

**TN-37**

# **Static Preloading of 1-DoF & 3-DoF Force Ring Sensors**

Written By

Ken Watkins, PCB Piezotronics, Inc.

# STATIC PRELOADING OF 1-DOF & 3-DOF FORCE RING SENSORS

Written by Ken Watkins, PCB Piezotronics, Inc.

## ABSTRACT

Technical note #35 is a general guideline for test engineers and technicians responsible for installing and preloading piezoelectric ring style force sensors. The preload process described herein is based on use of the sensor's resultant output as a measure of the applied preload. This methodology produces the most accurate results and duplicates the process followed by PCB® during sensor calibration.

There are numerous benefits of applying a static preload on piezoelectric force rings. The primary reasons include linear operation of the sensor throughout the entire measuring range and uniform load distribution.

The characteristics of piezoelectric force sensors mandate that the sensor-signal conditioner system be DC coupled to take advantage of the sensor's longer discharge time constant (DTC). The resultant extended DTC provides sufficient time to apply the static preload with reasonable repeatability and accuracy. This document describes two options for DC coupling the sensor-signal conditioner system. While both methodologies produce the same result, selection of one or the other is dependent on the equipment you have available.

## TOOLS AND EQUIPMENT NEEDED

Sensor installation hardware; supplied stud, bushing, antifriction washer or customer supplied alternate such as a grade 8 or better commercial cap head bolt.

In addition to the sensors and supplied accessories:

1. ICP® signal conditioner with DC coupling capability such as PCB® models 485C24, 482C27, or 483C28. If a DC coupled signal conditioner is not available, a standard BNC-T, in addition to an ICP® signal conditioner, works well.
2. Interface cable(s) between sensor and signal conditioner, such as PCB model number 002C10.
3. Sensor specific specification sheet and installation drawing.
4. Hand tools; including wrenches, six point socket set, ratchet, and breaker bar.
5. Anti-seize compound and lithium grease.
6. Mild degreaser such as denatured alcohol or acetone.
7. Clean, lint free cloth rags.

## MECHANICAL ASSEMBLY

Required hardware: Force sensor(s), mounting stud, bushing, anti-friction washer, and test apparatus.

- 1.
2. Apply a thin coating of anti-seize to the preload stud threads.
3. Thread the supplied preload stud into the base of the test apparatus such that the threads are fully engaged.
4. Locate the supplied bushing (one or two piece, model dependent) and place it over the preload stud. This will keep the sensor centered over the stud.
5. Place the sensor over the stud and bushing and orientate the connector in a convenient direction.
6. Check the fit of the assembly. The sensor should loosely slip over the bushing and stud.
7. Locate the supplied anti-friction washer, place it over the stud, and center it on the sensor.
8. Install the top mating surface of the test apparatus on the sensor(s) and perform a visual inspection to insure that sensor(s) and test apparatus are uniformly in contact with each other.
9. Hand tighten the assembly together to secure it in place.

### Typical Force Ring Sensor and Supplied Installation Accessories

**Force Ring Sensor**



**Preload Stud**



**Bushing**



**Anti-Friction Washer**

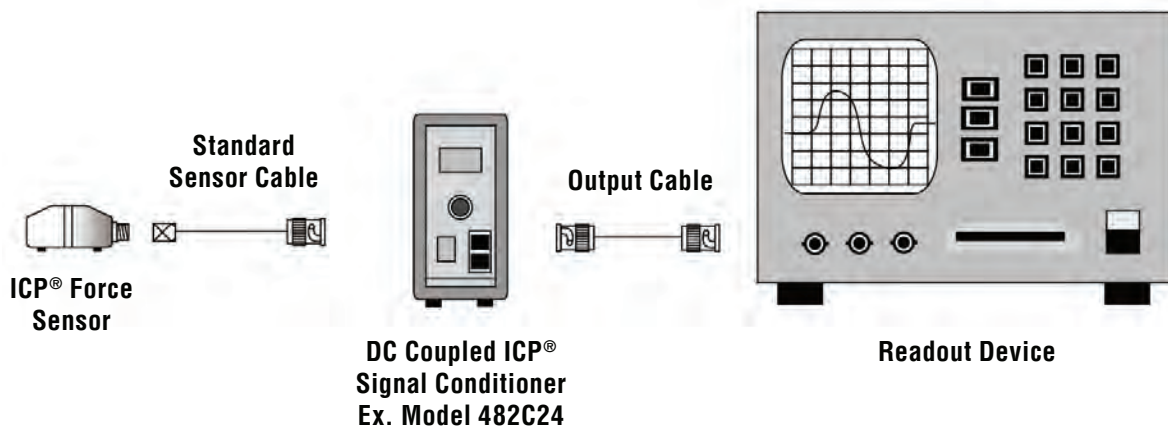


# ELECTRICAL ASSEMBLY

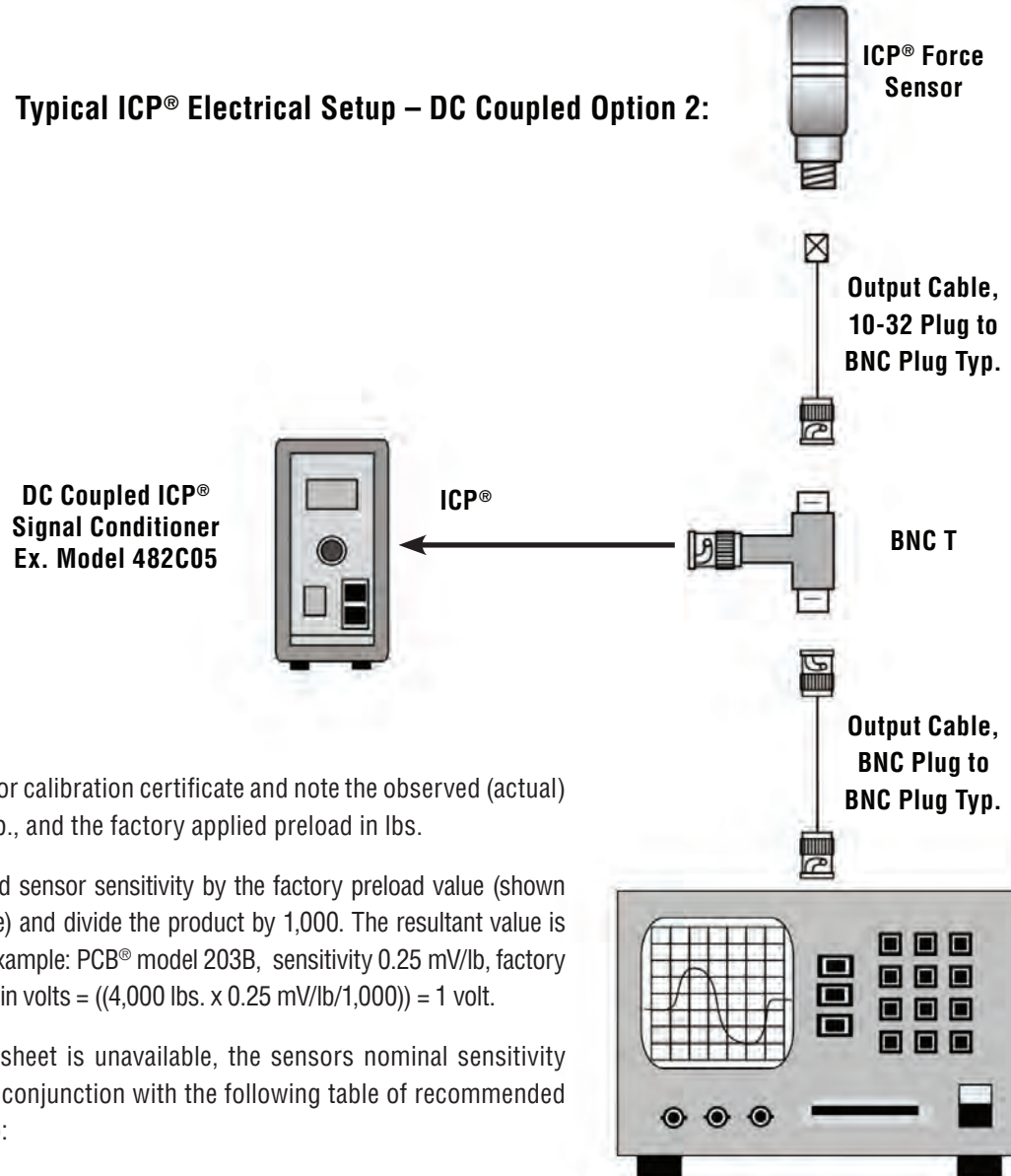
Required hardware: ICP® signal conditioner w/DC coupling (one channel per sensor) sensor interconnect cable(s), readout instrument (DVM or O-Scope), BNC plug to BNC plug cable(s), RG58/U.

1. On all respective instrumentation, confirm that the power is OFF.
2. Route and attach the cable between the sensor(s) and the ICP® signal conditioner, typically 10-32 to BNC plug. Note: The signal conditioner connection is marked either “sensor” or “ICP®” and is typically located on the back panel of the instrument.
3. Connect a 50 ohm coaxial cable between the “output” jack on the same channel on the ICP® signal conditioner to the readout device.
4. Power up all respective instrumentation and allow a sufficient warm-up period for stabilization. See respective manuals for specific period – if any.
5. Set the ICP® signal conditioner to DC coupled mode on the respective channel(s), where the sensor(s) are connected. See the signal conditioner manual for instructions, if needed.
6. Set the DVM to “DC Volts” or set the oscilloscope to “DC Coupling”. Note: The readout device will indicate 8 to 14 volts. This is the bias of the sensor and is the sensor zero reference point used when preloading the sensor. Upon completion of the preload, the host signal conditioner can be reconfigured back to AC coupling for a true zero volt-based output.
7. Refer to the discharge time constant (DTC) on the sensor’s specification sheet. Multiply the DTC value by five (5) seconds and allow the sensor/signal conditioner/readout system to sit at rest with no mechanical stimulus applied. This period can range from 250 to 10,000 seconds and is force sensor model dependent. The purpose of this time period (DTC x 5) is to allow the sensor to discharge fully.

## Typical ICP® Electrical Setup – DC Coupled Option 1:



## Typical ICP® Electrical Setup – DC Coupled Option 2:



## PRELOADING

1. Refer to the supplied sensor calibration certificate and note the observed (actual) sensor sensitivity in mV/lb., and the factory applied preload in lbs.
2. Multiply the actual observed sensor sensitivity by the factory preload value (shown on the calibration certificate) and divide the product by 1,000. The resultant value is the preload value in volts. Example: PCB® model 203B, sensitivity 0.25 mV/lb, factory preload 4,000 lbs. Preload in volts =  $((4,000 \text{ lbs.} \times 0.25 \text{ mV/lb}/1,000)) = 1 \text{ volt}$ .
3. If the factory calibration sheet is unavailable, the sensors nominal sensitivity plus 10% may be used in conjunction with the following table of recommended preload values (by model):

1-dof Force Ring Models	Recommended Z Axis Preload (lbs.)	3-dof Force Ring Models	Recommend Z Axis Preload (lbs.)
201B01	60	260A01	5,000
201B02	100	260A02	10,000
201B03	200	260A03	40,000
201B04	400	-	-
201B05	1,000	-	-
202B	2,000	-	-
203B	4,000	-	-
204C	8,000	-	-
205C	12,000	-	-
206C	16,000	-	-
207C	33,750	-	-

## PRELOADING (CONTINUED)

4. For 1-dof force sensor models, where preload values are  $\geq 16,000$  lbs., lithium grease may be applied to both sensor-mating surfaces to protect the sensor from damage due to slippage.
5. For 3-dof force sensor models, the required preload is ten (10) times the full-scale shear ( $F_x$ ,  $F_y$ ) range. This magnitude of preload is required to create sufficient clamp load so that forces applied to  $F_x$  and  $F_y$  do not result in joint slippage.
6. Calculated preload values up to 10 volts may be safely applied in one uniform increment without mechanical or electrical damage to the sensor. In cases of higher capacity sensors, or where a larger preload is required, the preload will need to be done in multiple increments to prevent damage to the sensor's on-board electronics. At the end of each increment, allow sufficient time for the sensor output to discharge back to the bias voltage prior to proceeding with the next increment (if needed). Reference the Electrical Assembly step seven (7) for the time required.

**CAUTION: THE RAPID APPLICATION OR REMOVAL OF LOAD ON THE SENSOR, RESULTING IN A TOTAL SENSOR OUTPUT GREATER THAN 20 VOLTS, CAN RESULT IN PERMANENT DAMAGE.**

Example: Model 260A02, 10,000 lb. preload,  $F_z$  axis sensitivity of 2.5 mV/lb. Preload in volts =  $((10,000 \times 2.5) / 1,000)$  or 25 volts. As the required preload is in excess of 10 volts, PCB recommends that the preload process be broken down into three equal increments of 8.3 volts. Note: Be sure to allow the sensor to fully discharge back to zero (0) volts prior to proceeding to the next increment.

7. Depending on the force magnitude of interest and the area over which the measurement will occur, multiple force ring sensors may be required. For those applications, it is recommended that all sensors be monitored and preloaded individually in a cross pattern.

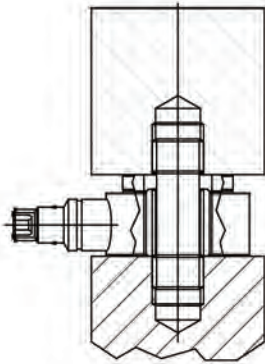
## SUMMARY

Whereas, the proceeding process for preloading PCB Force Ring Sensors can be overwhelming for the first time user, it is necessary to ensure proper operation of the sensor and to obtain sensor performance pursuant to the factory observed

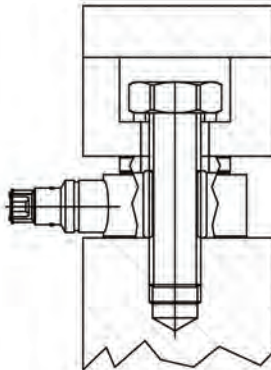
characteristics. For installations using a commercial fastener in lieu of the factory supplied preload stud, the preload process is essentially the same. Consult your local PCB Field Application Engineer to hear about special calibration options.

### Special Installation Options:

Typical with Supplied Mounting Hardware



Typical with Commercial Fastener





**3425 Walden Avenue, Depew, NY 14043 USA**

pcb.com | info@pcb.com | 800 828 8840 | +1 716 684 0001

© 2023 PCB Piezotronics - all rights reserved. PCB Piezotronics is a wholly-owned subsidiary of Amphenol Corporation. Endevo is an assumed name of PCB Piezotronics of North Carolina, Inc., which is a wholly-owned subsidiary of PCB Piezotronics, Inc. Accumetrics, Inc. and The Modal Shop, Inc. are wholly-owned subsidiaries of PCB Piezotronics, Inc. IMI Sensors and Larson Davis are Divisions of PCB Piezotronics, Inc. Except for any third party marks for which attribution is provided herein, the company names and product names used in this document may be the registered trademarks or unregistered trademarks of PCB Piezotronics, Inc., PCB Piezotronics of North Carolina, Inc. (d/b/a Endevo), The Modal Shop, Inc. or Accumetrics, Inc. Detailed trademark ownership information is available at [www.pcb.com/trademarkownership](http://www.pcb.com/trademarkownership).