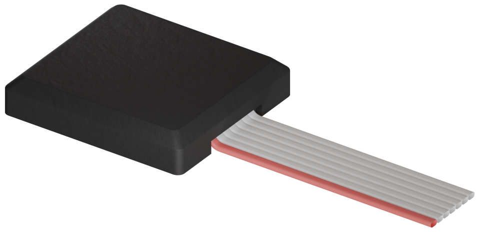
uSPa44

1 Overview

- Hall-effect-based tactile sensor
- Multi-taxel (distributed) sensing
- 3-axis force measurement per taxel
- Soft skin
- 133 Hz of sampling rate
- Provides temperature data (e.g. for drift compensation) for each sensing point
- 2 different sensitivities (pre-programmed)



2 Technical specification

	Value	Unit
Power voltage (microcontroller)	5	V
Power voltage (sensor)	2.2 - 3.6	V
Current consumption (microcontroller)	11.6 $\sim$ 26	mA
Current consumption (sensor)	40	mA
Sampling frequency	133	Hz
Dimensions (without cable)	24.6 x 22.6 x 5	mm
Measurement range (x & y) [*1]	$\pm$ 1350	LSB
Measurement range (z) [*1]	+16000	LSB
Noise (x & y) [*1]	$\pm$ 0.25	% to max range
Noise (z) [*1]	$\pm$ 0.03	% to max range
number of taxels	16	$--$

[*1] In case of sensitivity H

3 Sensitivity/ Resolution

uSPa44 features two distinct sensitivity settings denoted by the letters "L" or "H". This sensitivity configuration dictates the measurement range of the sensor. Detailed information regarding the sensor's response for a single sensing point (i.e., when force is applied to one taxel) is provided in Fig.1 and 2. The default setting for sensitivity across all standard models is "H". For inquiries regarding sensor modules with alternative sensitivity settings, please contact XELA Robotics.

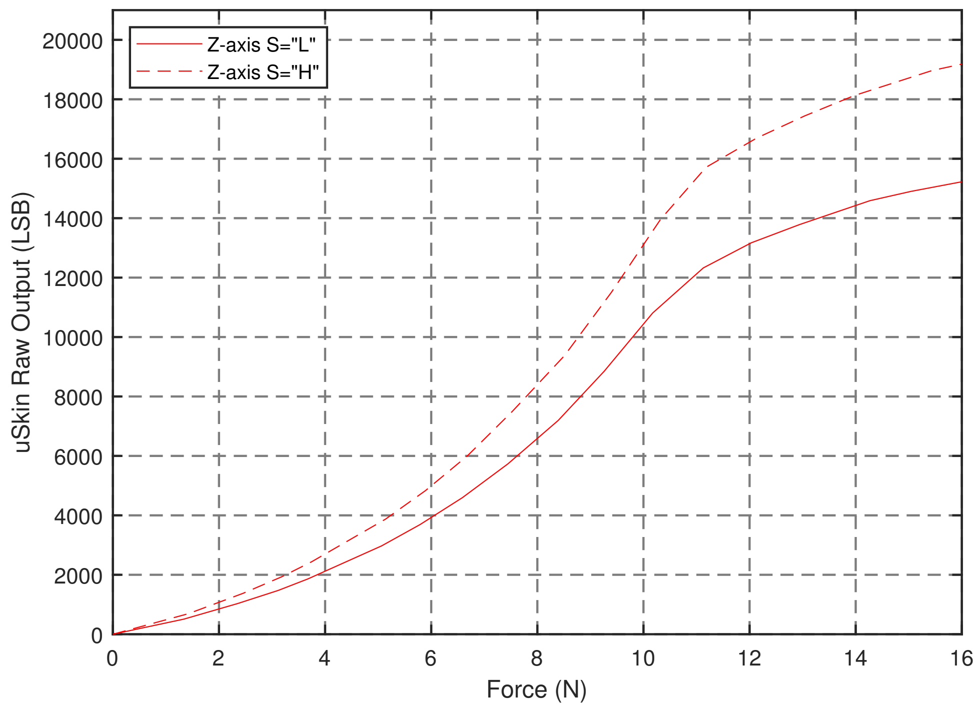


Figure 1: Sensor's normal force (z-axis) output with two sensitivity settings.

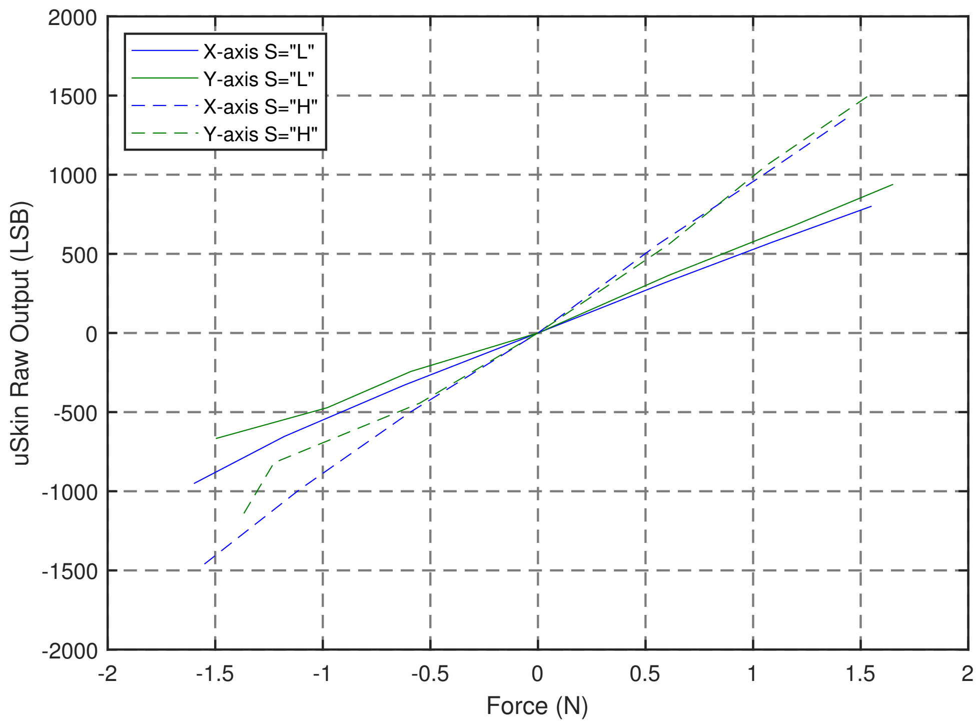


Figure 2:
Sensor's shear forces (x and y-axis) output with two sensitivity settings.

Sensitivity	Measurable Range				Resolution	
	Newton		LSB		N/LSB	
	x/y	z	x/y	z	x/y	z
L	±1.7	15.3	±830	15000	0.002	0.001
H (default)	±1.55	11.4	±1350	16000	0.001	0.0007

Table 1:
Summary of uSPa44's maximum measurable force and resolution according to the selected sensitivity.

4 Maximum Signal to Noise Ratio

Figure 3 and 4 show the output noise band of uSPa44 in two different sensitivity settings when there is no load applied. These 300 consecutive data for 3 seconds were used to calculate the noise of each axis which is represented in MSE (mean square error). The calculation result can be seen in Table 2.

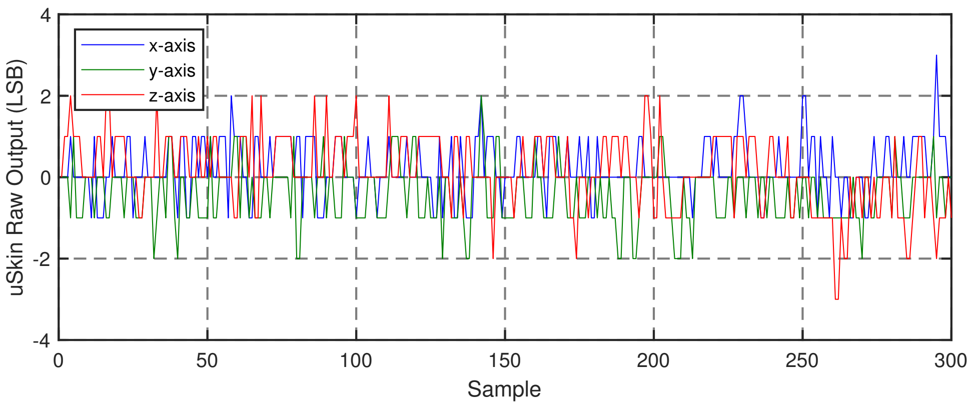


Figure 3: Output signal (high sensitivity) without load.

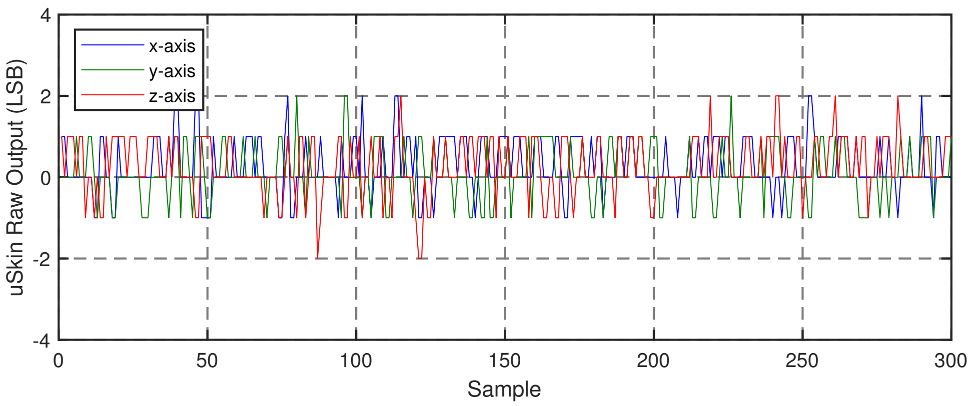


Figure 4: Output signal (low sensitivity) without load.

	Axis	MSE (LSB)	PSNR (dB)
Low	X/Y	0.5	61.49
	Z	0.58	85.88
High	X/Y	0.62	63.95
	Z	0.78	85.16

Table 2:
Peak signal to noise ratio of uSPa44.

The (MSNR) peak signal to noise ratio of uSPa44 was calculated by using equation 1. Here, MSE is the mean square error of 300 samples of uSkin reading when there is no load applied (see Fig. 3 and 4). MAX_I is the maximum measurable force (in LSB) taken from Table 1.

$$MSNR = 20 \cdot log_{10}(MAX_I) - 10 \cdot log_{10}(MSE) \quad (1)$$

5 Thermal Drift Compensation

The internal temperature of uSkin will rise after running the sensor for several minutes. As a result, uSkin sensor's output will also drift over time. As seen in Fig. 5, the z-axis is mostly affected with around 120 LSB drift when the temperature rises about 3.5 $^{\circ}C$.

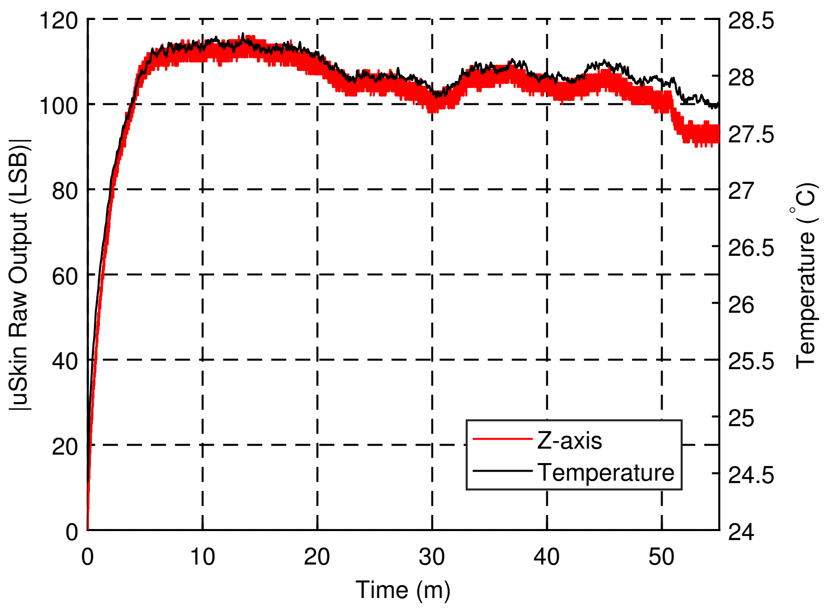


Figure 5:
Output fluctuation of uSkin (single taxel of S="H") due to temperature rise

To overcome this problem, uSkin sensor has a temperature compensation algorithm. The compensation result can be seen in Fig. 6.

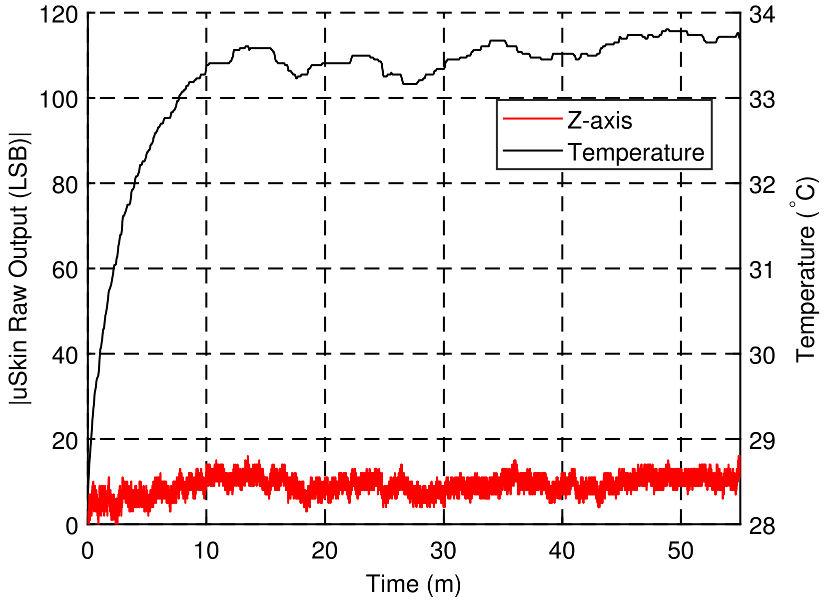


Figure 6:
Output of uSkin (single taxel) after compensation.

6 Hysteresis

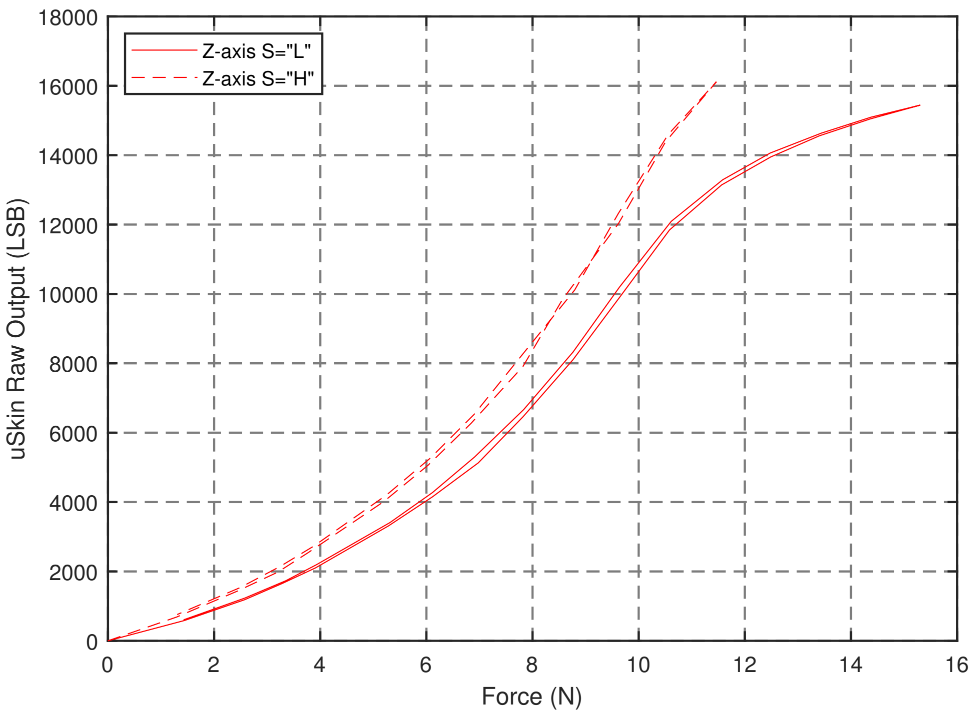


Figure 7:
uSPa44 loading and unloading response (z-axis).

Figure 7 shows the output of uSkin when loaded and unloaded with 7 step-wise forces. Each step is about three seconds. The hysteresis value is measured by first calculating the difference of uSkin output during the loading and unloading cycles at the mid point of the maximum loading force. The absolute value of the difference then divided by the output of uSkin during the maximum loading force. The hysteresis value of the z-axis for sensitivity low and high are 1.3 and 0.9% respectively.

7 Current Consumption

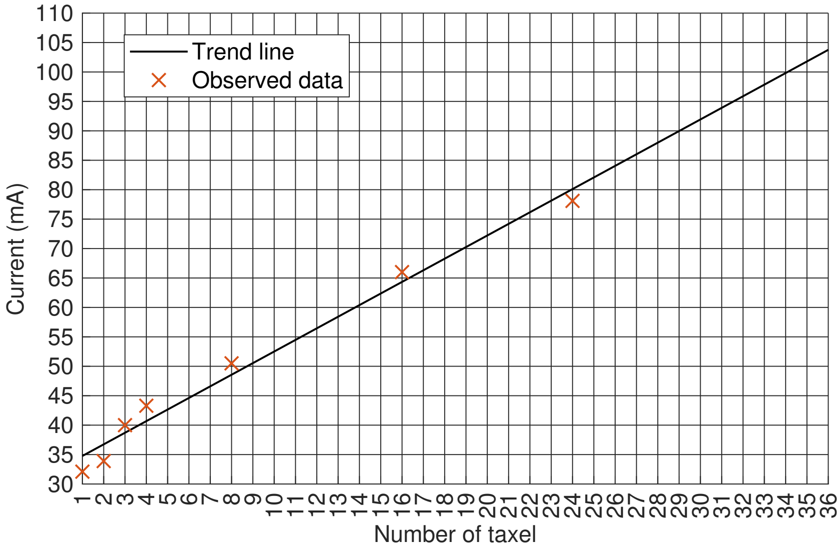


Figure 8: Current consumption model derived from various uSkin patch models including a microcontroller.

The current consumption of the uSkin sensor is directly influenced by the number of taxels integrated into each model. As depicted in Fig. 8, the current consumption increases proportionally with the number of taxels. We conducted measurements on several models, including the uSPa11 (1 taxel), a configuration of three daisy-chained uSPa11 units (3 taxels), as well as the uSPa21 (2 taxels), uSPa22 (4 taxels), uSPa44 with only 8 taxels running, uSPa44 (16 taxels), and uSPa46 (24 taxels).

The data presented in the graph also accounts for the peak current consumption of the integrated micro-controller. A linear trend model was created using first-order polynomial curve fitting based on the collected dataset, providing a predictive model for current consumption across different uSkin configurations.

8 Calibration

Sensor calibration serves various critical purposes, including the enhancement of sensor characteristics to achieve greater linearity, the reduction of cross-talk between axes, the minimization of differences in sensor responses across individual taxels, and the conversion of sensor output from Least Significant Bits (LSB) to the Newton unit. For example, as illustrated in Figure 1, the steepness of the uSPa44 (low sensitivity) sensor's response curve exhibits notable shifts at two forces: 4N and 9N of applied force.

In certain applications, such as those focused on basic shear force measurements, contact detection, or pattern generation for machine learning, the need for precise calibration is less critical. However, when precision is of importance, our sensor can be calibrated. XELA Robotics offers two distinct calibration options: standard and individual calibrations. The standard calibration is included with the sensor as a complimentary package. It involves the collection of data from multiple identical sensor models, followed by the computation of shared calibration parameters through advanced machine-learning techniques.

In contrast, individual calibration parameters are tailored exclusively for a specific sensor point. This individualized approach ensures a higher degree of calibration accuracy compared to the standard calibration parameters. Should you require individual calibration, we kindly encourage you to reach out to XELA Robotics for further details on associated fees and services.

9 Dimensions

The uSPa44 features a fully flat bottom surface, allowing direct mounting onto any flat surface. The distance between each taxel is 4.7 mm. Moreover, users can customize the cable length to their specifications, with options ranging from 30 cm, 50 cm, to 90 cm, providing flexibility to meet various installation requirements.

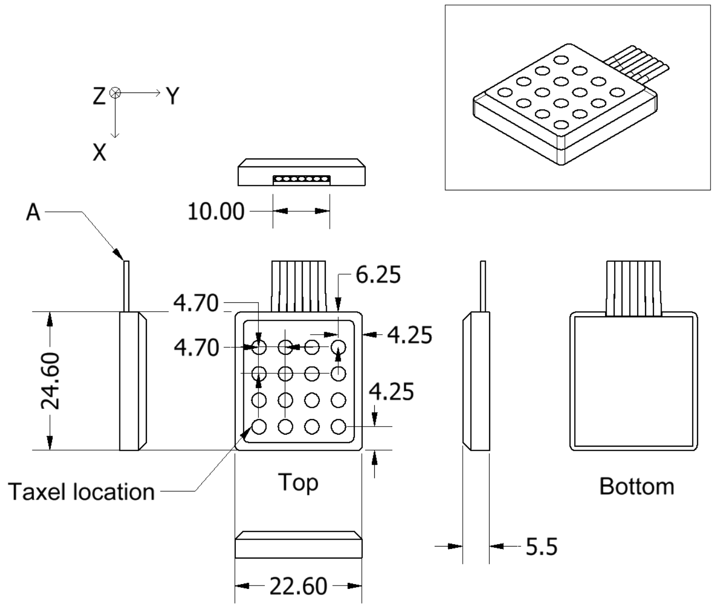


Figure 9:
uSPa44 drawing (units are in mm).