Bend Sensor® Technology
Electronic Interface
Design Guide

Contents

Introduction

This Design Guide is designed to help electrical designers build interfaces that result in the successful integration of Bend Sensor® components into products. Flexpoint Inc. has successfully developed and marketed products incorporating Bend Sensor® products. Most successful Bend Sensor® interfaces start with the same building blocks. This Design Guide comprises a collection of circuits that effectively empower the designer to modify and build customized circuits that complement their product.

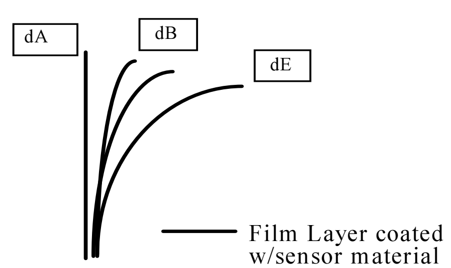
Bend Sensor® Potentiometer

In the late 1980's, a new product was being developed to be a thin (< 0.005" typ.) light weight potentiometer which, when integrated into a glove could provide analog feedback showing finger movement. After substantial development efforts a new product utilizing a bend sensitive ink was created. This new product known as the Bend Sensor® potentiometer was integrated for use in a consumer product known as the Nintendo Power Glove. Many companies have since recognized the simplicity and reliability of the sensor making it an ideal solution which very effectively addresses many issues and challenges associated with standard potentiometers.

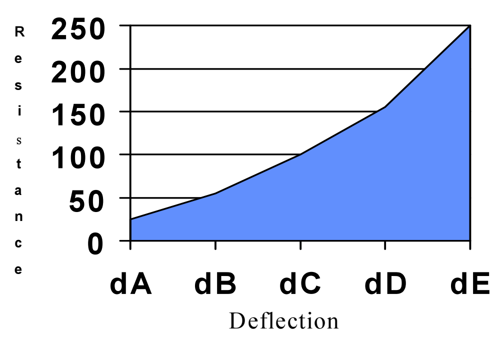
Description of the Bend Sensor® Potentiometer

The Bend Sensor® potentiometer is a product consisting of a coated substrate such as plastic that changes in electrical conductivity as it is bent. Electronic systems can connect to the sensor and measure with fine detail the amount of bending or movement that occurs. A movement of only one inch can yield over 200,000 data points.

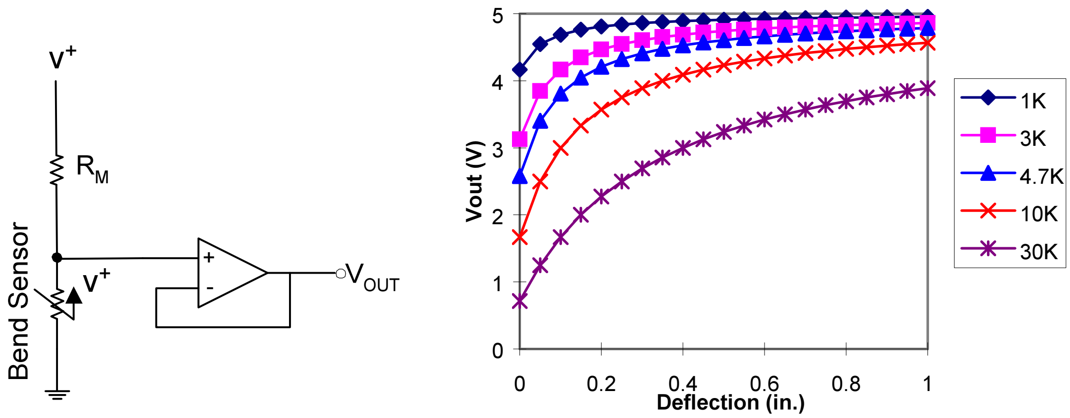
An example application is one where a sensor is attached to a door. As the door is opened one can measure how far the door has opened and how fast it is moving. The sensor is light weight, small, easily packaged and very reliable. The breadth of the applications for the Bend Sensor® is limited only by the customer's imagination.



Deflection of the sensor may be achieved through many options.



Resistance (k ohms) vs. Deflection of Sensor



Deflection vs. Voltage

Figure 1.0

Bend Sensor® Voltage Divider:

For a simple deflection-to-voltage conversion, the Bend Sensor® device is tied to a resistor R_M in a voltage divider configuration. The output is described by the equation:

$$V_{OUT} = (V+) / [1 + R_M / R_{Bend\ Sensor®}]$$

In the shown configuration, the output voltage increases with increasing deflection. If $R_{Bend\ Sensor®}$ and R_M are swapped, the output swing will decrease with increasing deflection. These two output forms are mirror images about the line $V_{OUT} = (V+) / 2$.

The measuring resistor, R_M, is chosen to maximize the desired deflection sensitivity range and to limit current. Suggested op-amps for single sided supply designs are LM358 and LM324. FET input devices such as LF355 and TL082 are also good. The low bias currents of these op-amps reduce the error due to the source impedance of the voltage divider.

A family of DEFLECTION vs. V_{OUT} curves is shown in Figure 1.0 for a standard Bend Sensor® device in a voltage divider configuration with various R_M resistors. A (V+) of +5V was used for these examples.

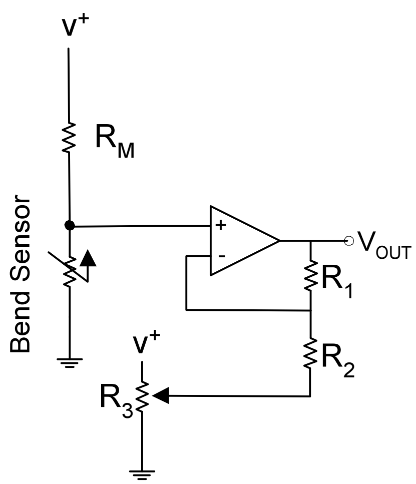


Figure 1.1

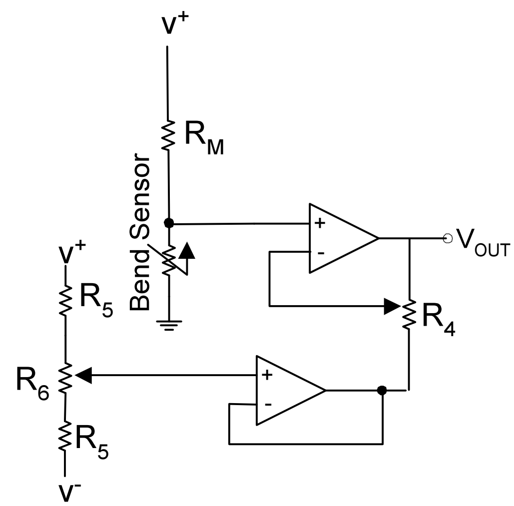


Figure 1.2

Adjustable Buffers:

Similar to the unity gain buffer, these interfaces isolate the output from the high source impedance of the Bend Sensor® device. These alternatives allow adjustment of the output offset and gain.

In Figure 1.1, the ratio of resistors R_2 and R_1 sets the gain of the output. Offsets resulting from the non-infinite Bend Sensor® resistance at zero deflection (or bias currents) can be trimmed out with the potentiometer, R_3. For best results, R_3 should be about one-twentieth of R_1 or R_2. Adding an additional pot at R_2 makes the gain easily adjustable. Broad range gain adjustment can be made by replacing R_2 and R_1 with a single pot.

The circuit in Figure 1.2 yields similar results to the previous one, but the offset trim is isolated from the adjustable gain. With this separation, there is no constraint on values for R_6. Typical values for R_5 and R_6 are around 10 kΩ.

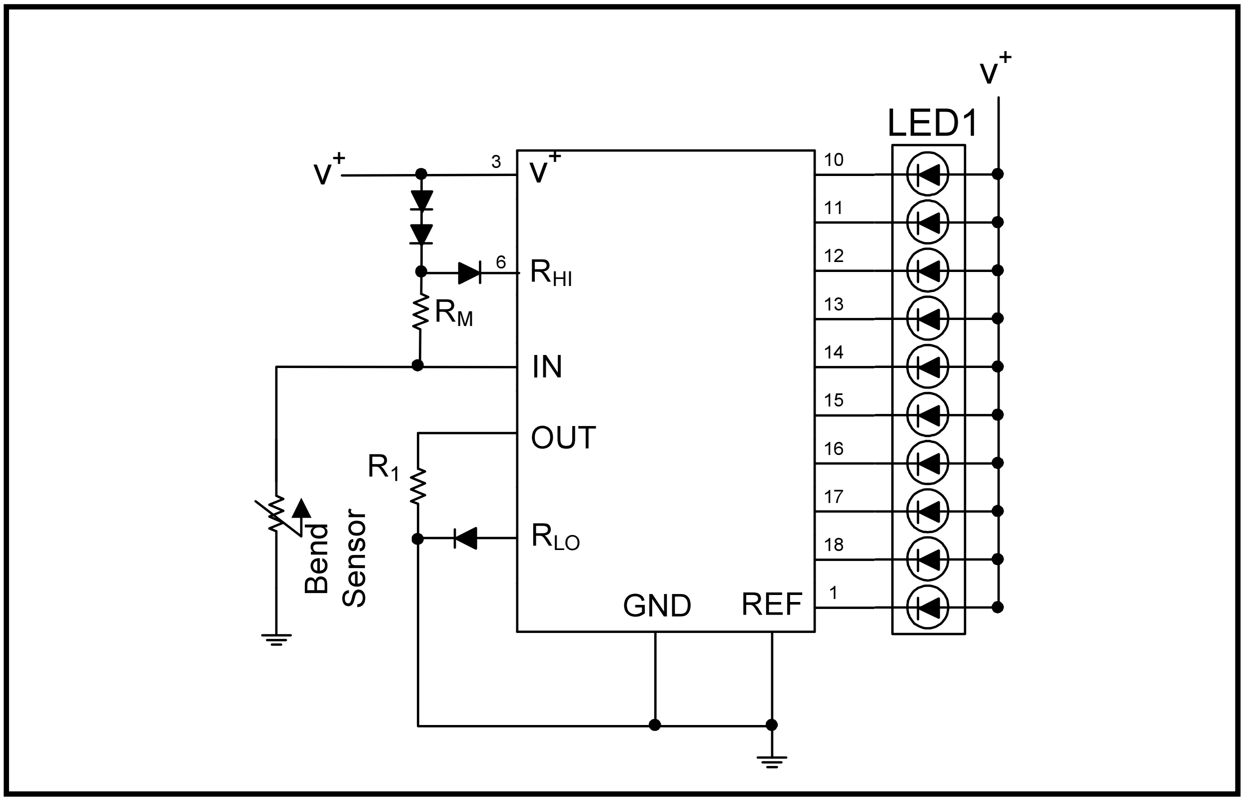


Figure 1.3 Flexpoint LED Display Demo for Bend Sensor® Device

Bend Sensor® LED Display Demo:

This simple Bend Sensor® LED display demo uses a display driver to translate an analog input into ten separate voltage levels. As each level is attained, current is drawn through an LED, lighting it. Consecutive LEDs in a bank are lit as the input voltage goes from high to low. The LM3915 is a logarithmic display driver. Since the voltage divider response curve, and therefore the input, is roughly logarithmic, a logarithmic driver better follows the response.

The input consists of the Bend Sensor® device in a simple voltage divider with R_M. The resistor R_M is chosen to maximize the use of the Bend Sensor® device dynamics. Replacing R_M with a resistor in series with a pot will allow the user to adjust the sensitivity range of the Bend Sensor® device. As the pot is adjusted to a low value, the high deflection dynamics of the Bend Sensor® device will be displayed. When the pot is adjusted to a high value, the low deflection dynamics will be displayed.

The display driver has an internal unity gain buffer at the input that isolates the Bend Sensor® device and minimizes bias current errors. In the configuration shown, a 9 volt battery is used as the voltage source. The top of the driver's ladder is about 7.2 volts (3 diode drops below V+), while the bottom is at about 0.6 V (1 diode drop above ground). The input ranges from 7.8 volts (2 diode drops below V+) to ground. At the output, R1 is used to control the amount of current drawn through the LEDs, and therefore controls LED brightness. Pin 9 of the driver can be tied to the voltage source if bar output instead of dot output is desired.

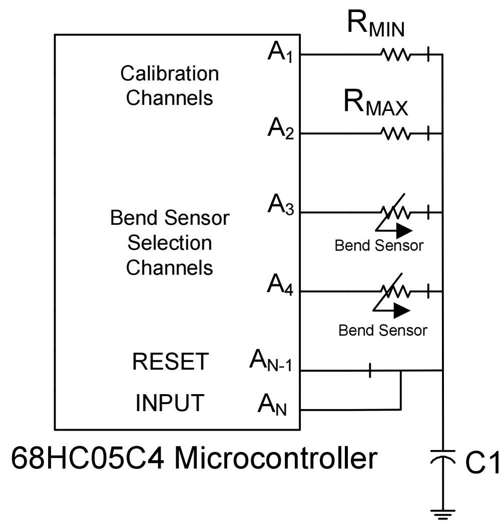


Figure 1.4

Multi-Channel Bend Sensor®-to-Digital Interface:

Sampling Cycle (any Bend Sensor® channel):

The microcontroller switches to a specific Bend Sensor® channel, toggling it high, while all other Bend Sensor® channels are toggled low. The RESET channel is toggled high, a counter starts and the capacitor C1 charges, with its charging rate controlled by the resistance of the Bend Sensor® (t~RC). When the capacitor reaches the high digital threshold of the INPUT channel, the counter shuts off, the RESET toggles low, and the capacitor discharges.

The number of "counts" it takes from the toggling of the RESET high to the toggling of the INPUT high is proportional to the resistance of the Bend Sensor® device. The resistors R_{MIN} and R_{MAX} are used to set a minimum and maximum "counts" and therefore the range of the "counts". They are also used periodically to re-calibrate the reference. A sampling cycle for R_{MIN} is run, the number of "counts" is stored and used as a new zero. Similarly, a sampling cycle for R_{MAX} is run and the value is stored as the maximum of the range (after subtracting the R_{MIN} value). Successive Bend Sensor® samplings are normalized to the new zero. The full range is "zoned" by dividing the normalized maximum "counts" by the number of desired zones. This will delineate the window size or width of each zone.

Continual sampling is done to record changes in Bend Sensor® resistance due to changes in deflection. Each Bend Sensor® device is selected sequentially.

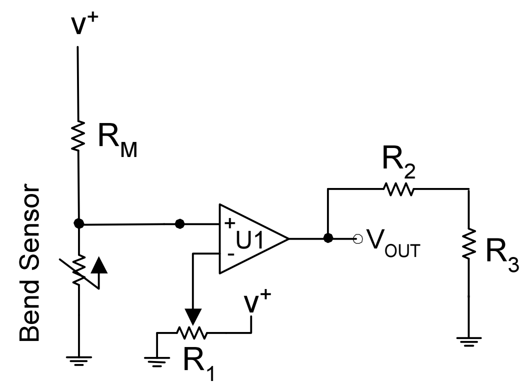


Figure 1.5

Bend Sensor® Variable Deflection Threshold Switch:

This simple circuit is ideal for applications that require on-off switching at a specified deflection, such as touch sensitive membrane, cut-off, and limit switches. For a variation of this circuit that is designed to control relay switching, see Figure 1.6 on the next page.

The Bend Sensor® device is arranged in a voltage divider with R_M. An op-amp, U1, is used as a comparator. The output of U1 is either high or low. The non-inverting input of the op-amp is driven by the output of the divider, which is a voltage that increases with deflection. At zero deflection, the output of the op-amp will be low. When the voltage at the non-inverting input of the op-amp exceeds the voltage of the inverting input, the output of the op-amp will toggle high. The triggering voltage, and therefore the deflection threshold, is set at the inverting input by the pot R_1. The hysteresis resistor, R_2, acts as a “debouncer”, eliminating any multiple triggering of the output that might occur.

Suggested op-amps are LM358 and LM324. Comparators like LM393 and LM339 also work quite well. The parallel combination of R_2 with R_3 is chosen to maximize the desired deflection sensitivity range. A typical value for this combination is about 47 kΩ.

The threshold adjustment pot, R_1, can be replaced by two fixed value resistors in a voltage divider configuration.

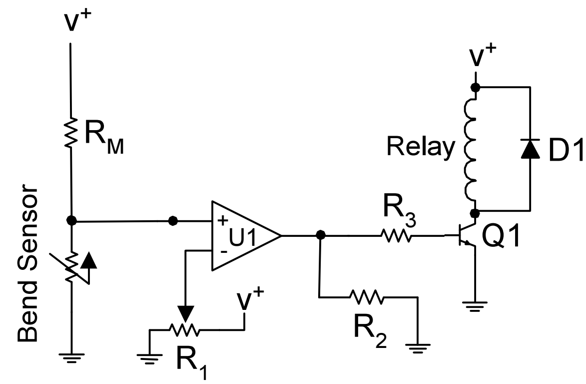


Figure 1.6

Bend Sensor® Variable Deflection Threshold Relay Switch:

This circuit is a derivative of the simple Bend Sensor® Variable Deflection Threshold Switch of Figure 1.5 on the previous page. It has use where the element to be switched requires higher current, like automotive and industrial control relays.

The Bend Sensor® device is arranged in a voltage divider with R_M. An op-amp, U1, is used as a comparator. The output of U1 is either high or low. The non-inverting input of the op-amp sees the output of the divider, which is a voltage that increases with deflection. At zero deflection, the output of the op-amp will be low. When the voltage at the non-inverting input of the op-amp exceeds the voltage of the inverting input, the output of the op-amp will toggle high. The triggering voltage, and therefore the deflection threshold, is set at the inverting input by the pot R_1. The transistor Q1 is chosen to match the required current specification for the relay. Any medium power NPN transistor should suffice. The threshold adjustment pot, R_1, can be replaced by two fixed value resistors in a voltage divider configuration. The diode D1 is included to prevent flyback, which could harm the relay and the circuitry.

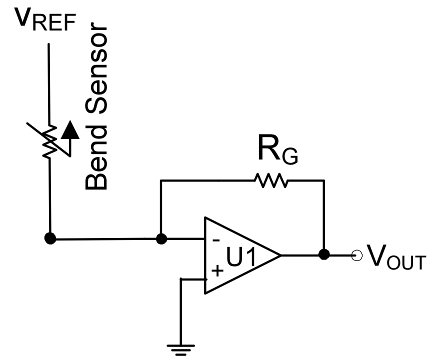


Figure 1.7

Bend Sensor® Resistance-to-Voltage Converter:

In this circuit, the Bend Sensor® potentiometer is the input of a resistance-to-voltage converter. The output of this amplifier is described by the equation:

$$V_{OUT} = V_{REF} * [-R_G / R_{Bend\ Sensor®}]$$

With a positive reference voltage, the output of the op-amp must be able to swing below ground, from 0V to $-V_{REF}$, therefore dual sided supplies are necessary. A negative reference voltage will yield a positive output swing, from 0V to $+V_{REF}$.

Since this is a simple inverse relation between V_{OUT} and $R_{Bend\ Sensor®}$, the output equation can be re-arranged to:

$$V_{OUT} = (-R_G * V_{REF}) / R_{Bend\ Sensor®}$$

V_{OUT} is inversely proportional to $R_{Bend\ Sensor®}$. Changing R_G and/or V_{REF} changes the response slope. The following is an example of the sequence used for choosing the component values and output swing:

For a human-to-machine variable control device, like a joystick, the maximum deflection applied to the Bend Sensor® is about 2”. The testing of a typical Bend Sensor® shows that the corresponding $R_{Bend\ Sensor®}$ at 2” is about 4.6 kΩ. If V_{REF} is -5V, and an output swing of 0V to +5V is desired, then R_G should be approximately equal to this minimum $R_{Bend\ Sensor®}$. R_G is set at 4.7 kΩ. A full swing of 0V to +5V is thus achieved. A set of DEFLECTION vs. V_{OUT} curves is shown on Figure 1.0 for a standard Bend Sensor® using this interface with a variety of R_G values.

The current through the Bend Sensor® should be limited to less than 1 mA/square cm of applied deflection. As with the voltage divider circuit, adding a resistor in parallel with $R_{Bend\ Sensor®}$ will give a definite rest voltage, which is essentially a zero-deflection intercept value. This can be useful when resolution at low deflections is desired.

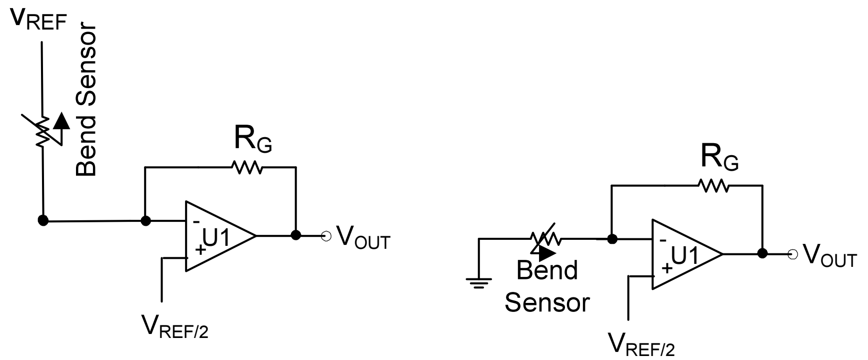


Figure 1.8 Figure 1.9

Additional Bend Sensor® Resistance-to-Voltage Converters:

These circuits are slightly modified versions of the resistance-to-voltage converter detailed on Figure 1.7. Please see Figure 1.7 on the previous page for more detail.

The output of Figure 1.8 is described by the equation:

$$V_{OUT} = V_{REF}/2 * [1 - R_G/R_{Bend\ Sensor®}]$$

The output swing of this circuit is from ($V_{REF}/2$) to 0V. In the case where R_G is greater than $R_{Bend\ Sensor®}$, the output will go into negative saturation.

The output of Figure 1.9 is described by the equation:

$$V_{OUT} = V_{REF}/2 * [1 + R_G/R_{Bend\ Sensor®}]$$

The output swing of this circuit is from ($V_{REF}/2$) to V_{REF}. In the case where R_G is greater than $R_{Bend\ Sensor®}$, the output will go into positive saturation.

For either of these configurations, a zener diode placed in parallel with R_G will limit the voltage built up across R_G. These designs yield one-half the output swing of the previous circuit, but only require single sided supplies and positive reference voltages.

Suggested op-amps are LM358 and LM324.

Bend Sensor® Linear Circuit:

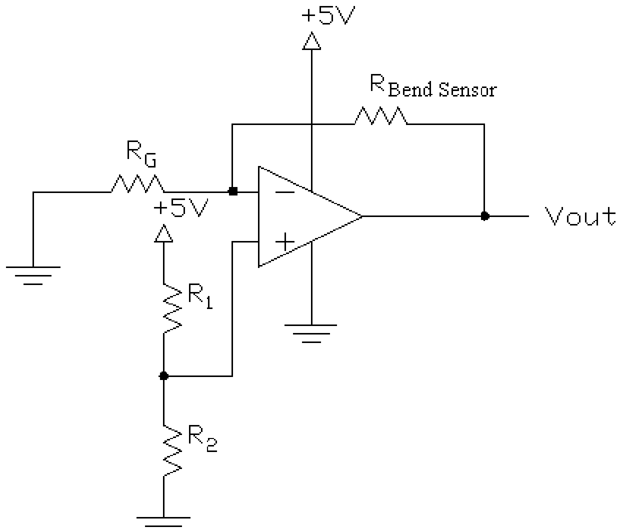


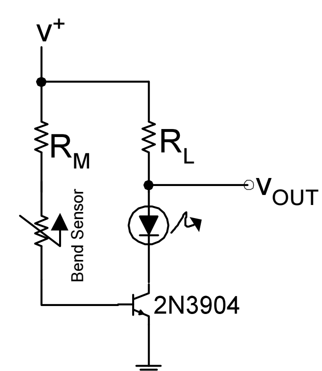
Figure 1.10

The output of Figure 1.10 is described by the equation:

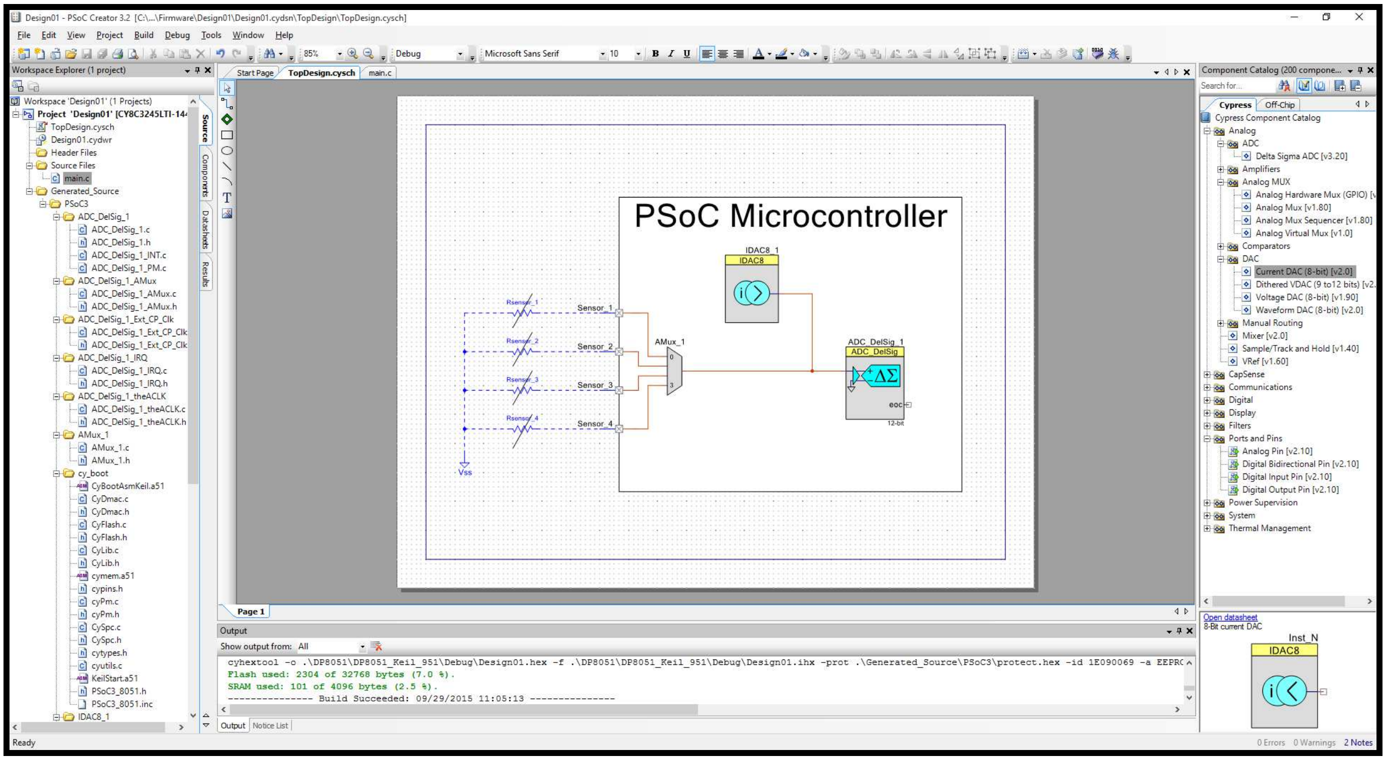
$$V_{OUT} = V_{REF}/2 * [1 + R_{Bend\ Sensor®}/ R_G]$$

Bend Sensor® Device LED Brightness:

For applications where some visual feedback is desired, this circuit is useful. Starting with the basics of the voltage divider, this circuit adds an LED that brightens with increasing deflection. The resistor RL limits the current through the LED. The transistor controls the current through the LED. Since the circuit depends on the hfe of the transistor, sensitivity may need to be tuned to accommodate the hfe spread of common transistors.



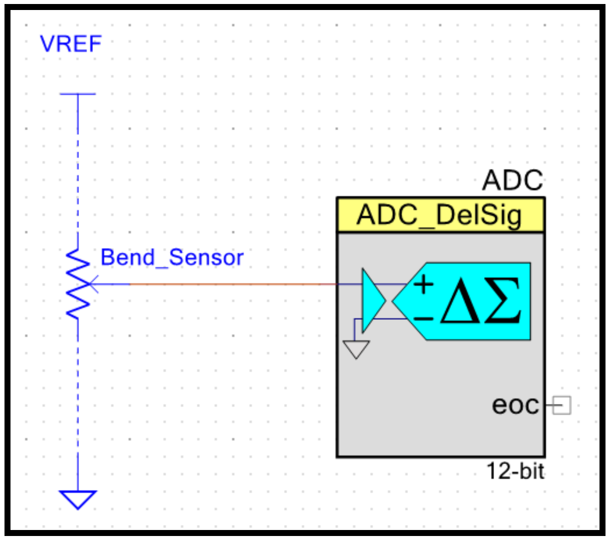
Bend Sensor® Measurement using a Cypress PSoC Microcontroller:



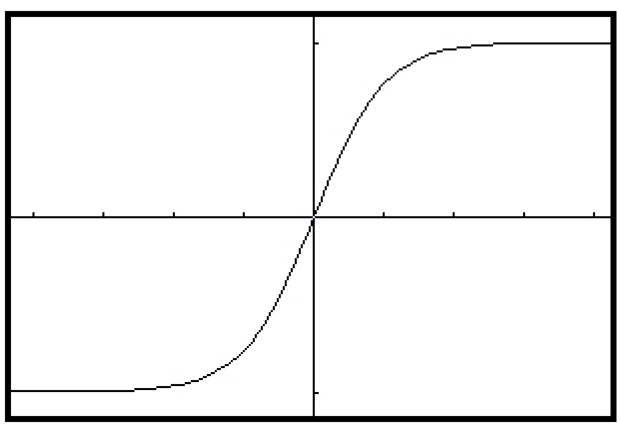
Cypress Semiconductor has a unique microcontroller that has a current DAC. When used in the circuit above the current source sinks current through the Bend Sensor® and generates a voltage across it which can be measured by the ADC. The current DAC also acts like a variable gain amplifier in the circuit which can be adjusted to make sure that the voltage across the Bend Sensor® is always within the range of the ADC. The Mux allows each Bend Sensor® to be measured separately. The PSoC can eliminate the need for any external components to measure the Bend Sensor®.

Bi-directional Bend Sensors®:

Flexpoint also makes Bi-directional Bend Sensors®. When bent in one direction one sensor increases in resistance while the other decreases in resistance. This allows for deflection to be measured in either direction. Bi-directional Bend Sensors® share one common pin. Therefore they can be measured individually using many of the above methods as long as the common pin can be tied to VREF or ground. The Bi-directional Bend Sensor® can also be used in a voltage divider circuit using each side as the top and bottom resistor. This looks similar to a potentiometer schematic:



In this configuration the voltage that the ADC will measure will increase or decrease depending on the direction the Bend Sensor® is bent. Because each individual Bend Sensor® cannot go to zero ohms of resistance the response curve looks similar to a hyperbolic tangent function:



There is however a linear region near the center of the curve (VREF / 2).

Summary:

There are many methods that can accomplish the successful implementation of the Bend Sensor® product into an application. Further it is important to consider the mechanical application of the sensors. For information regarding the placement of the sensor into your system refer to the **Bend Sensor® Technology Mechanical Application Design Guide**.

Please contact Flexpoint Sensor Systems @ 801-568-5111 if you have any questions or if e-mail is preferred, contact us at info@flexpoint.com.