F/T Transducer without Electronics (TWE)

Six-Axis

Force/Torque Transducer

Installation and Operation Manual

Manual #: 9620-05-TWE
February 2013
Foreword

CAUTION: This manual describes the function, application and safety considerations of this product. This manual must be read and understood before any attempt is made to install or operate the product, otherwise damage to the product or unsafe conditions may occur.

The information contained herein is CONFIDENTIAL and reserved exclusively for the customers and authorized agents of ATI Industrial Automation and may not be divulged to any third party without prior written consent from ATI. No warranty including implied warranties is made with regard to accuracy of this document or fitness of this device for a particular application. ATI Industrial Automation shall not be liable for any errors contained in this document or for any incidental or consequential damages caused thereby. ATI Industrial Automation also reserves the right to make changes to this manual at any time without prior notice.

Information contained in this document is the property of ATI Industrial Automation, Inc. and shall not be reproduced in whole or in part without prior written approval of ATI Industrial Automation, Inc. The information herein is subject to change without notice and should not be construed as a commitment on ATI Industrial Automation, Inc. This manual is periodically revised to reflect and incorporate changes made to the F/T system.

ATI Industrial Automation, Inc. assumes no responsibility for any errors or omissions in this document. Users' critical evaluation is welcome to assist in the preparation of future documentation (see the “What Do You Think” section at the end of this manual).

In consideration that ATI Industrial Automation, Inc. (ATI) products are intended for use with robotic and/or automated machines, ATI does not recommend the use of its products for applications wherein failure or malfunction of an ATI component or system threatens life or makes injury probable. Anyone who uses or incorporates ATI components within any potentially life threatening system must obtain ATI's prior consent based upon assurance to ATI that a malfunction of ATI's component does not pose direct or indirect threat of injury or death, and (even if such consent is given) shall indemnify ATI from any claim, loss, liability, and related expenses arising from any injury or death resulting from use of ATI components.

Copyright by ATI Industrial Automation, Inc., Apex, North Carolina. All Rights Reserved.

Published in the USA.
First printing November 2002.

FCC Compliance - Class B
This device complies with Part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) this device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

CE Conformity
Aside…
Please read the manual before calling customer service. Before calling, have the following information available:

- Serial number (e.g., FT01234).
- Transducer model (e.g., Nano17, Gamma, Theta, etc.).
- Calibration (e.g., US-15-50, SI-65-6, etc.)
- Accurate and complete description of the question or problem.
- Computer and software information. Operating system, PC type, drivers, application software and other relevant information in your configuration.

If possible be near the F/T system when calling.

How to Reach Us

Sales, Service and Information about ATI products:

ATI Industrial Automation
1031 Goodworth Drive
Apex, NC  27539 USA
www.ati-ia.com
Tel:    +1.919.772.0115
Fax:    +1.919.772.8259
E-mail: info@ati-ia.com

Technical support and questions:

Application Engineering
Tel:    +1.919.772.0115
Fax:    +1.919.772.8259
E-mail: ft_support@ati-ia.com
Intertek Testing Services
4317-A Park Dr NW
Norcross, GA 30093 USA

TEST RECORD
CENELEC STANDARD EN 60101-1: 1993

NOT TRANSFERABLE

Manufacturer’s name ATI Industrial Automation
Manufacturer’s address 503D Highway 70 East
Garner, NC 27529 USA
Type of equipment Sensor System
Model No. 9105-Ctrlr, 9105-Ctrlr-Ana, 9105-Ctrlr-Par, 9105-Ctrlr-AP
Serial No. FT3315, FT3512, FT3581, FT3599

We, the undersigned, hereby declare that the equipment specified above conforms to the above identified standard as described in the attached test record.

T.M. Bartol
Sr. Project Engineer

Douglas K. Tucker, P.E.
Staff Engineer
Table of Contents

1. Safety .............................................................................................................................................. 7
   1.1 General ........................................................................................................................................ 7
   1.2 Explanation of Warnings .............................................................................................................. 7
   1.3 Precautions ................................................................................................................................. 7

2. Product Overview .......................................................................................................................... 8
   2.1 Introduction ............................................................................................................................... 8
   2.2 Unpacking ................................................................................................................................. 8

3. Description ..................................................................................................................................... 9
   3.1 Transducer ............................................................................................................................... 9
   3.2 Transducer Cable ...................................................................................................................... 9

4. Operation ........................................................................................................................................ 10
   4.1 Transducer .............................................................................................................................. 10
      4.1.1 Mechanical Description .................................................................................................... 10
      4.1.2 Electrical Description ....................................................................................................... 11
   4.2 Signal Conditioning Circuitry .................................................................................................... 13
      4.2.1 Strain Gage Amplification and Hardware Bias ............................................................... 13
         4.2.1.1 Excitation ..................................................................................................................... 13
         4.2.1.2 Amplification ............................................................................................................... 14
         4.2.1.3 Hardware Bias ............................................................................................................ 14
   4.3 The TWE Calibration Spreadsheet ......................................................................................... 14
      4.3.1 Calibration Info (Raw) ....................................................................................................... 14
      4.3.2 Signal Conditioning ........................................................................................................... 15
      4.3.3 Calibration Info (Amplified) ............................................................................................ 15
      4.3.4 Sample Calculations ......................................................................................................... 15
   4.4 Getting Started .......................................................................................................................... 15

5. Advanced Topics .......................................................................................................................... 16
   5.1 Scheduled Maintenance ............................................................................................................. 16
      5.1.1 Periodic Inspection ............................................................................................................ 16
      5.1.2 Periodic Calibration ......................................................................................................... 16
   5.2 A Word about Resolution ......................................................................................................... 16
   5.3 Detecting Sensitivity Changes ................................................................................................. 16
   5.4 Thermistor Circuit (Legacy) ..................................................................................................... 17
      5.4.1 Companion Resistor and Excitation ................................................................................. 17
      5.4.2 Buffer Circuit ...................................................................................................................... 17

6. Troubleshooting ............................................................................................................................ 18

7. Terms and Conditions of Sale ...................................................................................................... 19
# Glossary of Terms

<table>
<thead>
<tr>
<th>Terms</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accuracy</td>
<td>See <em>Measurement Uncertainty</em>.</td>
</tr>
<tr>
<td>Compound Loading</td>
<td>Any load that is not purely in one axis.</td>
</tr>
<tr>
<td>FS</td>
<td><em>Full-Scale</em>.</td>
</tr>
<tr>
<td>F/T</td>
<td><em>Force and Torque</em>.</td>
</tr>
<tr>
<td>Fxy</td>
<td>The resultant force vector comprised of components Fx and Fy.</td>
</tr>
<tr>
<td>Hysteresis</td>
<td>A source of measurement caused by the residual effects of previously applied loads.</td>
</tr>
<tr>
<td>IP60</td>
<td>Ingress Protection Rating &quot;60&quot; designates protection against dust.</td>
</tr>
<tr>
<td>IP65</td>
<td>Ingress Protection Rating &quot;65&quot; designates protection against water spray.</td>
</tr>
<tr>
<td>IP68</td>
<td>Ingress Protection Rating &quot;68&quot; designates submergibility in fresh water, in this case, to a depth of 10 meters.</td>
</tr>
<tr>
<td>Maximum Single-Axis Overload</td>
<td>The largest amount of pure load (not compound loading) that the transducer can withstand without damage.</td>
</tr>
<tr>
<td>MAP</td>
<td><em>Mounting Adapter Plate</em>. The MAP part of the transducer is attached to the fixed surface or robot arm.</td>
</tr>
<tr>
<td>Measurement Uncertainty</td>
<td>The maximum expected error in measurements, as specified on the calibration certificate.</td>
</tr>
<tr>
<td>Overload</td>
<td>The condition where more load is applied to the transducer than it can measure. This will result in saturation.</td>
</tr>
<tr>
<td>Point of Origin</td>
<td>The point on the transducer from which all forces and torques are measured.</td>
</tr>
<tr>
<td>Quantization</td>
<td>The way the continuously variable transducer signal is converted into discreet digital values. Usually used when describing the change from one digital value to the next.</td>
</tr>
<tr>
<td>Resolution</td>
<td>The smallest change in load that can be measured. This is usually much smaller than accuracy.</td>
</tr>
<tr>
<td>Saturation</td>
<td>The condition where the transducer or data acquisition hardware has a load or signal outside of its sensing range.</td>
</tr>
<tr>
<td>TAP</td>
<td><em>Tool Adapter Plate</em>. The TAP part of the transducer is attached to the load that is to be measured.</td>
</tr>
<tr>
<td>TWE</td>
<td><em>F/T Transducer Without Electronics</em>, for advanced users who need to bypass standard ATI Industrial Automation electronics.</td>
</tr>
<tr>
<td>TWL</td>
<td>A TWE F/T transducer with environmental connector. See <em>TWE</em>.</td>
</tr>
<tr>
<td>Tool Transformation</td>
<td>Mathematically changing the measurement coordinate system by translating the origin and/or rotating the axes.</td>
</tr>
<tr>
<td>Transducer</td>
<td>The component that converts the sensed load into electrical signals.</td>
</tr>
<tr>
<td>Txy</td>
<td>The resultant torque vector comprised of components Tx and Ty.</td>
</tr>
</tbody>
</table>
1. Safety

1.1 General

The customer should verify that the transducer selected is rated for the maximum loads and moments expected during operation. Refer to transducer specifications in F/T Transducer Manual (9620-05-Transducer) or contact ATI for assistance. Particular attention should be paid to dynamic loads caused by robot acceleration and deceleration. These forces can be many times the value of static forces in high acceleration or deceleration situations.

1.2 Explanation of Warnings

The warnings included here are specific to the product(s) covered by this manual. It is expected that the user heed all warnings from the robot manufacturer and/or the manufacturers of other components used in the installation.

- Danger indicates that a situation could result in potentially serious injury or damage to equipment.

- Caution indicates that a situation could result in damage to the product and/or the other system components.

1.3 Precautions

**DANGER:** Do not attempt to disassemble the transducer. This will damage the instrumentation.

**DANGER:** Do not probe any openings in the transducer. This will damage the instrumentation.

**DANGER:** Take care to prevent excessive forces or moments from being applied to the transducer during handling or installation. The small Nano series is easily overloaded during rough handling and may be damaged.
2. Product Overview

2.1 Introduction

This section gives instructions for setting up the F/T TWE system. Chapters cover components shipped with the transducer and their descriptions.

CAUTION: The Force/Torque sensor and the calibration matrix provided with it have been assigned matching serial numbers when the transducer was calibrated. If these serial numbers assigned to your F/T system do not match, the Force/Torque output data will be incorrect.

2.2 Unpacking

- Check the shipping container and components for damage due to shipping. Any damage should be reported to ATI Industrial Automation.
- Check the packing list for omissions.
- The following are standard components for a TWE F/T system.
  - Transducer
  - Transducer cable (for 9105-T transducers)
  - CD containing calibration information

CAUTION: Do not touch any exposed instrumentation when you have the mounting adapter plate removed (for Gammas and larger).
3. Description

3.1 Transducer

The transducer is a compact, rugged, monolithic structure that converts force and torque into analog strain gage signals for the F/T controller. The transducer is commonly used as a wrist sensor mounted between a robot and a robot end-effector. Figure 3.1 shows the transducer with a standard tool adapter.

For further information regarding mechanical installation, specifications, and drawings, see F/T Transducer Manual (9620-05-Transducer).

![Figure 3.1—Transducer](image)

3.2 Transducer Cable

Aside...
The transducer is designed to withstand extremely high overloading through its use of strong materials and quality silicon strain gages.

The high-flex transducer cable is electrically shielded to protect transmission of transducer data. The cables used in the Nano and Mini models are integrated into the unit. Other models use detachable cables.
4. Operation

A complete TWE system consists of:
- An ATI F/T transducer and cable
- Your signal conditioning circuitry
- An ATI TWE calibration spreadsheet containing information specific to your transducer
- A way to convert analog data into numerical values, such as your data acquisition system
- A way to perform the mathematical operations required to convert raw voltages into forces and torques, such as a custom software application or ATI’s sample calculation spreadsheet

4.1 Transducer

4.1.1 Mechanical Description

The property of forces was first stated by Newton in his third law of motion: To every action there is always opposed an equal reaction; or, the mutual action of two bodies upon each other are always equal, and directed to contrary parts. The transducer reacts to applied forces and torques using Newton’s third law.

Figure 4.1—Applied force and torque vector on transducer

The force applied to the transducer flexes three symmetrically placed beams using Hooke’s law:

\[ \sigma = E \cdot \varepsilon \]

where:
- \( \sigma \) = Stress applied to the beam (\( \sigma \) is proportional to force)
- \( E \) = Elasticity modulus of the beam
- \( \varepsilon \) = Strain applied to the beam

Aside...
The transducer is a monolithic structure. The beams are machined from a solid piece of metal. This decreases hysteresis and increases the strength and repeatability of the structure.
Semiconductor strain gages are attached to the beams and are considered strain-sensitive resistors. The resistance of the strain gage changes as a function of the applied strain as follows:

\[ \Delta R = S_a \cdot R_o \cdot \varepsilon \]

where:
- \( \Delta R \) = Change in resistance of strain gage
- \( S_a \) = Gage factor of strain gage
- \( R_o \) = Resistance of strain gage unstrained
- \( \varepsilon \) = Strain applied to strain gage

The output voltages from the transducer’s gages are used to measure the change in resistance. They must be combined mathematically to be converted into forces and torques. This process is discussed in Section 4.3.

### 4.1.2 Electrical Description

Your transducer is instrumented with high-quality silicon strain gages. The high output of these silicon strain gages requires far less amplification than foil-based strain gages. The higher amplification required by foil strain gages boosts their signals and any noise present. Since silicon strain gages require less amplification there is less noise amplification. Silicon strain gages also allow transducers to survive higher overload conditions without damage.

The transducer uses six half-bridge strain gage pairs to sense loads. For all transducers except the Gamma, the excitation power supply (SG_{HI}, SG_{LO}) needs to be able to supply a 500Ω load. The Gamma requires the ability to supply a 275Ω load. Figure 4.2 shows the electrical equivalent schematic of the transducer.

Each half-bridge strain gage pair measures a portion of the total transducer load. A load places compressive strain on one member of the gage pair and equally tensile strain on the other member. The pair works together as a voltage divider to produce a signal representing the pair’s load.

![Figure 4.2—Transducer Equivalent Schematic](image-url)
TABLE 4.1—Wiring for Nano/Mini Integral Cables

<table>
<thead>
<tr>
<th>Pin</th>
<th>Wire Color</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>---</td>
<td>no connect</td>
</tr>
<tr>
<td>B</td>
<td>Yellow</td>
<td>SG4 output</td>
</tr>
<tr>
<td>C</td>
<td>Brown</td>
<td>SG5 output</td>
</tr>
<tr>
<td>D</td>
<td>Violet</td>
<td>SG2 output</td>
</tr>
<tr>
<td>E</td>
<td>Blue</td>
<td>SG3 output</td>
</tr>
<tr>
<td>F</td>
<td>Green</td>
<td>SG0 output</td>
</tr>
<tr>
<td>G</td>
<td>Orange</td>
<td>SG1 output</td>
</tr>
<tr>
<td>H</td>
<td>---</td>
<td>no connect</td>
</tr>
<tr>
<td>J</td>
<td>Black</td>
<td>SG_{LO} excitation input</td>
</tr>
<tr>
<td>K</td>
<td>Red</td>
<td>SG_{HI} excitation input</td>
</tr>
</tbody>
</table>

Table 4.2—Connector Connections in 9105-C-x-A Cables

<table>
<thead>
<tr>
<th>H</th>
<th>L</th>
<th>Wire Color</th>
<th>A</th>
<th>Signal</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>1</td>
<td>Red</td>
<td>K</td>
<td>SG_{HI}</td>
</tr>
<tr>
<td>10</td>
<td>4</td>
<td>Black</td>
<td>J</td>
<td>SG_{LO}</td>
</tr>
<tr>
<td>1</td>
<td>7</td>
<td>Brown</td>
<td>F</td>
<td>SG0</td>
</tr>
<tr>
<td>7</td>
<td>9</td>
<td>Yellow</td>
<td>G</td>
<td>SG1</td>
</tr>
<tr>
<td>17</td>
<td>11</td>
<td>Green</td>
<td>D</td>
<td>SG2</td>
</tr>
<tr>
<td>8</td>
<td>13</td>
<td>Blue</td>
<td>E</td>
<td>SG3</td>
</tr>
<tr>
<td>13</td>
<td>15</td>
<td>Violet</td>
<td>B</td>
<td>SG4</td>
</tr>
<tr>
<td>9</td>
<td>17</td>
<td>Grey</td>
<td>C</td>
<td>SG5</td>
</tr>
<tr>
<td>2</td>
<td>5</td>
<td>Orange</td>
<td>N/C</td>
<td>N/A</td>
</tr>
<tr>
<td>3</td>
<td>8</td>
<td>Brown/White</td>
<td>N/C</td>
<td>N/A</td>
</tr>
<tr>
<td>4</td>
<td>14</td>
<td>Blue/White</td>
<td>N/C</td>
<td>N/A</td>
</tr>
<tr>
<td>5</td>
<td>18</td>
<td>Grey/White</td>
<td>N/C</td>
<td>N/A</td>
</tr>
<tr>
<td>11</td>
<td>2</td>
<td>Red/White</td>
<td>N/C</td>
<td>N/A</td>
</tr>
<tr>
<td>12</td>
<td>10</td>
<td>Yellow/White</td>
<td>N/C</td>
<td>N/A</td>
</tr>
<tr>
<td>14</td>
<td>19</td>
<td>White</td>
<td>N/C</td>
<td>N/A</td>
</tr>
<tr>
<td>15</td>
<td>3</td>
<td>Black/White</td>
<td>N/C</td>
<td>N/A</td>
</tr>
<tr>
<td>16</td>
<td>6</td>
<td>Orange/White</td>
<td>N/C</td>
<td>N/A</td>
</tr>
<tr>
<td>18</td>
<td>16</td>
<td>Violet/White</td>
<td>N/C</td>
<td>N/A</td>
</tr>
<tr>
<td>19</td>
<td>20</td>
<td>White/Black</td>
<td>N/C</td>
<td>N/A</td>
</tr>
<tr>
<td>20</td>
<td>12</td>
<td>Green/White</td>
<td>N/C</td>
<td>N/A</td>
</tr>
</tbody>
</table>

H = 9105-C-H-A Transducer End
L = 9105-C-L-A Transducer End
A = 9105-C-x-A Electronics End

Table 4.3—Connector Pin Out for Nano/Mini Cables (Pin side of transducer connector)
Aside…
The transducer cable and connector affect the transducer’s calibration. There may be components inside of the connector required for proper transducer operation. Modifications to the connector must have these components intact. The total resistance of the cabling affects the transducer’s output span.

---

<table>
<thead>
<tr>
<th>Transducer Type</th>
<th>Mating Connector</th>
<th>Mount</th>
</tr>
</thead>
<tbody>
<tr>
<td>9105-TW</td>
<td>Amphenol T-3638-009</td>
<td>bulkhead mount</td>
</tr>
<tr>
<td>9105-TWE</td>
<td>Hirose HR25-9TP-20S</td>
<td>cable mount</td>
</tr>
<tr>
<td>9105-TWL</td>
<td>Lemo FGG.3K.320.CLA</td>
<td>cable mount</td>
</tr>
</tbody>
</table>

Table 4.3—Transducer Mating Connectors

CAUTION: Although the cables used by ATI Industrial Automation are robust, the individual wires in the cables must be handled with care to avoid damaging them. Correctly-sized wire strippers are required and the wires must be strain relieved and anchored wherever they are soldered to prevent breaking.

4.2 Signal Conditioning Circuitry

Signal conditioning circuitry has several purposes:

- To minimize noise by amplifying the transducer signal. Signal conditioning circuitry should be located near the transducer for best results.
- To provide high-impedance signals for a data acquisition system.
- To maximize the transducer’s resolution by optimizing the range of the output signals. This usually means amplifying the output and applying any necessary offset so that the transducer’s output range matches the input range of the data acquisition system’s analog-to-digital converter (ADC).

CAUTION: When any strain gage is saturated or otherwise inoperable, all transducer F/T readings are invalid. Therefore, it is vitally important to monitor for these conditions.

4.2.1 Strain Gage Amplification and Hardware Bias

The interface circuits to all six strain gage signals should have excitation, amplification, and hardware bias.

4.2.1.1 Excitation

We recommend an excitation of 0.000V and +5.000V using a low-noise, low-drift voltage source. Any drift in the output voltage will cause a gain error in the output. You can compensate for this drift by monitoring the power supply voltage and using it in the strain gage calculations. Since the noise present in the power source directly impacts the noise seen in your system it is important to use a low-noise source.

CAUTION: When any strain gage is saturated or otherwise inoperable, all transducer F/T readings are invalid. Therefore, it is vitally important to monitor for these conditions.
4.2.1.2 Amplification

The optimum amplification for each gage is calculated by the TWE calibration spreadsheet that is included on the system CD. These target gains will optimize the transducer’s output range. It is not necessary to match these gains exactly. However, setting the gain too high could cause early ADC saturation (decreased range), and setting it too low could cause a decrease in resolution. Although the ideal gains for the six channels are all different, they are typically similar, enabling you to use the same type of amplifier circuit for each, if you choose.

4.2.1.3 Hardware Bias

The nominal unloaded output of each of the half bridges is the voltage halfway between \(SG_{LO}\) (upper excitation voltage) and \(SG_{HI}\) (lower excitation voltage) or

\[
SG_{nom} = \frac{SG_{HI} + SG_{LO}}{2}
\]

All strain gage output voltages will have some offset bias voltage present. This offset bias voltage is the shift of the strain gage output from ideal unloaded output \((SG_{nom})\). The hardware bias values for your transducer were measured during calibration and can be found in the TWE calibration spreadsheet. Removing this offset voltage prior to amplifying the signals will allow you to use the most sensitive measurement range of your equipment. The most effective way to do this is to create a fixed bias reference voltage that is identical to this offset. This bias reference voltage will serve as your negative voltage input while the strain gage voltage is the positive.

An easy way to generate this bias reference voltage for each strain gage is with a 10-turn 200 Ohms potentiometer and two 1000 Ohms resistors (see figure 4.4). Adjust the reference output voltage to match the hardware bias vectors calculated by the TWE calibration spreadsheet.

![Figure 4.4—Example Bias Reference Voltage Circuit (user-supplied)](image)

4.3 The TWE Calibration Spreadsheet

To maximize accuracy, your transducer has been individually calibrated. On the distribution DC included with your transducer you will find an Excel document named \(FTxxxx\ TWE.xls\), where \(FTxxxx\) is the transducer’s serial number. This file contains the calibration information specific to your transducer. It will help you design your signal conditioning system by calculating the gains and hardware bias offsets to optimize the system’s range and resolution. It also provides sample calculations for converting voltages into forces and torques.

Most cells in the spreadsheet should not be modified. The cells that you need to enter data will be colored for your convenience. The four worksheets in the spreadsheet are described below:

4.3.1 Calibration Info (Raw)

The \textit{Calibration Info (Raw)} worksheet contains information specific to your transducer and should not be modified. The calibration matrix shown on this page does not take into account the circuitry that you are using to interface the transducer and should not be used in your calculations. The only important piece of information to note is the cell labeled \textit{Cal}. 
Therm. Resistor. This value, present only on transducers with the software temperature compensation option, is the resistance of the thermistor companion resistor that was used during our calibration process. Your companion resistor should match this resistor within 1%.

4.3.2 Signal Conditioning

The Signal Conditioning worksheet calculates the optimum gain and hardware bias for each of your strain gage channels based on the excitation voltage of your circuitry and the desired output range of the system. This worksheet also contains inputs for the actual values of the gains and thermistor circuitry (if applicable). These values are used to calculate the calibration matrix and other information on the next worksheet. You should only need to configure this worksheet once, unless you change your system.

4.3.3 Calibration Info (Amplified)

The Calibration Info (Amplified) worksheet contains calibration constants that have been adjusted for the characteristics of your signal conditioning circuitry (entered on the previous worksheet). All constants used for F/T conversion and temperature compensation are found on this worksheet.

4.3.4 Sample Calculations

The Sample Calculations worksheet demonstrates the calculations for converting raw voltages from your F/T system into forces and torques, with and without temperature compensation. Two measurements are required: an unloaded (reference) measurement and a loaded measurement. The unloaded measurement is used as a software biasing step to remove the effect of a constant load such as tooling weight.

4.4 Getting Started

1. On the Signal Conditioning worksheet of the TWE calibration spreadsheet, enter the high and low excitation voltages of your system and the maximum and minimum desired output of the system. If you are using a data acquisition system, the desired output range will be determined by the input range of the analog-to-digital converter (ADC).
2. The spreadsheet will use the information you entered in Step 1 to provide optimum gain settings for each gage. This amplification will allow the transducer to be used over its entire calibration range with maximum resolution. Adjust your signal conditioning to provide gains approximately equal to these values.
3. Measure the actual gains of each strain gage channel in your circuit and enter them into the spreadsheet.
4. Set up your hardware bias circuitry to subtract the hardware bias voltages calculated by the spreadsheet. This will ensure that the transducer’s full range will be available.
5. Test the complete system’s operation. With the transducer at rest, take a measurement of all six strain gage channels (and thermistor channel, if applicable) and enter these values into the Unloaded Measurement area on the Sample Calculations worksheet. Place a known load on the transducer and enter this measurement into the Loaded Measurement area. Verify that the F/T vector calculated by the spreadsheet is correct. If not, check all of the input values.
6. Incorporate the formulas on the Sample Calculations page and the calibration information on the Calibration Info (Amplified) page into your final application.

CAUTION: Before performing the F/T conversion, every voltage measurement should be checked for saturation of the A/D converter. If one or more of the six gage channels is saturated, forces and torques cannot be accurately calculated and the transducer may be in danger of damage due to excessive loading.
5. Advanced Topics

5.1 Scheduled Maintenance

5.1.1 Periodic Inspection

For most applications there are no parts that need to be replaced during normal operation. With industrial-type applications that continuously or frequently move the system’s cabling, you should periodically check the cable jack for signs of wear. The transducer must be kept free of excessive dust, debris, or moisture. Applications with metallic debris (i.e., electrically-conductive) must protect the transducer from this debris. Transducers without specific factory-installed protection are to be considered unprotected. The internal structure of the transducer can become clogged with particles and will become uncalibrated or even damaged.

5.1.2 Periodic Calibration

Periodic calibration of the transducer is required to maintain traceability to national standards. Follow any applicable ISO-9000-type standards for calibration. ATI Industrial Automation recommends annual recalibrations, especially for applications that frequently cycle the loads applied to the transducer.

5.2 A Word about Resolution

ATI’s transducers have a three sensing beam configuration, where the three beams are equally spaced around a central hub and attached to the outside wall of the transducer. This design transfers applied loads to multiple sensing beams and allows the transducer to increase its sensing range in a given axis if a counterpart axis has reduced loading (see the F/T Transducer Manual’s compound loading information).

The resolution of each transducer axis depends on how the applied load is spread among the sensing beams. The best resolution occurs in the scenario when the quantization of the gages is evenly distributed as load is applied. In the worst case scenario, the discrete value of all involved gages increases at the same time. The typical scenario will be somewhere in between these two.

F/T resolutions are specified as typical resolution, defined as the average of the worst and best case scenarios. Because both multi-gage effects can be modeled as a normal distribution, this value represents the most commonly perceived, average resolution. The DAQ F/T resolutions are based on real-number calculations and do not result in clean fractions. To express the values as clean fractions, we simply use the best values that a 16-bit data acquisition system could achieve. Although this misrepresents the actual performance of the transducers, it results in a close (and always conservative) estimate.

5.3 Detecting Sensitivity Changes

Sensitivity checking of the transducer can also be used to measure the transducer system’s health. This can be done by applying known loads to the transducer and verifying the system output matches the know loads.

For example, a transducer may have an end-effector attached to it:

1. If the end-effector has moving parts, they must be moved in a known position.
2. Place the transducer in an orientation that allows the gravity load from the end-effector to exert load on many transducer output axes.
3. Record the output readings.
4. Position the transducer to apply another load, this time causing the outputs to move far from the earlier readings.
5. Record the second set of output readings.
6. Find the differences from the first and second set of readings and use it as your sensitivity value.

Even if the values vary somewhat from sample set to sample set, they can be used to detect gross errors. Either the resolved outputs or the raw transducer voltages may be used (the same must be used for all steps of this process).

5.4 Thermistor Circuit (Legacy)

Note: This section only applies to transducers with the optional software temperature compensation option. For systems without the option, the transducer’s thermistor pins can remain unconnected.

The thermistor signal conditioning circuit consists of excitation, a companion resistor for the transducer’s thermistor, and a buffer or amplifier circuit to provide a high-impedance signal for the data acquisition system.

 Aside…

Information about the thermistor circuit is included in this manual for legacy reasons. The transducer’s standard hardware temperature compensation performs this function without the resulting loss of range or resolution of the thermistor method.

5.4.1 Companion Resistor and Excitation

The companion resistor (Rc) completes a half-bridge with the transducer’s thermistor. The resistor value should be within 1% of the one used in calibration (see TWE calibration spreadsheet) in order to provide linear output over temperature.

The companion resistor should be placed between the transducer’s Thermistor1 pin (see Figure 5.1) and SGLO. The transducer’s Thermistor2 pin should be connected to SGHI. Thermistor1 is the output of the thermistor half-bridge.

![Figure 5.1—Example Thermistor Reader](image)

5.4.2 Buffer Circuit

If your data acquisition system requires input impedance of 5 kΩ or less, you should probably implement a simple follower or amplifier circuit to provide a high-impedance output. If you design a simple voltage follower, then you should enter a gain of 1 and an offset of 0 into the TWE calibration spreadsheet for the thermistor circuit data. Otherwise, you will need to measure the gain and offset of the circuit. The offset is the voltage when the input is grounded; the gain is the ratio of (output-offset)/input.
6. Troubleshooting

This section includes answers to some issues that might arise when setting up and using the F/T system. The question or problem is listed followed by the probable answer or solution and are categorized for easy reference.

The information in this section should answer many questions that might arise in the field. Customer service is available to users who have problems or questions addressed in the manuals:

ATI Industrial Automation
Customer Service
Pinnacle Park
1031 Goodworth Drive
Apex, NC 27539 USA

Phone: +1.919.772.0115
Fax: +1.919.772.8259
E-mail: ft_support@ati-ia.com

Note:
Please read the F/T manuals before calling customer service. When calling, have the following information available:
1. Serial number(s)
2. Transducer type, e.g. Nano-17, Gamma, Theta
3. Calibration, e.g. US-15-50, SI-130-10
4. An accurate and complete description of the question or problem.
5. Controller revision. This is output in the initialization header message of the Controller.

If possible, the F/T system should be accessible when talking with an ATI Industrial Automation customer service representative.
7. Terms and Conditions of Sale

The following Terms and Conditions are a supplement to and include a portion of ATI’s Standard Terms and Conditions, which are on file at ATI and available upon request.

ATI warrants to Purchaser that force torque sensor products purchased hereunder will be free from defects in material and workmanship under normal use for a period of three (1) year from the date of shipment. This warranty does not cover components subject to wear and tear under normal usage or those requiring periodic replacement. ATI will have no liability under this warranty unless: (a) ATI is given written notice of the claimed defect and a description thereof within thirty (30) days after Purchaser discovers the defect and in any event not later than the last day of the warranty period; and (b) the defective item is received by ATI not later ten (10) days after the last day of the warranty period. ATI’s entire liability and Purchaser’s sole remedy under this warranty is limited to repair or replacement, at ATI’s election, of the defective part or item or, at ATI’s election, refund of the price paid for the item. The foregoing warranty does not apply to any defect or failure resulting from improper installation, operation, maintenance or repair by anyone other than ATI.

ATI will in no event be liable for incidental, consequential or special damages of any kind, even if ATI has been advised of the possibility of such damages. ATI’s aggregate liability will in no event exceed the amount paid by purchaser for the item which is the subject of claim or dispute. ATI will have no liability of any kind for failure of any equipment or other items not supplied by ATI.

No action against ATI, regardless of form, arising out of or in any way connected with products or services supplied hereunder may be brought more than one (1) year after the cause of action accrued.

No representation or agreement varying or extending the warranty and limitation of remedy provisions contained herein is authorized by ATI, and may not be relied upon as having been authorized by ATI, unless in writing and signed by an executive officer of ATI.

Unless otherwise agreed in writing by ATI, all designs, drawings, data, inventions, software and other technology made or developed by ATI in the course of providing products and services hereunder, and all rights therein under any patent, copyright or other law protecting intellectual property, shall be and remain ATI’s property. The sale of products or services hereunder does not convey any express or implied license under any patent, copyright or other intellectual property right owned or controlled by ATI, whether relating to the products sold or any other matter, except for the license expressly granted below.

In the course of supplying products and services hereunder, ATI may provide or disclose to Purchaser confidential and proprietary information of ATI relating to the design, operation or other aspects of ATI’s products. As between ATI and Purchaser, ownership of such information, including without limitation any computer software provided to Purchaser by ATI, shall remain in ATI and such information is licensed to Purchaser only for Purchaser’s use in operating the products supplied by ATI hereunder in Purchaser’s internal business operations.

Without ATI’s prior written permission, Purchaser will not use such information for any other purpose or provide or otherwise make such information available to any third party. Purchaser agrees to take all reasonable precautions to prevent any unauthorized use or disclosure of such information.

Purchaser will not be liable hereunder with respect to disclosure or use of information which: (a) is in the public domain when received from ATI; (b) is thereafter published or otherwise enters the public domain through no fault of Purchaser; (c) is in Purchaser’s possession prior to receipt from ATI; (d) is lawfully obtained by Purchaser from a third party entitled to disclose it; or (f) is required to be disclosed by judicial order or other governmental authority, provided that, with respect to such required disclosures, Purchaser gives ATI prior notice thereof and uses all legally available means to maintain the confidentiality of such information.