

Topic 16:  
Design, implementation and programming of the  
**Piezoelectric-Effect Sensor Interface**  
for the Slow Control System MPD-NICA,  
on the NImyRIO and LabView platforms.<sup>1</sup>

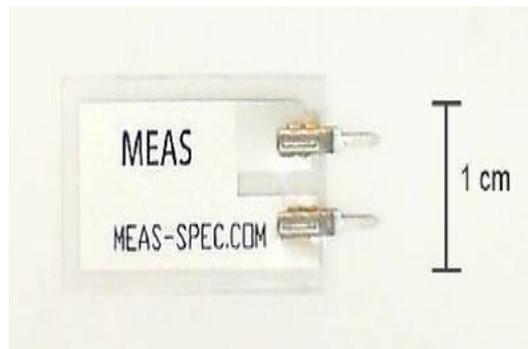
Marek Jerzy PERYT

*Faculty of Physics, Warsaw University of Technology  
Koszykowa 75, 00-662 Warszawa, Poland  
Joint Institute for Nuclear Research  
Dubna, J. Curie 6*

(Accepted June, 2018)

## 16 Piezoelectric-Effect Sensor

A Piezo Electric Sensor sandwiches a piezoelectric material between two plate electrodes. Deforming the sensor causes a charge displacement that appears as a measurable voltage between the plates, much like a parallel-plate capacitor. Combining the piezoelectric sensor with a charge-to-voltage converter provides a useful sensor to detect shock and vibration. Figure 16.1 pictures the NImyRIO StarterKit piezo sensor.



*Figure 16-1; NImyRIO StarterKit Piezo Sensor.*

### 16.1 Learning Objectives:

After completing the activities in this chapter you will be able to:

- [a] Describe the piezoelectric effect,
- [b] Design a charge-to-voltage converter as an interface circuit to the Analog Input,
- [c] Set the gain of the charge-to-voltage converter for different applications including a deflection sensor and a highly-sensitive vibration/shock sensor.

### 16.2 Component Demonstration

Follow these steps to demonstrate correct operation of the piezo sensor.

---

<sup>1</sup> Developed on the basis of educational materials: National Instruments, IBM, Reichle & De-Massari, Microsoft, Warsaw University of Technology, Joint Nuclear Institute Research

### 16.2.1 Select these parts from the NImyRIO StarterKit:

- [a] Piezo film sensor, DT-series,

[http://meas-spec.com/product/t\\_product.aspx?id=2478](http://meas-spec.com/product/t_product.aspx?id=2478)

- [b] AD 8541 rail-to-rail single-supply op amp,

<http://www.analog.com/AD8541>

- [c] 100 pF ceramic disk capacitor, marking “101”,

<http://www.vishay.com/docs/45171/kseries.pdf>

- [d] 0,001  $\mu$ F ceramic disk capacitor, marking “102”

<http://www.vishay.com/docs/45171/kseries.pdf>

- [e] Resistor, 10 M $\Omega$

- [f] Resistor, 10 k $\Omega$  (2 x)

- [g] Breadboard

- [h] Jumper wires, M-F (3 x)

### 16.2.2 Build the interface circuit:

Refer to the schematic diagram and recommended breadboard layout shown in Figure 16.2 on the following page.

The piezo sensor interface circuit requires three connections to NI myRIO MXP Connector B (see Figure A.1):

- [a] +5-volt supply  $\rightarrow$  B/+5 V (pin 1)

- [b] Ground  $\rightarrow$  B/GND (pin 6)

- [c] Sensor output  $\rightarrow$  B/AIO (pin 3)

### 16.2.3 Run the demonstration VI:

- [a] Download

<http://www.ni.com/academic/myrio/project-guide-vis.zip>

- [b] if you have not done so previously and unpack the contents to a convenient location,

- [c] Open the project Piezoelectric-Effect Sensor demo.lvproj contained in the subfolder Piezoelectric-Effect Sensor demo,

- [d] Expand the hierarchy button (a plus sign) for the myRIO item and then open Main.vi by double-clicking,

- [e] Confirm that NImyRIO is connected to your computer, and

- [f] Run the VI either by clicking the Run button on the toolbar or by pressing Ctrl+R.

Expect to see a “Deployment Process” window showing how the project compiles and deploys (downloads) to NImyRIO before the VI starts running.

---

NOTE: You may wish to select the “Close on successful completion” option to make the VI start automatically.

---

### 16.2.4 Expected results:

The demo VI displays the piezo sensor amplifier output much like an oscilloscope display. You should observe that the voltage is a constant close to 2.5 volts. Flex the piezo sensor and you should see a corresponding change in the voltage; observe the difference as you flex the sensor one way and then the other. Next, try flicking the sensor and jostling the breadboard. You should see a decaying sinusoid similar to an underdamped second-order system. Experiment to determine the sensitivity of the sensor, i.e., what is the lightest disturbance that still registers on the display?

Click the Stop button or press the escape key to stop the VI and to reset NlmyRIO.

### 16.2.5 Troubleshooting tips:

- [a] Not seeing the expected results? Confirm the following points:
- [b] Glowing power indicator LED on NlmyRIO,
- [c] Black Run button on the toolbar signifying that the VI is in runmode,
- [d] Correct op amp wiring – be certain that you understand the pinout of the AD8541,
- [e] Correct MXP connector terminals—ensure that you are using Connector B and that you have the correct pin connections.

### 16.3 Interface Theory

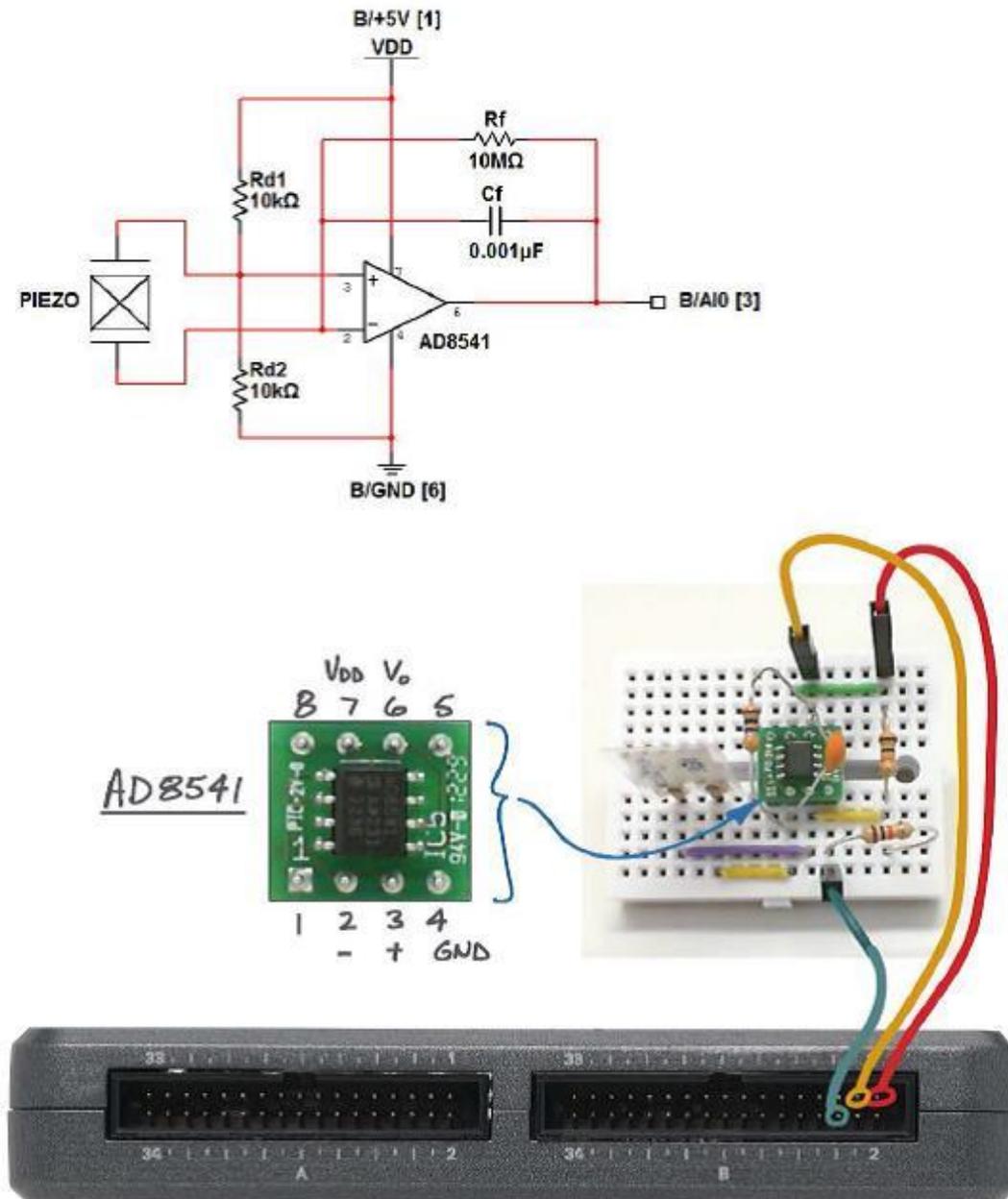


Figure 16-2; Demonstration circuit for piezo sensor: schematic diagram, recommended breadboard layout, and connection to NI MyRIO MXP Connector B.

### 16.3.1 Interface circuit:

The piezo sensor acts like a charge pump (current source) when flexed. The interface circuit is a charge-to-voltage converter based on an op amp.

Study the video *Piezo Sensor Interfacing Theory* (5:13)

<https://www.youtube.com/watch?v=dHaPUJ7n-UI&feature=youtu.be>

to learn about the piezoelectric effect, charge-to-voltage converters, and choice of feedback capacitor to control the sensitivity of the sensor.

### 16.4 Basic Modifications

[a] Study the video *Piezoelectric-Effect Sensor Demo Walk-Through* (2:54)

<https://www.youtube.com/watch?v=b1me4f-3iOE&feature=youtu.be>

- [b] To learn the design principles of Piezoelectric-Effect Sensor demo, and then try making these modifications to the block diagram of Main.vi:
- [c] Add the on board LED Express VI (myRIO | Onboard subpalette) as a “bump” indicator; use the Programming | Comparison | In Range and Coerce VI as the upper-limit and lower-limit range test for the analog input Read VI. Confirm that the LED flashes briefly when you bump the sensor. Try one or more of the following methods to increase the sensitivity of your bump sensor:
- [d] Increase the charge-to-voltage converter gain by 10<sub>x</sub> by changing the feedback capacitance to 100 pF.
- [e] Right-click on the wave form chart Y-axis, select auto scaling mode, and observe the minimum and maximum values of the sensor waveform when the sensor is at rest. Use this information to more precisely set the threshold values for the In Range and Coerce VI.
- [f] Add mass to the sensor tab (modelling clay works well). Try to make the bump indicator flash at the slightest disturbance such as tapping on the table.

### 16.5 Integrated Project Ideas

Now that you know how to use the piezo sensor consider integrating it with other devices to create a complete system, for example:

- [a] Wireless Sensor (Topic 40)
- [b] Data Logger (Topic 41)

### 16.6 For More Information

Fundamentals of Piezoelectric Shock and Vibration Sensors by Digi-Key Tech Zone ~ Detect excessive shock and vibration that could damage equipment:

<http://www.digikey.com/us/es/techzone/sensors/resources/articles/fundamentals-of-piezoelectric-sensors.html>

Bicycle Anti-Theft Alarm Circuit Diagram by Electronic Circuit Diagrams & Schematics ~ Alarm circuit based on the same piezo sensor in the NImyRIO StarterKit:

<http://circuitsstream.blogspot.com/2013/05/bicycle-anti-theft-alarm-circuit-diagram.html>

Signal Conditioning Piezoelectric Sensors by Texas Instruments ~ Piezo Electric Sensor principle of operation and circuit model, voltage-mode amplifier and charge-mode amplifier circuits:

<http://www.ti.com/lit/an/sloa033a/sloa033a.pdf>

---

**Bibliography:**

---

- [a] [www.jinr.ru](http://www.jinr.ru)
- [b] [www.ni.com](http://www.ni.com)
- [c] [www.nica.if.pw.edu.pl](http://www.nica.if.pw.edu.pl)
- [d] The Multi-Purpose Detector – MPD to Study Heavy Ion Collisions at NICA; (CDR Conceptual Design Report) Version 1.4; Project leaders: A. N. Sissakian, A. S. Sorin, V. D. Kekelidze.
- [e] [http://meas-spec.com/product/t\\_product.aspx?id=2478](http://meas-spec.com/product/t_product.aspx?id=2478)
- [f] <http://www.analog.com/AD8541>
- [g] <http://www.vishay.com/docs/45171/kseries.pdf>
- [h] <http://www.vishay.com/docs/45171/kseries.pdf>
- [i] <http://www.ni.com/academic/myrio/project-guide-vis.zip>
- [j] <https://www.youtube.com/watch?v=dHaPUJ7n-UI&feature=youtu.be>
- [k] <https://www.youtube.com/watch?v=b1me4f-3iOE&feature=youtu.be>
- [l] <http://www.digikey.com/us/es/techzone/sensors/resources/articles/fundamentals-of-piezoelectric-sensors.html>
- [m] <http://circuitsstream.blogspot.com/2013/05/bicycle-anti-theft-alarm-circuit-diagram.html>
- [n] <http://www.ti.com/lit/an/sloa033a/sloa033a.pdf>