TN-W0028
MicroStrain Technical Note

Measuring Torque with the SG-Link®

SG-Link®
(Applies to V-Link®, SG-Link®, SG-Link® OEM, HS-Link®)

Overview
MicroStrain's SG-Link® Wireless Strain Node has one differential input channel (strain channel) designed to support strain gauges of 350 ohm resistance or greater. This technical note presents a simplified step-by-step approach to applying strain gauges, connecting the strain gauges to the SG-Link®, configuring the SG-Link®, and calibrating the system to output torque. It is assumed that the user is familiar with MicroStrain's SG-Link® and Node Commander® software as well as strain gauge operation.

Applying the Strain Gauges and Connecting to the SG-Link®
- In our example, we are using an SG-Link® with a half bridge completion on channel 1.
- We are also using one Vishay® Part Number CEA-XX-187UV-350 350Ω strain gauge. We applied it to a 2 inch diameter aluminum tube with the SG-Link® mounted nearby as shown in *Figure 1*. SG-Link® shown has an internal fractal antenna. For high g force environments, MicroStrain makes a high g version of the SG-Link® OEM.

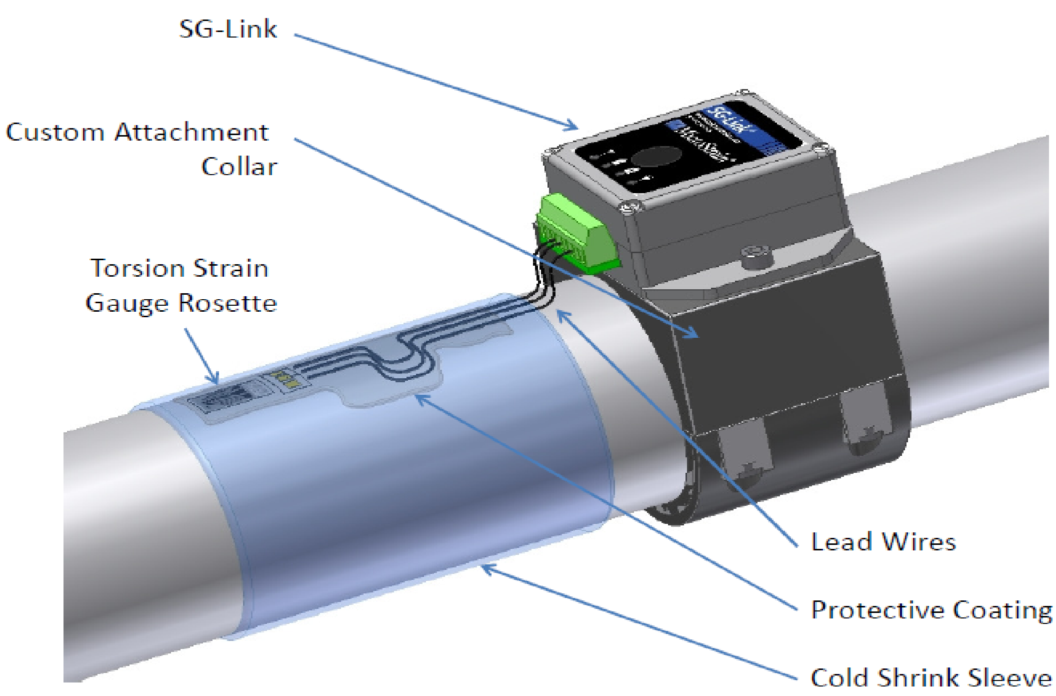


***Figure 1** – Typical installation set-up which provides good anchoring against centrifugal and tangential forces generated by rotating components. A well executed installation is important to alleviate mechanical/fatigue failure in lead-wire connections. Adhesives and protective coats should be carefully selected from Vishay Micro-Measurement offerings.*

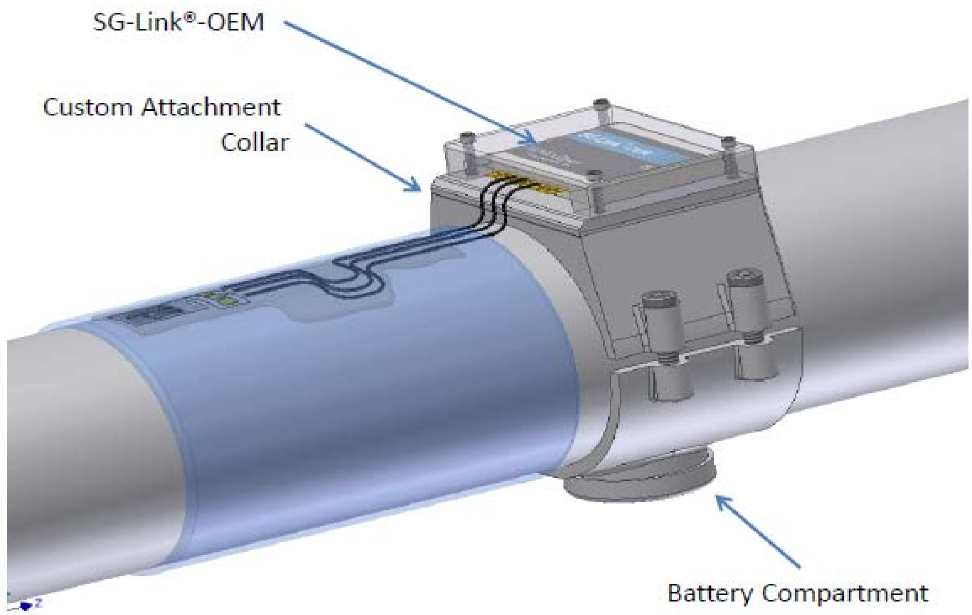


Figure 2 *- SG-Link® OEM with high G resistant components shown in custom enclosure and attachment collar. This product can be equipped with components capable of operating in 3000 G environment. The battery compartment shown here fits a coin cell (2032).*

- An alternative product for this application is the SG-Link®-OEM with high G-force option. It is fitted with special components which operate in environments up to 3000 G. This wireless node is much smaller than the standard SG-Link®. In the configuration shown in *Figure 2*, a coin cell battery #2032 is employed. This battery can supply 40 mAh of capacity (PowerStream Li-Ion # Lir2032). For a 2 inch pipe, a rotation speed of 50 revolutions per second would produce 3000 G at the pipe outer diameter. Sampling at 2048Hz, the user would gather 40 samples per rotation and the battery would last approximately 2 hours. Obviously, larger capacity batteries would produce longer duration data sets.
- Note that a strain gauge rosette is used which orients two gauges at ± 45° as shown in *Figure 2*.
- Four strain gauges can be arranged in a single full bridge. This doubles the sensitivity to torsion and also makes the system insensitive to bending and axial loading.
- In order to protect the strain gauges we are using a contact tab to connect wire leads between the strain gauges and the SG-Link®.

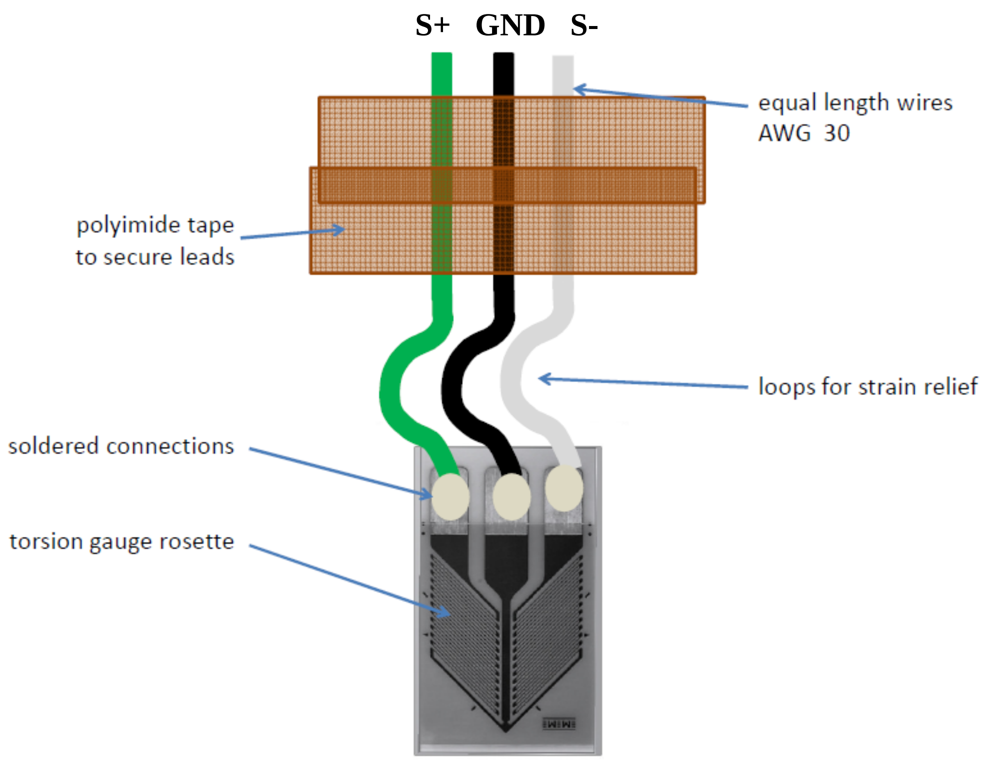


***Figure 3** – Half bridge wiring set-up.*

- **Important:** Make sure that you have ordered your SG-Link® with the internal bridge completed as 350 Ohm half bridge. If you are uncertain, please confirm this with your MicroStrain support engineer.
- Connect the strain gauge leads to the SG-Link® or SG-Link®-OEM as shown in *Table 1* and *Figure 3* and *Figure 4* respectively.

Wire	Pin
Black	GND
Green	S+
White	S-

***Table 1** – Correct wire and pin connections between the SG-Link® and the strain gauge.*

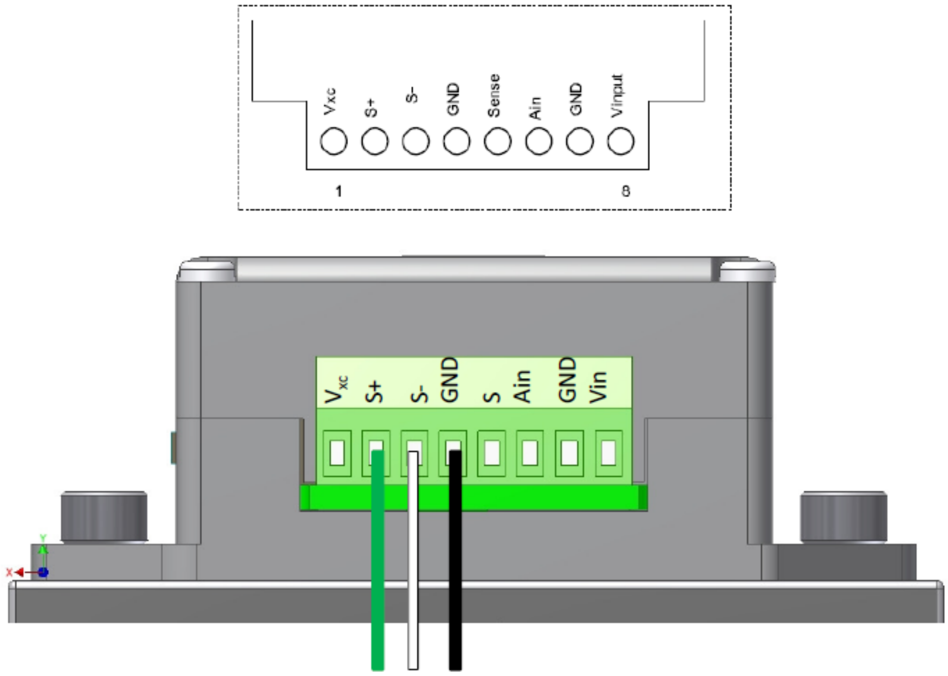


***Figure 3** – Image showing correct wire and pin connections between the SG-Link® and the strain gauges.*

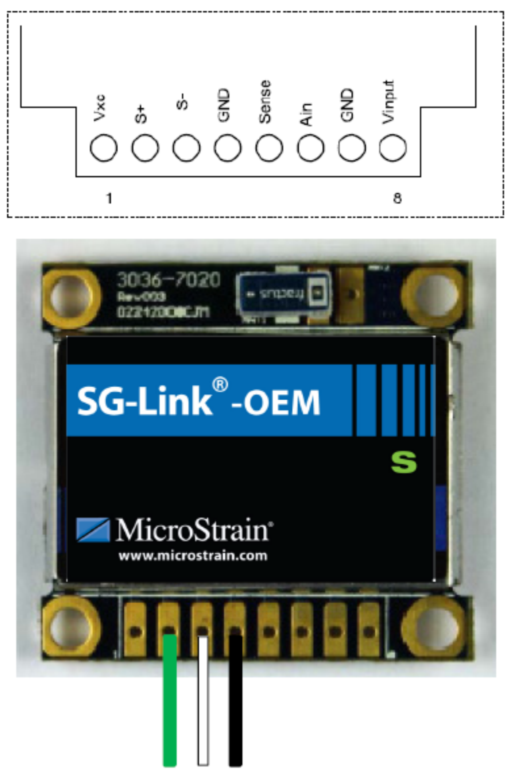


***Figure 4** - Wiring to terminal connections between SG-Link® -OEM and the strain gauges.*

Calibrating the system

- Power-up the SG-Link® and launch Node Commander® software.
- Establish communication with the SG-Link® as normal.
- Navigate to the Configuration screen and enable the channel to which you connected the strain gauge (channel 1 in this case).
- Continue to the Channel 1 Configuration screen.
- Set the appropriate Hardware Gain.
- Select the Midscale bullet under the Auto-Balance button.
- Click the Auto-Balance button.
- If everything is wired correctly the system will balance to ~2048 +/- 50 with an offset ~512 +/- 30.
- Select Strain under Class and µStrain (microstrain) under Units in the Conversion Coefficients frame as shown in *Figure 4*.

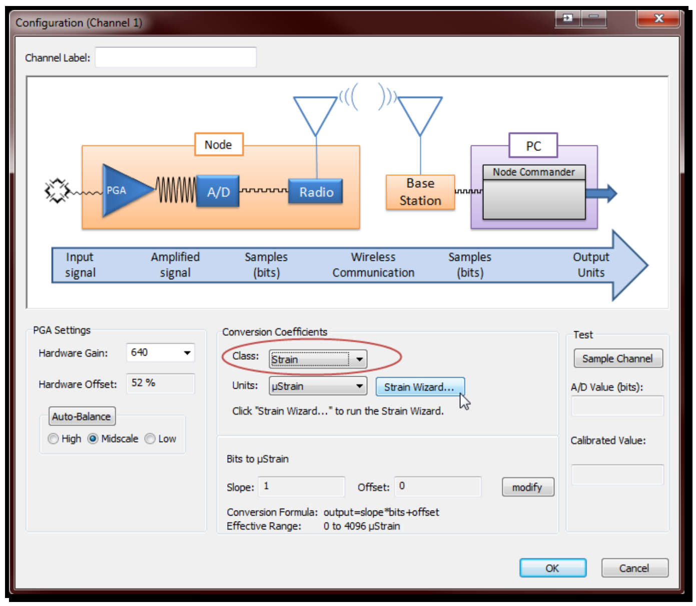


***Figure 4** – Channel 1 Configuration screen in Node Commander® software indicating location of conversion coefficients.*

- Click the Strain Wizard button.
- Work your way through the Strain Wizard using the values appropriate to your setup, complete and accept the calibration.
- Note the resulting ***slope*** on the Channel 1 Configuration screen as shown in *Figure 5*. This slope will be used to create a new value for this field which will be input to yield torque as an output from the SG-Link®.

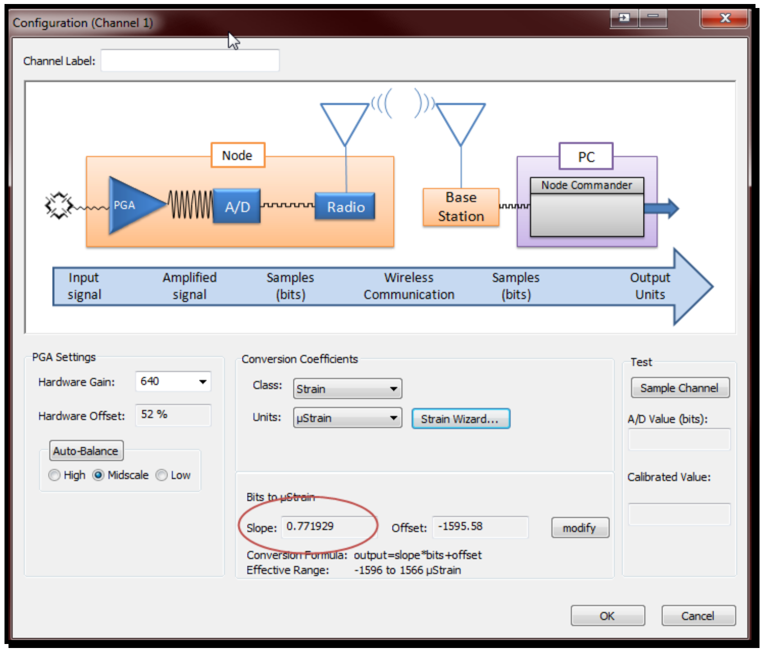


***Figure 5** – Channel 1 Configuration screen in Node Commander® software indicating location of slope.*

Derivation of a transfer function that will yield torque values from your SG-Link®

In order to convert your strain gauge readings into torque, a transfer function must be derived for the particular material you are measuring. This transfer function will relate torque directly to your measurement in bits from your SG-Link® and will replace the slope value just generated in Node Commander®.

For convenience, we will call this function, F. Mathematically, we desire $T = FX$, where T is torque (in inch-pounds in our example below) and X is the SG-Link® reading in bits and F is the transfer function.

First, perform a shunt calibration using the Strain Wizard provided in your Node Commander® Software. Record the output value in bits/microstrain. For convenience, we define the quantity with the letter, S_C.

S_C = Strain Wizard shunt calibration coefficient in microstrain/bit

Therefore, the following quantities should be known for the material and cylindrical shaft of the component you are measuring:

Young's Modulus, E (pounds per square inch, for example)
Poisson's ratio, ν
(Or, G, shear modulus, can be used directly in place of deriving it from E and ν)
D, outer diameter of shaft
d, inner diameter of a hollow shaft

Given that,

$\tau = G\gamma$ (Hooke's law) and that, $T = 2\tau J / D$ (torque on a cylindrical shaft)

where, $\tau \equiv$ shear stress, $\gamma \equiv$ shear strain, $G \equiv$ shear modulus, $J \equiv$ polar moment, and $D \equiv$ diameter of the shaft, we derive the following by substitution;

$$T = 2G\gamma J / D$$

This relates torque to strictly measurable quantities. Now,

$$G = E/(2(1+\nu))$$

$J = \pi(D^4 - d^4)/32$, where *D* is the outer diameter of the shaft and *d* is the inner diameter.

ϒ is related to your SG-Link® measurement by the following;

$$\gamma = XS_C$$

Where, *X* is the strain gauge measurement from the SG-Link® in bits and *C* is the shunt calibration value in microstrain/bit.

By substitution,

$$T = 2EXS_C J/((2(1+\nu))D) \text{ or, } T = EXS_C J/((1+\nu)D)$$

Since, $T = FX$, $F = T/X$ and, therefore, $F = ES_C J/((1+\nu)D)$

$$F = ES_C J/((1+\nu)D)$$

Solve for the transfer function now by inserting the values for the material of the test sample and the appropriate geometric values.

Now, the quantity F can be manually inserted into the Node Commander® Strain Wizard as the coefficient needed to convert bits to inch-pounds (or another unit of measure for torque). With this, your output will be automatically converted to torque.

- Calculate new slope value utilizing the transfer function, *F*:

  For our example the material properties are: Aluminum Alloy 6061: $E=10\text{x}10^6$ psi, $\nu=0.33$, $D=2.0$", $d=1.87$"

  By performing a shunt calibration using the Strain Wizard in the Node Commander® software, the slope (coefficient) was found to be 0.771929. This is the S_C value of the transfer function, F.

  $S_C=0.771929$ microstrain/bit

  Inserting the appropriate values (in English units here) into the transfer function yields:

  $F=(10\text{x}10^6 \text{ x } 0.771929\text{x}10^{-6} \text{ x } (\pi/32) \text{ x } (2^4-1.87^4))/(((1+0.33))\text{x}2)$ **= 1.07456 in-lb/bit**

- Returning to Node Commander ® software, navigate to the Channel 1 Configuration screen as before.
- Select Custom Units under Class and Other under Units in the Conversion Coefficients frame.

- Click the Modify button and enter the Torque slope 0.178462 into the Slope textbox and 0 (zero) into the Offset textbox as shown in *Figure 6*. Click Lock button to set.

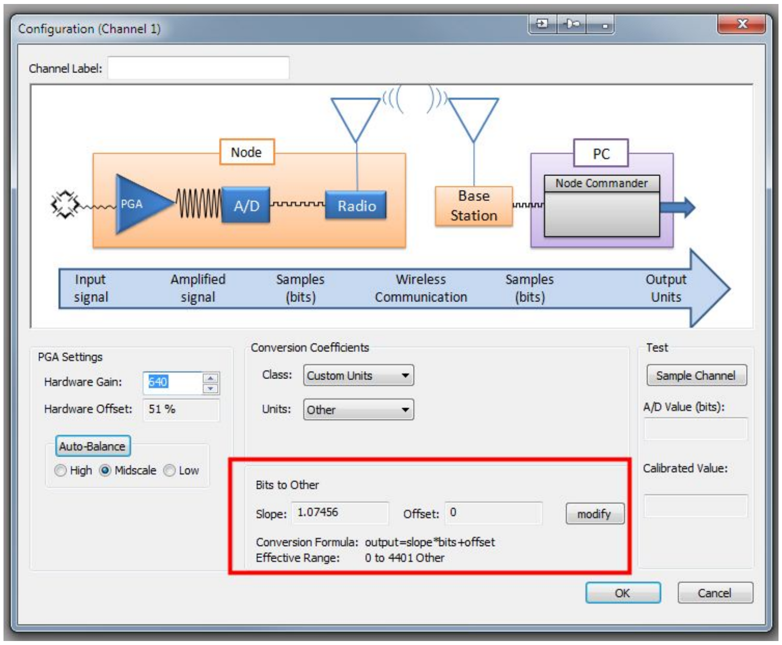
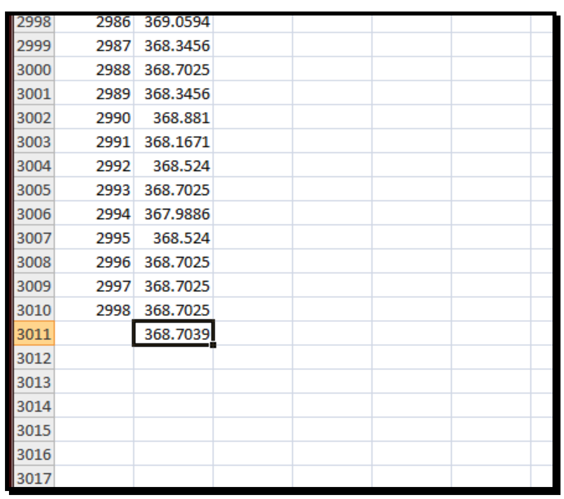


***Figure 6** – Channel 1 Configuration screen in Node Commander® software indicating location of slope and offest textboxes.*

- Click OK and return to the Configuration screen.
- Click the Streaming tab and set the Sweeps to 3000.
- Click Apply, click OK and exit the Configuration screen.
- With no load on the tube, Stream the node.
- When streaming has ended, right-click on the Stream graph and select Save Stream.
- Open the Stream file in a spreadsheet such as Microsoft Excel and average the values of the Channel 1 stream.
- In our example we get 368.7039 as shown in *Figure 7*.



2998	2986	369.0594
2999	2987	368.3456
3000	2988	368.7025
3001	2989	368.3456
3002	2990	368.881
3003	2991	368.1671
3004	2992	368.524
3005	2993	368.7025
3006	2994	367.9886
3007	2995	368.524
3008	2996	368.7025
3009	2997	368.7025
3010	2998	368.7025
3011		368.7039
3012		
3013		
3014		
3015		
3016		
3017		

***Figure 7** – Stream file opened in Microsoft Excel showing the average values of the Channel 1 stream.*

- This operation gives us an Offset we can apply in Node Commander® software that will zero the torque output under no load.
- Returning to Node Commander® software, navigate to the Channel 1 Configuration screen as before.
- Click the Modify button and enter the -368.7039 (yes, that is minus 368.7039) in the Offset textbox. Click Lock button to set.
- Stream the node again to verify that the node is outputting at or near 0 (zero) when no load is applied to the tube.
- The SG-Link® system is now calibrated to output torque in inch-lb

Support
MicroStrain support engineers are always available to expand on this subject and support you in any way we can. To contact us, please visit http://www.microstrain.com/support_overview.aspx.

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