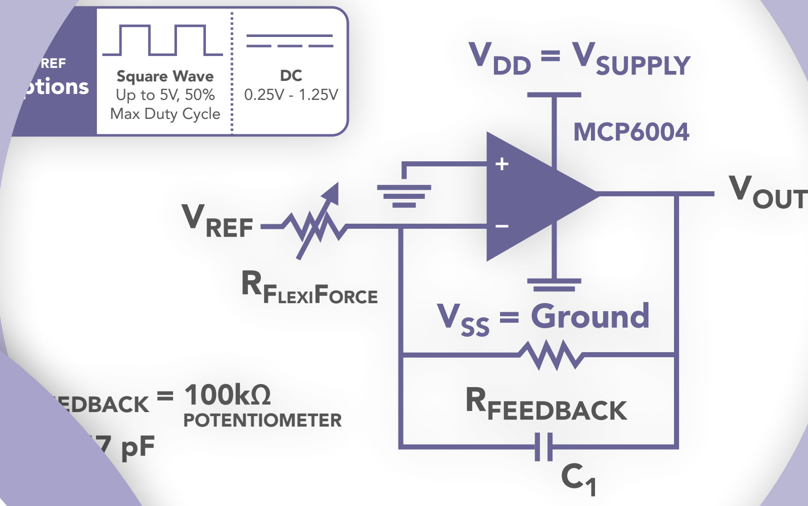
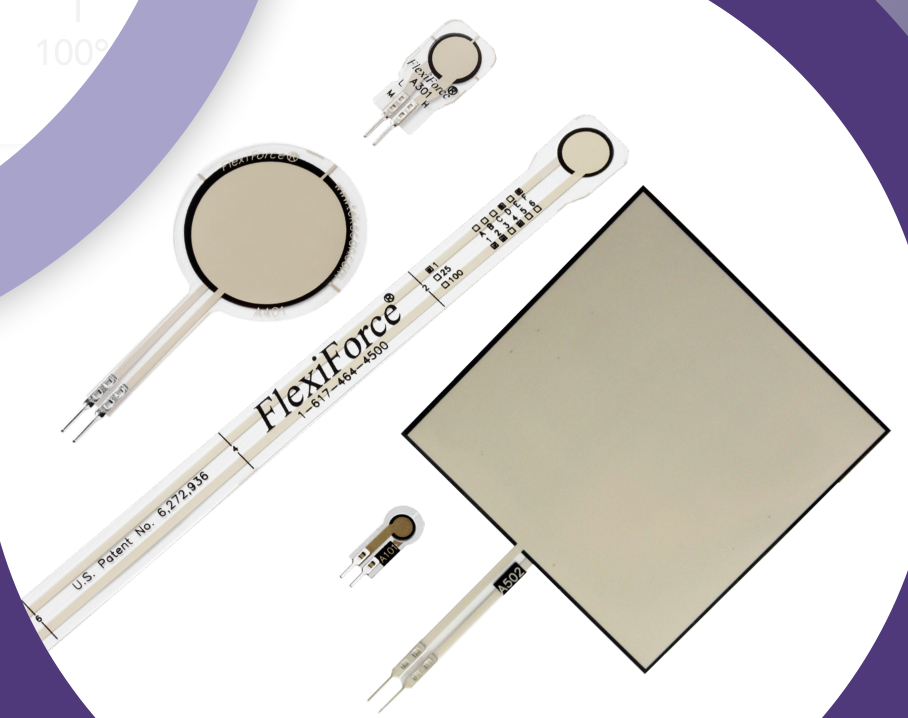
Tekscan™



FlexiForce™ Integration Guide

EDITION 1



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COMPANY & SENSOR OVERVIEW

PURPOSE

The purpose of this document is to provide critical design information for OEM design engineers who are looking to optimize sensor feedback and response within their device while meeting their project's budgetary constraints. The information in this document will help the design engineer to:

- Gain an understanding of FlexiForce™ touch sensors to help optimize their design and reduce the cost of the force sensing module.
- Minimize the overall project time of designing and embedding a FlexiForce sensor - from prototype to production implementation.

COMPANY OVERVIEW

Tekscan is the world leader in ultra-thin force & pressure measurement sensors and systems. Tekscan's sensors and systems are used in a continually expanding array of important applications in industry, medicine, and dentistry. Our team of full-time, experienced application, electrical, mechanical, and software engineers has a proven track record of exceptional results in very challenging design applications.

Tekscan's FlexiForce division specializes in designing and manufacturing custom and off-the-shelf standard sensor options for OEM applications as well as R&D and Test & Measurement applications. The unique construction and durability of these force-sensitive resistor sensors enables Tekscan custom-design force sensors to meet the specific needs of many OEM customers.

The FlexiForce product allows engineers to overcome challenges of size and space by providing a force-sensitive layer built on thin, light, and flexible material that is mechanically ideal for integrating into sleeker, smaller devices and applications. Our sensors are integrated into many applications and products in various industries including: medical, industrial, and robotic.

Tekscan™

QUALITY

- Privately held company, established in 1987.
- ISO 9001 & 13485 certfied facility.
- Technical team made up of electrical, mechanical, application, and software engineers, located in Boston, MA, who consults directly with customers through the design process.

GROWTH

- Over half of Tekscan's business is international.
- Average staff increase of 10% per year since 2006.
- More than 100 employees.
- Tekscan has achieved 13 years of consecutive growth.

SOLID FINANCIAL STANDING

- We are continually investing in our manufacturing equipment and processes to maximize our yields while controlling costs.
- No debt as a company makes choosing Tekscan as your business partner a sound investment.

SENSOR OVERVIEW

The FlexiForce sensor is an ultra-thin and flexible printed pressure sensitive variable resistor circuit, which can be easily integrated into applications with tight space constraints. With its paper-thin construction, flexibility, and force measurement capabilities, the FlexiForce touch sensor can measure force between almost any two surfaces and is durable enough to stand up to most environments. FlexiForce has better force sensing properties, linearity, hysteresis, drift, and temperature sensitivity than any other thin force sensors.

As shown in **Fig. 1**, FlexiForce sensors are constructed of two layers of substrate. This substrate is composed of polyester film (or Polyimide in the case of the High-Temperature Sensors). On each layer, an electrically conductive material (silver) is applied, followed by a pressure-sensitive layer. Adhesive is then used to laminate the two layers of substrate together to form the sensor. The silver circle on top of the pressure-sensitive layer defines the "active sensing area." Silver extends from the sensing area to the connectors at the other end of the sensor, forming the conductive leads.

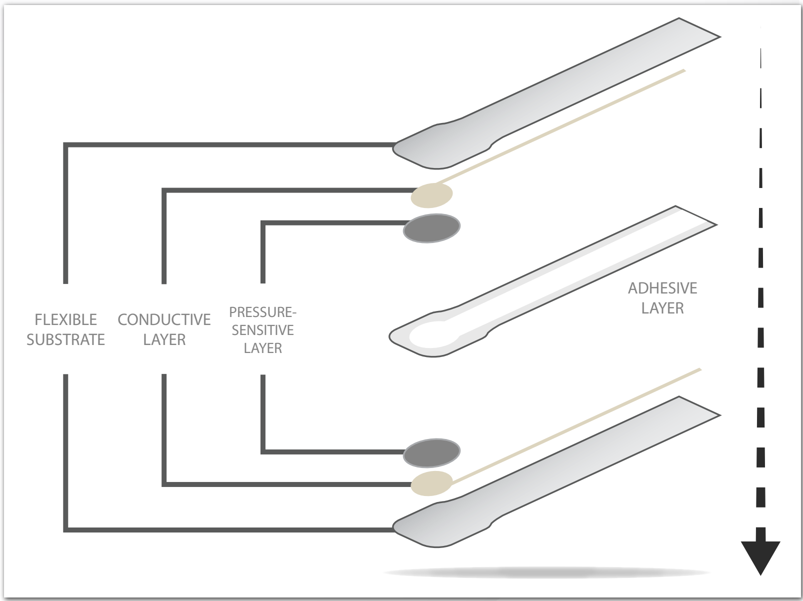


FIGURE 1: COMPOSITION OF A FLEXIFORCE SENSOR

STANDARD SENSOR OPTIONS (AVAILABLE OFF-THE-SHELF)

PHYSICAL PROPERTIES

	A101 (Click to View Product Page)	A201 (Click to View Product Page)	HT201 (Click to View Product Page)	A301 (Click to View Product Page)	ESS301 (Click to View Product Page)	A401 (Click to View Product Page)	A502 (Click to View Product Page)
Thickness	.203 mm (0.008 in.)						
Length	15.6 mm (0.62 in.)	197 mm (7.75 in.) 152 mm (6 in.) 102 mm (4 in.) 51 mm (2 in.)		25.4 mm (1.0 in.)		56.8 mm (2.24 in.)	81.3 mm (3.20 in.)
Width	7.6 mm (0.30 in.)	14 mm (0.55 in.)				31.8 mm (1.25 in.)	55.9 mm (2.20 in.)
Sensing Area	3.8 mm diameter (0.15 in.)	9.53 mm diameter (0.375 in.)				25.4 mm diameter (1.0 in.)	50.8 mm x 50.8 mm (2 in. x 2 in.)
Connector	2-pin male square pin	3-pin male square pin		2-pin male square pin			

TYPICAL PERFORMANCE

The specs listed below are based on ideal loading conditions under a bladder. For information on Sensor Response Time, please contact a FlexiForce Applications Engineer.

	Standard Pressure-Sensitive Layer (A101, A201, A301, A401, A502)	High Temp Pressure-Sensitive Layer (HT201)	Enhanced Stability Pressure-Sensitive Layer (ESS301)
Linearity Error	<±3% of full scale	<±3% of full scale	<±8.6% of full scale
Repeatability	<±2.5%	<±3.5%	<±2.5%
Hysteresis	<4.5% of full scale	<3.6% of full scale	<5.5% of full scale
Drift	<5% per logarithmic time scale	<3.3% per logarithmic time scale	<3.8% per logarithmic time scale
Operating Temperatures	-40°C - 60°C (-40°F - 140°F)	-40°C - 240°C (-40°F - 400°F)	-40°C - 85°C (-40°F - 185°F)
Force Range	Up to 4,440 N (1,000 lb)	Up to 222 N (50 lb)	Up to 440 N (100 lb)
Temperature Sensitivity	Output variance up to 0.2% per degree F	Output variance up to 0.16% per degree F	Output variance up to 0.2% per degree F
Durability	≥ 1 million actuations	≥ 1 million actuations	≥ 1 million actuations

STANDARD SENSOR OPTIONS (AVAILABLE OFF THE SHELF)

LINEARITY ERROR: ±3% OF FULL SCALE

Linearity refers to the sensor's response (conductance output) to the applied load, over the range of the sensor. This response should ideally be linear; and any non-linearity of the sensor is the amount that its output deviates from this line. A calibration is performed to "linearize" this output as much as possible. FlexiForce standard sensors are linear within ±3%.

REPEATABILITY: ±2.5%

Repeatability is the ability of the sensor to respond in the same way to a repeatedly applied force. As with most measurement devices, it is customary to exercise, or "condition" a sensor before calibrating it or using it for measurement. This is done to reduce the amount of change in the sensor response due to repeated loading and unloading. A sensor is conditioned by loading it to 110% of the test weight four or five times. Follow the full procedure in the Conditioning Sensors section.

DRIFT: <5% PER LOG TIME

Drift is the change in sensor output when a constant force is applied over a period of time. If the sensor is kept under a constant load, the resistance of the sensor will continually decrease, and the output will gradually increase. It is important to take drift into account when calibrating the sensor, so that its effects can be minimized. The simplest way to accomplish this is to perform the sensor calibration in a time frame similar to that which will be used in the application.

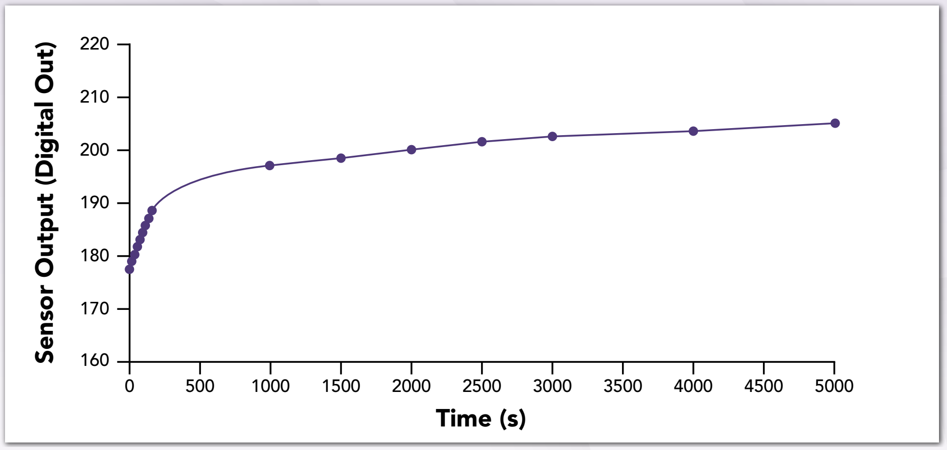


FIGURE 2: SENSOR DRIFT

HYSTERESIS: <4.5% OF FULL SCALE

Hysteresis is the difference in the sensor output response during loading and unloading, at the same force. For static forces, and applications in which force is only increased, and not decreased, the effects of hysteresis are minimal. If an application includes load decreases, as well as increases, there may be error introduced by hysteresis that is not accounted for by calibration.

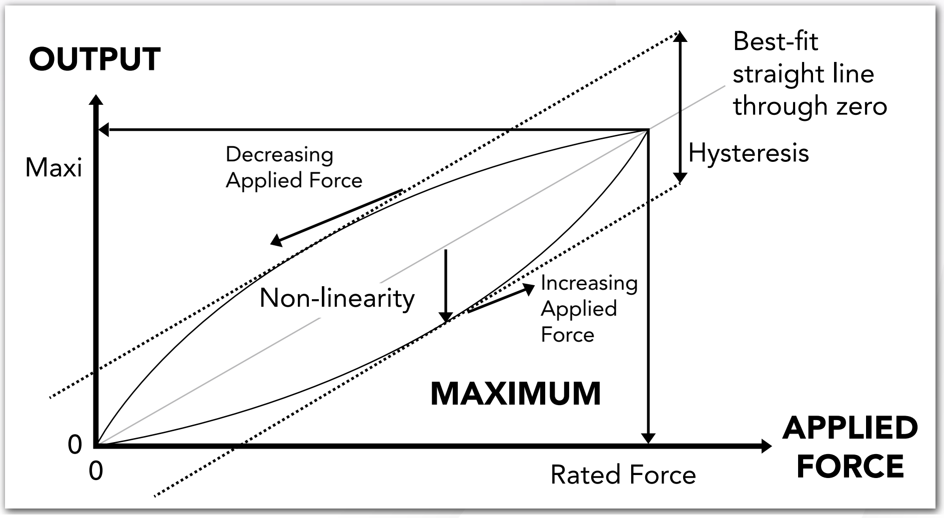


FIGURE 3: HYSTERESIS

BEST PRACTICES

Our team of FlexiForce engineers has collaborated with OEM manufacturers in various industries and applications to successfully integrate our sensors into their products. Every application and customer is unique, making the integration process a challenge. We recognize that every application and customer is unique, and our experience in working across varied applications and environments helps ensure a smoother integration process.

The following pages will share key areas of consideration when selecting, loading and calibrating FlexiForce sensors.

WE STRONGLY ADVISE WORKING WITH OUR DEDICATED TEAM OF MECHANICAL, ELECTRICAL, AND APPLICATION ENGINEERS TO ENSURE A SUCCESSFUL PROJECT OUTCOME.

SENSOR LOADING

Recommendations:

- Ensure a consistent mechanical loading through the active area of the sensor to obtain a linear output.
- Use controlled loading for better sensor performance.
- If load area is larger than the sensor's active area, apply a puck **(Fig. 10, page 15)** to the active sensing area to guarantee consistent loading.

CAUTION: SENSOR LOADING WARNING

- If the sensor load is not consistent and controlled, you will not obtain a linear output as shown in **Fig. 4 (page 12)**. When loading is not applied to the active area of the sensor, the output of the sensor can be erratic and/or nonlinear. Localized high pressure points on the sensor may result in non-linear output. Manufacturing tolerances can cause stress concentrations with high stress points resulting in non-linear output.

Pros Use Pucks

Customer Challenge: A customer's device produced inconsistent results whenever an uneven distribution of force was delivered to the active sensing area.

TEKSCAN'S SOLUTION:

Our team of expert engineers determined that the customer's embedded FlexiForce sensor application design did not incorporate a load concentrator, or "puck." Pucks should be sized to cover 70-85% of the sensing area to improve force transmission. There are 3 key reasons to use pucks:

1) To ensure that 100% of the applied force is concentrated within the sensing area.
2) To provide a better representative sample of repeatable data when the load area is significantly smaller (less than 30% of the sensing area).
3) To protect against sensor damage from point loads delivered at very high pressures.

Testing should be performed with different materials to determine the best puck material for the application. Neoprene, polycarbonate, delrin, aluminum, stainless steel are a few examples that could be used for pucks.

SO ASK YOURSELF:
Am I considering the impacts that uneven force distribution or repetitive forces can have on my device's performance?

BEFORE YOU BUILD

SENSOR SELECTION

Recommendations:

- Before selecting a FlexiForce sensor, talk to our team of engineers to ensure you end up with the proper sensor for your application. Our team will be able to advise you on which sensor works best with your electrical circuit and mechanical design.
- Force range, environmental conditions, and validation tests are key factors in selecting a FlexiForce sensor. Application specifics, load, timeline, and operating temperature are all integral factors to consider while designing a successful product.
- Our team of engineers recommends using a sensor with a lower force range and adjusting the circuit during electrical testing. This results in a more cost-effective solution for production implementation.

CAUTION: SENSOR SELECTION WARNING

- Choosing the wrong FlexiForce sensor may lead to inaccurate sensor output or a non-functioning sensor. If you choose the wrong sensor due to force range, it is likely you will have to redesign your electrical circuit or make mechanical alterations to your product design.
- If your application involves certain environmental conditions, such as high temperatures, using the wrong type of sensor will lead to sensor and design failure.

Smarter Sensor Selection

Customer Challenge: A customer selected their embedded FlexiForce sensor model on the basis of an application-specific force range, yet experienced issues with sensor output and resolution.

TEKSCAN'S SOLUTION:

Our team of expert engineers determined that while the sensor's force range was acceptable for their application, the customer's design required a sensor that could achieve a higher resolution through the dynamic range of the application. Force ranges are just one aspect to consider when selecting the optimal FlexiForce sensor for your application. **Always contact our support team before purchasing your sensor – we will ask the right questions to make sure the sensor you choose will achieve your specific goals.**

SO ASK YOURSELF:
What different internal or external variables could influence my device's sensor performance?

BEFORE YOU BUILD

CALIBRATION

Recommendation:

- Calibration of the sensor should be incorporated into your design – this is critical after assembly. The more calibration range you have available, the easier, lower-cost and more flexible your product will be to assemble and produce.

CAUTION: CALIBRATION WARNING

- Dealing with large mechanical and electrical tolerances can be a hurdle with sensor integration and can impact obtaining a linear sensor output. Creating a calibration process is important for eliminating part and assembly variability from the system and end product.

Calibration Always Adds Value

Customer Challenge: A customer was planning to embed multiple FlexiForce sensors in their product design. The company felt calibration of all sensors was too costly and involve too much process time. Over time, sensor accuracy suffered.

TEKSCAN'S SOLUTION:

FlexiForce sensors require individual calibration – and in some cases, periodic calibration in the field – which can spell the difference between a reliable product and a failed design if ignored. We highly advise designing a calibration protocol for production calibrating every sensor within its assembly to eliminate potential inaccuracies and help extend the life of the sensor within the application. This can help avoid costly product redesigns.

SO ASK YOURSELF:

Am I addressing FlexiForce calibration requirements within my design?

CIRCUITRY

Recommendation:

- Our suggested **op-amp circuit** is recommended to maintain a constant voltage across the sensor and produces the most linear output for your sensor.

CAUTION: CIRCUITRY WARNING

- Alternative circuits tend to result in apparent non-linear behavior. If you choose to use a constant current, voltage divider, or additional in-line resistance with the sensor, the linearity of the sensor will be altered. Our team of engineering experts is happy to help customers with circuit integration.

Never Short on Circuits

Customer Challenge: A customer design included a resistor in line with an embedded FlexiForce sensor, which greatly reduced the linearity of the sensor.

TEKSCAN'S SOLUTION:
Our team of expert engineers helped the customer rework their electrical circuit to successfully integrate within the design constraints and operate with the desired performance. Always contact us before specifying your device's circuitry. We also recommend the OEM QuickStart Board and the OEM Development Kit as great resources to help you determine how circuits will perform in your design.

Scan here to learn about our OEM Quickstart Board.

SO ASK YOURSELF:
What type of circuit performance & attributes are important to me? Cost? Linearity? Resolution? Dynamic range?

Circuit Saturation

Customer Challenge: A customer's designed circuitry was not performing correctly with several sensors from a batch. Some would saturate before reaching the maximum force, others would produce too low an output through the force range.

TEKSCAN'S SOLUTION:
Our team of engineers helped the customer rework their electrical circuit to include adjustability and tenability to work with all sensors within Tekscan's sensor variation specification.

SO ASK YOURSELF:
Will my circuit function appropriately across a sensor variation of +/- 40%?

CALIBRATION OVERVIEW

Calibration is the method by which the sensor's electrical output is correlated to an engineering unit of force, such as pounds or Newtons. To calibrate:

1) Apply a known force to the sensor, and equate the sensor resistance output to this force.

2) Repeat this step with a number of known forces that approximate the load range to be used in testing.

3) Plot Force versus Conductance (1/R). A linear interpolation can then be done between zero load and the known calibration loads to determine the actual force range that matches the sensor output range. This must be done for each sensor as there is significant variation in electrical sensitivity from sensor to sensor.

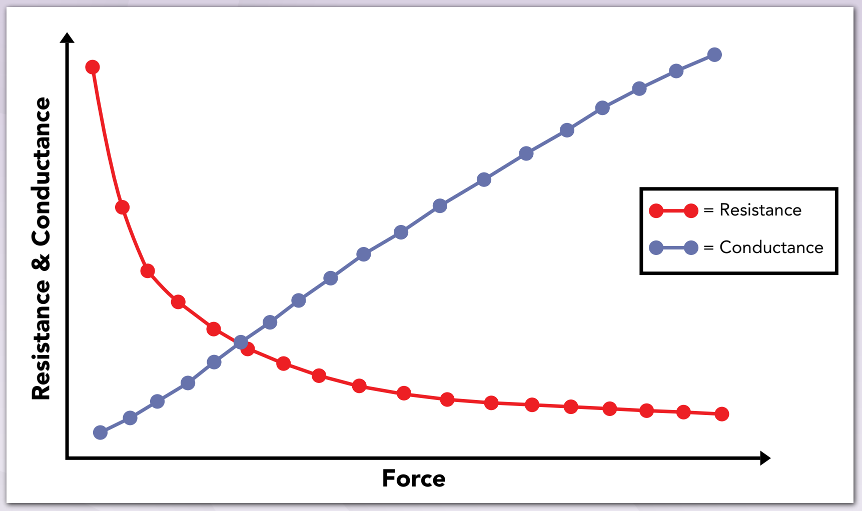


FIGURE 4: RESISTANCE & CONDUCTANCE CURVE

FLEXIFORCE ADVANTAGES VS. COMPETITORS

- **Area independent:** The top to bottom FlexiForce transduction method provides an **area independent** output that measures force not pressure. This feature allows for more consistent force measurement.

- **Accuracy and Linearity:** The change in resistance occurs in the z-axis, normal to the plane of the sensor, resulting in improved accuracy and linearity.

- **Durability and Higher Forces:** A standard FlexiForce sensor can measure and withstand forces over 1,000 lb. This large dynamic force range provides maximum design flexibility.

- **100% Tested:** FlexiForce sensors are 100% tested for both sensor properties and sensor-to-sensor variation. This ensures that our customers receive fully functioning sensors that meet their specifications.

INTEGRATING THE FLEXIFORCE SENSOR

MECHANICAL INTEGRATION

SENSOR TOLERANCES

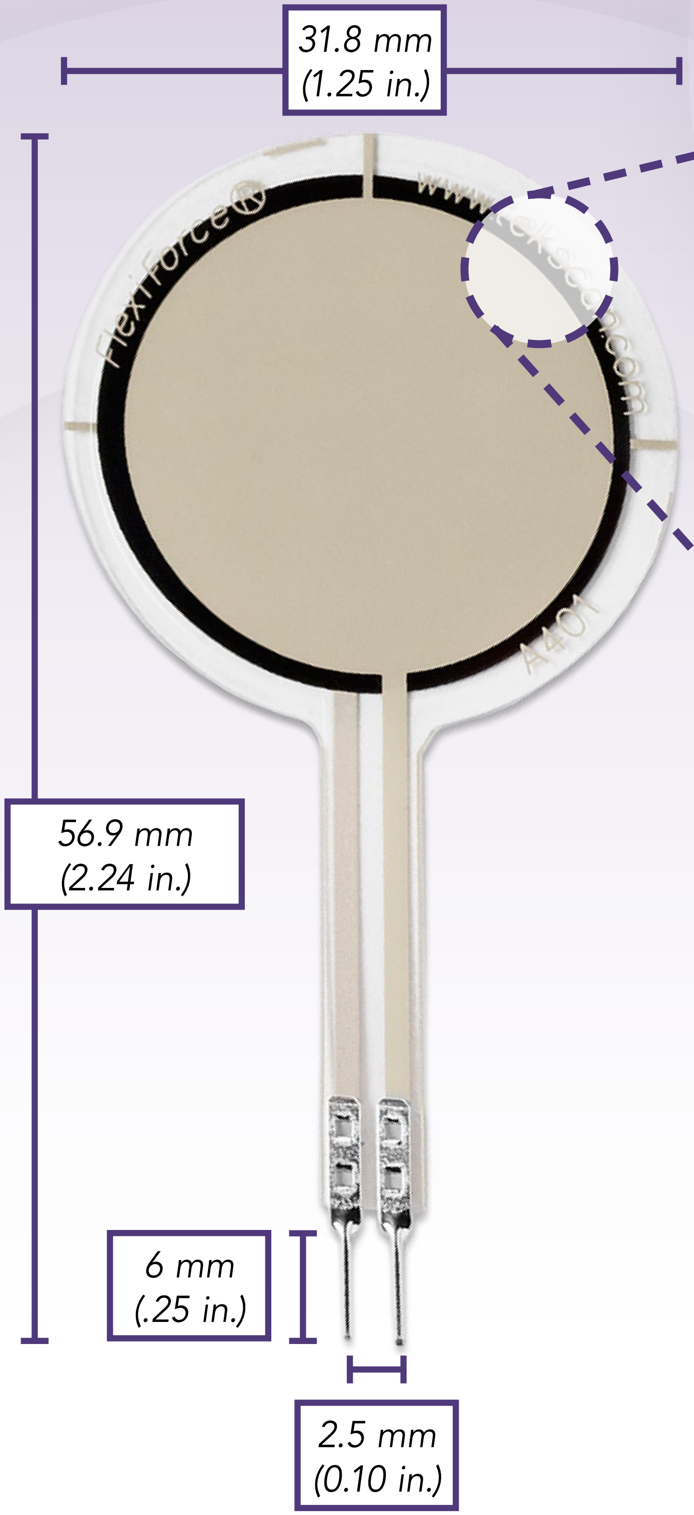


FIGURE 5: TYPICAL SENSOR LAYOUT
(A401 PICTURED)

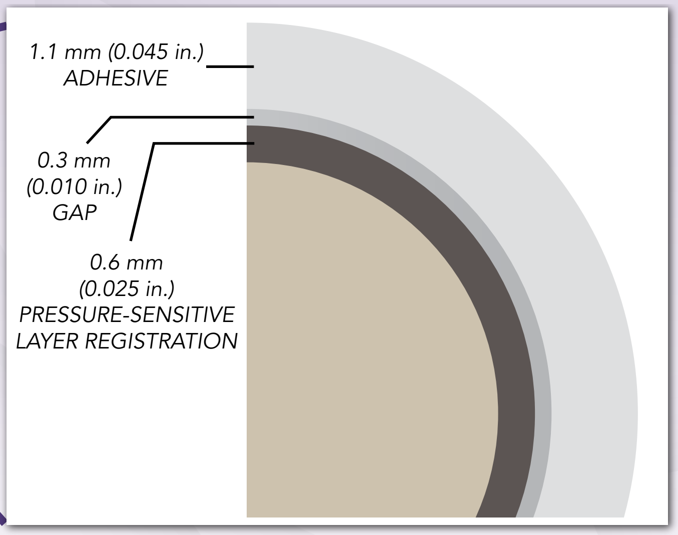


FIGURE 6: SENSING AREA DETAIL

MECHANICAL LOADING/FIXTURING

- The active sensing area, or force sensing area, of a FlexiForce sensor is the silver area within the black perimeter. In the case of standard FlexiForce sensors, this is always a silver circle:

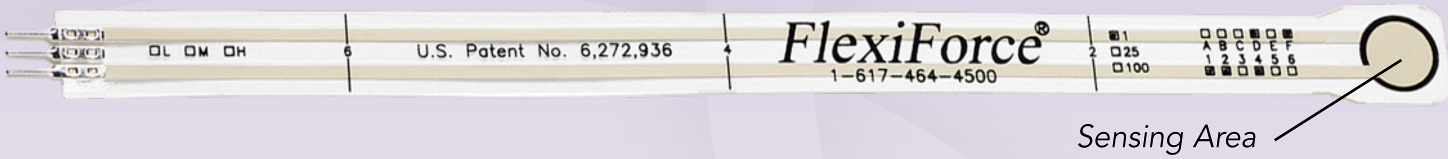


FIGURE 8: FLEXIFORCE A201 SENSOR

- Concentrate all of the force on the active sensing area to ensure best repeatability
  - Ideal characteristics for load applicator:
    - > Ensures force applied is normal/perpendicular to the plane of the sensor (see Minimize Shear below).
    - > Ensures force is always applied to the same location on the sensor.
    - > Ensures force is always applied 100% within the silver-colored sensing area. We recommend under-sizing the load applicator to ensure load remains within the active sensing area after taking into account part-to-part tolerances of customer device and sensors.
  - When a load actuator is not ideal, use a "puck" (see **Fig. 10**):
    - > If the load actuator is too large for the sensing area, a puck (shim) will allow for 100% of the force to be transferred to the active sensing area. A puck can also be used when the surface area of the applied load is much smaller than the active sensing area. Using a puck will result in a more robust design as it improves measuring capabilities.
    - > The puck should be adhered to the active sensing area to ensure load is always applied to the same location on the sensor (thin double-sided tape is typically used).
    - > For the puck material, we recommend using the softest interface material that will still maintain dimensional stability at applied force levels. This ensures there is no squirming/shear force resulting from the compression of the puck, and also reduces any chance of "edge loading" (high pressure zones along the edges of the active sensing area) that might occur with too hard a material.
  - Sometimes it is not possible to concentrate 100% of the force on the sensing area (aka offloading). In such cases, it is important that the sensor is calibrated in the final device/setup so that any change in sensor output due to offloading is taken into account.

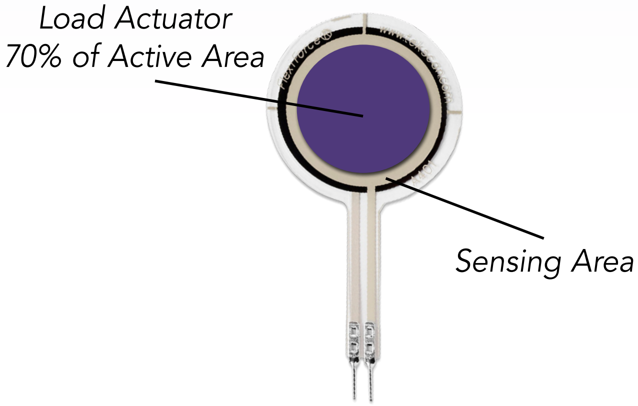


FIGURE 9: LOAD ACTUATOR POSITIONING

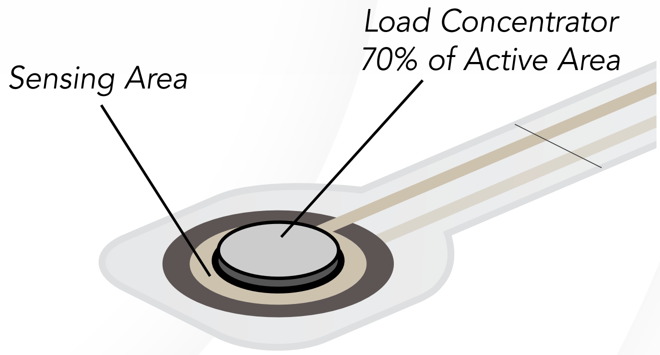


FIGURE 10: MECHANICAL "PUCK" FOR LOAD CONCENTRATION

- Minimize sensor surface shear
  - Applied force must be normal/perpendicular to the plane of the active sensing area.
  - Small shear forces will decrease force sensitivity over time. If you see this decrease, shear force exposure should be examined. On a short-term basis can be recalibrated. Long-term – could result in inadequate force resolution.
  - Large shear forces can break the adhesive bond between the top and bottom substrate layers of the sensor, resulting in sensor failure.

VENTING/"PILLOWING"

- Standard FlexiForce sensors, and most custom sensors, are vented to equalize the internal pressure at the sensing area region with the external atmospheric pressure. Without the vent, there is the possibility of pressure build up, or "pillowing", within the sensor which would affect force sensing repeatability.

- The vent could serve as a possible pathway for external contaminants, such as oils, chemicals, etc. to enter the sensor. This needs to be accounted for in both the design of the sensor and the design of the surrounding fixture/device.

- Internal venting designs are available with custom sensors to seal the sensor from harsh environments.

CLEANING/CHEMICAL COMPATIBILITIES AND CONCERNS

- Sensors can be lightly cleaned using Isopropyl Alcohol. To clean take a rag or cloth that is slightly damp and quickly wipe the surface of the sensor. Be sure not let the damp rag or cloth linger on the surface of the sensor, especially if pin connectors are installed as the pins create an opening that can quickly wick the alcohol. It is important not to immerse sensors into the alcohol, even if quickly dipping.

- Sensors should not be immersed in any liquids or oils. Take care that any adhesive or over-coating materials do not outgas near the sensing area or any open vents that may be present on the sensor.

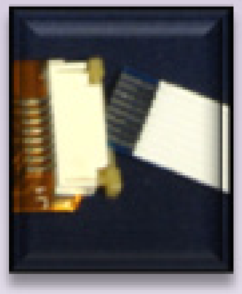
MOUNTING

- Typically mounting is done with thin, double-sided tape. Tekscan can provide this as a "peel 'n stick" backing on the sensors. Most Tekscan custom sensors are supplied with 3M tape part # 9482PC.

- Holes can be designed in sensors for screw/clamp type mounting.

- **DO NOT USE** – Hard setting adhesives or epoxies that will affect the way force is transmitted to the sensing area, or any compound that could potentially outgas and contaminate the pressure sensitive materials within the sensor.

TERMINATION OPTIONS



ZIF Compatible Termination – ZIF/LIF compatible termination is available on a custom basis. ZIF/LIF connectors allow for ease of assembly and provide a small connector footprint and height for applications with tight space constraints. Please contact a Tekscan Representative for more information about spacing and size guidelines.

Conductive Epoxies or Z-Axis conductive tapes – Conductive epoxies or z-axis conductive tapes can be applied to the exposed traces of a FlexiForce sensor to connect the sensors directly to an FPC/PCB. This method results in the lowest sensor price to the customer because the additional manufacturing steps for pin crimps or ZIF compatible terminations are not required. It also provides the lowest possible mated height compared to any other electrical termination options.

Pins and Solder Tabs – Standard FlexiForce sensors are available with pins that can be inserted into PCB headers with 2.54 mm (0.1 in) spacing or they can be soldered to directly. A variety of connector pins, pin housings, and solder tabs are available on a custom basis.

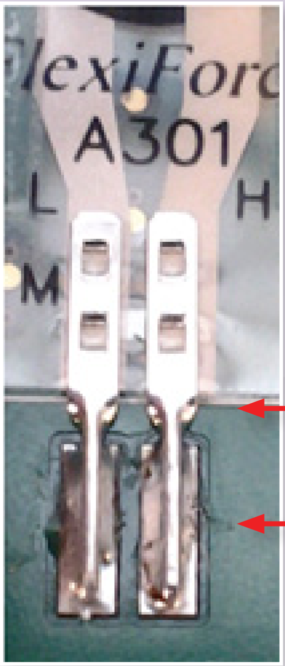
CONSIDERATIONS FOR SOLDERING FLEXIFORCE SENSORS TO PCB SOLDER TABS

NOTE: It is recommended that solder flux NOT be used when soldering FlexiForce sensors. The flux has a tendency to run and creep into the sensor via the crimped area of the pins. The flux can then penetrate the sensing area of the sensor via the air vent running down the middle of the sensor and result in an unusable sensor. In cases where flux is necessary, use as little as possible and take great care to ensure no flux gets on crimped area of pins.

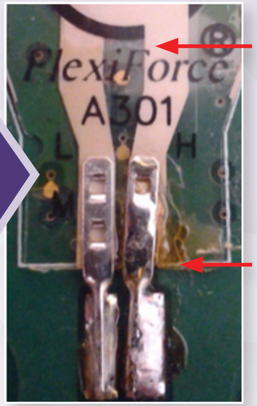
- **Soldering Iron Tip Diameter:** 1.6 mm (.063 in) or smaller
- **Soldering Temperature:** Lead-free solder at 454.4°C (850°F)
- Tin solder pads, tin soldering tip
- Solder sensor pin to tinned solder pad, applying solder/soldering iron for **no more than 3 seconds at a time**. If more time is needed to complete soldering, remove soldering iron from pin, allow sensor to cool for 5-7 seconds and reapply solder/soldering iron.
  - An alligator clip may also be used to sink heat away from the sensor as shown on the right. This is beneficial in applications where it can be used, but not necessary.

ALLIGATOR CLIP EXAMPLE

EXAMPLE OF A PROPERLY SOLDERED SENSOR



EXAMPLES OF A IMPROPERLY SOLDERED SENSORS



PROCEDURE FOR VERIFYING SOLDER TECHNIQUE

1. Place unsoldered sensor on PCB
2. Use calibration loading fixture to apply 3-5 step load, measuring resistance at each load. Precondition sensor with 3 or 4 loadings at max load before taking measurements
3. Solder sensor to PCB
4. Apply the same preconditioning and loading profile to sensor, measuring resistance at each load
5. Compare measurements before and after soldering. All values should be within 5% of each other for a given sensor

ELECTRICAL INTEGRATION

RECOMMENDED EXCITATION CIRCUIT (DUAL SOURCE) - OPTIMAL FORCE RANGE ADJUSTMENT

The dual source circuit provides excellent linearity in voltage output with respect to force applied to the FlexiForce sensor. It also provides the most versatility in terms of force range adjustment by adjusting the circuit parameters of excitation voltage (V_{REF}) and the feedback resistor ($R_{FEEDBACK}$). With this circuit, the user can effectively change the force range of the same FlexiForce sensor from under 4.4 N (1 lb) to over 4,448.2 N (1,000 lb).

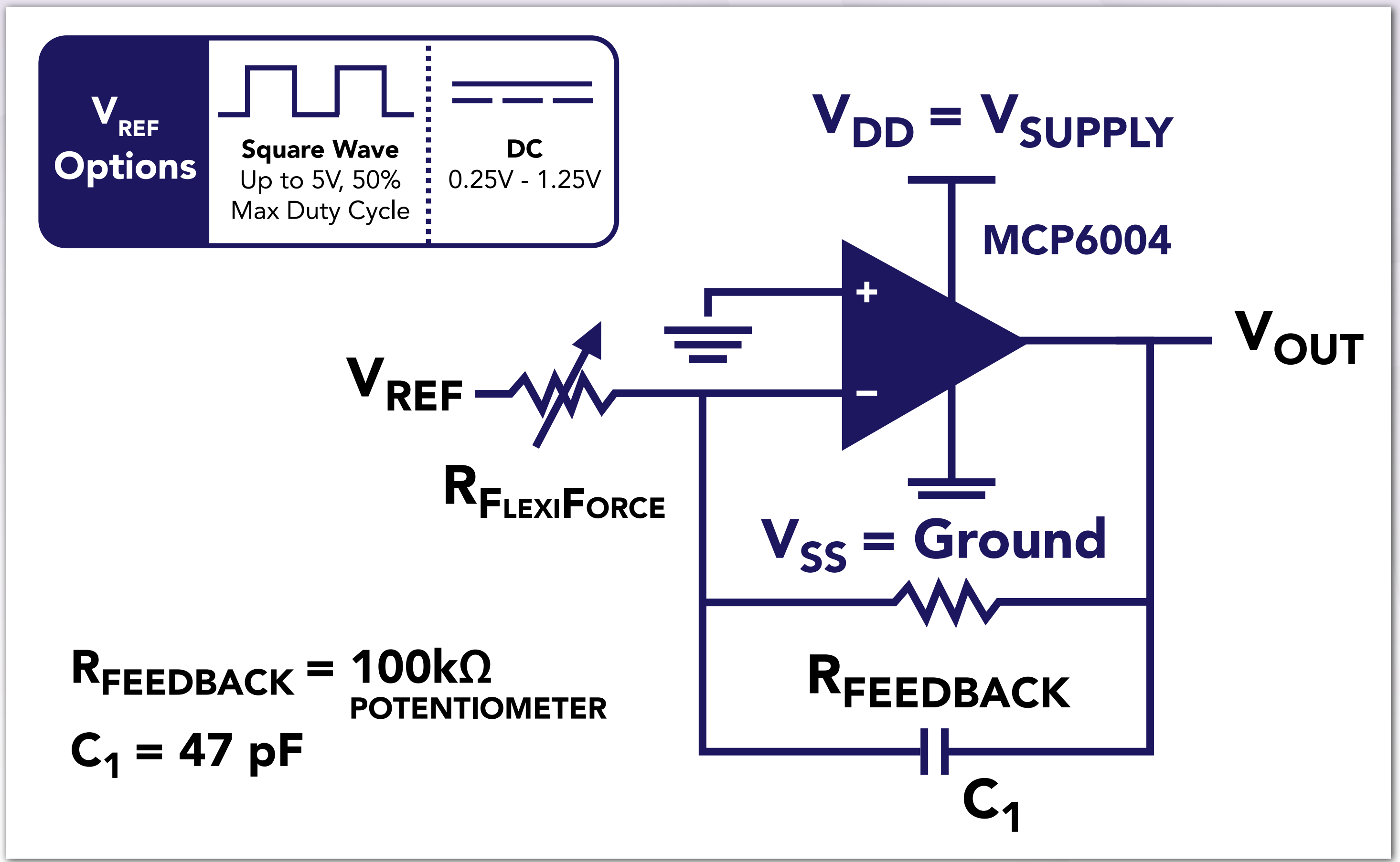


FIGURE 11: DUAL SOURCE EXCITATION CIRCUIT

100K potentiometer and 47 pF are general recommendations; your specific sensor may be best suited with a different potentiometer and capacitor. Testing should be performed to determine this.

Polarity of V_{REF} must be opposite the polarity of V_{SUPPLY}.

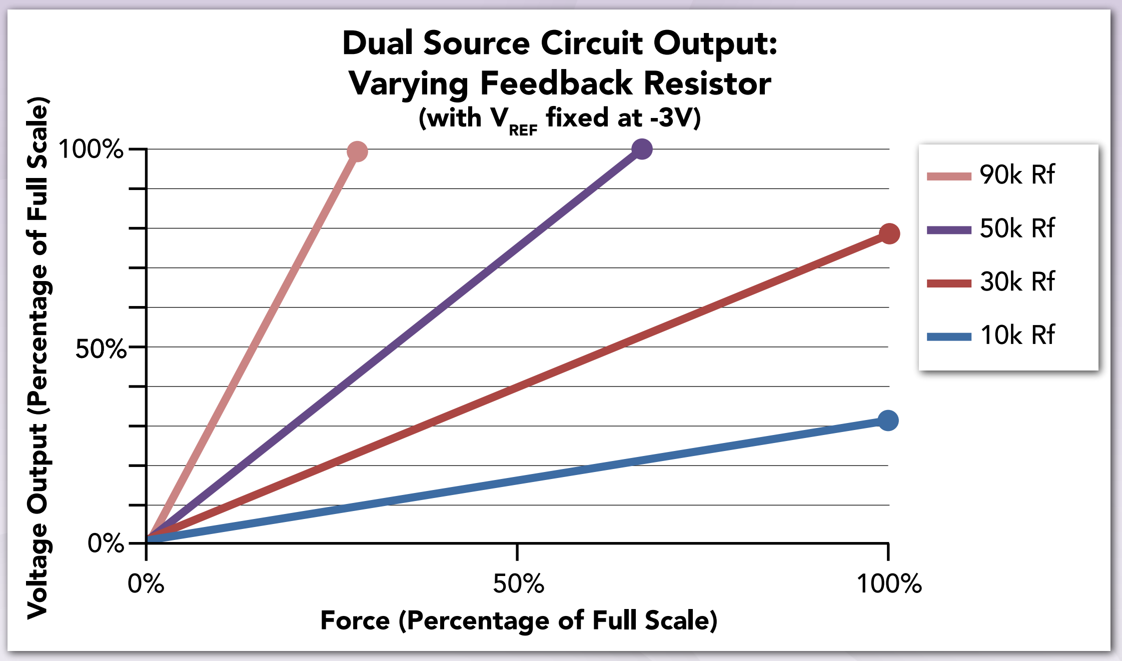


FIGURE 12

Fig. 12 shows the relationship of the output voltage vs. force applied to the sensor with drive voltage, V_{REF}, fixed at -3 volts. By inspecting this graph, it is seen that decreasing Rf decreases the sensitivity of the circuit output for a given force (extended force range). Conversely, larger Rf values increase the slope of the voltage output versus force curve and therefore increase the sensitivity of the circuit (decreased force range). **Fig. 13** shows the V_{OUT} versus Force relationship with a varying drive voltage, V_{REF}, and fixed Rf resistance value of 50kΩ. Similarly to the effects of varying the feedback resistor value, an increase drive voltage will result in higher sensitivity (decreased force range) and a decreased voltage will result in lower sensitivity (extended force range).

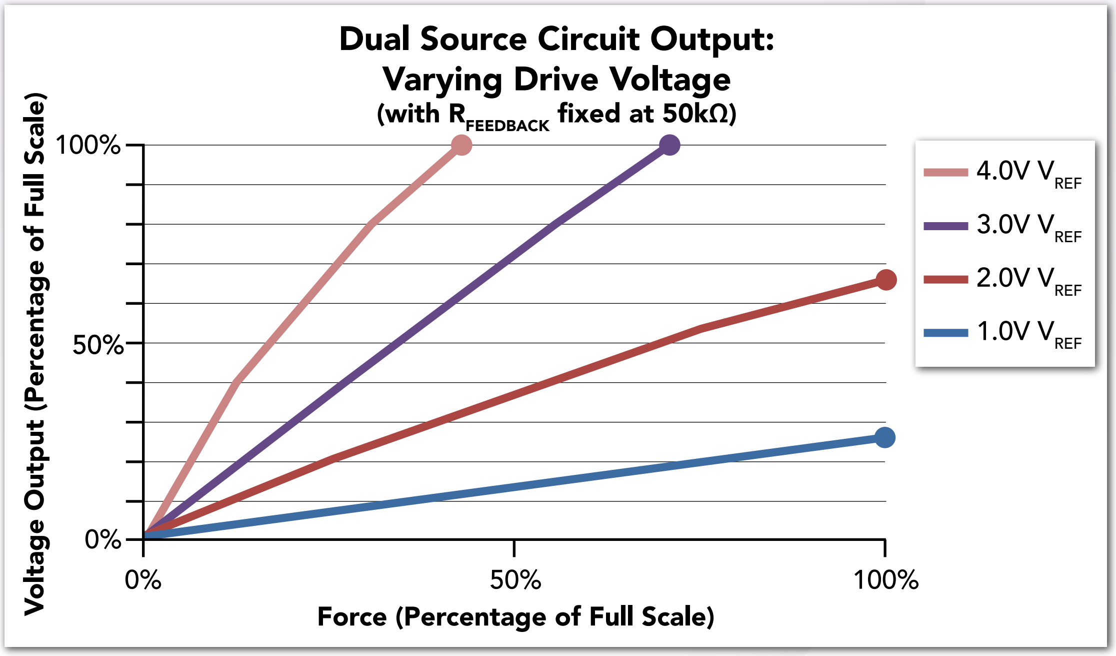


FIGURE 13

RECOMMENDED EXCITATION CIRCUIT (SINGLE SOURCE) - LOW/BATTERY POWER DEVICES

The single source circuit also provides excellent voltage vs. force linearity while also being easy to implement in a portable device. However, the range of force adjustment that can be achieved by adjusting sensor excitation voltage and the feedback resistor is more limited than with the recommended dual circuit. This circuit is the better choice for implementing in a device once the proper circuit parameters and sensor sensitivity have been defined.

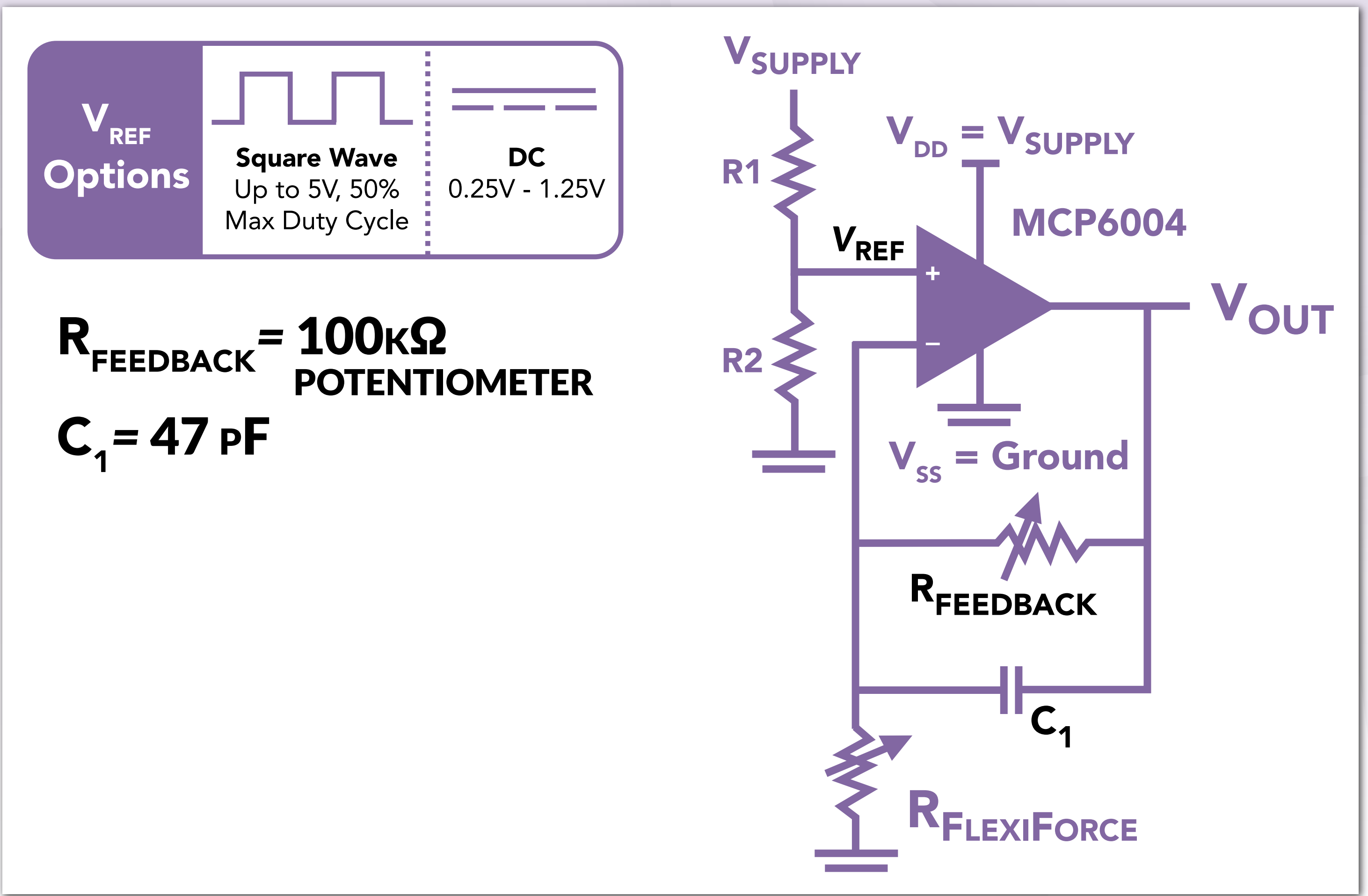


FIGURE 14: SINGLE SOURCE EXCITATION CIRCUIT

100K potentiometer and 47 pF are general recommendations; your specific sensor may be best suited with a different potentiometer and capacitor. Testing should be performed to determine this.

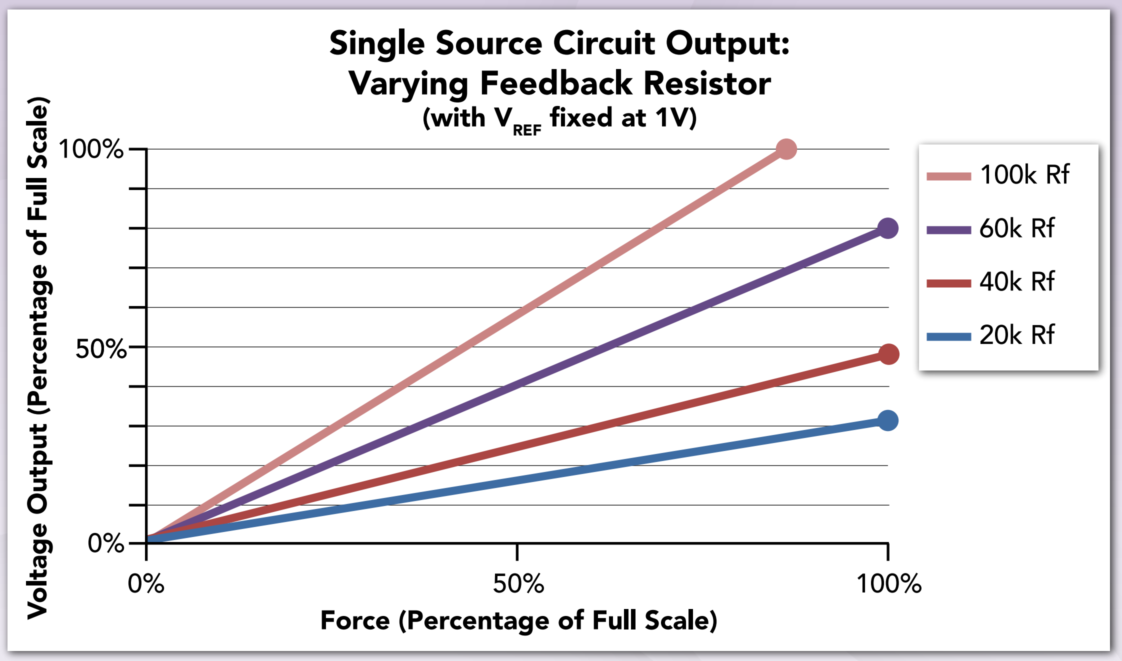


FIGURE 15

Fig. 15 above shows the relationship of the output voltage versus the force applied to the sensor with the sensor drive voltage, V_{REF}, fixed at 1 volt. By inspection of this graph it is seen that decreasing Rf will decrease the sensitivity of the circuit output for a given force (extended force range). Conversely, a larger Rf value will increase the slope of the voltage output versus force curve and therefore increase the sensitivity of the circuit (decreased force range). **Fig. 16** shows the V_{OUT} versus Force relationship with a varying drive voltage, V_{REF}, and fixed Rf resistance value of 50kΩ. Similarly to the effects of varying the feedback resistor value, an increase drive voltage will result in higher sensitivity (decreased force range) and a decreased voltage will result in lower sensitivity (extended force range).

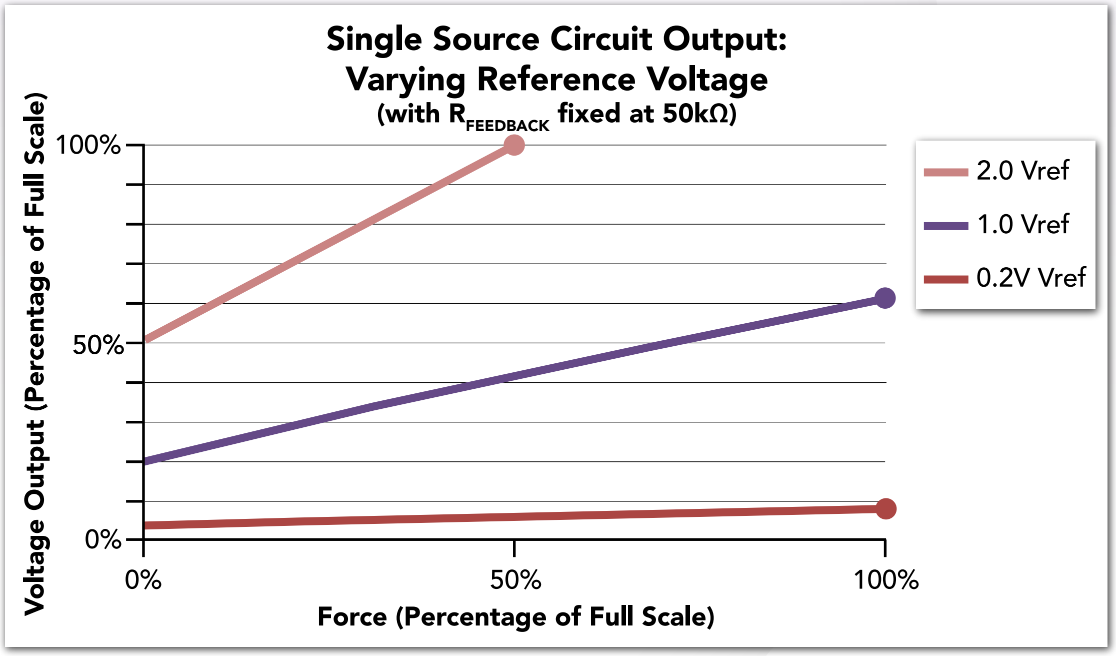


FIGURE 16

MODIFIED SINGLE SOURCE CIRCUIT (TRI-STATE CIRCUIT) - IDEAL CIRCUIT FOR OEM'S

The tri-state circuit is virtually identical to the single source circuit mentioned above except that it allows for the adjustment of the sensor drive voltage via the use of a digital out on your microprocessor. This allows for the digital adjustment of the force range (sensitivity) which provides the ideal method to compensate for mechanical and electrical variations from both the sensor and the mechanical stack-up of the loading apparatus/device.

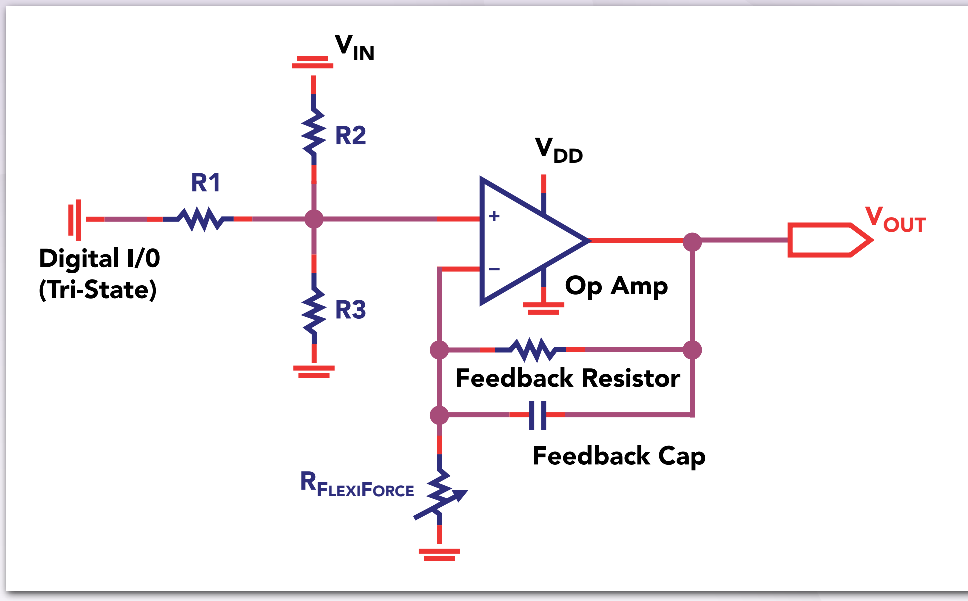


FIGURE 17

NOT RECOMMENDED EXCITATION CIRCUIT (VOLTAGE DIVIDER) - DOES NOT REQUIRE OP-AMP CHIP

The voltage divider circuit is by far the simplest and most compact circuit configuration that can be used with FlexiForce sensors. However, the output is very non-linear which typically limits this circuit to applications requiring less accuracy.

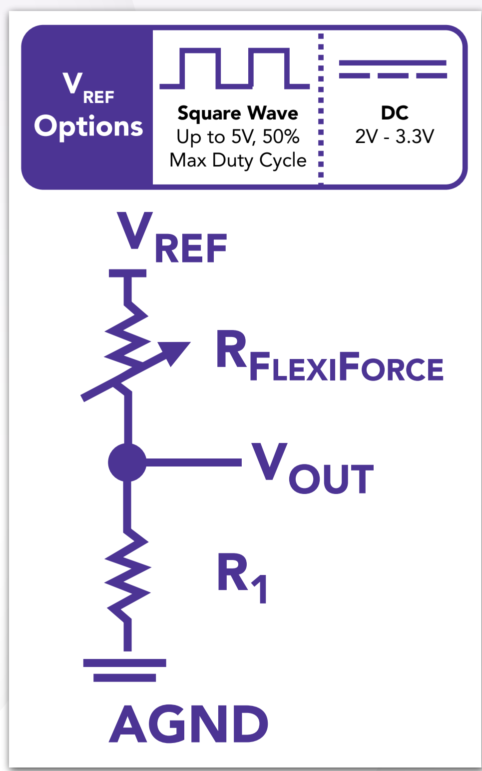


FIGURE 18

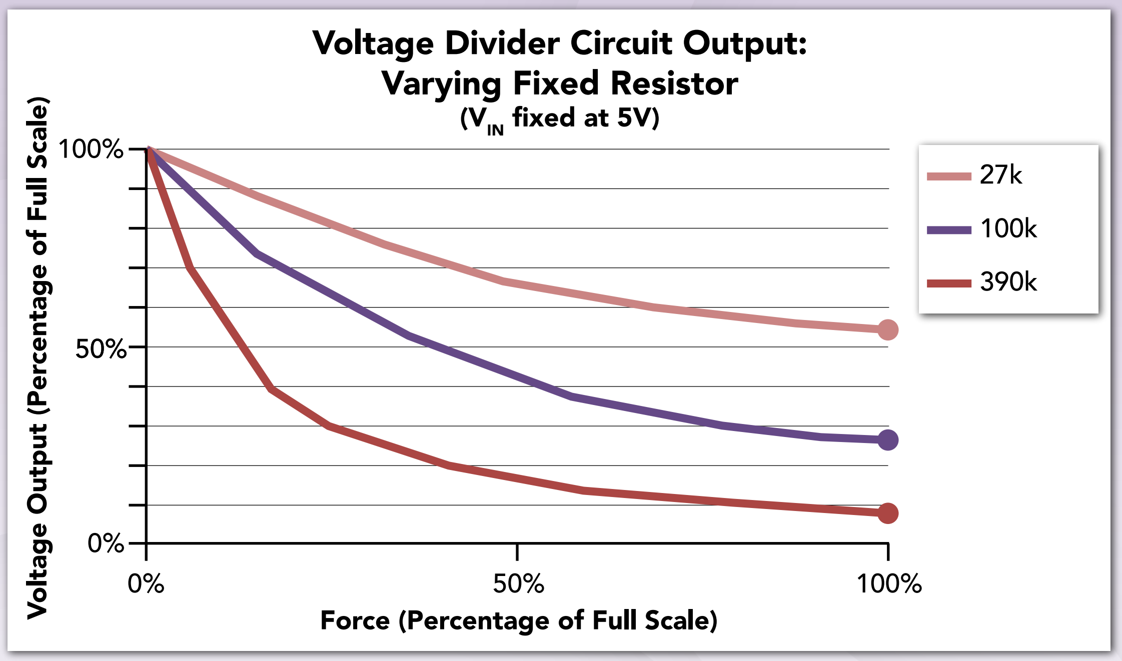


FIGURE 19

Fig. 19 shows the relationship of the output voltage versus the force applied to the sensor with VIN fixed at 5 volts. The feedback resistor value can be adjusted to optimize sensitivity, but increased sensitivity also results in increased non-linearity with this circuit configuration.

CUSTOMIZED SENSOR PROCESS

CUSTOM SENSOR FORM AND QUOTATION

- The custom sensor form asks for all the necessary design details, prototype and production schedule, and desired piece price target so that Tekscan can provide a quick turn around on quote.

- After the custom sensor form is received, we provide a formal quotation at the requested prototype and production quantities. A detailed concept drawing is also included with the quote.

CUSTOM QUOTATION

- Quotation includes detailed design concept drawing, NRE, prototype pricing, and production volume pricing

- Design and Tooling (NRE) Fee consists of:
  - Engineering design time for sensor concept and final tooling design.
  - Test hardware and software.
  - Production grade printing screens for internal sensor layers (conductive, semi-conductive, adhesive, dielectric).
  - Production grade die cutting tools necessary for manufacturing tools alignment and for cutting sensors from manufactured sheet-form.

COST DRIVING FACTORS

- Overall size of sensor is a major cost driver. The sensors are all manufactured in a sheet form so the total number of sensors that can be made in one sheet has a major impact on production throughput.

- Sensor electrical termination configuration is also a major cost driver. ZIF compatible configurations and solder tabs increase sensor cost. The ideal connection method is to connect directly to sensor traces via conductive adhesive and/or heat bonding.

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