Digital F/T System

Compilation of Manuals

Digital F/T System

Installation and Operation Manual



Document #:9620-20-Digital F/T

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F/T Transducer

Six-Axis
Force/Torque Sensor System

Installation and Operation Manual



Document #: 9620-05-Transducer Section

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> Note
>
> Please read the manual before calling customer service. Before calling, have the following information available:
>
> 1. Serial number (e.g., FT01234)
> 2. Transducer model (e.g., Nano17, Gamma, Theta, etc.)
> 3. Calibration (e.g., US-15-50, SI-65-6, etc.)
> 4. Accurate and complete description of the question or problem
> 5. Computer and software information. Operating system, PC type, drivers, application software, and other relevant information about your configuration.
>
> If possible, be near the F/T system when calling.

How to Reach Us

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Glossary of Terms

Term	Definition
Calibration	The act of measuring a transducer's raw response to loads and creating data used in converting the response to forces and torques.
End-Effector	Any object attached to the robot flange (wrist) that serves a function. This would include robotic grippers, robotic tool changers, robotic crash protection, robotic rotary joint, robotic press tooling, compliance device, robotic paint gun, robotic deburring tool, robotic arc welding gun, robotic transgun, etc. End-effector is also known as robotic peripheral, robotic accessory, robot or robotic tool, end-of-arm (EOAT) tooling, or end-of-arm device.
F/T	Force/Torque.
F/T Transducer	Converts force and torque into an electrical signal.
Hysteresis	A source of measurement error caused by the residual effects of previously applied loads.
MAP	The Mounting Adapter plate (MAP) is the adapter plate that attaches to the fixed surface or robot arm.
Modbus	Modbus Protocol is a messaging structure used for master-slave/client-server communication between intelligent devices.
NI	National Instruments Corporation, the owner of the National Instruments and LabVIEW trademarks. (www.ni.com) Maker of Data Acquisition Cards used by ATI in force sensors.
Overload	The condition where more load is applied to the transducer than it can measure. This will result in saturation.
Saturation	The condition where the transducer or data acquisition hardware has a load or signal outside of its sensing range.
TAP	Tool Adapter plate (TAP) is the transducer surface that attaches to the load to be measured.
Tool Transformation	Mathematically changing the measurement coordinate system by translating the origin and/or rotating the axes.
Transducer	Transducer is the component that converts the sensed load into electrical signals.
UDINT	A data type representing an unsigned integer with 32 bits.
UINT	A data type representing an unsigned integer with 16 bits.
USINT	A data type representing an unsigned integer with 8 bits.

1. Safety

The safety section describes general safety guidelines to be followed with this product, explanation of the notification found in this manual, and safety precaution that apply to the product. More specific notification are imbedded within the sections of the manual where they apply.

1.1 Explanation of Notifications

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



DANGER: Notification of information or instructions that if not followed will result in death or serious injury. The notification provides information about the nature of the hazardous situation, the consequences of not avoiding the hazard, and the method for avoiding the situation.



WARNING: Notification of information or instructions that if not followed could result in death or serious injury. The notification provides information about the nature of the hazardous situation, the consequences of not avoiding the hazard, and the method for avoiding the situation.



CAUTION: Notification of information or instructions that if not followed could result in moderate injury or will cause damage to equipment. The notification provides information about the nature of the hazardous situation, the consequences of not avoiding the hazard, and the method for avoiding the situation.

NOTICE: Notification of specific information or instructions about maintaining, operating, installation, or setup of the product that if not followed could result in damage to equipment. The notification can emphasize but is not limited to specific grease types, good operating practices, or maintenance tips.

1.2 General Safety Guidelines

The customer should verify that the transducer selected is rated for maximum loads and moments expected during operation. Refer to F/T Transducer Manual (9620-05-Transducer Section—Installation and Operation Manual) found in Net F/T Installation and Operation Manual (9610-05-1022) or contact ATI Industrial Automation 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.

1.3 Safety Precautions



CAUTION: Do not remove any fasteners or disassemble transducers without a removable mounting adapter plate. These include Nano, Mini, IP-rated, and some Omega transducers. This will cause irreparable damage to the transducer and void the warranty. Leave all fasteners in place and do not disassemble the transducer.



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



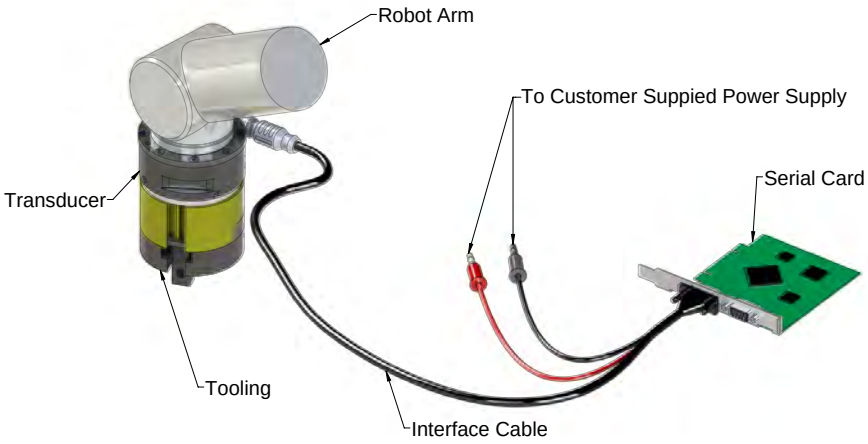
CAUTION: Do not exert excessive force on the transducer. The transducer is a sensitive instrument and can be damaged by applying force exceeding the single-axis overload values of the transducer and cause irreparable damage. Small Nano and Mini transducers can easily be overloaded during installation. Refer to the F/T Transducer manual (9620-05-Transducer Section) for specific transducer overload values.

2. Product Overview

The Digital F/T connects using a high-speed RS-485 interface cable. The transducer's six strain gage values are digitized and sent over the high-speed interface cable to the host computer through a Serial Card, where software provided by ATI or customer software calculates the F/T data.

NOTICE: The system requires a computer with a RS-485 interface capable of communicating at 1.25 megabits/second.

Figure 2.1—Product Overview



2.1 Serial Card

The Serial Card provides a RS-485 serial bus interface for ATI's RS-485 interface cable. The Serial Card interfaces with a user supplied computer. The serial card has to support a 1.25 MB baud rate.

2.2 Interface cable

A NET sensor to RS485 interface cable (9105-CF-MTS-DB9-X.X) is required to connect the transducer to the Serial Card and user power supply.

2.3 Power Supply

The Digital F/T system requires a customer supplied power supply with a voltage output of +12 VDC to +18 VDC and ability to supply 3 watts.

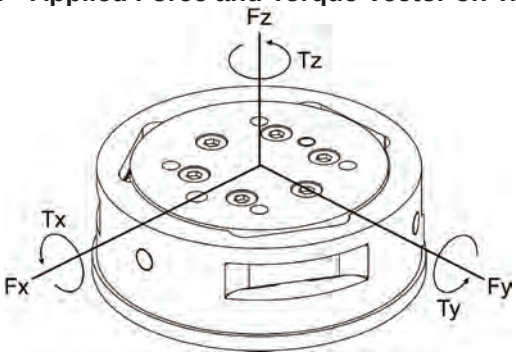
2.4 Transducers

The Digital F/T System connects directly to Net Transducers.

2.4.1 Transducer Functionality

The property of forces was first stated by Newton in his third law of motion: For every action there is always an opposed or 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 torque using Newton's third law.

Figure 2.2—Applied Force and Torque Vector on Transducer



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

$\sigma = E \cdot \varepsilon$

σ = Stress applied to the beam (σ is proportional to force)

E = Elasticity modulus of the beam

ε = Strain applied to the beam

NOTICE: 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:

$\Delta R = S_a \cdot R_O \cdot \varepsilon$

ΔR = Change in resistance of strain gage

S_a = Gage factor of strain gage

R_O = Resistance of strain gage unstrained

ε = Strain applied to strain gage

3. Installation

This section gives you information for the computer and system setup of the Digital F/T system.

3.1 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 the Digital F/T system:
  - Transducer
  - Interface cable (9105-CF-MTS-DB9-X.X)
  - Serial Card and its CD
  - ATI CD containing software, calibration documentation, and manuals.



CAUTION: The transducer and serial card are susceptible to damage from electrostatic discharge whenever they are not connected to a plugged-in computer. Do not touch the electronics or the connector pins when handling the transducer.

3.2 Installing the Serial Card

Install the serial card hardware and its accompanying software following the instructions included with the hardware.

3.3 Configuring the Serial Card for Use with the Digital F/T System

Before using the Digital F/T with a National Instruments RS-485 serial interface, it is necessary to properly configure the communication and driver settings of the card for a two-wire interface and to use the card's FIFO buffers effectively:

3.3.1 Two Wire Communications

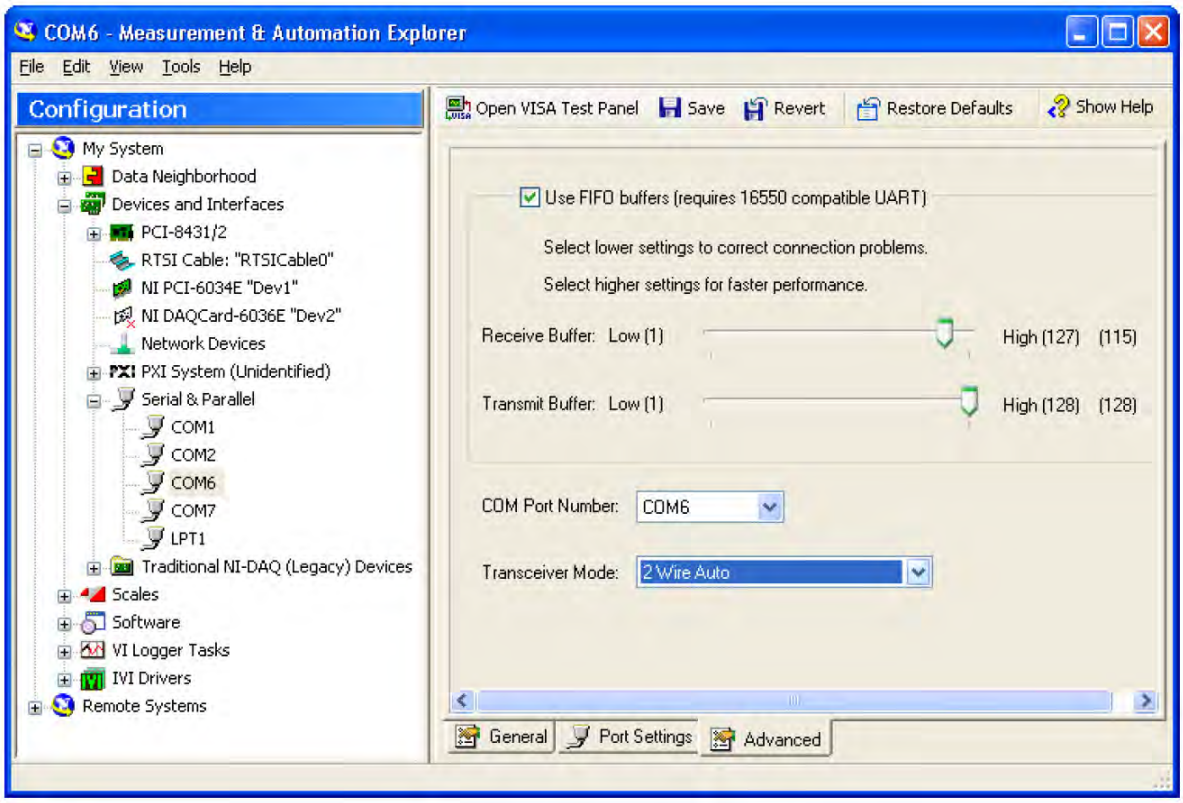
The Digital F/T control board uses a two-wire (half duplex) RS-485 connection. In this configuration, the same lines are used for transmitting and receiving data, therefore only one device at a time can transmit. Without proper configuration, this will also result in any data sent out by the master transmitter being echoed back to the master receiver, resulting in additional work for the software running on the master computer, as the echo will have to be read and discarded. National Instruments serial devices can be configured to automatically disable the receiver while transmitting to avoid receiving this echo.

3.3.2 FIFO Buffers

The National Instruments serial card has a hardware buffer that can hold up to 128 bytes. When the number of bytes in this hardware buffer reaches a configurable threshold, the card signals an interrupt so the client software can retrieve that data out of the hardware buffer. If the threshold level is set too close to the size of the hardware buffer, the client software may not finish pulling data out of the hardware buffer before the hardware buffer is completely filled up, resulting in lost data.

To configure the FIFO buffers and two wire communication, open Measurement and Automation Explorer for your serial card, select the serial device the sensor is to be connected to, open the "Advanced" properties panel, select the "2 Wire Auto" method in the "Transceiver Mode" pull down menu and set the FIFO buffer "Receive Buffer" threshold to a value lower than the maximum. The following example uses a threshold size of 64, which should work for most uses, but you can set the value higher or lower if you find your custom software has very specific timing requirements.

Figure 3.1—Measurement and Automation Explorer



In this configuration, the National Instruments serial device will disable the receiver while transmitting by default. If you have other software which requires the echo to be present in two-wire mode, or uses a four-wire (full duplex) connection, you will have to use one of the following methods:

- Use another serial interface for that software.
- Change the default Transceiver Mode every time you switch between the ATI software and your other software.
- Rewrite the other software to manually configure the NI serial interface for the correct mode when it is started. The NI-Serial help file details how manually configure the NI serial interface in the section "RS-485 Transceiver Control".
- Write custom software for the Digital F/T that handles the echoed characters.
- Save MAX settings and close program.

3.4 Installing the Interface cable

Power down the computer with the serial card installed, ensure that computer in still plugged in. Before the transducer is installed, install the interface cable to the transducer and customer supplied power supply while set out on a clean work surface. Connect the interface cable to the transducer and power supply then to the serial card. After installing the interface cable the computer and power supply can be powered up.

CAUTION: The transducer and serial card are susceptible to damage from electrostatic discharge whenever they are not connected to a plugged-in computer. Do not touch the electronics or the connector pins when handling the transducer.

CAUTION: Do not exert excessive force on the transducer. The transducer is a sensitive instrument and can be damaged by applying force exceeding the single-axis overload values of the transducer and cause irreparable damage. Refer to the F/T Transducer Installation and Operation Manual (9620-05-Transducer Section) for transducer overload values.

3.5 Installing the software

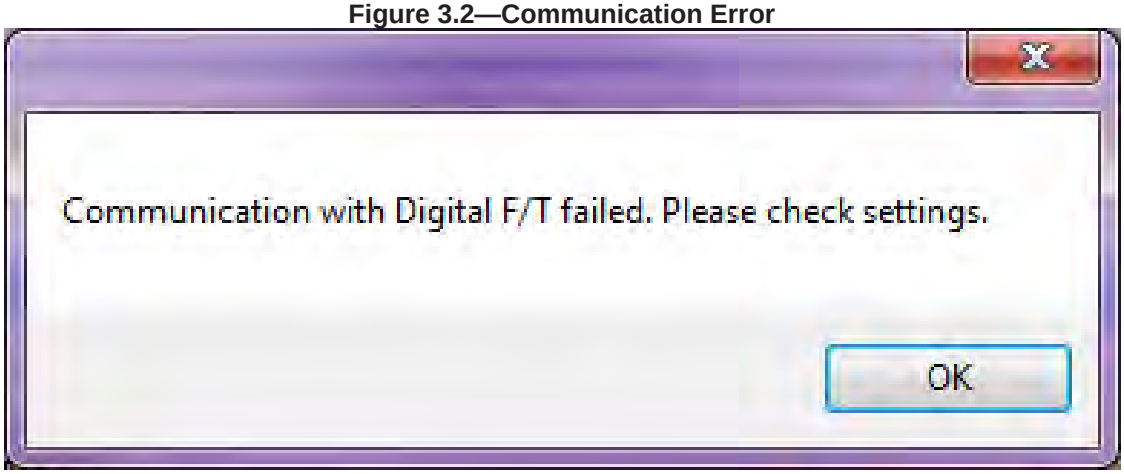
Install the ATI F/T software by inserting the CD into your computer. The installation program should start automatically. If it does not start automatically, you will need to run SETUP.EXE found in the root directory of the CD. Follow the installation instructions given by the program. The ATI F/T software CD contains software and calibration data that your computer uses to convert the transducer readings into usable force and torque output. It also contains Microsoft Windows drivers, sample programs, and detailed help files. The most recent release of the software can be downloaded from *http://www.ati-ia.com/Library/download.aspx.*

3.6 Demo Quick Start Guide:

The demo program monitors the raw strain gage values for saturation, when it is running. This will give feedback to help to avoid overloads and causing irreparable damage to the transducer. Smaller transducers can easily be irreparably damaged by applying small loads using tools (moment arm increases applied loads) when mounting the transducer.

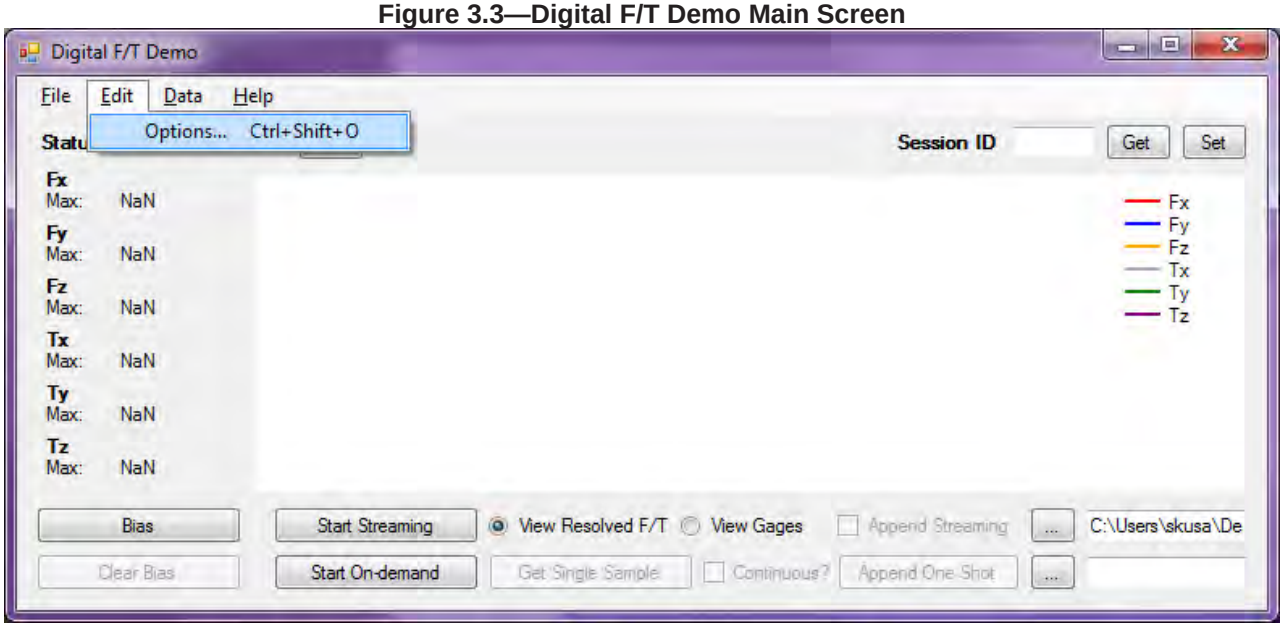
NOTICE: Each transducer has a maximum measurement range and a maximum overload capacity. **Exceeding the transducer's overload capacity can cause permanent damage.** Smaller transducers have lower overload capacities. Tx and Ty are usually the easiest axes to accidentally overload. Strain gage saturation is the first indication that you are approaching a mechanical overload condition, and saturation always causes inaccurate F/T data, so it is critical that you monitor the F/T system for strain gage saturation.

Figure 3.2—Communication Error



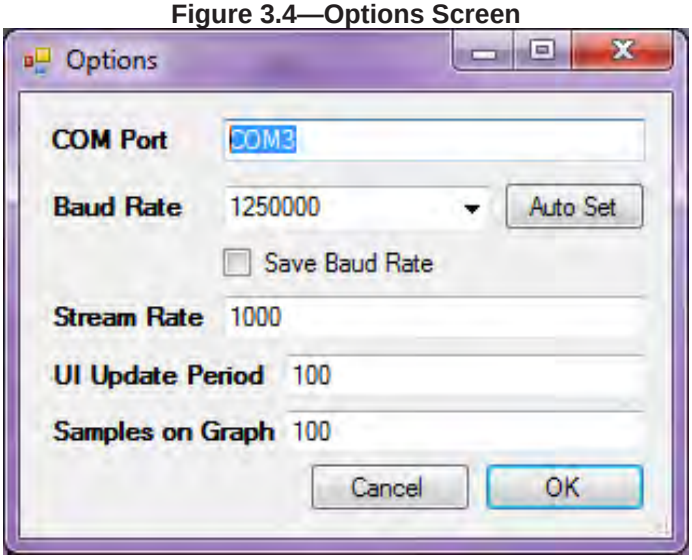
Open the demo software. The first time you run it, it will probably not be configured to talk to the correct port that you have connected the transducer to, and you will receive this message:

Figure 3.3—Digital F/T Demo Main Screen



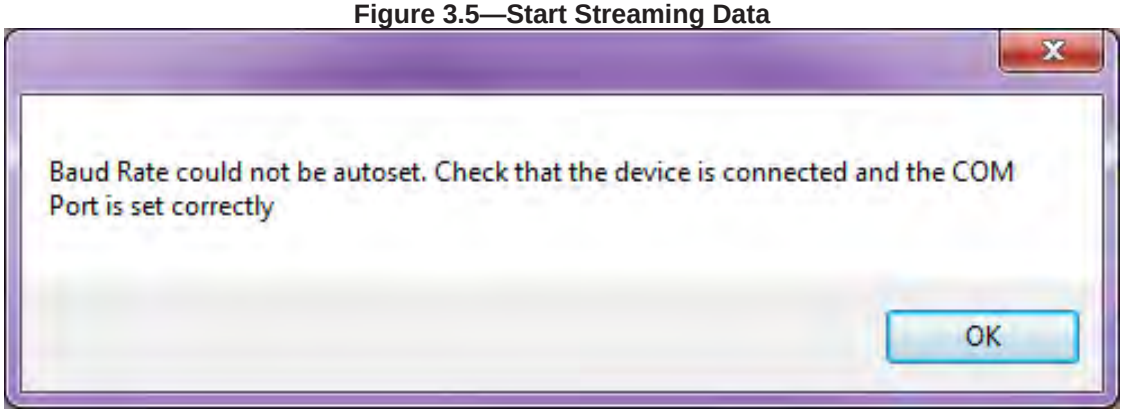
Open the "Edit"->"Options" menu item to enter the settings screen.

Figure 3.4—Options Screen



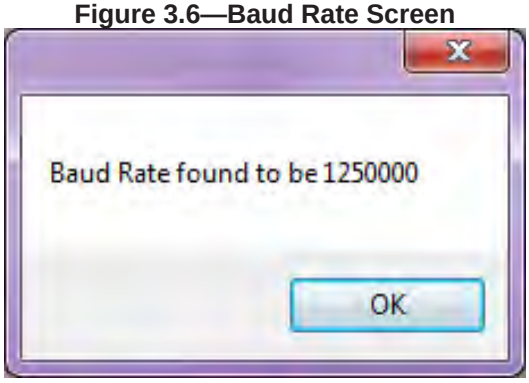
On the options screen, enter the name of the COM port you have the transducer connected to. If you are not sure which port on the serial card you have connected the transducer to, you may have to try more than one port name before you find the correct port name.

Figure 3.5—Start Streaming Data



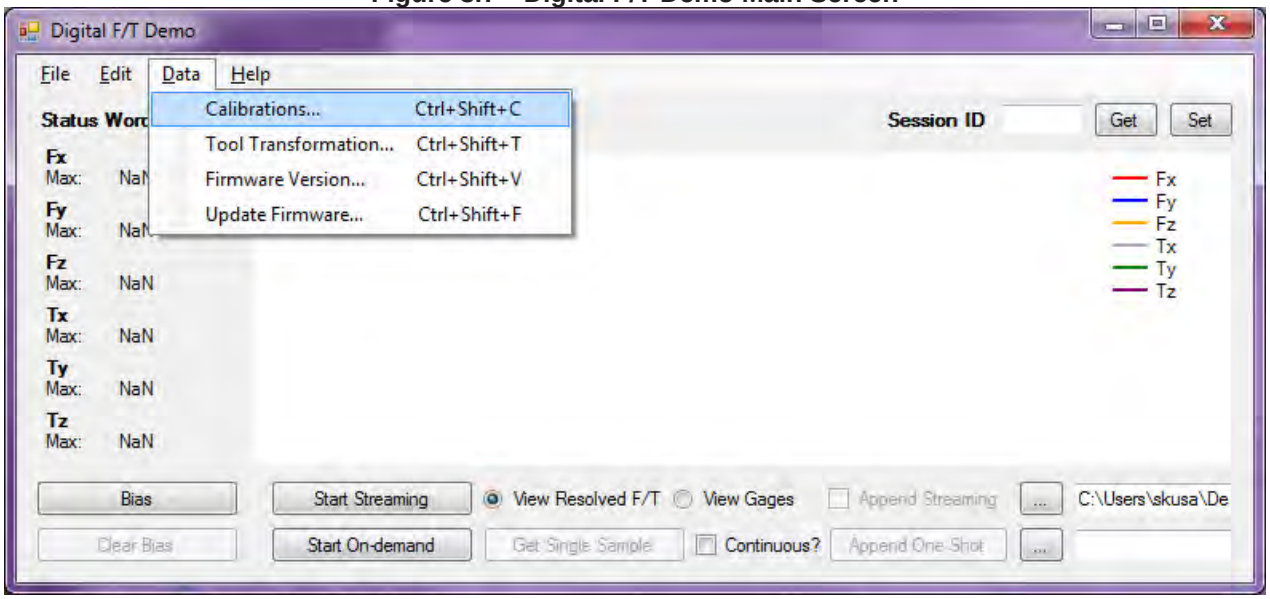
To test if the port you have entered is correct, press the "Auto Set" button next to the "Baud Rate" field. If you have entered the COM port wrong, or the sensor is disconnected or powered off, you will receive this message:

Figure 3.6—Baud Rate Screen



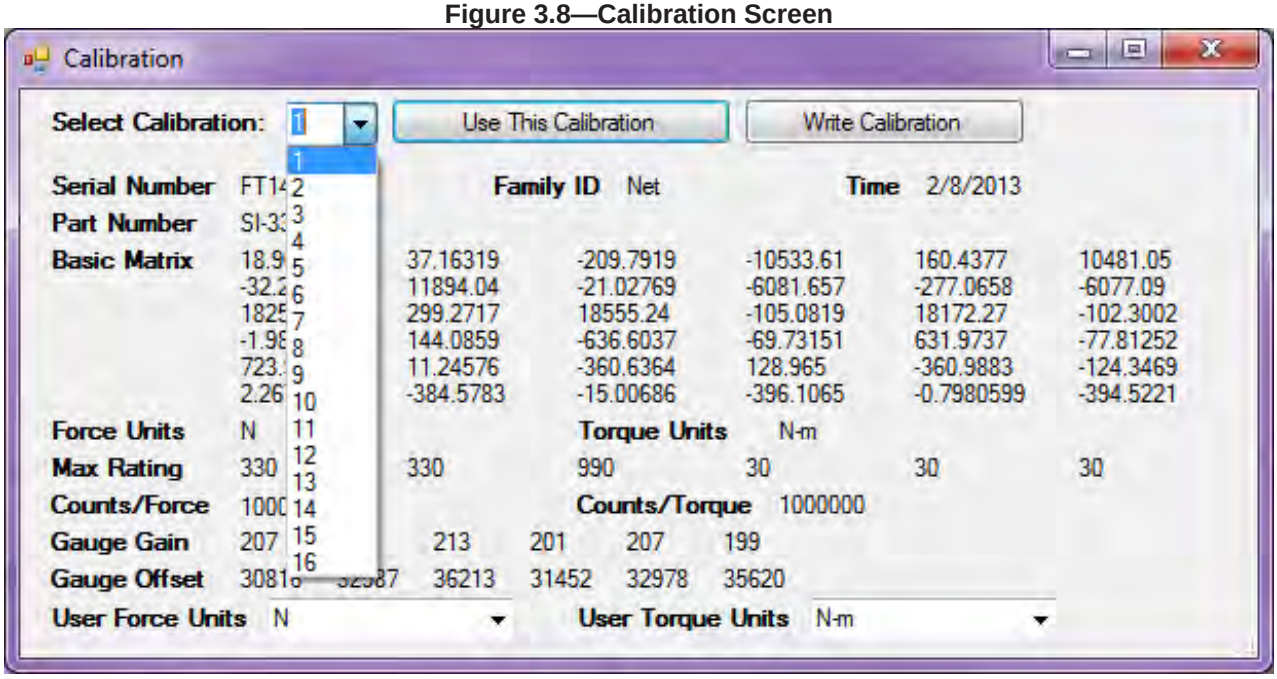
If the sensor is powered on and connected to the port you have entered, you will receive a success message like this:

Figure 3.7—Digital F/T Demo Main Screen



Press OK on the options screen to return to the main screen. Open the "Data"->"Calibrations" menu item to select the calibration:

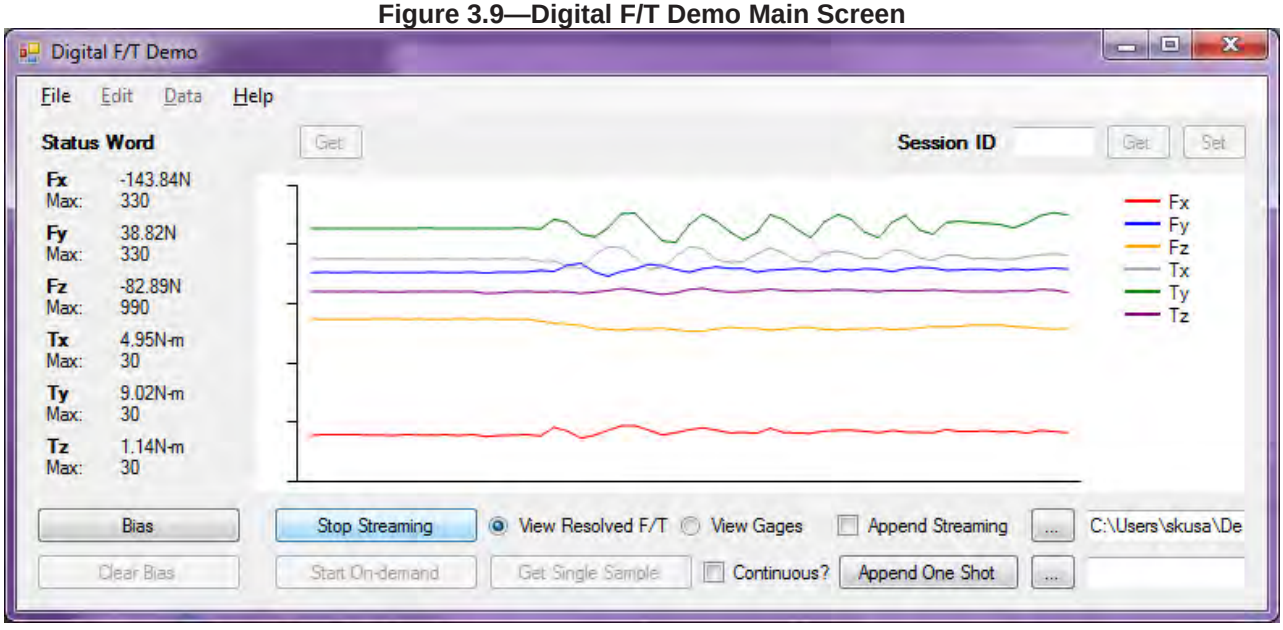
Figure 3.8—Calibration Screen



One the calibration screen, select the calibration index for the calibration you wish to activate from the "Select Calibration" pulldown. If you did not order multiple calibrations on your sensor, only the first calibration will have any data:

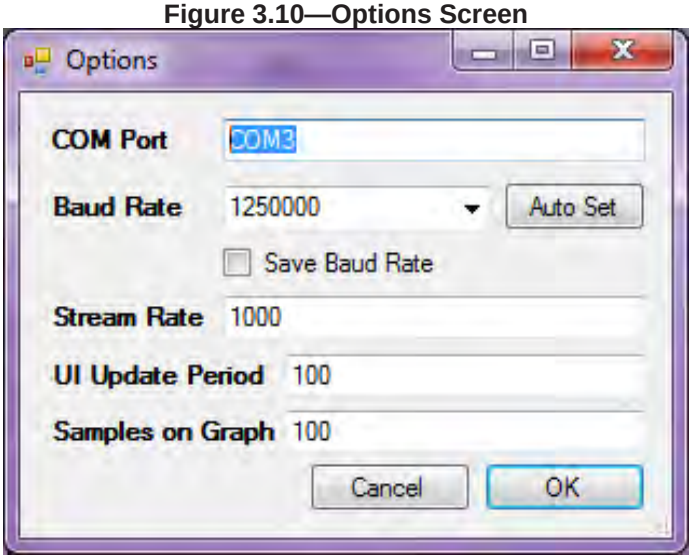
Once you have selected the calibration you wish to activate, click the "Use This Calibration" button to close the calibration screen and return to the main form.

Figure 3.9—Digital F/T Demo Main Screen



Click the "Start Streaming" or "Start On-Demand" button to start receiving data. If you press the "Start On-Demand" button, you can either press "Get Single Sample" when you wish to read a sample, or check the "Continuous" checkbox to have the demo automatically request data at the UI update period. Once you are receiving data, apply a gentle load to the sensor, being careful not to overload the sensor, to verify that you are able to read changes in the F/T data.

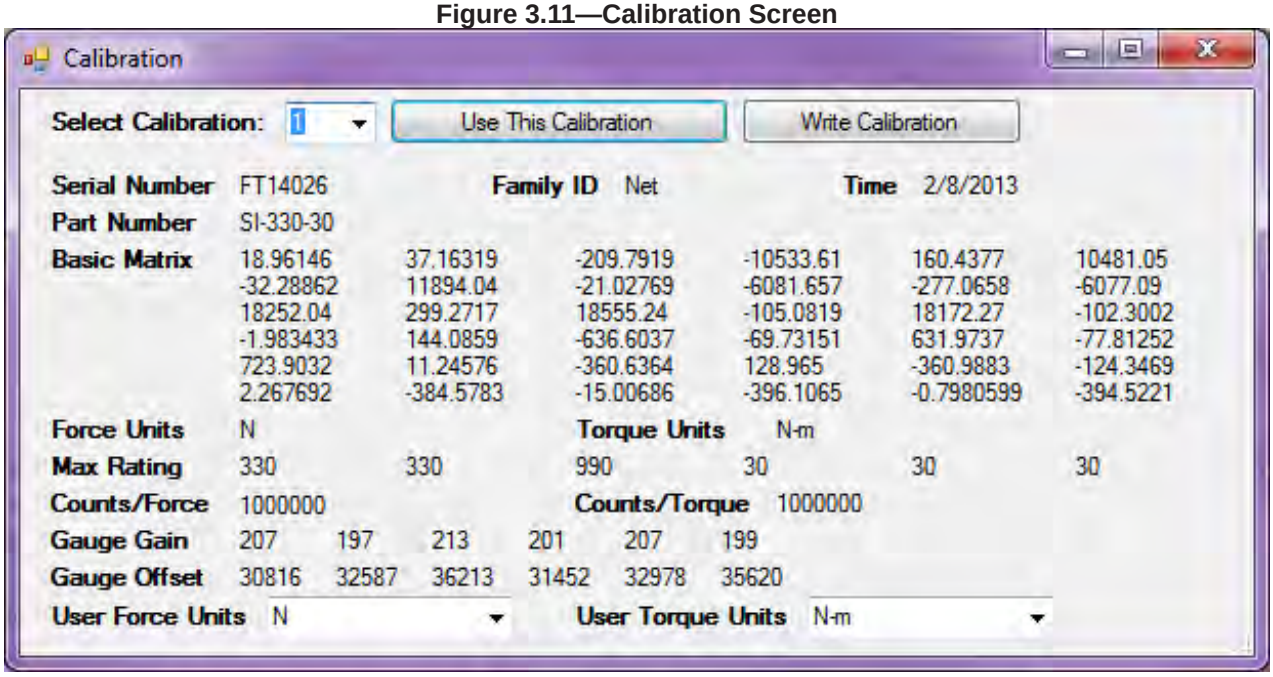
Figure 3.10—Options Screen



Option Screen Controls:

- COM Port: The name of the serial port the sensor is attached to.
- Baud Rate: The baud rate the sensor is configured for. Can be changed by the user.
- Auto Set: Will automatically scan all the available baud rates to see if the sensor is connected.
- Save Baud Rate: This checkbox must be checked before changing the baud rate in order for the new baud rate to be stored permanently during a power cycle.
- Stream Rate: The rate to configure the Digital F/T to stream data at. The maximum possible rates are 7000 at 1250000 baud, 500 at 115200 baud, and 50 at 19200 baud.
- UI Update Period: The number of milliseconds between UI updates. If “On-demand” sampling is selected, this is also the rate at which on-demand samples are requested from the sensor.
- Samples On Graph: The number of samples to keep in the history on the main screen graph.

Figure 3.11—Calibration Screen

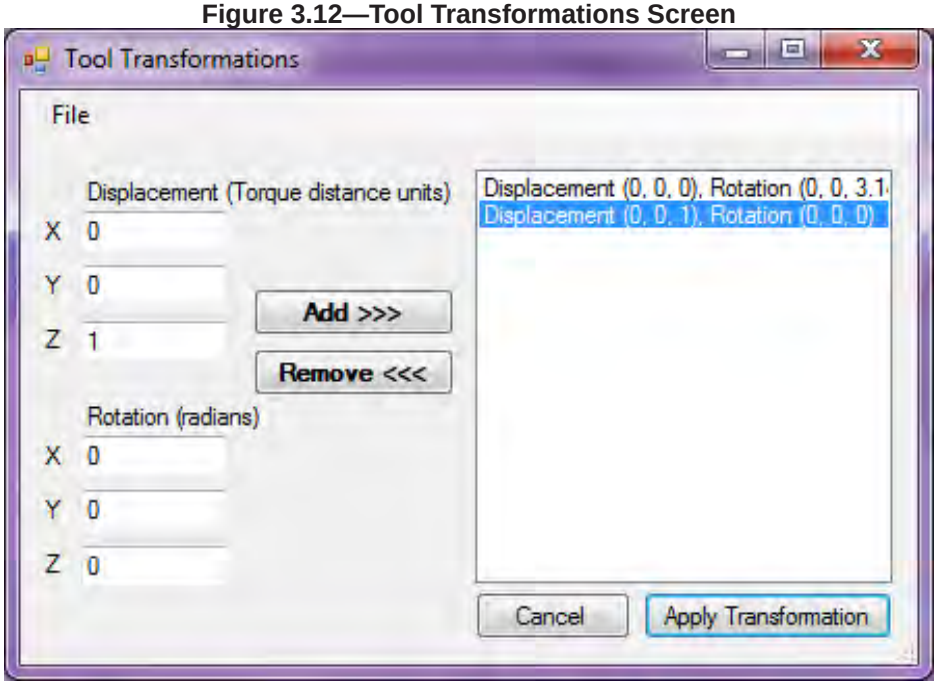


Calibration screen, available from the “Data”->”Calibrations” menu item on the main form.

Calibration Screen Controls:

- Select Calibration: This pulldown allows you to select the calibration to load into the sensor. If you did not order multiple calibrations for your sensor, only the first calibration will have any useful data.
- Use This Calibration: Activates the selected calibration and User Force and Torque Units and closes the form.
- Write Calibration: Prompts user for a calibration file, which can be loaded into the selected calibration index. This should only be used if the calibration data stored in the sensor becomes corrupted, and only the calibration file or files which were included on the CD with the sensor should be written to the sensor. Writing any calibration data that was not provided by ATI for your specific sensor will render the system uncalibrated.
- User Force Units: The force units to display on the main screen.
- User Torque Units: The torque units to display on the main screen.

Figure 3.12—Tool Transformations Screen



Tool Transformations Screen, available from "Data"->"Tool Transformations" menu item on main screen:

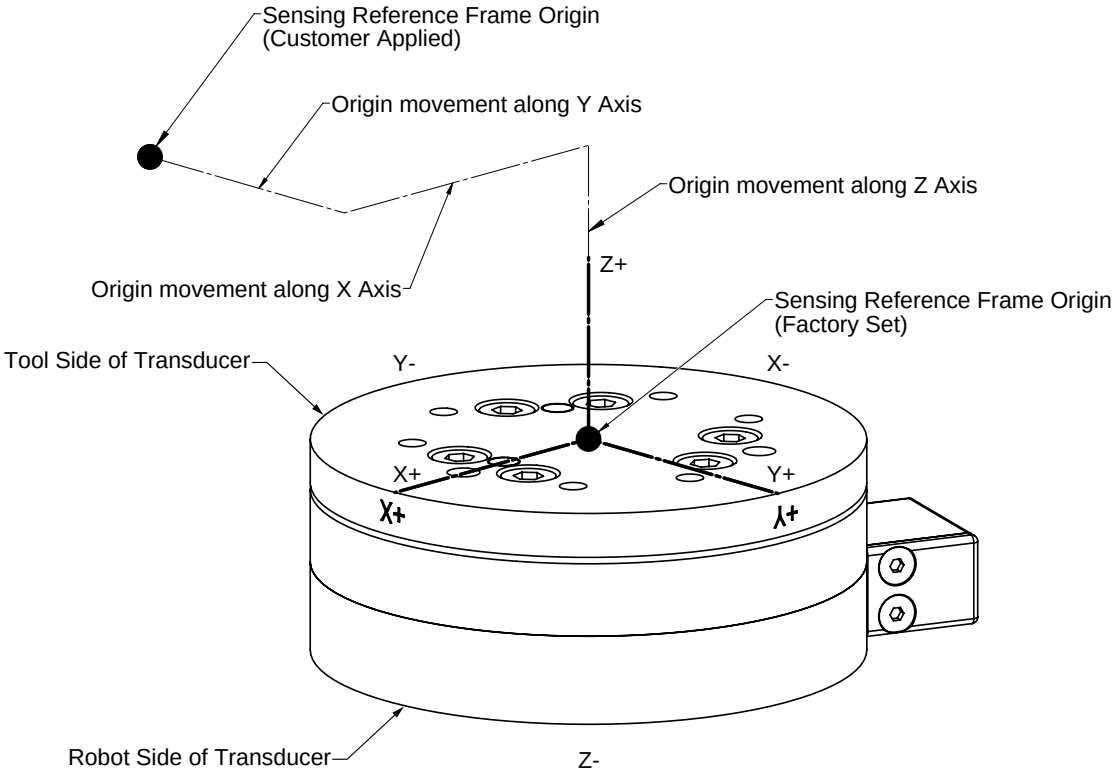
The tool transformation allows you to enter a series of tool transformations in order to measure the forces and torques acting at a point other than the origin of the sensor. The tool transformations are applied in the order you enter them, so you can determine, for example, if rotations occur before displacements by entering a tool transformation with only rotations before the rotation with displacements. If you specify both rotations and displacements within a particular tool transformation, displacements are performed first, in the order X, Y, Z, then rotations are performed, in the order X, Y, Z.

Tool Transformations Screen Controls:

- Displacement X, Y, and Z: The displacement along each axis is measured in the distance component of the calibration's torque units, so if your sensor was calibrated to use Newton-meters as the torque unit, the displacement is measured in meters.
- Rotations X, Y, and Z: The rotation about each axis, in radians.
- Add: Adds the current tool transformation to the transformation queue.
- Remove: Removes the highlighted transformation from the queue, and fills the displacement and rotation controls with the values of the removed transformation.
- Cancel: Returns to the main form without applying any changes you made to the transformation queue.
- Apply Transformation: Applies transformations in the queue and returns to the main form.

  Displacement allows the customer to move the sensing reference frame origin along the X, Y, and Z axes. Displacement should be calculated and values should be entered before rotation. Displacement is measured in units which are set as either Nm or in-lbs. on the Calibration Screen. Refer to *Figure 3.8*.

Figure 3.13—Displacement of Sensing Reference Frame Origin



Rotation allows the customer to rotate the axes while maintaining the frame origin. *Figure 3.14* shows the direction of rotation about the axis. Rotation is measured in radians.

When a value is entered for X, Y, or Z the following will result:

- X value will rotate Y and Z about X in the direction shown (see *Figure 3.14*).
- Y value will rotate X and Z about Y in the direction shown.
- Z value will rotate X and Y about Z in the direction shown.

In a tool transformation, the order of the rotations matters. The X-rotation occurs first, followed by rotation about Y (in its new orientation), then Z. Therefore, you MUST express your rotations in this order.

Figure 3.14—Rotating Reference Frame

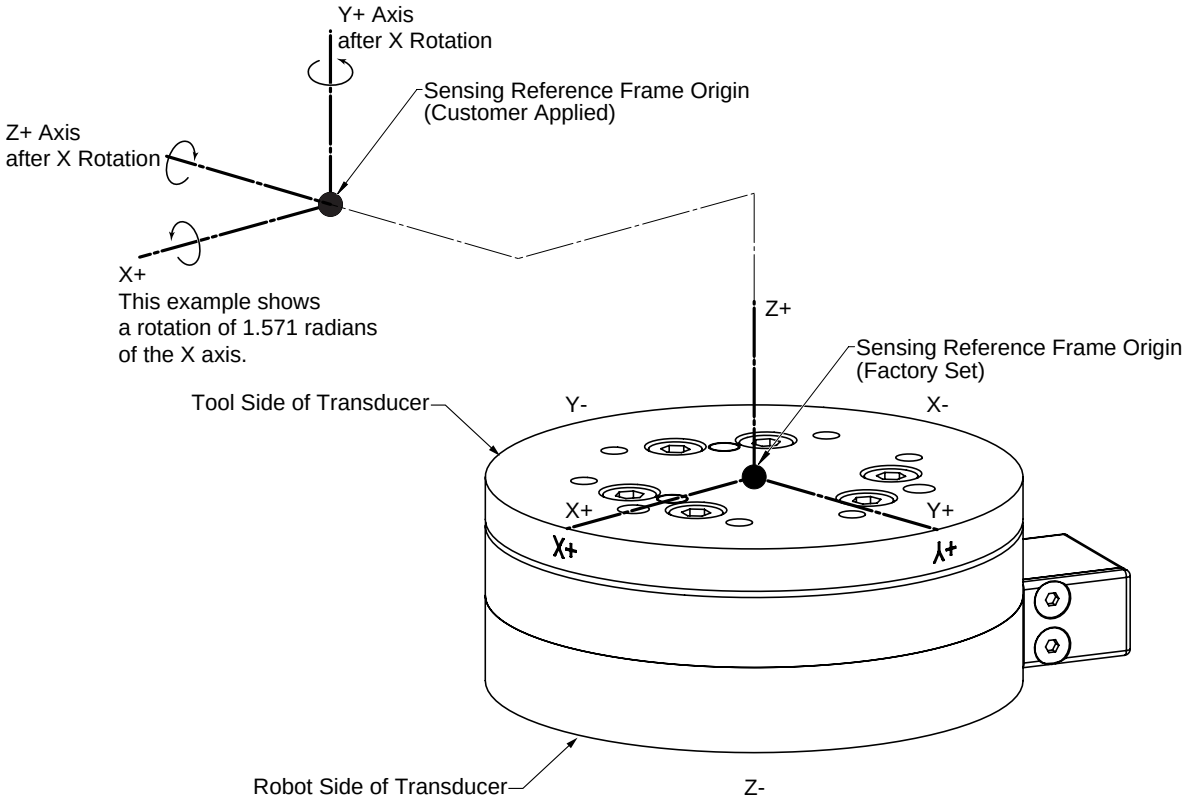
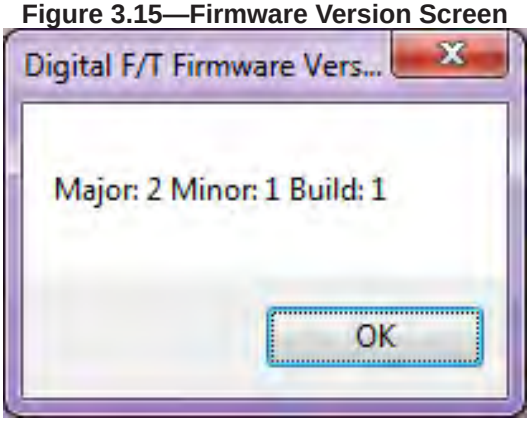


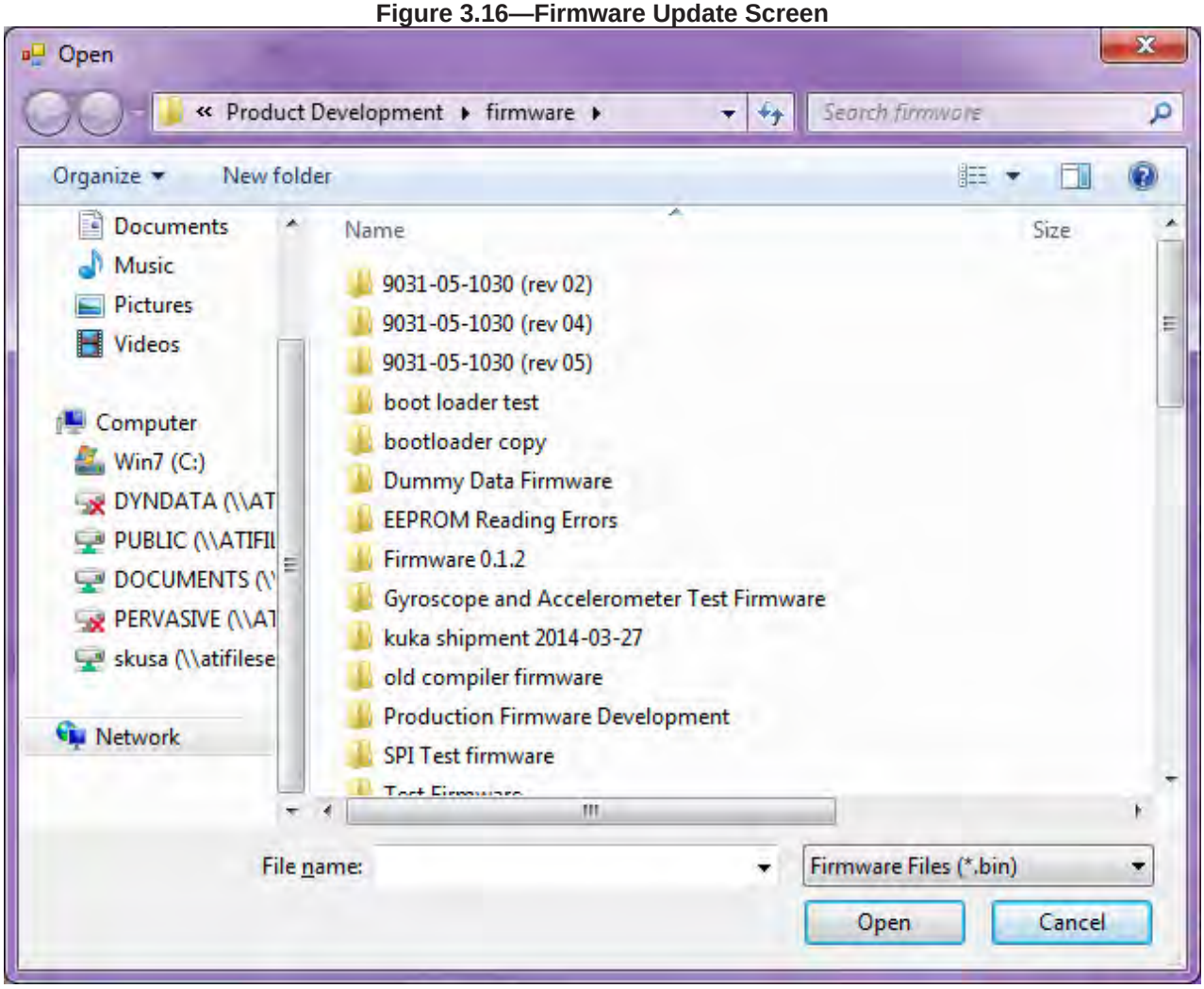
Figure 3.15—Firmware Version Screen



Firmware Version screen, available from "Data"->"Firmware Version" menu item on the main form.

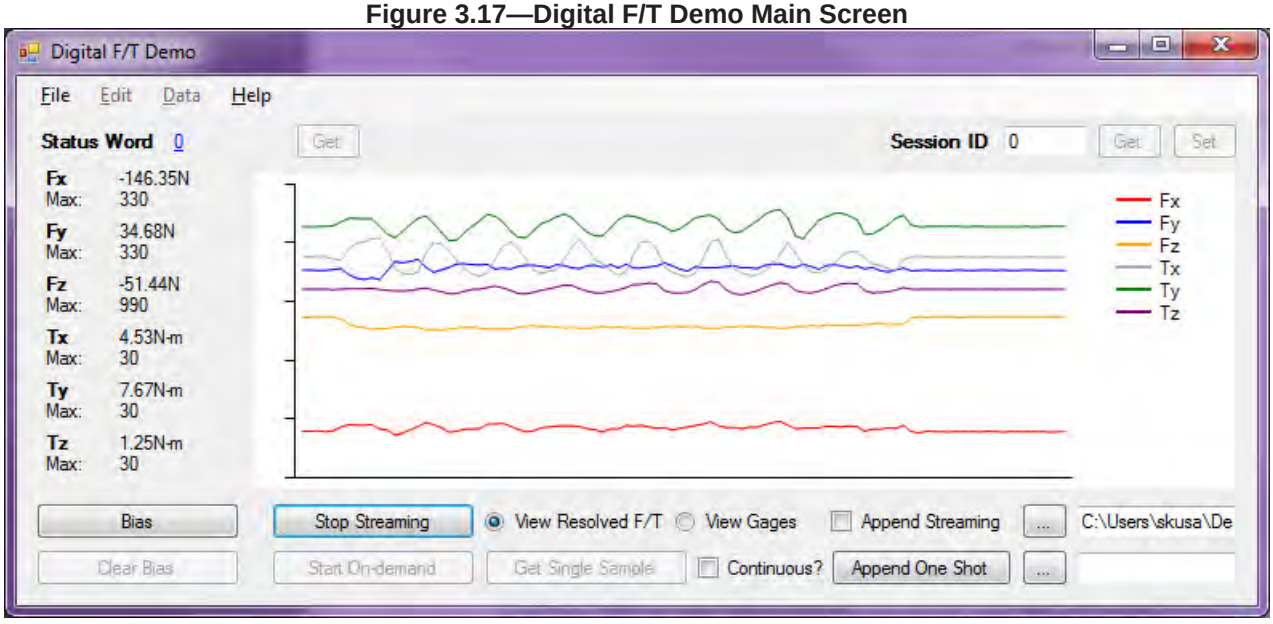
This screen shows the current firmware installed on the sensor. Press the OK button to dismiss and return to the main form.

Figure 3.16—Firmware Update Screen



You can use this to update the firmware on the Digital F/T. Only firmware files distributed from ATI for your specific device should be uploaded. The use of any other kind of file will render the sensor permanently inoperable.

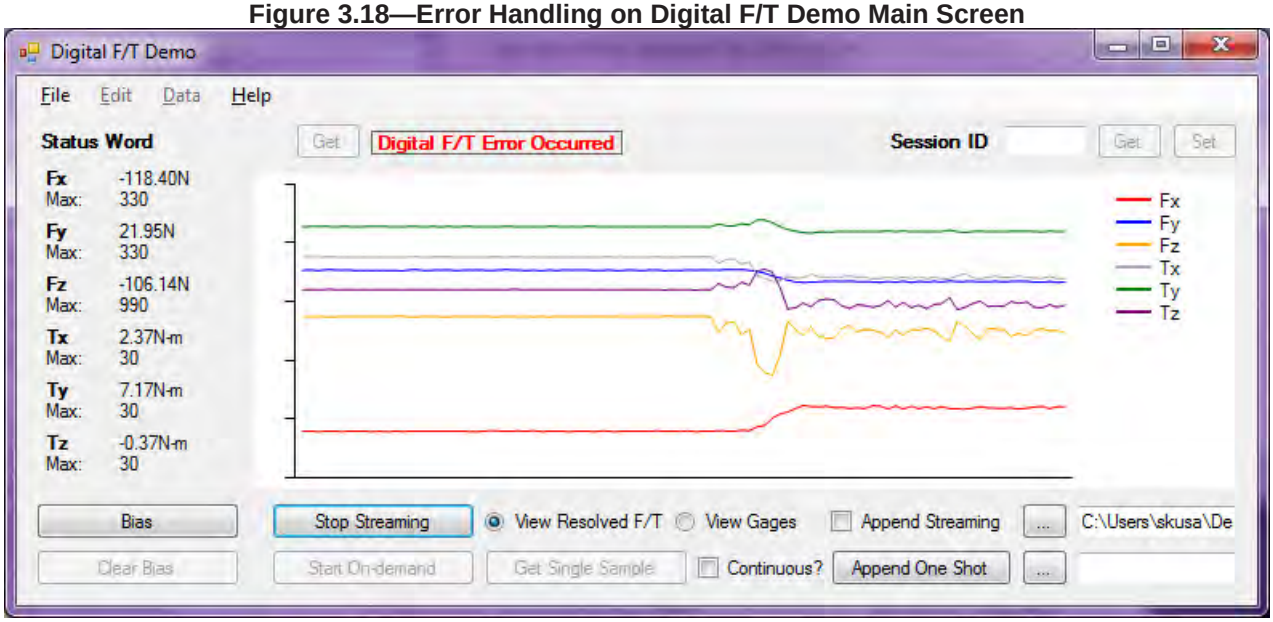
Figure 3.17—Digital F/T Demo Main Screen



Main Screen Controls:

- Bias: Takes the current reading and subtracts it from all future readings, using the current load as a tare.
- Clear Bias: Removes all previous tare points, so the sensor readings are raw outputs.
- Start Streaming/Stop Streaming: Toggles the streaming output of the sensor. When streaming, the sensor sends data at the frequency specified in the Streaming Rate field on the Options screen.
- Start On-demand/Stop On-demand: Toggles the on-demand output of the sensor. When the sensor is in on-demand mode, it outputs data only in response to requests from the user. This is useful for getting data at exact points in time.
- View Resolved F/T / View Gages: Switches the display and collected data between force/torque values and strain gages. The strain gage data is useful for diagnostic purposes if you ever have to call ATI Industrial Automation for support.
- Get Single Sample: When in on-demand mode, you can press this button to read a single sample and display it. The demo will not read another sample until you press the Get Single Sample button again, or activate another mode of reading data by using the Start Streaming button or the “Continuous?” checkbox.
- Continuous? : When in on-demand mode, the continuous checkbox causes the demo to request samples every time the UI updates.
- Append Streaming: When in streaming mode, activate this checkbox to append streaming data samples read from the sensor to the file specified next to the Append Streaming checkbox.
- Append One Shot: When in streaming or on-demand mode, this button is available to append only the most recent sample to the file specified next to the Append One Shot button.
- Status Word – Get button: Reads the current status word from the sensor and displays it. Clicking on the status word will bring up a window describing the meaning of any error codes present in the status word.
- Session ID – Get Button: Reads the current session ID.
- Session ID – Set Button: Write the value in the session ID field to the sensor’s session ID. The session ID is useful in automated applications to make sure the sensor has not been reset.

Figure 3.18—Error Handling on Digital F/T Demo Main Screen



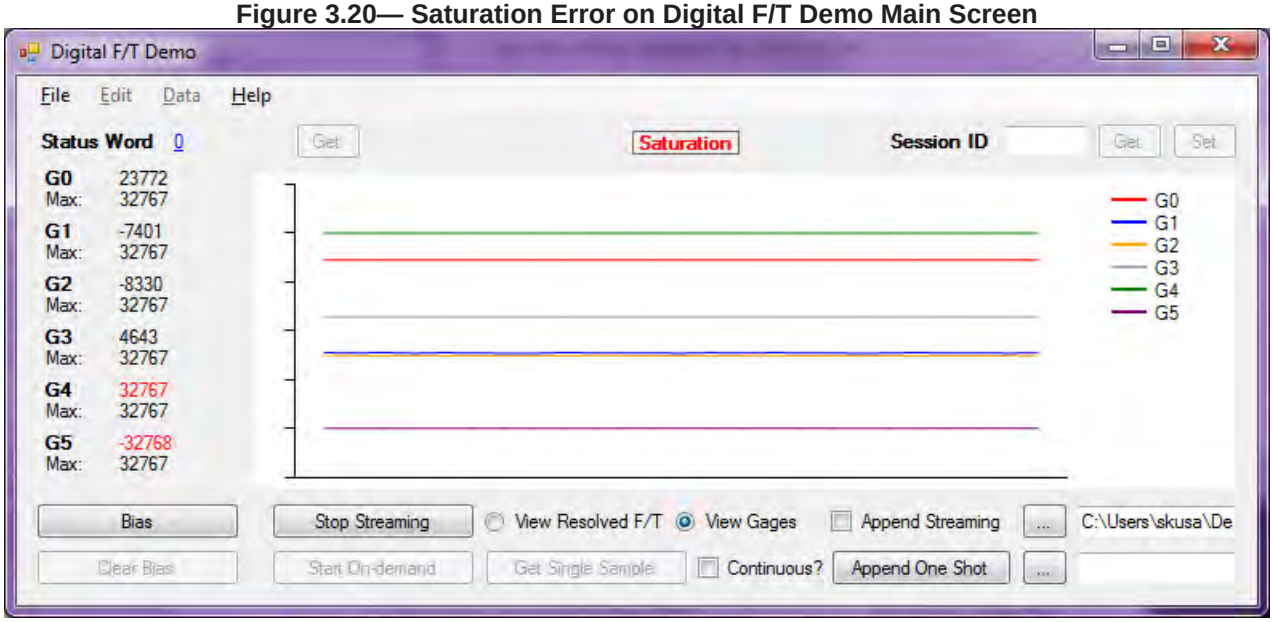
The text "Digital F/T Error Occurred" appears when a sample is read that contains an error bit. To determine the actual error code, you must stop streaming or on-demand mode and click the Status Word – Get button:

Figure 3.19—Firmware Version Screen



Once you have read the Status Word, clicking on the code will bring up a window telling you what the error code means:

Figure 3.20— Saturation Error on Digital F/T Demo Main Screen



Saturation occurs whenever one or more gages is saturated. You can determine which gages are saturated by selecting "View Gages" and looking for gage values that are either 32767 or -32768 counts. These gage values will be highlighted in red.

NOTICE: When any strain gage is saturated or otherwise inoperable, **all transducer F/T readings are invalid.**

3.7 Installing the Transducer

Information on transducer installation can be found in the F/T Transducer Manual, 9620-05-Transducer Section, *F/T Transducer Installation, Operation, and Specification Manual*.

4. Operation

This section gives you information for the operation of the Digital F/T system.

4.1 Multiple Calibrations

Some transducers have multiple calibrations, usually to allow the transducer to have larger range in one instance and finer resolution in another. Changing to another calibration is done by loading the new calibration. This is done in the demo software through the *Data/Calibration* menu item.

NOTICE: When any strain gage is saturated or otherwise inoperable, **all transducer F/T readings are invalid.**

4.2 Detecting Sensitivity Changes

Sensitivity checking of the transducer can also be used to measure the transducer system‘s health. This is done by applying known loads to the transducer and verifying the system output matches the known loads. For example, a transducer mounted to a robot arm may have an end-effector attached to it.

If the end-effector has moving parts, they must be moved in a known position. Place the robot arm in an orientation that allows the gravity load from the end-effector to exert load on many transducer output axes.

Record the output readings.

Position the robot arm to apply another load, this time causing the outputs to move far from the earlier readings.

Record the second set of output readings.

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. Maintenance

This section gives you information for the maintenance of the Digital F/T system.

5.1 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 jacket 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 transducers can become clogged with particles and will become no longer calibrated or even damaged.

5.2 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 recommends annual calibrations, especially for applications that frequently cycle the loads applied to the transducer.

5.3 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 (see 9620-05-Transducer Section—Installation and Operation Manual).

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 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. Although this misrepresents the actual performance of the transducers, it results in a close (and always conservative) estimate.

6. Troubleshooting

Bad data from the transducer's strain gages can cause errors in force/torque readings. These errors can result in problems with transducer biasing and accuracy. Listed below are the basic conditions of bad data. Use this to troubleshoot your problem.

Symptom	Cause	Resolution
Noise	Noise can be caused by mechanical vibrations and electrical disturbances, possibly from a poor ground. It can also indicate component failure within the system.	Make sure that the DC supply voltage for the Digital F/T has little to no noise superimposed.
Drift	Drift is caused by temperature change, mechanical coupling, or internal failure. Mechanical coupling is caused when a physical connection is made between the tool plate and the transducer body (i.e., filings between the tool adapter plate and the transducer body).	Check for debris around transducer.
Hysteresis	Hysteresis is caused by mechanical coupling (explained in Drift section) or internal failure.	Check for debris around transducer.

If, after configuring the NI Serial device for two-wire RS485 mode, the Digital FT does not respond to commands, it is possible you have encountered a bug in the National Instruments driver software whereby the correct transceiver mode is not always activated. Make sure you have installed the latest NI Serial driver software from *www.ni.com*. If you are experienced with using an oscilloscope, it will be helpful to make sure that the transmit lines on the NI Serial device are actually activating when the software tries to send data. If the card is transmitting correctly, but the sensor is not responding, contact ATI for support with the Digital FT. If the card does not transmit when in "2 Wire Auto" transceiver mode, and you have the latest NI Serial software, try putting the card and NI Serial software in another computer and attempting to use it in the other computer. If it still does not work, you may have to contact National Instruments for support with the NI Serial device.

7. Specifications

7.1 Storage and Operating Conditions

Table 7.1—Temperature

Component	Storage Temperature, °C	Operating Temperature, °C
Digital F/T	-40 to +100	-20 to +70
Transducer	See Transducer Section Manual *http://www.ati-ia.com/app_content/documents/9620-05-Transducer%20Section.pdf*	See Transducer Section Manual *http://www.ati-ia.com/app_content/documents/9620-05-Transducer%20Section.pdf*

8. Programming Information

This section contains programming information about the Digital F/T System.

8.1 Physical Serial Interface

The interface cable by default runs at 1.25 megabaud. The baud rate can also be set to 115,200 or 19,200, although this will result in slower streaming output rates.

Table 8.1—Streaming Output Rates

Baud Rate	Streaming Sample Speed
1,250,000	7000 Hz
115,200	500 Hz
19,200	100 Hz

The interface cable uses a two-wire half-duplex configuration – the sensor cannot receive bytes while it is writing. Therefore, to stop streaming, it is necessary to send a jamming sequence of at least 14 characters, which is one byte longer than a streaming sample.

The transducer uses a 9-bit format with 8 bits of data and the last bit used for 'even' parity.

8.2 Data Types

This section gives the definitions for the different data types used.

Table 8.2—Data Type Definitions

Term	Definition
float	IEEE 754-2008 binary32 (aka 'single') floating point number.
int16	16-bit signed integer
int32	32-bit signed integer
uint8	8-bit unsigned integer
uint16	16-bit unsigned integer

8.3 Modbus Interface

The Modbus interface follows the timing and checksum rules specified in the "Modbus Over Serial Line" specification at *http://www.modbus.org/specs.php*.

The analog board runs as a Modbus slave until the 'start streaming' custom Modbus command is sent, after which it starts streaming data until it receives a 14-byte jamming sequence (the jamming sequence can consist of random character values).

If you are writing your own Modbus interface to the Digital F/T, you must support the "Read Holding Registers" (Section 6.3 in the "Modbus Protocol Specification" v1.1b) command and one or both of the "Write Single Register" (Section 6.6) and "Write Multiple Registers" (Section 6.12) commands. You must also be able to send Custom (aka "User-Defined") function codes.

Each serial Modbus packet has the following structure (taken from Section 2.3 of the "Modbus Serial Line Protocol and Implementation Guide" v1.02):

Address Field (always 10 for Digital F/T	Function Code	Data (may be up to 252 bytes and contain a structure with multiple fields)	CRC High Byte	CRC Low Byte

The sensor uses a fixed Modbus slave address of 10, and only communicates using the binary "RTU" serial Modbus packet format. The CRC calculation for the binary RTU mode, including sample source code, is described in Section 6.2.2 of the "Modbus Serial Line Protocol and Implementation Guide" v1.02.

8.3.1 Custom Service Codes

Each custom service code uses the same serial Modbus command and response format:

Slave Address (10)	Function Code Command: The function code to execute. Response: The function code executed (same as command).	Data	CRC High Byte	CRC Low Byte

Table 8.3—Custom Service Codes

Code	Description	Data	Response
106	Unlock storage command: Use this function code before writing gains and offsets for selected calibration.	1 data byte – 0xaa to unlock, 0x18 to lock.	A Modbus packet with one data byte of value 1 for successful execution, or a standard Modbus error packet if unsuccessful.
70	Start strain gage streaming	1 data byte with value 0x55.	A Modbus packet with one data byte with value 1 for successful reception, or a standard Modbus error packet if unsuccessful. After successful reception of a command to start strain gage streaming, the sensor will delay for 20 ms to give the client time to disable the Modbus protocol. After this 20 ms delay, the sensor will begin sending out streaming data samples that are not encapsulated in Modbus frames.

8.3.2 Important Holding Register Addresses

Addresses are base 0:

Table 8.4—Important Holding Register Addresses

Address	Description
0x00e3	Calibration 1
0x01a3	Calibration 2
0x0263	Calibration 3
0x0323	Calibration 4
0x03e3	Calibration 5
0x04a3	Calibration 6
0x0563	Calibration 7
0x0623	Calibration 8
0x06e3	Calibration 9
0x07a3	Calibration 10
0x0863	Calibration 11
0x0923	Calibration 12
0x09e3	Calibration 13
0x0aa3	Calibration 14
0x0b63	Calibration 15
0x0c23	Calibration 16
0x001D	Status Word
0x0000-0x0005	Active Gain pots
0x0006-0x000B	Active Offset DACs
0x000C	Optional “Session ID” register
0x001F	Baud Rate Register. Values: **Register Value** / **Baud Rate** 0 / 1,250,000 1 / 19,200 2 / 115,200 The value is only stored to non-volatile memory if bit 0 of the “Mode” register is a ‘1’. Baud rate changes take effect immediately.
0x001E	Mode Register. Set bit 0 of this register to a ‘1’ in order to save changes to the baud rate. The mode bit must be set before the baud rate is changed in order to save the new baud rate.

8.4 Data Structures

8.4.1 Endianness

The Digital F/T stores all numbers in big-endian (aka “Network Order”) format. If your host system uses a little-endian (“Byte-swapped”) format, any custom software you write will have to swap the bytes in each numeric field before performing any calculations using those values.

8.4.2 Streaming Sample Format

```
{
int16   G0;
int16   G2;
int16   G4;
int16   G1;
int16   G3;
int16   G5;
uint8   check;
}
```

The fields G0–G5 make up the gage vector. When calculating F/T values, this vector is multiplied with the calibration matrix using the standard matrix multiplication algorithm.

NOTICE: The strain gages are sent in the order (G0, G2, G4, G1, G3, G5), and must be reordered to (G0, G1, G2, G3, G4, G5) before performing F/T calculations (or the calibration matrix itself can be reordered to accommodate the streaming sample ordering). The streaming sample is structured this way in order to sample the gages which cooperate on the most axes as close together as possible.

The ‘check’ field is a single byte containing a checksum and a status bit:

Table 8.5—Streaming Sample Check Bitmap

Bit Number	Meaning
0–6	Additive checksum
7	Status

The additive checksum can be calculated using the following algorithm. The '&' operator in the following pseudocode indicates a bitwise 'and' operation, and the 'sampleBytes' parameter contains the 13 bytes that make up a streaming sample packet.

```
CheckSample( sampleBytes:array of bytes ) : true/false
    checkSum = 0
    for i = 0 to 11
            checkSum = checkSum + sampleBytes[i]
    next i
    if ( checkSum & 0x7f ) <> ( sampleBytes[12] & 0x7f )
            return false        /* checksum does not match. */
    else
            return true         /* checksum matches. */
    end if
```

The status bit is 0'if the system is healthy, or 1'if there is an error code. If the status bit indicates an error, stop streaming by sending a jamming sequence of 14 bytes, then use standard Modbus to read the system status holding register to get the full error code. The jamming sequence can consist of arbitrary values, any character value will stop streaming.

Since there is no contingency in Modbus for high-speed streaming data, the streaming samples are not sent in standard Modbus packets – they are sent without any encapsulation. This requires the client software to disable any Modbus processing of received packets while data streaming is active.

8.4.3 Status Word

The status word is a bitmap which contains information about the errors that can occur in various subsystems of the Digital F/T sensor:

Table 8.6—Status Word Bitmap

Bit Number	Meaning If Set
0	Watchdog reset – the analog board was reset by the watchdog timer.
1	Excitation voltage too high.
2	Excitation voltage too low.
3	Artificial analog ground out of range.
4	Power supply too high.
5	Power supply too low.
6	Not used.
7	Error accessing stored settings in EEPROM.
8	Invalid configuration data.
9	Strain gage bridge supply current too high.
10	Strain gage bridge supply current too low.
11	Thermistor too high.
12	Thermistor too low.
13	DAC reading out of range.
14	Not used.
15	Any error sets this bit.

8.4.4 Calibration Structure

Calibration data is read using standard Modbus holding register read commands. You cannot write data to the calibration structures.

```
{
uint8   CalibSerialNumber[8];
uint8   CalibPartNumber[32];
uint8   CalibFamilyId[4];
uint8   CalibTime[20];
float   BasicMatrix[6][6];
uint8   ForceUnits;
uint8   TorqueUnits;
float   MaxRating[6];
int32   CountsPerForce;
int32   CountsPerTorque;
uint16  GageGain[6];
uint16  GageOffset[6];
uint8   Resolution[6];
uint8   Range[6];
uint16  ScaleFactor16[6];
uint8   UserField1[16];
uint8   UserField2[16];
uint8   SpareData[16];
}
```

Table 8.7—Calibration Structure Fields

Address	Description
CalibSerialNumber	The serial number of the calibration as a null-terminated ASCII string.
CalibPartNumber	The ATI part number of the calibration as a null-terminated ASCII string.
CalibFamilyID	The ATI Calibration family as a null-terminated ASCII string.
CalibTime	The date the calibration was released as a null-terminated ASCII string in a format like '1970-01-01 00:00:00'.
BasicMatrix	The calibration matrix. Multiply this matrix with the gage vector to get a vector containing the force and torque values.
ForceUnits	An integer which encodes the force units of the calibration. **Code** / **Force Unit**: 1 Pound; 2 Newton; 3 Kilopound; 4 KiloNewton; 5 Kilogram-equivalent force; 6 Gram-equivalent force
TorqueUnits	An integer which encodes the torque units of the calibration. **Code** / **Force Unit**: 1 Pound-inch; 2 Pound-foot; 3 Newton-meter; 4 Newton-millimeter; 5 Kilogram(-equivalent)-centimeter; 6 KiloNewton-meter
MaxRating	The maximum rated load of each axis, in the order [Force X, Force Y, Force Z, Torque X, Torque Y, Torque Z].
CountsPerForce	The counts per unit force of the calibration.
CountsPerTorque	The counts per unit torque of the calibration.
GageGain	The gain values used for each of the six strain gages in this calibration.
GageOffset	The offset values used for each of the six strain gages in this calibration.
Resolution	Not used in this product.
Range	Not used in this product.
ScaleFactor	Not used in this product.
UserField1	Not used in this product.
UserField2	Not used in this product.
SpareData	Not used in this product.

Each calibration structure is 338 bytes long, so to read the settings for a particular calibration, start at the address of the desired calibration from *Table 8.4* and read 169 holding registers, since each register is two bytes wide. It will be necessary to split the reading up into multiple Modbus commands, due to length restrictions in the Modbus protocol.

8.5 Tool Transformations

A tool transformation is a mathematical procedure that allows you to calculate the force and torque values that are acting at a point other than the origin of the sensor itself, and also allows you to rotate the reference frame, for example to line up the sensor axes with your tooling axes. The transformation is calculated by applying rotation and translation matrices to the original calibration matrix (the "BasicMatrix" element of the calibration structure).

In general, the transform takes the following form:

Equation 1

$$[R]_{6x6}[D]_{6x6}[C]_{6x6}[G]_{6x1} = [F]_{6x1}$$

Where:

R = Rotation matrix

D = Displacement (translation) matrix

C = Calibration matrix

G = Raw gage values

F = Resolved force/torque values

The rotation matrix is defined as:

$$R = \begin{bmatrix} cy \cdot cz & sx \cdot sy \cdot sz + cx \cdot sz & sx \cdot sz - cx \cdot sy \cdot cz & 0 & 0 & 0 \\ -cy \cdot sz & -sx \cdot sy \cdot sz + cx \cdot cz & sx \cdot cz + cx \cdot sy \cdot sz & 0 & 0 & 0 \\ sy & -sx \cdot cy & cx \cdot cy & 0 & 0 & 0 \\ 0 & 0 & 0 & cy \cdot cz & sx \cdot sy \cdot sz + cx \cdot sz & sx \cdot sz - cx \cdot sy \cdot cz \\ 0 & 0 & 0 & -cy \cdot sz & -sx \cdot sy \cdot sz + cx \cdot cz & sx \cdot cz + cx \cdot sy \cdot sz \\ 0 & 0 & 0 & sy & -sx \cdot cy & cx \cdot cy \end{bmatrix}$$

Where "s" and "c" indicate the sin and cosine operations respectively, and "x", "y", and "z" are the rotations about the x, y, and z axes respectively.

This displacement matrix is defined as:

Equation 2

$$D = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & dz & -dy & 1 & 0 & 0 \\ -dz & 0 & dx & 0 & 1 & 0 \\ dy & -dx & 0 & 0 & 0 & 1 \end{bmatrix}$$

Where "dx", "dy", and "dz" are the displacements along the x, y, and z axes respectively. The units of the displacements must match the distance components of the torque units used in your calibration (e.g., if your sensor reports torque in Newton-meters, the displacements must be measured in meters).

Because matrix math is associative, you can pre-calculate the factor from "Equation 1" and use the resulting matrix in all subsequent force/torque calculations, until you wish to create a new tool transformation.

It is important to note that the tool transformation procedure, as described here, applies the displacements and rotations in the following order:

1. Displacements. The order of axis displacements does not matter, as long as they are all done together with no rotations between displacements.
2. Rotation about X.
3. Rotation about Y.
4. Rotation about Z.

If you wish to apply the elements of the transform in a different order, you can either calculate the rotation and displacement matrices using the order appropriate to your application or you can apply the algorithm as described above multiple times, and only apply one element of the transform (e.g., one rotation or one displacement) at each step, as in the following pseudocode:

```
RegularTransform( x:matrix, y:transform ) : matrix
/* Procedure described above. */

RemoveFirstTransform( y:queue of transforms ) : transform
/* Removes first element from y and returns that element, or returns a null value if y is empty. */

OrderedTransform( x:matrix, y:queue of transforms ) : matrix
    z = RemoveFirstTransform( y )
if ( null = z )
        return x
else
    return OrderedTransform( RegularTransform( x, z ), y )
```

To use the above algorithm to apply transform elements in a particular order, you would construct a queue containing the transform elements in the order you wish to apply them, and then call the OrderedTransform method with the original calibration matrix and your transform list as arguments.

8.6 To Read Calibrated F/T Data from the Sensor

1. Set the sensor up to use the correct RS-485 baud rate for your application. By default, the sensor runs at 1,250,000 baud.
2. Optionally set the session ID register to protect against unexpected reboots.
3. Read the calibration information for the calibration you wish to activate, and apply any tool transformations you wish to apply to the calibration matrix to create the active calibration matrix.
4. Send the ‘Unlock storage command’ to unlock the active gain and offset hardware settings.
5. Write the active gain and offset hardware settings using the “GageGain’ and “GageOffset” values from the calibration structure. You must do this every time the sensor is reset, because these values are not stored to nonvolatile memory.
6. Send the “unlock storage command’ again to lock the gain and offset against accidental writing.
7. Send the “Start Streaming” command.
8. When each streaming sample is received, check the status bit for system health and the checksum for sample validity. If the status bit is 1, indicating a system error, go to step 11 to stop streaming, then read the system status word using standard Modbus.
9. To bias (tare) the sensor, take a reading when the sensor is in its default or unloaded state. Save these gage values as the “bias vector”. For each subsequent sample, subtract the bias vector from the sampled strain gage vector to remove the bias from the calculated F/T data.
10. Multiply the strain gage vector (with the bias vector subtracted) by the active calibration matrix to calculate the F/T values. The resulting vector will contain the force and torque values, scaled by the counts per force and counts per torque reported in the calibration structure.
11. When you are ready to stop streaming, send a jamming sequence of 14 bytes (one byte longer than the streaming sample size) to ensure the sensor receives at least one character. Wait before sending any more Modbus commands to allow the sensor’s internal Modbus stack to timeout and throw away the characters from the jamming sequence.

9. 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 one 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 with 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 than (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 the 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 year after the cause of action accrued.

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F/T Transducer

Six-Axis
Force/Torque Sensor System

Installation and Operation Manual



Document #: 9620-05-Transducer Section

Engineered Products for Robotic Productivity
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Note

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

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

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For additional information or assistance, please refer to the following contacts:

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Glossary

Term	Definition
Accuracy	See Measurement Uncertainty.
Calibration Certificate	A statement that says the equipment measures correctly. These statements usually mean the equipment has been tested against national standards. The statements are produced as a result of calibration or re-calibration.
Calibration	The act of measuring a transducer's raw response to loads and creating data used in converting the response to forces and torques.
Compound Loading	Any load that is not purely in one axis.
Coordinate Frame	See Point of Origin
DAQ F/T	An F/T Sensor System that uses industry standard data acquisition fasteners (usually computer cards) to convert the transducer signals into digital data.
DAQ	Data Acquisition device.
DoF	Degrees of Freedom. See Six Degrees of Freedom.
F/T Controller	The electronics that connect to mux transducers.
F/T	Force and Torque.
Force	The push or pull exerted on an object.
FS	Full-Scale
Full-Scale Error	A measurement of sensing error. For example, if the calibrated measurement range of a sensor is 100 Newtons and the sensor is accurate to within 1 Newton, that sensor will have a Full-Scale Error of 1% (1% = 0.01 = 1 N / 100 N).
Fxy	The resultant force vector comprised of components Fx and Fy.
Hysteresis	A source of measurement error caused by the residual effects of previously applied loads.
IP60	Ingress Protection Rating "60" designates protection against dust
IP65	Ingress Protection Rating "65" designates protection against water spray
IP68	Ingress Protection Rating "68" designates submergibility in fresh water, in this case, to a depth of 10 meters
MAP	Mounting Adapter Plate. The transducer's MAP attaches to the fixed surface or robot arm.
Max. Single-Axis Overload	The largest amount of load in a single axis (all other axes are unloaded) that the transducer can withstand without damage.
Measurement Uncertainty	The maximum expected error in measurements, as specified on the calibration certificate.
Moment	When something receives a torque, we say a moment is applied to it.
Mux Box	A box that holds mux electronics for transducers that are too small for on-board electronics.
Mux	Short for multiplexer. F/T Controller Sensor Systems use mux electronics to interface to the transducer signals.
Net F/T	An F/T Sensor System that connects to the customer's monitoring equipment via Ethernet or CAN bus or DeviceNet.
Offset Compensation	Correction of errors that change the zero point of a transducer's readings.
Overload	The condition where more load is applied to the transducer than it can measure. This will result in saturation.
Point of Origin	The point on the transducer from which all forces and torques are measured.

Term	Definition
Quantization	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.
Re-calibration	The periodic verification of measurement equipment, like transducers, calipers and voltmeters, to prove it still measures correctly. The equipment may be adjusted if it doesn't measure correctly.
Reaction Torque	Torque applied that does not result in movement. Think of the twisting you attempt to put on a screw or bolt when it does not move. ATI transducers sense reaction torque.
Resolution	The smallest change in load that can be measured. This is usually much smaller than accuracy.
Rotary Torque	Torque resulting in something moving. Generally this refers to the torque on things like drive shafts. ATI transducers cannot sense rotational torque.
Saturation	The condition where the transducer or data acquisition fasteners has a load or signal outside of its sensing range.
Sensor System	The entire assembly consisting of parts from transducer to data acquisition card.
Six Degrees of Freedom	Fx, Fy, Fz, Tx, Ty and Tz.
Six-axis Force/Torque Sensor	A device that measures the outputting forces and torques from all three Cartesian coordinates (x, y and z). A six-axis force/torque transducer is also known as a multi-axis force/torque transducer, multi-axis load cell, F/T sensor, or six-axis load cell.
Span Compensation	Correction of errors that affect the sensitivity of a transducer.
TAP	Tool Adapter Plate. The TAP part of the transducer is attached to the load that is to be measured.
Tool Transformation	Mathematically changing the measurement coordinate system by translating the origin and/or rotating the axes.
Torque	The measurement of force exerted on an object causing it to rotate.
Transducer	The component that converts the sensed load into electrical signals.
Txy	The resultant torque vector comprised of components Tx and Ty.

1. Safety

The safety section describes general safety guidelines to be followed with this product, explanations of the notifications found in this manual, and safety precautions that apply to the product. There is no personnel safety risk associated with the intended design of the products described within this manual. Product specific notifications are imbedded within the sections of this manual (where they apply).

1.1 Explanation of Notifications

These notifications are used in all of ATI manuals and are not specific to this product. The user should heed all notifications from the robot manufacturer and/or the manufacturers of other components used in the installation.



DANGER: Notification of information or instructions that if not followed will result in death or serious injury. The notification provides information about the nature of the hazardous situation, the consequences of not avoiding the hazard, and the method for avoiding the situation.



WARNING: Notification of information or instructions that if not followed could result in death or serious injury. The notification provides information about the nature of the hazardous situation, the consequences of not avoiding the hazard, and the method for avoiding the situation.



CAUTION: Notification of information or instructions that if not followed could result in moderate injury or will cause damage to equipment. The notification provides information about the nature of the hazardous situation, the consequences of not avoiding the hazard, and the method for avoiding the situation.

NOTICE: Notification of specific information or instructions about maintaining, operating, installing, or setting up the product that if not followed could result in damage to equipment. The notification can emphasize, but is not limited to: specific grease types, best operating practices, and maintenance tips.

1.2 General Safety Guidelines

The customer should verify that the transducer selected is rated for maximum loads and moments expected during operation. For this information, refer to *Section 5—Transducer Specifications* or contact an ATI representative 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.

1.3 Safety Precautions



CAUTION: Do not remove any fasteners or disassemble transducers without a removable mounting adapter plate. These include Nano, Mini, IP-rated, and some Omega transducers. This will cause irreparable damage to the transducer and void the warranty. Leave all fasteners in place and do not disassemble the transducer.



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



CAUTION: Do not exert excessive force on the transducer. The transducer is a sensitive instrument and can be damaged by applying force exceeding the single-axis overload values of the transducer and cause irreparable damage. Small Nano and Mini transducers can easily be overloaded during installation. For specific transducer overload values, refer to *Section 5—Transducer Specifications*.

2. Product Overview

A transducer is a device that measures the outputting forces and torques from all three Cartesian coordinates (x, y, and z). A six-axis force/torque transducer is also known as a multi-axis force/torque transducer, multi-axis load cell, F/T sensor, or six-axis load cell.

The ATI Multi-Axis Force/Torque (F/T) sensor system measures all six components of force and torque. The system consists of a transducer, shielded high-flex cable, and intelligent data acquisition system (Ethernet/DeviceNet interface or F/T controller). F/T sensors are used throughout industry for product testing, robotic assembly, grinding, and polishing. In research, ATI sensors are used in robotic surgery, haptics, rehabilitation, neurology, and many others applications.

3. Installing the Transducer

Information on the transducer environment, IP rating, mounting, and routing of the transducer cable are included in the following sections.

3.1 Transducer Environment

To ensure proper operation, the IP rating of the transducer must match or exceed the transducer's environment. Unless otherwise specified, a transducer has no special IP protection. In this case, the transducer may be used only in benign environments with no dust, debris, liquids, or sprays. For information on the transducer's temperature performance, refer to *Section 4.1—Accuracy over Temperature*.

CAUTION: Damage to the outer jacketing of the transducer cable could enable moisture or water to enter an otherwise sealed transducer. Ensure the cable jacketing is in good condition to prevent transducer damage.

NOTICE: Transducers may react to exceptionally strong and changing electromagnetic fields, such as those produced by magnetic resonance imaging (MRI) machines.

NOTICE: Transducers without an IP protection may exhibit a small offset in readings when exposed to strong light.

3.2 Mounting the Transducer

There are two different mounting methods for transducers. The first method has a fixed bolt pattern on the tool side of the transducer and a removable adapter plate on the mounting (robot or other device) side. The adapter plate needs to be removed from the transducer and machined with the mounting bolt pattern to match the robot or other device. If the device covers the mounting fasteners used to connect the transducer, the removable adapter plate can't be used alone. If this is the case a user designed interface plate is needed between the transducer and the robot or other device. For more details, refer to *Section 3.2.1—Interface Plate Design* and *Section 3.2.2—Mounting the Transducer with a Removable Mounting Adapter Plate.*

The second method is for transducers with non-removable adapter plates with fixed bolt patterns on both the tool and mounting sides of the transducer (Nano, Mini, IP-rated and some Omega transducers). This type may require a user designed interface plate to attach the transducer to the robot or other device. For more information, refer to *Section 3.2.1—Interface Plate Design* and *Section 3.2.3—Mounting the Transducer with a Non-removable Adapter Plate*.

CAUTION: Do not remove any fasteners or disassemble transducers without a removable adapter plate, these include Nano, Mini, IP-rated, and some Omega transducers. Disassembly causes irreparable damage to the transducer and voids the warranty. Leave all fasteners in place and do not disassemble the transducer.

To determine if the adapter plate is removable for a transducer, refer to the product drawings in *Section 5—Transducer Specifications*. Mount the transducer to a structure with sufficient mechanical strength. Not doing so can lead to sub-optimum performance.

3.2.1 Interface Plate Design

Interface plates may be required between the robot or other device and the transducer and between the transducer and the tooling. If the robot, other device, or tooling covers the mounting fasteners for the transducer, an interface plate is required. Custom interface plates are available from ATI upon request.

There are two types of mounting adapter plate (robot side). For small transducers such as Nano, Mini, IP-rated, and some Omega, the mounting adapter plate is factory installed and should not be removed or machined. The mounting interface plate must be machined with the corresponding bolt pattern and dowel locations, refer to the transducer drawings. Links to drawings are included in *Section 5—Transducer Specifications*.

Larger transducers have removable mounting adapter plates (refer to *Section 3.2.2—Mounting the Transducer with a Removable Mounting Adapter Plate*). Machine the mounting interface plate to match the bolt pattern and dowel hole in the removable mounting adapter plate.

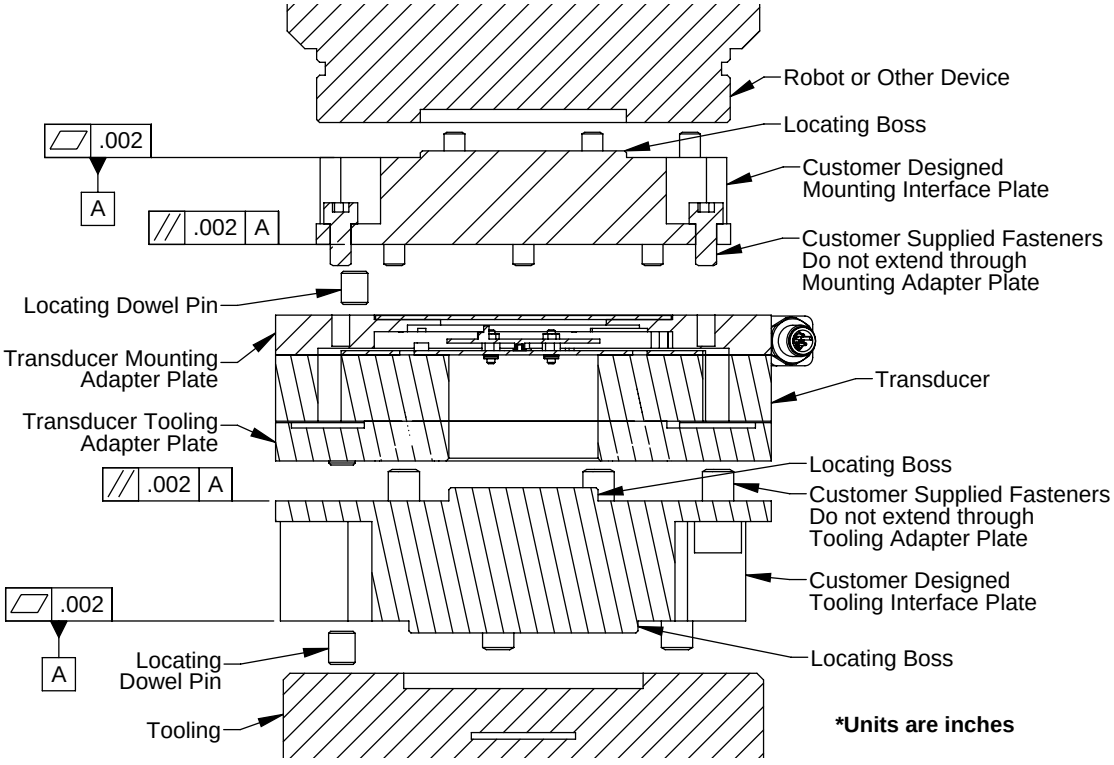
The transducer tooling adapter plate is factory installed and the bolt circle is shown with the transducer in drawings; for links to the drawings, refer to *Section 5—Transducer Specifications*. Most large F/T tool adapters follow the ISO 9409-1 mounting pattern. Machine the tooling interface plate to attach to this bolt circle.

NOTICE: The tool may not contact any other part of the transducer except the tool mounting surface. If the tool contacts any other part of the transducer, the transducer will not properly sense loads. Make sure the tool mounts to the tool mounting surface and does not contact any other part of the transducer.

If the customer chooses to design and build a mounting or tooling interface plate, consider the following points. Links to the product drawings are in *Section 5—Transducer Specifications*.

- The interface plate should be designed to include bolt holes for mounting, dowel pins, and a boss for accurate positioning on the robot or other devices and to the adapter plate. These locating features should orient the X and Y axis of the Transducer to the X and Y axis of the robot.
- The thickness of the interface plate must be great enough to provide the necessary thread engagement for the mounting fasteners.
- Mounting fasteners must not be too long. They should not extend through the adapter plate to avoid interference with the electronics inside the transducer. For thread depth, mounting patterns, and other details, refer to the drawings.
- The interface plate must be properly designed to provide rigid mounting for the transducer. The interface plate should not distort under maximum sensor range of the transducer .
- The interface plate design must provide a flat and parallel mounting surface for the transducer.

Figure 3.1—Interface Plate Design Specification



3.2.2 Mounting the Transducer with a Removable Mounting Adapter Plate

First, determine if the transducer can attach directly to the robot/device arm or if an interface plate is needed. If an interface plate is need for the robot side and/or tool side, refer to *Section 3.2.1—Interface Plate Design* for details to design an interface plate before continuing with this procedure.

1. Remove power to the transducer.
2. Remove all mounting fasteners from the mounting adapter plate and set aside.

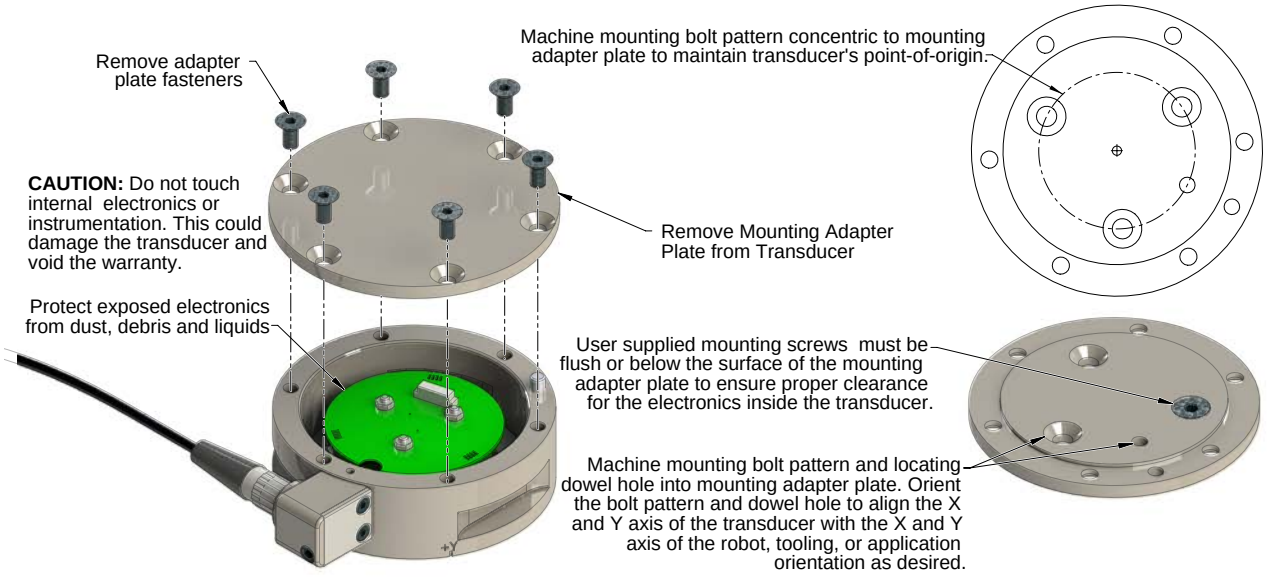
> **CAUTION:** Do not touch internal electronics or instrumentation. This could damage the transducer and void the warranty. When the adapter plate is removed protect the exposed electronics from dust, debris, liquids, and other foreign objects.

3. Remove the adapter plate from the transducer. Machine the mounting bolt pattern from the robot, interface plate, or other device into the removable adapter plate. Make sure the bolt pattern and dowel hole orient the X and Y axis of the transducer with the X and Y axis of the robot.

> **NOTICE:** Customers who machine their own interface patterns should avoid placing all mounting features in the center of the adapter plate. A larger bolt circle provides the most accurate readings because it induces less bending in the plate.

> **CAUTION:** Mounting fasteners should not extend into the transducer beyond the adapter plate surface. This could cause damage to the internal electronics. When machining the removable adapter plate, make sure the heads of the fasteners are flush or below the surface of the adapter plate.

Figure 3.2—Removable Adapter Plate



4. Mount removable adapter plate to the robot, other device, or interface plate using customer supplied fasteners. If fasteners do not have pre-applied adhesive, apply Loctite 222® to the fasteners.

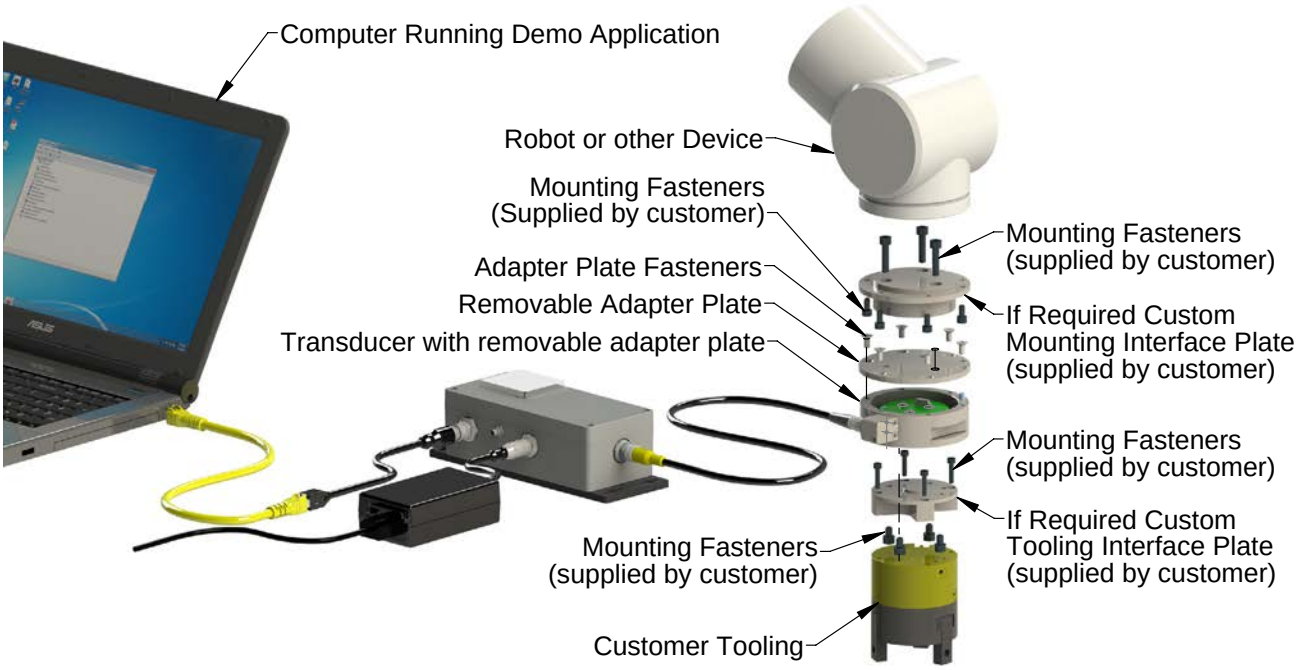
> **NOTICE:** Make sure the adapter plate orients the transducer so that the connector is at the appropriate location to route the cabling properly (refer to *Section 3.3—Routing the Transducer Cable*).

5. Attach the transducer to the removable adapter plate, hand tighten fasteners.
6. Connect power to the transducer, and wait until demo application displays **load data** when applying force on the transducer.

CAUTION: Do not exceed the transducer's overload ratings. If smaller transducers are not carefully installed, irreparable damage can occur by applying small loads using tools (moment arm increases applied loads). When installing, use the demo application to monitor for gage saturation errors. If an error occurs, stop applying force to the transducer and wait until the error clears to continue installation. If error does not clear, it may indicate loss of power or the overload value has been exceeded.

7. Monitor the demo application for gage saturation errors during installation. If an error is displayed, stop applying the force to the transducer and wait until the error clears. Then continue installation.
8. Tighten the fasteners mounting the transducer to the removable adapter plate.

Figure 3.3—Installing Transducers with Removable Mounting Adapter Plates



CAUTION: Do not use fasteners that will exceed the customer interface depth specified for the transducer. Using longer fasteners will penetrate the body of the transducer and damage the electronics, voiding the warranty. Use fasteners that provide the customer interface depth specified for the transducer. Refer to the transducer drawing.

NOTICE: The tool may not contact any other part of the transducer except the tool mounting surface. If the tool contacts any other part of the transducer it will not properly sense loads. Make sure the tool mounts to the tool mounting surface and does not contact any other part of the transducer.

9. Monitor the demo application for gage saturation errors during installation. If an error is displayed stop applying the force to the transducer and wait until the error clears before continuing installation.
10. With customer supplied fasteners, attach the customer tooling or tooling interface plate to the transducer. The transducer has a mounting pattern on the tool side of the transducer. If fasteners do not have pre-applied adhesive, apply Loctite 222.

3.2.3 Mounting the Transducer with a Non-removable Adapter Plate

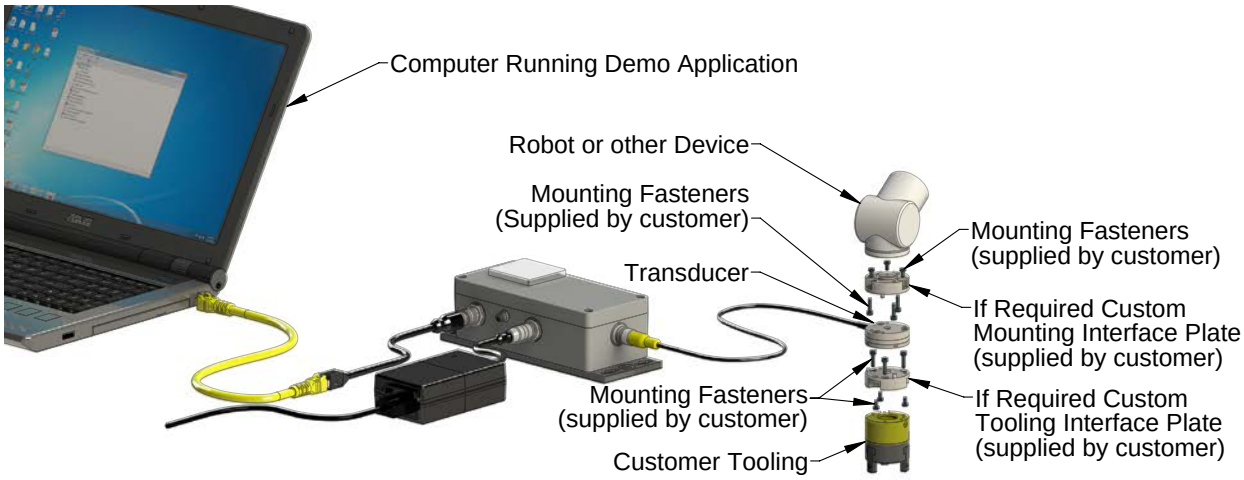
CAUTION: Do not attempt to drill, tap, machine, or otherwise modify or disassemble the transducer. Such work could damage the transducer and will void the warranty. Use the mounting bolt pattern provided to attach the transducer to the robot or other device and to mount the tool to the transducer. See the transducer drawings for details.

CAUTION: Do not use fasteners that will exceed the customer interface depth specified on for the transducer. Using longer fasteners will penetrate the body of the transducer, damage the electronics, and void the warranty. Use fasteners that provide the customer interface depth specified for the transducer. Refer to the transducer drawing.

CAUTION: Do not exceed the transducer's overload ratings. If smaller transducers are not carefully installed, irreparable damage can occur by applying small loads using tools (moment arm increases applied loads). When installing, use the demo application to monitor for gage saturation errors. If an error occurs, stop applying force to the transducer and wait until the error clears to continue installation. If error does not clear, it may indicate loss of power or the overload value has been exceeded.

1. During installation, monitor the demo application for gage saturation errors. If an error is displayed, stop applying the force to the transducer, and wait until the error clears before continuing installation.
2. Mount the transducer to the user-designed interface plate, directly to the robot, or other device with customer supplied fasteners. If fasteners do not have pre-applied adhesive, apply Loctite 222 to the fasteners.

Figure 3.4—Installing Transducers with Non-removable Adapter Plates (Net F/T System Shown)



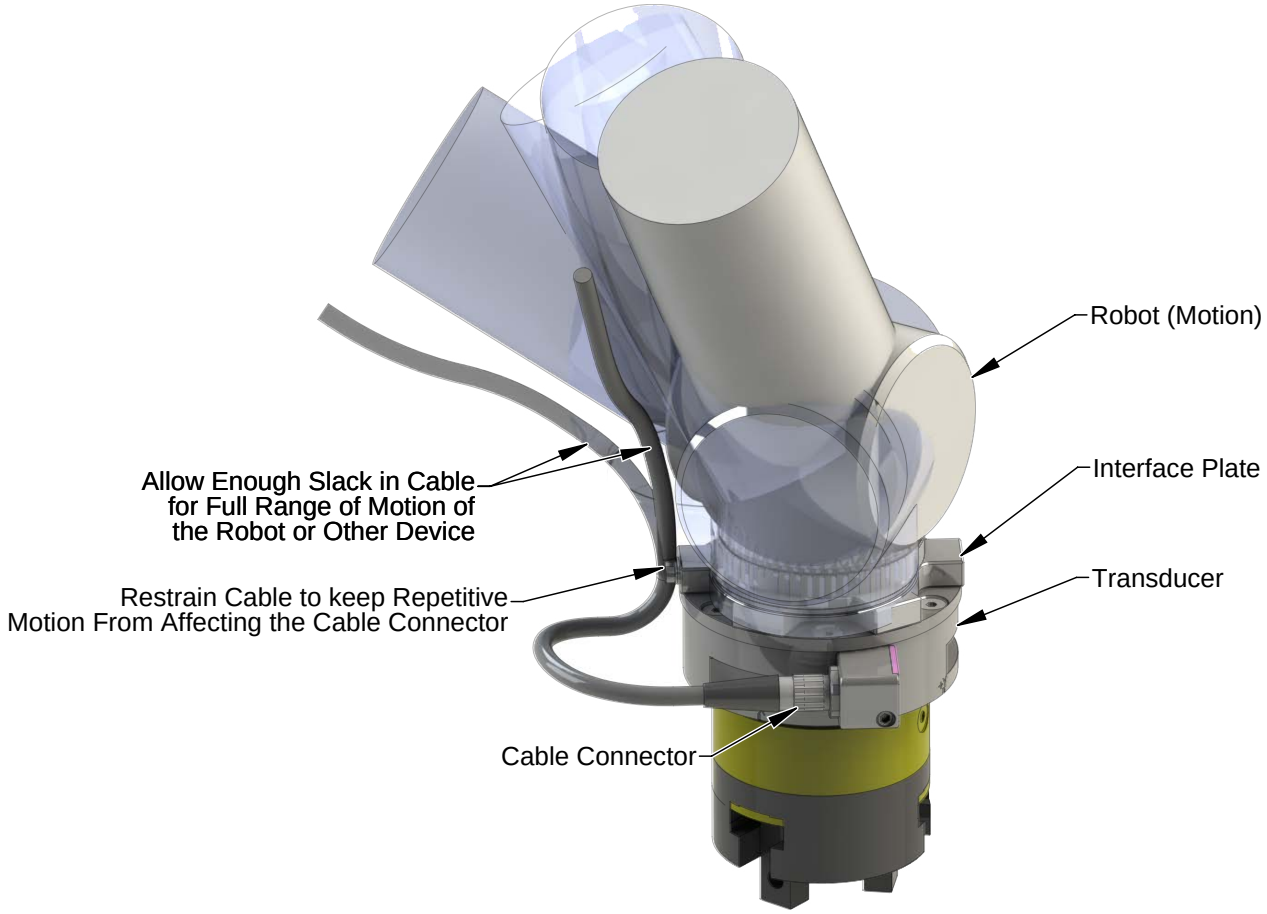
NOTICE: The tool may not touch any other part of the transducer except the tool mounting surface. If the tool touches any other part of the transducer it will not properly sense loads. Make sure the tool mounts to the tool mounting surface and does not touch any other part of the transducer.

3. Monitor the demo application for gage saturation errors during installation. If an error is displayed stop applying the force to the transducer and wait until the error clears before continuing installation.
4. Attach the customer tooling or tooling interface plate to the transducer with customer supplied fasteners, the transducer provides a mounting pattern on the tool side of the transducer. If fasteners do not have pre-applied adhesive, apply Loctite 222 to the fasteners.

3.3 Routing the Transducer Cable

The application for the transducer determines the best cable routing method and the proper cable bending radius. Some applications keep the transducer and cable static. Other applications are dynamic and can put the transducer and cable through repetitive motions. It is important not to expose the transducer cable connectors to this repetitive motion and properly restrain the cable close to the transducer connection

Figure 3.5—Restrain Transducer Cable Close to Cable Connector



CAUTION: Do not subject the transducer cable connector to the repetitive motion of the robot or other device. Subjecting the connector to the repetitive motion will cause damage to the connector. Restrain the cable close to the connector to keep the repetitive motion of the robot from affecting the cable connector.

CAUTION: When routing cables do not bend the cable to a smaller radius than the minimum bending radius specified in *Table 3.1*. The cable will fail due to fatigue from the repetitive motion. When routing the cable make sure the cable bends are larger then the minimum dynamic bending radius specified for the cable type.

CAUTION: Do not stress or over bend the transducer cable, especially where it is attached to the transducer. This is particularly important on the Nano and Mini series of transducers. For these transducers, do not bend the cable any closer than 25 mm (1 inch) to the transducer. Sharp bends must be avoided as they can damage the cable and transducer and will void the warranty.

Figure 3.6—Transducer Bending Radius

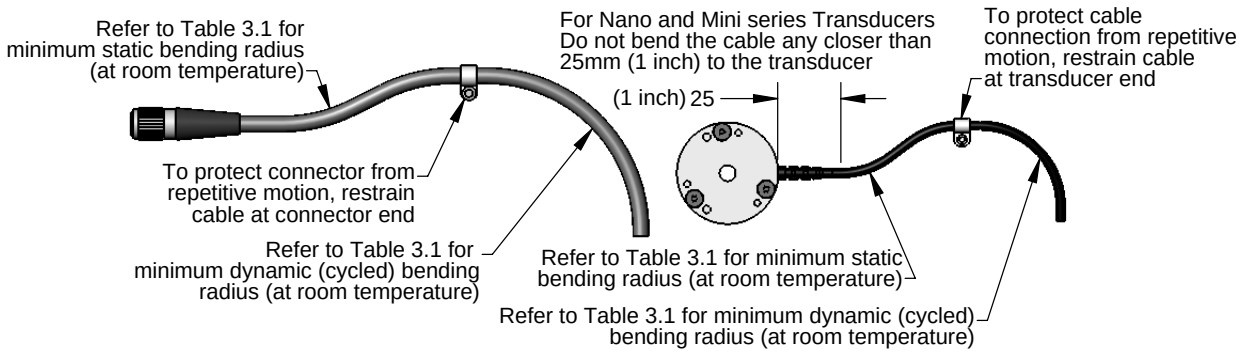


Table 3.1—Transducer Cable Bending Radius

Cable Type	Cable Dia. (mm)	Static Bending Radius (at room temperature)		Dynamic Bending Radius (at room temperature)	
		mm	inch	mm	inch
9105-TW	3.2	16	0.63	32	1.26
9105-C3	4.4	22	0.87	44	1.73
9105-CM	4.4	22	0.87	44	1.73
9105-CW	4.4	22	0.87	44	1.73
9105-CT	6.1	30.5	1.20	61	2.40
9105-C	3.2	16	0.63	32	1.26
	4.4	22	0.87	44	1.73
	6.1	30.5	1.20	61	2.40
	10.0	50	1.97	100	3.94
9105-C-MTR	8.4	42	1.65	84	3.31
9105-C-MTS	8.4	42	1.65	84	3.31
9105-CF-MTR 9105-CF-MTS	8.5	42.5	1.67	85	3.35

Note: Temperature affects cable flexibility. ATI recommends increasing the minimum dynamic bending radius for lower temperatures.

Route the transducer cable so that it is not stressed, pulled, kinked, cut, or otherwise damaged throughout the full range of motion. See the accompanying system manual for the transducer cable interfacing. If the desired application results in the cable rubbing, then use a loose plastic spiral wrap for protection.

CAUTION: Be careful not to crush the cable by over tightening tie wraps or walking on the cable, since this may damage the cable.

CAUTION: Cables on the Nano and Mini transducers are permanently attached to the transducer and cannot be disconnected. Do not attempt to disassemble these transducers, this will damage the transducer and void the warranty. Do not attempt to replace the cable. Contact ATI service for assistance.

CAUTION: Nano and Mini integral cables and cables of the 9105-C-H type must not subject the transducer end connection to more than 10 lbf (45 N) of side-to-side or pull force or permanent damage will result.

CAUTION: Larger transducers have removable cables. Do not attempt to disconnect these transducer cables by pulling on the cable itself or the connector boot; this can damage the system.

4. Operation Topics

4.1 Accuracy over Temperature

Typical gain errors introduced over temperature for F/T transducers with fasteners temperature compensation are listed in the following table. Changes in sensitivity are independent of the transducer's rated accuracy at room temperature; add the two accuracy ratings to find an overall estimated accuracy at a certain temperature. This overall accuracy assumes that the unloaded and loaded measurements were taken at the same temperature. Drift error over temperature is not compensated and varies with each transducer. For best results, take a reference reading or execute the bias function at the current temperature before applying the load of interest.

Table 4.1—Error Introduced Over Temperature for Non-Gamma Transducers

Deviation from 22°C	Typical Gain Error
± 5°C	0.1%
± 15°C	0.5%
± 25°C[1]	1%
± 50°C[1]	5%

Note:
1. Deviation is bounded by transducer operational limits in *Section 4.3—Environmental*.

Table 4.2—Error Introduced Over Temperature for Gamma Transducers

Deviation from 22°C	Typical Gain Error
± 5°C	0.1%
± 15°C	0.5%
± 25°C[1]	1.5%
± 50°C[1]	7%

Note:
1. Deviation is bounded by transducer operational limits in *Section 4.3—Environmental*

4.2 Tool Transformation Effects

All transducer working specifications pertain to the factory point-of-origin only. This includes the transducer's range, resolution, and accuracy. The transducer working specifications at a customer-applied point-of-origin differ from those at the factory point-of-origin.

4.3 Environmental

The F/T system is designed to be used in standard laboratory or light-manufacturing conditions. Transducers with an IP60 designation are able to withstand dusty environments, those with an IP65 designation are able to withstand dusty environments and wash down, and those with an IP68 designation are able to withstand dusty environments and fresh-water immersion to a specified depth. Transducers without IP65 or IP68 designation may be used in environments with up to 95% relative humidity, non-condensing.

Table 4.3—Transducer Temperature Ranges

Transducer Model Series	Storage	Operation	Unit
9105-TIF Transducer	-25 to +80	0 to +60	°C
9105-TW Transducer	-25 to +80	0 to +80	
9105-TW-MINI/NANO Transducer[2]	-40 to +100	0 to +100	
9105-T Transducer	-20 to 80	0 to +70	
9105-TWE Transducer	-25 to 85	0 to +85	
9105-NET Transducer	0 to +85	0 to +85	
9105-ECAT Transducer	0 to +70	0 to +70	

Note:

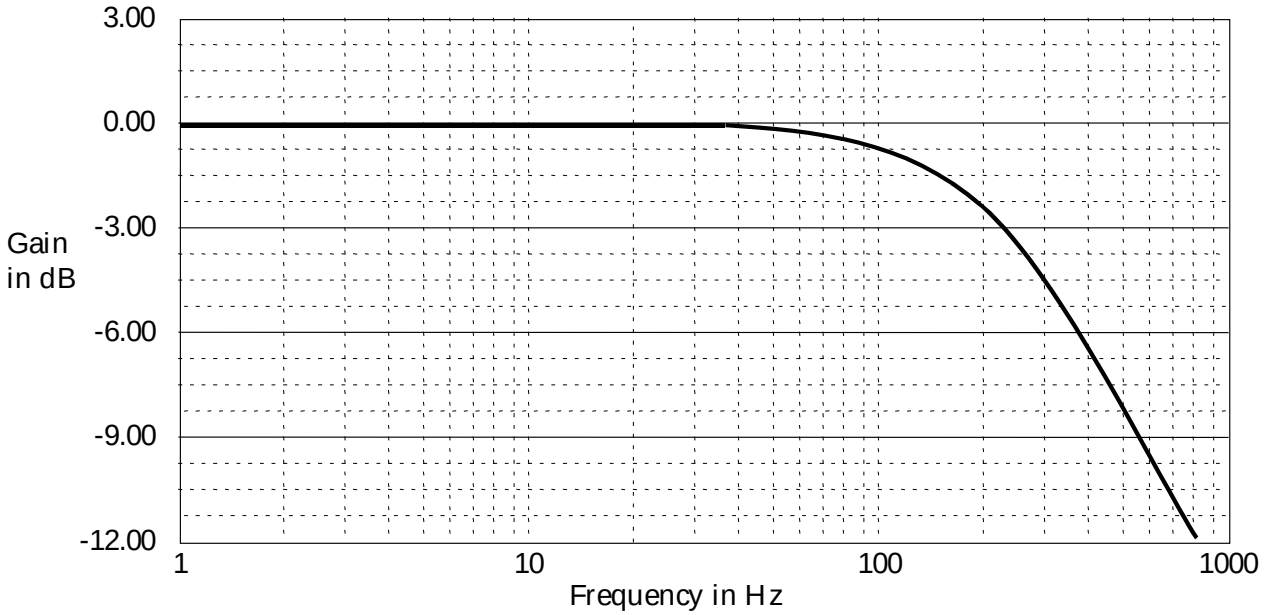
1. These temperature ranges specify the storage and operation ranges in which the transducer can survive without damage. They do not take accuracy into account.
2. Wider temperature ranges are available upon request.

4.4 Mux Transducer Input Filter Frequency Response

NOTICE: Mux transducers are only used in 9105-CTL, 9105-CON, and 9105-CTE systems.

The input filter used in 9105-T transducers and in the Mux box is used to prevent aliasing. This filtering is not used in 9105-TIF (DAQ) or a TWE transducers.

Figure 4.1—Mux input filter frequency response (-3dB @ 235Hz)



4.5 Transducer Strain Gage Saturation

The F/T sensor's strain gages are optimally placed to share information between the forces and torques applied to the sensor. Because of this sharing, it is possible to saturate the transducer with a complex load that has components below the rated load of the sensor. However, this arrangement allows a greater sensing range and resolution.

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

5. Transducer Specifications

5.1 Notes on the Specification Section

5.1.1 ATI Website

All transducer specifications and additional information are also available on the ATI website: *https://www.ati-ia.com/products/ft/ft_ModelListing.aspx*.

5.1.2 About CTL Calibration Specifications

CTL refers to F/T systems that use the F/T Controller. Transducers used in these systems either have a 9105-T-x model transducer or include a Mux Box. The output resolution of CTL systems is different from other systems. CTL systems also provide analog voltage outputs that represent each of the six axes. CTL transducers have their own calibration specification listings because of these differences.

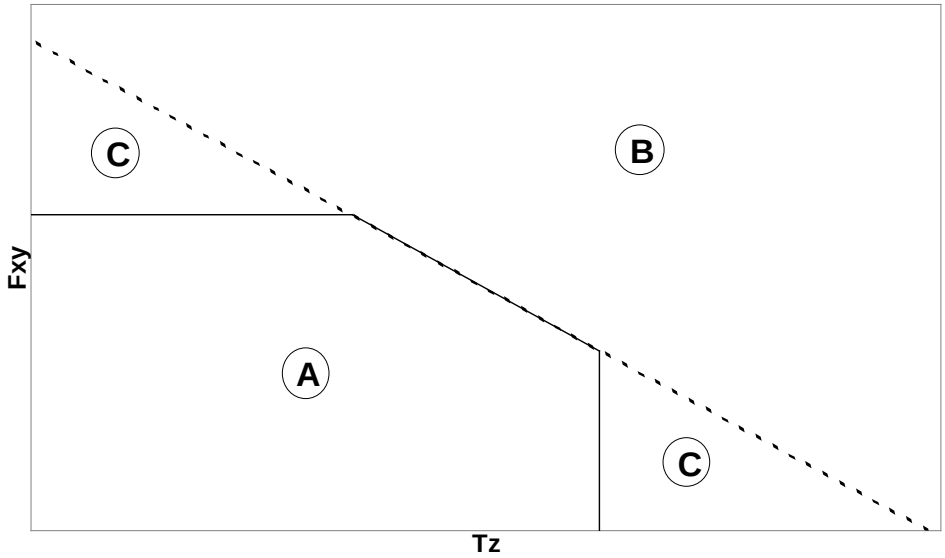
5.1.3 Complex Loading Graph Description

The graphs in the sections for each transducer may be used to estimate a sensor's range under complex loading. Each page represents one sensor body with either English or Metric units. The top graph represents combinations of forces in the X and/or Y directions with torques about the Z-axis. The bottom graph represents combinations of Z-axis forces with X- and/or Y-axis torques. The graphs contain several different calibrations, distinguished by line weight.

The sample graph shown in *Figure 5.1* shows how operating ranges can change with complex loading. The regions are indicated by the following labels:

A. Normal operating region. You can expect to achieve rated accuracy in this region.
B. Saturation region. Any load in this region will report a gage saturation condition.
C. Extended operating region. In this region, the sensor will operate correctly but the full-scale accuracy is not guaranteed.

Figure 5.1—Complex Loading Sample Graph



5.2 Nano17 Titanium

In addition to the information in the following sections, refer to the ATI website:

Table 5.1—Nano17 Titanium Drawing and Web Links		
Model	**Drawing Part Number**	**ATI Website Address**
Nano17 Titanium	*9230-05-1336*	*https://www.ati-ia.com/products/ft/ft_models.aspx?id=Nano17+Titanium*

5.2.1 Nano17 Titanium Physical Properties

Table 5.2—Nano17 Titanium Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±35 lbf	±160 N
Fz	±70 lbf	±310 N
Txy	±8.9 inf-lb	±1 Nm
Tz	±10 inf-lb	±1.2 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	2.7×10^4 lb/in	4.8×10^6 N/m
Z-axis force (Kz)	3.8×10^4 lb/in	6.6×10^6 N/m
X-axis & Y-axis torque (Ktx, Kty)	1.2×10^3 lbf-in/rad	1.4×10^2 Nm/rad
Z-axis torque (Ktz)	2.0×10^3 lbf-in/rad	2.2×10^2 Nm/rad
Resonant Frequency		
Fx, Fy, Tz	3000 Hz	3000 Hz
Fz, Tx, Ty	3000 Hz	3000 Hz
Physical Specifications		
Weight[1]	0.0223 lb	0.0101 kg
Diameter[1]	0.669 in	17 mm
Height[1]	0.571 in	14.5 mm
Note: 1. Specifications include standard interface plates.		

5.2.2 Calibration Specifications (excludes CTL calibrations)

Table 5.3— Nano17 Titanium Calibrations (excludes CTL calibrations)1, 2									
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**	**Fx,Fy (lbf)**	**Fz (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**
Nano17 Titanium	US-1.8-0.4	1.8	3.15	0.4	0.4	1/3400	1/2720	7/92800	1/18560
Nano17 Titanium	US-3.6-0.8	3.6	6.3	0.8	0.8	1/1700	1/1360	7/46400	1/9280
Nano17 Titanium	US-7.2-1.6	7.2	12.6	1.6	1.6	1/850	1/680	7/23200	1/4640
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz (N)**	**Tx,Ty (Nmm)**	**Tz (Nmm)**	**Fx,Fy (N)**	**Fz (N)**	**Tx,Ty (Nmm)**	**Tz (Nmm)**
Nano17 Titanium	SI-8-0.05	8	14.1	50	50	1/682	1/682	3/364	5/728
Nano17 Titanium	SI-16-0.1	16	28.2	100	100	1/341	1/341	3/182	5/364
Nano17 Titanium	SI-32-0.2	32	56.4	200	200	1/171	1/171	3/92	5/184
		Sensing Ranges				**Resolution (DAQ, Net F/T)[3]**			

Notes:
1. These system resolutions quoted are the effective resolution after dropping eight counts of noise. The effective resolution can be improved with filtering.
2. Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.
3. DAQ resolutions are typical for a 16-bit data acquisition system.

5.2.3 CTL Calibration Specifications

Table 5.4— Nano17 Titanium CTL Calibrations1, 2									
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**	**Fx,Fy (lbf)**	**Fz (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**
Nano17 Titanium	US-1.8-0.4	1.8	3.15	0.4	0.4	1/1700	1/1360	7/46400	1/9280
Nano17 Titanium	US-3.6-0.8	3.6	6.3	0.8	0.8	1/850	1/680	7/23200	1/4640
Nano17 Titanium	US-7.2-1.6	7.2	12.6	1.6	1.6	1/425	1/340	7/11600	1/2320
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz (N)**	**Tx,Ty (Nmm)**	**Tz (Nmm)**	**Fx,Fy (N)**	**Fz (N)**	**Tx,Ty (Nmm)**	**Tz (Nmm)**
Nano17 Titanium	SI-8-0.05	8	14.1	50	50	1/341	1/341	3/182	5/364
Nano17 Titanium	SI-16-0.1	16	28.2	100	100	2/341	2/341	3/91	5/182
Nano17 Titanium	SI-32-0.2	32	56.4	200	200	2/171	2/171	3/46	5/92
		Sensing Ranges				**Resolution (Controller)**			

Notes:
1. CTL resolutions are typical. System resolutions quoted are the effective resolution after dropping eight counts of noise. The effective resolution can be improved with filtering.
2. Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.

5.2.4 CTL Analog Output

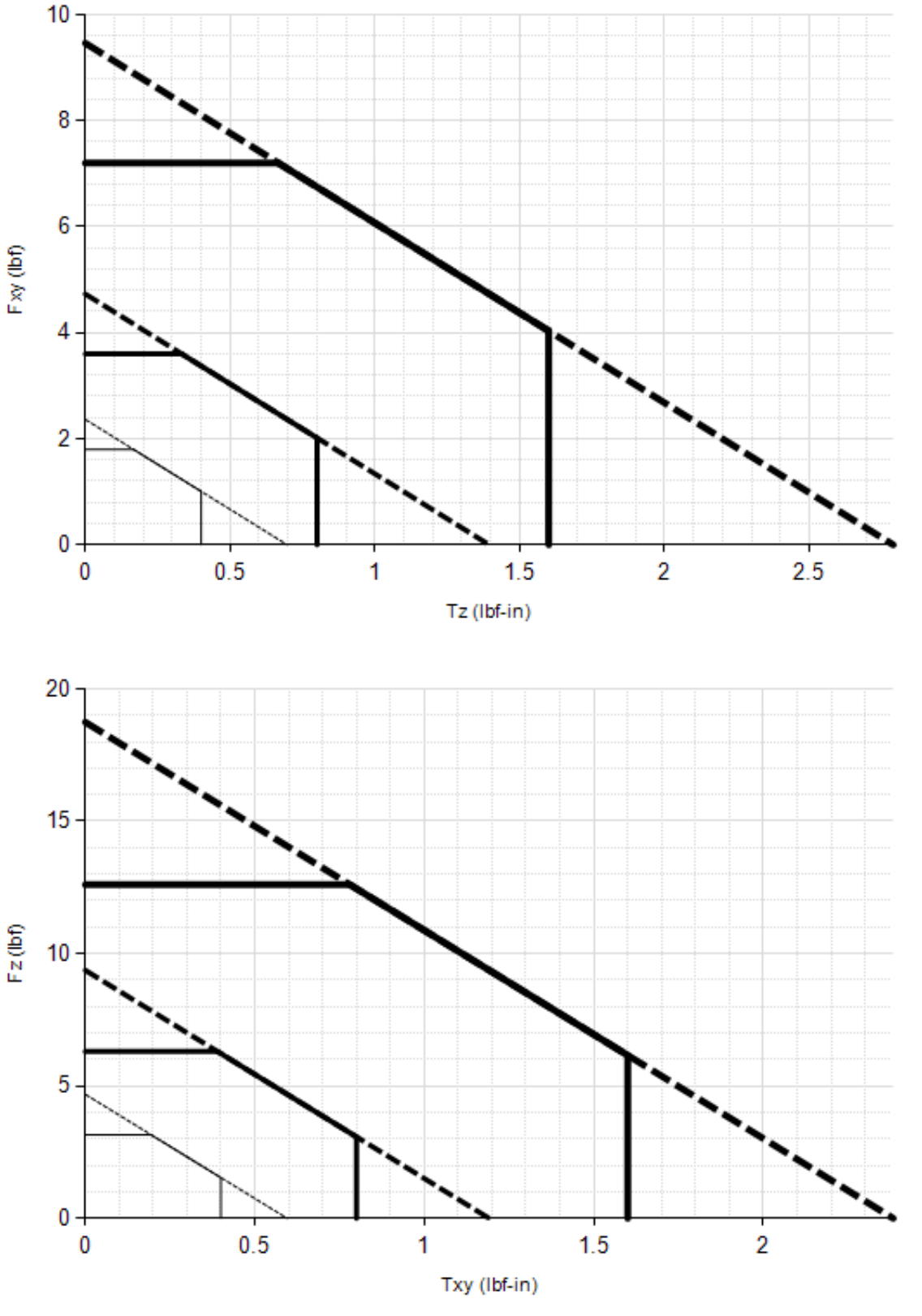
Table 5.5— Nano17 Titanium Analog Output							
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz (lbf)**	**Tx,Ty,Tz (lbf-in)**	**Fx,Fy (lbf/V)**	**Fz (lbf/V)**	**Tx,Ty,Tz (lbf-in/V)**
Nano17 Titanium	US-1.8-0.4	±1.8	±3.15	±0.4	0.18	0.315	0.04
Nano17 Titanium	US-3.6-0.8	±3.6	±6.3	±0.8	0.36	0.63	0.08
Nano17 Titanium	US-7.2-1.6	±7.2	±12.6	±1.6	0.72	1.26	0.16
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz (N)**	**Tx,Ty,Tz (Nmm)**	**Fx,Fy (N/V)**	**Fz (N/V)**	**Tx,Ty,Tz (Nmm/V)**
Nano17 Titanium	SI-8-0.05	±8	±14.1	±50	0.8	1.41	5
Nano17 Titanium	SI-16-0.1	±16	±28.2	±100	1.6	2.82	10
Nano17 Titanium	SI-32-0.2	±32	±56.4	±200	3.2	5.64	20
		Analog Output Range			**Analog ±10V Sensitivity[1]**		

Notes:
1. ±5V Sensitivity values are double the listed ±10V Sensitivity values.

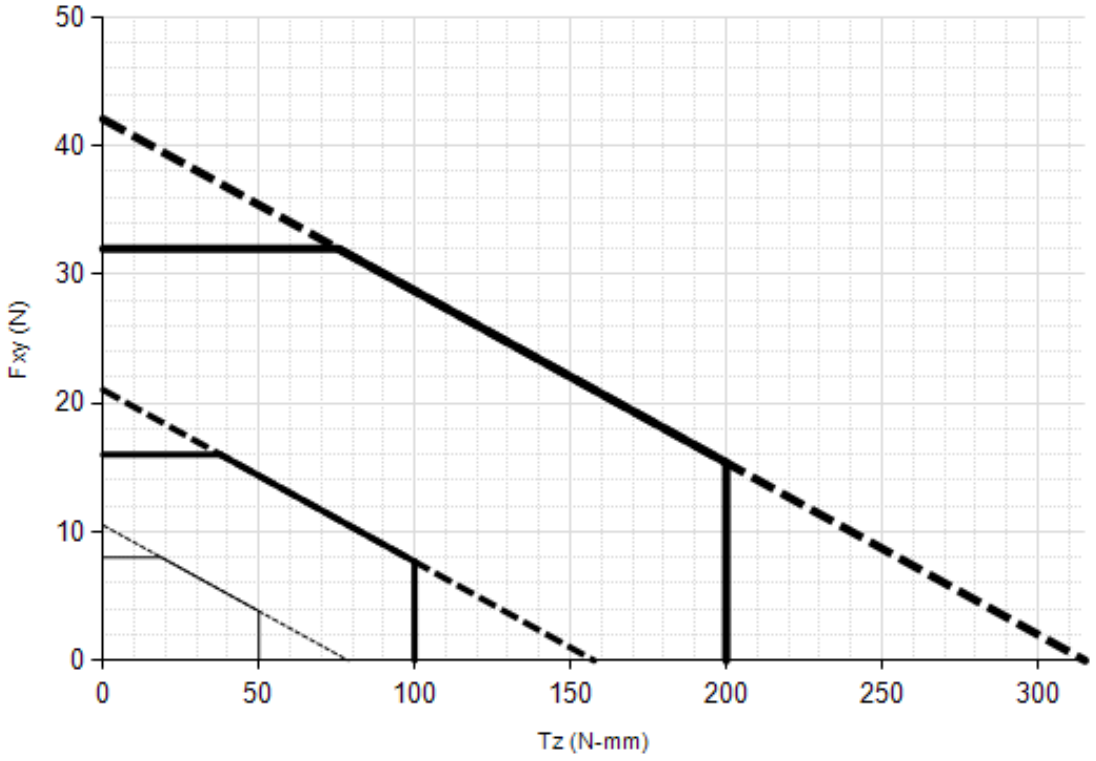
5.2.5 CTL Counts Value

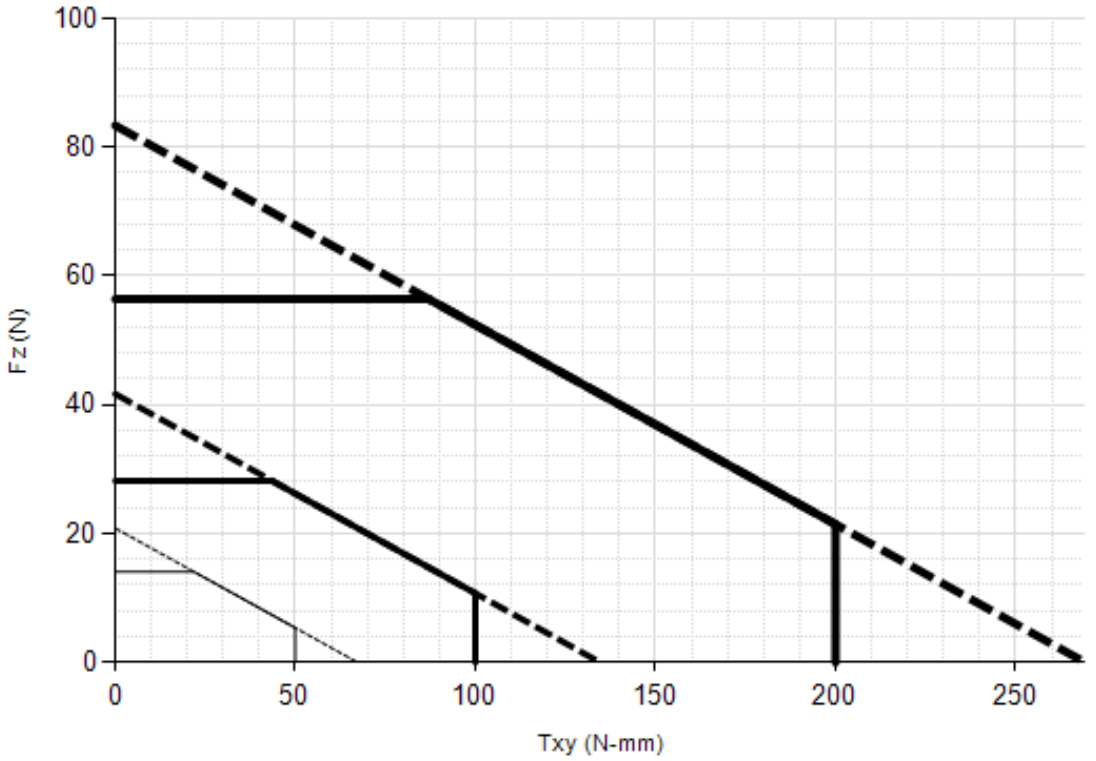
Table 5.6—Counts Value					
Sensor	**Calibration**	**Fx, Fy, Fz (/ lbf)**	**Tx, Ty, Tz (/ lbf-in)**	**Fx, Fy, Fz (/ N)**	**Tx, Ty, Tz (/ Nmm)**
Nano17 Titanium	US-1.8–0.4 / SI-8–0.05	54400	371200	1280	256
Nano17 Titanium	US-3.6–0.8 / SI-16–0.1	27200	185600	640	128
Nano17 Titanium	US-7.2–1.6 / SI-32–0.2	13600	82800	320	64
Nano17 Titanium	Tool Transform Factor	0.0022 in/lbf		0.0375 mm/N	
		Counts Value – Standard (US)		**Counts Value – Metric (SI)**	

5.2.6 Nano17 Titanium (US Calibration Complex Loading)



5.2.7 Nano17 Titanium (SI Calibration Complex Loading)





SI-8-0.05 SI-16-0.1 SI-32-0.2

5.3 Nano17 Specifications (Includes IP65/IP68 Versions)

In addition to the information in the following sections, refer to the ATI website:

Table 5.7—Nano17 Drawing and Web Links		
Model	**Drawing Part Number**	**ATI Website Address**
Nano17	*9230-05-1073*	*https://www.ati-ia.com/products/ft/ft_models.aspx?id=Nano17*
Nano17-E	*9230-05-1311*	
Nano17 IP65/IP68	*9230-05-1364*	*https://www.ati-ia.com/products/ft/ft_models.aspx?id=Nano17+IP65%2fIP68*

5.3.1 Nano17 Physical Properties

Table 5.8—Nano17 Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±56 lbf	±250 N
Fz	±110 lbf	±480 N
Txy	±14 inf-lb	±1.6 Nm
Tz	±16 inf-lb	±1.8 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	4.7×10^4 lb/in	8.2×10^6 N/m
Z-axis force (Kz)	6.5×10^4 lb/in	1.1×10^7 N/m
X-axis & Y-axis torque (Ktx, Kty)	2.1×10^3 lbf-in/rad	2.4×10^2 Nm/rad
Z-axis torque (Ktz)	3.4×10^3 lbf-in/rad	3.8×10^2 Nm/rad
Resonant Frequency		
Fx, Fy, Tz	7200 Hz	7200 Hz
Fz, Tx, Ty	7200 Hz	7200 Hz
Physical Specifications		
Weight[1]	0.02 lb	0.00907 kg
Diameter[1]	0.669 in	17 mm
Height[1]	0.571 in	14.5 mm
Note: 1. Specifications include standard interface plates.		

5.3.2 Nano17 IP65/IP68 Physical Properties

Table 5.9—Nano17 IP65/IP68 Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±56 lbf	±250 N
Fz	±110 lbf	±480 N
Txy	±14 inf-lb	±1.6 Nm
Tz	±16 inf-lb	±1.8 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	4.7×10^4 lb/in	8.2×10^6 N/m
Z-axis force (Kz)	6.5×10^4 lb/in	1.1×10^7 N/m
X-axis & Y-axis torque (Ktx, Kty)	2.1×10^3 lbf-in/rad	2.4×10^2 Nm/rad
Z-axis torque (Ktz)	3.4×10^3 lbf-in/rad	3.8×10^2 Nm/rad
Resonant Frequency		
Fx, Fy, Tz	2200 Hz	2200 Hz
Fz, Tx, Ty	2200 Hz	2200 Hz
Physical Specifications		
Weight[1]	0.09 lb	0.0408 kg
Diameter[1]	0.79 in	20.1 mm
Height[1]	0.873 in	22.2 mm
Note: 1. Specifications include standard interface plates.		

CAUTION: When submerged, IP68 transducers exhibit a decrease in Fz range related to the submersion depth. This loss is the result of pressure-induced preloading on the transducer. The preload can be masked by biasing the transducer at the depth prior to applying the load to be measured. The following estimates are for room temperature fresh water at sea level.

	Submersion Depth	
IP68 Nano17	**US**	**Metric**
Fz preload at 4 m depth	2.01 lb	8.93 N
Fz preload at other depths	-0.15 lb/ft × depth In Feet	-2.23 N/m × depth In Meters

5.3.3 Calibration Specifications (excludes CTL calibrations)

Table 5.10— Nano17 Calibrations (excludes CTL calibrations)1, 2									
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz³ (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**	**Fx,Fy (lbf)**	**Fz³ (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**
Nano17	US-3-1	3	4.25	1	1	1/1280	1/1280	1/8000	1/8000
Nano17	US-6-2	6	8.5	2	2	1/640	1/640	1/4000	1/4000
Nano17	US-12-4	12	17	4	4	1/320	1/320	1/2000	1/2000
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz³ (N)**	**Tx,Ty (Nmm)**	**Tz (Nmm)**	**Fx,Fy (N)**	**Fz³ (N)**	**Tx,Ty (Nmm)**	**Tz (Nmm)**
Nano17	SI-12-0.12	12	17	120	120	1/320	1/320	1/64	1/64
Nano17	SI-25-0.25	25	35	250	250	1/160	1/160	1/32	1/32
Nano17	SI-50-0.5	50	70	500	500	1/80	1/80	1/16	1/16
		Sensing Ranges				**Resolution (DAQ, Net F/T)⁴**			

Notes:
1. These system resolutions quoted are the effective resolution after dropping eight counts of noise. The effective resolution can be improved with filtering.
2. Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.
3. For IP68 version see caution on physical properties page.
4. DAQ resolutions are typical for a 16-bit data acquisition system.

5.3.4 CTL Calibration Specifications

Table 5.11— Nano17 CTL Calibrations1, 2									
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz³ (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**	**Fx,Fy (lbf)**	**Fz³ (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**
Nano17	US-3-1	3	4.25	1	1	1/640	1/640	1/4000	1/4000
Nano17	US-6-2	6	8.5	2	2	1/320	1/320	1/2000	1/2000
Nano17	US-12-4	12	17	4	4	1/160	1/160	1/1000	1/1000
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz³ (N)**	**Tx,Ty (Nmm)**	**Tz (Nmm)**	**Fx,Fy (N)**	**Fz³ (N)**	**Tx,Ty (Nmm)**	**Tz (Nmm)**
Nano17	SI-12-0.12	12	17	120	120	1/160	1/160	1/32	1/32
Nano17	SI-25-0.25	25	35	250	250	1/80	1/80	1/16	1/16
Nano17	SI-50-0.5	50	70	500	500	1/40	1/40	1/8	1/8
		Sensing Ranges				**Resolution (Controller)**			

Notes:
1. CTL resolutions are typical. System resolutions quoted are the effective resolution after dropping eight counts of noise. The effective resolution can be improved with filtering.
2. Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.
3. For IP68 version see caution on physical properties page.

5.3.5 CTL Analog Output

Table 5.12— Nano17 Analog Output							
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz[2] (lbf)**	**Tx,Ty,Tz (lbf-in)**	**Fx,Fy (lbf/V)**	**Fz[2] (lbf/V)**	**Tx,Ty,Tz (lbf-in/V)**
Nano17	US-3-1	±3	±4.25	±1	0.3	0.425	0.1
Nano17	US-6-2	±6	±8.5	±2	0.6	0.85	0.2
Nano17	US-12-4	±12	±17	±4	1.2	1.7	0.4
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz[2] (N)**	**Tx,Ty,Tz (Nmm)**	**Fx,Fy (N/V)**	**Fz[2] (N/V)**	**Tx,Ty,Tz (Nmm/V)**
Nano17	SI-12-0.12	±12	±17	±120	1.2	1.7	12
Nano17	SI-25-0.25	±25	±35	±250	2.5	3.5	25
Nano17	SI-50-0.5	±50	±70	±500	5	7	50
		Analog Output Range			**Analog ±10V Sensitivity[1]**		

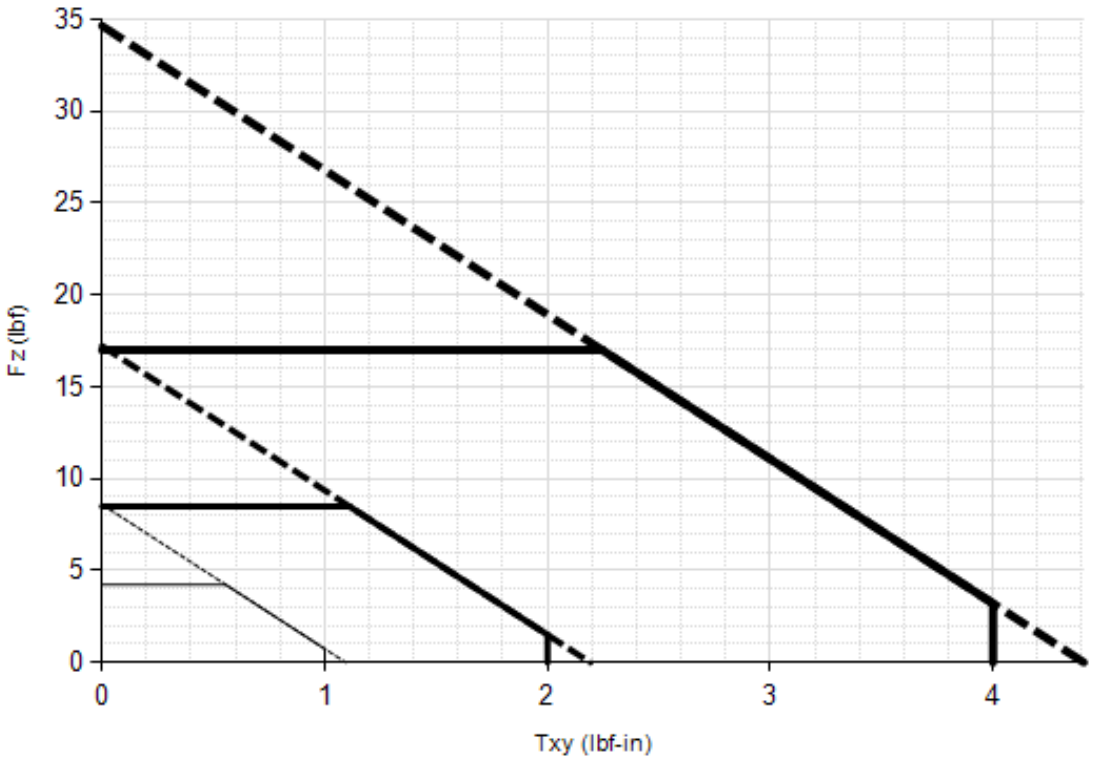
Notes:
1. ±5V Sensitivity values are double the listed ±10V Sensitivity values.
2. For IP68 version see caution on physical properties page.

5.3.6 CTL Counts Value

Table 5.13—Counts Value					
Sensor	**Calibration**	**Fx, Fy, Fz (/ lbf)**	**Tx, Ty, Tz (/ lbf-in)**	**Fx, Fy, Fz (/ N)**	**Tx, Ty, Tz (/ Nmm)**
Nano17	US-3–1 / SI-12–0.25	5120	32000	1280	256
Nano17	US-6–2 / SI-25–0.25	2560	16000	640	128
Nano17	US-12–4 / SI-50–0.5	1280	8000	320	64
Nano17	Tool Transform Factor	0.0016 in/lbf		0.05 mm/N	
		Counts Value – Standard (US)		**Counts Value – Metric (SI)**	

5.3.7 Nano17 (US Calibration Complex Loading)(Includes IP65/IP68)[1]

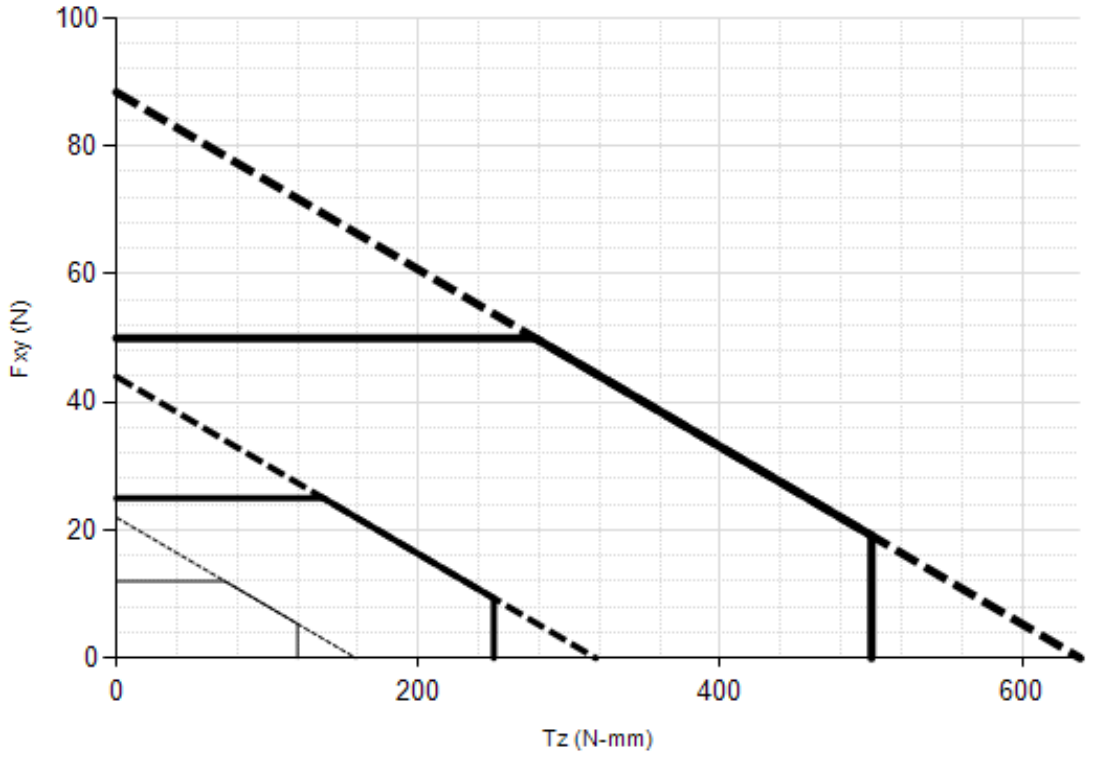


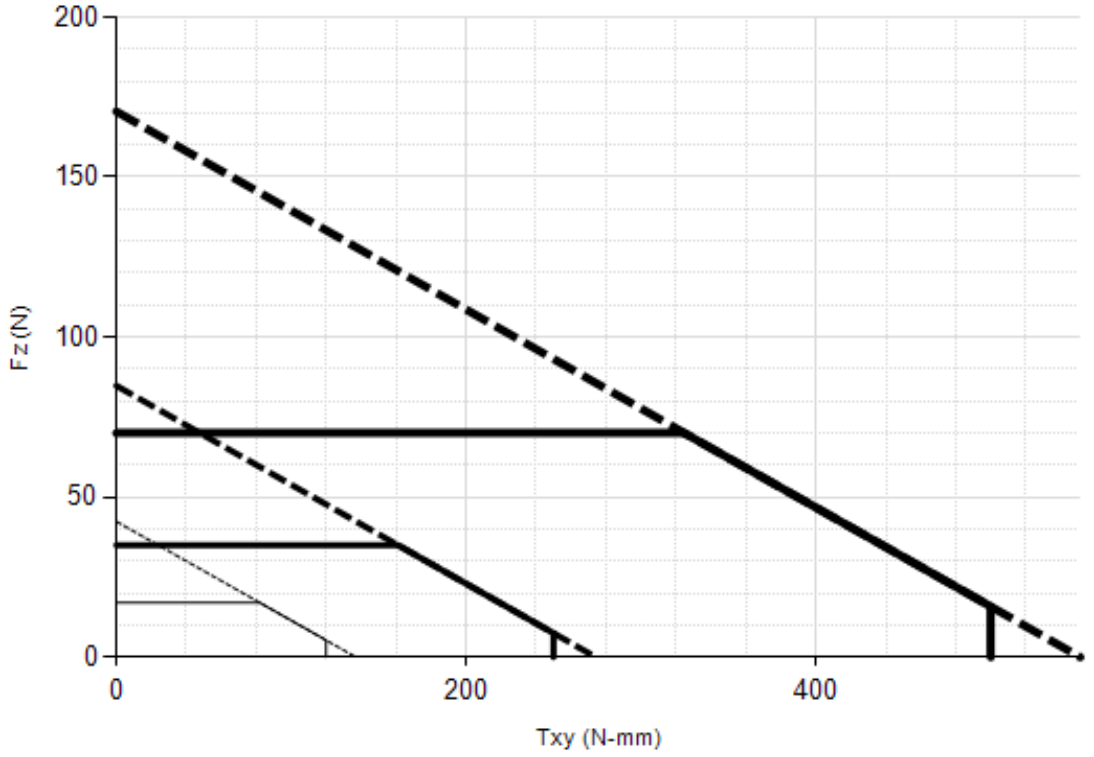


US-3-1 US-6-2 US-12-4

Note: 1. For IP68 version see caution on physical properties page.

5.3.8 Nano17 (SI Calibration Complex Loading)(Includes IP65/IP68)[1]





SI-12-0.12 SI-25-0.25 SI-50-0.5

Note: 1. For IP68 version see caution on physical properties page.

5.4 Nano25 Specifications (Includes IP65/IP68 Versions)

In addition to the information in the following sections, refer to the ATI website:

Table 5.14—Nano25 Drawing and Web Links		
Model	**Drawing Part Number**	**ATI Website Address**
Nano25	*9230-05-1083*	*https://www.ati-ia.com/products/ft/ft_models.aspx?id=Nano25*
Nano25-E	*9230-05-1312*	
Nano25 IP65/ IP68 (Axial Cable Exit)	*9230-05-1259*	*https://www.ati-ia.com/products/ft/ft_models.aspx?id=Nano25+IP65%2fIP68*
Nano25 IP65/ IP68 (Radial Cable Exit)	*9230-05-1337*	

5.4.1 Nano25 Physical Properties

Table 5.15—Nano25 Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±520 lbf	±2300 N
Fz	±1600 lbf	±7300 N
Txy	±380 inf-lb	±43 Nm
Tz	±560 inf-lb	±63 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	3.0×10^5 lb/in	5.3×10^7 N/m
Z-axis force (Kz)	6.3×10^5 lb/in	1.1×10^8 N/m
X-axis & Y-axis torque (Ktx, Kty)	5.7×10^4 lbf-in/rad	6.5×10^3 Nm/rad
Z-axis torque (Ktz)	8.1×10^4 lbf-in/rad	9.2×10^3 Nm/rad
Resonant Frequency		
Fx, Fy, Tz	3600 Hz	3600 Hz
Fz, Tx, Ty	3800 Hz	3800 Hz
Physical Specifications		
Weight[1]	0.14 lb	0.0634 kg
Diameter[1]	0.984 in	25 mm
Height[1]	0.85 in	21.6 mm
Note: 1. Specifications include standard interface plates.		

5.4.2 Nano25 IP65/IP68 Physical Properties

Table 5.16—Nano25 IP65/IP68 Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±520 lbf	±2300 N
Fz	±1600 lbf	±7300 N
Txy	±380 inf-lb	±43 Nm
Tz	±560 inf-lb	±63 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	3.0×10^5 lb/in	5.3×10^7 N/m
Z-axis force (Kz)	6.3×10^5 lb/in	1.1×10^8 N/m
X-axis & Y-axis torque (Ktx, Kty)	5.7×10^4 lbf-in/rad	6.5×10^3 Nm/rad
Z-axis torque (Ktz)	8.1×10^4 lbf-in/rad	9.2×10^3 Nm/rad
Resonant Frequency		
Fx, Fy, Tz	3400 Hz	3400 Hz
Fz, Tx, Ty	3500 Hz	3500 Hz
Physical Specifications		
Weight[1]	0.3 lb	0.136 kg
Diameter[1]	1.1 in	28 mm
Height[1]	1.08 in	27.5 mm
Note: 1. Specifications include standard interface plates.		

CAUTION: When submerged, IP68 transducers exhibit a decrease in Fz range related to the submersion depth. This loss is the result of pressure-induced preloading on the transducer. The preload can be masked by biasing the transducer at the depth prior to applying the load to be measured. The following estimates are for room temperature fresh water at sea level.

Submersion Depth		
IP68 Nano17	**US**	**Metric**
Fz preload at 4 m depth	4.33 lb	19.3 N
Fz preload at other depths	-0.33 lb/ft × depthInFeet	-4.81 N/m × depthInMeters

NOTICE: The outer body of the IP65 and the IP68 versions of the Nano25 are electrically floating from the rest of the system. If the transducer signal has additional noise, it may be necessary to electrically connect the transducer body to the case of the F/T system.

5.4.3 Calibration Specifications (excludes CTL calibrations)

Table 5.17— Nano25 Calibrations (excludes CTL calibrations)[1, 2, 4]									
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz[3] (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**	**Fx,Fy (lbf)**	**Fz[3] (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**
Nano25	US-25-25	25	100	25	25	1/224	3/224	1/160	1/320
Nano25	US-50-50	50	200	50	30	1/112	3/112	1/80	1/160
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**
Nano25	SI-125-3	125	500	3	3	1/48	1/16	1/1320	1/2640
Nano25	SI-250-6	250	1000	6	3.4	1/24	1/8	1/660	1/1320
		Sensing Ranges				**Resolution (DAQ, Net F/T)[5]**			

Notes:
1. These system resolutions quoted are the effective resolution after dropping four counts of noise. The effective resolution can be improved with filtering.
2. Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.
3. For IP68 version see caution on physical properties page.
4. Applying moments beyond ±30 lbf-in (±3.4Nm) in Tz can cause hysteresis and permanent zero-point change in the Nano25 (applies to all versions of the Nano25).
5. DAQ resolutions are typical for a 16-bit data acquisition system.

5.4.4 CTL Calibration Specifications

Table 5.18— Nano25 CTL Calibrations[1, 2, 4]									
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz[3] (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**	**Fx,Fy (lbf)**	**Fz[3] (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**
Nano25	US-25-25	25	100	25	25	1/112	3/112	1/80	1/160
Nano25	US-50-50	50	200	50	30	1/56	3/56	1/40	1/80
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**
Nano25	SI-125-3	125	500	3	3	1/24	1/8	1/660	1/1320
Nano25	SI-250-6	250	1000	6	3.4	1/12	1/4	1/330	1/660
		Sensing Ranges				**Resolution (Controller)**			

Notes:
1. CTL resolutions are typical. System resolutions quoted are the effective resolution after dropping eight counts of noise. The effective resolution can be improved with filtering.
2. Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.
3. For IP68 version see caution on physical properties page.
4. Applying moments beyond ±30 lbf-in (±3.4Nm) in Tz can cause hysteresis and permanent zero-point change in the Nano25 (applies to all versions of the Nano25).

5.4.5 CTL Analog Output

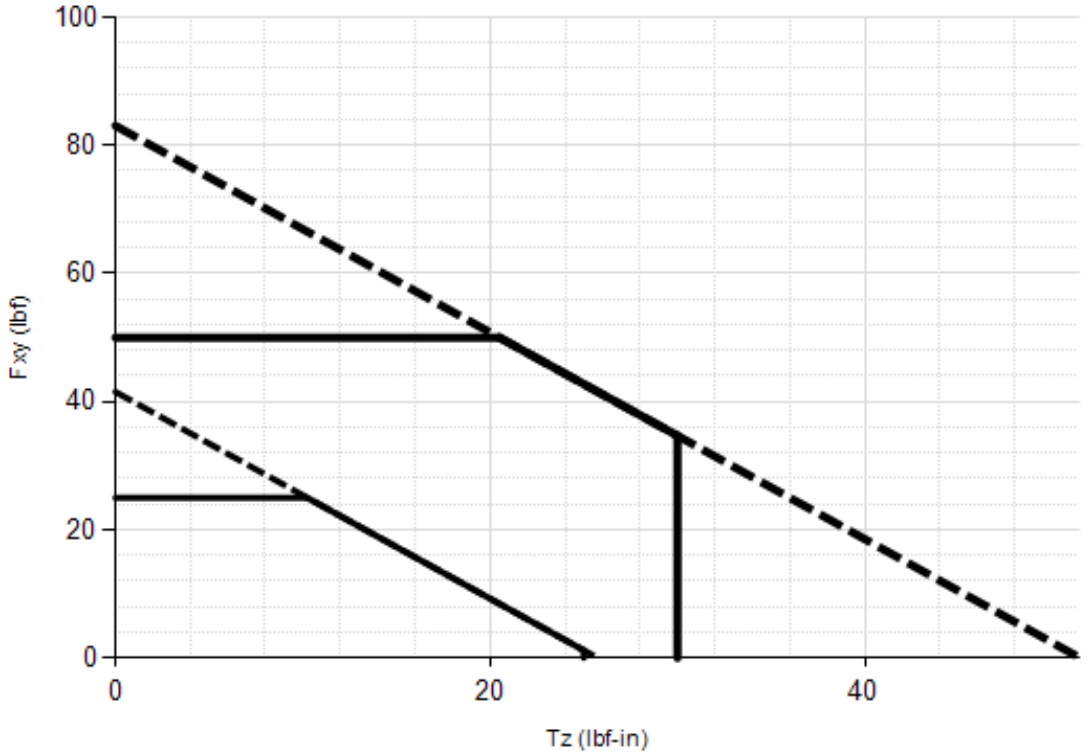
Table 5.19— Nano25 Analog Output							
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz[2] (lbf)**	**Tx,Ty,Tz (lbf-in)**	**Fx,Fy (lbf/V)**	**Fz[2] (lbf/V)**	**Tx,Ty,Tz (lbf-in/V)**
Nano25	US-25-25	±25	±100	±25	2.5	10	2.5
Nano25	US-50-50	±50	±200	±50	5	20	5
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz[2] (N)**	**Tx,Ty,Tz (Nmm)**	**Fx,Fy (N/V)**	**Fz[2] (N/V)**	**Tx,Ty,Tz (Nm/V)**
Nano25	SI-125-3	±125	±500	±3	12.5	50	0.3
Nano25	SI-250-6	±250	±1000	±6	25	100	0.6
		Analog Output Range			**Analog ±10V Sensitivity[1]**		

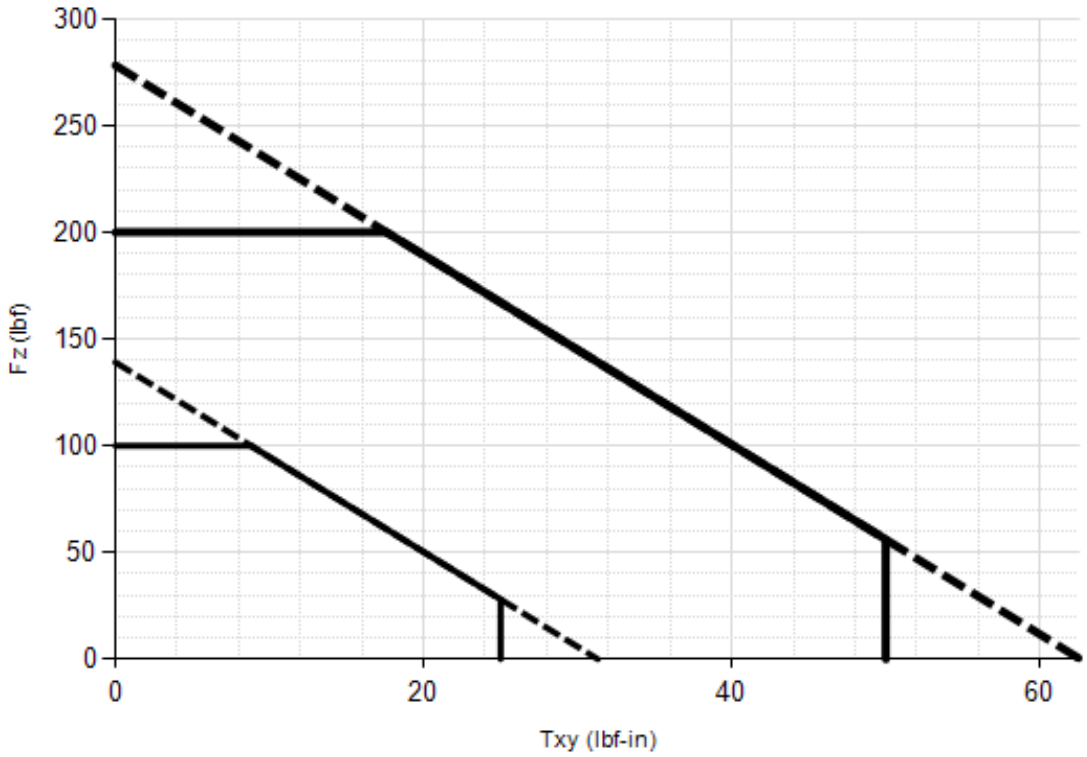
Notes:
1. ±5V Sensitivity values are double the listed ±10V Sensitivity values.
2. For IP68 version see caution on physical properties page.

5.4.6 CTL Counts Value

Table 5.20—Counts Value					
Sensor	**Calibration**	**Fx, Fy, Fz (/ lbf)**	**Tx, Ty, Tz (/ lbf-in)**	**Fx, Fy, Fz**	**Tx, Ty, Tz**
Nano25	US-25–25 / SI-125–3	896	1280	192 / N	10560 / N
Nano25	US-50–50 / SI-250–6	448	640	96 / Nm	5280 / Nm
Nano25	Tool Transform Factor	0.007 in/lbf		0.18182 mm/N	
		Counts Value – Standard (US)		**Counts Value – Metric (SI)**	

5.4.7 Nano25 (US Calibration Complex Loading)(Includes IP65/IP68)[1]

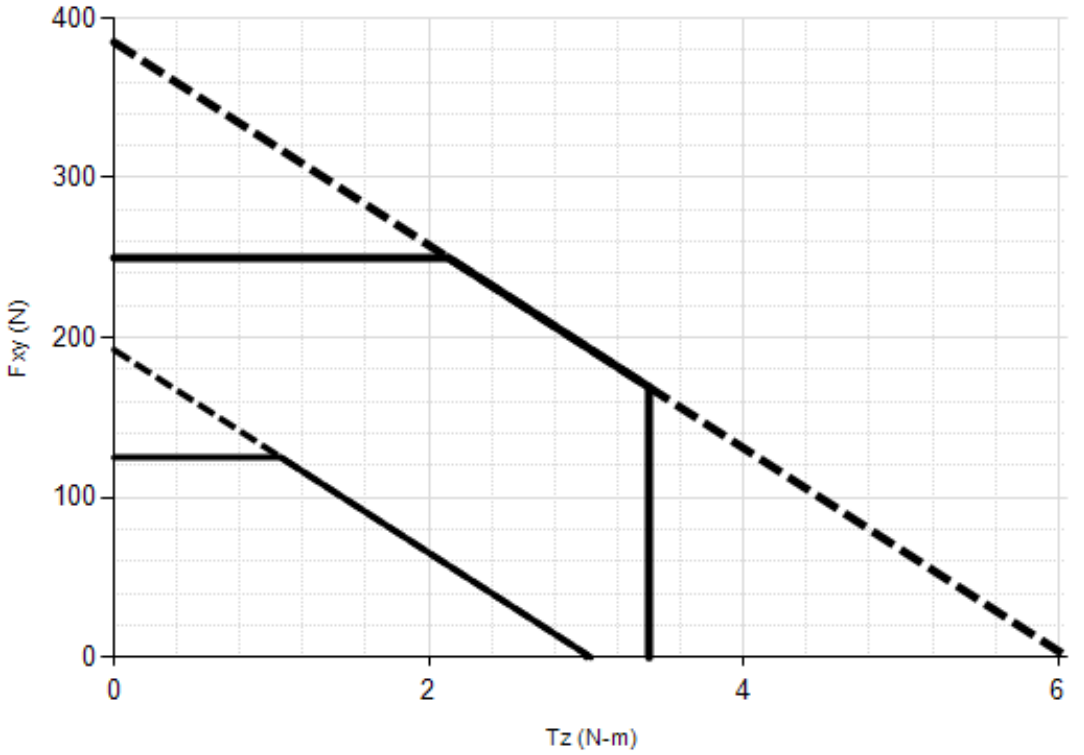


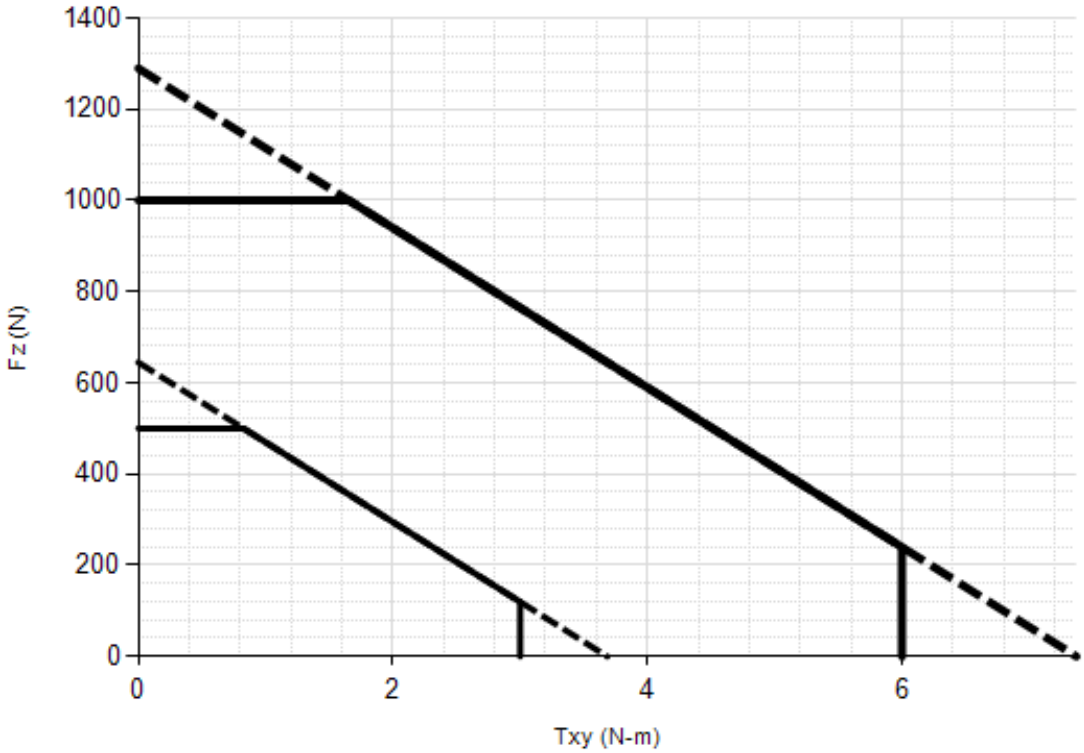


US-25-25 US-50-50

Note: 1. For IP68 version see caution on physical properties page.

5.4.8 Nano25 (SI Calibration Complex Loading)(Includes IP65/IP68)[1]





SI-125-3 SI-250-6

Note: 1. For IP68 version see caution on physical properties page.

5.5 Nano43 Specifications

In addition to the information in the following sections, refer to the ATI website:

Table 5.21—Nano43 Drawing and Web Links		
Model	**Drawing Part Number**	**ATI Website Address**
Nano25	*9230-05-1110*	*https://www.ati-ia.com/products/ft/ft_models.aspx?id=Nano43*

5.5.1 Nano43 Physical Properties

Table 5.22—Nano43 Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±68 lbf	±300 N
Fz	±86 lbf	±380 N
Txy	±29 inf-lb	±3.2 Nm
Tz	±41 inf-lb	±4.6 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	2.9×10^4 lb/in	5.2×10^6 N/m
Z-axis force (Kz)	2.9×10^4 lb/in	5.2×10^6 N/m
X-axis & Y-axis torque (Ktx, Kty)	6.8×10^3 lbf-in/rad	7.7×10^2 Nm/rad
Z-axis torque (Ktz)	1.0×10^4 lbf-in/rad	1.1×10^3 Nm/rad
Resonant Frequency		
Fx, Fy, Tz	2800 Hz	2800 Hz
Fz, Tx, Ty	2300 Hz	2300 Hz
Physical Specifications		
Weight[1]	0.0854 lb	0.0387 kg
Diameter[1]	1.69 in	43 mm
Height[1]	0.454 in	11.5 mm
Note: 1. Specifications include standard interface plates.		

NOTICE: The outer body of the Nano43 is electrically floating from the rest of the system. If the transducer signal has additional noise, it may be necessary to electrically connect the transducer body to the case of the F/T system.

5.5.2 Calibration Specifications (excludes CTL calibrations)

Table 5.23— Nano43 Calibrations (excludes CTL calibrations)[1, 2]									
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**	**Fx,Fy (lbf)**	**Fz (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**
Nano43	US-2-1	2	2	1	1	1/2320	1/2320	1/4640	1/4640
Nano43	US-4-2	4	4	2	2	1/1160	1/1160	1/2320	1/2320
Nano43	US-8-4	8	8	4	4	1/580	1/580	1/1160	1/1160
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz (N)**	**Tx,Ty (Nmm)**	**Tz (Nmm)**	**Fx,Fy (N)**	**Fz (N)**	**Tx,Ty (Nmm)**	**Tz (Nmm)**
Nano43	SI-9-0.125	9	9	125	125	1/512	1/512	1/40	1/40
Nano43	SI-18-0.25	18	18	250	250	1/256	1/256	1/20	1/20
Nano43	SI-36-0.5	36	36	500	500	1/128	1/128	1/10	1/10
		Sensing Ranges				**Resolution (DAQ, Net F/T)[3]**			

Notes:
1. These system resolutions quoted are the effective resolution after dropping eight counts of noise. The effective resolution can be improved with filtering.
2. Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.
3. DAQ resolutions are typical for a 16-bit data acquisition system.

5.5.3 CTL Calibration Specifications

Table 5.24— Nano43 CTL Calibrations[1, 2]									
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**	**Fx,Fy (lbf)**	**Fz (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**
Nano43	US-2-1	2	2	1	1	1/1160	1/1160	1/2320	1/2320
Nano43	US-4-2	4	4	2	2	1/580	1/580	1/1160	1/1160
Nano43	US-8-4	8	8	4	4	1/290	1/290	1/580	1/580
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz (N)**	**Tx,Ty (Nmm)**	**Tz (Nmm)**	**Fx,Fy (N)**	**Fz (N)**	**Tx,Ty (Nmm)**	**Tz (Nmm)**
Nano43	SI-9-0.125	9	9	125	125	1/256	1/256	1/20	1/20
Nano43	SI-18-0.25	18	18	250	250	1/128	1/128	1/10	1/10
Nano43	SI-36-0.5	36	36	500	500	1/64	1/64	1/5	1/5
		Sensing Ranges				**Resolution (Controller)**			

Notes:
1. CTL resolutions are typical. System resolutions quoted are the effective resolution after dropping eight counts of noise. The effective resolution can be improved with filtering.
2. Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.

5.5.4 CTL Analog Output

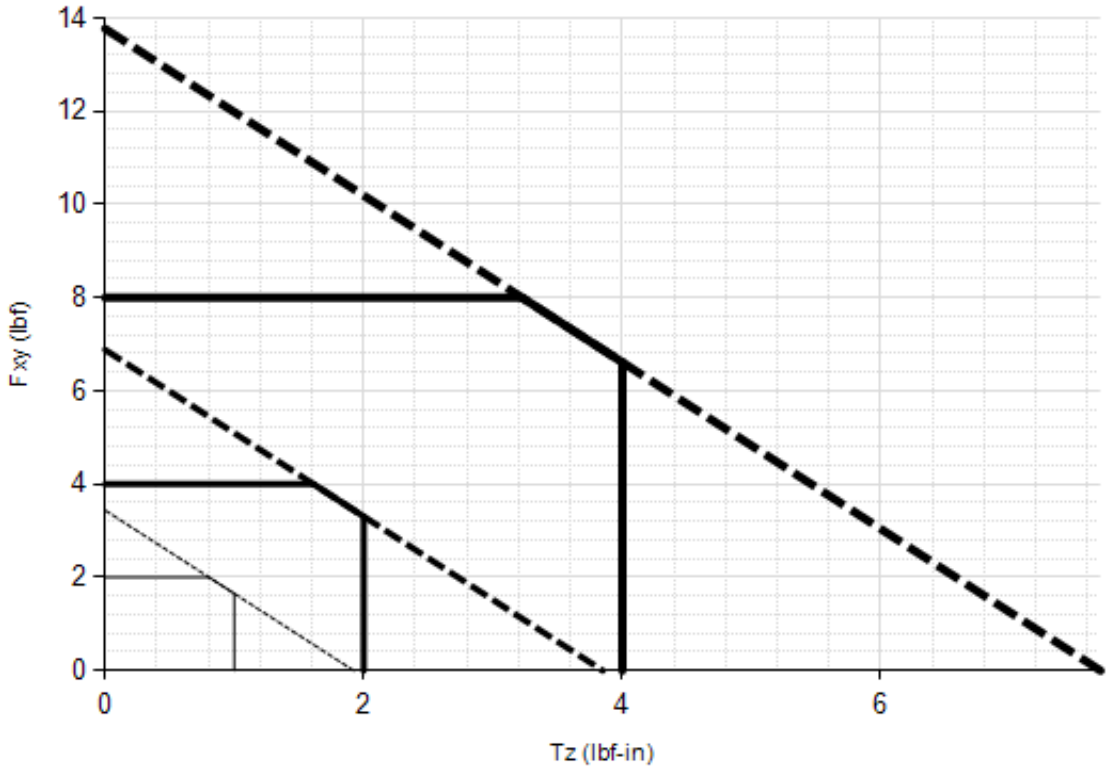
Table 5.25— Nano43 Analog Output							
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz (lbf)**	**Tx,Ty,Tz (lbf-in)**	**Fx,Fy (lbf/V)**	**Fz (lbf/V)**	**Tx,Ty,Tz (lbf-in/V)**
Nano43	US-2-1	N/A	N/A	N/A	N/A	N/A	N/A
Nano43	US-4-2	±4	±4	±2	0.4	0.4	0.2
Nano43	US-8-4	±8	±8	±4	0.8	0.8	0.4
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz (N)**	**Tx,Ty,Tz (Nmm)**	**Fx,Fy (N/V)**	**Fz (N/V)**	**Tx,Ty,Tz (Nm/V)**
Nano43	SI-9-0.125	N/A	N/A	N/A	N/A	N/A	N/A
Nano43	SI-18-0.25	±18	±18	±250	1.8	1.8	25
Nano43	SI-36-0.5	±36	±36	±500	3.6	3.6	50
		Analog Output Range			**Analog ±10V Sensitivity[1]**		

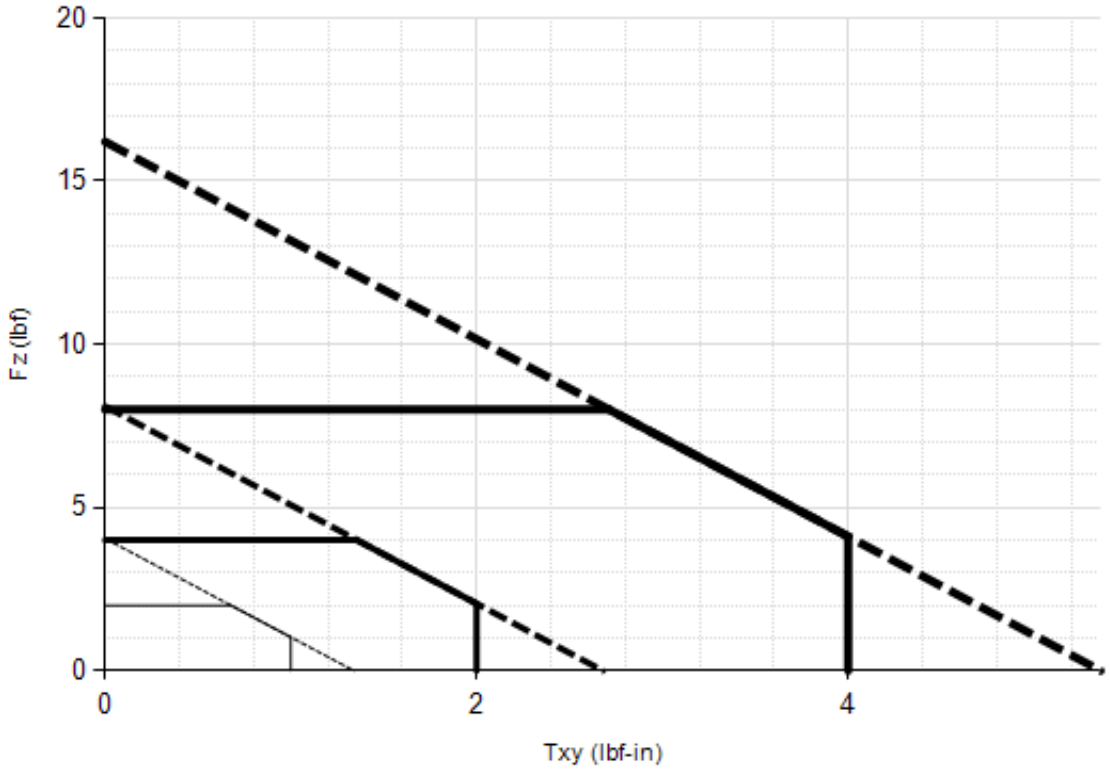
Notes:
1. ±5V Sensitivity values are double the listed ±10V Sensitivity values.

5.5.5 CTL Counts Value

Table 5.26—Counts Value					
Sensor	**Calibration**	**Fx, Fy, Fz (/ lbf)**	**Tx, Ty, Tz (/ lbf-in)**	**Fx, Fy, Fz (/ N)**	**Tx, Ty, Tz (/ Nmm)**
Nano43	US-2-1 / SI-9-0.125	N/A	N/A	N/A	N/A
Nano43	US-4–2 / SI-18–0.25	4640	9280	1024	80
Nano43	US-8–4 / SI-36–0.5	2320	4640	512	40
Nano43	Tool Transform Factor	0.005 in/lbf		0.128 mm/N	
		Counts Value – Standard (US)		**Counts Value – Metric (SI)**	

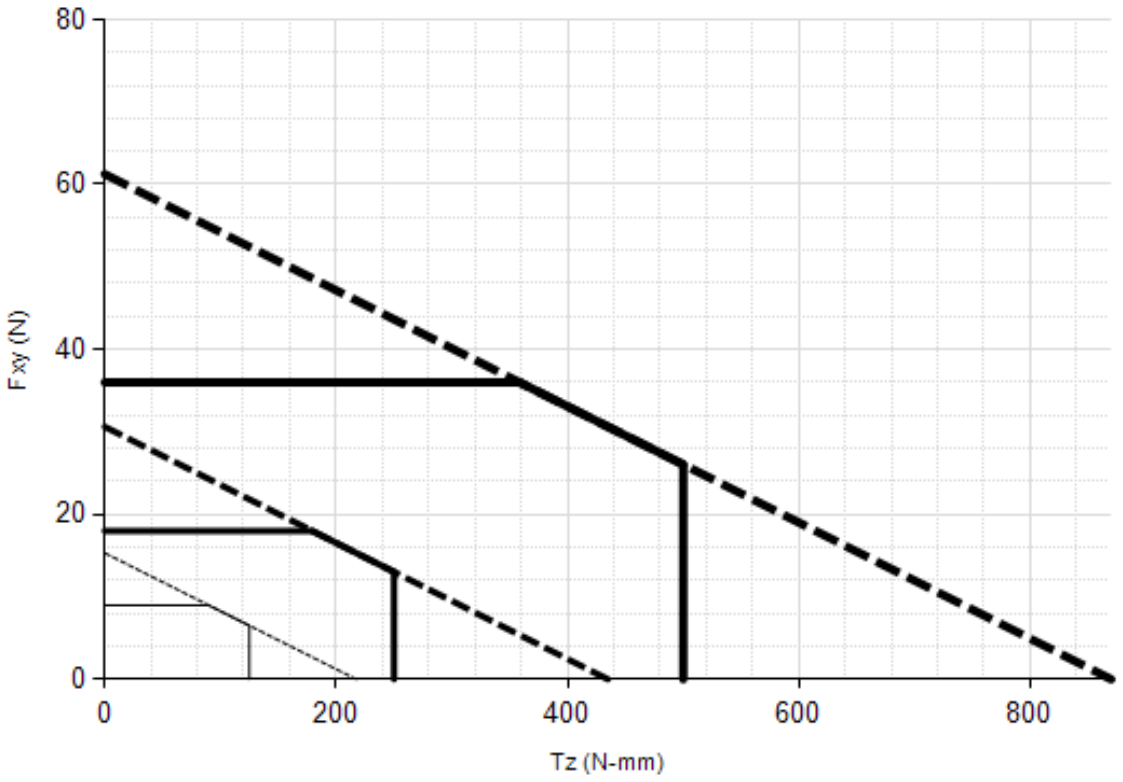
5.5.6 Nano43 (US Calibration Complex Loading)

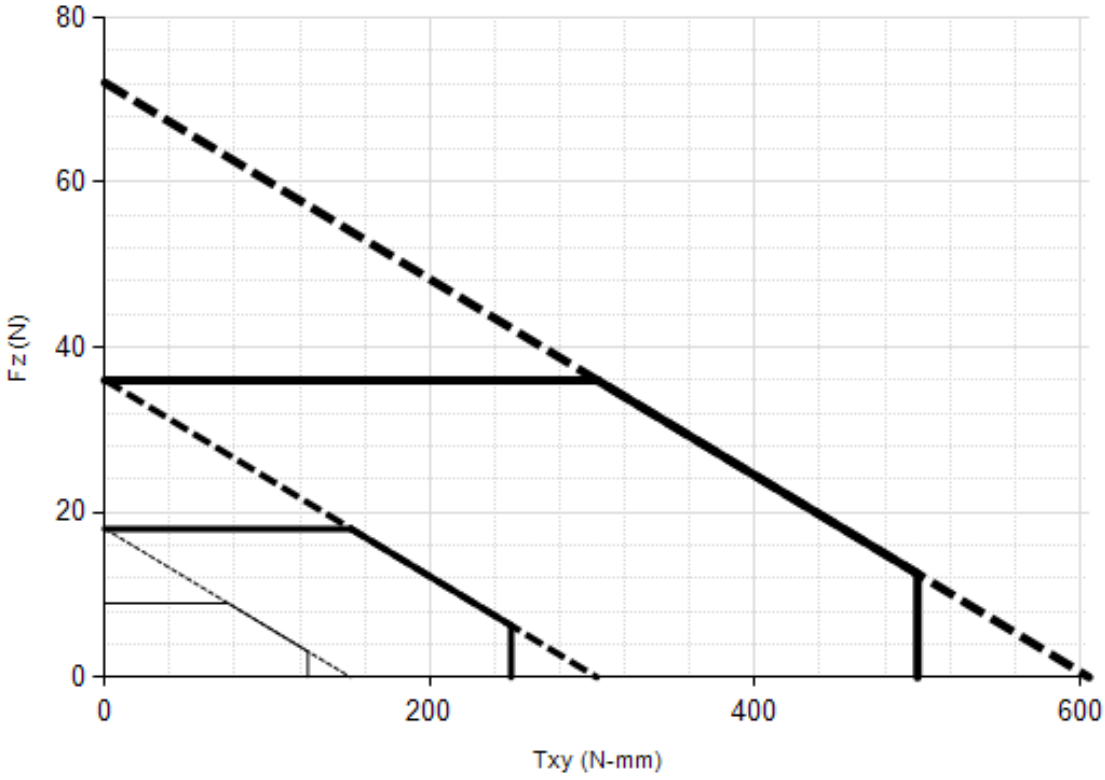




US-2-1 US-4-2 US-8-4

5.5.7 Nano43 (SI Calibration Complex Loading)





SI-9-0.125 SI-18-0.25 SI-36-0.5

5.6 Mini27 Titanium Specifications

In addition to the information in the following sections, refer to the ATI website:

Table 5.27—Mini27 Drawing and Web Links		
Model	**Drawing Part Number**	**ATI Website Address**
Mini27	*9230-05-1420*	*https://www.ati-ia.com/products/ft/ft_models.aspx?id=Mini27+Titanium*
Mini27-E	*9230-05-1553*	

5.6.1 Mini27 Titanium Physical Properties

Table 5.28—Mini27 Titanium Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±330 lbf	±1500 N
Fz	±1000 lbf	±4600 N
Txy	±270 inf-lb	±30 Nm
Tz	±360 inf-lb	±40 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	$1.8x10^5$ lb/in	$3.1x10^7$ N/m
Z-axis force (Kz)	$3.6x10^5$ lb/in	$6.4x10^7$ N/m
X-axis & Y-axis torque (Ktx, Kty)	$4.0x10^4$ lbf-in/rad	$4.5x10^3$ Nm/rad
Z-axis torque (Ktz)	$5.8x10^4$ lbf-in/rad	$6.5x10^3$ Nm/rad
Resonant Frequency		
Fx, Fy, Tz	N/A	N/A
Fz, Tx, Ty	N/A	N/A
Physical Specifications		
Weight[1]	0.0736 lb	0.0334 kg
Diameter[1]	1.06 in	27 mm
Height[1]	0.715 in	18.2 mm
Note: 1. Specifications include standard interface plates.		

5.6.2 Calibration Specifications (excludes CTL calibrations)

Table 5.29—Mini27 Titanium Calibrations (excludes CTL calibrations)[1, 2]									
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**	**Fx,Fy (lbf)**	**Fz (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**
Mini27 Titanium	US-10-18	10	20	18	10	1/400	3/400	1/400	1/800
Mini27 Titanium	US-20-36	20	40	36	20	1/200	3/200	1/200	1/400
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**	**Fx,Fy (N)**	**Fz (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**
Mini27 Titanium	SI-40-2	40	80	2	1	3/200	3/100	3/8000	1/4000
Mini27 Titanium	SI-80-4	80	160	4	2	3/100	3/50	3/4000	1/2000
		Sensing Ranges				**Resolution (DAQ, Net F/T)[3]**			

Notes:
1. These system resolutions quoted are the effective resolution after dropping four counts of noise. The effective resolution can be improved with filtering.
2. Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.
3. DAQ resolutions are typical for a 16-bit data acquisition system.

5.6.3 CTL Calibration Specifications

Table 5.30— Mini27 Titanium CTL Calibrations[1, 2]									
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**	**Fx,Fy (lbf)**	**Fz (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**
Mini27 Titanium	US-10-18	10	20	18	10	1/200	3/200	1/200	1/400
Mini27 Titanium	US-20-36	20	40	36	20	1/100	3/100	1/100	1/200
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**	**Fx,Fy (N)**	**Fz (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**
Mini27 Titanium	SI-40-2	40	80	2	1	3/100	3/50	3/4000	1/2000
Mini27 Titanium	SI-80-4	80	160	4	2	3/50	3/25	3/2000	1/1000
		Sensing Ranges				**Resolution (Controller)**			

Notes:
1. CTL resolutions are typical. System resolutions quoted are the effective resolution after dropping eight counts of noise. The effective resolution can be improved with filtering.
2. Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.

5.6.4 CTL Analog Output

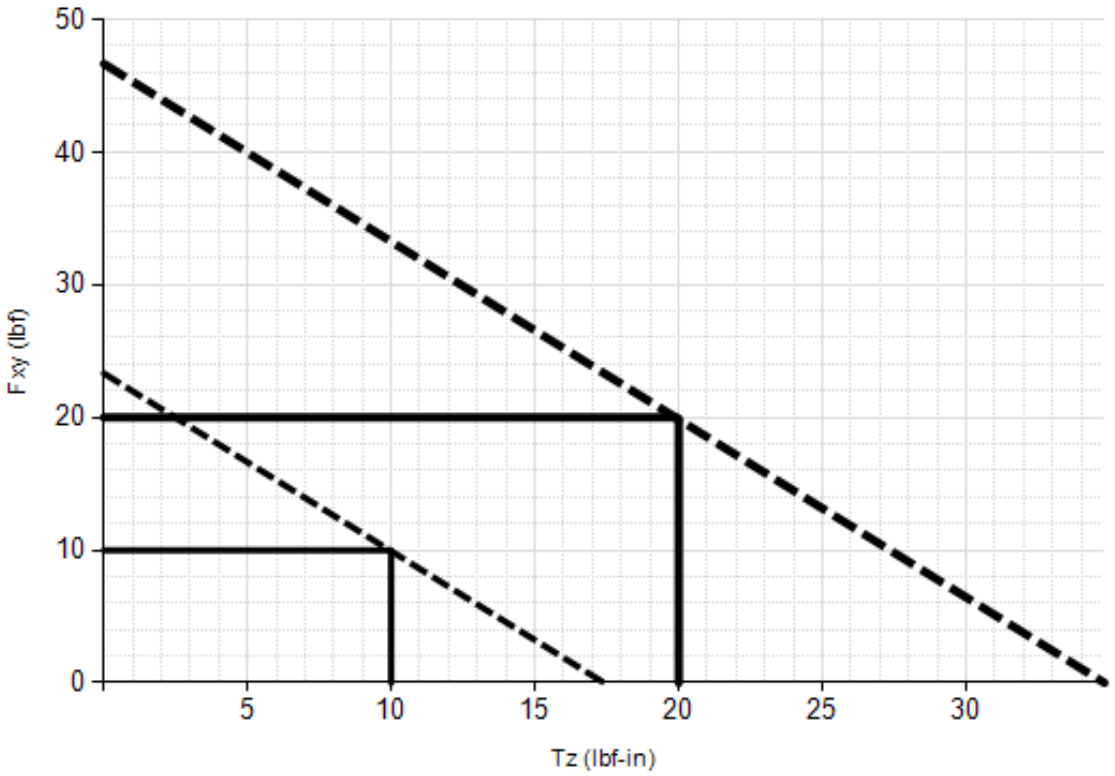
Table 5.31— Mini27 Titanium Analog Output							
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz (lbf)**	**Tx,Ty,Tz (lbf-in)**	**Fx,Fy (lbf/V)**	**Fz (lbf/V)**	**Tx,Ty,Tz (lbf-in/V)**
Mini27 Titanium	US-10-18	±10	±20	±18	1	2	1.8
Mini27 Titanium	US-20-36	±20	±40	±36	2	4	3.6
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz (N)**	**Tx,Ty,Tz (Nmm)**	**Fx,Fy (N/V)**	**Fz (N/V)**	**Tx,Ty,Tz (Nm/V)**
Mini27 Titanium	SI-40-2	±40	±80	±2	4	8	0.2
Mini27 Titanium	SI-80-4	±80	±160	±4	8	16	0.4
		Analog Output Range			**Analog ±10V Sensitivity[1]**		

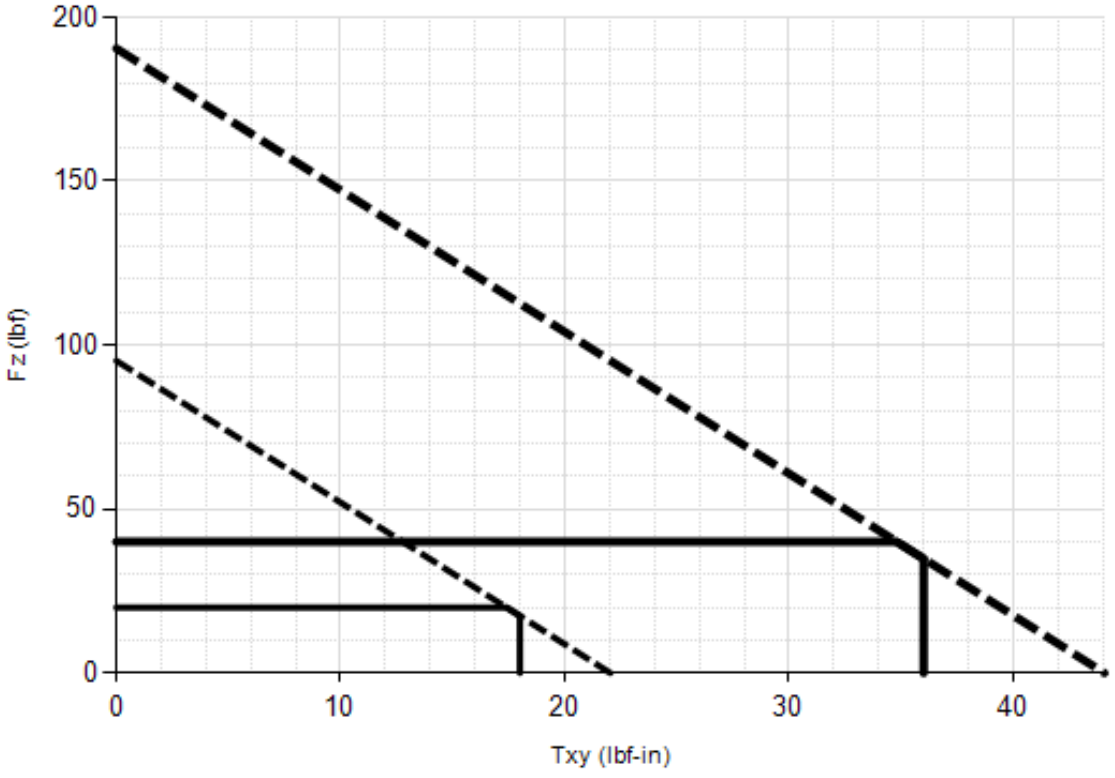
Notes:
1. ±5V Sensitivity values are double the listed ±10V Sensitivity values.

5.6.5 CTL Counts Value

Table 5.32—Counts Value					
Sensor	**Calibration**	**Fx, Fy, Fz (/ lbf)**	**Tx, Ty, Tz (/ lbf-in)**	**Fx, Fy, Fz (/ N)**	**Tx, Ty, Tz (/ Nm)**
Mini27 Titanium	US-1–18 / SI-40–2	3200	3200	800	32000
Mini27 Titanium	US-20–36 / SI-80–4	1600	1600	400	16000
Mini27 Titanium	Tool Transform Factor	0.01 in/lbf		0.25 mm/N	
		Counts Value – Standard (US)		**Counts Value – Metric (SI)**	

5.6.6 Mini27 Titanium (US Calibration Complex Loading)





US-10-18 US-20-36

5.6.7 Mini27 Titanium (SI Calibration Complex Loading)





SI-40-2 SI-80-4

5.7 Mini40 Specifications (Includes IP65/IP68 Versions)

In addition to the information in the following sections, refer to the ATI website:

Table 5.33—Mini40 Drawing and Web Links		
Model	**Drawing Part Number**	**ATI Website Address**
Mini40-A (axial exit)and Mini40-R (radial exit)	*9230-05-1278*	*https://www.ati-ia.com/products/ft/ft_models.aspx?id=Mini40*
Mini40-E	*9230-05-1314*	
Mini40 IP65/IP68	*9230-05-1421*	*https://www.ati-ia.com/products/ft/ft_models.aspx?id=Mini40+IP65%2fIP68*

5.7.1 Mini40 Physical Properties

Table 5.34—Mini40 Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±180 lbf	±810 N
Fz	±530 lbf	±2400 N
Txy	±170 inf-lb	±19 Nm
Tz	±180 inf-lb	±20 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	6.1×10^4 lb/in	1.1×10^7 N/m
Z-axis force (Kz)	1.2×10^5 lb/in	2.0×10^7 N/m
X-axis & Y-axis torque (Ktx, Kty)	2.5×10^4 lbf-in/rad	2.8×10^3 Nm/rad
Z-axis torque (Ktz)	3.6×10^4 lbf-in/rad	4.0×10^3 Nm/rad
Resonant Frequency		
Fx, Fy, Tz	3200 Hz	3200 Hz
Fz, Tx, Ty	4900 Hz	4900 Hz
Physical Specifications		
Weight[1]	0.11 lb	0.0499 kg
Diameter[1]	1.57 in	40 mm
Height[1]	0.482 in	12.2 mm
Note: 1. Specifications include standard interface plates.		

5.7.2 Mini40 IP65/IP68 Physical Properties

Table 5.35—Mini40 IP65/IP68 Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±180 lbf	±810 N
Fz	±530 lbf	±2400 N
Txy	±170 inf-lb	±19 Nm
Tz	±180 inf-lb	±20 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	6.1×10^4 lb/in	1.1×10^7 N/m
Z-axis force (Kz)	1.2×10^5 lb/in	2.0×10^7 N/m
X-axis & Y-axis torque (Ktx, Kty)	2.5×10^4 lbf-in/rad	2.8×10^3 Nm/rad
Z-axis torque (Ktz)	3.6×10^4 lbf-in/rad	4.0×10^3 Nm/rad
Resonant Frequency		
Fx, Fy, Tz	1400 Hz	1400 Hz
Fz, Tx, Ty	1300 Hz	1300 Hz
Physical Specifications		
Weight[1]	0.6 lb	0.272 kg
Diameter[1]	2.1 in	53.3 mm
Height[1]	0.83 in	21.1 mm
Note: 1. Specifications include standard interface plates.		

CAUTION: When submerged, IP68 transducers exhibit a decrease in Fz range related to the submersion depth. This loss is the result of pressure-induced preloading on the transducer. The preload can be masked by biasing the transducer at the depth prior to applying the load to be measured. The following estimates are for room temperature fresh water at sea level.

Submersion Depth		
IP68 Mini40	**US**	**Metric**
Fz preload at 4 m depth	17.0 lb	75.5 N
Fz preload at other depths	-1.29 lb/ft × depthInFeet	-18.9 N/m × depthInMeters

5.7.3 Calibration Specifications (excludes CTL calibrations)

Table 5.36— Mini40 Calibrations (excludes CTL calibrations)[1, 2]

Sensor	(US) Standard Calibration	Fx,Fy (lbf)	Fz[3] (lbf)	Tx,Ty (lbf-in)	Tz (lbf-in)	Fx,Fy (lbf)	Fz[3] (lbf)	Tx,Ty (lbf-in)	Tz (lbf-in)
Mini40	US-5-10	5	15	10	10	1/800	1/400	1/800	1/800
Mini40	US-10-20	10	30	20	20	1/400	1/200	1/400	1/400
Mini40	US-20-40	20	60	40	40	1/200	1/100	1/200	1/200
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**
Mini40	SI-20-1	20	60	1	1	1/200	1/100	1/8000	1/8000
Mini40	SI-40-2	40	120	2	2	1/100	1/50	1/4000	1/4000
Mini40	SI-80-4	80	240	4	4	1/50	1/25	1/2000	1/2000
		Sensing Ranges				**Resolution (DAQ, Net F/T)[4]**			

Notes:
1. These system resolutions quoted are the effective resolution after dropping four counts of noise. The effective resolution can be improved with filtering.
2. Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.
3. For IP68 version see caution on physical properties page.
4. DAQ resolutions are typical for a 16-bit data acquisition system.

5.7.4 CTL Calibration Specifications

Table 5.37— Mini40 CTL Calibrations[1, 2]									
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz[3] (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**	**Fx,Fy (lbf)**	**Fz[3] (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**
Mini40	US-5-10	5	15	10	10	1/400	1/200	1/400	1/400
Mini40	US-10-20	10	30	20	20	1/200	1/100	1/200	1/200
Mini40	US-20-40	20	60	40	40	1/100	1/50	1/100	1/100
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**
Mini40	SI-20-1	20	60	1	1	1/100	1/50	1/4000	1/4000
Mini40	SI-40-2	40	120	2	2	1/50	1/25	1/2000	1/2000
Mini40	SI-80-4	80	240	4	4	1/25	2/25	1/1000	1/1000
		Sensing Ranges				**Resolution (Controller)**			

Notes:
1. CTL resolutions are typical. System resolutions quoted are the effective resolution after dropping eight counts of noise. The effective resolution can be improved with filtering.
2. Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.
3. For IP68 version see caution on physical properties page.

5.7.5 CTL Analog Output

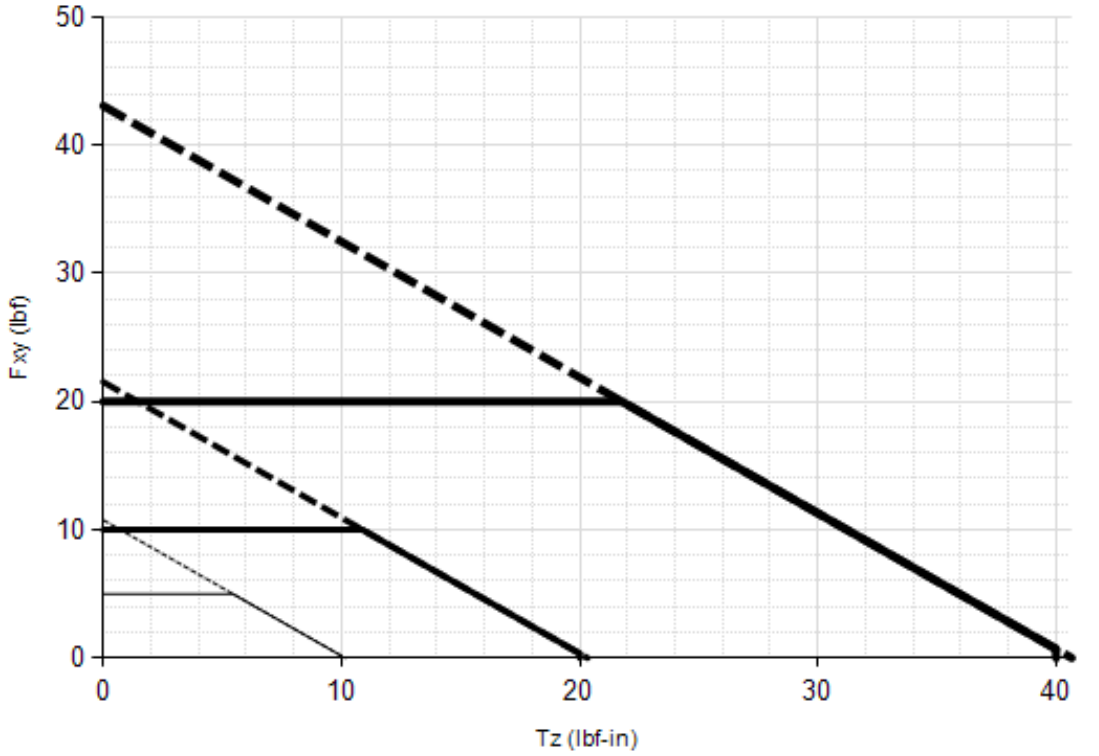
Table 5.38— Mini40 Analog Output							
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz[2] (lbf)**	**Tx,Ty,Tz (lbf-in)**	**Fx,Fy (lbf/V)**	**Fz[2] (lbf/V)**	**Tx,Ty,Tz (lbf-in/V)**
Mini40	US-5-10	±5	±15	±10	0.5	1.5	1
Mini40	US-10-20	±10	±30	±20	1	3	2
Mini40	US-20-40	±20	±60	±40	2	6	4
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz[2] (N)**	**Tx,Ty,Tz (Nm)**	**Fx,Fy (N/V)**	**Fz[2] (N/V)**	**Tx,Ty,Tz (Nm/V)**
Mini40	SI-20-1	±20	±60	±1	2	6	0.1
Mini40	SI-40-2	±40	±120	±2	4	12	0.2
Mini40	SI-80-4	±80	±240	±4	8	24	0.4
		Analog Output Range			**Analog ±10V Sensitivity[1]**		

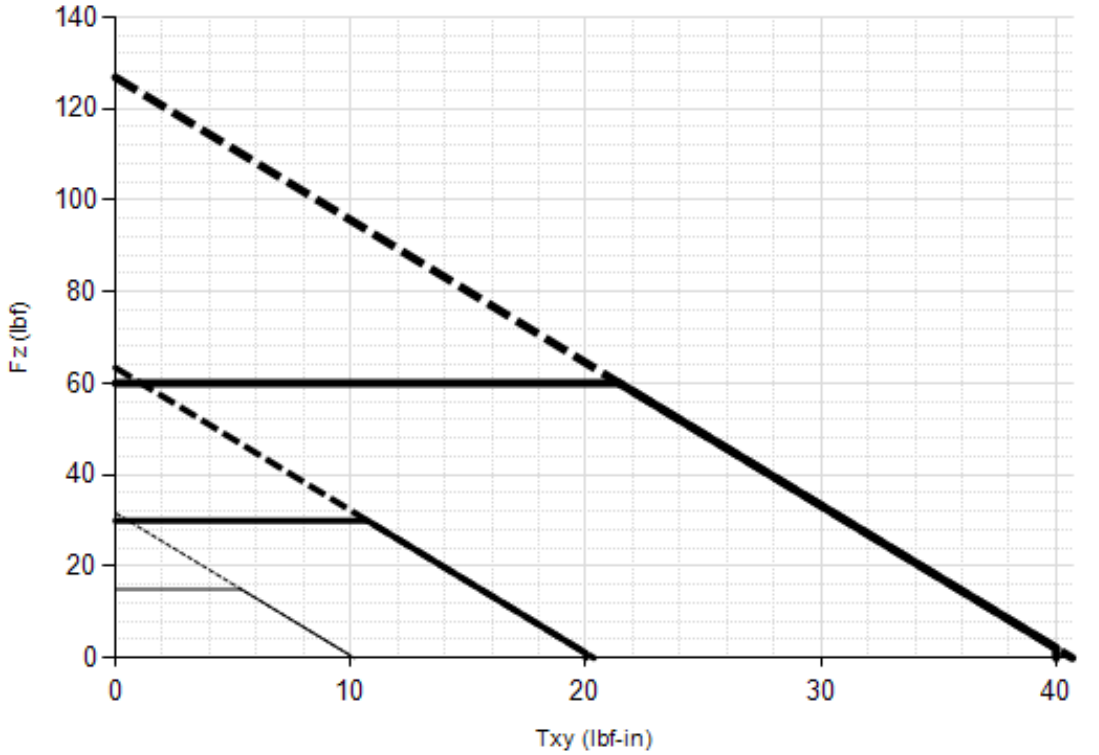
Notes:
1. ±5V Sensitivity values are double the listed ±10V Sensitivity values.
2. For IP68 version see caution on physical properties page.

5.7.6 CTL Counts Value

Table 5.39—Counts Value					
Sensor	**Calibration**	**Fx, Fy, Fz (/ lbf)**	**Tx, Ty, Tz (/ lbf-in)**	**Fx, Fy, Fz (/ N)**	**Tx, Ty, Tz (/ Nm)**
Mini40	US-5–10 / SI-20–1	3200	3200	800	32000
Mini40	US-10–20 / SI-40–2	1600	1600	400	16000
Mini40	US-20–40 / SI-80-4	800	800	200	8000
Mini40	Tool Transform Factor	0.01 in/lbf		0.25 mm/N	
		Counts Value – Standard (US)		**Counts Value – Metric (SI)**	

5.7.7 Mini40 (US Calibration Complex Loading)(Includes IP65/IP68)[1]

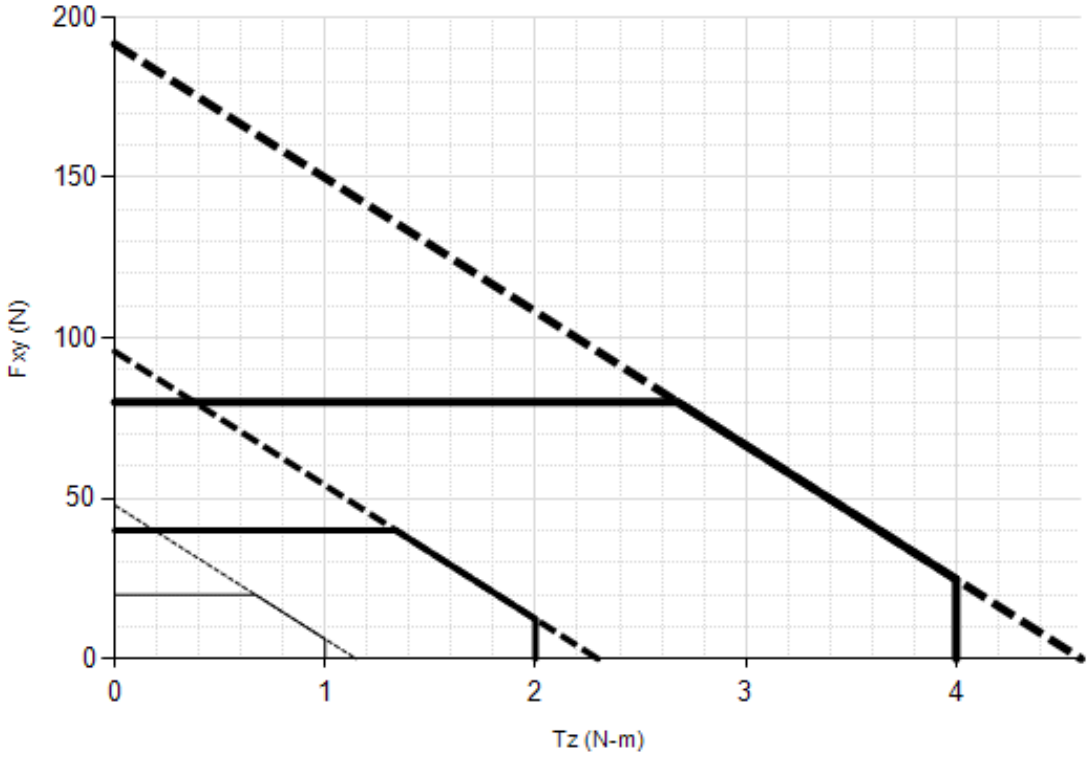


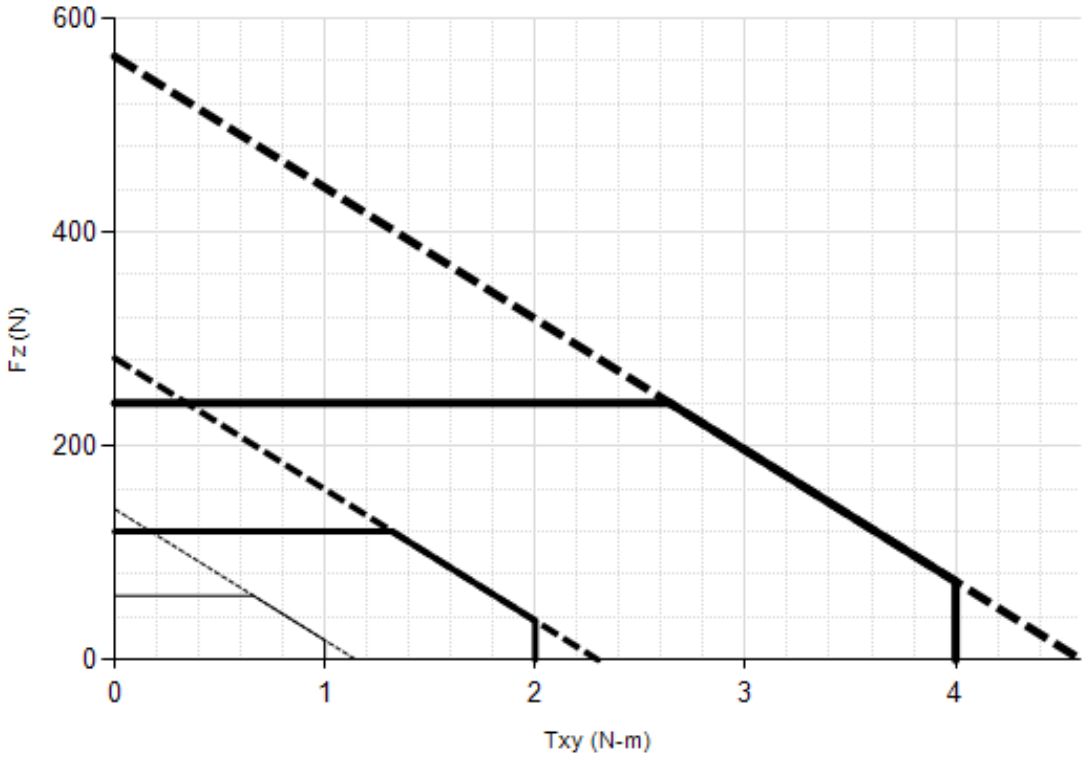


US-5-10 US-10-20 US-20-40

Note: 1. For IP68 version see caution on physical properties page.

5.7.8 Mini40 (SI Calibration Complex Loading)(Includes IP65/IP68)[1]





SI-20-1 SI-40-2 SI-80-4

Note: 1. For IP68 version see caution on physical properties page.

5.8 Mini43LP Specifications

In addition to the information in the following sections, refer to the ATI website:

Table 5.40—Mini43LP Drawing and Web Links		
Model	**Drawing Part Number**	**ATI Website Address**
Mini43LP	9230-05-1615	*https://www.ati-ia.com/app_content/Documents/9230-05-1615.auto.pdf*

5.8.1 Mini43LP Physical Properties

Table 5.41—Mini43LP Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	281 lb	1250 N
Fz	281 lb	1250 N
Txy	133 lb-in	15 Nm
Tz	221 lb-in	25 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	1.9×10^5 lb/in	1.1×10^4 N/m
Z-axis force (Kz)	1.2×10^5 lb/in	2.1×10^4 N/m
X-axis & Y-axis torque (Ktx, Kty)	4.1×10^4 lbf-in/rad	2.7×10^5 Nm/rad
Z-axis torque (Ktz)	1.3×10^5 lbf-in/rad	8.9×10^5 Nm/rad
Resonant Frequency		
Fx, Fy, Tz	5200 Hz	
Fz, Tx, Ty	7300 Hz	
Physical Specifications		
Weight[1]	0.11 lb	0.05 kg
Diameter[1]	1.69 in	43 mm
Height[1]	0.31 in	79.92 mm

5.8.2 Calibration Specifications

Table 5.42—Mini43LP Calibrations[1, 2]									
Sensor	**(US) Standard Calibration**	**Fx,Fy (lb)**	**Fz (lb)**	**Tx,Ty (lb-in)**	**Tz (lb-in)**	**Fx,Fy (lb)**	**Fz (lb)**	**Tx,Ty (lb-in)**	**Tz (lb-in)**
Mini43LP	US-50-25	50	50	25	44	0.025	0.025	0.012	0.022
Mini43LP	US-25-12.5	25	25	12.5	22	0.013	0.13	0.006	0.011
Mini43LP	US-12.5-6	12.5	12.5	6	11	0.006	0.006	0.003	0.005
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**	**Fx,Fy (N)**	**Fz (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**
Mini43LP	SI-250-3	250	250	3	5	0.125	0.125	0.001	0.002
Mini43LP	SI-125-1.5	125	125	1.5	2.5	0.063	0.063	0.001	0.001
Mini43LP	SI-62-0.75	62	62	0.75	1.25	0.006	0.006	0	0.001
		Sensing Ranges				**Resolution[3]**			

Notes:
1. These system resolutions quoted are the effective resolution after dropping four counts of noise. The effective resolution can be improved with filtering.
2. Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.
3. Resolutions are typical for a 16-bit data.

5.8.3 CTL Analog Output

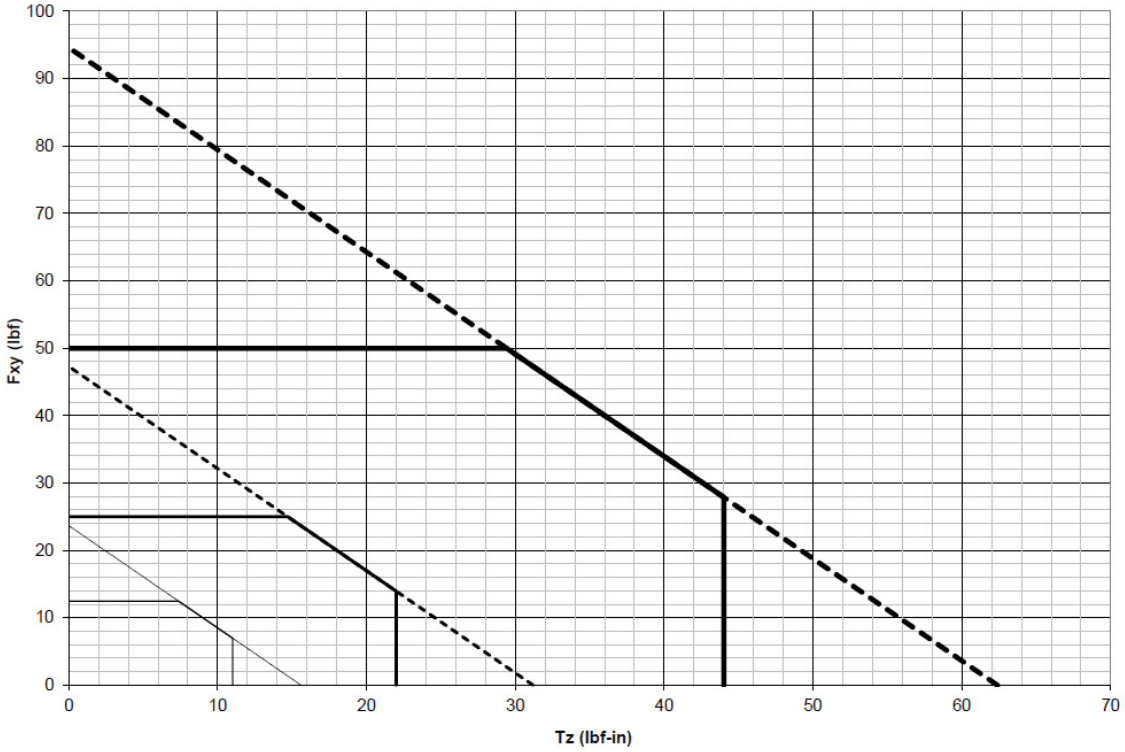
Table 5.43—Mini43LP Analog Output							
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz[2] (lbf)**	**Tx,Ty,Tz (lbf-in)**	**Fx,Fy (lbf/V)**	**Fz[2] (lbf/V)**	**Tx,Ty,Tz (lbf-in/V)**
Mini43LP	US-12.5-6	±12.5	±6	±11	1.25	0.6	1.1
Mini43LP	US-25-12.5	±25	±12.5	±22	2.5	1.25	2.2
Mini43LP	US-50-25	±50	±25	±44	5	2.5	4.4
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz[2] (N)**	**Tx,Ty,Tz (Nm)**	**Fx,Fy (N/V)**	**Fz[2] (N/V)**	**Tx,Ty,Tz (Nm/V)**
Mini43LP	SI-62-0.75	±62	±0.75	±1.25	6.2	0.075	0.125
Mini43LP	SI-125-1.5	±125	±1.5	±2.5	12.5	0.15	0.25
Mini43LP	SI-250-3	±250	±3	±5	25	0.3	0.5
		Analog Output Range			**Analog ±10V Sensitivity[1]**		

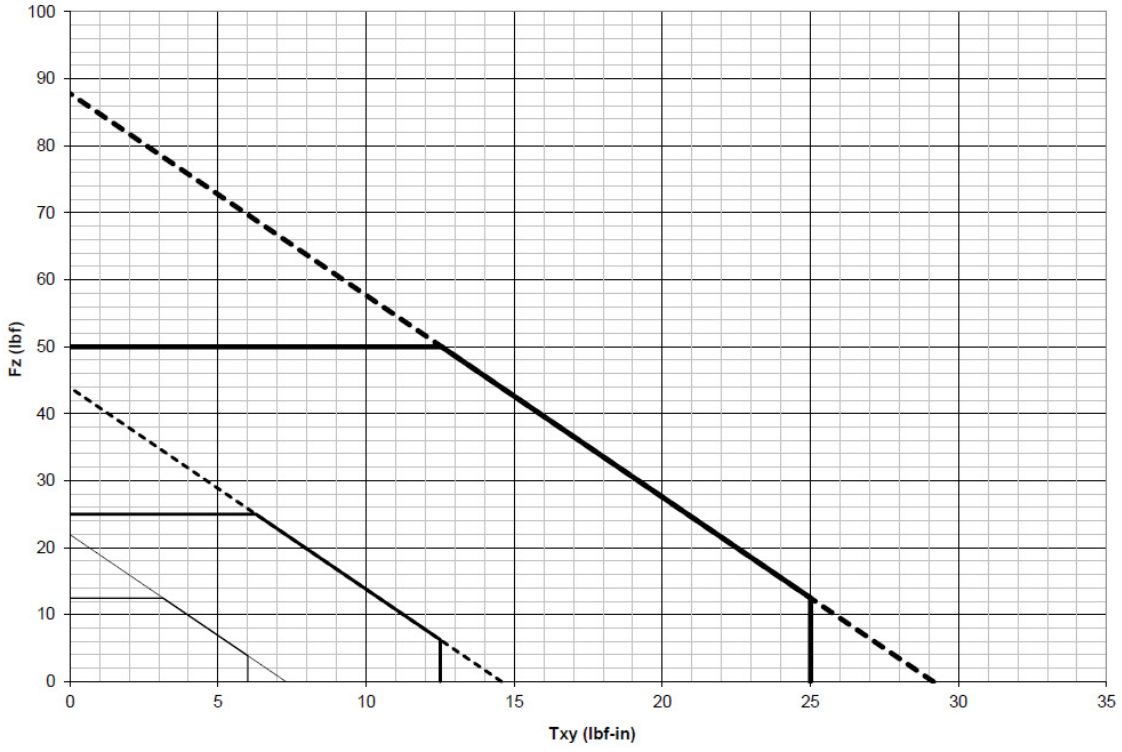
Notes:
1. ±5V Sensitivity values are double the listed ±10V Sensitivity values.

5.8.4 CTL Counts Value

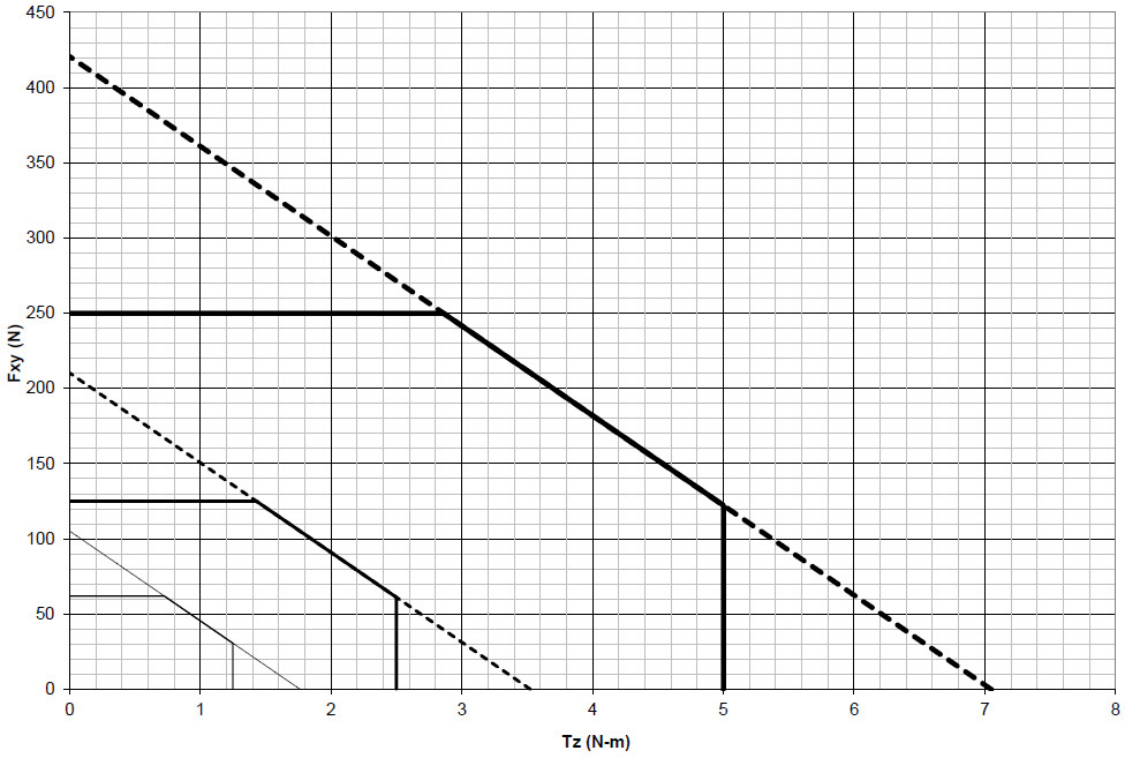
Table 5.44—Counts Value					
Sensor	**Calibration**	**Fx, Fy, Fz (/ lbf)**	**Tx, Ty, Tz (/ lbf-in)**	**Fx, Fy, Fz (/ N)**	**Tx, Ty, Tz (/ Nm)**
Mini45 Titanium	US-12.5-6 / SI-62-0.75	640	736	128	6560
Mini45 Titanium	US-25-12.5 / SI-125-1.5	320	368	64	3280
Mini45 Titanium	US-50-25 / SI-250-3	160	184	32	1640
		Counts Value – Standard (US)		**Counts Value – Metric (SI)**	

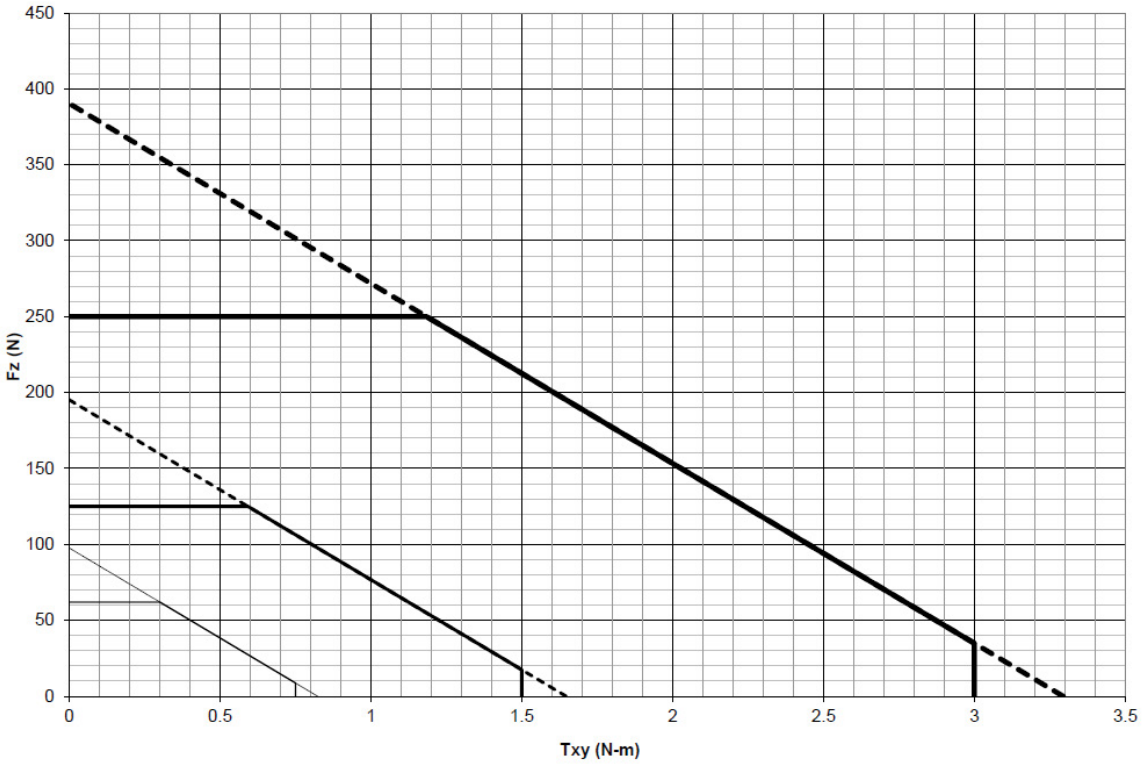
5.8.5 Mini43LP (US Calibration Complex Loading)





5.8.6 Mini43LP (SI Calibration Complex Loading)





5.9 Mini45 Titanium Specifications

In addition to the information in the following sections, refer to the ATI website:

Table 5.45—Mini45 Drawing and Web Links		
Model	**Drawing Part Number**	**ATI Website Address**
Mini45 Titanium Axial Exit	*9230-05-1440*	*https://www.ati-ia.com/products/ft/ft_models.aspx?id=Mini45+Titanium*
Mini45 Titanium Right Angle E-Exit	*9230-05-1441*	

5.9.1 Mini45 Titanium Physical Properties

Table 5.46—Mini45 Titanium Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±670 lbf	±3000 N
Fz	±1400 lbf	±6400 N
Txy	±590 inf-lb	±67 Nm
Tz	±720 inf-lb	±81 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	2.5×10^5 lb/in	4.3×10^7 N/m
Z-axis force (Kz)	3.3×10^5 lb/in	5.7×10^7 N/m
X-axis & Y-axis torque (Ktx, Kty)	8.6×10^4 lbf-in/rad	9.7×10^3 Nm/rad
Z-axis torque (Ktz)	1.8×10^5 lbf-in/rad	2.0×10^4 Nm/rad
Resonant Frequency		
Fx, Fy, Tz	5800 Hz	5800 Hz
Fz, Tx, Ty	4600 Hz	4600 Hz
Physical Specifications		
Weight[1]	0.22 lb	0.0998 kg
Diameter[1]	1.77 in	45 mm
Height[1]	0.69 in	17.5 mm
Note: 1. Specifications include standard interface plates.		

5.9.2 Calibration Specifications (excludes CTL calibrations)

Table 5.47— Mini45 Titanium Calibrations (excludes CTL calibrations)[1, 2]									
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**	**Fx,Fy (lbf)**	**Fz (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**
Mini45 Titanium	US-15-25	15	30	25	25	3/800	1/160	1/300	1/400
Mini45 Titanium	US-30-50	30	60	50	50	3/400	1/80	1/150	1/200
Mini45 Titanium	US-60-100	60	120	100	100	3/200	1/40	1/75	1/100
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**	**Fx,Fy (N)**	**Fz (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**
Mini45 Titanium	SI-60-3	60	120	3	3	1/60	7/240	3/8000	1/3200
Mini45 Titanium	SI-120-6	120	240	6	6	1/30	7/120	3/4000	1/1600
Mini45 Titanium	SI-240-12	240	480	12	12	1/15	7/60	3/2000	1/800
		Sensing Ranges				**Resolution (DAQ, Net F/T)[3]**			

Notes:
1. These system resolutions quoted are the effective resolution after dropping four counts of noise. The effective resolution can be improved with filtering.
2. Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.
3. DAQ resolutions are typical for a 16-bit data acquisition system.

5.9.3 CTL Calibration Specifications

Table 5.48— Mini45 Titanium CTL Calibrations[1, 2]									
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**	**Fx,Fy (lbf)**	**Fz (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**
Mini45 Titanium	US-15-25	15	30	25	25	3/400	1/80	1/150	1/200
Mini45 Titanium	US-30-50	30	60	50	50	3/200	1/40	1/75	1/100
Mini45 Titanium	US-60-100	60	120	100	100	3/100	1/20	2/75	1/50
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**	**Fx,Fy (N)**	**Fz (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**
Mini45 Titanium	SI-60-3	60	120	3	3	1/30	7/120	3/4000	1/1600
Mini45 Titanium	SI-120-6	120	240	6	6	1/15	7/60	3/2000	1/800
Mini45 Titanium	SI-240-12	240	480	12	12	2/15	7/30	3/1000	1/400
		Sensing Ranges				**Resolution (Controller)**			

Notes:
1. CTL resolutions are typical. System resolutions quoted are the effective resolution after dropping eight counts of noise. The effective resolution can be improved with filtering.
2. Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.

5.9.4 CTL Analog Output

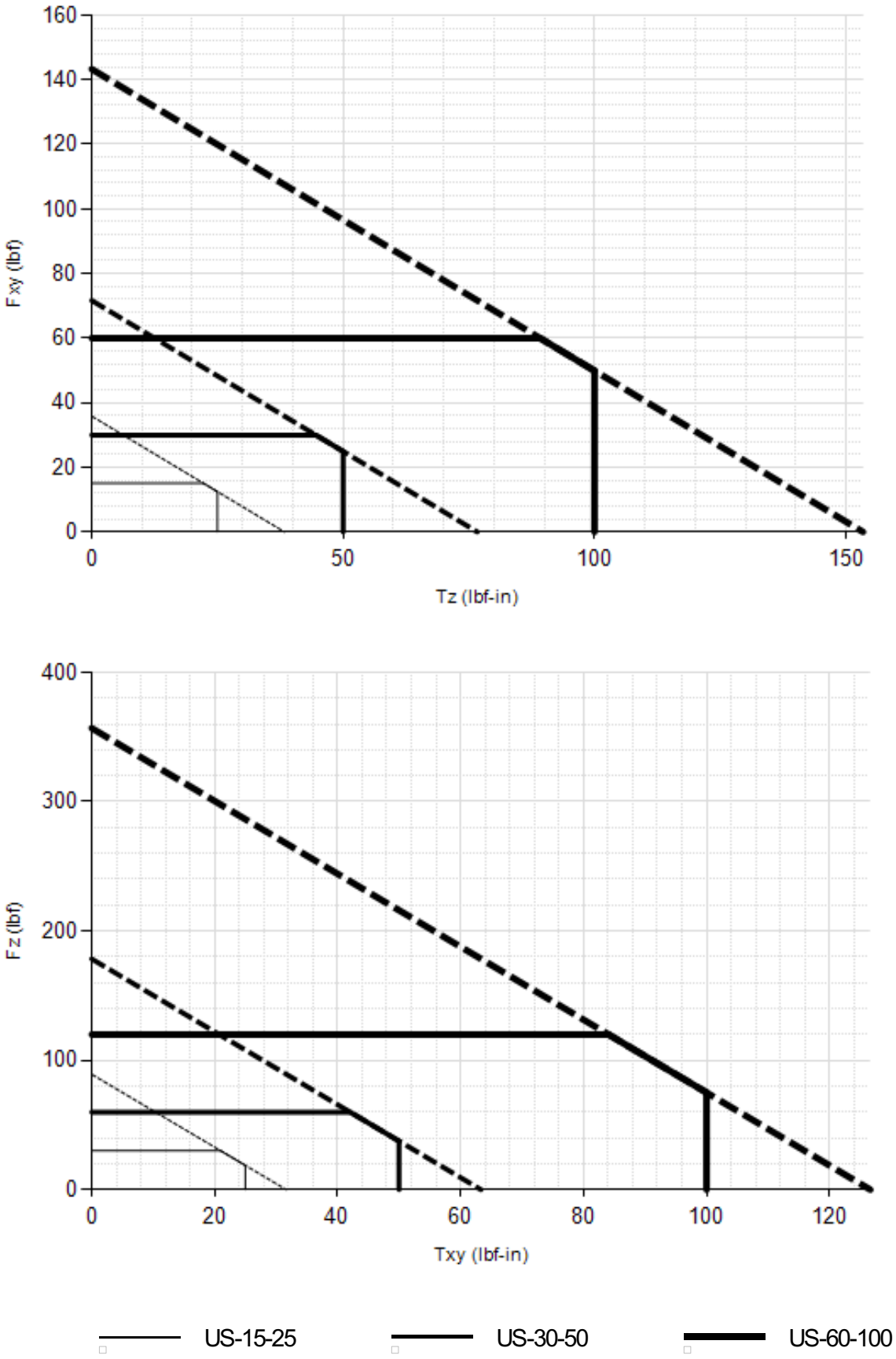
Table 5.49— Mini45 Titanium Analog Output							
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz (lbf)**	**Tx,Ty,Tz (lbf-in)**	**Fx,Fy (lbf/V)**	**Fz (lbf/V)**	**Tx,Ty,Tz (lbf-in/V)**
Mini45 Titanium	US-15-25	±15	±30	±25	1.5	3	2.5
Mini45 Titanium	US-30-50	±30	±60	±50	3	6	5
Mini45 Titanium	US-60-100	±60	±120	±100	6	12	10
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz (N)**	**Tx,Ty,Tz (Nmm)**	**Fx,Fy (N/V)**	**Fz (N/V)**	**Tx,Ty,Tz (Nm/V)**
Mini45 Titanium	SI-60-3	±60	±120	±3	6	12	0.3
Mini45 Titanium	SI-120-6	±120	±240	±6	12	24	0.6
Mini45 Titanium	SI-240-12	±240	±480	±12	24	48	1.2
		Analog Output Range			**Analog ±10V Sensitivity[1]**		

Notes:
1. ±5V Sensitivity values are double the listed ±10V Sensitivity values.

5.9.5 CTL Counts Value

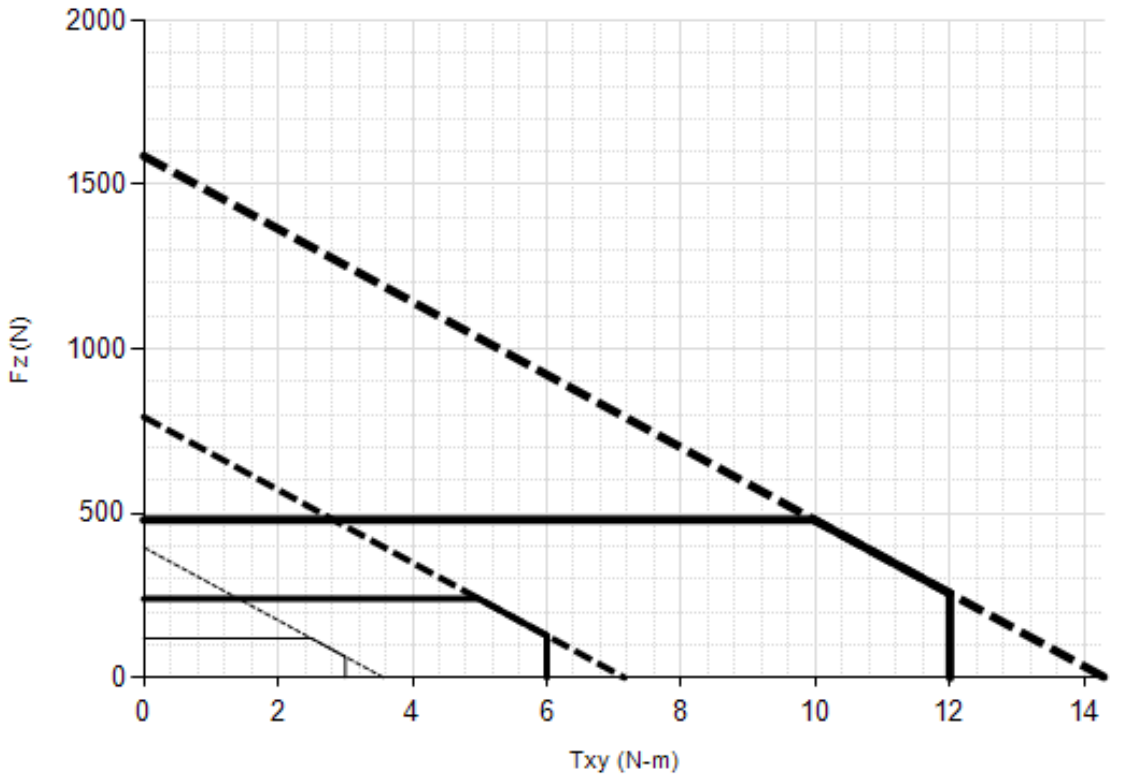
Table 5.50—Counts Value					
Sensor	**Calibration**	**Fx, Fy, Fz (/ lbf)**	**Tx, Ty, Tz (/ lbf-in)**	**Fx, Fy, Fz (/ N)**	**Tx, Ty, Tz (/ Nm)**
Mini45 Titanium	US-15-25 / SI-60-3	640	704	128	6016
Mini45 Titanium	US-30-50 / SI-120-6	320	352	64	3008
Mini45 Titanium	US-60-100 / SI-240-12	160	176	32	1504
Mini45 Titanium	Tool Transform Factor	0.009091 in/lbf		0.21277 mm/N	
		Counts Value – Standard (US)		**Counts Value – Metric (SI)**	

5.9.6 Mini45 Titanium (US Calibration Complex Loading)



5.9.7 Mini45 Titanium (SI Calibration Complex Loading)





SI-60-3 SI-120-6 SI-240-12

5.10 Mini45 Specifications (Includes IP65/IP68 Versions)

In addition to the information in the following sections, refer to the ATI website:

Table 5.51—Mini45 Drawing and Web Links		
Model	**Drawing Part Number**	**ATI Website Address**
Mini45-A (axial exit)and Mini45-R (radial exit)	*9230-05-1094*	*https://www.ati-ia.com/products/ft/ft_models.aspx?id=Mini45*
Mini45-E	*9230-05-1315*	
Mini45-ERA	*9230-05-1338*	
Mini45-AE	*9230-05-1431*	
Mini45 IP65/IP68	*9230-05-1443*	*https://www.ati-ia.com/products/ft/ft_models.aspx?id=Mini45+IP65%2fIP68*

5.10.1 Mini45 Physical Properties

Table 5.52—Mini45 Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±1100 lbf	±5100 N
Fz	±2300 lbf	±10000 N
Txy	±1000 inf-lb	±110 Nm
Tz	±1200 inf-lb	±140 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	4.2×10^5 lb/in	7.4×10^7 N/m
Z-axis force (Kz)	5.6×10^5 lb/in	9.8×10^7 N/m
X-axis & Y-axis torque (Ktx, Kty)	1.5×10^5 lbf-in/rad	1.7×10^4 Nm/rad
Z-axis torque (Ktz)	3.1×10^5 lbf-in/rad	3.5×10^4 Nm/rad
Resonant Frequency		
Fx, Fy, Tz	5600 Hz	5600 Hz
Fz, Tx, Ty	5400 Hz	5400 Hz
Physical Specifications		
Weight[1]	0.202 lb	0.0917 kg
Diameter[1]	1.77 in	45 mm
Height[1]	0.618 in	15.7 mm
Note: 1. Specifications include standard interface plates.		

5.10.2 Mini45 IP65/IP68 Physical Properties

Table 5.53—Mini45 IP65/IP68 Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±1100 lbf	±5100 N
Fz	±2300 lbf	±10000 N
Txy	±1000 inf-lb	±110 Nm
Tz	±1200 inf-lb	±140 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	4.2×10^5 lb/in	7.4×10^7 N/m
Z-axis force (Kz)	5.6×10^5 lb/in	9.8×10^7 N/m
X-axis & Y-axis torque (Ktx, Kty)	1.5×10^5 lbf-in/rad	1.7×10^4 Nm/rad
Z-axis torque (Ktz)	3.1×10^5 lbf-in/rad	3.5×10^4 Nm/rad
Resonant Frequency		
Fx, Fy, Tz	5200 Hz	5200 Hz
Fz, Tx, Ty	4200 Hz	4200 Hz
Physical Specifications		
Weight[1]	0.861 lb	0.391 kg
Diameter[1]	2.28 in	57.9 mm
Height[1]	0.988 in	25.1 mm

Note:
1. Specifications include standard interface plates.

CAUTION: When submerged, IP68 transducers exhibit a decrease in Fz range related to the submersion depth. This loss is the result of pressure-induced preloading on the transducer. The preload can be masked by biasing the transducer at the depth prior to applying the load to be measured. The following estimates are for room temperature fresh water at sea level.

Submersion Depth		
IP68 Mini45	**US**	**Metric**
Fz preload at 4 m depth	17.0 lb	75.5 N
Fz preload at other depths	-1.29 lb/ft × depthInFeet	-18.9 N/m × depthInMeters

5.10.3 Calibration Specifications (excludes CTL calibrations)

Table 5.54— Mini45 Calibrations (excludes CTL calibrations)[1, 2]									
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz[3] (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**	**Fx,Fy (lbf)**	**Fz[3] (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**
Mini45	US-30-40	30	60	40	40	1/80	1/80	1/88	1/176
Mini45	US-60-80	60	120	80	80	1/40	1/40	1/44	1/88
Mini45	US-120-160	120	240	160	160	1/20	1/20	1/22	1/44
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**
Mini45	SI-145-5	145	290	5	5	1/16	1/16	1/752	1/1504
Mini45	SI-290-10	290	580	10	10	1/8	1/8	1/376	1/752
Mini45	SI-580-20	580	1160	20	20	1/4	1/4	1/188	1/376
		Sensing Ranges				**Resolution (DAQ, Net F/T)[4]**			

Notes:
1. These system resolutions quoted are the effective resolution after dropping four counts of noise. The effective resolution can be improved with filtering.
2. Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.
3. For IP68 version see caution on physical properties page.
4. DAQ resolutions are typical for a 16-bit data acquisition system.

5.10.4 CTL Calibration Specifications

Table 5.55— Mini45 CTL Calibrations[1, 2]									
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz[3] (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**	**Fx,Fy (lbf)**	**Fz[3] (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**
Mini45	US-30-40	30	60	40	40	1/40	1/40	1/44	1/88
Mini45	US-60-80	60	120	80	80	1/20	1/20	1/22	1/44
Mini45	US-120-160	120	240	160	160	1/10	1/10	1/11	1/22
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**
Mini45	SI-145-5	145	290	5	5	1/8	1/8	1/376	1/752
Mini45	SI-290-10	290	580	10	10	1/4	1/4	1/188	1/376
Mini45	SI-580-20	580	1160	20	20	1/2	1/2	1/94	1/188
		Sensing Ranges				**Resolution (Controller)**			

Notes:
1. CTL resolutions are typical. System resolutions quoted are the effective resolution after dropping eight counts of noise. The effective resolution can be improved with filtering.
2. Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.
3. For IP68 version see caution on physical properties page.

5.10.5 CTL Analog Output

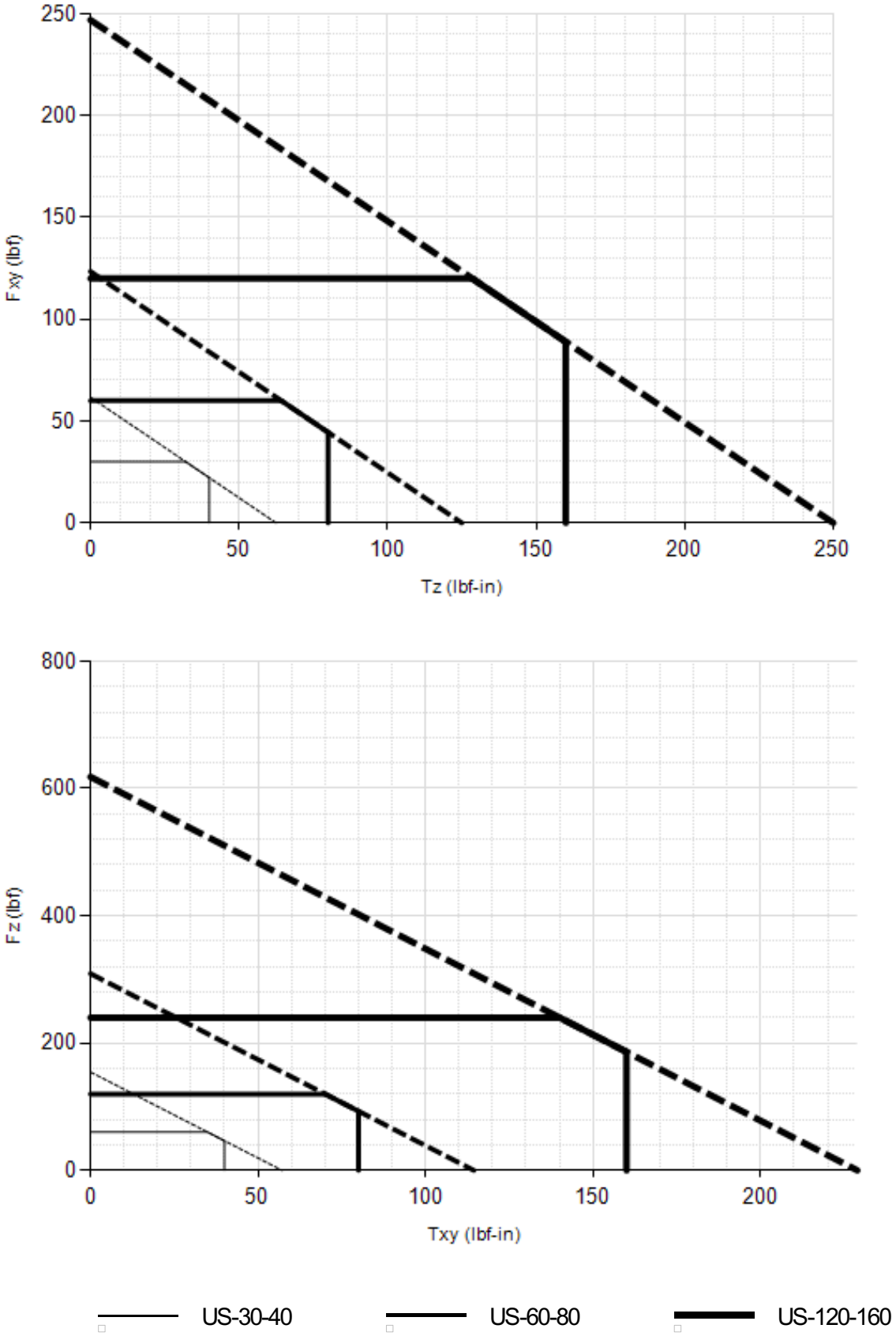
Table 5.56— Mini45 Analog Output							
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz[2] (lbf)**	**Tx,Ty,Tz (lbf-in)**	**Fx,Fy (lbf/V)**	**Fz[2] (lbf/V)**	**Tx,Ty,Tz (lbf-in/V)**
Mini45	US-30-40	±30	±60	±40	3	6	4
Mini45	US-60-80	±60	±120	±80	6	12	8
Mini45	US-120-160	±120	±240	±160	12	24	16
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz[2] (N)**	**Tx,Ty,Tz (Nm)**	**Fx,Fy (N/V)**	**Fz[2] (N/V)**	**Tx,Ty,Tz (Nm/V)**
Mini45	SI-145-5	±145	±290	±5	14.5	29	0.5
Mini45	SI-290-10	±290	±580	±10	29	58	1
Mini45	SI-580-20	±580	±1160	±20	58	116	2
		Analog Output Range			**Analog ±10V Sensitivity[1]**		

Notes:
1. ±5V Sensitivity values are double the listed ±10V Sensitivity values.
2. For IP68 version see caution on physical properties page.

5.10.6 CTL Counts Value

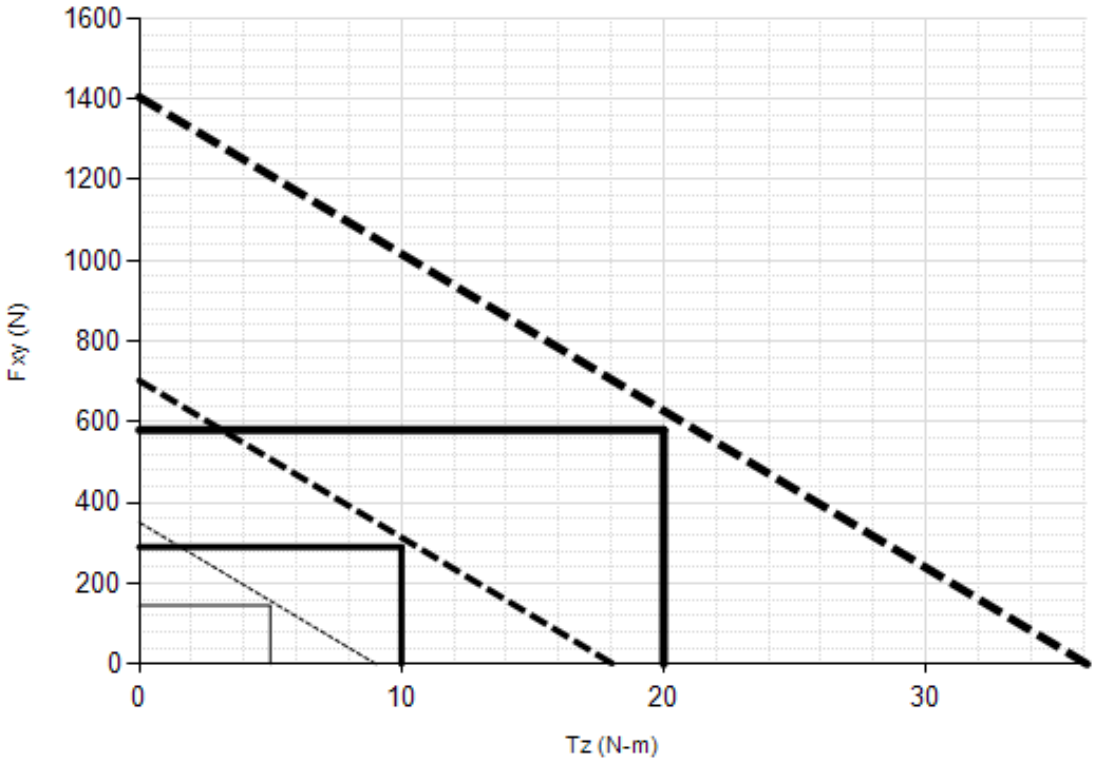
Table 5.57—Counts Value					
Sensor	**Calibration**	**Fx, Fy, Fz (/ lbf)**	**Tx, Ty, Tz (/ lbf-in)**	**Fx, Fy, Fz (/ N)**	**Tx, Ty, Tz (/ Nm)**
Mini45	US-30–40 / SI-145–5	640	704	128	6016
Mini45	US-60–80 / SI-290–10	320	352	64	3008
Mini45	US-120–160 / SI-580–20	160	176	32	1504
Mini45	Tool Transform Factor	0.009091 in/lbf		0.21277 mm/N	
		Counts Value – Standard (US)		**Counts Value – Metric (SI)**	

5.10.7 Mini45 (US Calibration Complex Loading)(Includes IP65/IP68)[1]



Note: 1. For IP68 version see caution on physical properties page.

5.10.8 Mini45 (SI Calibration Complex Loading)(Includes IP65/IP68)[1]





SI-145-5 SI-290-10 SI-580-20

Note: 1. For IP68 version see caution on physical properties page.

5.11 Mini58 Specifications (Includes IP60/IP65/IP68 Versions)

In addition to the information in the following sections, refer to the ATI website:

Table 5.58—Mini58 Drawing and Web Links		
Model	**Drawing Part Number**	**ATI Website Address**
Mini58	*9230-05-1383*	*https://www.ati-ia.com/products/ft/ft_models.aspx?id=Mini58*
Mini58-ERA	*9230-05-1522*	
Mini58 IP60	*9230-05-1437*	*https://www.ati-ia.com/products/ft/ft_models.aspx?id=Mini58+IP60*
Mini58 IP65/IP68	*9230-05-1454*	*https://www.ati-ia.com/products/ft/ft_models.aspx?id=Mini58+IP65%2fIP68*

5.11.1 Mini58 Physical Properties

Table 5.59—Mini58 Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±4800 lbf	±21000 N
Fz	±11000 lbf	±48000 N
Txy	±5300 inf-lb	±590 Nm
Tz	±7100 inf-lb	±800 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	$1.4x10^6$ lb/in	$2.5x10^8$ N/m
Z-axis force (Kz)	$2.1x10^6$ lb/in	$3.7x10^8$ N/m
X-axis & Y-axis torque (Ktx, Kty)	$9.3x10^5$ lbf-in/rad	$1.1x10^5$ Nm/rad
Z-axis torque (Ktz)	$1.8x10^6$ lbf-in/rad	$2.0x10^5$ Nm/rad
Resonant Frequency		
Fx, Fy, Tz	3000 Hz	3000 Hz
Fz, Tx, Ty	5700 Hz	5700 Hz
Physical Specifications		
Weight[1]	0.76 lb	0.345 kg
Diameter[1]	2.28 in	58 mm
Height[1]	1.18 in	30 mm
Note: 1. Specifications include standard interface plates.		

5.11.2 Mini58 IP60 Physical Properties

Table 5.60—Mini58 IP60 Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±4800 lbf	±21000 N
Fz	±11000 lbf	±48000 N
Txy	±5300 inf-lb	±590 Nm
Tz	±7100 inf-lb	±800 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	$1.4x10^6$ lb/in	$2.5x10^8$ N/m
Z-axis force (Kz)	$2.1x10^6$ lb/in	$3.7x10^8$ N/m
X-axis & Y-axis torque (Ktx, Kty)	$9.3x10^5$ lbf-in/rad	$1.1x10^5$ Nm/rad
Z-axis torque (Ktz)	$1.8x10^6$ lbf-in/rad	$2.0x10^5$ Nm/rad
Resonant Frequency		
Fx, Fy, Tz	N/A	N/A
Fz, Tx, Ty	N/A	N/A
Physical Specifications		
Weight[1]	1.15 lb	0.522 kg
Diameter[1]	3.23 in	82 mm
Height[1]	1.42 in	36.2 mm
Note: 1. Specifications include standard interface plates.		

5.11.3 Mini58 IP65/IP68 Physical Properties

Table 5.61—Mini58 IP65/IP68 Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±4800 lbf	±21000 N
Fz	±11000 lbf	±48000 N
Txy	±5300 inf-lb	±590 Nm
Tz	±7100 inf-lb	±800 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	$1.4x10^6$ lb/in	$2.5x10^8$ N/m
Z-axis force (Kz)	$2.1x10^6$ lb/in	$3.7x10^8$ N/m
X-axis & Y-axis torque (Ktx, Kty)	$9.3x10^5$ lbf-in/rad	$1.1x10^5$ Nm/rad
Z-axis torque (Ktz)	$1.8x10^6$ lbf-in/rad	$2.0x10^5$ Nm/rad
Resonant Frequency		
Fx, Fy, Tz	N/A	N/A
Fz, Tx, Ty	N/A	N/A
Physical Specifications		
Weight[1]	1.77 lb	0.804 kg
Diameter[1]	2.58 in	65.4 mm
Height[1]	1.48 in	37.6 mm
Note: 1. Specifications include standard interface plates.		

CAUTION: When submerged, IP68 transducers exhibit a decrease in Fz range related to the submersion depth. This loss is the result of pressure-induced preloading on the transducer. The preload can be masked by biasing the transducer at the depth prior to applying the load to be measured. The following estimates are for room temperature fresh water at sea level.

Submersion Depth		
IP68 Mini58	**US**	**Metric**
Fz preload at 4 m depth	24.3 lb	108 N
Fz preload at other depths	-1.86 lb/ft × depthInFeet	-27.1 N/m × depthInMeters

5.11.4 Calibration Specifications (excludes CTL calibrations)

Table 5.62— Mini58 Calibrations (excludes CTL calibrations)[1, 2]									
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz[3] (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**	**Fx,Fy (lbf)**	**Fz[3] (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**
Mini58	US-150-250	150	375	250	250	5/112	1/16	1/20	7/240
Mini58	US-300-500	300	750	500	500	5/56	1/8	1/10	7/120
Mini58	US-600-1000	600	1500	1000	1000	5/28	1/4	1/5	7/60
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**
Mini58	SI-700-30	700	1700	30	30	1/6	7/24	9/1600	1/320
Mini58	SI-1400-60	1400	3400	60	60	1/3	7/12	9/800	1/160
Mini58	SI-2800-120	2800	6800	120	120	3/4	1 1/4	9/400	1/80
		Sensing Ranges				**Resolution (DAQ, Net F/T)[4]**			

Notes:
1. These system resolutions quoted are the effective resolution after dropping four counts of noise. The effective resolution can be improved with filtering.
2. Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.
3. For IP68 version see caution on physical properties page.
4. DAQ resolutions are typical for a 16-bit data acquisition system.

5.11.5 CTL Calibration Specifications

Table 5.63— Mini58 CTL Calibrations[1, 2]									
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz[3] (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**	**Fx,Fy (lbf)**	**Fz[3] (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**
Mini58	US-150-250	150	375	250	250	5/56	1/8	1/10	7/120
Mini58	US-300-500	300	750	500	500	5/28	1/4	1/5	7/60
Mini58	US-600-1000	600	1500	1000	1000	5/14	1/2	2/5	7/30
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**
Mini58	SI-700-30	700	1700	30	30	1/3	7/12	9/800	1/160
Mini58	SI-1400-60	1400	3400	60	60	2/3	1 1/6	9/400	1/80
Mini58	SI-2800-120	2800	6800	120	120	1 1/2	2 1/2	9/200	1/40
		Sensing Ranges				**Resolution (Controller)**			

Notes:
1. CTL resolutions are typical. System resolutions quoted are the effective resolution after dropping eight counts of noise. The effective resolution can be improved with filtering.
2. Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.
3. For IP68 version see caution on physical properties page.

5.11.6 CTL Analog Output

Table 5.64— Mini58 Analog Output							
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz[2] (lbf)**	**Tx,Ty,Tz (lbf-in)**	**Fx,Fy (lbf/V)**	**Fz[2] (lbf/V)**	**Tx,Ty,Tz (lbf-in/V)**
Mini58	US-150-250	±150	±375	±250	15	37.5	25
Mini58	US-300-500	±300	±750	±500	30	75	50
Mini58	US-600-1000	±600	±1500	±1000	60	150	100
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz[2] (N)**	**Tx,Ty,Tz (Nm)**	**Fx,Fy (N/V)**	**Fz[2] (N/V)**	**Tx,Ty,Tz (Nm/V)**
Mini58	SI-700-30	±700	±1700	±30	70	170	3
Mini58	SI-1400-60	±1400	±3400	±60	140	340	6
Mini58	SI-2800-120	±2800	±6800	±120	280	680	12
		Analog Output Range			**Analog ±10V Sensitivity[1]**		

Notes:
1. ±5V Sensitivity values are double the listed ±10V Sensitivity values.
2. For IP68 version see caution on physical properties page.

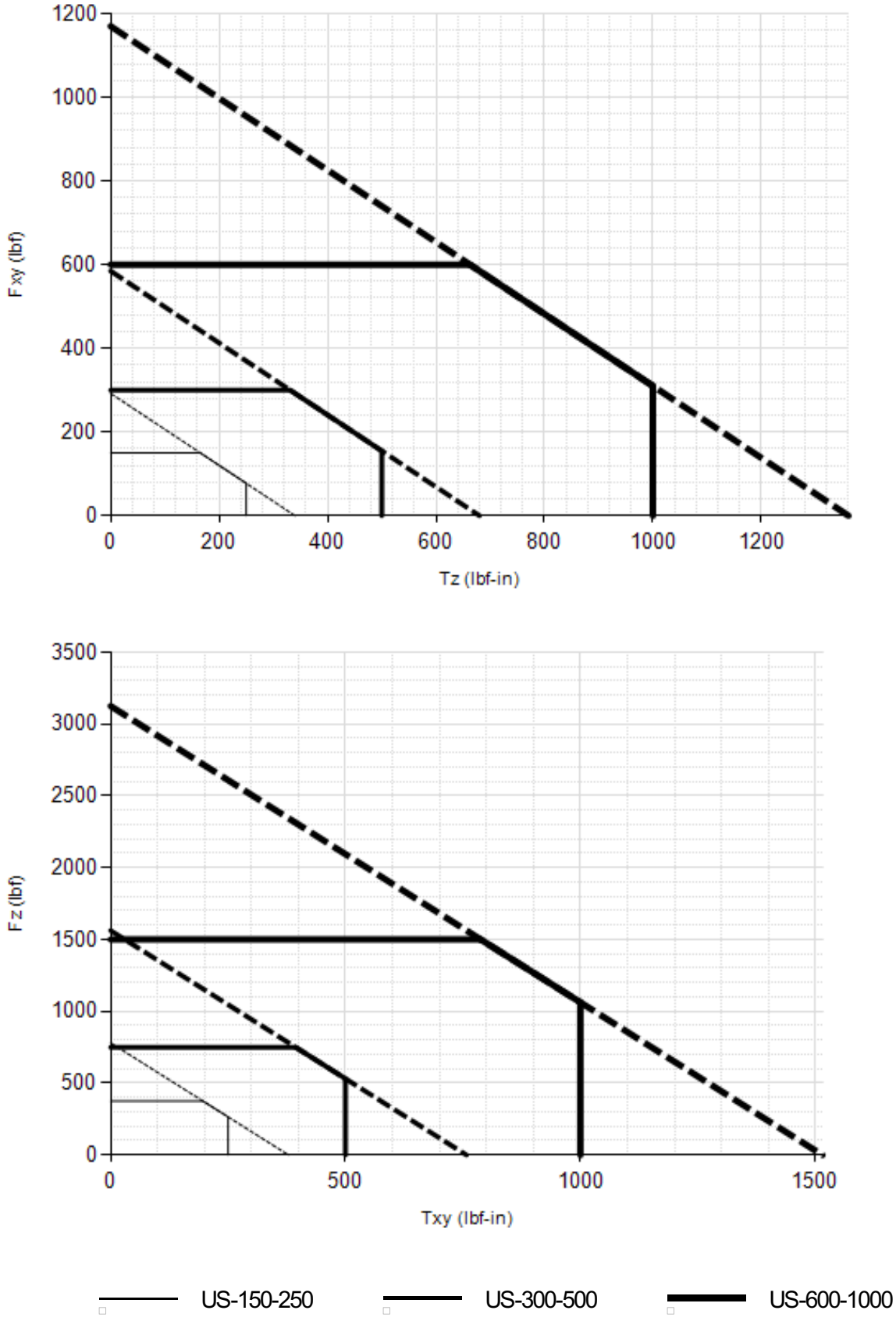
5.11.7 CTL Counts Value

Table 5.65—Counts Value					
Sensor	**Calibration**	**Fx, Fy, Fz (/ lbf)**	**Tx, Ty, Tz (/ lbf-in)**	**Fx, Fy, Fz (/ N)**	**Tx, Ty, Tz (/ Nm)**
Mini58	US-150-250 / SI-700-30	448	960	96	6400
Mini58	US-300-500 / SI-1400-60	224	480	48	3200
Mini58	US-600-1000 / SI-2800-120	112	240	16	1600
Mini58	Tool Transform Factor	See Tool Transform Factor table			
		Counts Value – Standard (US)		**Counts Value – Metric (SI)**	

5.11.8 Tool Transform Factor

Table 5.66—Tool Transform Factor			
Sensor	**Calibration**	**US (English)**	SI (Metric)
Mini58	US-150-250 / SI-700-30	0.00467 in/lbf	0.150 mm/N
Mini58	US-300-500 / SI-1400-60	0.00467 in/lbf	0.150 mm/N
Mini58	US-600-1000 / SI-2800-120	0.00467 in/lbf	0.150 mm/N

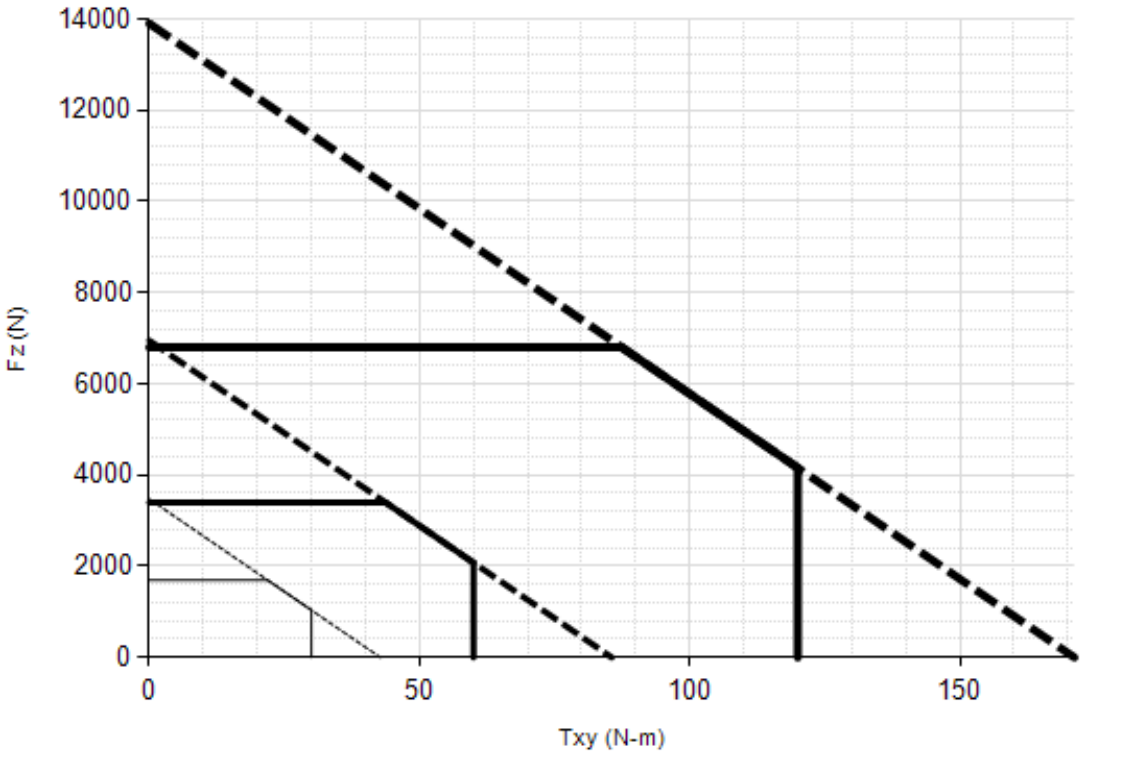
5.11.9 Mini58 (US Calibration Complex Loading)(Includes IP60/IP65/IP68)[1]



Note: 1. For IP68 version see caution on physical properties page.

5.11.10 Mini58 (SI Calibration Complex Loading)(Includes IP60/IP65/IP68)[1]





SI-700-30 SI-1400-60 SI-2800-120

Note: 1. For IP68 version see caution on physical properties page.

5.12 Mini85 Specifications

In addition to the information in the following sections, refer to the ATI website:

Table 5.67—Mini85 Drawing and Web Links		
Model	**Drawing Part Number**	**ATI Website Address**
Mini85	*9230-05-1383*	*https://www.ati-ia.com/products/ft/ft_models.aspx?id=Mini85*
Mini85 with 20 mm through hole	*9230-05-1323*	

5.12.1 Mini85 Physical Properties

Table 5.68—Mini85 Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±2800 lbf	±13000 N
Fz	±6100 lbf	±27000 N
Txy	±4400 inf-lb	±500 Nm
Tz	±5400 inf-lb	±610 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	4.4×10^5 lb/in	7.7×10^7 N/m
Z-axis force (Kz)	6.8×10^5 lb/in	1.2×10^8 N/m
X-axis & Y-axis torque (Ktx, Kty)	7.2×10^5 lbf-in/rad	8.1×10^4 Nm/rad
Z-axis torque (Ktz)	1.2×10^6 lbf-in/rad	1.3×10^5 Nm/rad
Resonant Frequency		
Fx, Fy, Tz	2400 Hz	2400 Hz
Fz, Tx, Ty	3100 Hz	3100 Hz
Physical Specifications		
Weight[1]	1.4 lb	0.635 kg
Diameter[1]	3.35 in	85.1 mm
Height[1]	1.17 in	29.8 mm
Note: 1. Specifications include standard interface plates.		

5.12.2 Calibration Specifications (excludes CTL calibrations)

Table 5.69— Mini85 Calibrations (excludes CTL calibrations)[1, 2]									
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**	**Fx,Fy (lbf)**	**Fz (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**
Mini85	US-105-185	105	210	185	185	1/52	7/260	5/168	1/48
Mini85	US-210-370	210	420	370	370	5/128	3/64	5/84	1/24
Mini85	US-420-740	420	840	740	740	5/64	3/32	5/42	1/12
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**	**Fx,Fy (N)**	**Fz (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**
Mini85	SI-475-20	475	950	20	20	9/112	3/28	5/1496	7/2992
Mini85	SI-950-40	950	1900	40	40	9/56	3/14	5/748	7/1496
Mini85	SI-1900-80	1900	3800	80	80	9/28	3/7	5/374	7/748
		Sensing Ranges				**Resolution (DAQ, Net F/T)[3]**			

Notes:
1. These system resolutions quoted are the effective resolution after dropping four counts of noise. The effective resolution can be improved with filtering.
2. Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.
3. DAQ resolutions are typical for a 16-bit data acquisition system.

5.12.3 CTL Calibration Specifications

Table 5.70— Mini85 CTL Calibrations[1, 2]									
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**	**Fx,Fy (lbf)**	**Fz (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**
Mini85	US-105-185	105	210	185	185	1/26	7/130	5/84	1/24
Mini85	US-210-370	210	420	370	370	5/64	3/32	5/42	1/12
Mini85	US-420-740	420	840	740	740	5/32	3/16	5/21	1/6
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**	**Fx,Fy (N)**	**Fz (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**
Mini85	SI-475-20	475	950	20	20	9/56	3/14	5/748	7/1496
Mini85	SI-950-40	950	1900	40	40	9/28	3/7	5/374	7/748
Mini85	SI-1900-80	1900	3800	80	80	9/14	6/7	5/187	7/374
		Sensing Ranges				**Resolution (Controller)**			

Notes:
1. CTL resolutions are typical. System resolutions quoted are the effective resolution after dropping eight counts of noise. The effective resolution can be improved with filtering.
2. Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.

5.12.4 CTL Analog Output

Table 5.71— Mini85 Analog Output							
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz (lbf)**	**Tx,Ty,Tz (lbf-in)**	**Fx,Fy (lbf/V)**	**Fz (lbf/V)**	**Tx,Ty,Tz (lbf-in/V)**
Mini85	US-105-185	±105	±210	±185	10.5	21	18.5
Mini85	US-210-370	±210	±420	±370	21	42	37
Mini85	US-420-740	±420	±840	±740	42	84	74
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz (N)**	**Tx,Ty,Tz (Nm)**	**Fx,Fy (N/V)**	**Fz (N/V)**	**Tx,Ty,Tz (Nm/V)**
Mini85	SI-475-20	±475	±950	±20	47.5	95	2
Mini85	SI-950-40	±950	±1900	±40	95	190	4
Mini85	SI-1900-80	±1900	±3800	±80	190	380	8
		Analog Output Range			**Analog ±10V Sensitivity[1]**		

Notes:
1. ±5V Sensitivity values are double the listed ±10V Sensitivity values.

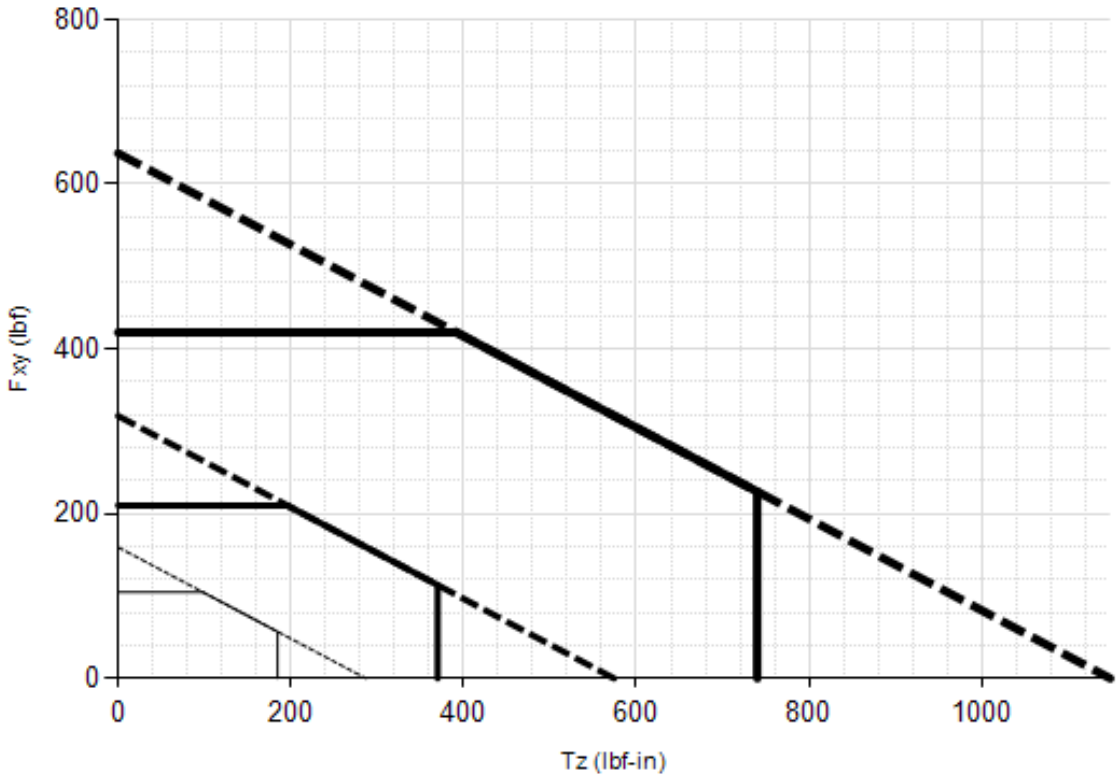
5.12.5 CTL Counts Value

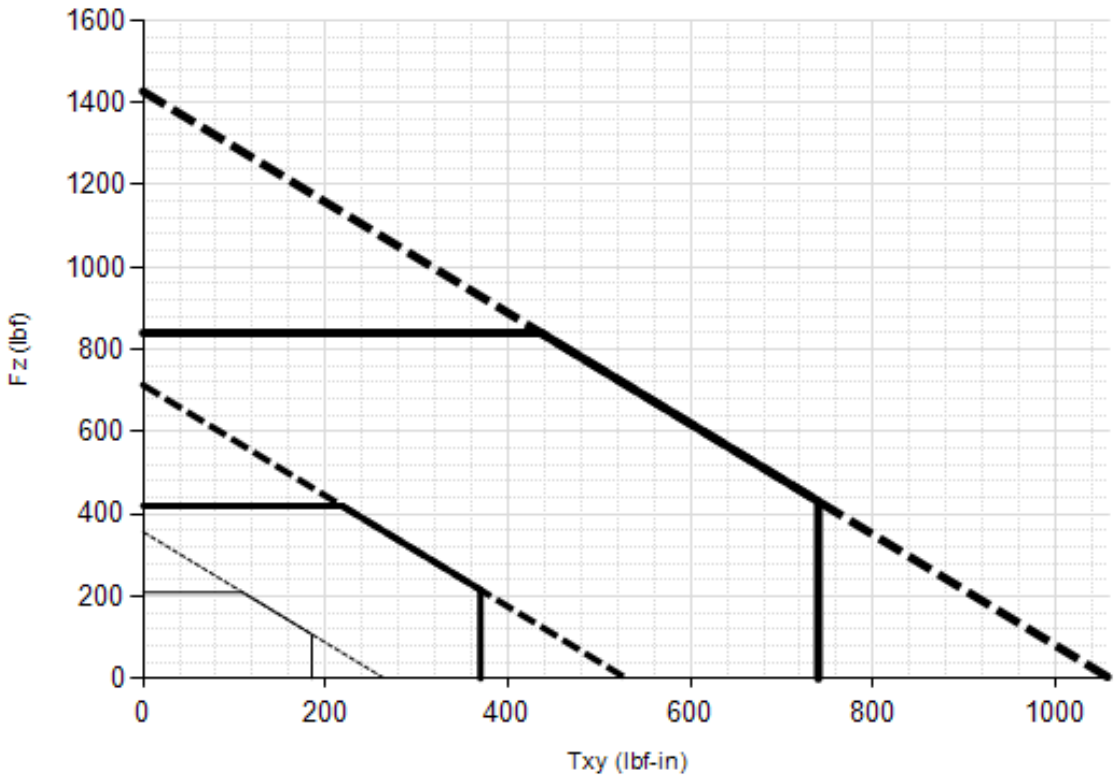
Table 5.72—Counts Value					
Sensor	**Calibration**	**Fx, Fy, Fz (/ lbf)**	**Tx, Ty, Tz (/ lbf-in)**	**Fx, Fy, Fz (/ N)**	**Tx, Ty, Tz (/ Nm)**
Mini85	US-105-185 / SI-475-20	1040	1344	448	11968
Mini85	US-210-370 / SI-950-40	512	672	224	5984
Mini85	US-420-740 / SI-1900-80	256	336	112	2992
Mini85	Tool Transform Factor	See Tool Transform Factor table			
		Counts Value – Standard (US)		**Counts Value – Metric (SI)**	

5.12.6 Tool Transform Factor

Table 5.73—Tool Transform Factor			
Sensor	**Calibration**	**US (English)**	SI (Metric)
Mini85	US-105-185 / SI-475-20	0.00774 in/lbf	0.374 mm/N
Mini85	US-210-370 / SI-950-40	0.00762 in/lbf	0.374 mm/N
Mini85	US-420-740 / SI-1900-80	0.00762 in/lbf	0.374 mm/N

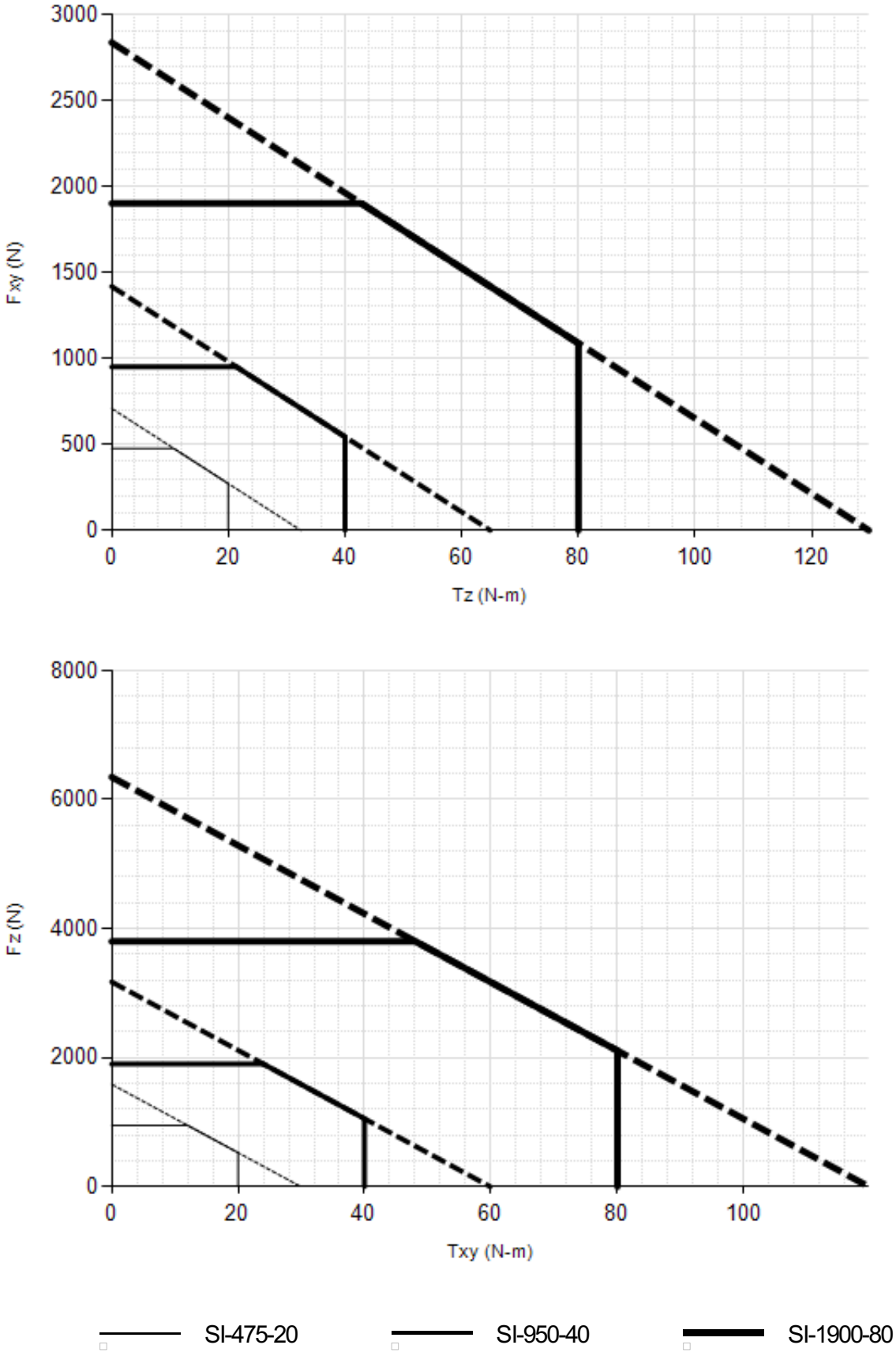
5.12.7 Mini85 (US Calibration Complex Loading)(Includes IP60)





US-105-185 US-210-370 US-420-740

5.12.8 Mini85 (SI Calibration Complex Loading)(Includes IP60)



5.13 Gamma Specifications (Includes IP60/IP65/IP68 Versions)

In addition to the information in the following sections, refer to the ATI website:

Table 5.74—Gamma Drawing and Web Links		
Model	**Drawing Part Number**	**ATI Website Address**
Gamma Mux[1] transducer without standard mounting adapter	*9230-05-1103*	*https://www.ati-ia.com/products/ft/ft_models.aspx?id=Gamma*
Gamma DAQ/NET transducer with mounting adapter plate	*9230-05-1329*	
Gamma adapter mounting plate (non-IP rated)	*9230-05-1057*	
Gamma IP60	*9230-05-1335*	*https://www.ati-ia.com/products/ft/ft_models.aspx?id=Gamma+IP60*
Gamma IP65	*9230-05-1307*	*https://www.ati-ia.com/products/ft/ft_models.aspx?id=Gamma+IP65*
Gamma IP65 ECAT	*9230-05-1508*	
Gamma IP68	*9230-05-1386*	*https://www.ati-ia.com/products/ft/ft_models.aspx?id=Gamma+IP68*
Note: 1. Mux transducers are used in F/T Controller systems.		

5.13.1 Gamma Physical Properties

Table 5.75—Gamma Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±280 lbf	±1200 N
Fz	±930 lbf	±4100 N
Txy	±700 inf-lb	±79 Nm
Tz	±730 inf-lb	±82 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	5.2×10^4 lb/in	9.1×10^6 N/m
Z-axis force (Kz)	1.0×10^5 lb/in	1.8×10^7 N/m
X-axis & Y-axis torque (Ktx, Kty)	9.3×10^4 lbf-in/rad	1.1×10^4 Nm/rad
Z-axis torque (Ktz)	1.4×10^5 lbf-in/rad	1.6×10^4 Nm/rad
Resonant Frequency		
Fx, Fy, Tz	1400 Hz	1400 Hz
Fz, Tx, Ty	2000 Hz	2000 Hz
Physical Specifications		
Weight[1]	0.562 lb	0.255 kg
Diameter[1]	2.97 in	75.4 mm
Height[1]	1.31 in	33.3 mm
Note: 1. Specifications include standard interface plates.		

5.13.2 Gamma IP60 Physical Properties

Table 5.76—Gamma IP60 Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±280 lbf	±1200 N
Fz	±930 lbf	±4100 N
Txy	±700 inf-lb	±79 Nm
Tz	±730 inf-lb	±82 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	5.2×10^4 lb/in	9.1×10^6 N/m
Z-axis force (Kz)	1.0×10^5 lb/in	1.8×10^7 N/m
X-axis & Y-axis torque (Ktx, Kty)	9.3×10^4 lbf-in/rad	1.1×10^4 Nm/rad
Z-axis torque (Ktz)	1.4×10^5 lbf-in/rad	1.6×10^4 Nm/rad
Resonant Frequency		
Fx, Fy, Tz	1200 Hz	1200 Hz
Fz, Tx, Ty	1200 Hz	1200 Hz
Physical Specifications		
Weight[1]	1.03 lb	0.467 kg
Diameter[1]	3.9 in	99.1 mm
Height[1]	1.56 in	39.6 mm
Note: 1. Specifications include standard interface plates.		

5.13.3 Gamma IP65 Physical Properties

Table 5.77—Gamma IP65 Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±280 lbf	±1200 N
Fz	±930 lbf	±4100 N
Txy	±700 inf-lb	±79 Nm
Tz	±730 inf-lb	±82 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	5.2×10^4 lb/in	9.1×10^6 N/m
Z-axis force (Kz)	1.0×10^5 lb/in	1.8×10^7 N/m
X-axis & Y-axis torque (Ktx, Kty)	9.3×10^4 lbf-in/rad	1.1×10^4 Nm/rad
Z-axis torque (Ktz)	1.4×10^5 lbf-in/rad	1.6×10^4 Nm/rad
Resonant Frequency		
Fx, Fy, Tz	1000 Hz	1000 Hz
Fz, Tx, Ty	970 Hz	970 Hz
Physical Specifications		
Weight[1]	2.4 lb	1.09 kg
Diameter[1]	4.37 in	111 mm
Height[1]	2.06 in	52.3 mm
Note: 1. Specifications include standard interface plates.		

5.13.4 Gamma IP68 Physical Properties

Table 5.78—Gamma IP68 Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±280 lbf	±1200 N
Fz	±930 lbf	±4100 N
Txy	±700 inf-lb	±79 Nm
Tz	±730 inf-lb	±82 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	5.2×10^4 lb/in	9.1×10^6 N/m
Z-axis force (Kz)	1.0×10^5 lb/in	1.8×10^7 N/m
X-axis & Y-axis torque (Ktx, Kty)	9.3×10^4 lbf-in/rad	1.1×10^4 Nm/rad
Z-axis torque (Ktz)	1.4×10^5 lbf-in/rad	1.6×10^4 Nm/rad
Resonant Frequency		
Fx, Fy, Tz	1250 Hz	1250 Hz
Fz, Tx, Ty	940 Hz	940 Hz
Physical Specifications		
Weight[1]	4.37 lb	1.98 kg
Diameter[1]	4.37 in	111 mm
Height[1]	2.06 in	52.3 mm
Note: 1. Specifications include standard interface plates.		

CAUTION: When submerged, IP68 transducers exhibit a decrease in Fz range related to the submersion depth. This loss is the result of pressure-induced preloading on the transducer. The preload can be masked by biasing the transducer at the depth prior to applying the load to be measured. The following estimates are for room temperature fresh water at sea level.

Submersion Depth		
IP68 Gamma	**US**	**Metric**
Fz preload at 4 m depth	-42.9 lb	-191 N
Fz preload at other depths	-3.27 lb/ft × depthInFeet	-47.4 N/m × depthInMeters

5.13.5 Calibration Specifications (excludes CTL calibrations)

Table 5.79— Gamma Calibrations (excludes CTL calibrations)[1, 2]									
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz[3] (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**	**Fx,Fy (lbf)**	**Fz[3] (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**
Gamma	US-7.5-25	7.5	25	25	25	1/640	1/320	1/320	1/320
Gamma	US-15-50	15	50	50	50	1/320	1/160	1/160	1/160
Gamma	US-30-100	30	100	100	100	1/160	1/80	1/80	1/80
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**
Gamma	SI-32-2.5	32	100	2.5	2.5	1/160	1/80	1/2000	1/2000
Gamma	SI-65-5	65	200	5	5	1/80	1/40	10/13333	10/13333
Gamma	SI-130-10	130	400	10	10	1/40	1/20	1/800	1/800
		Sensing Ranges				**Resolution (DAQ, Net F/T)[4]**			

Notes:
1. These system resolutions quoted are the effective resolution after dropping four counts of noise. The effective resolution can be improved with filtering.
2. Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.
3. For IP68 version see caution on physical properties page.
4. DAQ resolutions are typical for a 16-bit data acquisition system.

5.13.6 CTL Calibration Specifications

Table 5.80— Gamma CTL Calibrations[1, 2]									
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz[3] (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**	**Fx,Fy (lbf)**	**Fz[3] (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**
Gamma	US-7.5-25	7.5	25	25	25	1/320	1/160	1/160	1/160
Gamma	US-15-50	15	50	50	50	1/160	1/80	1/80	1/80
Gamma	US-30-100	30	100	100	100	1/80	1/40	1/40	1/40
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**
Gamma	SI-32-2.5	32	100	2.5	2.5	1/80	1/40	1/1000	1/1000
Gamma	SI-65-5	65	200	5	5	1/40	1/20	5/3333	5/3333
Gamma	SI-130-10	130	400	10	10	1/20	1/10	1/400	1/400
		Sensing Ranges				**Resolution (Controller)**			

Notes:
1. CTL resolutions are typical. System resolutions quoted are the effective resolution after dropping eight counts of noise. The effective resolution can be improved with filtering.
2. Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.
3. For IP68 version see caution on physical properties page.

5.13.7 CTL Analog Output

Table 5.81— Gamma Analog Output							
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz[2] (lbf)**	**Tx,Ty,Tz (lbf-in)**	**Fx,Fy (lbf/V)**	**Fz[2] (lbf/V)**	**Tx,Ty,Tz (lbf-in/V)**
Gamma	US-7.5-25	±7.5	±25	±25	0.75	2.5	2.5
Gamma	US-15-50	±15	±50	±50	1.5	5	5
Gamma	US-30-100	±30	±100	±100	3	10	10
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz[2] (N)**	**Tx,Ty,Tz (Nm)**	**Fx,Fy (N/V)**	**Fz[2] (N/V)**	**Tx,Ty,Tz (Nm/V)**
Gamma	SI-32-2.5	±32	±100	±2.5	3.2	10	0.25
Gamma	SI-65-5	±65	±200	±5	6.5	20	0.5
Gamma	SI-130-10	±130	±400	±10	13	40	1
		Analog Output Range			**Analog ±10V Sensitivity[1]**		

Notes:
1. ±5V Sensitivity values are double the listed ±10V Sensitivity values.
2. For IP68 version see caution on physical properties page.

5.13.8 CTL Counts Value

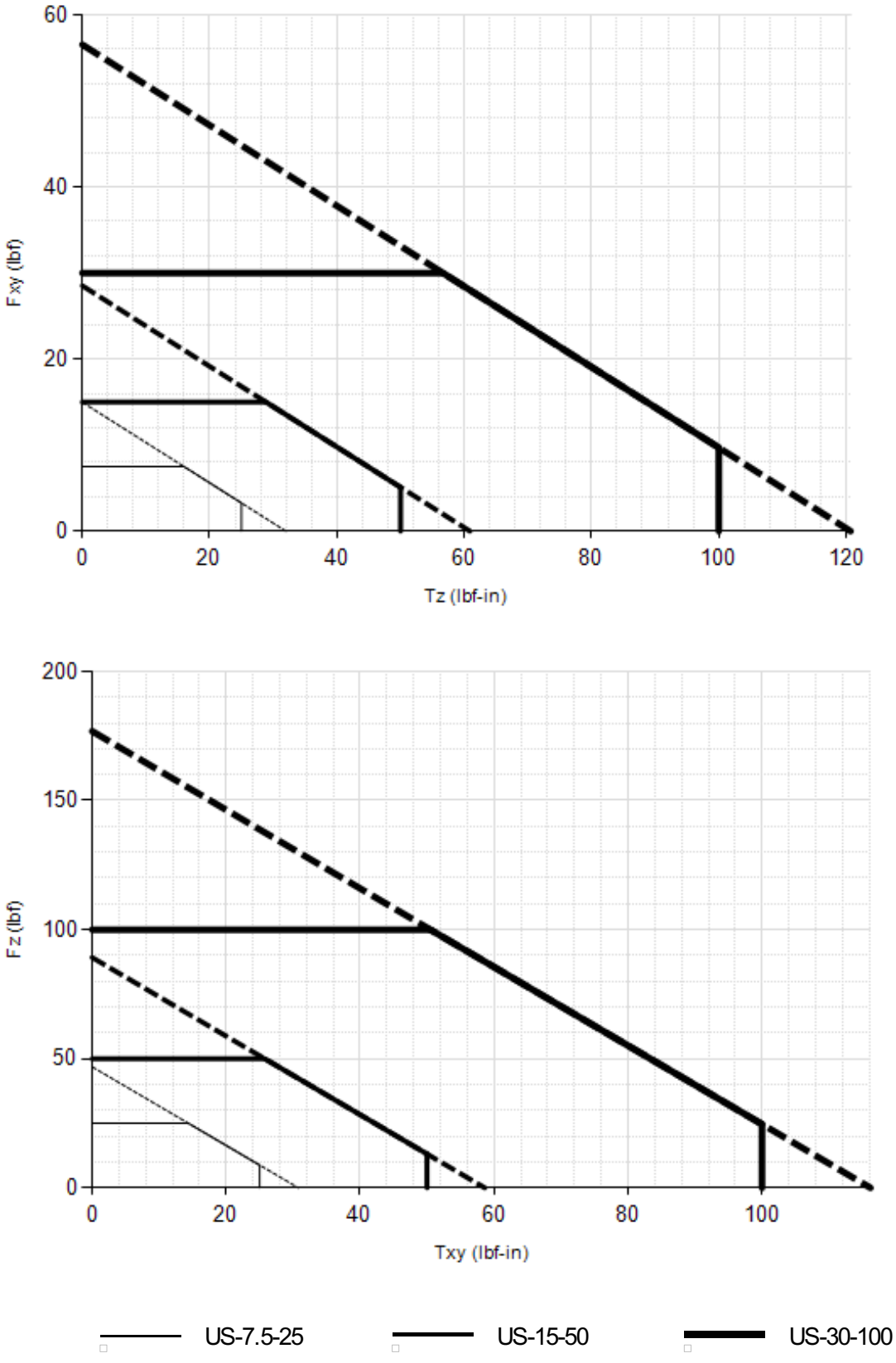
Table 5.82—Counts Value					
Sensor	**Calibration**	**Fx, Fy, Fz (/ lbf)**	**Tx, Ty, Tz (/ lbf-in)**	**Fx, Fy, Fz (/ N)**	**Tx, Ty, Tz (/ Nm)**
Gamma	US-7.5–25 / SI-32–2.5	2560	2560	640	8000
Gamma	US-15–50 / SI-65–5	1280	1280	320	5333.33
Gamma	US-30–100 / SI-130–10	640	640	160	3200
Gamma	Tool Transform Factor	See Tool Transform Factor table			
		Counts Value – Standard (US)		**Counts Value – Metric (SI)**	

5.13.9 Tool Transform Factor

Table 5.83—Tool Transform Factor			
Sensor	**Calibration**	**US (English)**	SI (Metric)
Gamma	US-7.5–25 / SI-32–2.5	0.01 in/lbf	0.8 mm/N
Gamma	US-15–50 / SI-65–5	0.01 in/lbf	0.6 mm/N
Gamma	US-30–100 / SI-130–10	0.01 in/lbf	0.y h5 mm/N

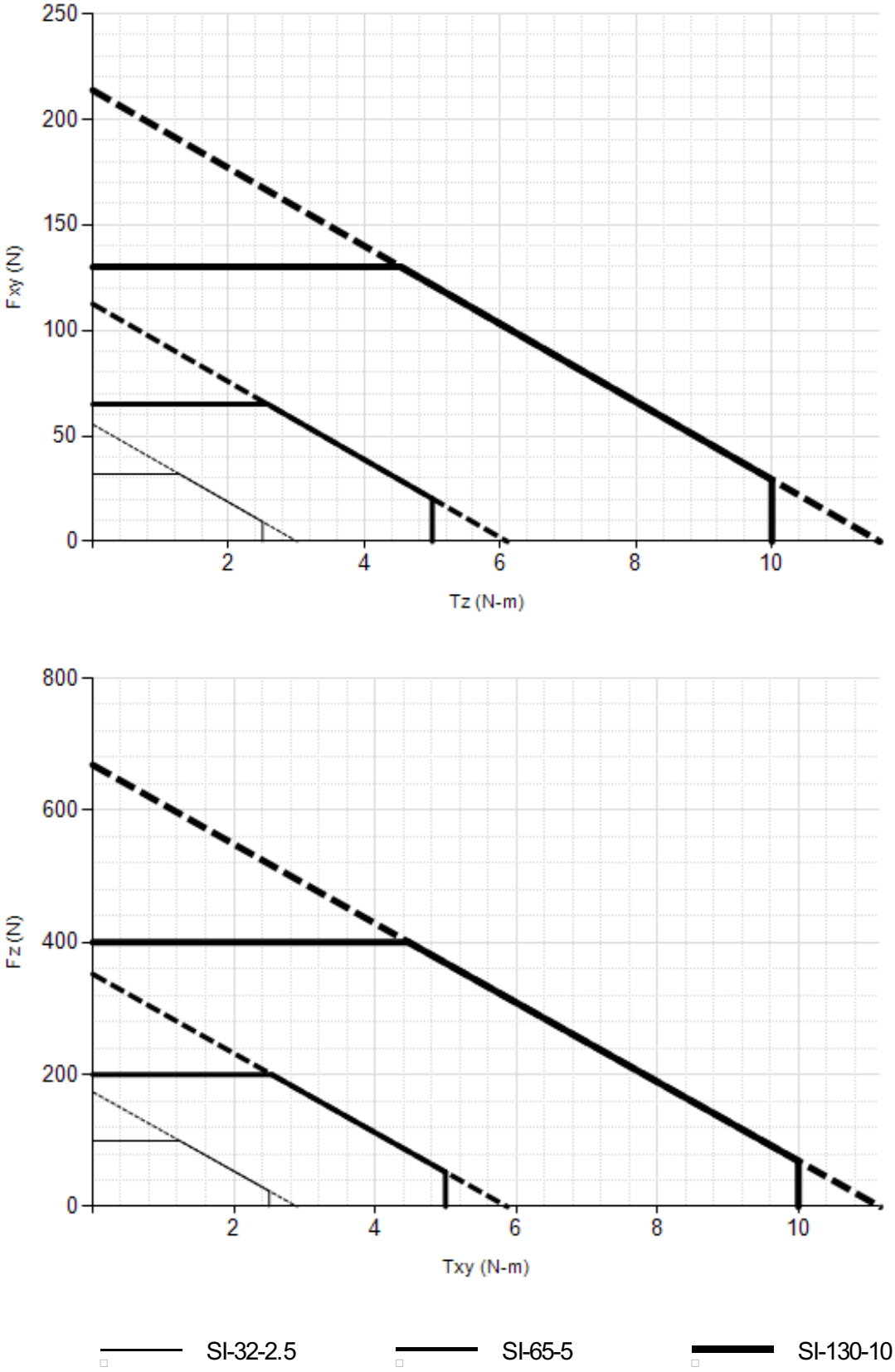
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5.13.10 Gamma (US Calibration Complex Loading) (Includes IP60/IP65/IP68)[1]



Note: 1. For IP68 version see caution on physical properties page.

5.13.11 Gamma (SI Calibration Complex Loading) (Includes IP60/IP65/IP68)[1]



Note: 1. For IP68 version see caution on physical properties page.

5.14 Delta Specifications (Includes IP60/IP65/IP68 Versions)

In addition to the information in the following sections, refer to the ATI website:

Table 5.84—Delta Drawing and Web Links		
Model	**Drawing Part Number**	**ATI Website Address**
Delta Mux[1] transducer without standard mounting adapter	*9230-05-1102*	*https://www.ati-ia.com/products/ft/ft_models.aspx?id=Delta*
Delta DAQ/NET transducer with mounting adapter plate	*9230-05-1330*	
Delta adapter mounting plate (non-IP rated)	*9230-05-1063*	
Delta IP60	*9230-05-1262*	*https://www.ati-ia.com/products/ft/ft_models.aspx?id=Delta+IP60*
Delta IP60 ECAT	*9230-05-1510*	
Delta IP65	*9230-05-1267*	*https://www.ati-ia.com/products/ft/ft_models.aspx?id=Delta+IP65*
Delta IP65 ECAT	*9230-05-1469*	
Delta IP68	*9230-05-1272*	*https://www.ati-ia.com/products/ft/ft_models.aspx?id=Delta+IP68*
Note: 1. Mux transducers are used in F/T Controller systems.		

5.14.1 Delta Physical Properties

Table 5.85—Delta Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±840 lbf	±3700 N
Fz	±2300 lbf	±10000 N
Txy	±2500 inf-lb	±280 Nm
Tz	±3600 inf-lb	±400 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	2.0×10^5 lb/in	3.6×10^7 N/m
Z-axis force (Kz)	3.4×10^5 lb/in	5.9×10^7 N/m
X-axis & Y-axis torque (Ktx, Kty)	4.6×10^5 lbf-in/rad	5.2×10^4 Nm/rad
Z-axis torque (Ktz)	8.1×10^5 lbf-in/rad	9.1×10^4 Nm/rad
Resonant Frequency		
Fx, Fy, Tz	1500 Hz	1500 Hz
Fz, Tx, Ty	1700 Hz	1700 Hz
Physical Specifications		
Weight[1]	2.01 lb	0.913 kg
Diameter[1]	3.72 in	94.5 mm
Height[1]	1.31 in	33.3 mm
Note: 1. Specifications include standard interface plates.		

5.14.2 Delta IP60 Physical Properties

Table 5.86—Delta IP60 Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±840 lbf	±3700 N
Fz	±2300 lbf	±10000 N
Txy	±2500 inf-lb	±280 Nm
Tz	±3600 inf-lb	±400 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	2.0×10^5 lb/in	3.6×10^7 N/m
Z-axis force (Kz)	3.4×10^5 lb/in	5.9×10^7 N/m
X-axis & Y-axis torque (Ktx, Kty)	4.6×10^5 lbf-in/rad	5.2×10^4 Nm/rad
Z-axis torque (Ktz)	8.1×10^5 lbf-in/rad	9.1×10^4 Nm/rad
Resonant Frequency		
Fx, Fy, Tz	1100 Hz	1100 Hz
Fz, Tx, Ty	1100 Hz	1100 Hz
Physical Specifications		
Weight[1]	4 lb	1.81 kg
Diameter[1]	4.6 in	117 mm
Height[1]	1.85 in	47.1 mm
Note: 1. Specifications include standard interface plates.		

5.14.3 Delta IP65 Physical Properties

Table 5.87—Delta IP65 Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±840 lbf	±3700 N
Fz	±2300 lbf	±10000 N
Txy	±2500 inf-lb	±280 Nm
Tz	±3600 inf-lb	±400 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	2.0×10^5 lb/in	3.6×10^7 N/m
Z-axis force (Kz)	3.4×10^5 lb/in	5.9×10^7 N/m
X-axis & Y-axis torque (Ktx, Kty)	4.6×10^5 lbf-in/rad	5.2×10^4 Nm/rad
Z-axis torque (Ktz)	8.1×10^5 lbf-in/rad	9.1×10^4 Nm/rad
Resonant Frequency		
Fx, Fy, Tz	880 Hz	880 Hz
Fz, Tx, Ty	920 Hz	920 Hz
Physical Specifications		
Weight[1]	3.91 lb	1.77 kg
Diameter[1]	4.96 in	126 mm
Height[1]	2.06 in	52.2 mm
Note: 1. Specifications include standard interface plates.		

5.14.4 Delta IP68 Physical Properties

Table 5.88—Delta IP68 Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±840 lbf	±3700 N
Fz	±2300 lbf	±10000 N
Txy	±2500 inf-lb	±280 Nm
Tz	±3600 inf-lb	±400 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	2.0×10^5 lb/in	3.6×10^7 N/m
Z-axis force (Kz)	3.4×10^5 lb/in	5.9×10^7 N/m
X-axis & Y-axis torque (Ktx, Kty)	4.6×10^5 lbf-in/rad	5.2×10^4 Nm/rad
Z-axis torque (Ktz)	8.1×10^5 lbf-in/rad	9.1×10^4 Nm/rad
Resonant Frequency		
Fx, Fy, Tz	950 Hz	950 Hz
Fz, Tx, Ty	960 Hz	960 Hz
Physical Specifications		
Weight[1]	5.8 lb	2.63 kg
Diameter[1]	4 in	102 mm
Height[1]	2.06 in	52.2 mm
Note: 1. Specifications include standard interface plates.		



CAUTION: When submerged, IP68 transducers exhibit a decrease in Fz range related to the submersion depth. This loss is the result of pressure-induced preloading on the transducer. The preload can be masked by biasing the transducer at the depth prior to applying the load to be measured. The following estimates are for room temperature fresh water at sea level.

Submersion Depth		
IP68 Delta	**US**	**Metric**
Fz preload at 10 m depth	161 lb	716 N
Fz preload at other depths	-4.9 lb/ft × depthInFeet	-72 N/m × depthInMeters

5.14.5 Calibration Specifications (excludes CTL calibrations)

Table 5.89— Delta Calibrations (excludes CTL calibrations)[1, 2]									
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz[3] (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**	**Fx,Fy (lbf)**	**Fz[3] (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**
Delta	US-50-150	50	150	150	150	1/128	1/64	3/128	1/64
Delta	US-75-300	75	225	300	300	1/64	1/32	3/64	1/32
Delta	US-150-600	150	450	600	600	1/32	1/16	3/32	1/16
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**
Delta	SI-165-15	165	495	15	15	1/32	1/16	1/528	1/528
Delta	SI-330-30	330	990	30	30	1/16	1/8	5/1333	5/1333
Delta	SI-660-60	660	1980	60	60	1/8	1/4	10/1333	10/1333
		Sensing Ranges				**Resolution (DAQ, Net F/T)[4]**			

Notes:
1. These system resolutions quoted are the effective resolution after dropping four counts of noise. The effective resolution can be improved with filtering.
2. Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.
3. For IP68 version see caution on physical properties page.
4. DAQ resolutions are typical for a 16-bit data acquisition system.

5.14.6 CTL Calibration Specifications

Table 5.90— Delta CTL Calibrations[1, 2]									
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz[3] (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**	**Fx,Fy (lbf)**	**Fz[3] (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**
Delta	US-50-150	50	150	150	150	1/64	1/32	3/64	1/32
Delta	US-75-300	75	225	300	300	1/32	1/16	3/32	1/16
Delta	US-150-600	150	450	600	600	1/16	1/8	3/16	1/8
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**
Delta	SI-165-15	165	495	15	15	1/16	1/8	1/264	1/264
Delta	SI-330-30	330	990	30	30	1/8	1/4	10/1333	10/1333
Delta	SI-660-60	660	1980	60	60	1/4	1/2	5/333	5/333
		Sensing Ranges				**Resolution (Controller)**			

Notes:
1. CTL resolutions are typical. System resolutions quoted are the effective resolution after dropping eight counts of noise. The effective resolution can be improved with filtering.
2. Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.
3. For IP68 version see caution on physical properties page.

5.14.7 CTL Analog Output

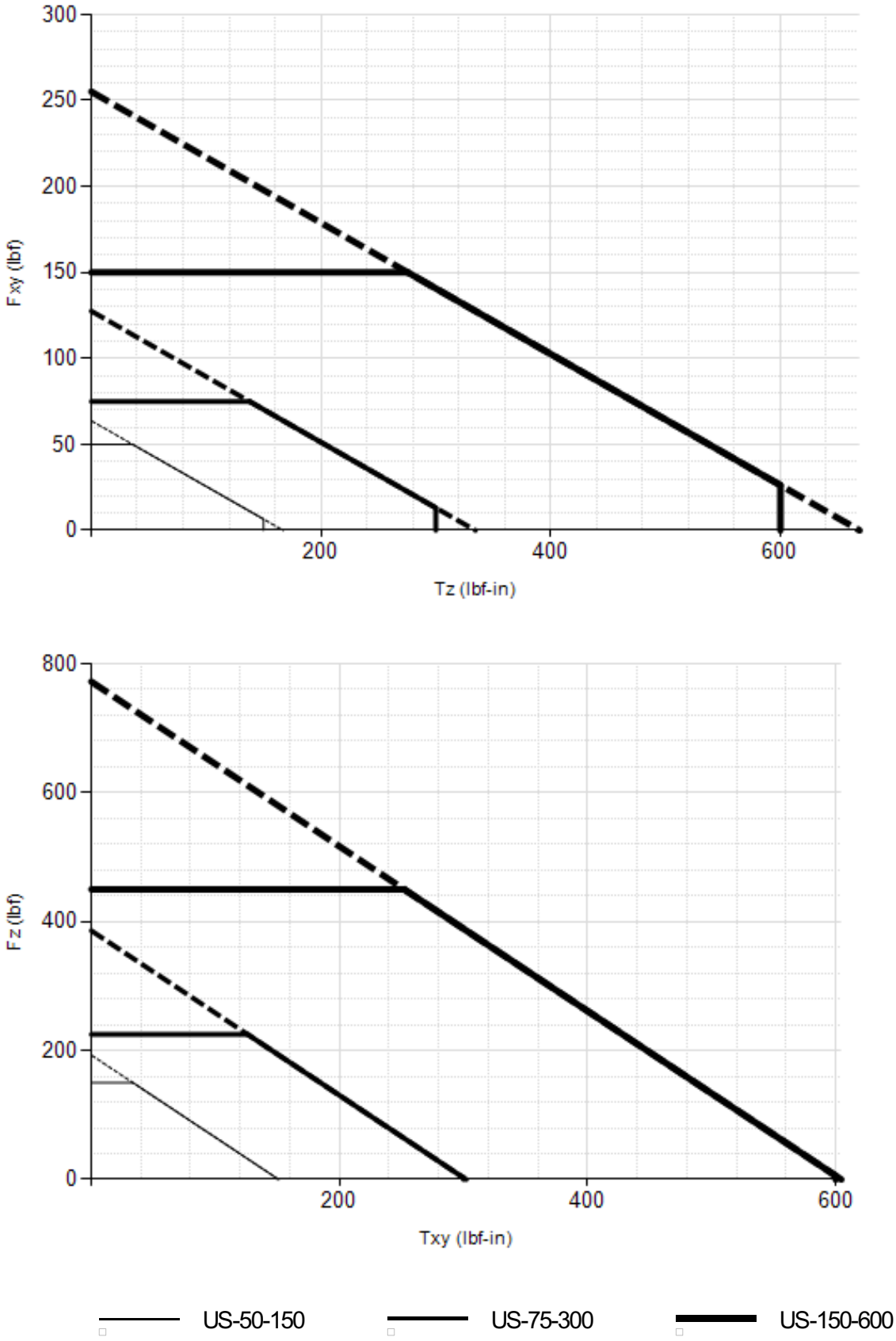
Table 5.91— Delta Analog Output							
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz[2] (lbf)**	**Tx,Ty,Tz (lbf-in)**	**Fx,Fy (lbf/V)**	**Fz[2] (lbf/V)**	**Tx,Ty,Tz (lbf-in/V)**
Delta	US-50-150	±50	±150	±150	5	15	15
Delta	US-75-300	±75	±225	±300	7.5	22.5	30
Delta	US-150-600	±150	±450	±600	15	45	60
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz[2] (N)**	**Tx,Ty,Tz (Nm)**	**Fx,Fy (N/V)**	**Fz[2] (N/V)**	**Tx,Ty,Tz (Nm/V)**
Delta	SI-165-15	±165	±495	±15	16.5	49.5	1.5
Delta	SI-330-30	±330	±990	±30	33	99	3
Delta	SI-660-60	±660	±1980	±60	66	198	6
		Analog Output Range			**Analog ±10V Sensitivity[1]**		

Notes:
1. ±5V Sensitivity values are double the listed ±10V Sensitivity values.
2. For IP68 version see caution on physical properties page.

5.14.8 CTL Counts Value

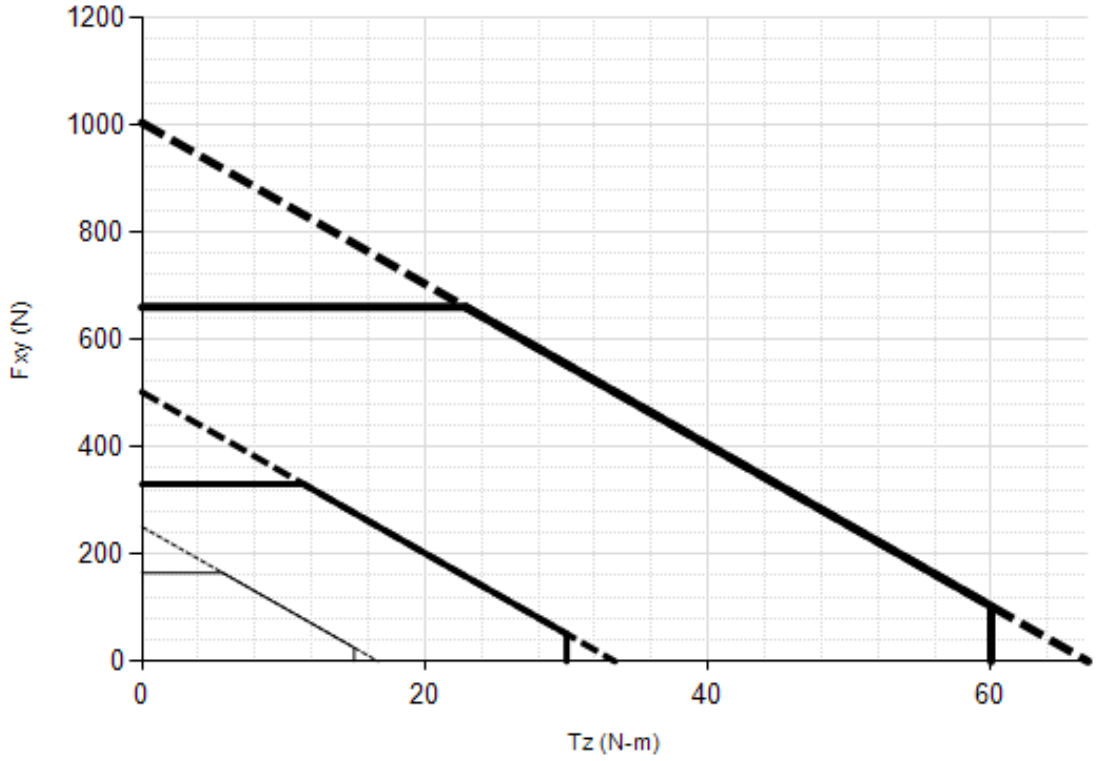
Table 5.92—Counts Value					
Sensor	**Calibration**	**Fx, Fy, Fz (/ lbf)**	**Tx, Ty, Tz (/ lbf-in)**	**Fx, Fy, Fz (/ N)**	**Tx, Ty, Tz (/ Nm)**
Delta	US-7.5–25 / SI-32–2.5	512	512	128	2112
Delta	US-15–50 / SI-65–5	256	256	64	1066.67
Delta	US-30–100 / SI-130–10	128	128	32	533.333
Delta	Tool Transform Factor	0.01 in/lbf		0.6 mm/N	
		Counts Value – Standard (US)		**Counts Value – Metric (SI)**	

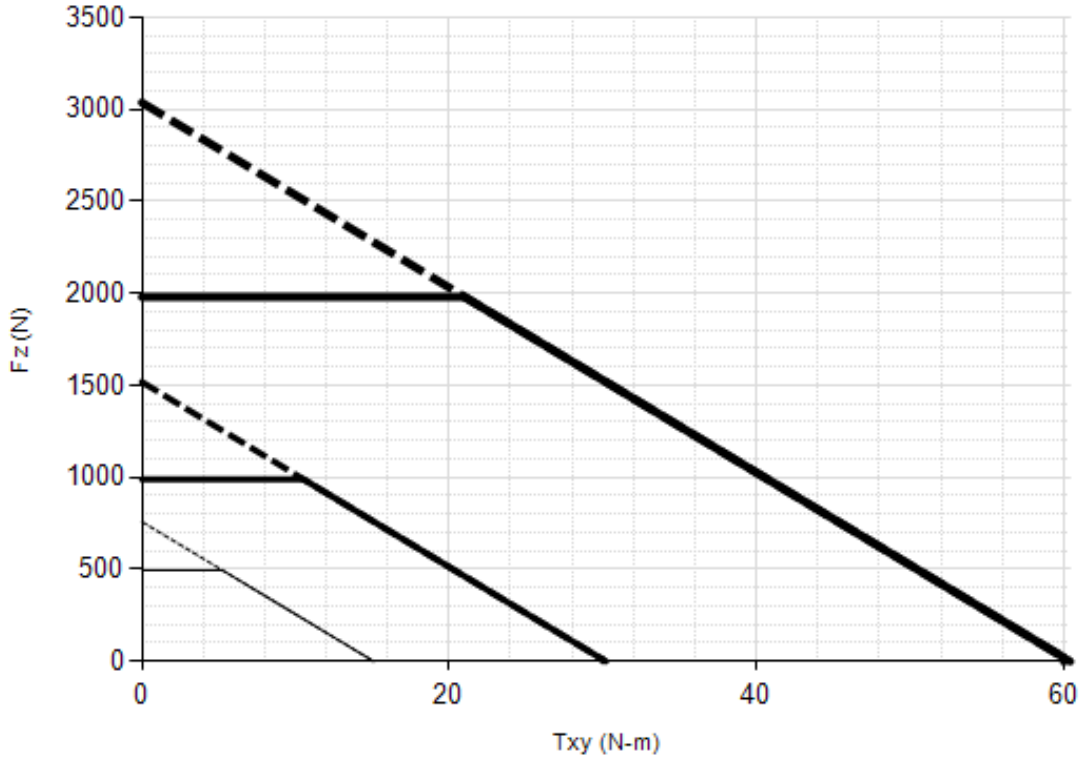
5.14.9 Delta (US Calibration Complex Loading)(Includes IP60/IP65/IP68)[1]



Note: 1. For IP68 version see caution on physical properties page.

5.14.10 Delta (SI Calibration Complex Loading)(Includes IP60/IP65/IP68)[1]





SI-165-15 SI-330-30 SI-660-60

Note: 1. For IP68 version see caution on physical properties page.

5.15 Theta Specifications (Includes IP60/IP65/IP68 Versions)

In addition to the information in the following sections, refer to the ATI website:

Table 5.93—Theta Drawing and Web Links		
Model	**Drawing Part Number**	**ATI Website Address**
Theta Mux[1] transducer without standard mounting adapter	*9230-05-1104*	*https://www.ati-ia.com/products/ft/ft_models.aspx?id=Theta*
Theta DAQ/NET transducer with mounting adapter plate	*9230-05-1331*	
Theta adapter mounting plate (non-IP rated)	*9230-05-1076*	
Theta IP60	*9230-05-1263*	*https://www.ati-ia.com/products/ft/ft_models.aspx?id=Theta+IP60*
Theta IP65	*9230-05-1268*	*https://www.ati-ia.com/products/ft/ft_models.aspx?id=Theta+IP65%2fIP68*
Theta IP68-10m	*9230-05-1273*	
Note: 1. Mux transducers are used in F/T Controller systems.		

5.15.1 Theta Physical Properties

Table 5.94—Theta Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±4500 lbf	±20000 N
Fz	±11000 lbf	±51000 N
Txy	±18000 inf-lb	±2000 Nm
Tz	±18000 inf-lb	±2000 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	4.0×10^5 lb/in	7.1×10^7 N/m
Z-axis force (Kz)	6.9×10^5 lb/in	1.2×10^8 N/m
X-axis & Y-axis torque (Ktx, Kty)	3.0×10^6 lbf-in/rad	3.4×10^5 Nm/rad
Z-axis torque (Ktz)	4.7×10^6 lbf-in/rad	5.3×10^5 Nm/rad
Resonant Frequency		
Fx, Fy, Tz	680 Hz	680 Hz
Fz, Tx, Ty	820 Hz	820 Hz
Physical Specifications		
Weight[1]	11 lb	4.99 kg
Diameter[1]	6.1 in	155 mm
Height[1]	2.41 in	61.1 mm
Note: 1. Specifications include standard interface plates.		

5.15.2 Theta IP60 Physical Properties

Table 5.95—Theta IP60 Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±4500 lbf	±20000 N
Fz	±11000 lbf	±51000 N
Txy	±18000 inf-lb	±2000 Nm
Tz	±18000 inf-lb	±2000 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	4.0×10^5 lb/in	7.1×10^7 N/m
Z-axis force (Kz)	6.9×10^5 lb/in	1.2×10^8 N/m
X-axis & Y-axis torque (Ktx, Kty)	3.0×10^6 lbf-in/rad	3.4×10^5 Nm/rad
Z-axis torque (Ktz)	4.7×10^6 lbf-in/rad	5.3×10^5 Nm/rad
Resonant Frequency		
Fx, Fy, Tz	N/A	N/A
Fz, Tx, Ty	N/A	N/A
Physical Specifications		
Weight[1]	19 lb	8.62 kg
Diameter[1]	7.63 in	194 mm
Height[1]	2.91 in	74 mm
Note: 1. Specifications include standard interface plates.		

5.15.3 Theta IP65/IP68 Physical Properties

Table 5.96—Theta IP65/IP68 Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±4500 lbf	±20000 N
Fz	±11000 lbf	±51000 N
Txy	±18000 inf-lb	±2000 Nm
Tz	±18000 inf-lb	±2000 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	4.0×10^5 lb/in	7.1×10^7 N/m
Z-axis force (Kz)	6.9×10^5 lb/in	1.2×10^8 N/m
X-axis & Y-axis torque (Ktx, Kty)	3.0×10^6 lbf-in/rad	3.4×10^5 Nm/rad
Z-axis torque (Ktz)	4.7×10^6 lbf-in/rad	5.3×10^5 Nm/rad
Resonant Frequency		
Fx, Fy, Tz	N/A	N/A
Fz, Tx, Ty	N/A	N/A
Physical Specifications		
Weight[1]	19.8 lb	9 kg
Diameter[1]	6.41 in	163 mm
Height[1]	2.95 in	74.8 mm
Note: 1. Specifications include standard interface plates.		

CAUTION: When submerged, IP68 transducers exhibit a decrease in Fz range related to the submersion depth. This loss is the result of pressure-induced preloading on the transducer. The preload can be masked by biasing the transducer at the depth prior to applying the load to be measured. The following estimates are for room temperature fresh water at sea level.

Submersion Depth		
IP68 Theta	**US**	**Metric**
Fz preload at 10 m depth	429 lb	1907 N
Fz preload at other depths	-13 lb/ft × depthInFeet	-191 N/m × depthInMeters

5.15.4 Calibration Specifications (excludes CTL calibrations)

Table 5.97— Theta Calibrations (excludes CTL calibrations)1, 2									
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz³ (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**	**Fx,Fy (lbf)**	**Fz³ (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**
Theta	US-200-1000	200	500	1000	1000	1/32	1/16	1/8	1/8
Theta	US-300-1800	300	875	1800	1800	5/68	5/34	5/16	5/16
Theta	US-600-3600	600	1500	3600	3600	1/8	1/4	1/2	1/2
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz³ (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**	**Fx,Fy (N)**	**Fz³ (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**
Theta	SI-1000-120	1000	2500	120	120	1/4	1/4	1/40	1/80
Theta	SI-1500-240	1500	3750	240	240	1/2	1/2	1/20	1/40
Theta	SI-2500-400	2500	6250	400	400	1/2	1	1/20	1/20
		Sensing Ranges				**Resolution (DAQ, Net F/T)⁴**			

Notes:
1. These system resolutions quoted are the effective resolution after dropping four counts of noise. The effective resolution can be improved with filtering.
2. Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.
3. For IP68 version see caution on physical properties page.
4. DAQ resolutions are typical for a 16-bit data acquisition system.

5.15.5 CTL Calibration Specifications

Table 5.98— Theta CTL Calibrations1, 2									
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz³ (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**	**Fx,Fy (lbf)**	**Fz³ (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**
Theta	US-200-1000	200	500	1000	1000	1/16	1/8	1/4	1/4
Theta	US-300-1800	300	875	1800	1800	5/34	5/17	5/8	5/8
Theta	US-600-3600	600	1500	3600	3600	1/4	1/2	1	1
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz³ (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**	**Fx,Fy (N)**	**Fz³ (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**
Theta	SI-1000-120	1000	2500	120	120	1/2	1/2	1/20	1/40
Theta	SI-1500-240	1500	3750	240	240	1	1	1/10	1/20
Theta	SI-2500-400	2500	6250	400	400	1	2	1/10	1/10
		Sensing Ranges				**Resolution (Controller)**			

Notes:
1. CTL resolutions are typical. System resolutions quoted are the effective resolution after dropping eight counts of noise. The effective resolution can be improved with filtering.
2. Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.
3. For IP68 version see caution on physical properties page.

5.15.6 CTL Analog Output

Table 5.99— Theta Analog Output							
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz[2] (lbf)**	**Tx,Ty,Tz (lbf-in)**	**Fx,Fy (lbf/V)**	**Fz[2] (lbf/V)**	**Tx,Ty,Tz (lbf-in/V)**
Theta	US-200-1000	±200	±500	±1000	20	50	100
Theta	US-300-1800	±300	±875	±1800	30	87.5	180
Theta	US-600-3600	±600	±1500	±3600	60	150	360
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz[2] (N)**	**Tx,Ty,Tz (Nm)**	**Fx,Fy (N/V)**	**Fz[2] (N/V)**	**Tx,Ty,Tz (Nm/V)**
Theta	SI-1000-120	±1000	±2500	±120	100	250	12
Theta	SI-1500-240	±1500	±3750	±240	150	375	24
Theta	SI-2500-400	±2500	±6250	±400	250	625	40
		Analog Output Range			**Analog ±10V Sensitivity[1]**		

Notes:
1. ±5V Sensitivity values are double the listed ±10V Sensitivity values.
2. For IP68 version see caution on physical properties page.

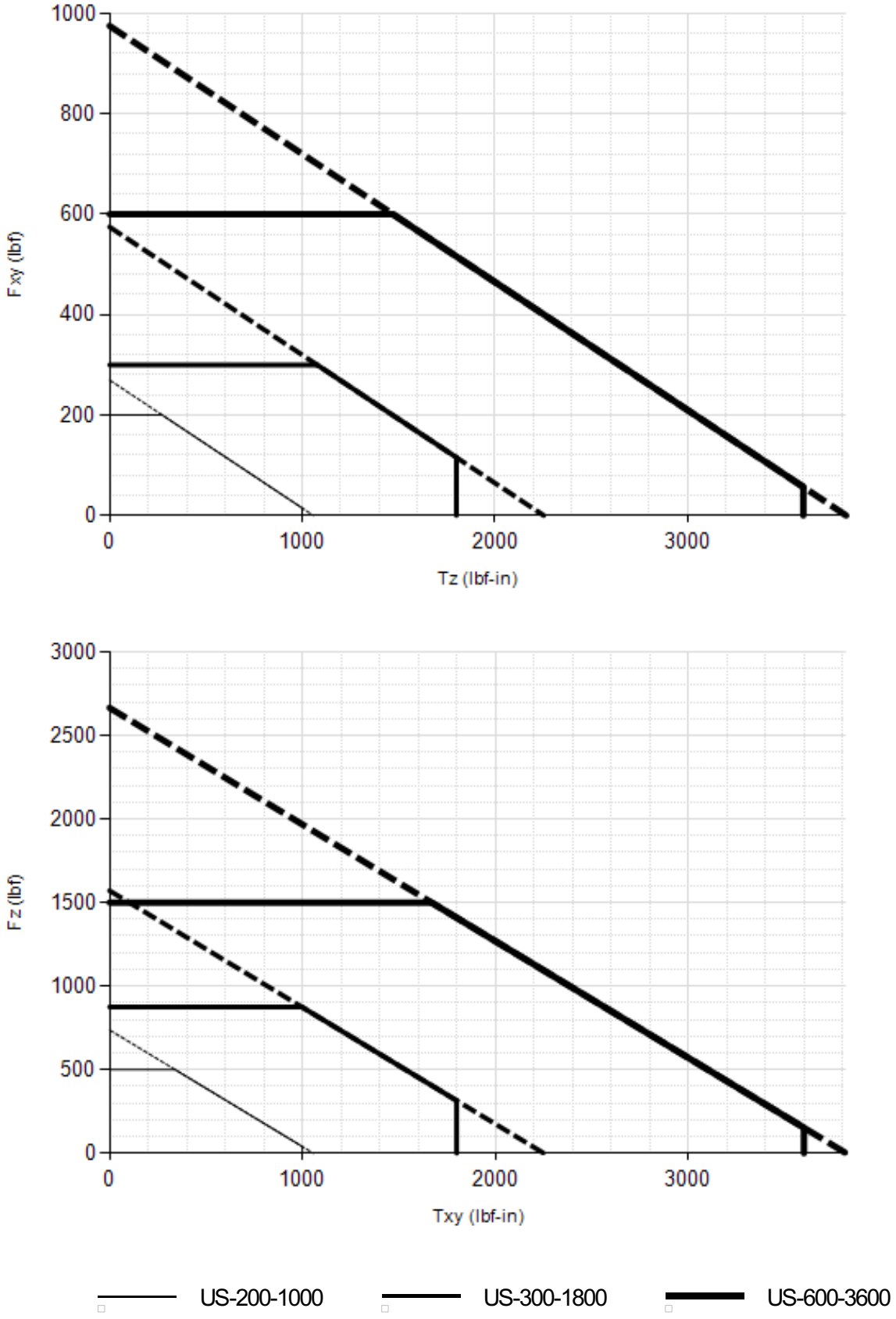
5.15.7 CTL Counts Value

Table 5.100—Counts Value					
Sensor	**Calibration**	**Fx, Fy, Fz (/ lbf)**	**Tx, Ty, Tz (/ lbf-in)**	**Fx, Fy, Fz (/ N)**	**Tx, Ty, Tz (/ Nm)**
Theta	US-200–1000 / SI-1000–120	128	64	32	320
Theta	US-300–1800 / SI-1500–240	54.4	12.8	16	160
Theta	US-600–3600 / SI-2500–400	32	16	16	80
Theta	Tool Transform Factor	See Tool Transform Factor table			
		Counts Value – Standard (US)		**Counts Value – Metric (SI)**	

5.15.8 Tool Transform Factor

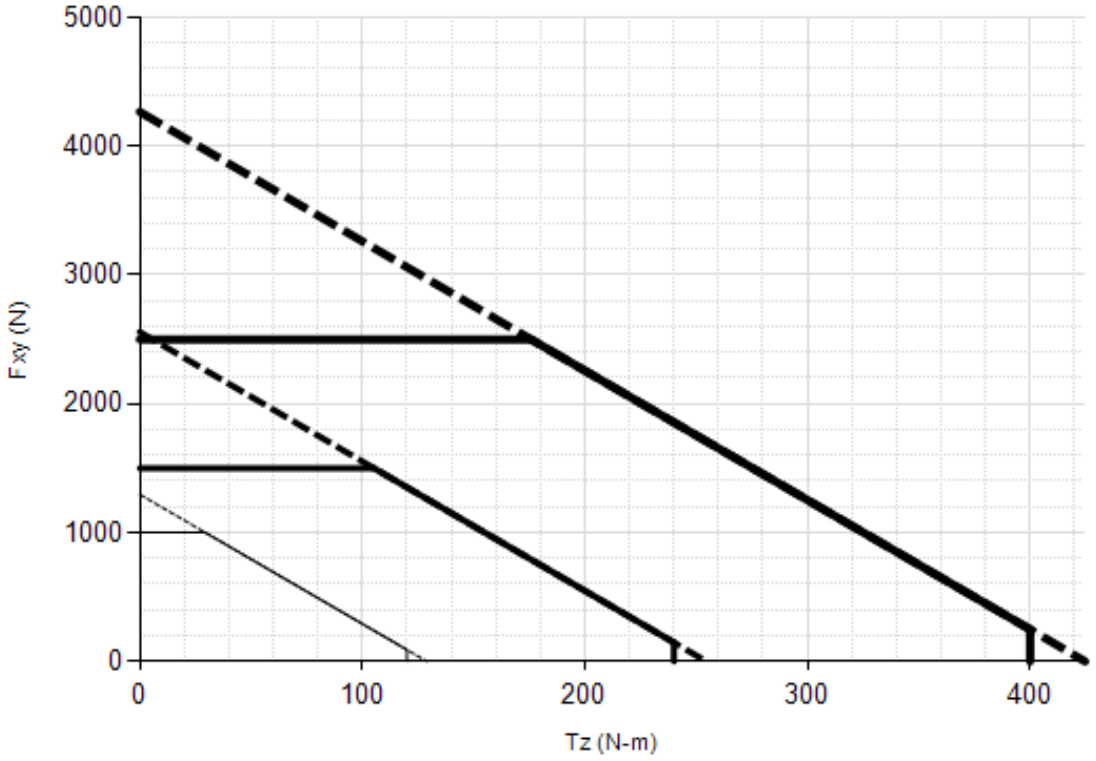
Table 5.101—Tool Transform Factor			
Sensor	**Calibration**	**US (English)**	SI (Metric)
Theta	US-200–1000 / SI-1000–120	0.02 in/lbf	1 mm/N
Theta	US-300–1800 / SI-1500–240	0.0425 in/lbf	1 mm/N
Theta	US-600–3600 / SI-2500–400	0.02 in/lbf	2 mm/N

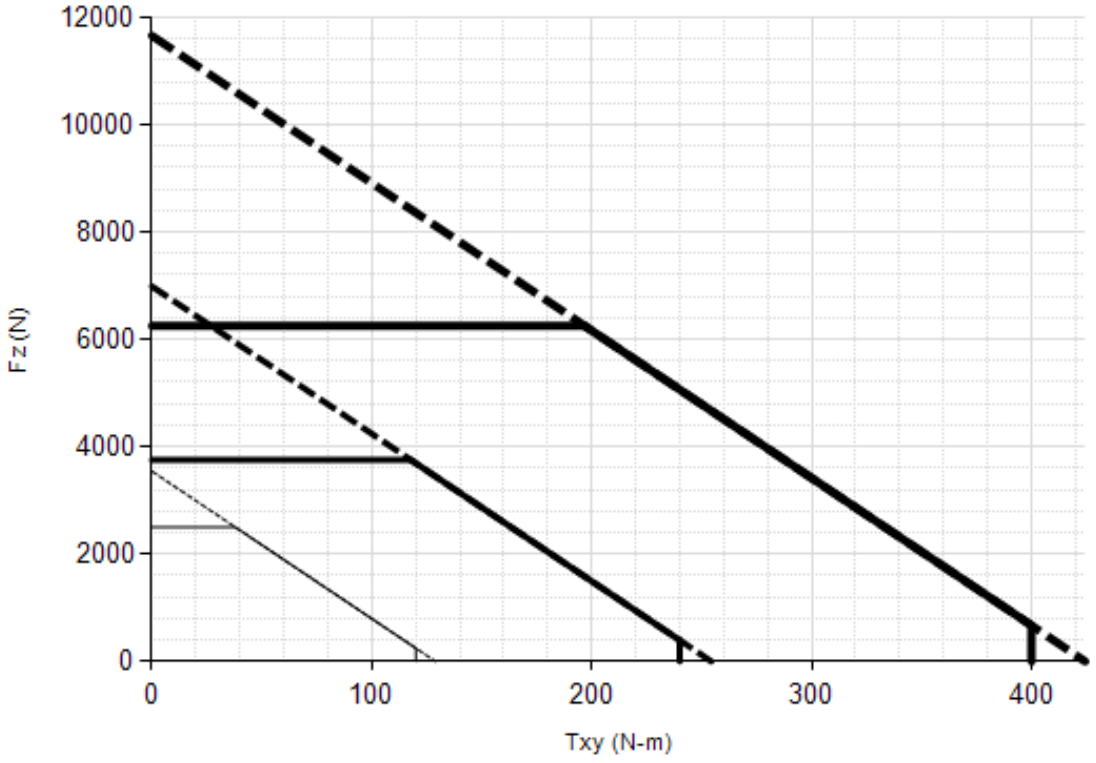
5.15.9 Theta (US Calibration Complex Loading)(Includes IP60/IP65/IP68)[1]



Note: 1. For IP68 version see caution on physical properties page.

5.15.10 Theta (SI Calibration Complex Loading)(Includes IP60/IP65/IP68)[1]





SI-1000-120 SI-1500-240 SI-2500-400

5.16 Omega85 Specifications (Includes IP60/IP65/IP68 Versions)

In addition to the information in the following sections, refer to the ATI website:

Table 5.102—Omega85 Drawing and Web Links		
Model	**Drawing Part Number**	**ATI Website Address**
Omega85	*9230-05-1341*	*https://www.ati-ia.com/products/ft/ft_models.aspx?id=Omega85*
Omega85 IP65	*9230-05-1382*	*https://www.ati-ia.com/products/ft/ft_models.aspx?id=Omega85+IP65%2fIP68*
Omega85 IP68	*9230-05-1396*	

5.16.1 Omega85 Physical Properties

Table 5.103—Omega85 Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±2800 lbf	±13000 N
Fz	±6100 lbf	±27000 N
Txy	±4400 inf-lb	±500 Nm
Tz	±5400 inf-lb	±610 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	4.4×10^5 lb/in	7.7×10^7 N/m
Z-axis force (Kz)	6.8×10^5 lb/in	1.2×10^8 N/m
X-axis & Y-axis torque (Ktx, Kty)	7.2×10^5 lbf-in/rad	8.1×10^4 Nm/rad
Z-axis torque (Ktz)	1.2×10^6 lbf-in/rad	1.3×10^5 Nm/rad
Resonant Frequency		
Fx, Fy, Tz	2100 Hz	2100 Hz
Fz, Tx, Ty	3000 Hz	3000 Hz
Physical Specifications		
Weight[1]	1.45 lb	0.658 kg
Diameter[1]	3.35 in	85.1 mm
Height[1]	1.32 in	33.4 mm
Note: 1. Specifications include standard interface plates.		

5.16.2 Omega85 IP65/IP68 Physical Properties

Table 5.104—Omega85 IP65/IP68 Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±2800 lbf	±13000 N
Fz	±6100 lbf	±27000 N
Txy	±4400 inf-lb	±500 Nm
Tz	±5400 inf-lb	±610 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	4.4×10^5 lb/in	7.7×10^7 N/m
Z-axis force (Kz)	6.8×10^5 lb/in	1.2×10^8 N/m
X-axis & Y-axis torque (Ktx, Kty)	7.2×10^5 lbf-in/rad	8.1×10^4 Nm/rad
Z-axis torque (Ktz)	1.2×10^6 lbf-in/rad	1.3×10^5 Nm/rad
Resonant Frequency		
Fx, Fy, Tz	N/A	N/A
Fz, Tx, Ty	N/A	N/A
Physical Specifications		
Weight[1]	4.2 lb	1.91 kg
Diameter[1]	3.65 in	92.7 mm
Height[1]	1.52 in	38.7 mm
Note: 1. Specifications include standard interface plates.		

CAUTION: When submerged, IP68 transducers exhibit a decrease in Fz range related to the submersion depth. This loss is the result of pressure-induced preloading on the transducer. The preload can be masked by biasing the transducer at the depth prior to applying the load to be measured. The following estimates are for room temperature fresh water at sea level.

Submersion Depth		
IP68 Omega85	**US**	**Metric**
Fz preload at 10 m depth	128 lb	570 N
Fz preload at other depths	-3.9 lb/ft × depthInFeet	-57 N/m × depthInMeters

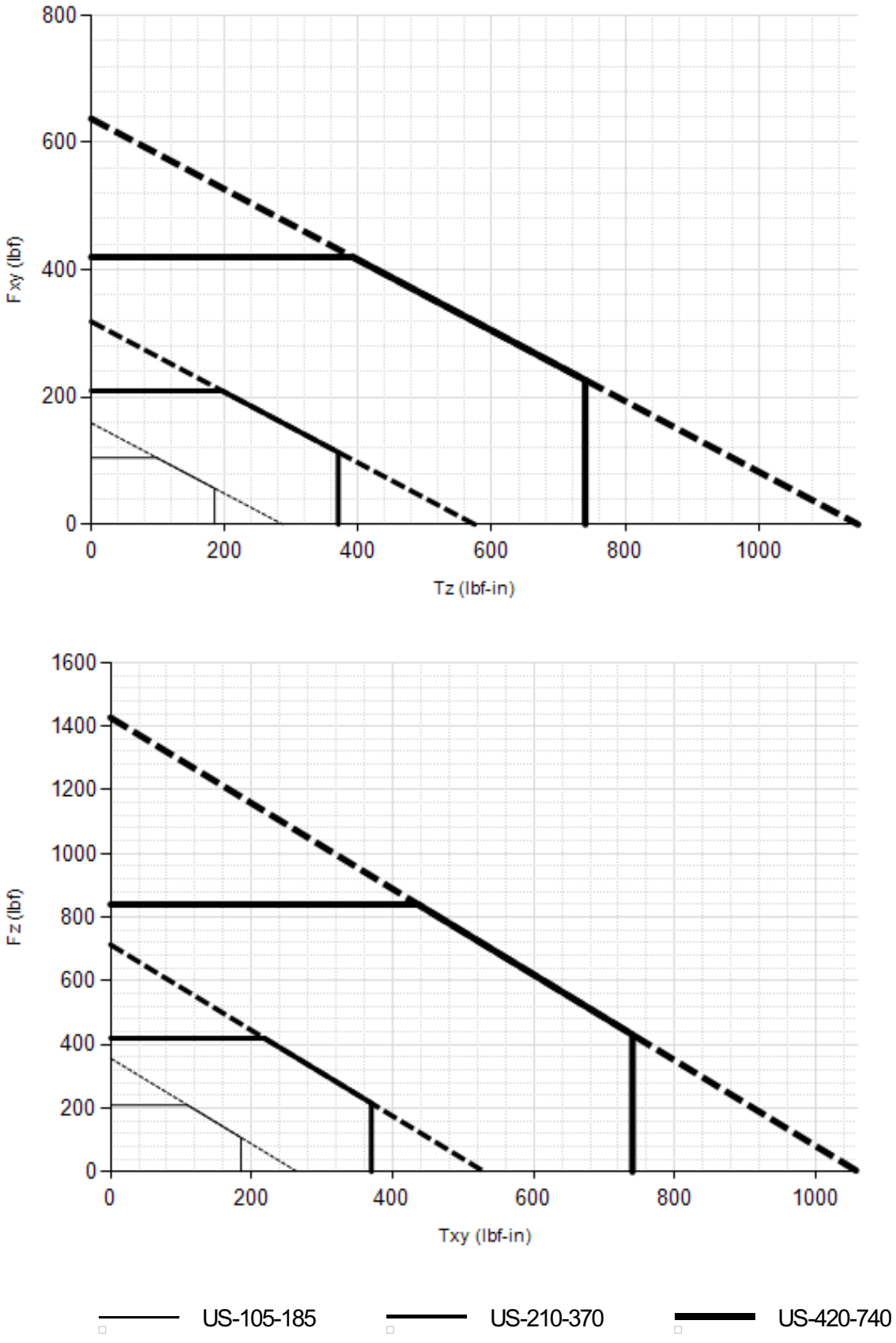
5.16.3 Calibration Specifications (excludes CTL calibrations)

Table 5.105— Omega85 Calibrations (excludes CTL calibrations)[1, 2]									
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz[3] (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**	**Fx,Fy (lbf)**	**Fz[3] (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**
Omega85	US-105-185	105	210	185	185	1/52	3/130	3/112	1/48
Omega85	US-210-370	210	420	370	370	5/128	3/64	3/56	1/24
Omega85	US-420-740	420	840	740	740	5/64	3/32	3/28	1/12
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**
Omega85	SI-475-20	475	950	20	20	1/14	3/28	5/1496	7/2992
Omega85	SI-950-40	950	1900	40	40	1/7	3/14	5/748	7/1496
Omega85	SI-1900-80	1900	3800	80	80	2/7	3/7	5/374	7/748
		Sensing Ranges				**Resolution (DAQ, Net F/T)[4]**			

Notes:
1. These system resolutions quoted are the effective resolution after dropping four counts of noise. The effective resolution can be improved with filtering.
2. Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.
3. For IP68 version see caution on physical properties page.
4. DAQ resolutions are typical for a 16-bit data acquisition system.

NOTICE: The Omega85 does not support an on-board mux board, therefore it cannot be used with the F/T Controller. For Controller F/T systems we recommend the Mini85.

5.16.4 Omega85 (US Calibration Complex Loading)(Includes IP65/IP68)[1]



Note: 1. For IP68 version see caution on physical properties page.

5.17 Omega160 Specifications (Includes IP60/IP65/IP68 Versions)

NOTICE: For transducer versions without a through hole and without an IP rating, use a metallic adapter plate that covers the center hole.

In addition to the information in the following sections, refer to the ATI website:

Table 5.106—Omega160 Drawing and Web Links

Model	Drawing Part Number	ATI Website Address
Omega160 Mux[1] without mounting adapter plate	*9230-05-1093*	*https://www.ati-ia.com/products/ft/ft_models.aspx?id=Omega160*
Omega160 DAQ/NET with mounting adapter plate	*9230-05-1131*	
TIF Omega160 with 53 mm hole	*9230-05-1412*	
Omega160 IP60	*9230-05-1264*	*https://www.ati-ia.com/products/ft/ft_models.aspx?id=Omega160+IP60*
Omega160 IP60 ECAT	*9230-05-1487*	
Omaga160 IP65	*9230-05-1269*	*https://www.ati-ia.com/products/ft/ft_models.aspx?id=Omega160+IP65%2fIP68*
Omega160 IP68-10 m	*9230-05-1274*	
Omega160 IP65 ECAT	*9230-05-1499*	

Note:
1. Mux transducers are used in F/T Controller systems.

5.17.1 Omega160 Physical Properties

Table 5.107—Omega160 Physical Properties

Single-Axis Overload	(US) Standard Units	(SI) Metric Units
Fxy	±3900 lbf	±18000 N
Fz	±11000 lbf	±48000 N
Txy	±15000 inf-lb	±1700 Nm
Tz	±17000 inf-lb	±1900 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	4.0×10^5 lb/in	7.0×10^7 N/m
Z-axis force (Kz)	6.8×10^5 lb/in	1.2×10^8 N/m
X-axis & Y-axis torque (Ktx, Kty)	2.9×10^6 lbf-in/rad	3.3×10^5 Nm/rad
Z-axis torque (Ktz)	4.6×10^6 lbf-in/rad	5.2×10^5 Nm/rad
Resonant Frequency		
Fx, Fy, Tz	1300 Hz	1300 Hz
Fz, Tx, Ty	1000 Hz	1000 Hz
Physical Specifications		
Weight[1]	6 lb	2.72 kg
Diameter[1]	6.16 in	157 mm
Height[1]	2.2 in	55.9 mm

Note:
1. Specifications include standard interface plates.

5.17.2 Omega160 IP160 Physical Properties (Includes ECAT)

Table 5.108—Omega160 IP160 Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±3900 lbf	±18000 N
Fz	±11000 lbf	±48000 N
Txy	±15000 inf-lb	±1700 Nm
Tz	±17000 inf-lb	±1900 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	4.0×10^5 lb/in	7.0×10^7 N/m
Z-axis force (Kz)	6.8×10^5 lb/in	1.2×10^8 N/m
X-axis & Y-axis torque (Ktx, Kty)	2.9×10^6 lbf-in/rad	3.3×10^5 Nm/rad
Z-axis torque (Ktz)	4.6×10^6 lbf-in/rad	5.2×10^5 Nm/rad
Resonant Frequency		
Fx, Fy, Tz	1100 Hz	1100 Hz
Fz, Tx, Ty	1000 Hz	1000 Hz
Physical Specifications		
Weight[1]	16.9 lb	7.67 kg
Diameter[1]	7.63 in	194 mm
Height[1]	2.27 in	57.7 mm
Note: 1. Specifications include standard interface plates.		

5.17.3 Omega160 IP65/IP68 Physical Properties

Table 5.109—Omega160 IP65/IP68 Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±3900 lbf	±18000 N
Fz	±11000 lbf	±48000 N
Txy	±15000 inf-lb	±1700 Nm
Tz	±17000 inf-lb	±1900 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	4.0×10^5 lb/in	7.0×10^7 N/m
Z-axis force (Kz)	6.8×10^5 lb/in	1.2×10^8 N/m
X-axis & Y-axis torque (Ktx, Kty)	2.9×10^6 lbf-in/rad	3.3×10^5 Nm/rad
Z-axis torque (Ktz)	4.6×10^6 lbf-in/rad	5.2×10^5 Nm/rad
Resonant Frequency		
Fx, Fy, Tz	1200 Hz	1200 Hz
Fz, Tx, Ty	900 Hz	900 Hz
Physical Specifications		
Weight[1]	16 lb	7.26 kg
Diameter[1]	6.5 in	165 mm
Height[1]	2.59 in	65.9 mm
Note: 1. Specifications include standard interface plates.		

CAUTION: When submerged, IP68 transducers exhibit a decrease in Fz range related to the submersion depth. This loss is the result of pressure-induced preloading on the transducer. The preload can be masked by biasing the transducer at the depth prior to applying the load to be measured. The following estimates are for room temperature fresh water at sea level.

Submersion Depth		
IP68 Omega160	**US**	**Metric**
Fz preload at 10 m depth	429 lb	1907 N
Fz preload at other depths	-13 lb/ft × depthInFeet	-191 N/m × depthInMeters

5.17.4 Calibration Specifications (excludes CTL calibrations)

Table 5.110— Omega160 Calibrations (excludes CTL calibrations)1, 2									
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz³ (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**	**Fx,Fy (lbf)**	**Fz³ (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**
Omega160	US-200-1000	200	500	1000	1000	1/32	1/16	1/8	1/8
Omega160	US-300-1800	300	875	1800	1800	5/68	5/34	5/16	5/16
Omega160	US-600-3600	600	1500	3600	3600	1/8	1/4	1/2	1/4
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz³ (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**	**Fx,Fy (N)**	**Fz³ (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**
Omega160	SI-1000-120	1000	2500	120	120	1/4	1/4	1/40	1/80
Omega160	SI-1500-240	1500	3750	240	240	1/4	1/2	1/20	1/40
Omega160	SI-2500-400	2500	6250	400	400	1/2	3/4	1/20	1/20
		Sensing Ranges				**Resolution (DAQ, Net F/T)[4]**			

Notes:
1. These system resolutions quoted are the effective resolution after dropping four counts of noise. The effective resolution can be improved with filtering.
2. Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.
3. For IP68 version see caution on physical properties page.
4. DAQ resolutions are typical for a 16-bit data acquisition system.

5.17.5 CTL Calibration Specifications

Table 5.111— Omega160 CTL Calibrations1, 2									
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz³ (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**	**Fx,Fy (lbf)**	**Fz³ (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**
Omega160	US-200-1000	200	500	1000	1000	1/16	1/8	1/4	1/4
Omega160	US-300-1800	300	875	1800	1800	5/34	5/17	5/8	5/8
Omega160	US-600-3600	600	1500	3600	3600	1/4	1/2	1	1/2
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz³ (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**	**Fx,Fy (N)**	**Fz³ (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**
Omega160	SI-1000-120	1000	2500	120	120	1/2	1/2	1/20	1/40
Omega160	SI-1500-240	1500	3750	240	240	1/2	1	1/10	1/20
Omega160	SI-2500-400	2500	6250	400	400	1	1 1/2	1/10	1/10
		Sensing Ranges				**Resolution (Controller)**			

Notes:
1. CTL resolutions are typical. System resolutions quoted are the effective resolution after dropping eight counts of noise. The effective resolution can be improved with filtering.
2. Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.
3. For IP68 version see caution on physical properties page.

5.17.6 CTL Analog Output

Table 5.112— Omega160 Analog Output							
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz[2] (lbf)**	**Tx,Ty,Tz (lbf-in)**	**Fx,Fy (lbf/V)**	**Fz[2] (lbf/V)**	**Tx,Ty,Tz (lbf-in/V)**
Omega160	US-200-1000	±200	±500	±1000	20	50	100
Omega160	US-300-1800	±300	±875	±1800	30	87.5	180
Omega160	US-600-3600	±600	±1500	±3600	60	150	360
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz (N)**	**Tx,Ty,Tz (Nm)**	**Fx,Fy (N/V)**	**Fz[2] (N/V)**	**Tx,Ty,Tz (Nm/V)**
Omega160	SI-1000-120	±1000	±2500	±120	100	250	12
Omega160	SI-1500-240	±1500	±3750	±240	150	375	24
Omega160	SI-2500-400	±2500	±6250	±400	250	625	40
		Analog Output Range			**Analog ±10V Sensitivity[1]**		

Notes:
1. ±5V Sensitivity values are double the listed ±10V Sensitivity values.
2. For IP68 version see caution on physical properties page.

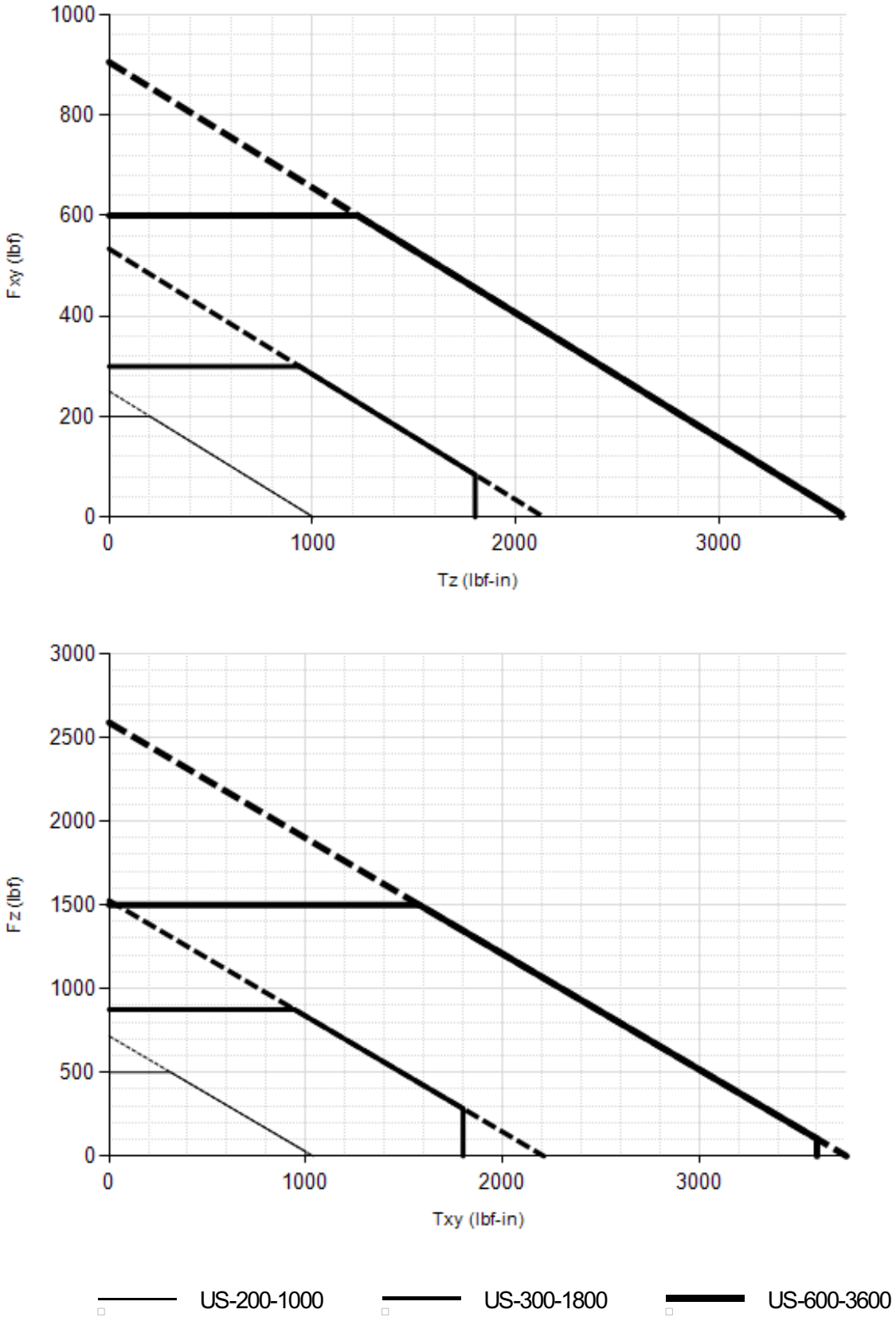
5.17.7 CTL Counts Value

Table 5.113—Counts Value					
Sensor	**Calibration**	**Fx, Fy, Fz (/ lbf)**	**Tx, Ty, Tz (/ lbf-in)**	**Fx, Fy, Fz (/ N)**	**Tx, Ty, Tz (/ Nm)**
Omega160	US-200–1000 / SI-1000–120	128	64	32	320
Omega160	US-300–1800 / SI-1500–240	54.4	12.8	16	160
Omega160	US-600–3600 / SI-2500–400	32	16	16	80
Omega160	Tool Transform Factor	See Tool Transform Factor table			
		Counts Value – Standard (US)		**Counts Value – Metric (SI)**	

5.17.8 Tool Transform Factor

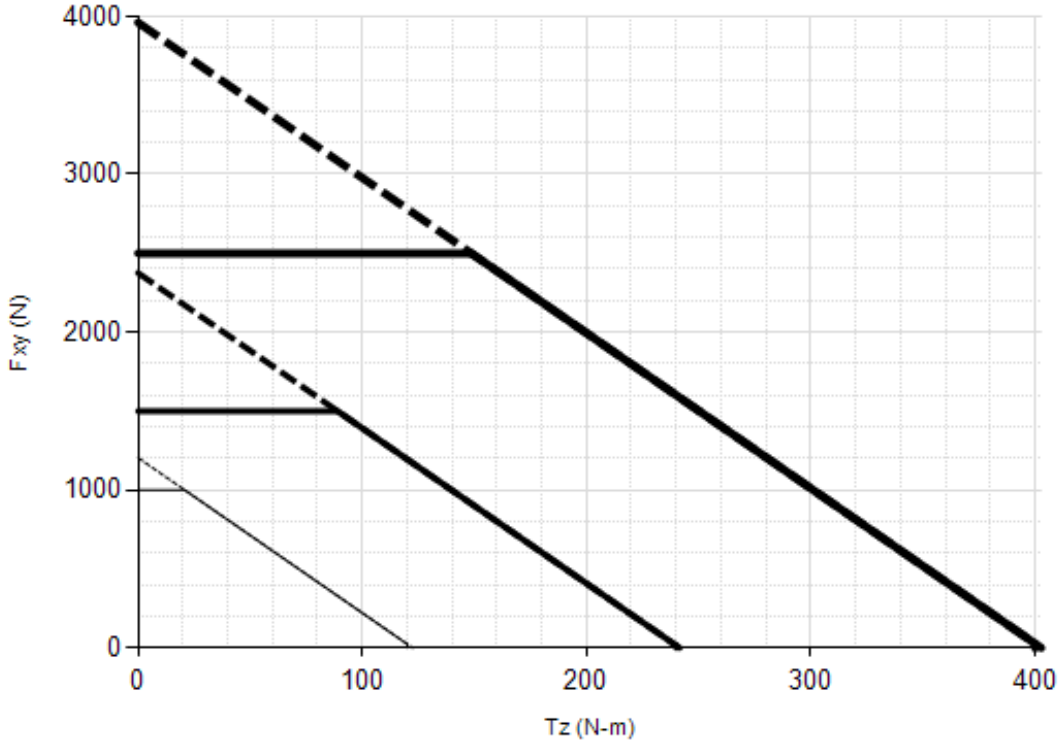
Table 5.114—Tool Transform Factor			
Sensor	**Calibration**	**US (English)**	SI (Metric)
Omega160	US-200–1000 / SI-1000–120	0.02 in/lbf	1 mm/N
Omega160	US-300–1800 / SI-1500–240	0.0425 in/lbf	1 mm/N
Omega160	US-600–3600 / SI-2500–400	0.02 in/lbf	2 mm/N

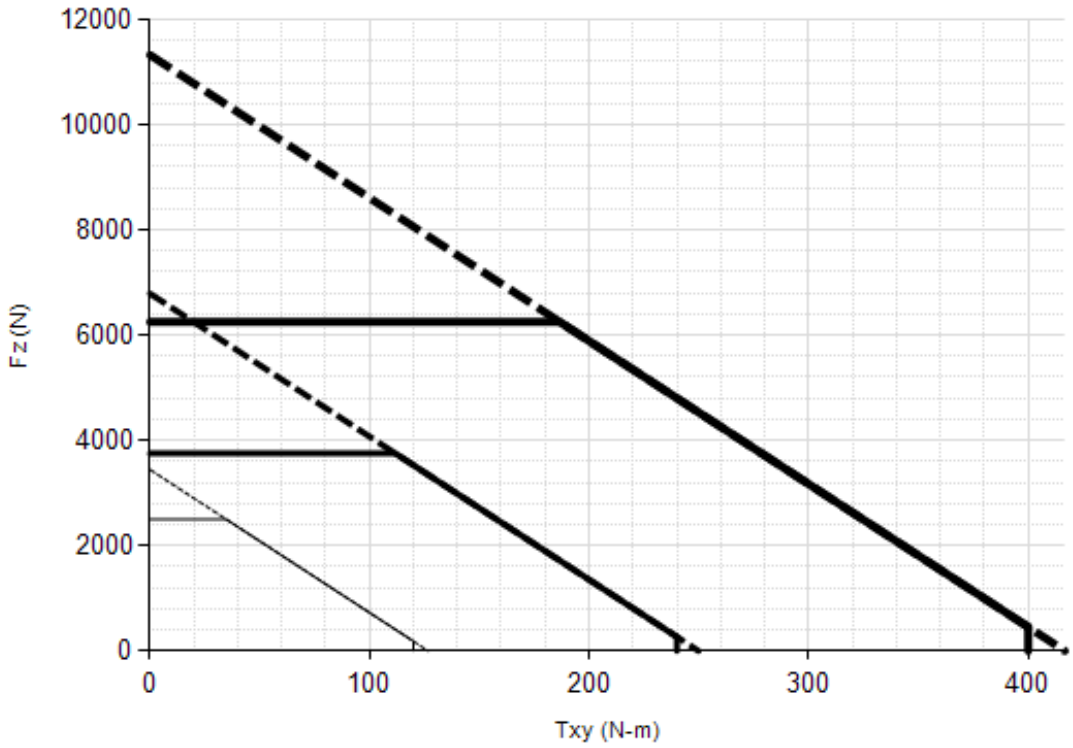
5.17.9 Omega160 (US Calibration Complex Loading) (Includes IP60/IP65/IP68)[1]



Note: 1. For IP68 version see caution on physical properties page.

5.17.10 Omega160 (SI Calibration Complex Loading) (Includes IP60/IP65/IP68)[1]





SI-1000-120 SI-1500-240 SI-2500-400

Note: 1. For IP68 version see caution on physical properties page.

5.18 Omega190 Specifications

In addition to the information in the following sections, refer to the ATI website:

Table 5.115—Omega190 Drawing and Web Links		
Model	**Drawing Part Number**	**ATI Website Address**
Omega190 DAQ/Net	*9230-05-1095*	*https://www.ati-ia.com/products/ft/ft_models.aspx?ID=Omega190*

5.18.1 Omega190 Physical Properties

Table 5.116—Omega190 Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±8000 lbf	±36000 N
Fz	±25000 lbf	±110000 N
Txy	±60000 lbf-in	±6800 Nm
Tz	±60000 lbf-in	±6800 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	$1.4x10^6$ lb/in	$2.4x10^8$ N/m
Z-axis force (Kz)	$2.1x10^6$ lb/in	$3.6x10^8$ N/m
X-axis & Y-axis torque (Ktx, Kty)	$1.4x10^7$ lbf-in/rad	$1.5x10^6$ Nm/rad
Z-axis torque (Ktz)	$2.8x10^7$ lbf-in/rad	$3.2x10^6$ Nm/rad
Resonant Frequency		
Fx, Fy, Tz	N/A	N/A
Fz, Tx, Ty	N/A	N/A
Physical Specifications		
Weight[1]	14 lb	6.35 kg
Diameter[1]	7.48 in	190 mm
Height[1]	2.2 in	55.9 mm

Note:
1. Specifications include standard interface plates.

5.18.2 Calibration Specifications (excludes CTL calibrations)

Table 5.117— Omega190 Calibrations (excludes CTL calibrations)1, 2									
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz[3] (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**	**Fx,Fy (lbf)**	**Fz[3] (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**
Omega190	US-400-3000	400	1000	3000	3000	5/64	5/32	15/32	5/16
Omega190	US-800-6000	800	2000	6000	6000	5/32	5/16	15/16	5/8
Omega190	US-1600-12000	1600	4000	12000	12000	5/16	5/8	1 7/8	1 1/4
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**
Omega190	SI-1800-350	1800	4500	350	350	3/8	3/4	5/96	5/144
Omega190	SI-3600-700	3600	9000	700	700	3/4	1 1/2	5/48	5/72
Omega190	SI-7200-1400	7200	18000	1400	1400	1 1/2	3	5/24	5/36
		Sensing Ranges				**Resolution (DAQ, Net F/T)[4]**			

Notes:
1. These system resolutions quoted are the effective resolution after dropping four counts of noise. The effective resolution can be improved with filtering.
2. Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.
3. For IP68 version see caution on physical properties page.
4. DAQ resolutions are typical for a 16-bit data acquisition system.

5.18.3 CTL Calibration Specifications

Table 5.118— Omega190 CTL Calibrations1, 2									
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz[3] (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**	**Fx,Fy (lbf)**	**Fz[3] (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**
Omega190	US-400-3000	400	1000	3000	3000	5/32	5/16	15/16	5/8
Omega190	US-800-6000	800	2000	6000	6000	5/16	5/8	1 7/8	1 1/4
Omega190	US-1600-12000	1600	4000	12000	12000	5/8	1 1/4	3 3/4	2 1/2
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**
Omega190	SI-1800-350	1800	4500	350	350	3/4	1 1/2	5/48	5/72
Omega190	SI-3600-700	3600	9000	700	700	1 1/2	3	5/24	5/36
Omega190	SI-7200-1400	7200	18000	1400	1400	3	6	5/12	5/18
		Sensing Ranges				**Resolution (Controller)**			

Notes:
1. CTL resolutions are typical. System resolutions quoted are the effective resolution after dropping eight counts of noise. The effective resolution can be improved with filtering.
2. Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.
3. For IP68 version see caution on physical properties page.

5.18.4 CTL Analog Output

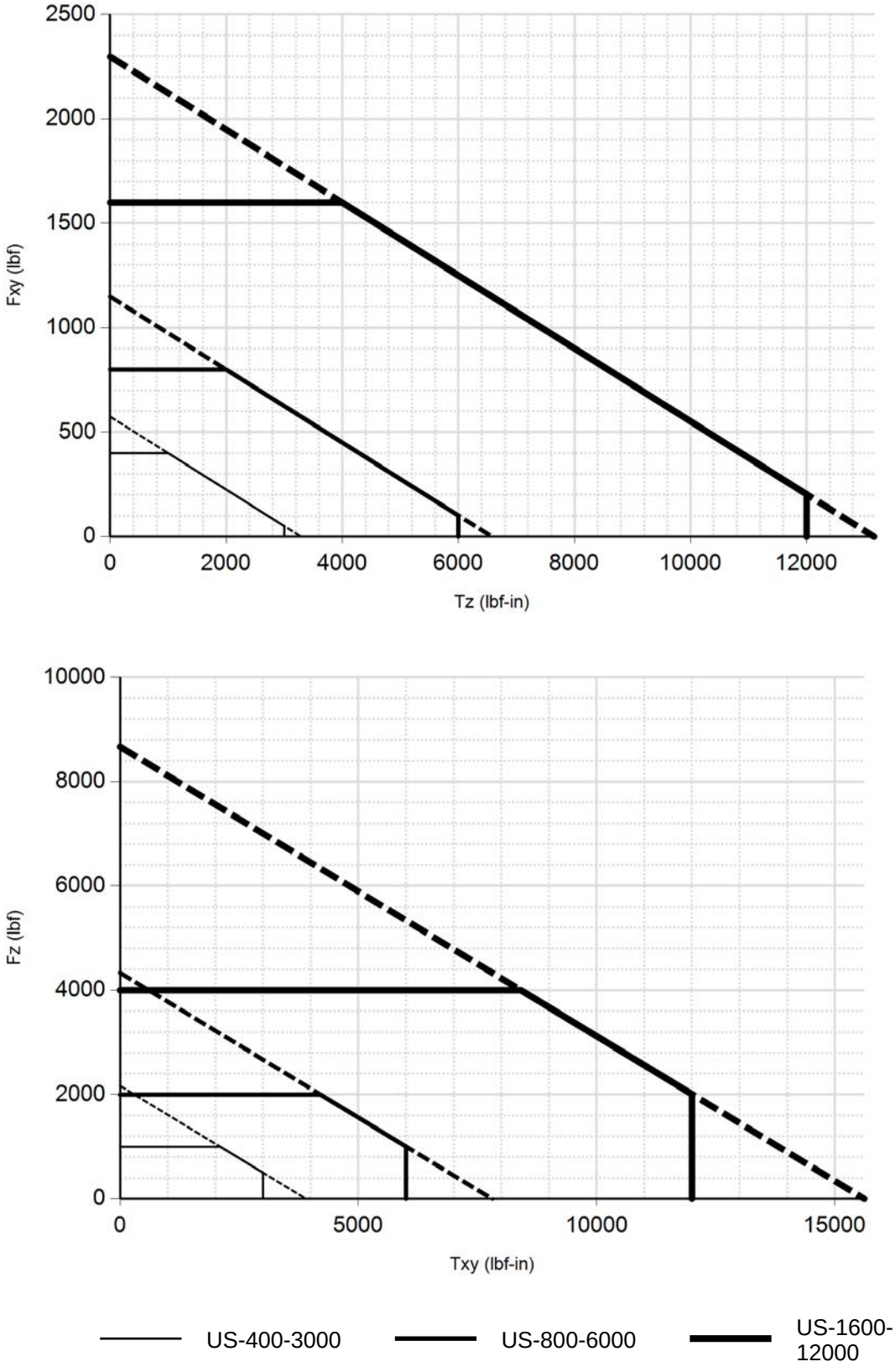
Table 5.119— Omega190 Analog Output							
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz[2] (lbf)**	**Tx,Ty,Tz (lbf-in)**	**Fx,Fy (lbf/V)**	**Fz[2] (lbf/V)**	**Tx,Ty,Tz (lbf-in/V)**
Omega190	US-400-3000	±400	±1000	±3000	40	100	300
Omega190	US-800-6000	±800	±2000	±6000	80	200	600
Omega190	US-1600-12000	±1600	±4000	±12000	160	400	1200
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz[2] (N)**	**Tx,Ty,Tz (Nm)**	**Fx,Fy (N/V)**	**Fz[2] (N/V)**	**Tx,Ty,Tz (Nm/V)**
Omega190	SI-1800-350	±1800	±4500	±350	180	450	35
Omega190	SI-3600-700	±3600	±9000	±700	360	900	70
Omega190	SI-7200-1400	±7200	±18000	±1400	720	1800	140
		Analog Output Range			**Analog ±10V Sensitivity[1]**		

Notes:
1. ±5V Sensitivity values are double the listed ±10V Sensitivity values.
2. For IP68 version see caution on physical properties page.

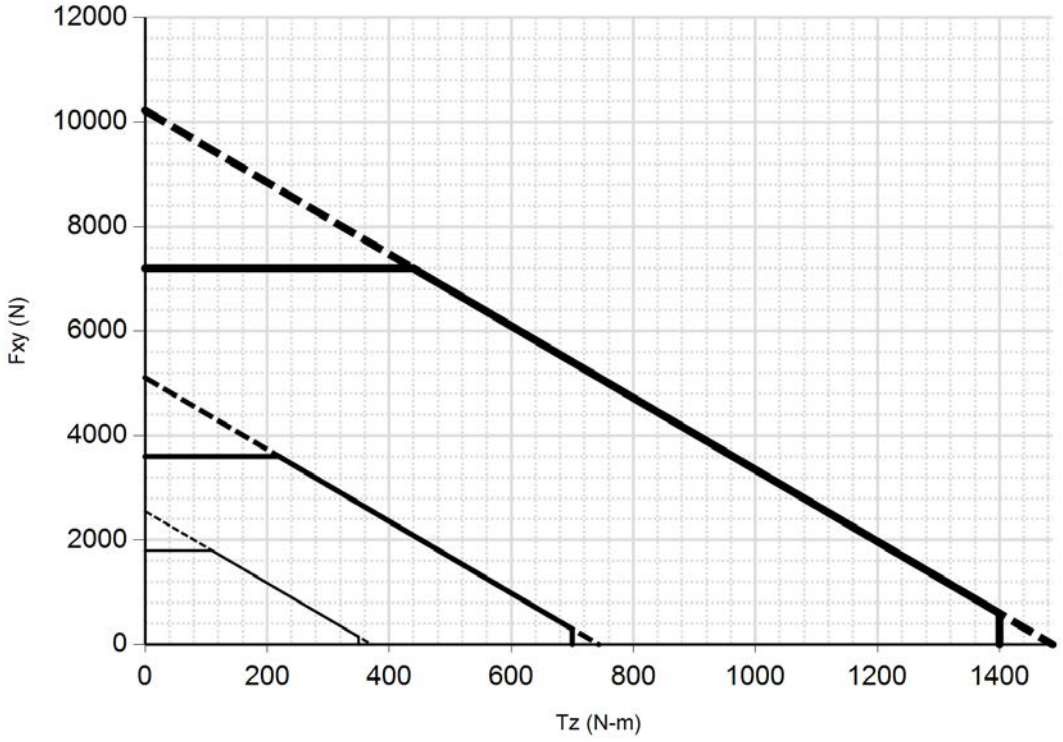
5.18.5 CTL Counts Value

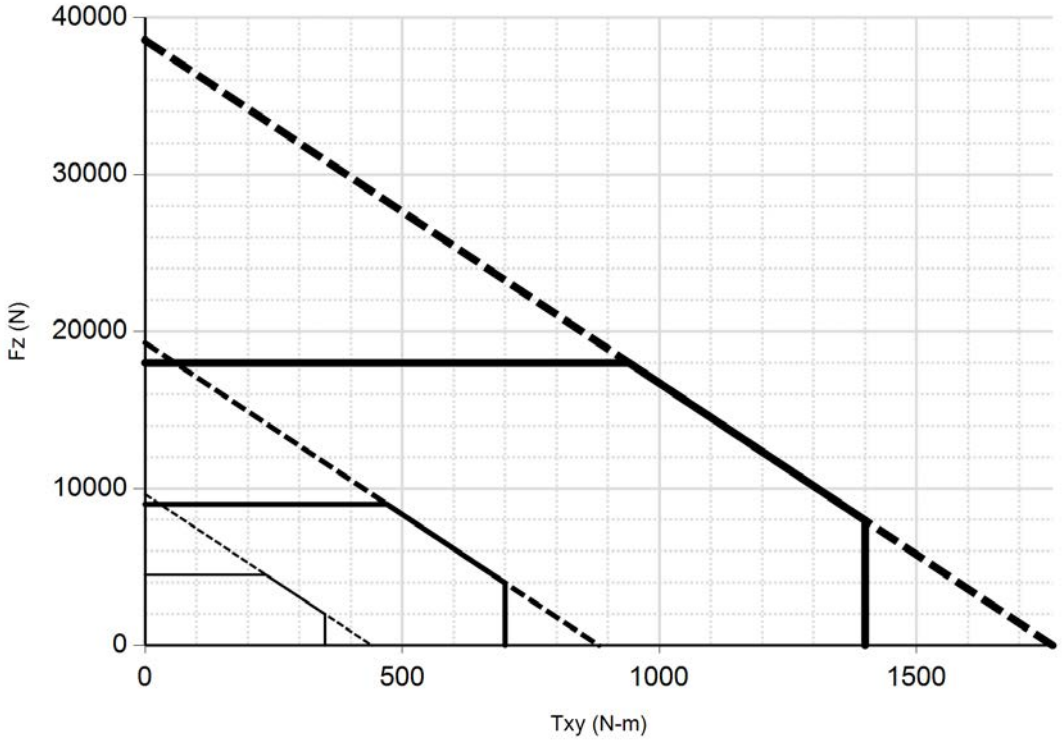
Table 5.120—Counts Value					
Sensor	**Calibration**	**Fx, Fy, Fz (/ lbf)**	**Tx, Ty, Tz (/ lbf-in)**	**Fx, Fy, Fz (/ N)**	**Tx, Ty, Tz (/ Nm)**
Omega190	US-400-3000 / SI-1800-350	153.6	307.2	32	230.4
Omega190	US-800-6000 / SI-3600-700	76.8	153.6	16	115.2
Omega190	US-1600-12000 / SI-7200-1400	38.4	76.8	8	57.6
Omega190	Tool Transform Factor	0.005 in/lbf		1.3889 mm/N	
		Counts Value – Standard (US)		**Counts Value – Metric (SI)**	

5.18.6 Omega190 (US Calibration Complex Loading)



5.18.7 Omega190 (SI Calibration Complex Loading)





SI-1800-350 SI-3600-700 SI-7200-1400

5.19 Omega191 Specifications (Includes IP60/IP65/IP68 Versions)

NOTICE: For transducer versions without a through hole and without an IP rating, use a metallic adapter plate that covers the center hole.

In addition to the information in the following sections, refer to the ATI website:

Table 5.121—Omega191 Drawing and Web Links

Model	Drawing Part Number	ATI Website Address
Omega191 DAQ/Net	*9230-05-1464*	*https://www.ati-ia.com/products/ft/ft_models.aspx?id=Omega191*
Omega191 IP60	*9230-05-1470*	*https://www.ati-ia.com/products/ft/ft_models.aspx?id=Omega191+IP60*
Omega191 IP65 Mux[1]/DAQ/Net	*9230-05-1471*	*https://www.ati-ia.com/products/ft/ft_models.aspx?id=Omega191+IP65%2fIP68*
Omega191 IP68 Mux[1]/DAQ/Net	*9230-05-1472*	

Note:
1. Mux transducers are used in F/T Controller systems.

5.19.1 Omega191 Physical Properties

Table 5.122—Omega191 Physical Properties

Single-Axis Overload	(US) Standard Units	(SI) Metric Units
Fxy	±8000 lbf	±36000 N
Fz	±25000 lbf	±110000 N
Txy	±60000 inf-lb	±6800 Nm
Tz	±60000 inf-lb	±6800 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	$1.4x10^6$ lb/in	$2.4x10^8$ N/m
Z-axis force (Kz)	$2.1x10^6$ lb/in	$3.6x10^8$ N/m
X-axis & Y-axis torque (Ktx, Kty)	$1.4x10^7$ lbf-in/rad	$1.5x10^6$ Nm/rad
Z-axis torque (Ktz)	$2.8x10^7$ lbf-in/rad	$3.2x10^6$ Nm/rad
Resonant Frequency		
Fx, Fy, Tz	N/A	N/A
Fz, Tx, Ty	N/A	N/A
Physical Specifications		
Weight[1]	20.8 lb	9.41 kg
Diameter[1]	7.48 in	190 mm
Height[1]	2.52 in	64 mm

Note:
1. Specifications include standard interface plates.

5.19.2 Omega191 IP60 Physical Properties

Table 5.123—Omega191 IP60 Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±8000 lbf	±36000 N
Fz	±25000 lbf	±110000 N
Txy	±60000 inf-lb	±6800 Nm
Tz	±60000 inf-lb	±6800 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	$1.4x10^6$ lb/in	$2.4x10^8$ N/m
Z-axis force (Kz)	$2.1x10^6$ lb/in	$3.6x10^8$ N/m
X-axis & Y-axis torque (Ktx, Kty)	$1.4x10^7$ lbf-in/rad	$1.5x10^6$ Nm/rad
Z-axis torque (Ktz)	$2.8x10^7$ lbf-in/rad	$3.2x10^6$ Nm/rad
Resonant Frequency		
Fx, Fy, Tz	1200 Hz	1200 Hz
Fz, Tx, Ty	1200 Hz	1200 Hz
Physical Specifications		
Weight[1]	31 lb	14.1 kg
Diameter[1]	9.37 in	238 mm
Height[1]	2.9 in	73.7 mm
Note: 1. Specifications include standard interface plates.		

5.19.3 Omega191 IP65/IP68 Physical Properties

Table 5.124—Omega191 IP65/IP68 Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±8000 lbf	±36000 N
Fz	±25000 lbf	±110000 N
Txy	±60000 inf-lb	±6800 Nm
Tz	±60000 inf-lb	±6800 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	$1.4x10^6$ lb/in	$2.4x10^8$ N/m
Z-axis force (Kz)	$2.1x10^6$ lb/in	$3.6x10^8$ N/m
X-axis & Y-axis torque (Ktx, Kty)	$1.4x10^7$ lbf-in/rad	$1.5x10^6$ Nm/rad
Z-axis torque (Ktz)	$2.8x10^7$ lbf-in/rad	$3.2x10^6$ Nm/rad
Resonant Frequency		
Fx, Fy, Tz	1400 Hz	1400 Hz
Fz, Tx, Ty	980 Hz	980 Hz
Physical Specifications		
Weight[1]	29 lb	13.2 kg
Diameter[1]	8.03 in	204 mm
Height[1]	2.94 in	74.8 mm
Note: 1. Specifications include standard interface plates.		

CAUTION: When submerged, IP68 transducers exhibit a decrease in Fz range related to the submersion depth. This loss is the result of pressure-induced preloading on the transducer. The preload can be masked by biasing the transducer at the depth prior to applying the load to be measured. The following estimates are for room temperature fresh water at sea level.

Submersion Depth		
IP68 Omega191	**US**	**Metric**
Fz preload at 10 m depth	661 lb	2941 N
Fz preload at other depths	-20 lb/ft × depthInFeet	-294 N/m × depthInMeters

5.19.4 Calibration Specifications (excludes CTL calibrations)

Table 5.125— Omega191 Calibrations (excludes CTL calibrations)1, 2									
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz³ (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**	**Fx,Fy (lbf)**	**Fz³ (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**
Omega191	US-400-3000	400	1000	3000	3000	5/64	5/32	15/32	5/16
Omega191	US-800-6000	800	2000	6000	6000	5/32	5/16	15/16	5/8
Omega191	US-1600-12000	1600	4000	12000	12000	5/16	5/8	1 7/8	1 1/4
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz³ (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**	**Fx,Fy (N)**	**Fz³ (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**
Omega191	SI-1800-350	1800	4500	350	350	3/8	3/4	5/96	5/144
Omega191	SI-3600-700	3600	9000	700	700	3/4	1 1/2	5/48	5/72
Omega191	SI-7200-1400	7200	18000	1400	1400	1 1/2	3	5/24	5/36
		Sensing Ranges				**Resolution (DAQ, Net F/T)[4]**			

Notes:
1. These system resolutions quoted are the effective resolution after dropping four counts of noise. The effective resolution can be improved with filtering.
2. Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.
3. For IP68 version see caution on physical properties page.
4. DAQ resolutions are typical for a 16-bit data acquisition system.

5.19.5 CTL Calibration Specifications

Table 5.126— Omega191 CTL Calibrations1, 2									
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz³ (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**	**Fx,Fy (lbf)**	**Fz³ (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**
Omega191	US-400-3000	400	1000	3000	3000	5/32	5/16	15/16	5/8
Omega191	US-800-6000	800	2000	6000	6000	5/16	5/8	1 7/8	1 1/4
Omega191	US-1600-12000	1600	4000	12000	12000	5/8	1 1/4	3 3/4	2 1/2
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz³ (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**	**Fx,Fy (N)**	**Fz³ (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**
Omega191	SI-1800-350	1800	4500	350	350	3/4	1 1/2	5/48	5/72
Omega191	SI-3600-700	3600	9000	700	700	1 1/2	3	5/24	5/36
Omega191	SI-7200-1400	7200	18000	1400	1400	3	6	5/12	5/18
		Sensing Ranges				**Resolution (Controller)**			

Notes:
1. CTL resolutions are typical. System resolutions quoted are the effective resolution after dropping eight counts of noise. The effective resolution can be improved with filtering.
2. Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.
3. For IP68 version see caution on physical properties page.

5.19.6 CTL Analog Output

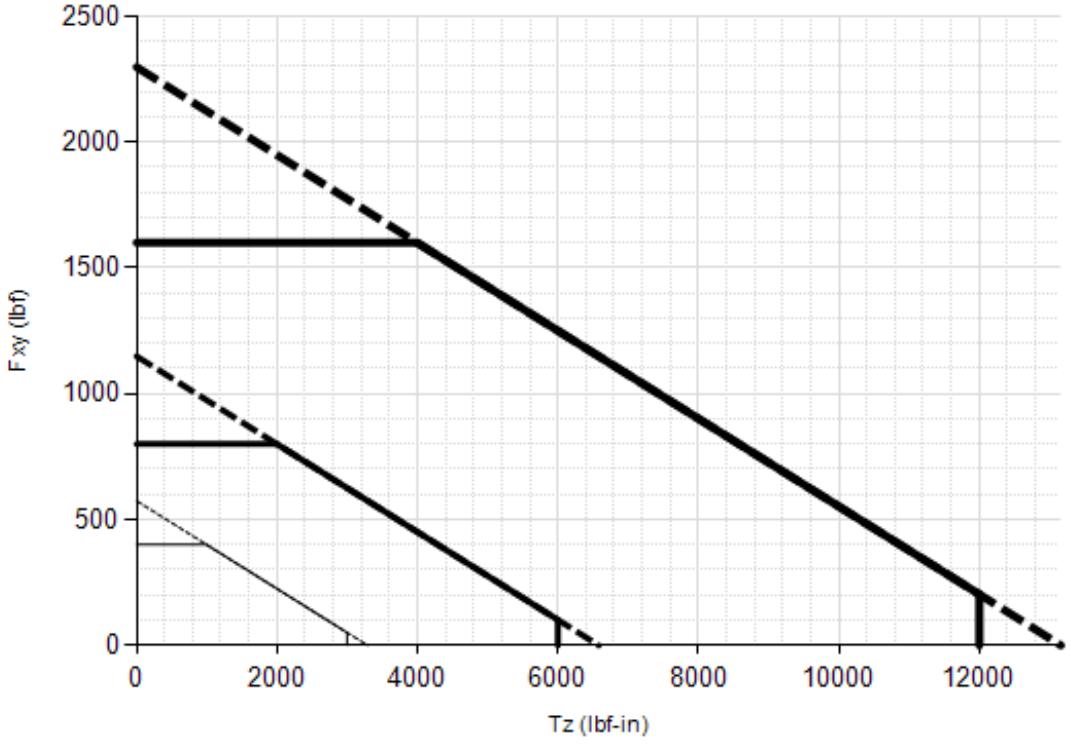
Table 5.127— Omega191 Analog Output							
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz[2] (lbf)**	**Tx,Ty,Tz (lbf-in)**	**Fx,Fy (lbf/V)**	**Fz[2] (lbf/V)**	**Tx,Ty,Tz (lbf-in/V)**
Omega191	US-400-3000	±400	±1000	±3000	40	100	300
Omega191	US-800-6000	±800	±2000	±6000	80	200	600
Omega191	US-1600-12000	±1600	±4000	±12000	160	400	1200
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz[2] (N)**	**Tx,Ty,Tz (Nm)**	**Fx,Fy (N/V)**	**Fz[2] (N/V)**	**Tx,Ty,Tz (Nm/V)**
Omega191	SI-1800-350	±1800	±4500	±350	180	450	35
Omega191	SI-3600-700	±3600	±9000	±700	360	900	70
Omega191	SI-7200-1400	±7200	±18000	±1400	720	1800	140
		Analog Output Range			**Analog ±10V Sensitivity[1]**		

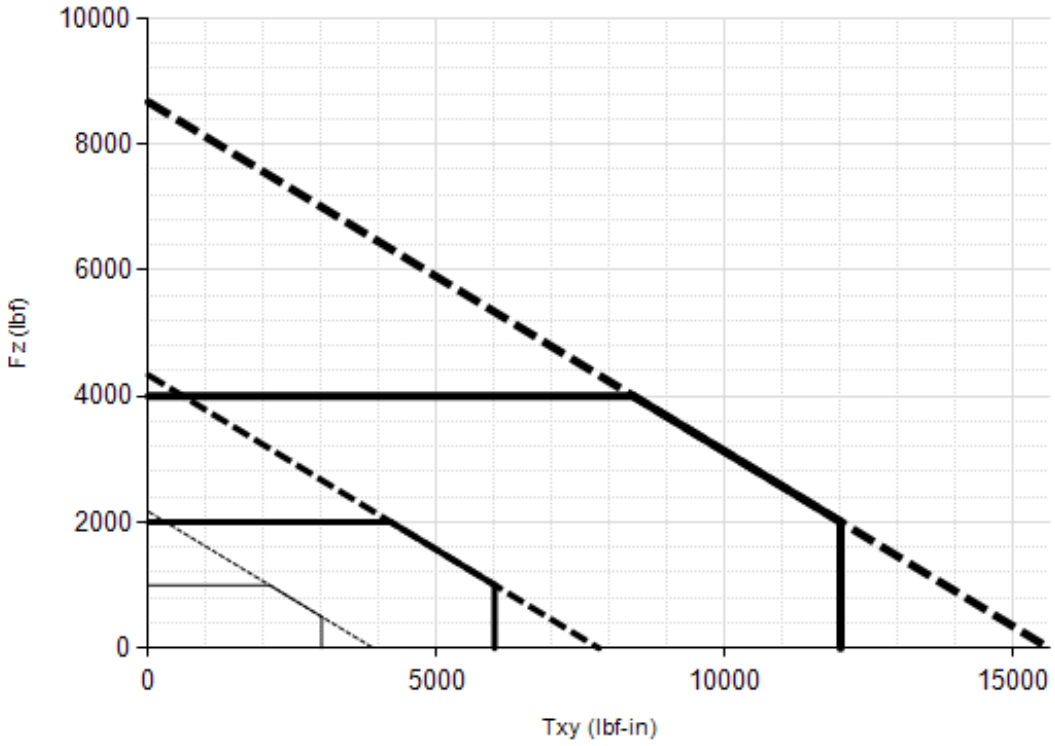
Notes:
1. ±5V Sensitivity values are double the listed ±10V Sensitivity values.
2. For IP68 version see caution on physical properties page.

5.19.7 CTL Counts Value

Table 5.128—Counts Value					
Sensor	**Calibration**	**Fx, Fy, Fz (/ lbf)**	**Tx, Ty, Tz (/ lbf-in)**	**Fx, Fy, Fz (/ N)**	**Tx, Ty, Tz (/ Nm)**
Omega191	US-400-3000 / SI-1800-350	153.6	307.2	32	230.4
Omega191	US-800-6000 / SI-3600-700	76.8	153.6	16	115.2
Omega191	US-1600-12000 / SI-7200-1400	38.4	76.8	8	57.6
Omega191	Tool Transform Factor	0.005 in/lbf		1.3889 mm/N	
		Counts Value – Standard (US)		**Counts Value – Metric (SI)**	

5.19.8 Omega191 (US Calibration Complex Loading) (Includes IP60/IP65/IP68)[1]

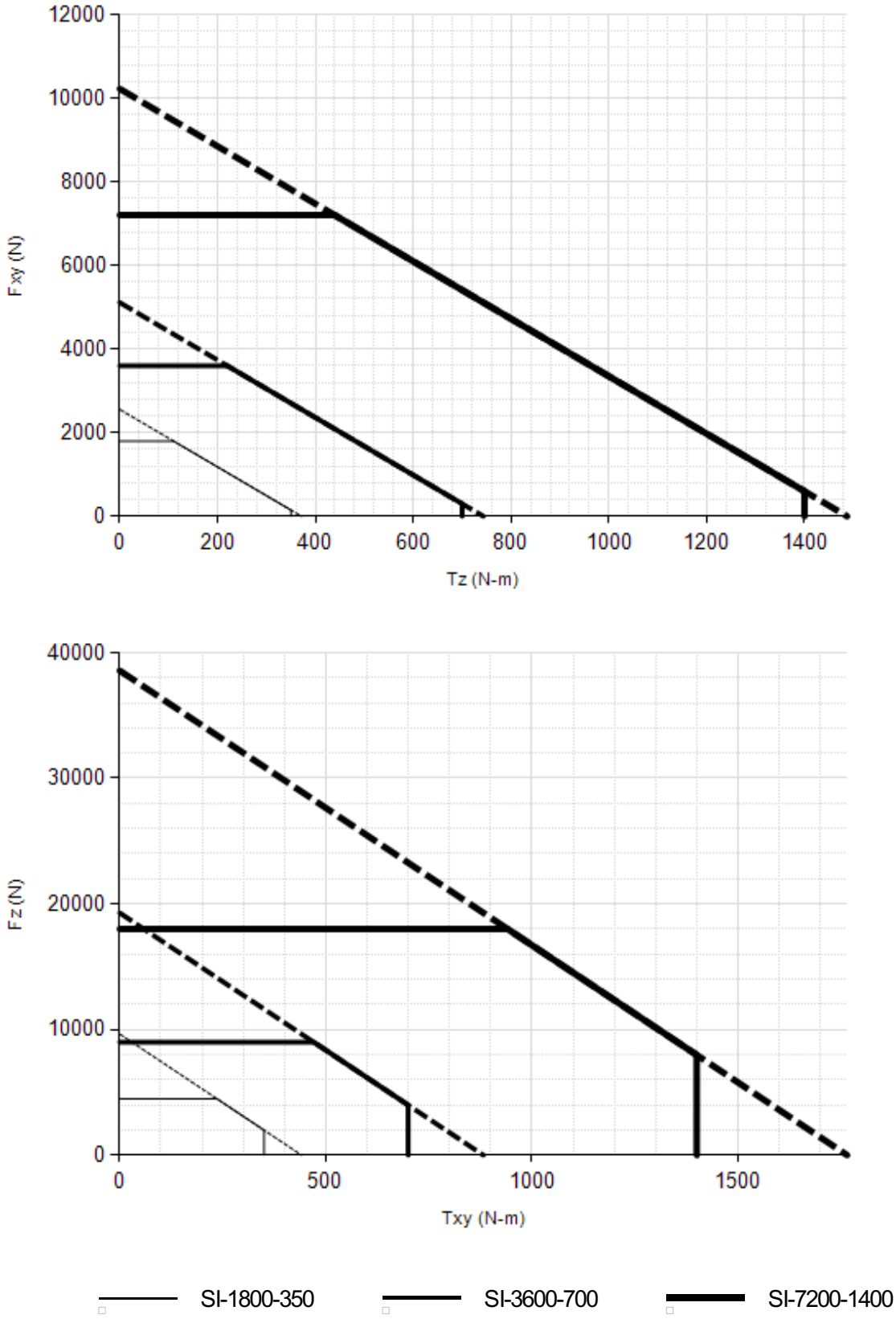




US-400-3000 US-800-6000 US-1600-12000

Note: 1. For IP68 version see caution on physical properties page.

5.19.9 Omega191 (SI Calibration Complex Loading) (Includes IP60/IP65/IP68)[1]



Note: 1. For IP68 version see caution on physical properties page.

5.20 Omega250 Specifications (Includes IP60/IP65/IP68)

In addition to the information in the following sections, refer to the ATI website:

Table 5.129—Omega250 Drawing and Web Links		
Model	**Drawing Part Number**	**ATI Website Address**
Omega250 DAQ/Net	*9230-05-1468*	*https://www.ati-ia.com/products/ft/ft_models.aspx?id=Omega250+IP60*
Omega250 IP60	*9230-05-1266*	
Omega250 IP65	*9230-05-1271*	*https://www.ati-ia.com/products/ft/ft_models.aspx?id=Omega250+IP65%2fIP68*
Omega250 IP68-10 m	*9230-05-1276*	

5.20.1 Omega250 Physical Properties (Includes IP60/IP65/IP68)

Table 5.130—Omega250 Physical Properties (Includes IP60/IP65/IP68)		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±37000 lbf	±160000 N
Fz	±74000 lbf	±330000 N
Txy	±180000 inf-lb	±21000 Nm
Tz	±220000 inf-lb	±25000 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	2.4×10^6 lb/in	4.2×10^8 N/m
Z-axis force (Kz)	3.2×10^6 lb/in	5.6×10^8 N/m
X-axis & Y-axis torque (Ktx, Kty)	2.7×10^7 lbf-in/rad	3.0×10^6 Nm/rad
Z-axis torque (Ktz)	5.5×10^7 lbf-in/rad	6.2×10^6 Nm/rad
Resonant Frequency		
Fx, Fy, Tz	780 Hz	780 Hz
Fz, Tx, Ty	770 Hz	770 Hz
Physical Specifications		
Weight[1]	70 lb	31.8 kg
Diameter[1]	11.6 in	295 mm
Height[1]	3.74 in	94.9 mm
Note: 1. Specifications include standard interface plates.		

CAUTION: When submerged, IP68 transducers exhibit a decrease in Fz range related to the submersion depth. This loss is the result of pressure-induced preloading on the transducer. The preload can be masked by biasing the transducer at the depth prior to applying the load to be measured. The following estimates are for room temperature fresh water at sea level.

Submersion Depth		
IP68 Omega250	**US**	**Metric**
Fz preload at 10 m depth	-1138 lb	-5061 N
Fz preload at other depths	-35 lb/ft × depthInFeet	-506 N/m × depthInMeters

5.20.2 Calibration Specifications (excludes CTL calibrations)

Table 5.131— Omega250 Calibrations (excludes CTL calibrations)1, 2									
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz³ (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**	**Fx,Fy (lbf)**	**Fz³ (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**
Omega250	US-900-4500	900	1800	4500	4500	1/2	1/2	1	1
Omega250	US-1800-9000	1800	3600	9000	9000	1	1	2	2
Omega250	US-3600-18000	3600	7200	18000	18000	2	2	5	5
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz³ (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**	**Fx,Fy (N)**	**Fz³ (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**
Omega250	SI-4000-500	4000	8000	500	500	1	2	1/8	1/8
Omega250	SI-8000-1000	8000	16000	1000	1000	2	4	1/4	1/4
Omega250	SI-16000-2000	16000	32000	2000	2000	4	8	1/2	1/2
		Sensing Ranges				**Resolution (DAQ, Net F/T)⁴**			

Notes:
1. These system resolutions quoted are the effective resolution after dropping four counts of noise. The effective resolution can be improved with filtering.
2. Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.
3. For IP68 version see caution on physical properties page.
4. DAQ resolutions are typical for a 16-bit data acquisition system.

5.20.3 CTL Calibration Specifications

Table 5.132— Omega250 CTL Calibrations1, 2									
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz³ (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**	**Fx,Fy (lbf)**	**Fz³ (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**
Omega250	US-900-4500	900	1800	4500	4500	1	1	2	2
Omega250	US-1800-9000	1800	3600	9000	9000	2	2	5	5
Omega250	US-3600-18000	3600	7200	18000	18000	5	5	10	10
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz³ (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**	**Fx,Fy (N)**	**Fz³ (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**
Omega250	SI-4000-500	4000	8000	500	500	2	4	1/4	1/4
Omega250	SI-8000-1000	8000	16000	1000	1000	4	8	1/2	1/2
Omega250	SI-16000-2000	16000	32000	2000	2000	8	16	1	1
		Sensing Ranges				**Resolution (Controller)**			

Notes:
1. CTL resolutions are typical. System resolutions quoted are the effective resolution after dropping eight counts of noise. The effective resolution can be improved with filtering.
2. Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.
3. For IP68 version see caution on physical properties page.

5.20.4 CTL Analog Output

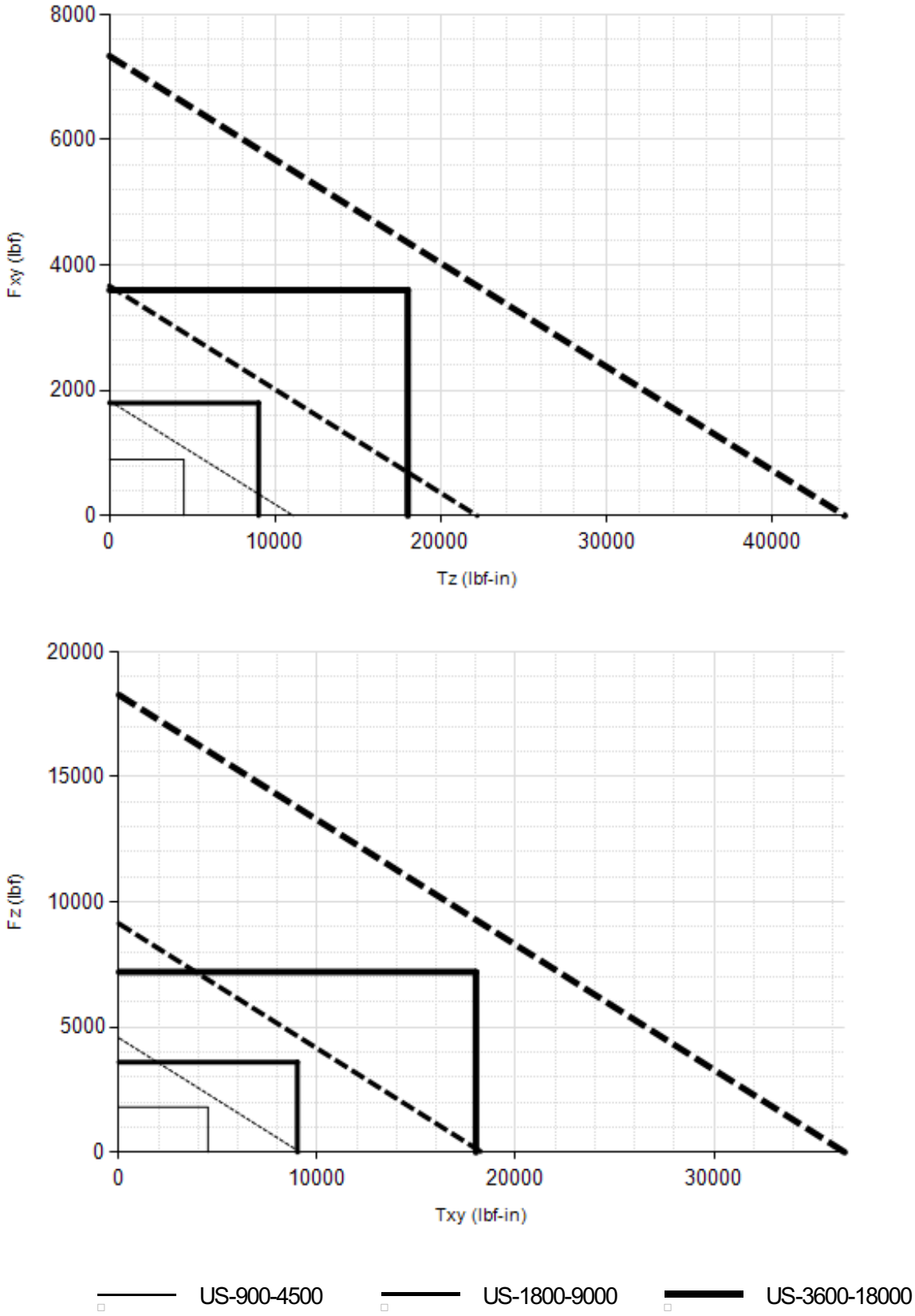
Table 5.133— Omega250 Analog Output							
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz[2] (lbf)**	**Tx,Ty,Tz (lbf-in)**	**Fx,Fy (lbf/V)**	**Fz[2] (lbf/V)**	**Tx,Ty,Tz (lbf-in/V)**
Omega250	US-900-4500	±900	±1800	±4500	90	180	450
Omega250	US-1800-9000	±1800	±3600	±9000	180	360	900
Omega250	US-3600-18000	±3600	±7200	±18000	360	720	1800
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz[2] (N)**	**Tx,Ty,Tz (Nm)**	**Fx,Fy (N/V)**	**Fz[2] (N/V)**	**Tx,Ty,Tz (Nm/V)**
Omega250	SI-4000-500	±4000	±8000	±500	400	800	50
Omega250	SI-8000-1000	±8000	±16000	±1000	800	1600	100
Omega250	SI-16000-2000	±16000	±32000	±2000	1600	3200	200
		Analog Output Range			**Analog ±10V Sensitivity[1]**		

Notes:
1. ±5V Sensitivity values are double the listed ±10V Sensitivity values.
2. For IP68 version see caution on physical properties page.

5.20.5 CTL Counts Value

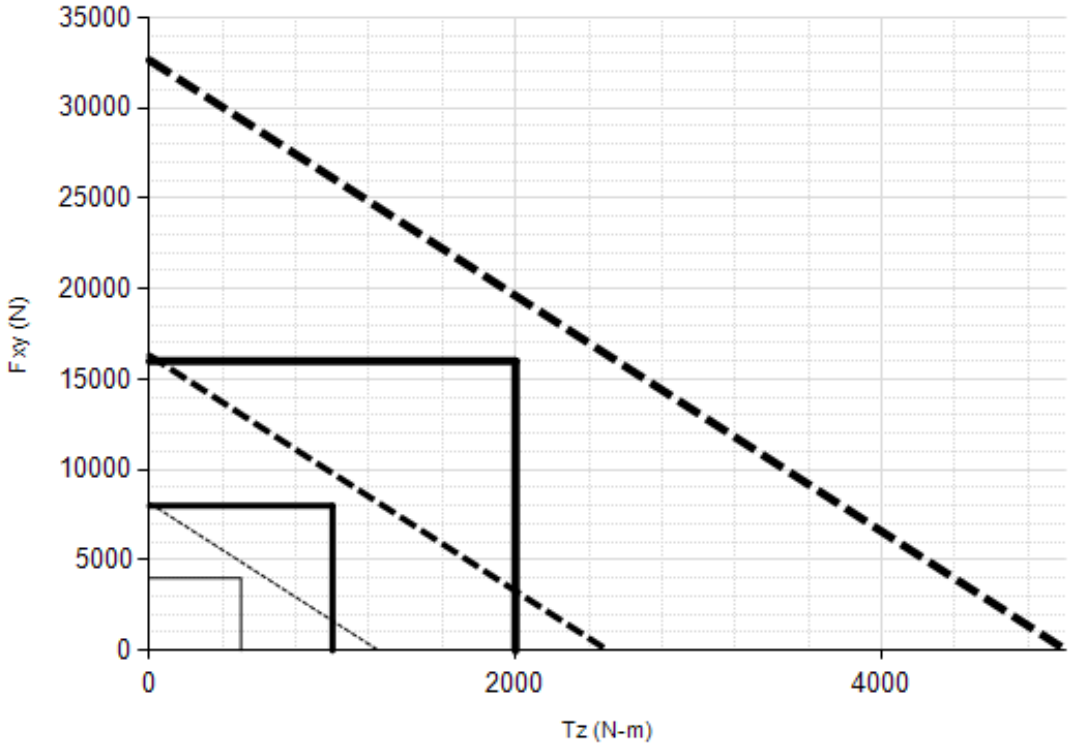
Table 5.134—Counts Value					
Sensor	**Calibration**	**Fx, Fy, Fz (/ lbf)**	**Tx, Ty, Tz (/ lbf-in)**	**Fx, Fy, Fz (/ N)**	**Tx, Ty, Tz (/ Nm)**
Omega250	US-900–4500 / SI-4000–500	8	4	4000	32000
Omega250	US-1800–9000 / SI-8000–1000	4	2	2000	16000
Omega250	US-3600–18000 / SI-16000-2000	2	1	1000	8000
Omega250	Tool Transform Factor	0.02 in/lbf		1.25 mm/N	
		Counts Value – Standard (US)		**Counts Value – Metric (SI)**	

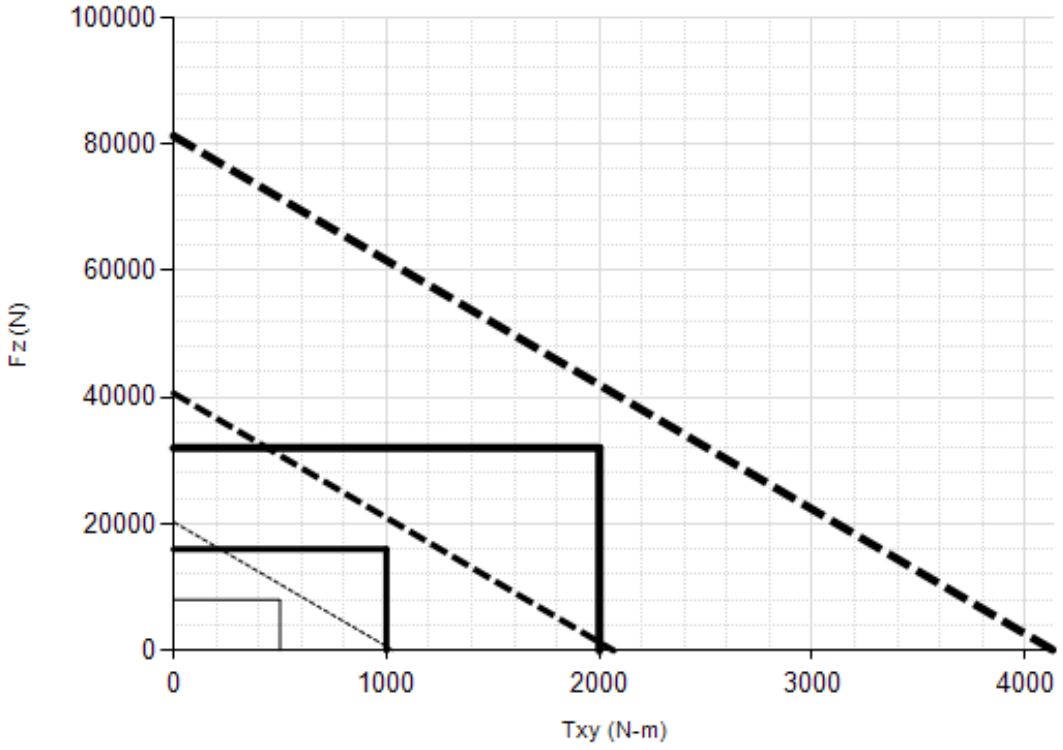
5.20.6 Omega250 (US Calibration Complex Loading) (Includes IP60/IP65/IP68)[1]



Note: 1. For IP68 version see caution on physical properties page.

5.20.7 Omega250 (SI Calibration Complex Loading) (Includes IP60/IP65/IP68)[1]





SI-4000-500 SI-8000-1000 SI-16000-2000

Note: 1. For IP68 version see caution on physical properties page.

5.21 Omega331 Specifications (Includes IP65)

In addition to the information in the following sections, refer to the ATI website:

Table 5.135—Omega331 Drawing and Web Links		
Model	**Drawing Part Number**	**ATI Website Address**
Omega331	*9230-05-1158*	*https://www.ati-ia.com/products/ft/ft_models.aspx?id=Omega331*
Omega331 IP65	*9230-05-1360*	

5.21.1 Omega331 Physical Properties (Includes IP65)

Table 5.136—Omega331 Physical Properties (Includes IP60/IP65)		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±53000 lbf	±240000 N
Fz	±120000 lbf	±520000 N
Txy	±280000 inf-lb	±32000 Nm
Tz	±320000 inf-lb	±36000 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	6.9×10^6 lb/in	1.2×10^9 N/m
Z-axis force (Kz)	7.3×10^6 lb/in	1.3×10^9 N/m
X-axis & Y-axis torque (Ktx, Kty)	8.1×10^7 lbf-in/rad	9.2×10^6 Nm/rad
Z-axis torque (Ktz)	2.1×10^8 lbf-in/rad	2.4×10^7 Nm/rad
Resonant Frequency		
Fx, Fy, Tz	N/A	N/A
Fz, Tx, Ty	N/A	N/A
Physical Specifications		
Weight[1]	104 lb	47 kg
Diameter[1]	13 in	330 mm
Height[1]	4.22 in	107 mm
Note: 1. Specifications include standard interface plates.		

5.21.2 Calibration Specifications (excludes CTL calibrations)

Table 5.137— Omega331 Calibrations (excludes CTL calibrations)1, 2									
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**	**Fx,Fy (lbf)**	**Fz (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**
Omega331	US-2250-13000	2250	5250	13000	13000	3/8	1	3 3/4	1 7/8
Omega331	US-4500-26000	4500	10500	26000	26000	3/4	2	7 1/2	3 3/4
Omega331	US-9000-52000	9000	21000	52000	52000	1 1/2	4	15	7 1/2
Sensor	**(SI) Metric Calibration**	**Fx,Fy (kN)**	**Fz (kN)**	**Tx,Ty (kNm)**	**Tz (kNm)**	**Fx,Fy (kN)**	**Fz (kN)**	**Tx,Ty (kNm)**	**Tz (kNm)**
Omega331	SI-10000-1500	10	22	1.5	1.5	1/640	1/240	3/8000	3/16000
Omega331	SI-20000-3000	20	44	3	3	1/320	1/120	3/4000	3/8000
Omega331	SI-40000-6000	40	88	6	6	1/160	1/60	3/2000	3/4000
		Sensing Ranges				**Resolution (DAQ, Net F/T)[3]**			

Notes:
1. These system resolutions quoted are the effective resolution after dropping four counts of noise. The effective resolution can be improved with filtering.
2. Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.
3. DAQ resolutions are typical for a 16-bit data acquisition system.

5.21.3 CTL Calibration Specifications

Table 5.138— Omega331 CTL Calibrations1, 2									
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**	**Fx,Fy (lbf)**	**Fz (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**
Omega331	US-2250-13000	2250	5250	13000	13000	3/4	2	7 1/2	3 3/4
Omega331	US-4500-26000	4500	10500	26000	26000	1 1/2	4	15	7 1/2
Omega331	US-9000-52000	9000	21000	52000	52000	3	8	30	15
Sensor	**(SI) Metric Calibration**	**Fx,Fy (kN)**	**Fz (kN)**	**Tx,Ty (kNm)**	**Tz (kNm)**	**Fx,Fy (kN)**	**Fz (kN)**	**Tx,Ty (kNm)**	**Tz (kNm)**
Omega331	SI-10000-1500	10	22	1.5	1.5	1/320	1/120	3/4000	3/8000
Omega331	SI-20000-3000	20	44	3	3	1/160	1/60	3/2000	3/4000
Omega331	SI-40000-6000	40	88	6	6	1/80	1/30	3/1000	3/2000
		Sensing Ranges				**Resolution (Controller)**			

Notes:
1. CTL resolutions are typical. System resolutions quoted are the effective resolution after dropping eight counts of noise. The effective resolution can be improved with filtering.
2. Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.

5.21.4 CTL Analog Output

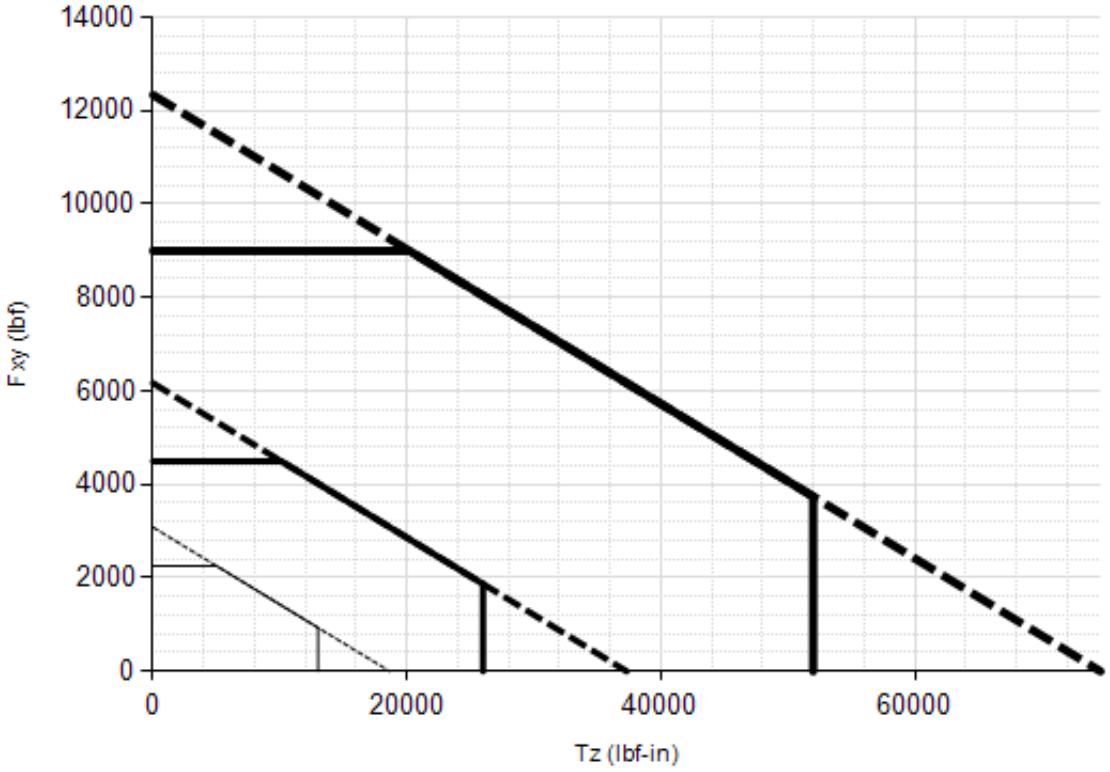
Table 5.139— Omega331 Analog Output							
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz (lbf)**	**Tx,Ty,Tz (lbf-in)**	**Fx,Fy (lbf/V)**	**Fz (lbf/V)**	**Tx,Ty,Tz (lbf-in/V)**
Omega331	US-2250-13000	±2250	±5250	±13000	225	525	1300
Omega331	US-4500-26000	±4500	±10500	±26000	450	1050	2600
Omega331	US-9000-52000	±9000	±21000	±52000	900	2100	5200
Sensor	**(SI) Metric Calibration**	**Fx,Fy (kN)**	**Fz (kN)**	**Tx,Ty,Tz (kNm)**	**Fx,Fy (kN/V)**	**Fz (kN/V)**	**Tx,Ty,Tz (kNm/V)**
Omega331	SI-10000-1500	±10	±22	±1.5	1	2.2	0.15
Omega331	SI-20000-3000	±20	±44	±3	2	4.4	0.3
Omega331	SI-40000-6000	±40	±88	±6	4	8.8	0.6
		Analog Output Range			**Analog ±10V Sensitivity[1]**		

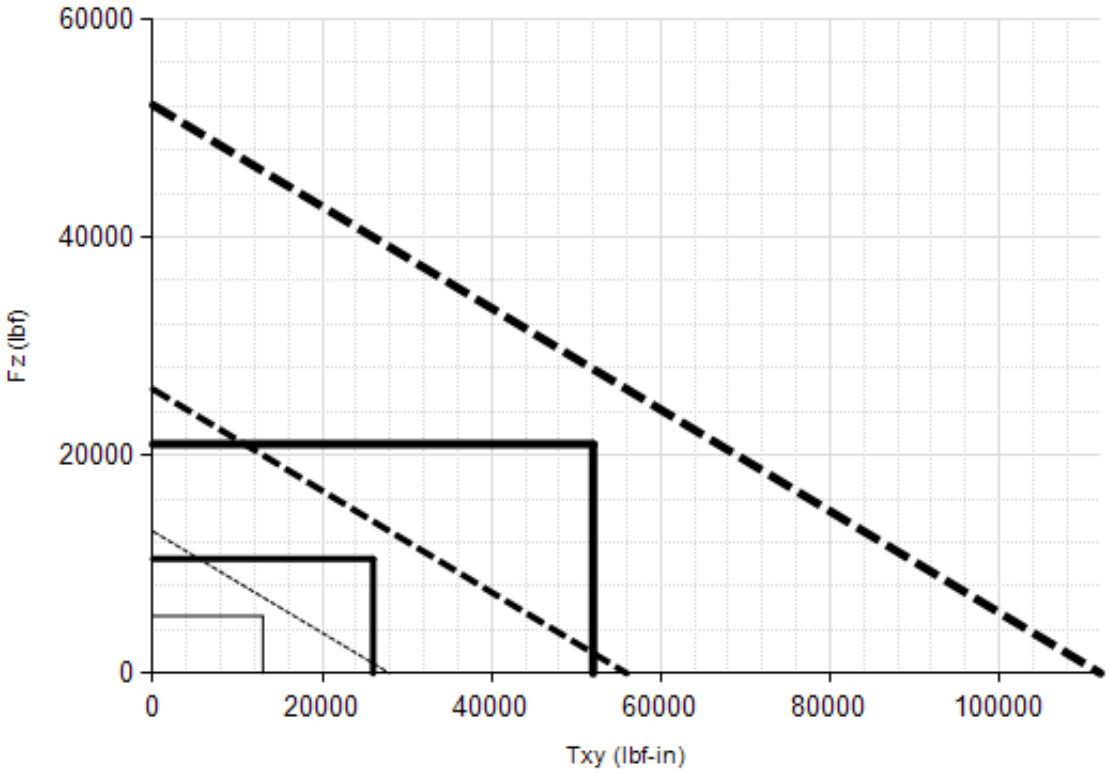
Notes:
1. ±5V Sensitivity values are double the listed ±10V Sensitivity values.

5.21.5 CTL Counts Value

Table 5.140—Counts Value					
Sensor	**Calibration**	**Fx, Fy, Fz (/ lbf)**	**Tx, Ty, Tz (/ lbf-in)**	**Fx, Fy, Fz (/ kN)**	**Tx, Ty, Tz (/ kNm)**
Omega331	US-2250–13000 / SI-10000–1500	32	6.4	7680	64000
Omega331	US-4500–26000 / SI-20000–3000	16	3.2	3840	32000
Omega331	US-9000–52000 / SI-40000–6000	8	1.6	1920	16000
Omega331	Tool Transform Factor	0.05 in/lbf		1.2 mm/N	
		Counts Value – Standard (US)		**Counts Value – Metric (SI)**	

5.21.6 Omega331 (US Calibration Complex Loading) (Includes IP65)

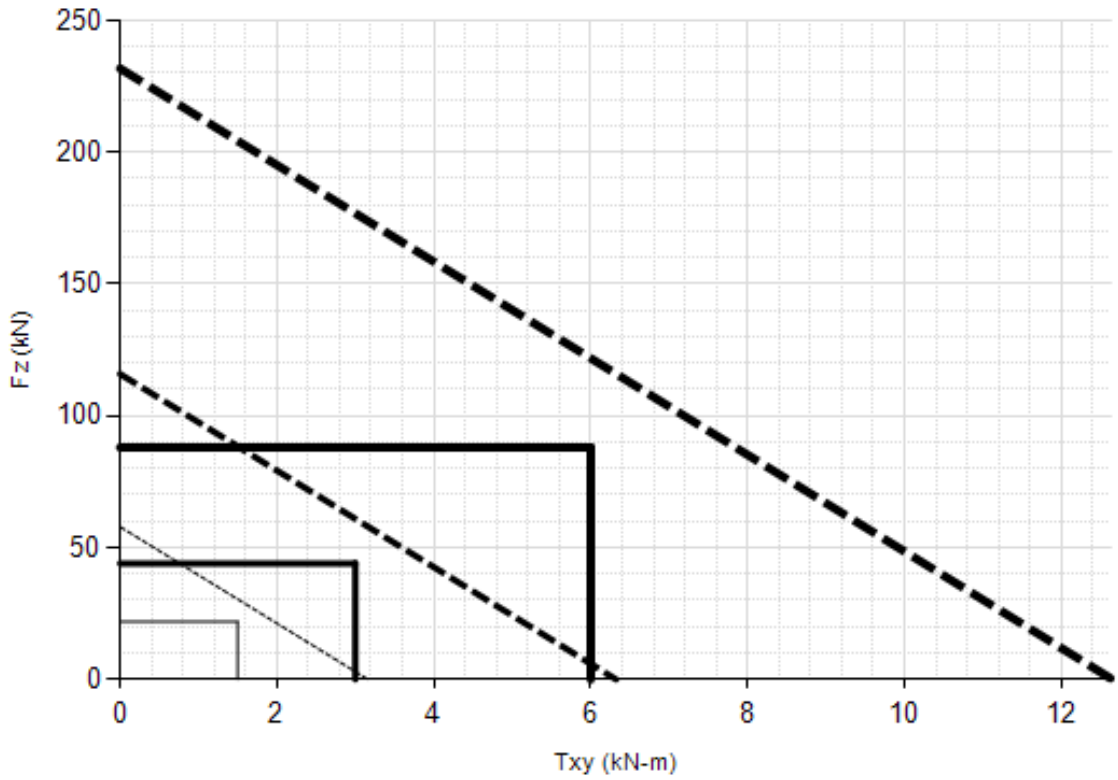




US-2250-13000 US-4500-26000 US-9000-52000

5.21.7 Omega331 (SI Calibration Complex Loading) (Includes IP65)





SI-10000-1500 SI-20000-3000 SI-40000-6000

6. Diagnostics and Maintenance

6.1 Reducing Noise

6.1.1 Mechanical Vibration

In many cases, perceived noise is actually a real fluctuation of force and/or torque. This fluctuation is caused by vibrations in the tooling or the robot arm. Many F/T systems offer filtering or averaging that can smooth out noise. If this is not sufficient, consider adding a digital filter to the application software.

6.1.2 Electrical Interference

If interference by motors or other noise-generating equipment is observed, check the F/T's ground connections.

If sufficient grounding is not possible or does not reduce the noise, consider using averaging or filtering.

6.2 Detecting Failures (Diagnostics)

6.2.1 Detecting Sensitivity Changes

Sensitivity checking of the transducer can also be used to measure the transducer system's health. Apply known loads to the transducer and verifying the system output matches the known loads, for example: a transducer mounted to a robot arm may have an end-effector attached to it. If the end-effector has moving parts, they must be moved in a known position.

This check is done by completing the following steps:

1. Place the robot arm in an orientation that allows the gravity load from the end-effector to exert load on many transducer output axes.
2. Record the output readings.
3. Position the robot arm to apply another load (this time causing the outputs to move far from the earlier readings).
4. Record the second set of output readings.
5. Find the differences from the first and second set of readings, and use it as the 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).



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

6.3 Scheduled Maintenance

6.3.1 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 jacket for signs of wear. These applications should implement the procedures discussed in *Section 6.2—Detecting Failures (Diagnostics)* to detect any failures.

Transducers that are not IP60, IP65, or IP68 rated must be kept free of excessive dust, debris, or moisture. IP60-rated transducers must be kept free of excessive moisture. Debris and dust should be kept from accumulating on or in a transducer.

6.3.2 Periodic Calibration

Periodic calibration of the transducer and its electronics 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.

6.4 A Note on Servicing Transducer Cabling

6.4.1 Calibrations

In many cases the transducer cable comprises part of the calibrated transducer. In these cases, changing the length or type of the cable can affect the calibration. When making cabling changes, check with ATI Industrial Automation to ensure the system's calibration is not be affected.

6.4.2 Cabling and Connectors

The transducer cables and connectors are not designed to be serviced by users, for example: the high flex life stranding in the cables is difficult to service and if improperly assembled, the stranding fails.

However, in some cases, users many need to temporarily remove the connector on a cable that is permanently attached to a transducer such as Nano and Mini models. When reattaching the wires to the connector, encase each conductor in heat shrink tubing at the connection to prevent premature fatiguing of the mechanical connection. Also, exactly reconnect any components contained in the connector; otherwise, improper service impacts system performance and accuracy.

To prevent transducer damage, ensure the cable jacketing is in proper condition. Damage to the outer jacketing of the transducer cable enables moisture or water to enter an otherwise sealed transducer.

6.5 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 three beam configuration transfers applied loads to multiple sensing beams. Also if a counterpart axis has reduced, this configuration allows the transducer to increase its sensing range in a given axis.

The resolution of each transducer axis depends on how the applied load is spread among the sensing beams. The best resolution occurs 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.

F/T resolutions are specified as typical resolution which is 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. Although this misrepresents the actual performance of the transducers, it results in a close (and always conservative) estimate.

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 one 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 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.