# uSkin 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
- Built-in temperature drift compensation
- 2 different sensitivities (pre-programmed)

## 2 Technical specification

| | Value | Unit |
|---|---|---|
| Power voltage (sensor) | 2.2 - 3.6 | $V$ |
| Power voltage (microcontroller) | 5 | $V$ |
| Current consumption | 17.5 (43.5[*1]) | $mA$ |
| Sampling frequency | 133 | $Hz$ |
| Dimensions | 24.6*22.6*5.5 (without cable) | $mm$ |
| Weight | 3.6 (without cable) | $g$ |
| Measurement range (x & y) [*2] | ± 1800 | $LSB$ |
| Measurement range (z) [*2] | +17400 | $LSB$ |
| Noise (x & y) [*2] | ± 0.027 | % to max range |
| Noise (z) [*2] | ± 0.042 | % to max range |
| number of taxels | 16 | −− |

*1 including the microcontroller

*2 In case of sensitivity H

## 3 Sensitivity/ Resolution

uSPa44-S has two different sensitivity settings, indicated by the letter "S" or "H". This sensitivity setting will determine the sensor's measurement range. The details of the sensor's response (for one sensing point, i.e. force is applied to one taxel) can be seen in Fig. 1 and 2. The standard model of uSPa44 has sensitivity "H" as its default setting. Please contact XELA Robotics in order to request a uSPa44 with different sensitivities.

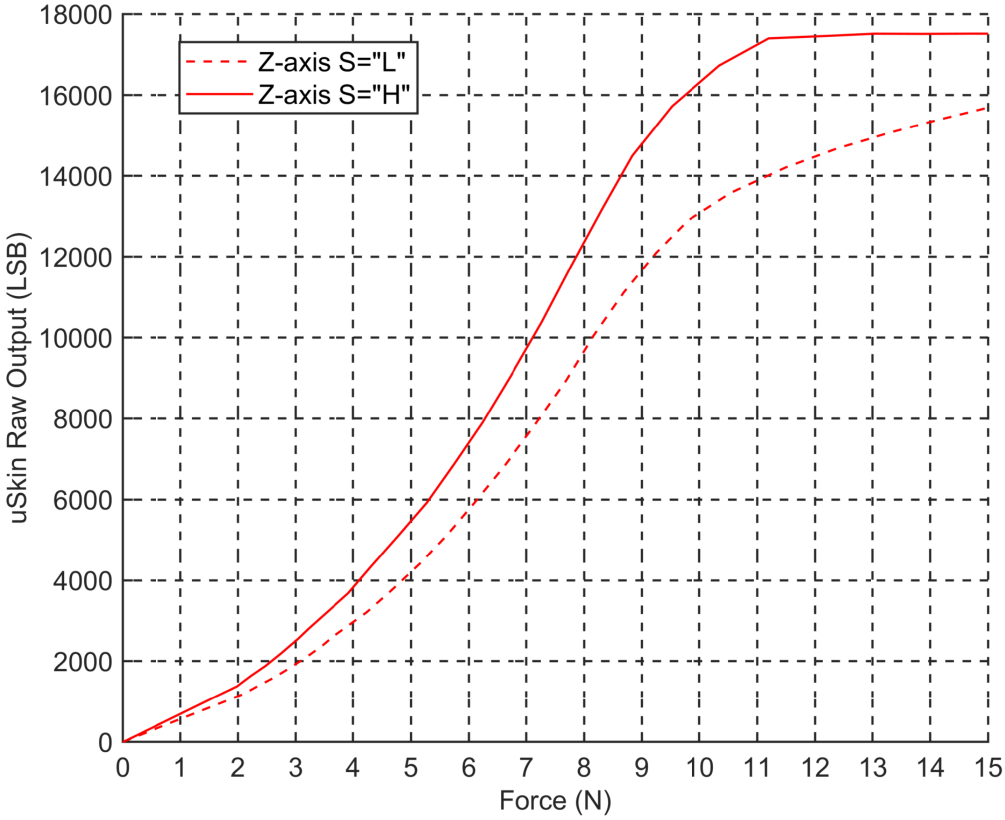


Figure 1:
uSPa44 normal force (z-axis) output with two sensitivity settings

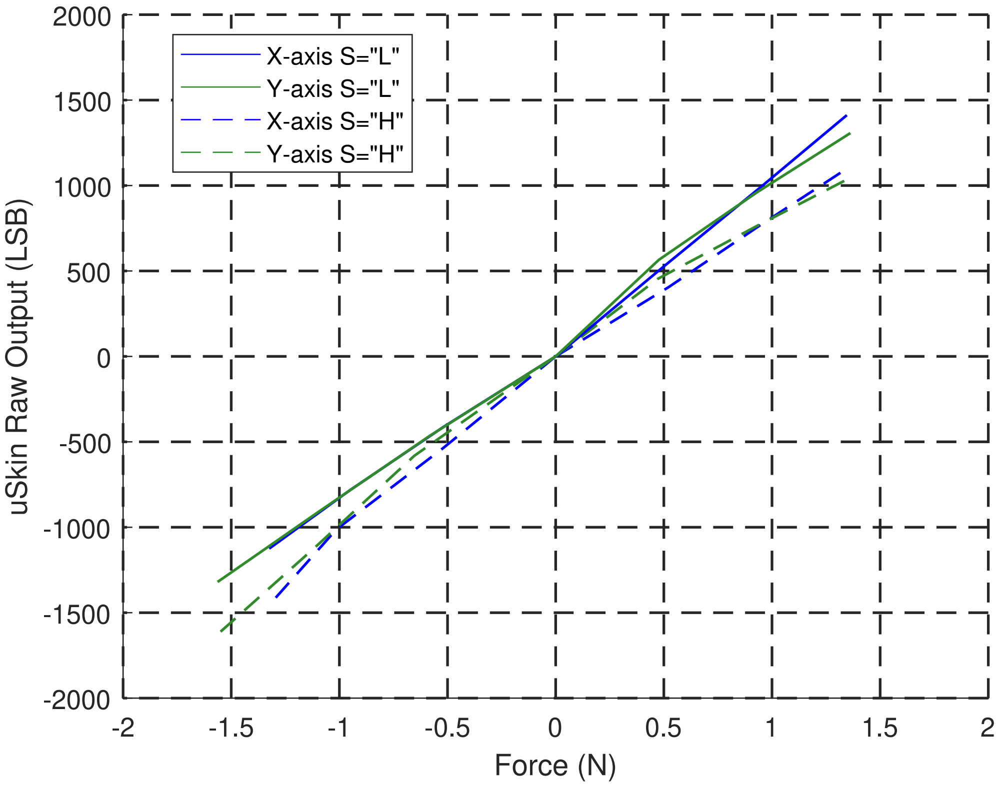


Figure 2:
uSPa44 shear forces (x and y-axis) output with two sensitivity settings

| Sensitivity | Measurable Range | | | | Resolution | |
|---|---|---|---|---|---|---|
| | Newton | | LSB | | N/LSB | |
| | x/y | z | x/y | z | x/y | z |
| **H (default)** | ±1.3 | 11 | ±1400 | 17400 | 0.001 | 0.0018 |
| L | ±1.3 | 15 | ±1100 | 15600 | 0.0013 | 0.0025 |

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.

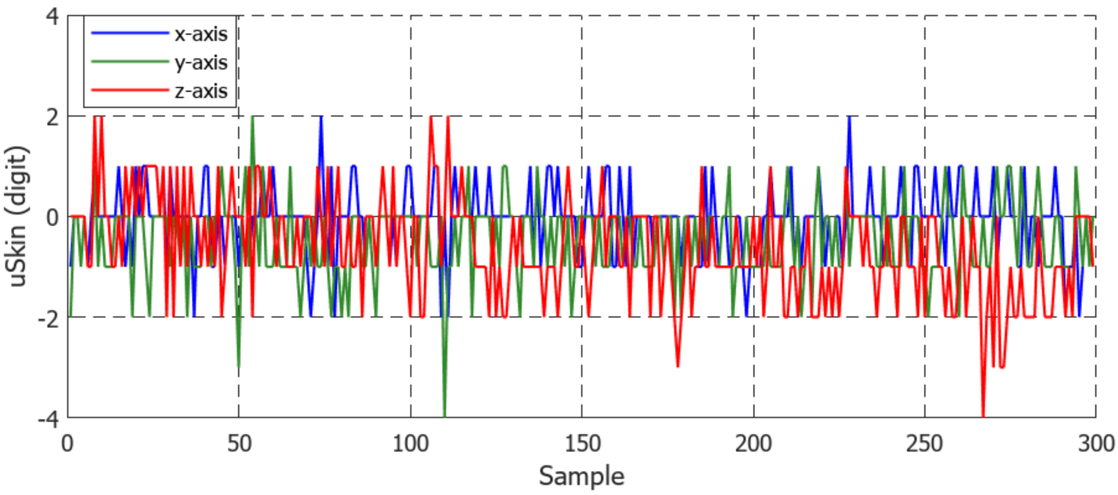


Figure 3:
uSPa44-H (High sensitivity) output signal without load

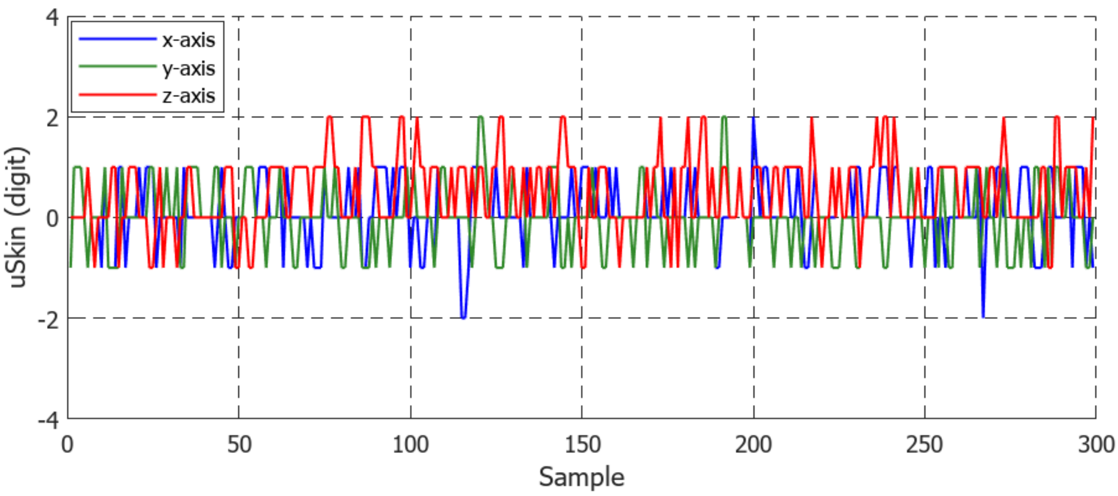


Figure 4:
uSPa44-L (low sensitivity) output signal without load

| | Axis | MSE (digit) | PSNR (dB) |
|---|---|---|---|
| High | X/Y | 0.83 | 63.73 |
| | Z | 1.38 | 83.41 |
| Low | X/Y | 0.46 | 64.20 |
| | Z | 0.79 | 84.89 |

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 digit) taken from Table 1.

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

# 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 digits drift when the temperature rises about 3.5 $^{\circ}C$.

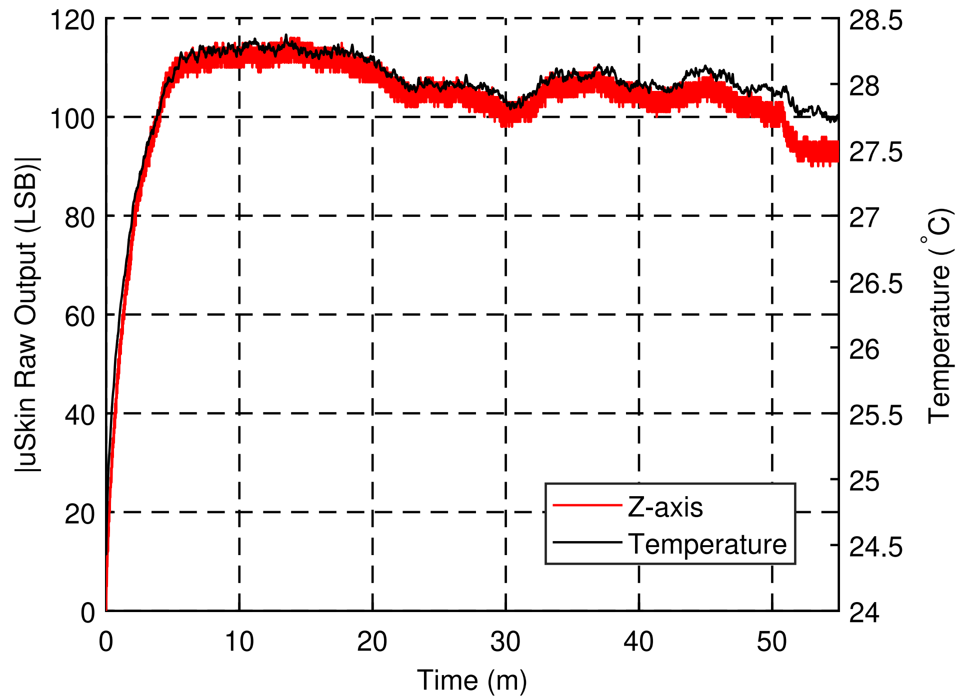


Figure 5:
Output fluctuation of uSkin (single taxel of S="H") due to temperature rise

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

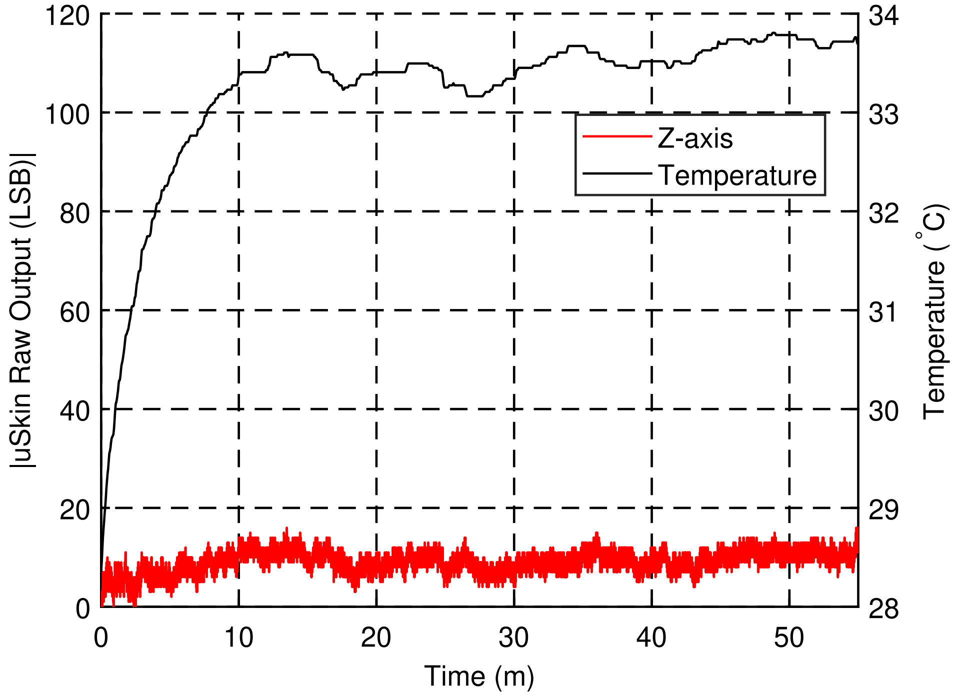


Figure 6:
Output of uSkin (single taxel) after compensation

## 6 Hysteresis

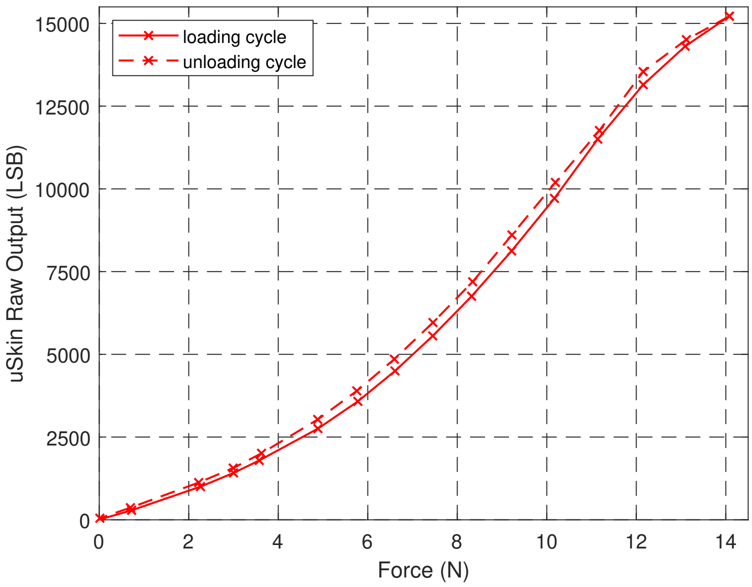


Figure 7:
uSPa44-L (Low sensitivity) z-axis

Figure 7 shows the output of uSkin when loaded and unloaded with step-wise forces. Each step is about two 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 is 2.6 %

# 7 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-L sensor's response curve exhibits notable shifts at two key thresholds: 4N and 8N 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 may be somewhat less critical. However, when precision is of paramount 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 uSPa44 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.

# 8 Dimensions

The bottom surface of the uSPa44 model is fully flat, making this model possible to be mounted directly on any flat surface. The distance between each taxel is 4.7 mm. The cable length can be customized according to the user's needs (30, 50 or 90 cm).