Integration Guide

Force Sensing Potentiometer

To be used in conjunction with current FSP series data-sheets available at www.ohmite.com

Integration Guide

Force Sensing Potentiometer

CONTENTS

Integration Guide

Force Sensing Potentiometer

1 Force Sensing Potentiometer (FSP) Overview

This guide covers Ohmite's standard Force Sensing Potentiometer offerings FSP01CE, FSP02CE and FSP03CE. These sensors operate as both position and force sensors offering users the ability to control menu navigation, device function, movement, audio control and many other HMI interaction in a more reliable and intuitive manner. Adding additional opportunities for user interaction, haptic control lighting, and integration methods.

Interfacing to an FSP sensor is simple and can be achieved using a number of different methods either with a dedicated microcontroller outputting serial data to a host controller, or directly linked to the host with a few simple external passive components.

This guide provides all the necessary technical information for the successful integration of Ohmite's force sensing potentiometers into products such as:

- **Media controllers**
- **Computer and peripherals**
- **E-readers**
- **Industrial, scientific or medical devices**
- **Home automation and lighting control**
- **Midi controllers**
- **White goods**
- **IOT devices**

Integration Guide

Force Sensing Potentiometer

FSP01CE
Stacked view

A Top layer
B Spacer Adhesive
C Bottom layer
D Mount adhesive

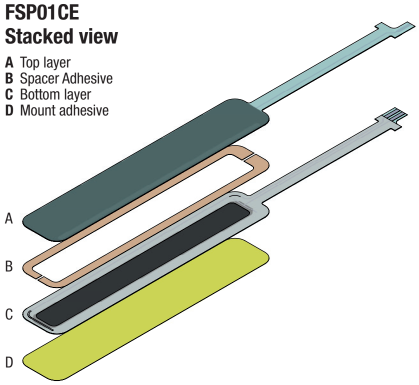

Figure 1. Linear Sensor Structure

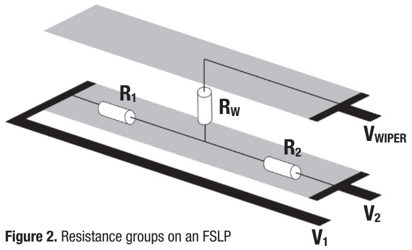

Figure 2. Resistance groups on an FSLP

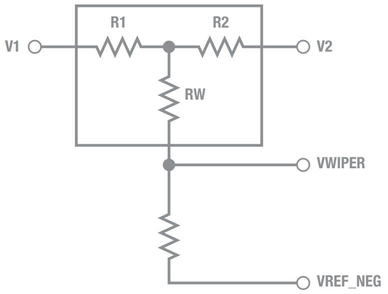

Figure 3. Force measurement setup schematic

2 FSP01CE/FSP02CE Introduction

Ohmite's FSP01CE & FSP02CE Force Sensing Potentiometers (FSPs) are high-feature-set, cost-effective touch sensors enabling intuitive control and navigation. FSPs are "single touch" devices that simultaneously report both touch position and variable force. They are easy to integrate, high resolution, low-power, and ideal for a wide range of HMI/MMI applications & markets. Interfacing is simple via a host processor without the need for a dedicated MCU. FSPs are dynamically reconfigurable in firmware enabling multiple functions from a single sensor.

3 FSP01CE/FSP02CE Construction

Force-Sensing Resistor (FSR) construction can generally be categorized into two types, Shunt Mode or Thru Mode*. These alternate types exhibit different Force vs. Resistance characteristics. Ohmite's FSP01CE and FSP02CE are based on Thru mode sensor construction which has solid top and bottom electrodes both over-printed with an FSR layer. Current passes through the FSR ink from one layer to the other requiring electrical connections on both top and bottom layers. (See Figure 1.)

4 FSP01CE/FSP02CE Connection and Sampling

Figure 2 shows the general resistance groups in a Force Sensing Potentiometer (FSP). R_1 + R_2 is the total resistance of the resistive layer on the Sensor while R_W is the Force resistance between the conductive and resistive layer when force is applied on the Sensor. The actual values of R_1 and R_2 depend on the location along the length of the Sensor where the force is applied.

Figure 3 shows the general schematic for how the FSP can be setup for measuring the force being applied to it.

For best results, a microcontroller with an analog to digital converter (ADC) module should be used to measure the position and relative force of touch along the length of the sensor.

The pins shown in Figure 3 need to be connected to the microcontroller as follows:

- **V_1 – Digital pin**
- **V_2 – ADC pin**
- **V_{WIPER} – ADC pin**
- **V_{REF_NEG} – Digital pin**

4.1 Position Measurement

The position of the touch location can be measured similarly to measuring the position of a standard potentiometer.

- Set all lines to 0 Volts to clear any existing charge from the sensor and reduce any noise on the readings
- Setup V_1 as an output pin on the microcontroller and make it output a digital HIGH signal.
- Setup V_2 as an output pin on the microcontroller and make it output a digital LOW signal.
- V_{REF_NEG} must be setup as an input pin on the microcontroller and set to LOW (this ensures that no current flows through R_{REF}) and drains any further charge due to setting the other pins
- Setup V_{WIPER} as an input pin (which ensures that no current flows through R_W) and wait a few microseconds then take an ADC measurement, A_{POS}, from the pin. A_{POS} represents the voltage across R_2 which will be directly proportional to the position of the touch.

A second reading with V_1 set to LOW and V_2 set to HIGH can be taken to check the validity of the first reading. The second reading should be roughly equal to the bit count of the ADC - A_{POS}

For very light touches R_W may have a high resistance of 500 Kohms or more therefore depending on the input resistance of the ADC a high impedance buffer may improve positional measurement accuracy.

*Further details on FSR types can be found in Ohmite's FSR Integration Guide at **www.ohmite.com**

4 FSP01CE/FSP02CE Connection and Sampling (continued)

4.2 Force Measurement

The relative touch force will be proportional to R_W. However it is not possible to measure R_W independently of R_1 and/or R_2 and as R_1 and R_2 change depending on the location of touch the simplest approach of measuring V_{WIPER} relative to V_{REF_NEG} will yield a different result for the same relative force at different points along the sensor.

A number of different methods are explained below that can be used to measure the touch force, each of which has it's own advantages and disadvantages. These are further discussed in **Table 1** on the following page.

4.2.1 Method 1

- Setup V_1 as an output pin on the microcontroller and make it output a digital HIGH signal.
- Setup V_{REF_NEG} as an output pin on the microcontroller and make it output a digital LOW signal.
- Setup V_2 and V_{WIPER} as an input pins
- Take an ADC measurement, A_+, from pin V_2
- Take an ADC measurement, A_-, from pin V_{WIPER}
- Calculate the relative force using the following formula

$$F = \frac{A_-}{(A_+ - A_-)}$$

4.2.2 Method 2

- Setup V_1 as an output pin on the microcontroller and make it output a digital HIGH signal.
- Setup V_{REF_NEG} as an output pin on the microcontroller and make it output a digital LOW signal.
- Setup V_2 as an output pin on the microcontroller and make it output a digital HIGH signal.
- Setup V_{WIPER} as an input pin
- Take an ADC measurement, A_{WIPER}, from pin V_{WIPER}
- Using the measured analog value of the position, A_{POS}, the values for R_1 and R_2 can be approximated and the value of R_W (the resistance which represents the inverse of the force) can be calculated

$$p = \frac{A_{POS}}{ADC_{MAX}} = \frac{A_{POS}}{1023}$$

$$R_1 = (1 - p)(R_1 + R_2)$$

$$R_2 = p(R_1 + R_2)$$

$$\frac{A_{WIPER}}{ADC_{MAX}} = \frac{R_{REF}}{\frac{R_1 R_2}{R_1 + R_2} + R_W + R_{REF}} = \frac{R_{REF}}{p(1 - p)(R_1 + R_2) + R_W + R_{REF}}$$

$$R_W = R_{REF}\left(\frac{ADC_{MAX}}{V_{WIPER}}\right) - p(1 - p)(R_1 + R_2) - R_{REF}$$

$$F \approx \frac{1}{R_W}$$

4.2.3 Method 3

This method first measures V_{WIPER} with V_1 at a HIGH voltage and V_2 as a high impedance pin. Then, the microcontroller switches V_2 to a HIGH output voltage and V_1 to a high impedance pin. V_{WIPER} will be measured again. The average of the two measurements will give an approximation for the force.

- Setup V_{REF_NEG} as an output pin on the microcontroller and make it output a digital LOW signal.
- Setup V_{WIPER} as an input pin
- Setup V_1 as an output pin on the microcontroller and make it output a digital HIGH signal.
- Setup V_2 as an input pin
- Take an ADC measurement, A_{WIPER_1}, from pin V_{WIPER}
- Setup V_2 as an output pin on the microcontroller and make it output a digital HIGH signal.
- Setup V_1 as an input pin
- Take an ADC measurement, A_{WIPER_2}, from pin VW_{IPER}
- Take an average of A_{WIPER_1} and A_{WIPER_2} to get an estimate for the force

$$F \approx \frac{1}{2}(A_{WIPER\_1} + A_{WIPER\_2})$$

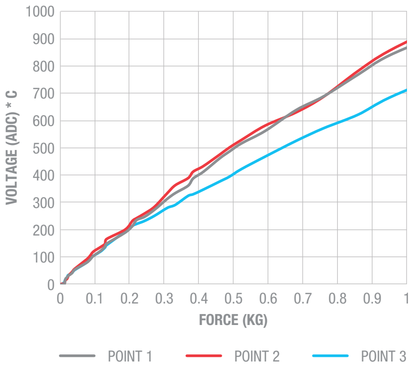

Figure 4. Method 1 test results

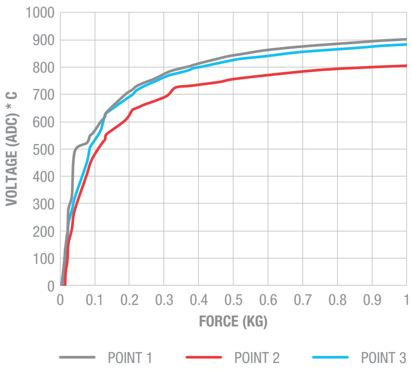

Figure 5. Method 2 test results

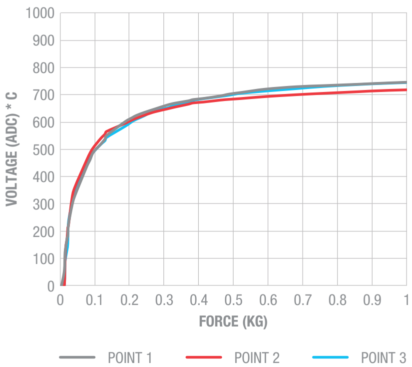

Figure 6. Method 3 test results

Integration Guide

Force Sensing Potentiometer

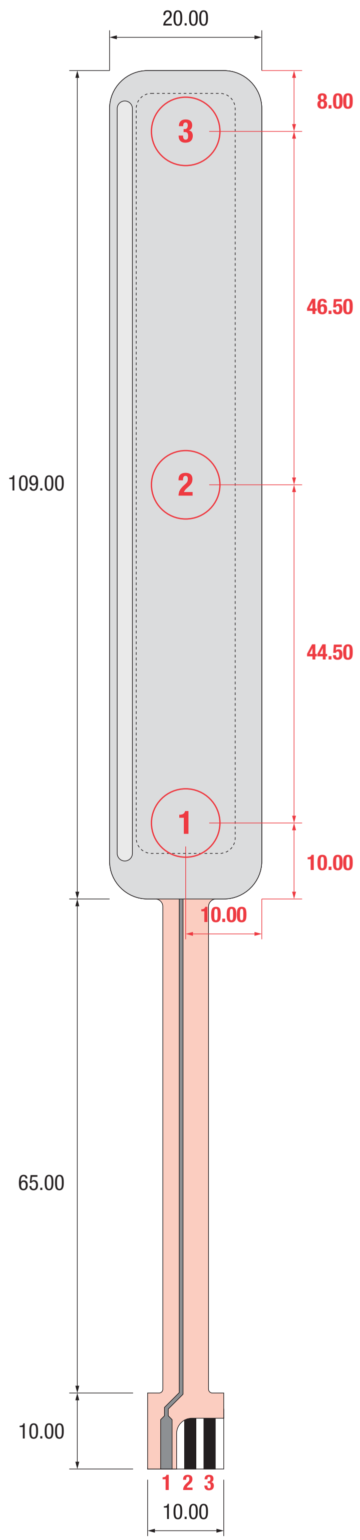

Figure 7. Test results for the 3 methods with force measurements taken at various locations along the FSP (units:mm)

4 FSP01CE/FSP02CE Connection and Sampling (continued)

4.2 Force Measurement (continued)

The test results from these three methods are shown in **Figures 4, 5 and 6** and the test positions are shown in **Figure 7.** The advantages and disadvantages for the three methods are discussed in **Table 1** along with the complexity of the sampling firmware and hardware required. The best method for the project requirements should be chosen considering a balance of required force accuracy, electronic complexity and cost.

Method	Advantages	Disadvantages	Complexity
1	• Less dependent on the position of the applied force on the FSLP than method 2 at low forces • Linear relationship between applied force and ADC output • Linearity continues beyond 1kg finger force	• Applying force near one end of the pot where the voltage is high, results in a different ADC output comparing to other places on the POT • The measured data is noisier at higher forces (can be resolved by using an ADC with higher resolution) • The need to take two analog readings can introduce inaccuracies	2 ADC pins are required. The System needs some form of averaging in order to increase the resolution and read more accurate data. Also, the nature of the method demands working with arithmetic and floating points. Hence, a fast microcontroller (preferably more than 8Mhz) and relatively complex hardware is needed.
2	• Only one analog reading is needed, which make the circuit simpler and more accurate • More stable and reliable data	• Force output is dependent on the position of applied force on FSLP • Force output has an exponential characteristic and can saturate beyond 1Kg finger force	Only single ADC pin is needed which makes both the firmware and the hardware easy to implement.
3	• Produces more stable and reliable data • This method is least dependent on the position of applied force	• At higher forces greater than 500g ADC output becomes dependent on the position of applied force on FSLP • Data has an exponential characteristic and starts to saturate beyond 1kg finger force	Two GPIO pins and one ADC pin are required. Furthermore, the system needs to constantly toggle the GPIO pins and use arithmetic which demands fast microcontroller (preferably 8Mhz and up) and relatively complex hardware.

Table 1. Advantages and disadvantages of the three methods for measuring the force of an FSP

5 FSP01CE/FSP02CE Recommendations

For the majority of force sensing potentiometer implementations Method 1 is most likely the best compromise. It is a simple approach electronically and outputs a very liner response to force. Even though it suffers from reduced resolution at higher forces this is generally not a critical requirement for most applications. Furthermore it's position dependency is only relevant for finger forces greater than 200-300g which is sufficient for most applications.

Where increased resolution at higher forces is a requirement in the application Methods 2 or 3 can be employed, and if high finger force consistency is relevant then Method 3 should be chosen.

Integration Guide

Force Sensing Potentiometer

FSP03CE
Stacked view

A Top layer
B Spacer Adhesive
C Bottom layer
D Mount adhesive

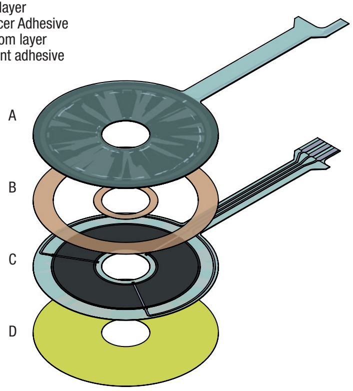

Figure 8. Ring Sensor Structure

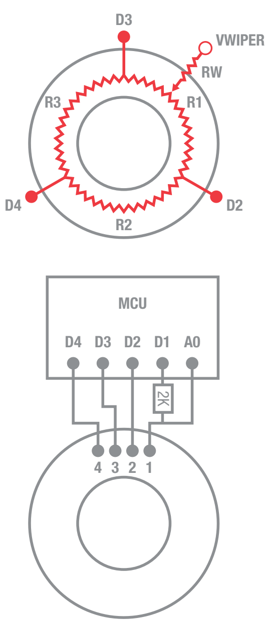

Figure 9. Circuit Diagram for the Ring Sensor and MCU Connection

6 FSP03CE Introduction

Ohmite's FSP03CE Ring sensor is a force sensing potentiometer which allows highly accurate angular touch position measurement as well as relative touch force detection. This is achieved with a continuous ring resistor with 3 electrodes placed at 120° around the circle. A wiper layer with FSR ink makes contact with this ring resistor at the point of touch and the allows for various voltage measurements to be taken to determine the touch position and relative force in a similar method as an FSP.

The FSP03CE ring sensor can be used for advanced HMI and MMI applications where circular motion and gestures are required to be used, for example menu navigation, rotation control, or radial position detection.

7 FSP03CE Construction

The FSP03CE Ring Sensor is similar in construction to the FSP01CE and FSP02CE Sensors. It is constructed of 4 primary layers (see Figure 8):

- **A top PET layer with graphic, conductive, dielectric, and an FSR ink print,**
- **A spacer adhesive layer,**
- **A bottom PET layer also with conductive, dielectric and an FSR ink print**
- **A mounting adhesive on the rear.**

The main active area of the Ring Sensor is a ring of printed carbon ink divided in three arcs by three electrodes placed on the ring 120° from each other.

Pin name	Pin number	Description
Drive 1	3	First drive electrode on the ring
Drive 1	2	Second drive electrode on the ring
Drive 3	4	Third drive electrode on the ring
Wiper	1	Wiper PIN

Table 2. Pin Out

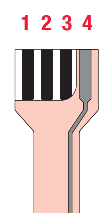

Figure 10. Ring Sensor Pin Numbers

Any microcontroller which provides the required GPIO pins and an ADC can be used to interface to the sensor.

Figure 9 shows the circuit diagram the ring sensor and connection to the MCU. In this diagram, digital pins 2, 3 and 4 of the MCU are connected to pins 2, 3 and 4 of the sensor respectively. Pin 1, is connected to an analog pin of the MCU and is also connected to digital pin 1 via a 2KΩ resistor. This pin acts as a virtual ground for measuring the force, and will be floating when calculating the position. Please note that pin 3 of the sensor, is in fact the first electrode (0° reference).

OHMITE®

8 FSP03CE General Theory of Operation

There are 3 basic stages to the scanning procedure for the Ohmite Ring Sensor:

- **Stage 1: Detect which two pins are closest to the touch position**
- **Stage 2: Use these 2 pins to measure the relative position of touch between the pins**
- **Stage 3: Measure the relative force of the touch by using similar techniques as described above for the FSP force measurements**

8.1 Identifying the pins closest to the touch position

- Drive pin 3 to low voltage, while pins 2 and 4 are high.
- Measure the ADC value of the wiper and save it as a variable, V1 for example.
- Repeat the same process for pins 3 and 4 as well.
- Once you have all the 3 ADC values, comparing them can detect the closest 2 pins. The lowest value would be for the closest and the second lowest value would be related to the second closest pin. The highest value indicates the furthest pin from the point of touch.

8.2 Position Measurement

To calculate the angle, the pin furthest from the point of the touch which was determined in the previous section, will be left floating. Thus, if the furthest pin is pin 4 (as shown in **Figure 9** on the previous page), then:

- Configure pin4 as an input pin, so that it floats.
- Drive pin 2 to high voltage and pin 3 to low voltage. This way, **the potential is increasing clockwise in the 120° interval**, where the touch is happening.
- Save ADC value of wiper pin as rawAngle.
- Map the rawAngle to angle using this equation:

$$angle = \frac{(rawAngle - minADC) \times (maxAngle - minAngle)}{(maxADC - minADC)} + minAngle1$$

Where:

- maxAngle and minAngle are the angles of the 2 closest pins i.e. in **Figure 9** D3 is at 0° and D2 is at 120° therefore maxAngle = 120 and minAngle = 0.
- minADC and maxADC are the minimum and maximum achievable ADC values. For example for an 8-bit controller these can be assumed to 0 and 256, but for a more accurate touch position these should be measured for a particular electronic configuration.

8.3 Force Measurement

To measure the force all the bottom pins D2, D3 and D4 should be driven high and D1 should be driven low. This creates a voltage divider circuit with the 2K reference resistor and the ADC value measured will be relative to the force applied to the sensor. The different force sensing methods described above for use with an FSP sensor can then be used depending on the required accuracy and constraints of the electronics as discussed.

9 Contact

Headquarters	27501 Bella Vista Parkway, Warrenville IL, 60555 - USA
Toll-Free	1-866-9-OHMITE
International	1-847-258-0300
Fax	1-847-574-7522
Web	www.ohmite.com
Email	info@ohmite.com