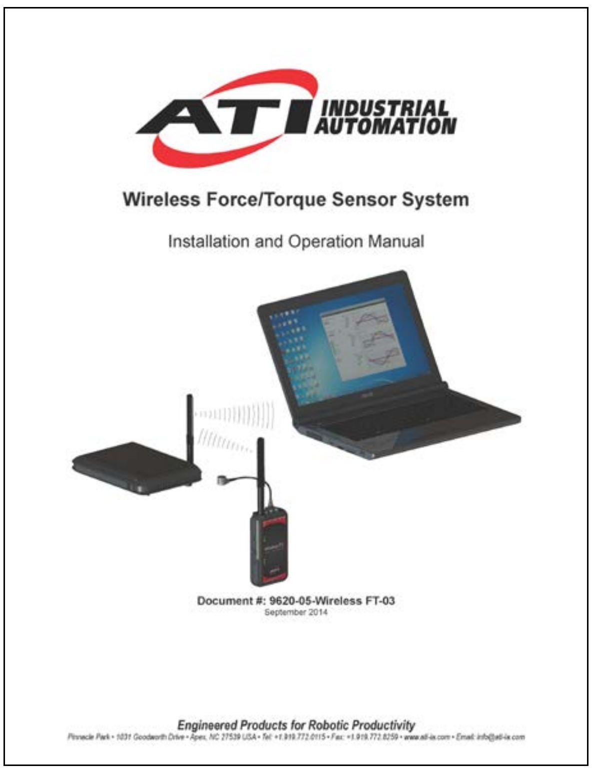
Wireless F/T

Network Force/Torque Sensor System

Compilation of Manuals


Wireless Force/Torque Sensor System

Installation and Operation Manual

Document #: 9620-05-Wireless FT-03

September 2014

Engineered Products for Robotic Productivity


F/T Transducer

Six-Axis

Force/Torque Transducer

Installation and Operation Manual

Manual #: 9620-05-Transducer Section

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Document #: 9610-05-1031

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Wireless Force/Torque Sensor System

Installation and Operation Manual

Document #: 9620-05-Wireless FT-05
March 2015

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Foreword

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

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

Sale, Service and Information about ATI products:

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Table of Contents

Glossary of Terms

Terms	Definitions
ADC	Analog to Digital Converter.
Big-endian	Indicates the most significant byte of a value is stored first.
DHCP	Dynamic Host Configuration Protocol (DHCP) is an automatic method for Ethernet equipment to obtain an IP address. The WNet system can obtain its IP address using DHCP on networks that support this protocol.
Ethernet Network Switch	Ethernet network switches are electronic devices that connect multiple Ethernet cables to an Ethernet network while directing the flow of traffic.
F/T	Force/Torque.
Gateway Settings	The address of the router that handles a network’s Ethernet traffic.
IEEE	The Institute of Electrical and Electronics Engineer, inc.
IP Address	An Internet Protocol Address (IP Address) is an electronic address assigned to an Ethernet device so that it may send and receive Ethernet data. IP addresses may be either manually selected by the user or automatically assigned by the DHCP protocol.
IPv4	Internet Protocol version 4 (IPv4) is a standard used for specifying the electronic address of an Ethernet device. The Wireless F/T supports only IPv4.
MAC Address	Media Access Control Addresses (MAC Addresses) are the unique addresses given to every Ethernet device when it is manufactured, to be used as an electronic Ethernet serial number.
Network Order	The order in which data values are placed on a network. The WNet’s network order is big-endian
RDT	Raw Data Transfer (RDT) is a fast and simple WNet protocol for control and data transfer via UDP.
RSSI	Received Signal Strength Indicator.
Sensor System	The assembly consisting of all components from the transducer to the WNet box.
SSID	Is the name of a wireless local area network.
Subnet Mask	A string of numbers used to indicate which portion of a network’s IP addresses is common to all devices on the local network.
TCP	Transmission Control Protocol (TCP) is a method of exchanging information frequently used over Ethernet.
UDP	User Datagram Protocol (UDP) is a low-level method of transmitting data over Ethernet. While UDP is faster than TCP, unlike TCP lost UDP data is not resent.
USB	Universal Serial Bus (USB). The WNet’s USB port conforms to this computer peripheral cabling standard.
WLAN	Wireless Local Area Network (WLAN). The WNet system conforms to the IEEE 802.11 WLAN standard.
WNet	Wireless F/T

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.

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.

ATTENTION: Le non-respect des informations ou des instructions contenues dans la notice peut entraîner des blessures moyennement graves ou causer des dommages à l'équipement. La notice fournit des informations sur la nature de la situation dangereuse, les conséquences si le danger n'est pas évité, et la méthode pour éviter la 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) 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 the Wireless F/T. This will cause irreparable damage to the Wireless F/T and void the warranty. Leave all fasteners in place and do not disassemble the Wireless F/T.

ATTENTION: Ne pas retirer les attaches ni démonter le Wireless F/T. Cecicausera des dommages irréparables au Wireless F/T et annulera la garantie. Laisser toutes les attaches en place et ne pas démonter le Wireless F/T.

2. System Overview

The Wireless F/T can measure six degree of freedom forces and torques (Fx, Fy, Fz, Tx, Ty, and Tz) from multiple transducers and streams the data to an existing wireless access point on the network. This data can be used for data collection, real-time motion control, or user-defined signal processing by the user's host device. The Wireless F/T can also store the data on a memory card.

The range and performance of the Wireless F/T device is derived from the IEEE 802.11 standard. Actual performance may vary due to conditions, wireless infrastructure, and other variables. Refer to *Section 9—Specifications* for more details.

Figure 2.1—Signal Path to a Computer, Using a Wireless Access Point

The Wireless F/T is a small wireless device for controlling up to six ATI Multi-Axis Force/Torque transducers. The device supports ATI's TW-type transducers such as the Nano and Mini. Transducers with integrated electronics are not supported. The device is equipped with a MicroSD card slot used to collect and store data. The Wireless F/T is contained in an impact, splash, and dust resistant housing.

The Wireless F/T unit is provided with an external antenna that can be pivoted 90° so the unit can be used in small confined spaces. Fixed mounting is accommodated with the four robust threaded inserts on the back plate of the housing. The unit is provided with a removable belt clip for mobile applications. The Wireless F/T can be powered by a rechargeable battery, or can b e powered with the 5 VDC external power adapter using the USB connector. The battery can be charged internally or externally.

The Wireless F/T includes a rechargeable battery, antenna, external power adapter, USB cable, and removable belt clip. Optional desktop battery charger and international power cords are available, refer to *Section 8—Serviceable Parts* for more details.

2.1 Three Transducer Wireless F/T

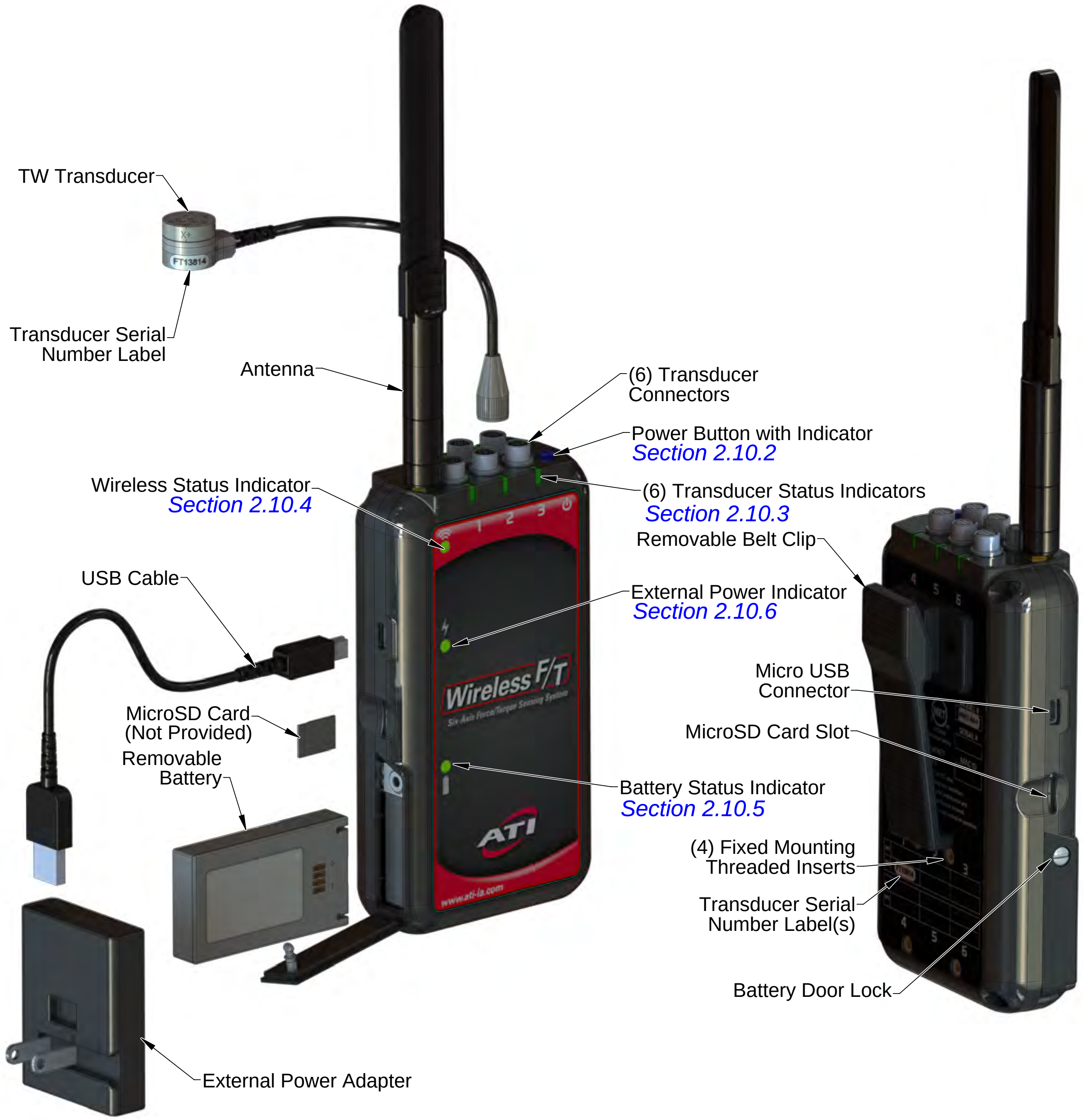
The three Transducer Wireless F/T model can interface with up to three ATI Multi-Axis Force/Torque transducers simultaneously. Each of the three transducer connectors has a transducer status indicator. The device has a rechargeable battery that can power the device for approximately two hours at full measurement rate with all three transducers enabled. The battery life is extended significantly when using fewer transducers.

Figure 2.2—Three Transducer Wireless F/T

2.2 Six Transducer Wireless F/T

The six Transducer Wireless F/T model can interface with up to six ATI Multi-Axis Force/Torque transducers simultaneously. Each of the six transducer connectors has a transducer status indicator. The device has a rechargeable battery that can power the device for approximately one hour at full measurement rate with all six transducers enabled. The battery life is extended significantly when using fewer transducers.

Figure 2.3—Six Transducer Wireless F/T



2.3 Antenna

The Wireless F/T Unit has been certified for use with the antenna provided. The antenna can pivot 90° to allow the Wireless F/T unit to fit into small confined spaces.

2.4 Micro USB Connector

The Wireless F/T unit has a Micro USB connector that can be used to power the unit and charge the battery using the external power adapter.

2.5 MicroSD Card Slot

The Wireless F/T unit has a MicroSD card slot that can be used to store data on a customer supplied MircoSD card. The file system supports files sizes up to 4 G bytes. If using a MicroSD card to store data, the system will create a subdirectory *\ATI* and a *Fn.dat* data file on the MicroSD card. If multiple sessions are saved on the MicroSD card the system will sequence the data file *F1.dat, F2.dat* ... etc. Refer to *Section 5—Command Interface* for more information.

2.6 External Power Adapter

The external power adapter is a 5 V 10 W plug mounted power supply that can operate the unit and charge the battery. The adapter operates on 100 to 240 VAC and provides a USB Micro-A output connector. Removable plug adapters are available for use with various power socket types.

2.7 USB Cable

The USB cable connects the external power adapter to the Wireless F/T unit by way of its USB Type A and Micro-B USB connectors.

2.8 Mounting features

Refer to *Section 11—Drawings* for information on mounting features.

2.8.1 Removable Belt Clip

The Wireless F/T unit has a removable belt clip for easy mounting and removal from human or humanoid robot applications.

2.8.2 Threaded Holes

Four threaded holes are available when the belt clip is removed.

2.9 Removable Battery

A rechargeable lithium-polymer battery is provided with the Wireless F/T unit. The battery can be charged inside the Wireless F/T using the external power adapter through the micro USB connector or using the optional desktop battery charger. Refer to *Section 6.2—Battery Recharging and Replacement* for more information.

2.10 Controls and Indicators

The Wireless F/T has controls and integrated status indicators. The Status indicator information is periodically transmitted over the wireless network to the host device. See *Figure 2.2*—three Transducer Wireless F/T model or *Figure 2.3*— six Transducer Wireless F/T model for location of controls and indicators.

2.10.1 Power Button

The Power Button turns the unit on and off, has an integrated system status indicator, and supports auto power-off. The Power Button supports the following functionality:

Table 2.1—Power Button Functionality

Press Duration	Description
Momentary	Powers on the unit.
Two Seconds	Powers off the unit
Ten Seconds	Power cycles the system.

Power cycling the system will reset the DHCP, IP address, subnet mask, gateway settings, and authenticated user password to the last saved settings.

2.10.2 Power Button Indicator

This indicator is located within the recessed Power Button.

Table 2.2—System Status Indicator	
Behavior	**Description**
Off	Indicates the system is either off or in charging-only mode.
Steady Blue	Indicates the system is on.

2.10.3 Transducer Status Indicators

The Wireless F/T has a transducer status indicator on the top of the device, beside its corresponding connector.

Table 2.3—Transducer Status Indicators	
Behavior	**Description**
Steady Green	Indicates normal transducer operation.
Steady Red	Indicates a fault with the transducer.
Off	Indicates the transducer is off, the entire unit is off, or the unit is in charging-only mode.

2.10.4 Wireless Status Indicator

The wireless status indicator is on the front of the Wireless F/T below the antenna connector.

Table 2.4—Wireless Status Indicator	
Behavior	**Description**
Steady Green	Indicates the unit is connected to an Access Point and there are no current wireless errors.
Flashing Green	Indicates the unit is attempting to connect to an Access Point.
Steady Red	Indicates the unit is connected to an Access Point, and an error has been recently detected.
Flashing Red	Indicates the wireless subsystem is recovering from a lock-up condition. Refer to *Section 7—Troubleshooting*
Off	Indicates the unit is either off or in charging-only mode.

2.10.5 Battery Status Indicator

The battery indicator is on the front of the device next to the battery compartment.

Table 2.5—Battery Status Indicator	
Behavior	**Description**
Steady Green	Indicates the battery is charged.
Flashing Green	Indicates the battery is charging.
Flashing Red	Indicates the battery charge is below 25%.
Steady Red	Indicates a battery fault, such as the battery voltage is too low, or the battery is too warm, or is missing.
Off	Indicates the unit is off.

2.10.6 External Power Indicator

The external power indicator is on the front of the unit next to the left-side located USB connector.

Table 2.6—External Power Status Indicator	
Behavior	**Description**
Steady Green	Indicates the external power source connected to the USB port is operating normally.
Steady Red	Indicates the external power source connected to the USB port is not supplying proper voltage.
Off	Indicates there is no external power adapter connected to the USB port, or it is not functioning.

3. Initial Configuration and Installation of your Wireless F/T System

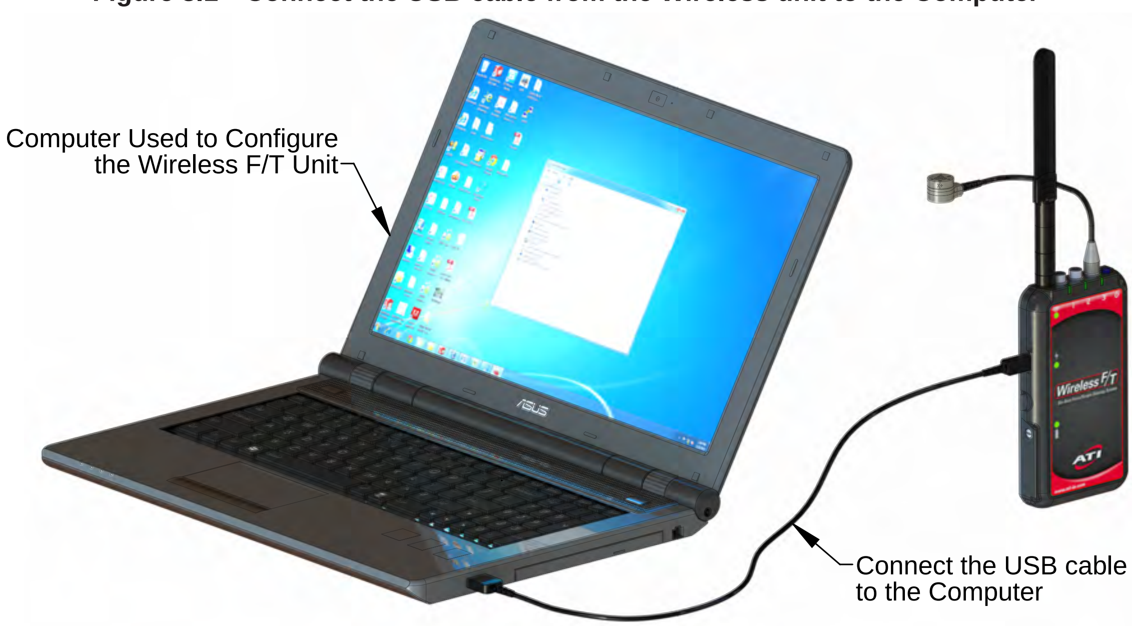
This section explains how to configure the basic functionality of your Wireless F/T system. The Wireless F/T system consist of several components: Wireless F/T unit, transducer(s), external power adapter and plugs, USB cable, and software CD. The Wireless F/T unit must be set up and configured before installing the transducer so that forces can be monitored during installation.

3.1 Preparing your Wireless F/T for configuration

1. Unpack the system components from the container.
2. Use a flat head screw driver to open the battery door (Note: ¼ turn clockwise to open and ¼ turn counterclockwise to close). Insert the battery with the label facing the front of the Wireless F/T Unit, then close and secure the battery door.
3. Connect the USB cable to the Wireless F/T unit and the external power adapter provided. Plug the power adapter into the wall.
4. Wait for the battery charge status indicator to transition from flashing to solid green indicating the battery is fully charged. Note: This could take a few hours with a factory-new battery.
5. Attach the antenna to the Wireless F/T Unit.
6. Connect the transducer cable to the connector on the Wireless F/T unit. Ensuring each Transducer and the corresponding Wireless F/T connector position are labeled with the same serial number, refer to *Figure 2.2* or *Figure 2.3*. (Note: Transducer cable will need to be rotated until the alignment notch is oriented properly). Tighten the connector finger tight.
7. Disconnect the USB cable from the power supply and plug into USB port on the computer to be used to configure the Wireless F/T unit. Refer to *Figure 3.1*. Note: A computer connected to the USB port may not provide sufficient power to keep the battery fully charged.

NOTICE: You will need Java version 1.7 or higher on your PC to run the provided Wireless F/T Java Demo. This can be downloaded at *http://www.java.com/* while you wait for the battery to charge.

Figure 3.1—Connect the USB cable from the Wireless unit to the Computer



3.2 Initial Configuration

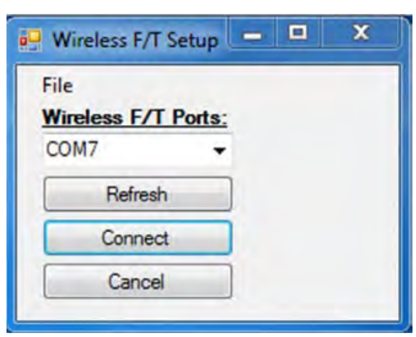
The Wireless F/T must be configured for your wireless network before you will be able to communicate with the device. The following procedure will provide the steps needed to properly configure the Wireless F/T.

1. After connecting the Wireless F/T to the computer with the provided USB cable, it will begin to obtain the proper COM port drivers. This may take a few minutes. If they do not install on their own, install the Virtual Communication Port Driver per the instructions for your operating system found at: *http://www.ftdichip.com/Support/Documents/InstallGuides.htm*
2. Power on the Wireless F/T unit by momentarily depressing the power button on the top of the device. The device will initiate a power up sequence and the Wireless Status Indicator LED will begin flashing green as it scans for wireless networks.
3. Remove the Wireless F/T software CD from the package and insert it into the CD drive on your computer and locate the setup.exe file within the utilities directory, or visit our website (*http://www.ati-ia.com/library/download.aspx*) to locate the setup.exe file.
4. Copy or download the file to the directory desired and double click to open the program.
5. Follow the instructions within the Setup Wizard to install the Wireless F/T Settings Editor.

Figure 3.2—Setup Wizard

6. Locate the Wireless F/T Setup Editor in the ATI Industrial Automation folder under All Programs on your Windows Start bar and double click to open the program.

Figure 3.3—Wireless F/T Setup program

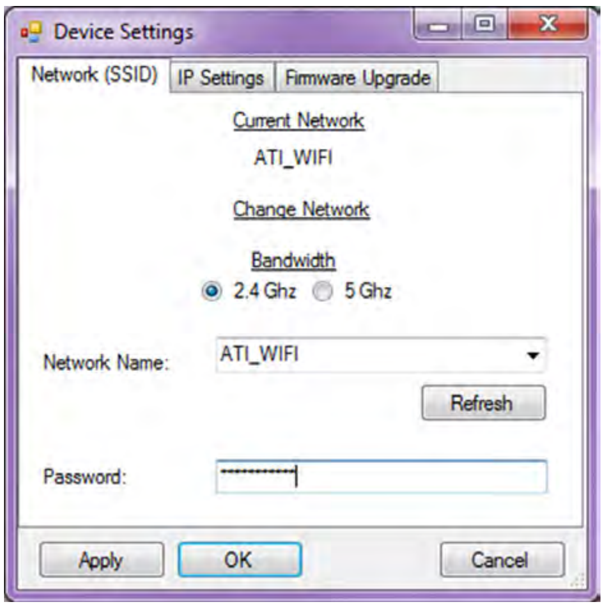


7. Select the COM port corresponding to your Wireless F/T and press the connect button. You may need to press the "Refresh" button if no COM ports are shown.

8. Obtain your WLAN Network Name (SSID), password, and frequency band (bandwidth 2.4 GHz or 5 GHz) from your network administrator. If your wireless network is not shown, press the "Refresh" button. Note: This will result in the Wireless F/T unit resetting while it attempts to locate nearby wireless networks. If you are switching between the 2.4 GHz and 5 GHz bands, you will need to input the Network Name manually as the Wireless F/T cannot scan one band for networks while connected to the other, consequently the networks will not show in the pull down list.

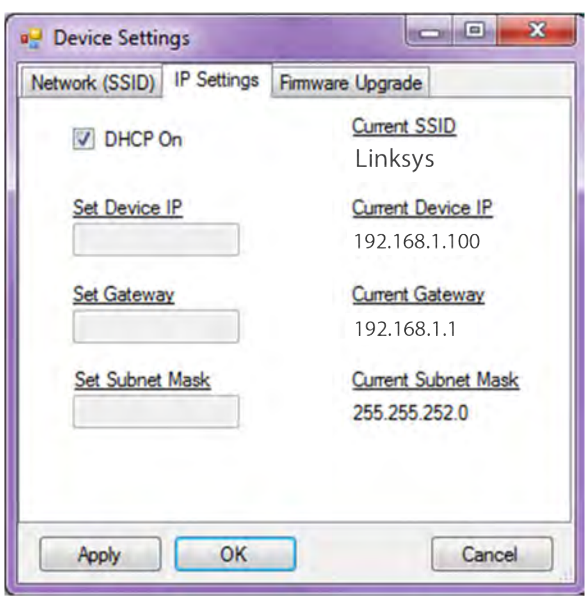
NOTICE: For 5 GHz Band, due to the Indoor/Outdoor rating of the Wireless F/T, the device is only allowed to connect to channels 149, 153, 157, 161, and 165. Many 5 GHz routers will default to a restricted "indoor only" channel. If you have connection issues, you may need to check your router settings and ensure it is connected to one of the channels listed above.

Figure 3.4—Network (SSID) Settings



9. Select the "IP Settings" tab. Note that in this example DHCP is enabled. If a static IP address is desired, deselect DHCP and enter the Device IP dedicated to the Wireless F/T, the access point Default Gateway, and Subnet Mask into the fields shows in *Figure 3.5*.

Figure 3.5—IP Settings



10. When you have made all the appropriate changes to the device settings, press the "OK" button to apply the changes. The window will automatically close at this point and the Wireless F/T will reset upon exit.
11. Once the Wireless F/T has been powered up completely, the Wireless Status Indicator LED will transition from flashing to solid green if it has properly connected to your wireless network. If the device does not connect properly, please verify the network settings entered above.

NOTICE: The Wireless F/T can transmit a large volume of data across a wireless network. It is suggested that you use a dedicated wireless access point so that you do not affect other wireless devices on your network. A dedicated high strength local wireless network will result in the most reliable connection.

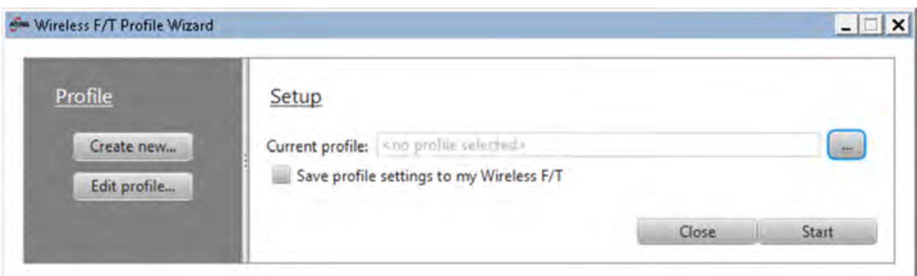
3.3 The Wireless F/T Java Demo Application

3.3.1 Creating a test profile

The following steps are provided to create a test profile on the Wireless F/T Java Demo application.

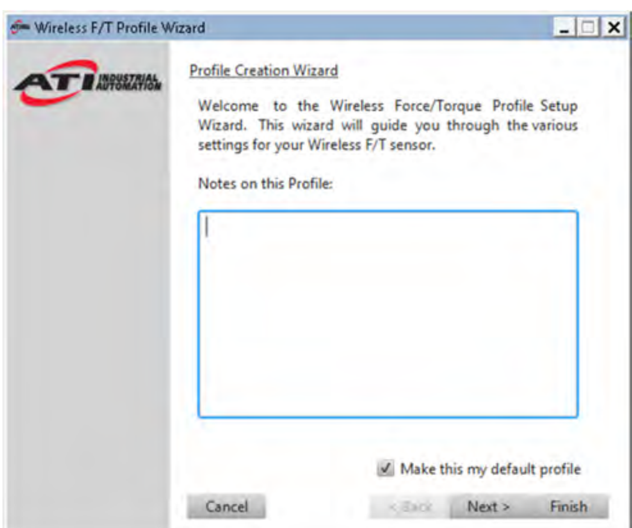
1. Remove the Wireless F/T software CD from the package and insert it into the CD drive on your computer and locate the WirelessFTJavaDemo.jar file within the Demo directory, or visit our website (*http://www.ati-ia.com/library/download.aspx*) and locate the WirelessFTJavaDemo.jar file.
2. Copy or download the file to the directory desired and double click to open the program.
3. Use the Wireless F/T Profile Wizard to create a new profile for the device by pressing the "Create new…" button.

Figure 3.6—Profile Creation



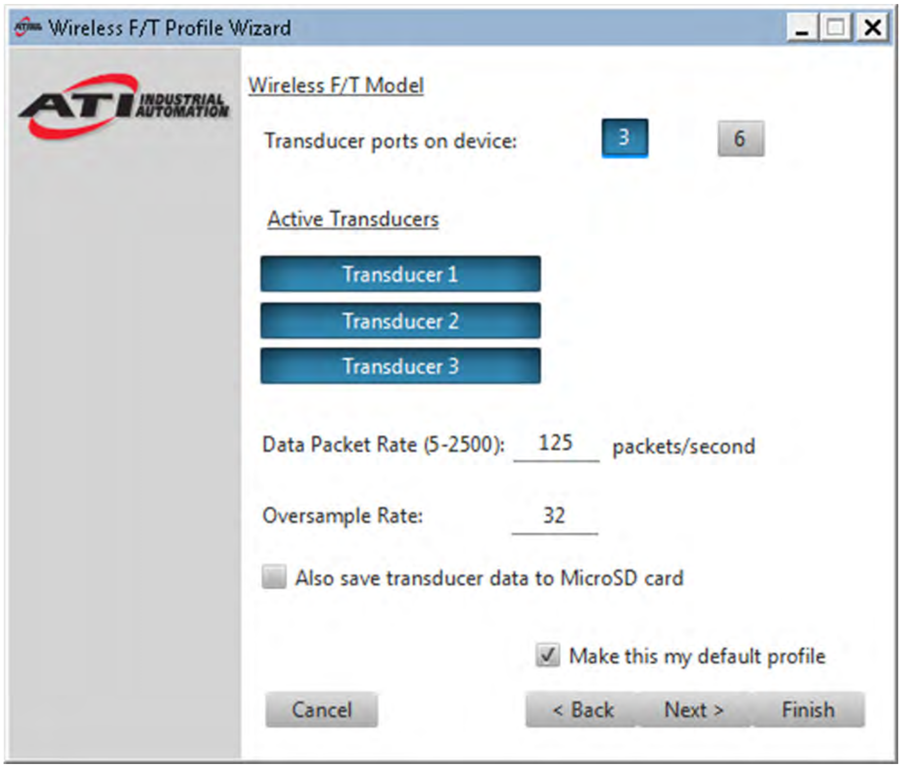
4. Use this initial welcome page to add any notes that you'll want to be able to reference when you review this profile in the future.

Figure 3.7—Welcome



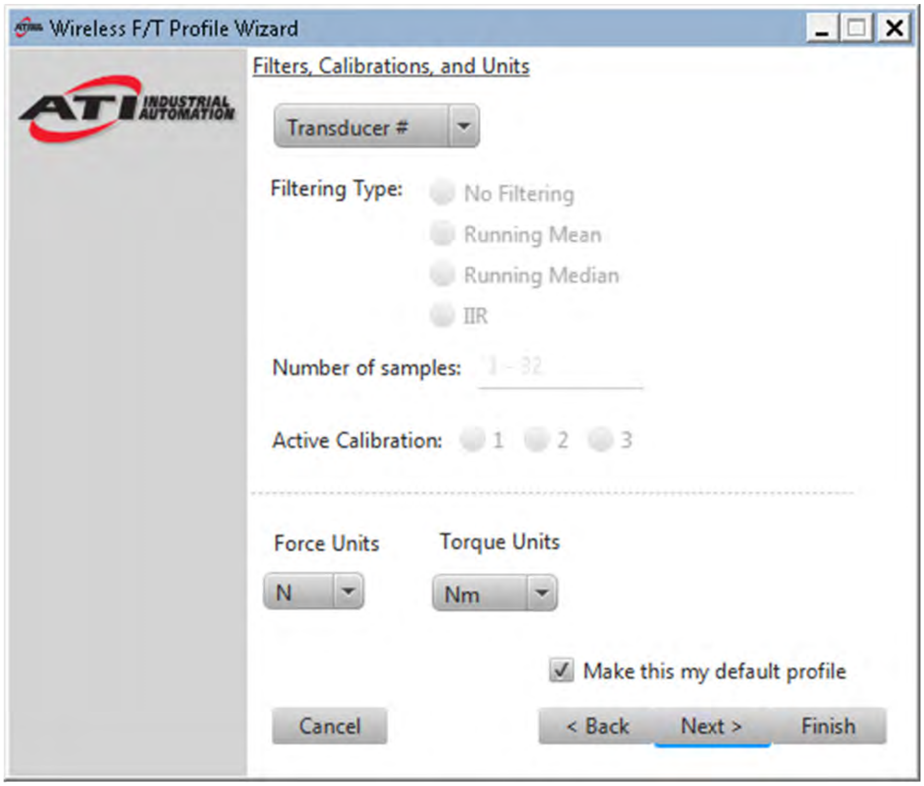
5. Use this page to configure the basic settings of your Wireless F/T system.

Figure 3.8—Transducer Settings



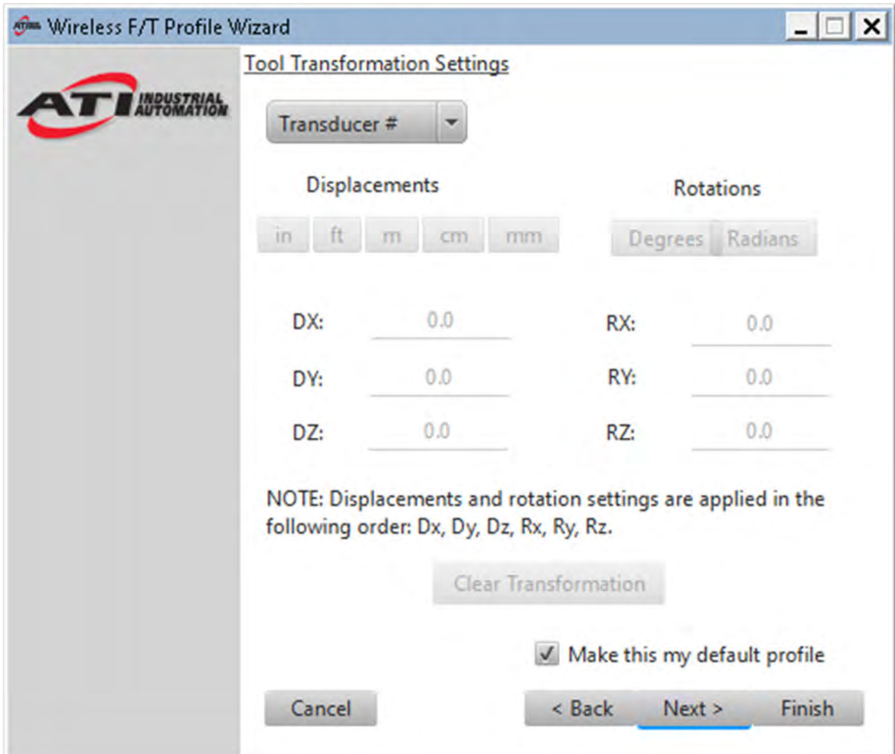
6. Use this page to add any filters to your data and to select the proper calibration for each transducer (if a sensor contains multiple calibrations).

Figure 3.9—Filters and Calibrations



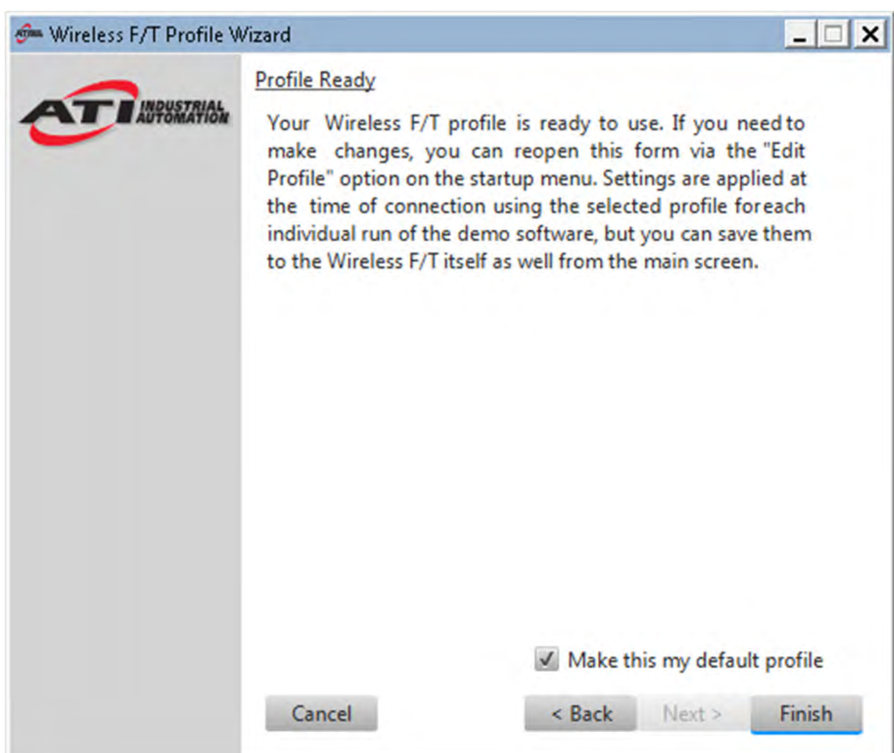
7. Use this page to add any Tool Transformations needed for your specific application. Refer to _Section_ —— for more information.

Figure 3.10—Tool Transformations



8. Your new Wireless F/T profile is now ready to use. Press the Finish button to exit.

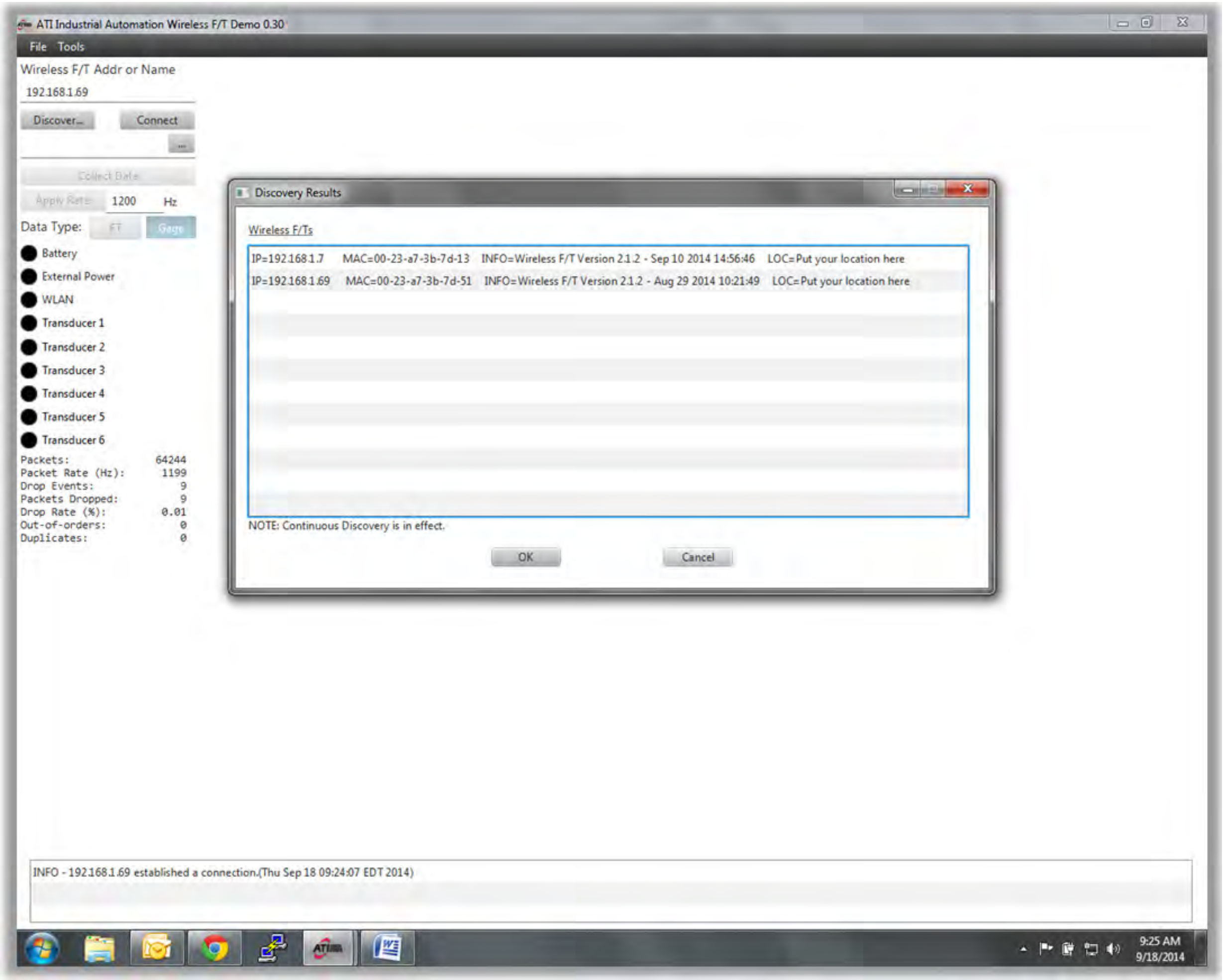
Figure 3.11—Your Profile is Ready



3.3.2 Connecting to the Wireless F/T

1. Select the proper profile and press the Start button as shown in Figure 3.6.
2. Press the "Discover…" button to find which Wireless F/T devices are currently on the network your PC is connected to.
3. Once you have selected the proper device, press the "Connect" button. The application will begin displaying streaming data from the active transducers connected to the Wireless F/T Unit.

Figure 3.12—Establish a Connection



- See *Section 3.3.3—Data Collection* for using the data collection features
- The data rate can be dynamically adjusted by inputting a value (between 10-4000) and clicking the "Apply Rate" button.
- The data type displayed can be switched to F/T data or Gage (diagnostic) data by clicking the corresponding buttons.
- The LED Status from the Wireless F/T unit will also be displayed in this left column.
- Red text for a transducer indicates that the transducer is loaded beyond its measurement range and is saturated.
- Data packet transmission statistics are provided. This is useful for determining an optimal packet rate and also gives an indication of wireless network strength.
- The "Bias" button for each transducer will set the current load level as the new zero point.
- The "Unbias" button will remove the offset (if Bias had been pressed).
- An onscreen log of messages is displayed at the bottom of the screen.

3.3.3 Data Collection

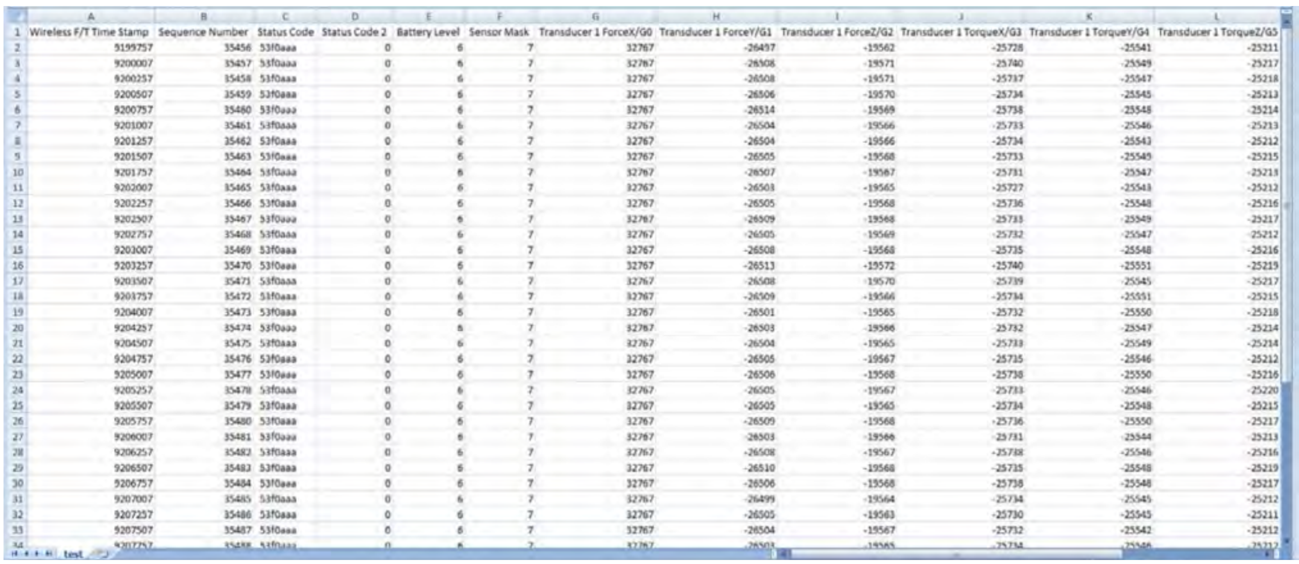
There are two ways data can be stored. Data can be collected and stored on a file on a PC or network directory, and/or it can be collected and stored on the customer's MicroSD card plugged into the Wireless F/T unit.

3.3.3.1 Collecting and Storing Data on a PC or Network File

To collect data to a file, click the "…" button to the left of the field and select a location and filename for your data. Click the "Collect Data" button to begin. Once you have completed your test, click the "Stop" button to finish collecting data.

The measurement data is stored in comma-separated value format (CSV) so it can easily be read by spreadsheets and data-analysis programs. Name your file with a .CSV extension. If you are planning on collecting large amounts of data, it is a good idea to understand any limitations your spreadsheet or data analysis program may have on the number of rows it can use.

Figure 3.13—Sample CSV Data File Opened in a Spread Sheet

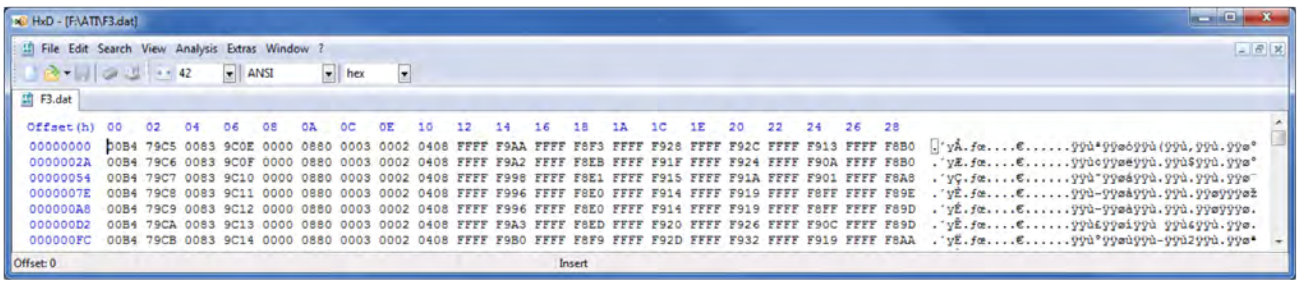


	A	B	C	D	E	F	G	H	I	J	K	L
1	Wireless F/T Time Stamp	Sequence Number	Status Code	Status Code 2	Battery Level	Sensor Mask	Transducer 1 ForceX/G0	Transducer 1 ForceY/G1	Transducer 1 ForceZ/G2	Transducer 1 TorqueX/G3	Transducer 1 TorqueY/G4	Transducer 1 TorqueZ/G5
2	9199757	35456	53f0aaa	0	6	7	32767	-26497	-19562	-25728	-25541	-25211
3	9200007	35457	53f0aaa	0	6	7	32767	-26508	-19571	-25740	-25549	-25217
4	9200257	35458	53f0aaa	0	6	7	32767	-26508	-19571	-25737	-25547	-25218
5	9200507	35459	53f0aaa	0	6	7	32767	-26506	-19570	-25734	-25545	-25213
6	9200757	35460	53f0aaa	0	6	7	32767	-26514	-19569	-25738	-25548	-25214
7	9201007	35461	53f0aaa	0	6	7	32767	-26504	-19566	-25733	-25546	-25213
8	9201257	35462	53f0aaa	0	6	7	32767	-26504	-19566	-25734	-25543	-25212
9	9201507	35463	53f0aaa	0	6	7	32767	-26505	-19568	-25733	-25545	-25215
10	9201757	35464	53f0aaa	0	6	7	32767	-26507	-19567	-25731	-25547	-25213
11	9202007	35465	53f0aaa	0	6	7	32767	-26503	-19565	-25727	-25543	-25212
12	9202257	35466	53f0aaa	0	6	7	32767	-26505	-19568	-25736	-25548	-25216
13	9202507	35467	53f0aaa	0	6	7	32767	-26509	-19568	-25733	-25549	-25217
14	9202757	35468	53f0aaa	0	6	7	32767	-26505	-19569	-25732	-25547	-25212
15	9203007	35469	53f0aaa	0	6	7	32767	-26508	-19568	-25735	-25548	-25216
16	9203257	35470	53f0aaa	0	6	7	32767	-26513	-19572	-25740	-25551	-25219
17	9203507	35471	53f0aaa	0	6	7	32767	-26508	-19570	-25739	-25545	-25217
18	9203757	35472	53f0aaa	0	6	7	32767	-26509	-19566	-25734	-25551	-25215
19	9204007	35473	53f0aaa	0	6	7	32767	-26501	-19565	-25732	-25550	-25218
20	9204257	35474	53f0aaa	0	6	7	32767	-26503	-19566	-25732	-25547	-25214
21	9204507	35475	53f0aaa	0	6	7	32767	-26504	-19565	-25733	-25549	-25214
22	9204757	35476	53f0aaa	0	6	7	32767	-26505	-19567	-25735	-25546	-25212
23	9205007	35477	53f0aaa	0	6	7	32767	-26506	-19568	-25738	-25550	-25216
24	9205257	35478	53f0aaa	0	6	7	32767	-26505	-19567	-25733	-25546	-25220
25	9205507	35479	53f0aaa	0	6	7	32767	-26505	-19565	-25734	-25548	-25215
26	9205757	35480	53f0aaa	0	6	7	32767	-26509	-19568	-25736	-25550	-25217
27	9206007	35481	53f0aaa	0	6	7	32767	-26503	-19566	-25731	-25544	-25213
28	9206257	35482	53f0aaa	0	6	7	32767	-26508	-19567	-25738	-25546	-25216
29	9206507	35483	53f0aaa	0	6	7	32767	-26510	-19568	-25735	-25548	-25219
30	9206757	35484	53f0aaa	0	6	7	32767	-26506	-19568	-25738	-25548	-25217
31	9207007	35485	53f0aaa	0	6	7	32767	-26499	-19564	-25734	-25545	-25212
32	9207257	35486	53f0aaa	0	6	7	32767	-26505	-19563	-25730	-25545	-25211
33	9207507	35487	53f0aaa	0	6	7	32767	-26504	-19567	-25732	-25542	-25212
34	9207757	35488	53f0aaa	0	6	7	32767	-26503	-19565	-25734	-25546	-25212

3.3.3.2 Collecting and Storing Data on a MicroSD Card

1. Check the “Record transducer data on MicroSD” field on the general Settings tab of the WNET Profile Wizard. This will cause FT samples sent by the device to be saved on its MicroSD card in the form of .dat files. These files are raw hex data (fig. 3.14), but can be converted to CSV files by the demo program.
2. When you are finished collecting wireless data, plug your WNET into a computer via USB.
3. Without changing your profile, press “Start” and the demo will begin like usual.
4. To retrieve your files, press File → Extract MicroSD Data and then select the file you wish to convert to user-friendly CSV. If you do not wish to convert the files, simply navigate to the WNET’s MicroSD over USB like you would a flash drive and retrieve them with the file browser.

Figure 3.14—Sample Data File



3.4 Mounting the Wireless F/T Unit

Keep in mind that a unobstructed environment from the Wireless F/T to the wireless access point will improve signal strength. If an external power adapter is being used, refer to *Section 3.5—External Power Adapter Installation* for information.

3.4.1 Typical Belt Clip Installation

Attach the Wireless F/T using the belt clip to a suitable and safe location. Refer to *Section 4—Installing the Transducer* for installation instruction for the transducer and routing the transducer cable.

3.4.2 Typical Fixed Installation

Refer to *Section 11—Drawings* for details on the threaded insert hole pattern used when installing the Wireless F/T in a fixed location. Refer to *Section 4—Installing the Transducer* for installation instruction for the transducer and routing the transducer cable.

3.5 External Power Adapter Installation

The unit does not require a battery to be present in order to be powered by an external power adapter. The external power adapter can be used after the initial configuration is complete. Plug the external power adapter.

For installations that will repeatedly bend the USB cable, route the external power adapter cable so that it is not stressed, pulled, kinked, cut, or otherwise damaged throughout the full range of motion. If the desired application results in the cable rubbing, then use a loose plastic spiral wrap for protection. Connect the USB cable to the power supply and to the Wireless F/T’s USB connector.

4. Installing the Transducer

Information on the environment, mounting the transducer, interface plate design, and routing the transducer cable can be found in the F/T Transducer Installation and Operation manual (9620-Transducer Section). The transducer must be monitored during installation for gage saturation errors. Refer *Section 3.3.2—Connecting to the Wireless F/T* to monitor the transducer during installation.

CAUTION: Do not exceed the single-axis overload value of the transducer. Smaller transducers can easily be irreparably damaged by applying small loads using tools (moment arm increases applied loads) when mounting the transducer. Always monitor the transducer using the demo application for Gage saturation errors during installation. 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.

ATTENTION: Ne pas dépasser la valeur de surcharge de l'axe unique du transducteur. Les petits transducteurs peuvent être irrémédiablement endommagés suite à l'application de petites charges en utilisant des outils (le bras de levier augmente les charges appliquées) lors du montage du transducteur. Toujours surveiller le transducteur à l'aide de l'application de démonstration en cas d'erreurs de calibration saturée lors de l'installation. Cesser d'appliquer la force au transducteur et attendre que l'erreur disparaisse pour continuer l'installation. Si l'erreur ne disparaît pas, cela peut indiquer une perte de puissance ou un dépassement de la valeur de surcharge.

5. Command Interface

The Wireless F/T unit must be installed, setup and configured prior to using any command interfaces. Refer to *Section 3—Initial Configuration and Installation of your Wireless F/T System* for installation, setup, and configuration of the WNet unit.

5.1 Communication Interfaces

The Wireless F/T can be setup and configured using a text-based command prompt console interface.

The Console Interface can be accessed two ways:

- Over the USB connection by way of a virtual serial port
- Wirelessly by way of a Telnet connection. The unit listens on port 23

5.2 Commands

These commands are available to any user, including commands to enter authenticated user and technician user modes. All users can read any information about the system, including values that only authenticated or technician users can write to.

The console interface is a text-based command prompt interface that allows the user to read and update system settings.

Enter most commands without operands to display current status.

5.3 Basic Wireless F/T commands:

`HELP, H,` or `?` – Prints help text

These commands print a summary of the console commands supported by the Wireless F/T.

`BRIGHT` *i* – Set Indicator brightness

where:

i = integer from 0 to 100

This command sets the brightness level of the unit's indicators. Brightness ranges from 0 to 100, where 0 is completely dark and 100 is completely on.

`D` *s* – Dump UDP Packets to Console

where:

s = ON or OFF

This command controls the dumping of outgoing UDP data packets to the console. See *Section 5.10—Data Packet* for information on the packets.

Command	Action
D ON	Console receives dump of outgoing UDP packets
D OFF	Console dumping of outgoing UDP packets disabled
D	Toggles the dumping of outgoing UDP packets to the console

```
>D

Dump Packet On
>8030cd06 000001be 06150216 00000000 0a 07 0000062f 00000c3d 0000040e f.
8030cd27 000001bf 06150216 00000000 0a 07 00000630 00000c3d 0000040d f.
8030cd47 000001c0 06150216 00000000 0a 07 0000062f 00000c3d 0000040c f.
```

.
.
.

`POWER` _s_ – Set Power Mode

where:

_s_ = ON, OFF, or CHARGE

This command controls the unit's power mode.

Command	Action
POWER ON	Turns unit on (just like pushing the power button).
POWER OFF	Turns unit completely off and not charging (no USB connection).
POWER CHARGE	Turns unit off but charging (USB connection to power source)

The POWER command will also report the unit's power status when issued without arguments.

```
>POWER
POWER On
>
```

`RESET` – Reset Unit

This command resets the unit. This will cause a disconnect from the console when connected via the virtual serial port. Any settings not saved with the SAVEALL command will be lost. If the unit is connected to a computer via USB, the unit will enter charging mode.

`SAVEALL` – Save All Settings

This command saves all settings so that they will survive a unit reset or power cycle.

```
>SAVEALL
All parameters saved to Serial Flash Primary
All parameters saved to Serial Flash Secondary
>
```

`T` _s_ – Transmit UDP Packets to WLAN

This command controls the transmission of UDP data packets to the WLAN.

Command	Action
T ON	Enable transmission of UDP packets to the WLAN
T OFF	Disable transmission of UDP packets to the WLAN
T	Toggles the transmission of UDP packets to the WLAN

`VERSIONS` – Display Component Versions

This command displays the versions of the four updatable components of the Wireless F/T. The following is an example of the command output:

```
>VERSIONS
Component   Version
---------   -------
Firmware    2.1.3 - Jan  1 2010 10:10:37
WLAN Module 1.2.3.4.5.6
CPLD 0      02
CPLD 1      none
>
```

`XPWR` *s1 s2* **– Transducer Power Control**

where:

s1 = 1, 2, 3, 4, 5, 6, or *

s2 = ON or OFF

This command enables and disables transducers. Unneeded transducers may be powered down using the XPWR command to save battery power. The first argument to the XPWR command, s1, selects the transducer targeted. If the first argument is an asterisk, then the command applies to all transducers simultaneously. The second argument to the XPWR command, s2, determines the power state to be set.

Command	Action
XPWR 1 ON	Enables transducer 1
XPWR * ON	Enables all transducers
XPWR 2 OFF	Disables transducer 2

The XPWR command returns a line that summarizes the state change followed by the system prompt. Following this are outputs for each transducer that has a change in power state. The XPWR command will output Analog power = OFF in AUTO mode when power to all transducers has been turned off. When all transducers are off and a transducer is turned on, Analog power = ON in AUTO mode will be output.

```
>XPWR
Tr Auto   Now
-- ----   ---
 1 OFF    OFF
 2 OFF    OFF
 3 OFF    OFF
Analog power = OFF in AUTO mode
>XPWR 1 ON
Transducer 1 = ON
>Analog power = ON in AUTO mode
PWR:  2010 Jan  1 10:10:37 Transducer 1 ON
XPWR * ON
Transducer 123 = ON
>PWR:  2010 Jan  1 10:10:43 Transducer 2 ON
PWR:  2010 Jan  1 10:10:43 Transducer 3 ON
XPWR * OFF
Transducer 123 = OFF
>PWR:  2010 Jan  1 10:10:49 Transducer 1 OFF
Analog power = OFF in AUTO mode
PWR:  2010 Jan  1 10:10:49 Transducer 2 OFF
PWR:  2010 Jan  1 10:10:49 Transducer 3 OFF
```

The XPWR command will also generate a report of the current transducer power status when issued without arguments. The Auto column is XPWR command setting. The Now column shows the power port’s actual state.

```
>XPWR
Tr Auto   Now
-- ----   ---
 1 ON     ON
 2 OFF    OFF
 3 ON     ON
Analog power = ON in AUTO mode
>
```

5.4 Commands for modifying wireless settings:

`BAND` *s* **– Selects WLAN Frequency Band**

where:

s = 2.4 or 5

This command selects whether the Wireless F/T uses the 2.4 GHz or the 5 GHz frequency band for WLAN communications. The new frequency band selection will take place after either a WLAN OFF/ON cycle or after a unit reset or unit power cycle, assuming the new BAND setting has been saved with the SAVEALL command.

Command	Action
BAND 2.4	Selects the 2.4 GHz frequency band for the WLAN
BAND 5	Selects the 5 GHz frequency band for the WLAN

The BAND command will also generate a report of the current WLAN frequency band when issued without arguments:

```
>BAND
Band = 5 GHz
>BAND 2.4
Change takes effect after reset: Band = 2.4 GHz
>WLAN OFF
WLAN: 2010 Jan  1 10:10:37 Power OFF
>WLAN ON
WLAN: 2010 Jan  1 10:10:41 Power ON
>WLAN: 2010 Jan  1 10:10:43 Got WLAN ready response
```

`DESTIP` *n1.n2.n3.n4* **– Set Default Destination IP Address**

where:

n1, *n2*, *n3*, and *n4* are integers from 0 to 255 representing an IPV4 address

This command sets the WLAN destination IP address for outgoing UDP data packets. Note that this IP address will only stay in effect until modified, either by this command again, or by the receipt of a UDP command to send packets to some other IP address. The DESTIP command will also report the current destination IP address when issued without arguments.

```
>DESTIP
Destination IP = 192.168.1.22
>DESTIP 192.168.1.3
Destination IP was 192.168.1.22 = 192.168.1.3
>
```

`DEVIP` *n1.n2.n3.n4* **– Set Default Device IP Address**

where:

n1, *n2*, *n3*, and *n4* are integers from 0 to 255 representing an IPV4 address

This command sets the default IP address of the unit. The default IP address is active when DHCP is not used. The DEVIP command will also report the default device IP address when issued without arguments.

```
>DEVIP
Device IP = 192.168.1.100
>DEVIP 192.168.1.101
Device IP was 192.168.1.100 = 192.168.1.101
>
```

`GATEIP` *n1.n2.n3.n4* **– Set Default Gateway IP Address**

where:

n1, n2, n3, and *n4* are integers from 0 to 255 representing an IPV4 address

This command sets the default gateway IP address for the WLAN. The default gateway IP address is active when DHCP is not used. The GATEIP command will also report the current default gateway IP address when issued without arguments.

```
>GATEIP
Gateway IP = 192.168.1.1
>GATEIP 192.168.1.2
Gateway IP was 192.168.1.1 = 192.168.1.2
>
```

`IP` **– Display IP Parameters**

This command prints the communication parameters. This can be useful for debugging WLAN connection issues. For example:

```
>IP
>ip
Parameter       Active          Default         MAC
---------       ------          -------         ---
SSID            MY_WIFI1        MY_WIFI1
DESTIP          0.0.0.0         0.0.0.0
GATEIP          192.168.1.22    192.168.0.2     32-24-3F-6A-88-85
DEVIP           192.168.1.123   192.168.1.100   31-41-59-26-53-59
NET MASK        255.255.255.0   255.255.255.0
DNS Server 1    192.168.1.1
DNS Server 2    192.168.1.2
ANTENNA         External
BAND            2.4 GHz
NET CHANNEL     1
NET DHCP        On
NET LOC         Balance Test #2
NET MODE        Normal CLIENT Mode
NET UDPACT      BUFFER
TXPWR           2
LOCALE          Europe
WLAN Connected  Yes
Channel number  3
Network type    Infra
Security level  WEP
DHCP Mode       DHCP
Open sockets    4
Sock State  Type   MyPort RemPort  RemIP
---- -----  ----   ------ -------  -----
  1  Open   UDPout  49152   49152  0.0.0.0
  2  Open   UDPin   49152       0  0.0.0.0
  3  Open   TCPin      23       0  0.0.0.0
  4  Open   UDPin   51000       0  0.0.0.0
>
```

NET AP – Display Detected WLAN Access Points

This command displays access points detected during the last scan of access points. If WLAN is OFF, NET AP will return the access points detected prior to setting WLAN to OFF. For example :

```
>NET AP

##  Ch Secur RSSI  SNR NType        MAC        SSID
--  -- ----- ----  --- -----        ---        ----
 1   1 WPA2   -39  -39 Infra 32-24-3F-6A-88-85 MY_WIFI1
 2   6 WPA2   -69  -13 Infra 31-41-59-26-53-59 MY_WIFI2

>
```

NET CHANNEL *n* – Set WLAN Channel for AP or GO Modes

where:

n = integer from 1 to 13, 149, 153, 157, 161, or 165

This command selects the channel number that the unit will use if it becomes an Access Point (AP) or a WiFi Direct™ Group Owner (GO). The NET CHANNEL command will also report its current value when issued without arguments.

```
>NET CHANNEL 6
NET CHANNEL 6
>NET CHANNEL
NET CHANNEL 6
>
```

NET DHCP *s* – Turns WLAN DHCP On or Off

where:

s = ON or OFF

This command turns DHCP support on and off. Enabling DHCP support allows the connected WLAN access point to automatically set the GATEIP, DEVIP, and NET MASK values if the access point supports DHCP. The NET DHCP command will also report its current value when issued without arguments.

```
>NET DHCP
NET DHCP Off
>NET DHCP ON
NET DHCP On
>
```

NET DATE *yyyy/mm/dd* - Set System Date

where:

yyyy = integer; the current year
mm = integer; the current month from 1 to 12
dd = integer; the current day from 1 to 31

This command allows you to change the system date. If NTP synchronization is running, it will overwrite any changes made by using the NET DATE command. The NET DATE command will also report its current value when issued without arguments

Note: The system date and time will default to 2010 Jan 1 00:00:00 at power up or reset.

```
>NET DATE 2010/01/01
2010 Jan  1 10:10:37
>NET DATE
2010 Jan  1 10:10:38
>
```

`NET TIME` *hh:mm:ss* **– Set System Time**

where:

hh = integer; the current hour from 0 to 23

mm = integer; the current minute from 0 to 59

ss = integer; the current second from 0 to 59

This command allows you to change the system time. If NTP synchronization is running, it will overwrite any changes made by using the NET TIME command. The NET TIME command will also report its current value when issued without arguments.

Note: The system date and time will default to 2010 Jan 1 00:00:00 at power up or reset.

```
>NET TIME 10:10:37
2010 Jan  1 10:10:37
>NET TIME
2010 Jan  1 10:10:38
>
```

`NET DNS` *s* **– Find IP Address(es) of Given URL**

where:

s = a string of up to 89 ASCII characters making up a valid URL

This command allows you to find any IP addresses associated with a given URL. If the URL does not have an associated Internet IP address, the command will not generate a response. The NET DNS command can be used to determine if connected WLAN network has connectivity to the wider internet. For example:

```
>NET DNS fifa.com
>## IP-Address
-- ----------
 1 184.26.143.136
 2 184.26.143.147
NET DNS BadAddress.com
>
```

`NET KEY` *s* **– Set WLAN Network Key**

where:

s = a string of up to 64 ASCII-encoded characters

This command sets the WLAN network key (sometimes called PSK) that is used with WEP, WPA, and WPA2 encryption. The WLAN network key, sometimes called network password, is required to connect to encrypted WLANs. The use of quotation marks is optional except when removing the network key (NET KEY “”). The WLAN system administrator should provide the required network key. The NET KEY command will also report its current value when issued without arguments.

```
>NET KEY
NET KEY = ‘somepassword’
>NET KEY secretphrase
NET KEY = ‘secretphrase’
>NET KEY “”
NET KEY = ‘’
>
```

`NET LOC` *"s"* – Set Unit Location Description

where:

s = a string of up to 39 ASCII-encoded characters

This command stores or recalls a location description. The location description is intended to help identify individual units when accessed remotely. The NET LOC command will also report its current value when issued without arguments.

```
>NET LOC "Balance Tester #2"
LOCATION was 'Widget Maker' now 'Balance Tester #2'
>NET LOC
LOCATION = 'Balance Tester #2'
>
```

`NET MASK` *n1.n2.n3.n4* – Set WLAN Subnet Mask

where:

n1, *n2*, *n3*, and *n4* are integers from 0 to 255 representing an IPV4 address

This command sets the default WLAN subnet mask. The subnet mask is used to determine what subnet an IP address belongs to. If DHCP is not used, the WLAN system administrator should provide the required subnet mask. The NET MASK command will also report its current value when issued without arguments.

```
>NET MASK 255.255.255.0
Net Mask was 255.255.255.254 = 255.255.255.0
>NET MASK
Net Mask = 255.255.255.0
>
```

`NET MODE` *s* – Set WLAN Connection Mode

where:

s = CLIENT or DIRECT

This command selects either client mode (connect to an existing wireless access point) or WiFi Direct™ mode.

Command	Action
NET MODE CLIENT	Selects WLAN access points as unit's wireless mode
NET MODE DIRECT	Selects WiFi Direct devices as the unit's wireless mode

```
>NET MODE
NET MODE DIRECT or Autonomous GO
>NET MODE CLIENT
NET MODE Normal CLIENT Mode
>
```

`NET UDPACT` *s* – Packet Action During WLAN Flow Control

where:

s = BUFFER or DROP

This command controls how the unit handles the transducer data when it needs to pause from sending data packets to the WLAN.

Command	Action
NET UDPACT BUFFER	Data will be buffered during the flow control period, and then sent when the period ends. Data will only be lost if the flow control period lasts longer than available buffer storage. This mode minimizes missing data, and is preferred for data logging applications.
NET UDPACT DROP	Data will be dropped (deleted) during the flow control period. Data transmission will resume at the end of the flow control event. This mode minimizes latency, and is preferred for control applications

```
>NET UDPACT
NET UDPACT DROP
>NET UDPACT BUFFER
NET UDPACT BUFFER
>
```

`RESETIP` – Restore All IP Settings to Factory Defaults

This command restores all IP settings to the factory defaults. Any changes take effect with the next join to an access point.

```
>RESETIP
All IP settings restored to factory defaults
>
```

`RSSI` - Display WLAN Received Signal Strength Indicator

This command displays the wireless power for the unit's WLAN reception. RSSI (Received Signal Strength Indicator) is a measurement of the power present in a received radio signal. For example:

```
>RSSI
RSSI from MY_WIFI using External antenna: -45 dBm
>
```

`SSID` *s* – Set Access Point SSID (WLAN Network Name)

where:

s = a string of up to 32 ASCII characters

This command allows you to view and set the SSID. A new SSID setting will be effective after the next Join to an access point. An SSID is the name of a WLAN. SSIDs are case-sensitive text strings. The WLAN system administrator should provide the required SSID. The SSID command will also report its current value when issued without arguments.

```
>SSID
SSID = ‘OLD_WIFI’
>SSID MY_WIFI
SSID was ‘OLD_WIFI’ now ‘MY_WIFI’
>
```

`WLAN` *s* – Enable or Disable WLAN Communications

where:

s = ON or OFF

The WLAN command turns on and off WLAN communications. Turning off WLAN communications will reduce battery consumption. The WLAN command will also report its current value when issued without arguments.

Command	Action
WLAN ON	Enables WLAN communications
WLAN OFF	Disables WLAN communications

```
>WLAN
WLAN: Power ON
>WLAN OFF
WLAN: 2010 Jan  1 10:10:37 Power OFF
>WLAN
WLAN: Power OFF
>WLAN ON
WLAN: 2010 Jan  1 10:10:39 Power ON
>WLAN: 2010 Jan  1 10:10:41 Got WLAN ready response
>
```

5.5 Commands related to the Transducer output:

`RATE` *n1 {n2}* – Set Packet Rate with Optional Oversampling

where:

n1 = integer from 5 to 4000, representing the packet send rate in Hertz

n2 = {optional} integer from 1 to 4000÷n1, representing the oversample value.

This command allows you to set the rate at which data packets are sent to the destination IP address or the MicroSD card, and how many times to oversample.

The packet send rate's units are Hertz. Packet send rates can be from 5 to 4000 Hz. The upper limit is the highest rate possible under ideal conditions: only one transducer, oversampling set to 1, filtering disabled, no matrix multiply, no other WLAN traffic or interference, MicroSD logging disabled, and an application that can tolerate a large number of dropped packets.

The oversample value defaults to 1 if no value is entered for that argument. The packet send rate multiplied by the oversampling value cannot exceed 4000.

There are three major reasons to use oversampling :

a. Resolution. Oversampling can be used to achieve higher effective resolution when noise is present. For example, to add the equivalent of one extra bit of resolution read the transducer twice and average the results.

b. Noise filtering. If multiple samples are taken of the same quantity with uncorrelated noise added to each sample, then averaging n samples reduces the noise power by a factor of 1/n.

c. Anti-aliasing. Oversampling can make it easier to implement analog anti-aliasing filters.

The fastest packet rate usable in an application depends on (in approximate order of expected significance):

a. Processor speed on the receiving end. Examples:

    i. A desktop system running Windows 7 with an Intel Core i5 CPU (3.10 GHz, 8 GB of RAM) had no problem keeping up with a 1200 Hz packet rate.

    ii. A laptop running Windows XP with an Intel Centrino Duo (1.66 GHz, 1 GB of RAM) had trouble keeping up with much more than a 100 Hz packet rate.

b. Your application's tolerance for dropped packets.

c. The number of active transducers in the system. Rates decrease as transducer data increases.

$$\text{Packet length} = 6 \times 4 \times \text{Number\_Of\_Transducers} + 18 \text{ bytes}$$

d. If using UDP:

  i. Any other wireless radio traffic.

  ii. Any radio frequency interference in your environment

  iii. Any other network traffic (for example in the router)

  iv. The mode: BUFFER mode (to minimize dropouts) or DROP mode (to minimize latency).

e. If writing to a MicroSD card, its maximum write latency and other hardware characteristics.

f. The amount of oversampling in use.

g. Filter type

h. Number of filter taps for filters other than IIR.

i. Matrix Multiply enabling. If enabled, the maximum rate will be less than if disabled.

Best wireless performance will be achieved using a dedicated wireless access point free of other network traffic.

The factory default is to send packets at 10 Hz (every 100 mS), with an oversample rate of 32. This means that one out of every 32 packets is sent.

```
>rate
Packet rate =   10 Hz
ADC    rate =  320 Hz
Oversample  =   32
>rate 125 32
Packet rate =  125 Hz
ADC    rate = 4000 Hz
Oversample  =   32
>
```

`BIAS` *s1 s2* **– Set Transducer Bias**

where:

s1 = 1, 2, 3, 4, 5, 6, or *

s2 = ON or OFF

This command allows you to set or remove the bias point of any one or all transducers. The bias point is an offset to be applied to a transducer's output by the unit. Setting a transducer's bias point will make it read zero for the load applied at the time the bias was set.

```
>BIAS 1 OFF
Sensor bias cleared 1
>BIAS * ON
Sensor bias set 123
>
```

`TRANS` *n* – Set Active Transducer

where:

n = integer from 1 to 6

This command allows you to change the active transducer. The active transducer is the transducer for which the CALIB command applies. The TRANS command will also report which transducer is active and show each transducer's active calibration, when issued without arguments.

```
>TRANS 2
Active: Transducer = 2 Calibration = 1
>TRANS
Tr Active-Calibrations
-- -------------------
 1  1
 2  1 <-- Active Transducer
 3  1
>
```

`CALIB` *n* – Set Active Calibration

where:

n = 1, 2, or 3

This command allows you to change the active calibration. The active calibration is the one currently for data collection. The CALIB command will also report which transducer is active and show each transducer's active calibration, when issued without arguments.

```
>CALIB 3
Active: Transducer = 2 Calibration = 3
>CALIB
Tr Active-Calibrations
-- -------------------
 1  1
 2  3 <-- Active Transducer
 3  1
>
```

`FILTER` *s1 s2 n* **– Set Filtering**

where:

s1 = 1, 2, 3, 4, 5, 6, or *

s2 = MEAN, MEDIAN, or IIR

n = integer from 1 to 31 for MEAN and MEDIAN, from 1 to 32767 for IIR

This command allows you to set the low-pass filter type to be applied to transducer data. Low pass filtering can be applied to reduce unwanted noise in transducer data.

Filter Type	Description	*n* Range
Mean	Running average filter of the last n samples	1 to 31
Median	Running median filter with n samples	1 to 31
IIR	IIR filter with a time constant of n	1 to 32767

Note that a 31-sample MEAN filter running in all six transducers executes in about 65 µS, while a 31-sample MEDIAN filter in all six transducers executes in about 480 µS, on average. Consequently, the maximum possible packet rate, set by the RATE command, is lower for an n-sample MEDIAN filter than for an n-sample MEAN filter.

The FILTER command will also report the current filter settings for all transducers, when issued without arguments.

```
>FILTER 1 MEAN 8
Transducer 1 MEAN  8
>FILTER 2 MEDIAN 16
Transducer 2 MEDIAN 16
>FILTER 3 IIR 512
Transducer 3 IIR 512
>FILTER
Tr Filter  Taps
-- ------  ----
 1 MEAN      8
 2 MEDIAN   16
 3 IIR     TC 512
>
```

5.6 Commands related to the functionality of the MicroSD card reader:

`SD` **- Print Memory Card Diagnostic Information**

With no operands, this command prints a lengthy list of technical information about the user's memory card.

`SD [FORMAT]` **- Format Memory Card**

This command allows you to format the MicroSD card. All existing data on the MicroSD card will be lost. The command will ask you to verify that you want to format the disk before it actually deletes any data. To cancel, type N then press <ENTER>. To proceed, type Y then press <ENTER>. Any data streaming over the WLAN will be interrupted while the format is taking place.

```
>SD FORMAT
SD:   2010 Jan  1 10:10:28 Are you sure? ALL data on the SD card will be
lost!
nSD:   2010 Jan  1 10:10:34 Format canceled
>SD FORMAT
SD:   2010 Jan  1 10:10:41 Are you sure? ALL data on the SD card will be
lost!
ySD:   2010 Jan  1 10:10:46 Formatting Drive 0:
Erasing sectors 200 to 1dcfff AU: 239 timeout: 30,875 mS
SD:   2010 Jan  1 10:10:48 Format complete
>
```

`SCD` *s* – Change Memory Card Directory

where:

s = a string of ASCII characters that form a valid directory name

This command allows you to display and change the path on the memory card. The SCD command will report the current path when issued without arguments.

```
>SCD /ATI
0:/ATI
>SCD /
0:/
>
```

`SDEL` *s* – Delete Memory Card File(s)

where:

s = a string of ASCII characters that form a valid file name

This command deletes the selected file(s) in the current directory on the user memory card.

```
>SDEL F3.dat
Erasing sectors 380 to 3df AU: 1 timeout: 1,125 mS
F3.DAT deleted
Files deleted: 1
>SDEL BadFileName
Files deleted: 0
>
```

`SDIR` – Print Memory Card Directory

This command prints a directory of all files in the current path on the user memory card.

```
>SDIR
 Directory of 0:/ATI
 2010/01/01 10:10 <DIR>              .
 2010/01/01 10:10 <DIR>              ..
 2010/01/01 10:10              4     ATI.ini
 2010/01/01 10:11        112,398     F1.dat
 2010/01/01 10:14         33,792     F2.dat
 2010/01/01 10:18         33,066     F3.dat
        4 File(s)        179,260 bytes total
        2 Dir (s)
>
```

`SDREC` *s* – Control Streaming Packets to Memory Card

where:

s = ON or OFF

This command controls the saving of streaming data to the user memory card. All data is placed in the \ATI subdirectory, which is automatically created when necessary. The file ati.ini is also created within this subdirectory if it is not already present. Each time that streaming starts, a new file Fn.dat file is created, where n is the next sequential file number. The data is saved as binary data in the same format as the UDP data packets described in section 5.10 Data Packet.

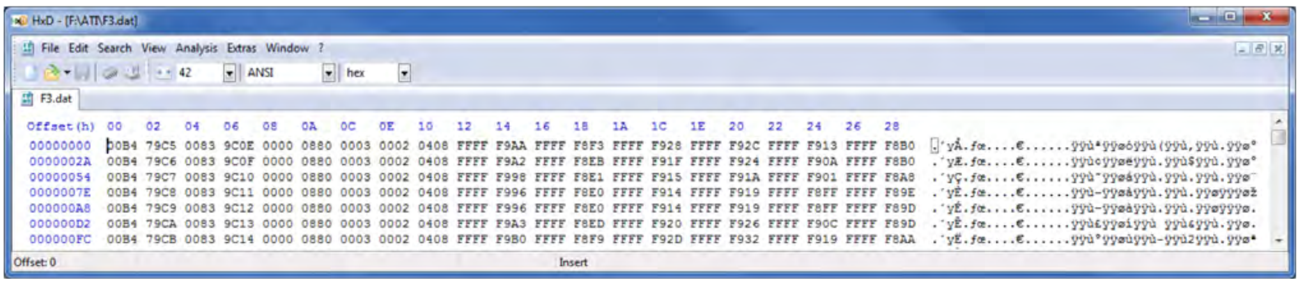
Note that the file system only supports file sizes up to 4 G bytes.

```
>SDREC ON
SDFS: Opening F1.dat
MicroSD streaming is On
>SDREC OFF
SDFS: Closed: F1.dat CARD Packets: Generated: 1,703 Dropped: 0 Max Write
Latency: 64 mS
MicroSD streaming is Off
>
```

The data can be read by placing the memory card into a computer that supports the FAT file system. A MicroSD adapter may be required.

When viewed with the freeware HxD utility (http://mh-nexus.de/en/hxd/), data for a single transducer may look like:

Figure 5.1—Fn.dat file format



Note that if an interruption occurs while this data is being written (such as the removal of the MicroSD card or the battery) the open file will generally lose any data written within the last two seconds. The interruption may also cause lost file system clusters, which will reduce the storage capacity of the card. Lost clusters may be repaired either by formatting the card (using the SD FORMAT command, which will cause the loss of all data on the card), or by putting the card into a computer and running the SCANDISK utility. On Windows 7 machines this can be done by opening Windows Explorer, right-clicking on the drive letter of the MicroSD card, selecting Properties, clicking the Tools tab, pressing the Check Now… button, and then pressing Start

5.7 Commands related to NTP time synchronization:

Network Time Protocol is a protocol for synchronizing clocks between computer systems over packet-switched networks. The Wireless F/T uses NTP to synchronize its clock to that of a single user-selectable NTP server. Any other devices should be synchronized to the same NTP server. This NTP implementation has as its goal accuracy on the order of a millisecond, but it cannot be any more accurate than its time source. More information about NTP can be found at http://www.ntp.org/.

Every NTP command produces a short table containing its enable status, the current NTP server, the current time zone relative to UTC, and the daylight savings time status:

```
Parameter Value
--------- -----
Enable    1
Server    pool.ntp.org
TimeZone  -5:00
DST       OFF
```

All packets generated by the Wireless F/T have a time stamp in units of milliseconds. NTP settings are controlled using the NTP commands.

`NTP ENABLE` _n_ – Controls NTP Synchronization

where:

_n_ = 0 or 1

This command controls whether NTP synchronization is enabled or disabled. The NTP ENABLE command should not be used without an offset. Doing so will disable NTP synchronization.

Command	Action
NTP ENABLE 0	Disables NTP synchronization
NTP ENABLE 1	Enables NTP synchronization

After NTP synchronization is enabled, the unit will attempt to contact the time server previously set with the NTP SERVER command. If successful, the unit will output a table with NTP Field information. If unsuccessful, no NTP Field table will be output.

```
>NTP SERVER pool.ntp.org
Parameter Value
--------- -----
Enable    0
Server    pool.ntp.org
TimeZone  -5:00
DST       OFF
>NTP ENABLE 1
Parameter Value
--------- -----
Enable    1
Server    pool.ntp.org
TimeZone  -5:00
DST       OFF
>
NTP-Field      Value
---------      -----
Server         pool.ntp.org
LeapSecInd     None
Version        3
Mode           Server
Stratum        2 => Secondary reference
PollInterval   2 ^    4 seconds
Precision      2 ^  -22 seconds
RootDelay      0.000198 seconds
RootDispersion 0.022568 seconds
ReferenceId    216.229.0.179
Reference      2010 Jan  1 10:10:16.798053
Originate      2010 Jan  1 10:10:20.212445
Receive        2010 Jan  1 10:10:20.262260
Transmit       2010 Jan  1 10:10:20.262286


>NTP ENABLE 0
Parameter Value
--------- -----
Enable    0
Server    pool.ntp.org
TimeZone  -5:00
DST       OFF
>
```

`NTP SERVER` *s* – Set NTP Server URL or IP Address

where:

s = a string of up to 89 characters representing a valid URL or IPV4 address

This command selects an NTP server to use. The NTP SERVER command should not be used without an argument. Doing so will set the NTP server to an indeterminate value. Generally, closer NTP servers will provide better the time synchronization, assuming the servers have similar accuracies. If you are trying to synchronize multiple pieces of equipment you should use the same time server for all of them. The server can be entered as a URL or as an IP address, but a URL is preferred.

```
>NTP SERVER pool.ntp.org
Parameter Value
--------- -----
Enable    0
Server    pool.ntp.org
TimeZone  -5:00
DST       OFF
>
```

Your organization may already have its own NTP time server. You may want to install an NTP server in a PC or for additional accuracy buy a precision NTP server in dedicated hardware . Public NTP time servers are also available. NTP best practices discourage the use of Stratum 1 time servers by end-use devices, such as the Wireless F/T.

`NTP ZONE` *s* – UTC Time-Zone Offset

where:

s = string representing the time zone offset in hours and minutes.

This command sets the difference between local time and Coordinated Universal Time (UTC) time. The string, s, cannot have leading zeros. Negative offsets must be preceded by a dash. Valid examples are: 1000, 100, 0, 500, 800. The NTP ZONE command should not be used without an offset. Doing so will set the UTC time zone offset to zero. Information on UTC time-zone offsets can be found at http://en.wikipedia.org/wiki/List_of_UTC_time_offsets.

```
>NTP ZONE -500
Parameter Value
--------- -----
Enable    0
Server    pool.ntp.org
TimeZone  -5:00
DST       OFF
>
```

`NTP DST` *s* – Daylight savings time

where:

s = ON or OFF

This command sets whether daylight savings time is on or off.

```
>NTP DST ON
Parameter Value
--------- -----
Enable    0
Server    pool.ntp.org
TimeZone  -5:00
DST       ON
>
```

5.8 UDP Interface

The Wireless F/T unit listens on UDP port 49152 for commands. Any streaming UDP packets are sent to the current Destination IP address until a UDP command is received. When the Wireless F/T unit receives a UDP command from any IP address, the UDP packets are sent to whichever port the request came from.

The UDP server uses binary format for commands and responses. All multi-byte values use big-endian, which is the same as network order.

5.9 UDP Command Format

All UDP commands to the WNET unit have the following format:

Table 5.1—UDP Command Format

Field Name	Format	Length (bytes)	Comments
length	unsigned short	2	Total length of this message, including CRC
sequence	unsigned char	1	Sequence number. Used to identify missing messages.
command	unsigned char	1	Command number
payload	unsigned char(s)	length - 6	Command operands (if any)
crc	unsigned short	2	See Appendix A – UDP Command CRC Calculation, for details

This format can be rendered into C as:

```
struct udp_RecvFrame_S

{
    unsigned short length;        // Total length of this message
    unsigned char  sequence;      // sequence number of this message
    unsigned char  command;       // command number
    unsigned char  parameters[0]; // command operands
} __attribute__ ((__packed__));
```

These commands are currently implemented:

Table 5.2—Current Command Implementation

Number	Name	Comments
1	Start streaming	Start streaming for either a fixed or unlimited number of packets
2	Stop streaming	Stops streaming
3	Set packet transmission rate	Sets packet transmission rate. All transducers use the same rate.
4	Ping	Sends a no-payload Pong response back to the sender.
5	Reset telnet socket	Closes any open telnet socket.

1. Start Streaming.
   This command starts the transmission of UDP data packets for either a fixed or unlimited number of packets.

Table 5.3—UDP Command Format

Field Name	Format	Length (bytes)	Comments
count	unsigned long	4	Number of samples to send, 0 = unlimited

2. Stop Streaming
   This command stops the transmission of UDP data packets. There are no parameters.

3. Set Packet Transmission Rate
   This command sets the UDP data packet transmission rate. The packet transmission rate will be truncated to the next lowest multiple of the Analog to Digital Converter (ADC) sampling rate. For example, if a packet transmission rate of 900 µS is requested when the ADC sampling rate is 400 µS, the packet transmission rate will be set to 800 µS. The packet transmission rate will be set no lower than the ADC sampling rate. All Transducers use the same packet transmission rate. The change in packet transmission rate takes effect immediately.

Table 5.4—UDP Command Format

Field Name	Format	Length (bytes)	Comments
rate	unsigned long	4	Packet transmission rate in µS

4. Ping
   This command sends a no-payload Pong response back to the sender.
5. Reset Telnet Socket
   This command closes any open telnet socket. This command is useful to issue just before connecting to the unit, in case a previous session was not properly closed out.

5.10 Data Packet

Streaming UDP and SD card data packets have the following format:

Table 5.5—UDP Command Format

Field Name	Format	Length (bytes)	Comments
timeStamp	unsigned long	4	Internal time stamp in seconds (20-bits integer, 12-bits fraction). Seconds starts at 1/1/2010 if time synchronized, or since power up if not synchronized, modulo 20 bits.
sequence	unsigned long	4	Sequence number. Used to identify missing messages.
statusCode1	unsigned long	4	Wireless F/T Status Word 1 for Transducers 1 to 3 (see below)
statusCode2	unsigned long	4	Wireless F/T Status Word 2 for Transducers 4 to 6 (see below)
batteryLevel	unsigned char	1	Indication of battery life remaining
transMask	unsigned char	1	Transducer data in block mask: 0x01 = Transducer 1, 0x02 = T2, …
Tr Ch0 (if present)	signed long	4	Data for first Transducer, Channel 0
Tr Ch1 (if present)	signed long	4	Data for first Transducer, Channel 1
Tr Ch2 (if present)	signed long	4	Data for first Transducer, Channel 2
Tr Ch3 (if present)	signed long	4	Data for first Transducer, Channel 3
Tr Ch4 (if present)	signed long	4	Data for first Transducer, Channel 4
Tr Ch5 (if present)	signed long	4	Data for first Transducer, Channel 5
Tr data (if present)	6 signed longs	24	Data for next Transducer, Channels 0 to 5
Tr data(if present)	6 signed longs	24	Data for next Transducer, Channels 0 to 5
Tr data (if present)	6 signed longs	24	Data for next Transducer, Channels 0 to 5
Tr data (if present)	6 signed longs	24	Data for next Transducer, Channels 0 to 5
Tr data (if present)	6 signed longs	24	Data for next Transducer, Channels 0 to 5
length	unsigned short	2	Total length of this message, including CRC

For UDP, note that each individual UDP datagram may contain one or more of these packets.

For memory card files, note that F*.dat files usually contain more than one of these packets.

Table 5.6—Wireless F/T Status Word 1

Bit	31	30	29	28	27	26	25	24
Field	spare		Bridge Voltage Too Low			Saturated Data		
			T3	T2	T1	T3	T2	T1
Bit	**23**	**22**	**21**	**20**	**19**	**18**	**17**	**16**
Field	Reserved		T3		T2		T1	
	0	0	Bridge	AFE	Bridge	AFE	Bridge	AFE
Bit	**15**	**14**	**13**	**12**	**11**	**10**	**9**	**8**
Field	Reserved		Reserved		Battery Indicator		External-Power Indicator	
	0	0	0	0	Green	Red	Green	Red
Bit	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
Field	WLAN Indicator		T3 Indicator		T2 Indicator		T1 Indicator	
	Green	Red	Green	Red	Green	Red	Green	Red

Table 5.7—Wireless F/T Status Word 2

Bit	31	30	29	28	27	26	25	24
Field	spare		Bridge Voltage Too Low			Saturated Data		
			T6	T5	T4	T6	T5	T4
Bit	**23**	**22**	**21**	**20**	**19**	**18**	**17**	**16**
Field	Reserved		T6		T5		T4	
	0	0	Bridge	AFE	Bridge	AFE	Bridge	AFE
Bit	**15**	**14**	**13**	**12**	**11**	**10**	**9**	**8**
Field	Reserved		Reserved		Reserved		Reserved	
	0	0	-	-	-	-	-	-
Bit	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
Field	Reserved		T6 Indicator		T5 Indicator		T4 Indicator	
	-	-	Green	Red	Green	Red	Green	Red

The Bridge bits indicate if a transducer is powered. The AFE bits indicate if the Wireless F/T is ready to read that transducer's values.

The System indicator combines the results for all Digital Board faults.

The length of the packet depends on the number of transducers that are powered, and can be calculated using the following equation:

PacketLength(in bytes) = 18 + NumberOfOneBits(transMask) × 24

This packet format can be rendered into C as:

```
#define NUMBER_OF_ANALOG_BOARDS 2
#define NUMBER_OF_TRANSDUCERS   6
#define NUMBER_OF_STRAIN_GAGES  6

struct TxPacket_S
{
    unsigned long  timeStamp;
    unsigned long  sequence;
    unsigned long  statusCode[NUMBER_OF_ANALOG_BOARDS];
    unsigned char  batteryLevel;
    unsigned char  transMask;
      signed long  sg[NUMBER_OF_TRANSDUCERS][NUMBER_OF_STRAIN_GAGES];
} __attribute__ ((__packed__));
```

More than one of these packets may be sent as in a single UDP datagram.

5.11 Processor Firmware Update Procedure

The Wireless F/T device has the ability to be updated in the field. From a user's perspective, the procedure is:

1. Use the Java demo application on the PC to download the binary image appl.bin to the Wireless F/T unit.
2. Reset the Wireless F/T unit.

Note: if you are operating over WLAN, contact with the unit will be lost when the update procedure starts, and will not resume until it is complete. If you are operating through a serial port, you will be able to watch the process as it occurs.

6. Maintenance

Under normal conditions, no special maintenance is necessary, however it is recommended that periodic inspections be performed to assure long-lasting performance and to assure that unexpected damage has not occurred. Refer to *Section 6.1—Preventive Maintenance* for a schedule and items that should be visually inspected at regular intervals. Wireless F/T devices operating on battery power should be monitored periodically for battery status.

Spare parts are available from ATI Industrial Automation. Please call for recommendations.

6.1 Preventive Maintenance

The Wireless F/T is designed to provide a long life with regular maintenance. A visual inspection and preventive maintenance schedule is provided in the *Table 6.1*. Assembly details are provided in *Section 11—Drawings*.

Table 6.1—Preventative Maintenance Checklist	
Repetitive motion Frequency	**Inspection Schedule**
More than 1 per minute	Weekly
Less than 1 per minute	Monthly
Cabling	
□ Visually inspect the power supply and transducer cabling for wear or damage. If wear or damage is visible, replace cabling and adjust routing or protect cabling with a loose plastic spiral wrap. □ Visually inspect cable connection for looseness, tighten connection or replace cable as needed	
Mounting Fasteners	
□ Inspect mounting fasteners, verify they are tight and have the proper torque.	

6.2 Battery Recharging and Replacement

The batteries can be charged internally using the USB port above the battery compartment or externally in a battery charger.

6.2.1 Charging Battery Internally

The battery can be charged internally using the external power adapter and a USB cable that connects the external power adapter to the Wireless F/T. **Note:** The computer connected to the USB port does not provide sufficient source to keep the battery charged.

6.2.2 Charging Battery Externally

The battery can be charged externally and swapped out while a second battery is charging. It will result in a brief power-down condition.

1. Loosen the quarter-turn fastener on the battery compartment and open the door.
2. Slide the battery out and replace it with a fully charged battery.
3. Close the door and tighten the quarter-turn fastener.

7. Troubleshooting

The system contains few components and provides trouble-free operation once properly installed. The following table is provided to assist with troubleshooting the system.

Table 7.1—Troubleshooting		
Symptom	**Possible Cause**	**Correction**
Nonexistent or intermittent communication	Low battery power	Charge battery, (if battery does not retain a charge replace battery).
	Worn or damaged cabling	Inspect and test power supply and transducer cabling and replace as needed.
	External power adapter failing or not functioning	Replace external power adapter
	Obstruction between Wireless F/T and wireless access point	Remove obstruction or reposition Wireless F/T, or the wireless access point to obtain an unobstructed environment
	Wireless network component failing or not functioning	Test components and replace as needed
	Wireless F/T failing or not functioning	Test Wireless F/T and replace as needed
	Transducer not functioning	Refer to the F/T Installation and Operation manual for troubleshooting information.
	External antenna not present or not correct part	Install correct external antenna
WLAN and transducers do not work but USB communications work fine	Unit is in CHARGE power mode, not ON power mode	Momentarily press power button or issue POWER ON command
Wireless status indicator is flashing red	This typically happens when trying to transmit to a UDP address that does not exist	

8. Serviceable Parts

Description	Part Number
Wireless F/T WNet-3	9105-WNET3
Wireless F/T WNet-6	9105-WNET6
Battery	5515-3.70000-01
External Battery Charger	9105-WNETEBC
Antenna	9105-WNETANT
Wireless F/T Power Supply, Wall Adapter Type	9105-WNETPS
USB A Male to USB B Male cable, 0.9m	9105-C-USAA-MINIB-0.9

9. Specifications

The specifications section covers characteristics of the Wireless F/T device. Other components such as transducer, cabling may be found in the specific product manual on our website. Drawings may also be found in the product catalog and on our website. 2-D and 3-D models are also available on our website.

Contact ATI for specific information and drawings regarding your installation. We encourage you to use our applications department to review your designs and answer your questions.

9.1 Wireless Characteristics

Wireless Local Area Network (WLAN)	IEEE 802.11 b/g/n 2.4 GHz / 5.0 GHz
Typical Range (Antenna attached)	
Office Type Environment	30 m (98 ft)
unobstructed environment	100 m (328 ft)
Note: Only certified with the antenna attached.	

9.2 Power Requirements

Battery Power	
Internal battery	3.7V Lithium-polymer rechargeable
Typical battery life (Max, streaming rate and transducers used)	
WNet-3	2 hrs
WNet-6	1 hr
Power consumption	2A at 5 VDC
External power adapter	5VDC

9.3 Physical Characteristics

Size	
Wireless WNet-3 (Excluding Antenna & mating connectors)	156 mm x 82 mm x 19.7 mm (6.15 in x 3.23 in x 0.775 in)
Wireless WNet-6 (Excluding Antenna & mating connectors)	156 mm x 82 mm x 33 mm (6.15 in x 3.22 in x 1.3 in)
Antenna	100 mm (3.9 in)
Weight	
Wireless WNet-3	0.6 lbs (0.27 kg)
Wireless WNet-6	0.6 lbs (0.27 kg)
Mounting	See Section 13—Drawings
Operating ambient Temperature (Non-Charging)	0°C to +50°C (Note: battery runtime may decrease above 35°C ambient).
Battery charging ambient temperature	0°C to +35°C
Storage ambient temperature	-20°C to 45°C
Humidity	85% maximum, non-condensing

9.4 Transducer Inputs

Figure 9.1—8-Pin Connector Female, Transducer Connector

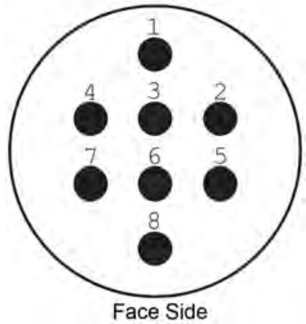


Table 9.1—Transducer Connector Specifications	
Pin Assignments	**Signal**
Pins 1,2,4,5,7,8	Strain gage input
Pin 3	Ground
Pin 6	5V bridge supply (20mA max)
Maximum Ratings	
Absolute maximum strain gage input range	-7 VDC to 7 VDC

9.4.1 Analog Transducer Data Filtering

Figure 9.2 shows the frequency response of the WNet hardware filter. The graph does not include the effects of any mechanical filtering (which occurs in any spring and mass system).

Figure 9.2—WNet Analog Filtering Frequency Response (typical)

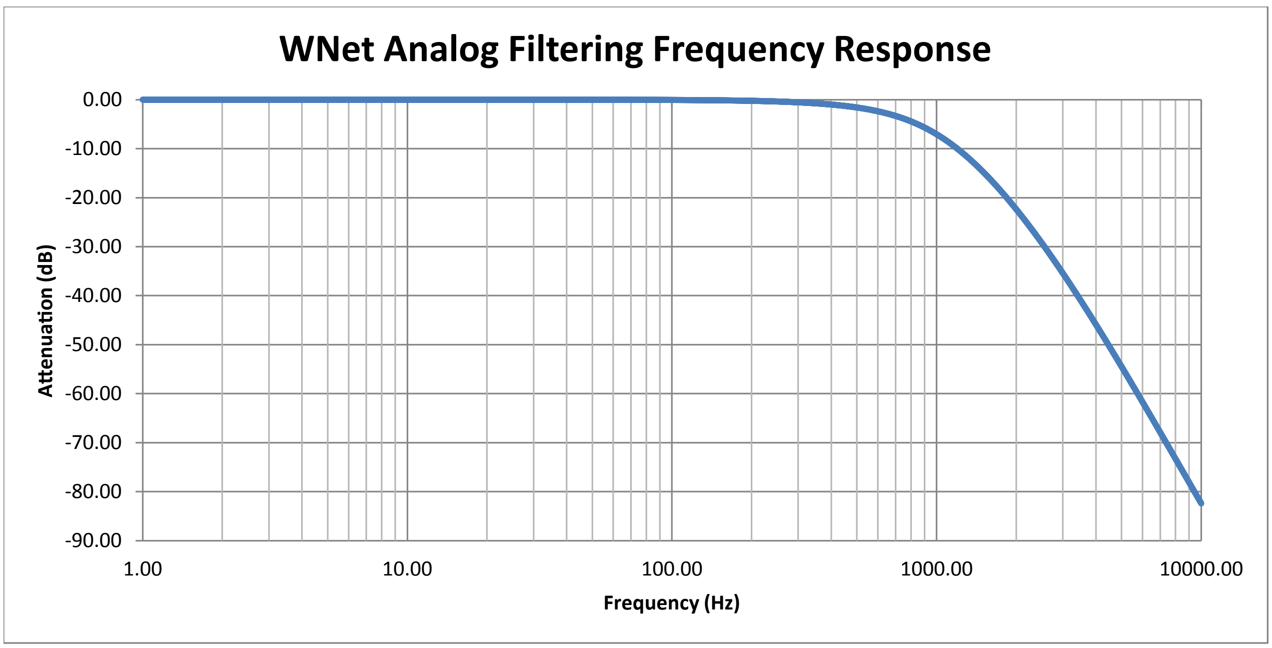
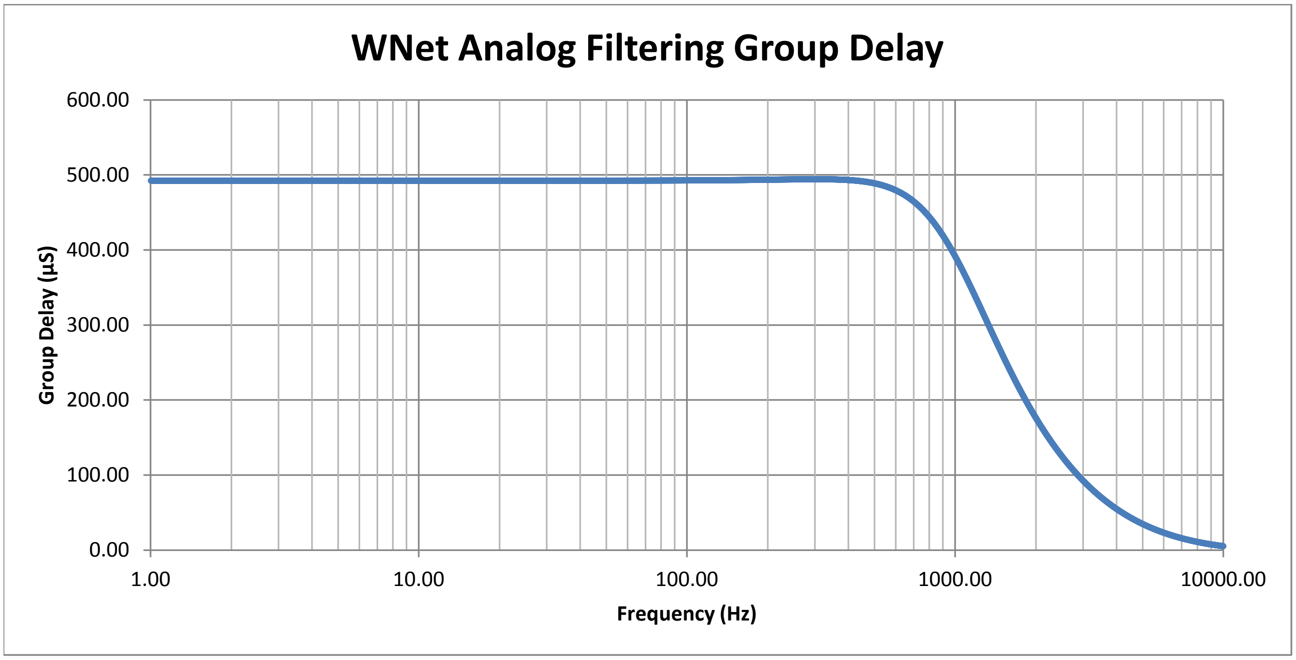


Figure 9.3 shows the group delay of the WNet hardware filter. These delays do not show the wireless delays in your network or computer. The WNet transmits F/T data to a wireless device with a delay of 1333µS with no software filtering enabled.

Figure 9.3—WNet Analog Filtering Group Delays (calculated)



10. Regulatory Information

10.1 FCC Statement

Declaration of Conformity with FCC Rules for Electromagnetic Compatibility

We, ATI Industrial Automation of 1031 Goodworth Drive, Apex, NC 27539, declare under our sole responsibility that the Wireless Multi-Axis Force/Torque Transmitter models, WNET-NA-x, FTWN-NA-x, comply with Part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) this device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

IMPORTANT NOTICE:

Federal Communications Commission Notice

This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at their own expense.

FCC Radiation Exposure Statement

The SAR limit for North America is 1.6 W/kg averaged over one gram of tissue. This product (FCC ID: 2ACKB-9105WNET) has also been tested against this SAR limit. The highest SAR value reported under this standard during product certification for use when properly worn on the body is 1.04 W/kg.

This device was tested for typical body-worn operations with the back of the device kept 0mm from the body. To maintain compliance with IC RF exposure requirements, use accessories that do not contain metallic components in its assembly. The use of accessories that do not satisfy these requirements may not comply with IC RF exposure requirements, and should be avoided.

Modifications

Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

10.2 Canadian Compliance Statement

This device complies with Industry Canada licence-exempt RSS standard(s). Operation is subject to the following two conditions: (1) this device may not cause interference, and (2) this device must accept any interference, including interference that may cause undesired operation of the device.

Le présent appareil est conforme aux CNR d'Industrie Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes : (1) l'appareil ne doit pas produire de brouillage, et (2) l'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.

This device has been designed to operate with the antenna listed below, and having a maximum gain of 2 dBi. Antennas not included in this list or having a gain greater than 2 dBi are strictly prohibited for use with this device. The required antenna impedance is 50 ohms.

- Pulse Electronics wireless external dual band antenna part number W1043

Cet appareil a été désigné pour opérer avec l'antenne listée ci-dessous, et ayant un gain maximal de 2 dBi. Les antennes qui ne sont pas incluses dans cette liste ou qui ont un gain plus de 2 dBi sont strictement interdites d'être utilisées avec cet appareil. L'impédance de l'antenne requise est de 50 ohms.

- Antenne externe bi-bande sans fil, de la compagnie 'Pulse Electronics', numéro de pièce W1043.

IMPORTANT NOTICE:

IC Radiation Exposure Statement

The SAR limit for North America is 1.6 W/kg averaged over one gram of tissue. This product (IC ID: 12098A-9105WNET) has also been tested against this SAR limit. The highest SAR value reported under this standard during product certification for use when properly worn on the body is 1.04 W/kg.

This device was tested for typical body-worn operations with the back of the device kept 0mm from the body. To maintain compliance with IC RF exposure requirements, use accessories that do not contain metallic components in its assembly. The use of accessories that do not satisfy these requirements may not comply with IC RF exposure requirements, and should be avoided.

La limite SAR pour l'Amérique du Nord est de 1,6 W/kg en moyenne par gramme de tissu. Ce produit (ID IC: 12098A-9105WNET) a également été testé contre cette limite SAR.

La valeur SAR la plus élevée signalée sous cette norme lors de la certification du produit pour utilisation quand porté correctement sur le corps est de 1,04 W/kg.

Cet appareil a été testé pour des opérations portables typiques avec l'arrière de l'appareil maintenu à 0 mm du corps. Pour respecter les normes d'exposition RF IC, veuillez utiliser des accessoires qui ne contiennent pas de composants métalliques. L'utilisation d'accessoires ne satisfaisant pas à ces exigences peut ne pas se conformer aux exigences d'exposition RF IC et devrait être évitée.

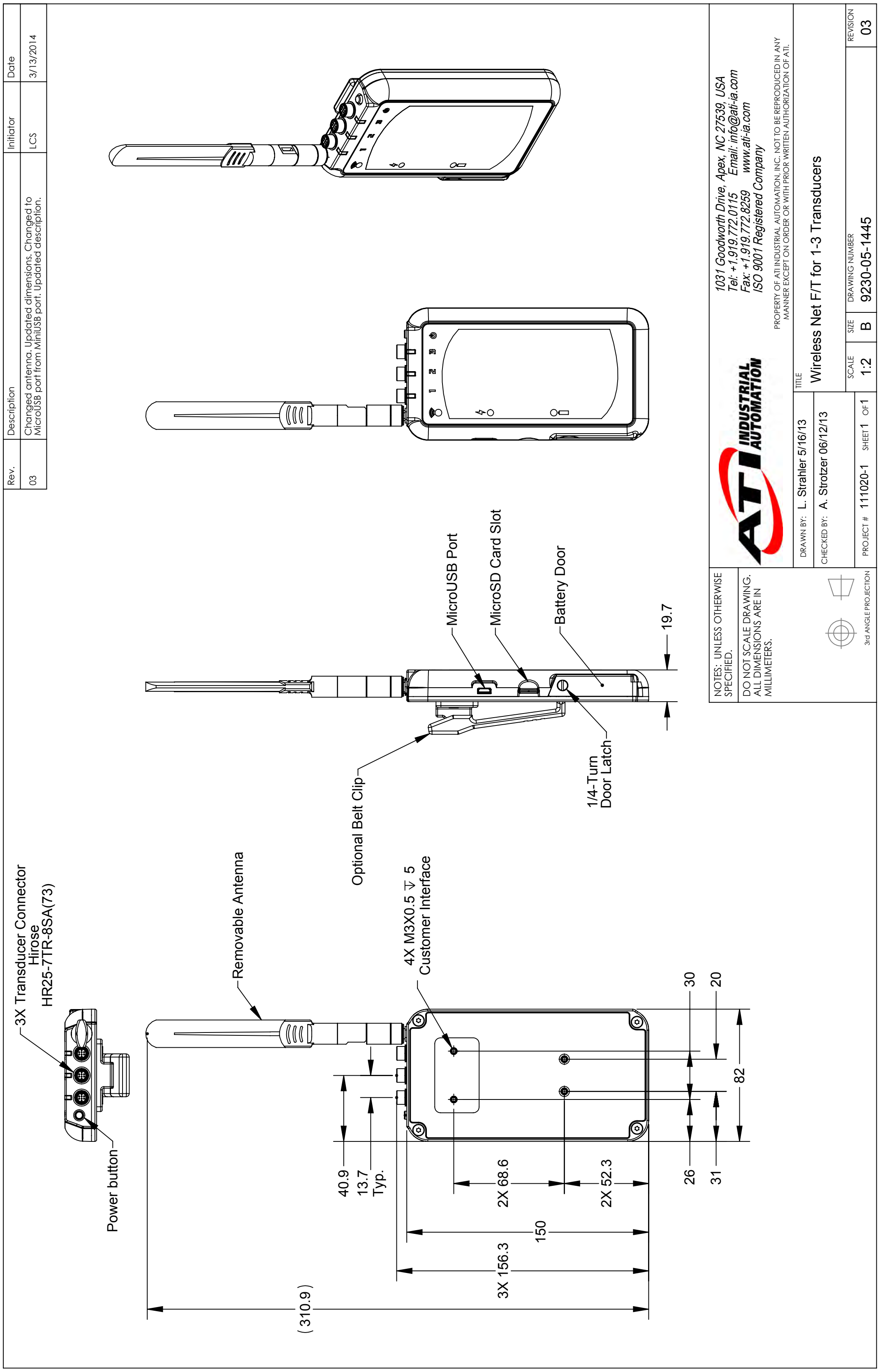
IC Statement

This Class A digital apparatus complies with Canadian ICES-003.

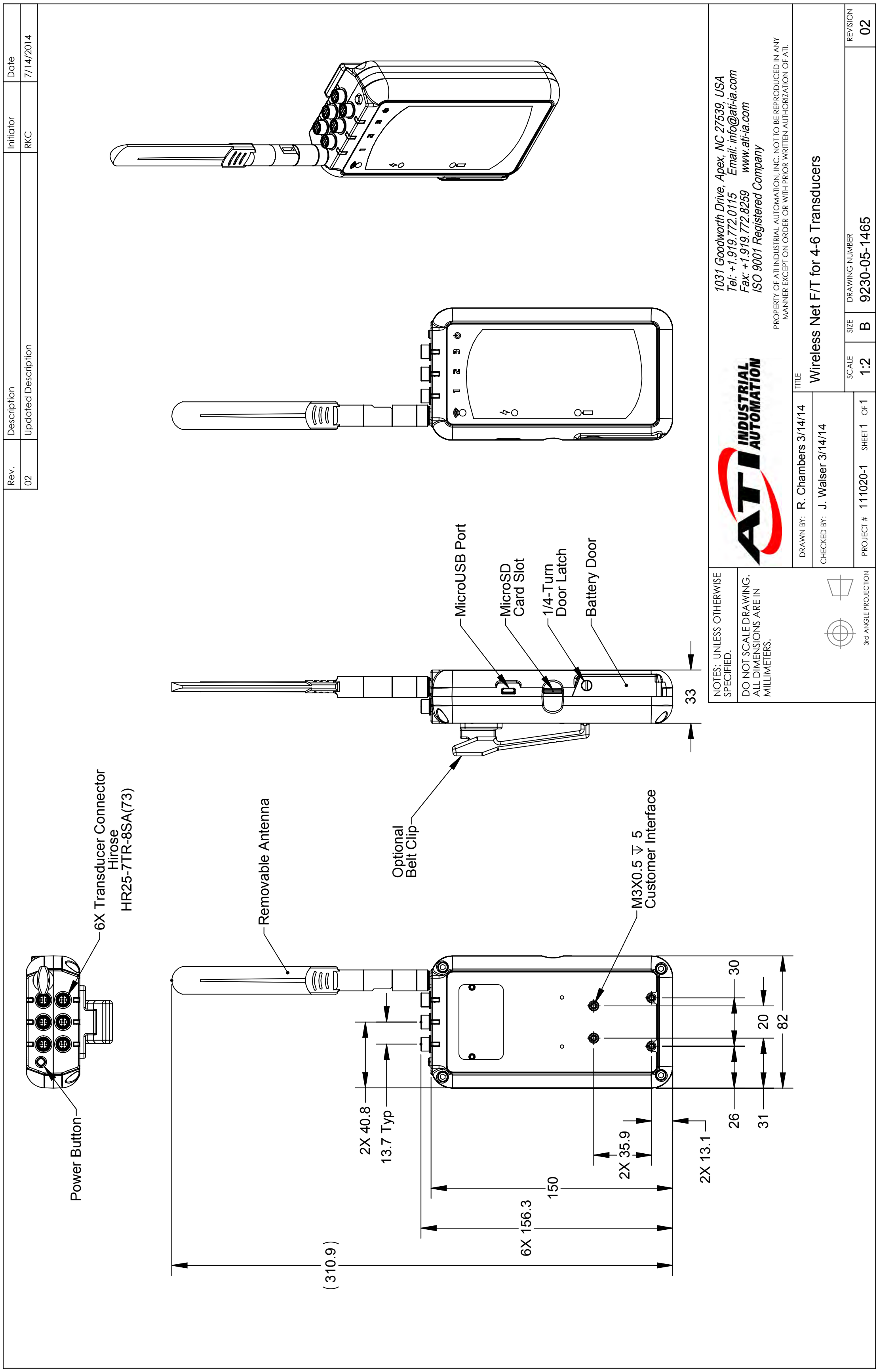
Cet appareil numérique de la classe A est conforme à la norme NMB-003 du Canada.

11. Drawings

11.1 Wireless Net F/T for 3 Transducers



11.2 Wireless Net F/T for 6 Transducers



12. 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.

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 expressed 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 of 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 to maintain the confidentiality of such information.

Appendix A – UDP Command CRC Calculation

All UDP commands sent to the Wireless F/T must include a two-byte CRC (Cyclic Redundancy Check) value. This value is used for error checking the command request and is based on the data in the command structure to be sent.

The following C code performs the calculation of the CRC value. To calculate the value, pass a pointer to the command structure along with the command length in bytes minus two to the function crcBuf().

```
// If FAST is defined, then the CRC is determined using a lookup table instead of
calculations
#define FAST 1

// Both versions use the CRC-16-CCITT polynomial: x^16 + x^12 + x^5 + 1 = 0x11021

#if FAST
unsigned short crcByte(unsigned short crc, unsigned char ch) // lookup table version
(bigger & faster)
{

       static const unsigned short ccitt_crc16_table[256] =
       {

              0x0000, 0x1021, 0x2042, 0x3063, 0x4084, 0x50a5, 0x60c6, 0x70e7,
              0x8108, 0x9129, 0xa14a, 0xb16b, 0xc18c, 0xd1ad, 0xe1ce, 0xf1ef,
              0x1231, 0x0210, 0x3273, 0x2252, 0x52b5, 0x4294, 0x72f7, 0x62d6,
              0x9339, 0x8318, 0xb37b, 0xa35a, 0xd3bd, 0xc39c, 0xf3ff, 0xe3de,
              0x2462, 0x3443, 0x0420, 0x1401, 0x64e6, 0x74c7, 0x44a4, 0x5485,
              0xa56a, 0xb54b, 0x8528, 0x9509, 0xe5ee, 0xf5cf, 0xc5ac, 0xd58d,
              0x3653, 0x2672, 0x1611, 0x0630, 0x76d7, 0x66f6, 0x5695, 0x46b4,
              0xb75b, 0xa77a, 0x9719, 0x8738, 0xf7df, 0xe7fe, 0xd79d, 0xc7bc,
              0x48c4, 0x58e5, 0x6886, 0x78a7, 0x0840, 0x1861, 0x2802, 0x3823,
              0xc9cc, 0xd9ed, 0xe98e, 0xf9af, 0x8948, 0x9969, 0xa90a, 0xb92b,
              0x5af5, 0x4ad4, 0x7ab7, 0x6a96, 0x1a71, 0x0a50, 0x3a33, 0x2a12,
              0xdbfd, 0xcbdc, 0xfbbf, 0xeb9e, 0x9b79, 0x8b58, 0xbb3b, 0xab1a,
              0x6ca6, 0x7c87, 0x4ce4, 0x5cc5, 0x2c22, 0x3c03, 0x0c60, 0x1c41,
              0xedae, 0xfd8f, 0xcdec, 0xddcd, 0xad2a, 0xbd0b, 0x8d68, 0x9d49,
              0x7e97, 0x6eb6, 0x5ed5, 0x4ef4, 0x3e13, 0x2e32, 0x1e51, 0x0e70,
              0xff9f, 0xefbe, 0xdfdd, 0xcffc, 0xbf1b, 0xaf3a, 0x9f59, 0x8f78,
              0x9188, 0x81a9, 0xb1ca, 0xa1eb, 0xd10c, 0xc12d, 0xf14e, 0xe16f,
              0x1080, 0x00a1, 0x30c2, 0x20e3, 0x5004, 0x4025, 0x7046, 0x6067,
              0x83b9, 0x9398, 0xa3fb, 0xb3da, 0xc33d, 0xd31c, 0xe37f, 0xf35e,
              0x02b1, 0x1290, 0x22f3, 0x32d2, 0x4235, 0x5214, 0x6277, 0x7256,
              0xb5ea, 0xa5cb, 0x95a8, 0x8589, 0xf56e, 0xe54f, 0xd52c, 0xc50d,
              0x34e2, 0x24c3, 0x14a0, 0x0481, 0x7466, 0x6447, 0x5424, 0x4405,
              0xa7db, 0xb7fa, 0x8799, 0x97b8, 0xe75f, 0xf77e, 0xc71d, 0xd73c,
              0x26d3, 0x36f2, 0x0691, 0x16b0, 0x6657, 0x7676, 0x4615, 0x5634,
              0xd94c, 0xc96d, 0xf90e, 0xe92f, 0x99c8, 0x89e9, 0xb98a, 0xa9ab,
              0x5844, 0x4865, 0x7806, 0x6827, 0x18c0, 0x08e1, 0x3882, 0x28a3,
              0xcb7d, 0xdb5c, 0xeb3f, 0xfb1e, 0x8bf9, 0x9bd8, 0xabbb, 0xbb9a,
              0x4a75, 0x5a54, 0x6a37, 0x7a16, 0x0af1, 0x1ad0, 0x2ab3, 0x3a92,
              0xfd2e, 0xed0f, 0xdd6c, 0xcd4d, 0xbdaa, 0xad8b, 0x9de8, 0x8dc9,
              0x7c26, 0x6c07, 0x5c64, 0x4c45, 0x3ca2, 0x2c83, 0x1ce0, 0x0cc1,
              0xef1f, 0xff3e, 0xcf5d, 0xdf7c, 0xaf9b, 0xbfba, 0x8fd9, 0x9ff8,
              0x6e17, 0x7e36, 0x4e55, 0x5e74, 0x2e93, 0x3eb2, 0x0ed1, 0x1ef0

       };

    return ccitt_crc16_table[((crc >> 8) ^ ch) & 0xff] ^ (crc << 8);
}
```

```
#else
unsigned short crcByte(unsigned short crc, unsigned char ch) // direct calculation
version (smaller & slower)
{
        unsigned short crc_new = (unsigned char)(crc >> 8) | (crc << 8);
        crc_new ^= ch;
        crc_new ^= (unsigned char)(crc_new & 0xff) >> 4;
        crc_new ^=  crc_new         << 12;
        crc_new ^= (crc_new & 0xff) <<  5;
        return crc_new;
}
#endif

#define CRC_INIT 0x1234 // this is the seed value used for along with the buffer's
first byte
unsigned short crcBuf(const void * buff, unsigned long len)
{
        unsigned long  i;
        unsigned short crc = CRC_INIT;
        const char * buf = buff;

        for(i = 0; i < len; i++)
        {
                crc = crcByte(crc, buf[i]);
        }

        return crc;
}
```

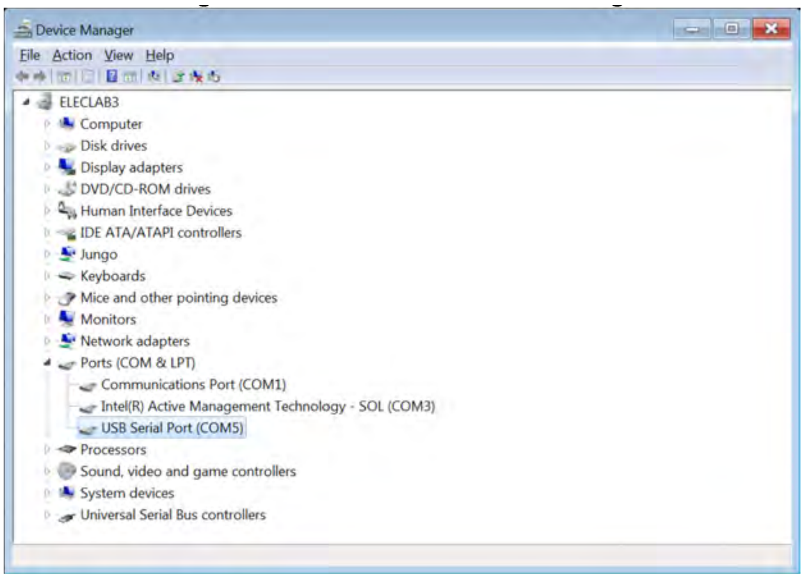
Appendix B – Initial Configuration Using a Telnet Progam (PuTTY)

B.1 Initial Configuration Using a Telnet Program

The Wireless F/T must be configured before communicating with the device. The following procedure will help provide steps to configure the Wireless F/T.

1. Install Virtual Communication Port Driver from the following website: http://www.ftdichip.com/Support/Documents/InstallGuides.htm
   Select the instructions for the operating system running on the computer being used to configure the wireless F/T system. Follow the instructions to load the device driver on the computer.
2. Find the serial port number used by the Wireless unit by opening Device Manager (you can get to it by typing “Device Manager” in the Windows 7 Start Menu search bar), expanding the “Ports (COM & LPT)” section, and finding a connection labeled “USB Serial Port (COMx)” If there’s more than one serial port, you may have to disconnect the USB cable and see which COM port is removed in the device manager, then reconnect the USB cable. The example in Figure 5.2 shows Wireless F/T is connected to COM5.

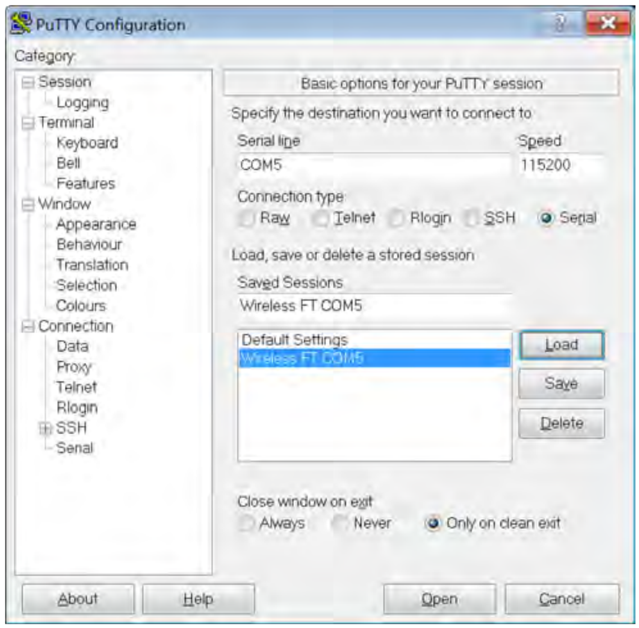
Figure 14.1—Windows 7 Device Manager



3. Install a telnet terminal program like PuTTY. Visit http://putty.org to download the executable file (putty.exe) for the PuTTY program.
4. Open (PuTTY) terminal program by clicking on the (putty) icon and selecting Run from the pop up window.

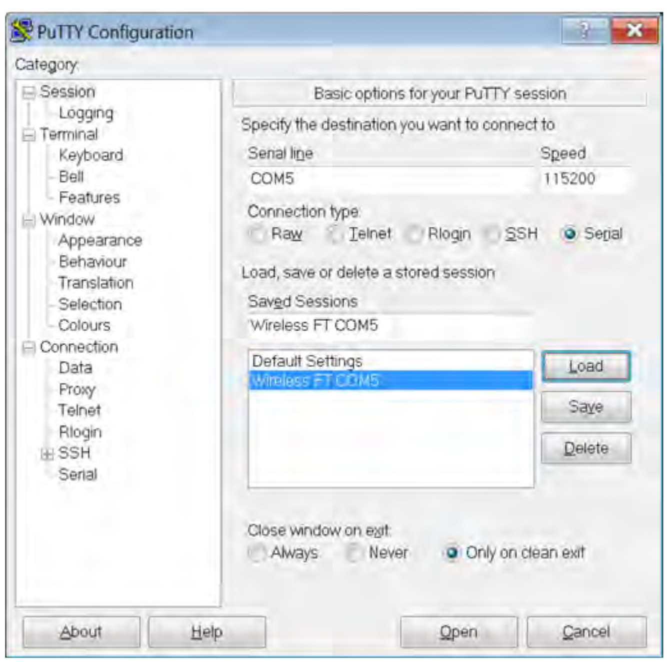
5. In the Category pane click on Connection > Serial and fill in the following fields:
    - Serial line to connect to COM5 (Enter the Com port the Wireless unit is using)
    - Speed (baud) 115200
    - Data bits 8
    - Stop bits 1
    - Parity None
    - Flow control None

Figure 14.2—PuTTy Terminal Program



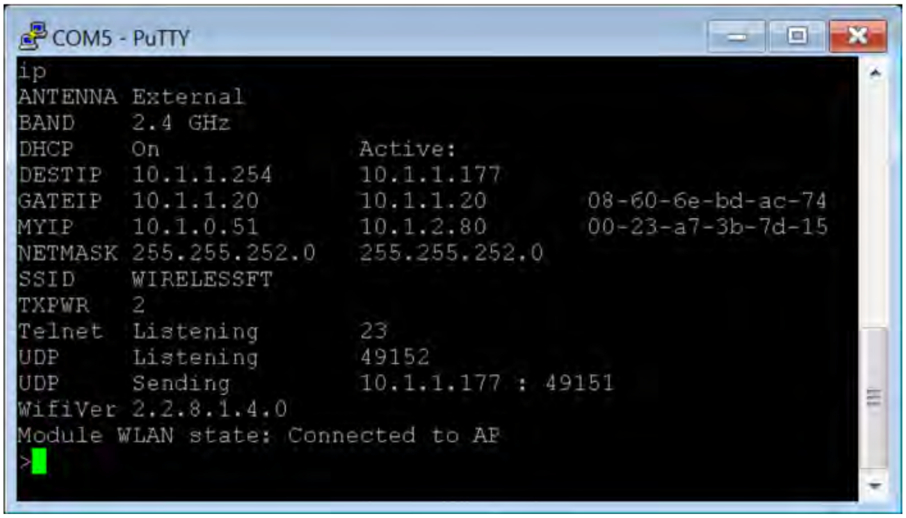
6. In the Category pane click on Session, The Serial Line should now be the COM port and Speed should be the values entered in the previous step. In the Saved Sessions field enter Wireless FT COM5 and select save. This will allow you to use this configuration at another time.

Figure 14.3—PuTTY Configuration



7. Connect to the console, e.g. by pressing "Open" in PuTTy. Information will appear as the unit attempts to connect to a wireless network.
8. In the COMx – PuTTY Window type "d" and press Enter key.
9. In the COMx – PuTTY Window type "t" and press Enter key. (Turns off the wireless connection on the unit).
10. Test that the unit is working by entering "IP" followed by the Enter key. This is the IP command, and will present the current IP settings. Refer to the following example screen.

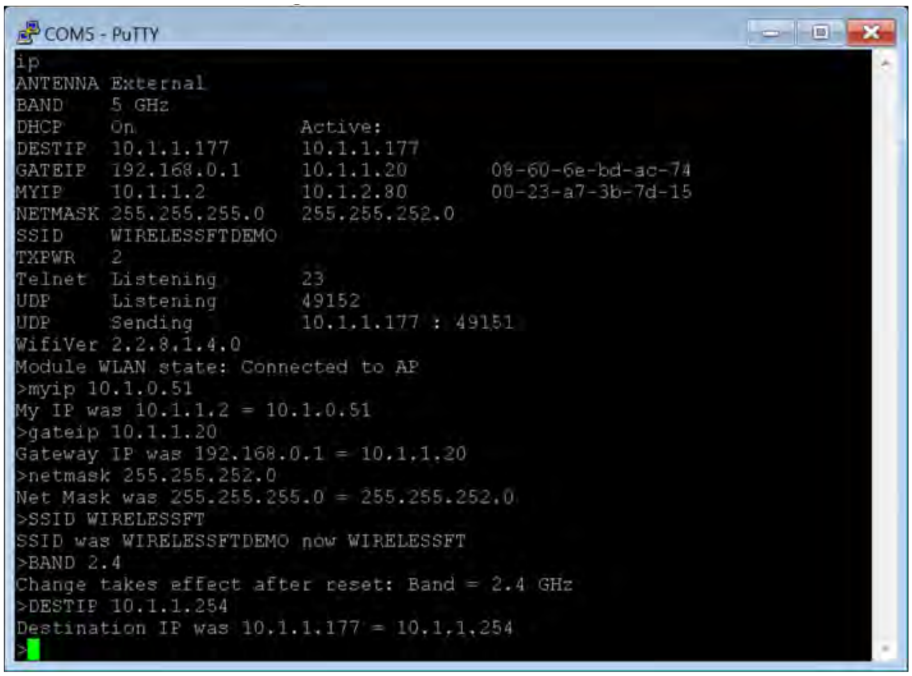
Figure 14.4—Test the Connection



11. Obtain the following information from your network administrator: IP Address to use for the unit, Subnet Mask, Default Gateway, SSID, whether the Wi-Fi network operates on 2.4 or 5 gigahertz spectrum, IP address of the computer you're using to communicate with the unit.

12. Enter these commands in any order: (Commands are not case sensitive except where indicated)
    j. “MYIP <unitip>”, e.g. “MYIP 192.168.1.50”
    k. “NETMASK <subnetmask>”
    l. “GATEIP <defaultgateway>”
    m. “SSID <ssid>” Network<ssid> (Is case sensitive)
    n. “BAND <x>” where x is “2.4” for 2.4 gigahertz or “5” for 5 gigahertz.
    o. “DESTIP <yourcomputersip>”

Figure 14.5—Test the Connection



13. Enter the “SAVEALL” command followed by the “RESET” command for the new settings to take effect.
14. Close the terminal program.
15. Press the On/Off switch for two seconds to power down. Then press again to power up. After initialization the unit will connect to the wireless network and begin streaming data.
16. Disconnect the USB cable from the Wireless F/T unit and the computer.

Appendix C– Sampling other signals using Wireless F/T inputs

C.1 Introduction

This appendix explains how to sample arbitrary analog or digital signals using transducer inputs on a Wireless F/T interface. These requirements include design of a signal conditioning circuit and calibration of the Wireless F/T inputs for analog signal sampling. This feature could be used to help synchronize F/T data with other sensors by using an empty transducer input to record a digital trigger signal.

C.2 Definitions

Internal Calibration – Wireless F/T analog signal calibration using only internal voltage references.

External Calibration – Wireless F/T analog signal calibration using external voltage references.

C.3 Wireless F/T Digital Input Sampling

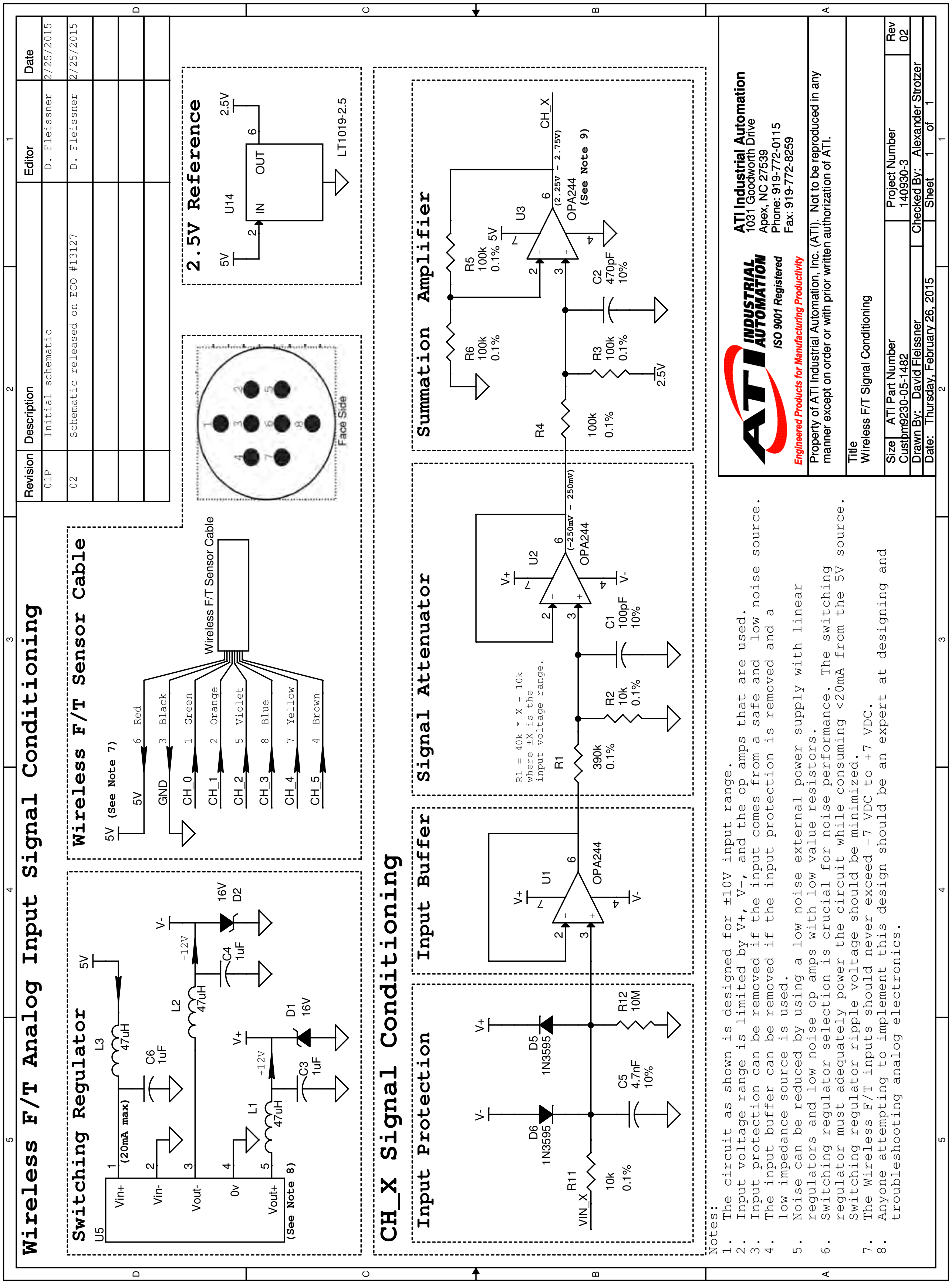
Wireless F/T inputs can safely handle 3.3V or 5V logic signals. These signals will saturate the ADC and provide basic digital signal readings. The Wireless F/T amplifier electronics include a 2nd order 1kHz low-pass filter which will restrict usable digital signals to ~250 Hz.

C.4 Wireless F/T Analog Input Sampling

In order to sample an analog signal using a Wireless F/T you will probably need a signal conditioning circuit. The signal conditioning circuit must be designed to meet the requirements listed in *Table 16.1*. The following page shows an example signal conditioning circuit designed to take ±10 VDC in and output 2.5 VDC ±250 mVDC. The voltage data output by the Wireless F/T will not include the 2.5V input offset.

Table 16.1— Wireless F/T Input Specifications	
Absolute Maximum Input Voltage	See *Table 9.1*
Nominal Input Voltage	2.5 VDC
Maximum Full Scale Input Signal Range	2.5 VDC ±250 mVDC
Minimum Full Scale Input Signal Range	2.5 VDC ±30 mVDC
Input Impedance	5 MΩ
5V Supply Maximum Current	20mA
Note: 1. Exceeding this input voltage range could irreparably damage the Wireless F/T internal electronics.	

Figure 16.1—Rotating Reference Frame

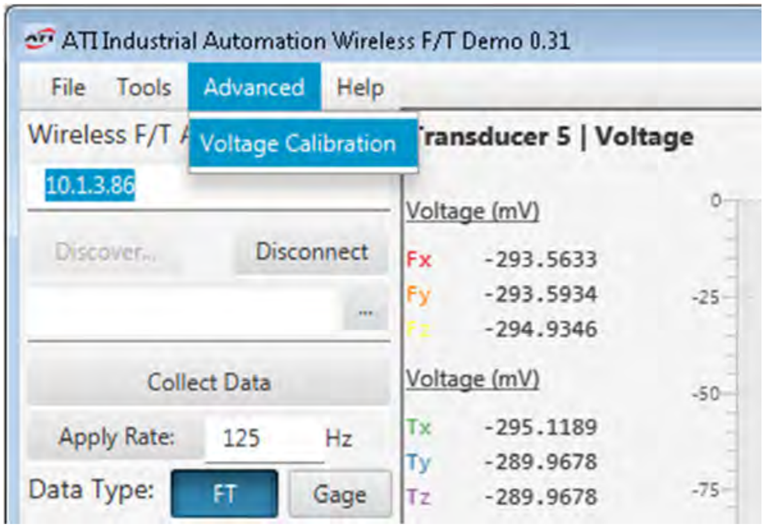


C.5 Wireless F/T Analog Input Calibration

Calibrating the Wireless F/T to read in an analog voltage can be performed using the Wireless F/T Java demo. Calibration slot 3 will be pre-calibrated by ATI using the Internal Calibration method below.

Access the Voltage Calibration window in the Java demo by going to Advanced->Voltage Calibration.

Figure 16.2—Access the Voltage Calibration Window



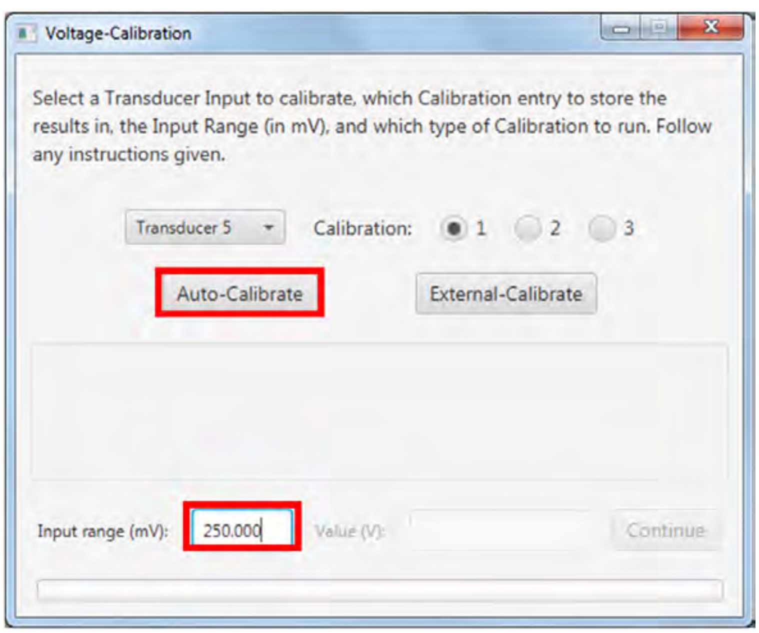
The Wireless F/T Java demo offers two methods to perform an analog input calibration:

C.5.1 Internal Calibration

The internal calibration method is performed only using the internal voltage references in the Wireless F/T. This calibration method is as simple as the press of a button and does not require external calibration equipment. However, expect some amount of gain error (±1% is common) when using the internal calibration method.

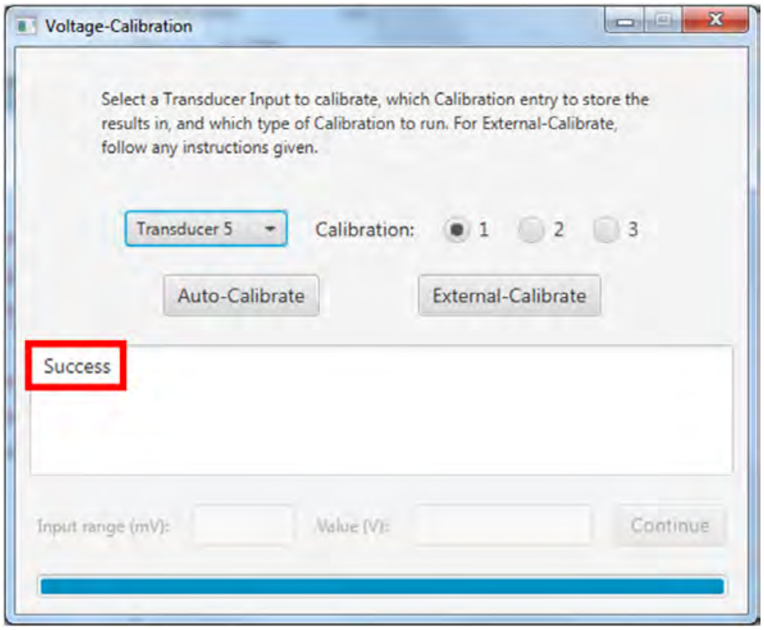
1. From the Voltage-Calibration window in the Wireless F/T Java demo click on the Auto-Calibrate button. The input range can be set using the Input Range box at the bottom of the window.

Figure 16.3—Set Input Range - Internal Calibration



2. Once the internal calibration is complete, close the Voltage-Calibration window, apply your 2.5V reference to the inputs of the Wireless F/T, and bias the transducer input you just calibrated.

Figure 16.4—Apply the Input Range - Internal Calibration

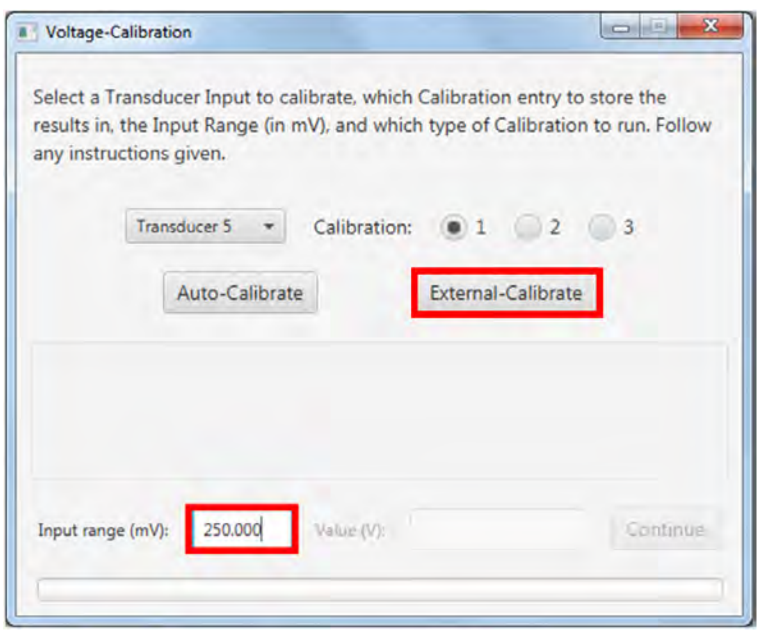


C.5.2 External Calibration

The external calibration method is performed by using external voltage references to calibrate the Wireless F/T inputs. This calibration method is more difficult to set up than the internal calibration but results in a more accurate calibration. The accuracy of this calibration method is primarily limited by the stability and accuracy of the external reference voltages.

1. From the Voltage-Calibration window in the Wireless F/T Java demo click on the External-Calibrate button. The input range can be set using the Input Range box at the bottom of the window.

Figure 16.5—Set Input Range - External Calibration



2. Follow the instructions given in the Voltage-Calibration window.

Figure 16.6—Select a Transducer to Calibrate - External Calibration

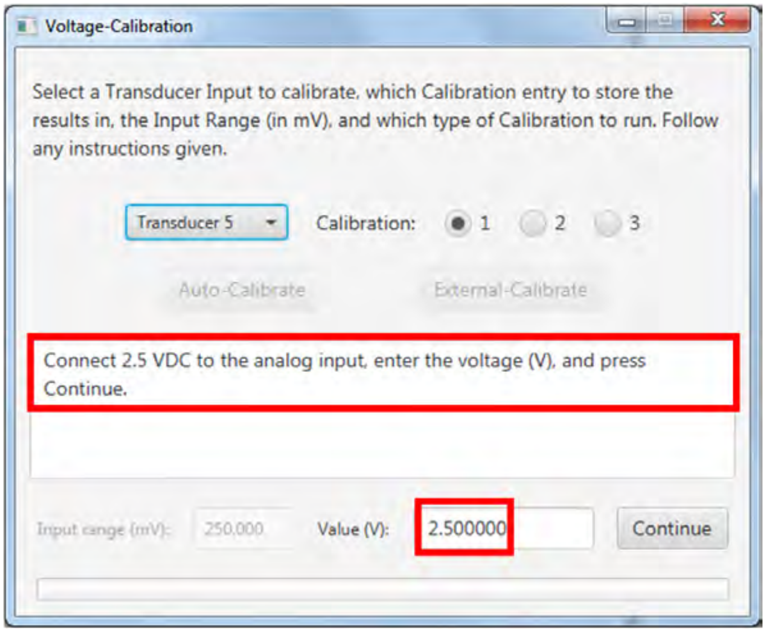
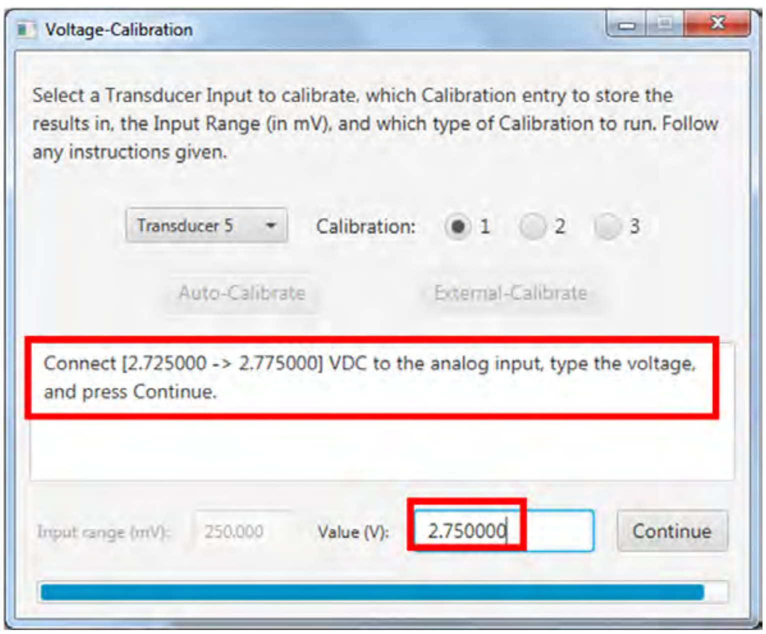
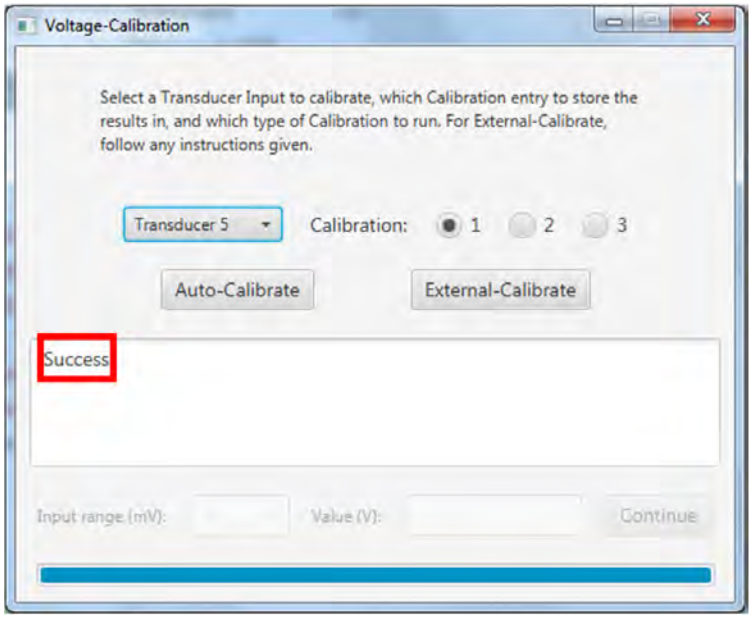


Figure 16.7—Select a Transducer Input to Calibrate - External Calibration



3. Once the external calibration is complete, close the Voltage-Calibration window, apply your 2.5V reference to the inputs of the Wireless F/T, and bias the transducer input you just calibrated. See the Wireless F/T manual for more details about biasing a transducer input.

Figure 16.8—Apply the Input Range - External Calibration



C.6 Troubleshooting

Figure 16.9— Troubleshooting		
Symptom	**Possible Cause**	**Correction**
Excessive noise	Too much power supply ripple	Use power supply with lower ripple voltage
	Op amps oscillating	Place ceramic decoupling capacitors near op amp supply pins
5V supply from Wireless F/T turns off unexpectedly	Drawing >20mA from 5V supply	Use power supply with higher efficiency at small loads
		Use 2.5V reference with lower supply current
		Use op amps with lower supply current
		Use external supply with higher current limit
Unexpected readings after calibration	Transducer input has not been biased	Bias transducer input with 2.5V reference connected to input
	External calibration had invalid input voltage	Repeat external calibration. Internal calibration can also be used to verify all hardware.

F/T Transducer

Six-Axis Force/Torque Sensor System

Installation and Operation Manual

Document #: 9620-05-Transducer Section

March 2016

Engineered Products for Robotic Productivity

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Foreword

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FCC Compliance - Class A

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

CE Conformity CE

CTL Transducers

This device complies with EMC Directive 89/336/EEC and conforms to the following standards:
EN50081-1:1992, EN50082-1:1992, CISPR 22:1993 (EN55022:1994), IEC 1000-4-2:1995,
IEC 1000-4-3:1995, IEC 1000-4-4:1995

DAQ Transducers

This device complies with EMC Directive 89/336/EEC and conforms to the following standards:
EN55011:1998, ANSI C63.4:1992, EN61000-4-2:1995, EN61000-4-3:1995, EN61000-4-4:1995,
EN61000-4-6:1995.

Net F/T Transducers

This device complies with EMC Directive 2004/108/EC and conforms to the following standards:
EN61326:1997+A1:1998+A2:2000,EN55022:1998_A1:2000+A2:2003,
EN61000-4-2:1995+A1:1998+A2:2001, EN61000-4-3:2000, EN61000-4-4:2004,
EN610000-4-5:1995+A1:1996, EN61000-4-6:1996+A1:2001, EN61000-4-8:1995, EN61000-4-11:2001.

TWE Transducers

This device complies with EMC Directive 89/336/EEC and conforms to the following standards:
EN50081-1:1992, EN50082-1:1992, CISPR 22:1993 (EN55022:1994), IEC 1000-4-2:1995,
IEC 1000-4-3:1995, IEC 1000-4-4:1995

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

Sale, Service and Information about ATI products:

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

Table of Contents

Glossary of Terms

Accuracy	See Measurement Uncertainty.
ActiveX Component	A reusable software component for the Windows applications.
Calibration	The act of measuring a transducer's raw response to loads and creating data used in converting the response to forces and torques.
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.
Compound Loading	Any load that is not purely in one axis.
Coordinate Frame	See Point of Origin
DAQ	Data Acquisition device.
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.
DoF	Degrees of Freedom. See Six Degrees of Freedom.
Force	The push or pull exerted on an object.
FS	Full-Scale
F/T	Force and Torque.
F/T Controller	The electronics that connect to mux transducers.
Fxy	The resultant force vector comprised of components Fx and Fy.
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).
HTC	Fasteners Temperature Compensation. This is a method of improving the temperature performance of transducers. Usually this refers to span temperature compensation. Sometimes it also includes offset temperature compensation. HTC is better than STC.
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
LabVIEW	A graphical programming environment created for data acquisition tasks by National Instruments.
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.
MAP	Mounting Adapter Plate. The transducer's MAP attaches to the fixed surface or robot arm.
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	Short for multiplexer. F/T Controller Sensor Systems use mux electronics to interface to the transducer signals.
Mux Box	A box that holds mux electronics for transducers that are too small for on-board electronics.
Net F/T	An F/T Sensor System that connects to the customer's monitoring equipment via Ethernet or CAN bus or DeviceNet.
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.
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.
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.
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. Our transducers sense reaction torque.
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.
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. Our 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-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.
Six Degrees of Freedom	Fx, Fy, Fz, Tx, Ty and Tz.
Span Compensation	Correction of errors that affect the sensitivity of a transducer.
STC	Software Temperature Compensation. A method of improving temperature performance of transducers. This method is not as good as HTC.
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.
Visual Basic	A Microsoft programming environment for developing Windows-based applications.

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 transducer specifications in *Section 5—Transducer Specifications* of this manual or contact ATI for assistance. Particular attention should be paid to dynamic loads caused by robot acceleration and deceleration. These forces can be many times the value of static forces in high acceleration or deceleration situations.

1.3 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

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 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). Force/Torque sensors are used throughout industry for product testing, robotic assembly, grinding, and polishing. In research, our sensors are used in robotic surgery, haptics, rehabilitation, neurology, and many others applications.

3. Installing the Transducer

This section will provide information on the environment, transducer IP rating, mounting the transducer, and routing the transducer cable.

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. Refer to *Section 4.1—Accuracy over Temperature* for information on the transducer's temperature performance.

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 your device covers the mounting fasteners used to connect the transducer, you will not be able to use the removable adapter plate alone. If this is the case a user designed interface plate will be needed between the transducer and the robot or other device. Refer to *Section 3.2.1—Interface Plate Design* for more details.. Refer to *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. Refer to *Section 3.2.1—Interface Plate Design* for more details. Refer to *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. This will cause irreparable damage to the transducer and void the warranty. Leave all fasteners in place and do not disassemble the transducer.

Refer to the product drawings in *Section 5—Transducer Specifications* to determine if the adapter plate is removable for our transducer. 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 will be required. Custom interface plates are available from ATI upon request.

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

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

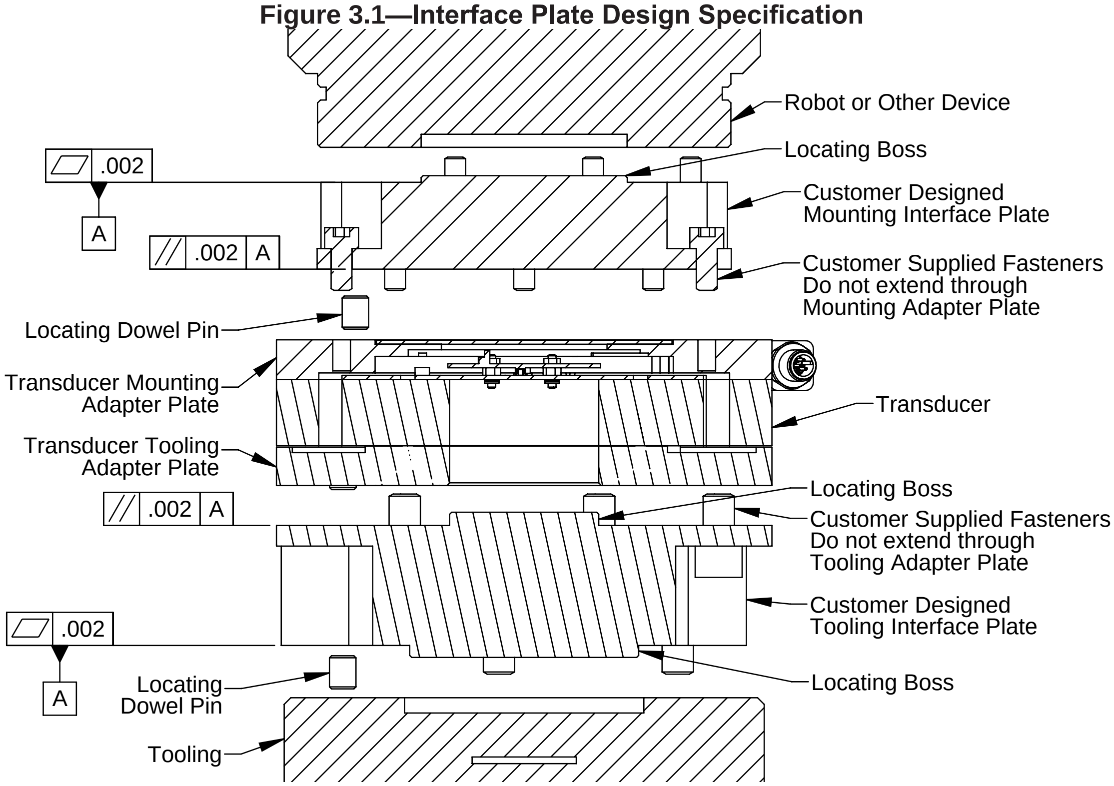
The transducer tooling adapter plate is factory installed and the bolt circle is shown with the transducer in *Section 5—Transducer Specifications*. Most large F/T tool adapters follow the ISO 9409-1 mounting pattern. Machine the tooling interface plate to attach to this bolt circle.

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 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.

If the customer chooses to design and build an mounting or tooling interface plate, the following should be considered:

- 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. Refer to *Section 5—Transducer Specifications* for thread depth, mounting patterns, and other details.
- 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. Refer to *Section 5—Transducer Specifications* for specifications.
- The interface plate design must provide a flat and parallel mounting surface for the transducer. Refer to *Figure 3.1*.

Figure 3.1—Interface Plate Design Specification



3.2.2 Mounting the Transducer with a Removable Mounting Adapter Plate

Check to see if when mounting the transducer to the robot or other device you will have access to the mounting screws for attaching the transducer. If not, a user designed interface plate will be needed on one or both sides of the transducer, refer to *Section 3.2.1—Interface Plate Design* for details in designing an interface plate before continuing with this procedure.

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

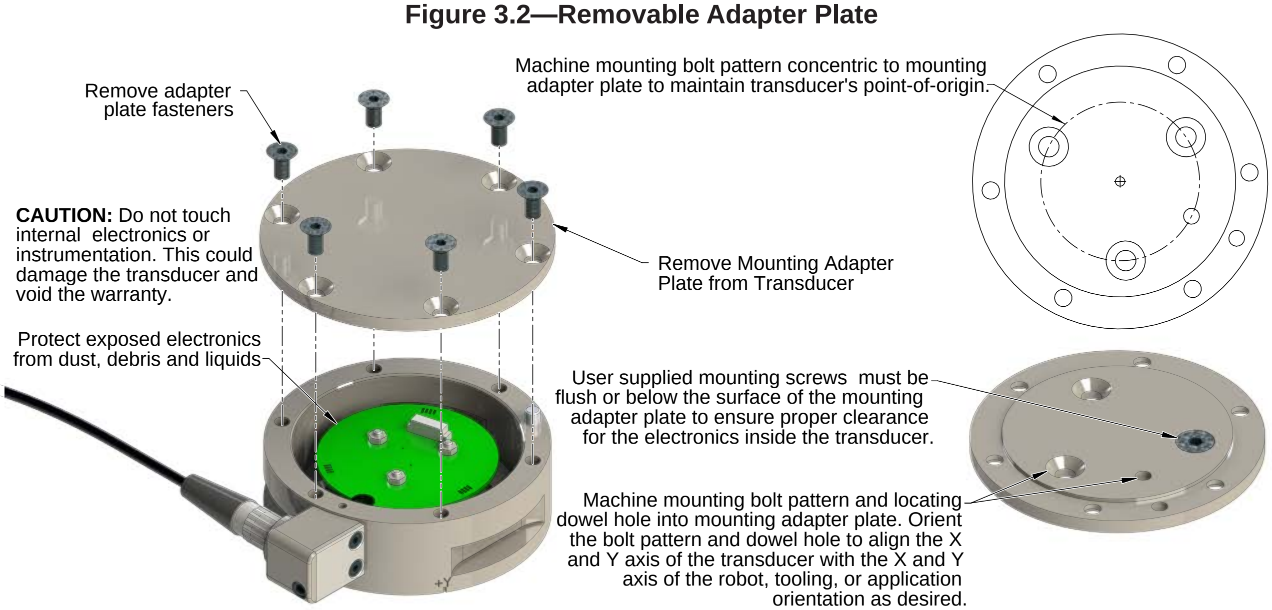
CAUTION: Do not touch internal electronics or instrumentation. This could damage the transducer and void the warranty. When the adapter plate is removed protect the exposed electronics from dust, debris, liquids, and other foreign objects.

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 machining their own interface patterns should avoid concentrating all mounting features in the center of the adapter plate. A larger bolt circle will provide the most accurate readings as it will induce 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*.

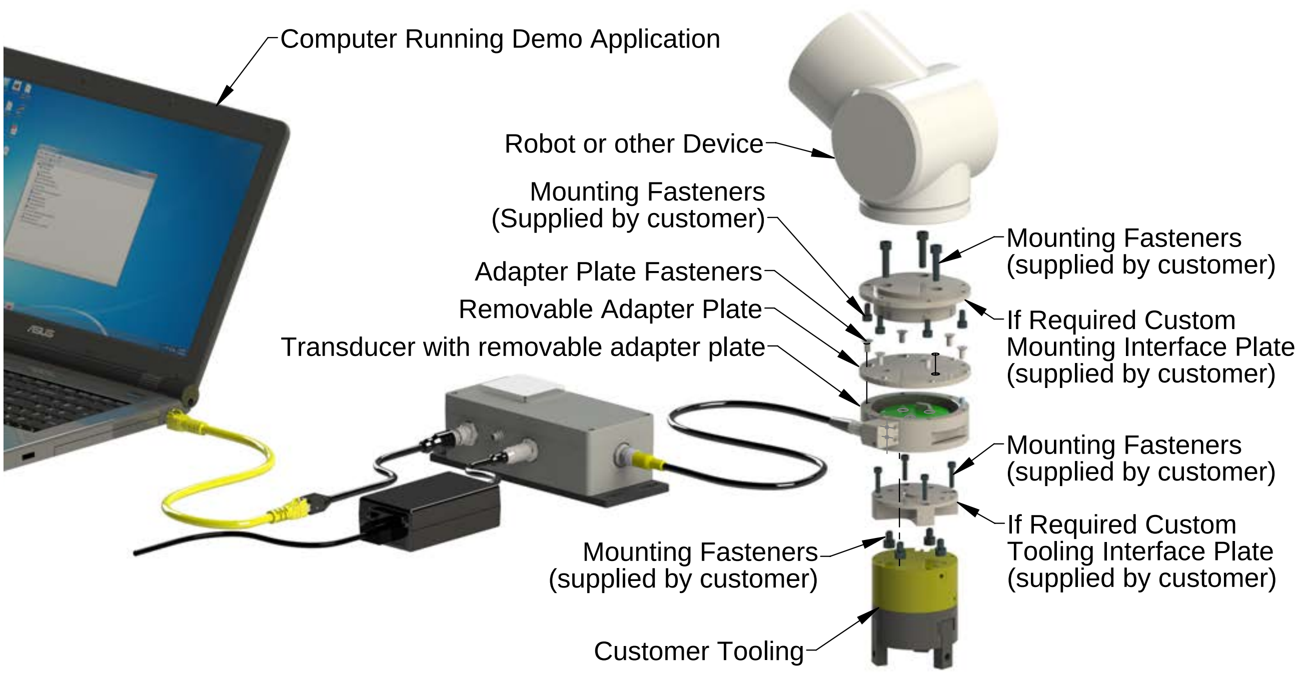
5. Attach the transducer to the removable adapter plate, hand tighten fasteners.

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. Smaller transducers can easily be irreparably damaged by applying small loads using tools (moment arm increases applied loads) when mounting the transducer. Always monitor the transducer using the demo application for gage saturation errors during installation. 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 before continuing 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. 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.

3.2.3 Mounting the Transducer with a Non-removable Adapter Plate

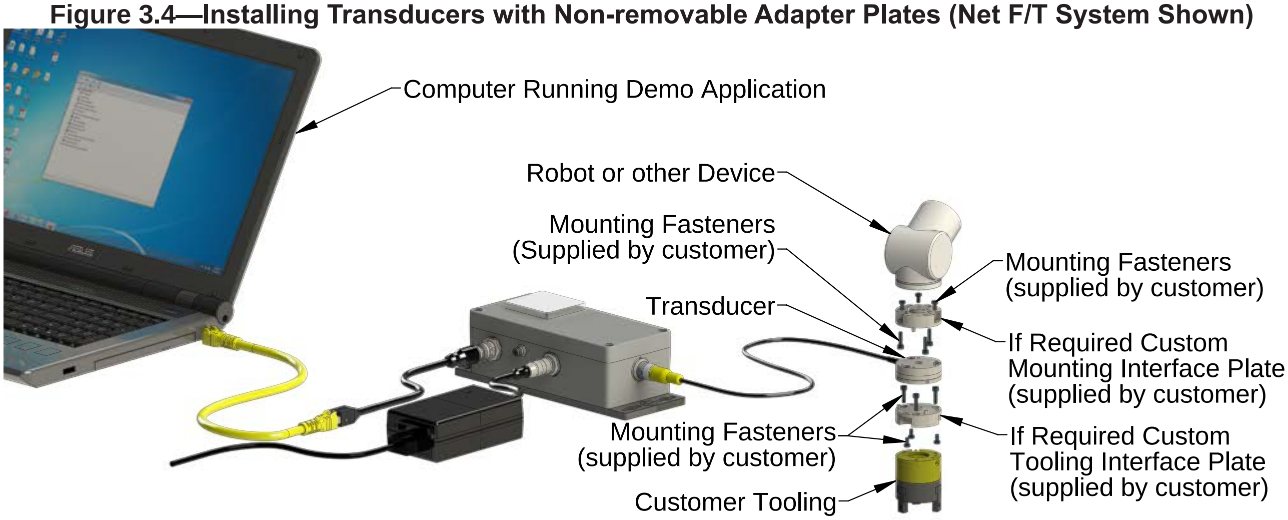
CAUTION: Do not attempt to drill, tap, machine, or otherwise modify or disassemble the transducer. This could damage the transducer and will void the warranty. Use the mounting bolt pattern provided to attach the transducer to the robot or other device and to mount the tool to the transducer. See the 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 and damage the electronics, voiding the warranty. Use fasteners that provide the customer interface depth specified for the transducer. Refer to the transducer drawing.

CAUTION: Do not exceed the single-axis overload value of the transducer. Smaller transducers can easily be irreparably damaged by applying small loads using tools (moment arm increases applied loads) when mounting the transducer. Always monitor the transducer using the demo application for gage saturation errors during installation. 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. 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.
2. Mount transducer to 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)



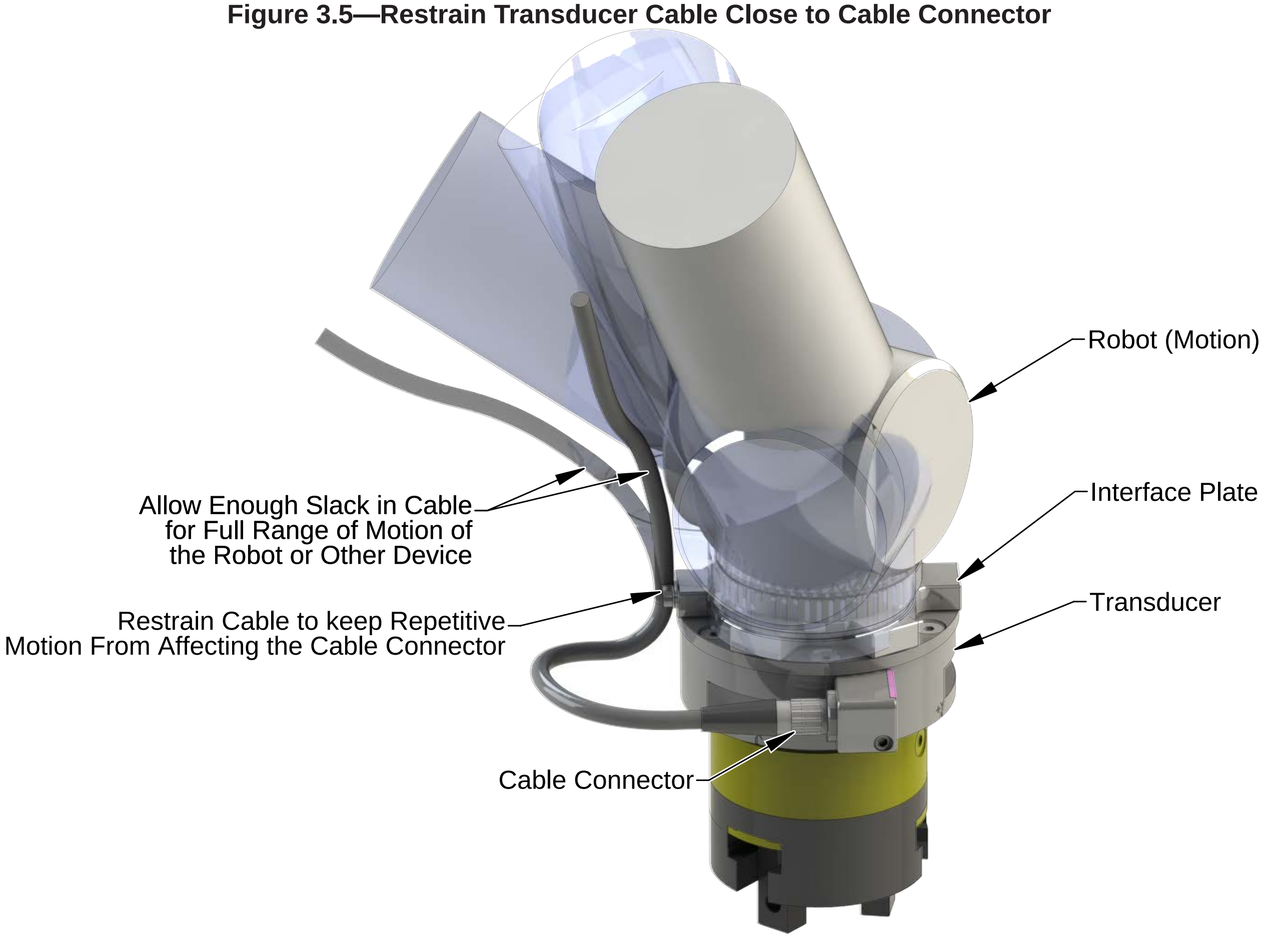
NOTICE: The tool may not touch any other part of the transducer except the tool mounting surface. If the tool touches any other part of the transducer it will not properly sense loads. Make sure the tool mounts to the tool mounting surface and does not touch any other part of the transducer.

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 transducer can be used in a variety of applications that will affect how best to route the cable and determine the proper bending radius to use. Some applications will allow the transducer and the cable to remain in a static condition. Some applications require the transducer to be in a dynamic condition that requires the cable to be subjected to repetitive motion. 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

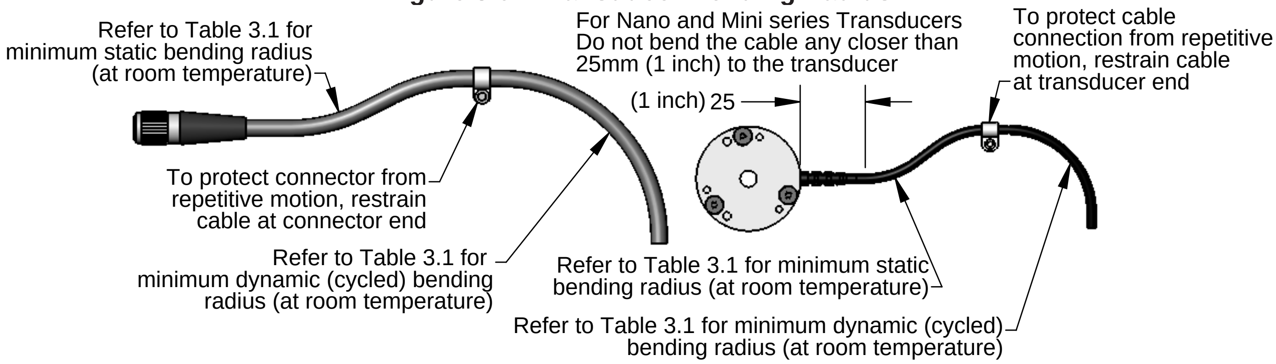


Table 3.1—Transducer Cable Bending Radius

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 will affect cable flexibility. ATI recommends increasing the minimum dynamic bending radius for lower temperatures.

The transducer cable must be routed 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 your system.

4. Topics

4.1 Accuracy over Temperature

Typical gain errors introduced over temperature for F/T transducers with fasteners temperature compensation are listed below. These changes in sensitivity are independent of the transducer's rated accuracy at room temperature; the two accuracy ratings must be added 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, a reference reading should be taken or bias function executed 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 will 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 - Non-IP-Rated

Transducer Model Series	Storage	Operation	Units
9105-TIF Transducer	-25 to +85	-25 to +85	°C
9105-TW Transducer	-40 to +100	-40 to +100	°C
9105-TW-…-H Transducer	-25 to +85	-25 to +85	°C
9105-T Transducer	-20 to +80	0 to +70	°C
9105-NET Transducer	-40 to +85	-40 to +85	°C

Note: These temperature ranges specify the storage and operation ranges in which the transducer can survive without damage. They do not take accuracy into account.

Table 4.4—Transducer Temperature Ranges - IP60, IP65, and IP68

Transducer Model Series	Storage	Operation	Units
9105-TIF Transducer	-5 to +75	0 to +60	°C
9105-TW Transducer	-5 to +105	-5 to +105	°C
9105-T Transducer	-5 to +105	0 to +70	°C
9105-NET Transducer	-65 to +150	0 to +70	°C

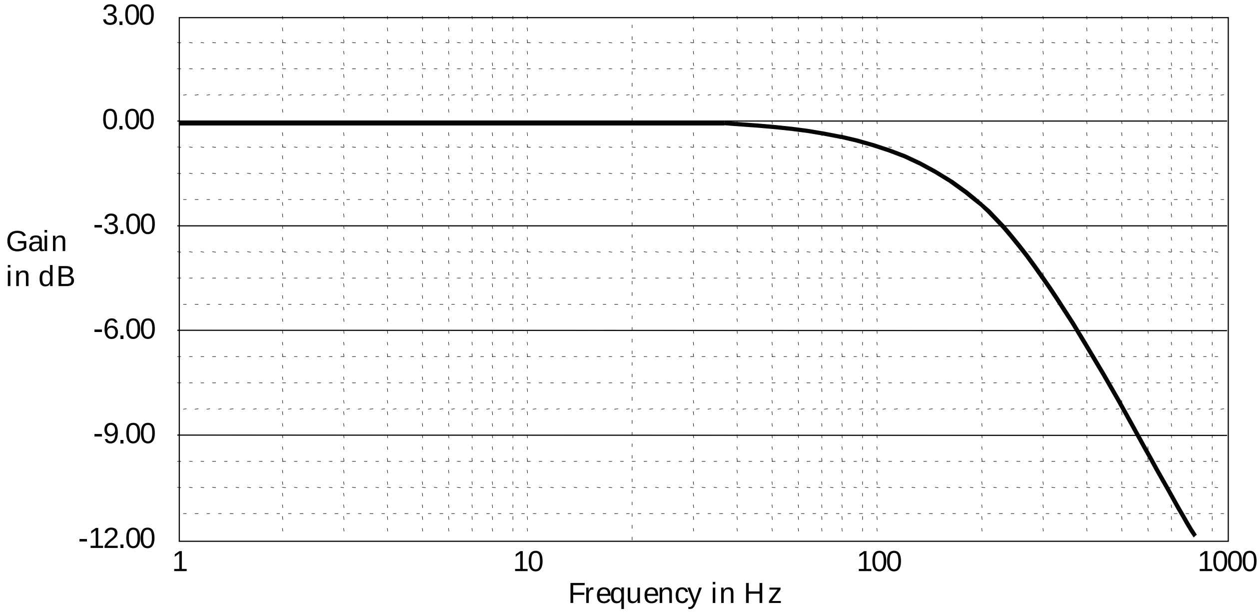
Note: These temperature ranges specify the storage and operation ranges in which the transducer can survive without damage. They do not take accuracy into account.

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 our 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

5.1.1 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.

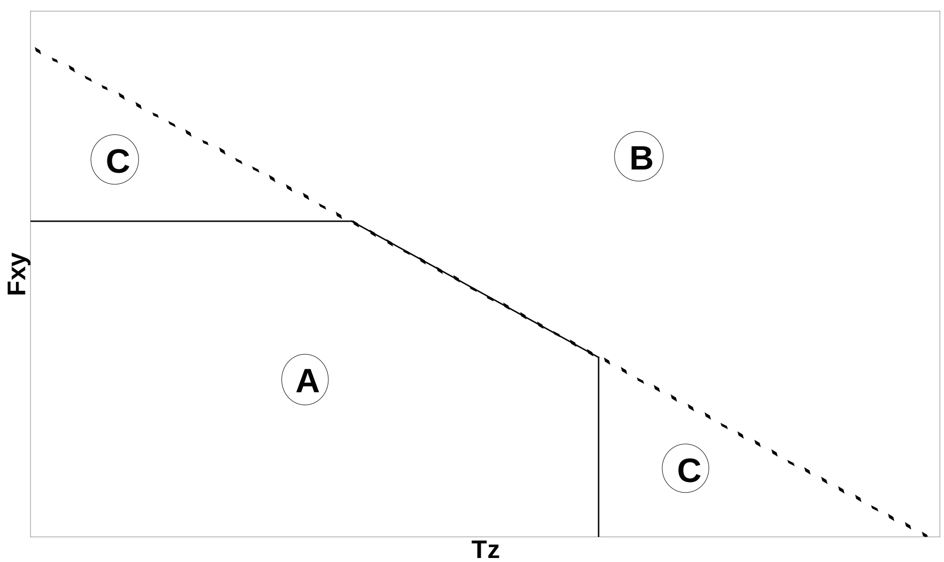
5.1.2 Complex Loading Graph Description

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 labels indicate the following regions:

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

5.2.1 Nano17 Titanium Physical Properties

Table 5.1—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 5.2— 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 (Nm)**	**Tz (Nm)**	**Fx,Fy (N)**	**Fz (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**
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 5.3— Nano17 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)**
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 (Nm)**	**Tz (Nm)**	**Fx,Fy (N)**	**Fz (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**
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 Analog Output

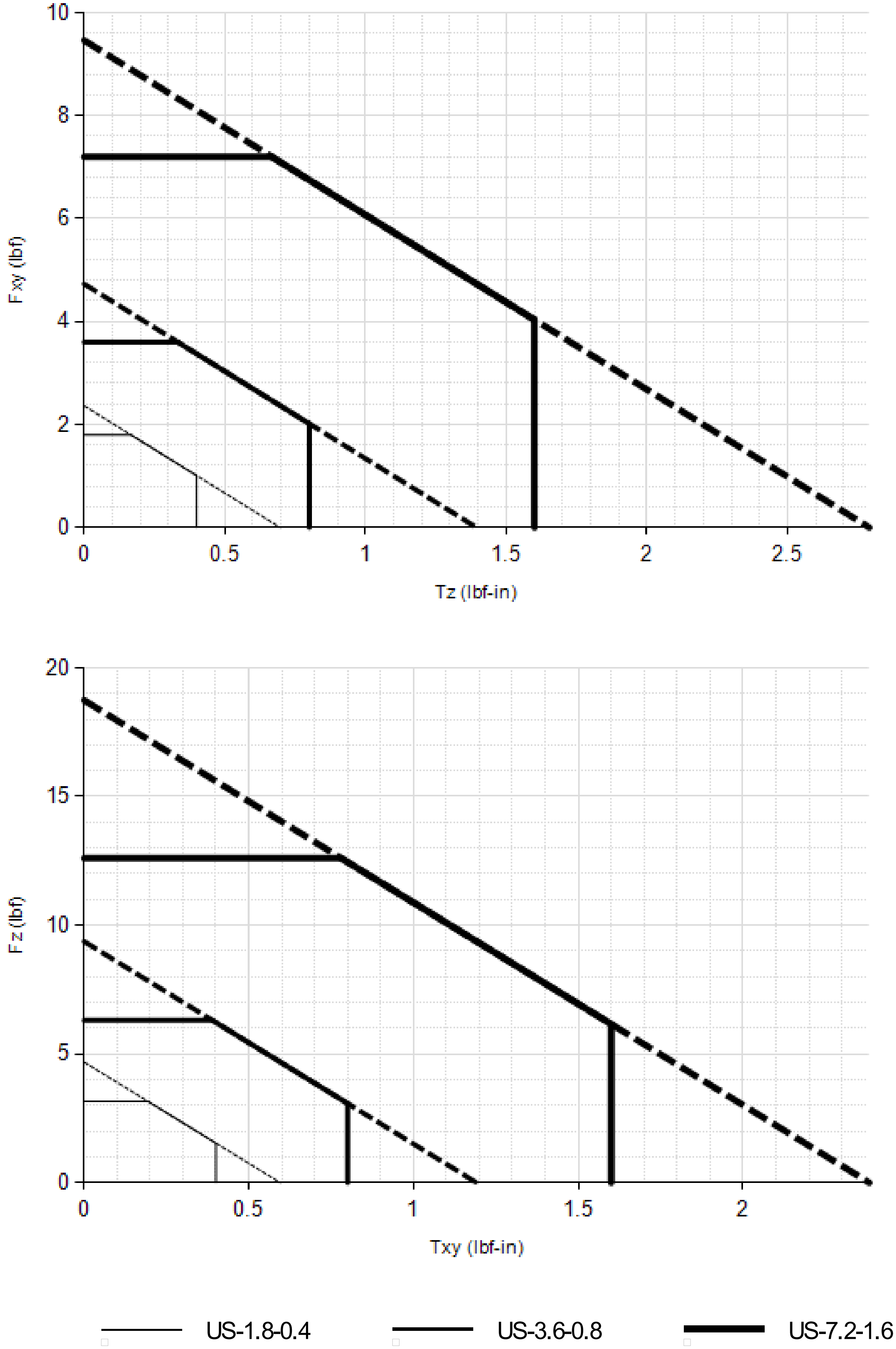
Table 5.4— Nano17 Titanium Analog Output							
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz (lbf)**	**Tx,Ty,Tz (lbf-in)**	**Fx,Fy (lbf/V)**	**Fz (lbf/V)**	**Tx,Ty,Tz (lbf-in/V)**
Nano17 Titanium	US-1.8-0.4	±1.8	±3.15	±0.4	0.18	0.315	0.04
Nano17 Titanium	US-3.6-0.8	±3.6	±6.3	±0.8	0.36	0.63	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 (Nm/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.

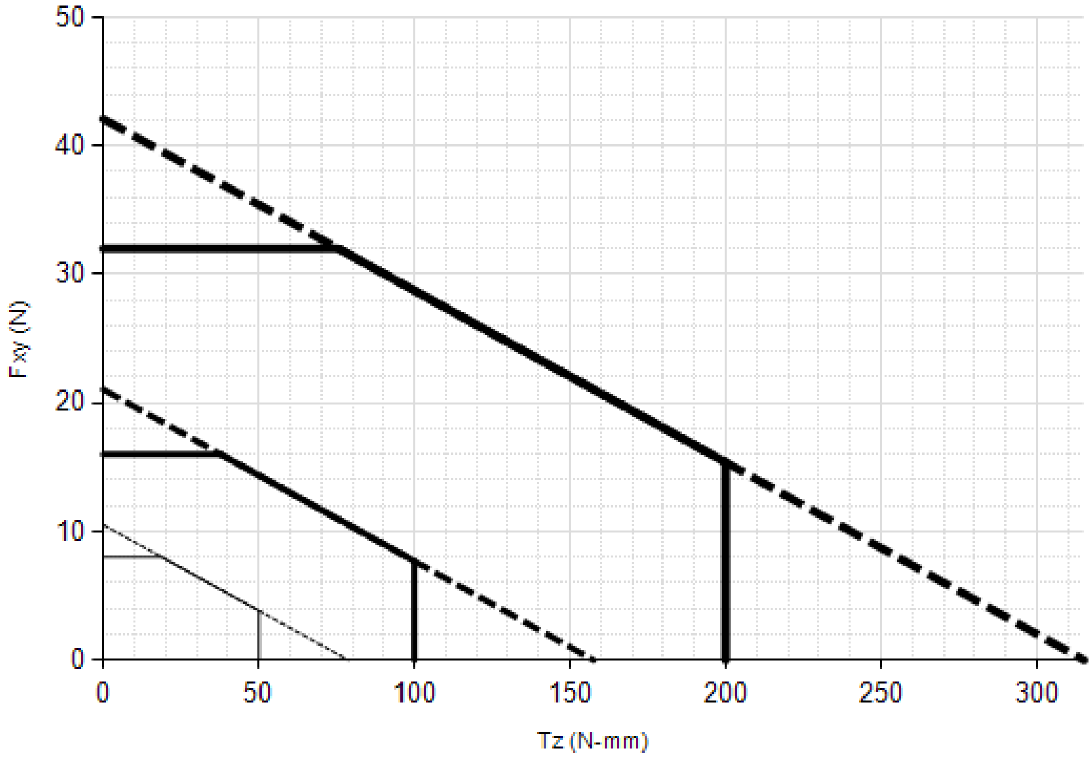
5.2.5 Counts Value

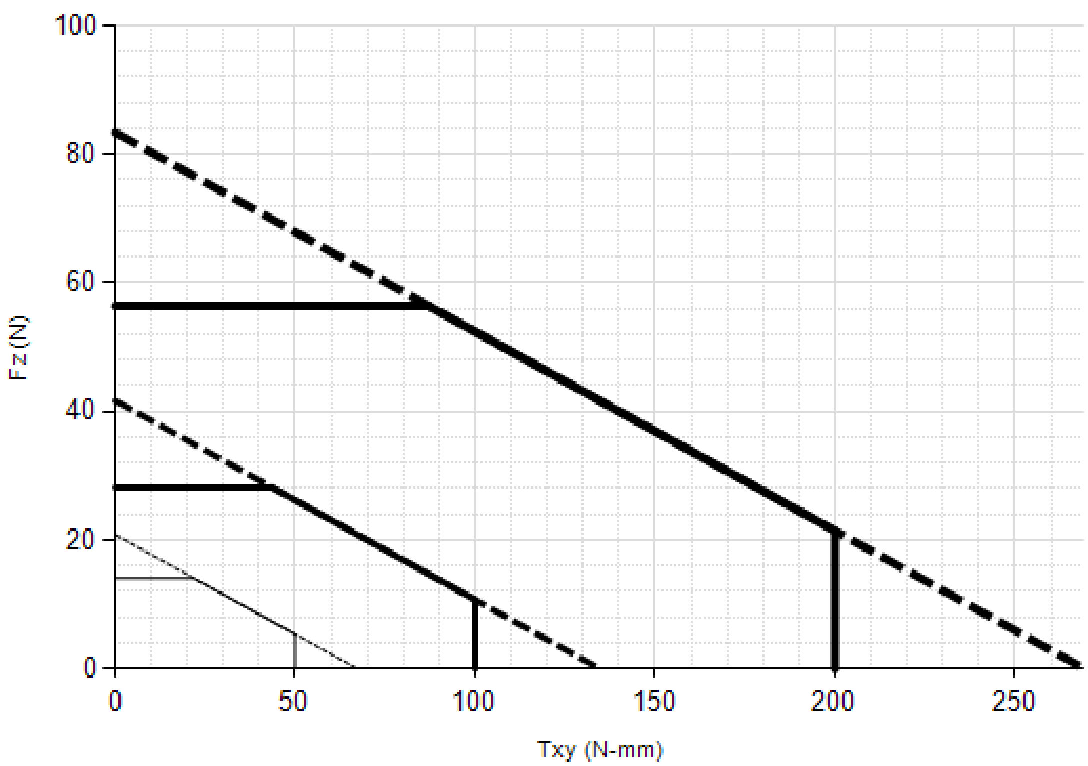
Table 5.5—Counts Value					
Sensor	**Calibration**	**Fx, Fy, Fz (/ lbf)**	**Tx, Ty, Tz (/ lbf-in)**	**Fx, Fy, Fz (/ N)**	**Tx, Ty, Tz (/ Nmm)**
Nano17 Titanium	US-1.8–0.4 / SI-8–0.05	54400	371200	1280	256
Nano17 Titanium	US-3.6–0.8 / SI-16–0.1	27200	185600	640	128
Nano17 Titanium	US-7.2–1.6 / SI-32–0.2	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)



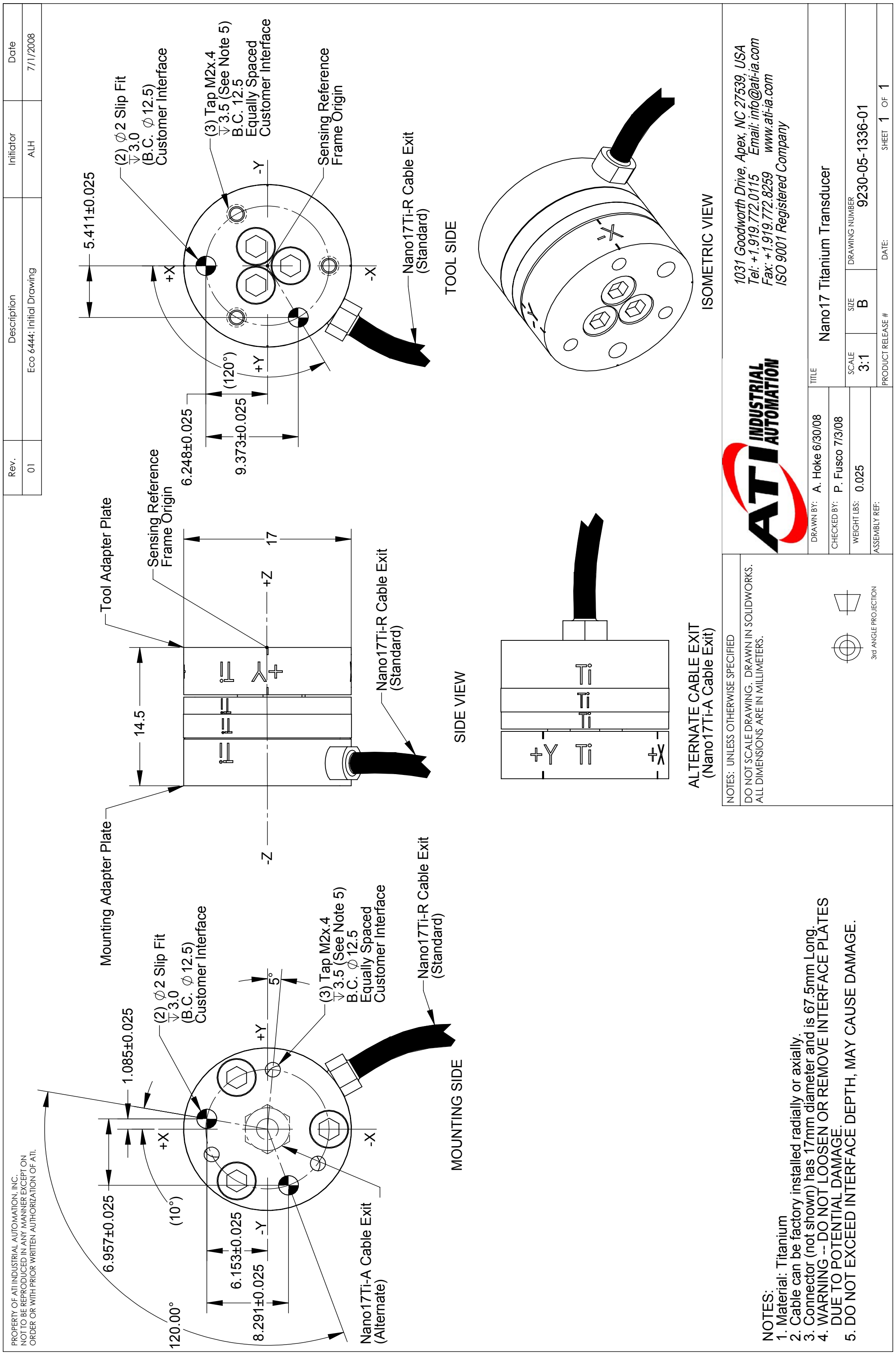
5.2.7 Nano17 Titanium (SI Calibration Complex Loading)





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

5.2.8 Nano17 Titanium Transducer Drawing



5.3 Nano17 Specifications (Includes IP65/IP68 Versions)

5.3.1 Nano17 Physical Properties

Table 5.6—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 5.7—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 5.8— Nano17 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)
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)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**
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 5.9— Nano17 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)
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)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**
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 Analog Output

Table 5.10— 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 (Nm/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]**		

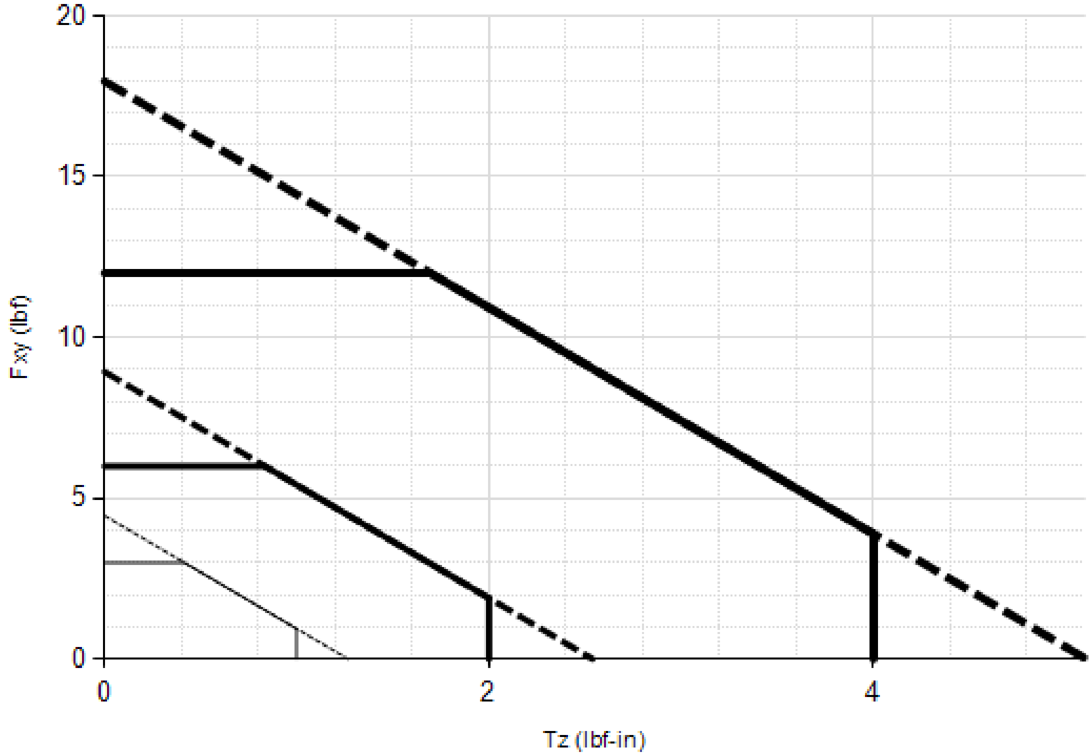
Notes:
1. ±5V Sensitivity values are double the listed ±10V Sensitivity values.
2. For IP68 version see caution on physical properties page.

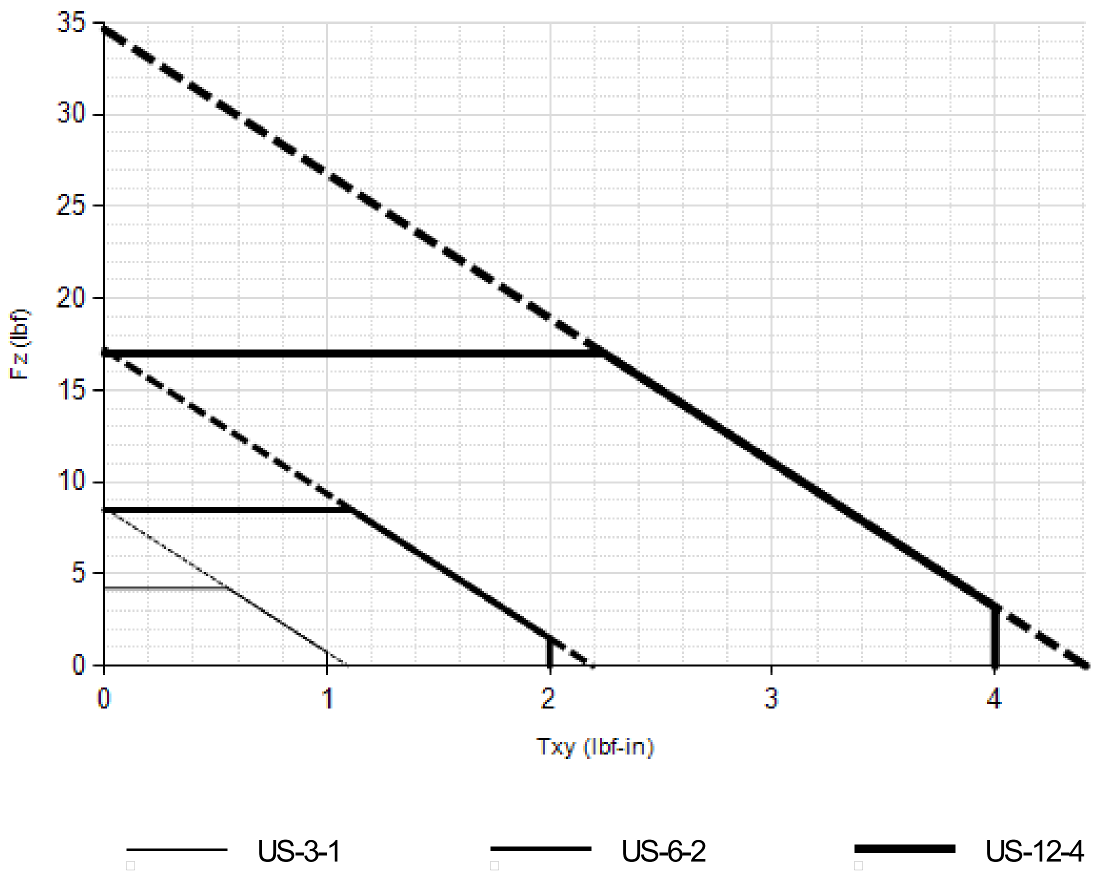
5.3.6 Counts Value

Table 5.11—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)**	

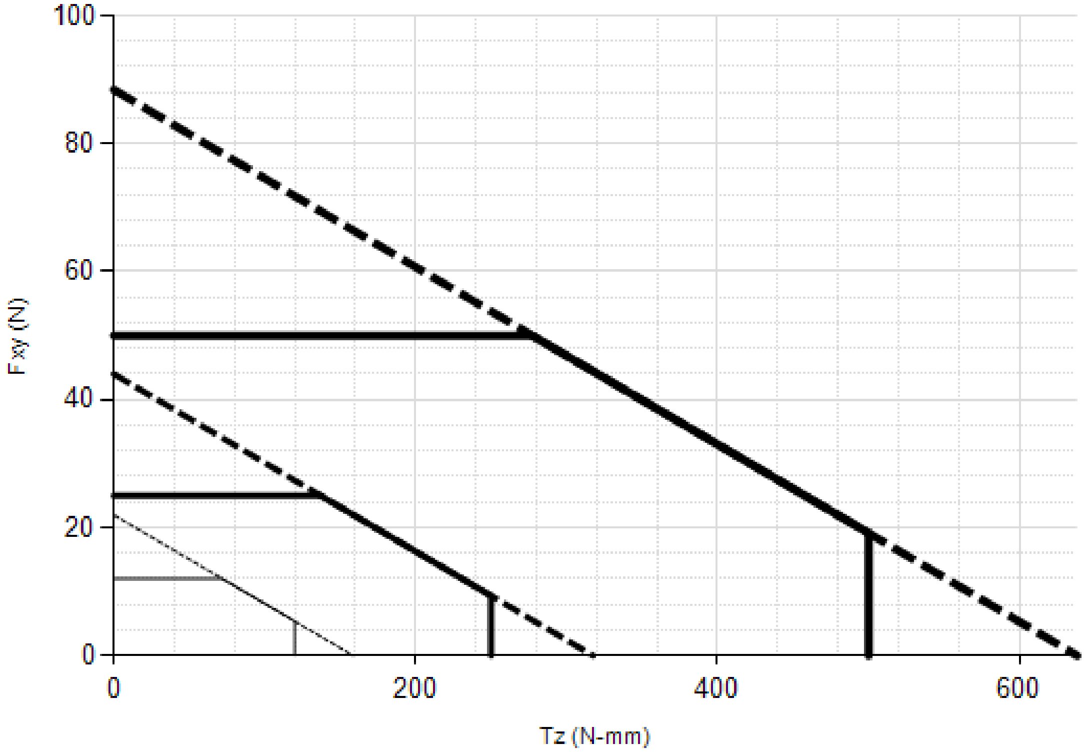
5.3.7 Nano17 (US Calibration Complex Loading)(Includes IP65/IP68)[1]

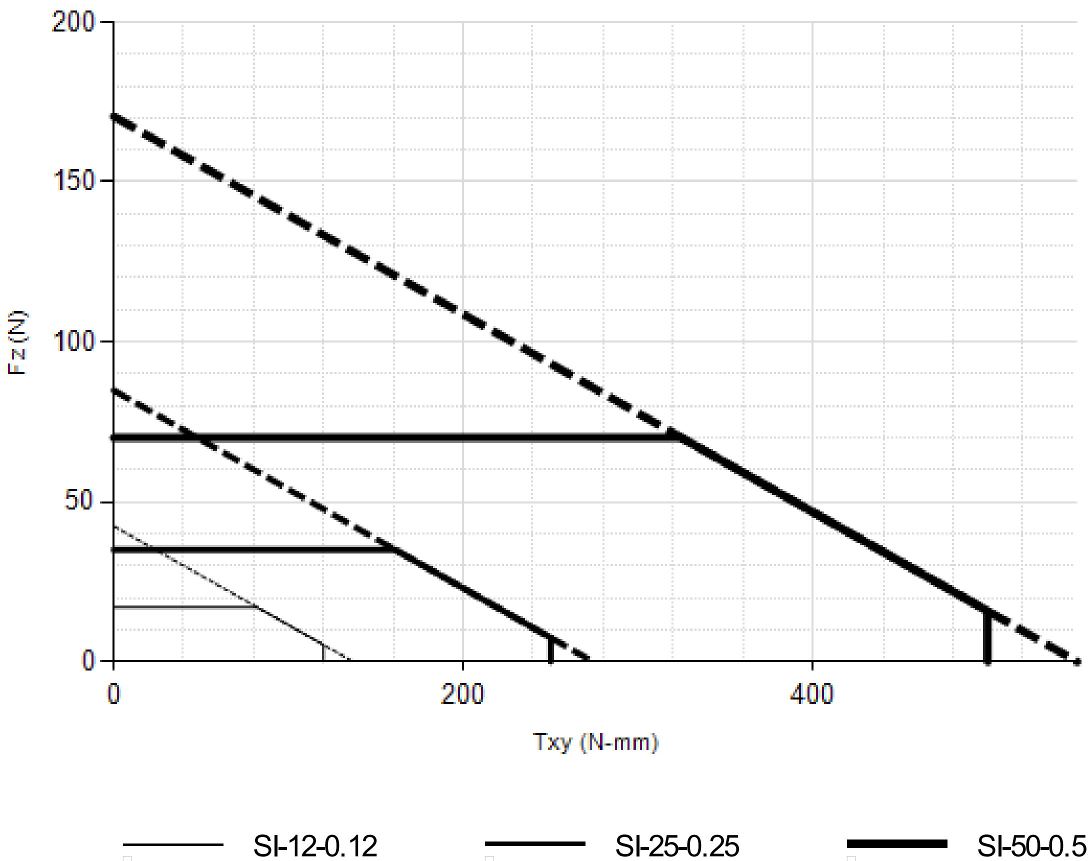




Note: 1. For IP68 version see caution on physical properties page.

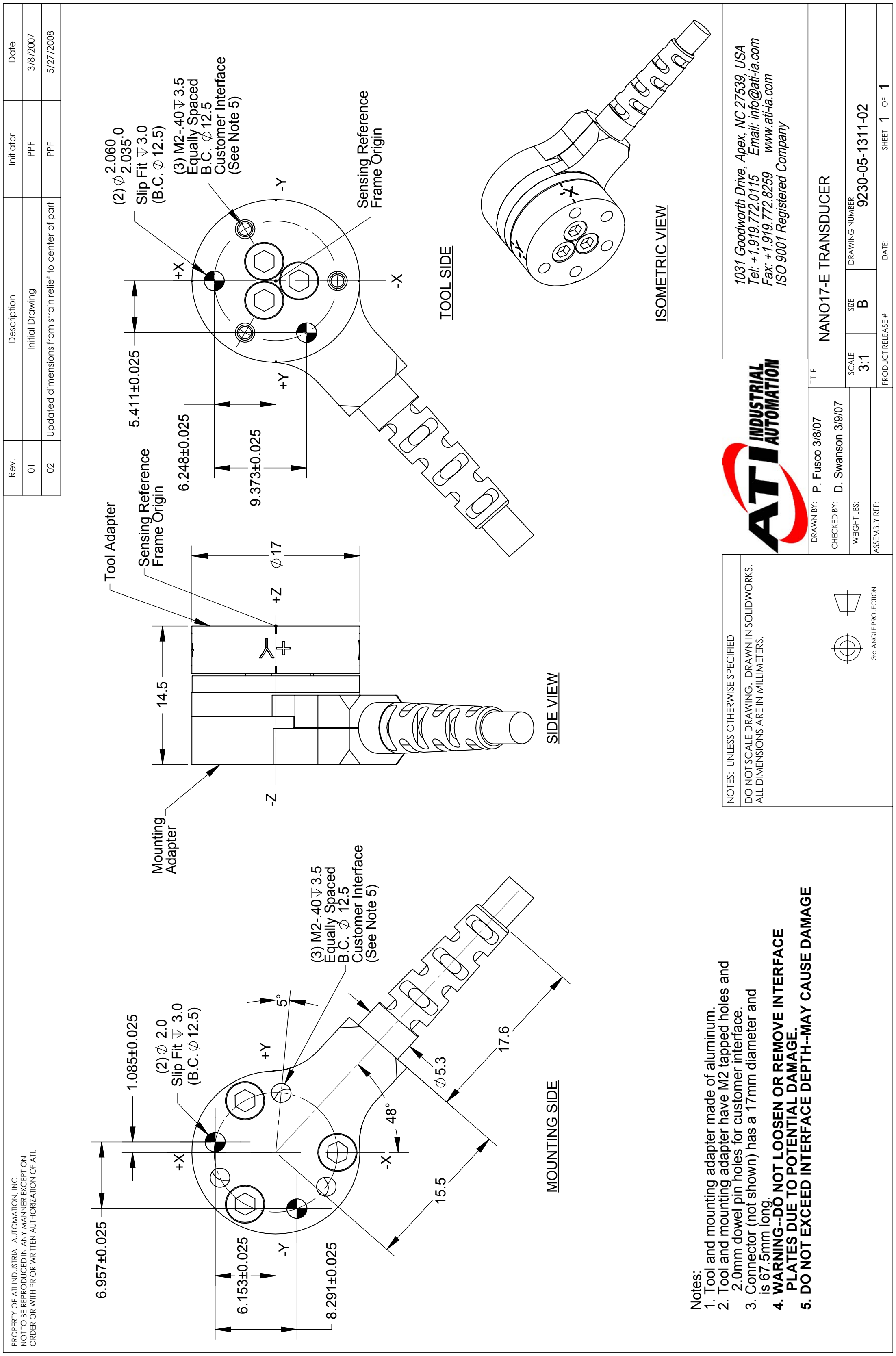
5.3.8 Nano17 (SI Calibration Complex Loading)(Includes IP65/IP68)[1]



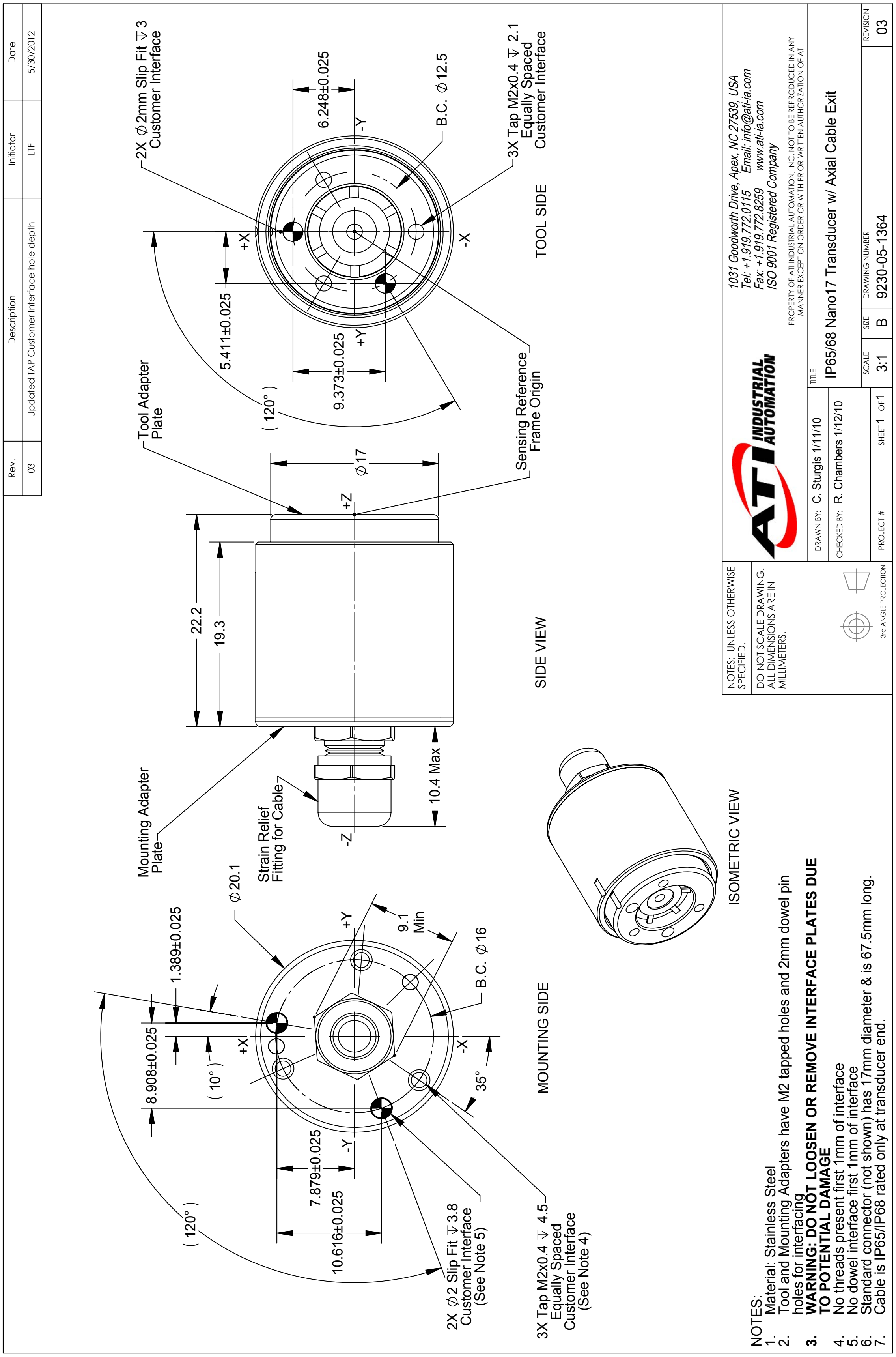


Note: 1. For IP68 version see caution on physical properties page.

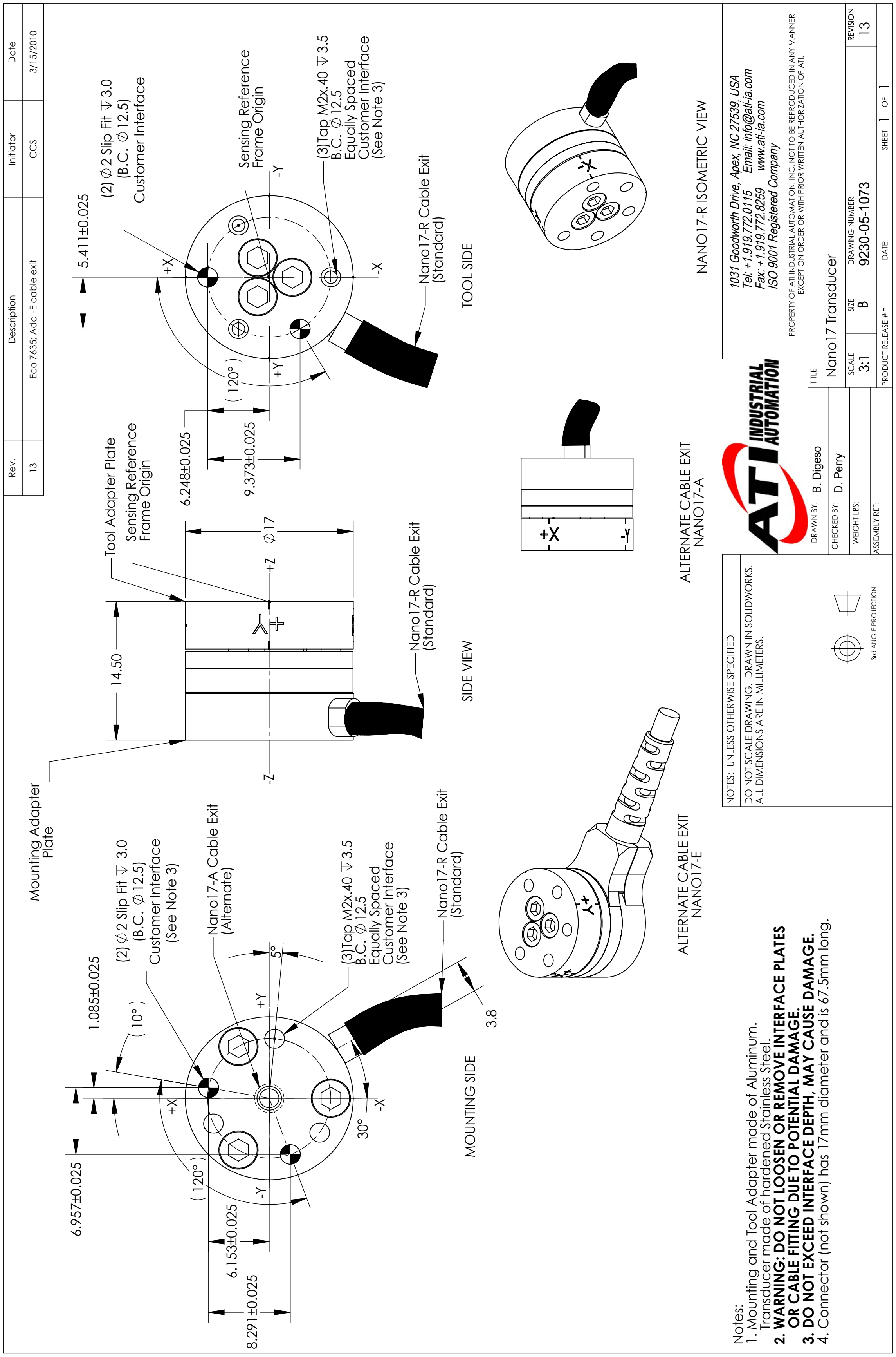
5.3.9 Nano17-E Transducer Drawing



5.3.10 Nano17 IP65/IP68 Transducer with Axial Cable Exit Drawing



5.3.11 Legacy Nano17 Transducer Drawing



5.4 Nano25 Specifications (Includes IP65/IP68 Versions)

5.4.1 Nano25 Physical Properties

Table 5.12—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 5.13—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 5.14— 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 5.15— 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 Analog Output

Table 5.16— 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]**		

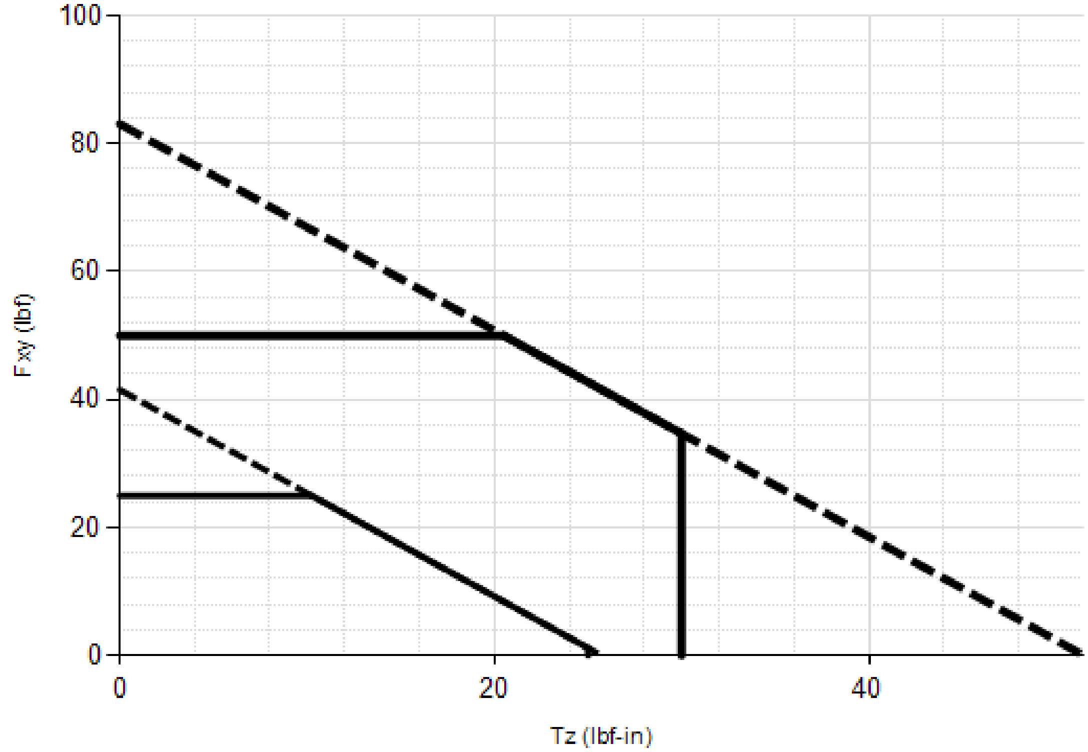
Notes:
1. ±5V Sensitivity values are double the listed ±10V Sensitivity values.
2. For IP68 version see caution on physical properties page.

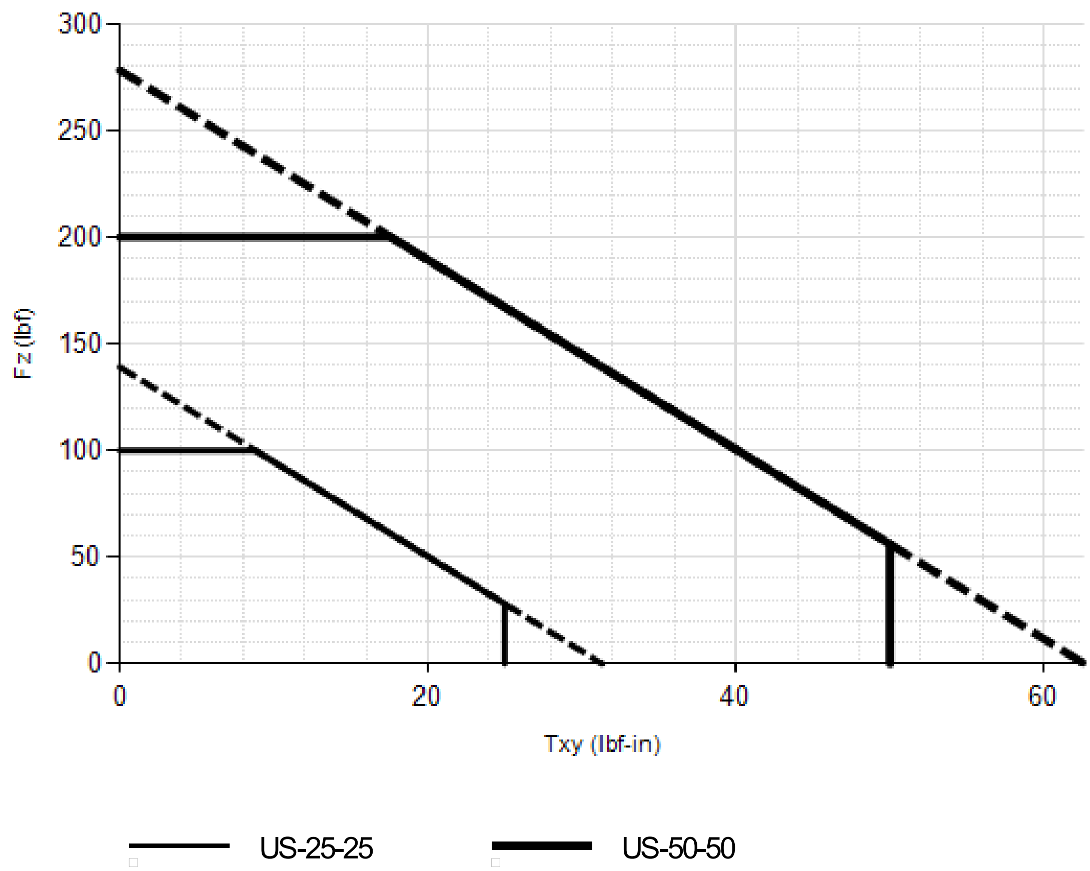
5.4.6 Counts Value

Table 5.17—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)**	

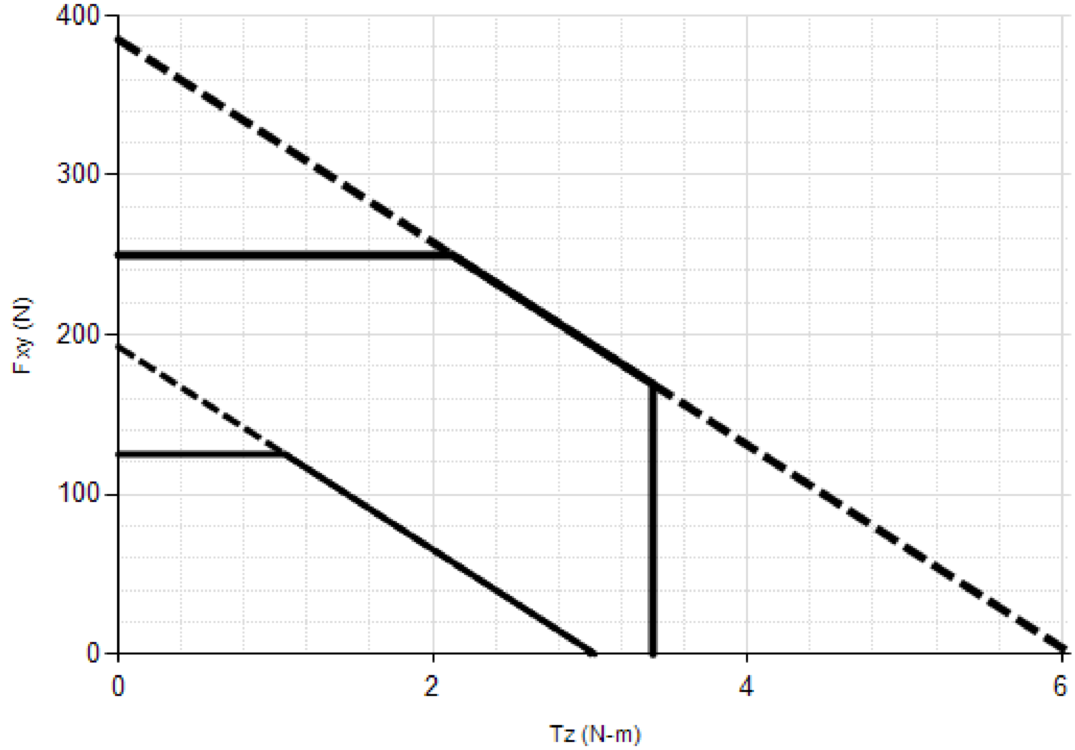
5.4.7 Nano25 (US Calibration Complex Loading)(Includes IP65/IP68)[1]

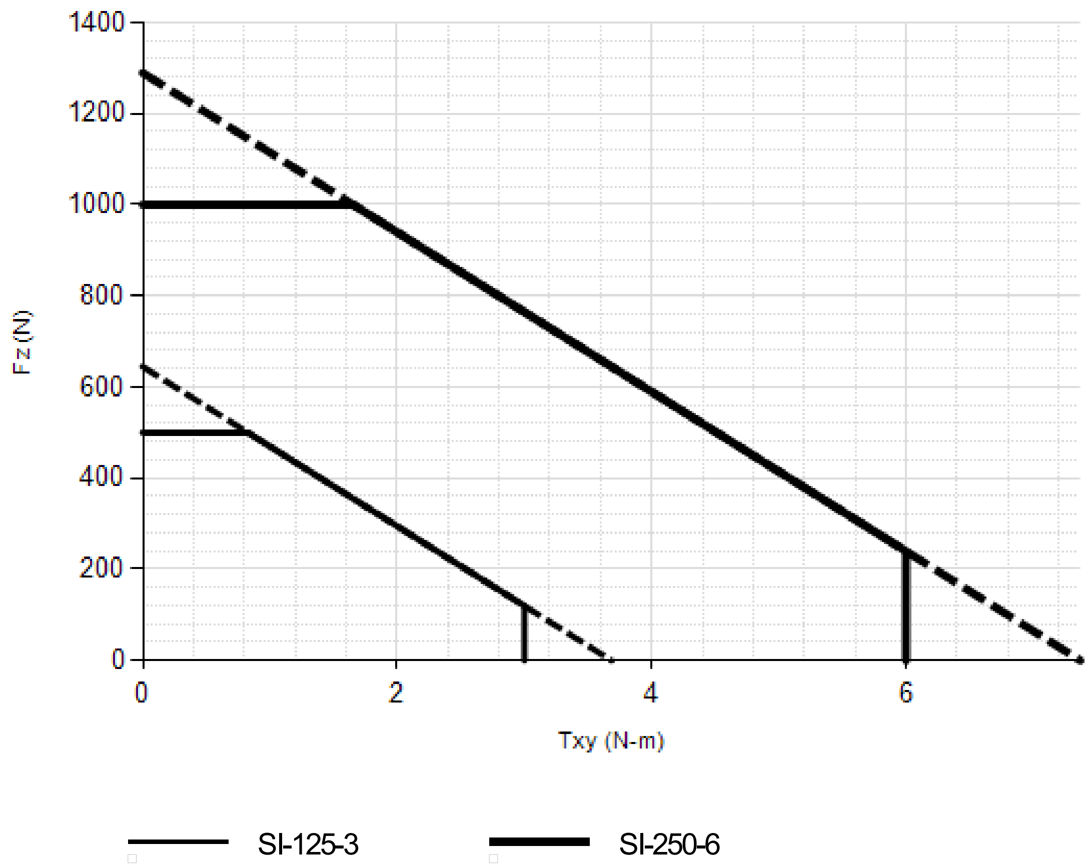




Note: 1. For IP68 version see caution on physical properties page.

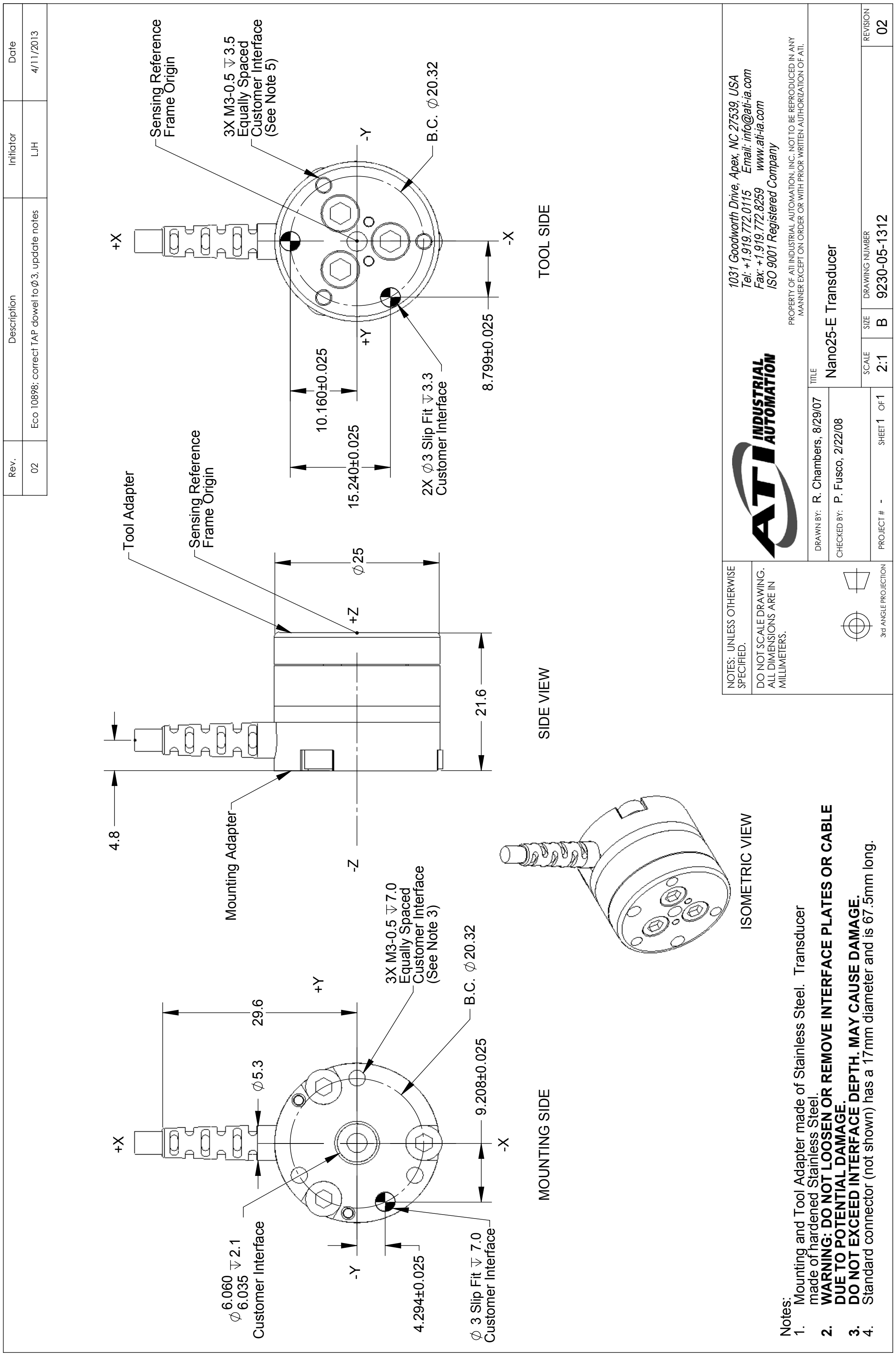
5.4.8 Nano25 (SI Calibration Complex Loading)(Includes IP65/IP68)[1]



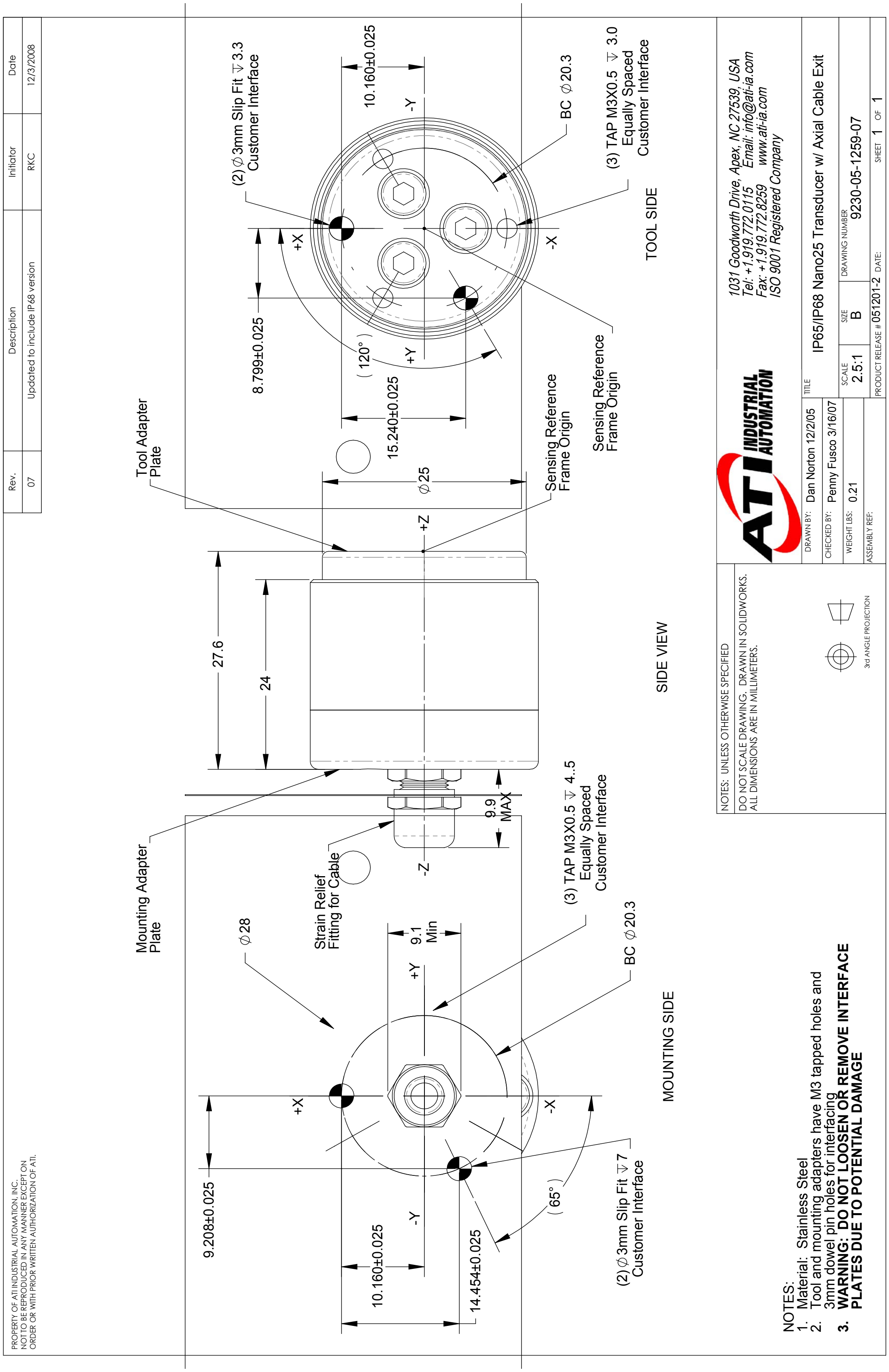


Note: 1. For IP68 version see caution on physical properties page.

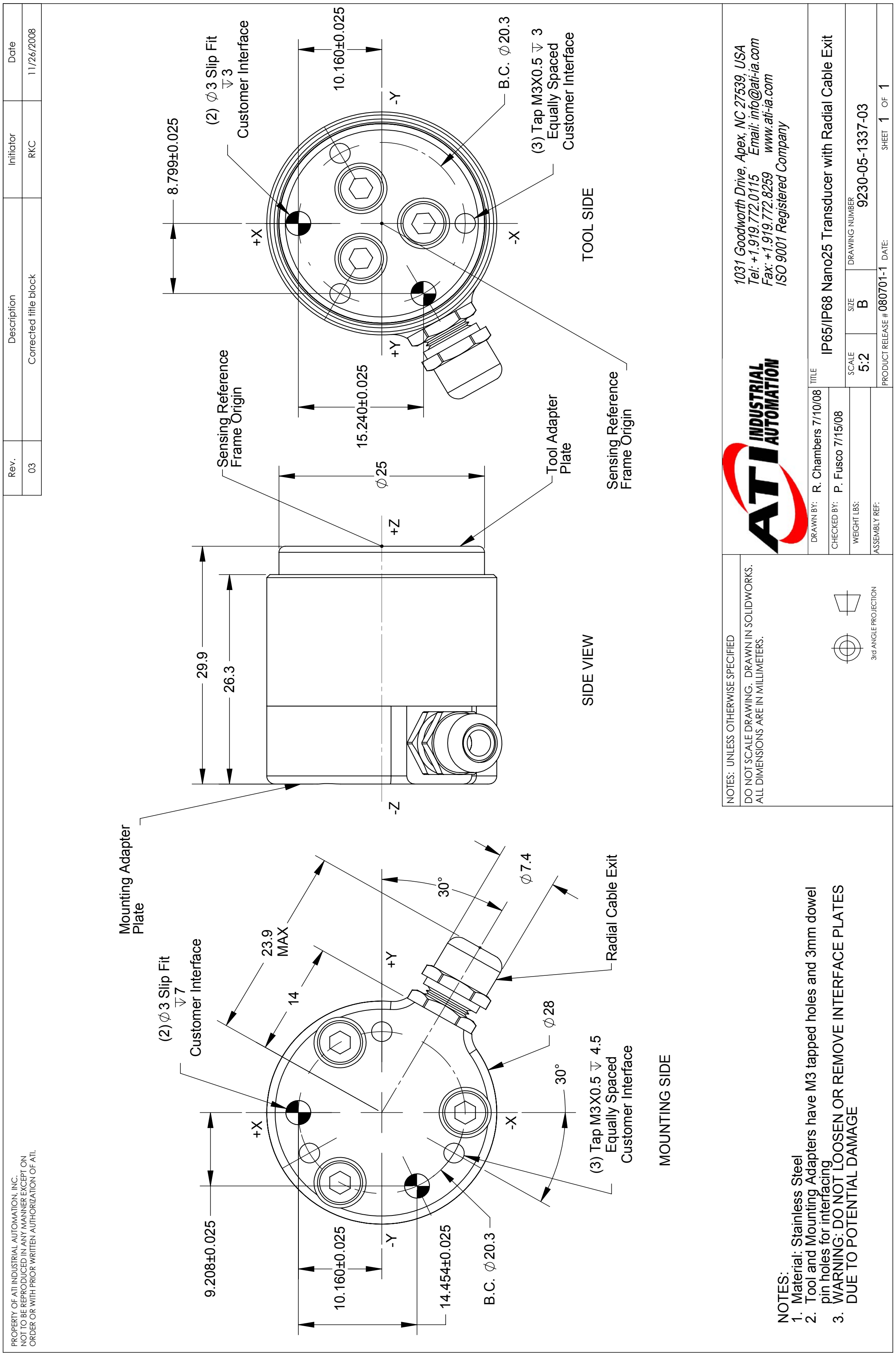
5.4.9 Nano25-E Transducer Drawing



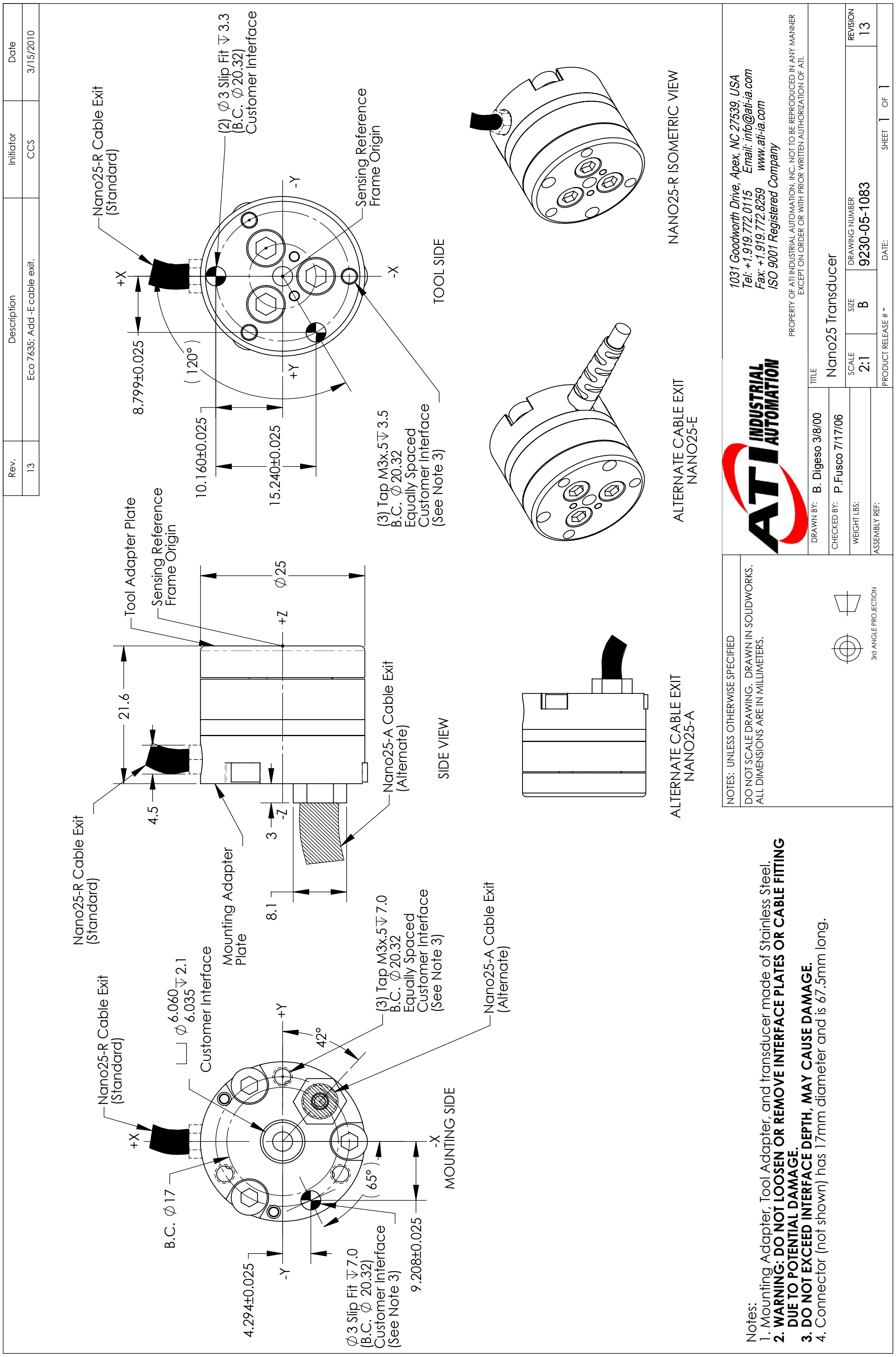
5.4.10 Nano25 IP65/IP68 Transducer with Axial Cable Exit Drawing



5.4.11 Nano25 IP65/IP68 Transducer with Radial Cable Exit Drawing



5.4.12 Legacy Nano25 Transducer Drawing



5.5 Nano43 Specifications

5.5.1 Nano43 Physical Properties

Table 5.18—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 5.19— 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 (Nm)**	**Tz (Nm)**	**Fx,Fy (N)**	**Fz (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**
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 5.20— 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 (Nm)**	**Tz (Nm)**	**Fx,Fy (N)**	**Fz (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**
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 Analog Output

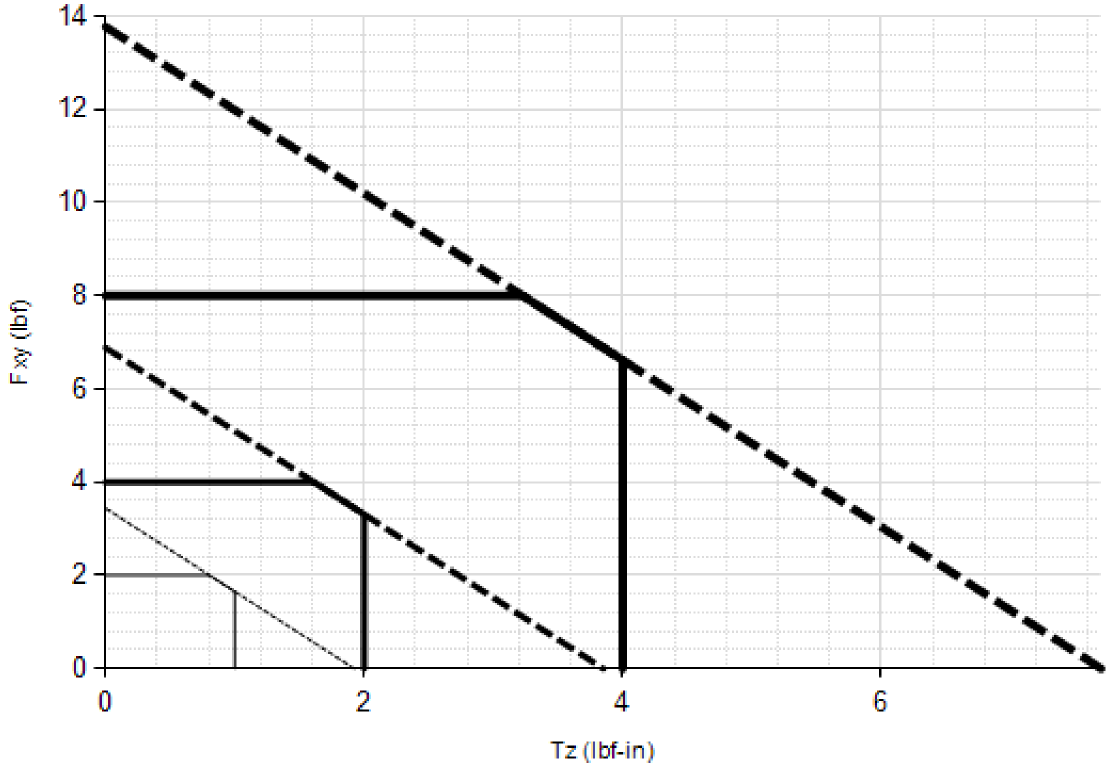
Table 5.21— Nano43 Analog Output							
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz (lbf)**	**Tx,Ty,Tz (lbf-in)**	**Fx,Fy (lbf/V)**	**Fz (lbf/V)**	**Tx,Ty,Tz (lbf-in/V)**
Nano43	US-2-1	N/A	N/A	N/A	N/A	N/A	N/A
Nano43	US-4-2	±4	±4	±2	0.4	0.4	0.2
Nano43	US-8-4	±8	±8	±4	0.8	0.8	0.4
Sensor	**(SI) 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]**		

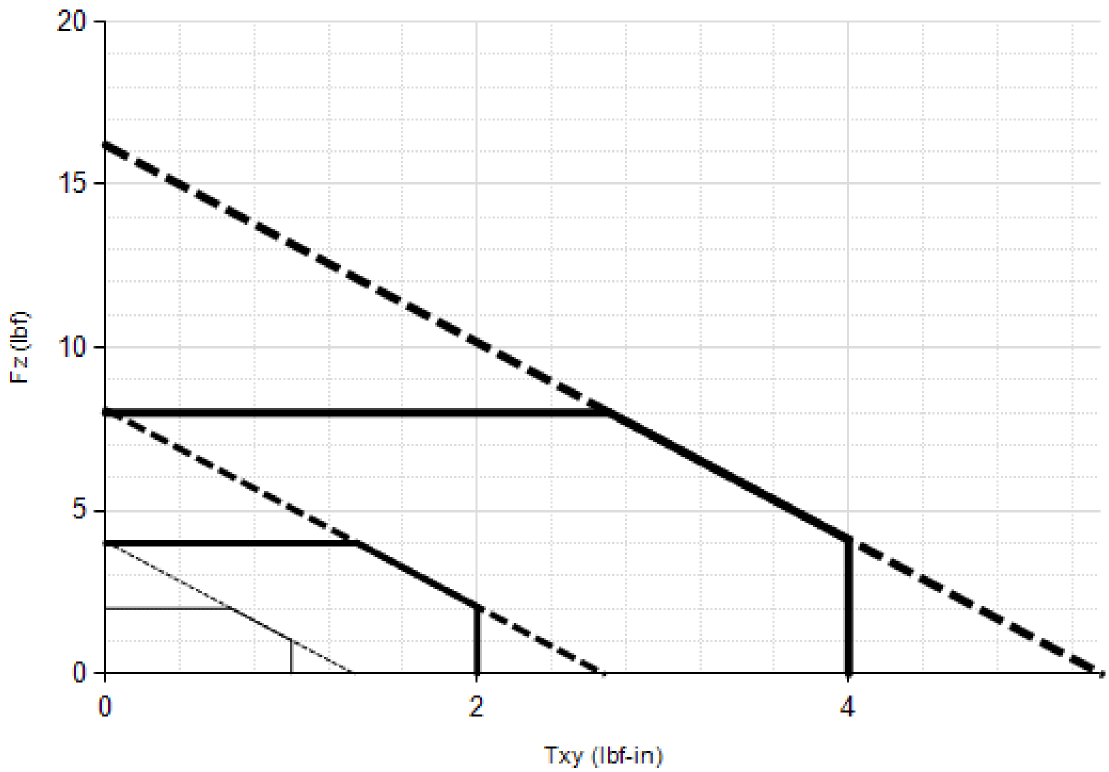
Notes:
1. ±5V Sensitivity values are double the listed ±10V Sensitivity values.

5.5.5 Counts Value

Table 5.22—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)**	

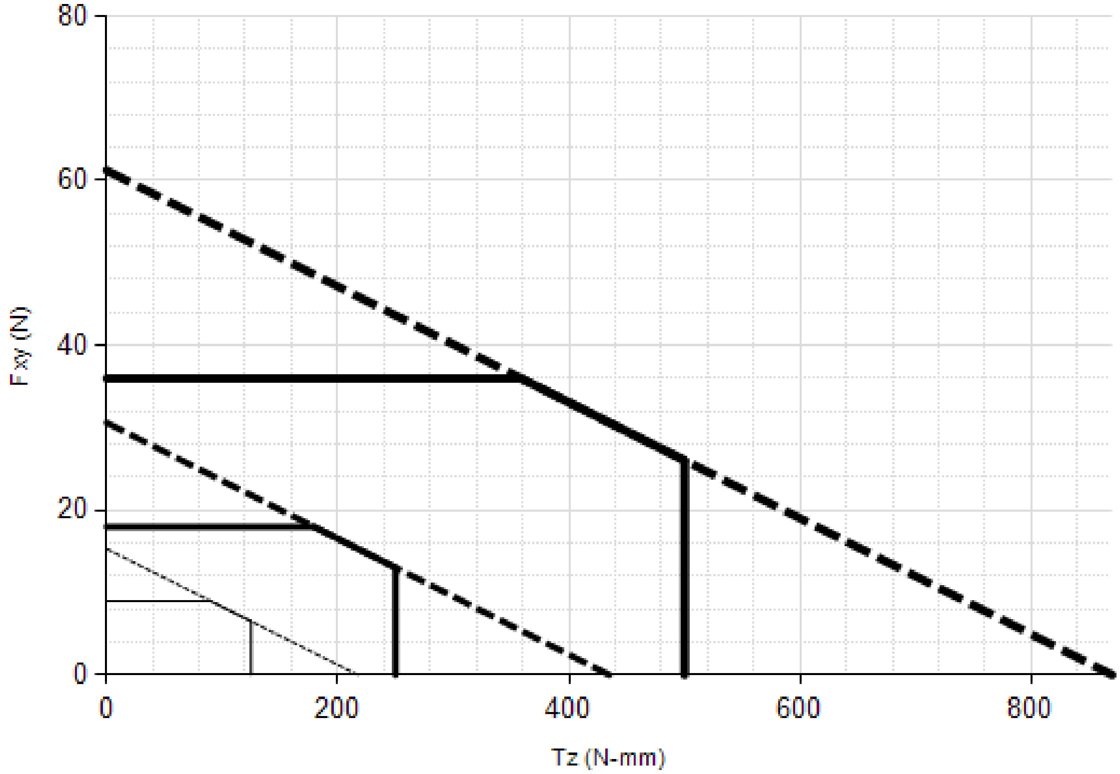
5.5.6 Nano43 (US Calibration Complex Loading)

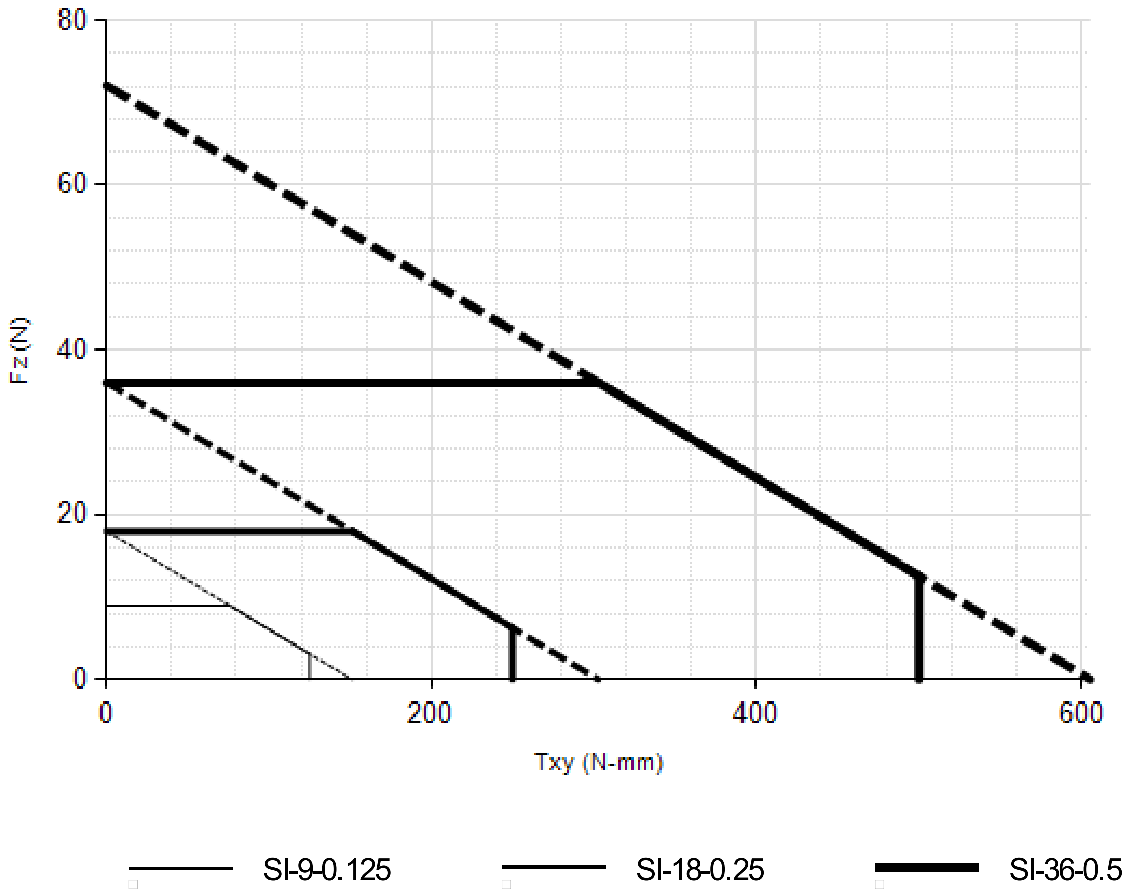




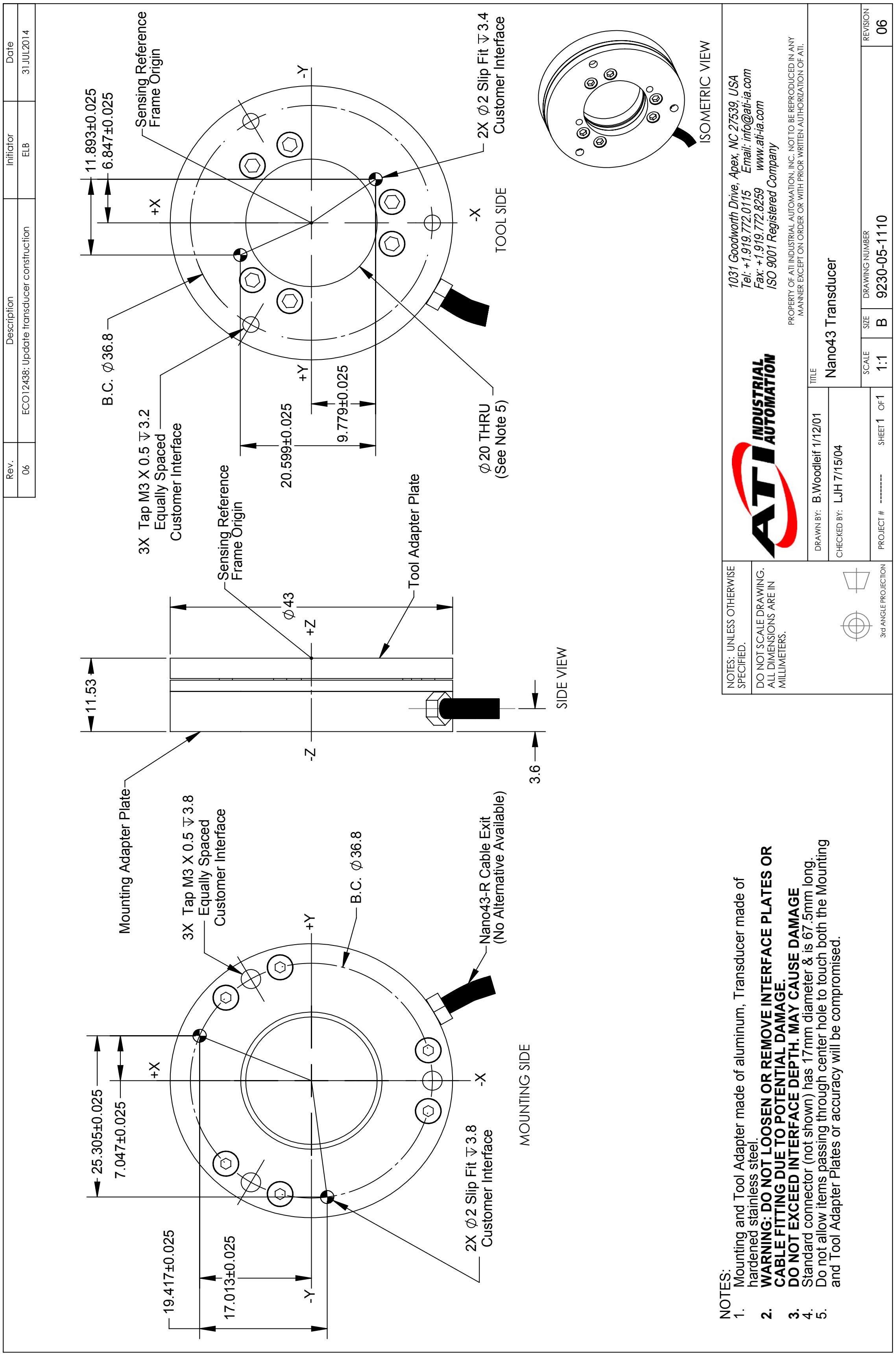
US-2-1 US-4-2 US-8-4

5.5.7 Nano43 (SI Calibration Complex Loading)





5.5.8 Nano43 Transducer Drawing



5.6 Mini27 Titanium Specifications

5.6.1 Mini27 Titanium Physical Properties

Table 5.23—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)	1.8×10^{5} lb/in	3.1×10^{7} N/m
Z-axis force (Kz)	3.6×10^{5} lb/in	6.4×10^{7} N/m
X-axis & Y-axis torque (Ktx, Kty)	4.0×10^{4} lbf-in/rad	4.5×10^{3} Nm/rad
Z-axis torque (Ktz)	5.8×10^{4} lbf-in/rad	6.5×10^{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 5.24— 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 5.25— 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 Analog Output

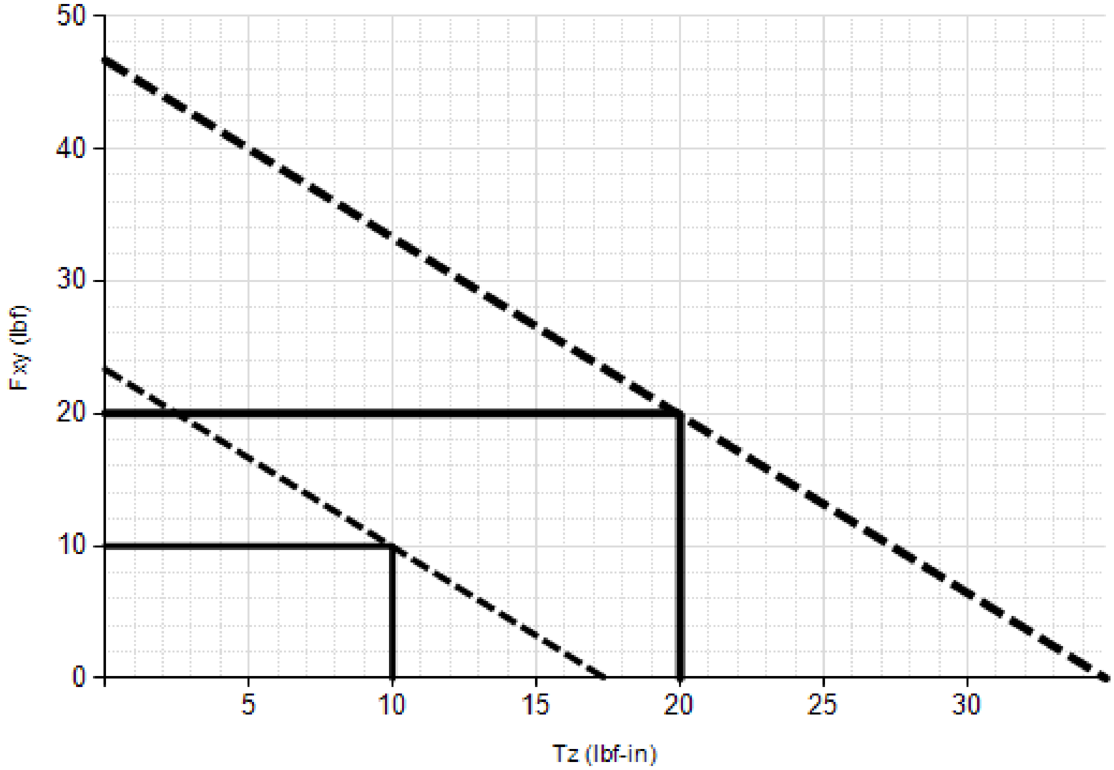
Table 5.26— Mini27 Titanium Analog Output							
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz (lbf)**	**Tx,Ty,Tz (lbf-in)**	**Fx,Fy (lbf/V)**	**Fz (lbf/V)**	**Tx,Ty,Tz (lbf-in/V)**
Mini27 Titanium	US-10-18	±10	±20	±18	1	2	1.8
Mini27 Titanium	US-20-36	±20	±40	±36	2	4	3.6
Sensor	**(SI) Metric 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]**		

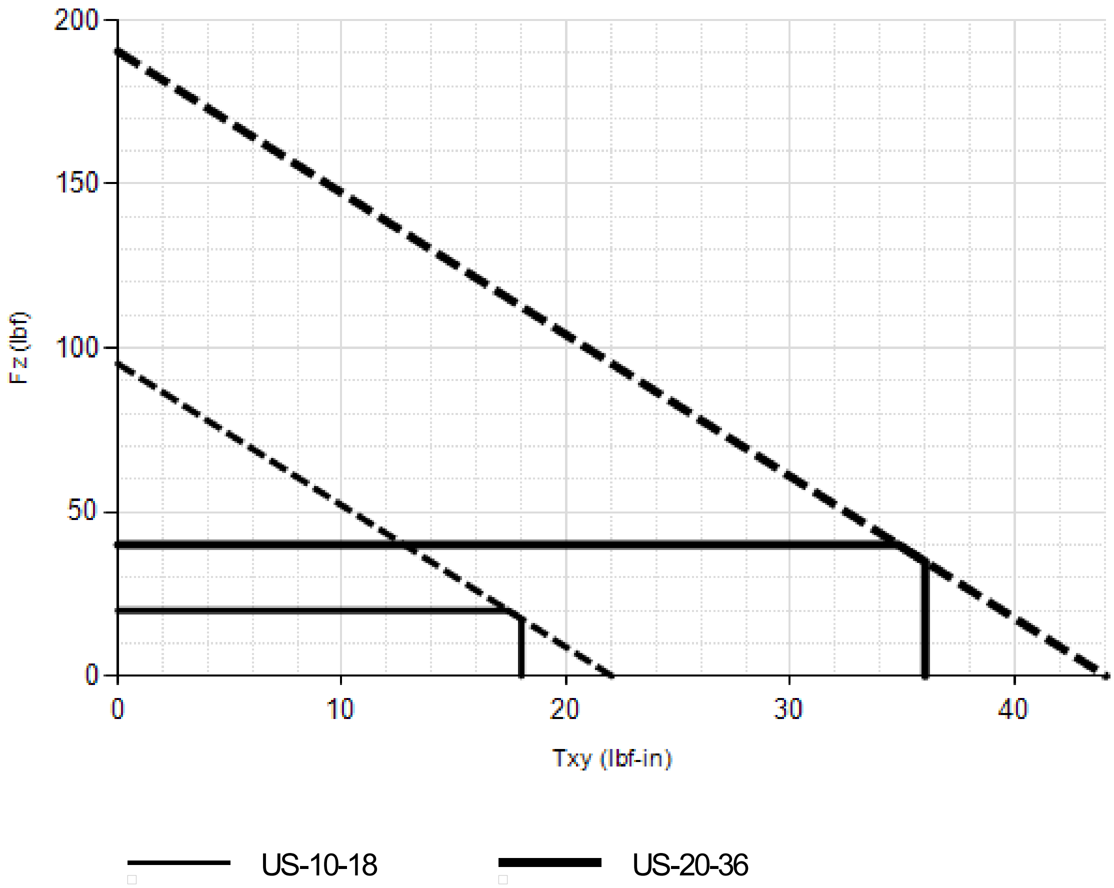
Notes:
1. ±5V Sensitivity values are double the listed ±10V Sensitivity values.

5.6.5 Counts Value

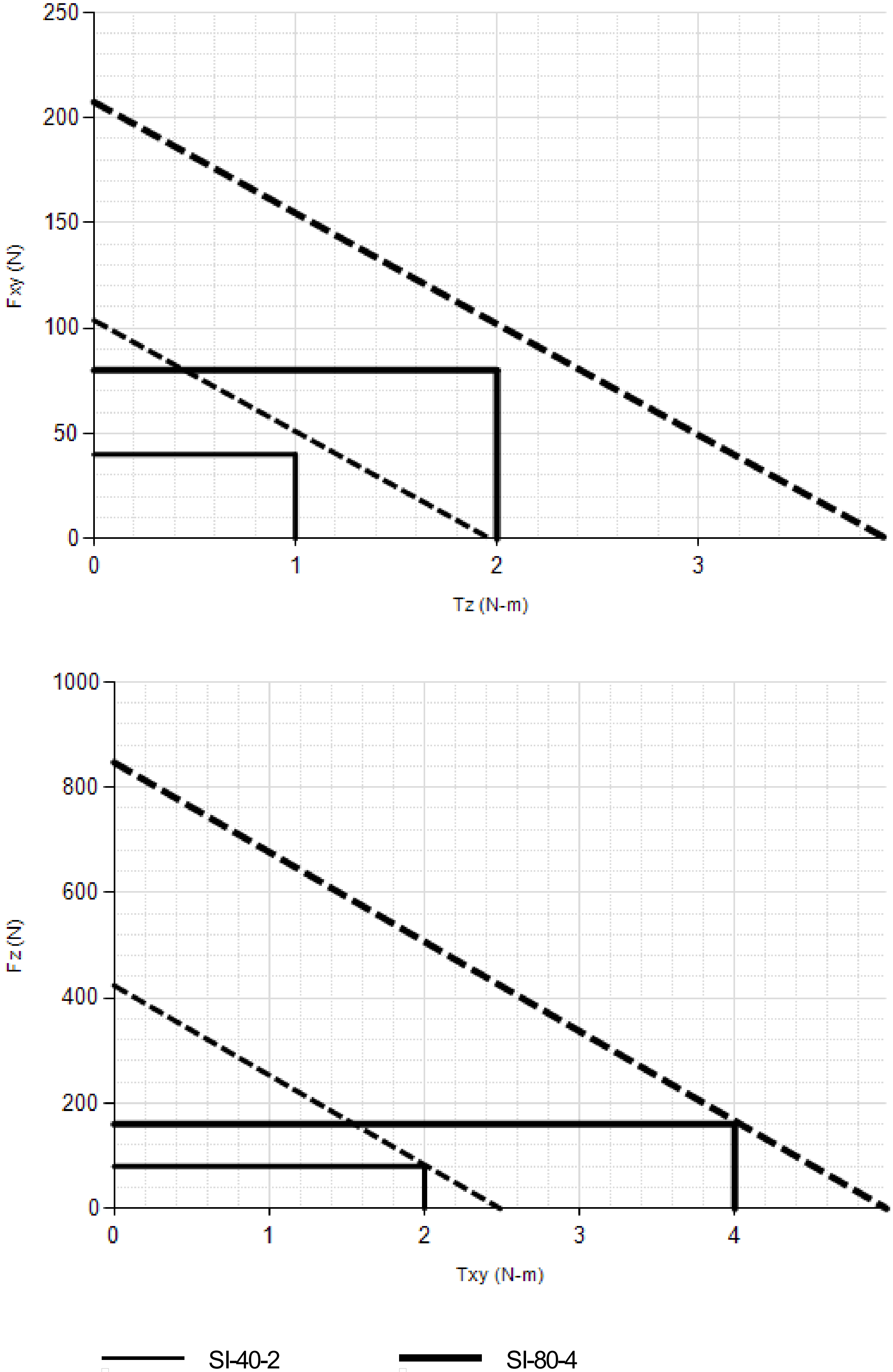
Table 5.27—Counts Value					
Sensor	**Calibration**	**Fx, Fy, Fz (/ lbf)**	**Tx, Ty, Tz (/ lbf-in)**	**Fx, Fy, Fz (/ N)**	**Tx, Ty, Tz (/ Nm)**
Mini27 Titanium	US-1–18 / SI-40–2	3200	3200	800	32000
Mini27 Titanium	US-20–36 / SI-80–4	1600	1600	400	16000
Mini27 Titanium	Tool Transform Factor	0.01 in/lbf		0.25 mm/N	
		Counts Value – Standard (US)		**Counts Value – Metric (SI)**	

5.6.6 Mini27 Titanium (US Calibration Complex Loading)

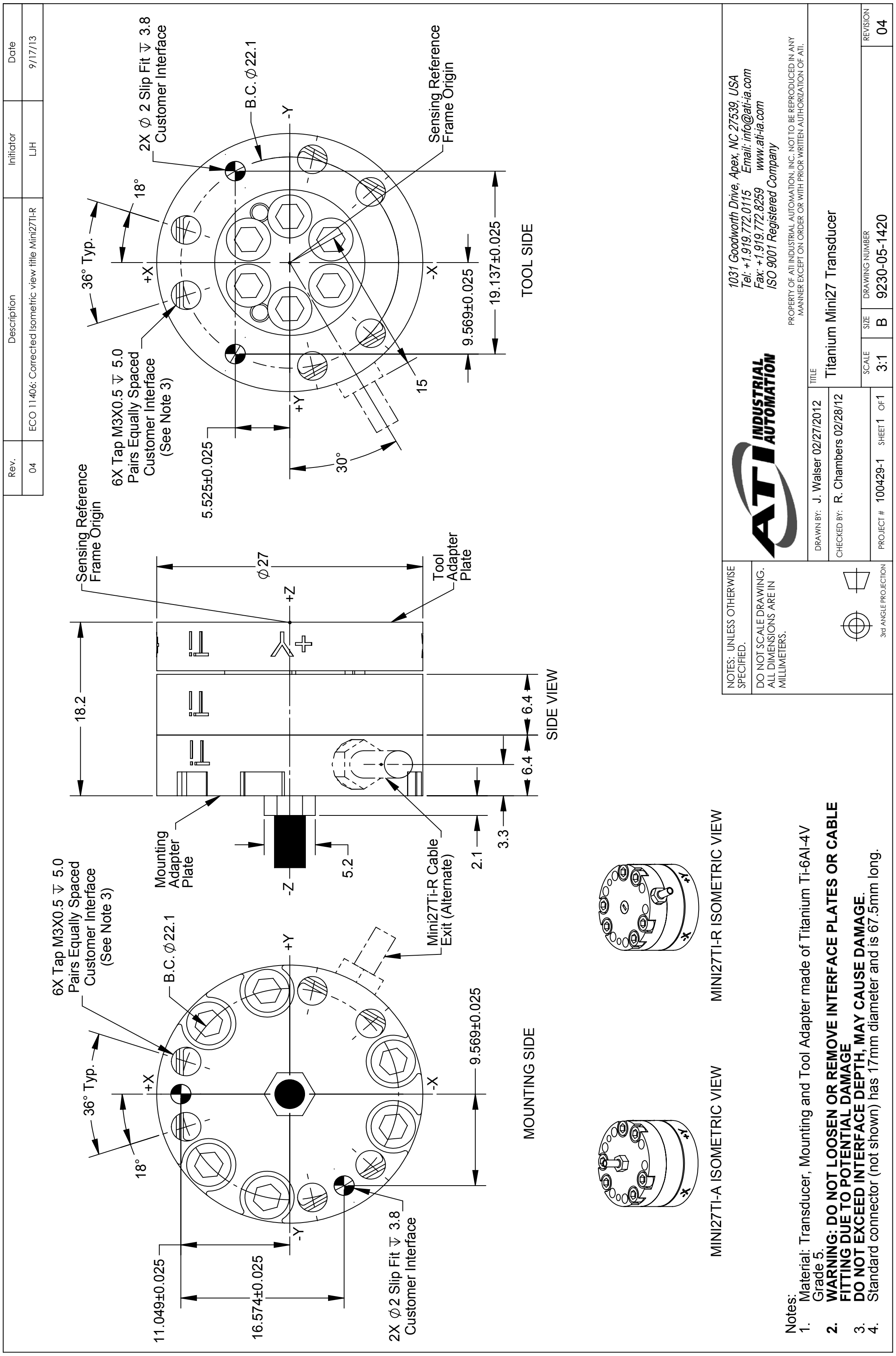




5.6.7 Mini27 Titanium (SI Calibration Complex Loading)



5.6.8 Mini27 Titanium Transducer Drawing



5.7 Mini40 Specifications (Includes IP65/IP68 Versions)

5.7.1 Mini40 Physical Properties

Table 5.28—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 5.29—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 5.30— 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 5.31— 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 Analog Output

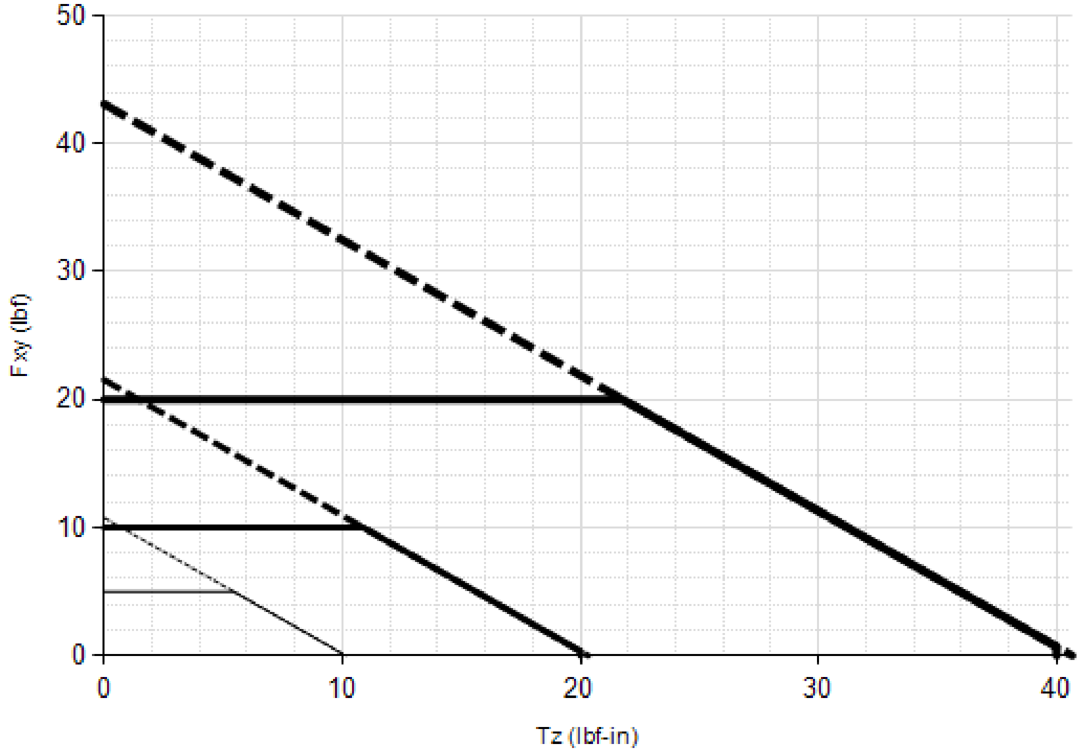
Table 5.32— Mini40 Analog Output							
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz[2] (lbf)**	**Tx,Ty,Tz (lbf-in)**	**Fx,Fy (lbf/V)**	**Fz[2] (lbf/V)**	**Tx,Ty,Tz (lbf-in/V)**
Mini40	US-5-10	±5	±15	±10	0.5	1.5	1
Mini40	US-10-20	±10	±30	±20	1	3	2
Mini40	US-20-40	±20	±60	±40	2	6	4
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz[2] (N)**	**Tx,Ty,Tz (Nmm)**	**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]**		

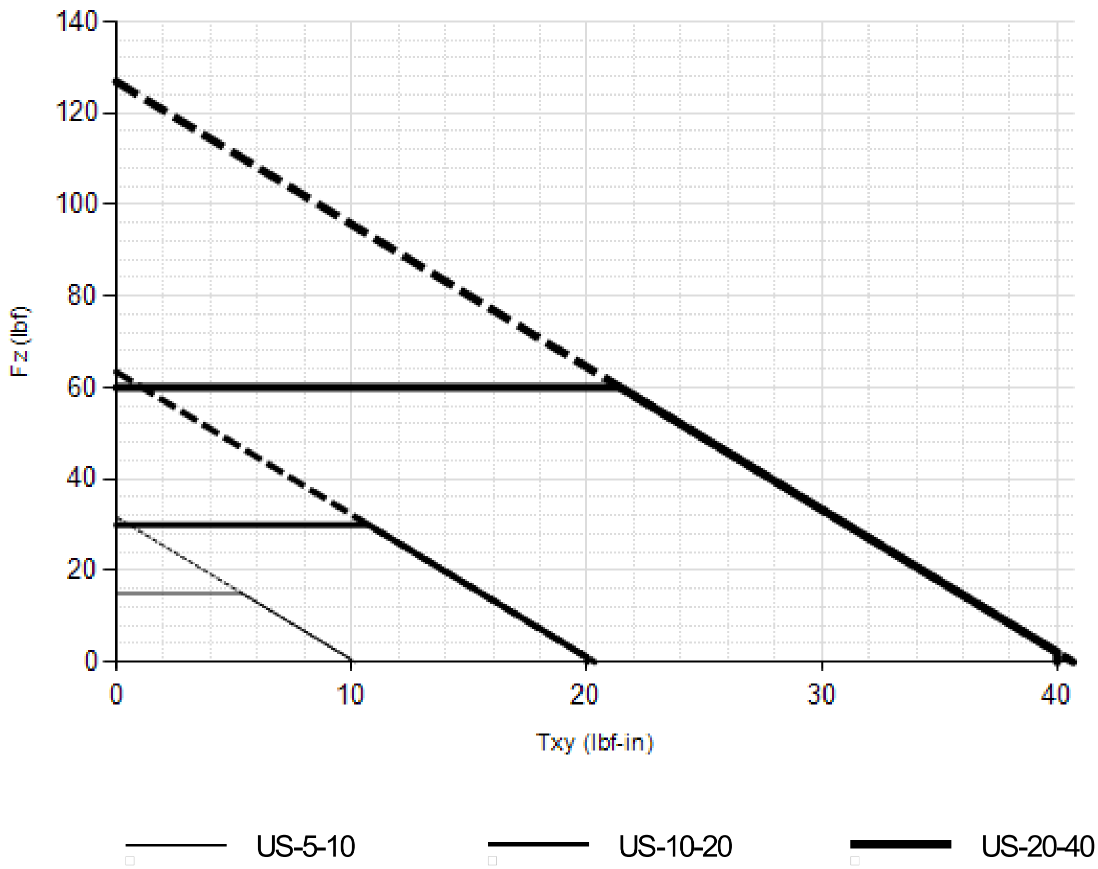
Notes:
1. ±5V Sensitivity values are double the listed ±10V Sensitivity values.
2. For IP68 version see caution on physical properties page.

5.7.6 Counts Value

Table 5.33—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)**	

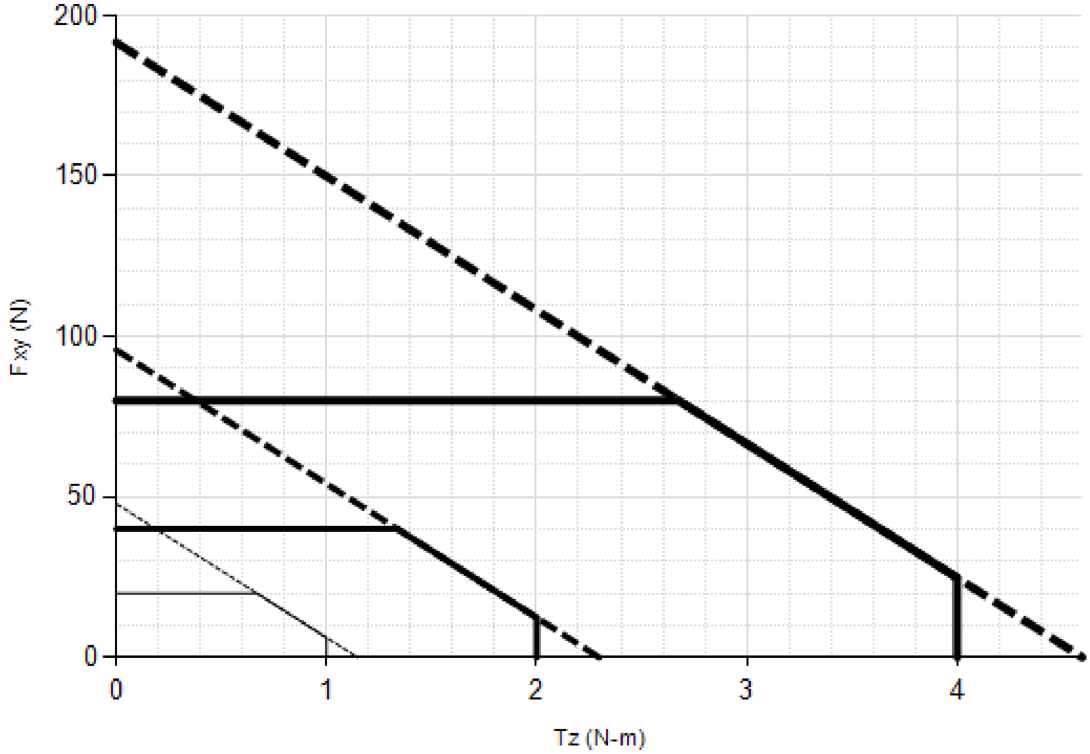
5.7.7 Mini40 (US Calibration Complex Loading)(Includes IP65/IP68)[1]

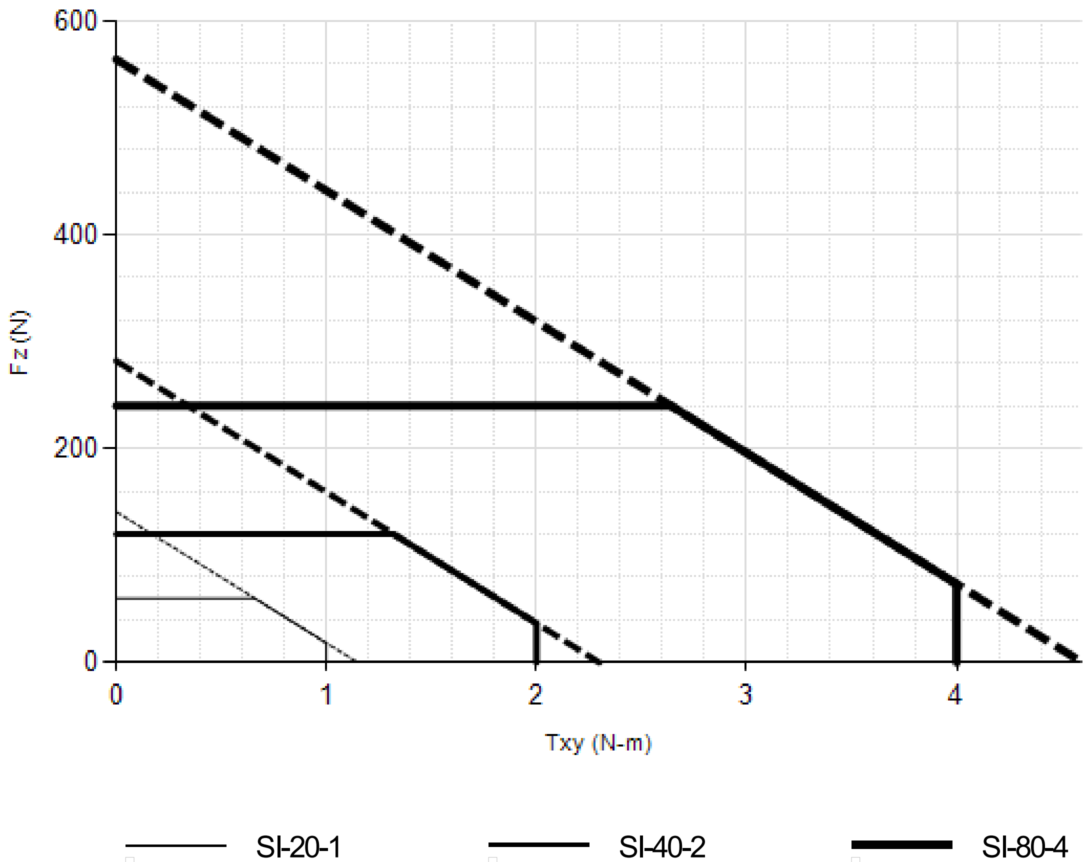




Note: 1. For IP68 version see caution on physical properties page.

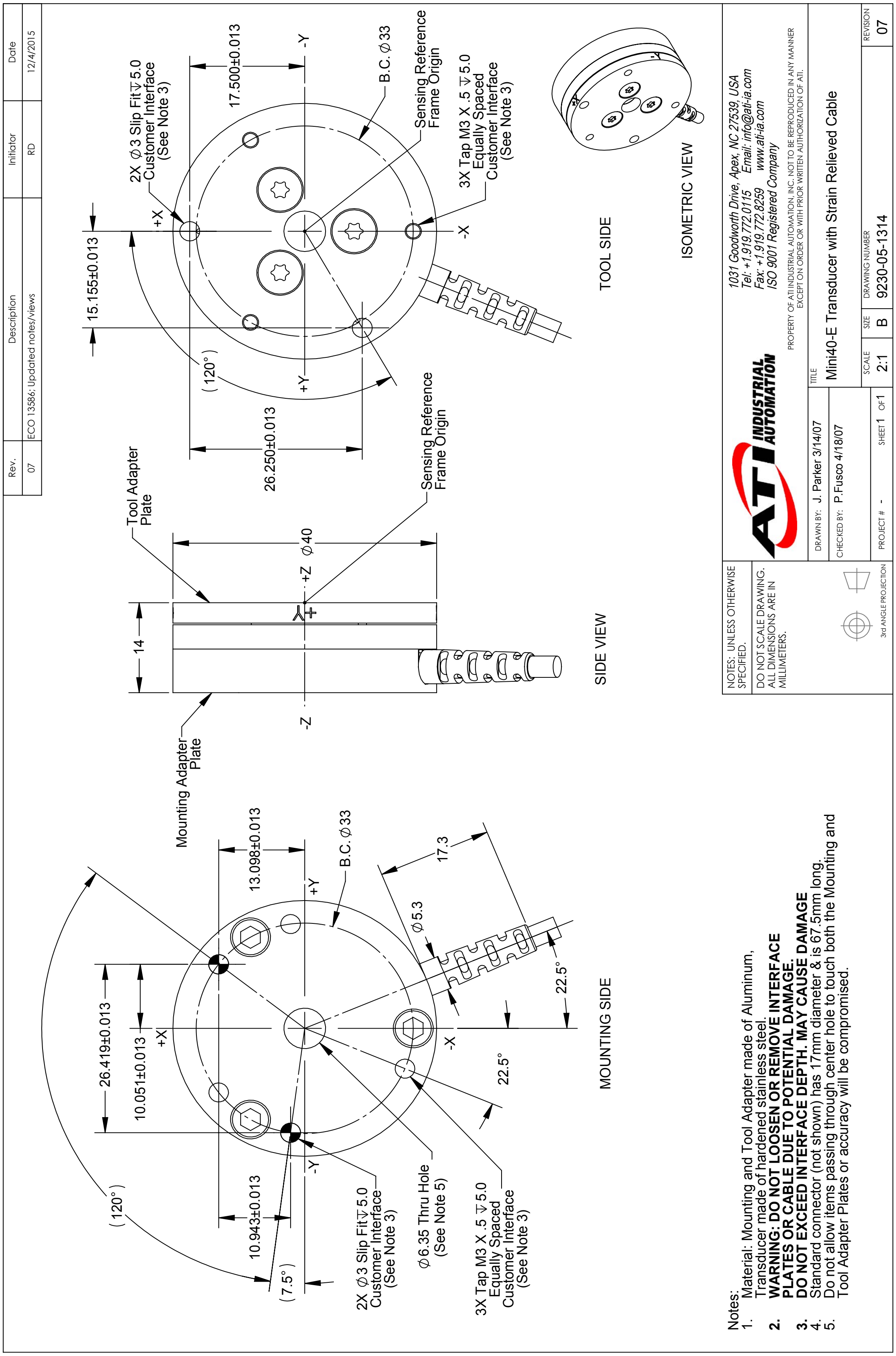
5.7.8 Mini40 (SI Calibration Complex Loading)(Includes IP65/IP68)[1]



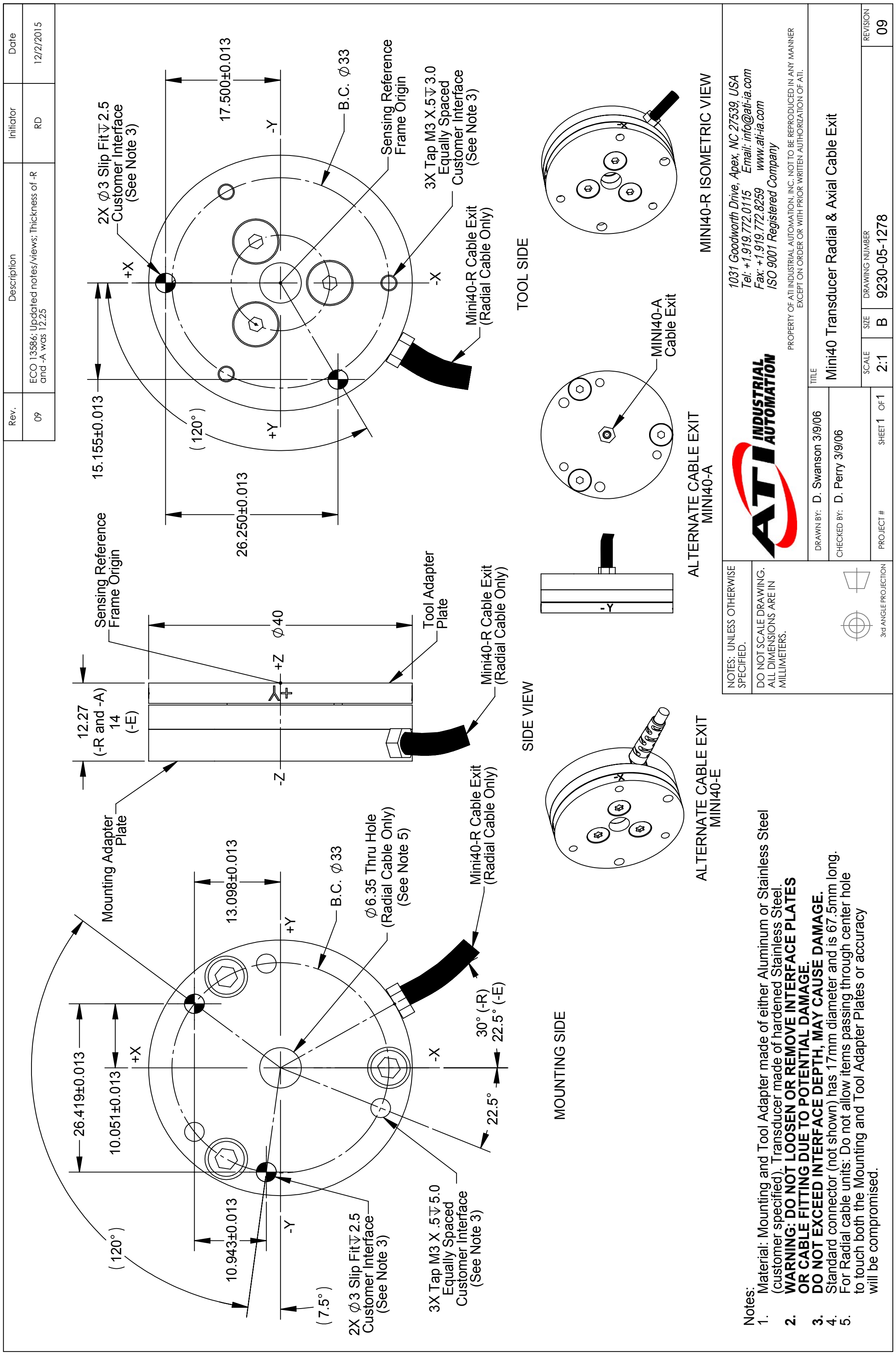


Note: 1. For IP68 version see caution on physical properties page.

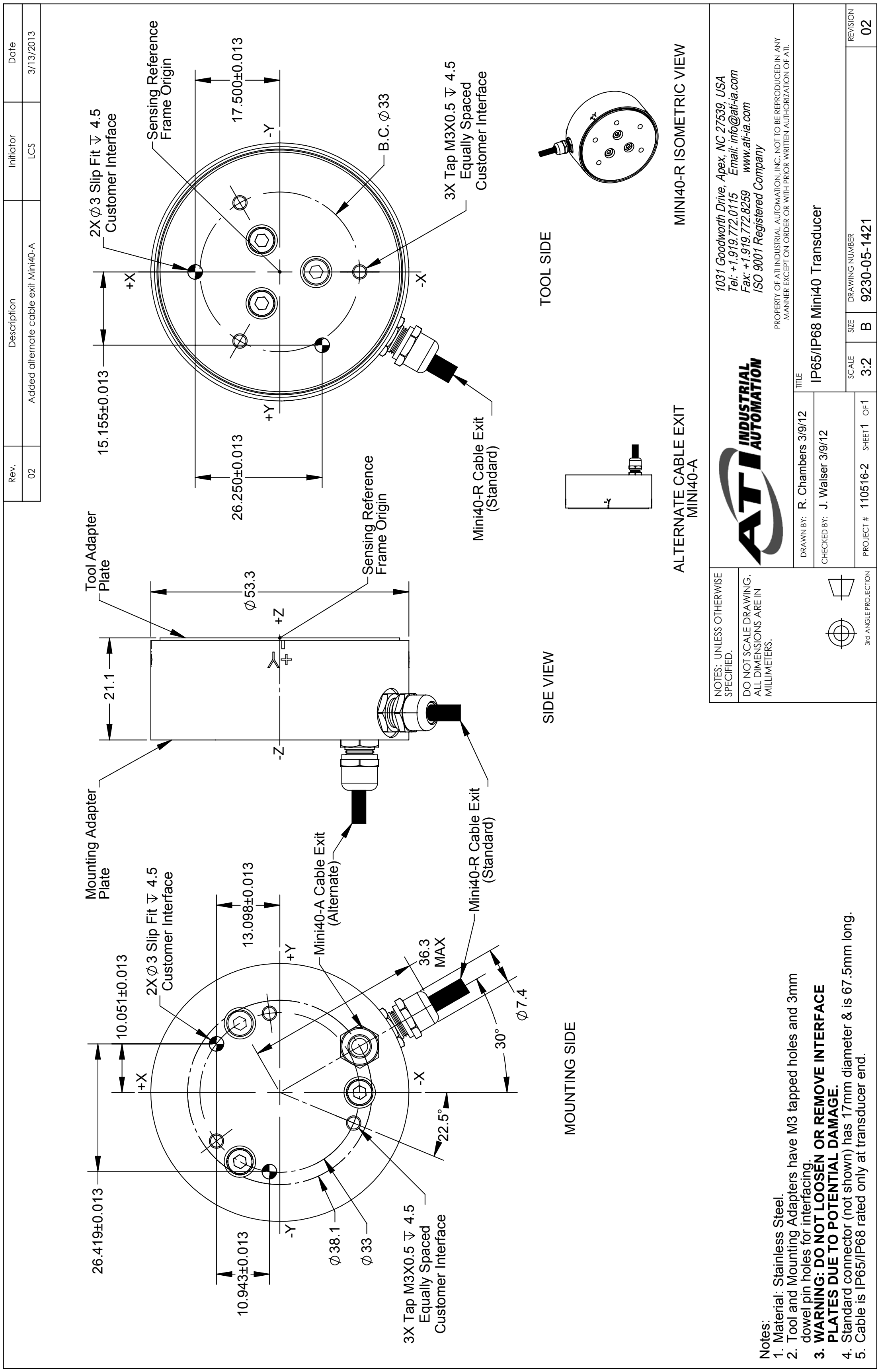
5.7.9 Mini40-E Transducer Drawing



5.7.10 Legacy Mini40 Transducer Drawing



5.7.11 Mini40 IP65/IP68 Transducer Drawing



5.8 Mini45 Titanium Specifications

5.8.1 Mini45 Titanium Physical Properties

Table 5.34—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.		

5.8.2 Calibration Specifications (excludes CTL calibrations)

Table 5.35— 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.

5.8.3 CTL Calibration Specifications

Table 5.36— 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.

5.8.4 Analog Output

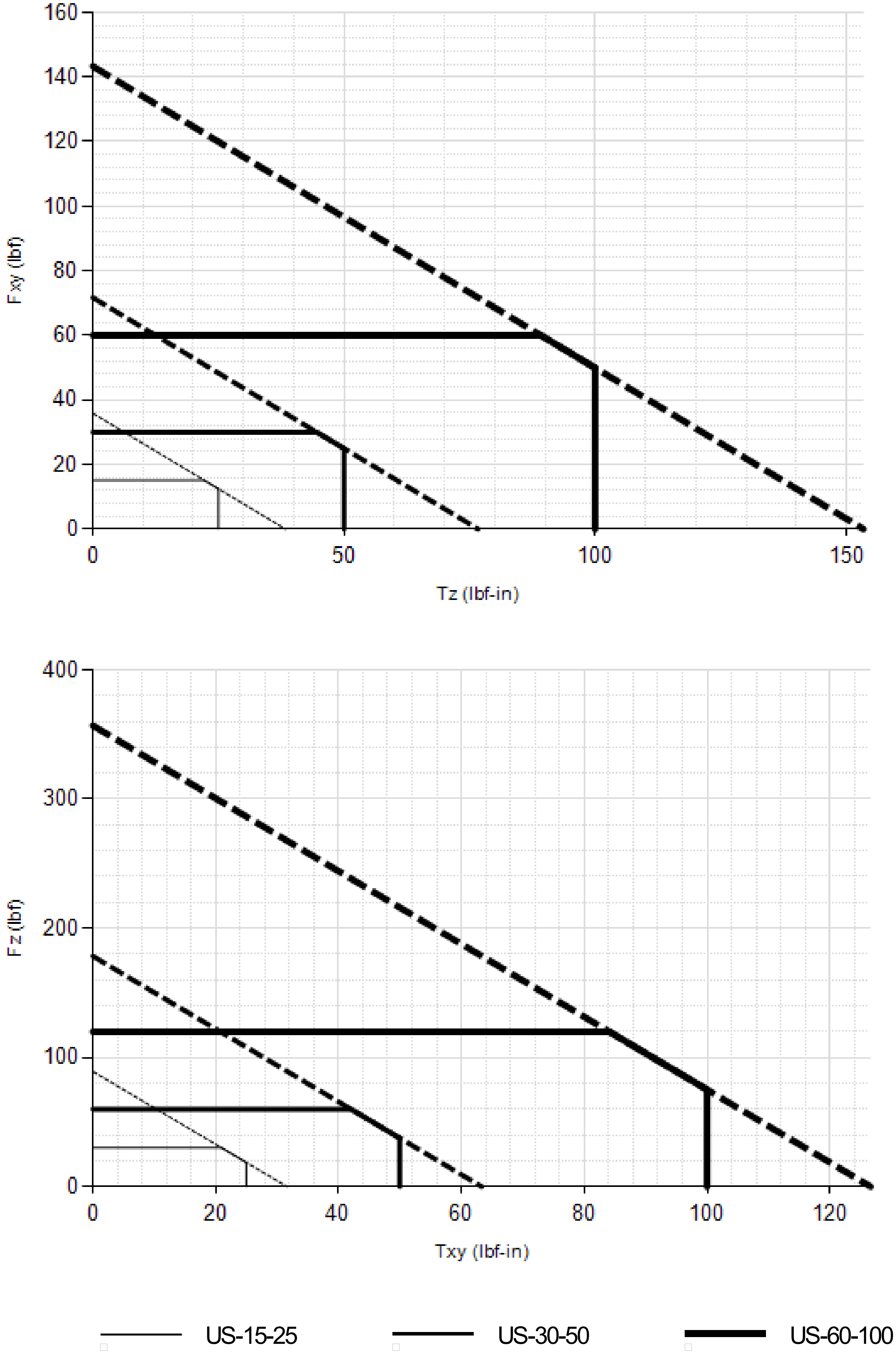
Table 5.37— Mini45 Titanium Analog Output							
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz (lbf)**	**Tx,Ty,Tz (lbf-in)**	**Fx,Fy (lbf/V)**	**Fz (lbf/V)**	**Tx,Ty,Tz (lbf-in/V)**
Mini45 Titanium	US-15-25	±15	±30	±25	1.5	3	2.5
Mini45 Titanium	US-30-50	±30	±60	±50	3	6	5
Mini45 Titanium	US-60-100	±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.

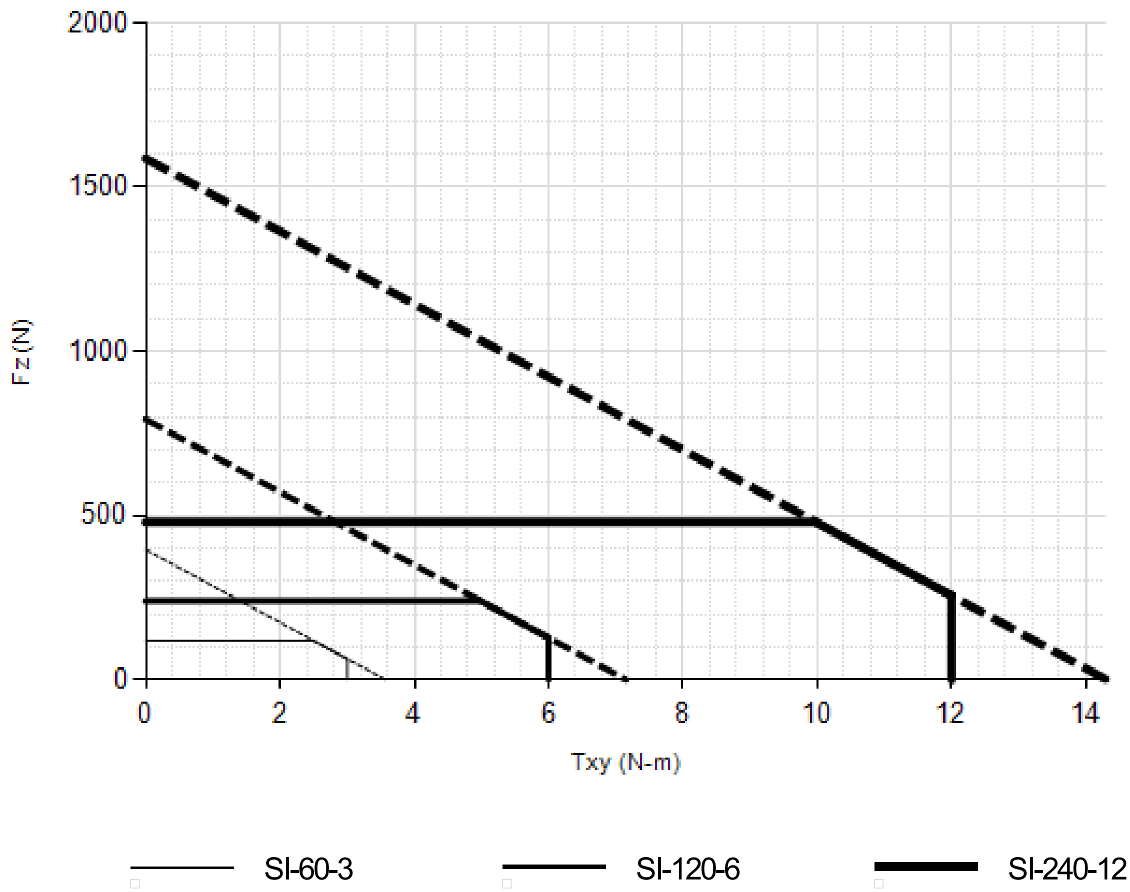
5.8.5 Counts Value

Table 5.38—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)**	

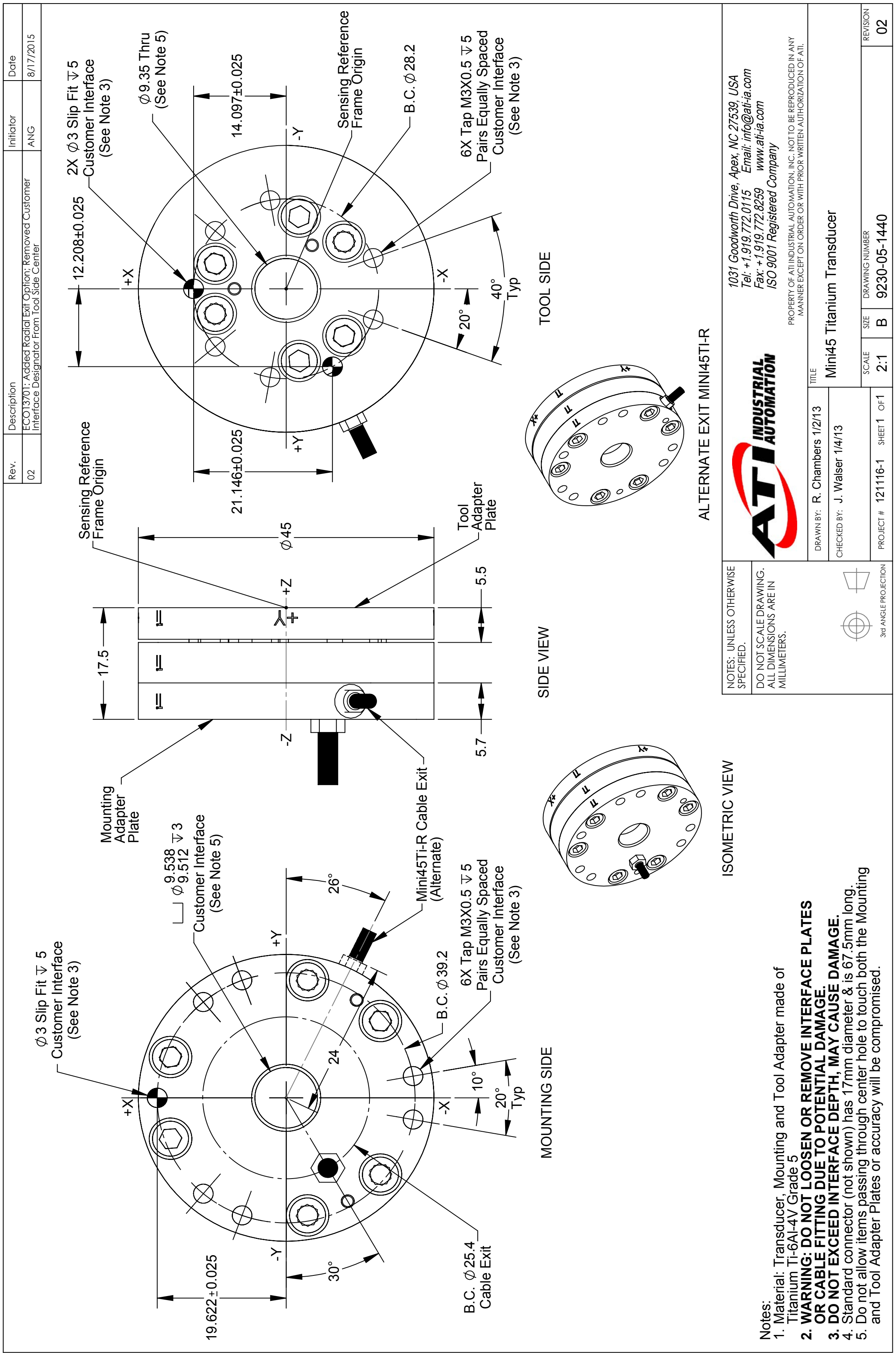
5.8.6 Mini45 Titanium (US Calibration Complex Loading)



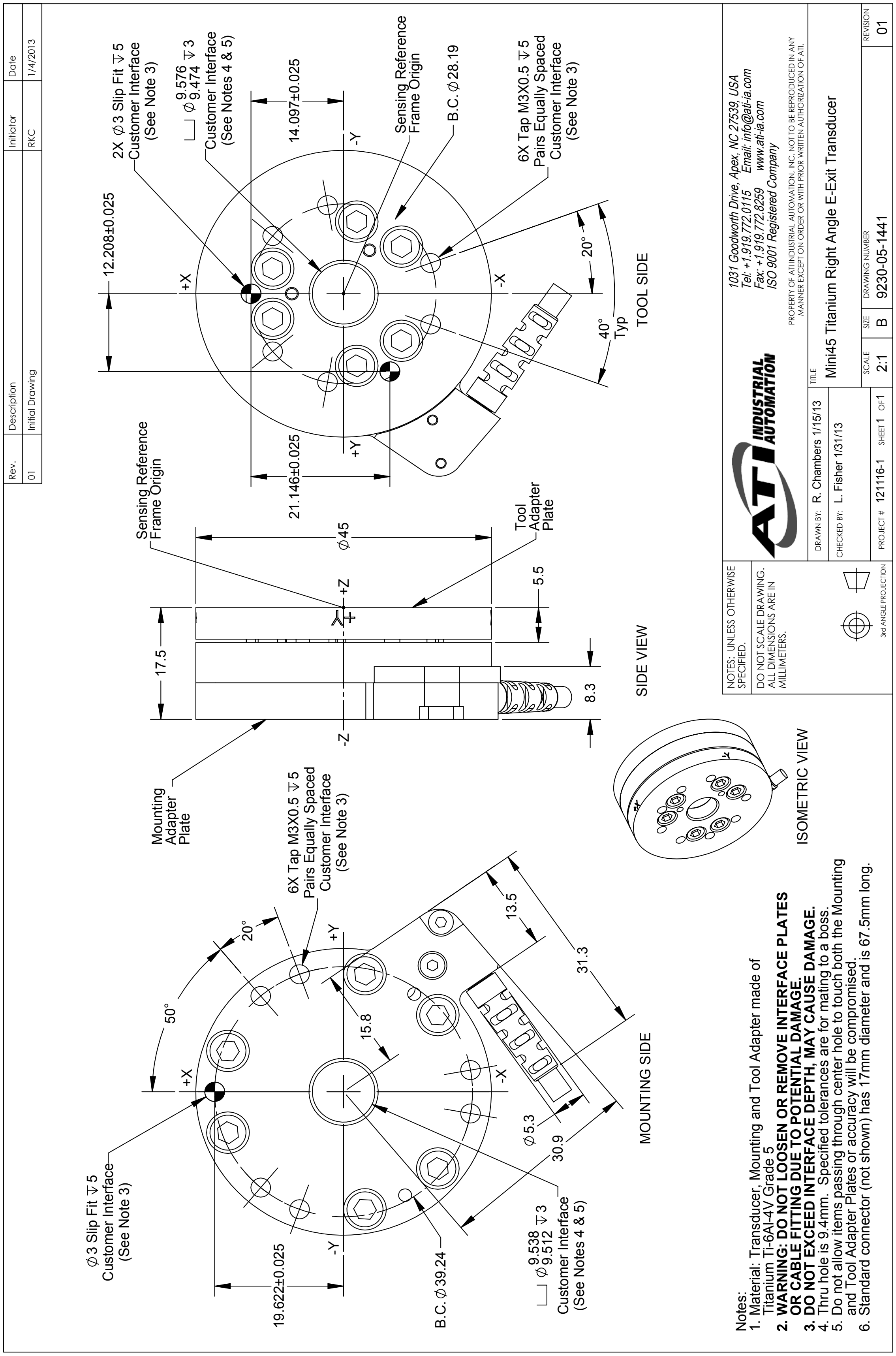
5.8.7 Mini45 Titanium (SI Calibration Complex Loading)



5.8.8 Mini45 Titanium Axial Exit Transducer Drawing



5.8.9 Mini45 Titanium Right Angle E-Exit Transducer Drawing



5.9 Mini45 Specifications (Includes IP65/IP68 Versions)

5.9.1 Mini45 Physical Properties

Table 5.39—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)	$4.2x10^{5}$ lb/in	$7.4x10^{7}$ N/m
Z-axis force (Kz)	$5.6x10^{5}$ lb/in	$9.8x10^{7}$ N/m
X-axis & Y-axis torque (Ktx, Kty)	$1.5x10^{5}$ lbf-in/rad	$1.7x10^{4}$ Nm/rad
Z-axis torque (Ktz)	$3.1x10^{5}$ lbf-in/rad	$3.5x10^{4}$ 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.		

5.9.2 Mini45 IP65/IP68 Physical Properties

Table 5.40—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)	$4.2x10^{5}$ lb/in	$7.4x10^{7}$ N/m
Z-axis force (Kz)	$5.6x10^{5}$ lb/in	$9.8x10^{7}$ N/m
X-axis & Y-axis torque (Ktx, Kty)	$1.5x10^{5}$ lbf-in/rad	$1.7x10^{4}$ Nm/rad
Z-axis torque (Ktz)	$3.1x10^{5}$ lbf-in/rad	$3.5x10^{4}$ 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

5.9.3 Calibration Specifications (excludes CTL calibrations)

Table 5.41— 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.

5.9.4 CTL Calibration Specifications

Table 5.42— 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.

5.9.5 Analog Output

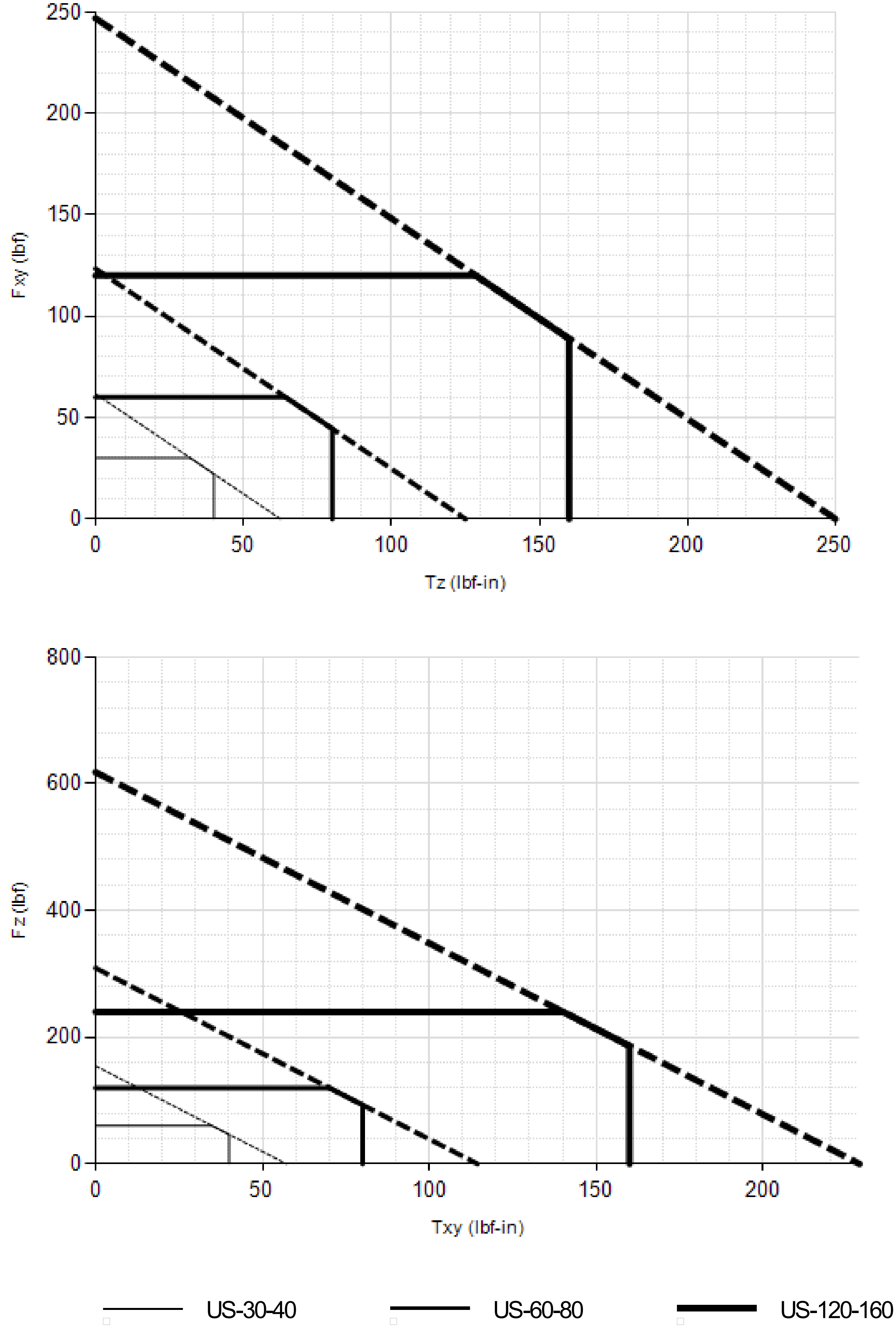
Table 5.43— Mini45 Analog Output							
Sensor	(US) Standard Calibration	Fx,Fy (lbf)	Fz[2] (lbf)	Tx,Ty,Tz (lbf-in)	Fx,Fy (lbf/V)	Fz[2] (lbf/V)	Tx,Ty,Tz (lbf-in/V)
Mini45	US-30-40	±30	±60	±40	3	6	4
Mini45	US-60-80	±60	±120	±80	6	12	8
Mini45	US-120-160	±120	±240	±160	12	24	16
Sensor	(SI) Metric Calibration	Fx,Fy (N)	Fz[2] (N)	Tx,Ty,Tz (Nmm)	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.

5.9.6 Counts Value

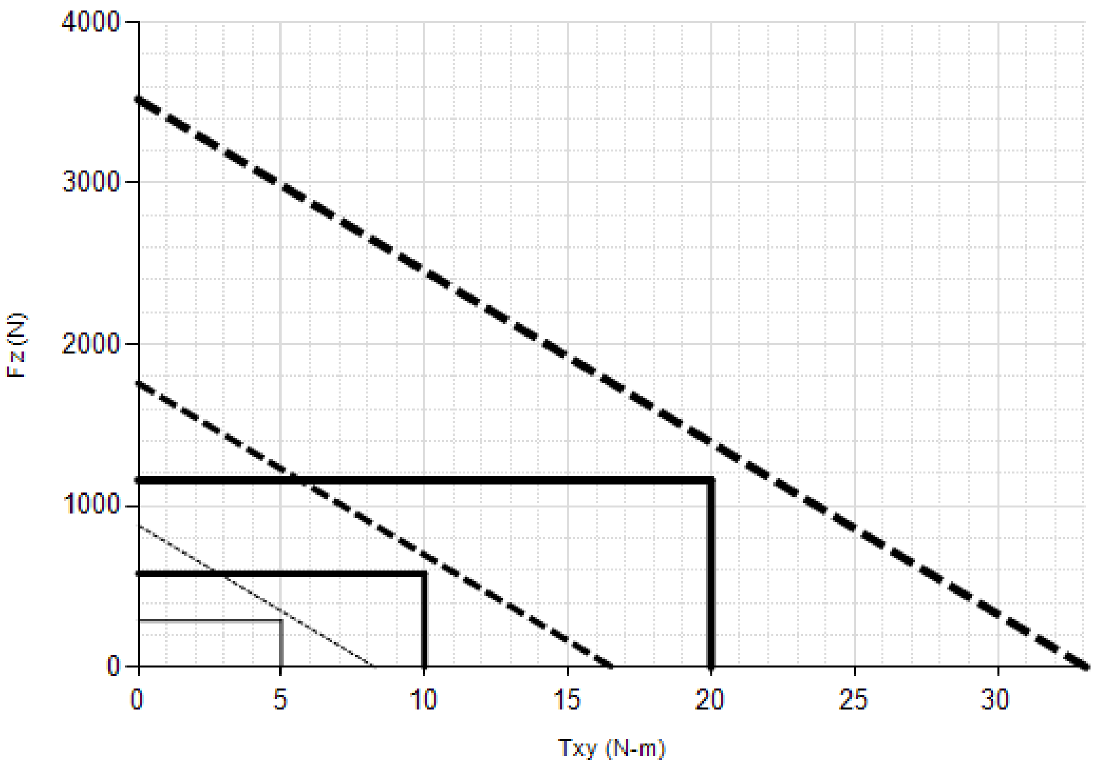
Table 5.44—Counts Value					
Sensor	Calibration	Fx, Fy, Fz (/ lbf)	Tx, Ty, Tz (/ lbf-in)	Fx, Fy, Fz (/ N)	Tx, Ty, Tz (/ Nm)
Mini45	US-30–40 / SI-145–5	640	704	128	6016
Mini45	US-60–80 / SI-290–10	320	352	64	3008
Mini45	US-120–160 / SI-580–20	160	176	32	1504
Mini45	Tool Transform Factor	0.009091 in/lbf		0.21277 mm/N	
		Counts Value – Standard (US)		Counts Value – Metric (SI)	

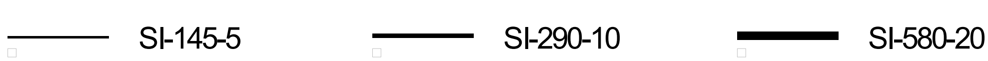
5.9.7 Mini45 (US Calibration Complex Loading)(Includes IP65/IP68)[1]



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

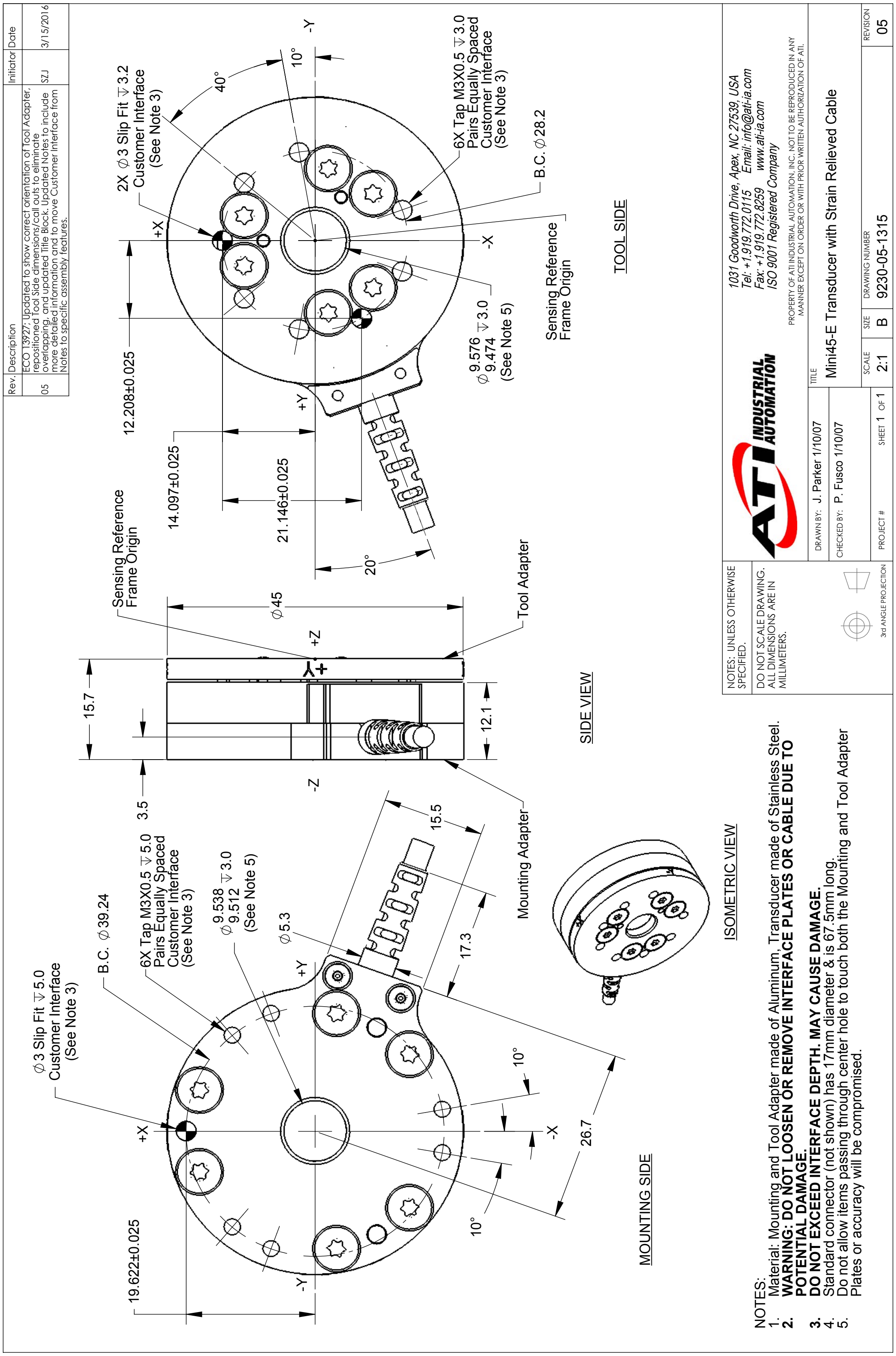
5.9.8 Mini45 (SI Calibration Complex Loading)(Includes IP65/IP68)[1]



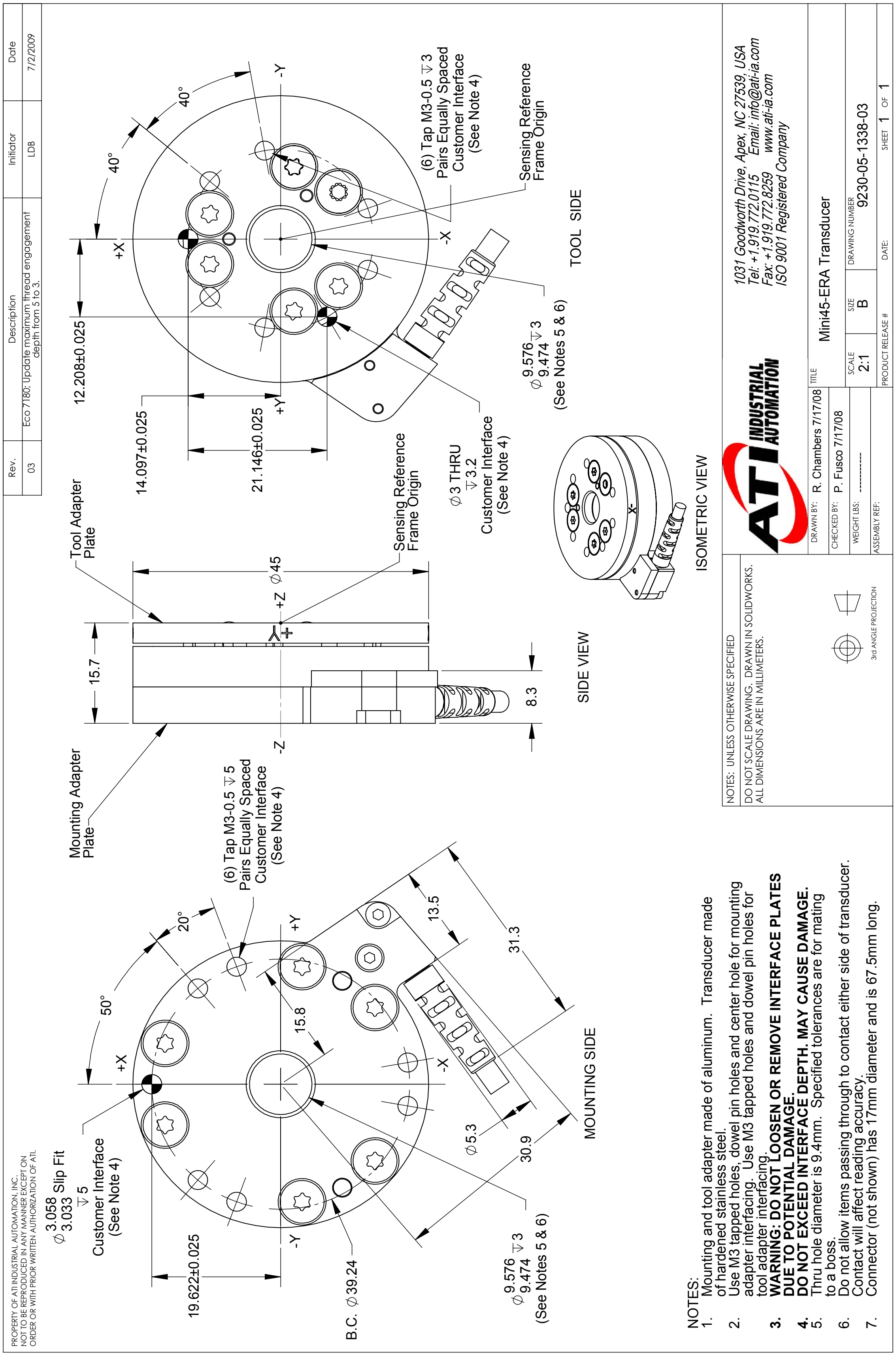


Note: 1. For IP68 version see caution on physical properties page.

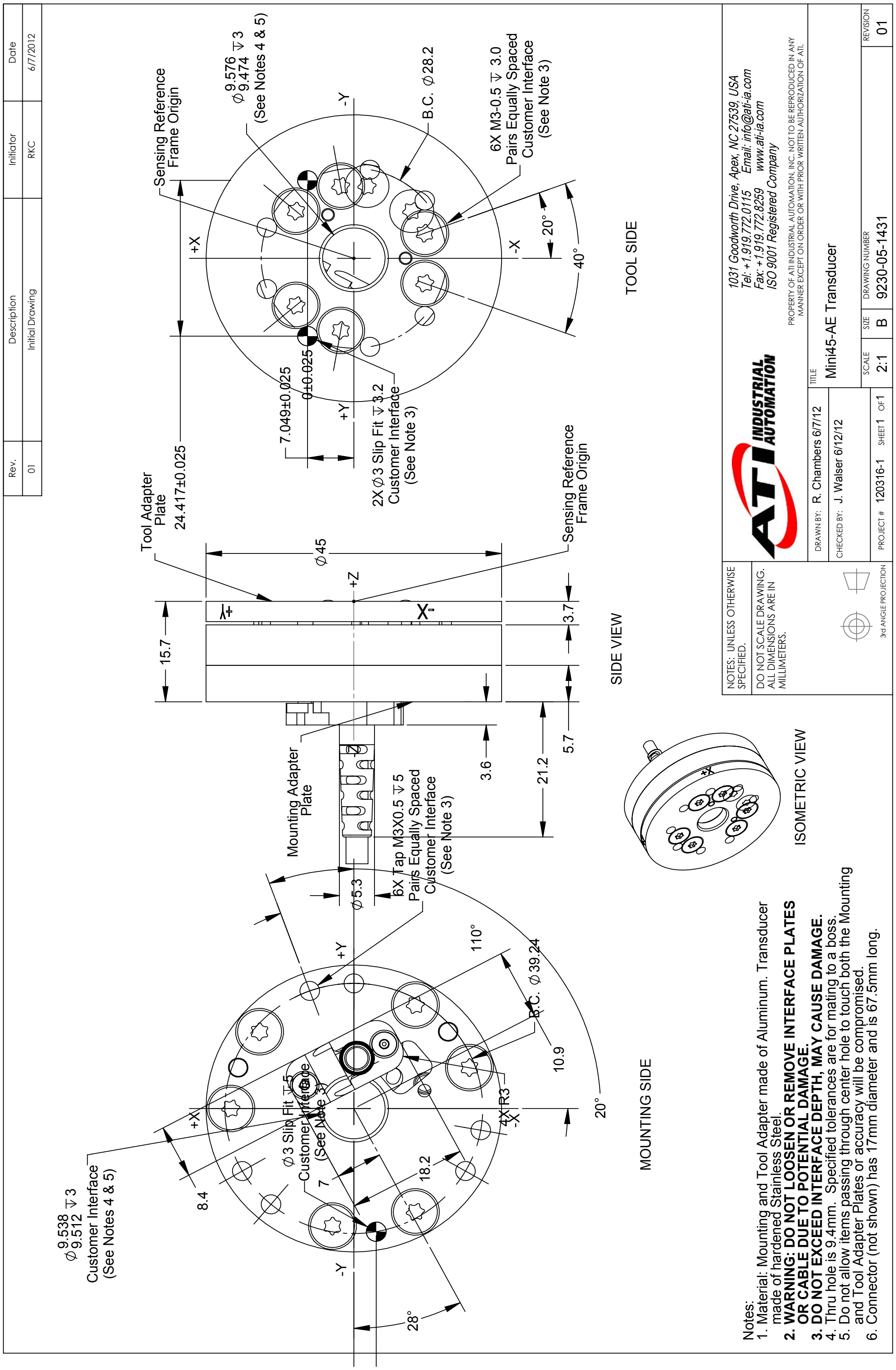
5.9.9 Mini45-E Transducer Drawing



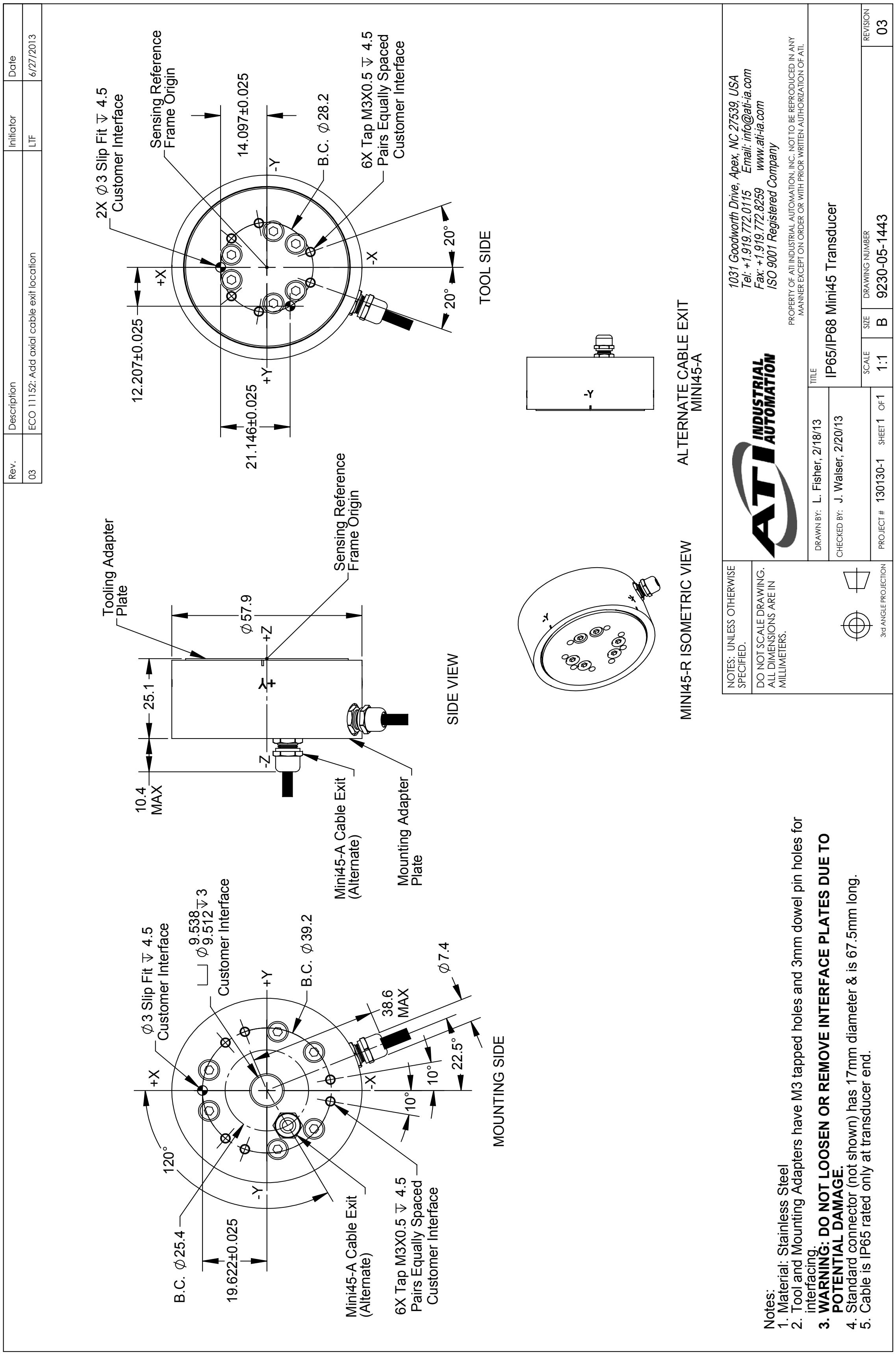
5.9.10 Mini45-ERA Transducer Drawing



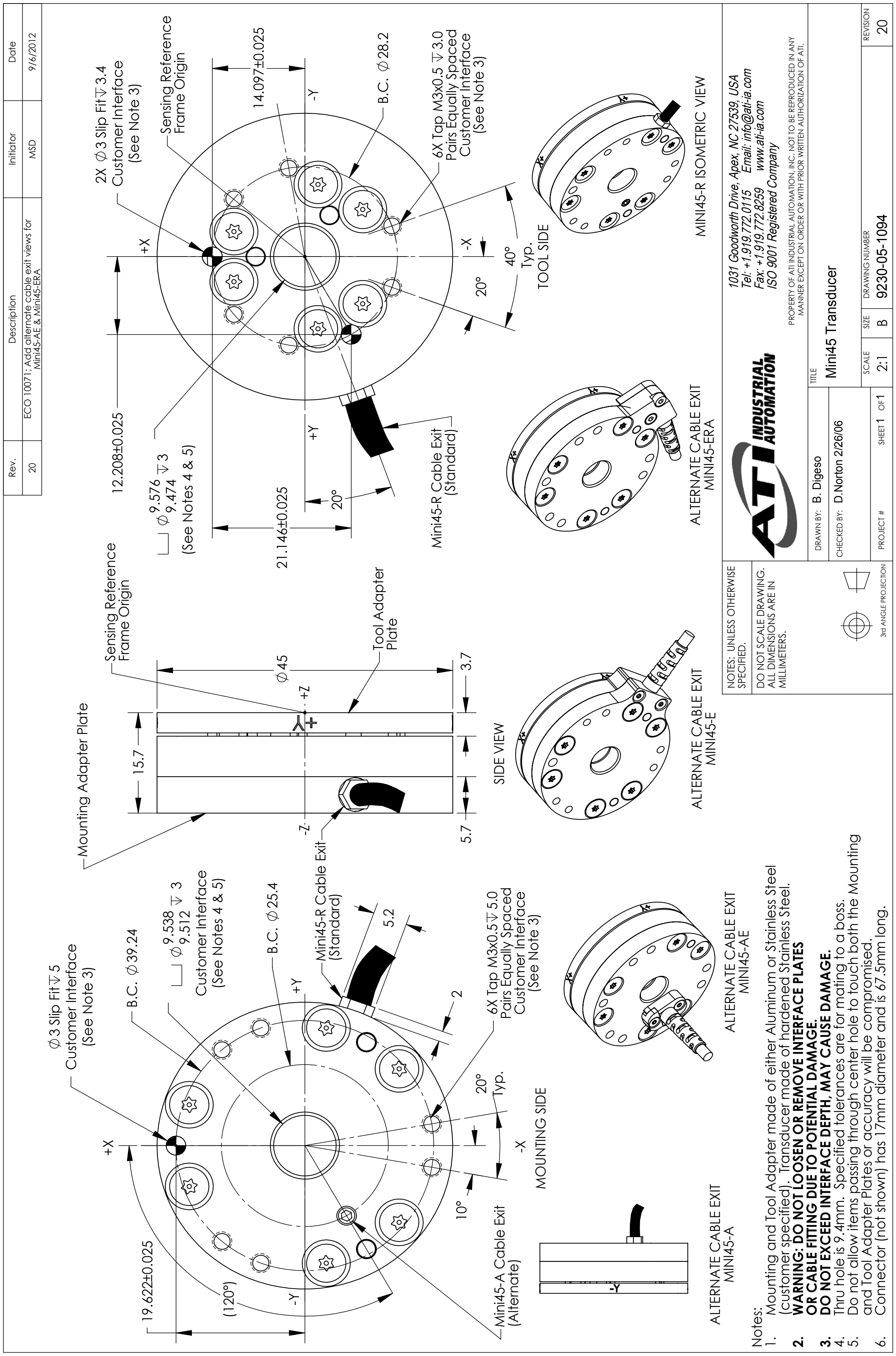
5.9.11 Mini45-AE Transducer Drawing



5.9.12 Mini45 IP65/IP68 Transducer Drawing



5.9.13 Legacy Mini45 Transducer Drawing



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

5.10.1 Mini58 Physical Properties

Table 5.45—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)	1.4×10^6 lb/in	2.5×10^8 N/m
Z-axis force (Kz)	2.1×10^6 lb/in	3.7×10^8 N/m
X-axis & Y-axis torque (Ktx, Kty)	9.3×10^5 lbf-in/rad	1.1×10^5 Nm/rad
Z-axis torque (Ktz)	1.8×10^6 lbf-in/rad	2.0×10^5 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.		

5.10.2 Mini58 IP60 Physical Properties

Table 5.46—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)	1.4×10^6 lb/in	2.5×10^8 N/m
Z-axis force (Kz)	2.1×10^6 lb/in	3.7×10^8 N/m
X-axis & Y-axis torque (Ktx, Kty)	9.3×10^5 lbf-in/rad	1.1×10^5 Nm/rad
Z-axis torque (Ktz)	1.8×10^6 lbf-in/rad	2.0×10^5 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.		

5.10.3 Mini58 IP65/IP68 Physical Properties

Table 5.47—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)	$1.4\text{x}10^{6}$ lb/in	$2.5\text{x}10^{8}$ N/m
Z-axis force (Kz)	$2.1\text{x}10^{6}$ lb/in	$3.7\text{x}10^{8}$ N/m
X-axis & Y-axis torque (Ktx, Kty)	$9.3\text{x}10^{5}$ lbf-in/rad	$1.1\text{x}10^{5}$ Nm/rad
Z-axis torque (Ktz)	$1.8\text{x}10^{6}$ lbf-in/rad	$2.0\text{x}10^{5}$ 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

5.10.4 Calibration Specifications (excludes CTL calibrations)

Table 5.48— 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.

5.10.5 CTL Calibration Specifications

Table 5.49— 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.

5.10.6 Analog Output

Table 5.50— Mini58 Analog Output							
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz² (lbf)**	**Tx,Ty,Tz (lbf-in)**	**Fx,Fy (lbf/V)**	**Fz² (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)**	**Fz² (N)**	**Tx,Ty,Tz (Nmm)**	**Fx,Fy (N/V)**	**Fz² (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 Sensitivity¹**		

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

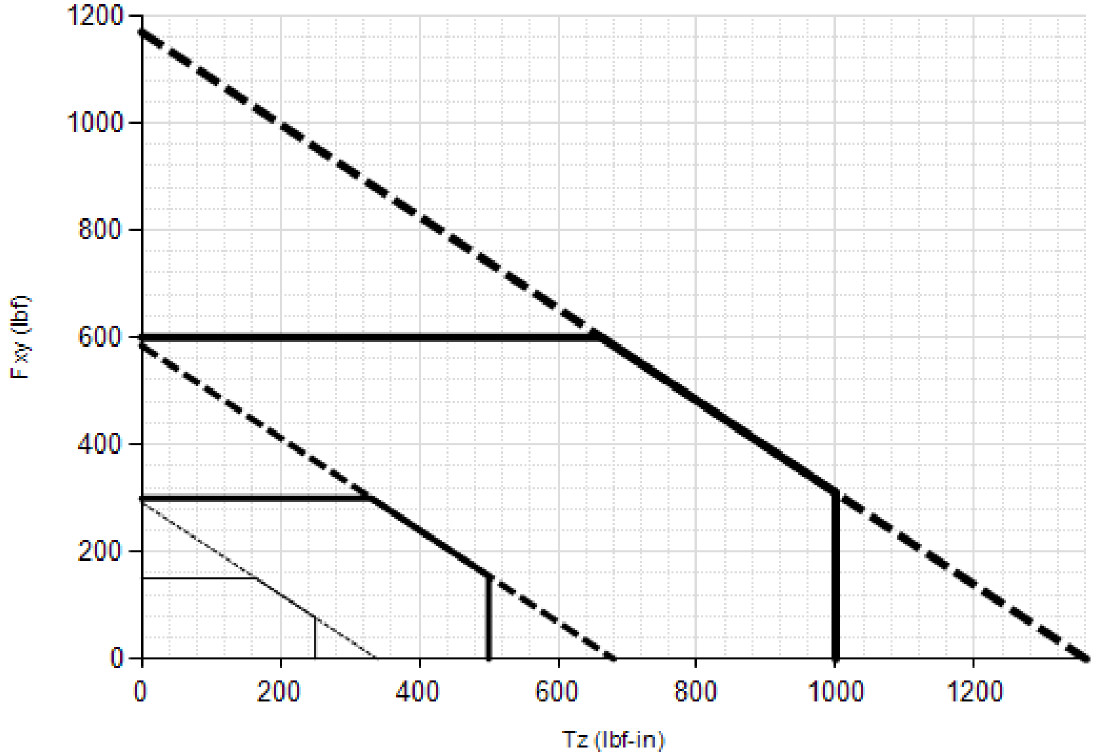
5.10.7 Counts Value

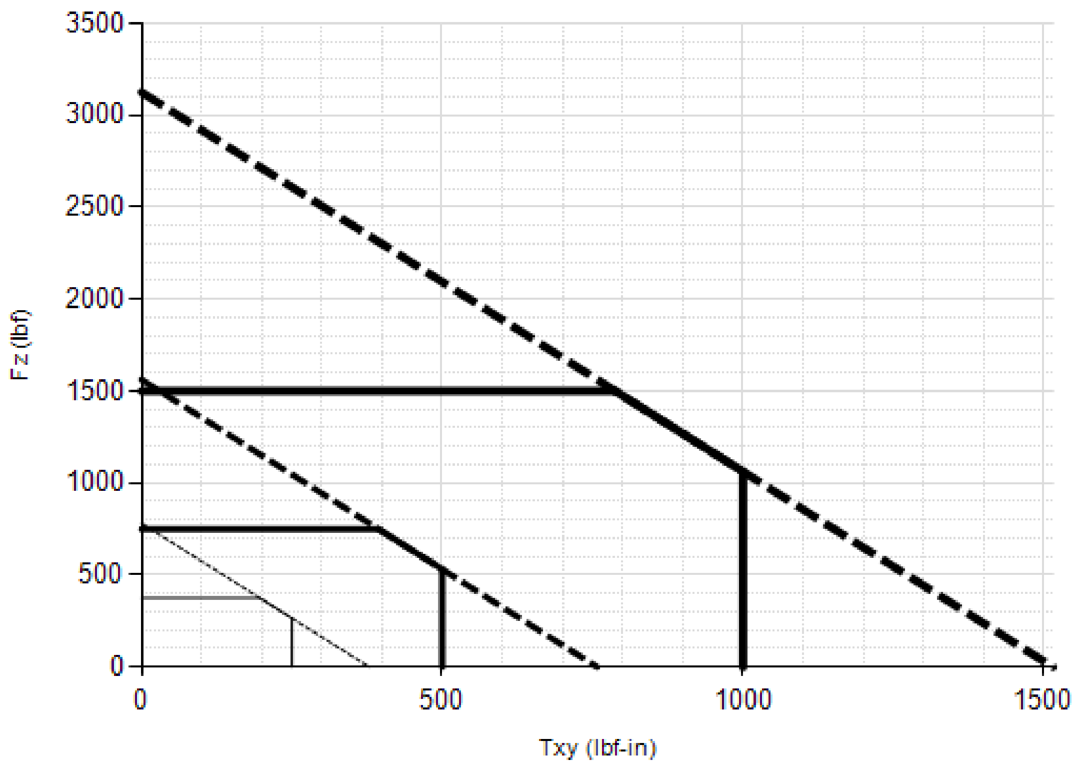
Table 5.51—Counts Value					
Sensor	**Calibration**	**Fx, Fy, Fz (/ lbf)**	**Tx, Ty, Tz (/ lbf-in)**	**Fx, Fy, Fz (/ N)**	**Tx, Ty, Tz (/ Nm)**
Mini58	US-150-250 / SI-700-30	448	960	96	6400
Mini58	US-300-500 / SI-1400-60	224	480	48	3200
Mini58	US-600-1000 / SI-2800-120	112	240	16	1600
Mini58	Tool Transform Factor	See Tool Transform Factor table			
		Counts Value – Standard (US)		**Counts Value – Metric (SI)**	

5.10.8 Tool Transform Factor

Table 5.52—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

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

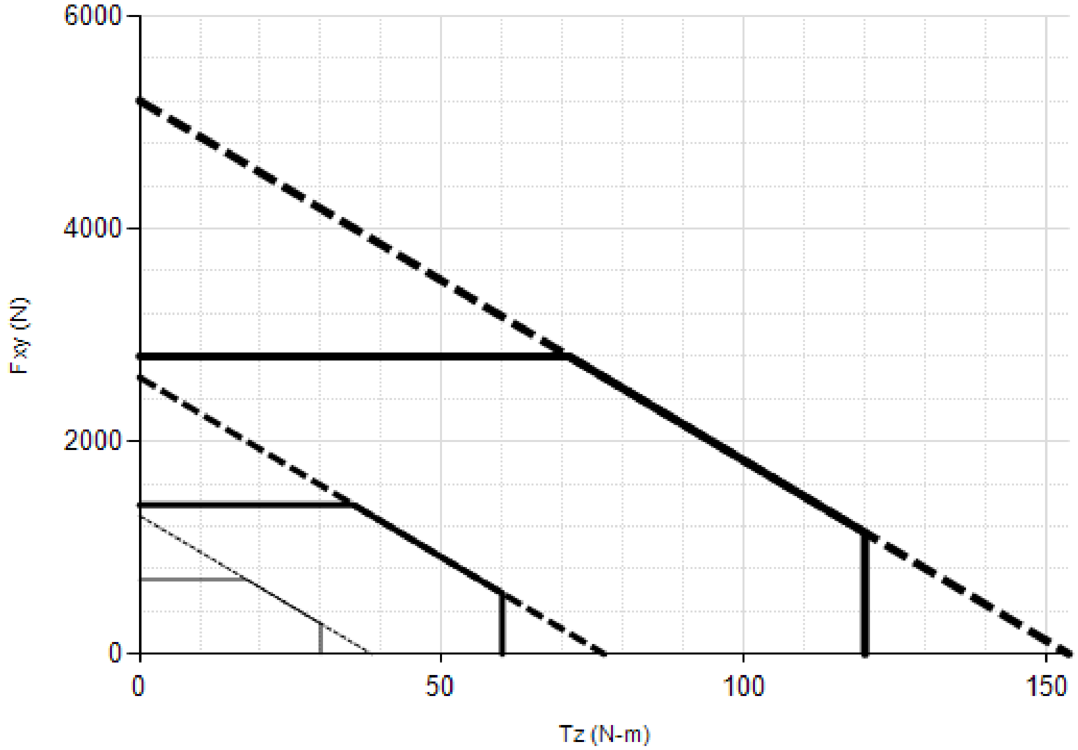


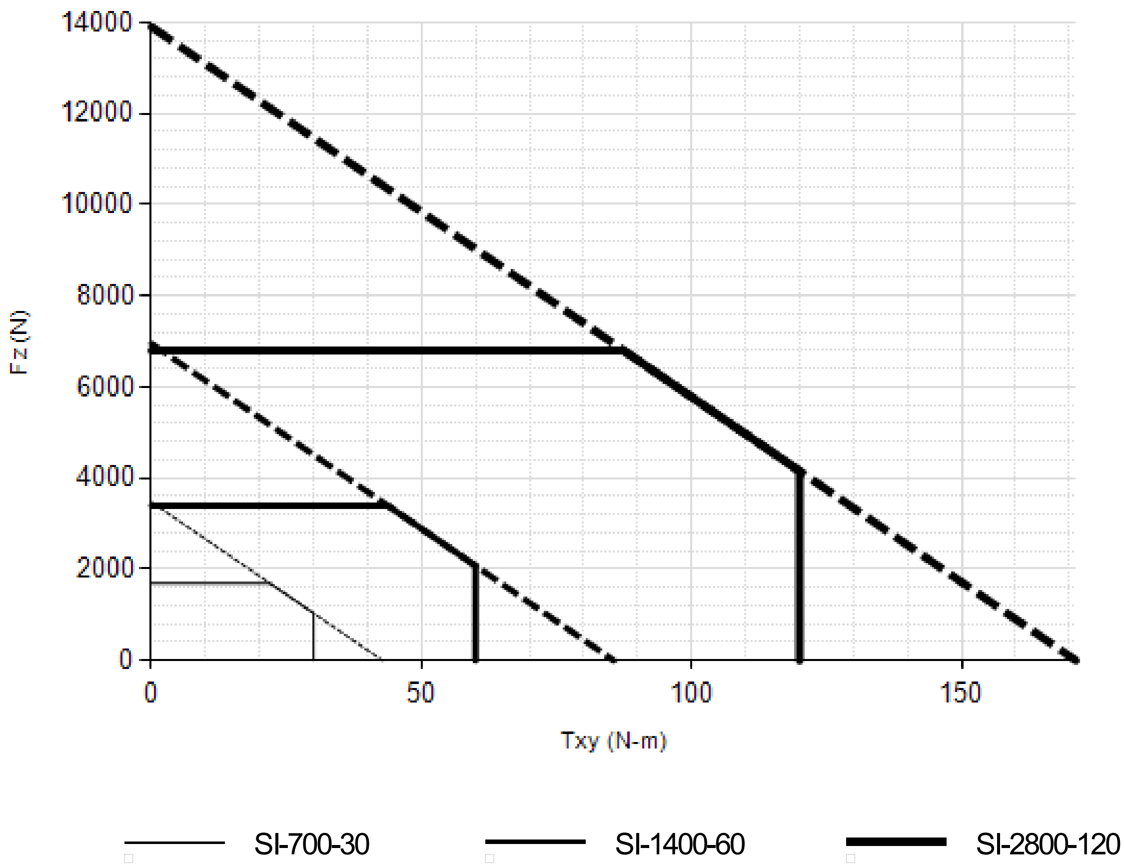


US-150-250 US-300-500 US-600-1000

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

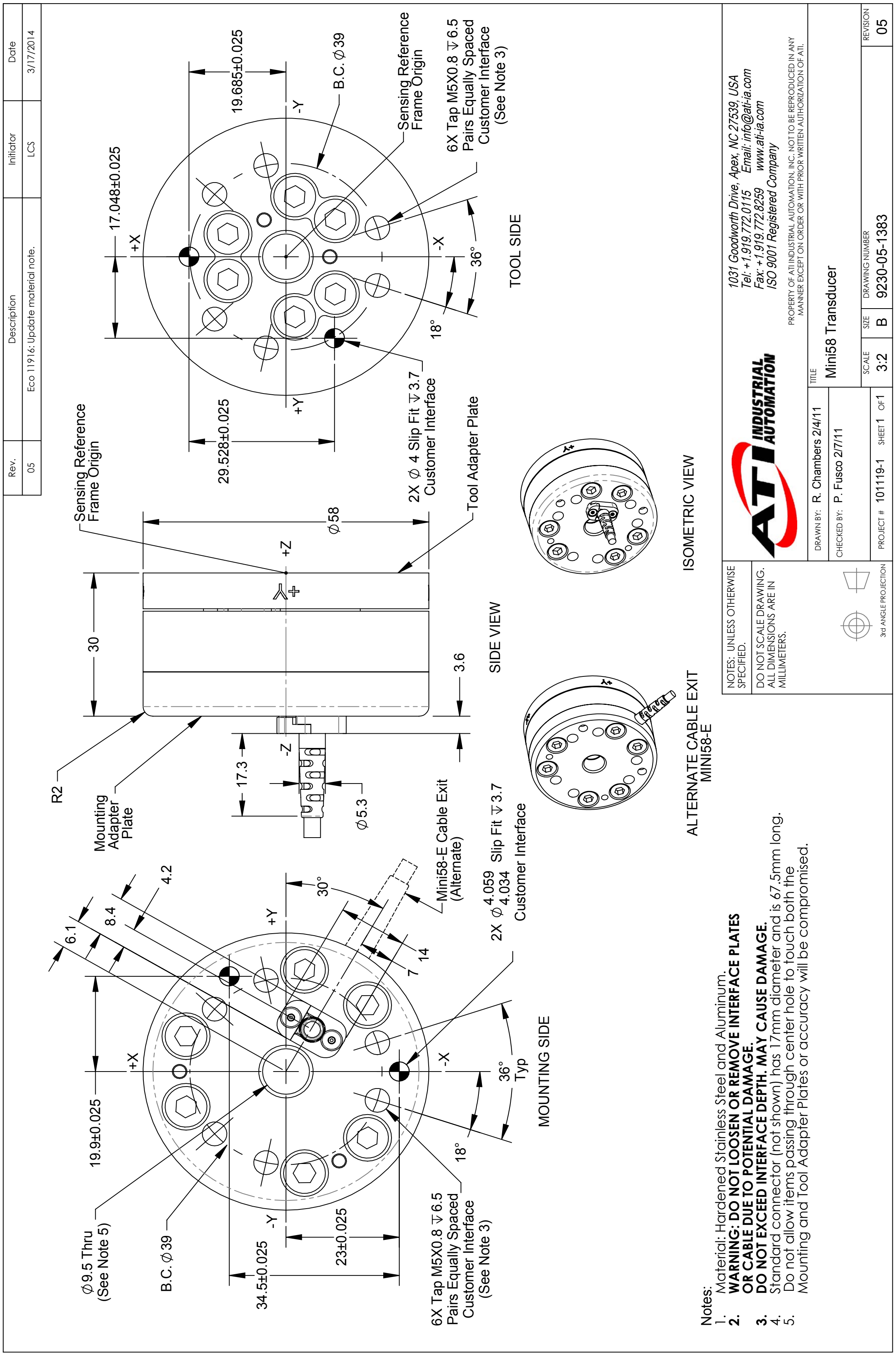
5.10.10 Mini58 (SI Calibration Complex Loading)(Includes IP60/IP65/IP68)[1]



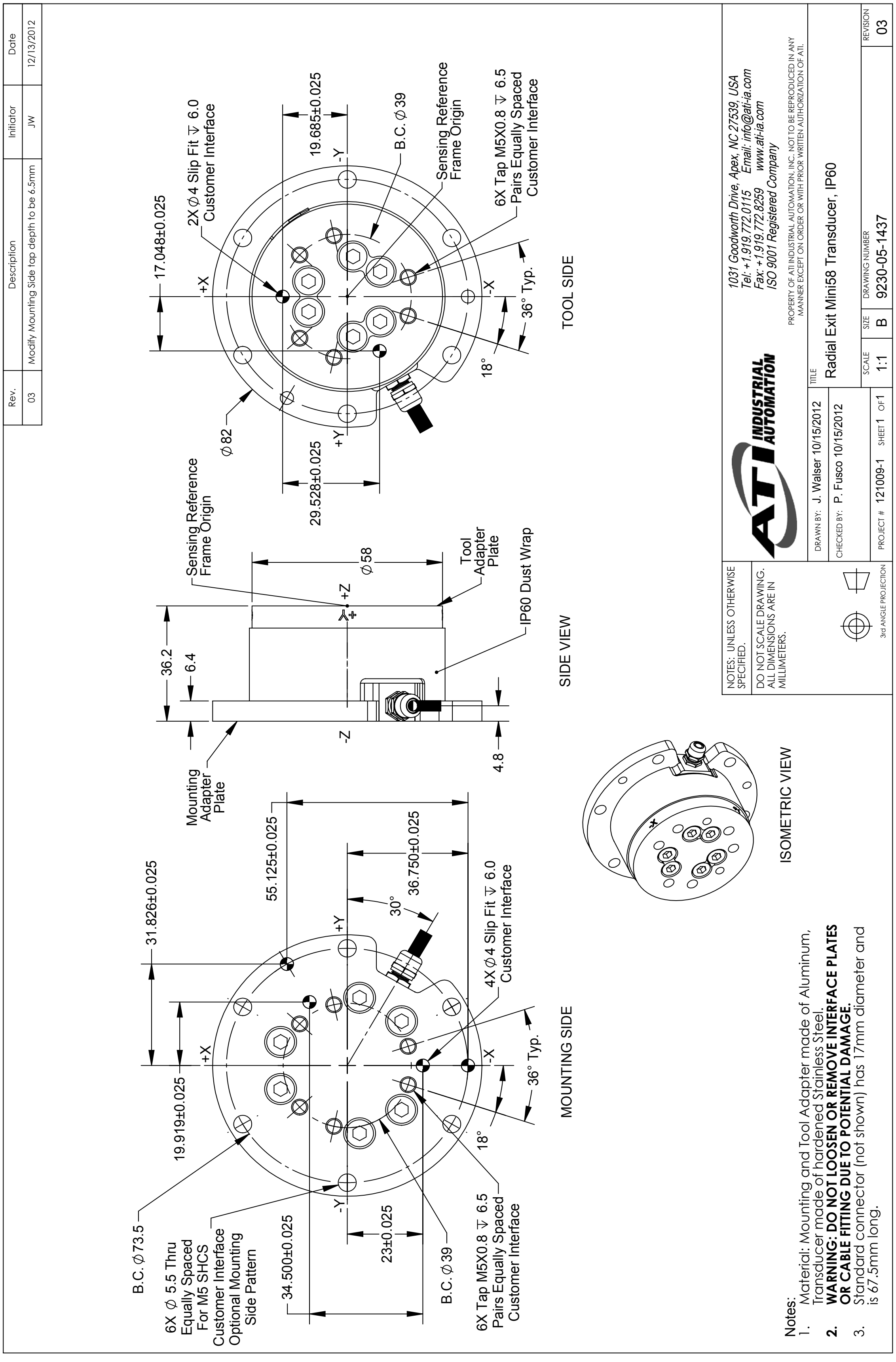


Note: 1. For IP68 version see caution on physical properties page.

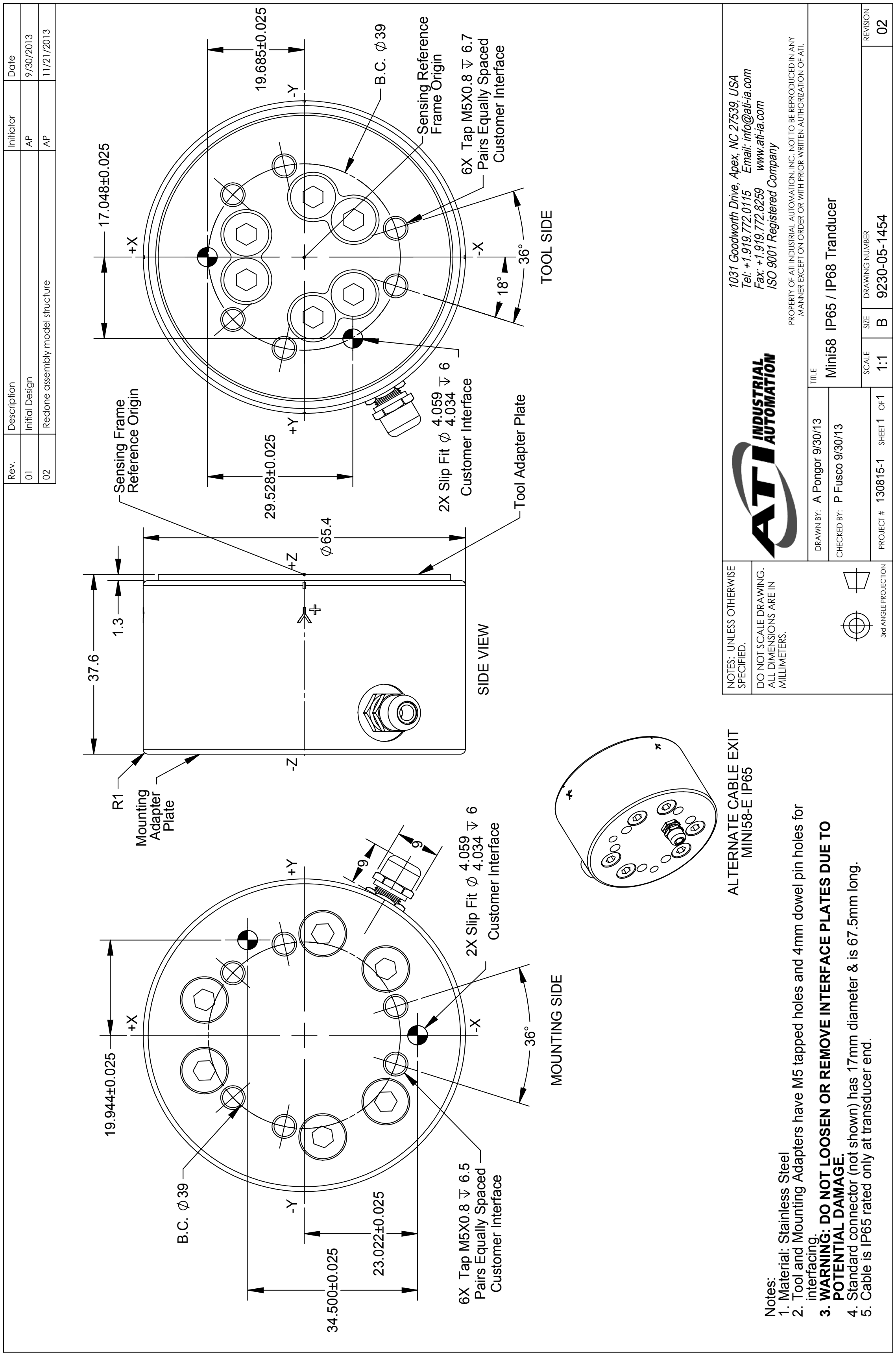
5.10.11 Mini58 Transducer Drawing



5.10.12 Mini58 IP60 Transducer Drawing



5.10.13 Mini58 IP65/IP68 Transducer Drawing



5.11 Mini85 Specifications (Includes IP60 Versions)

5.11.1 Mini85 Physical Properties

Table 5.53—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.

5.11.2 Calibration Specifications (excludes CTL calibrations)

Table 5.54— 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.

5.11.3 CTL Calibration Specifications

Table 5.55— 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.

5.11.4 Analog Output

Table 5.56— 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 (Nmm)**	**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.

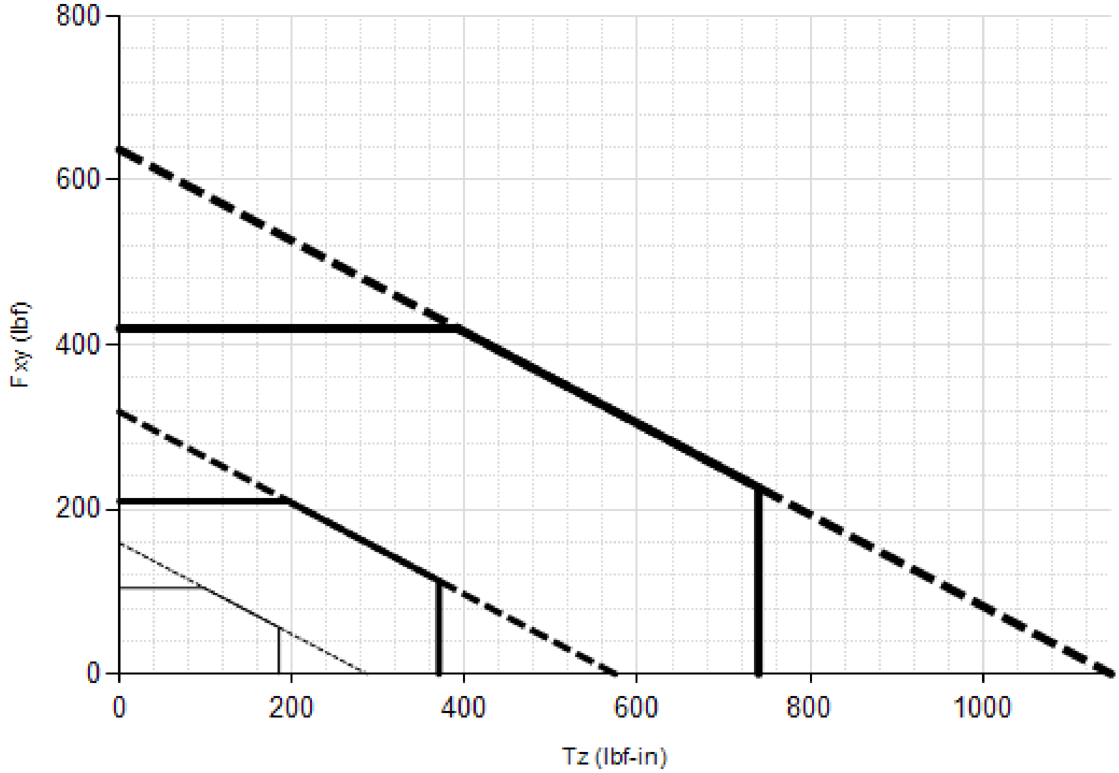
5.11.5 Counts Value

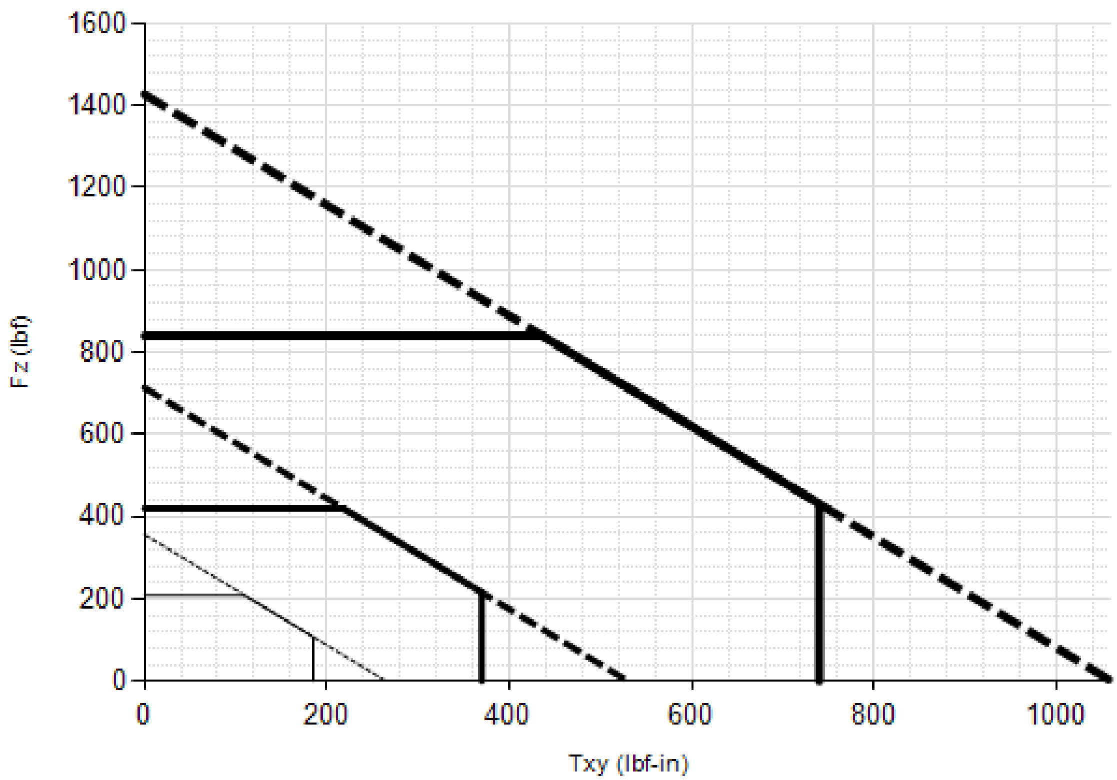
Table 5.57—Counts Value					
Sensor	**Calibration**	**Fx, Fy, Fz (/ lbf)**	**Tx, Ty, Tz (/ lbf-in)**	**Fx, Fy, Fz (/ N)**	**Tx, Ty, Tz (/ Nm)**
Mini85	US-105-185 / SI-475-20	1040	1344	448	11968
Mini85	US-210-370 / SI-950-40	512	672	224	5984
Mini85	US-420-740 / SI-1900-80	256	336	112	2992
Mini85	Tool Transform Factor	See Tool Transform Factor table			
		Counts Value – Standard (US)		**Counts Value – Metric (SI)**	

5.11.6 Tool Transform Factor

Table 5.58—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

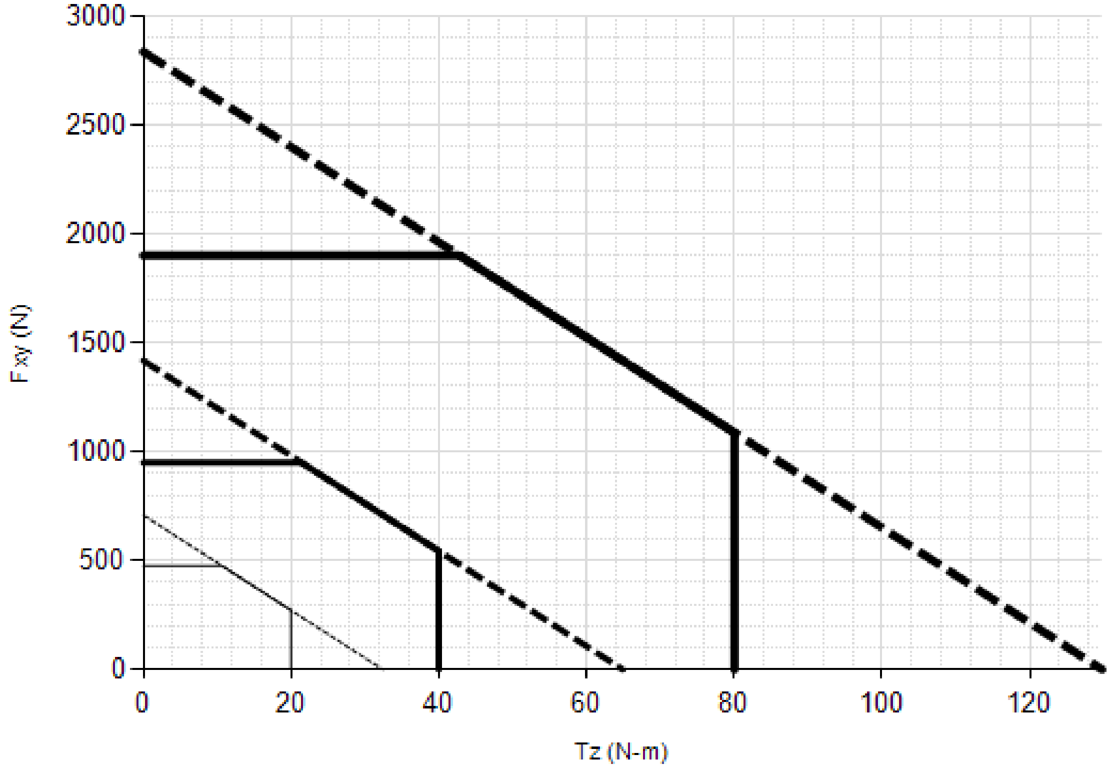
5.11.7 Mini85 (US Calibration Complex Loading)(Includes IP60)

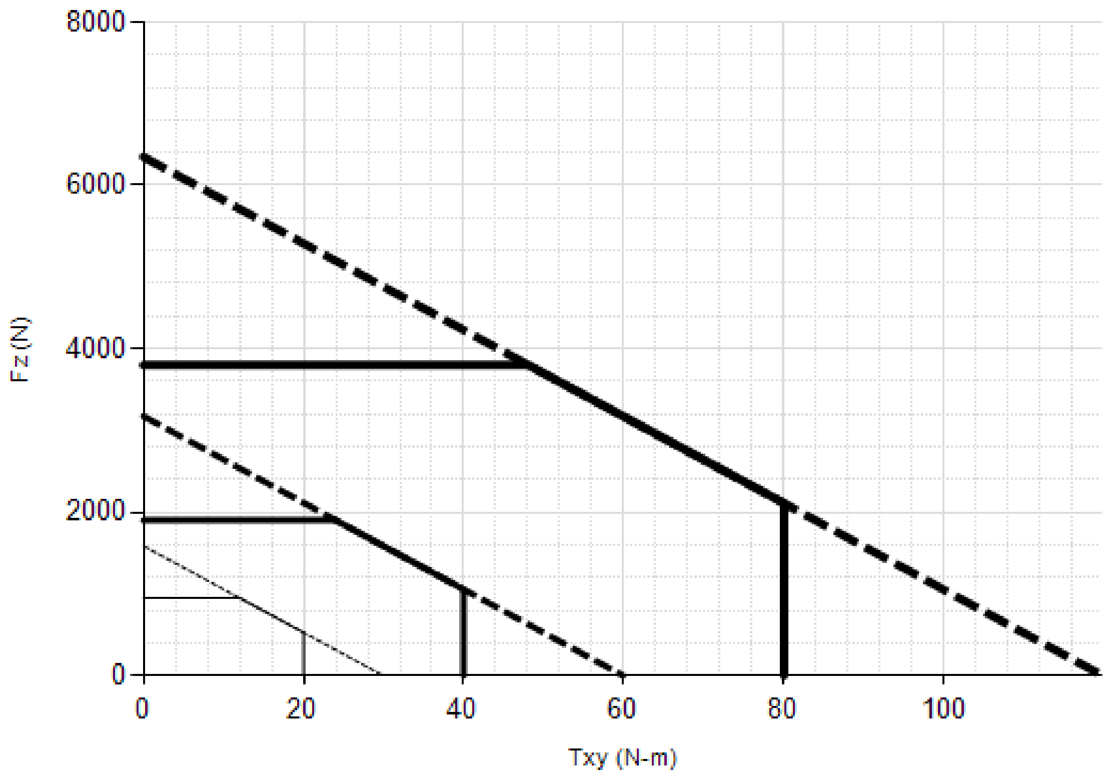




US-105-185 US-210-370 US-420-740

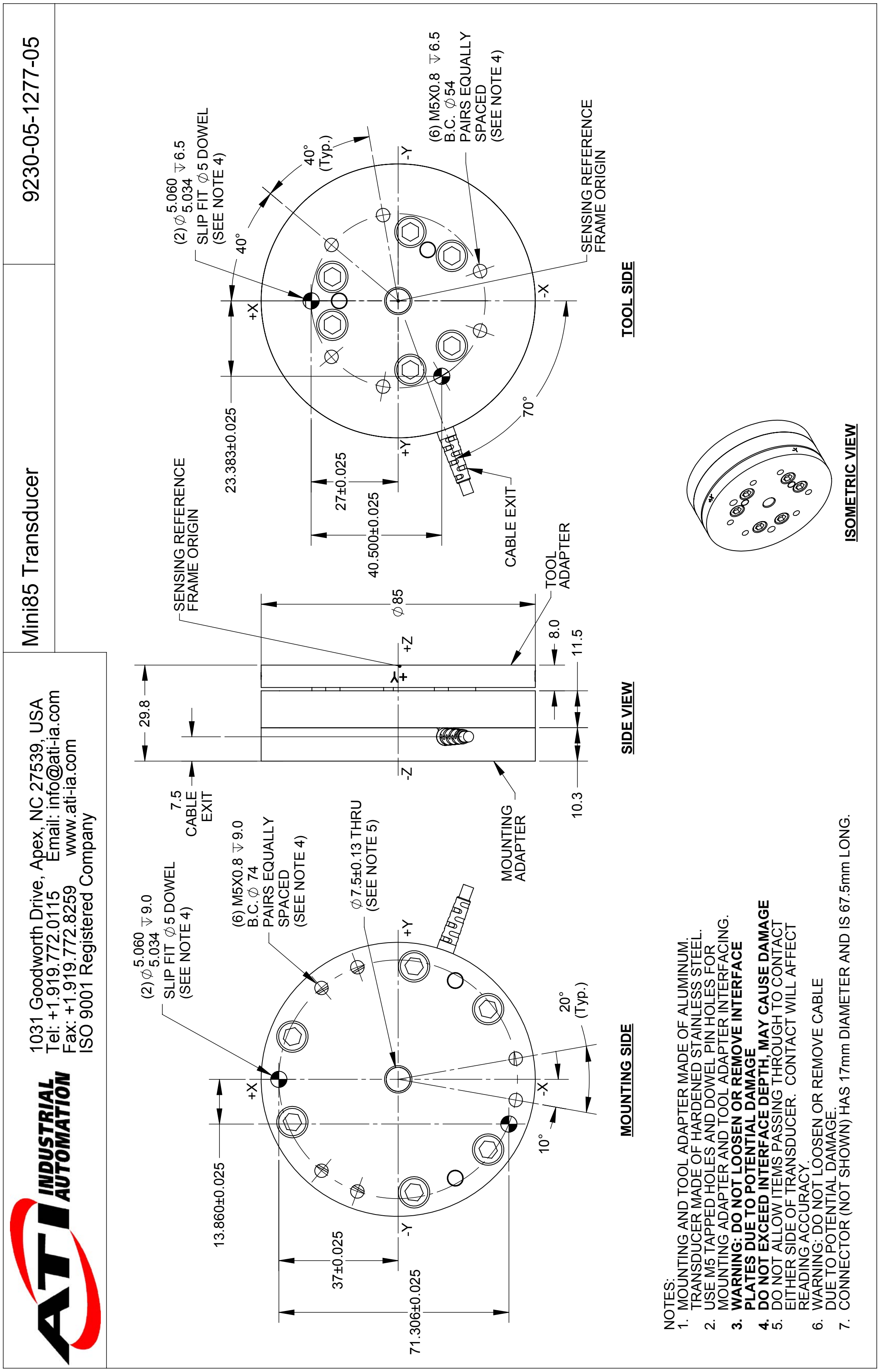
5.11.8 Mini85 (SI Calibration Complex Loading)(Includes IP60)



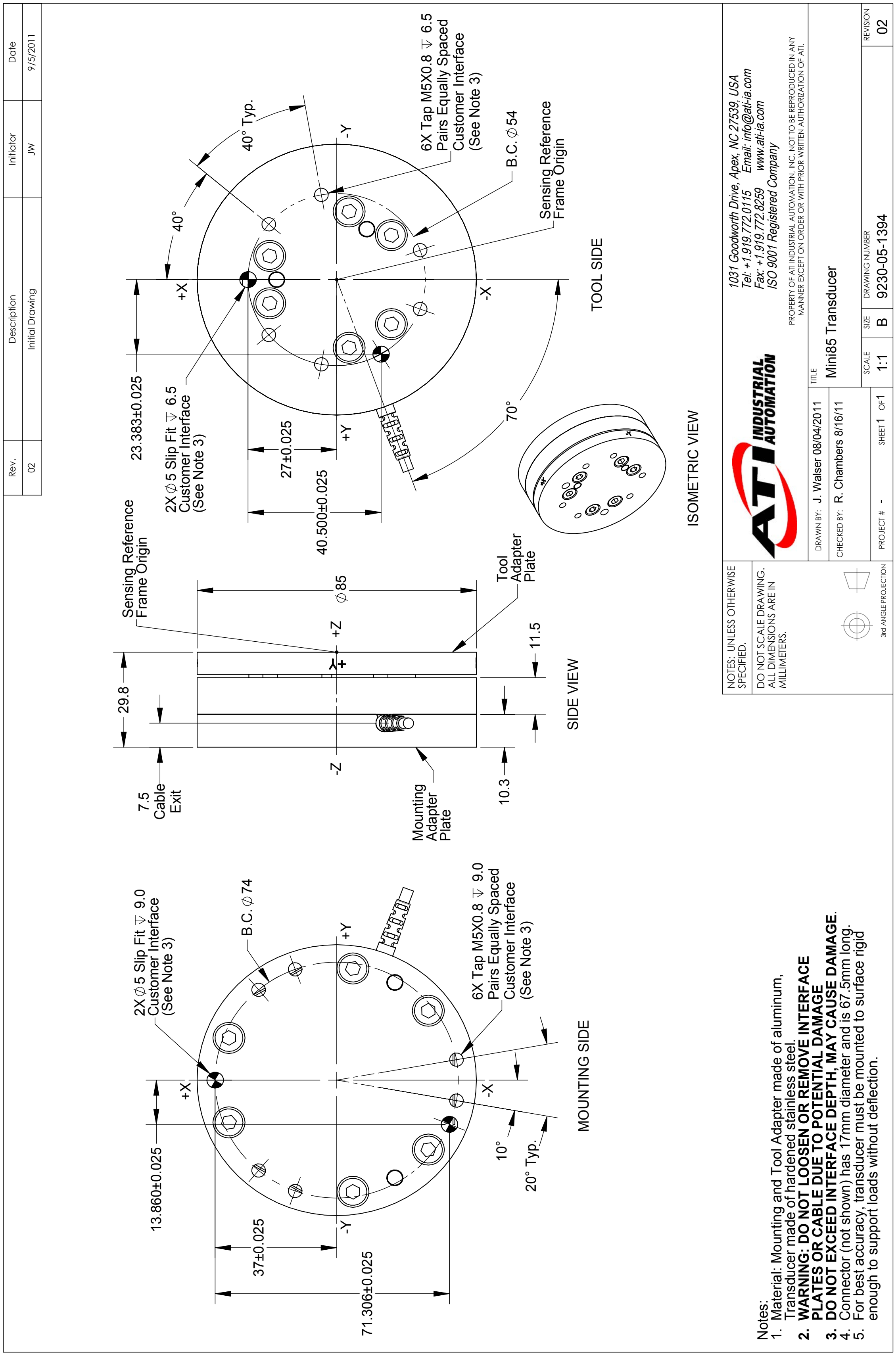


SI-475-20 SI-950-40 SI-1900-80

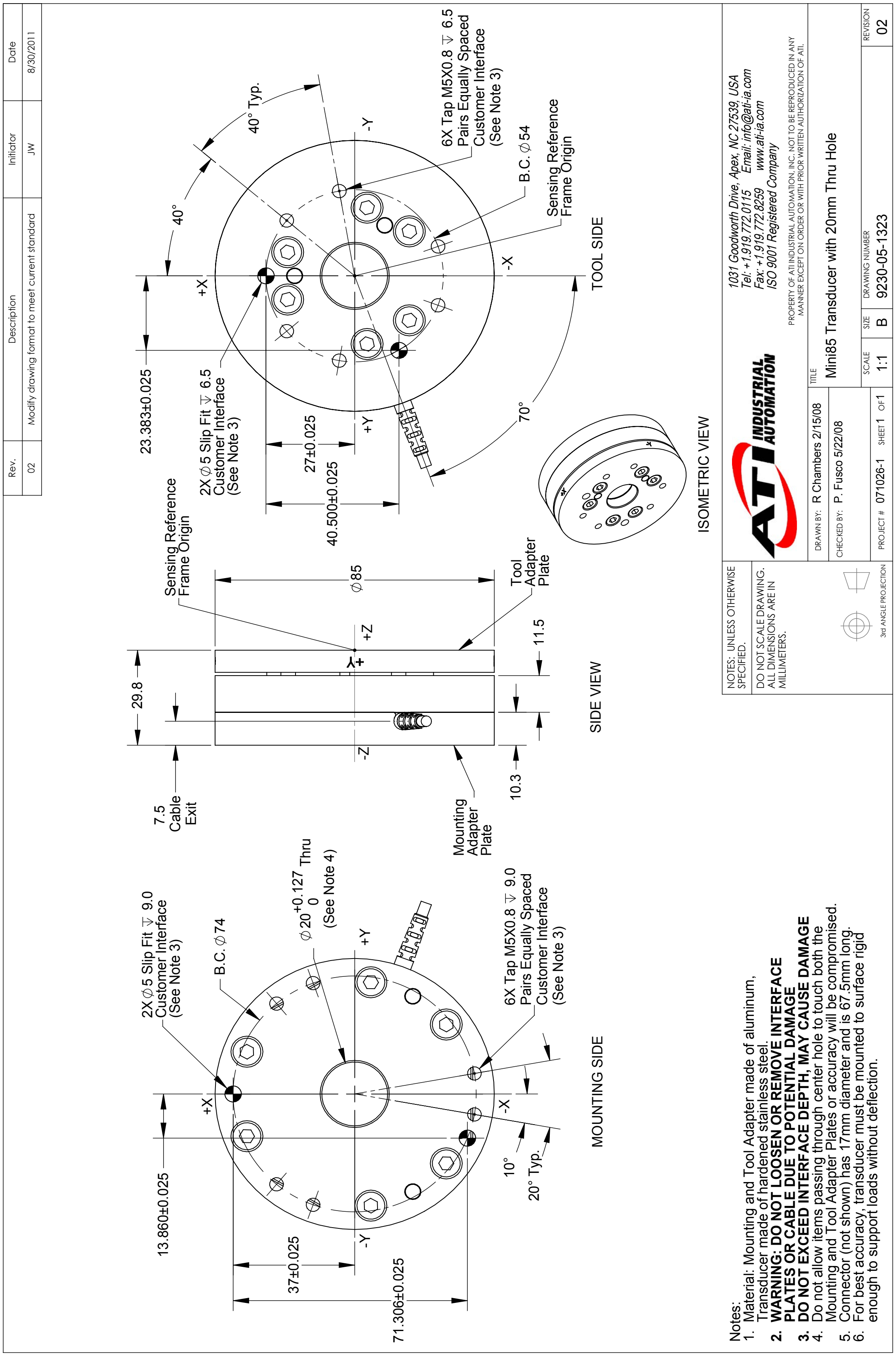
5.11.9 Mini85 Transducer Drawing



5.11.10 Mini85-E Transducer Drawing



5.11.11 Mini85 IP60 Transducer with 20mm Through-Hole Drawing



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

5.12.1 Gamma Physical Properties

Table 5.59—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.		

5.12.2 Gamma IP60 Physical Properties

Table 5.60—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.		

5.12.3 Gamma IP65 Physical Properties

Table 5.61—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.		

5.12.4 Gamma IP68 Physical Properties

Table 5.62—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

5.12.5 Calibration Specifications (excludes CTL calibrations)

Table 5.63— 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.

5.12.6 CTL Calibration Specifications

Table 5.64— 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.

5.12.7 Analog Output

Table 5.65— 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 (Nmm)**	**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.

5.12.8 Counts Value

Table 5.66—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)**	

5.12.9 Tool Transform Factor

Table 5.67—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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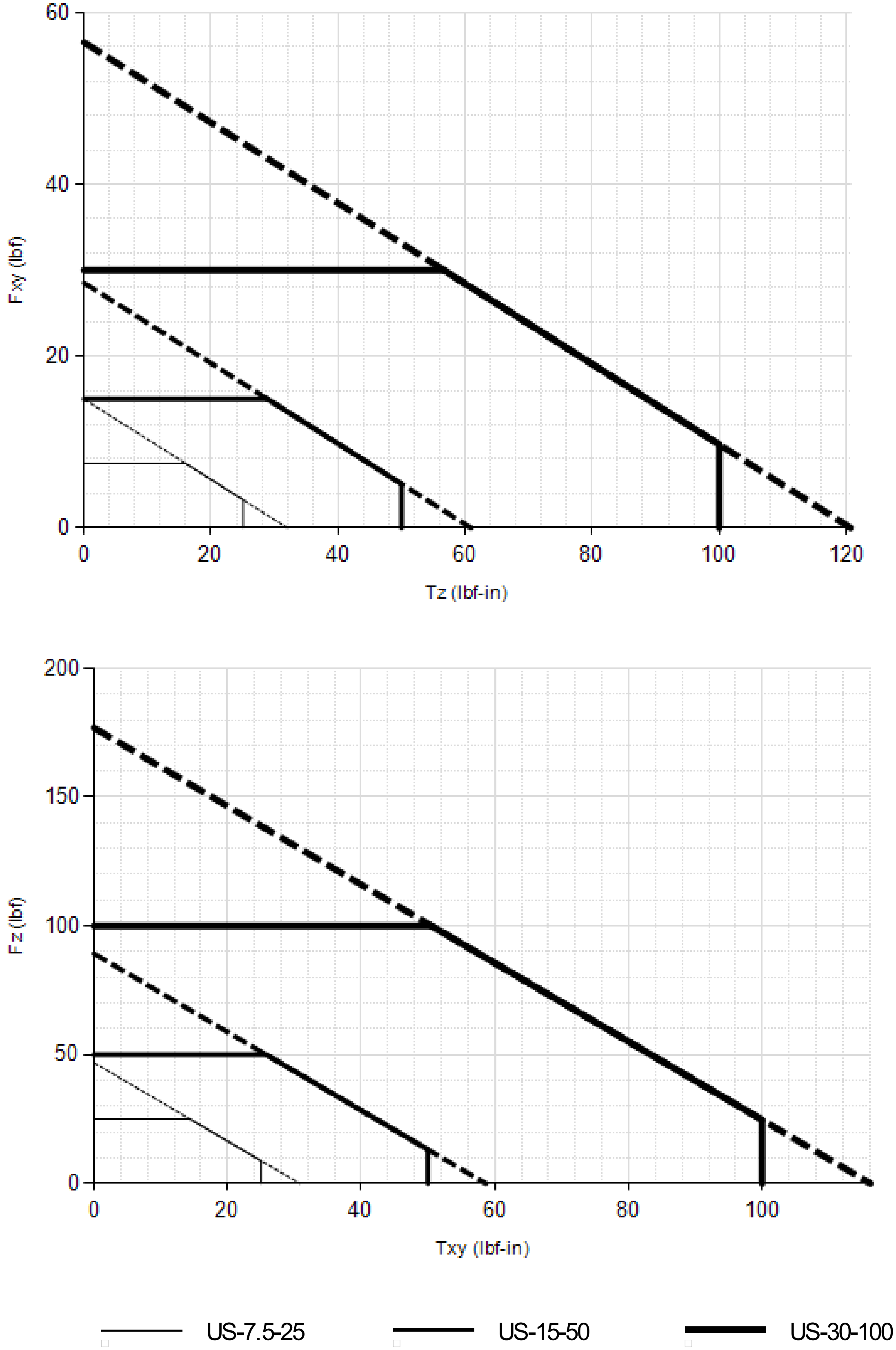
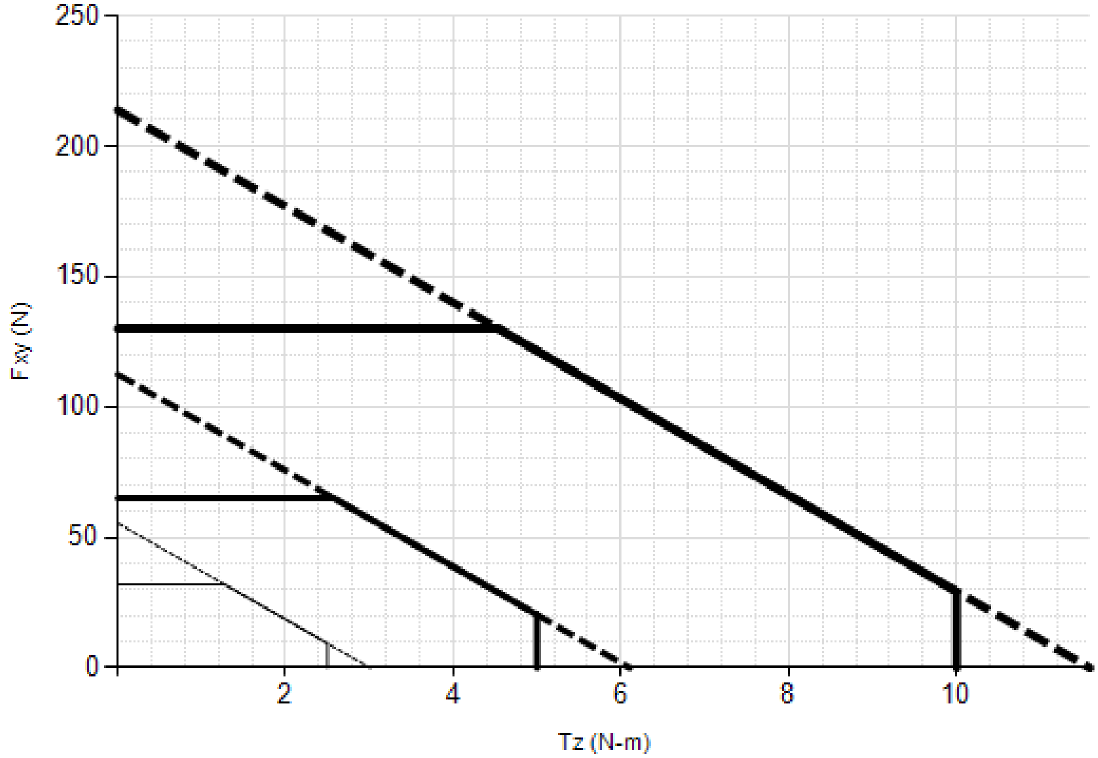
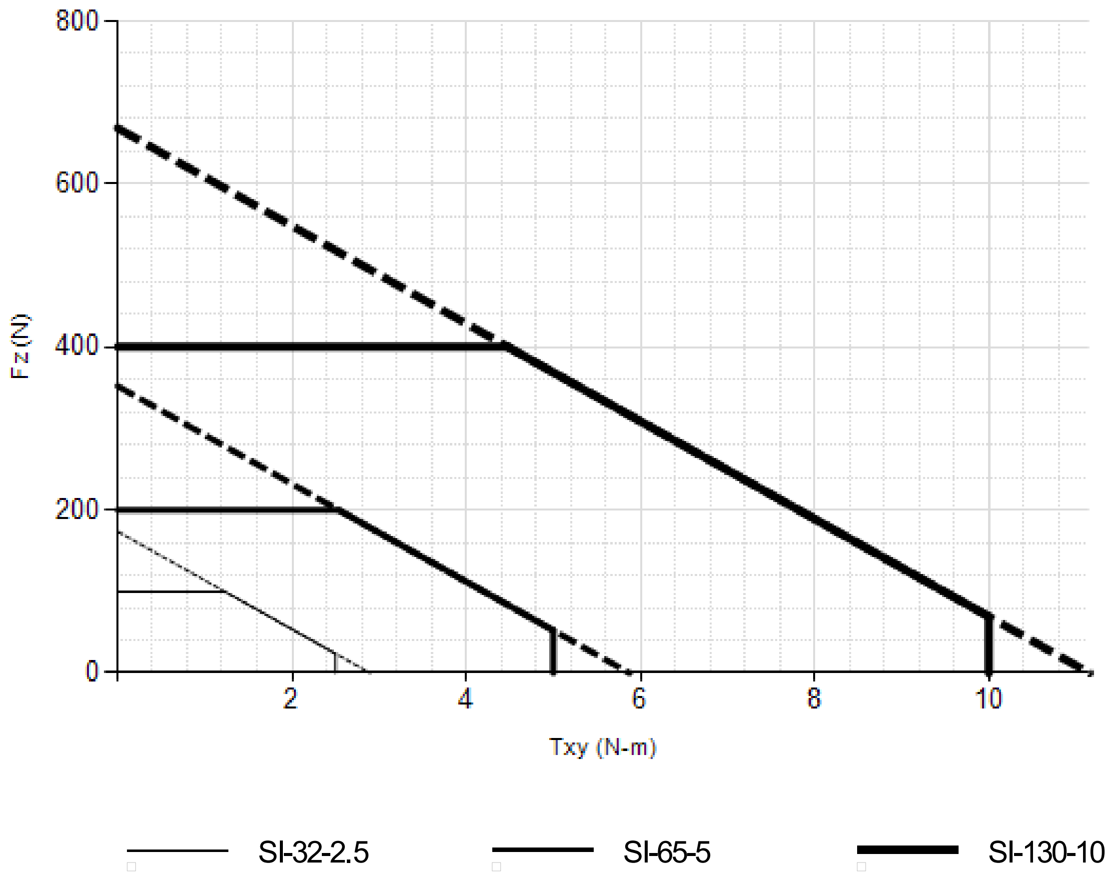
5.12.10 Gamma (US Calibration Complex Loading)(Includes IP60/IP65/IP68)[1]



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

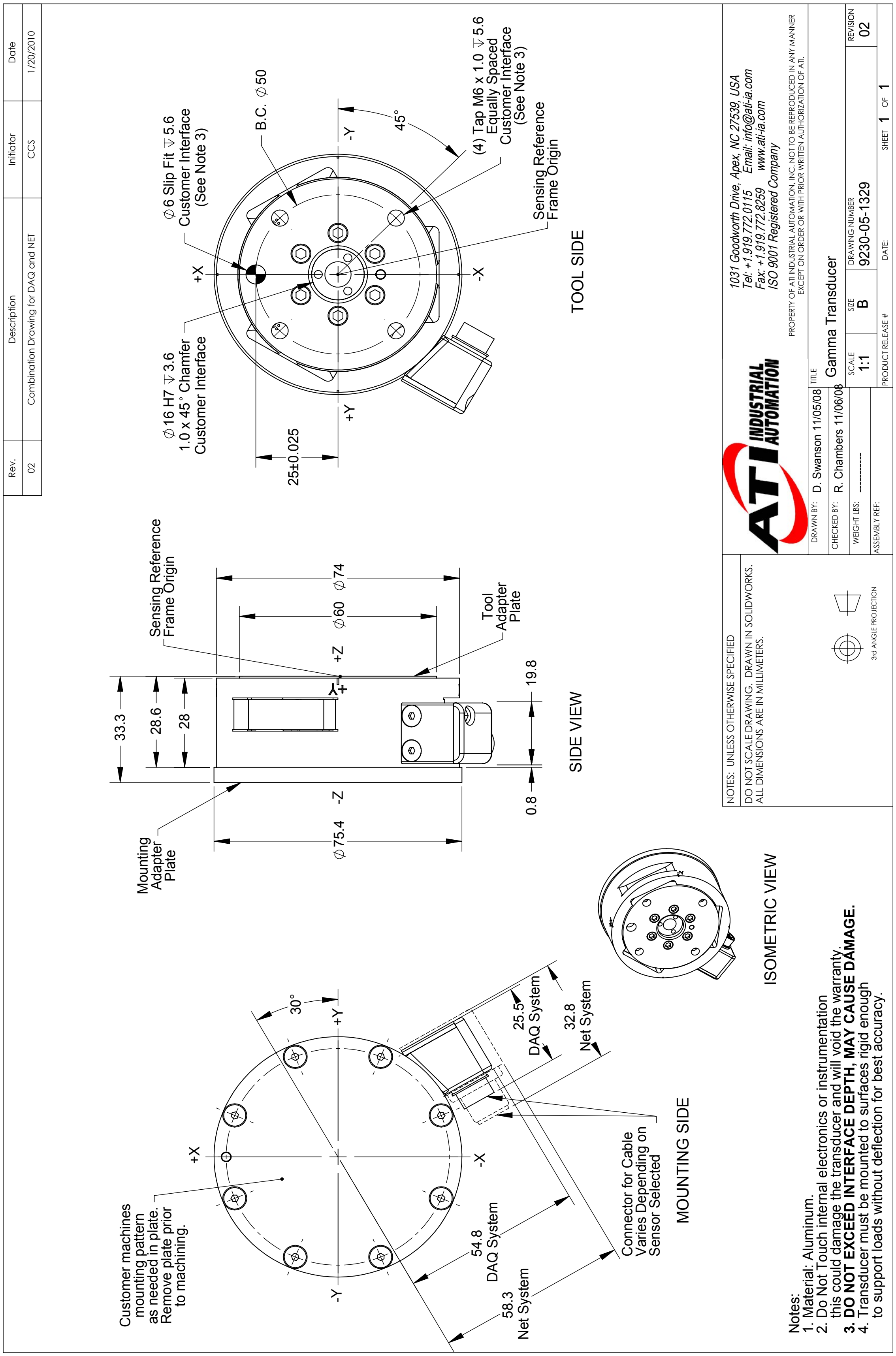
5.12.11 Gamma (SI Calibration Complex Loading)(Includes IP60/IP65/IP68)[1]



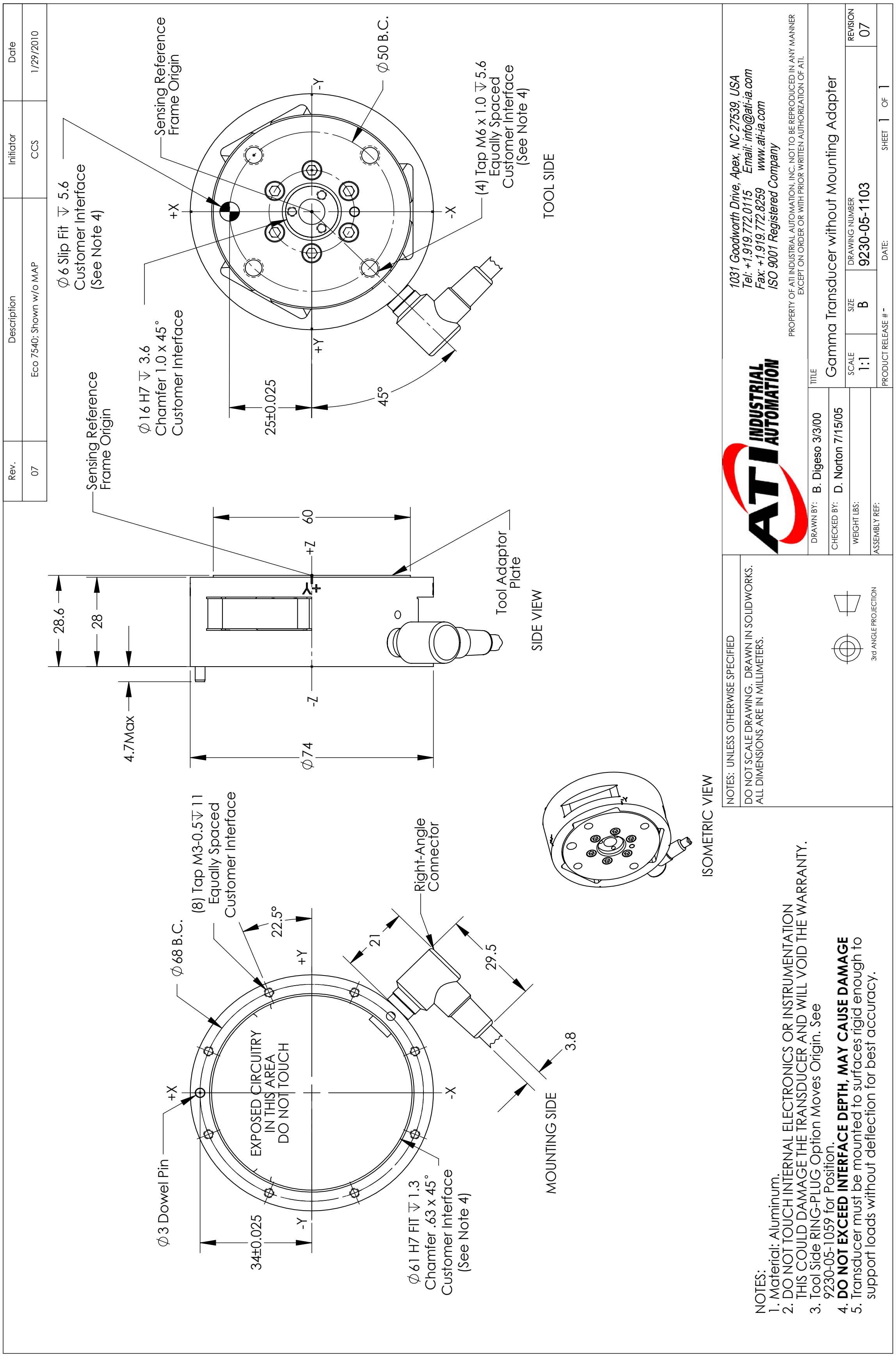


Note: 1. For IP68 version see caution on physical properties page.

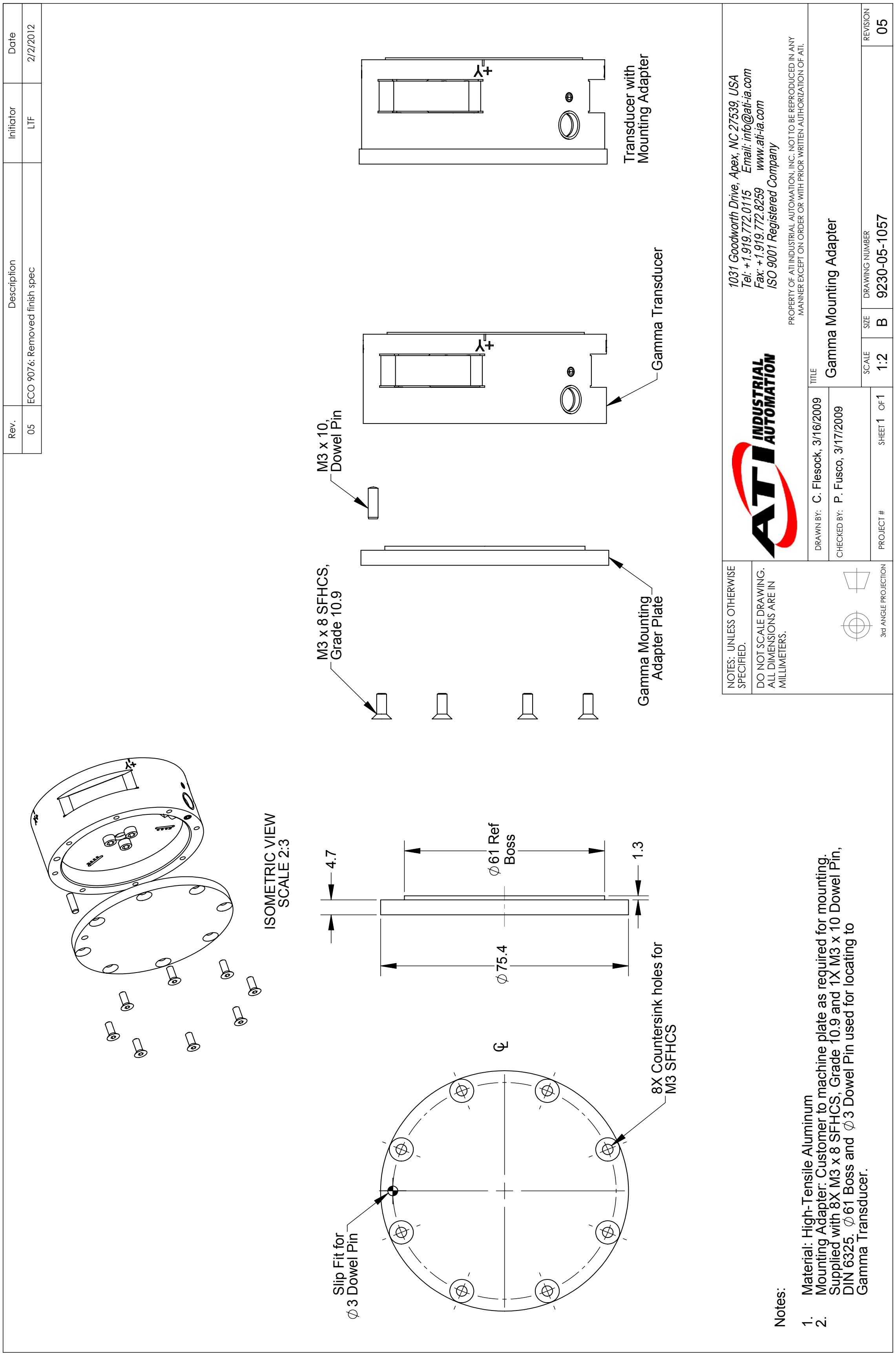
5.12.12 Gamma DAQ/Net Transducer Drawing



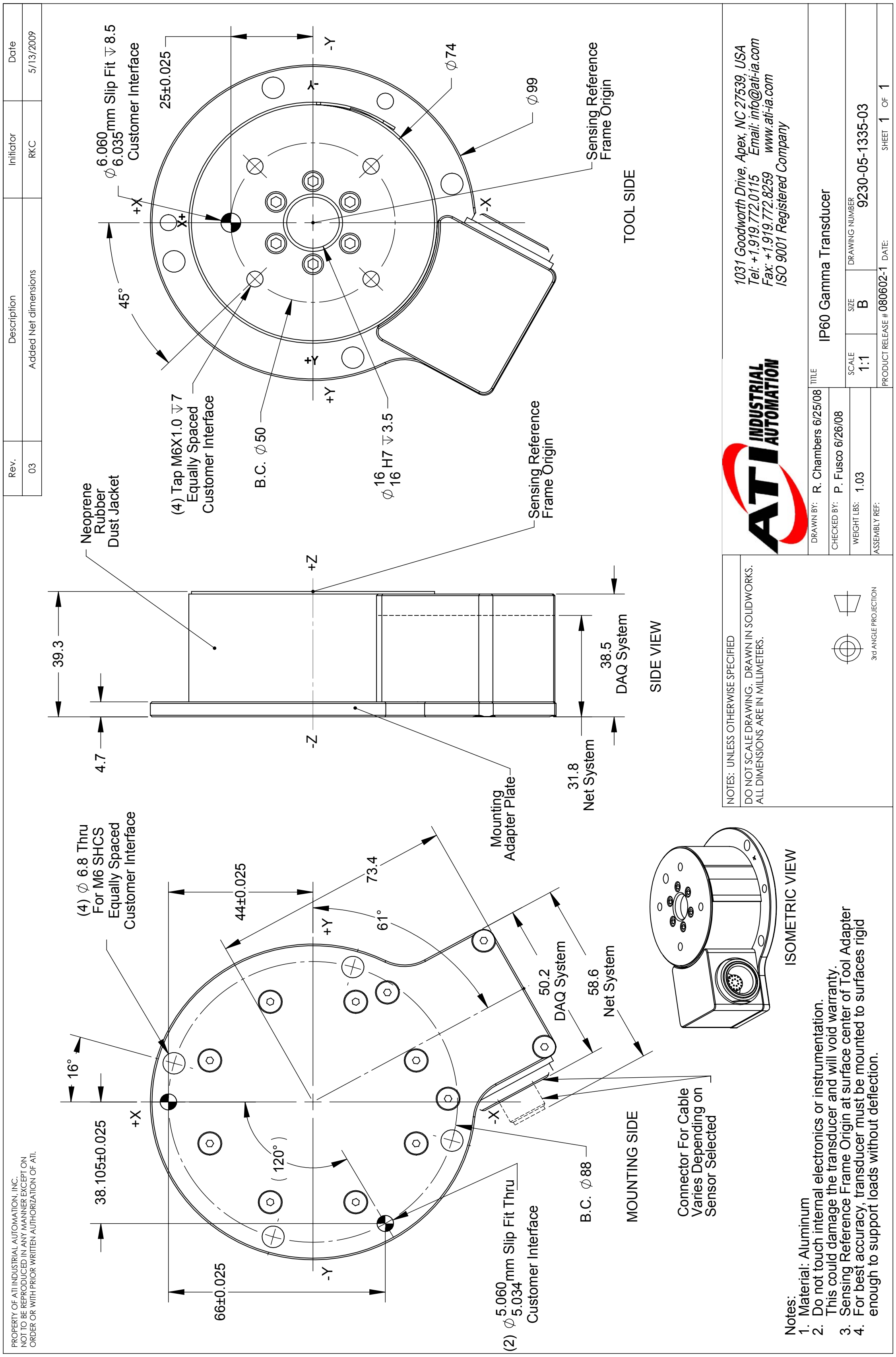
5.12.13 9105-T-Gamma Transducer without Mounting Adapter Drawing



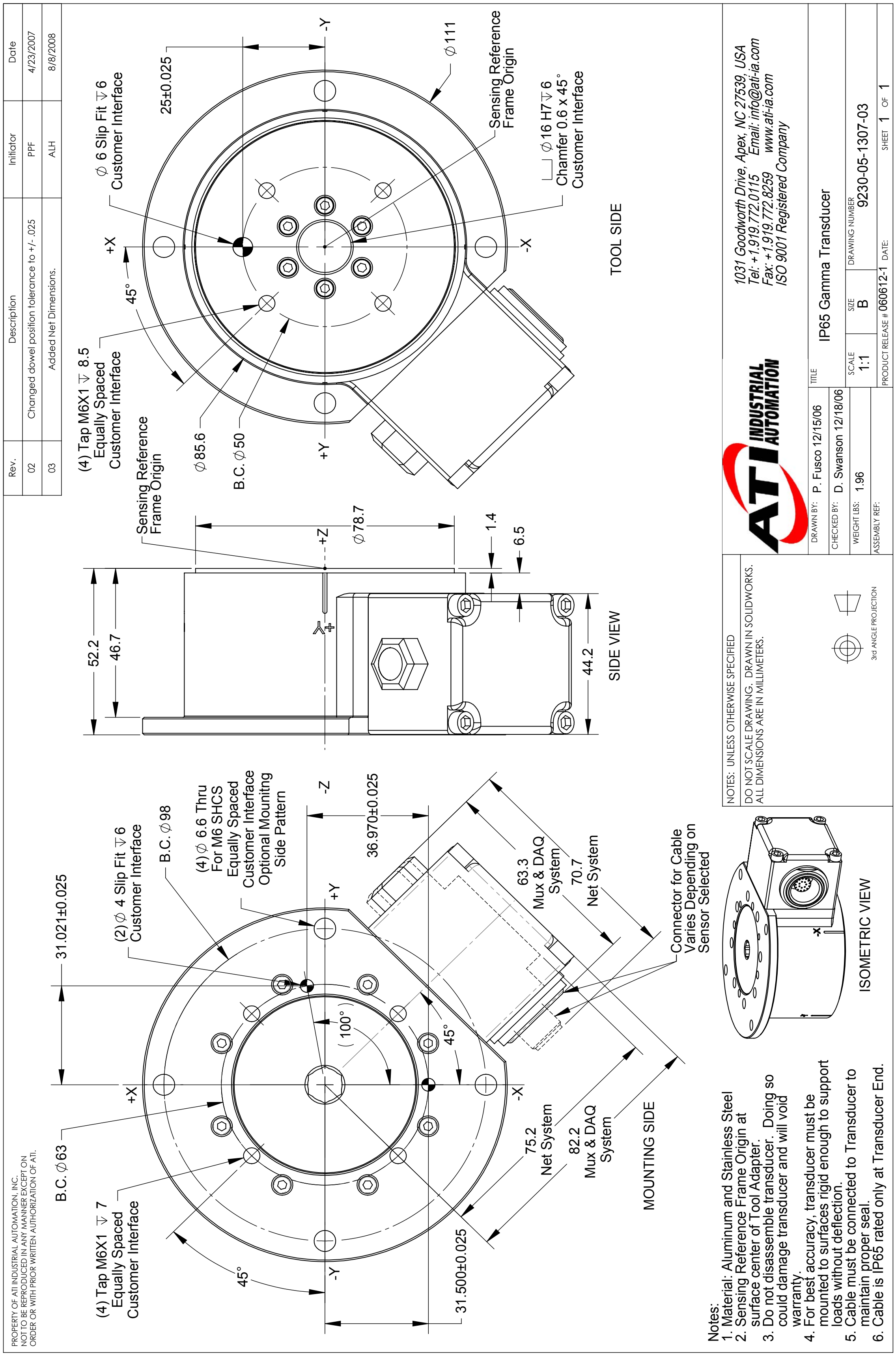
5.12.14 Gamma Mounting Adapter Plate Drawing



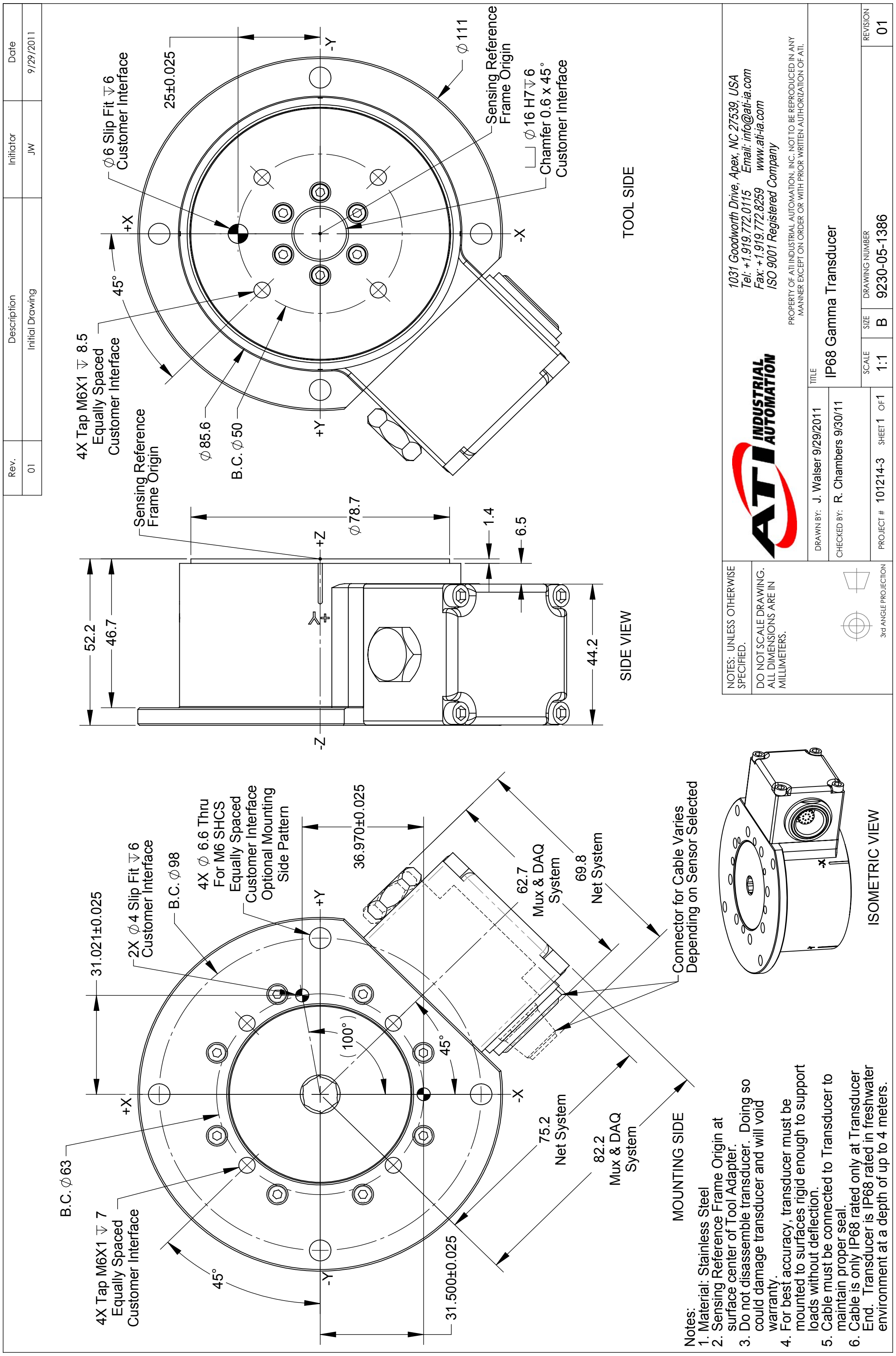
5.12.15 Gamma IP60 Transducer Drawing



5.12.16 Gamma IP65 Transducer Drawing



5.12.17 Gamma IP68 Transducer Drawing



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

5.13.1 Delta Physical Properties

Table 5.68—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)	$2.0x10^5$ lb/in	$3.6x10^7$ N/m
Z-axis force (Kz)	$3.4x10^5$ lb/in	$5.9x10^7$ N/m
X-axis & Y-axis torque (Ktx, Kty)	$4.6x10^5$ lbf-in/rad	$5.2x10^4$ Nm/rad
Z-axis torque (Ktz)	$8.1x10^5$ lbf-in/rad	$9.1x10^4$ 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.		

5.13.2 Delta IP60 Physical Properties

Table 5.69—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)	$2.0x10^5$ lb/in	$3.6x10^7$ N/m
Z-axis force (Kz)	$3.4x10^5$ lb/in	$5.9x10^7$ N/m
X-axis & Y-axis torque (Ktx, Kty)	$4.6x10^5$ lbf-in/rad	$5.2x10^4$ Nm/rad
Z-axis torque (Ktz)	$8.1x10^5$ lbf-in/rad	$9.1x10^4$ 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.		

5.13.3 Delta IP65 Physical Properties

Table 5.70—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)	$2.0x10^5$ lb/in	$3.6x10^7$ N/m
Z-axis force (Kz)	$3.4x10^5$ lb/in	$5.9x10^7$ N/m
X-axis & Y-axis torque (Ktx, Kty)	$4.6x10^5$ lbf-in/rad	$5.2x10^4$ Nm/rad
Z-axis torque (Ktz)	$8.1x10^5$ lbf-in/rad	$9.1x10^4$ 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.		

5.13.4 Delta IP68 Physical Properties

Table 5.71—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)	$2.0x10^5$ lb/in	$3.6x10^7$ N/m
Z-axis force (Kz)	$3.4x10^5$ lb/in	$5.9x10^7$ N/m
X-axis & Y-axis torque (Ktx, Kty)	$4.6x10^5$ lbf-in/rad	$5.2x10^4$ Nm/rad
Z-axis torque (Ktz)	$8.1x10^5$ lbf-in/rad	$9.1x10^4$ 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

5.13.5 Calibration Specifications (excludes CTL calibrations)

Table 5.72— 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.

5.13.6 CTL Calibration Specifications

Table 5.73— 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.

5.13.7 Analog Output

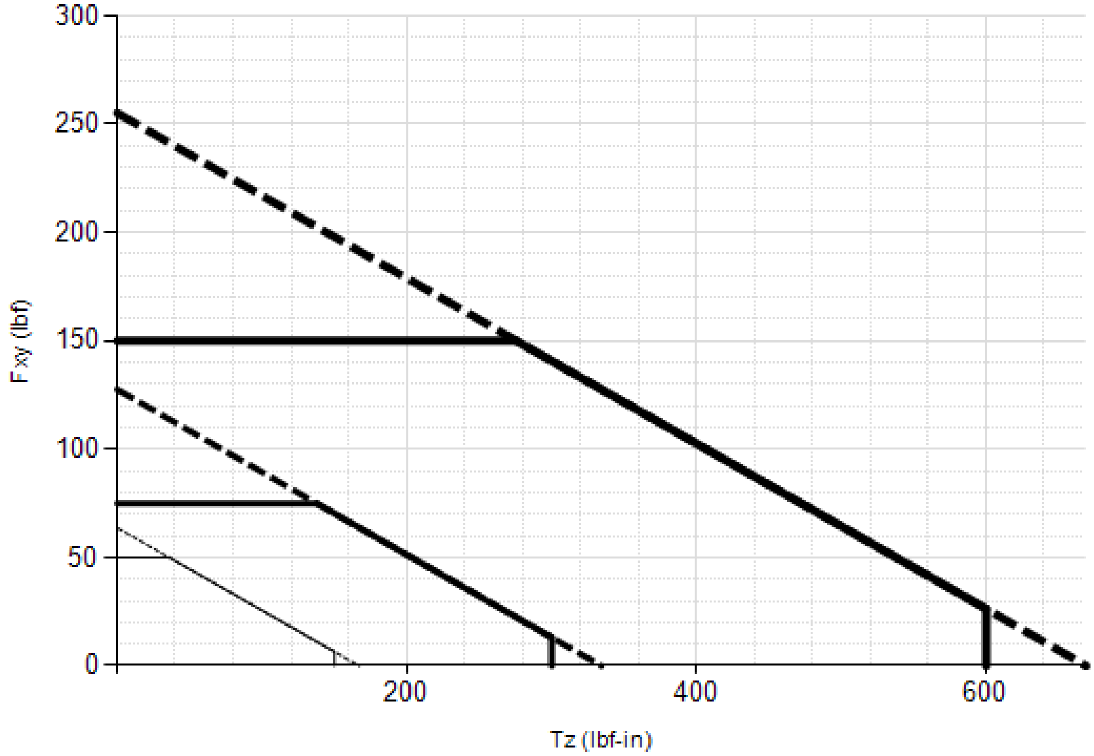
Table 5.74— Delta Analog Output							
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz[2] (lbf)**	**Tx,Ty,Tz (lbf-in)**	**Fx,Fy (lbf/V)**	**Fz[2] (lbf/V)**	**Tx,Ty,Tz (lbf-in/V)**
Delta	US-50-150	±50	±150	±150	5	15	15
Delta	US-75-300	±75	±225	±300	7.5	22.5	30
Delta	US-150-600	±150	±450	±600	15	45	60
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz[2] (N)**	**Tx,Ty,Tz (Nmm)**	**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]**		

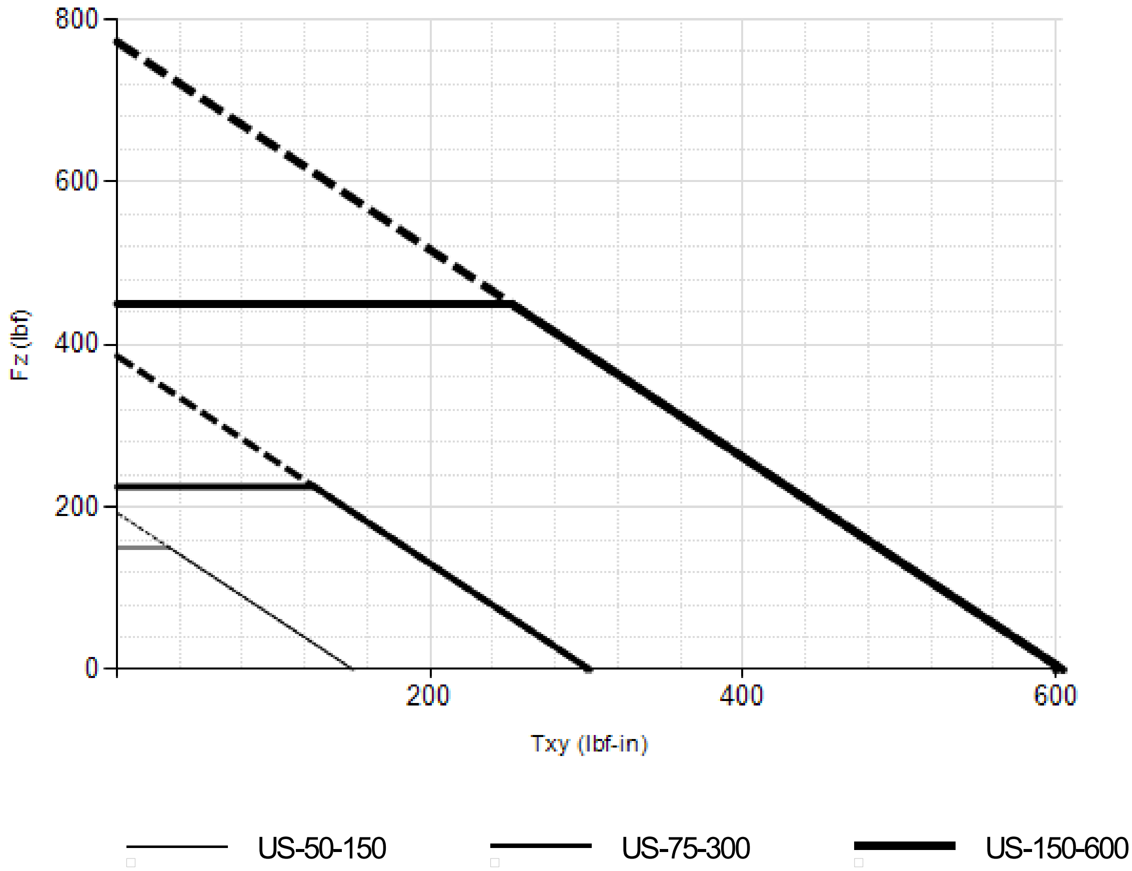
Notes:
1. ±5V Sensitivity values are double the listed ±10V Sensitivity values.
2. For IP68 version see caution on physical properties page.

5.13.8 Counts Value

Table 5.75—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)**	

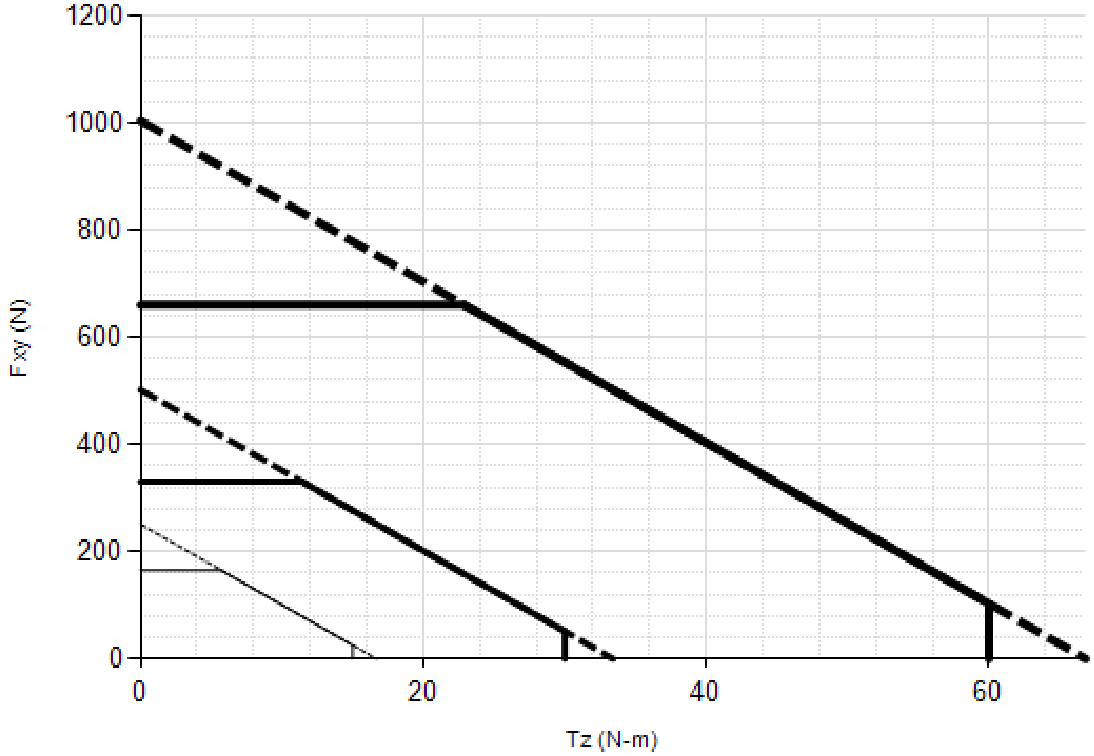
5.13.9 Delta (US Calibration Complex Loading)(Includes IP60/IP65/IP68)[1]

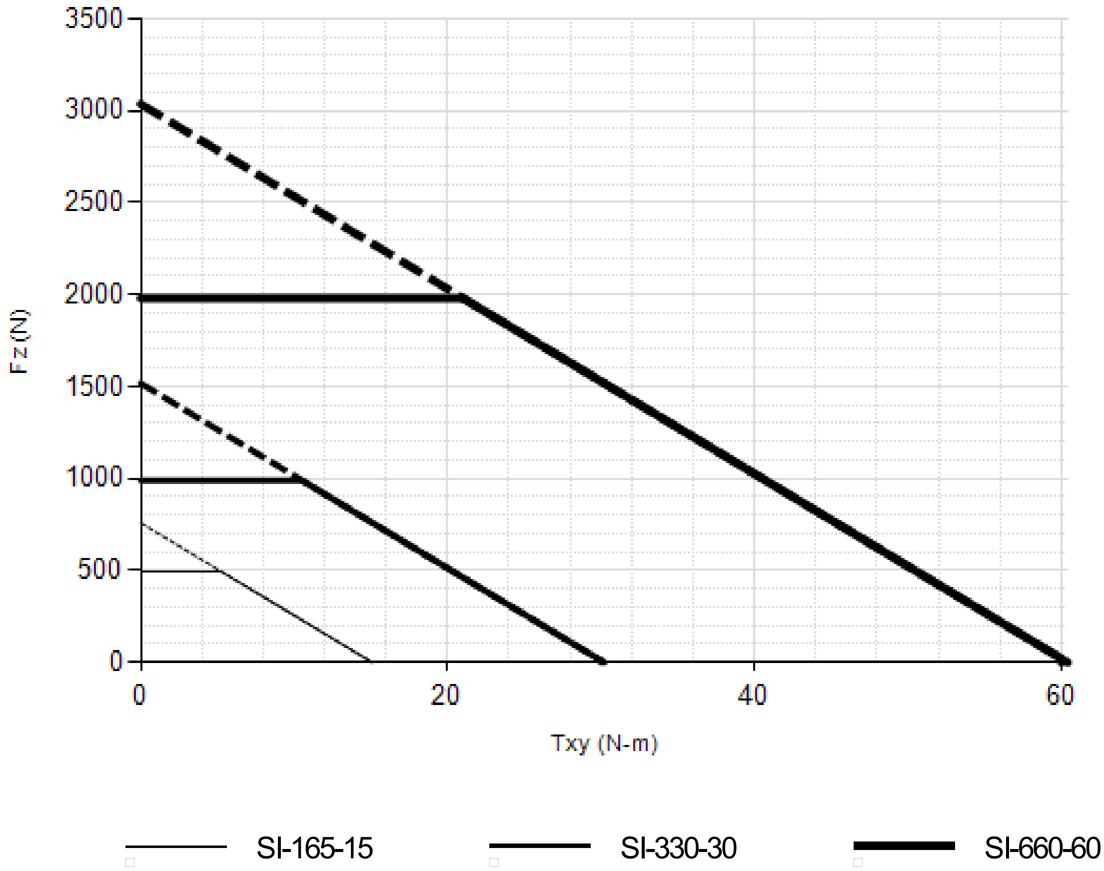




Note: 1. For IP68 version see caution on physical properties page.

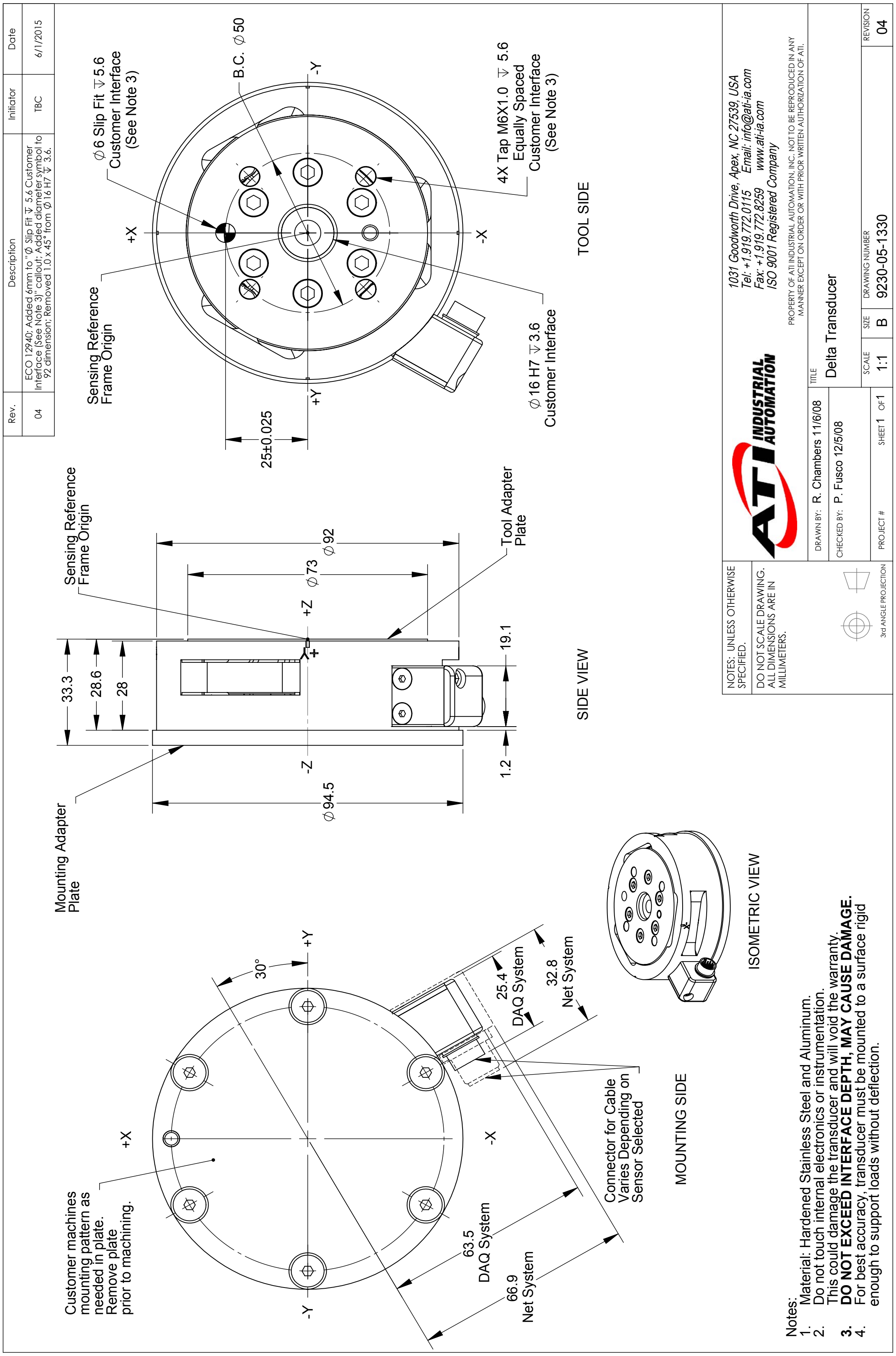
5.13.10 Delta (SI Calibration Complex Loading)(Includes IP60/IP65/IP68)[1]



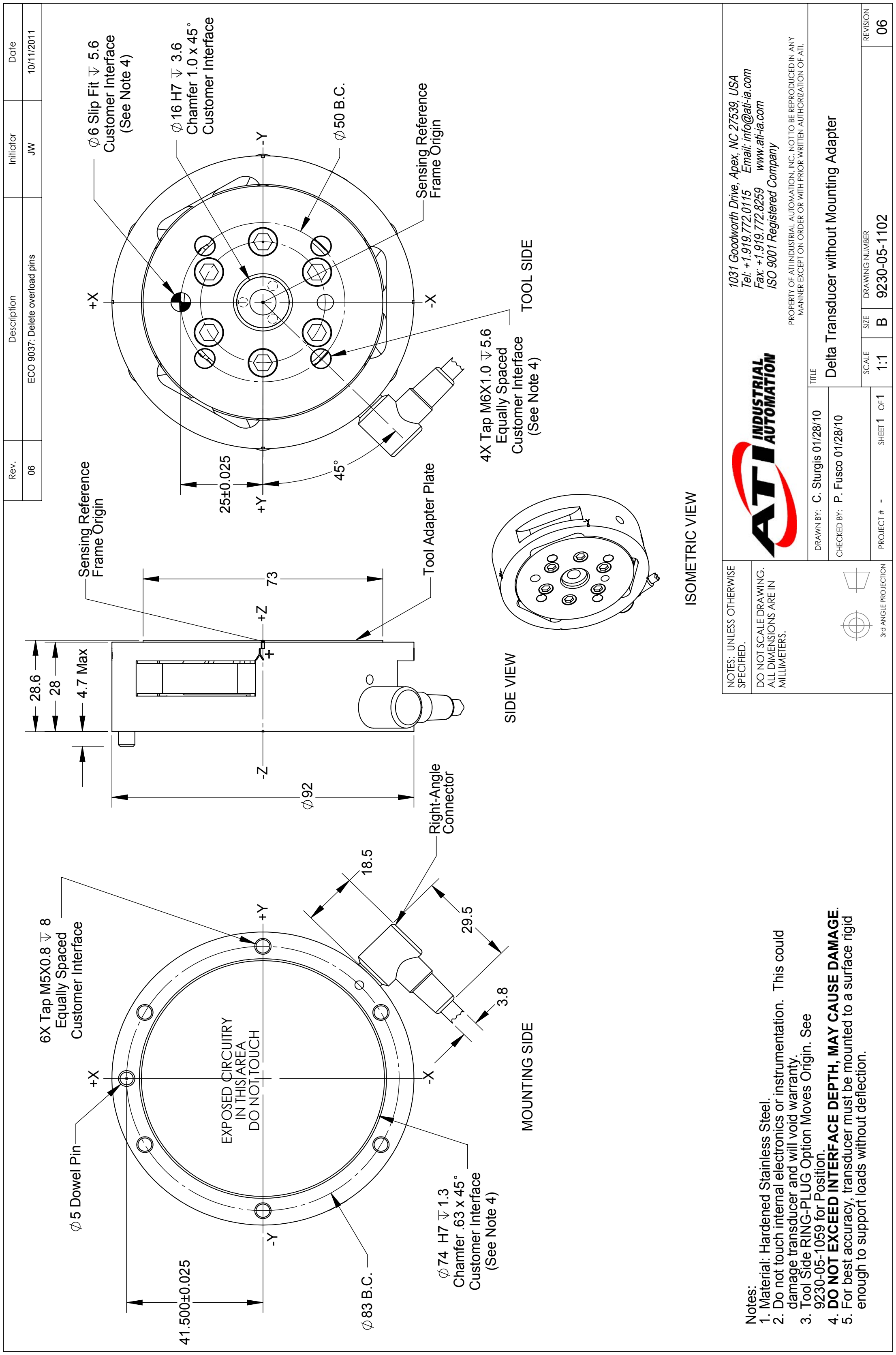


Note: 1. For IP68 version see caution on physical properties page.

5.13.11 Delta DAQ/Net Transducer Drawing

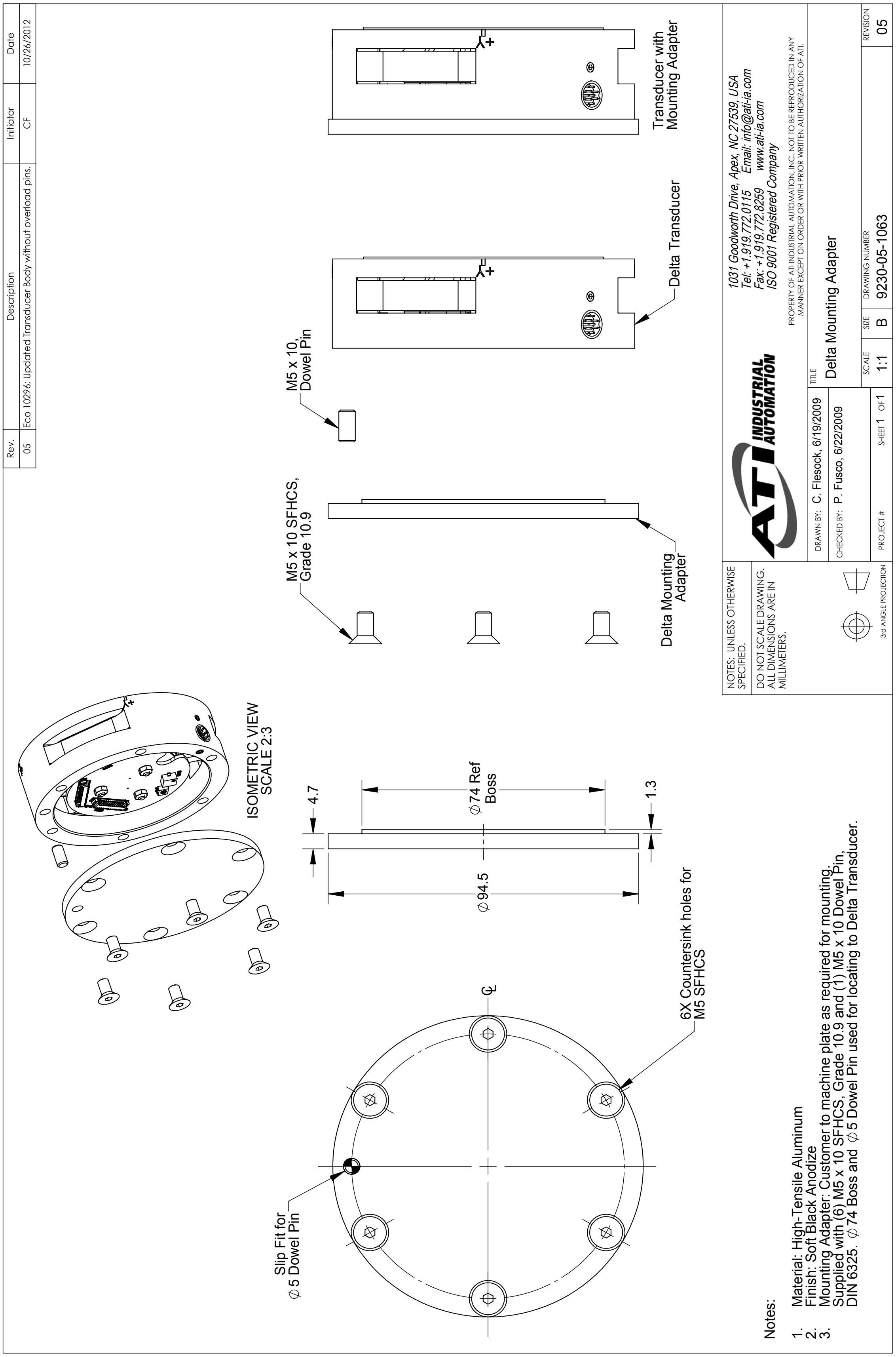


5.13.12 9105-T-Delta Transducer without Mounting Adapter Drawing

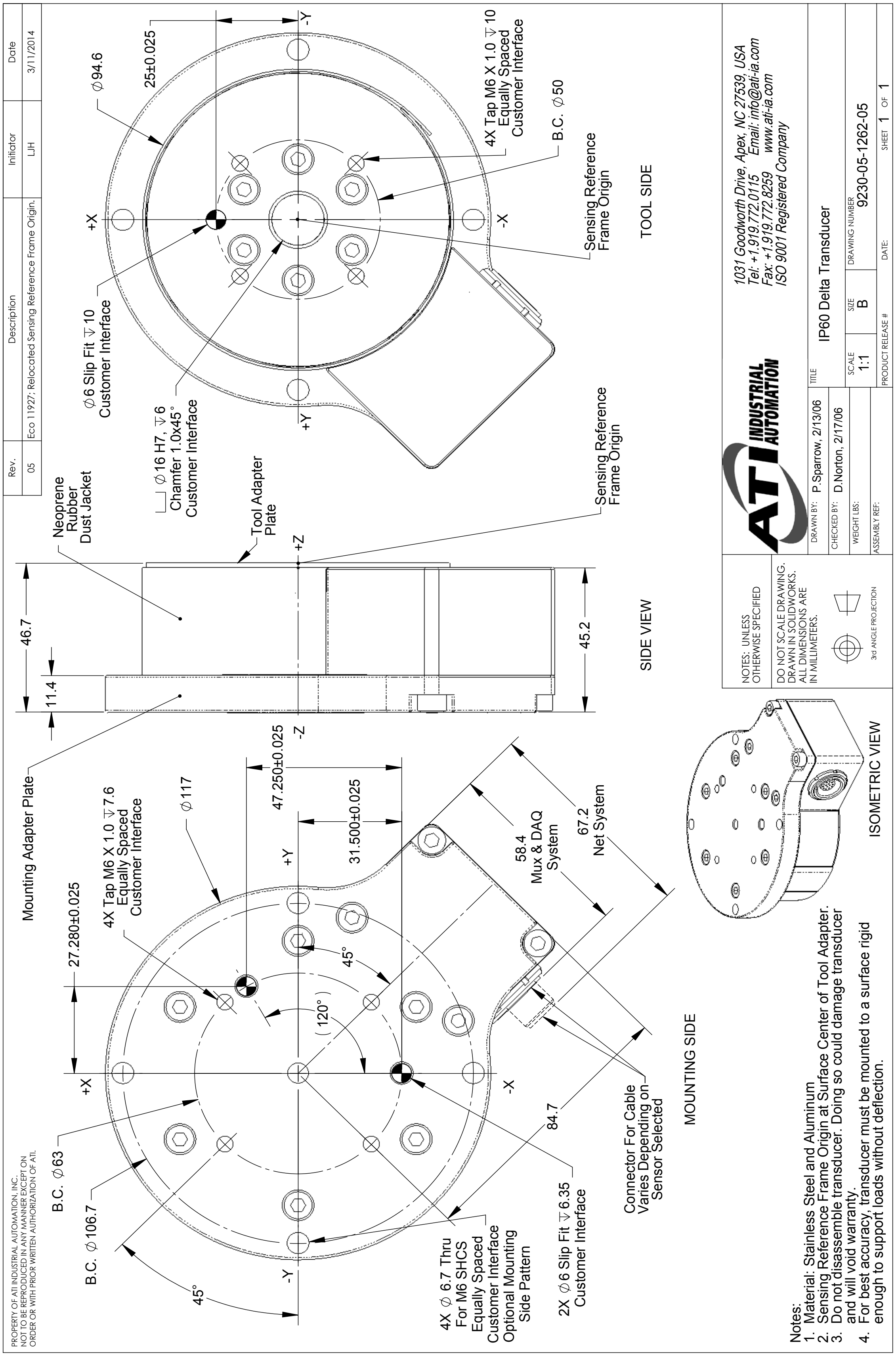


Note: Mux transducers are used in F/T Controller systems.

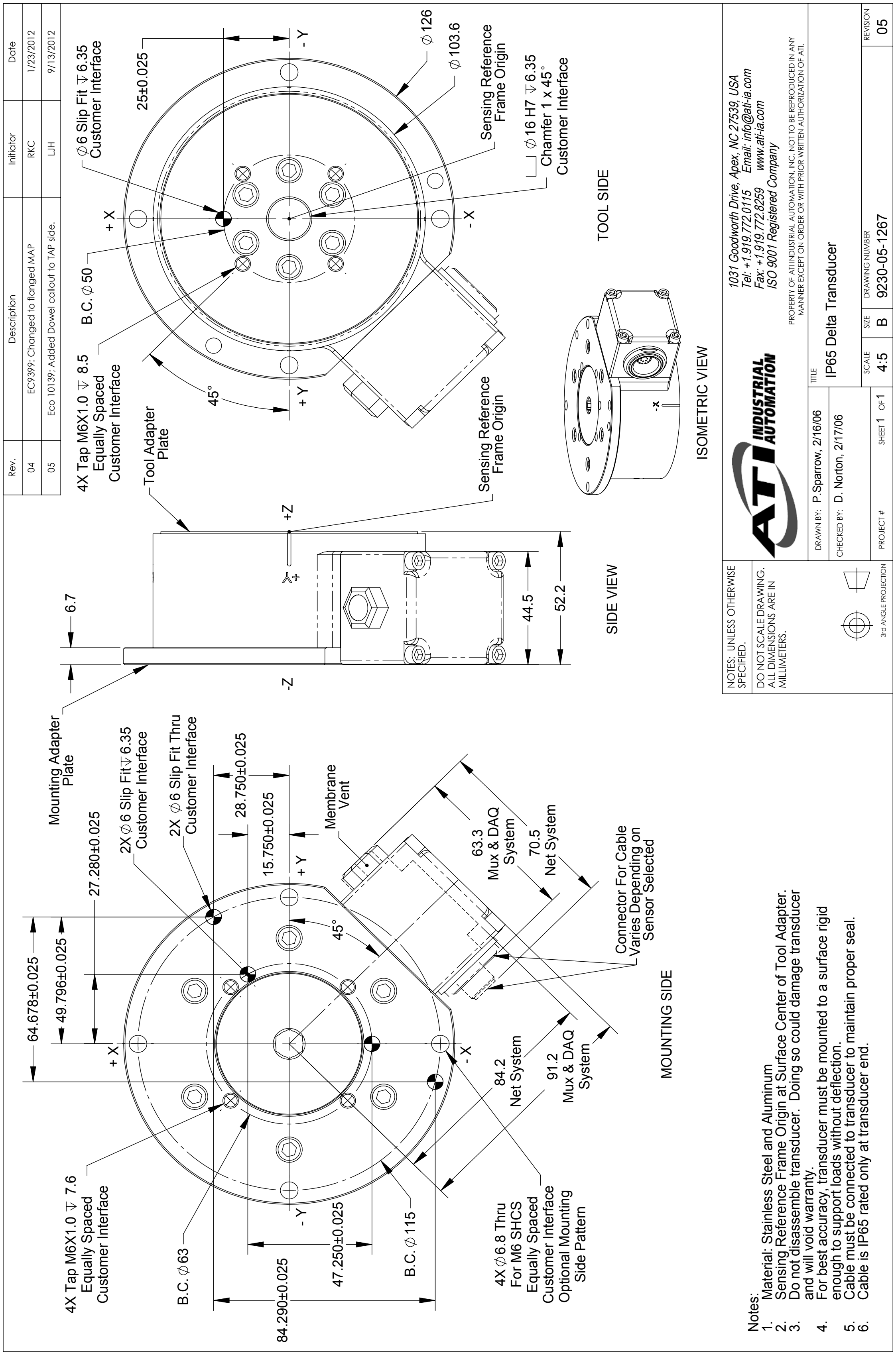
5.13.13 Delta Mounting Adapter Drawing



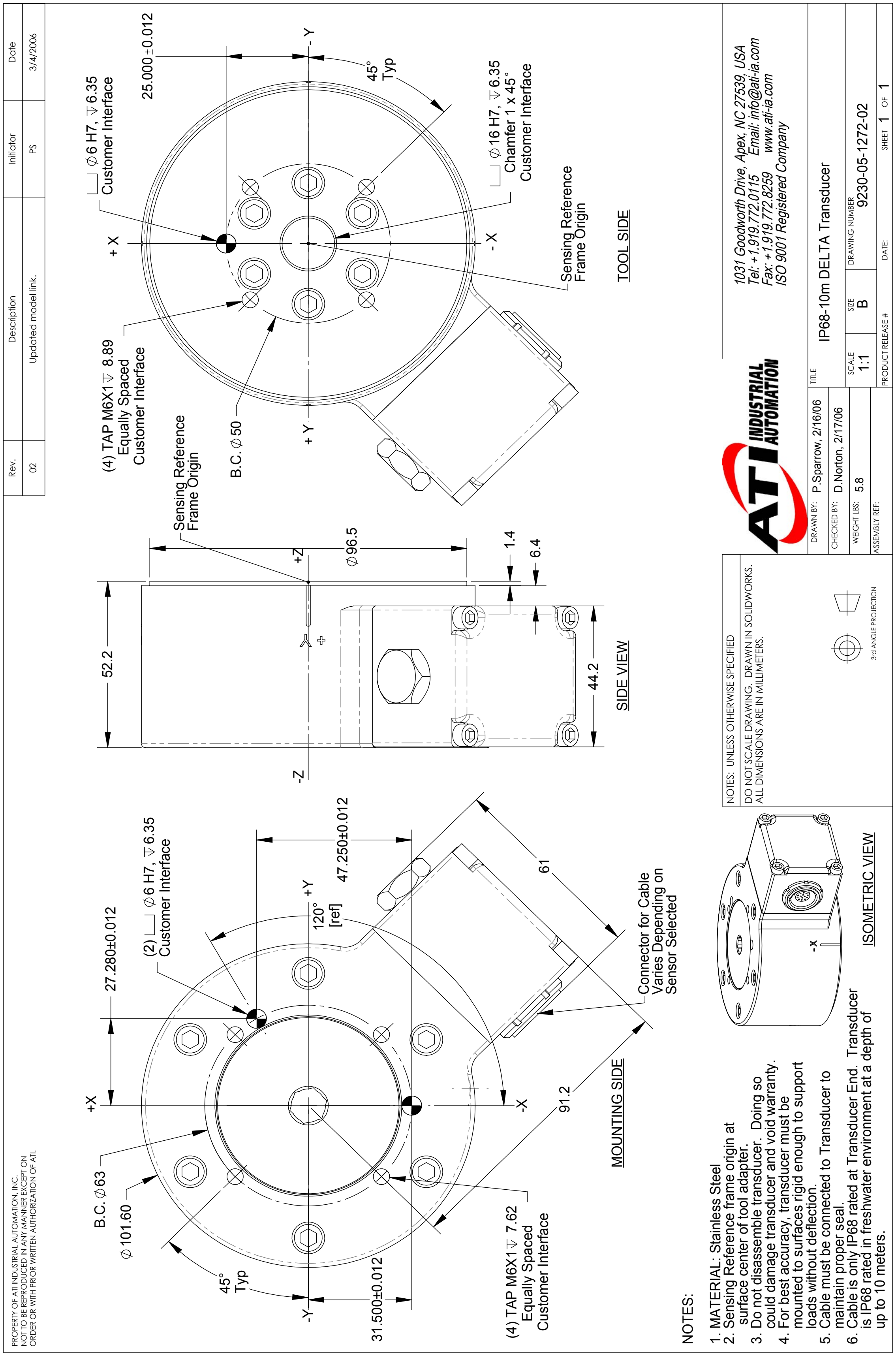
5.13.14 Delta IP60 Transducer Drawing



5.13.15 Delta IP65 Transducer Drawing



5.13.16 Delta IP68 Transducer Drawing



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

5.14.1 Theta Physical Properties

Table 5.76—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.		

5.14.2 Theta IP60 Physical Properties

Table 5.77—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.		

5.14.3 Theta IP65/IP68 Physical Properties

Table 5.78—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

5.14.4 Calibration Specifications (excludes CTL calibrations)

Table 5.79— Theta 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)
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)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**	**Fx,Fy (N)**	**Fz[3] (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.

5.14.5 CTL Calibration Specifications

Table 5.80— Theta 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)
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)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**	**Fx,Fy (N)**	**Fz[3] (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.

5.14.6 Analog Output

Table 5.81— 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 (Nmm)**	**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.

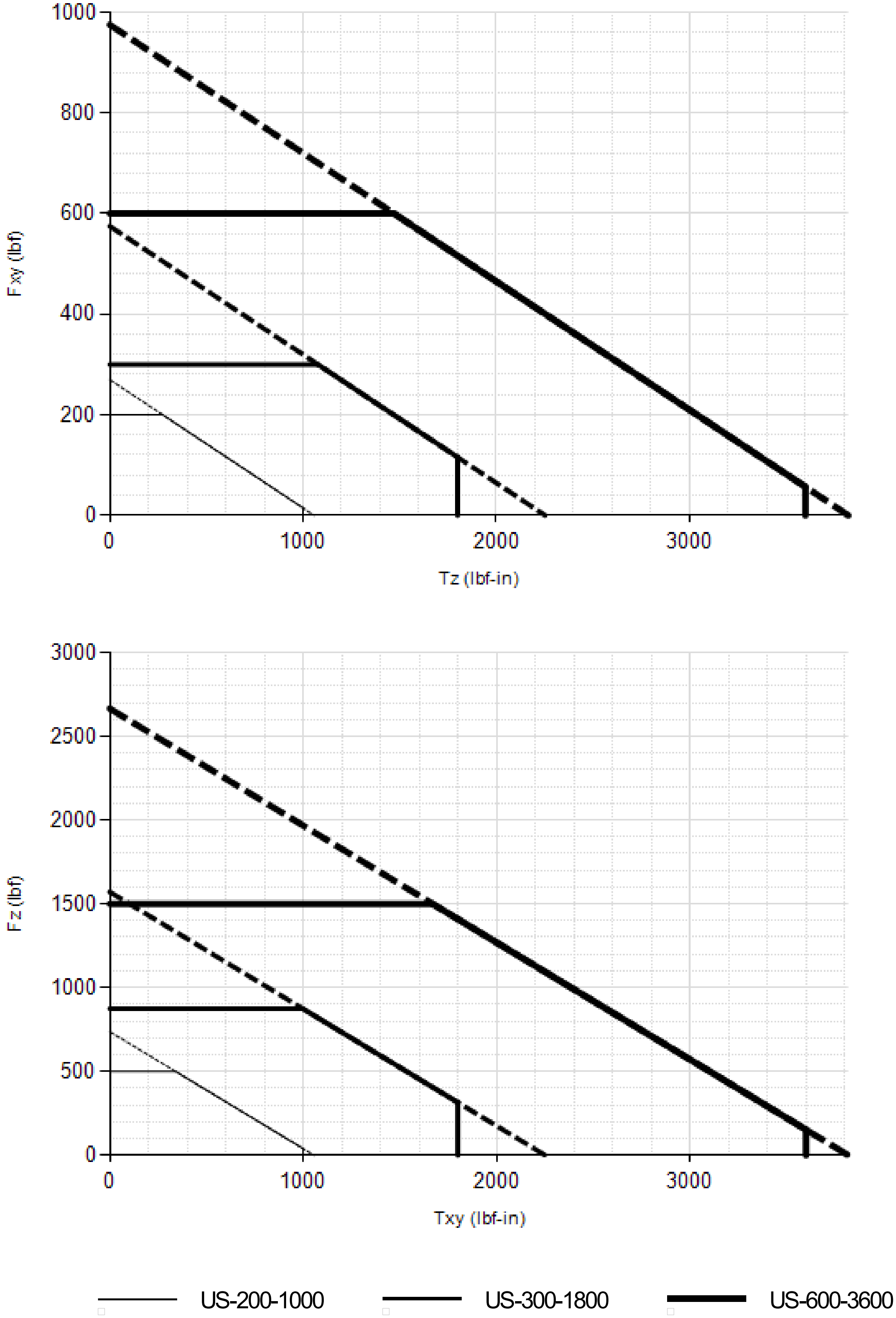
5.14.7 Counts Value

Table 5.82—Counts Value					
Sensor	**Calibration**	**Fx, Fy, Fz (/ lbf)**	**Tx, Ty, Tz (/ lbf-in)**	**Fx, Fy, Fz (/ N)**	**Tx, Ty, Tz (/ Nm)**
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)**	

5.14.8 Tool Transform Factor

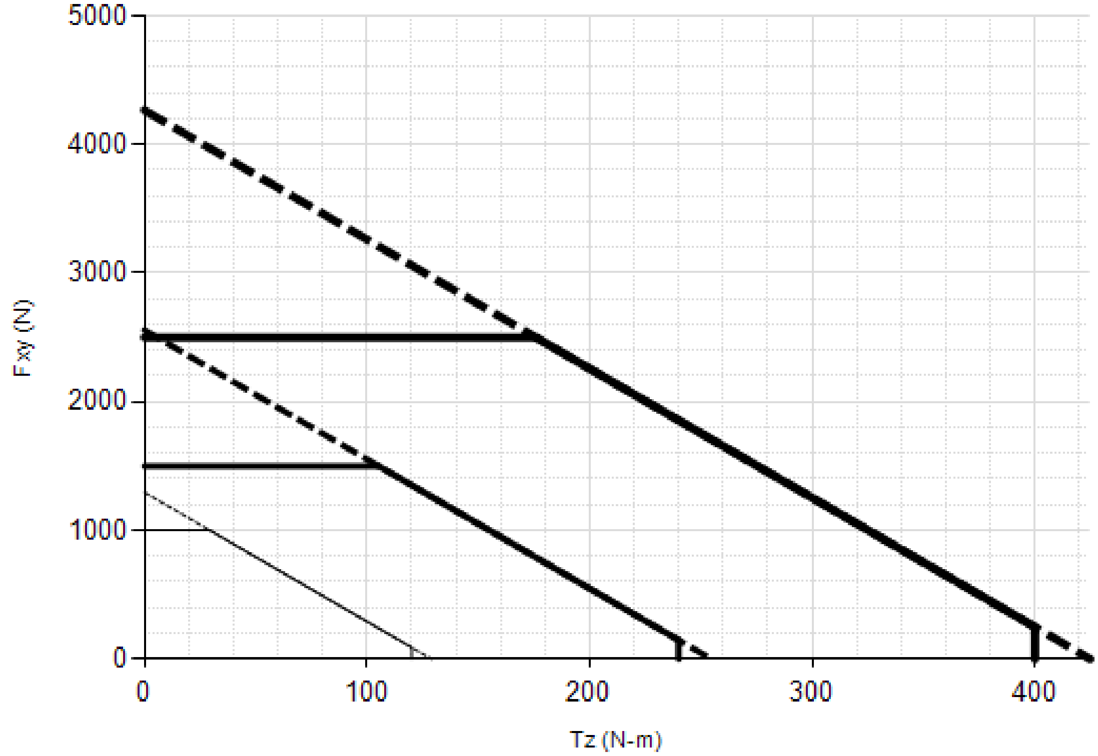
Table 5.83—Tool Transform Factor			
Sensor	**Calibration**	**US (English)**	SI (Metric)
Theta	US-200–1000 / SI-1000–120	0.02 in/lbf	1 mm/N
Theta	US-300–1800 / SI-1500–240	0.0425 in/lbf	1 mm/N
Theta	US-600–3600 / SI-2500–400	0.02 in/lbf	2 mm/N

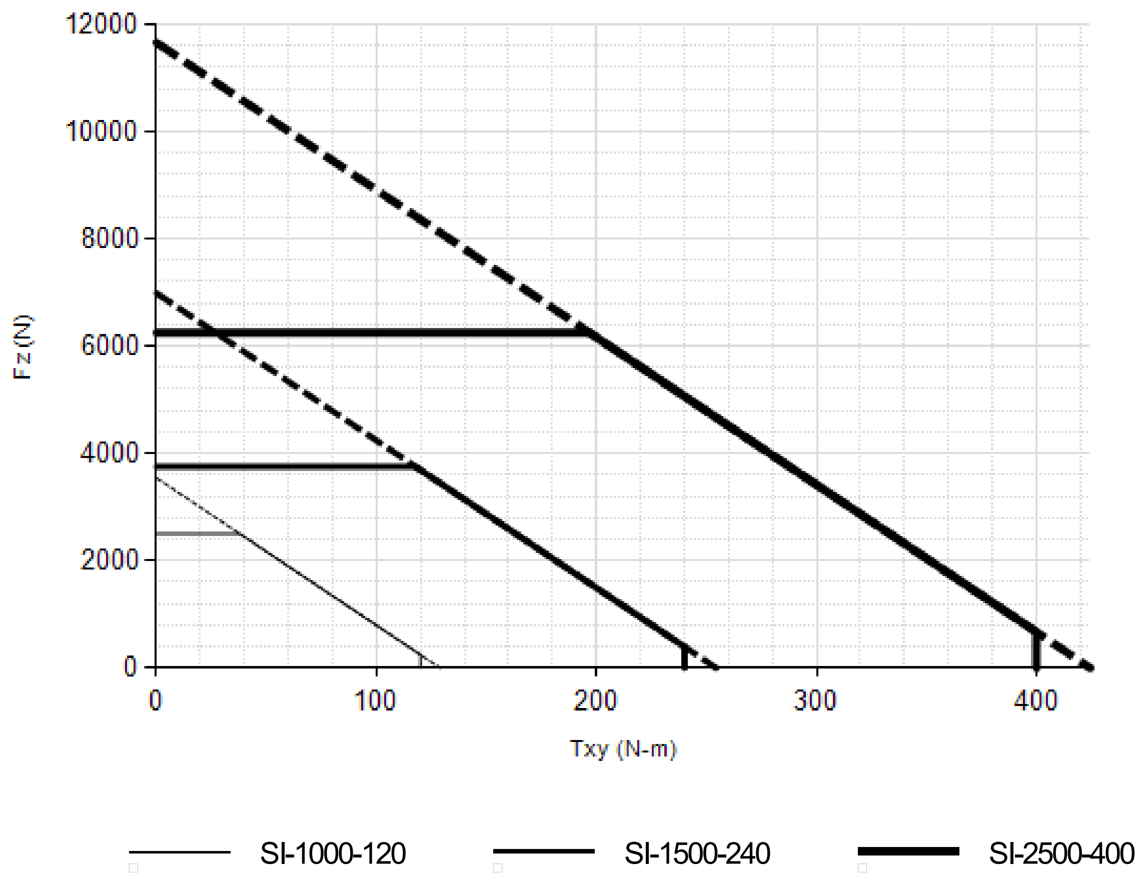
5.14.9 Theta (US Calibration Complex Loading)(Includes IP60/IP65/IP68)[1]



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

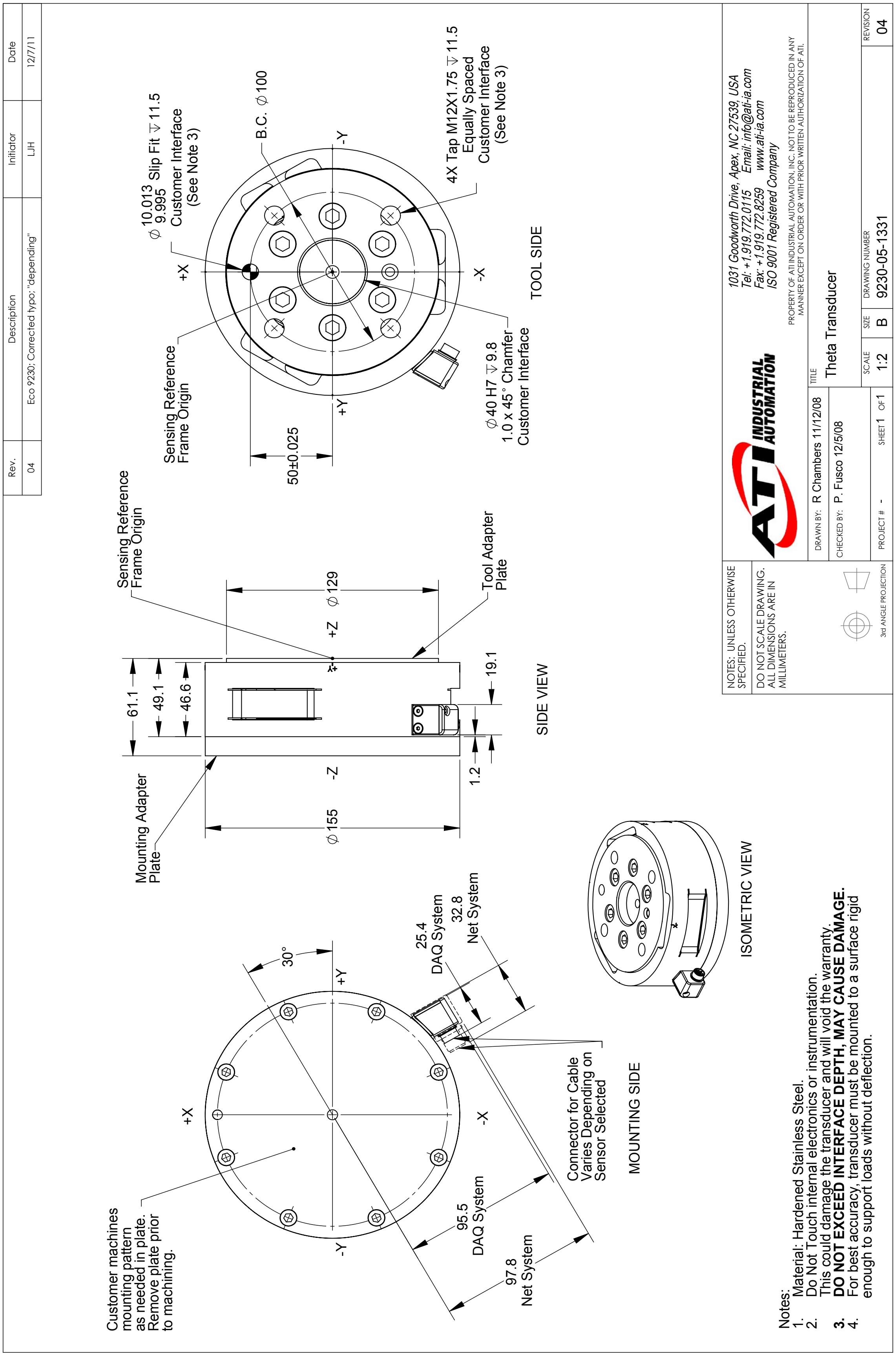
5.14.10 Theta (SI Calibration Complex Loading)(Includes IP60/IP65/IP68)[1]



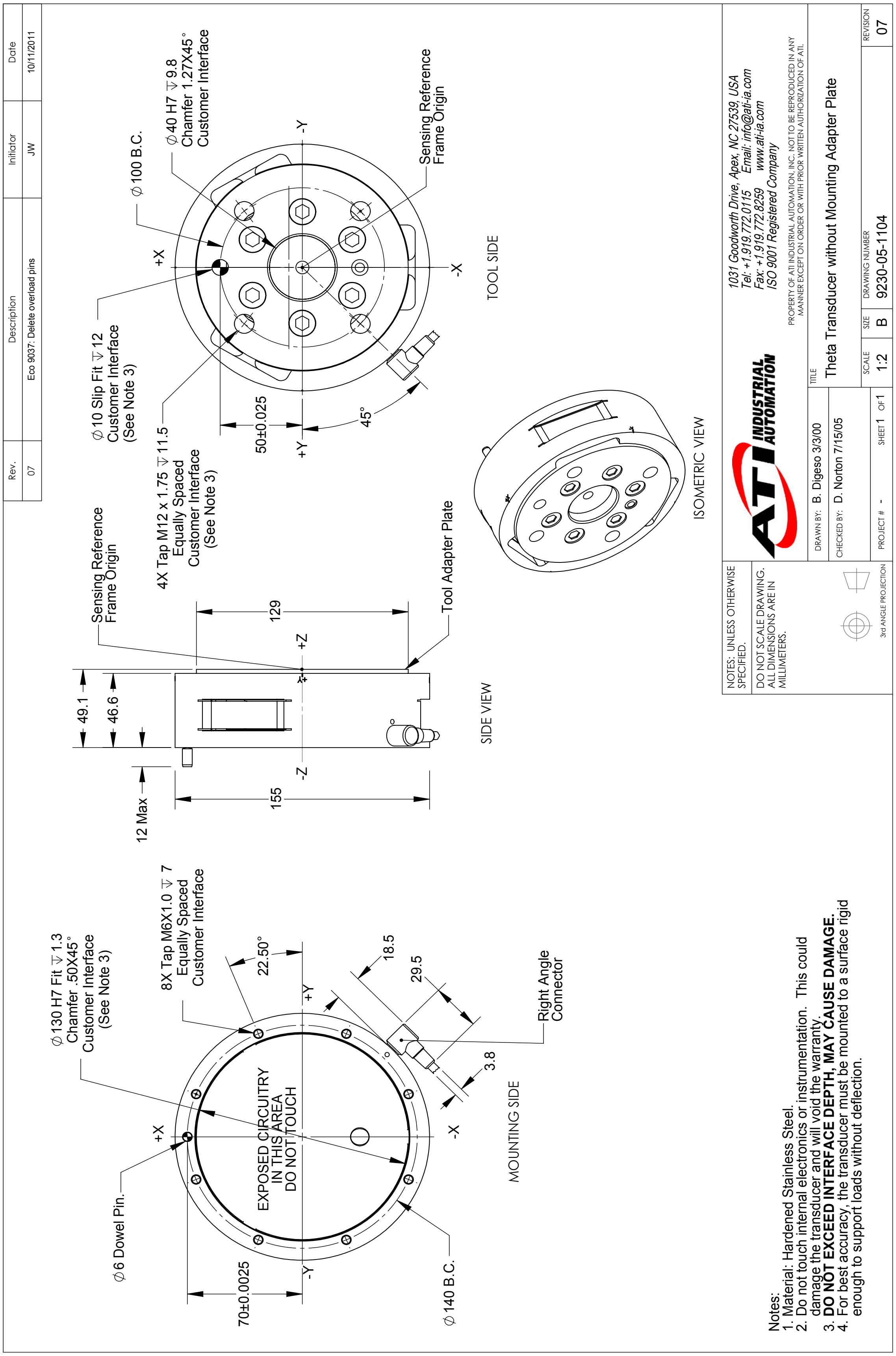


Note: 1. For IP68 version see caution on physical properties page.

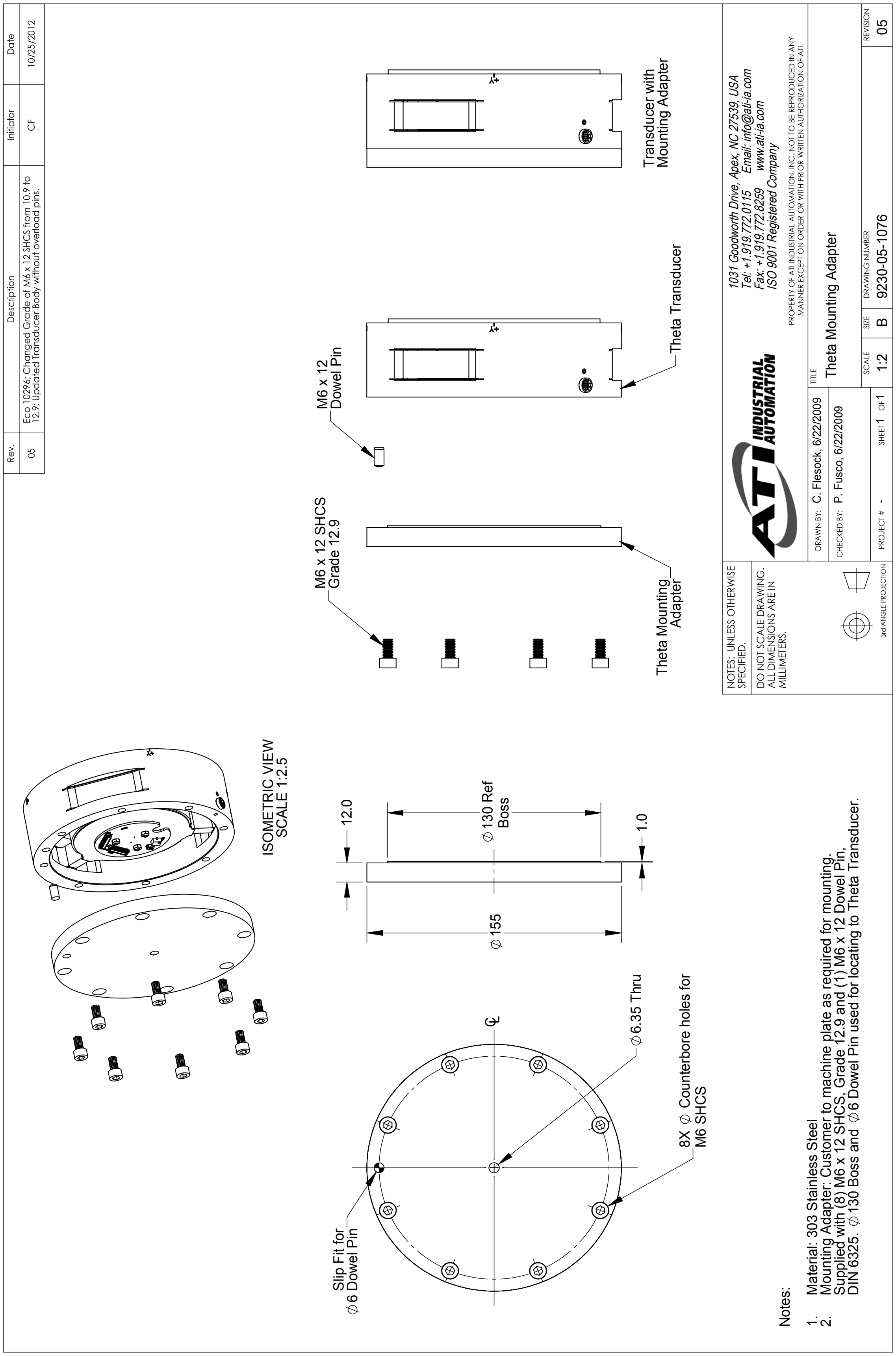
5.14.11 Theta DAQ/Net Transducer Drawing



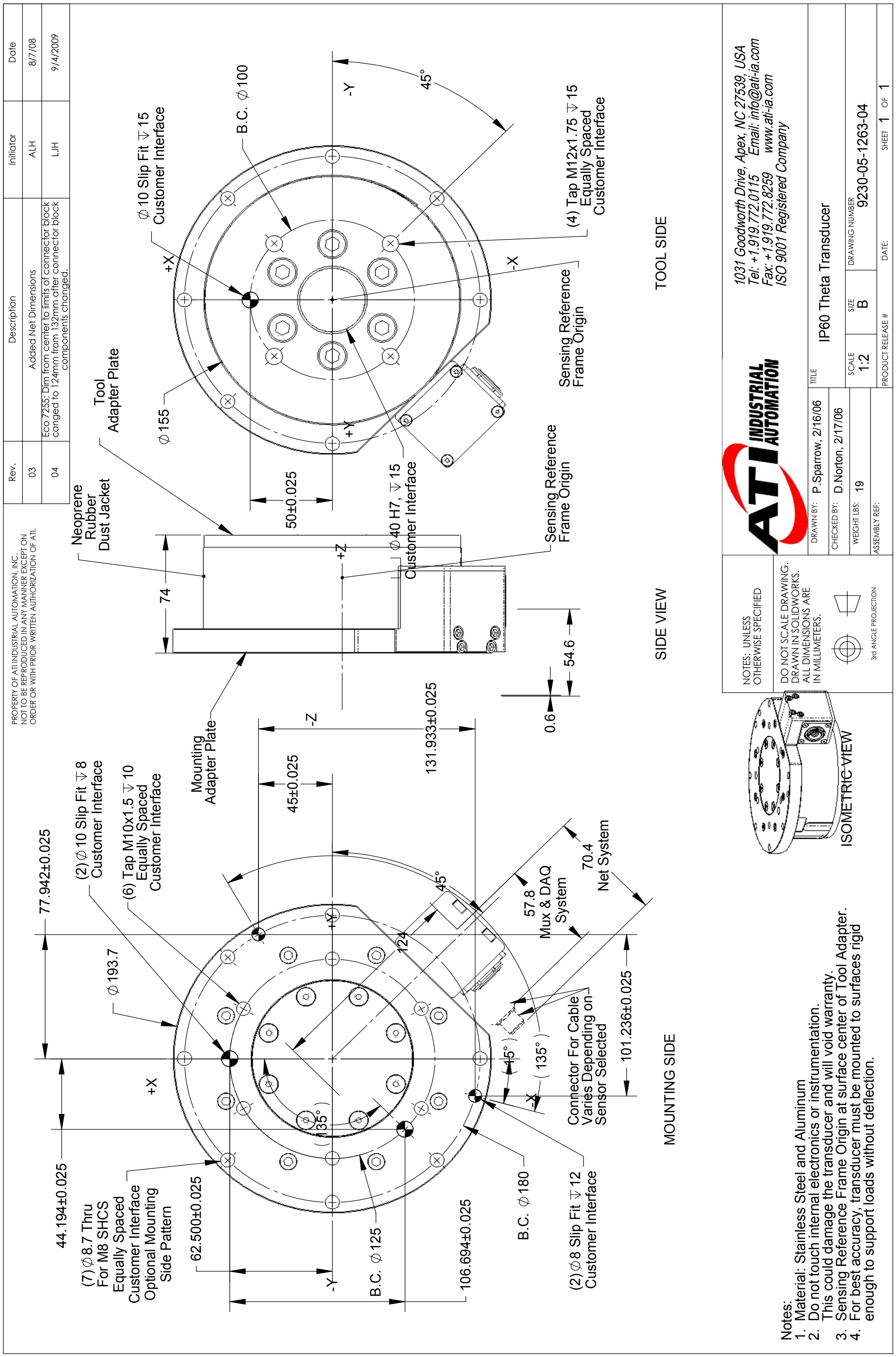
5.14.12 9105-T-Theta Transducer without Mounting Adapter Drawing



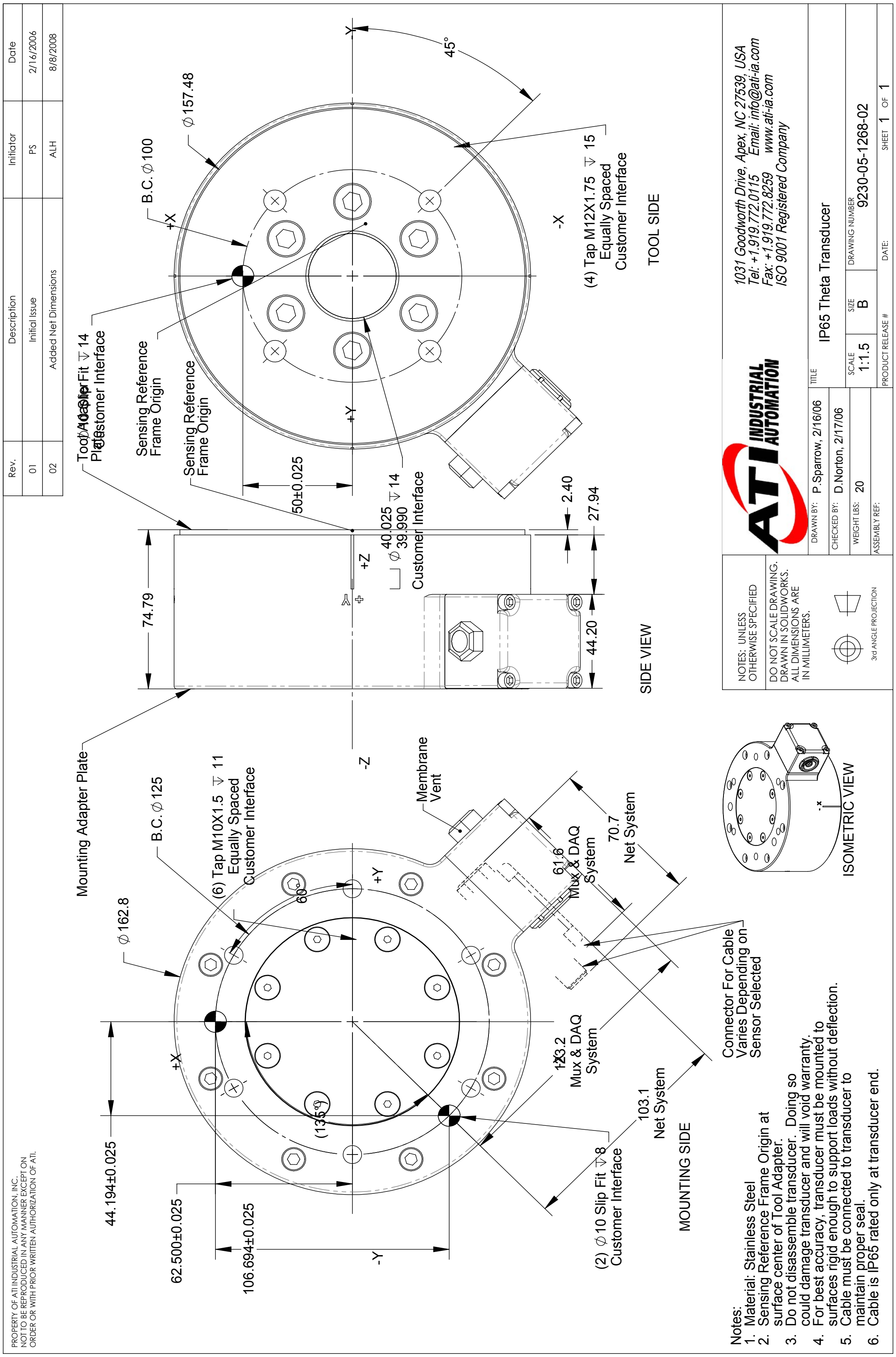
5.14.13 Theta Mounting Adapter Plate Drawing



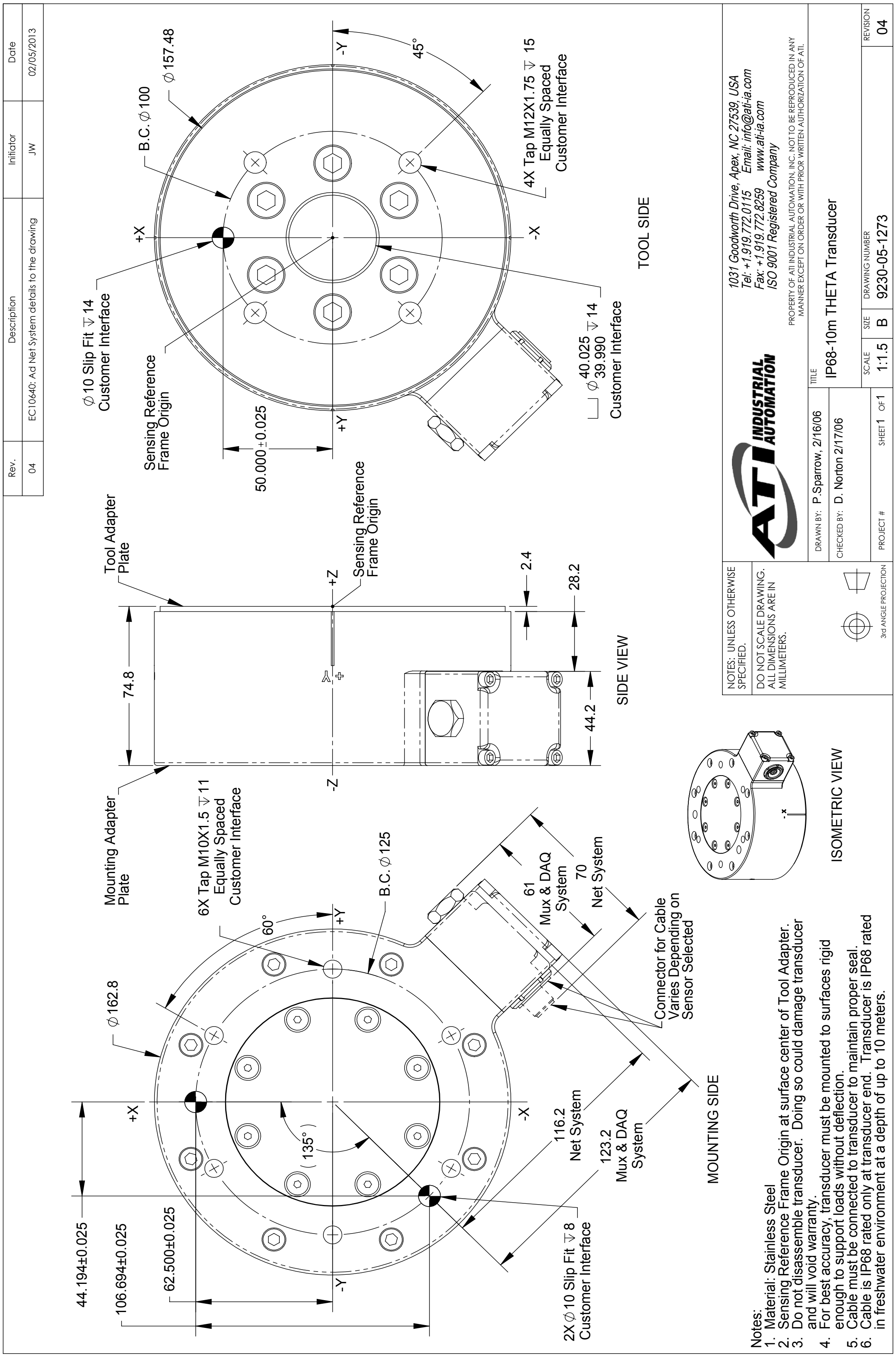
5.14.14 Theta IP60 Transducer Drawing



5.14.15 Theta IP65 Transducer Drawing



5.14.16 Theta IP68 Transducer Drawing



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

5.15.1 Omega85 Physical Properties

Table 5.84—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.		

5.15.2 Omega85 IP65/IP68 Physical Properties

Table 5.85—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

5.15.3 Calibration Specifications (excludes CTL calibrations)

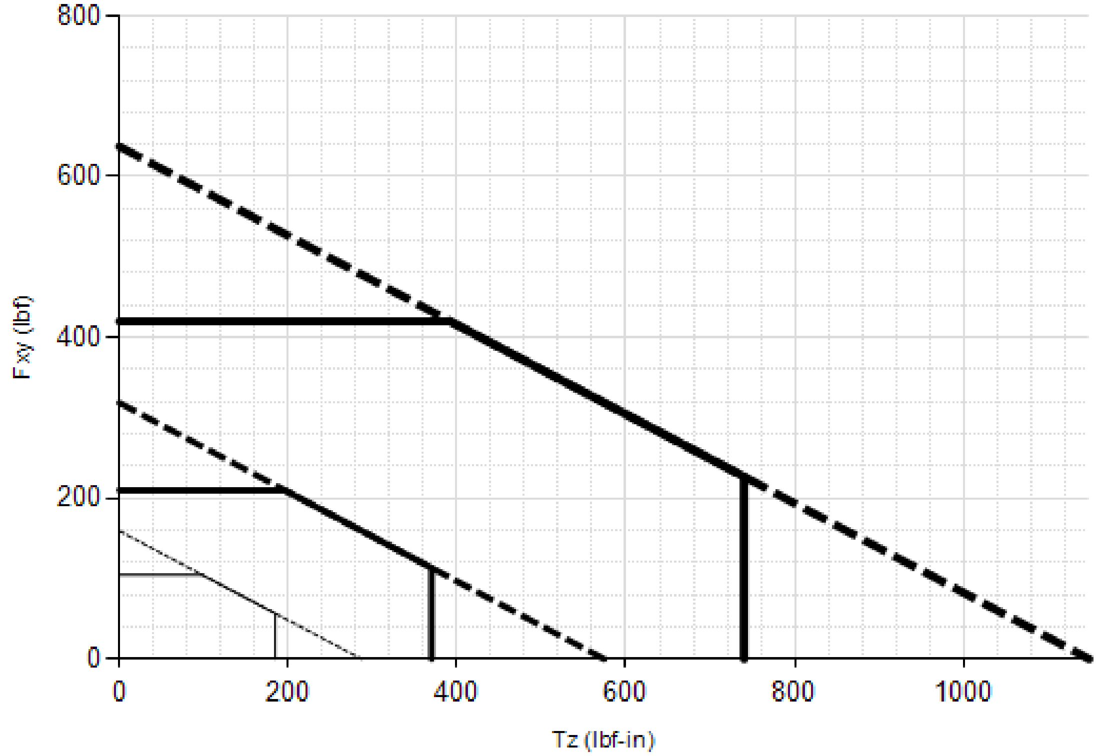
Table 5.86— Omega85 Calibrations (excludes CTL calibrations)[1, 2]

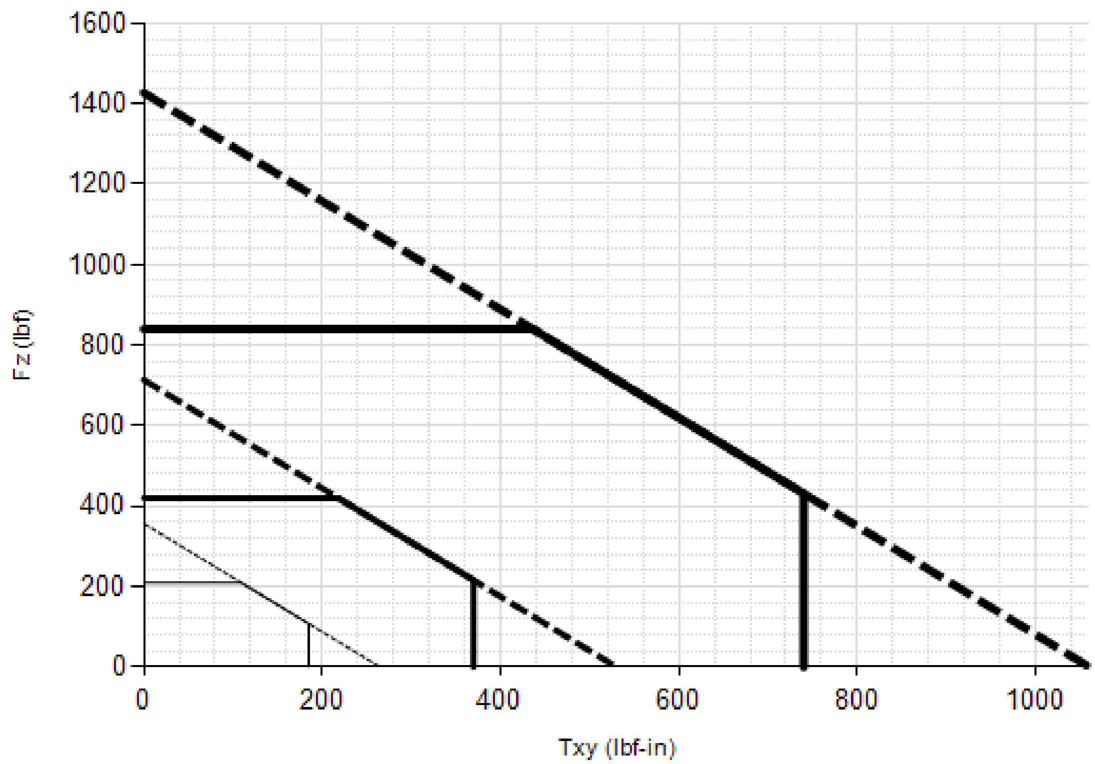
Sensor	(US) Standard Calibration	Fx,Fy (lbf)	Fz[3] (lbf)	Tx,Ty (lbf-in)	Tz (lbf-in)	Fx,Fy (lbf)	Fz[3] (lbf)	Tx,Ty (lbf-in)	Tz (lbf-in)
Omega85	US-105-185	105	210	185	185	1/52	3/130	3/112	1/48
Omega85	US-210-370	210	420	370	370	5/128	3/64	3/56	1/24
Omega85	US-420-740	420	840	740	740	5/64	3/32	3/28	1/12
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.

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

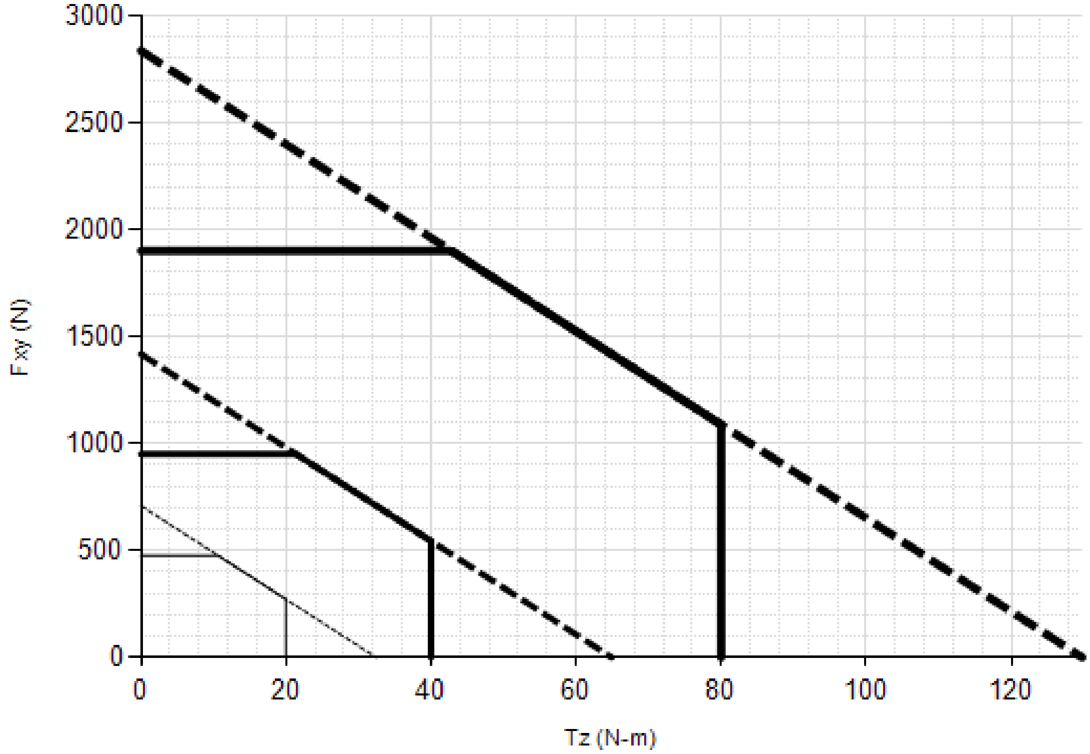


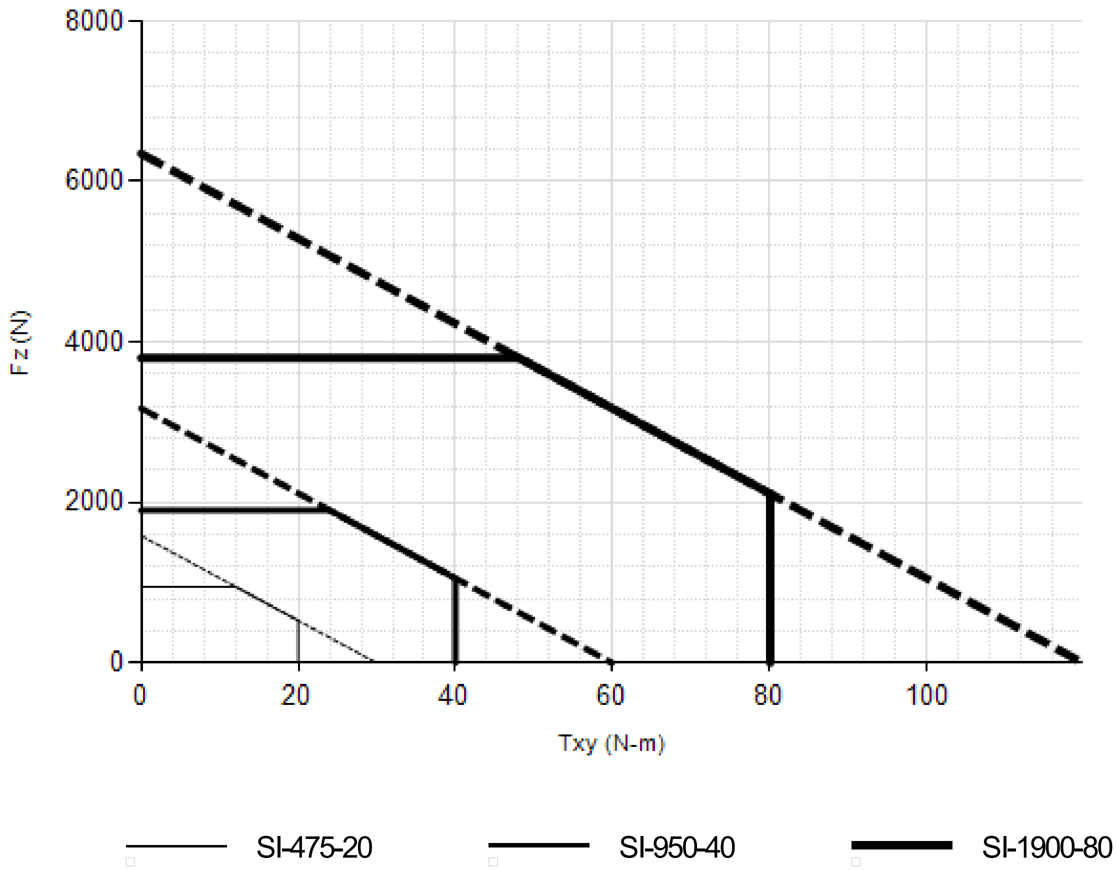


US-105-185 US-210-370 US-420-740

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

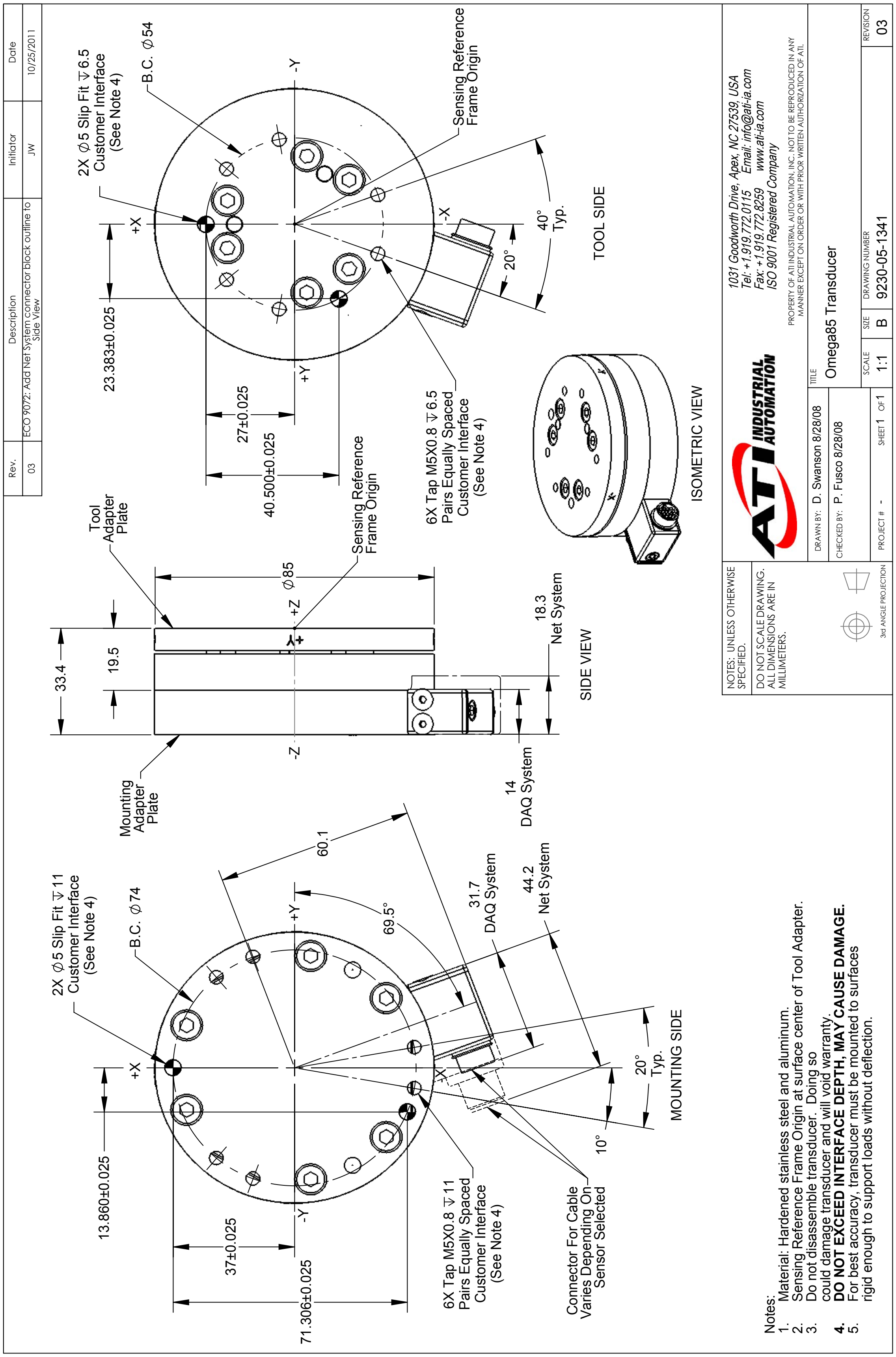
5.15.5 Omega85 (SI Calibration Complex Loading)(Includes IP65/IP68)[1]



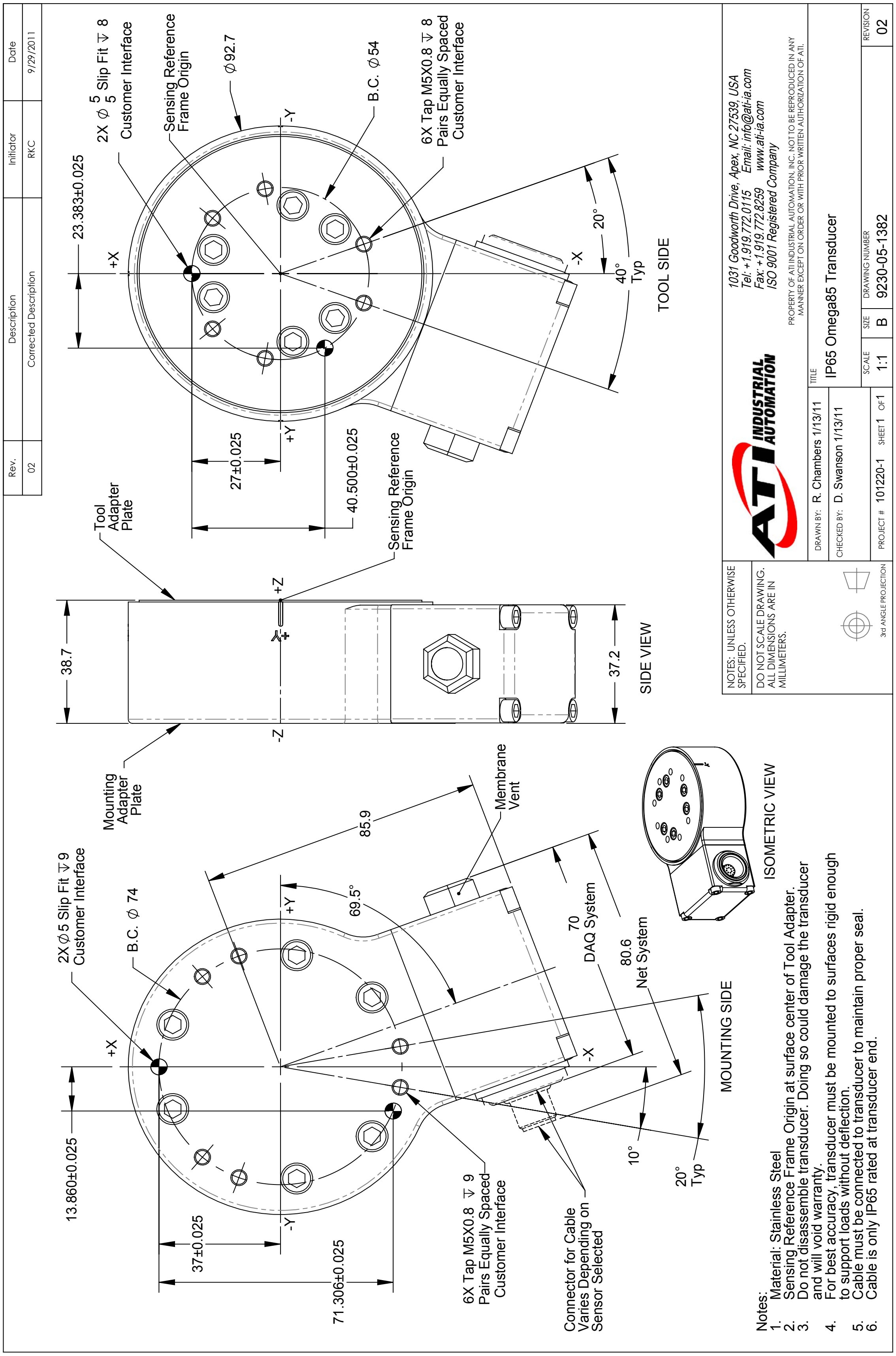


Note: 1. For IP68 version see caution on physical properties page.

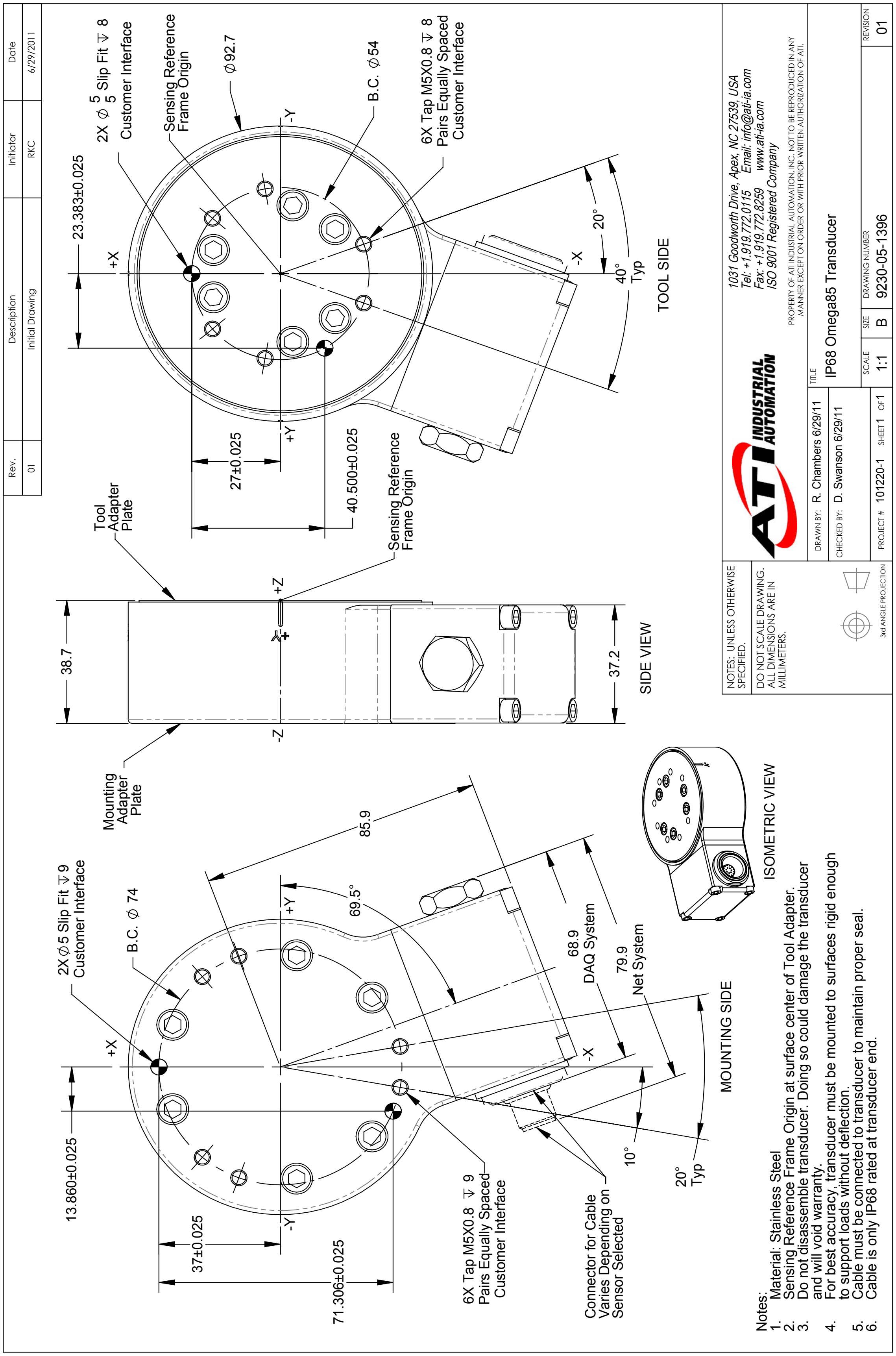
5.15.6 Omega85 Transducer Drawing



5.15.7 Omega85 IP65 Transducer Drawing



5.15.8 Omega85 IP68 Transducer Drawing



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

5.16.1 Omega160 Physical Properties

Table 5.87—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.		

5.16.2 Omega160 IP160 Physical Properties (Includes ECAT)

Table 5.88—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.		

5.16.3 Omega160 IP65/IP68 Physical Properties

Table 5.89—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

5.16.4 Calibration Specifications (excludes CTL calibrations)

Table 5.90— Omega160 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)**
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)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**	**Fx,Fy (N)**	**Fz[3] (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.

5.16.5 CTL Calibration Specifications

Table 5.91— Omega160 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)**
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)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**	**Fx,Fy (N)**	**Fz[3] (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.

5.16.6 Analog Output

Table 5.92— 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 (Nmm)**	**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.

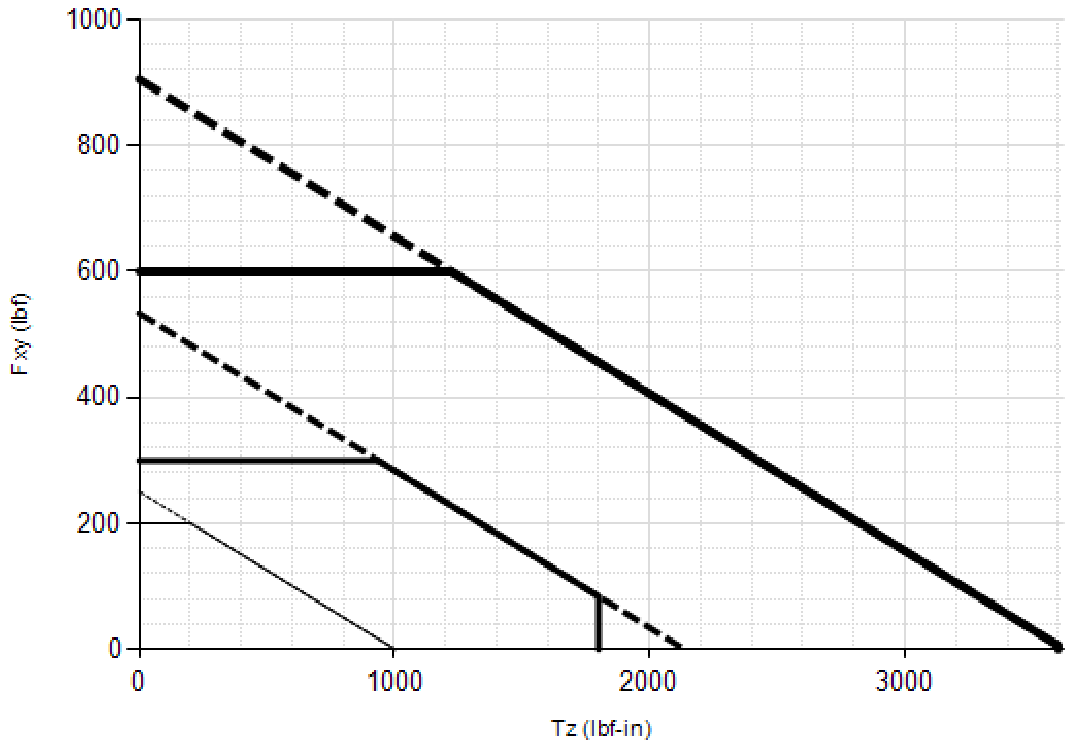
5.16.7 Counts Value

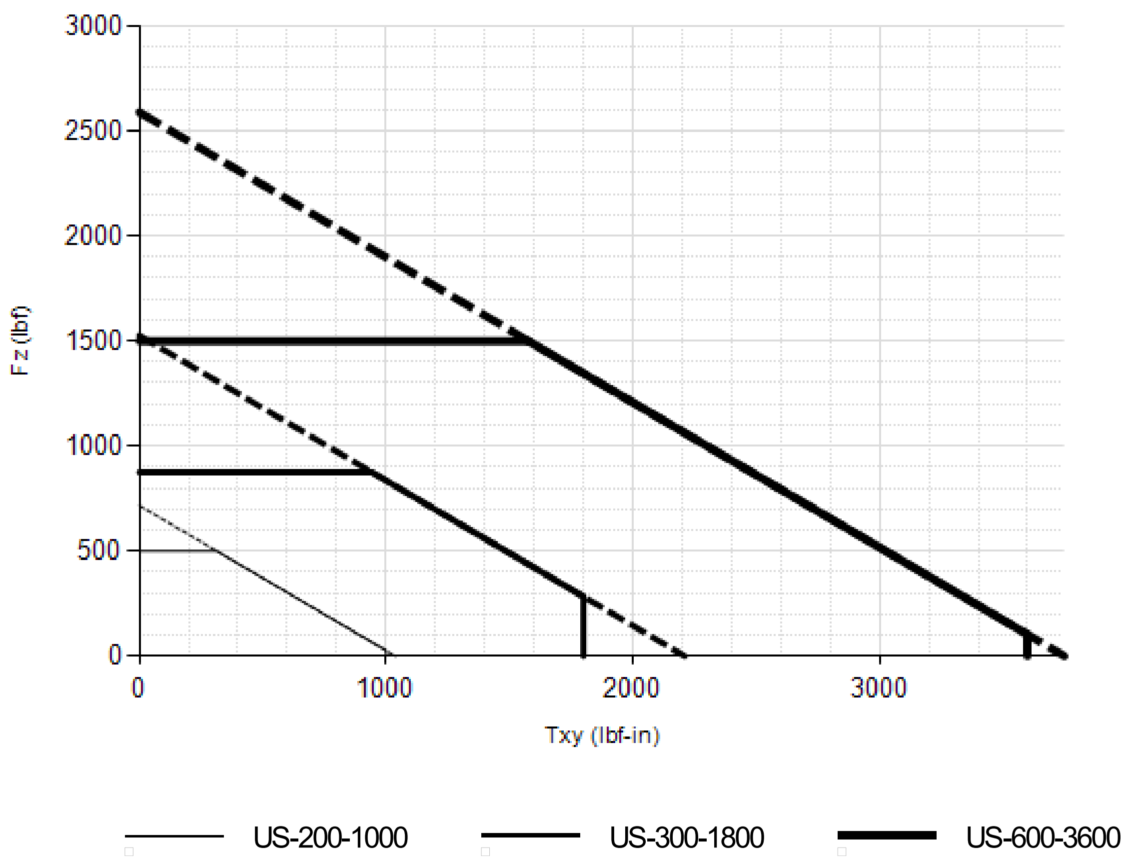
Table 5.93—Counts Value					
Sensor	**Calibration**	**Fx, Fy, Fz (/ lbf)**	**Tx, Ty, Tz (/ lbf-in)**	**Fx, Fy, Fz (/ N)**	**Tx, Ty, Tz (/ Nm)**
Omega160	US-200–1000 / SI-1000–120	128	64	32	320
Omega160	US-300–1800 / SI-1500–240	54.4	12.8	16	160
Omega160	US-600–3600 / SI-2500–400	32	16	16	80
Omega160	Tool Transform Factor	See Tool Transform Factor table			
		Counts Value – Standard (US)		**Counts Value – Metric (SI)**	

5.16.8 Tool Transform Factor

Table 5.94—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

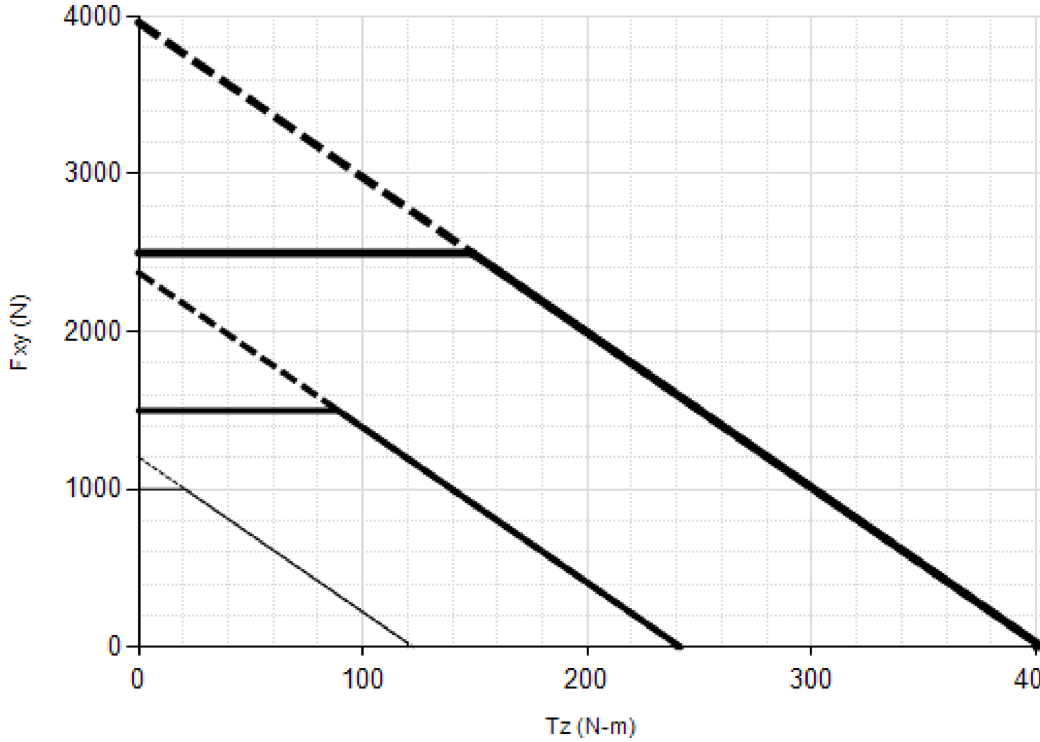
5.16.9 Omega160 (US Calibration Complex Loading) (Includes IP60/IP65/IP68)[1]

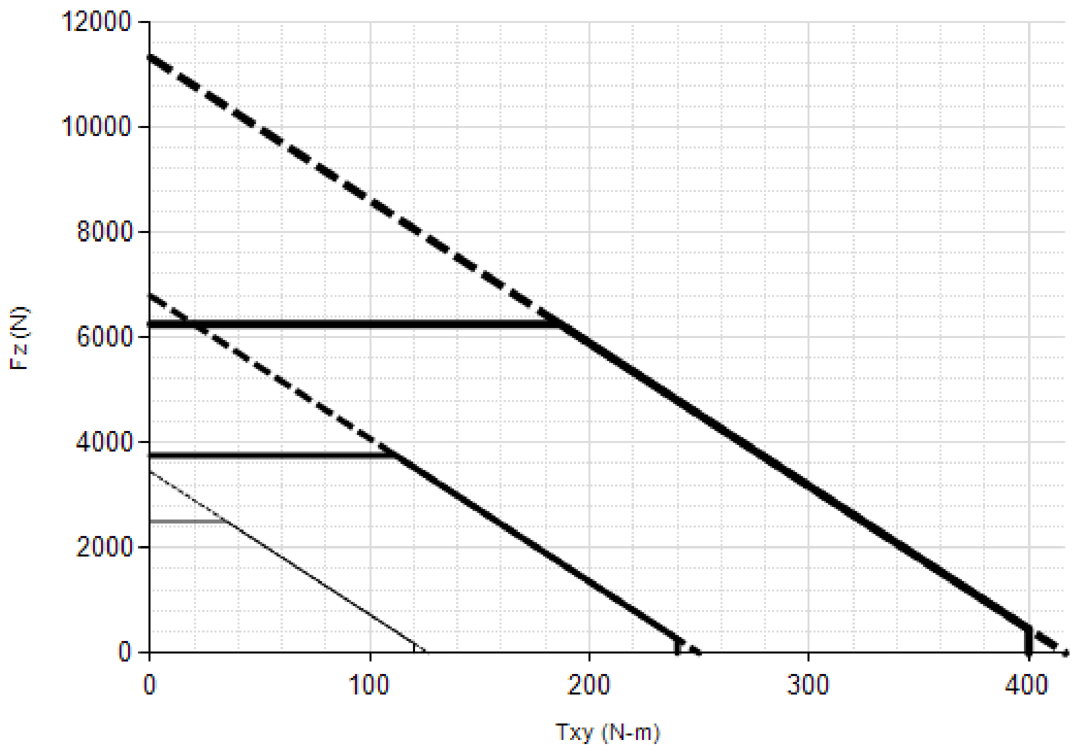




Note: 1. For IP68 version see caution on physical properties page.

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

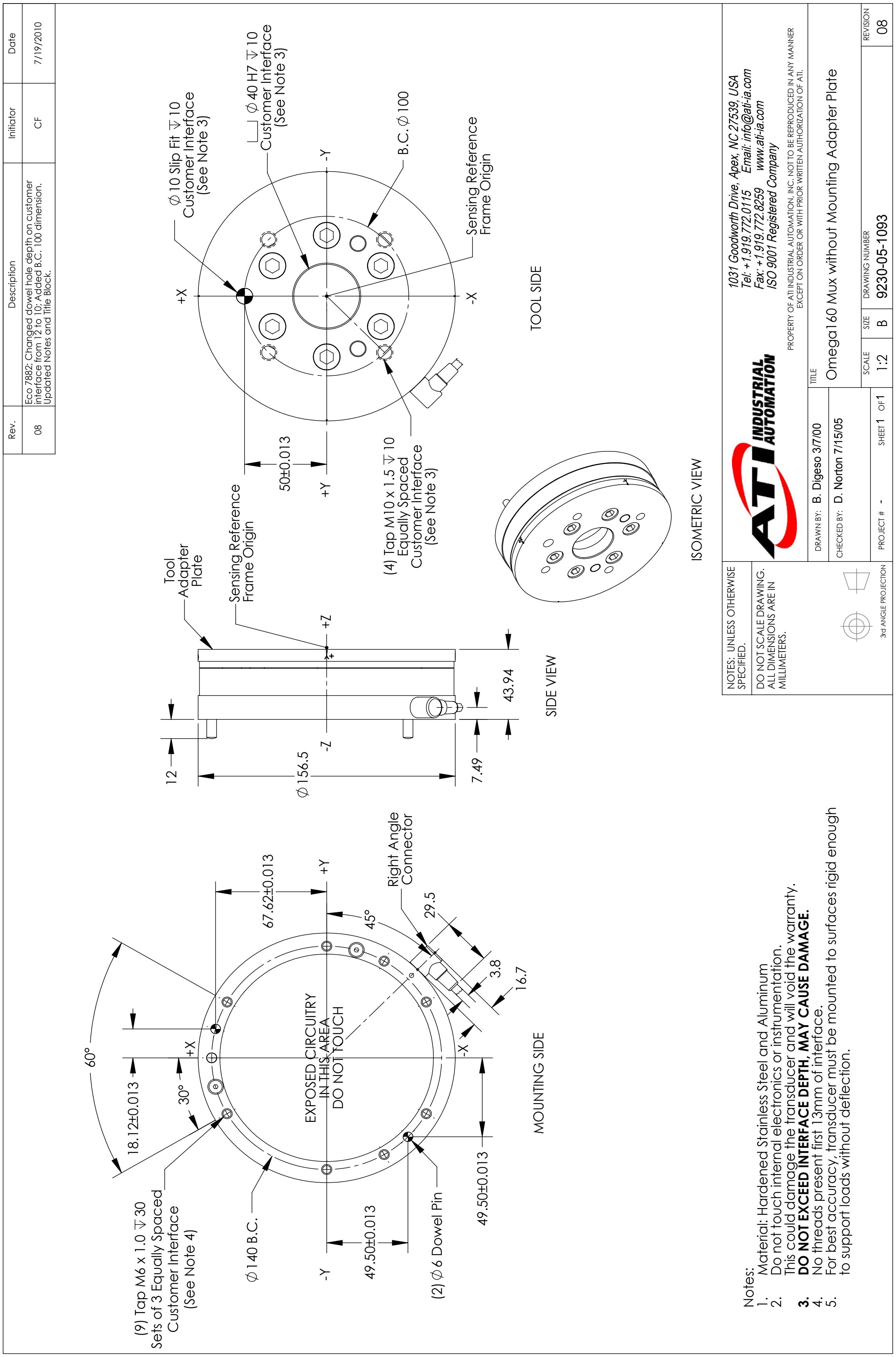




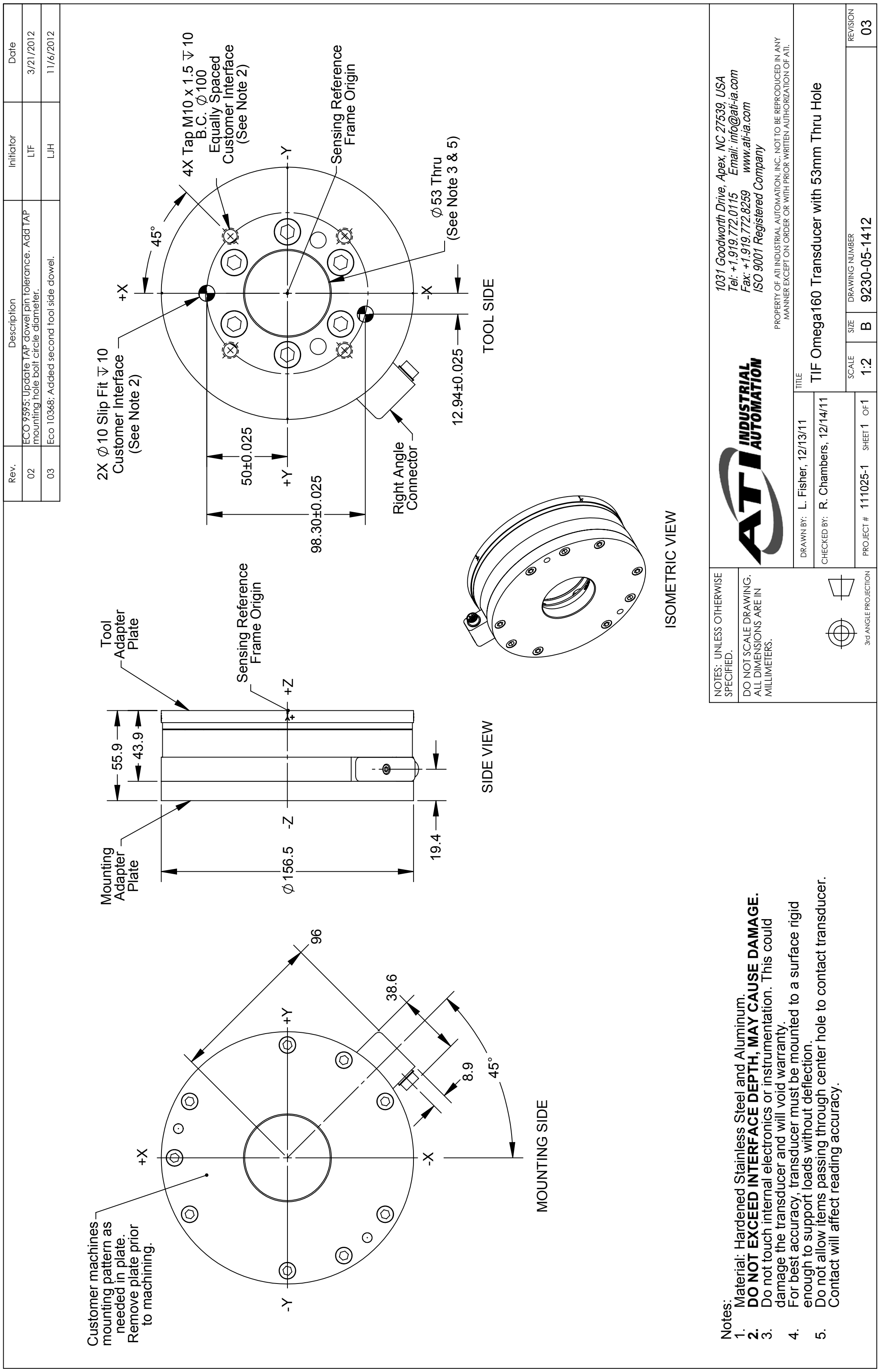
SI-1000-120 SI-1500-240 SI-2500-400

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

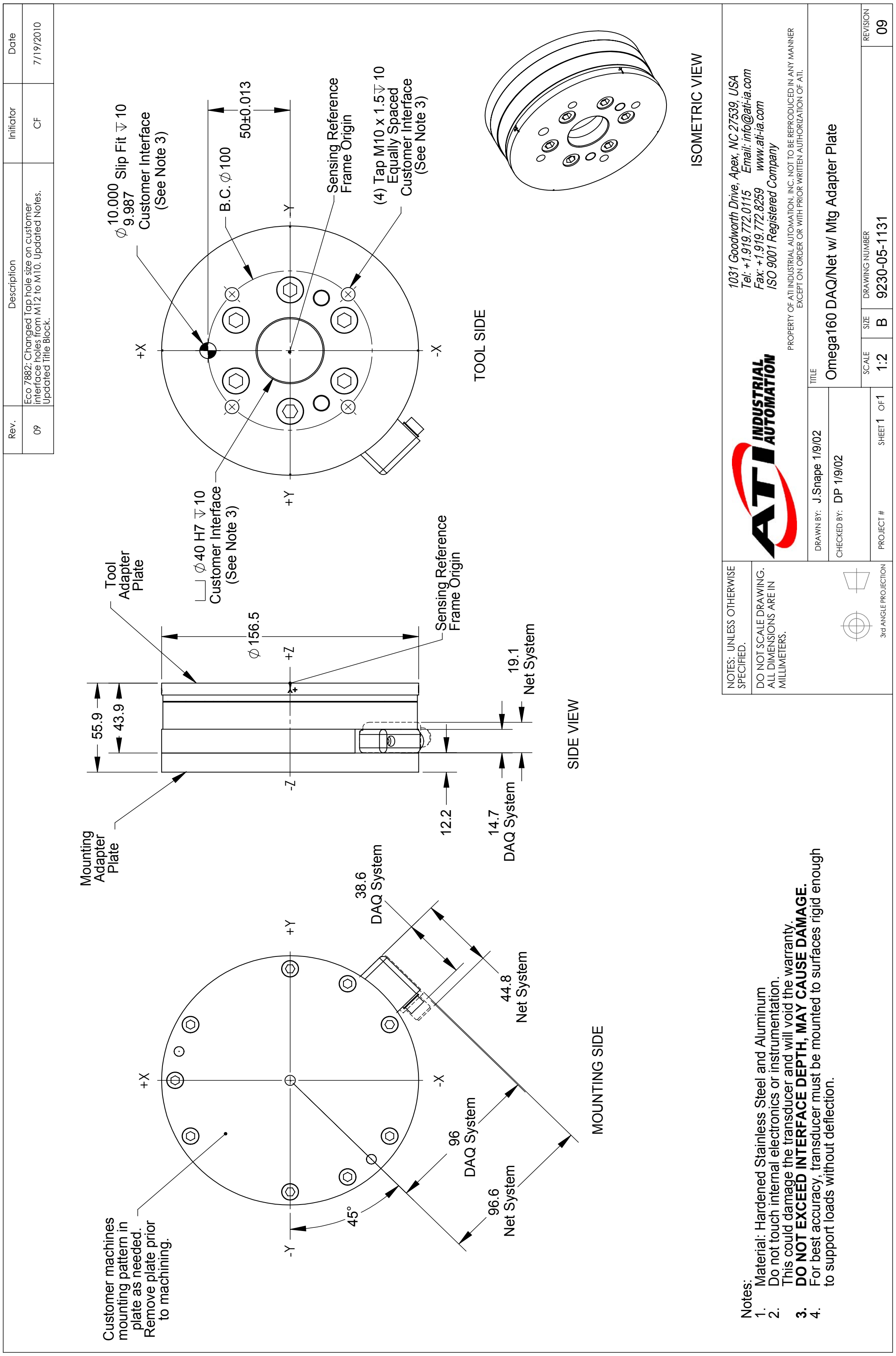
5.16.11 Omega160 Transducer without Mounting Adapter Drawing



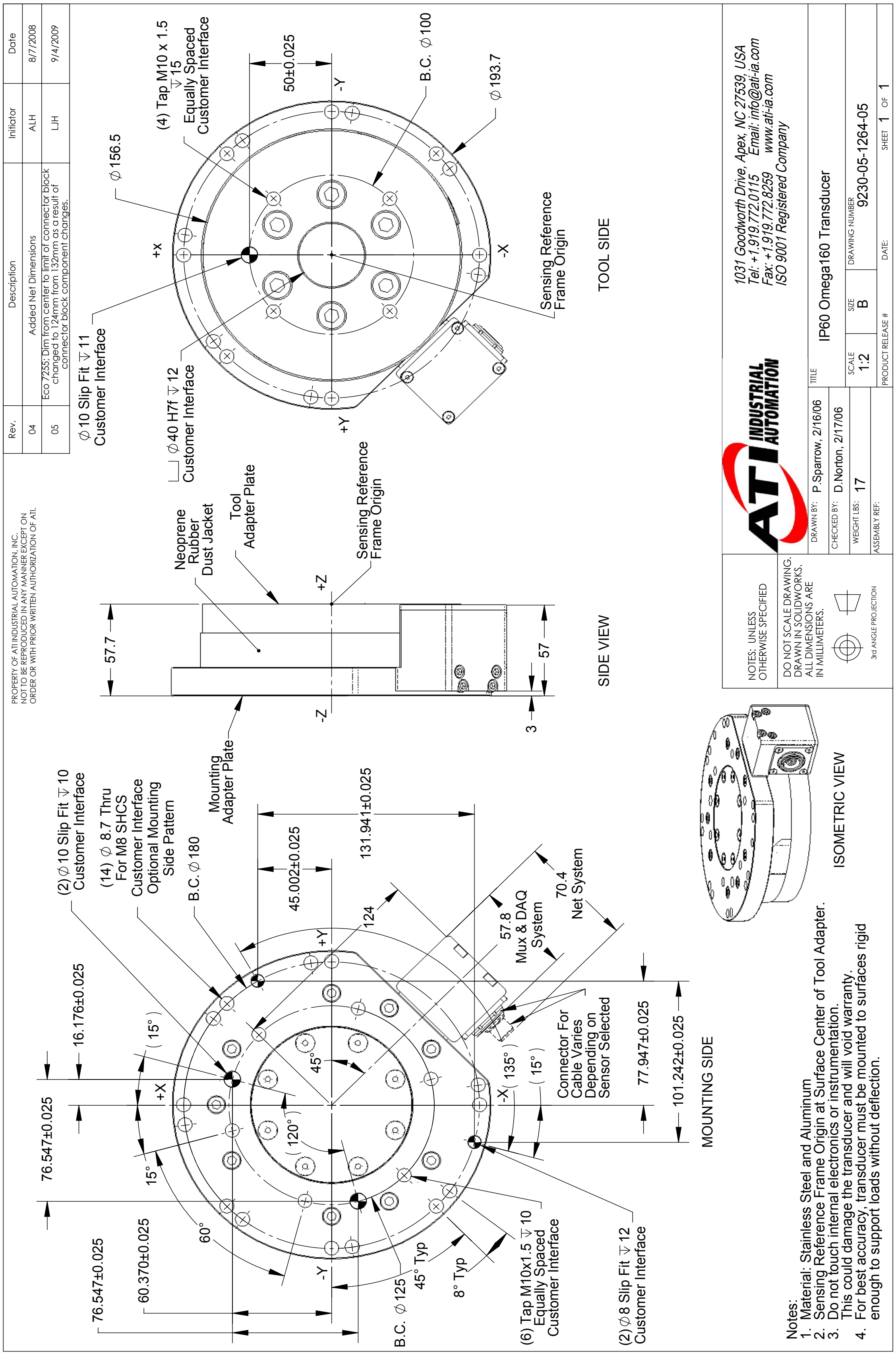
5.16.12 Omega160 Transducer with 53mm Through Hole



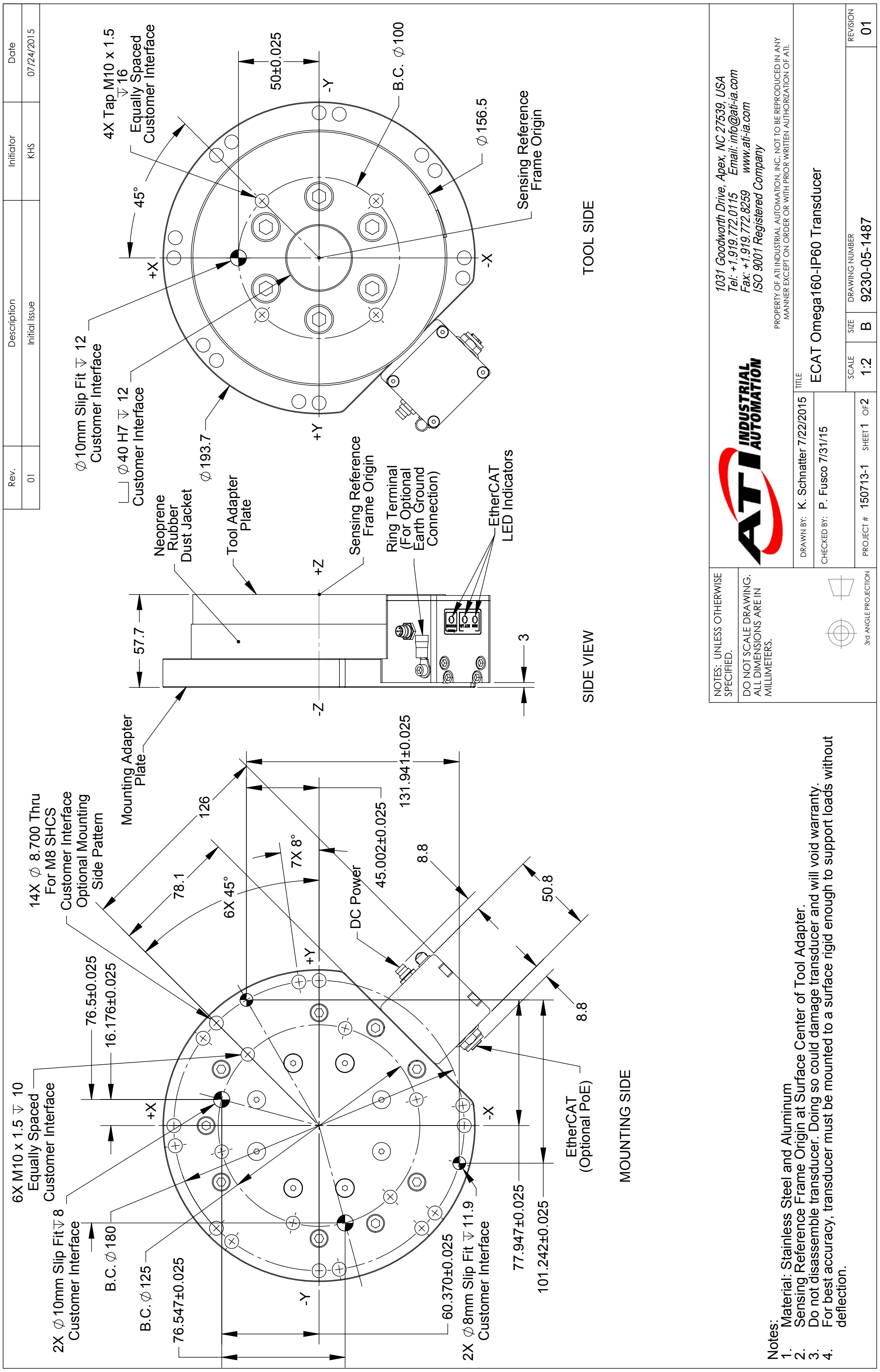
5.16.13 Omega160 Transducer with Mounting Adapter Drawing



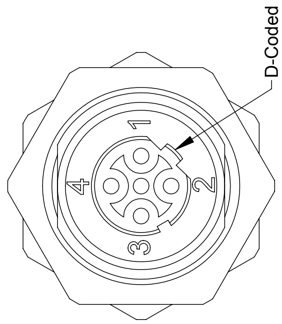
5.16.14 Omega160 IP60 Transducer Drawing



5.16.15 ECAT Omega160 IP60 Transducer Drawing

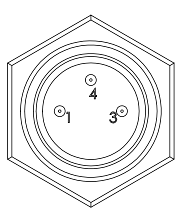


Pin No.	Signal
1	TX+
2	RX+
3	TX-
4	RX-
Shell	Connector Block Housing

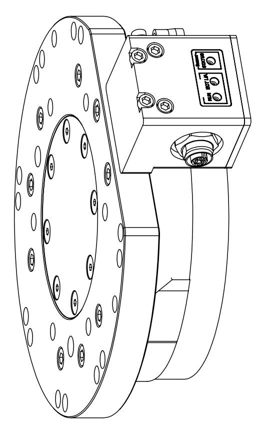


EtherCAT Connector
4 pin Female M12 D-Coded

Pin No.	Signal
1	V+
3	GND
4	N/C



DC Power Connector
3 pin Male M8



ISOMETRIC VIEW

NOTES: UNLESS OTHERWISE SPECIFIED.
DO NOT SCALE DRAWING.
ALL DIMENSIONS ARE IN MILLIMETERS.

3rd ANGLE PROJECTION

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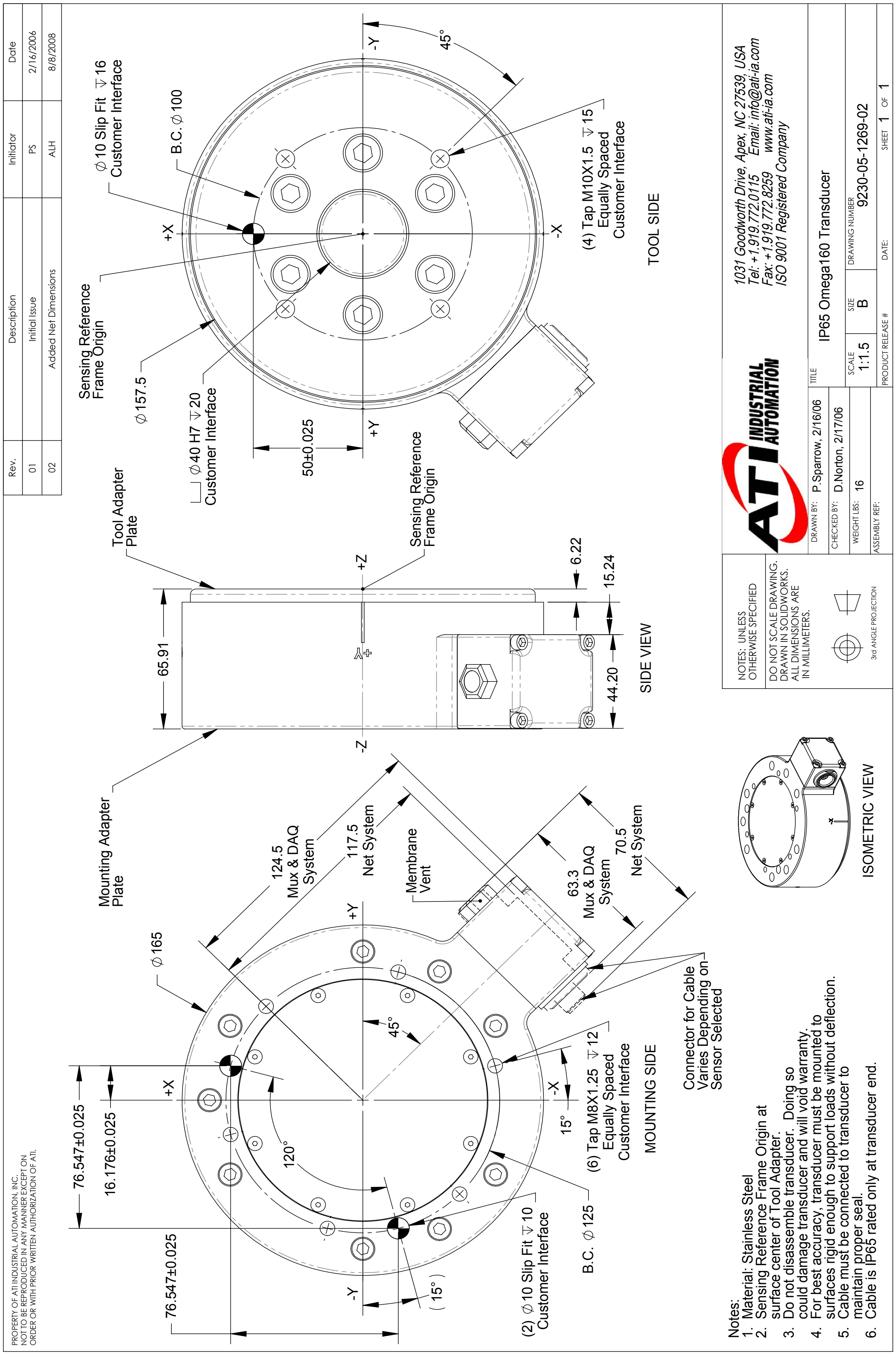
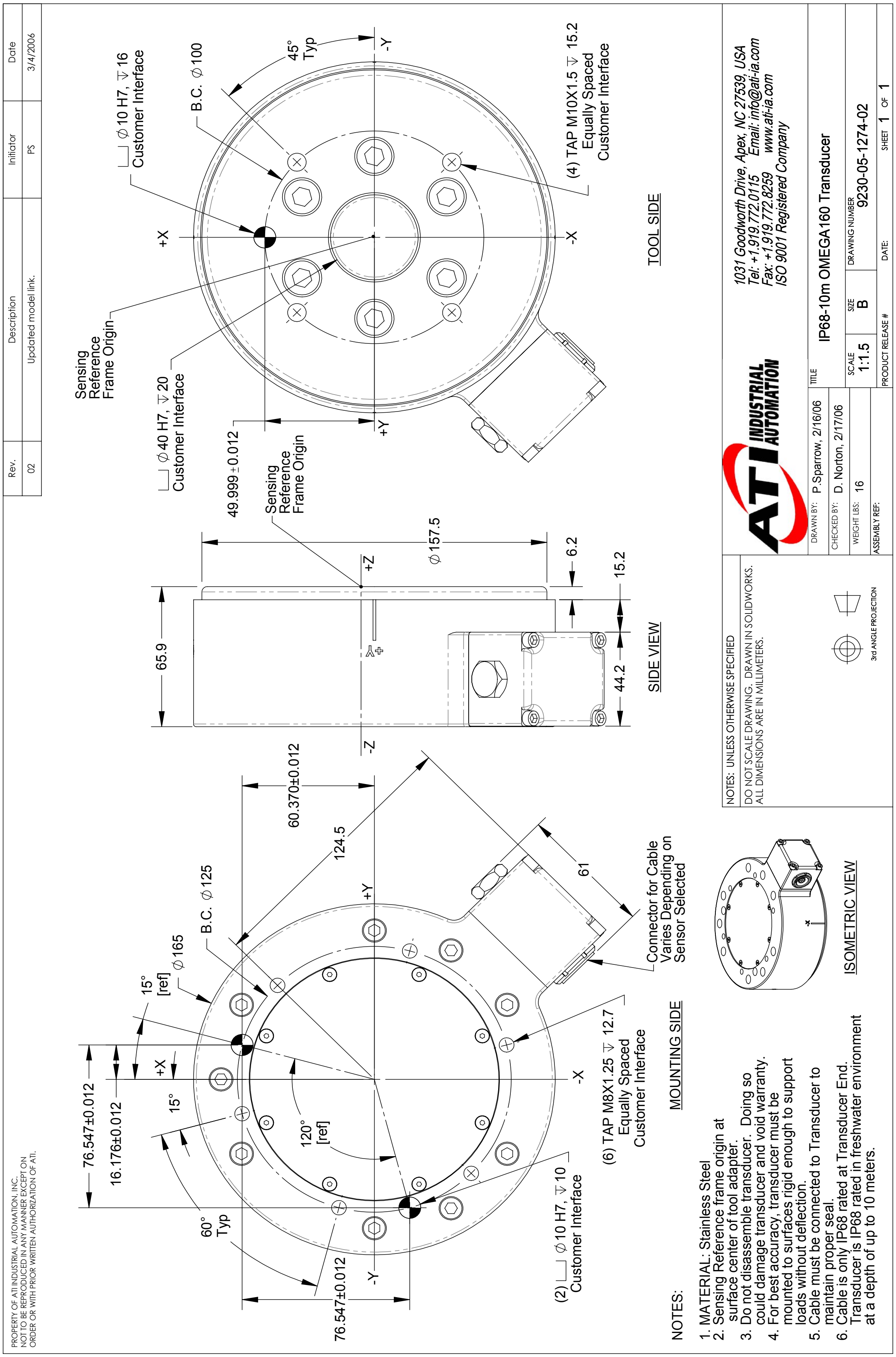
DRAWN BY: K. Schnatter 7/22/2015
CHECKED BY: P. Fusco 7/31/15
TITLE: ECAT Omega160-IP60 Transducer
PROJECT # 150713-1 SHEET 2 OF 2
SCALE 5:1 SIZE B DRAWING NUMBER 9230-05-1487 REVISION 01

5.16.16 Omega160 IP65 Transducer Drawing



5.16.17 Omega160 IP68 Transducer Drawing



5.17 Omega190 Specifications (Includes IP60/IP65/IP68 Versions)

5.17.1 Omega190 Physical Properties

Table 5.95—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)	1.4×10^{6} lb/in	2.4×10^{8} N/m
Z-axis force (Kz)	2.1×10^{6} lb/in	3.6×10^{8} N/m
X-axis & Y-axis torque (Ktx, Kty)	1.4×10^{7} lbf-in/rad	1.5×10^{6} Nm/rad
Z-axis torque (Ktz)	2.8×10^{7} lbf-in/rad	3.2×10^{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.

5.17.2 Omega190 IP60 Physical Properties

Table 5.96—Omega190 IP60 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)	1.4×10^{6} lb/in	2.4×10^{8} N/m
Z-axis force (Kz)	2.1×10^{6} lb/in	3.6×10^{8} N/m
X-axis & Y-axis torque (Ktx, Kty)	1.4×10^{7} lbf-in/rad	1.5×10^{6} Nm/rad
Z-axis torque (Ktz)	2.8×10^{7} lbf-in/rad	3.2×10^{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.

5.17.3 Omega190 IP65/IP68 Physical Properties

Table 5.97—Omega190 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 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	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 Omega190	**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

5.17.4 Calibration Specifications (excludes CTL calibrations)

Table 5.98— 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.

5.17.5 CTL Calibration Specifications

Table 5.99— Omega190 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	5/32	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.

5.17.6 Analog Output

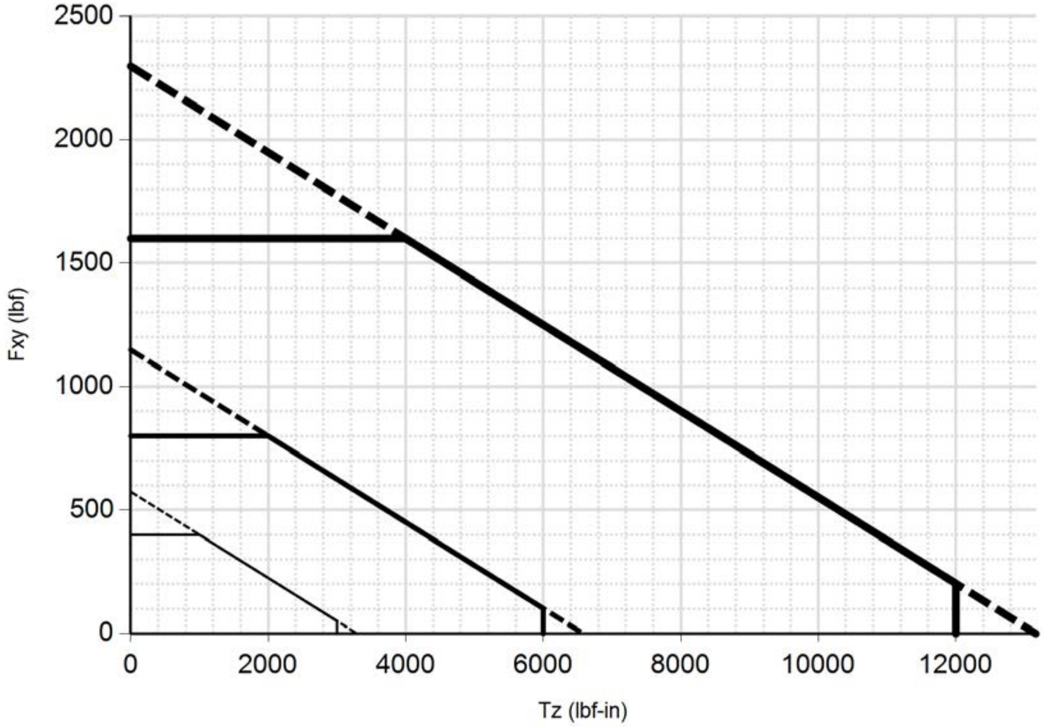
Table 5.100— Omega190 Analog Output							
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz[2] (lbf)**	**Tx,Ty,Tz (lbf-in)**	**Fx,Fy (lbf/V)**	**Fz[2] (lbf/V)**	**Tx,Ty,Tz (lbf-in/V)**
Omega190	US-400-3000	±400	±1000	±3000	40	100	300
Omega190	US-800-6000	±800	±2000	±6000	80	200	600
Omega190	US-1600-12000	±1600	±4000	±12000	160	400	1200
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz[2] (N)**	**Tx,Ty,Tz (Nmm)**	**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]**		

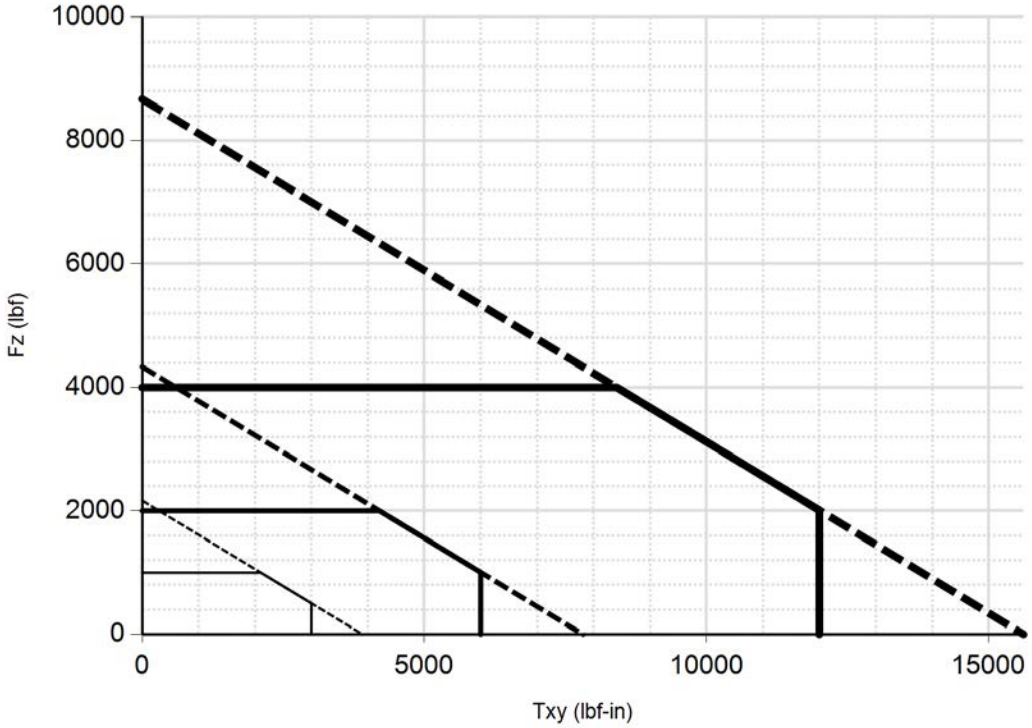
Notes:
1. ±5V Sensitivity values are double the listed ±10V Sensitivity values.
2. For IP68 version see caution on physical properties page.

5.17.7 Counts Value

Table 5.101—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)**	

5.17.8 Omega190 (US Calibration Complex Loading) (Includes IP60/IP65/IP68)[1]

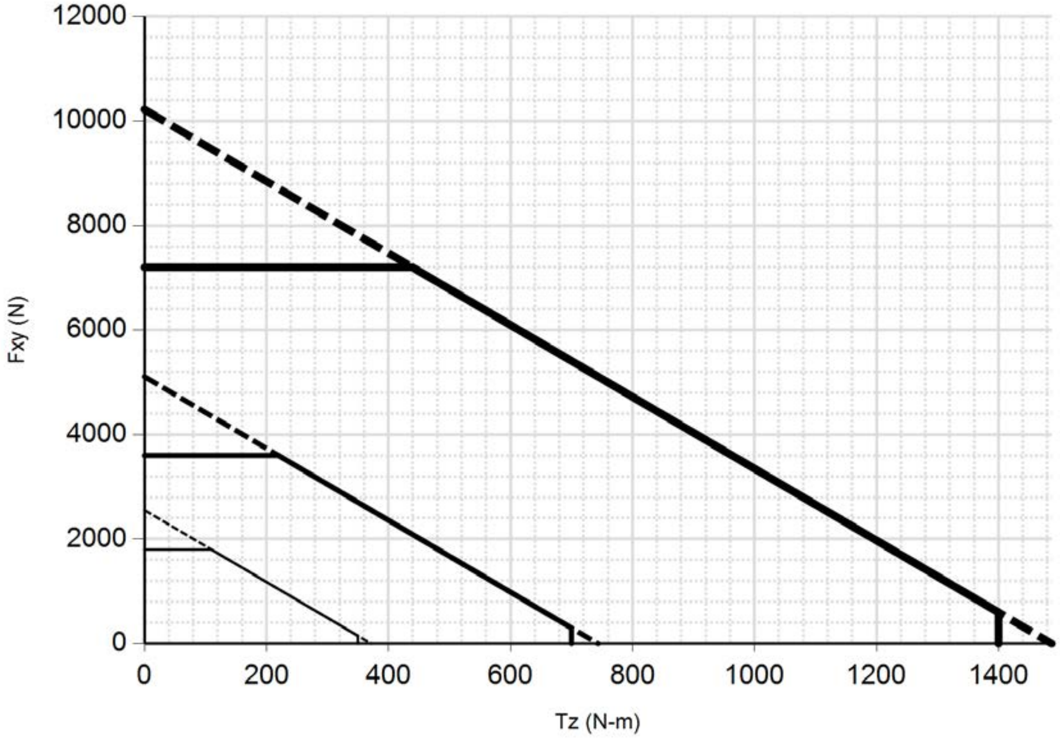


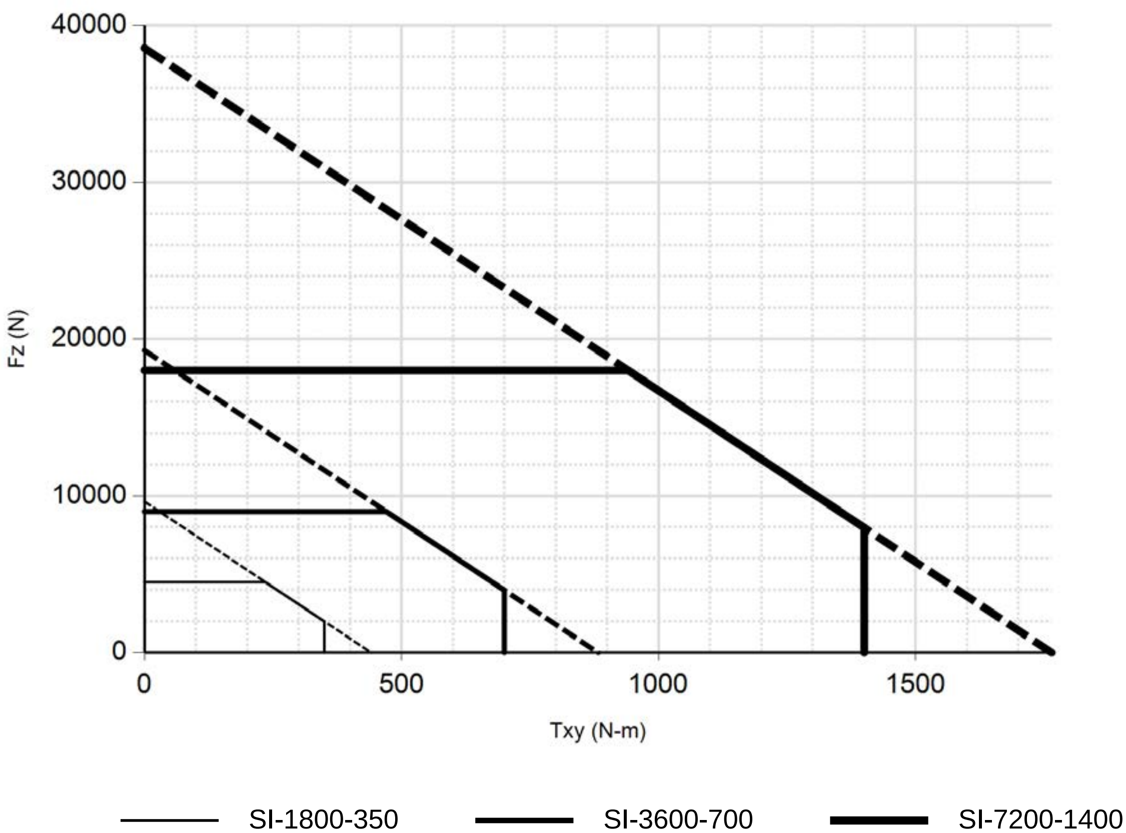


US-400-3000 US-800-6000 US-1600-12000

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

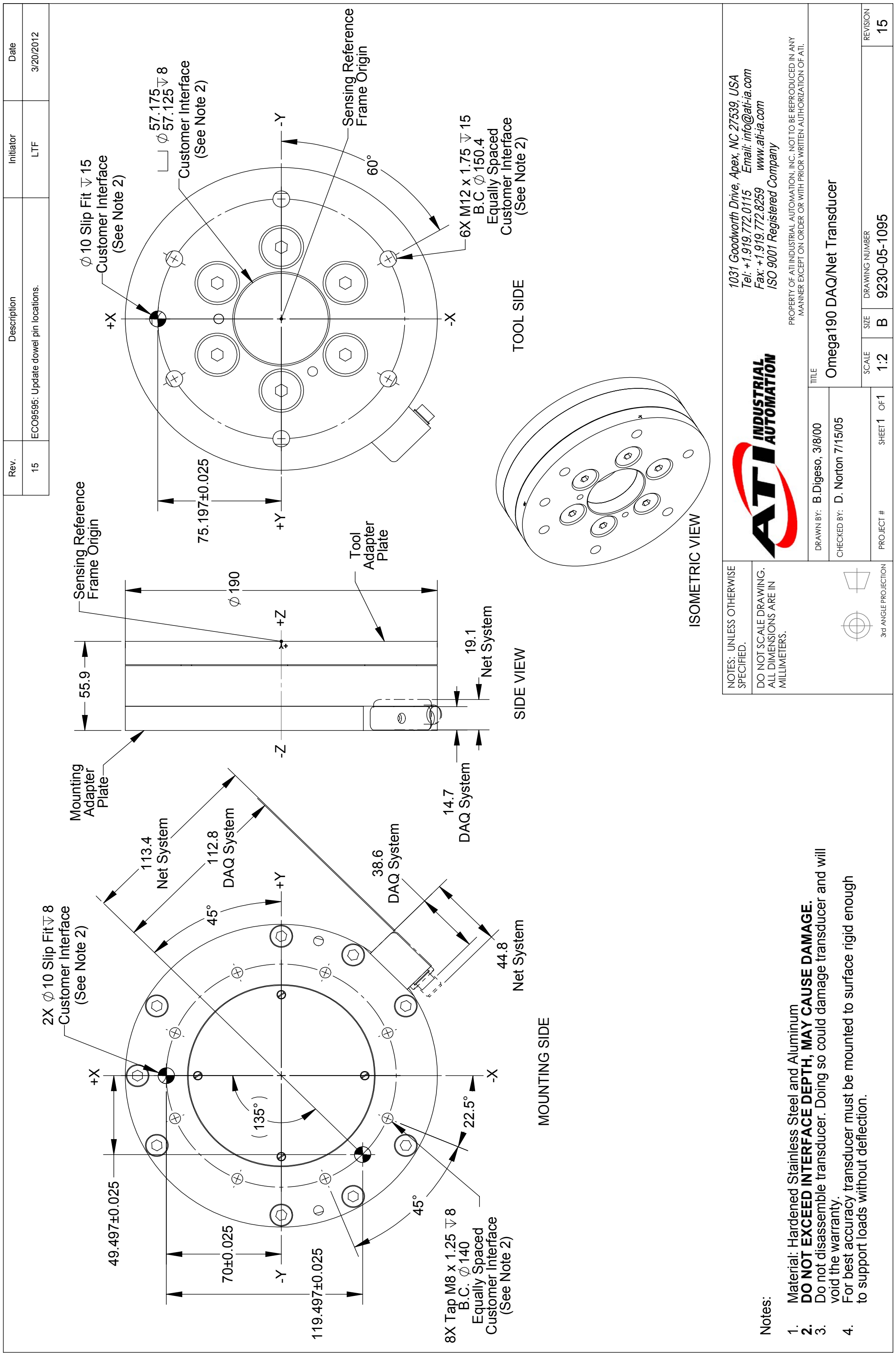
5.17.9 Omega190 (SI Calibration Complex Loading) (Includes IP60/IP65/IP68)[1]



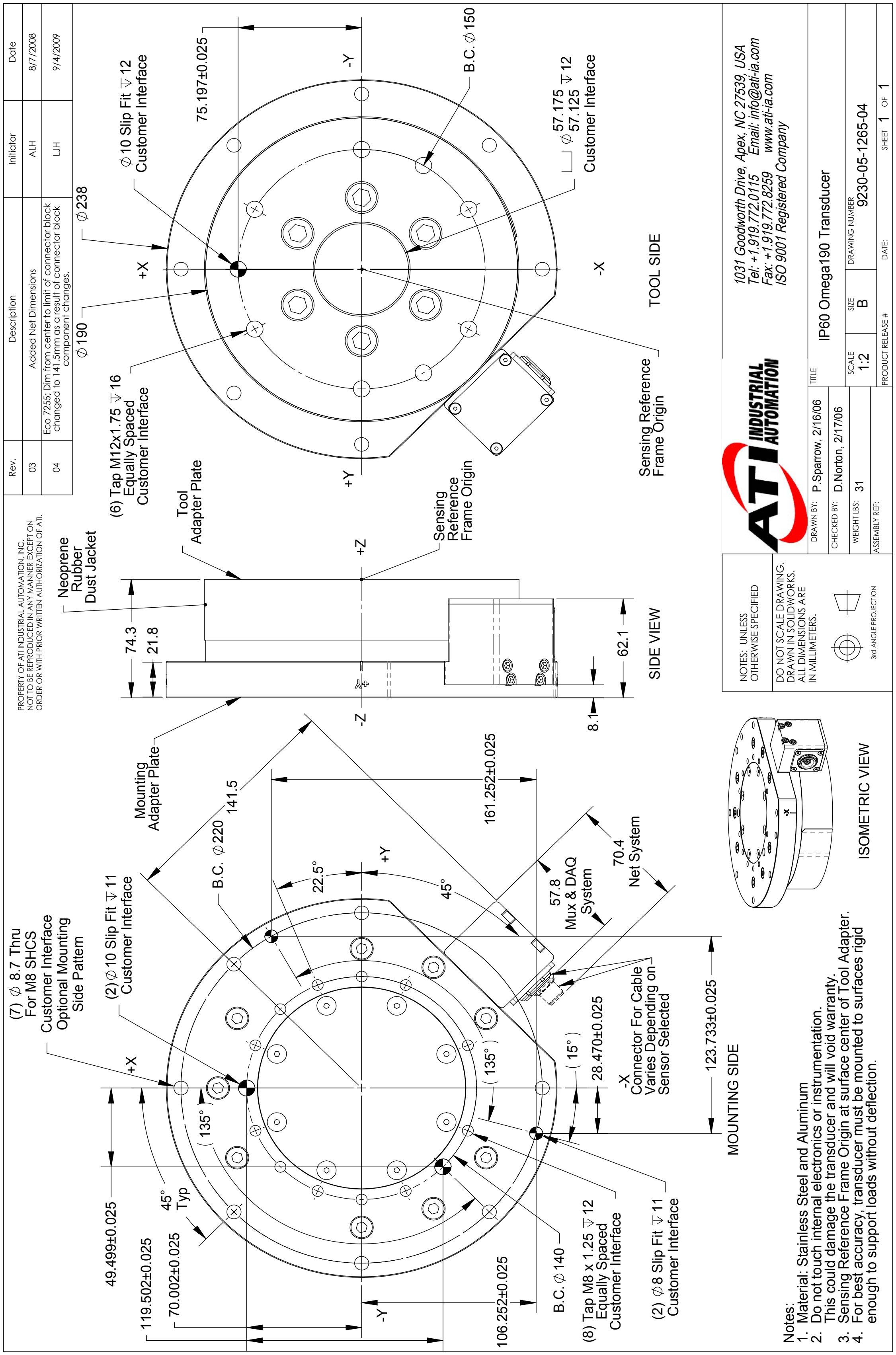


Note: 1. For IP68 version see caution on physical properties page.

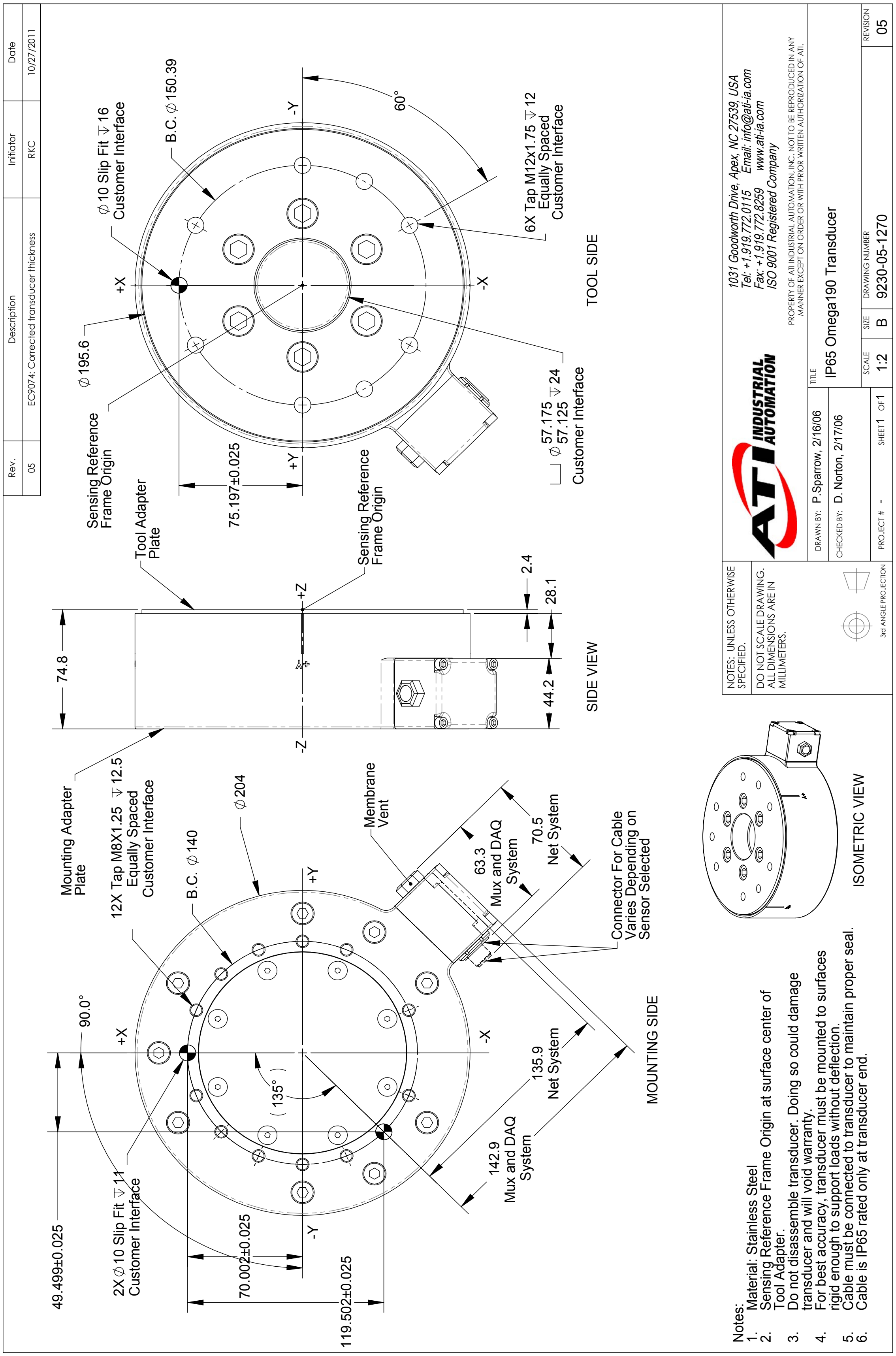
5.17.10 Omega190 DAQ/Net Transducer Drawing



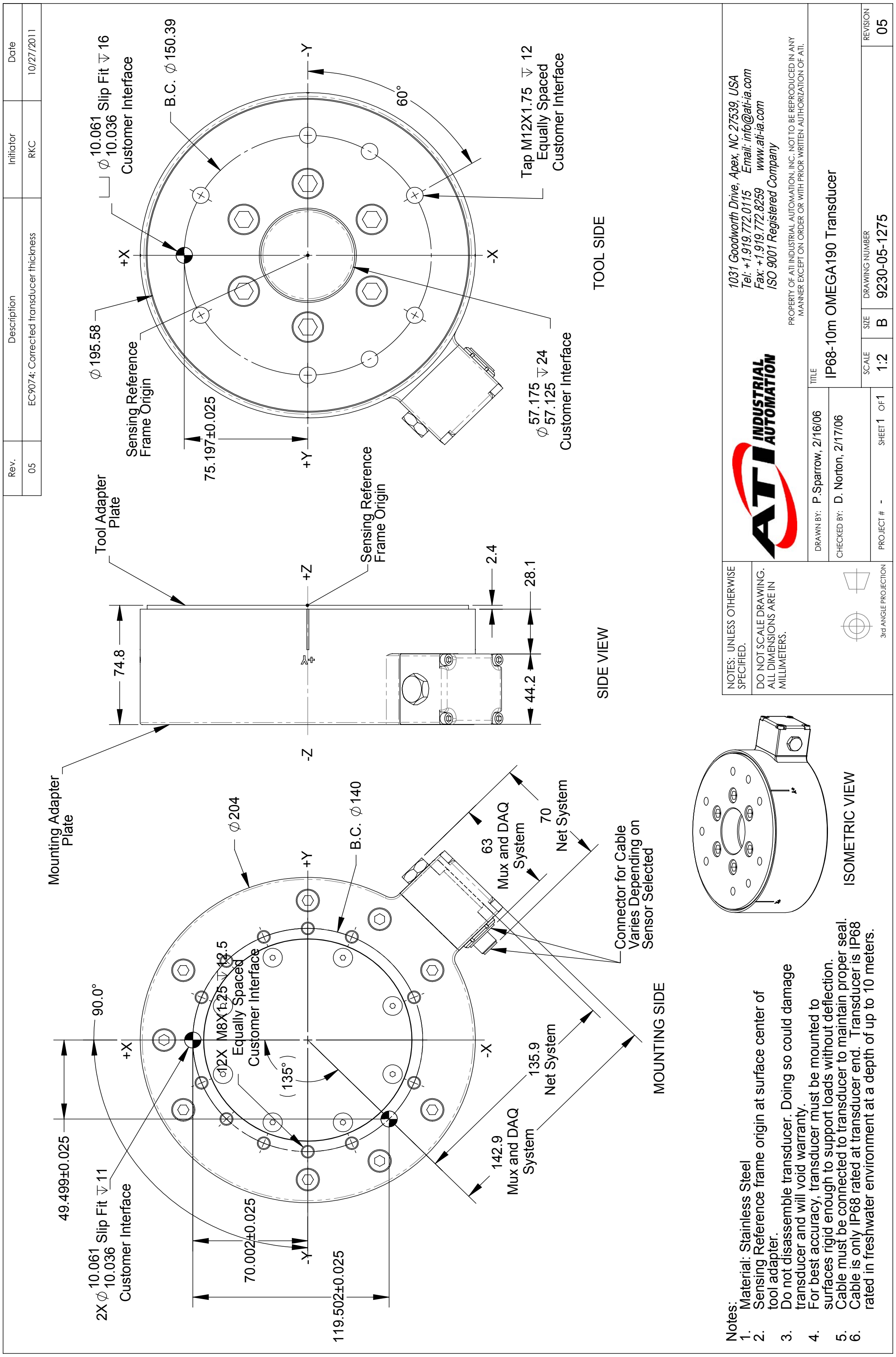
5.17.11 Omega190 IP60 Transducer Drawing



5.17.12 Omega190 IP65 Transducer Drawing



5.17.13 Omega190 IP68 Transducer Drawing



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

5.18.1 Omega191 Physical Properties

Table 5.102—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.		

5.18.2 Omega191 IP60 Physical Properties

Table 5.103—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.		

5.18.3 Omega191 IP65/IP68 Physical Properties

Table 5.104—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)	1.4×10^{6} lb/in	2.4×10^{8} N/m
Z-axis force (Kz)	2.1×10^{6} lb/in	3.6×10^{8} N/m
X-axis & Y-axis torque (Ktx, Kty)	1.4×10^{7} lbf-in/rad	1.5×10^{6} Nm/rad
Z-axis torque (Ktz)	2.8×10^{7} lbf-in/rad	3.2×10^{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

5.18.4 Calibration Specifications (excludes CTL calibrations)

Table 5.105— Omega191 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)**
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)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**	**Fx,Fy (N)**	**Fz[3] (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.

5.18.5 CTL Calibration Specifications

Table 5.106— Omega191 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)**
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)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**	**Fx,Fy (N)**	**Fz[3] (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.

5.18.6 Analog Output

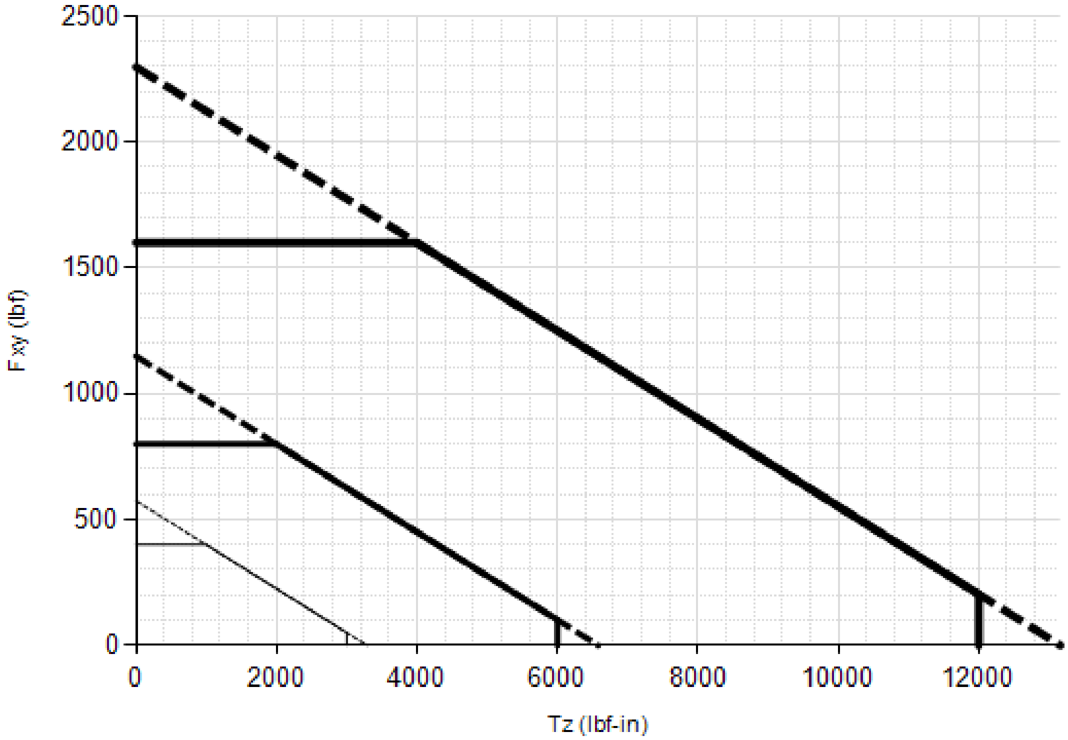
Table 5.107— Omega191 Analog Output							
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz[2] (lbf)**	**Tx,Ty,Tz (lbf-in)**	**Fx,Fy (lbf/V)**	**Fz[2] (lbf/V)**	**Tx,Ty,Tz (lbf-in/V)**
Omega191	US-400-3000	±400	±1000	±3000	40	100	300
Omega191	US-800-6000	±800	±2000	±6000	80	200	600
Omega191	US-1600-12000	±1600	±4000	±12000	160	400	1200
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz[2] (N)**	**Tx,Ty,Tz (Nmm)**	**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]**		

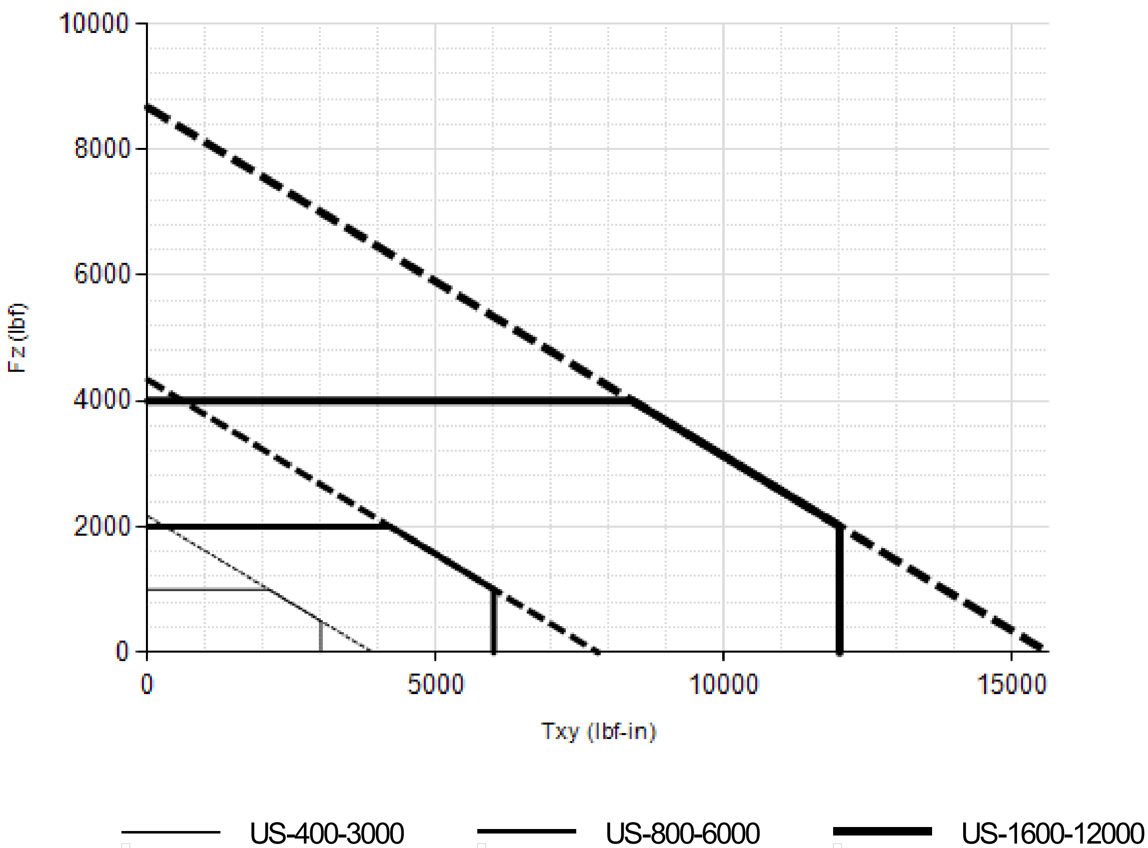
Notes:
1. ±5V Sensitivity values are double the listed ±10V Sensitivity values.
2. For IP68 version see caution on physical properties page.

5.18.7 Counts Value

Table 5.108—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)**	

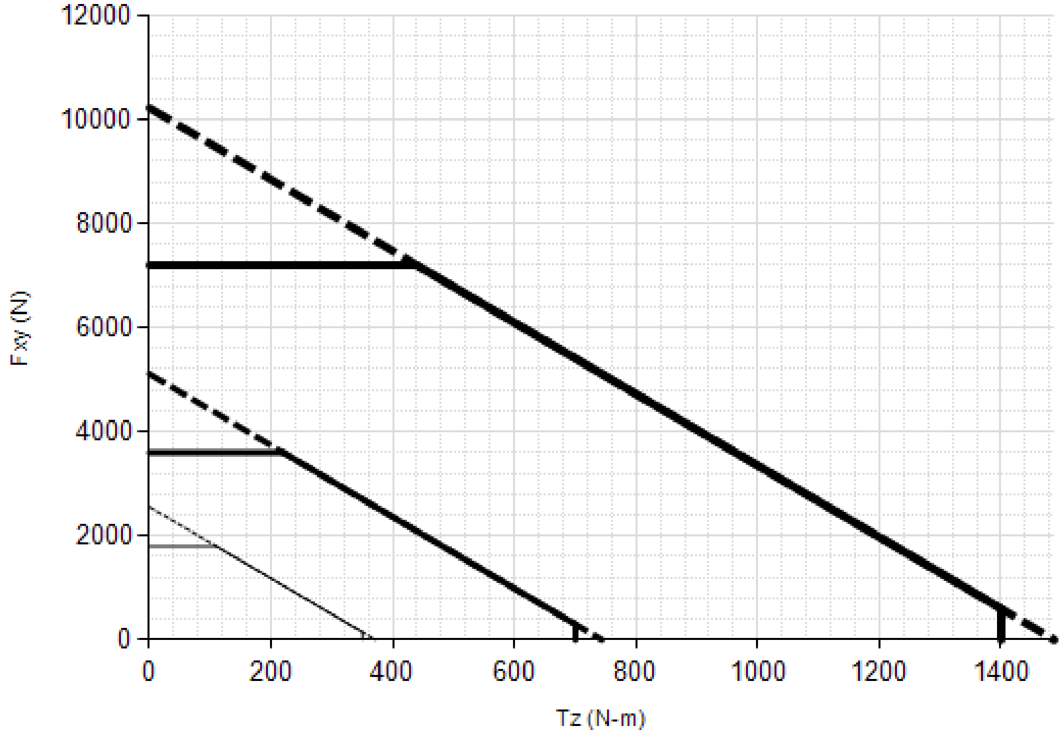
5.18.8 Omega191 (US Calibration Complex Loading) (Includes IP60/IP65/IP68)[1]

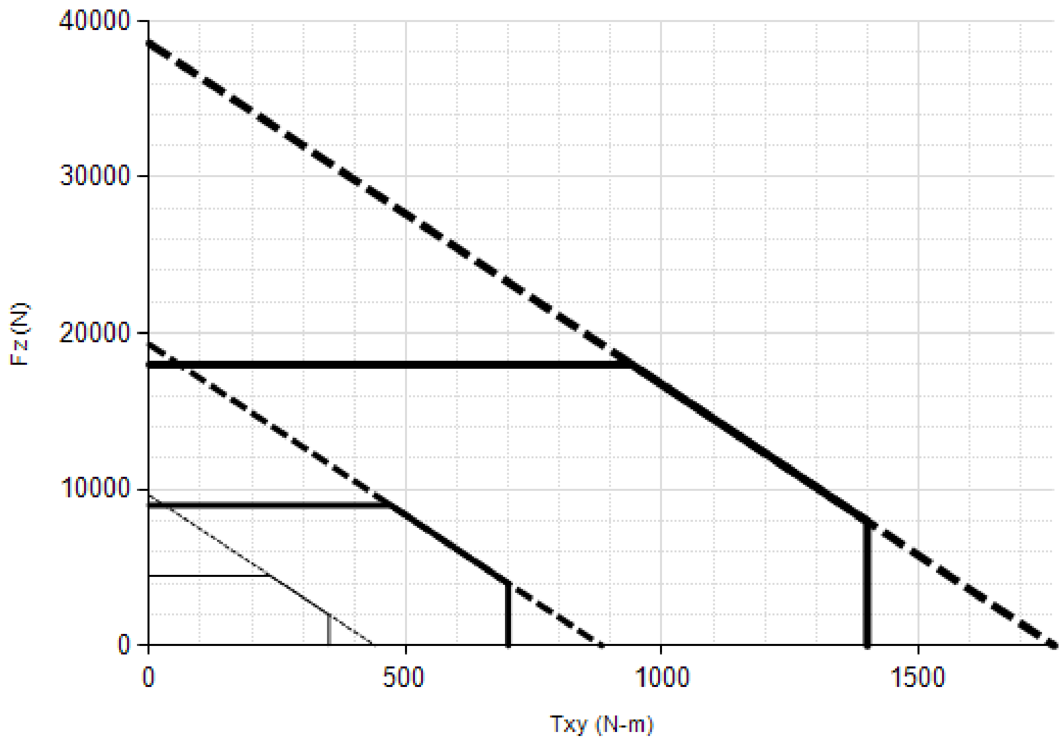




Note: 1. For IP68 version see caution on physical properties page.

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

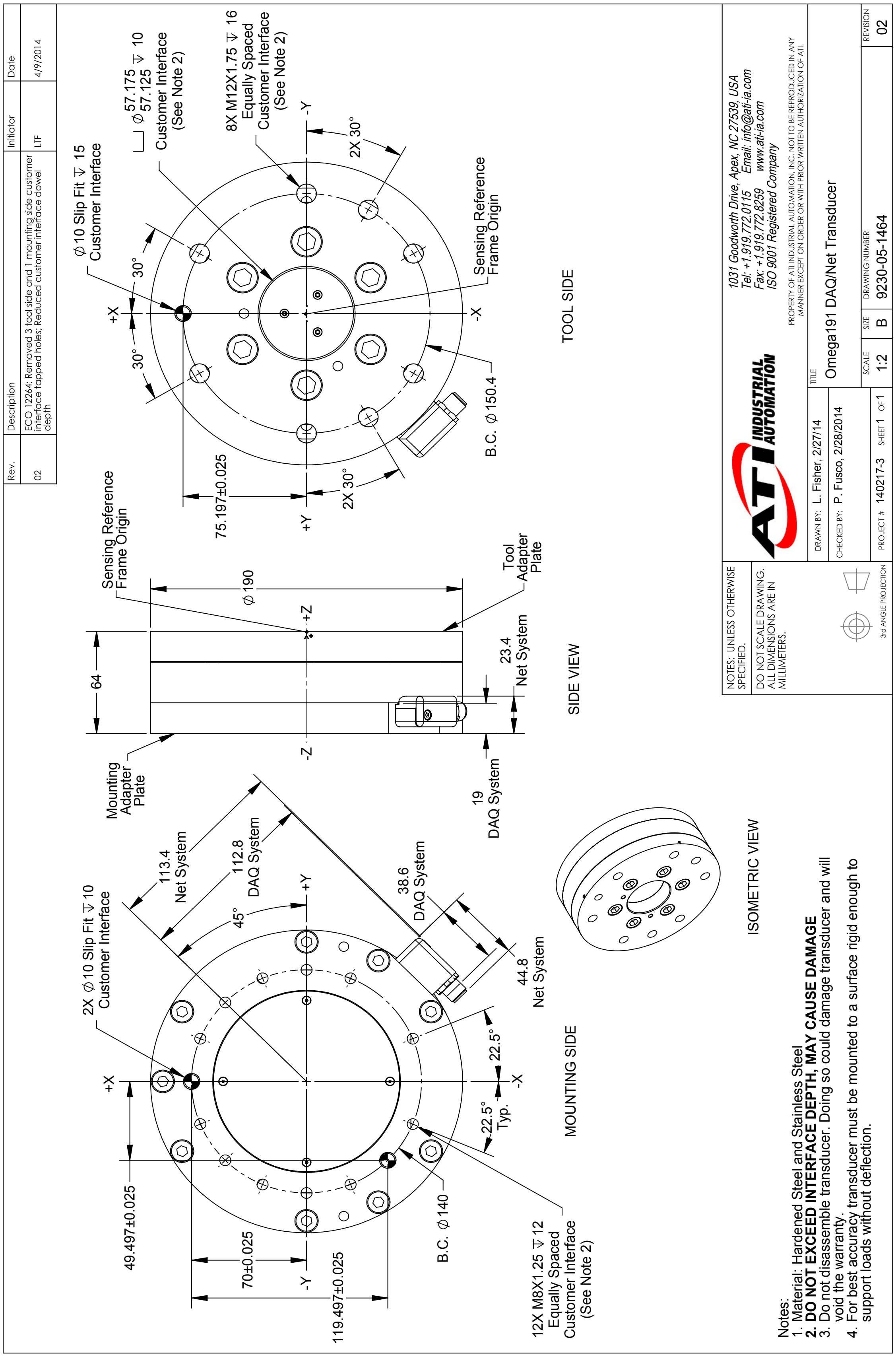




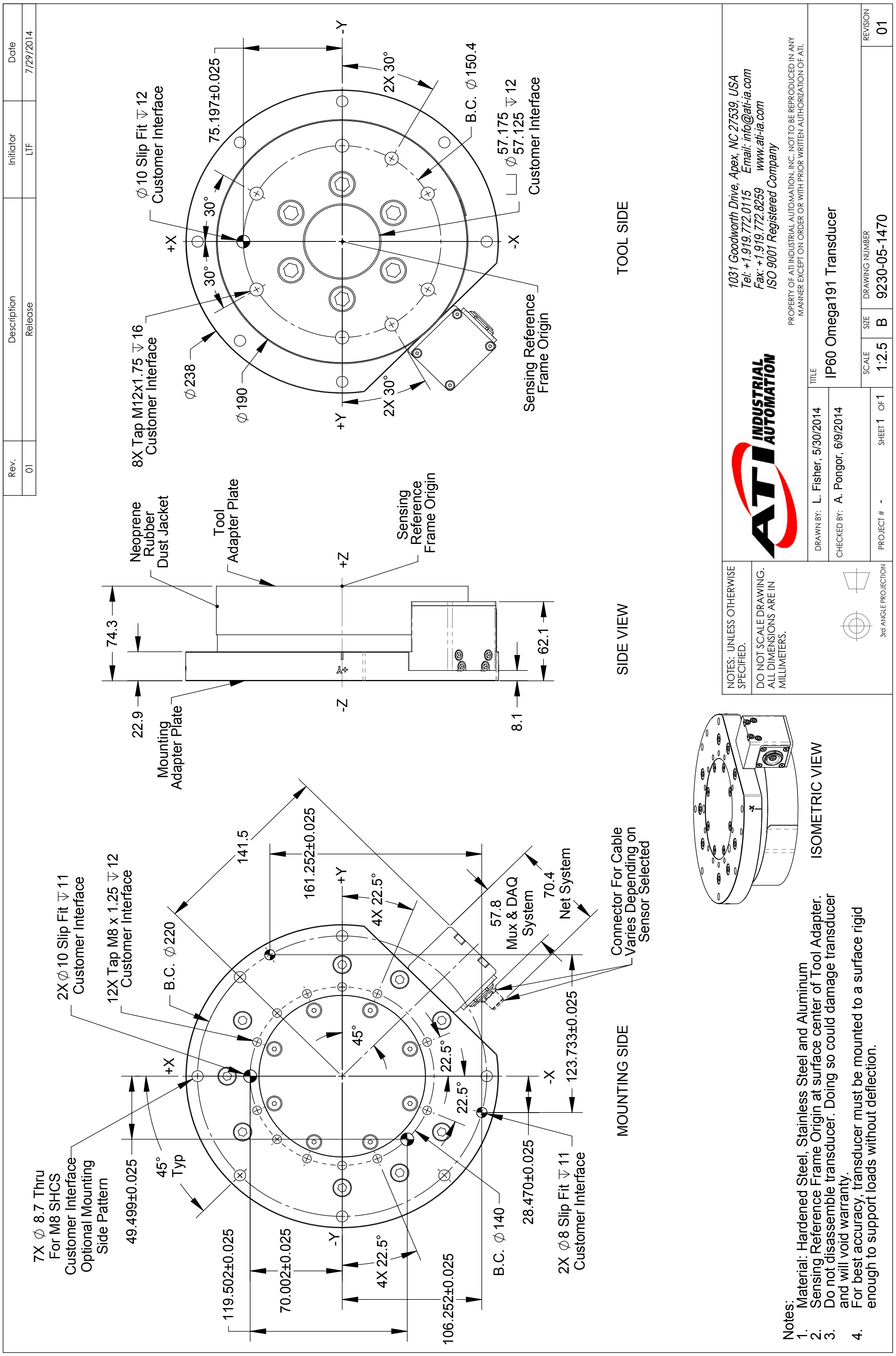
SI-1800-350 SI-3600-700 SI-7200-1400

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

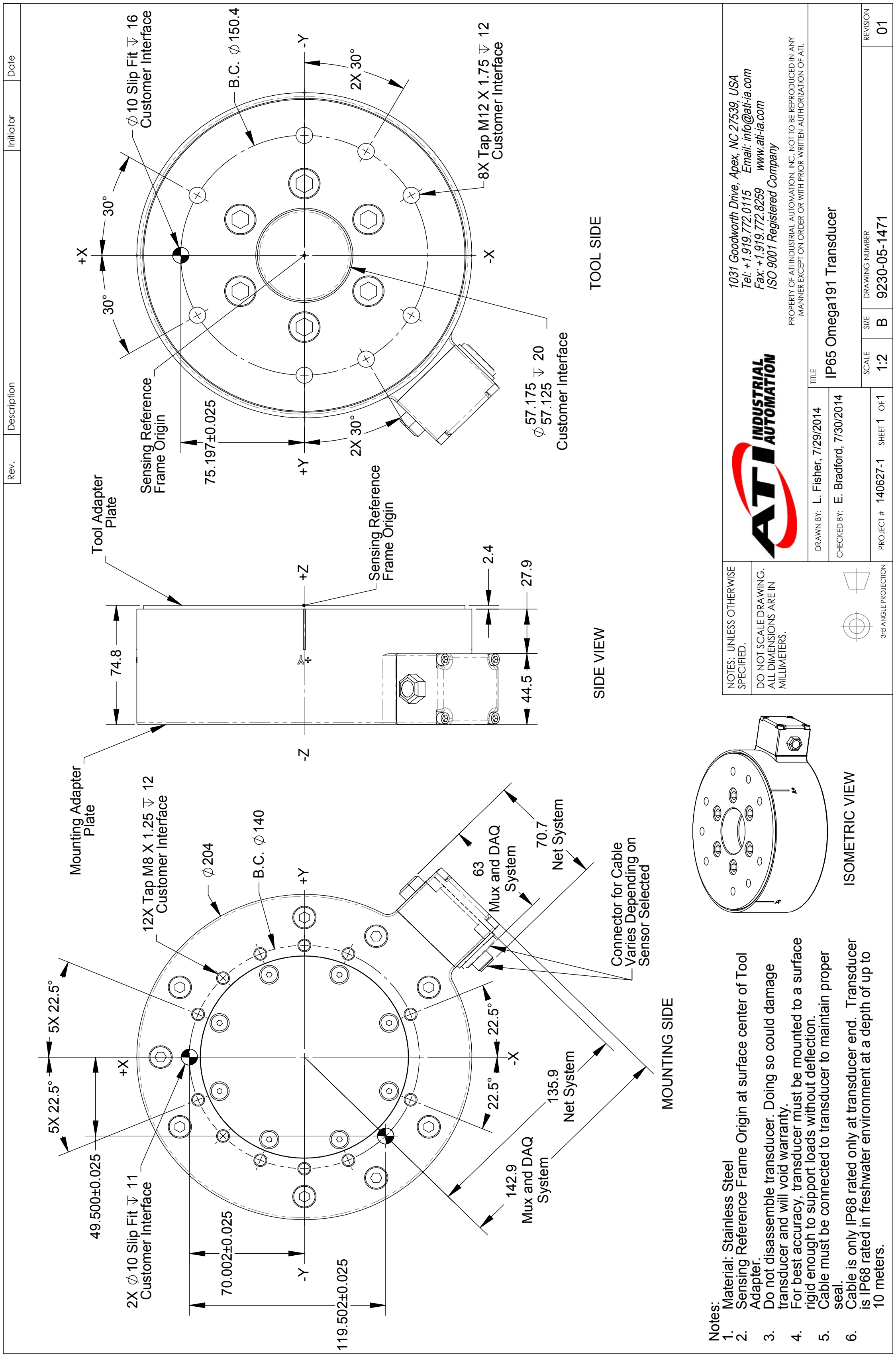
5.18.10 Omega191 DAQ/Net Transducer Drawing



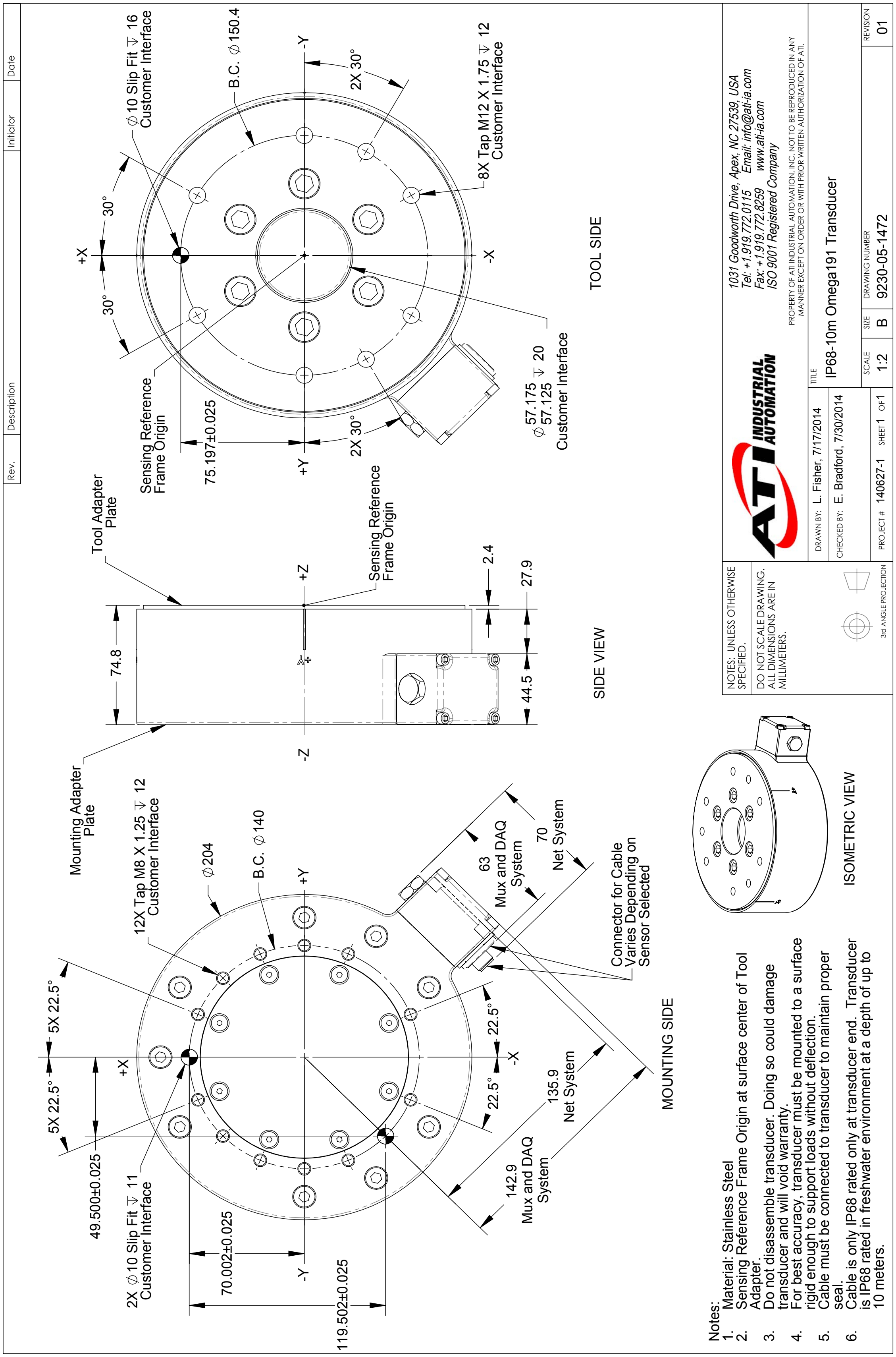
5.18.11 Omega191 IP60 Transducer Drawing



5.18.12 Omega191 IP65 Transducer Drawing



5.18.13 Omega191 IP68 Transducer Drawing



5.19 Omega250 Specifications (Includes IP60/IP65/IP68)

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

Table 5.109—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

5.19.2 Calibration Specifications (excludes CTL calibrations)

Table 5.110— Omega250 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)
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)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**	**Fx,Fy (N)**	**Fz[3] (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.

5.19.3 CTL Calibration Specifications

Table 5.111— Omega250 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)
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)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**	**Fx,Fy (N)**	**Fz[3] (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.

5.19.4 Analog Output

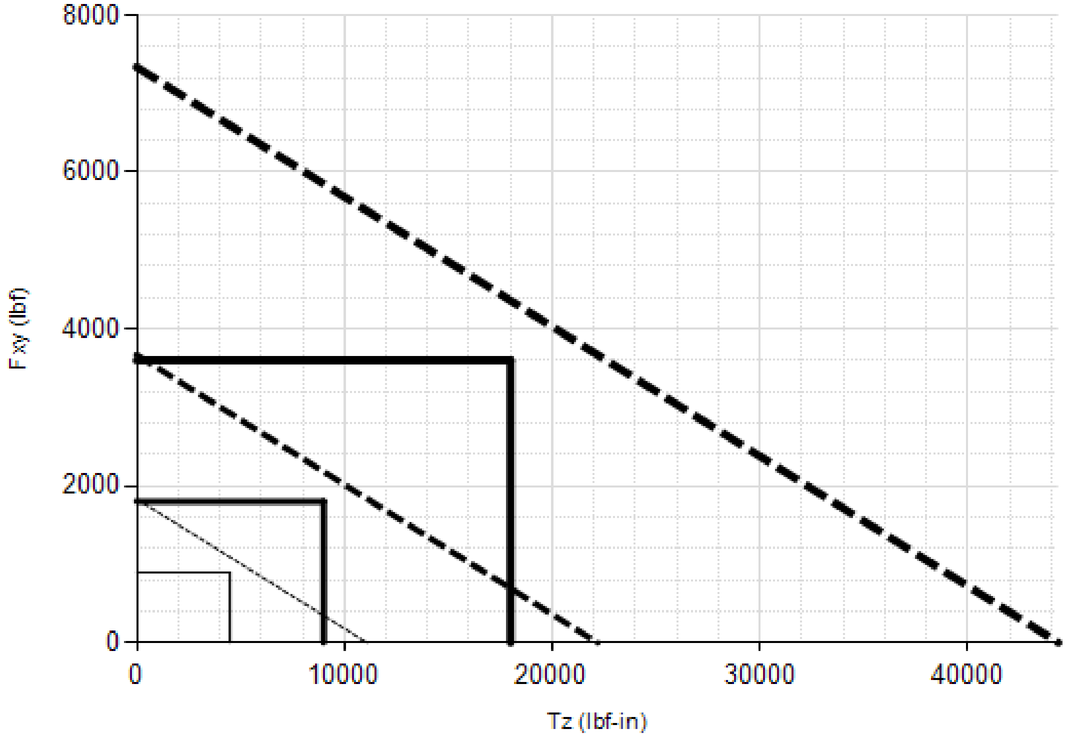
Table 5.112— Omega250 Analog Output							
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz[2] (lbf)**	**Tx,Ty,Tz (lbf-in)**	**Fx,Fy (lbf/V)**	**Fz[2] (lbf/V)**	**Tx,Ty,Tz (lbf-in/V)**
Omega250	US-900-4500	±900	±1800	±4500	90	180	450
Omega250	US-1800-9000	±1800	±3600	±9000	180	360	900
Omega250	US-3600-18000	±3600	±7200	±18000	360	720	1800
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz[2] (N)**	**Tx,Ty,Tz (Nmm)**	**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]**		

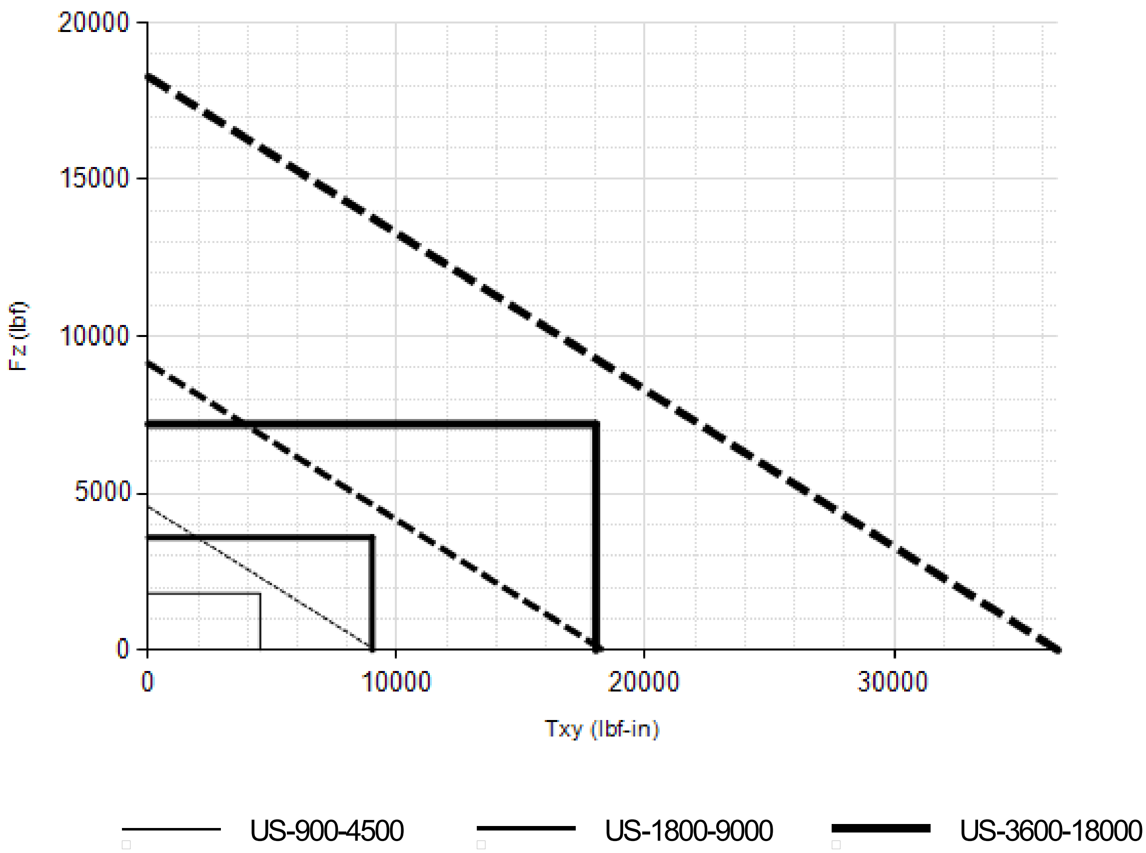
Notes:
1. ±5V Sensitivity values are double the listed ±10V Sensitivity values.
2. For IP68 version see caution on physical properties page.

5.19.5 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)**
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)**	

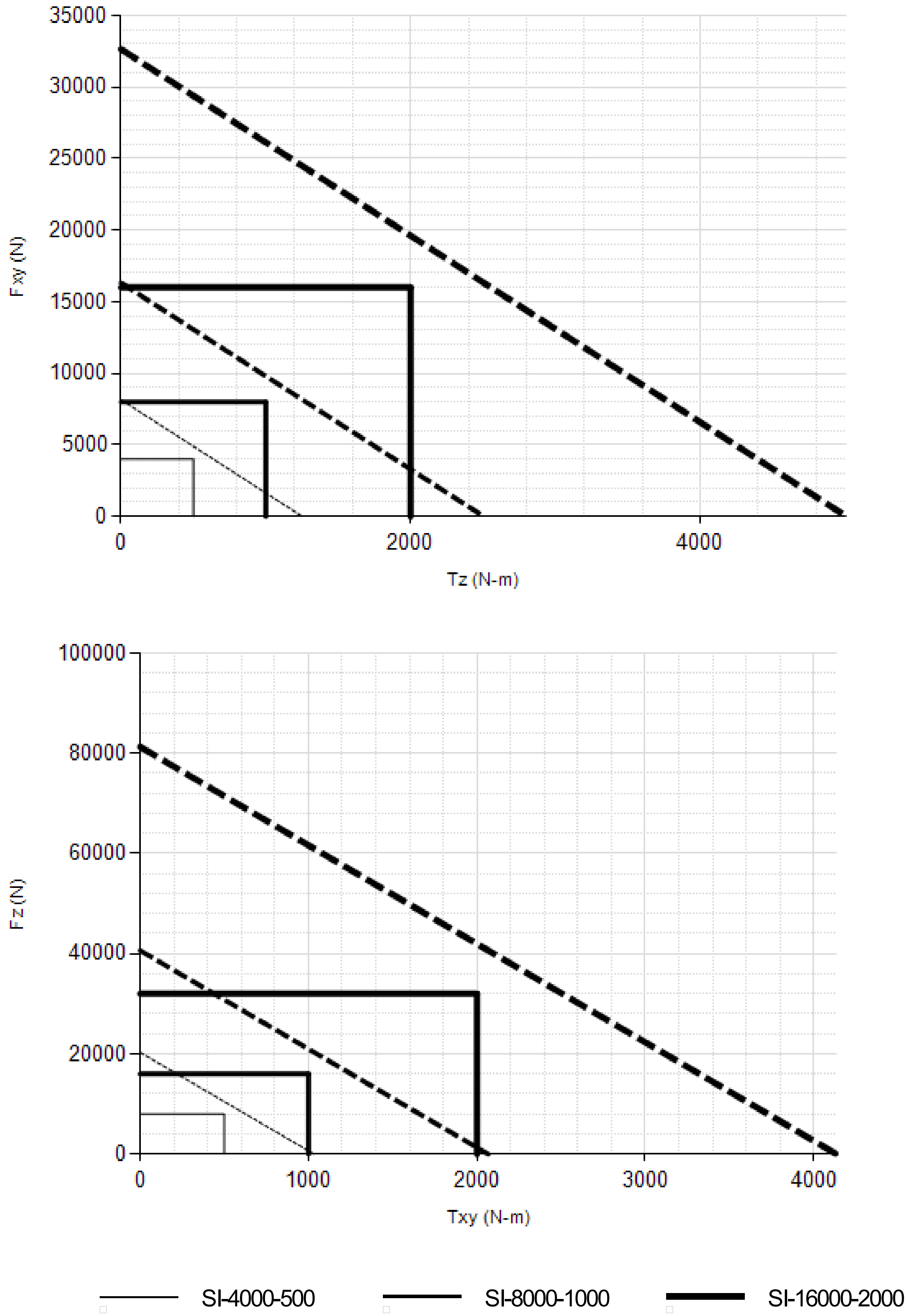
5.19.6 Omega250 (US Calibration Complex Loading) (Includes IP60/IP65/IP68)[1]





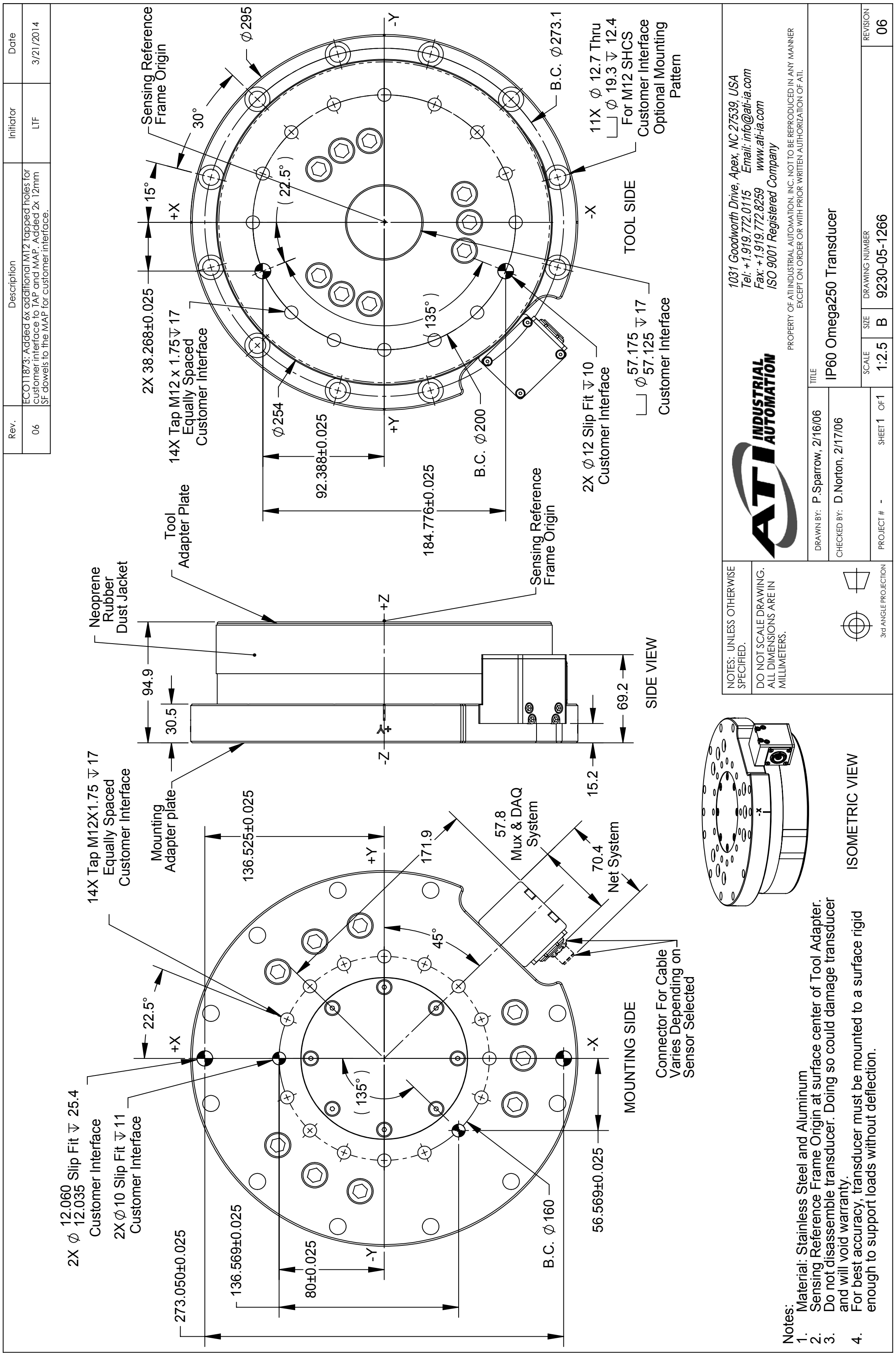
Note: 1. For IP68 version see caution on physical properties page.

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

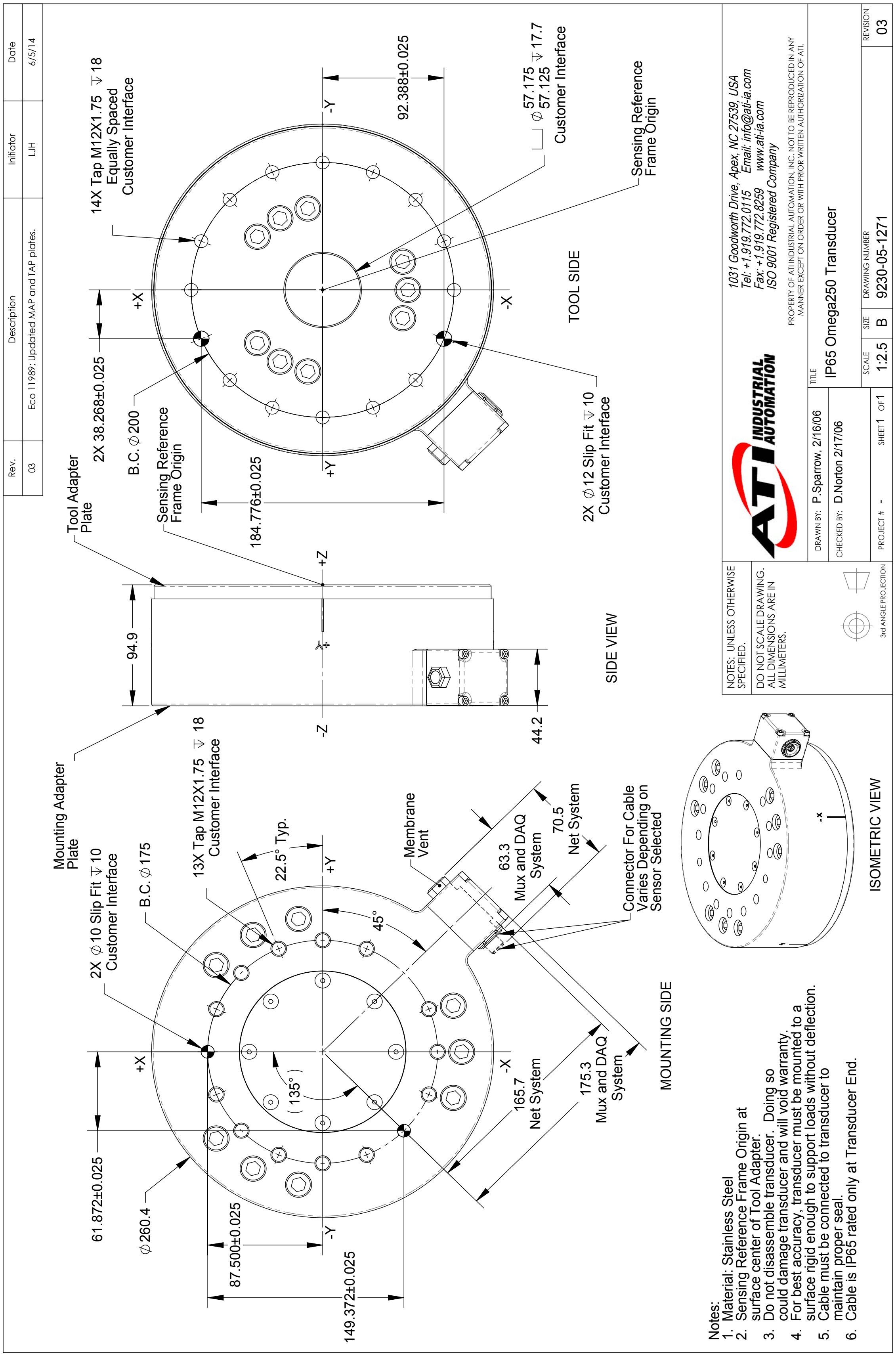


Note: 1. For IP68 version see caution on physical properties page.

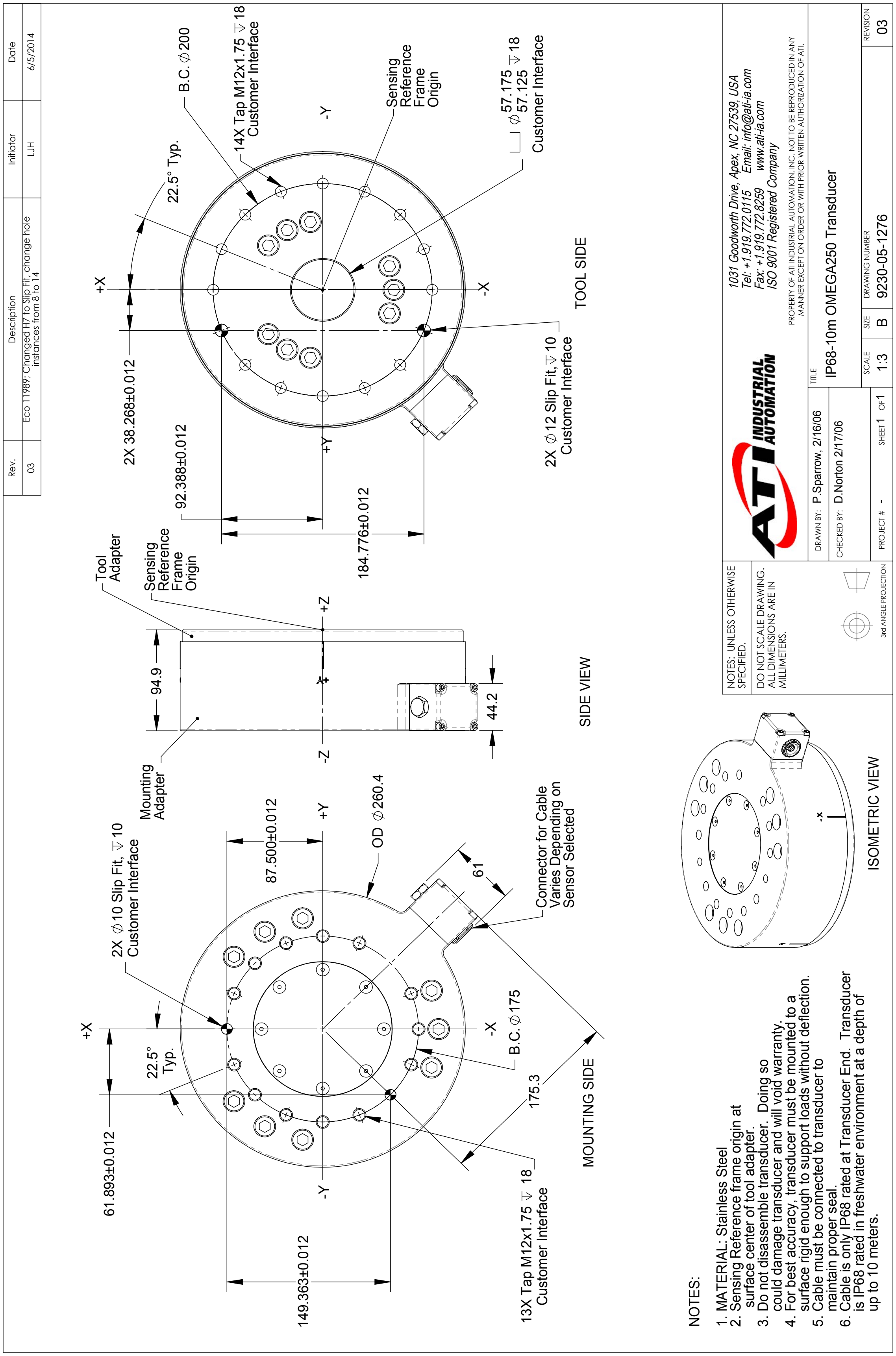
5.19.8 Omega250 IP60 Transducer Drawing



5.19.9 Omega250 IP65 Transducer Drawing



5.19.10 Omega250 IP68 Transducer Drawing



5.20 Omega331 Specifications (Includes IP65)

5.20.1 Omega331 Physical Properties (Includes IP65)

Table 5.114—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.		

5.20.2 Calibration Specifications (excludes CTL calibrations)

Table 5.115— 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.

5.20.3 CTL Calibration Specifications

Table 5.116— Omega331 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	3/4	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.

5.20.4 Analog Output

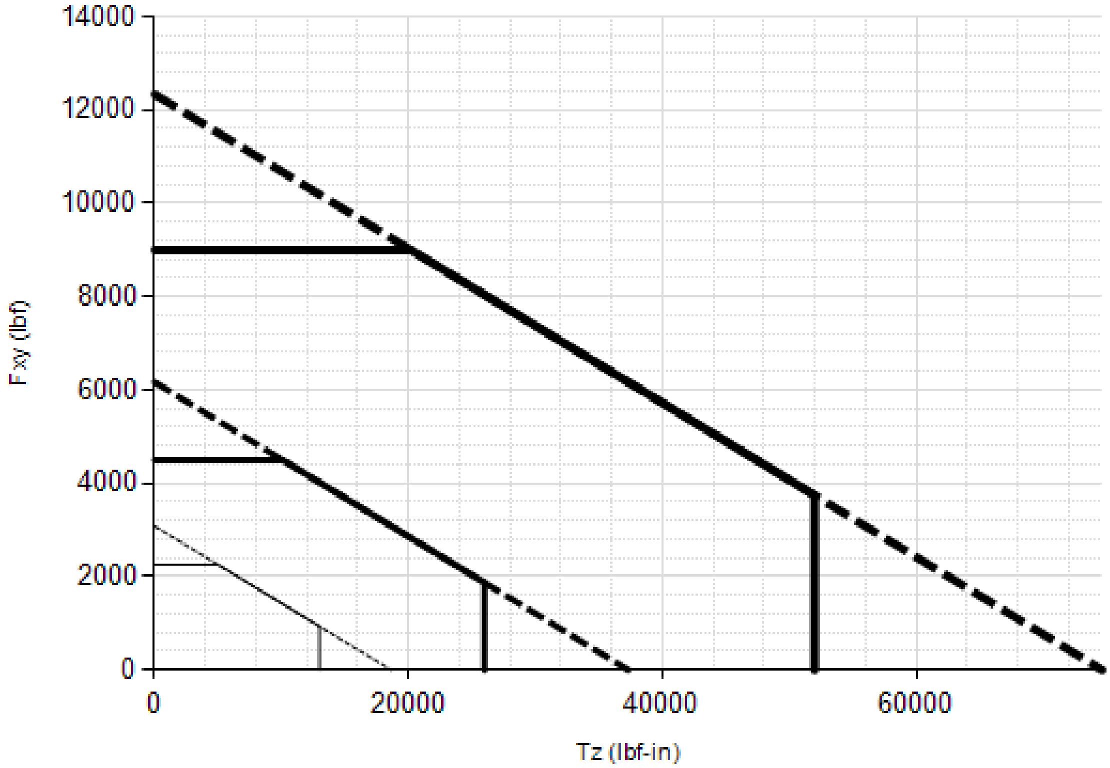
Table 5.117— Omega331 Analog Output							
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz (lbf)**	**Tx,Ty,Tz (lbf-in)**	**Fx,Fy (lbf/V)**	**Fz (lbf/V)**	**Tx,Ty,Tz (lbf-in/V)**
Omega331	US-2250-13000	±2250	±5250	±13000	225	525	1300
Omega331	US-4500-26000	±4500	±10500	±26000	450	1050	2600
Omega331	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]**		

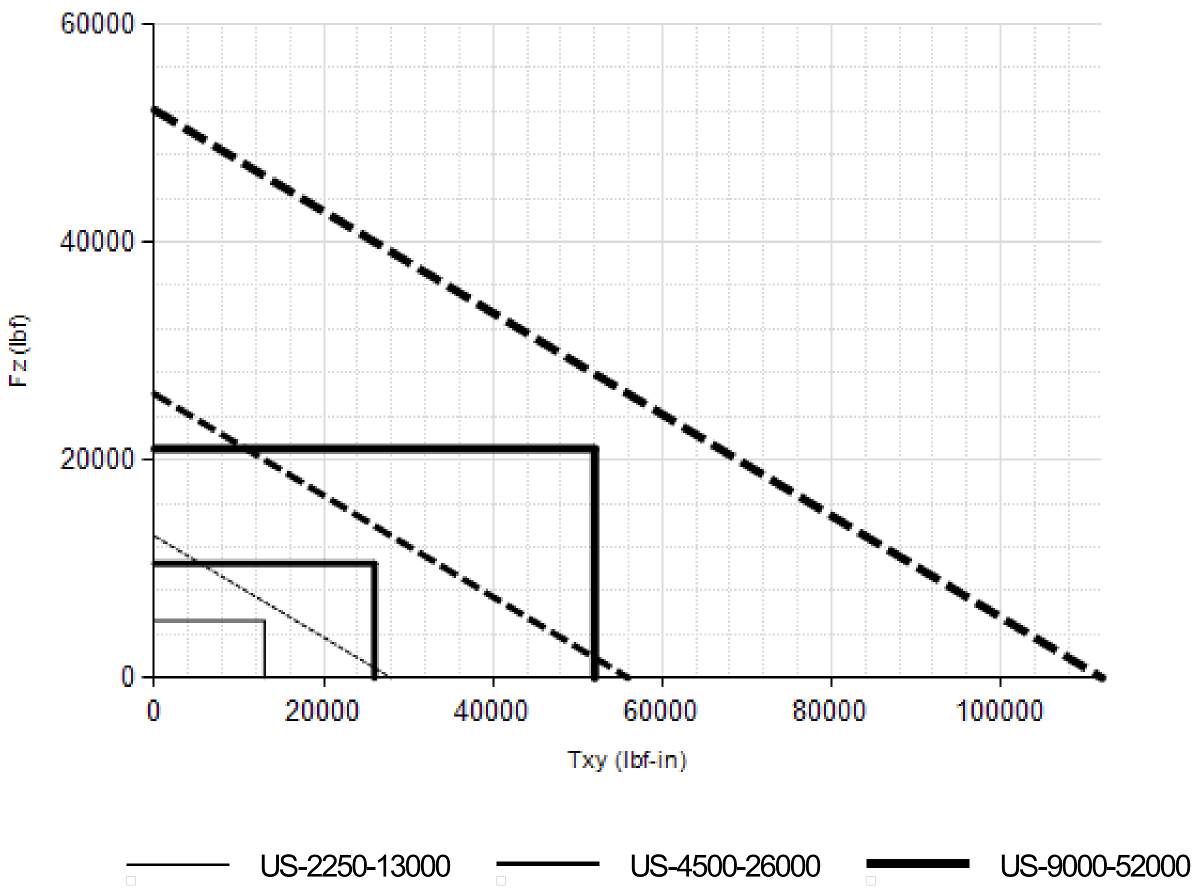
Notes:
1. ±5V Sensitivity values are double the listed ±10V Sensitivity values.

5.20.5 Counts Value

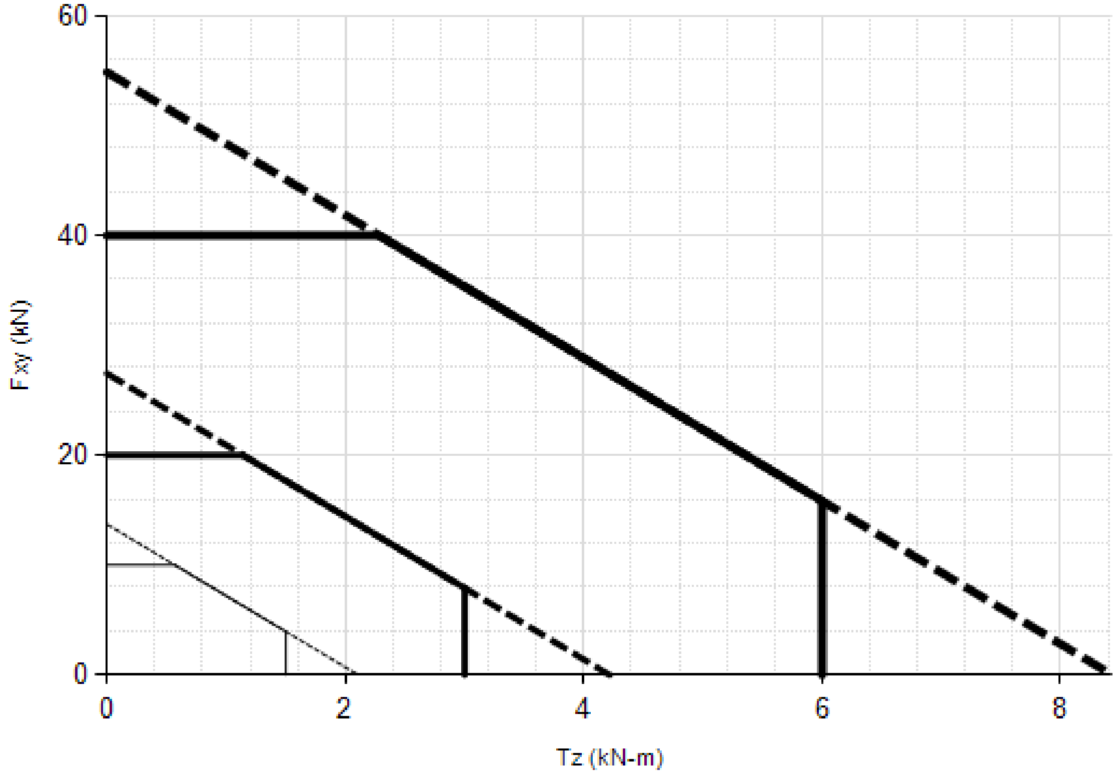
Table 5.118—Counts Value					
Sensor	**Calibration**	**Fx, Fy, Fz (/ lbf)**	**Tx, Ty, Tz (/ lbf-in)**	**Fx, Fy, Fz (/ kN)**	**Tx, Ty, Tz (/ kNm)**
Omega331	US-2250–13000 / SI-10000–1500	32	6.4	7680	64000
Omega331	US-4500–26000 / SI-20000–3000	16	3.2	3840	32000
Omega331	US-9000–52000 / SI-40000–6000	8	1.6	1920	16000
Omega331	Tool Transform Factor	0.05 in/lbf		1.2 mm/N	
		Counts Value – Standard (US)		**Counts Value – Metric (SI)**	

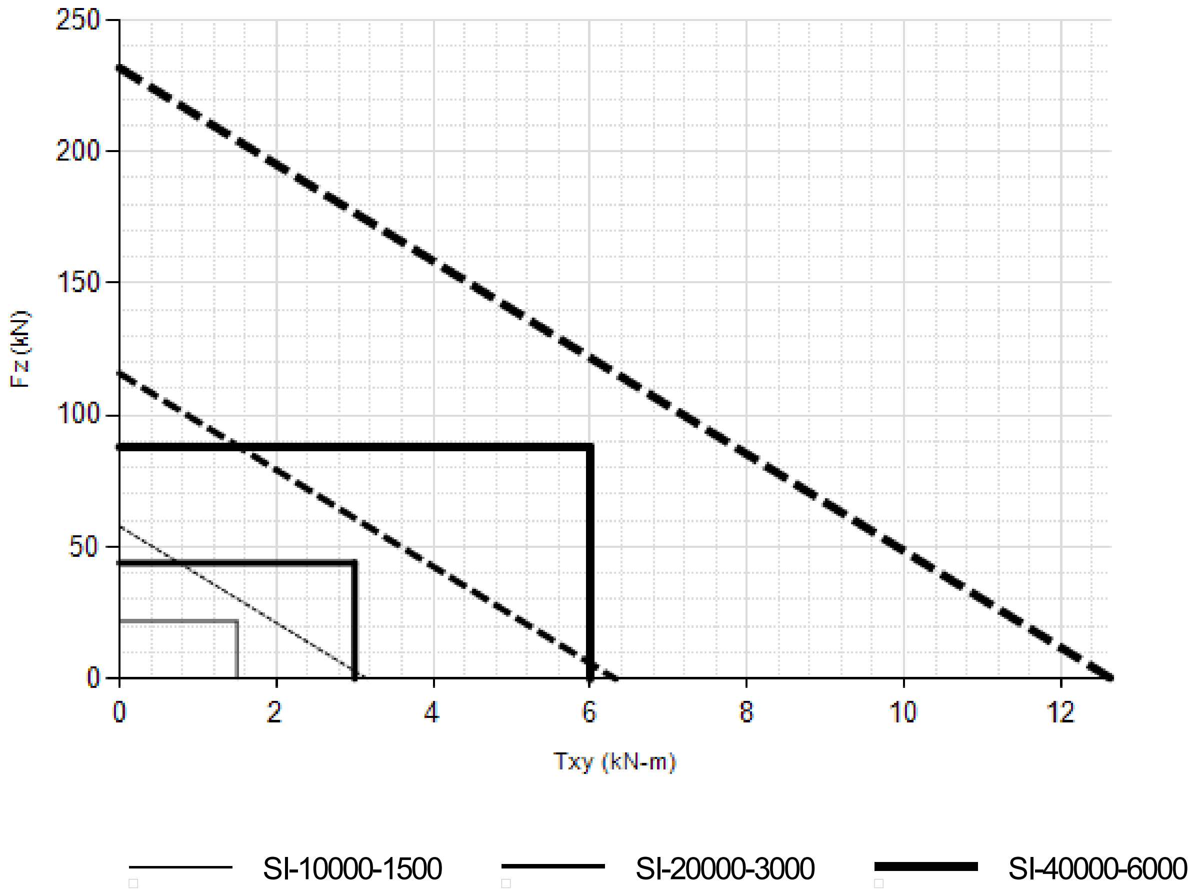
5.20.6 Omega331 (US Calibration Complex Loading) (Includes IP65)



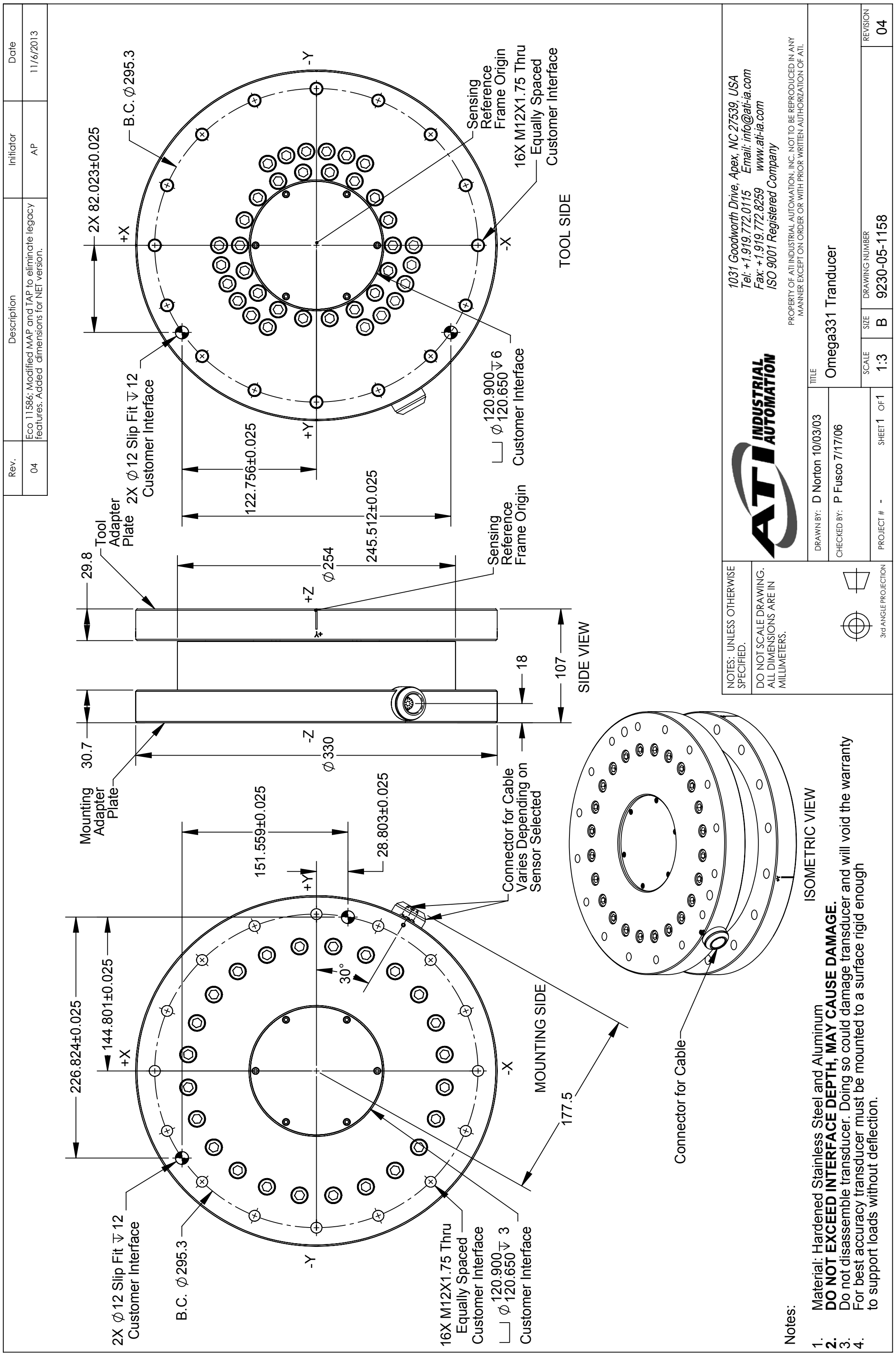


5.20.7 Omega331 (SI Calibration Complex Loading) (Includes IP65)

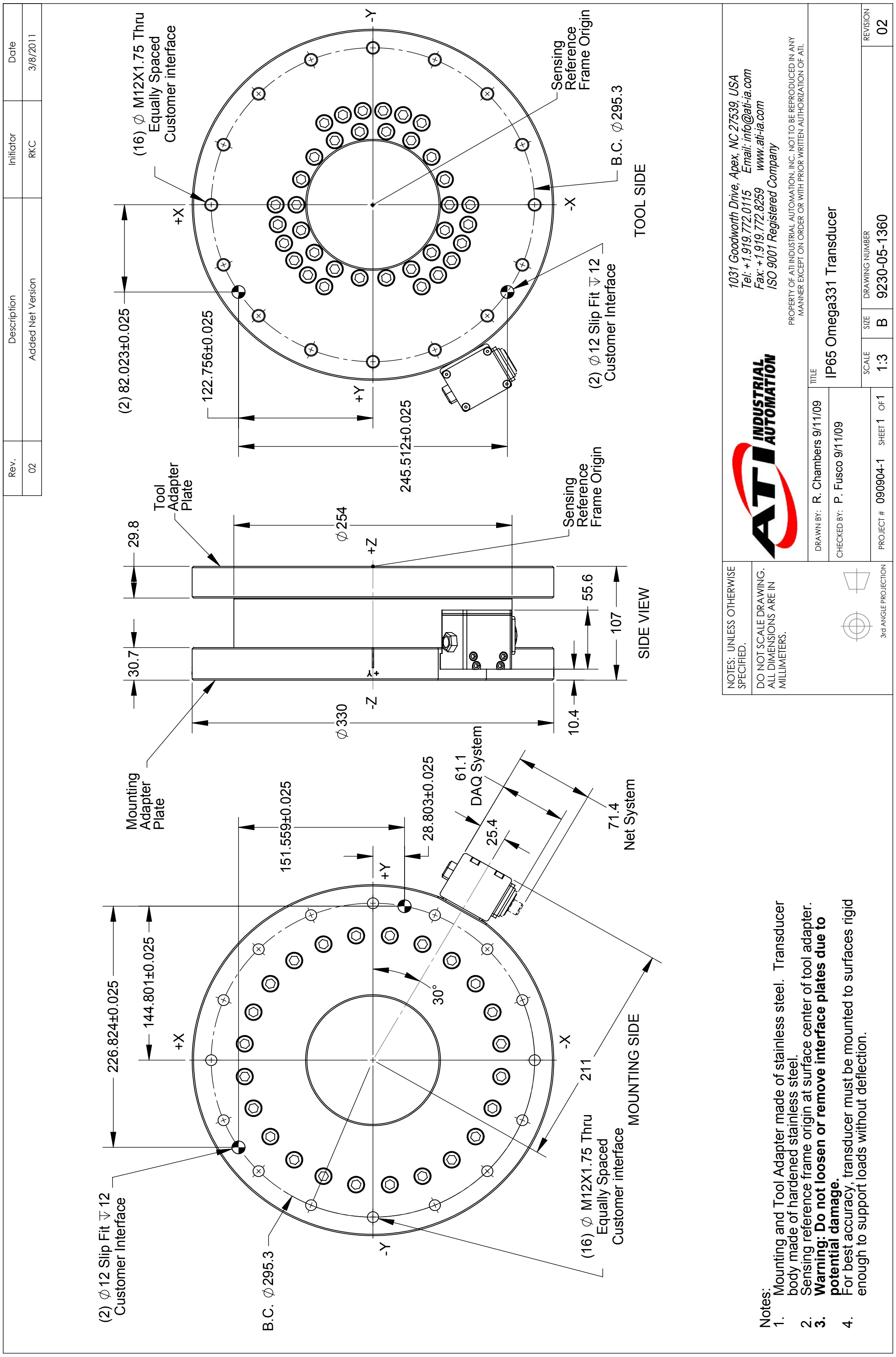




5.20.8 Omega331 Transducer Drawing



5.20.9 Omega331 IP65 Transducer Drawing



6. Advanced Topics

6.1 Reducing Noise

6.1.1 Mechanical Vibration

In many cases, perceived noise is actually a real fluctuation of force and/or torque, 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, you may want to add a digital filter to the application software.

6.1.2 Electrical Interference

Check the F/T's ground connections if you observe interference by motors or other noise-generating equipment.

Consider using averaging or filtering if sufficient grounding is not possible or does not reduce the noise.

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. 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).

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 5.2—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 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. Check with ATI Industrial Automation when making cabling changes to ensure your system's calibration will not be affected.

6.4.2 Cabling and Connectors

The transducer cables and connectors are not designed to be user serviceable. The high flex life stranding used in the cable is difficult to work with and will fail prematurely if improperly assembled.

However, there are special cases when customers find it necessary to temporarily remove the connector on a cable that is permanently attached to a transducer (such as found on the Nano and Mini series transducers). When reattaching the wires to the connector, it is vital that each conductor is encased in heat shrink tubing at the connection to prevent premature fatiguing of the mechanical connection. Also, any components contained in the connector must be reconnected exactly as found – failing to do so will impact system performance and accuracy.

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.

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 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.

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.

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.

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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.