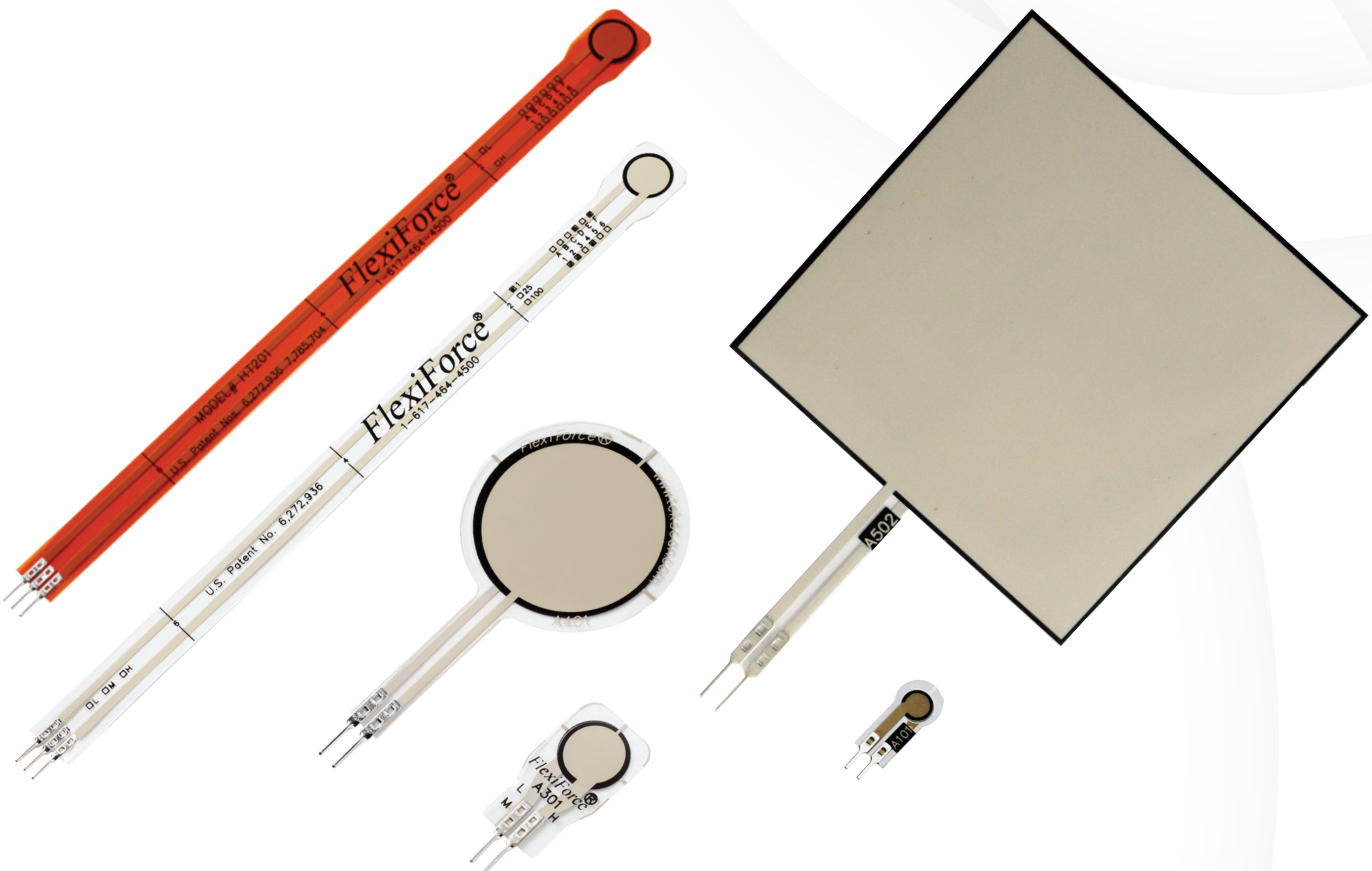
FlexiForce™ Sensor Durability, Drift, Recovery, **and its Impact on Your Design**



A summary of sensor performance experiments conducted by Tekscan Applications Engineers.

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Table of Contents

Introduction

Evaluating the durability and repeatability of an embedded sensing technology is a time-consuming and expensive process for OEMs. Sensor durability is often a key characteristic design engineers consider when evaluating force sensing technologies, especially when the application may require upwards of a million or more actuations over its time in use.

Given their thin, flexible form factor, FlexiForce™ touch sensors are a viable force-sensing resistor technology (FSR) for design engineers seeking an embedded sensing technology for their product design. FlexiForce touch sensors give design engineers the ability to capture force feedback in ultra-thin spaces, without adding more complexity to the design and its electronics. When driven with the recommended circuit (shown in **Figure 3 (pg 6)**), FlexiForce touch sensor technology has shown a superior linear output (<± 3%) compared to similar FSRs.

However, when working with a thin sensor technology in an application with a high-volume of force actuations, some may assume that the sensor linearity may change over use.

This whitepaper shares the findings of an million+ cycle durability test involving three different standard FlexiForce sensors in rigorous testing parameters. Following the rigorous testing period, all sensors were evaluated for durability and linearity after the testing was complete. A separate test also evaluated the recovery capabilities of FlexiForce sensors after 100, 1,000, and 10,000 cycle actuations.

All tests were conducted by Tekscan application engineers. Complete data profiles for all tests can be made available upon request.

Before Reading Onward

Please note that the testing parameters for these experiments are far more intense than what most validation testing would require. Most embedded applications will have varying loading cycles, shorter or longer off-loading periods, and an infinite number of operational permutations that may produce different results in your validation process. These experiments are meant to showcase typical FlexiForce sensor durability in an atypical testing framework.

Also, keep in mind that all testing was done at room temperature in controlled lab conditions. There are certain other environmental factors that may also impact sensor durability, drift, and recovery, including operating temperature or humidity.

An Overview of FlexiForce Touch Sensor Technology

FlexiForce touch sensors are a piezoresistive force sensor technology. They consist of semi-conductive material contained between two pieces of thin, flexible polyester.

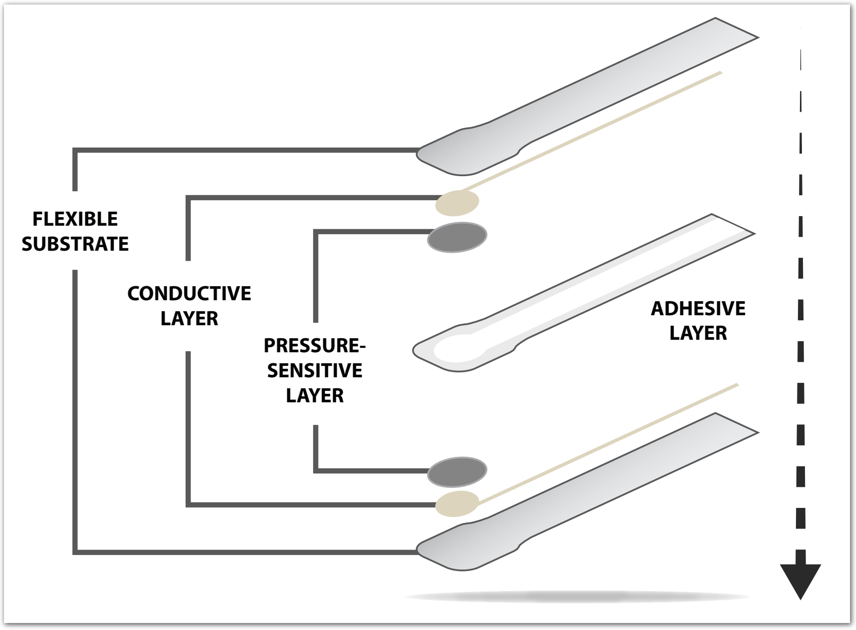


Figure 1: Construction of a FlexiForce touch sensor.

FlexiForce touch sensors are passive elements that act as a force-sensing resistor in an electrical circuit. When unloaded, the sensor has a high resistance (about <2MΩ) that drops when loaded. If you consider the inverse of resistance (conductance), the conductance response of touch sensors is linear as a function of force within the sensor's designated force range. The fact that they are passive, have linear a conductance response, and have a very large dynamic range of resistance, allows for the design engineer to use simpler electronics that do not require a lot of filtering.

FlexiForce sensors can be powered through a simple op amp circuit, or a voltage divider. When force is applied, the sensor resistance decreases as force increases, generating a change in the circuit's analog signal. This can be read by an analog-based system or digitized via an analog-to-digital converter to correlate feedback. Depending on the setup, the force range of the touch sensor can be adjusted by changing drive voltage and the resistance of the feedback resistor. This allows the user to have control over parameters such as *max force range*, and *measurement resolution* within that range.

Another benefit of this linearity is that touch sensors only require simple calibration. While force-sensing applications that employ load cells or strain gauges may need to be factory calibrated after repeated use, devices embedded with touch sensors can have their calibration routine embedded into the device firmware for on-the-fly recalibration.

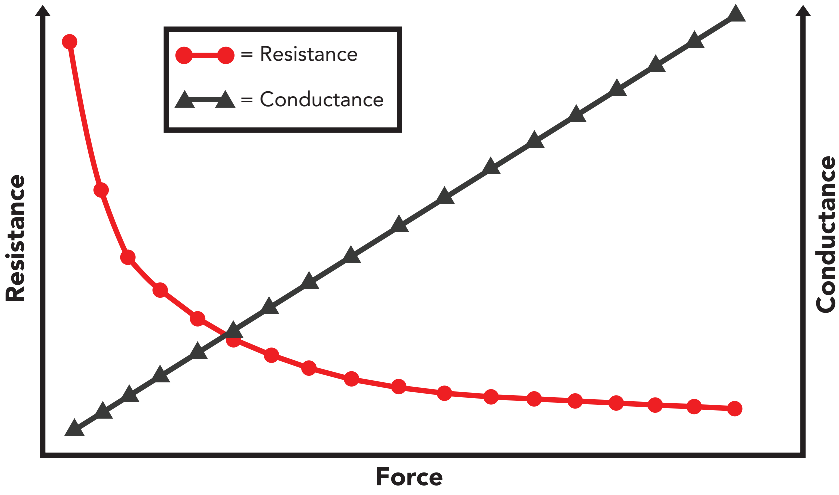


Figure 2: Force vs Resistance and Force vs Conductance of a FlexiForce touch sensor.

TEST A: FlexiForce Sensor Durability Assessment Following One Million Force Actuations Under Rigorous Parameters

Summary

Three different FlexiForce sensing technologies were normally actuated over one million times using pneumatic air cylinders. A step test was performed every 100,000 cycles so that linearity could be observed over the one million actuations.

Sensors Used

Standard Technology (A301)

- A301 is a standard 25 mm (1 in.) sensor, with a 14 mm (0.55 in.) sensing area
- This technology variety also encompasses A101, A201, A401, and A502 standard sensors

Enhanced Stability Series Technology (ESS301)

- Enhanced Stability Series (ESS) pressure-sensitive ink allows for better performance in high-temperature and high-humidity operating conditions
- ESS301 has the physical dimensions as the A301

High Temperature Technology (HT201)

- Operates in temperatures up to approximately 200°C (400°F)
- HT201 is a standard 191 mm (7.5 in.), with optional trimmed lengths, and a 14 mm (0.55 in.) sensing area

Test Overview

Loading Profile and Schematic

1. Sensors were pre-conditioned to 120% of test load 2.7 kg (6 lb) for 20 seconds, twice
2. 5up step profile to 2.3 kg (5 lb) with a 10-second dwell at each step
3. 2.3 kg (5 lb) load applied at 1 Hz, 50% duty cycle for 100,000 actuations
4. 5up step profile to 2.3 kg (5 lb) with a 10-second dwell at each step
5. 5 minute rest with no load
6. 5up step profile to 2.3 kg (5 lb) with a 10-second dwell at each step
7. Steps 3-7 were repeated until one million total actuations were reached

Interface Circuit

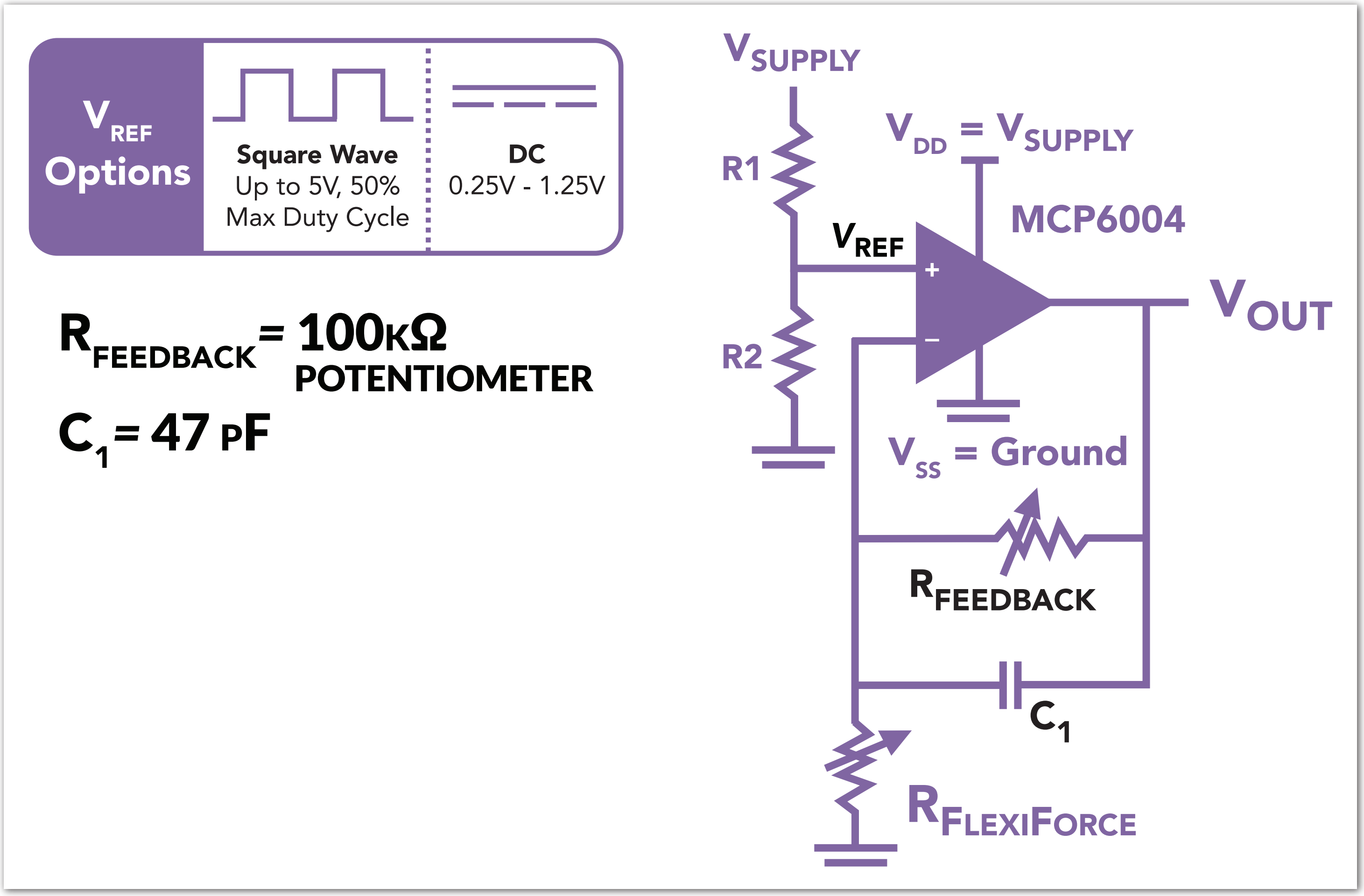


Figure 3: Recommended circuit - Non-Inverting Op Amp circuit (single source).

Results from Durability Trials

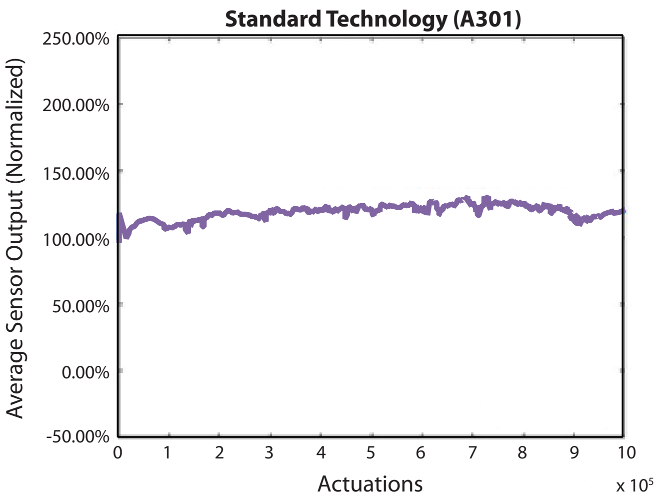


Figure 4: Standard technology output over one million actuations.

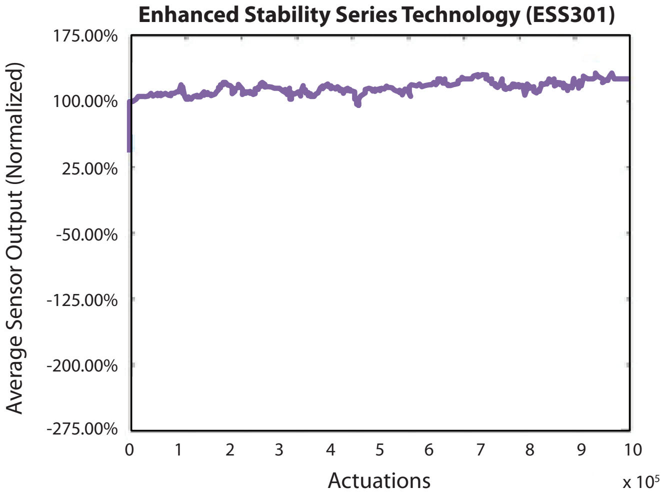


Figure 5: ESS technology output over one million actuations.

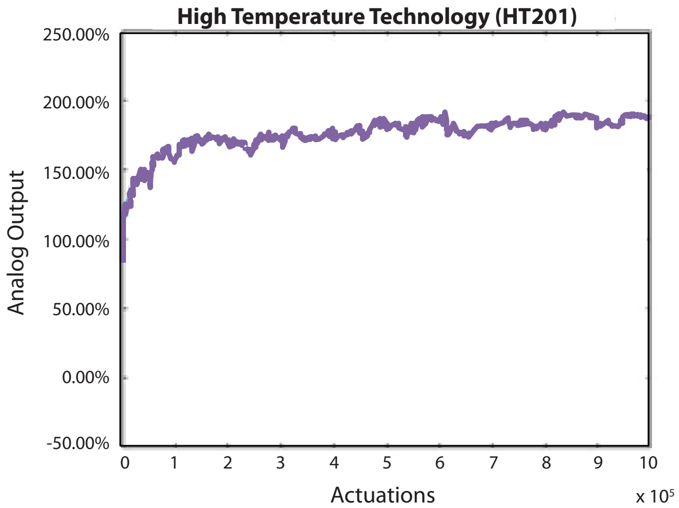


Figure 6: High temperature technology output over one million actuations.

Table 1

Sensor	Max % Change in Output Compared to Initial Output
Standard Technology	20%
Enhanced Stability Series Technology	23%
High Temperature Technology	61%

Table 2

Sensor	Max % Change in Output Compared to 500th Actuation
Standard Technology	10%
Enhanced Stability Series Technology	7%
High Temperature Technology	21%

Note: The viscoelastic behavior of the pressure-sensitive layer within the sensor results in a change in sensitivity under a repeated load of constant magnitude. The magnitude of that change is shown in **Table 1**. The majority of the change takes place within the first 500 actuations. From this point, the changes in output are shown in **Table 2.**

Linearity Results Before and After One Million Actuations

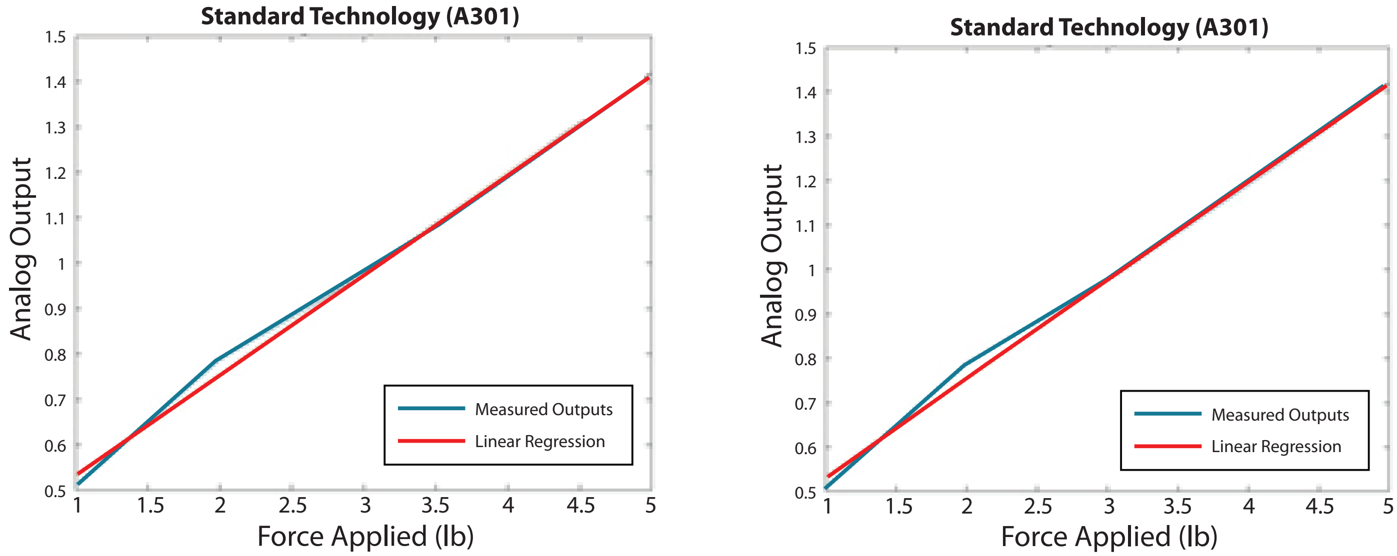


Figure 7: Standard technology sensor linearity before (left) and after (right) one million actuations.

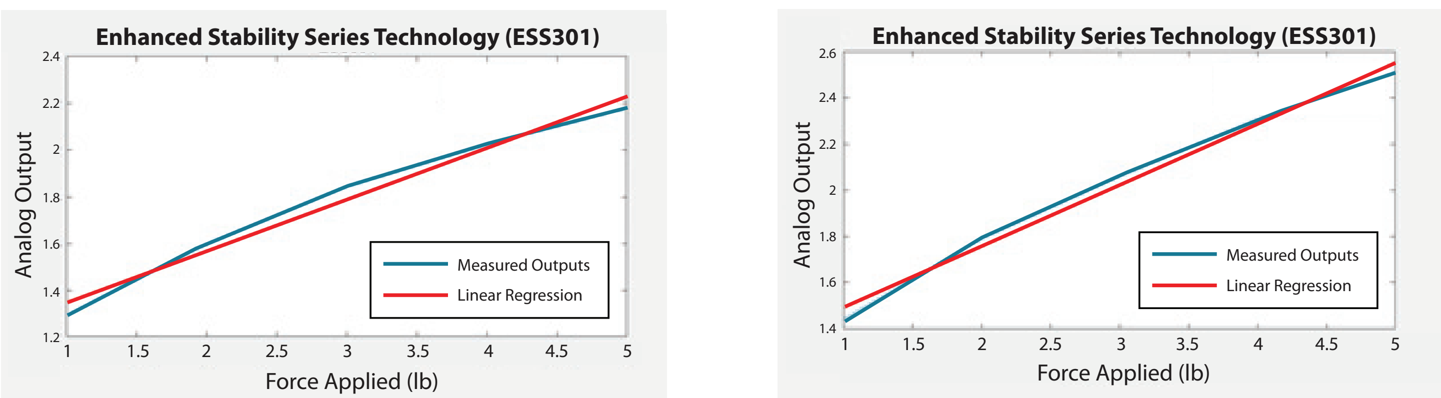


Figure 8: ESS sensor linearity before (left) and after (right) one million actuations.

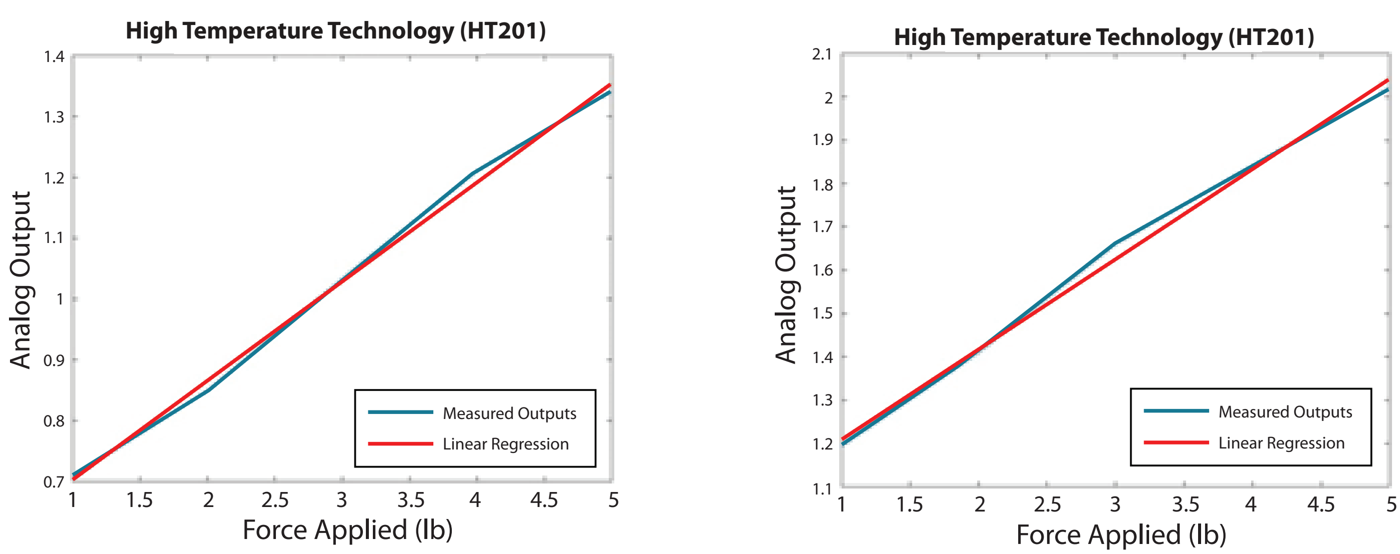


Figure 9: High temperature technology sensor linearity before (left) and after (right) one million actuations.

Observations & Recommendations

- The linearity error for all three sensor types remained well within Tekscan's published typical performance for each sensor (<±3% of full scale)
- None of the sensors showed signs of failure or compromised performance after over one million cycles
- There was a slight increase in sensitivity seen in the durability graphs at the beginning of each test. This sensitivity increase is caused by the viscoelastic behavior of the pressure-sensitive layer within the sensor.
    - In applications where higher accuracy and precision are required, proper conditioning and calibration protocols may mitigate the effects of this behavior.

TEST B: FlexiForce Sensor Cyclic Loading Recovery Evaluation

Summary

Standard technology sensors (A301) were normally actuated up to 10,000 times using pneumatic air cylinders. A step test was performed before the cyclic loading, and at various intervals after the cyclic loading. The sensor output at the end of the cyclic loading and each rest interval was compared to the output at the initial step test.

Sensors Used

Standard Technology (A301 (24 Total))

- A301 is a standard 25 mm (1 in.) sensor, with a 14 mm (0.55 in.) sensing area
- This technology variety also encompasses A101, A201, A401, and A502 standard sensors

Test Overview

Loading Profile and Schematic

1. All 24 sensors were conditioned to 125% of cyclic load (2.7 kg (6 lb)) for 30 seconds, twice
2. 5up step profile to 2.3 kg (5 lb) with a 10-second dwell at each step
3. One sample set had a 2.3 kg (5 lb) load applied at 1 Hz, 50% duty cycle for 100 cycles
4. Another sample set had a 2.3 kg (5 lb) load applied at 1 Hz, 50% duty cycle for 1,000 cycles
5. Another sample set had a 2.3 kg (5 lb) load applied at 1 Hz, 50% duty cycle for 10,000 cycles
6. 5 minutes rest with no load
7. 5up step profile to 2.3 kg (5 lb) with a 10-second dwell at each step
8. 30 minutes rest with no load
9. 5up step profile to 2.3 kg (5 lb) with a 10-second dwell at each step
10. 24 hour rest with no load
11. 5up step profile to 2.3 kg (5 lb) with a 10-second dwell at each step

Cyclic Testing Results

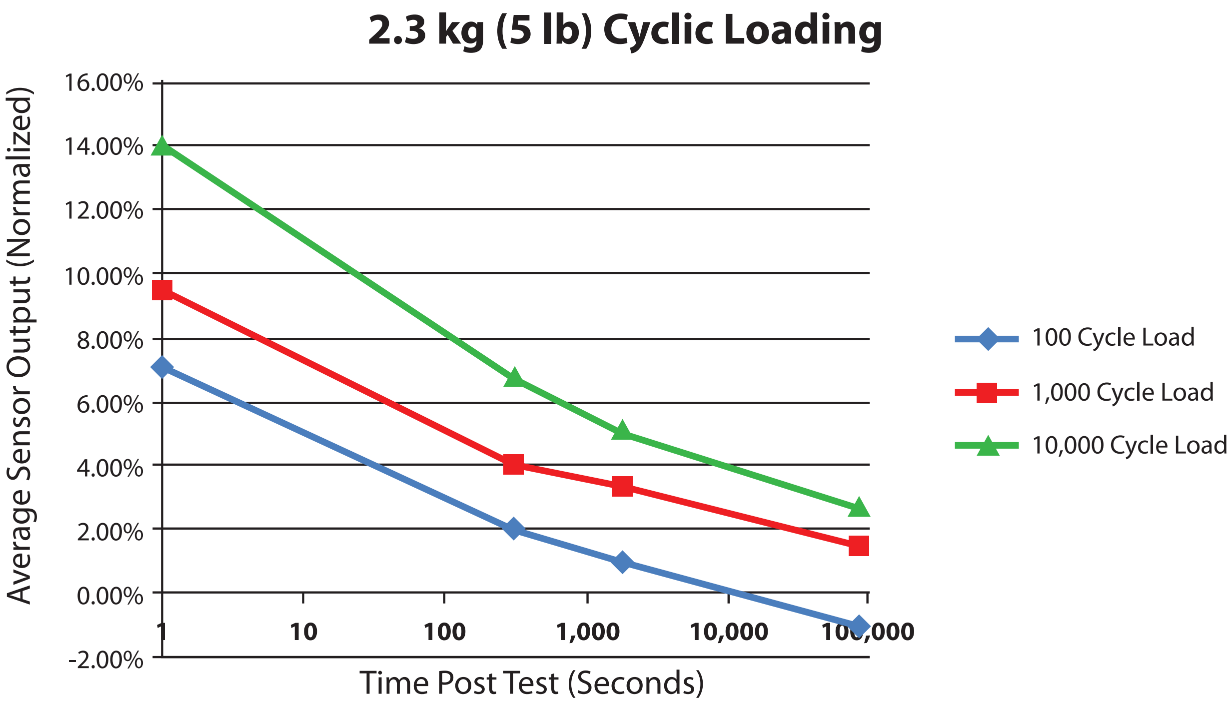


Figure 10: Averaged sensor output at each stage of testing.

Observations & Recommendations

- All sensors showed a logarithmic recovery to their initial sensitivity. All sensors returned to their initial sensitivity within typical repeatability error.
    - In applications where higher accuracy and precision are required, proper conditioning and calibration protocols may mitigate the effects of this behavior.
- None of the sensors showed signs of failure or compromised performance.

Implications for Design Engineers Assessing FlexiForce Touch Sensor Durability for Extreme Loading Actuation Applications

Based on the results shared in this whitepaper, design engineers can be confident that FlexiForce sensors will perform within the published specifications for linearity and repeatability error in high-volume actuation applications. This information is advantageous for design engineers evaluating FlexiForce touch sensors of all technology varieties for high-volume actuation embedded applications, especially if their application will account for recovery in some fashion. Given the extreme loading cycle parameters used in these studies, one can expect that FlexiForce sensors will perform favorably beyond a million cycles.

While the results from the durability and recovery trials are not absolute across every possible FlexiForce sensor that Tekscan manufactures, they provide a typical representation of sensor longevity as an embedded component in a high force-actuation application. Although there were some changes in performance, there were no sensor failures, nor considerable sensor wear and tear following the high-volume actuation testing.

Furthermore, as gathered from the sensor recovery testing, FlexiForce sensors showed the ability to recover with periodic breaks in time between cyclic actuations. Positive recovery results began in as little as five minutes of break time. In general, the more recovery time the sensors had between cyclic actuations, the stronger the sensor recovery.

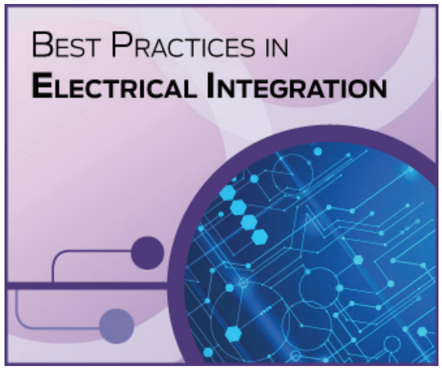
No matter the anticipated volume of actuations for an embedded application, Tekscan recommends that design engineers account for ways to concentrate the force load actuation onto the sensing area. Not only will this help ensure better FlexiForce accuracy, it will also help protect the sensor from long-term use.

For More FlexiForce Sensor Integration Assistance,

Consider These Free Resources:

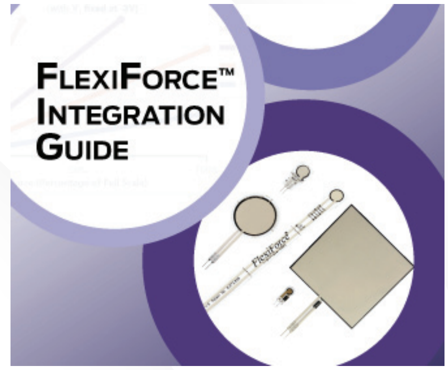
The **"Best Practices in Mechanical Integration"** guide provides key recommendations to consider during the prototyping phase of your OEM project, including:

- Applying load concentrators to ensure even loading
- Recommendations to minimize shear force and preserve sensitivity
- Methods for mounting the sensor, and more!



The **"Best Practices in Electrical Integration"** guide provides key recommendations for circuitry of your embedded design. The guide covers:

- Circuit selection
- Sensitivity adjustment processes
- Calibration procedure, and more!



The **"FlexiForce Integration Guide"** picks up where the Best Practice guides leave off, providing total guidance throughout the integration process. This guide is the next best thing to having a Tekscan Applications Engineer at your side.

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