The Force-Sensing-Resistor (FSR) is made of a proprietary carbon-based piezoresistive ink, typically screen printed on polyester film (PET). As force is applied to the FSR, the electrical resistance decreases. The FSR carbon ink formulation can be customized for application-specific requirements. There are two basic FSR configurations: the ShuntMode™ and the ThruMode™. The details of each will be explained later on in this document. The main purpose of a pressure sensor (tactile force sensor), such as an FSR, is to measure the forces applied to a specific area and then relay that information via selected output or electronics.

The diagrams below illustrate the relationship between the applied Pressure (Load) and the resulting Resistance of a Force Sensing Resistor. **Diagram 1** depicts the change in resistance as the pressure load is applied and then released. As the pressure load is increased, the resistance decreases. When the load is removed, the sensor’s resistance returns to its normal state. **Diagram 2** illustrates how carbon-based FSR ink particles become compressed under increasing loads, resulting in the conductive particles being closer in proximity to one another allowing for a shorter conductive path leading to a lower overall resistance.
## Force Sensing Resistor Characteristics

<table>
<thead>
<tr>
<th>PROPERTY</th>
<th>VALUE</th>
<th>NOTES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size Range</td>
<td>Limited only by printing equipment</td>
<td>Any shape, compound curves</td>
</tr>
<tr>
<td>Force Sensitivity Range</td>
<td>1 oz. to 20 lbs.</td>
<td>Mechanical interface dependent</td>
</tr>
<tr>
<td>Pressure Sensitivity Range</td>
<td>1 psi to 125 psi</td>
<td>Mechanical interface dependent</td>
</tr>
<tr>
<td>Part-to-Part Repeatability</td>
<td>Approx. +/-20% of average resistance</td>
<td>With consistent actuation</td>
</tr>
<tr>
<td>Maximum Current</td>
<td>0.5mA</td>
<td>Keep the current low. Overheating will destroy the FSR device.</td>
</tr>
<tr>
<td>Single Part Force Repeatability</td>
<td>+/-5% of established resistance</td>
<td>With consistent actuation</td>
</tr>
<tr>
<td>Force Resolution</td>
<td>1% full scale</td>
<td></td>
</tr>
<tr>
<td>Stand-off Resistance</td>
<td>100K Ohms to 1M Ohms</td>
<td>No load, formula dependent</td>
</tr>
<tr>
<td>Switch Travel</td>
<td>Zero to Thickness of Spacer</td>
<td></td>
</tr>
<tr>
<td>Devise Rise Time</td>
<td>1 msec</td>
<td></td>
</tr>
<tr>
<td>Lifecycle</td>
<td>1,000,000+ Actuations</td>
<td></td>
</tr>
<tr>
<td>Temperature Range</td>
<td>-15°F to +200°F</td>
<td>Substrate specification limitations</td>
</tr>
<tr>
<td>Device Thickness</td>
<td>Substrate and Spacer Dependent</td>
<td></td>
</tr>
</tbody>
</table>

*Force Sensing Carbon Ink can be custom blended for specific applications*
ShuntMode™ FSR

A ShuntMode™ FSR is comprised of conductive silver interdigitated fingers on the bottom PET film layer shorted by the FSR element on the top PET film layer. The ShuntMode™ FSR has a more dynamic range, would not saturate as quickly, and have a larger actuation force versus a comparable ThruMode™ FSR. These are good for high-volume applications since it uses less silver ink than the ThruMode™ FSR and thus lower cost. NOTE: these sensors can be manufactured in other geometries such as rectangular. The tails can be terminated with 2.54mm pitch female connectors (latching or non-latching), a 1mm pitch ZIF-style connection, or 2.54mm pitch male solder tabs.

**Top Circuit with printed FSR Carbon Ink:**
Typically 0.005” thick clear Polyester

**Spacer Layer:**
Typically 0.002” to 0.005” thick Spacer Adhesive

**Bottom Circuit with printed Conductive Silver Traces and Dielectric Tail Insulation:**
Typically 0.005” thick clear Polyester

**Rear/BOTTOM Pressure Sensitive Adhesive:**
Typically 0.002” to 0.005” thick PSA
ThruMode™ FSR

A ThruMode™ FSR is comprised of conductive silver electrodes overprinted with proprietary FSR carbon ink technology on both the top and bottom circuit layers. The Thru Mode™ FSR would saturate with a smaller force but also be more response to smaller forces versus a comparable ShuntMode™ FSR. The ThruMode™ FSR requires more carbon FSR ink and thus more costly. Very small size applications can benefit from a ThruMode™ device because this configuration does not use interdigitated fingers which have a print size limitation. NOTE: these sensors can be manufactured in other geometries such as rectangular. The tails can be terminated with 2.54mm pitch female connectors (latching or non-latching), a 1mm pitch ZIF-style connection, or 2.54mm pitch male solder tabs.

Top Circuit with printed Conductive Silver, FSR Carbon Ink, and Dielectric Tail Insulation:
Typically 0.005” thick clear Polyester

Spacer Layer:
Typically 0.002” to 0.005” thick Spacer Adhesive

Bottom Circuit with printed Conductive Silver, FSR Carbon Ink, and Dielectric Tail Insulation:
Typically 0.005” thick clear Polyester

Rear/Bottom Pressure Sensitive Adhesive:
Typically 0.002” to 0.005” thick PSA
ShuntMode™ Matrix Array FSR

A ShuntMode™ Matrix Array is used where measurements of multiple inputs of force and locations are needed simultaneously. It operates in the same manner as the single ShuntMode™ FSR shown above but constructed in a matrix of multiple sensors. The tails can be terminated with 2.54mm pitch female connectors (latching or non-latching), a 1mm pitch ZIF-style connection, or 2.54mm pitch male solder tabs.

Top Circuit with printed FSR Carbon Ink:
Typically 0.005” thick clear Polyester

Spacer Layer:
Typically 0.002” to 0.005” thick Spacer Adhesive

Printed Dielectric #2

Printed Conductive Silver Jumpers

Printed Dielectric #1

Bottom Circuit with printed Conductive Silver Traces:
Typically 0.005” thick clear Polyester

Rear/Bottom Pressure Sensitive Adhesive:
Typically 0.002” to 0.005” thick PSA
ThruMode™ Matrix Array FSR

A ThruMode™ Matrix Array is able to measure multiple position and force inputs. The Matrix array can be used in a variety of innovative musical, human input, and touch-sensing designs. It operates in the same manner as the single ThruMode™ FSR shown above but constructed in a matrix of multiple long, rectangular sensors. The tails can be terminated with 2.54mm pitch female connectors (latching or non-latching), a 1mm pitch ZIF-style connection, or 2.54mm pitch male solder tabs.

Top Circuit with printed Conductive Silver, FSR Carbon Ink, and Dielectric Insulation:
Typically 0.005” thick clear Polyester

Spacer Layer:
Typically 0.002” to 0.005” thick Spacer Adhesive

Bottom Circuit with printed Conductive Silver, FSR Carbon Ink, and Dielectric Insulation/Standoffs:
Typically 0.005” thick clear Polyester

Rear/Bottom Pressure Sensitive Adhesive:
Typically 0.002” to 0.005” thick PSA
Effect of the Spacer’s Thickness and Inside Diameter on Activation Force

As with a typical membrane switch, the top and bottom circuit layers can be spaced apart using various thicknesses of spacer material such as 3M 467MP double-stick pressure sensitive adhesive. The spacer thickness (height) and inside diameter (ID), as well as the thickness of the top circuit layer polyester (or deflecting film), will mechanically determine the amount of force required for the two conductive surfaces to come into contact.

A typical conductive membrane switch is fully conductive when force is applied and contact is made. A force sensing resistor can be in contact and maintain a high resistive state with light force in a “preloaded” condition. In this instance, a threshold circuit is used to set the limit at which the device is considered “in contact”.

Dielectric Dots (Standoffs)

Dielectric (insulator) dot patterns, or standoffs, can also be used for spacing the top and bottom circuits apart. The frequency or spacing and the height of the standoffs determine the amount of force needed for activation. The closer the standoffs are to each other, the more force is required to activate the sensor. See the ThruMode™ Matrix Array diagram above for an example of the use of dielectric standoffs.

Mounting the FSR

The FSR device works best when mounted to a rigid or semi-rigid backer so that when a force is applied to the sensor, there is a surface to push against. The FSR sensor can be adhered to a surface with an adhesive such as 3M 467MP pressure sensitive adhesive.

The Actuator

The actuator system is critical for improving the part-to-part reproducibility of the FSR device. The actuator references the device, or means in which the FSR device is “touched” or actuated. As the flexible top circuit film deflects and yields to the force applied by the actuator, initially there is a small area of contact between the FSR element and the circuit. As the force is increased, the area of contact also increases and the output becomes more conductive. These principles are minimized and a less dynamic range is accomplished when both substrates are rigid.

As long as the force is applied consistently, cycle-to-cycle repeatability is maintained. A Thin elastomer such as silicone rubber, placed between the actuator and the sensor can be used to absorb some error from inconsistent force distribution. In some instances, a silicone test probe can work as an equivalent to an actuator with a thin silicone pad.
Designing the actuator to ensure proper loading of the sensor is critical to a consistent FSR device. The actuator material is chosen specific to the application.

Make sure the actuator is about 20% smaller than the inside diameter of the spacer opening (dependent on spacer height). If the actuator is too close to the spacer, it can block the force.

An FSR is not a strain gage or load cell. It will consistently deliver a characteristic curve and can achieve 2% accuracy with a well-designed actuator system. A calibration system is suggested for applications where higher accuracy is required. Most applications will achieve a 55 to 15% accuracy, depending on the actuation system.

The Effects of Conductive Ink, Trace Width, and Trace Spacing on FSR Output

The trace (interdigitated finger) widths and the spacing between them will affect the output of the FSR device. The wider the traces and spaces between them, the more resistive the output. More resistive inks tend to be more linear and will tolerate higher forces while more conductive inks tend to work better within finger-activated devices.
Force Sensing Applications

Force Sensing Resistors can be used for such applications as computer input devices, musical instruments, medical instruments, robotics, automotive, interactive toys, sports, and more.

<table>
<thead>
<tr>
<th>MARKET</th>
<th>APPLICATIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consumer Products / Computer Devices</td>
<td>Up/Down or Force/Speed cursor control; Interactive musical instrument controllers; Interactive stylus signature recognition controller, “Smart” shelves/inventory control and “Smart” Point-of-Sale Displays</td>
</tr>
<tr>
<td>Musical Instruments</td>
<td>Electronic drum triggers, Foot pedal controllers, Interactive Dance Floor</td>
</tr>
<tr>
<td>Medical</td>
<td>Drug-delivery Infusion pumps, Podiatry foot gait analysis, Tool speed control, Patient turning alarm sensor, Training devices such as a CPR manikin, “Smart” surgical clamps/grippers, Real-time patient monitoring (bed frame sensors, clothing/shoe sensors)</td>
</tr>
<tr>
<td>Automotive / Industrial</td>
<td>Robotic fingertips, Assembly parts detection, Dynamic limit sensor, Motor speed control, Floor security panels, Seat occupancy detection, Electronic throttle and brake</td>
</tr>
<tr>
<td>Toys</td>
<td>Interactive dolls, RC controllers, Joysticks, Toy musical instruments</td>
</tr>
<tr>
<td>Sports</td>
<td>Target force and accuracy detection Grip monitor, Trolling motor speed control</td>
</tr>
</tbody>
</table>
Application Examples

Blockage Sensor for Drug-Delivery Infusion Pump/IV

If a blockage occurs in the patient’s IV line, the tubing within the pump expands. The sensor detects this expansion by sensing the pressure applied on the sensor by the tubing. The sensor then triggers an alarm to alert medical personnel of the blockage.

Sensor for Foot Pressure Mapping Kiosks

Force Sensors can be used to sense and map the various pressure points on human feet in order so custom orthotics can be prescribed. In the case of a foot pressure mapping kiosk, a force sensing resistor array of more than 2,000 individual sensors provides a detailed output so the custom software can accurately analyze the person’s foot pressure points.

PRODUCT USE: All statements, technical information and recommendations contained in this document are based upon tests or experience that Butler Technologies, Inc. believes are reliable. However, many factors beyond Butler Technologies’ control can affect the use and performance of a Force Sensing Resistor (FSR) in a particular application, including the conditions under which the product is used and the time and environmental conditions in which the product is expected to perform. Since these factors are uniquely within the user’s knowledge and control, it is essential that the user evaluate the Butler Technologies FSR to determine whether it is fit for a particular purpose and suitable for the user’s application.

Portions of the content in this Technical Guideline have been provided through the courtesy of Sensitronics LLC and MSD Consumer Care, Inc.