	🟢 Green LED Slow flashing (1 s)
SPI Mode, error state.	🟠 Orange LED Fast flashing (100 ms)
USB Mode, error state.	🟠 Orange LED Slow flashing (1 s)

⚠ If an error is indicated, please contact Touchlab for assistance with troubleshooting.

6. Test Setup

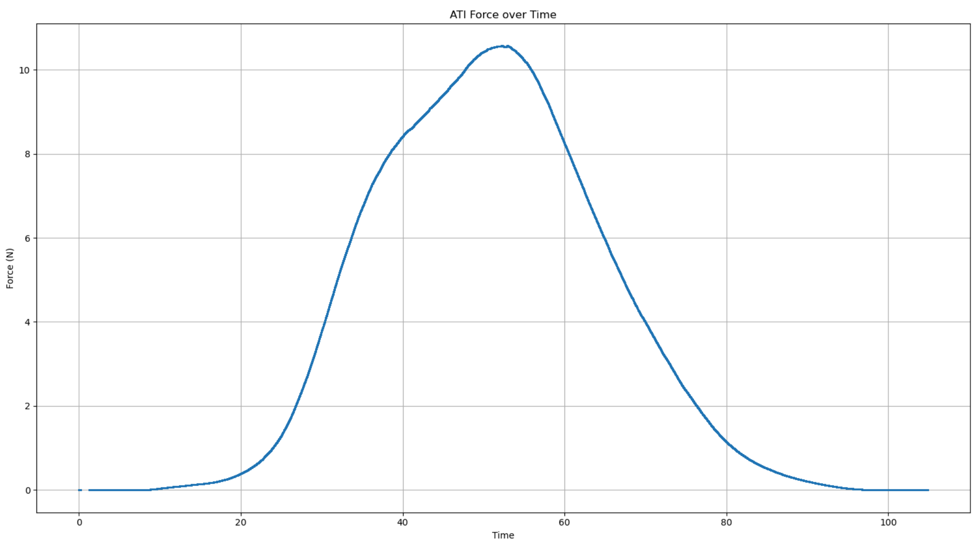
Test Rig

The fingertip is actuated by an ATI Nano17 force-torque sensor, mounted to a linear actuator. The ATI Nano17 has an attachment tool which is matched in size to the taxel, ensuring both that there is complete taxel coverage, and that we only compress a single taxel at a time. The ATI Nano17 outputs both force and torque along three axes each, which we use to ensure that the taxel is loaded normally, monitored and validated by a lack of significant response along five of the six axes measured.

Testing Methodology

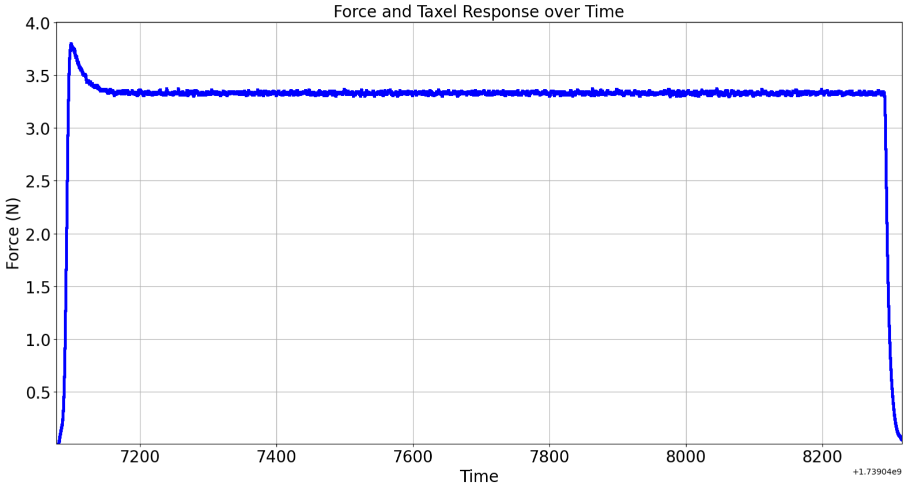
Each taxel of the fingertip undergoes the same series of tests, which include the following force profiles:

- **50x Smooth rising and falling actuations**: The target profile is triangular in shape, but smoothing functions are applied to the motor control to ensure a clean force signal.



Typical rising and falling force profile

- Static load profile (drift)



Typical static load (drift) profile

Data gathered from each test includes the response of all taxels, not just the taxel being tested, alongside the full output from the ATI Nano17.

7. General Limitations of Use

The robotic fingertip is designed for use within its operational limits. Users should be aware of constraints regarding durability, environmental conditions, and performance to ensure expected functionality and reliability.

⚠

- Avoid the handling of sharp objects, which may damage the transfer layer (blades, pins etc.).
- Avoid overload pressures exceeding 4300 kPa.
- Avoid use <0°C and >55°C.

Using the fingertip outside the recommended operating ranges may lead to reduced performance, potential damage, or malfunction. Any such usage falls outside of the intended design parameters and is not covered by the warranty.

8. Glossary of Terms

TERMS	DESCRIPTION
SPI	Serial Peripheral Interface
SPI_CLK	SPI - Clock
SPI_MISO	SPI - Master In Slave Out
SPI_MOSI	SPI - Master Out Slave In
SPI_CS#	SPI - Chip Select (Active Low)
MCU	Microcontroller Unit
AWG	American Wire Gauge
ID	Insulation Displacement
USB	Universal Serial Bus

Taxel	Tactile pixel

9. Legal Disclaimer Notice

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9.1. Technical Support & Contact Information

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- Website: www.touchlab.io