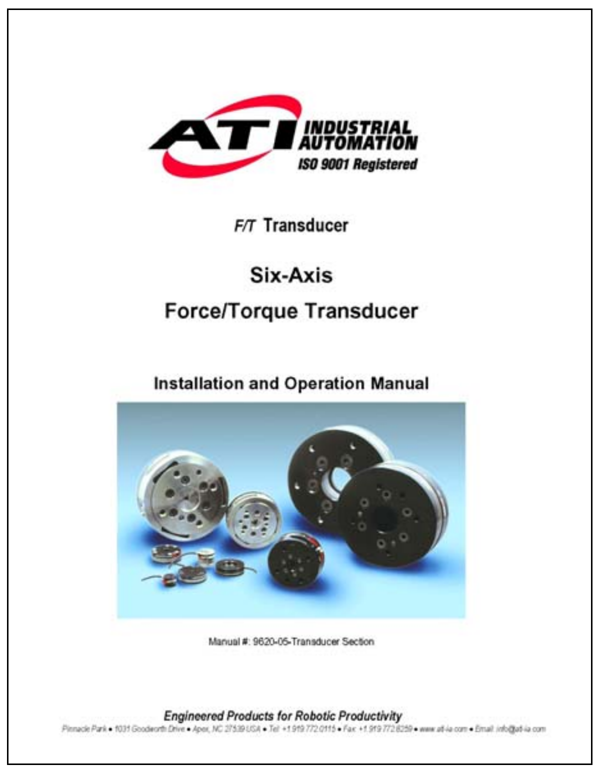
Net F/T

Network Force/Torque Sensor System

Compilation of Manuals



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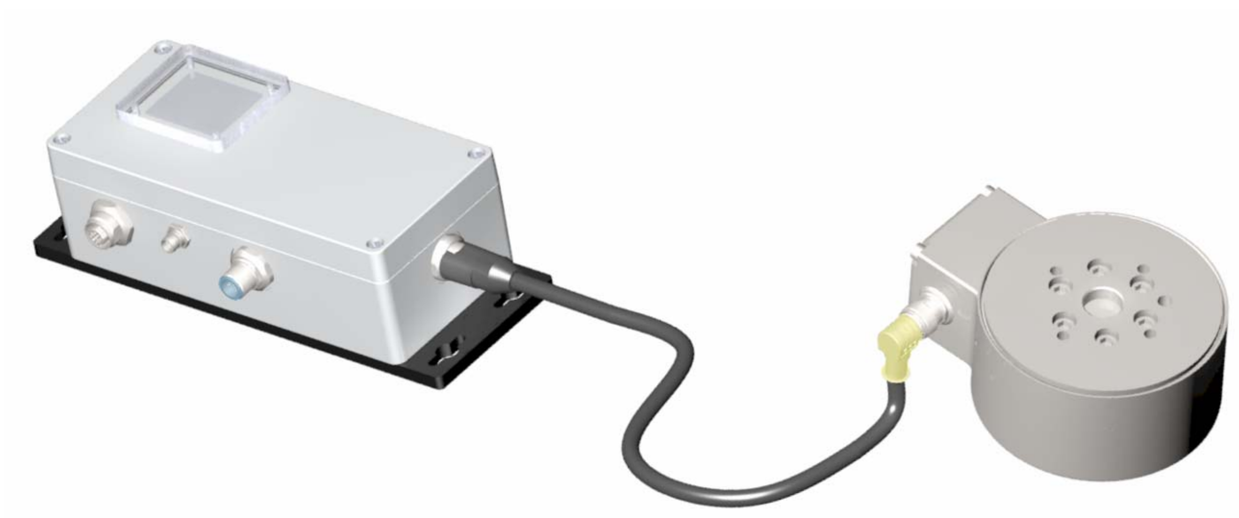
Net F/T

Network Force/Torque Sensor System

Installation and Operation Manual

For Firmware Versions up to 2.0.06



Document #: 9620-05-Net FT
August 2010

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Foreword

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.

FCC Compliance - Class A

This device complies with Part 15 Subpart B of the FCC Title 47. 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

This device complies with EMC Directive 2004/108/EC and conforms to the following standards: EN55022:1998+A1:2000 +A2:2003, EN61000-4-2:1995 +A1:1998+A2:2001, EN61000-4-3:2002, EN61000-4-4:2004, EN61000-4-5:1995 +A1:1996, EN61000-4-6:1996 +A1:2001, EN61000-4-8:1995, EN61000-4-11:2001.

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Statement of Compliance

Statement of Compliance

Manufacturer:	ATI Industrial Automation 1031 Goodworth Drive Apex, NC 27539 919-772-0115 x 222
Requester / Applicant:	Alexander Strotzer
Name of Equipment:	NetBox and Net FT Sensor
Model No.	Net FT
Type of Equipment:	Measurement, Control and Laboratory Use
Class of Equipment:	Class A
Application of Regulations:	FCC Title 47, Part 15, Subpart B and EMC Directive 2004/108/EC
Test Dates:	18 June 2007 to 21 June 2007

Guidance Documents:

Emissions: EN61326:1997 +A1:1998 +A2:2000

Immunity: EN61326:1997 +A1:1998 +A2:2000

Test Methods:

Emissions: EN55022:1998+A1:2000+A2:2003; FCC Part 15.107(b), 15.109(g),

Immunity: EN61000-4-2:1995 +A1:1998+A2:2001, EN61000-4-3:2002, EN61000-4-4:2004, EN61000-4-5:1995 +A1:1996, EN61000-4-6:1996 +A1:2001, EN61000-4-8:1995, EN61000-4-11:2001

The electromagnetic compatibility test and documented data described in this report has been performed and recorded by TUV Rheinland, in accordance with the standards and procedures listed herein. As the responsible authorized agent of the EMC laboratory, I hereby declare that a sample of one, of the equipment described above, has been shown to be compliant with the EMC requirements of the stated regulations and standards based on these results. If any special accessories and/or modifications were required for compliance, they are listed in the Executive Summary of this report.

This report must not be used to claim product endorsement by NVLAP or any agency of the U.S. Government. This report contains data that are not covered by NVLAP accreditation. This report shall not be reproduced except in full, without the written authorization of the laboratory.

Michael Moranha	19 September 2007	Randy Sherian	19 September 2007
Test Engineer	Date	NVLAP Signatory	Date

NVLAP 200094-0

FC 90552 and 100881

Industry Canada IC3755

Report Number: 30761612.001
EUT: NetBox and Net FT Sensor Model: Net FT
EMC / Rev 11/28/2006

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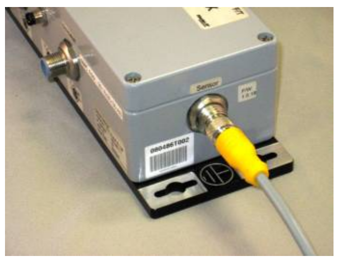
Quick Start

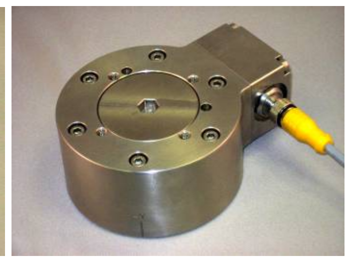
This quick-start guide will help you power your Net F/T and connect it to a Windows XP or Vista computer via Ethernet, access its web pages and use the Java demo program to see live force and torque data (you can download Java from www.java.com/getjava; do this before beginning this Quick Start). Your computer will need to have a LAN Ethernet connector.

This quick-start guide assumes the Net Box's DIP switch 9 is in the *ON* position. The DIP switch settings can be viewed through the window on the Net Box.

STEP 1 – Connect the Transducer to the Net Box

Some transducers have an integral cable; others have a cable that must be connected to the transducer. Connect the transducer cable to transducer connector on the end of the Net Box.

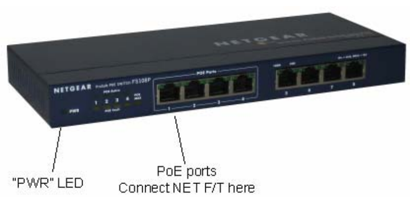




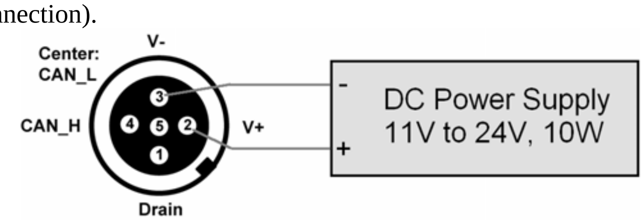
STEP 2 – Power the Net F/T

There are two ways to power the Net F/T. Power needs to be provided only using one of these methods:

Method 1: Use a Power-over-Ethernet (PoE) switch to deliver power to the Net F/T box. To do this you will need an Ethernet switch that supports PoE. Power will be automatically delivered to the Net F/T when you make the Ethernet connection to a PoE port on the switch.



Method 2: Connect a 24VDC power supply to the Net F/T box's *Pwr/CAN* connector. The power supply will need to be able to supply 10 Watts of power, and should be Class 1 (has an earth ground connection).



STEP 3 – Configure the Computer Ethernet Connection

For purposes of this quick start, your computer will be connected directly to the Net F/T and disconnected from your LAN. You will be temporarily giving your computer a fixed IP address of 192.168.1.100. It is important that the Ethernet cable to the Net F/T is disconnected from your computer during this step.

Please contact your IT department for assistance if you are uncomfortable making the following temporary changes to your computer's network configuration.

a. Unplug the Ethernet cable from the LAN port on your computer.

b. Open your computer's *Internet Protocol (TCP/IP) Properties* window. Follow the instructions below for your computer's operating system.

Windows Vista:

i. From the Start menu, select Control Panel.

ii. Click on *Control Panel Home*.

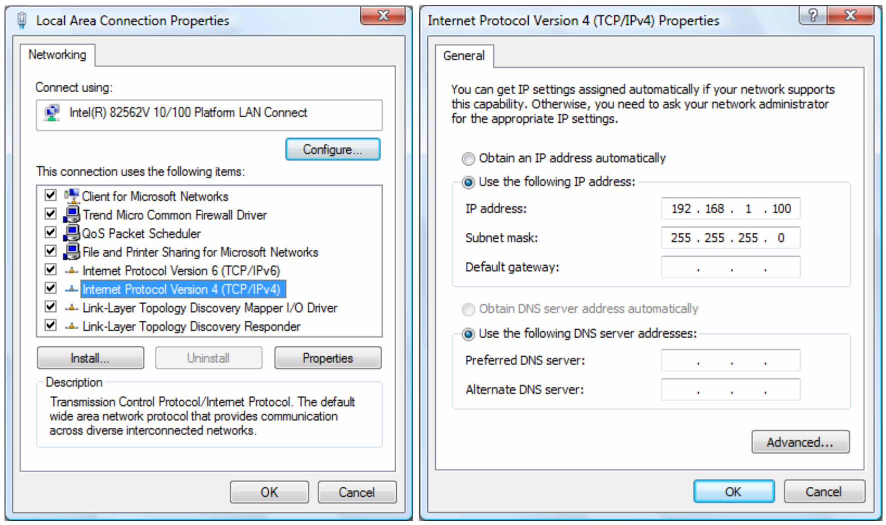
iii. Click on the *Network and Internet* icon.

iv. Click on the *Network and Sharing Center* icon.

v. Click on the *Manage Network Connections* task link.

vi. Right-click on *Local Area Connection* and select the *Properties* button.

vii. Select *Internet Protocol Version 4 (TCP/IPv4)* connection item and click on the *Properties* button.



Windows XP:

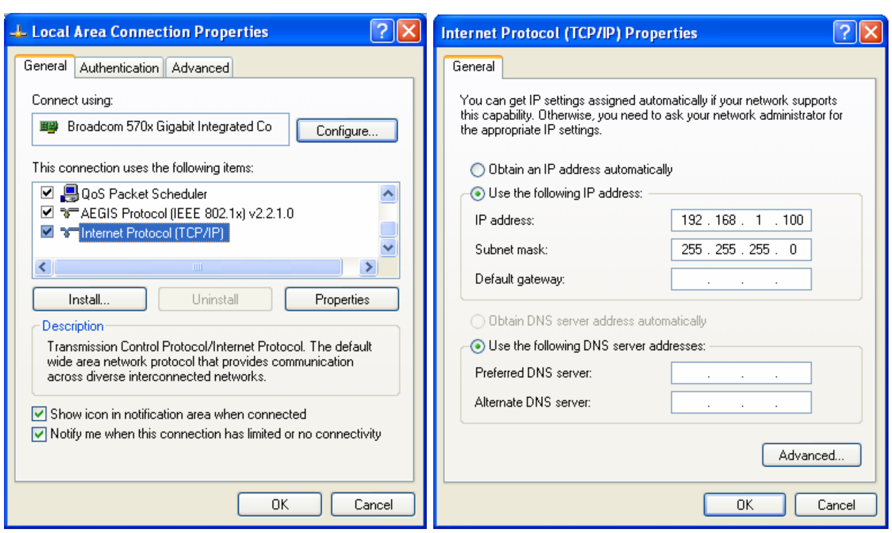
i. From the Start menu, select Control Panel.

ii. Open the *Network Connections* icon from within the Control Panel. If your Control Panel says *Pick a Category* at the top, you will need to first click on the *Network and Internet Connections* icon.

iii. Click on the *Network Connections* icon.

iv. Right-click on *Local Area Connection* and select *Properties*.

v. Select *Internet Protocol (TCP/IP)* connection item and click on the *Properties* button.



c. Record the values and settings shown in the properties window. You will need these later to return your computer to its original configuration.

d. Select the *Use the following IP address:* button.

e. In the *IP address:* field, enter *192.168.1.100*.

f. In the *Subnet mask:* field, enter *255.255.255.0*.

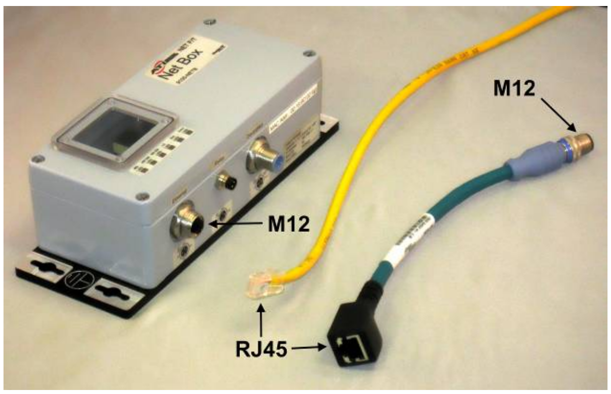
g. Click on the *OK* button.

h. Click on the *Local Area Connection Properties* window's *Close* button.

STEP 4 – Connect the Computer to the Net F/T

a. Connect the RJ-45 to M12 Ethernet adapter to the Net Box.

b. Connect the Ethernet cable to the Ethernet adapter.



c. Connect the other end of the Ethernet cable to your computer's LAN connection. You may need to wait a short while so your computer has time to recognize the connection.

STEP 5 – View the Net F/T's Web Pages

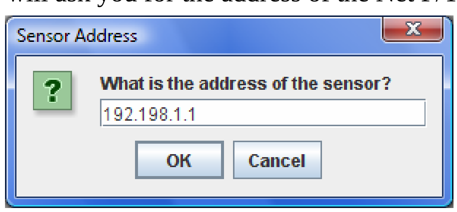
Enter the address *192.168.1.1* in your browser to view the Net F/T's *Welcome* page. (If the page is not found, you may need to clear previous 192.168.1.1 device entries from the computer by restarting the computer or, if you have administrative privileges, by going to the computer's *Start* menu, selecting *Run...*, and entering "`arp –d *`".)

STEP 6 – Run the Net F/T's Demo Program

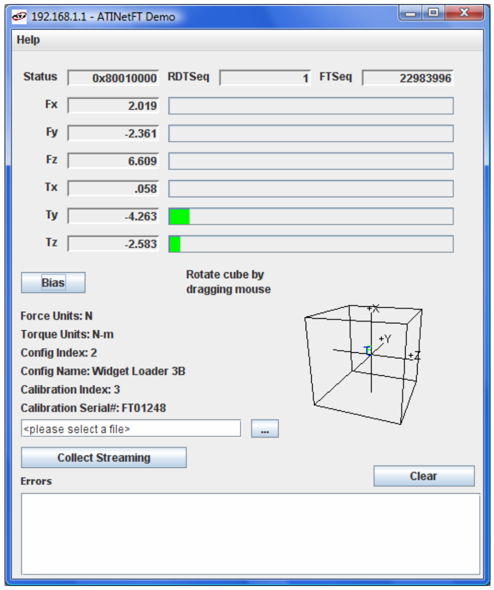
a. Click on the *Demo* link on the left side of the web page.

b. Click on the *Download Demo Application* button. This will launch the demo application.

c. The demo application will ask you for the address of the Net F/T. Enter *192.168.1.1* as the address.



d. Click *OK* to run the demo.

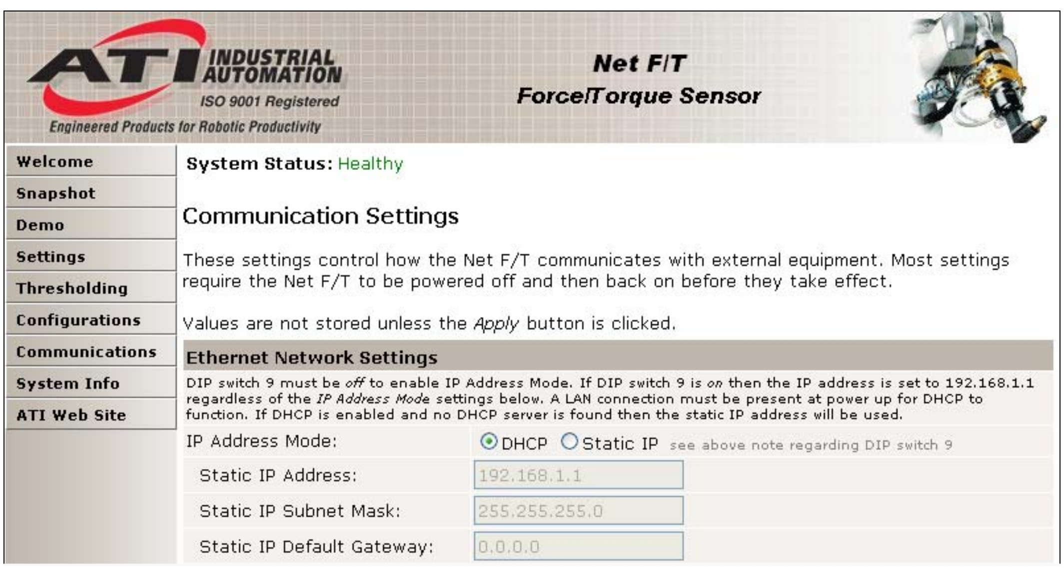


STEP 7 – Change the IP Address Settings

Ask your IT department if you should configure the Net F/T to use a static IP address or if you should use DHCP. If you will be using a static IP address, your IT department will need to give you an IP address, subnet mask, and gateway to use.

You will need to store this information on the Network Settings section of the Net F/T Communications page. Click on the *Communications* menu item to get to the Communications page (http://192.168.1.1/comm.htm).

If you are using a static IP address, select *Static IP*, enter the IP address, subnet mask, and gateway information as appropriate in the *Network Settings* section. If you are using DHCP select *DHCP*. See *Section 4.7—Communications Page (comm.htm)* of this manual for more information on these settings. See *Section 6.1–Finding Net F/Ts on the Network* to learn how to determine the DHCP-assigned IP address of a Net F/T.



Click on the *Apply* button to save the new settings.

STEP 8 – Exit Default IP Address Mode

Set the Net Box's DIP switch 9 to the *OFF* position. The settings that have been made will go into effect the next time the Net F/T is powered up.

Table of Contents

Glossary

Terms	Definitions
Accuracy	See *Measurement Uncertainty*.
Active Configuration	The configuration the system is currently using.
Calibration	The factory-supplied data used by Net F/T so it can report accurate transducer readings. Calibrations apply to a given loading range.
CAN	Controller Area Network (CAN) is a low level communication protocol used in some networks, including DeviceNet. The Net F/T system has a simple CAN protocol that can be used to read force and torque values.
CGI	Common Gateway Interface (CGI) is the method of using web URLs to communicate data and parameters back to a web device.
Compound Loading	Any force or torque load that is not purely in one axis.
Configuration	User-defined settings that include which force and torque units are reported, which calibration is to be used, and any tool transformation data.
Coordinate Frame	See *Point of Origin*.
DeviceNet™	A fieldbus communication network used mostly by devices in industrial settings, that communicates using CAN. DeviceNet is a trademark of ODVA.
DeviceNet Compatibility Mode	A feature of the Net F/T that allows it to respond like a certified DeviceNet device.
DHCP	Dynamic Host Configuration Protocol (DHCP) is an automatic method for Ethernet equipment to obtain an IP address. The Net F/T system can obtain its IP address using DHCP on networks that support this protocol.
Dup_MAC_ID test	The Duplicate MAC ID test is performed by a DeviceNet node (device) at power up to verify its MAC ID (device address) is not in use by another device.
EtherNet/IP™	EtherNet/IP (Ethernet Industrial Protocol) is a fieldbus communication network, used mostly by devices in industrial settings, that communicates using Ethernet. EtherNet/IP is a trademark of ControlNet International Ltd. used under license by ODVA.
Ethernet Network Switch	Ethernet network switches are electronic devices that connect multiple Ethernet cables to an Ethernet network while directing the flow of traffic.
FS	Full-Scale.
F/T	Force and Torque.
Fxy	The resultant force vector comprised of components Fx and Fy.
Hysteresis	A source of measurement caused by the residual effects of previously applied loads.
IP Address	An IP Address (Internet Protocol 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	IPV4 (Internet Protocol Version 4) describes IP addresses using four bytes, usually expressed in the dot-decimal notation, such as, *192.168.1.1* for example.
Java™	Java is a programming language often used for programs on web pages. The Net F/T demo is a Java application. Java is a registered trademark of Sun Microsystems, Inc.
MAC Address	MAC Addresses (Media Access Control Addresses) are the unique addresses given to every Ethernet device when it is manufactured, to be used as an electronic Ethernet serial number.
MAC ID	Media Access Code Identifier (MAC ID) is a unique number that is user assigned to each DeviceNet device on a DeviceNet network. Also called Node Address.

Terms	Definitions
Maximum Single-Axis Overload	The largest amount of pure load (not compound loading) that the transducer can withstand without damage.
MAP	The Mounting Adapter Plate (MAP) is the transducer plate that attaches to the fixed surface or robot arm.
Measurement Uncertainty	The maximum expected error in measurements, as specified on the calibration certificate.
Net Box	The component that contains the power supply and network interfaces of the Net F/T system.
Node Address	See *MAC ID*.
ODVA™	ODVA (Open DeviceNet Vendors Association, Inc.) is an organization that defines DeviceNet, EtherNet/IP, and other industrial networks. ATI Industrial Automation is a member of ODVA. ODVA is a registered trademark of Open DeviceNet Vendors Association, Inc.
Overload	The condition where more load is applied to the transducer than it can measure. This will result in saturation.
PoE	Power-over-Ethernet, or PoE, is a method of delivering electrical power to a PoE-compatible Ethernet device through the Ethernet cable. This simplifies installation of the Ethernet device since a separate power supply is not needed. The Net F/T system is PoE compatible.
Point of Origin	The location on the transducer from which all forces and torques are measured. Also known as the Coordinate Frame.
Quantization	The process of converting a continuously variable transducer signal into discrete digital values. Usually used when describing the change from one digital value to the next increment.
RDT	Raw Data Transfer (RDT) is a fast and simple Net F/T protocol for control and data transfer via UDP.
Resolution	The smallest change in load that can be measured. This is usually much smaller than accuracy.
Saturation	The condition where the transducer has a load outside of its sensing range.
Sensor System	The assembly consisting of all components from the transducer to the Net Box.
TAP	Tool Adapter Plate (TAP) is the transducer surface that attaches to the load to be measured.
TCP	Transmission Control Protocol (TCP) is a low-level method of transmitting data over Ethernet. TCP provides a slower, more reliable delivery of data than UDP.
Thresholding	A Net F/T function that performs a simple arithmetic comparison of a user-defined threshold to the loading on a transducer axis.
Tool Transformation	A method of mathematically shifting the measurement coordinate system to translate the point of origin and/or rotate its axes.
Transducer	Transducer is the component that converts the sensed load into electrical signals.
Txy	The resultant torque vector comprised of components Tx and Ty.
UDP	UDP (User Datagram Protocol) is a low-level method of transmitting data over Ethernet. While UDP is faster than TCP, unlike TCP lost UDP data is not resent.

1. Safety

1.1 General

The customer should verify that the transducer selected is rated for maximum loads and moments expected during operation. Refer to transducer specifications in 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.

1.2 Explanation of Warnings

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

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

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

1.3 Precautions

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

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

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

2. System Overview

The Network Force/Torque (Net F/T) sensor system is a multi-axis force and torque sensor system that simultaneously measures forces Fx, Fy, and Fz and torques Tx, Ty, and Tz. The Net F/T system communicates via EtherNet/IP, CAN Bus, Ethernet, and is compatible with DeviceNet. The Net F/T's web pages make it easy to set up and monitor.

The Net F/T system supports the following features:

2.1 Multiple Calibrations

The Net F/T can hold up to sixteen different transducer calibrations and each can have a different sensing range. The different calibrations are created with different load scenarios during the calibration process at the factory and stored in the Net F/T.

Multiple calibrations allow you to use a larger calibration for coarse adjustments and smaller calibrations for fine adjustments, or to use the same transducer in two or more very different loading regimes. Contact ATI Industrial Automation for information on obtaining additional transducer calibrations.

The calibration to use is determined by the calibration selected in the active configuration.

2.2 Multiple Configurations

The Net F/T also holds up to sixteen different user configurations. Each configuration is linked to a user-selected calibration and may have its own tool transformation. Configurations are useful when the Net F/T is used in a variety of tasks. The currently active configuration is user selected on the Net F/T's *Settings* web page.

2.3 Force and Torque Values

The Net F/T outputs scaled numbers, or counts, that represent the loading of each force and torque axis. The number of counts per force unit and counts per torque unit is specified by the calibration. If you wish to use different force and torque units (i.e., your transducer is calibrated to use pounds and pound-inches, but you wish to use Newtons and Newton-meters), you can change the output units on the Net F/T's *Configurations* web page.

2.4 System Status Code

Each Net F/T output data record contains a system status code which indicates the health of the transducer and the Net Box. See *Section 15.2—System Status Code* for details.

2.5 Thresholding

The Net F/T is capable of monitoring the force and torque levels of each axis and setting an output code if a reading crosses a threshold you define. The Net F/T can hold up to sixteen thresholds, and each threshold can be enabled and disabled individually or as a group. You can set up thresholding on the Net F/T's *Thresholding* web page.

2.6 Tool Transformations

The Net F/T is capable of measuring the forces and torques acting at a point other than the factory-defined point-of-origin (also known as the *sensing reference frame origin*). This change of reference is called a *tool transformation*. You specify tool transformations for each configuration on the Net F/T's *Configurations* web page.

2.7 Multiple Interfaces

The Net F/T system communicates via EtherNet/IP, CAN bus, Ethernet, and is compatible with DeviceNet. Each of these interfaces can be enabled and disabled on the Net F/T's *Communications* web page.

2.8 Power Supply

The Net F/T system accepts power through PoE (Power-over-Ethernet) or from a DC power source with an output voltage between 11V and 24V.

3. Getting Started

3.1 Introduction

This section gives instructions for setting up the Net F/T system.

3.2 Unpacking

- Check the shipping container and components for damage that occurred during shipping. Any damage should be reported to ATI Industrial Automation.
- Check the packing list for omissions.
- Standard components of a Net F/T system are:
  - Net F/T Transducer
  - Transducer cable (which may be integral to the transducer)
  - Net Box
  - ATI Industrial Automation CD containing software, calibration documents, and manuals (including this manual).
- Optional components:
  - Power supply: Plugs into a 100–240 VAC (50–60Hz) power outlet and supplies power to the Net Box through the *Pwr/CAN* connector
  - Ethernet switch supporting Power-over-Ethernet: Provides network connection and supplies power over the Ethernet connector
  - RJ45 to M12 Ethernet cable adapter
  - Mini to Micro (M12) DeviceNet adapter (for the *Pwr/CAN* connector)
  - DeviceNet cabling (for the *Pwr/CAN* connector)
  - Ethernet cabling
  - Robot-grade transducer cables of different lengths.

3.3 System Components Description

The Net F/T sensor system is a multi-axis force and torque sensor system that simultaneously measures forces Fx, Fy, Fz, and torques Tx, Ty, and Tz. The Net F/T system provides EtherNet/IP, CAN bus, and Ethernet communication interfaces and is compatible with DeviceNet.

In *Figure 3.3.1—Net F/T System Components*, the main components of the Net F/T system are displayed.

The **Net F/T Transducer** converts the force and torque loads into electrical signals and transmits them over the transducer cable. With the exception of very tiny transducers, like the Nano and Mini series, the signals are digital. The Nano and Mini series transducers are too small for on-board electronics and transmit analog signals.

The **Transducer Cable** is detachable and replaceable on transducers that use digital transmission. On other transducers, like the tiny Nano and Mini series, the transducer cable is an integral part of transducer and cannot be detached.

The **Net Box** is an IP65-rated aluminum housing that contains the power supplies and network interfaces. A digital-input version of the Net Box (NETB) is used with digital transducers while an analog-input version of the Net Box (NETBA) is used with analog transducers.

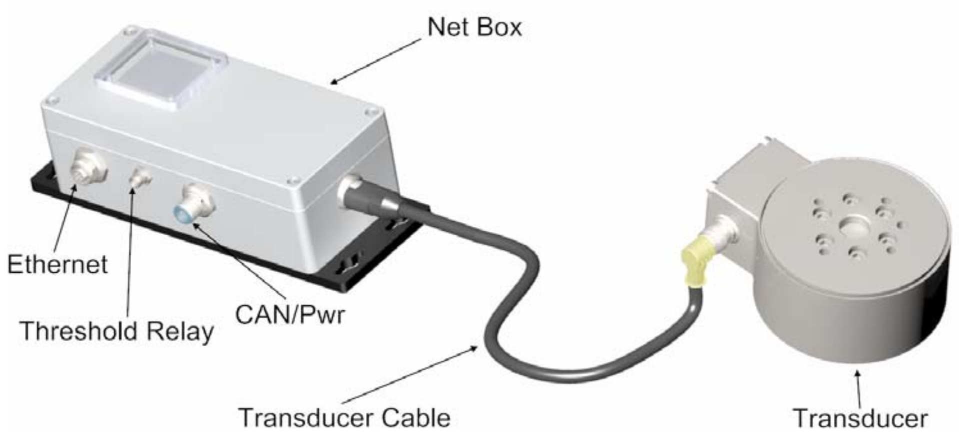


Figure 3.3.1—Net F/T System Components

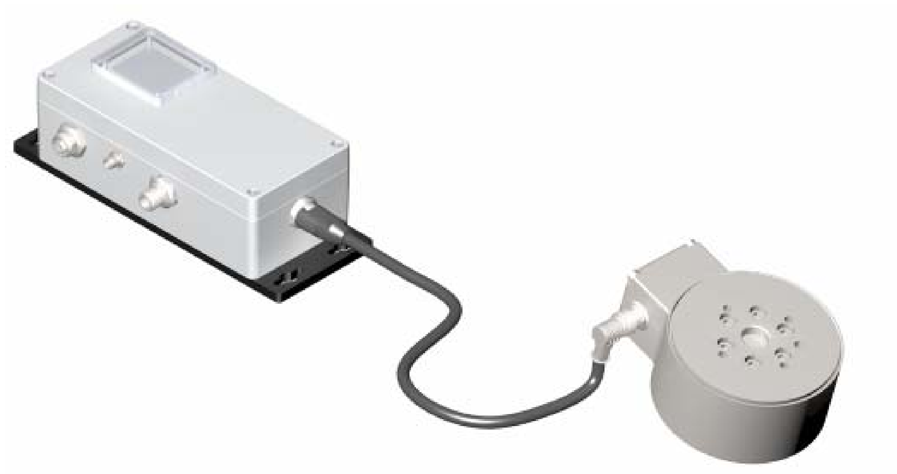


Figure 3.3.2—Sample NETB System

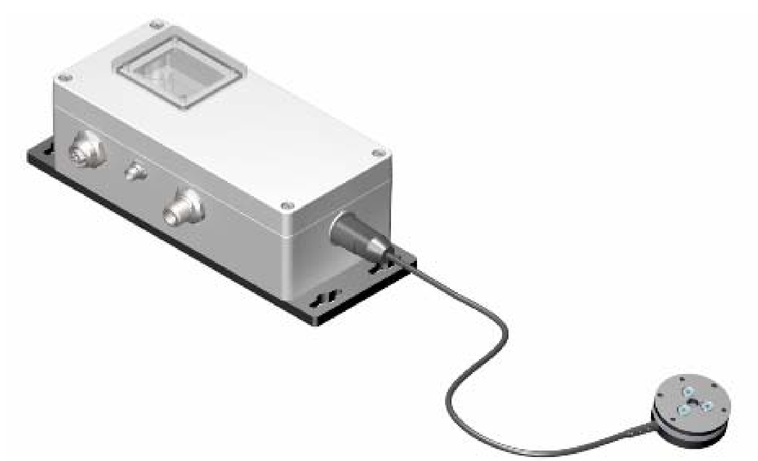


Figure 3.3.3—Sample NETBA System

3.3.1 F/T Transducer

The transducer is a compact, rugged, monolithic structure that senses forces and torques.

The F/T transducer is commonly used as a wrist transducer mounted between a robot and a robot end-effector. *Figure 3.3.4* shows a sample transducer.

- For further information not in this section, refer to F/T Transducer Manual (*9620-05-Transducer Section—Installation and Operation Manual.)*

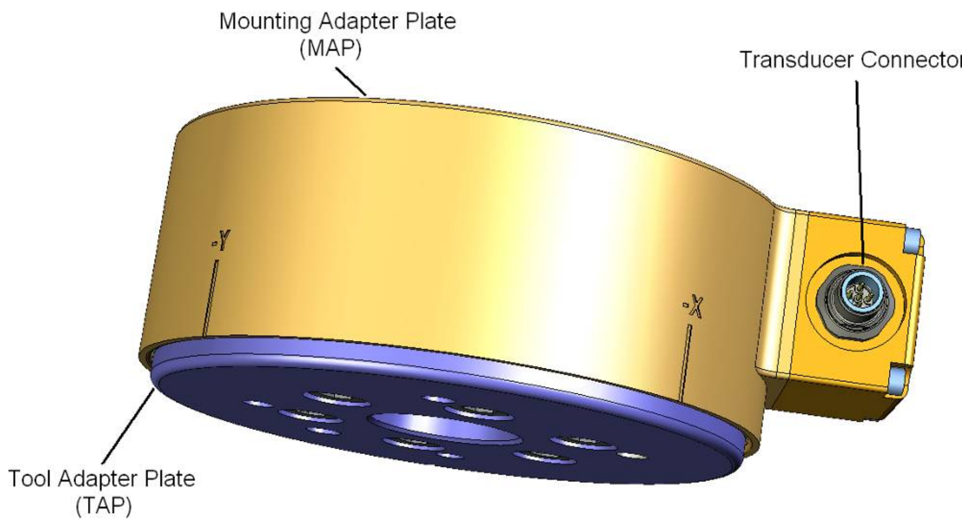


Figure 3.3.4—Sample Transducer (Omega160)

> ***Note:***
>
> The transducer is designed to withstand extremely high overloading because of its construction using strong materials and quality silicon strain gages. Some models use a hardened stainless steel with twice the strength of titanium for overload protection, while other transducers use mechanical overload pins to prevent damage.

3.3.2 Transducer Cable

The Transducer Cable delivers power from the Net Box to the transducer and transmits the transducer's strain gage data back to the Net Box.

Transducers with on-board electronics (ATI Industrial Automation part number prefix *9105-NET*) are connected to the Net Box (ATI Industrial Automation part number prefix *9105-NETB*) via industry standard M12 Micro DeviceNet cabling. Any DeviceNet-compatible cable with correct gender M12 Micro connectors can be used, but non-IP rated transducers are not compatible with right-angled connectors. ATI Industrial Automation supplies a robotic grade high-flex transducer cable with each Net F/T system. Many other DeviceNet cable choices are available to address different requirements. In case of special requirements, contact ATI Industrial Automation or an industrial cable manufacturer (see www.turck.com, www.woodhead.com, and others) for available products.

> ⚠ **WARNING:** Transducers are not compatible with DeviceNet. Do not attempt to directly connect a transducer to a DeviceNet network. Transducers must be connected to a Net Box.

ATI's 9105-C-MTS-MS cables can be connected to each other to make a multi-section cable.

> ***Note:***
>
> If a transducer is accidentally connected to a DeviceNet network, neither the transducer nor the network will be physically harmed. Communication errors may occur on the DeviceNet network while the transducer is connected.

Transducers that do not have on-board electronics (ATI Industrial Automation part number prefix *9105-TW*) usually have integral cabling. Those that require cabling must use an ATI Industrial Automation cable specifically made for these transducers. Transducers without the on-board electronics connect to Net Box version 9105-NETBA.

3.3.3 Net Box

The primary function of the Net Box is to process and communicate the transducer's force and torque readings to the user's equipment. Communication can be done through Ethernet, EtherNet/IP, and CAN Bus. The Net Box also responds to DeviceNet commands sent over the CAN Bus connection.

The Net Box should be mounted in an area that it is not exposed to temperatures outside of its working range (see *Section 16.1—Environmental*). It is designed to be used indoors in a non-dynamic, non-vibratory environment and may be mounted in any orientation. It is designed to meet IP65 ingress protection.

The Net Box should be grounded through at least one of the four mounting tabs.

The Net Box receives power through either a standard PoE (Power-over-Ethernet) switch or the *Pwr/CAN* connector.

3.4 Connecting the System Components

3.4.1 Connecting the Transducer to the Net Box

The Net F/T system normally ships with an off-the-shelf M12 DeviceNet cable to connect the transducer to the Net Box.

Plug the female M12 connector of this cable into the male M12 socket of the transducer. Then tighten its sleeve clockwise to lock the connector. See *Section 16.3.2–Connectors* for recommended connector torque levels.

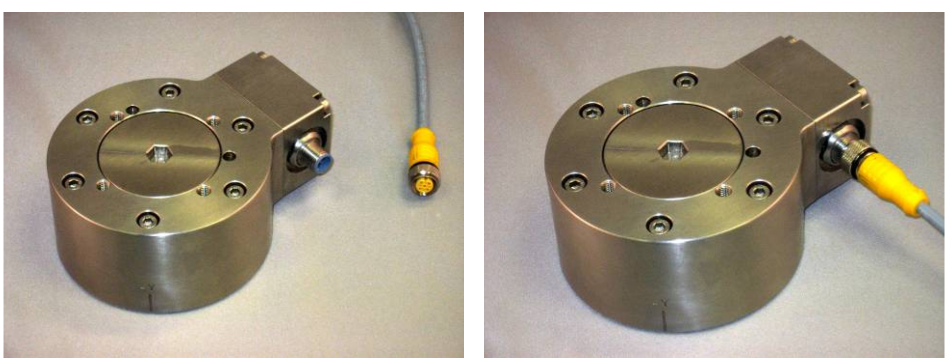


Figure 3.4.1—Connecting Transducer Cable to Transducer

Plug the male M12 connector into the female M12 socket marked *Transducer*. Then turn its sleeve in a clockwise direction until tightened to lock it to the socket. See *Section 16.3.2–Connectors* for recommended connector torque levels.

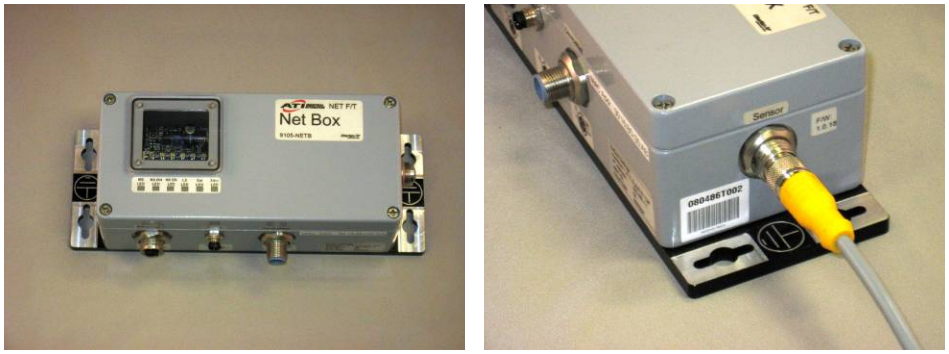


Figure 3.4.2—Connecting Transducer Cable to Net Box

To avoid disturbed transducer signals, especially in a noisy environment and when using long transducer cables, it is highly recommended to provide a low impedance ground connection for the transducer body.

3.4.2 Providing Power to the Net F/T

There are two ways to provide power to the Net F/T:

3.4.2.1 Option 1: Providing Power with PoE

The Net F/T's Power over Ethernet input is designed to IEEE 802.3af (Power over Ethernet) specifications.

The Net F/T system optionally ships with a PoE Ethernet switch. ATI Industrial Automation part number 9105-POESWITCH-1 (see *Figure 3.4.3—Sample PoE Ethernet Switch*), which provides PoE (Power-over-Ethernet) on four ports with RJ45 receptacles. Any PoE enabled device can get its power supply and communication signals from one of these ports. Any non-PoE device connected to these ports will receive an Ethernet connection without the power delivery. The Net F/T system accepts PoE and thus only needs one cable connection to function on an Ethernet network.

Figure 3.4.3—Sample PoE Ethernet Switch

- Connect the PoE switch to its external AC power supply.
- Connect the AC power supply to the AC mains. The *PWR* LED should turn on and glow green.
- Connect the PoE switch to your Ethernet network and connect the Net Box via RJ45 cable to one of the PoE ports. See *Section 3.4.3—Connecting to Ethernet* for information on making an Ethernet connection.

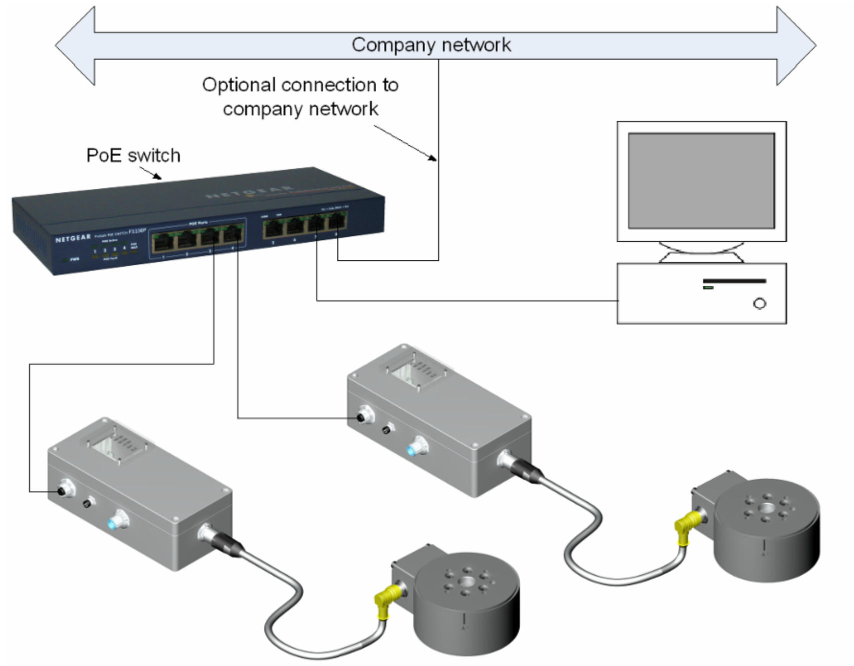


Figure 3.4.4—Connecting to the Ethernet

Once the Net Box is connected to the PoE switch, it should start up, first with red and green blinking LEDs. After approximately 20 seconds all LEDs should be green.

> ***Note:***
>
> If power is not provided to the *Pwr/CAN* connection then CAN bus baud rate, CAN bus base address, and DeviceNet MAC IDs are not correctly reported and communications over the *Pwr/CAN* connector are not available.

3.4.2.2 Option 2: Providing Power to *Pwr/CAN* Input

Instead of supplying power with the PoE option, you can use the 11V to 24V DC power input of the M12 *Pwr/CAN* connector. See *Section 16.3.2–Connectors* for recommended connector torque levels.

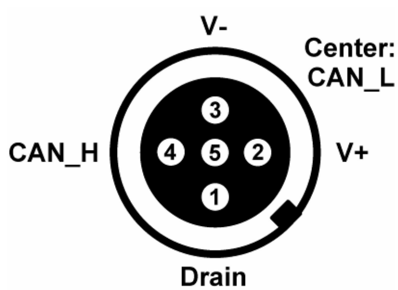


Figure 3.4.5—*Pwr/CAN* Micro Connector (view from male pin side)

The Net F/T may ship with an optional power adapter (ATI PN 9105-NETPS) that directly connects to the *Pwr/CAN* connector and delivers sufficient power for the Net F/T system.

Instead of using this power adapter, you can connect to your own DC power source as long as you provide sufficient voltage and current (see *Section 16.2–Connectors* for details) to the V+, V- inputs of the *Pwr/CAN* connector. ATI Industrial Automation offers an optional M12 female connector with screw terminals (ATI PN 1510-2312000-05) for field wiring to connect to your power source. Please note that although the connector provides access to CAN_H, CAN_L, and Drain connections, these pins should be left unconnected if they are not being used for CAN communications.

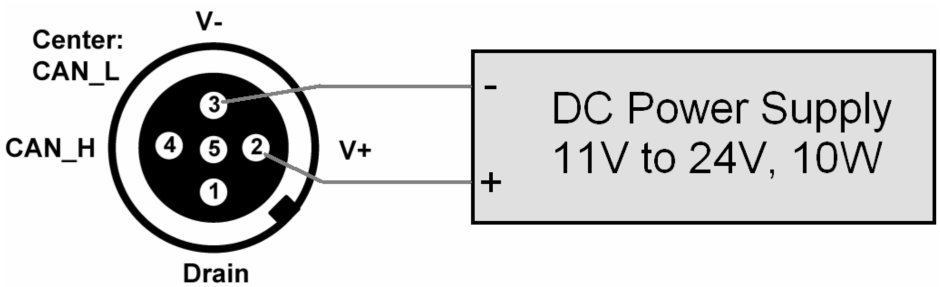


Figure 3.4.7—DC Power Source Connection (Using *Pwr/CAN* Connector)

3.4.3 Connecting to Ethernet

This section describes how to physically connect to Ethernet. See *Section 3.5—IP Address Configuration for Ethernet* for information on configuring your Net F/T's Ethernet settings and *Section 3.6—Connecting to Ethernet using a Windows Computer* for information on configuring a Windows XP or Windows Vista computer.

An industrial M12-4 Type-D Connector is provided for Ethernet connection. See *Section 16.3.2–Connectors* for recommended connector torque levels. The Net F/T system optionally ships with an off-the-shelf M12 Industrial Ethernet cable and/or an M12 to RJ45 adapter. The adapter allows the use of standard office-grade Ethernet cables with RJ45 connectors.

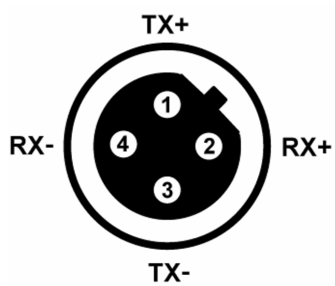


Figure 3.4.8—Ethernet M12-4, Type-D Connector (view from female pin side)

There are two ways that the Net Box can connect to Ethernet.

> ***Note:***
>
> To achieve the best Ethernet performance (and to reduce the likelihood of loosing data), we recommend connecting the Net Box directly to the host computer, as described in Option 2.

3.4.3.1 Option 1: Connect to an Ethernet Network

Use the M12 to RJ45 adapter to connect a standard RJ45 Ethernet cable to the Net Box. Be certain to tighten the sleeve fully clockwise to lock the connector.

Plug the other end of the Ethernet cable into the port of an Ethernet switch. See *Figure 3.4.9—Connecting to Ethernet* for a proposed setup.

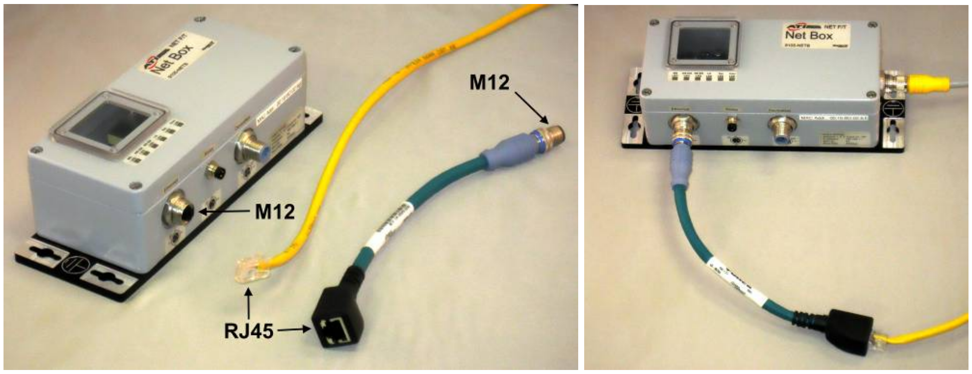


Figure 3.4.9—Connecting to Ethernet

3.4.3.2 Option 2: Connect Directly to a Computer's Ethernet Interface

The Net F/T system is connected directly to a computer's Ethernet port via a cable and is not connected to an Ethernet switch. Use the M12 to RJ45 adapter to connect a standard RJ45 Ethernet cable to the Net box. The most basic configuration would be a point-to-point connection between a computer's Ethernet interface and the Net F/T's Ethernet interface (see *Figure 3.4.10—Point-to-Point Ethernet Connection*). In this case, power has to be provided via the *Pwr/CAN* connector (see *Section 3.4.2.2—Option 2: Providing Power to the Pwr/CAN Input* for details). This configuration has the lowest latency and lowest chance of lost data packages and provides the best high-speed connection.

If necessary, the computer may be connected to an Ethernet network via a second Ethernet port on the computer. Note that most computers do not have a second Ethernet port and one may need to be installed. Doing so is outside the scope of this document. Contact your IT department for assistance.

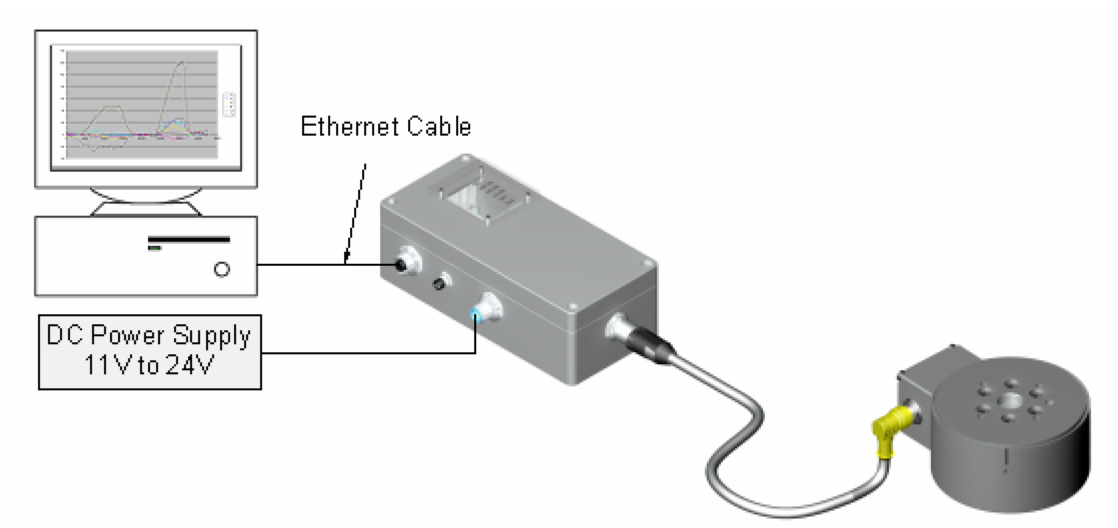


Figure 3.4.10—Point-to-Point Ethernet Connection

3.5 IP Address Configuration for Ethernet

The Net F/T system's IP address settings are only loaded upon power up, consequently the Net F/T must be power cycled for new IP address setting changes to be used. There are three ways the Net F/T system's IP address can be configured.

Method 1: Set IP address *192.168.1.1* by setting DIP switch 9 to the *ON* position.

Method 2: Set IP address to a static value stored on the Net F/T's Communication Settings web page (DIP switch 9 must be in the *OFF* position). This method is described in *Section 3.6—Connecting to Ethernet using a Windows Computer*.

Method 3: Let a DHCP server take care of the IP address assignment (DIP switch 9 must be in the *OFF* position). This option can be enabled in the Net F/T's web pages (see *Section 3.6—Connecting to Ethernet using a Windows Computer* for details). To use this method, a DHCP server must be present in the network. This is usually the case in company networks.

The Net F/T is shipped with DHCP enabled and the static IP address set to 192.168.1.1. The static IP address is automatically used if the network does not support DHCP. DHCP will not be used if a LAN connection is absent during power up.

3.6 Connecting to Ethernet using a Windows Computer

Most of the Ethernet configuration is performed via the Net F/T's web pages. To initially access the web pages, you will need to configure your Net F/T to work on your network by getting it assigned an IP address and telling it some basic information about your network.

For purposes of this initial connection, your computer will be connected directly to the Net F/T and disconnected from your LAN. You will be temporarily giving your computer a fixed IP address of 192.168.1.100. It is important that the Ethernet cable to the Net F/T is disconnected from your computer during this step.

> ***Note:***
>
> If your computer has multiple connections to Ethernet, such as a LAN connection and a wireless connection, be sure to select the LAN that will be connected to the Net F/T.

Step 1: Unplug the Ethernet cable from the LAN port on your computer.

Step 2: Open your computer's *Internet Protocol (TCP IP) Properties* window. Follow the instructions below for your computer's operating system.

Windows Vista

i. From the Start menu, select *Control Panel*.
ii. Click on *Control Panel Home*.
iii. Click on the *Network and Internet* icon.
iv. Click on the *Network and Sharing Center* icon.
v. Click on the *Manage Network Connections* task link.
vi. Right-click on *Local Area Connection* and select the "Properties" button.
vii. Select *Internet Protocol Version 4 (TCP/IPv4)* connection item and click on the *Properties* button.

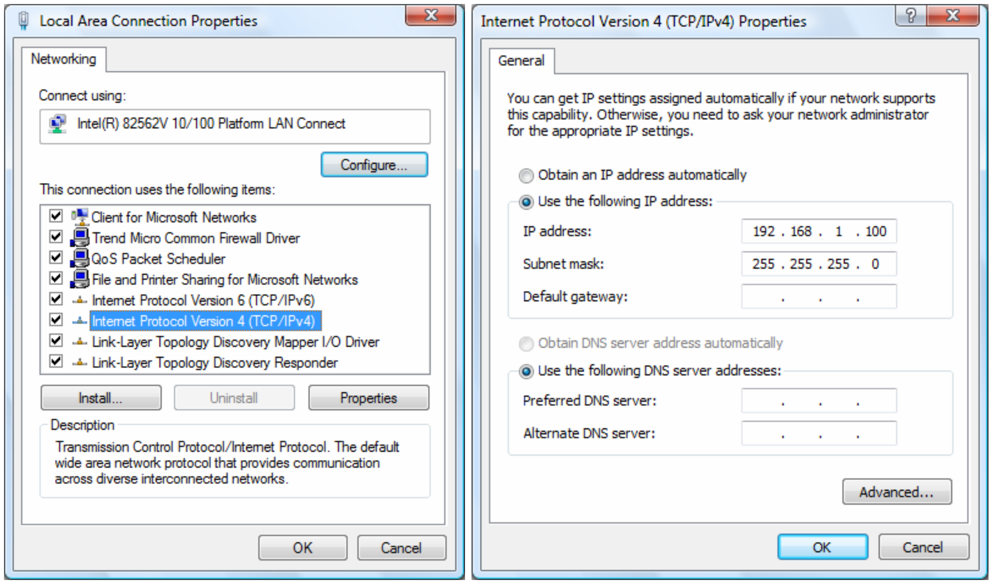


Figure 3.6.1—Windows Vista Networking Information

<u>**Windows XP**</u>

i. From the Start menu, select Control Panel.
ii. Open the *Network Connections* icon from within the Control Panel. If your Control Panel says *Pick a category* at the top, you will need to first click on the *Network and Internet Connections* icon.
iii. Click on the *Network Connections* icon.
iv. Right-click on *Local Area Connection* and select *Properties*.
v. Select *Internet Protocol (TCP/IP)* connection item and click on the *Properties* button.

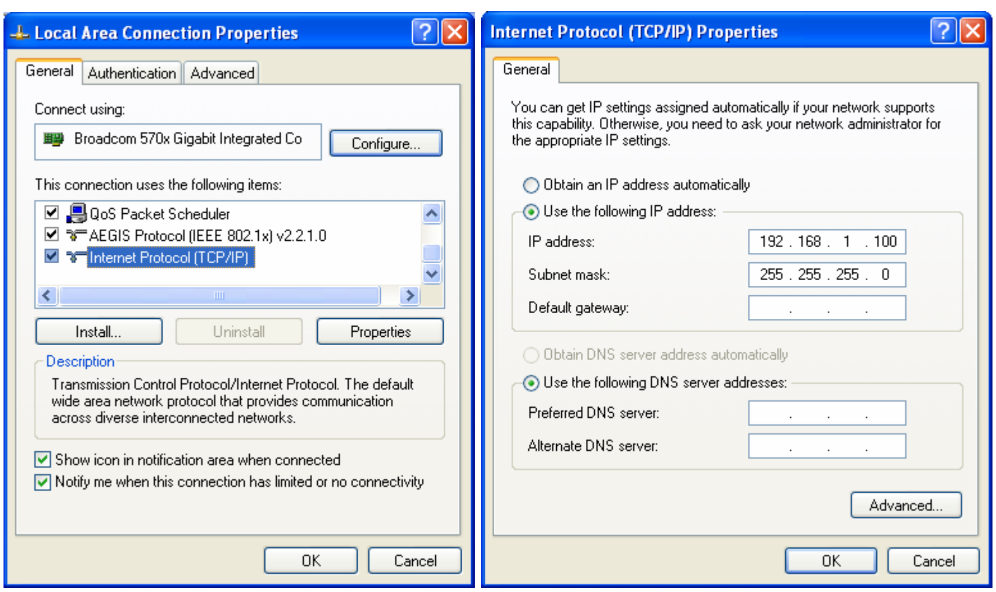


Figure 3.6.2—Windows XP Networking Information

Step 3: Record the values and settings shown in the properties window. You will need these later to return your computer to its original configuration.

Step 4: Select the *Use the following IP address* button.

Step 5: In the *IP address:* field, enter *192.168.1.100*.

Step 6: In the *Subnet mask:* field, enter *255.255.255.0*.

Step 7: Click on the *OK* button.

Step 8: Click on the *Local Area Connection Properties* window's *Close* button.

Step 9: Connect the Net F/T system to your computer's LAN connection using an Ethernet cable. You may need to wait a short while so your computer has time to recognize the connection.

Step 10: Enter the address *192.168.1.1* in your browser to view the Net F/T's *Welcome* page.

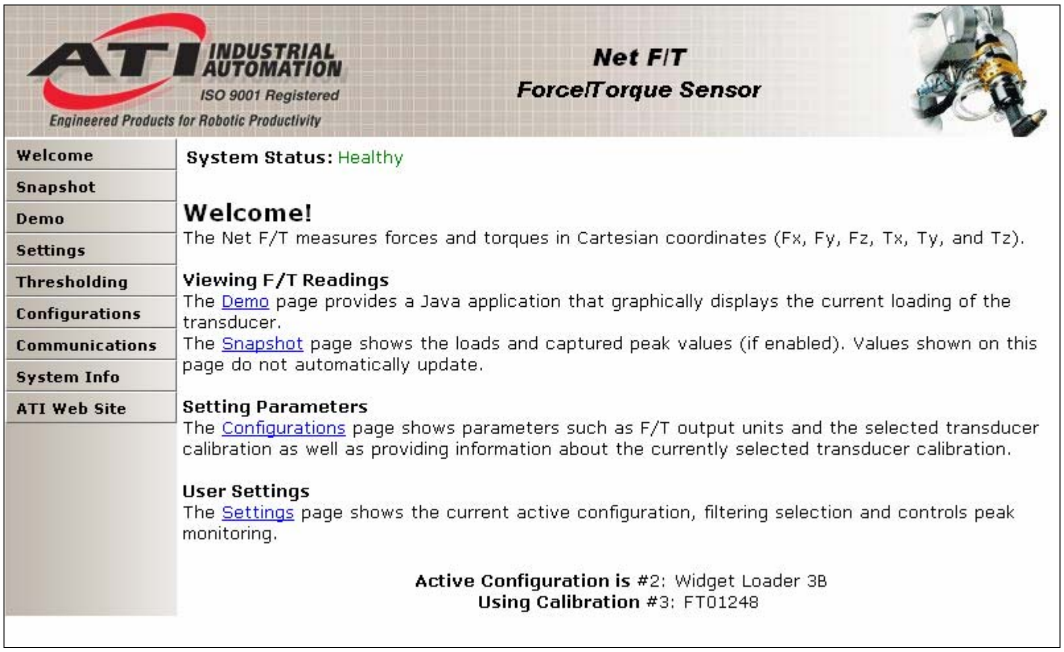


Figure 3.6.3—The Net F/T's Welcome Page

Step 11: On the left side of the page are menu buttons that link to various pages. Click on the *Communications* button.

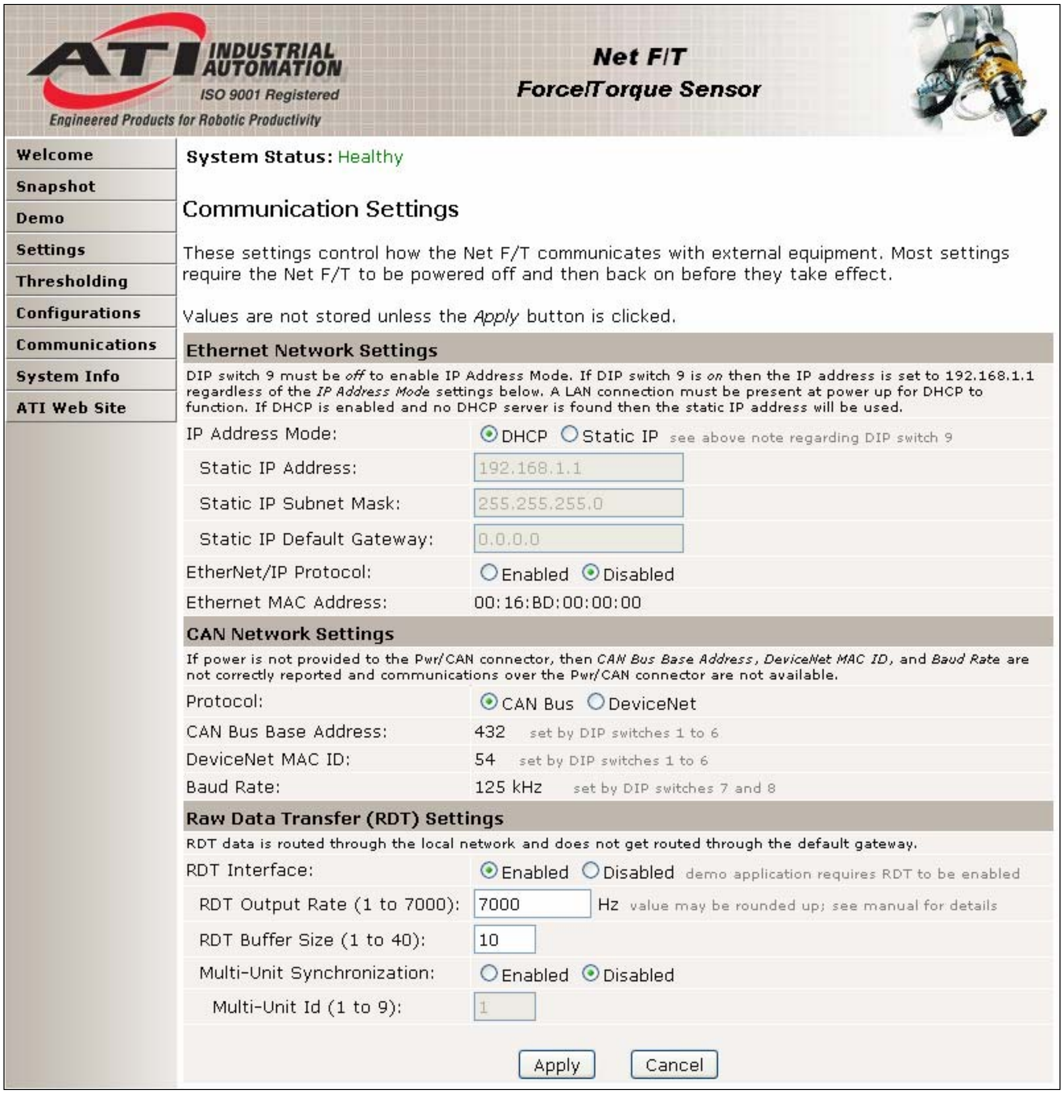


Figure 3.6.4—The Net F/T's Communications Page

Step 12a: If your IT department gave you settings for a **static IP** address, enter the appropriate values for the IP address, subnet mask, and default gateway, then press the *Apply* button. Power cycle the Net Box (if you are using PoE, just unplug the Net Box from PoE switch and then plug it back in). Skip to step 13.

Step 12b: If your IT department gave you settings for **DHCP**, press the *Enabled* radio button next to DHCP and then press the *Apply* button at the bottom. Power cycle the Net Box (if you are using PoE, just unplug the Net Box from the PoE switch and then plug it back in).

Next, determine the IP address assigned to the Net F/T by following the instructions in *Section 6.1–Finding Net F/Ts on the Network*.

> ***Note:***
>
> IP addresses assigned by a DHCP server are not permanent and may change if the Net F/T is disconnected from the network for a period of time. Contact your IT department for more information.

Step 13: Open up the TCP/IP properties of your local area connection again. Restore the settings to where they were before you reconfigured them (use the values you recorded in Step 3).

Step 14: Open up a new web browser window, enter the IP address you gave (or the DHCP server has assigned to the Net F/T) the Net F/T system into the browser's address bar, and press *Enter*. The Net F/T's *Welcome* page should display again. You can now communicate with the Net F/T over your network without needing to configure the communications settings again.

> ***Note:***
>
> If the Net FT Configuration Utility found the Net F/T, but the internet browser is unable to open the found IP address, you may need to clear previous device entries from the computer's ARP table by restarting the computer or, if you have administrative privileges, by going to the computer's *Start* menu, selecting *Run...*, and entering "`arp –d *`".
>
> This should only be necessary if another device previously occupied the same IP address that the Net F/T is now using.

3.7 Connecting to DeviceNet (using DeviceNet-Compatibility Mode)

The Net F/T system has a DeviceNet compatibility mode which allows operation over a DeviceNet network. The DeviceNet-compatibility mode fully implements all DeviceNet commands. The DeviceNet MAC ID address and baud rate settings follow *Section 3.9—DIP Switches and Termination Resistor*. For protocol information refer to *Section 11—DeviceNet-Compatibility Mode Operation*.

The Net F/T *Pwr/CAN* connector matches standard DeviceNet connectors and connections. The *Pwr/CAN* connector mates to a standard female DeviceNet M12 connector.

3.8 Connecting the Net Box to a CAN Bus Network

The Net F/T supports a basic CAN protocol. The CAN Bus base address and baud rate settings follow *Section 3.9—DIP Switches and Termination Resistor*. For protocol information refer to *Section 13—CAN Bus Operation*.

3.9 DIP Switches and Termination Resistor

The configuration DIP switches and termination resistor are located inside of the Net Box where they are safely protected form outside debris and liquids. The cover of the Net Box must be removed to gain access to these.

Before opening the Net Box, make sure that the box is unpowered and that you and the Net Box are electrically grounded.

To remove the cover, fully loosen each of the four screws that fasten the cover to the Net Box chassis. The cover can then be removed by lifting it straight up and off of the chassis.

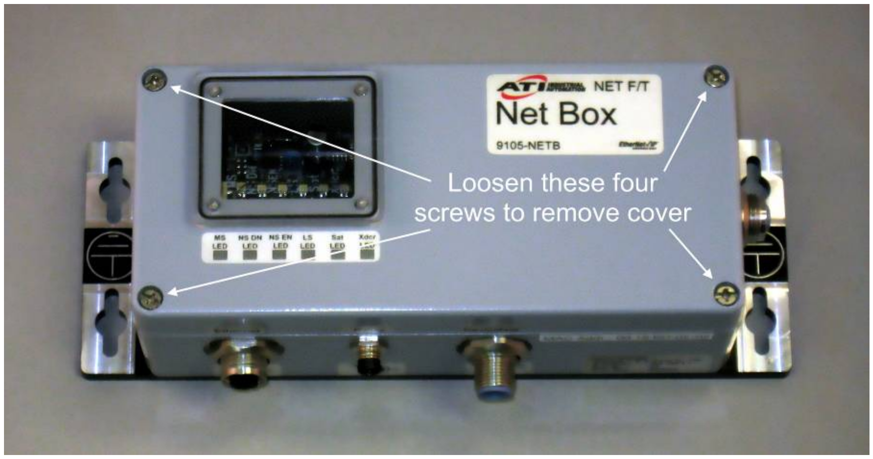


Figure 3.9.1—Net Box Cover Screws

The internal electronics have a clear shield to help protect them from debris or errant tool movements. There are access holes in the shield for the DIP switches and termination resistor jumper.

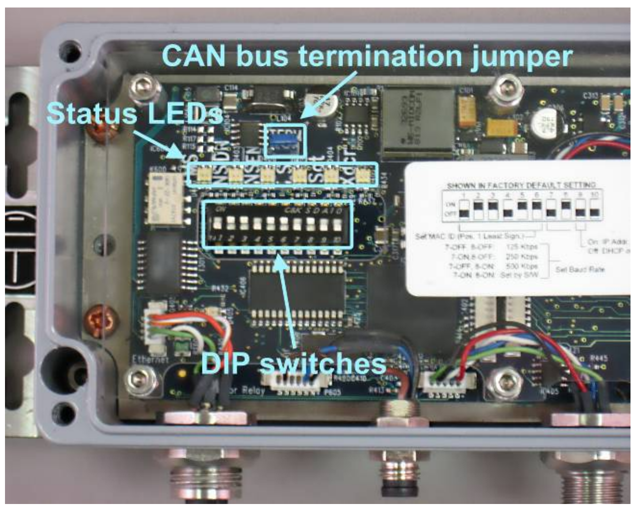


Figure 3.9.2—Net Box DIP Switches, Termination Resistor and LEDs

Before replacing the Net Box cover, you must ensure that no debris or liquids are in the chassis. To replace the Net Box cover, place the cover back on the chassis (verify that the window is above the LEDs and DIP switches) and tighten the four screws until each is snug.

3.9.1 Termination Resistor

By default, the Net Box ships with a CAN bus termination resistor installed. Remove the termination jumper if you want to disable the internal termination resistor. To remove the termination resistor, you will need to use a pair of tweezers or pliers to pull the jumper off. Safely store the jumper somewhere in case you need to re-enable the termination resistor.

3.9.2 Node Address

By default, the Net Box ships with a CAN Bus base address of 432 and DeviceNet MAC ID of 54. These are defined by the DIP switch settings (see *Figure 3.9.3—DIP Switch Settings* for details).

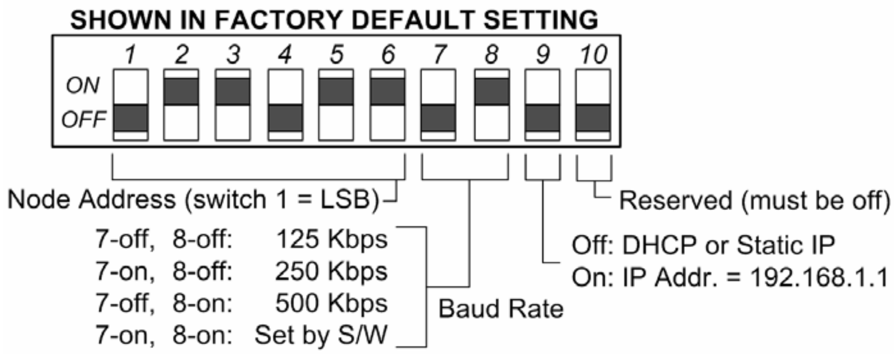


Figure 3.9.3—DIP Switch Settings

Use *Table 3.1—CAN Bus Base Address Switch Settings* and *Table 3.2—DeviceNet MAC ID Address Switch Settings* as an aid for finding the switch settings to set the desired address. The numbers on the left side of the colons are the desired MAC ID while the numbers on the right side represent the switch settings for switches 1 through 6 to select the MAC ID. The number *1* represents a switch in the *ON* position and the number *0* represents a switch in the *OFF* position.

Note:

The Net F/T can operate in either the CAN Bus protocol or the DeviceNet-Compatibility Mode protocol, but not both protocols. The desired protocol can be enabled on the Net F/T's *Communications* web page.

Both protocols use the same DIP switches to set their address. Be sure to use the correct address table for your protocol.

	1 2 3 4 5 6		1 2 3 4 5 6		1 2 3 4 5 6		1 2 3 4 5 6
0:	000000	128:	000010	256:	000001	384:	000011
8:	100000	136:	100010	264:	100001	392:	100011
16:	010000	144:	010010	272:	010001	400:	010011
24:	110000	152:	110010	280:	110001	408:	110011
32:	001000	160:	001010	288:	001001	416:	001011
40:	101000	168:	101010	296:	101001	424:	101011
48:	011000	176:	011010	304:	011001	432:	011011
56:	111000	184:	111010	312:	111001	440:	111011
64:	000100	192:	000110	320:	000101	448:	000111
72:	100100	200:	100110	328:	100101	456:	100111
80:	010100	208:	010110	336:	010101	464:	010111
88:	110100	216:	110110	344:	110101	472:	110111
96:	001100	224:	001110	352:	001101	480:	001111
104:	101100	232:	101110	360:	101101	488:	101111
112:	011100	240:	011110	368:	011101	496:	011111
120:	111100	248:	111110	376:	111101	504:	111111

Table 3.1—CAN Bus Base Address Switch Settings

	1 2 3 4 5 6		1 2 3 4 5 6		1 2 3 4 5 6		1 2 3 4 5 6
0:	000000	16:	000010	32:	000001	48:	000011
1:	100000	17:	100010	33:	100001	49:	100011
2:	010000	18:	010010	34:	010001	50:	010011
3:	110000	19:	110010	35:	110001	51:	110011
4:	001000	20:	001010	36:	001001	52:	001011
5:	101000	21:	101010	37:	101001	53:	101011
6:	011000	22:	011010	38:	011001	54:	011011
7:	111000	23:	111010	39:	111001	55:	111011
8:	000100	24:	000110	40:	000101	56:	000111
9:	100100	25:	100110	41:	100101	57:	100111
10:	010100	26:	010110	42:	010101	58:	010111
11:	110100	27:	110110	43:	110101	59:	110111
12:	001100	28:	001110	44:	001101	60:	001111
13:	101100	29:	101110	45:	101101	61:	101111
14:	011100	30:	011110	46:	011101	62:	011111
15:	111100	31:	111110	47:	111101	63:	111111

Table 3.2—DeviceNet MAC ID Address Switch Settings

Setting DIP switches 1 through 8 to *ON* will enable both DeviceNet MAC ID and baud rate to be set by software. If switches 7 or 8 are *OFF* then the DeviceNet MAC ID will not be set by software.

3.9.3 Baud Rate

By default, the Net Box ships with a baud rate of 500Kbps. This setting is defined by the DIP switch settings (see *Figure 3.9.3—DIP Switch Settings* for details).

Use *Table 3.3—Baud Rate Switch Settings* as an aid for finding the switch settings for the baud rate used by DeviceNet and CAN Bus.

	7 8
125 Kbps:	00
250 Kbps:	10
500 Kbps:	01
Selected by software:	11

Table 3.3—Baud Rate Switch Settings

3.10 Power-Up Cycle

With the transducer connected to the Net Box and the Net Box connected to an Ethernet network, the following should happen when you apply power to the Net Box:

- All Status LEDs blink green then red once in this order: *MS*, *NS DS*, *LS EN*, *LS*, *Sat*, *Xdcr*.
- Then the *Xdcr* LED glows red and *MS* LED blinks red. The *LS ES* LED blinks green if the Net Box is connected to a network.
- Approximately 20 seconds after power up, the *LS*, *MS*, and *Xdcr* LEDs should display green. This signals that the data acquisition hardware up and running.
- Refer to *Section 15—Troubleshooting* if the Net F/T does not power up as described above.

3.11 Status LEDs

The status LEDs indicate the general health and connectedness of the Net F/T. *Table 3.4–Status LED Descriptions* describes the possible LED states and meanings.

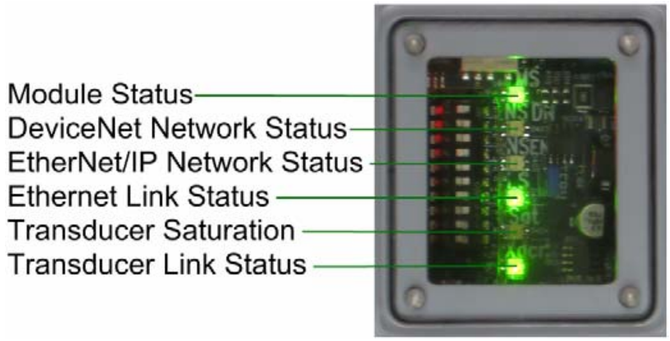


Figure 3.11.1—Status LEDs

Status LED Function	Name on PCB	LED State	Description
Module Status	**MS**	Off	No power
		Green	Correct operation
		Flashing Green	Awaiting EtherNet/IP and/or DeviceNet allocation to a master
		Flashing Red	Minor fault such as incorrect or inconsistent configuration
		Red	Unrecoverable fault
DeviceNet Compatibility-Mode Network Status	**NS DN**	Off	Pending duplicate MAC ID test or DeviceNet protocol not selected (or no power)
		Flashing Green	No connection to DeviceNet network
		Solid Green	DeviceNet master connected
		Flashing Red	DeviceNet I/O connection(s) timed out
		Red	DeviceNet network error
EtherNet/IP Network Status	**NS EN**	Off	EtherNet/IP is disabled or no IP address (or no power)
		Flashing Green	IP address is assigned, but no connection to EtherNet/IP network
		Green	EtherNet/IP network connected
		Flashing Red	EtherNet/IP connection(s) timed out
		Red	Duplicate IP address found
Ethernet Link Status	**LS EN**	Off	No link (or no power).
		Green	Link
		Solid Amber	Port disabled
		Flashing Green	Port activity
		Flashing Amber	Ethernet data collision
		Red	Major on-board Ethernet fault
Transducer Saturation	**Sat**	Off	Transducer is not saturated (or no power)
		Red	Transducer saturation
Sensor Link Status	**Xdcr**	Green	Data acquisition hardware operational
		Red	Data acquisition hardware error or executing power-up sequence

Table 3.4—Status LED Descriptions

4. Web Pages

4.1 Introduction

The Net F/T's web pages provide full configuration options for the Net F/T sensor system. There are several pages, which can be selected by the menu bar on the left side.

The Net F/T's web pages use simple HTML and browser scripting and the pages do not require any plug-ins. If browser scripting is disabled some non-critical user interface features are not available. The demo program is written in Java and requires Java to be installed on the computer.

The system status is displayed on all pages near the top of the page. This is the system status at the time the page was loaded. To display the current system status the page must be reloaded. Possible system status conditions are listed in *Section 15.2–System Status Code*.

Figure 4.1.1—Menu Bar

4.2 Welcome Page (index.htm)

By entering the Net F/T IP address into the browser address field, you will get to the Net F/T home page, the *Welcome* page.

The *Welcome* page gives a quick overview of the Net F/T's main functions. The bottom of the page lists the active configuration and the calibration used by this configuration.

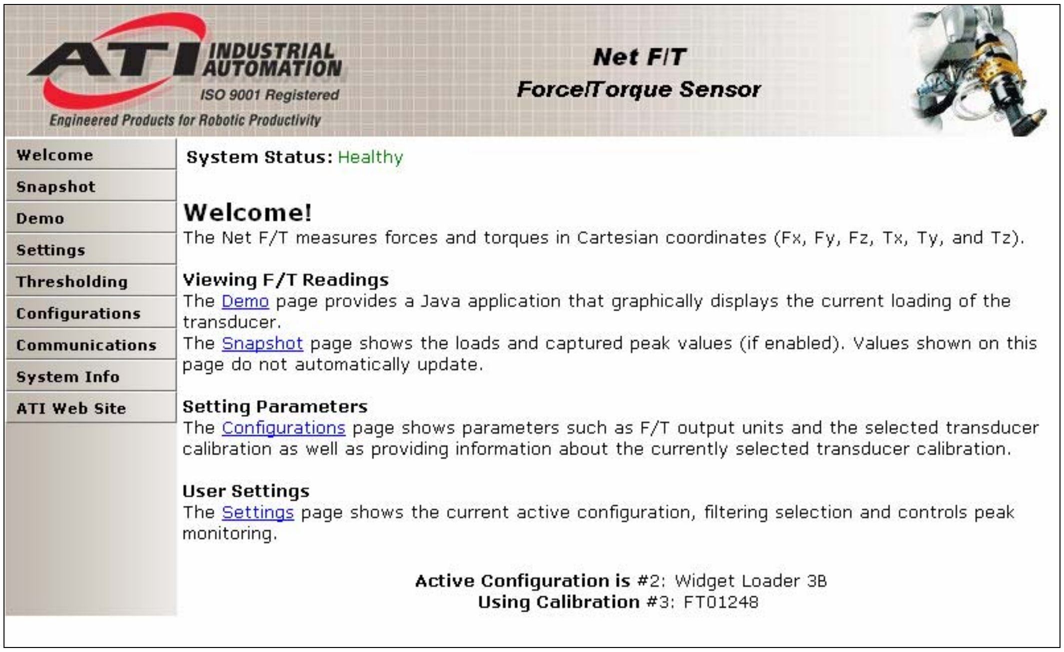


Figure 4.2.1—Welcome Page

4.3 Snapshot Page (rundata.htm)

This page allows you to view the current transducer loading, the maximum and minimum peaks (if peak monitoring is enabled on the *Settings* page), and the status of thresholding conditions.

The information displayed on this page is static and does not update after the page is loaded. To see current information the page must be reloaded.

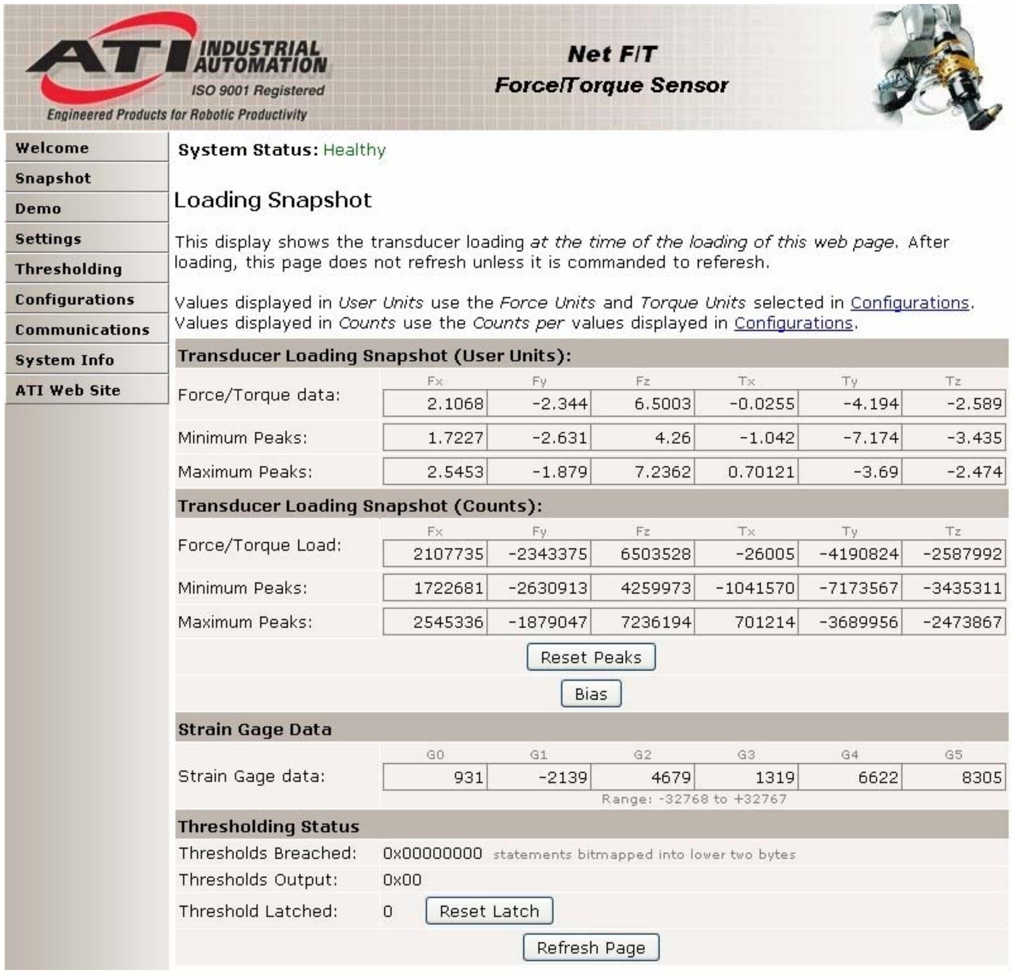


Figure 4.3.1—Snapshot Page

Transducer Loading Snapshot (User Units):

Force/Torque Data: Displays the force and torque data scaled in the user units selected in the *Configurations* page. If any strain gages are saturated, these values will be invalid and displayed in red with a line through them.

Minimum Peaks: Displays the minimum peak values captured scaled in the user units selected in the *Configurations* page.

Maximum Peaks: Displays the maximum peak values captured scaled in the user units selected in the *Configurations* page.

Transducer Loading Snapshot (Counts):

Force/Torque Data: Displays the force and torque data scaled with the *Counts per Force* and *Counts per Torque* displayed in the *Configurations* page. If any strain gages are saturated, these values will be invalid and displayed in red with a line through them.

Minimum Peaks: Displays the minimum peak values captured scaled with the *Counts per Force* and *Counts per Torque* displayed in the *Configurations* page.

Maximum Peaks: Displays the maximum peak values captured scaled with the *Counts per Force* and *Counts per Torque* displayed in the *Configurations* page.

Reset Peaks button: Clears the captured peaks and reloads the *Snapshot* page.

Bias button: Tares the force and torque values at the current readings and reloads the *Snapshot* page. This sets the current load level as the new zero point. This can be undone by setting the *Software Bias Vector* to all zeros on the *Settings* page.

Strain Gage Data:

Strain Gage Data: Displays the transducer's raw strain gage information for easy troubleshooting of saturation errors. Saturated strain gage values are displayed in red.

> ***Note:***
>
> When saturation occurs, the reported force and torque values are invalid.

> ***Note:***
>
> Individual strain-gage values do not correspond to individual force and torque axes.

> ***Note:***
>
> The transducer readings on this page are captured as the web page requests them. It is possible that the readings towards the bottom of the page come from later F/T data records than the readings towards the top of the page.

Thresholding Status:

Thresholds Breached: Indicates which threshold conditions are or have been true. Each bit in the lower two bytes of this hexadecimal number represents a thresholding statement. *Table 4.1–Bit Patterns for Thresholds Breached* shows the bit pattern representing each thresholding statement number. The *Thresholds Breached* value is cleared to zero by the reset latch function.

#:	Bit Pattern	#:	Bit Pattern	#:	Bit Pattern	#:	Bit Pattern
0:	0x00000001	4:	0x00000010	8:	0x00000100	12:	0x00001000
1:	0x00000002	5:	0x00000020	9:	0x00000200	13:	0x00002000
2:	0x00000004	6:	0x00000040	10:	0x00000400	14:	0x00004000
3:	0x00000008	7:	0x00000080	11:	0x00000800	15:	0x00008000

Table 4.1—Bit Patterns for Thresholds Breached

Thresholds Output: Displays the Thresholds Output value set by bitwise or'ing the Output Codes of all true thresholding statements.

Threshold Latched: Displays a one if any threshold conditions are or have been true. The *Threshold Latched* value is cleared to zero by the reset latch function.

Reset Latch button: Clears any threshold latching and reloads the *Snapshot* page. If no threshold conditions remain true then *Thresholds Breached*, *Thresholds Output*, and

Threshold Latched will all be set to zero and the System Status: Threshold Level Latched condition will be cleared.

Refresh Page button: Reloads the *Snapshot* page with updated values. This is the same as using the browser's reload or refresh command.

4.4 Demo Page (demo.htm)

This page allows you to download the Java Demo Application, which is described in *Section 5—Java Demo Application.*

Figure 4.4.1—Demo Page

4.5 Settings Page (setting.htm)

This page allows you to chose the active configuration and to specify certain global settings that are effective across all configurations, such as filtering, peak monitoring, and the bias (offset) vector. Changes on this page are not implemented until the *Apply* button is clicked.

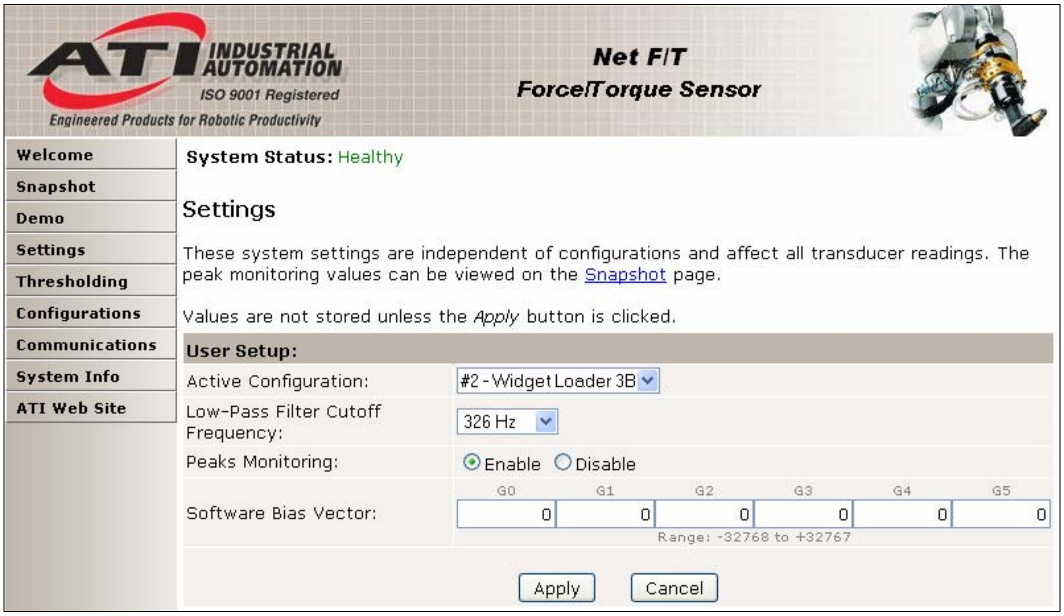


Figure 4.5.1—Settings Page

Active Configuration:	Selects one of sixteen configurations. See *Section 4.7—Configurations Page (config.htm)* for more information on configurations.
Low-Pass Filter Cutoff Frequency:	Selects the cutoff frequency for low-pass filtering. Selecting *No Filter* disables low-pass filtering. See *Section 16.2—Transducer Data Filtering* for filter information.
Peaks Monitoring:	If enabled each axis's lowest and highest F/T values will be saved as minimum and maximum peaks. The *Reset Peaks* button clears the peaks. You can find the *Reset Peaks* button on the *Snapshot* web page. The Peak Measurement feature can be useful for crash detection and during teaching or finding out how close the application gets to the transducer's limits.
Software Bias Vector:	This is the bias offset applied to the transducer strain gage readings. Clicking the *Bias* button on the *Snapshot* web page will change these values. This bias may be removed by setting the software bias vector to all zeros. Note that the strain gage readings do not have a one to one correspondence to force and torque readings.

4.6 Thresholding Page (moncon.htm)

This page allows you to set up threshold conditions. Threshold conditions compare the transducer readings to simple user-defined threshold statements. When a statement is true its user-defined output code is enabled. All of the enabled output codes are bitwise or'ed together to form the threshold output. The threshold output is available on the *Snapshot* page.

Each threshold condition can be configured for:

- the axis to monitor
- the type of comparison to perform
- the threshold value to use for the comparison
- the output code to send when the comparison is true

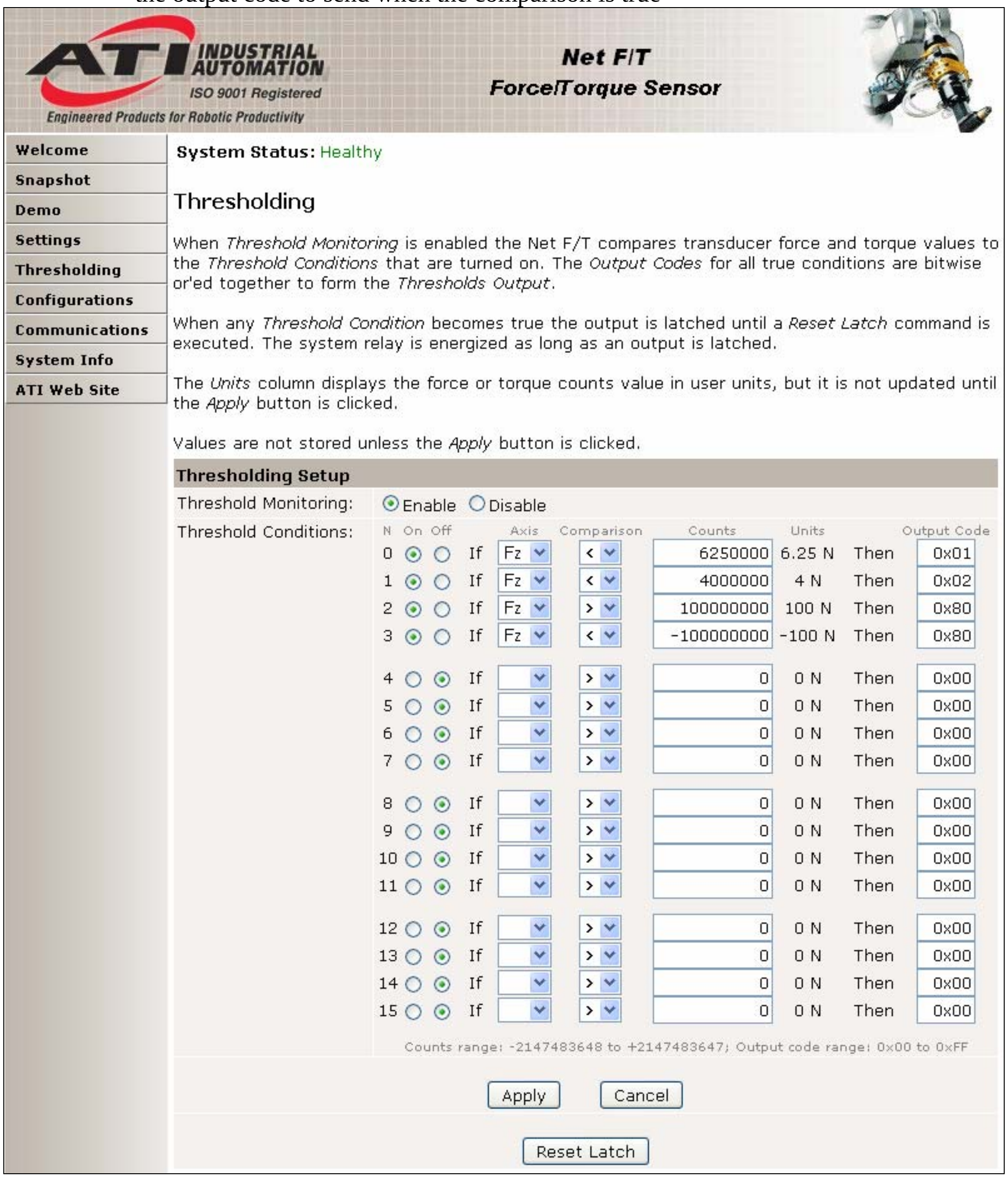


Figure 4.6.1—Thresholding Page

In case of any enabled threshold condition becoming true, the following will occur:

- The threshold's output code is updated.
- Bit 16 of the system status code (see *Section 15.2– System Status Code*) will be set to one.
- The threshold relay will close, connecting pin 3 to pin 4 of the Threshold Relay connector (see *Figure 4.6.2—Threshold Relay Connector Pin Assignment (male-pin side view)*.

Bit 16 and the threshold relay will hold these states until a reset latch command is sent. The reset latch command can be sent by clicking the *Reset Latch* button on the *Snapshot* web page. See *Section 4.3–Snapshot Page (rundata.htm)* for additional information.

Threshold Condition Elements:

N: Statement number.

On / Off: Selects which statements are to be included in the processing of threshold conditions.

Axis: Selects the axis to be used in the comparison statement. Available axes are:

Menu Value	Description
blank	Statement disabled
Fx	Fx axis
Fy	Fy axis
Fz	Fz axis
Tx	Tx axis
Ty	Ty axis
Tz	Tz axis

Table 4.2—Thresholding Statement Axis Selections

Comparison: Selects the type of comparison to perform. Available comparisons are:

Menu Value	Description
>	Greater Than
<	Less Than

Table 4.3—Thresholding Statement Comparison Selections

Counts: The loading level to be compared to the transducer reading. This value is displayed in the units of the active configuration after the *Apply* button is clicked.
To determine the *Counts* value to use from a value in user units, multiply the value in user units by *Counts per Force* (or *Counts per Torque* if appropriate).

Example:

Desired Loading Level 6.25N
Force Units: N (from *Configurations* page)
Counts per Force value 1000000 (from *Configurations* page)

Counts = Desired Loading Level × Counts per Force
= 6.25 N × 1000000 counts/N
= 6250000 counts

Note:

Comparison levels are stored as counts and only change when the user inputs new counts values. Changing the configuration or the force units or the torque units will not change or adjust the counts values.

Units: Displays the counts value in the units of the active configuration. This value is only updated after the *Apply* button is clicked.

Output Code: When this statement's comparison is found true, this 8-bit value will be bitwise or'ed with the *Output Code* values of all other true statements to form the threshold output. Any set bits remain latched until *Reset Latch* is called. If no statements have been true the threshold output will be zero. The value is displayed in hexadecimal in the format *0x00*. Output codes may be entered in the hexadecimal format or they may be entered in decimal.

Reset Latch button: Clears any threshold latching and reloads the *Thresholding* page. If no threshold conditions remain true then *Thresholds Breached*, *Thresholds Output*, and *Threshold Latched* will all be set to zero and the System Status: Threshold Level Latched condition will be cleared.

4.6.1 Threshold Relay

The threshold relay closes its contacts when *Threshold Latched* is true. This allows external electrical equipment to react when this occurs. Possible uses include control of E-stop circuits.

For increased reliability, it is best to monitor both the normally open (NO) and normally closed (NC) relay contacts. This allows detection of some cabling or relay issues.

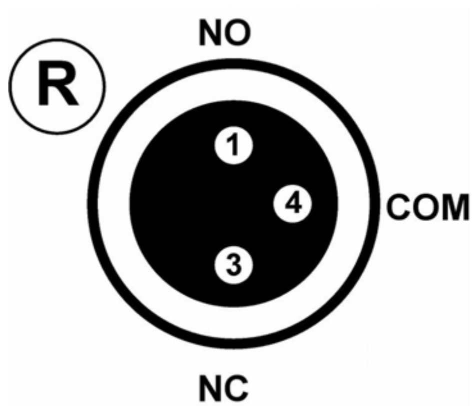


Figure 4.6.2—Threshold Relay Connector Pin Assignment (male-pin side view)

> ***Note:***
>
> To use thresholding, *Threshold Monitoring* must be enabled and each desired threshold condition needs to be set to *On*.

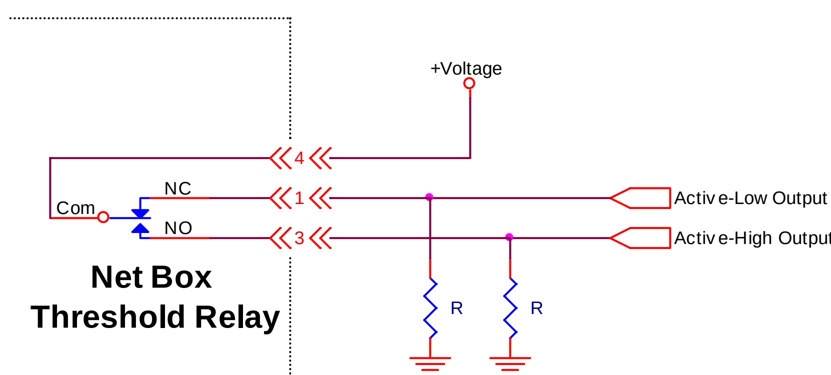


Figure 4.6.3—Example Circuit for Threshold Relay Monitoring

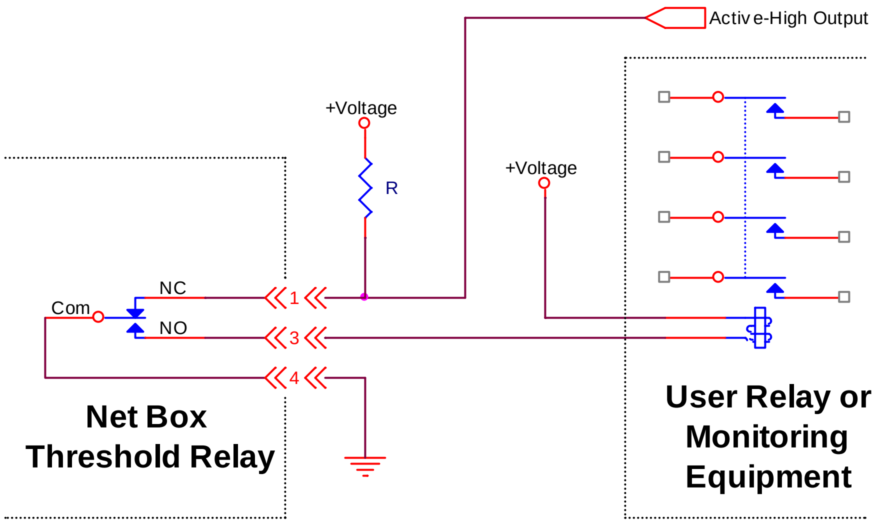


Figure 4.6.4—Example Circuit for a Relay Interface

The threshold relay contacts (NC, NO, and Com) are protected against overload by a self-resetting fuse. The maximum guaranteed fuse hold current is 50mA.

The relay will completely close its contacts within 6ms.

4.7 Configurations Page (config.htm)

This page allows you to specify the output parameters of the sensor system. Up to sixteen configurations can be defined. Changing configurations allows a different transducer calibration and tool transformation to be used. Changes on this page are not implemented until the *Apply* button is clicked.

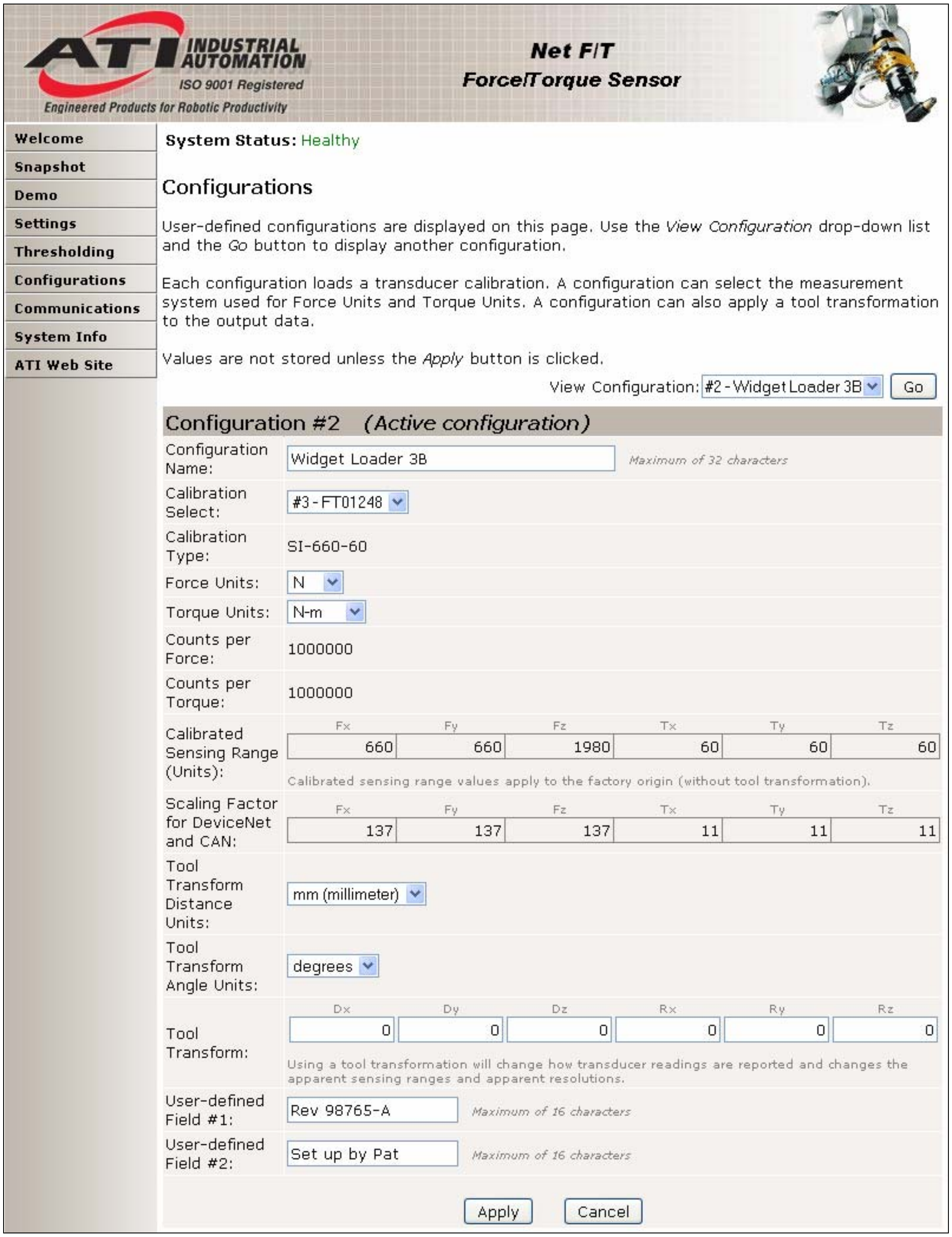


Figure 4.7.1—Configurations Page

View Configuration:	Selects the configuration to be viewed and edited. Clicking the *Go* button updates the page with the selected configuration.
Configuration Name:	Defines a name for the configuration.
Calibration Select:	Selects the transducer calibration to use for this configuration. A transducer will have at least one calibration. (Many Net F/T systems will only have one calibration available.)

If a different calibration is selected, the values displayed in fields *Calibration Type*, *Counts per Force*, *Counts per Torque*, *Calibrated Sensing Range* and *Scaling Factor for DeviceNet and CAN* will not be updated until the *Apply* button is clicked.

Calibration Type: Displays the calibration associated with the selected calibration. If a new calibration is selected, this field will not be updated until the *Apply* button is clicked.

Force Units: Selects the force measurement units to use. Available force measurement units are:

Menu Value	Description
lbf	Pound-force
N	Newtons
klbf	Kilopound-force
kN	Kilonewton
kgf	Kilogram-force
gf	Gram-force

Table 4.4—Force Unit Selections

If new force units are selected, the values displayed in fields *Counts per Force* and *Calibrated Sensing Range* are not updated until the *Apply* button is clicked.

Torque Units: Selects the torque measurement units to use. Available torque measurement units are:

Menu Value	Description
lbf-in	Pound-force-inch
lbf-ft	Pound-force-feet
N-m	Newton-meter
N-mm	Newton-millimeter
kgf-cm	Kilogram-force-centimeter
kN-m	Kilonewton-meter

Table 4.5—Torque Unit Selections

If new torque units are selected, the values displayed in fields *Counts per Torque* and *Calibrated Sensing Range* are not updated until the *Apply* button is clicked.

Counts per Force: Force values in counts are equal to the force values in selected units multiplied by this factor. The application program has to divide each force counts value by the *Counts per Force* value to obtain the real force data. See *Section 9.2—Calculating F/T Values for RDT* information and *Section 12.4—Calculating F/T Values for CIP* information.

If a new *Force Units* has been selected, this field will not be updated until the *Apply* button is clicked.

Counts per Torque: Torque values in counts are equal to the torque values in selected units multiplied by this factor. The application program has to divide each torque counts value by the *Counts per Torque* value to obtain the real torque data. See *Section 9.2—Calculating F/T*

Values for RDT information and *Section 12.4—Calculating F/T Values for CIP* information.

If a new *Torque Units* has been selected, this field will not be updated until the *Apply* button is clicked.

Calibrated Sensing Range: The transducer is calibrated up to these values in the selected force and torque measurement units. This applies to single-axis load conditions at the factory origin (no tool transformation). For complex load conditions, refer to the F/T Transducer Manual (*9620-05-Transducer Section—Installation and Operation Manual*).

If a new calibration is selected, a new force unit is select, or a new torque unit is selected, this field will not be updated until the *Apply* button is clicked.

Scaling Factor for DeviceNet and CAN: In order to reduce the amount of data transmitted via DeviceNet or CAN Bus, the force and torque values are reduced to 16 bits using this factor. See *Section 12.4.2–DeviceNet* and *Section 13.5–Calculating F/T Values for CAN*.

Tool Transform Distance Units: This is the distance units used for the distance vector in the tool transformation (see *Tool Transform* below for details). Available transform distance units are:

Menu Value	Description
in (inch)	inch
ft (foot)	foot
mm (millimeter)	millimeter
cm (centimeter)	centimeter
m (meter)	meter

Table 4.6—Tool Transform Distance Unit Selections

Changing the *Tool Transform Distance Units* does not change or rescale the tool transform values.

Tool Transform Angle Units: This is the angular units used for the rotation vector in the tool transformation (see *Tool Transform* below for details). Available transform angle units are:

Menu Value	Description
degrees	degrees (°)
radians	radians

Table 4.7—Tool Transform Angle Unit Selections

Changing the *Tool Transform Angle Units* does not change or rescale the tool transform values.

Tool Transform: Tool transform offsets are defined here. To keep the transducer's point of origin at the factory-defined location these values need to be all zero. Descriptions of the values and the order in which the values are applied to the factory-defined point of origin are as follows:

Column	Description	Order
Dx	Distance to move X axis	1
Dy	Distance to move Y axis	2
Dz	Distance to move Z axis	3
Rx	Rotation angle about X axis	4
Ry	Rotation angle about Y axis	5
Rz	Rotation angle about Z axis	6

Table 4.8—Tool Transform Values and Execution Order

Forces and torques are by default reported with respect to the factory point of origin[1]. The tool transformation function allows measurement of the forces and torques at some point other than the origin of the transducer. Tool transformations are particularly useful when this point is chosen as the point-of-contact between the robotic end-effector (tool) and the object being worked. A tool transformation can translate the reported origin a distance (Dx, Dy and Dz) from the factory origin and also rotate the reported origin (Rx, Ry and Rz) about the factory origin. A tool transformation allows a coordinate frame to be created that aligns resolved force/torque components with the natural axes of the task geometry.

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.

User-defined Field #1: Defines a short note for this configuration.

User-defined Field #2: Defines a second short note for this configuration.

4.8 Communication Settings Page (comm.htm)

This page allows you to view and set system networking options. Usually these settings are set once when the system is first installed and do not need to be changed later.

For information on setting the system to work with your network refer to *Section 3–Getting Started*.

[1] The factory point of origin places the X, Y, and Z axes as shown on the transducer drawings in the F/T Transducer Manual (*9620-05-Transducer Section—Installation and Operation Manual*).

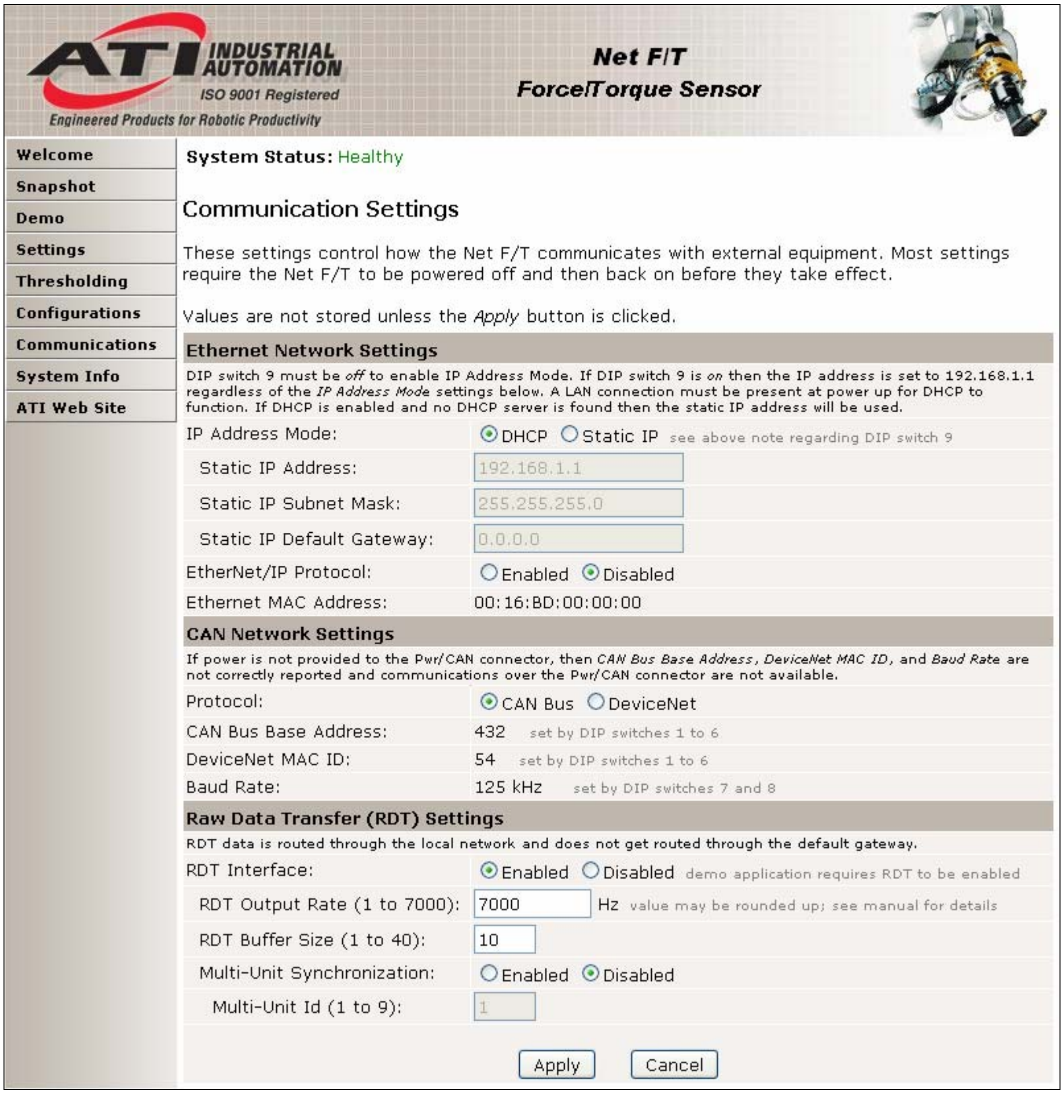


Figure 4.8.1—Communications Page

Ethernet Network Settings:

IP Address Mode:	Controls how the Net F/T determines its IP Address. If *DHCP* is selected, it will obtain an IP address from the Ethernet network's DHCP server. If the Net Box does not receive an address from the DHCP server within 30 seconds after power up, it will default to use the static IP settings. If *Static IP* is selected, the *Static IP Address* and *Static IP Subnet Mask* will be used for the IP address.

> ***Note:***
>
> DHCP-assigned addresses are not permanent and may change if the Net F/T is disconnected from the network for a period of time. Contact your IT department for more information. If this occurs, you can determine the changed IP address by following the instructions in *Section 6.1–Finding Net F/Ts on the Network*.
>
> Static IP addresses are often more desirable in permanent Net F/T installations because the address will not change.

Static IP Address:	Sets the static IP address. Refer to *Section 3.5—IP Address Configuration for Ethernet* for usage details. Contact your IT department for information on what static IP address to assign.
Static IP Subnet Mask:	Sets the subnet mask portion of the IP address. Many networks use the default *255.255.255.0*. Contact your IT department for information on what static IP subnet mask to assign.
Static IP Default Gateway:	Sets the default gateway. Contact your IT department for information on what default gateway to assign.
EtherNet/IP Protocol:	Controls whether or not the Net F/T uses EtherNet/IP. EtherNet/IP is only needed for industrial networks using the EtherNet/IP protocol. Most non-industrial applications will leave *EtherNet/IP* disabled.
Ethernet MAC Address:	The unique address given to this Net F/T at the time of manufacture. This address can be used to uniquely identify this Net F/T from other Net F/Ts and other Ethernet devices.

CAN Network Settings:

Protocol:	Controls which protocol will be used on the *Pwr/CAN* connector. When *CAN Bus* is selected the basic CAN protocol described in *Section 13–CAN Bus Operation* is used. When *DeviceNet* is selected the DeviceNet-compatibility mode protocol described in *Section 11—DeviceNet Compatibility-Mode Operation* is used. It is best to select *CAN Bus* when neither protocol is needed; otherwise a DeviceNet protocol failure will be signaled.
CAN Bus Base Address:	Displays the base address to be used by the CAN bus protocol. See *Section 3.9.2–Node Address* for information on setting this address.
DeviceNet MAC ID:	Displays the DeviceNet MAC ID address to be used by the DeviceNet compatibility-mode protocol. See *Section 3.9.2–Node Address* for information on setting this address.
Baud Rate:	Displays the CAN bus baud rate used by the CAN network. See *Section 3.9.3–Baud Rate* for information on setting the baud rate.

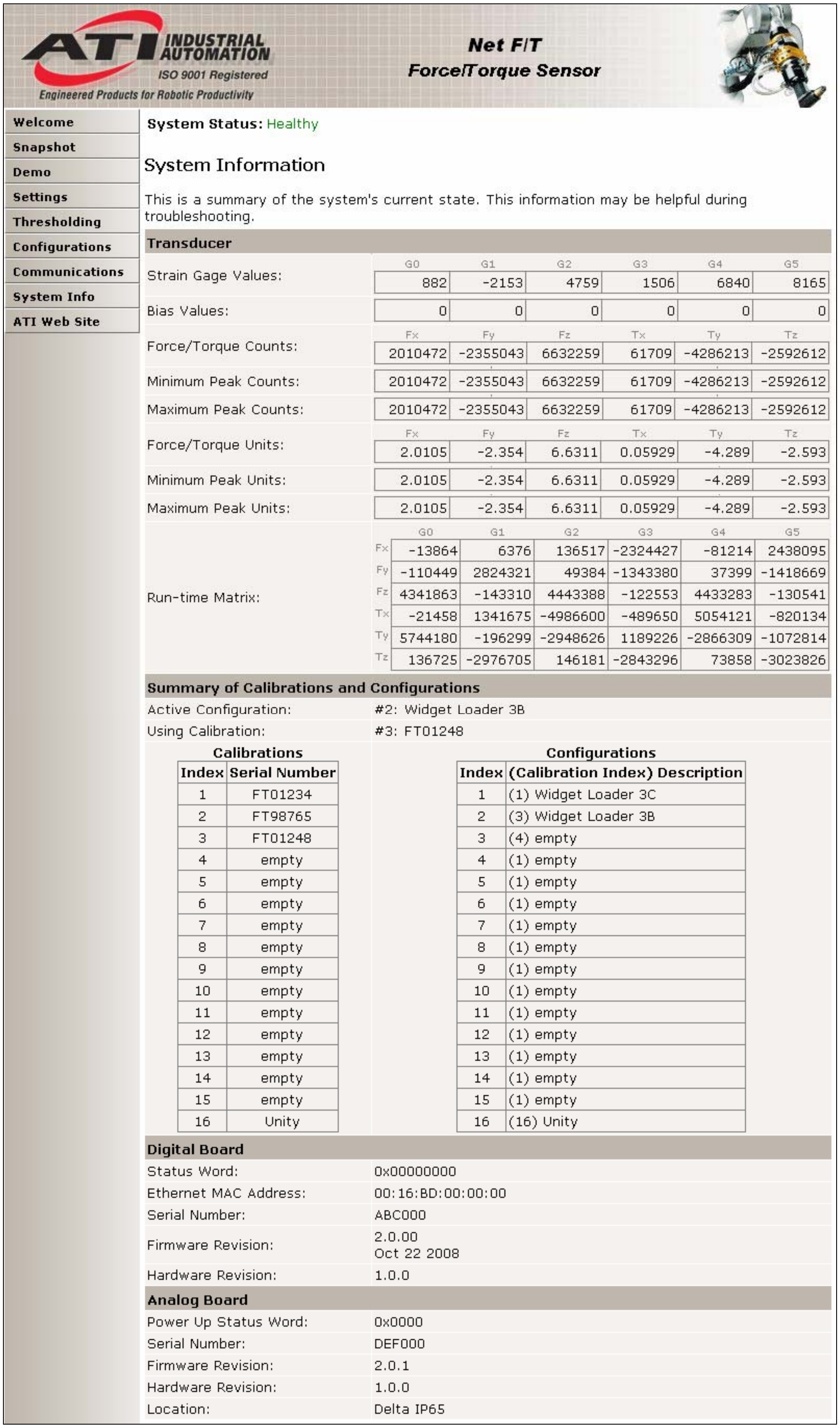
> ***Note:***
>
> The values displayed for *CAN Bus Base Address*, *DeviceNet MAC ID*, and *Baud Rate* are only valid if power is supplied to the *Pwr/CAN* connector. Otherwise indeterminate data is displayed.

Raw Data Transfer (RDT) Settings:

RDT Interface:	If enabled, the Net Box will be allowed to establish a point-to-point UDP connection to a host computer. This is the fastest way to read F/T data from the sensor system. In *Section 9—UDP Interface using RDT* the RDT interface is described in detail. RDT data is routed through the local network and does not get routed through the default gateway.
RDT Output Rate:	The rate per second at which the Net Box will send streaming RDT data to a host. It can be adjusted in integer fractions of 7000. (e.g., 7000÷2=3500 or 7000÷3=2333). If you enter a different sample rate, the Net F/T will automatically change to the next higher possible sample rate.
RDT Buffer Size:	The RDT interface can operate in different modes. One of these is the *Buffer Mode* where the Net Box sends more than one data package per sample. Multiple data packages are buffered and sent in one block. This reduces the amount of overhead data to be sent with the effect of reducing the overall network traffic. The number of data sets per block is the Buffer Mode Size.
Multi-Unit Synchronization:	If enabled, the Net Box will synchronize its RDT data output with other Net F/T sensor systems on the same network. In a network with only one sensor system, this option should be disabled. Refer to *Section 9.3—Multi-Unit Mode* for details. Multi-Unit IDs must be assigned for this to work correctly.
Multi-Unit ID:	If *Multi-Unit Synchronization* is enabled, each Net F/T using multi-unit synchronization needs to have a unique ID assigned to it.

4.9 System Information Page (manuf.htm)

The *System Information* page shows a summary of the system's current state. This page is used during troubleshooting by ATI Industrial Automation.



ATI INDUSTRIAL AUTOMATION
ISO 9001 Registered
Engineered Products for Robotic Productivity

Net F/T
Force/Torque Sensor

Welcome
Snapshot
Demo
Settings
Thresholding
Configurations
Communications
System Info
ATI Web Site

System Status: Healthy

System Information

This is a summary of the system's current state. This information may be helpful during troubleshooting.

Transducer

	G0	G1	G2	G3	G4	G5
Strain Gage Values:	882	-2153	4759	1506	6840	8165
Bias Values:	0	0	0	0	0	0

	Fx	Fy	Fz	Tx	Ty	Tz
Force/Torque Counts:	2010472	-2355043	6632259	61709	-4286213	-2592612
Minimum Peak Counts:	2010472	-2355043	6632259	61709	-4286213	-2592612
Maximum Peak Counts:	2010472	-2355043	6632259	61709	-4286213	-2592612

	Fx	Fy	Fz	Tx	Ty	Tz
Force/Torque Units:	2.0105	-2.354	6.6311	0.05929	-4.289	-2.593
Minimum Peak Units:	2.0105	-2.354	6.6311	0.05929	-4.289	-2.593
Maximum Peak Units:	2.0105	-2.354	6.6311	0.05929	-4.289	-2.593

Run-time Matrix:

	G0	G1	G2	G3	G4	G5
Fx	-13864	6376	136517	-2324427	-81214	2438095
Fy	-110449	2824321	49384	-1343380	37399	-1418669
Fz	4341863	-143310	4443388	-122553	4433283	-130541
Tx	-21458	1341675	-4986600	-489650	5054121	-820134
Ty	5744180	-196299	-2948626	1189226	-2866309	-1072814
Tz	136725	-2976705	146181	-2843296	73858	-3023826

Summary of Calibrations and Configurations

Active Configuration: #2: Widget Loader 3B
Using Calibration: #3: FT01248

Calibrations

Index	Serial Number
1	FT01234
2	FT98765
3	FT01248
4	empty
5	empty
6	empty
7	empty
8	empty
9	empty
10	empty
11	empty
12	empty
13	empty
14	empty
15	empty
16	Unity

Configurations

Index	(Calibration Index) Description
1	(1) Widget Loader 3C
2	(3) Widget Loader 3B
3	(4) empty
4	(1) empty
5	(1) empty
6	(1) empty
7	(1) empty
8	(1) empty
9	(1) empty
10	(1) empty
11	(1) empty
12	(1) empty
13	(1) empty
14	(1) empty
15	(1) empty
16	(16) Unity

Digital Board

Status Word:	0x00000000
Ethernet MAC Address:	00:16:BD:00:00:00
Serial Number:	ABC000
Firmware Revision:	2.0.00 Oct 22 2008
Hardware Revision:	1.0.0

Analog Board

Power Up Status Word:	0x0000
Serial Number:	DEF000
Firmware Revision:	2.0.1
Hardware Revision:	1.0.0
Location:	Delta IP65

Figure 4.9.1—System Information Page

4.10 ATI Web Site Menu Item

This is a link to ATI Industrial Automation’s web site. The Net F/T’s Ethernet network must be connected to the Internet to reach this web site.

5. Java Demo Application

The Java demo application provides a simple interface to view and collect F/T data from a connected computer. The computer will need to have Java version 6.0 (runtime 1.6.0) or later installed. (Java can be downloaded from www.java.com/getjava.)

5.1 Starting the Demo

The demo can be downloaded from the *Demo* page. Click the *Download Demo Application* button and follow your browser's instructions. The file *ATINetFT.jar* will be downloaded. If the browser does not automatically run the downloaded file, you will need to manually open the file on your computer.

Figure 5.1.1—Demo Page

The demo program opens with the following window:

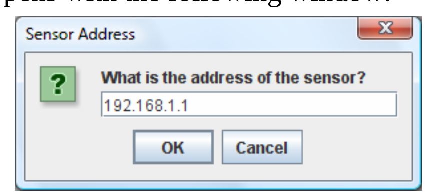


Figure 5.1.2—Net Box IP Address Request

If the window does not appear, it may be hidden under the browser window. In this case you may have to minimize the browser window.

Enter the IP address of the Net Box. The IP address of the Net F/T is displayed on the Demo page in the paragraph above the *Download Demo Application* button. The main window of the Java Demo application should open.

The first time the demo is used it may trigger a firewall alert. This is a normal response for any program that uses the network. In this case it will be necessary to tell the firewall to allow the program to use network connections. If the firewall is told to block connections the utility will not be able to contact the Net F/T. In this case you may need your IT department to undo the firewall block.

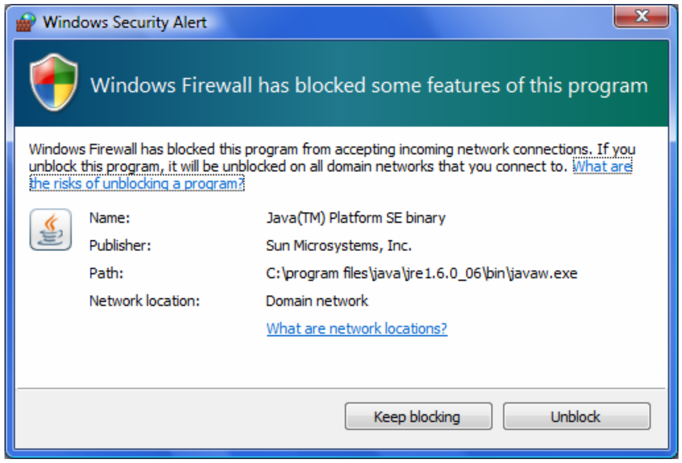


Figure 5.1.3—Windows Vista Firewall Alert

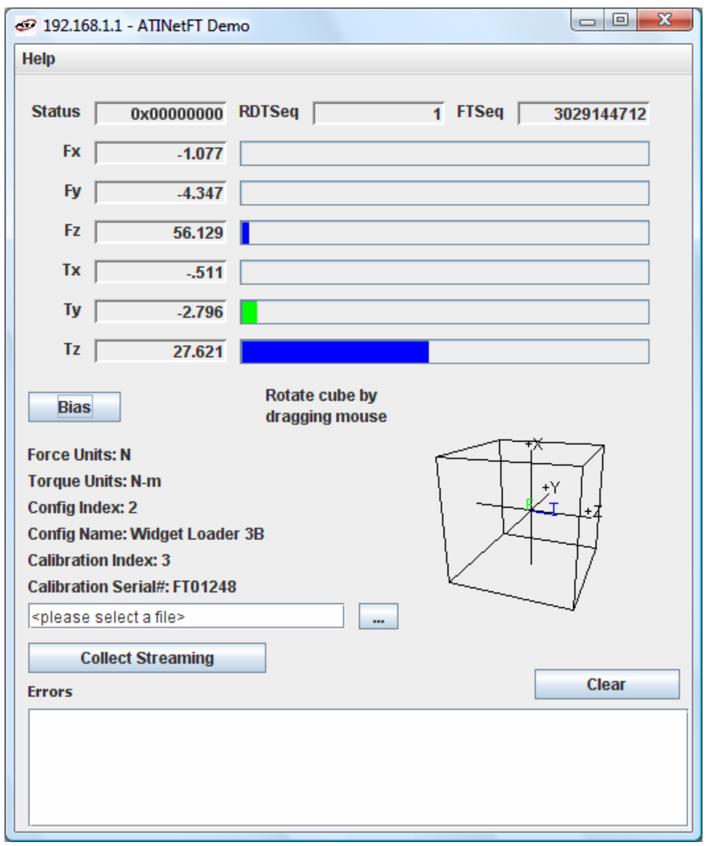


Figure 5.1.4—Java Demo Application

If the demo is unable to make contact with the Net F/T the force and torque values will display zero and the *Force Units* and other configuration-related items will each display a question mark.

5.2 Data Display with the Demo

The main screen features a live display of the current F/T data, sequence numbers, and status code. During normal operation the application requests single records, so the RDT sequence remains constant.

5.3 Collecting Data with the Demo

To collect data, first select a file to save the data in, either by pressing the "…" button to the right of the file selection field, or by directly typing the file path into the field. Once you have selected the file, press the *Start Collecting* button. The application will send out a request for high-speed data to the Net F/T sensor system. You can see the RDT sequence incrementing now because the application requests more than a single record when in high-speed mode.

The measurement data are stored in comma-separated value format (CSV) so it can be read by spreadsheets and data-analysis programs. Name your file with a *.CSV* extension and you can open it with a double-click.

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 work with.

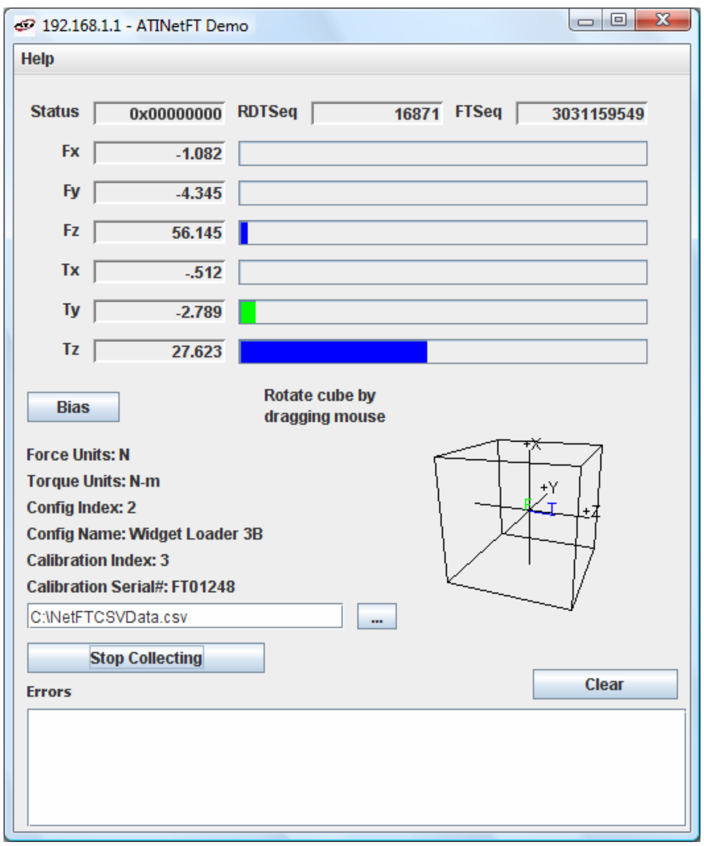


Figure 5.3.1—Java Demo Application while Collecting Data

To stop collecting data, click the *Stop Collecting* button (the *Collect Streaming* button changes to *Stop Collecting* during collections).

Information stored in the CSV file is organized as follows:

Line 1: **Start Time.** The date and time when the measurement was started.

Line 2: **RDT Sample Rate.** The speed (in samples per second) at which the measurement data were sent from the Net F/T to the host computer. The speed is the *RDT Output Rate* defined on the *Communications* page.

Line 3: **Force Units.** This is the force unit selected on the *Configuration* page.

Line 4: **Counts per Unit Force.** All force values Fx, Fy, Fz in the CSV file must be divided by this number to get the force values in the selected unit.

Line 5: **Torque Units.** This is the torque selected on the *Configuration* page.

Line 6: **Counts per Unit Torque.** All torque values Tx, Ty, Tz in the CSV file must be divided by this number to get the torque values in the selected unit.

Line 7: **Header Row.** This row names each of the columns of CSV data.

Column:	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**
Name:	Status (hex)	RDT Sequence	F/T Sequence	Fx	Fy	Fz	Tx	Ty	Tz	Time

Table 5.1—CSV File Column Headings

Column A: **Status (hex)** is the 32-bit system status code for this row. Each bit signals a certain diagnostic condition. Normally this code is zero. A non-zero status code normally means that the Net F/T system needs attention. See *Section 15.2—System Status Code* for a detailed description of the status code.

Column B: **RDT Sequence** is a number that starts at one and is incremented with each set of data that is sent from the Net F/T to the host computer**.**

Elapsed measurement time can be found with using the formula:

$$\text{Elapsed Measurement Time} = \frac{\text{RDT Sequence Number}}{\text{RDT Sample Rate}}$$

Missing sequences indicate that data packages were lost. To avoid lost samples, see *Section 14.1—Improving Ethernet Throughput*.

Column C: **F/T Sequence** is a number that is incremented with each new F/T measurement. The Net F/T measures at a constant rate of 7000 samples per second.

Column D: **Fx** is the Fx axis reading in counts.

Column E: **Fy** is the Fy axis reading in counts.

Column F: **Fz** is the Fz axis reading in counts.

Column G: **Tx** is the Tx axis reading in counts.

Column H: **Ty** is the Ty axis reading in counts.

Column I: **Tz** is the Tz axis reading in counts.

Column J: **Time** is the time the demo program received the data row from the Net F/T. This time stamp is created by the computer and is limited to the clock resolution of the computer.

	A	B	C	D	E	F	G	H	I	J
1	Start Time: 10/28/08 4:45 PM									
2	RDT Sample Rate: 7000									
3	Force Units: N									
4	Counts per Unit Force: 1000000.0									
5	Torque Units: N-m									
6	Counts per Unit Torque: 1000000.0									
7	Status (hex)	RDTSequence	F/T Sequence	Fx	Fy	Fz	Tx	Ty	Tz	Time
8	0x80010000	1	3031142679	-1082088	-4344421	56145954	-512907	-2789325	27622278	Tue Oct 28 16:45:31 EDT 2008
9	0x80010000	2	3031142680	-1082080	-4344397	56146508	-512897	-2790736	27622288	Tue Oct 28 16:45:31 EDT 2008
10	0x80010000	3	3031142681	-1082060	-4343688	56146485	-513175	-2791845	27621563	Tue Oct 28 16:45:31 EDT 2008
11	0x80010000	4	3031142682	-1082341	-4342832	56147539	-513359	-2791420	27621240	Tue Oct 28 16:45:31 EDT 2008
12	0x80010000	5	3031142683	-1082371	-4342861	56148597	-512138	-2790008	27621264	Tue Oct 28 16:45:31 EDT 2008
13	0x80010000	6	3031142684	-1082385	-4342524	56148628	-511978	-2790022	27621981	Tue Oct 28 16:45:31 EDT 2008
14	0x80010000	7	3031142685	-1082389	-4342191	56148118	-512436	-2789687	27622688	Tue Oct 28 16:45:31 EDT 2008
15	0x80010000	8	3031142686	-1082363	-4341816	56149196	-512870	-2791481	27622352	Tue Oct 28 16:45:31 EDT 2008
16	0x80010000	9	3031142687	-1082350	-4342498	56149183	-513193	-2791443	27622000	Tue Oct 28 16:45:31 EDT 2008
17	0x80010000	10	3031142688	-1082658	-4343039	56148680	-513432	-2789853	27623085	Tue Oct 28 16:45:31 EDT 2008
18	0x80010000	11	3031142689	-1082649	-4343057	56148669	-514051	-2788802	27623093	Tue Oct 28 16:45:31 EDT 2008
19	0x80010000	12	3031142690	-1082364	-4342864	56147033	-513374	-2790000	27622309	Tue Oct 28 16:45:31 EDT 2008
20	0x80010000	13	3031142691	-1081778	-4342833	56145442	-513406	-2792379	27622237	Tue Oct 28 16:45:31 EDT 2008
21	0x80010000	14	3031142692	-1081805	-4343552	56144381	-513136	-2790561	27622936	Tue Oct 28 16:45:31 EDT 2008
22	0x80010000	15	3031142693	-1081820	-4344608	56142267	-513644	-2789069	27623972	Tue Oct 28 16:45:31 EDT 2008
23	0x80010000	16	3031142694	-1082089	-4345096	56141691	-513861	-2789611	27622892	Tue Oct 28 16:45:31 EDT 2008
24	0x80010000	17	3031142695	-1082344	-4345231	56143795	-513900	-2790895	27621519	Tue Oct 28 16:45:31 EDT 2008
25	0x80010000	18	3031142696	-1082342	-4345217	56143265	-513897	-2791596	27621503	Tue Oct 28 16:45:31 EDT 2008
26	0x80010000	19	3031142697	-1081777	-4345564	56142209	-513490	-2792190	27621809	Tue Oct 28 16:45:31 EDT 2008
27	0x80010000	20	3031142698	-1081488	-4346106	56141657	-513765	-2790886	27621793	Tue Oct 28 16:45:31 EDT 2008

NetFTCSVData

Figure 5.3.2—Sample Data Opened in Spreadsheet

5.4 The Errors Display of the Demo

The error list at the bottom of the screen keeps track of errors that have occurred and the times they occurred (see *Figure 5.4.1* for an example). Refer to *Section 15.3.3—Java Demo* if you need help with error messages. See *Section 14.1 – Improving Ethernet Throughput* if there are excessive *IO Exception: Receive timed out* errors.

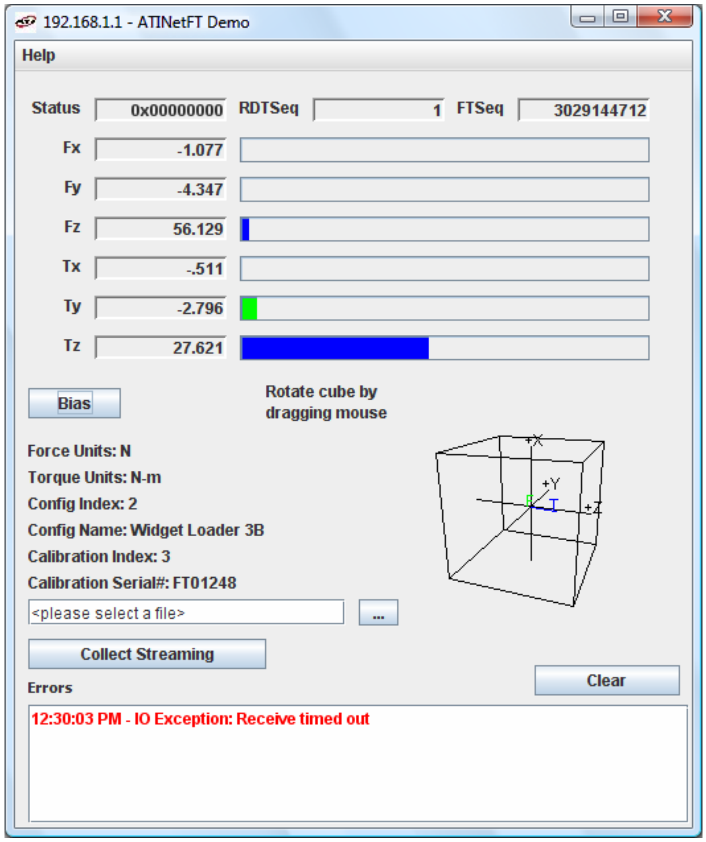


Figure 5.4.1—Java Demo Application with an Error Message

5.5 Developing Your Own Java Application

Experienced Java programmers can develop Net F/T applications using the files in the Java directory of the Net F/T CD. The source code for the Java demo is included in this directory.

6. Net F/T Configuration Utility

The Net F/T Configuration Utility is a Windows program that can find Net F/Ts on an Ethernet network, back up configurations to a computer, restore configurations, and display saved configuration files.

The utility's installation package is in the *Utilities* directory of the Net F/T CD. Install the file by opening the *NetFT_Configuration_Utility_Setup.msi* file. The utility will be installed in the *ATI Industrial Automation* item in the program lists of Windows' *Start* menu.

6.1 Finding Net F/Ts on the Network

Launch *Net F/T Configuration Utility*. Click the Find Net F/T button.

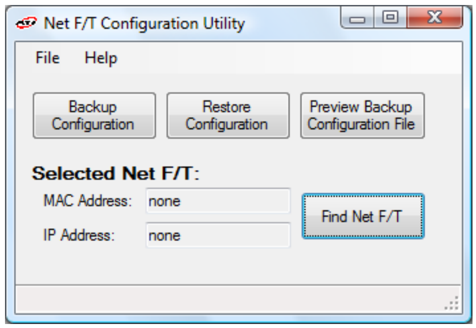


Figure 6.1.1—Net F/T Configuration Utility

If your system has multiple connections to Ethernet a *Select Connection* window will appear. If this is the case, click on the entry *192.168.1.100* and then click *OK*.

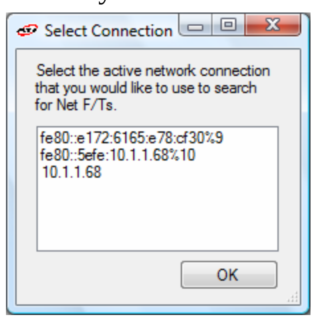


Figure 6.1.2—Selecting an Ethernet Connection

The first time the utility is used it may trigger a firewall alert. This is a normal response for any program that uses the network. In this case it will be necessary to tell the firewall to allow the program to use network connections. If the firewall is told to block connections the utility will not be able to contact the Net F/T. In this case you may need your IT department to undo the firewall block.

If the firewall alert appears it is likely that the utility will not find any Net F/Ts during that search. In this case it will be necessary to click the *Find Net F/T* button again and start over.

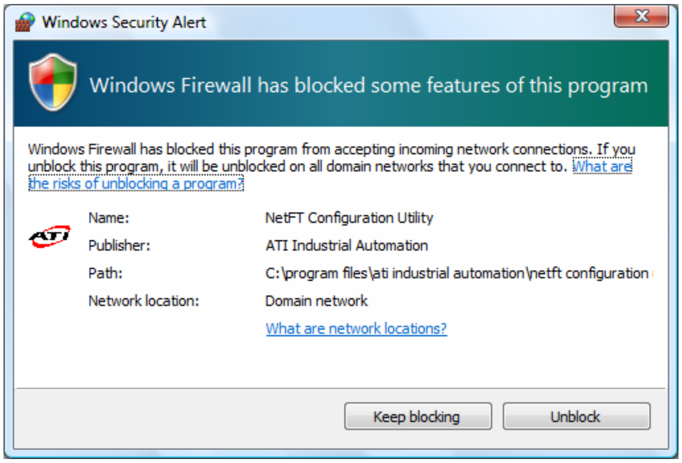


Figure 6.1.3—Windows Vista Firewall Alert

After a slight delay, the program will report back all Net F/Ts found on the network(s). Locate the line that has a MAC ID that matches the MAC ID printed on the Net Box and remember the IP address listed.

Note that the MAC ID listed may have a different format from the Net Box's printed label. In the following example, *Figure 6.4— Net F/Ts Found*, the MAC ID is *00-16-BD-00-00-00*, which matches the printed label *MAC ID: 0016BD000000* and the IP address is *192.168.1.1*.

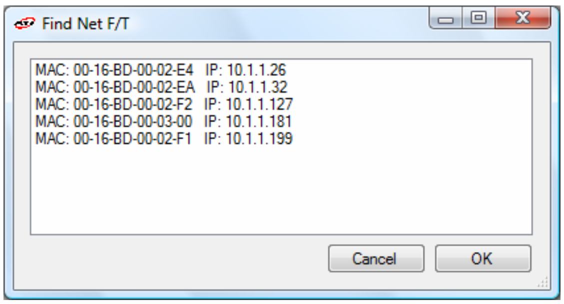


Figure 6.1.4—Net F/Ts Found

The IP address you just found is the address assigned by the DHCP server. You will be using this address to communicate with your Net F/T. Click on this line and then click on *OK*.

Note:

If the Net FT Configuration Utility found the Net F/T, but the internet browser is unable to open the found IP address, you may need to clear previous device entries from the computer's ARP table by restarting the computer or, if you have administrative privileges, by going to the computer's *Start* menu, selecting *Run...*, and entering "*arp –d **".

This should only be necessary if another device previously occupied the same IP address that the Net F/T is now using.

Note:

IP addresses assigned by a DHCP server are not permanent and may change if the Net F/T is disconnected from the network for a period of time. Contact your IT department for more information.

6.2 Backing Up a Configuration to a Computer

The Net F/T Configuration Utility can read the configurations stored in a Net F/T and store them on the local computer. A replacement Net F/T can be easily be set up to replace a damaged Net F/T by restoring a previously backed up configuration file to the new Net F/T. The configuration file contains all user-settable Net F/T information.

To back up a Net F/T, first launch *Net F/T Configuration Utility*. Select the desired Net F/T using the steps in *Section 6.1–Finding Net F/Ts on the Network.*

Next, click on the *Backup Configuration* button to start the process. A save file dialog window will appear. Select a location and file name for the configuration file and click *OK*.

The utility will take a few moments to save the information.

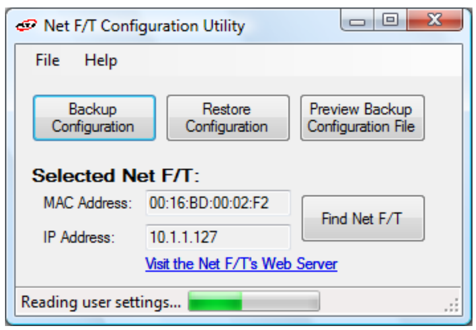


Figure 6.2.1—Backup Configuration

Note:

The NETBA type Net Boxes also contain calibration information for its transducer(s). This transducer calibration information is not saved by the utility. Replacement NETBA type Net Boxes will need to have the transducer calibrations loaded by another method. Contact ATI Industrial Automation for more information.

NETB type Net Boxes do not contain transducer calibration information.

6.3 Restoring a Saved Configuration

A previously-saved configuration file can be loaded into a Net F/T using the restore configuration feature.

To restore a configuration, first launch *Net F/T Configuration Utility*. Select the desired Net F/T using the steps in *Section 6.1–Finding Net F/Ts on the Network.*

Next, click on the *Restore Configuration* button to start the process. An open file dialog window will appear. Select a location and file name of the configuration file and click *OK*.

A confirmation message will appear before the configuration file is loaded into the Net F/T.

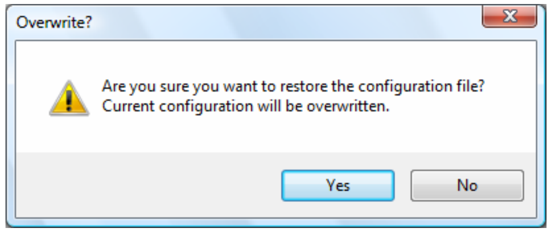


Figure 6.3.1—Restore Confirmation

After the configuration file has been loaded, a completion message will appear. Click OK to dismiss the message. You will need to power cycle the Net F/T to finish the restoration.

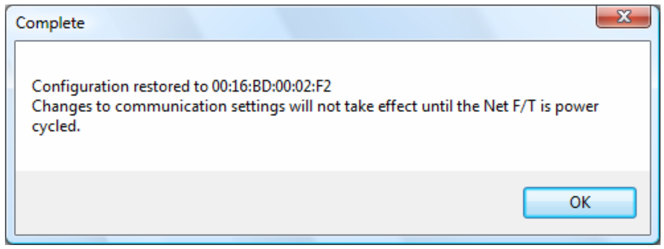


Figure 6.3.2—Restoration Complete

6.4 Inspecting a Saved Configuration File

The Net F/T configuration utility allows you to view some of the information stored in a saved configuration file.

To view a configuration, first launch *Net F/T Configuration Utility*. Click the *Preview Backup Configuration File* button. An open file dialog window will appear. Select a location and file name of the configuration file and click *OK*.

A preview window will open. When finished, click *Close* to dismiss the window.

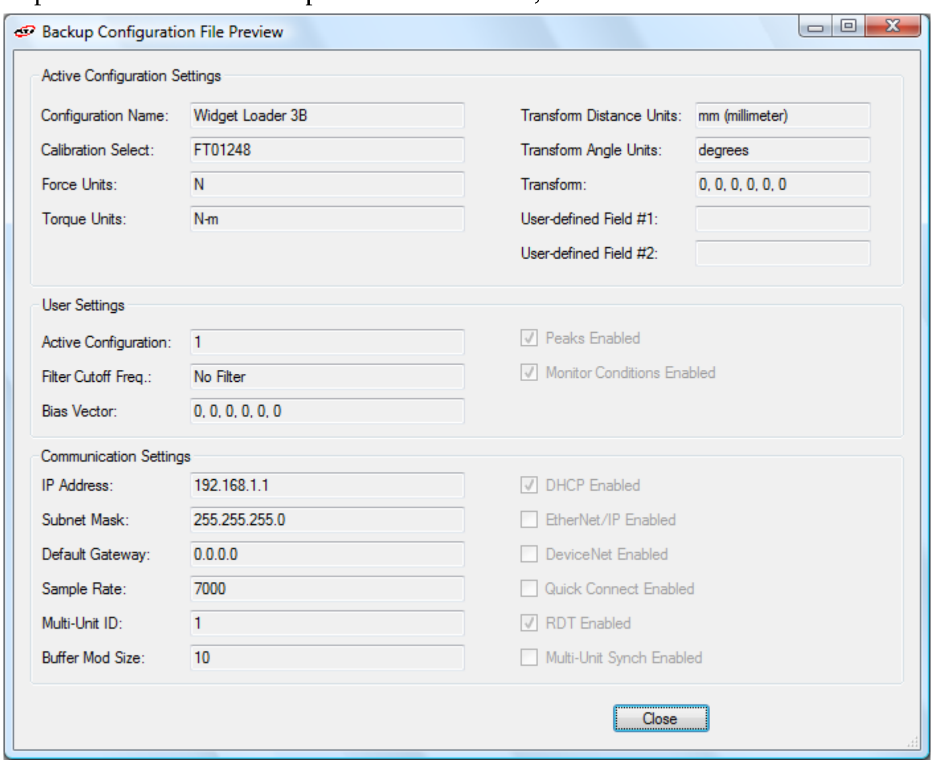


Figure 6.4.1—Backup Configuration File Preview

7. Common Gateway Interface (CGI)

The Net F/T can be configured over Ethernet using the standard HTTP *get* method, which sends configuration variables and their values in the requested URL.

Each variable is only settable from the CGI page which is responsible for that variable. The following tables list each CGI page and the settable variables associated with it.

URLs are constructed using the syntax:

http://<netFTAddress>/<CGIPage.cgi>?<firstVariableAssignment><&nextVariable Assignment>

where:

http://	indicates an HTTP request
<netFTAddress>	is the Ethernet address of the Net F/T system
/	a separator
<CGIPage.cgi>	the name of the CGI page that holds the variables you will be accessing
?	a separator marking the start of variable assignments
<firstVariableAssignment>	a variable assignment using the format described below
<&nextVariableAssignment>	a variable assignment using the format described below, but the variable name is proceeded by an ampersand. This variable assignment is optional and may be repeated for multiple variables.

Variables are assigned new values using the syntax:

variableName=newValue

where:

variableName	is the name of the variable to be assigned
=	indicates assignment
newValue	is the value to be assigned to the variable. Text for text variables should not be enclosed in quotes. To include the ampersand character in text for a text variable use *%26*. Floating point numbers are limited to twenty characters.

Example:

http://192.168.1.1/setting.cgi?setcfgsel=2&setuserfilter=0&setpke=1

tells the Net F/T at IP address 192.168.1.1 to set CGI variables *setcfgsel* to 2, *setuserfilter* to 0, and *setpke* to 1.

The maximum length of these URLs may be determined by a number of factors external to the Net F/T. Exceeding the maximum length may result in an error or variables being incorrectly set.

7.1 Settings CGI (setting.cgi)

This CGI allows you to specify certain global settings such as low-pass filter selection, peak monitoring enable, software bias vector, and active configuration selection. See *Section 4.5—Settings Page (setting.htm)* for related information.

<table>
<tr><th>Variable Name</th><th>Allowed Values</th><th>Description</th></tr>
<tr><td>setcfgsel</td><td>integers: 0 to 15</td><td>Sets the active configuration. Note that the value used by setcfgsel is one less than the configuration numbers displayed on the web pages.</td></tr>
<tr><td>setuserfilter</td><td>integers: 0 to 12</td><td>Sets the cutoff frequency of the low-pass filtering as follows:
<table>
<tr><th>Value</th><th>Cutoff</th><th>Value</th><th>Cutoff</th><th>Value</th><th>Cutoff</th></tr>
<tr><td>0</td><td>no filter</td><td>5</td><td>35 Hz</td><td>10</td><td>2000 Hz</td></tr>
<tr><td>1</td><td>838 Hz</td><td>6</td><td>18 Hz</td><td>11</td><td>2500 Hz</td></tr>
<tr><td>2</td><td>326 Hz</td><td>7</td><td>8 Hz</td><td>12</td><td>3000 Hz</td></tr>
<tr><td>3</td><td>152 Hz</td><td>8</td><td>5 Hz</td><td></td><td></td></tr>
<tr><td>4</td><td>73 Hz</td><td>9</td><td>1500 Hz</td><td></td><td></td></tr>
</table></td></tr>
<tr><td>setpke</td><td>integers: 0 or 1</td><td>Enable (value = 1) or disable (value = 0) peak logging</td></tr>
<tr><td>setbiasn</td><td>integers: -32768 to 32767</td><td>Sets the offset value for strain gage n. For example, setbias3=0 would zero the bias of the fourth strain gage (Strain gages are enumerated starting at zero.)</td></tr>
</table>

Table 7.1—setting.cgi Variables

7.2 Thresholding CGI (moncon.cgi)

This CGI defines and controls thresholding statements. Thresholding statements can be turned off or on and need to have an axis, a comparison type, a comparison counts value, and an output code defined. Refer to *Section 4.6–Thresholding Page (moncon.htm)* for more information on thresholding.

<table>
<tr><th>Variable Name</th><th>Allowed Values</th><th>Description</th></tr>
<tr><td>setmce</td><td>Integers: 0 or 1</td><td>Enable (value = 1) or disable (value = 0) all threshold statement processing.</td></tr>
<tr><td>mcen</td><td>Integers: 0 or 1</td><td>Enable (value = 1) or disable (value = 0) threshold statement n.</td></tr>
<tr><td>mcxn</td><td>Integers: -1 to 5</td><td>Selects the axis evaluated by threshold statement n.
<table>
<tr><th>Value</th><th>Description</th><th>Menu Value</th></tr>
<tr><td>-1</td><td>Statement disabled</td><td>blank</td></tr>
<tr><td>0</td><td>Fx axis</td><td>Fx</td></tr>
<tr><td>1</td><td>Fy axis</td><td>Fy</td></tr>
<tr><td>2</td><td>Fz axis</td><td>Fz</td></tr>
<tr><td>3</td><td>Tx axis</td><td>Tx</td></tr>
<tr><td>4</td><td>Ty axis</td><td>Ty</td></tr>
<tr><td>5</td><td>Tz axis</td><td>Tz</td></tr>
</table></td></tr>
<tr><td>mccn</td><td>Integers: -1 or 1</td><td>Selects the comparison performed in threshold statement n.
<table>
<tr><th>Value</th><th>Description</th><th>Menu Value</th></tr>
<tr><td>-1</td><td>Less Than</td><td><</td></tr>
<tr><td>1</td><td>Greater Than</td><td>></td></tr>
</table></td></tr>
<tr><td>mcvn</td><td>Integers: -2147483648 to +2147483647</td><td>Sets the counts value to compare the current axis value by threshold statement n.</td></tr>
<tr><td>mcon</td><td>Hexadecimal: 0x00 to 0xFF</td><td>Sets the output code for threshold statement n.</td></tr>
<tr><td colspan="3">where n is an integer ranging from 0 to 15 representing the threshold statement index</td></tr>
</table>

Table 7.2—moncon.cgi Variables

7.3 Configurations CGI (config.cgi)

This CGI allows you to specify the output parameters of the sensor system. Any of the sixteen configurations can be defined. Changing configurations allows you to change which transducer calibration to use and what tool transformations to apply to that calibration.

When using config.cgi the *cfgid* value specifies which configuration is targeted. For example, *http://<netFTAddress>/config.cgi?cfgid=3&cfgnam=test123* sets the name of the fourth configuration (which is at index 3) to *test123*.

See *Section 4.7—Configurations Page (config.htm)* for related information.

Variable Name	Allowed Values	Description
cfgid	integers: 0 to 15	Zero-based index of the configuration to be set during this CGI call. **This variable is required for all calls to config.cgi.**
cfgnam	Text string of up to 32 characters	Sets the configuration name.
cfgcalsel	integers: 0 to 15	Sets the calibration used by the configuration.

<table>
<tr><th>Variable Name</th><th>Allowed Values</th><th>Description</th></tr>
<tr><td>cfgfu</td><td>Integers: 1 to 6</td><td>Sets the force units used by the configuration. This value determines the Counts per Force and Max Ratings values on the config.htm user web page.
<table>
<tr><th>Value</th><th>Description</th><th>Menu Value</th></tr>
<tr><td>1</td><td>Pound-force</td><td>lbf</td></tr>
<tr><td>2</td><td>Newtons</td><td>N</td></tr>
<tr><td>3</td><td>Kilopound-force</td><td>klbf</td></tr>
<tr><td>4</td><td>Kilonewton</td><td>kN</td></tr>
<tr><td>5</td><td>Kilogram-force</td><td>kgf</td></tr>
<tr><td>6</td><td>Gram-force</td><td>gf</td></tr>
</table></td></tr>
<tr><td>cfgtu</td><td>Integers: 1 to 6</td><td>The torque units used by the configuration. This value determines the Counts per Torque and Max Ratings values on the config.htm user web page.
<table>
<tr><th>Value</th><th>Description</th><th>Menu Value</th></tr>
<tr><td>1</td><td>Pound-force-inch</td><td>lbf-in</td></tr>
<tr><td>2</td><td>Pound-force-feet</td><td>lbf-ft</td></tr>
<tr><td>3</td><td>Newton-meter</td><td>N-m</td></tr>
<tr><td>4</td><td>Newton-millimeter</td><td>N-mm</td></tr>
<tr><td>5</td><td>Kilogram-force-centimeter</td><td>kgf-cm</td></tr>
<tr><td>6</td><td>Kilonewton-meter</td><td>kN-m</td></tr>
</table></td></tr>
<tr><td>cfgtdu</td><td>Integers: 1 to 5</td><td>The distance measurement units used by the configuration’s tool transformation.
<table>
<tr><th>Value</th><th>Description</th><th>Menu Value</th></tr>
<tr><td>1</td><td>inch</td><td>in (inch)</td></tr>
<tr><td>2</td><td>foot</td><td>ft (foot)</td></tr>
<tr><td>3</td><td>millimeter</td><td>mm (millimeter)</td></tr>
<tr><td>4</td><td>centimeter</td><td>cm (centimeter)</td></tr>
<tr><td>5</td><td>meter</td><td>m (meter)</td></tr>
</table></td></tr>
<tr><td>cfgtau</td><td>Integers: 1 or 2</td><td>The rotation units used by the configuration’s tool transformation.
<table>
<tr><th>Value</th><th>Description</th><th>Menu Value</th></tr>
<tr><td>1</td><td>degrees (°)</td><td>degrees</td></tr>
<tr><td>2</td><td>radians</td><td>radians</td></tr>
</table></td></tr>
<tr><td>cfgtfx0</td><td>Floating point</td><td>Sets the tool transformation distance Dx. Distance must be in cfgtdu distance units.</td></tr>
<tr><td>cfgtfx1</td><td>Floating point</td><td>Sets the tool transformation distance Dy. Distance must be in cfgtdu distance units.</td></tr>
<tr><td>cfgtfx2</td><td>Floating point</td><td>Sets the tool transformation distance Dz. Distance must be in cfgtdu distance units.</td></tr>
<tr><td>cfgtfx3</td><td>Floating point</td><td>Sets the tool transformation rotation Rx. Rotation must be in cfgtau angular units.</td></tr>
<tr><td>cfgtfx4</td><td>Floating point</td><td>Sets the tool transformation rotation Ry. Rotation must be in cfgtau angular units.</td></tr>
<tr><td>cfgtfx5</td><td>Floating point</td><td>Sets the tool transformation rotation Rz. Rotation must be in cfgtau angular units.</td></tr>
</table>

Variable Name	Allowed Values	Description
cfgusra	Text string of up to 16 characters	Stores text in user-defined field #1.
cfgusrb	Text string of up to 16 characters	Stores text in user-defined field #2.

Table 7.3—config.cgi Variables

7.4 Communications CGI (comm.cgi)

This CGI sets the networking options of the Net Box. Refer to *Section 4.8—Communication Settings Page (comm.htm)* for more information on the parameters.

<table>
<tr><th>Variable Name</th><th>Allowed Values</th><th>Description</th></tr>
<tr><td>comnetdhcp</td><td>Integers: 0 or 1</td><td>Sets DHCP behavior.<table><tr><th>Value</th><th>Description</th></tr><tr><td>0</td><td>Use DHCP if available on network</td></tr><tr><td>1</td><td>Use software-defined static IP values</td></tr></table></td></tr>
<tr><td>comnetip</td><td>Any IPV4 address in dot-decimal notation</td><td>Sets the static IP address to be used when DHCP is disabled.</td></tr>
<tr><td>comnetmsk</td><td>Any IPV4 subnet mask in dot-decimal notation</td><td>Sets the subnet mask to be used when DHCP is disabled.</td></tr>
<tr><td>comnetgw</td><td>Any IPV4 address in dot-decimal notation</td><td>Sets the gateway to be used when DHCP is disabled.</td></tr>
<tr><td>comeipe</td><td>Integers: 0 or 1</td><td>Enable (value = 1) or disable (value = 0) EtherNet/IP protocol.</td></tr>
<tr><td>comdnte</td><td>Integers: 0 or 1</td><td>Selects CAN bus protocol.<table><tr><th>Value</th><th>Description</th></tr><tr><td>0</td><td>Basic CAN protocol</td></tr><tr><td>1</td><td>DeviceNet compatibility-mode protocol</td></tr></table></td></tr>
<tr><td>comrdte</td><td>Integers: 0 or 1</td><td>Enable (value = 1) or disable (value = 0) RDT interface.</td></tr>
<tr><td>comrdtrate</td><td>1 to 7000</td><td>Sets the RDT output rate in Hertz. The actual value used may be rounded up; see Section 4.7 – The Communications Page for details.</td></tr>
<tr><td>comrdtbsiz</td><td>Integers: 1 to 40</td><td>RDT Buffer Mode buffer size.</td></tr>
<tr><td>comrdtmsyn</td><td>Integers: 0 or 1</td><td>Enable (value = 1) or disable (value = 0) multi-unit synchronization.</td></tr>
<tr><td>comrdtmuid</td><td>Integers: 0 to 9</td><td>Multi-unit synchronization index.</td></tr>
</table>

Table 7.4—comm.cgi Variables

8. System Settings XML Pages

The Net F/T's current settings can be retrieved in XML format using standard Ethernet HTTP requests. This enables programs to read system settings such as the *Counts per Force* value. The Net F/T's Java demo application uses data provided in these XML pages to correctly scale displayed data.

In the following tables, the data types of XML elements are as follows:

Data Type	Description
DINT	Signed double integer (32 bit)
ENABL	Boolean using *Enabled* to represent 1 and *Disabled* to represent 0
HEX*n*	Hexadecimal number of *n* bits, prefixed with *0x*.
INT	Signed integer (16 bit)
REAL	Floating-point number (32 bit)
SINT	Signed short integer (8 bit)
STRING*n*	String of *n* characters
UDINT	Unsigned double integer (32 bit)
UINT	Unsigned integer (16 bit)
USINT	Unsigned short integer (8 bit)

Table 8.1—Types Used by XML Elements

The values of all data types are presented as an ASCII strings.

Arrays are represented if the suffix *[i]* is attached to the data type, where *i* indicates the number of values in the array. Array values in an XML element may be separated by a semicolon, comma, or space.

8.1 System and Configuration Information (netftapi2.xml)

The XML page *netftapi2.xml* retrieves the system setup and active configuration. To retrieve information about other configurations, those configurations must be made active prior to the request.

A configuration index can be specified when requesting this configuration information. This is done by appending *?index=n* to the request, where *n* is the index of the desired configuration. If a configuration index is not specified the active configuration will be assumed.

For example, to retrieve configuration information for the second configuration the requested page would be *netftapi2.xml?index=1*.

The reference column in *Table 8.2 – XML Elements in netftapi2.xml* indicates which .htm page and .cgi function access this element. Refer to the corresponding entry in *Section 4–Web Pages* or *Section 7–Common Gateway Interface (CGI)* for related information.

XML Element	Data Type	Description	Reference
runstat	HEX32	System status code	–
runft	DINT[6]	Force and torque values in counts	rundata
runpkmx	DINT[6]	Maximum peak values in counts	rundata

XML Element	Data Type	Description	Reference
runpkmn	DINT[6]	Minimum peak values in counts	rundata
runsg	INT[6]	Strain gage values	rundata
runmcb	HEX32	Thresholds breached	rundata
runmco	HEX8	Thresholds output	rundata
runmcl	USINT	Threshold latched	rundata
setcfgsel	USINT	Active configuration	setting
setuserfilter	USINT	Low-pass filter cutoff frequency menu selection	setting
setpke	USINT	Peak monitoring processing status	setting
setbias	DINT[6]	Software bias vector	setting
setmce	USINT	Threshold processing status	moncon
mce	USINT[16]	Threshold statements' individual enabling	moncon
mcx	USINT[16]	Threshold statements' selected axes	moncon
mcc	USINT[16]	Threshold statements' comparisons	moncon
mcv	DINT[16]	Threshold statements' counts values for comparison	moncon
mco	HEX8[16]	Threshold statements' output codes	moncon
cfgnam	STRING32	Name of active configuration	config
cfgcalsel	USINT	Calibration used by active configuration	config
cfgcalsn	STRING8	Serial number of active configuration's calibration	config
cfgfu	USINT	Force units used by active configuration	config
scfgfu	STRING8	Name of force units used by active configuration	config
cfgtu	USINT	Torque units used by active configuration	config
scfgtu	STRING8	Name of torque units used by active configuration	config
cfgcpf	DINT	Counts per force as determined by the active configuration settings	config
cfgcpt	DINT	Counts per torque as determined by the active configuration settings	config
cfgmr	REAL[6]	Calibrated sensing ranges in units as determined by the active configuration settings	config
cfgtdu	USINT	Tool transformation distance units used by active configuration	config
scfgtdu	STRING16	Name of tool transformation distance units used by active configuration	config
cfgtau	USINT	Tool transformation rotation units used by active configuration	config
scfgtau	STRING8	Name of tool transformation rotation units used by active configuration	config
cfgtfx	REAL[6]	Tool transformation distances and rotations applied by active configuration	config
cfgusra	STRING16	User-defined field #1 for the active configuration	config
cfgusrb	STRING16	User-defined field #2 for the active configuration	config
comnetdhcp	ENABL	DHCP behavior setting	comm
comnetip	STRING15	Static IP address	comm
comnetmsk	STRING15	Static IP subnet mask	comm

<table>
<tr><th>XML Element</th><th>Data Type</th><th>Description</th><th>Reference</th></tr>
<tr><td>comnetgw</td><td>STRING15</td><td>Static IP gateway</td><td>comm</td></tr>
<tr><td>comeipe</td><td>ENABL</td><td>EtherNet/IP protocol setting</td><td>comm</td></tr>
<tr><td>nethwaddr</td><td>STRING17</td><td>Ethernet MAC Address</td><td>comm</td></tr>
<tr><td>comdnte</td><td>ENABL</td><td>CAN bus protocol setting</td><td>comm</td></tr>
<tr><td>comdntmac</td><td>USINT</td><td>DeviceNet MAC ID</td><td>comm</td></tr>
<tr><td>comdntbaud</td><td>USINT</td><td>CAN network baud rate:
<table><tr><th>Value</th><th>Baud Rate</th></tr><tr><td>0</td><td>125 kHz</td></tr><tr><td>1</td><td>250 kHz</td></tr><tr><td>2</td><td>500 kHz</td></tr><tr><td>3</td><td>SoftSet</td></tr></table></td><td>comm</td></tr>
<tr><td>comrdte</td><td>ENABL</td><td>RDT interface setting</td><td>comm</td></tr>
<tr><td>comrdtrate</td><td>UDINT</td><td>RDT output rate</td><td>comm</td></tr>
<tr><td>comrdtbsiz</td><td>USINT</td><td>RDT Buffer Mode buffer size</td><td>comm</td></tr>
<tr><td>comrdtmsyn</td><td>ENABL</td><td>Multi-unit synchronization setting</td><td>comm</td></tr>
<tr><td>comrdtmuid</td><td>USINT</td><td>Multi-unit synchronization index</td><td>comm</td></tr>
<tr><td>mfgdighwa</td><td>STRING17</td><td>Ethernet MAC Address</td><td>manuf</td></tr>
<tr><td>mfgdigsn</td><td>STRING8</td><td>Digital board serial number</td><td>manuf</td></tr>
<tr><td>mfgdigver</td><td>STRING8</td><td>Digital board firmware revision</td><td>manuf</td></tr>
<tr><td>mfgdigrev</td><td>STRING8</td><td>Digital board hardware revision</td><td>manuf</td></tr>
<tr><td>mfganasn</td><td>STRING8</td><td>Analog board serial number</td><td>manuf</td></tr>
<tr><td>mfganarev</td><td>STRING8</td><td>Analog board hardware revision</td><td>manuf</td></tr>
<tr><td>mfgtxdmdl</td><td>STRING16</td><td>Analog board location</td><td>manuf</td></tr>
<tr><td>netip</td><td>STRING15</td><td>IP address in use</td><td>–</td></tr>
<tr><td>runrate</td><td>UDINT</td><td>Internal sample rate for strain gage collection</td><td>–</td></tr>
</table>

Table 8.2—netftapi2.xml XML Elements

8.2 Calibration Information (netftcalapi.xml)

The XML page *netftcalapi.xml* retrieves information about a specific calibration. Retrieved calibration information has not been modified by any of the Net F/T's configuration settings.

A calibration index can be specified when requesting this calibration information. This is done by appending *?index=n* to the request, where *n* is the index of the desired calibration. If a calibration index is not specified the currently-used calibration will be assumed.

For example, to retrieve calibration information for the third calibration the requested page would be *netftcalapi.xml?index=2*.

XML Element	Data Type	Calibration Information
calsn	STRING8	Serial number
calpn	STRING32	Calibration type
caldt	STRING20	Calibration date
calfu	USINT	Force units (refer to config.cgi variable *cfgfu* for values)
scalfu	STRING8	Name of force units
caltu	USINT	Torque units used (refer to config.cgi variable *cfgtu* for values)
scaltu	STRING8	Name of torque units
calmr	REAL[6]	Calibrated sensing ranges in *calfu* and *caltu* units
calcpf	DINT	Counts per force unit
calcpt	DINT	Counts per torque unit
calsf	DINT[6]	Scaling factor for DeviceNet and CAN
calusra	STRING16	Calibration note field #1
calusrb	STRING16	Calibration note field #2

Table 8.3—netftcalapi.xml XML Elements

9. UDP Interface Using RDT

The Net F/T can output data at up to 7000 Hz over Ethernet using UDP. This method of fast data collection is called Raw Data Transfer (RDT). If the overhead of DeviceNet or EtherNet/IP is too much for your project, or you need extra speed in your data acquisition, RDT provides an easy method to get the forces, torques, and status codes of the Net F/T system.

9.1 RDT Protocol

There are six commands in the RDT protocol. These are listed in *Table 9.1–RDT Commands*. Any command received by the Net F/T will take precedence over any previously-received commands.

Command	Command Name	Command Response
0x0000	Stop streaming	none
0x0002	Start high-speed real-time streaming	RDT record(s)
0x0003	Start high-speed buffered streaming	RDT record(s)
0x0004	Start multi-unit streaming (synchronized)	RDT record(s)
0x0041	Reset Threshold Latch	none
0x0042	Set Software Bias	none

Table 9.1—RDT Commands

The three streaming modes are further described in *Table 9.2–Streaming Modes*.

Mode	Command	Speed	Situation Best Suited To
0x0002	Start high-speed real-time streaming	Fast (up to 7000 Hz)	Real-time response applications.
0x0003	Start high-speed buffered streaming	Fast (up to 7000 Hz), but comes in bursts (buffers)	Collecting data at high speed, but not responding to it in real-time. Buffer size is set on the *Communication Settings* web page. See *Section 4.7—The Communications Page.*
0x0004	Start multi-unit streaming (synchronized)	Slower, depending on the number of sensor systems involved	Multi-unit synchronization. The multi-unit ID number is set on the *Communication Settings* web page.

Table 9.2—Streaming Modes

To start the Net F/T outputting RDT messages, you first send an RDT request to it. The Net F/T listens for RDT requests on UDP port 49152. It also sends the RDT output messages from this port.

All RDT requests use the following RDT request structure:

```
{
   Uint16 command_header = 0x1234; // Required
   Uint16 command;                 // Command to execute
   Uint32 sample_count;            // Samples to output (0 = infinite)
}
```

Set the *command* field of the RDT request to the command from *Table 9.1—RDT Commands*. Set *sample_count* to the number of samples to output. If you set *sample_count* to zero, the Net Box will output continuously until you send an RDT request with *command* set to zero.

RDT records sent in request to an RDT request have this structure:

```
{
      Uint32 rdt_sequence;        // RDT sequence number of this packet.
      Uint32 ft_sequence;         // The record's internal sequence number
      Uint32 status;              // System status code

      // Force and torque readings use counts values
      Int32 Fx;                   // X-axis force
      Int32 Fy;                   // Y-axis force
      Int32 Fz;                   // Z-axis force
      Int32 Tx;                   // X-axis torque
      Int32 Ty;                   // Y-axis torque
      Int32 Tz;                   // Z-axis torque
}
```

rdt_sequence:	The position of the RDT record within a single output stream. The RDT sequence number is useful for determining if any records were lost in transit. For example, in a request for 1000 records, *rdt_sequence* will start at 1 and run to 1000. The RDT sequence counter will roll over to zero for the increment following 4294967295 (2^{32}-1).
ft_sequence:	The internal sample number of the F/T record contained in this RDT record. The F/T sequence number starts at 0 when the Net F/T is powered up and increments at the internal sample rate (7000 per sec). Unlike the RDT sequence number, *ft_sequence* does not reset to zero when an RDT request is received. The F/T sequence counter will roll over to zero for the increment following 4294967295 (2^{32}-1)
status:	Contains the system status code at the time of the record.
Fx, Fy, Fz, Tx, Ty, Tz:	The F/T data as counts values.

If using buffered mode, then the number of RDT records received in a UDP packet will be equal to the RDT buffer size displayed on the Communications page. See *Section 4.8–Communications Page (comm.htm)* for a description of *RDT Buffer Size*.

9.2 Calculating F/T Values for RDT

To obtain the real force and torque values, each force output value has to be divided by the *Counts per Force* and each torque output value has to be divided by the *Counts per Torque* factor. The *Counts per Force* and *Counts per Torque* factors can be obtained from netftapi2.xml page. See *cfgcpf* and *cfgcpt* in *Section 8.1–System and Configuration Information (netftapi2.xml)*.

9.3 Multi-Unit Mode

This mode allows multiple Net F/T systems to be used in unison. Multi-unit synchronization starts the sampling of all systems at approximately the same moment in time and then coordinate their transmissions to prevent communication collisions. Communications will remain coordinated for a time and then multi-unit synchronization will need to be stopped and restarted to resynchronize.

9.4 Multiple Clients

The RDT protocol is designed to respond to one client only. If a second client sends a command, the Net F/T will respond to the new client. Multiple clients could repeatedly request single packets, minimizing problems. (The Java demo operates in this manner.)

9.5 Notes on UDP and RDT Mode

RDT communications use UDP, with its minimal overhead, to maximize throughput. Unlike TCP, UDP does not check if a package was actually received.

In some Ethernet network configurations this can lead to the loss of RDT data sets. By checking the RDT sequence number of each set, it can be determined if a data set was lost. The RDT sequence number of each data set sent will be one greater than the last data set sent for that RDT request. If a received data set's RDT sequence number is not one greater than the last received data set, then a loss of data has occurred (the program must also account for roll over of the RDT sequence number).

The likelihood of data loss highly depends on the Ethernet network configuration and there are ways to reduce the probability of data loss to almost zero. Refer to *Section 14.1—Improving Ethernet Throughput* for details.

If there are multiple Net F/Ts on the same network, data collisions between Net F/Ts and the subsequent data losses can be eliminated by using the Net F/T's multi-unit synchronization function.

The maximum data latency, measured from the beginning of data acquisition to when the last data bit is sent to the Ethernet network, is less than 28μs.

10. EtherNet/IP Operation

10.1 Overview

The Net F/T operates as a Server on the EtherNet/IP network. It supports Class 3 Connected Explicit Messaging. UCMM Explicit Messaging, and Class 1 Connected Cyclic I/O Messaging. The Net F/T does not support any Client functionality.

EtherNet/IP uses the CIP protocol described in *Section 12–EtherNet/IP and DeviceNet CIP Model*.

EtherNet/IP Protocol must be enabled on the *Communications* page to use EtherNet/IP.

Class 1 Connection Information

	Instance	Size (bytes)
Configuration	128	0
Input	102	28
Output	100	0

10.2 Module and Network Status LED

The module status LED is identified on the Net Box as *MS*. It provides device status for power and proper operation. The EtherNet/IP network status LED is identified on the Net Box as *NS EN*. Refer to *Figure 3.10.1—Status LEDs* and *Table 3.4—Status LED Descriptions* for an outline of the LED operation.

11. DeviceNet-Compatibility Mode Operation

11.1 Overview

The Net F/T operates as a Group 2-Only Server on the DeviceNet network. It supports Explicit Messaging and Polled I/O messaging for the predefined master/Slave Connection set. The Net F/T DeviceNet Node does support the Unconnected Message Manager (UCMM).

DeviceNet-compatibility mode uses the CIP protocol described in *Section 12–EtherNet/IP and DeviceNet CIP Model*.

To use the Net F/T's DeviceNet-Compatibility Mode, *DeviceNet* must be selected on the *Communications* page and power must be present on the *Pwr/CAN* connector.

11.2 MAC ID

The MAC ID is set by either hardware or software configuration to a value from 0 to 63. In order for the MAC ID to be set by software, DIP switch positions 1 through 8 must be *ON*. If the MAC ID is set by software, the baud rate must also be set by software. For more information refer to *Section 3.9.2–Node Address* and *Table 3.2—DeviceNet MAC ID Address Switch Settings.* The factory set MAC ID is 54.

11.3 Baud Rate

Baud Rate is set by either hardware or software configuration to 125Kbps, 250Kbps or 500Kbps. The baud rate will be set by software when DIP switch positions 7 and 8 are *ON*. For more information refer to *Section 3.9.3–Baud Rate* and *Table 3.3—Baud Rate Switch Settings*. The factory set baud rate is 500Kbps.

11.4 Module and Network Status LED

The module status LED is identified on the Net Box as *MS*. It provides device status for power and proper operation. The DeviceNet network status LED is identified on the Net Box as *NS DN*. Refer to *Figure 3.10.1—Status LEDs* and *Table 3.4—Status LED Descriptions* for an outline of the LED operation.

11.5 EDS File

The DeviceNet EDS (Electronic Data Sheet) file for the system can be found in the *\EDS* directory on the system CD.

12. EtherNet/IP and DeviceNet CIP Model

12.1 Overview

The Net F/T operates as a Group 2-Only Server on the DeviceNet network. It supports Explicit Messaging and Polled I/O messaging for the predefined Master/Slave Connection set. The Net F/T DeviceNet Node does support the Unconnected Message Manager (UCMM).

The Net F/T operates as a Server on the EtherNet/IP network. It supports Class 3 Connected Explicit Messaging. UCMM Explicit Messaging and Class 1 Connected Cyclic I/O Messaging. The Net F/T does not support any Client functionality.

Name	Data Value
Vendor Number	555
Device Type	0
Product Code Number	1
Product Name	ATI Industrial Automation F/T

12.2 DeviceNet Input Bitmap

WORD (16-bit)	Name
0	Status word, bits 16 through 31
1	Fx (16-bit)
2	Fy (16-bit)
3	Fz (16-bit)
4	Tx (16-bit)
5	Ty (16-bit)
6	Tz (16-bit)

12.3 EtherNet/IP Input Bitmap

DWORD (32-bit)	Name
0	Status word (32-bit)
1	Fx (32-bit)
2	Fy (32-bit)
3	Fz (32-bit)
4	Tx (32-bit)
5	Ty (32-bit)
6	Tz (32-bit)

12.4 Calculating F/T Values for CIP

12.4.1 EtherNet/IP

To obtain the real force and torque values, each force output value has to be divided by the *Counts per Force* and each torque output value has to be divided by the *Counts per Torque* factor.

The *Counts per Force* and *Counts per Torque* factors can be obtained from the Configurations web page. See *Section 4.7—Configurations Page (config.htm)* for more information.

12.4.2 DeviceNet

In order to reduce the amount of data transmitted over DeviceNet, the force and torque values are reduced to 16 bits using the *Scaling Factor for DeviceNet and CAN* values (*Figure 12.4.1—Scaling Factors for DeviceNet and CAN*) before they are transmitted.

To obtain the force and torque values in user units, each received force value has to be divided by (*Counts per Force* ÷ *Scaling Factor for DeviceNet and CAN*) for the axis and each received torque value has to be divided by (*Counts per Torque* ÷ *Scaling Factor for DeviceNet and CAN*) for the axis.

The *Counts per Force*, *Counts per Torque*, and Scaling Factor for DeviceNet and CAN factors can be found on configurations web page. For more information, see *Section 4.7—Configurations Page (config.htm)*.

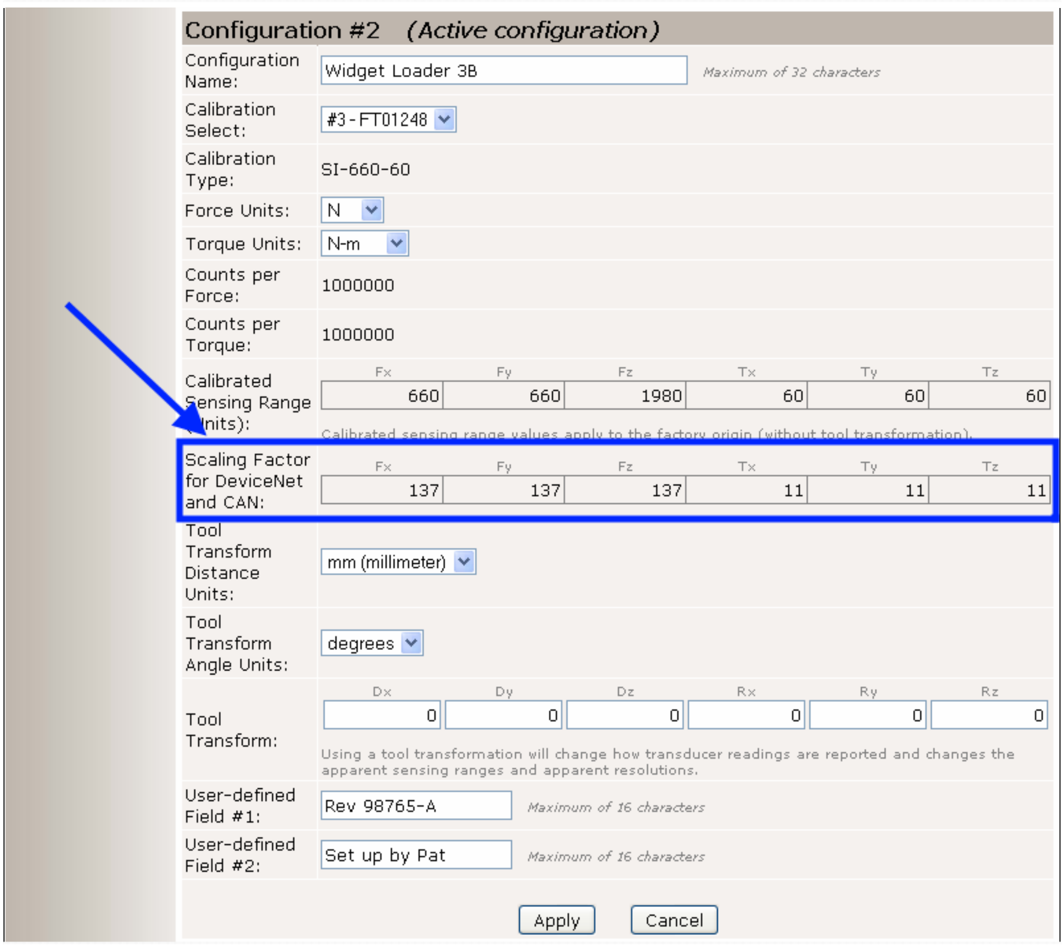


Figure 12.4.1—Scaling Factors for DeviceNet and CAN

12.5 Object Model

12.5.1 Data Types

The following is a description of all of the data types used in the object model:

Data Type	Description
BOOL	Boolean
BYTE	Bit String (8-bit)
DINT	Signed Double Integer (32-bit)
DWORD	Bit String (32-bit)
INT	Signed Integer (16-bit)
REAL	Floating Point
SHORT_STRING	Character string (1 byte per character, 1 byte length indicator)
SINT	Signed Short Integer (8-bit)
STRING	Character String (1 byte per character)
UDINT	Unsigned Double Integer (32-bit)
UINT	Unsigned Integer (16-bit)
USINT	Unsigned Short Integer (8-bit)
WORD	Bit String (16-bit)

12.5.2 Transducer Strain Gage Object (0x64—6 Instances)

Class Attributes (Instance 0)

Attribute ID	Name	Data Type	Default Data Value	Access Rule
1	Revision	UINT	N/A	Get
2	Max Instance	UINT	6	Get
3	Number of Instances	UINT	6	Get
100	Bias	USINT	N/A	Set

Bias – any set to non-zero value will bias, a set to zero will unbias the transducer readings.

Instance Attributes (Instance 1–6)

Attribute ID	Name	Data Type	Default Data Value	Access Rule
1	Raw Gage Reading	INT	N/A	Get
2	Gage Bias	INT	N/A	Get/Set

Instances 1–6 correspond to Gages 0–5 respectively.

Common Services

Service Codes	Implemented for		Service Name
	Class Level	Instance Level	
0x0E	Yes	Yes	Get_Attribute_Single
0x10	No	Yes	Set_Attribute_Single

Instances 1–6 correspond to Gages 0–5 respectively.

12.5.3 Transducer Force/Torque Object (0x65—6 Instances)

Class Attributes (Instance 0)

Attribute ID	Name	Data Type	Default Data Value	Access Rule
1	Revision	UINT	1	Get
2	Max Instance	UINT	6	Get

Attribute ID	Name	Data Type	Default Data Value	Access Rule
3	Number of Instances	UINT	6	Get

Instance Attributes (Instance 1–6)

Attribute ID	Name	Data Type	Default Data Value	Access Rule
1	Resolved Axis Data (32-bit)	DINT	N/A	Get
2	Resolved Axis Data (16-bit) (for DeviceNet)	INT	N/A	Get
3	Minimum Peak	DINT	N/A	Get/Set†
4	Maximum Peak	DINT	N/A	Get/Set†

Instances 1, 2, 3, 4, 5, 6 correspond to axis Fx, Fy, Fz, Tx, Ty, Tz respectively.
†Any set attribute value will reset the specified peak value.

Common Services

Service Codes	Implemented for		Service Name
	Class Level	Instance Level	
0x0E	Yes	Yes	Get_Attribute_Single
0x10	No	Yes	Set_Attribute_Single

12.5.4 Thresholding Output Object (0x66—1 Instance)

Class Attributes (Instance 0)

Attribute ID	Name	Data Type	Default Data Value	Access Rule
1	Revision	UINT	1	Get

Instance Attributes (Instance 1)

Attribute ID	Name	Data Type	Default Data Value	Access Rule
1	Thresholds Breached	DWORD	N/A	Get
2	Thresholds Output Result	BYTE	N/A	Get
3	Threshold Latched	BOOL	N/A	Get/Set†

†Threshold Latched – any set attribute value will reset value to *FALSE*.

Common Services

Service Codes	Implemented for		Service Name
	Class Level	Instance Level	
0x0E	Yes	Yes	Get_Attribute_Single
0x10	No	Yes	Set_Attribute_Single

12.5.5 System Status Object (0x67—1 Instance)

Class Attributes (Instance 0)

Attribute ID	Name	Data Type	Default Data Value	Access Rule
1	Revision	UINT	1	Get

Instance Attributes (Instance 1)

Attribute ID	Name	Data Type	Default Data Value	Access Rule
1	Status Code (32-bit)	DWORD	N/A	Get
2	Status Code (16-bit)†	WORD	N/A	Get

†This attribute is sized for DeviceNet.

Common Services

Service Codes	Implemented for		Service Name
	Class Level	Instance Level	
0x0E	Yes	Yes	Get_Attribute_Single

12.5.6 Configurations Object (0x71—16 Instances)

Class Attributes (Instance 0)

Attribute ID	Name	Data Type	Default Data Value	Access Rule
1	Revision	UINT	1	Get
2	Max Instance	UINT	n	Get
3	Number of Instances	UINT	n	Get

Instance Attributes (Instance 1–16)

Attribute ID	Name	Data Type	Default Data Value	Access Rule
1	Configuration Name	SHORT_STRING[32]	N/A	Get/Set
2	Calibration Selection (0 to 15)	USINT	N/A	Get/Set
3	Calibration Selection's Calibration Type	SHORT_STRING[32]	N/A	Get
4	User Force Units†	BYTE	N/A	Get/Set
5	User Torque Units‡	BYTE	N/A	Get/Set
6	User Transform – Dx	REAL	N/A	Get/Set
7	User Transform – Dy	REAL	N/A	Get/Set
8	User Transform – Dz	REAL	N/A	Get/Set
9	User Transform – Rx	REAL	N/A	Get/Set
10	User Transform – Ry	REAL	N/A	Get/Set
11	User Transform – Rz	REAL	N/A	Get/Set
12	User Transform Distance Units††	BYTE	N/A	Get/Set
13	User Transform Angle Units‡‡	BYTE	N/A	Get/Set
14	User Counts per Unit Force	UINT	N/A	Get
15	User Counts per Unit Torque	UINT	N/A	Get
16	User Max Rating – Fx	REAL	N/A	Get

Attribute ID	Name	Data Type	Default Data Value	Access Rule
17	User Max Rating – Fy	REAL	N/A	Get
18	User Max Rating – Fz	REAL	N/A	Get
19	User Max Rating – Tx	REAL	N/A	Get
20	User Max Rating – Ty	REAL	N/A	Get
21	User Max Rating – Tz	REAL	N/A	Get
100	User Defined Field #1	SHORT_STRING[16]	N/A	Get/Set
101	User Defined Field #2	SHORT_STRING[16]	N/A	Get/Set

† Refer to *cfgfu* in *Section 7.3–Configuration CGI (config.cgi)* for force units.
‡ Refer to *cfgtu* in *Section 7.3–Configuration CGI (config.cgi)* for torque units.
†† Refer to *cfgtdu* in *Section 7.3–Configuration CGI (config.cgi)* for tool transformation distance units.
‡‡ Refer to *cfgtau* in *Section 7.3–Configuration CGI (config.cgi)* for tool transformation angle units.

Common Services

Service Codes	Implemented for		Service Name
	Class Level	Instance Level	
0x0E	Yes	Yes	Get_Attribute_Single
0x10	No	Yes	Set_Attribute_Single

12.5.7 Settings Object (0x72—1 Instance)

Class Attributes (Instance 0)

Attribute ID	Name	Data Type	Default Data Value	Access Rule
1	Revision	UINT	1	Get

Instance Attributes (Instance 1)

Attribute ID	Name	Data Type	Default Data Value	Access Rule
1	Configuration Selection (0 to 15)	USINT	N/A	Get/Set
4	Peaks Enable/Disable	BOOL	N/A	Get/Set
5	Thresholding Enable/Disable	BOOL	N/A	Get/Set

Common Services

Service Codes	Implemented for		Service Name
	Class Level	Instance Level	
0x0E	Yes	Yes	Get_Attribute_Single
0x10	No	Yes	Set_Attribute_Single

12.5.8 Thresholding Settings Object (0x73—32 Instances)

Class Attributes (Instance 0)

Attribute ID	Name	Data Type	Default Data Value	Access Rule
1	Revision	UINT	1	Get
2	Max Instance	UINT	32	Get
3	Number of Instances	UINT	32	Get

Instance Attributes (Instance 1–32)

Attribute ID	Name	Data Type	Default Data Value	Access Rule
1	Enable/Disable	BOOL	N/A	Get/Set
2	Axis Number†	SINT	N/A	Get/Set
3	Comparison‡	SINT	N/A	Get/Set
4	Counts Value	DINT	N/A	Get/Set
5	Output Code	BYTE	N/A	Get/Set

† Refer to *mcxn* in *Section 7.2–Thresholding CGI (moncon.cgi)* for axis information.
‡ Refer to *mccn* in *Section 7.2–Thresholding CGI (moncon.cgi)* for comparison information.

Common Services

Service Codes	Implemented for		Service Name
	Class Level	Instance Level	
0x0E	Yes	Yes	Get_Attribute_Single
0x10	No	Yes	Set_Attribute_Single

13. CAN Bus Operation

13.1 Overview

The Net F/T supports a basic CAN protocol to allow reading of force/torque data and system status word over CAN without the need for a DeviceNet scanner.

The CAN Bus base address and Baud Rate settings are configured using the DIP switches. Refer to *Section 3.9—DIP Switches and Termination Resistor* for additional information.

To use the Net F/T's CAN bus protocol, *CAN Bus* must be selected on the *Communications* page and power must be present on the *Pwr/CAN* connector.

13.2 Protocol Description

A request data message sent to the Net F/T initiates copying of the current set of force and torque data into an output buffer and the subsequent transmission of the output buffer.

Depending on the request message identifier (REQUEST LONG or REQUEST SHORT), the Net F/T either sends 32-bit values packed into four messages or 16-bit values packed into two messages.

Values are in little endian format (least-significant byte first). For example, a 16-bit value received as 0x56 0x02 represents 0x0256. Signed numbers use 2's complement format. The 32-bit value received as 0x0F 0xCF 0xDA 0xDA 0xFD represents 0xFDDACF0F, which is a negative number (because the highest bit is set). Its decimal value is -35991793.

If a data request message is received during an ongoing transmission, the ongoing transmission will be terminated and the new request processed.

13.2.1 Request Long Data

Message to Net F/T	Response from Net F/T	CAN Identifier	Data length in bytes	1st–4th data bytes	5th–8th data bytes	Comment
Request Long Data		0	1	0x01 (BYTE)	N/A	Sends a copy of force and torque data in long format (an ongoing transmission will be terminated)
	Fx and Tx data	1	8	Fx value (DINT)	Tx value (DINT)	X-axis force and torque values in long format
	Fy and Ty data	2	8	Fy value (DINT)	Ty value (DINT)	Y-axis force and torque values in long format.
	Fz and Tz data	3	8	Fz value (DINT)	Tz value (DINT)	Z-axis force and torque values in long format.
	Status and sample number	4	8	system status (DINT)	sample number (DINT)	System status word and sample number in long format.

13.2.2 Request Short Data

Message to Net F/T	Response from Net F/T	CAN Identifier	Data length in bytes	1st–4th data bytes	5th–8th data bytes	Comment
Request Short Data		0	1	0x02 (BYTE)	N/A	Sends a copy of force and torque data in short format (an ongoing transmission will be terminated)
	Fx, Tx, Fy, and Tx data	5	8	Fx value (INT) Tx value (INT)	Fy value (INT) Ty value (INT)	X-axis force and torque values and Y-axis force and torque in short format

	Fz and Tz data, Status, and sample number	6	8	Fz value (INT) Tz value (INT)	system status (INT) sample number (INT)	Z-axis force and torque values, system status word, and sample in short format.

13.2.3 Bias Command

Message to Net F/T	Response from Net F/T	CAN Identifier	Data length in bytes	1st–4th data bytes	5th–8th data bytes	Comment
Bias		0	1	0x04 (BYTE)	N/A	Zeros the force and torque readings at the current loading level.

13.2.4 Clear Threshold Latch Command

Message to Net F/T	Response from Net F/T	CAN Identifier	Data length in bytes	1st–4th data bytes	5th–8th data bytes	Comment
Clear Threshold Latch		0	1	0x08 (BYTE)	N/A	Clears the threshold latch so it can respond to subsequent conditions.

13.3 Base Address

The CAN Bus base address is set by DIP switches 1 through 6. For more information refer to *Section 3.9.2–Node Address* and *Table 3.1—CAN Bus Base Address Switch Settings.* The factory set base address is 432.

13.4 Baud Rate

Baud Rate is set by either hardware or software configuration to 125Kbps, 250Kbps or 500Kbps. The baud rate will be set by software when DIP switch positions 7 and 8 are *ON*. For more information refer to *Section 3.9.3–Baud Rate* and *Table 3.3—Baud Rate Switch Settings*. The factory set baud rate is 500Kbps.

13.5 Calculating F/T Values for CAN

The Net F/T multiplies each force and torque value with a factor before it is sent over the CAN interface. This allows for sending force and torque values with the full resolution. The application program has to divide each force and torque value with a specific factor to obtain the real data.

Refer to *Section 12.2—DeviceNet Input Bitmap* for 16-bit data handling and *Section 12.3—EtherNet/IP Input Bitmap* for 32-bit data handling.

14. Advanced Topics

14.1 Improving Ethernet Throughput

In an optimum network setup, the Net F/T's 7000 samples per second of RDT data will arrive at the host computer with no loss of data

If you observe lost data samples, you may do one or all of the following:

14.1.1 Direct Connection between Net F/T and Host

To achieve the best Ethernet performance (and avoiding the loss of data packages), we recommend connecting the Net Box directly to the host computer. If you need to use a switch, then try to use only one switch between sensor system and host. Avoid going through several switches or going through a hub.

14.1.2 Choice of Operating System

The Windows operating system periodically performs housekeeping processes that can require a significant amount of processing power over a short amount of time. During these intervals, a loss of data can occur because Windows does not treat UDP data with a high enough priority. If a loss of data is not acceptable for your application, then the use of a real-time operating system is recommended.

14.1.3 Increasing Operating System Performance

The following items may also help you increase the performance of your computer system so it can best respond to the Net F/T's fast data rates:

Disable software firewall. One way to improve the Ethernet performance is not to have any software firewall activated. In some cases, this may require help from IT personnel.

Disable file and printer sharing. The processes associated what file and printer sharing can slow down an operating system's response to Ethernet data and may lead to lost data.

Disable unnecessary network services. Unnecessary network services and protocols can slow down an operating system's response to Ethernet data and may lead to lost data. For the best UDP performance, it may be necessary to turn off every network service except for TCP/IP.

Use an Ethernet traffic snooper. An Ethernet traffic snooper can be invaluable in detecting that there are processes using up Ethernet bandwidth and potentially slowing down the response of your computer's operating system. This is an advanced technique that your IT department may need to perform. The free software program Wireshark (www.wireshark.org) is commonly used for this type of investigation.

Use a dedicated computer. A dedicated measurement computer isolated from the company network will not be burdened by the company network processes.

Use the Net F/T's multi-unit synchronization capability if there are multiple Net F/Ts on the same network. This will eliminate data collisions from Net F/Ts transmitting at the same time.

14.1.4 Avoid Logging the Host to a Company Network

Being logged onto a network requires the periodic access to the Ethernet interface by processes other than your measurement application. This can lead to loss of UDP packages.

14.1.5 Use a Dedicated Network

Placing the Net F/T on a dedicated Ethernet network with no other devices on the network, other than the host computer, will remove data collisions and give the best network performance.

14.2 Reducing Noise

14.2.1 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. The Net F/T system offers digital low-pass filters that can dampen frequencies above a certain threshold. If this is not sufficient, you may want to add a digital filter to the application software.

14.2.2 Electrical Interference

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

Consider using the Net F/T's digital low pass filters if sufficient grounding is not possible or does not reduce the noise.

Verify that you are using a Class 1 power supply, which has an earth ground connection.

14.3 Detecting Failures (Diagnostics)

14.3.1 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).

14.4 Scheduled Maintenance

14.4.1 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 14.3—Detecting Failures (Diagnostics)* to detect any failures.

The transducer must be kept free of excessive dust, debris, or moisture. Applications with metallic debris (i.e., electrically-conductive) must protect the transducer from this debris. Transducers without specific factory-installed protection are to be considered unprotected. The internal structure of the transducers can become clogged with particles and will become uncalibrated or even damaged.

14.5 A Word about Resolution

ATI's transducers have a three sensing beam configuration where the three beams are equally spaced around a central hub and attached to the outside wall of the transducer. This design transfers applied loads to multiple sensing beams and allows the transducer to increase its sensing range in a given axis if a counterpart axis has reduced (see *9620-05-Transducer Section—Installation and Operation Manual*).

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

F/T resolutions are specified as typical resolution, defined as the average of the worst and best case scenarios. Because both multi-gage effects can be modeled as a normal distribution, this value represents the most commonly perceived, average resolution. Although this misrepresents the actual performance of the transducers, it results in a close (and always conservative) estimate.

15. Troubleshooting

15.1 Introduction

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

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

ATI Industrial Automation
Attn: F/T Customer Service
Pinnacle Park
1031 Goodworth Drive
Apex, NC 27539 USA

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

> ***Note:***
>
> Please read the F/T manuals before calling customer service. When calling, have the following information available:
>
> 1. Serial number(s)
> 2. Transducer type (e.g., Nano17, Gamma, Theta)
> 3. Calibration (e.g., US-15-50, SI-130-10)
> 4. An accurate and complete description of the question or problem.
> 5. All information that is displayed on Net F/T page *System Info* (*manuf.htm*).
>
> If possible, the F/T system should be accessible when talking with an ATI Industrial Automation customer service representative.

15.2 System Status Code

The Net F/T performs many diagnostic checks during operation and reports results in a 32-bit system status code. Each F/T record includes this system status code. The bit patterns for all present error conditions are or'ed together to form the system status code. If any error condition is present then bit 31 of the system status code is set.

Bit 16 is set if a threshold is latched. This bit does not indicate a system error.

The system status code should be:

0x00000000 if no errors and no threshold statements are breached

0x80010000 if no errors and a threshold statement is breached.

Any other code signals means there is a serious error. *Table 15.1–System Status Code Bit Assignments* describes possible errors and their bit assignments.

Bit	Bit Pattern	Description
31	0x80000000	Error bit (set if any error condition exists)
30	0x40000000	CPU or RAM error
29	0x20000000	Digital board error
28	0x10000000	Analog board error
27	0x08000000	Serial link communication error
26	0x04000000	Program memory verification error
25	0x02000000	Halted due to configuration errors
24	0x01000000	Settings validation error
23	0x00800000	Configuration settings incompatible with transducer calibration
22	0x00400000	Network communication failure
21	0x00200000	CAN communication error
20	0x00100000	RDT communication error
19	0x00080000	EtherNet/IP protocol failure
18	0x00040000	DeviceNet-compatibility mode protocol failure
17	0x00020000	Transducer Saturation or A/D operation error
16	0x00010000	Threshold latched
15	0x00008000	reserved
14	0x00004000	Watchdog timeout error
13	0x00002000	Stack check error
12	0x00001000	Serial EEPROM I2C communications failure
11	0x00000800	Serial flash SPI communications failure
10	0x00000400	Analog board watchdog timeout error
9	0x00000200	Excessive strain gage excitation current
8	0x00000100	Insufficient strain gage excitation current
7	0x00000080	Artificial analog ground out of range
6	0x00000040	Analog Board power supply too high
5	0x00000020	Analog Board power supply too low
4	0x00000010	Serial link data unavailable
3	0x00000008	Reference voltage or power monitoring error
2	0x00000004	Internal temperature error
1	0x00000002	HTTP protocol failure
0	0x00000001	reserved
–	0x00000000	Healthy

Table 15.1—System Status Code Bit Assignments

15.3 Questions and Answers

15.3.1 Powering Up

Question/Problem	Answer/Solution
Xdcr LED stays red after the twenty second power up phase	Check transducer cable connections. Verify transducer cable is not damaged. There may be an internal error in the Net Box.
Xdcr LED is red for the first twenty seconds after power up then turns green	This is normal operation.
The *LS EN* (Ethernet Link Status) is not green or flashing green	Check Ethernet cable connections.

15.3.2 Communications

Question/Problem	Answer/Solution
What IP address is assigned to the Net F/T?	See *Section 6.1—Finding Net F/Ts on the Network*.
How can the Net F/T system be set to the default IP address of *192.168.1.1*?	Set DIP switch 9 to the ON position (see *Section 3.9—DIP Switches and Termination Resistor*). The Net F/T must be power cycled for the new setting to be used.
DHCP is not assigning an IP address	Ethernet LAN must be connected during power up. *DHCP* is not selected as the *IP Address Mode* on the *Communications* page. The DHCP server waits more than thirty seconds to respond.
Browser cannot find the Net F/T on Ethernet network even though the Net F/T configuration utility reports an IP address	Clear the Windows computer's ARP table to remove memory of a previous device that used the same IP address as the Net F/T by restarting the computer or, if you have administrative privileges, by going to the computer's *Start* menu, selecting *Run...*, and entering "`arp –d *`".
Incorrect *CAN Bus Base Address*, *DeviceNet MAC ID*, and/or *Baud Rate* reported	Power must be present on the *Pwr/CAN* connector to correctly report these values.
System status reports *DeviceNet Protocol Failure* when using DeviceNet	DeviceNet is not available unless power is present on the *Pwr/CAN* connector.

15.3.3 Java Demo

Question/Problem	Answer/Solution
Demo displays zeros for force and torque values and question marks for configuration data	Check IP address and restart demo.
Excessive *IO exception: Receive timed out* errors	The Ethernet connection was interrupted. Check Ethernet cabling and Net F/T power.
Error message: *IO exception: <path and file name> (The process can not access the file because it is being used by another process)*	Selected file for data is in use by another program. Close file or change file name and press *Collect Streaming* again.
The message *Could not find the main class. Program will exit* appears in a window titled *Java Virtual Machine Launcher*.	Computer requires a newer version of Java. Java may be downloaded from www.java.com/getjava.

15.3.4 Web Pages

Question/Problem	Answer/Solution
The *Invalid Request* page appears	One or more entries on the previous web page were invalid or out of range. Go back to the previous page and review the last entry. Make only one change at a time to make debugging easier.
The *HTTP 1.0 401 Error - Unauthorized* page appears	You tried to access one of the protected pages of the web server. These pages are reserved for ATI Industrial Automation maintenance.

15.3.5 Errors with Force and Torque Readings

Bad data from the transducer's strain gages can cause errors in force/torque readings. These errors can result in problems with threshold monitoring, transducer biasing, and accuracy. Listed below are the basic conditions of bad data. Use this to troubleshoot your problem. In most cases, problems can be seen better while looking at the raw strain gage data, displayed on the *Snapshot* page. See *Section 4.3—Snapshot Page (rundata.htm)* for more details.

Question/Problem	Answer/Solution
Sat LED glows red (transducer saturation)	Saturation occurs if the transducer is loaded beyond its maximum measurement range or in the event of an electrical failure within the system. The error status will stay on until the saturation error stops. When the data from a raw decimal strain gage reads the positive or negative maximums (nominally -32768 or +32767), that gage is saturated. This sets the saturation error bit in the system status code (see …) and causes the *Sat* LED to turn red.
Noise	Jumps in raw strain gage readings (with transducer unloaded) greater than 80 counts is considered abnormal. Noise can be caused by mechanical vibrations and electrical disturbances, possibly from a poor ground. It can also indicate component failure within the system. See *Section 14.2—Reducing Noise.*
Drift	After a load is removed or applied, the raw gage reading does not stabilize, but continues to increase or decrease. This may be observed more easily in resolved data mode using the bias command. Drift is caused by temperature change, mechanical coupling, or internal failure. Mechanical coupling is caused when a physical connection is made between the tool plate and the transducer body (i.e., filings between the tool adapter plate and the transducer body). Some mechanical coupling is common, such as hoses and wires attached to a tool.
Hysteresis	When the transducer is loaded and then unloaded, gage readings do not return quickly and completely to their original readings. Hysteresis is caused by mechanical coupling (explained in Drift section) or internal failure.

15.3.6 Connection to Specific Equipment

Equipment Connection	Details
Fanuc robot controllers using EtherNet/IP	Set robot controller connection type to *Input Only* and set the robot controller as the EtherNet/IP scanner (client). When using Socket Messaging, set the transport type to *Multicast* for UDP or *Unicast* for TCP.

16. General Specifications

16.1 Environmental

The standard 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. Transducers with an IP65 designation can be washed down with fresh water. Transducers with an IP68 designation can be submerged in up to 10m of fresh water.

The Net Box is rated to IP65.

16.1.1 Storage and Operating Temperatures

The Net F/T transducer and Net Box can be stored and used at varying temperatures.

	Storage Temperature, °C	Operating Temperature, °C
Net Box	-40 to +100	-20 to +70

Table 16.1—Storage and Operating Temperatures

Note: These temperature ranges specify the storage and operation ranges in which the system can survive without damage. They do not take accuracy into account. See ATI Industrial Automation manual *9620-05-Transducer Section* for transducer environmental information.

When mated with appropriate connectors, the 9105-Net Box can be used in wet environments. The 9105-NETB Net Box can only be used in humidity up to 95% RH, non-condensing.

16.2 Transducer Data Filtering

Figure 16.2.1—Data Acquisition Subsystem Frequency Response (typical) shows the frequency response of the transducer's data acquisition hardware and various filtering options. The graph does not include the effects of any mechanical filtering (which occurs in any spring and mass system).

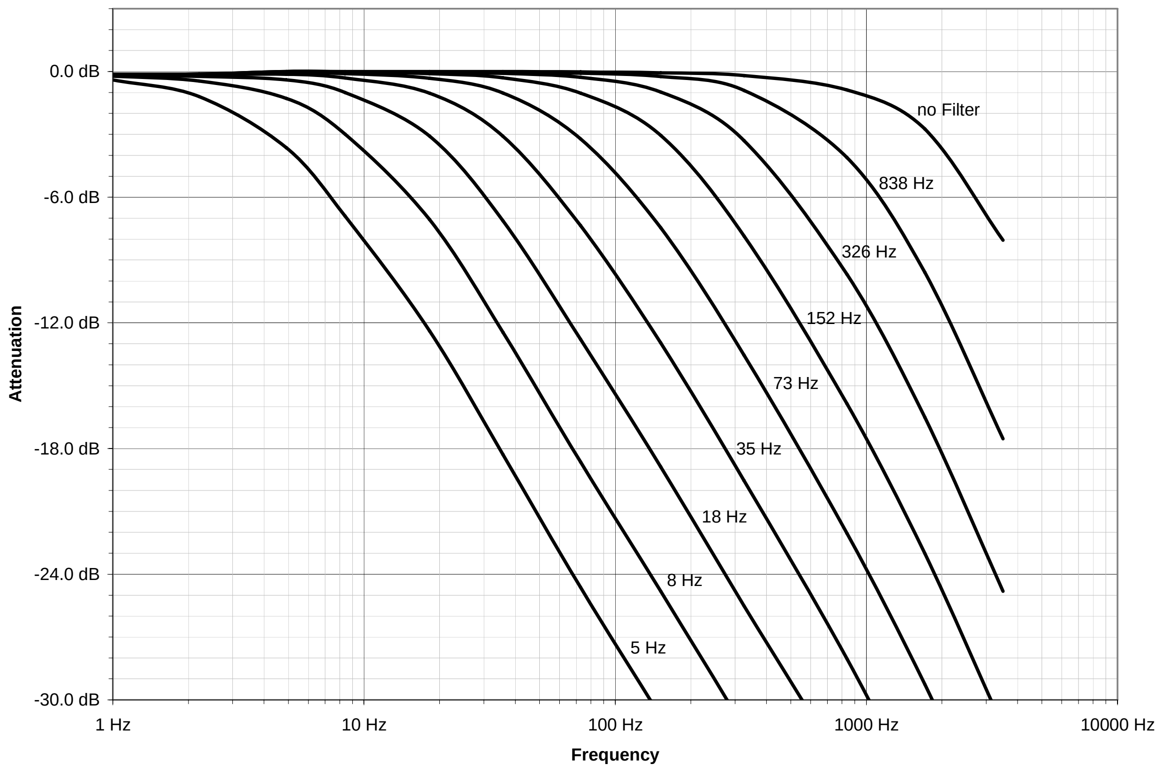


Figure 16.2.1—Data Acquisition Subsystem Frequency Response (typical)

Figure 16.2.2—Filtering Group Delays (calculated) shows the group delays that various levels of low-pass filtering add to the signals. These delays do not show the Ethernet delays in your network or computer. With no filtering enabled, the Net F/T delivers F/T data to its Ethernet port with a delay of 286µS.

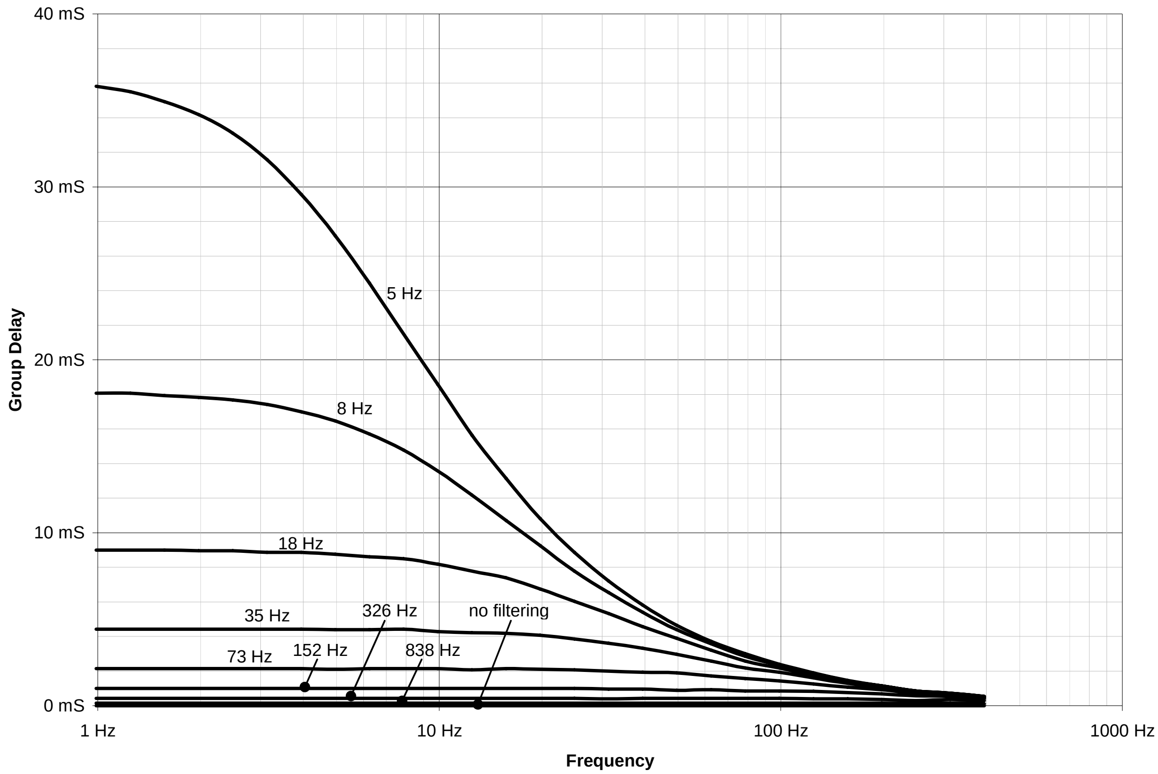


Figure 16.2.2—Filtering Group Delays (calculated)

16.3 Electrical Specifications

16.3.1 Power Supply

Power Source†	Minimum Voltage	Maximum Voltage	Maximum Power Consumption
Power over Ethernet‡	36V	57V	6W
Pwr/CAN	11V	25V	6W

†Power is drawn from only one power source at a time.

‡Conforms to IEEE 802.3af, class 0, receiving power from data lines.

A 9105-NET-GAMMA- transducer and its on-board electronics account for 2.4W of the systems power consumption. Other transducer models consume less power.

Table 16.2—Power Requirements

16.3.2 Communications

16.3.2.1 Ethernet Interface

The Ethernet interface is 10/100 Mbit and features both negotiation and auto crossover.

16.3.2.2 CAN Interface

The CAN interface supports 125 Kbps, 250 Kbps, and 500 Kbps (see *Section 3.9.3—Baud Rate*). A switchable termination resistor is available (see *Section 3.9.1—Termination Resistor*).

16.3.3 Connectors

Connector	Type	Recommended Torque	Maximum Torque
Ethernet	M12 D-Coded, 4-Pin, female	0.8 Nm to 1.0 Nm	3.0 Nm
Threshold Relay	M8 3-Pin, male	0.5 Nm to 0.6 Nm	1.0 Nm
Pwr/CAN	M12 5-Pin, female	0.8 Nm to 1.0 Nm	3.0 Nm
NETB Transducer	M12 5-Pin, male	0.8 Nm to 1.0 Nm	3.0 Nm
NETBA Transducer	Circular, female	0.7 Nm	

Table 16.3—Mechanical Specifications of Connectors

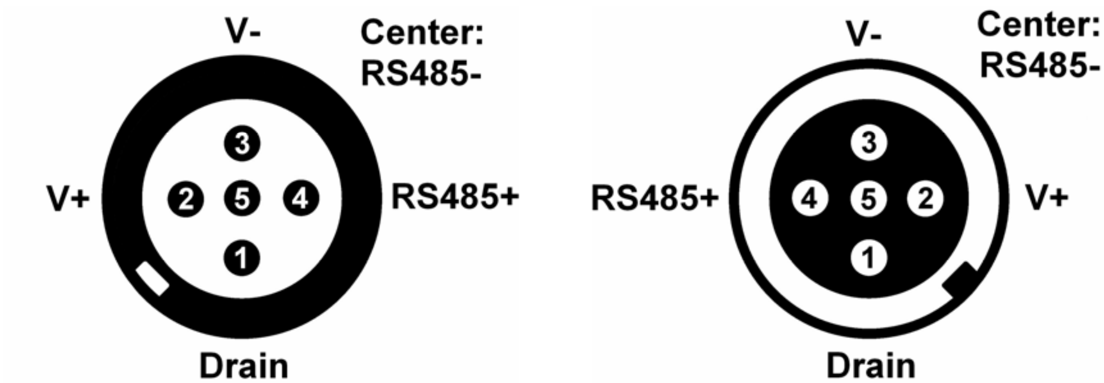
16.3.4 Threshold Relay Connector

The threshold relay contacts (NC, NO, or COM) are protected against overload by a resettable fuse. The maximum guaranteed fuse hold current is 50mA.

16.3.5 NetBox Transducer Cabling

Normally the NetBox is connected to the Transducer via an industry-standard DeviceNet cordset. In cases where this type of cordset cannot be used, the following must be observed:

- Cable specifications for DeviceNet Thick Cabling are ideal.
- The RS485+ and RS485- lines must form a twisted pair.
- The cable capacities should be low enough to work with 1.25 Mbps.
- The total resistance of each conductor should be no more than 0.5Ω.



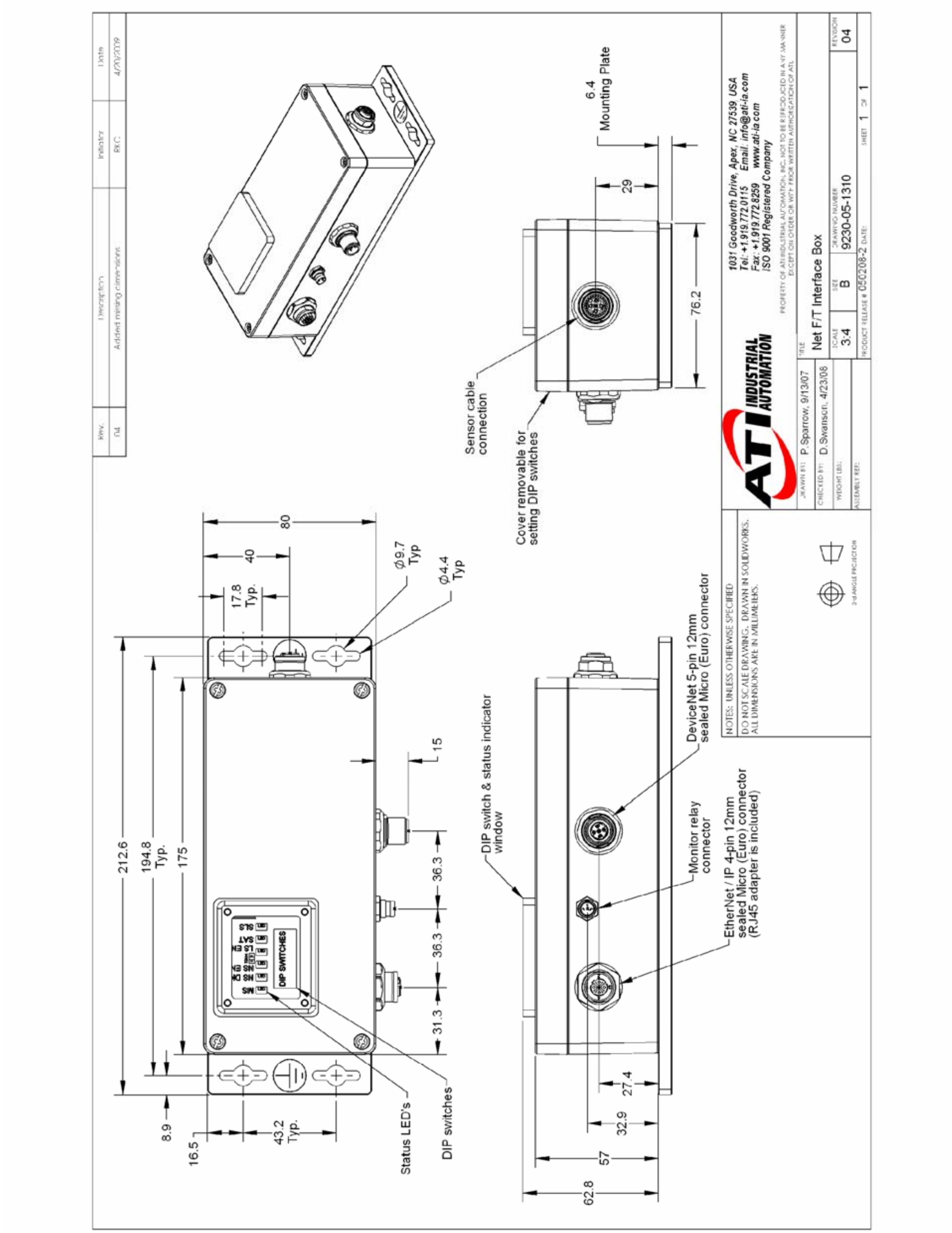
16.4 Net Box Weight

Condition	Weight
Without Mounting Plate	0.8 kg (1.8 lbs)
With Mounting Plate	1.1 kg (2.4 lbs)

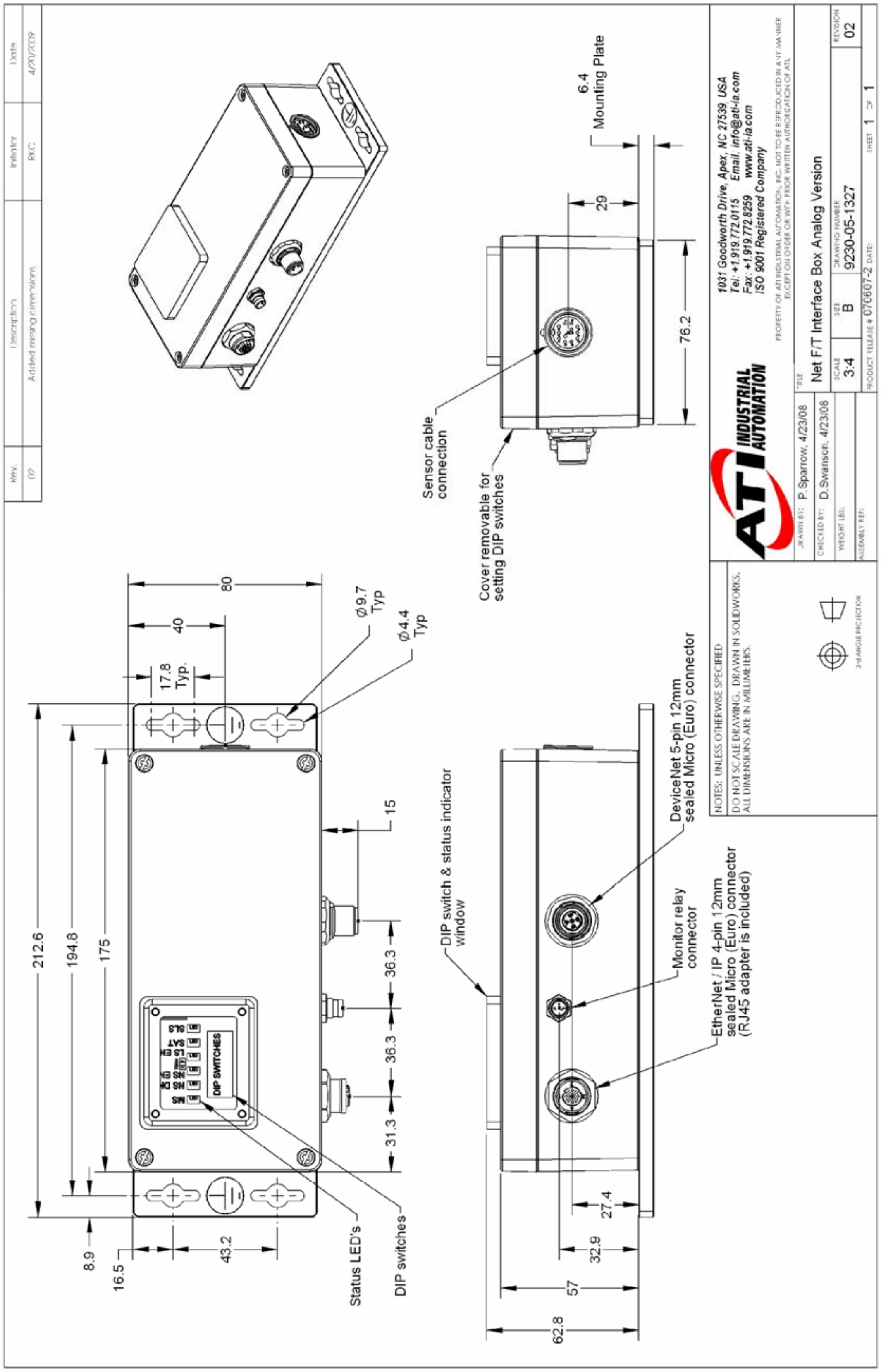
Table 16.4—Net Box Weight

17. Drawings

17.1 9105-NETB Drawing



17.2 9105-NETBA Drawing



18. 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.

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F/T **Transducer**

Six-Axis
Force/Torque Transducer

Installation and Operation Manual

Document # 9620-05-Transducer Section
August 2011

Engineered Products for Robotic Productivity
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Forward

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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.

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.

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

Aside

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/S, SI-65-6/S, 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, have access to the F/T system when calling.

How to Reach Us

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

Table of Contents

Glossary of Terms

Terms	Conditions
Accuracy	See *Measurement Uncertainty*.
Compound Loading	Any load that is not purely in one axis.
CTL	Denotes transducers and systems that use the F/T Controller interface.
DAQ	Denotes transducers and systems that use the data acquisition interface.
FS	**F**ull-**S**cale.
F/T	**F**orce and **T**orque.
Fxy	The resultant force vector comprised of components Fx and Fy.
Hysteresis	A source of measurement caused by the residual effects of previously applied loads.
IFPS	**I**nter**F**ace/**P**ower **S**upply box.
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.
Maximum Single-Axis Overload	The largest amount of pure load (not compound loading) that the transducer can withstand without damage.
MAP	**M**ounting **A**dapter **P**late. The transducer plate that attaches to the fixed surface or robot arm.
Measurement Uncertainty	The maximum expected error in measurements, as specified on the calibration certificate.
Mux Box	The component that contains transducer electronics for transducers that are too small to house them.
NI	**N**ational **I**nstruments Corporation, the owner of the *National Instruments* and *LabVIEW* trademarks. (www.ni.com)
Overload	The condition where more load is applied to the transducer than it can measure. This will result in saturation.
PC Card	A small computer card for use in most laptop computers.
PCMCIA Card	See *PC Card*. (*PCMCIA* has been renamed *PC Card* by its standards organization).
Point of Origin	The point on the transducer from which all forces and torques are measured.
PS	**P**ower **S**upply box.
Quantization	The process of converting a continuously variable transducer signal into discrete digital values. Usually used when describing the change from one digital value to the next.
Resolution	The smallest change in load that can be measured. This is usually much smaller than accuracy.
Saturation	The condition where the transducer or data acquisition hardware has a load or signal outside of its sensing range.
Sensor System	The entire assembly consisting of parts from transducer to controller.
TAP	**T**ool **A**dapter **P**late. The transducer surface that attaches to the load to be measured.
TWE	Denotes transducers that require user-amplification and data acquisition.
Tool Transformation	A method of mathematically shifting the measurement coordinate system resulting in a translated origin and/or rotated axes.
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

1.1 General

The customer should verify that the transducer selected is rated for the maximum loads and moments expected during operation. Refer to transducer specifications in Section 4 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.

1.2 Explanation of Warnings

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

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

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

1.3 Precautions

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

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

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

2. Installation

2.1 Introduction

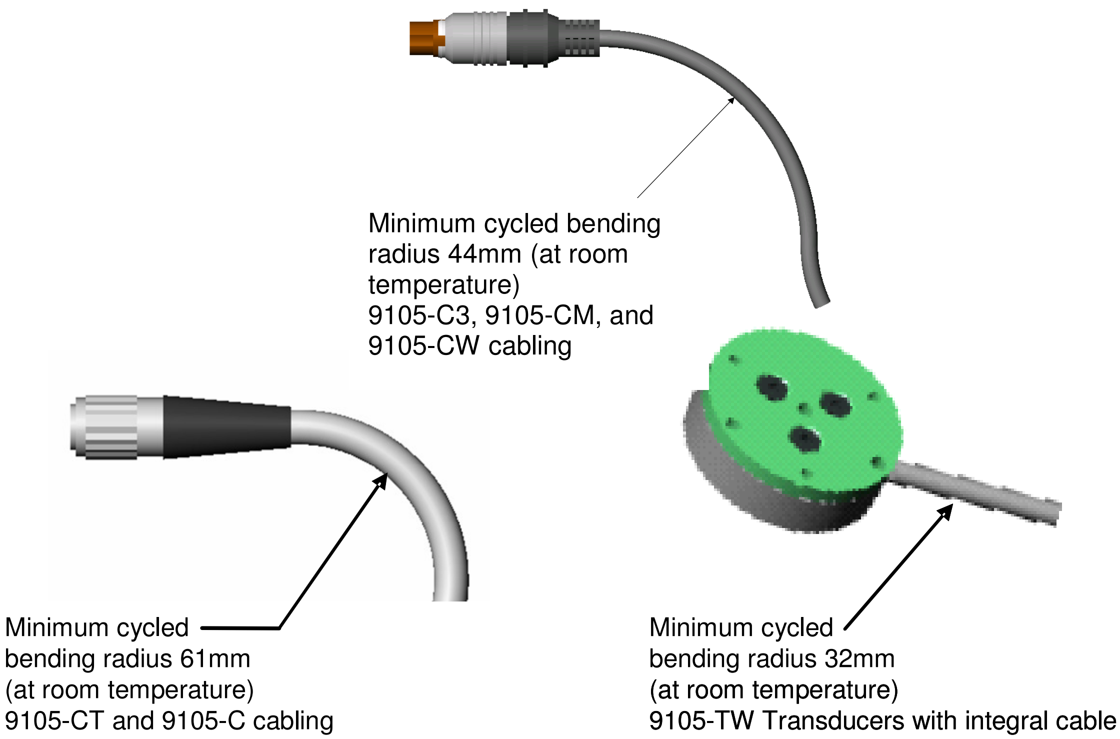
This section will assist the user in mounting the transducer, your tool, and the transducer cable.

2.2 Routing the Transducer Cable

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: When the cable is cycling below the minimum bending radius, the cable may fail due to fatigue. A smaller radius can be used if it is not being cycled.

The minimum cycled bending radius is different with significant temperature changes, increasing with lower temperature and decreasing for higher temperature.



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 25mm (1 inch) to the transducer. Sharp bends must be avoided as they can damage the cable and transducer and will void the warranty.

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 as damage will occur.
- 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.

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.

2.3 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 or debris and no liquids or spray.

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

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

Section 2.1 contains information on the transducer's temperature performance.

2.4 Mounting the Transducer

There are three different methods, I, II, and III, for mounting most F/T transducers. Mount the transducer to a structure with sufficient mechanical strength. Not doing so can lead to sub-optimum performance. **The Nano, Mini, Omega, and IP-rated transducers have mounting and tool adapters which cannot be removed, so only Method III can be used.** A detailed description of each method is given on the following pages and a brief description is given below.

2.4.1 Transducer Mounting Method I, Standard Adapter (summary)

Mounting Method I uses the standard mounting adapter to attach the transducer. This method is only available for transducers with customer-removable mounting adapter plates. You must machine the bolt pattern of your device (i.e.; robot) into the transducer's mounting adapter plate. You will not be able to use the mounting adapter alone if your device covers the mounting screws used to connect the transducer. If this is the case, use either Method II or Method III instead.

2.4.2 Transducer Mounting Method II, Ring-Plug Adapter (summary)

Mounting Method II uses the optional mounting ring-plug adapter as a replacement for the standard mounting adapter. You must machine the mounting plug to attach to your device. The mounting ring-plug adapter has the benefit of allowing the transducer to be connected and disconnected by hand (disconnecting may require a strap wrench). If the bolt pattern on your device can fit on the plug and you have access to the ring, then the mounting ring-plug adapter will work. If the bolt pattern is larger than the plug, use Method III.

2.4.3 Transducer Mounting Method III, User-Designed Interface (summary)

Mounting Method III uses your own interface plate to bolt directly to the transducer or (for the Nano, Mini, or Omega models) the mounting adapter.

The *Section 4—Transducer Specifications* contains detailed mechanical drawings of the transducer and all interface plates. Detailed descriptions of each method are shown on the next two pages.

> ***Aside:***
>
> Examine the sensor frame and cable routing section before modifying the mounting adapter plates. The F/T system's default sensor frame sets the tranducer's point-of-origin at the center of the mounting adapter's surface. See *Section 4—Transducer Specifications*, for drawings showing the default point of origin.

2.4.4 Transducer Mounting Method I, Standard Adapter

Use the mounting adapter to attach the transducer as follows:

- Ensure that you provide sufficient clearances between the mounted transducer and other fixtures and that total stack height is acceptable. Also check that after the mounting adapter is attached to the robot (or other device) you will have access to the mounting screws for attaching the transducer.
- Machine the mounting adapter plate for attaching to your robot (or other device) (see *Figure 2.1*). Mounting adapter plate dimensions are shown with the transducer in *Section 4—Transducer Specifications*. **All user-supplied screws must be flush with the inside of the mounting adapter to ensure proper clearance for the electronics inside the transducer.**
- Attach the mounting adapter to the robot (or other device). Attach the transducer to the mounting adapter with the screws and dowel pin provided. Thread locker is recommended to prevent the screws from backing out due to vibration (e.g.; Loctite thread locker No. 222).

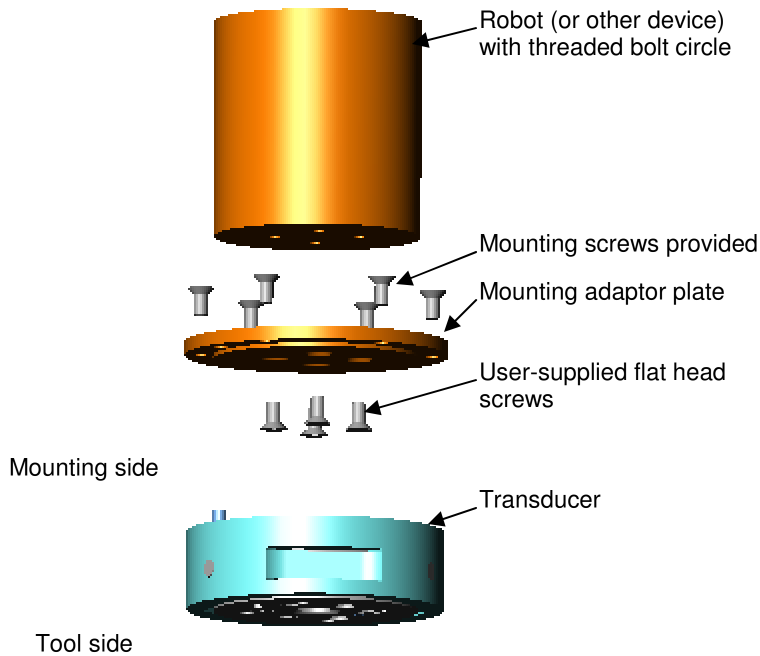


Figure 2.1—Attaching the transducer with the mounting adapter

2.4.5 Transducer Mounting Method II, Ring-plug Adapter

- Ensure that you provide sufficient clearances between the mounted transducer and other fixtures and that total stack height is acceptable. Also check that you will have room for tightening the mounting ring
- Machine the mounting plug for attaching to your robot (or other device). Mounting plug dimensions are shown with the transducer in *Section 4—Transducer Specifications* (see *Figure 2.2)*.
- Attach the mounting plug. Then attach the transducer to the mounting plug using the attached mounting ring and flange.

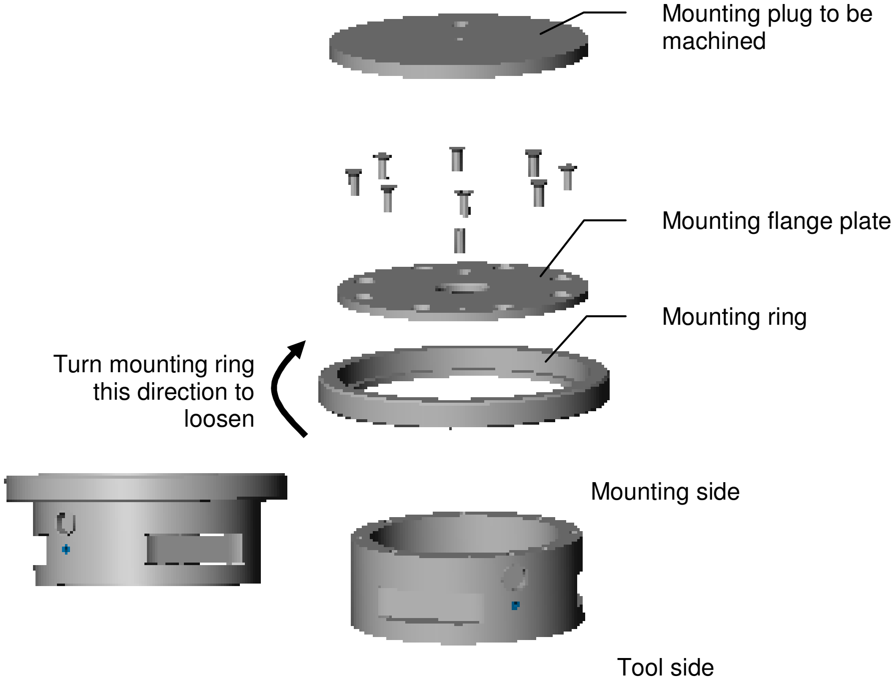


Figure 2.2—Using the mounting ring-plug adapter

> ***Aside:***
>
> How the ring/plug adapter works: The flange plate is held to the transducer with screws and dowel pins. The plug mates to the flange plate with a center boss and a dowel pin. The plug also mates to the ring with matching threads. When the ring is turned, the plug screws into the ring causing the plug to clamp to the flange plate.

> ***Aside:***
>
> If the ring cannot be removed by hand, use a strap wrench to loosen it. A strap wrench can be purchased through a supply company such as McMaster-Carr (PN-5378A1).

2.4.6 Transducer Mounting Method III, User-designed Interface

The transducer can be mounted using the bolt pattern provided. See *Section 4—Transducer Specifications*.

⚠ **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. Some transducers have removable plates that may be modified if removed. See drawings in *Section 4—Transducer Specifications* for details.

Aside:

Examine the cable routing (Section 2) before modifying the mounting adapter plates. The F/T System's default point-of-origin is at the center of the mounting adapter surface. See *Section 4—Transducer Specifications* for drawings showing the default point-of-origin.

2.5 Mounting Your Tool

There are two methods for mounting your tool to most F/T transducers. Method II is only available on the Gamma and Delta transducers. The two methods are described below.

2.5.1 Tool Mounting Method I, Standard Tool Adapter

The tool adapter is factory-installed and the bolt circle is shown with the transducer in *Section 4—Transducer Specifications.* Most F/T tool adapters follow the ISO 9409-1 mounting pattern. Machine your tool interface plate to attach to this bolt circle.

2.5.2 Tool Mounting Method II, Optional Tool Ring-plug Adapter

- This method is similar to the optional mounting ring-plug adapter. See *Section 2.4.5—Transducer Mounting Method II, Mounting Ring-plug Adapter* for details.
- Ensure that you provide sufficient clearances between the mounted transducer and other fixtures and that total stack height is acceptable. Also ensure that you will have room for tightening the tool ring
- Machine the tool plug for mounting to the end-effector. The dimensions of the tool plug are shown in *Figure 2.3*.
- Mount the tool plug to your tool. Then mount the transducer to the tool plug using the attached tool ring and tool flange. See the *Aside* notes in *Section 2.4.5* for how the ring-plug adapter works. The tool flange is not attached to the standard tool adapter, but replaces it.

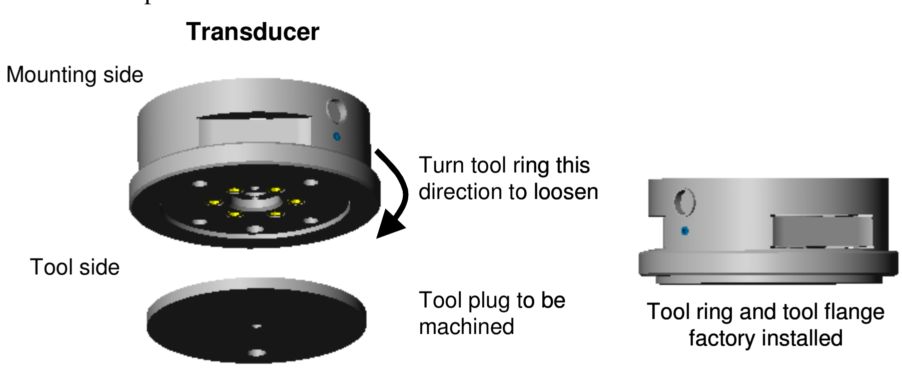


Figure 2.3—Using the tool ring-plug adapter

⚠ **CAUTION:** Your tool may only touch the tool adapter plate. If your tool touches any other part of the transducer it will not properly sense loads.

3. Topics

3.1 Accuracy over Temperature

Typical gain errors introduced over temperature for F/T transducers with hardware 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.

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

Table 3.1—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	1.5%
± 50°C	7%

Table 3.2—Error Introduced Over Temperature for Gamma Transducers

3.2 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.

3.3 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.

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.

Table 3.3—Transducer Temperature Ranges

3.4 Mux Transducer Input Filter Frequency Response

Note: 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.

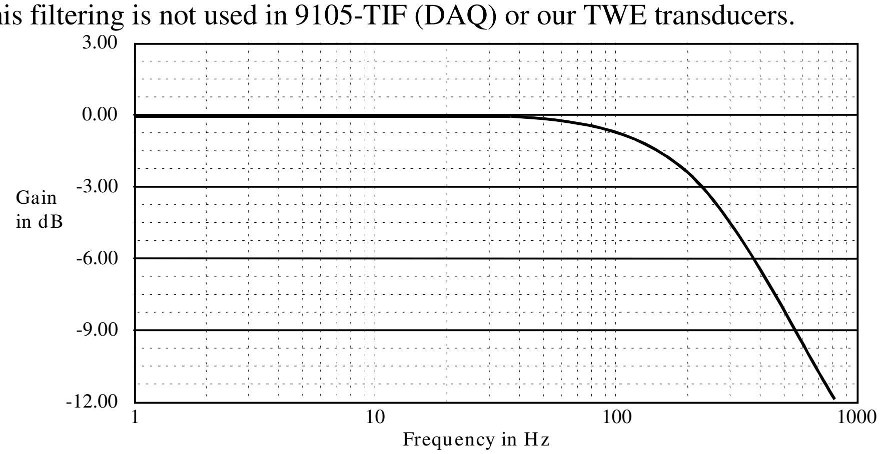


Figure 3.1—Mux input filter frequency response (-3dB @ 235Hz)

3.5 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**. Therefore, it is vitally important to monitor for these conditions.

4. Transducer Specifications

4.1 Notes

4.1.1 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.

4.1.2 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 3.2 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.

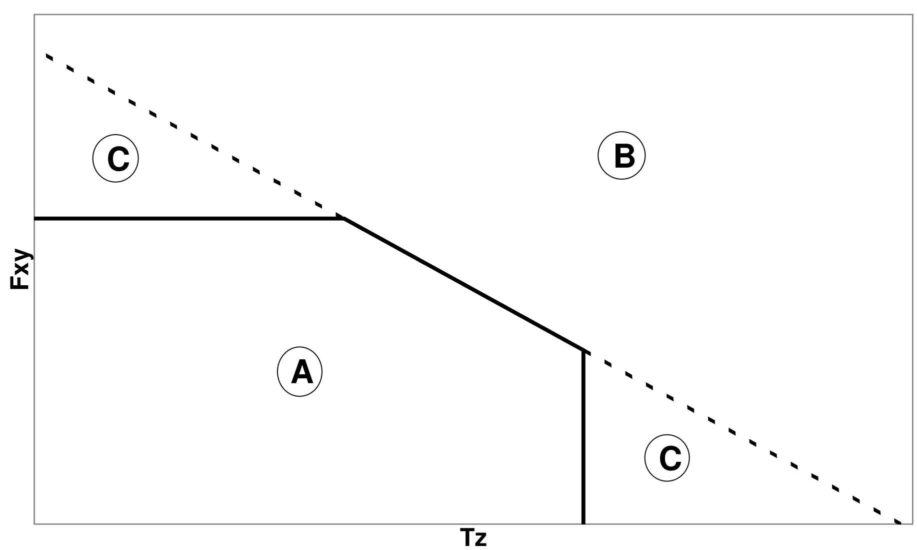


Figure 4.1—Complex loading sample graph

4.2 Nano17 Titanium

4.2.1 Calibration Specifications (excludes CTL calibrations)

US (English)

Calibration	Fx,Fy	Fz	Tx,Ty	Tz	Fx,Fy	Fz	Tx,Ty	Tz
US-1.8–0.4	1.8 lbf	3.15 lbf	0.4 lbf-in	0.4 lbf-in	1/3028 lbf	1/1721 lbf	1/13743 lbf-in	1/10430 lbf-in
US-3.6–0.8	3.6 lbf	6.3 lbf	0.8 lbf-in	0.8 lbf-in	1/1514 lbf	2/1721 lbf	2/13743 lbf-in	1/5215 lbf-in
US-7.2–1.6	7.2 lbf	12.6 lbf	1.6 lbf-in	1.6 lbf-in	1/757 lbf	5/2151 lbf	10/34357 lbf-in	2/5215 lbf-in
	SENSING RANGES				RESOLUTION			

SI (Metric)

Calibration	Fx,Fy	Fz	Tx,Ty	Tz	Fx,Fy	Fz	Tx,Ty	Tz
SI-8–0.05	8 N	14.1 N	50 Nmm	50 Nmm	1/681 N	1/387 N	462/60815 Nmm	127/23078 Nmm
SI-16–0.1	16 N	28.2 N	100 Nmm	100 Nmm	2/681 N	2/387 N	924/60815 Nmm	127/11539 Nmm
SI-32–0.2	32 N	56.4 N	200 Nmm	200 Nmm	5/851 N	10/967 N	1848/60815 Nmm	254/11539 Nmm
	SENSING RANGES				RESOLUTION			

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

4.2.2 CTL Calibration Specifications

US (English)

Calibration	Fx,Fy	Fz	Tx,Ty	Tz	Fx,Fy	Fz	Tx,Ty	Tz
US-1.8–0.4	1.8 lbf	3.15 lbf	0.4 lbf-in	0.4 lbf-in	1/1514 lbf	2/1721 lbf	2/13743 lbf-in	1/5215 lbf-in
US-3.6–0.8	3.6 lbf	6.3 lbf	0.8 lbf-in	0.8 lbf-in	1/757 lbf	5/2151 lbf	10/34357 lbf-in	2/5215 lbf-in
US-7.2–1.6	7.2 lbf	12.6 lbf	1.6 lbf-in	1.6 lbf-in	2/757 lbf	10/2151 lbf	5/8589 lbf-in	10/13037 lbf-in
SI (Metric)								
SI-8–0.05	8 N	14.1 N	50 Nmm	50 Nmm	2/681 N	2/387 N	924/60815 Nmm	127/11539 Nmm
SI-16–0.1	16 N	28.2 N	100 Nmm	100 Nmm	5/851 N	10/967 N	1848/60815 Nmm	254/11539 Nmm
SI-32–0.2	32 N	56.4 N	200 Nmm	200 Nmm	10/851 N	10/483 N	3080/50679 Nmm	508/11539 Nmm
	SENSING RANGES				**RESOLUTION**			

US (English)

Calibration	Fx,Fy	Fz†	Tx,Ty, Tz	Fx,Fy	Fz†	Tx,Ty, Tz
US-1.8–0.4	±3 lbf	±4.25 lbf	±1 lbf-in	0.3 lbf/V	0.425 lbf/V	0.1 lbf-in/V
US-3.6–0.8	±6 lbf	±8.5 lbf	±2 lbf-in	0.6 lbf/V	0.85 lbf/V	0.2 lbf-in/V
US-7.2–1.6	±1 lbf	±17 lbf	±4 lbf-in	1.2 lbf/V	1.7 lbf/V	0.4 lbf-in/V
SI (Metric)						
US-1.8–0.4	±12 N	±17 N	±120 Nmm	1.2 N/V	1.7 N/V	12 Nmm/V
US-3.6–0.8	±25 N	±35 N	±250 Nmm	2.5 N/V	3.5 N/V	25 Nmm/V
US-7.2–1.6	±50 N	±70 N	±500 Nmm	5 N/V	7 N/V	50 Nmm/V
	Analog Output Range			**Analog ±10V Sensitivity‡**		

Counts Value

Calibration	Fx, Fy, Fz	Tx, Ty, Tz	Fx, Fy, Fz	Tx, Ty, Tz
US-1.8–0.4	5120 / lbf	32000 / lbf-in	1280 / N	256 / Nmm
US-3.6–0.8	2560 / lbf	16000 / lbf-in	640 / N	128 / Nmm
US-7.2–1.6	1280 / lbf	8000 / lbf-in	320 / N	64 / Nmm
Tool Transform Factor	0.0016 in/unit		0.05 mm/unit	
	Counts Value – US (English)		**Counts Value – SI (Metric)**	

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. NOTE: Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.

‡ *±5V Sensitivity values are double the listed ±10V Sensitivity values.*

4.2.3 Nano17 Titanium Physical Properties

US (English)

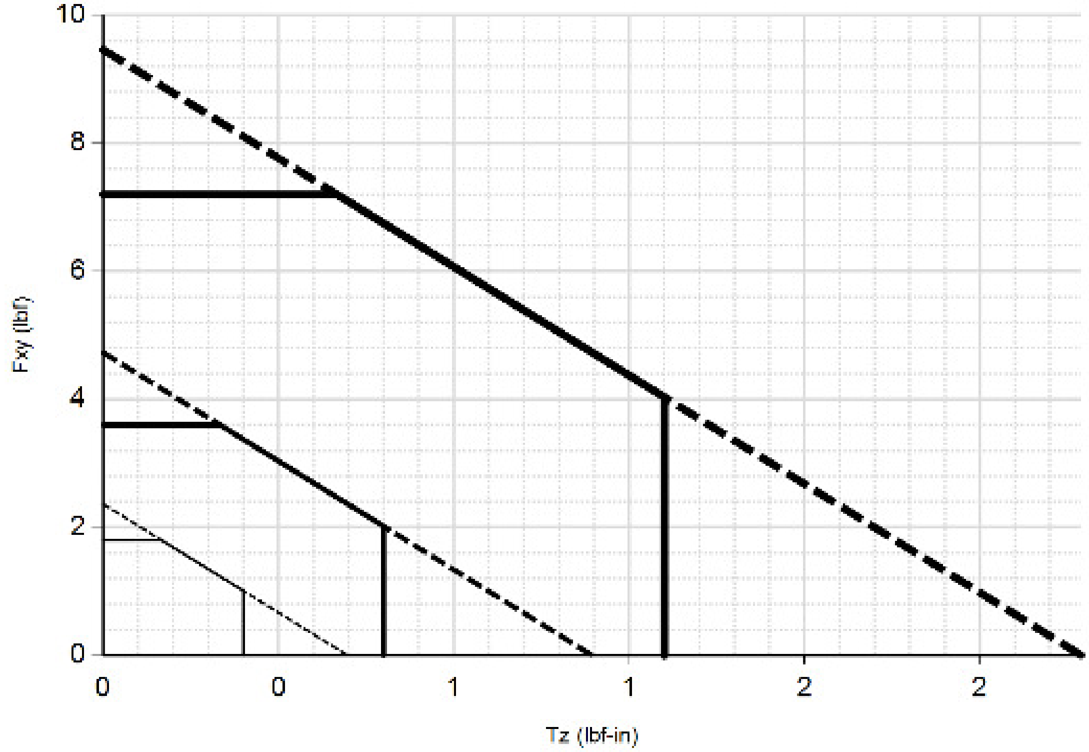
Single-Axis Overload	
Fxy	±35 lbf
Fz	±70 lbf
Txy	±9 lbf-in
Tz	±10 lbf-in
Stiffness (Calculated)	
X-axis & Y-axis forces (Kx, Ky)	2.7×10^{4} lb/in
Z-axis force (Kz)	3.8×10^{4} lb/in
X-axis & Y-axis torque (Ktx, Kty)	1.2×10^{3} lbf-in/rad
Z-axis torque (Ktz)	2.0×10^{3} lbf-in/rad
Resonant Frequency (Measured)	
Fx, Fy, Tz	3000 Hz
Fz, Tx, Ty	3000 Hz
Physical Specifications	
Weight*	0.022 lb
Diameter*	0.67 in
Height*	0.57 in

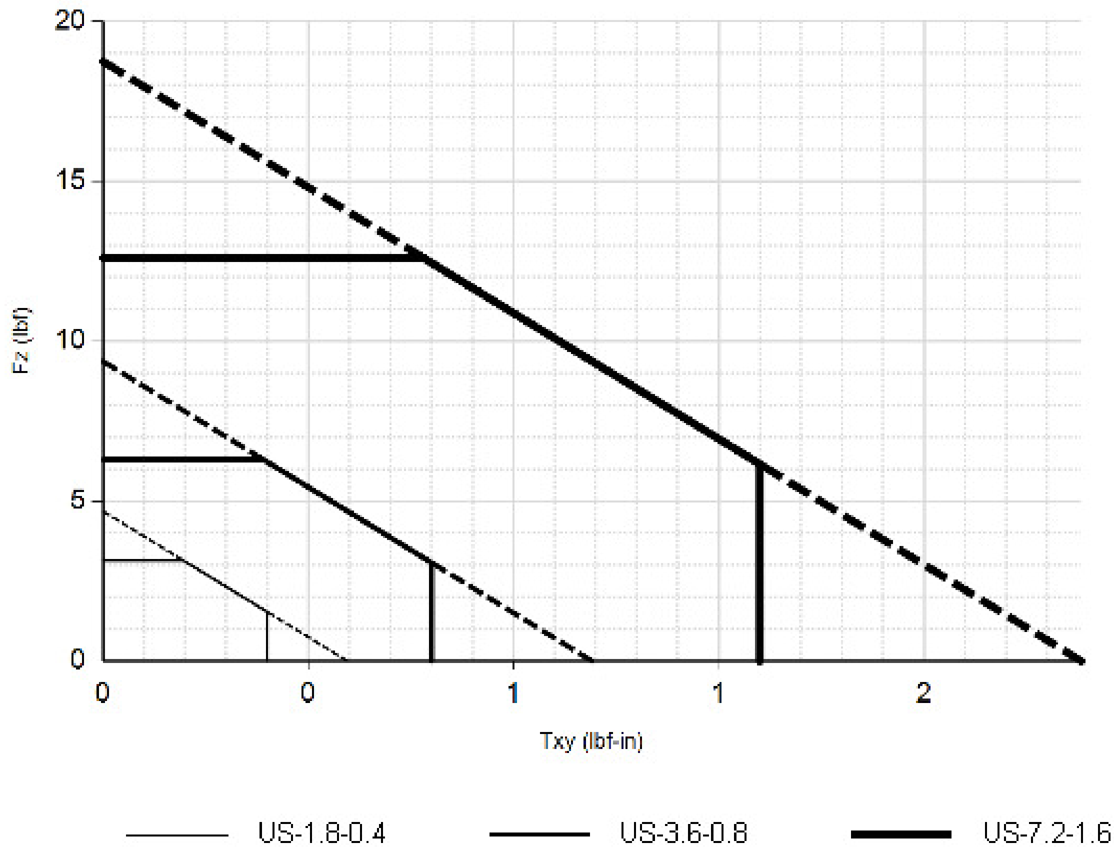
SI (Metric)

Single-Axis Overload	
Fxy	±160 N
Fz	±310 N
Txy	±1 Nm
Tz	±1.1 Nm
Stiffness (Calculated)	
X-axis & Y-axis forces (Kx, Ky)	4.8×10^{6} N/m
Z-axis force (Kz)	6.6×10^{6} N/m
X-axis & Y-axis torque (Ktx, Kty)	1.4×10^{2} Nm/rad
Z-axis torque (Ktz)	2.2×10^{2} Nm/rad
Resonant Frequency (Measured)	
Fx, Fy, Tz	3000 Hz
Fz, Tx, Ty	3000 Hz
Physical Specifications	
Weight*	0.00998 kg
Diameter*	17 mm
Height*	15 mm

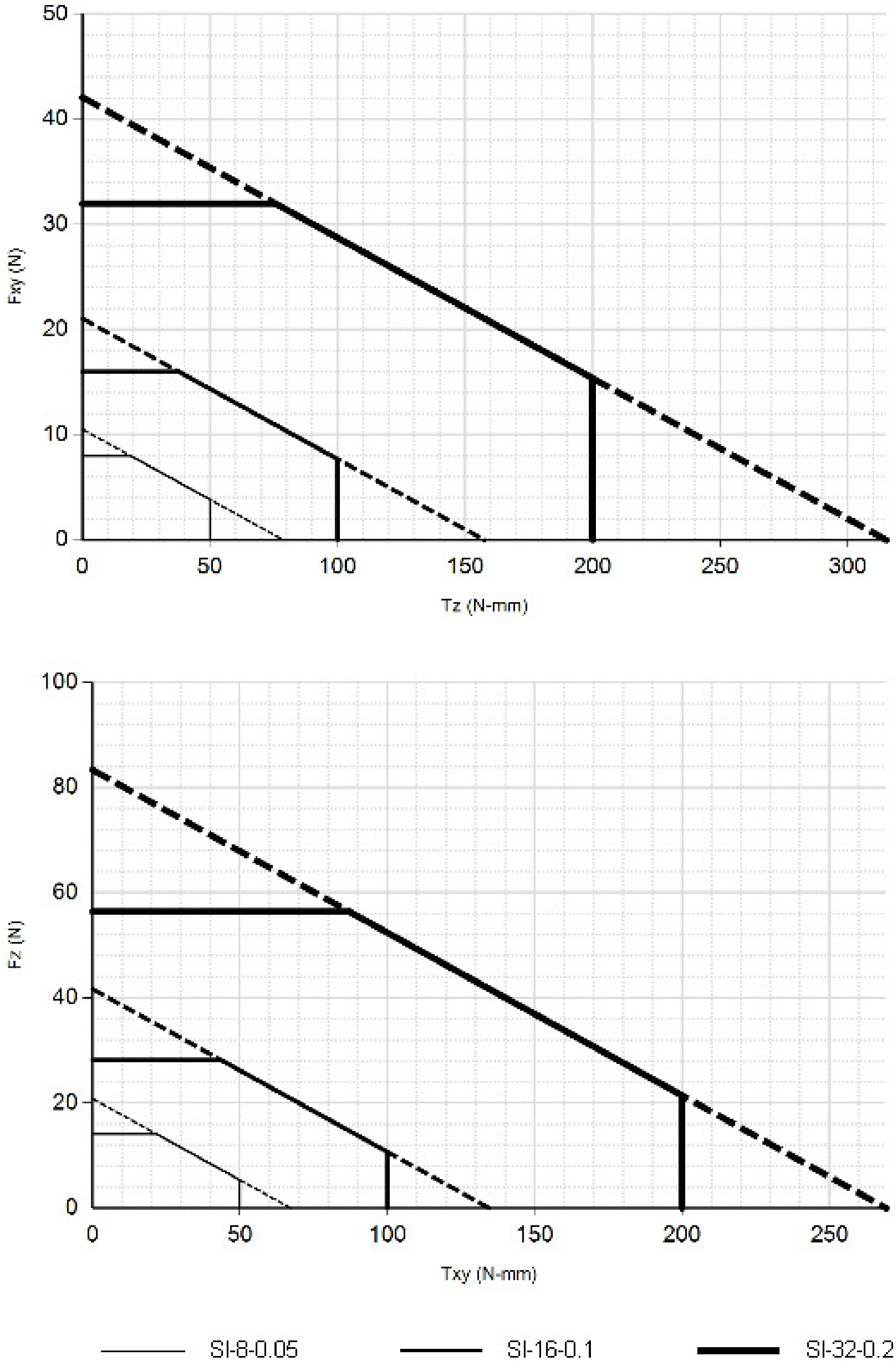
** Specifications include standard interface plate.*

4.2.4 Nano17 Titanium (US Calibration Complex Loading)

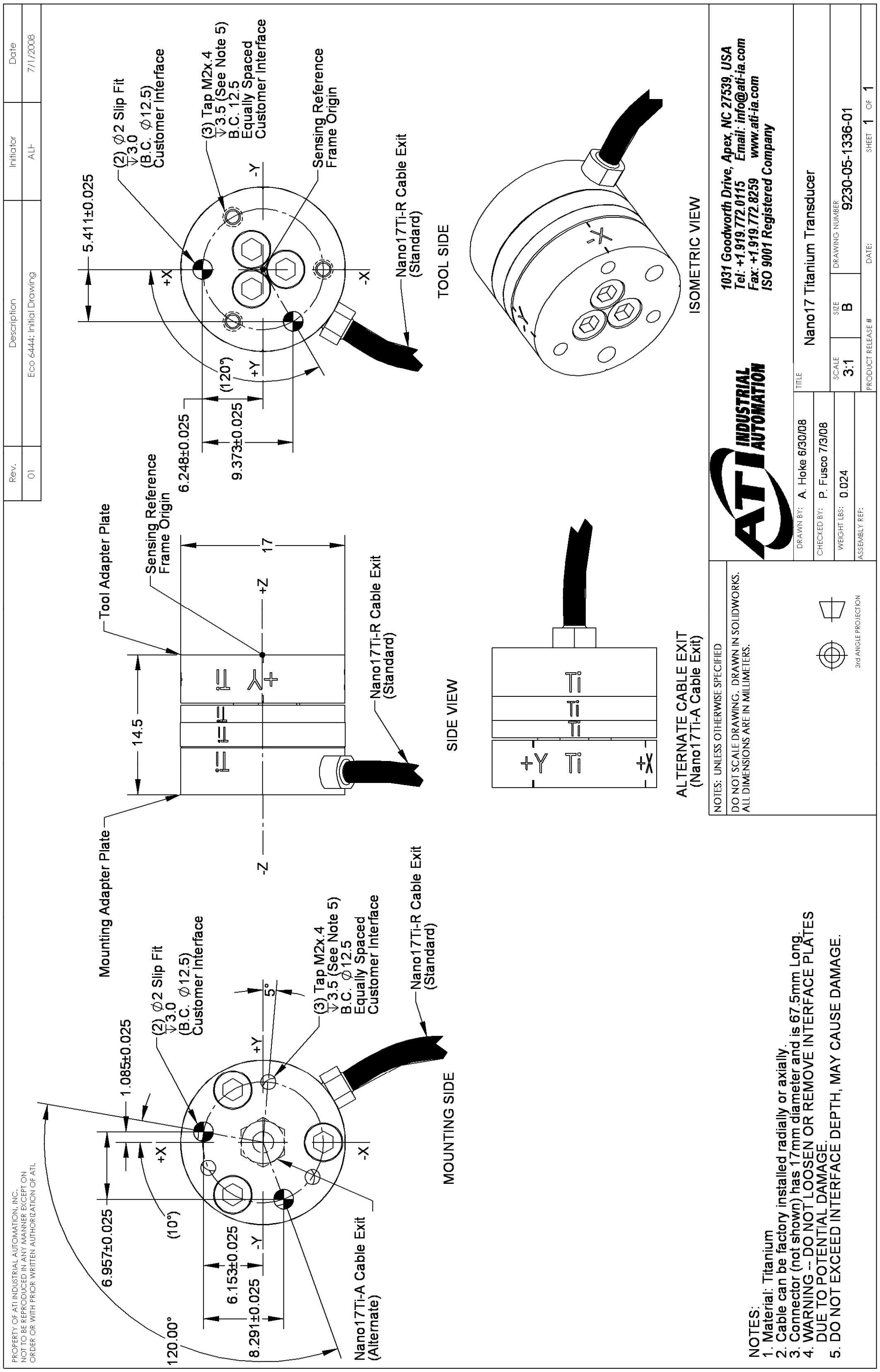




4.2.5 Nano17 Titanium (SI Calibration Complex Loading)



4.2.6 Nano17 Titanium Transducer Drawing



4.3 Nano17 (Includes IP65/IP68 Versions)

4.3.1 Calibration Specifications (excludes CTL calibrations)

US (English)

Calibration	Fx,Fy	Fz	Tx,Ty	Tz	Fx,Fy	Fz	Tx,Ty	Tz
US-3–1	3 lbf	4.25 lbf	1 lbf-in	1 lbf-in	1/1280 lbf	1/1280 lbf	1/8000 lbf-in	1/8000 lbf-in
US-6–2	6 lbf	8.5 lbf	2 lbf-in	2 lbf-in	1/640 lbf	1/640 lbf	1/4000 lbf-in	1/4000 lbf-in
US-12–4	12 lbf	17 lbf	4 lbf-in	4 lbf-in	1/320 lbf	1/320 lbf	1/2000 lbf-in	1/2000 lbf-in
	SENSING RANGES				RESOLUTION			

SI (Metric)

Calibration	Fx,Fy	Fz	Tx,Ty	Tz	Fx,Fy	Fz	Tx,Ty	Tz
SI-12–0.12	12 N	17 N	120 Nmm	120 Nmm	1/320 N	1/320 N	1/64 Nmm	1/64 Nmm
SI-25–0.25	25 N	35 N	250 Nmm	250 Nmm	1/160 N	1/160 N	1/32 Nmm	1/32 Nmm
SI-50–0.5	50 N	70 N	500 Nmm	500 Nmm	1/80 N	1/80 N	1/16 Nmm	1/16 Nmm
	SENSING RANGES				RESOLUTION			

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

4.3.2 CTL Calibration Specifications

US (English)

Calibration	Fx,Fy	Fz	Tx,Ty	Tz	Fx,Fy	Fz	Tx,Ty	Tz
US-3–1	3 lbf	4.25 lbf	1 lbf-in	1 lbf-in	1/640 lbf	1/640 lbf	1/4000 lbf-in	1/4000 lbf-in
US-6–2	6 lbf	8.5 lbf	2 lbf-in	2 lbf-in	1/320 lbf	1/320 lbf	1/2000 lbf-in	1/2000 lbf-in
US-12–4	12 lbf	17 lbf	4 lbf-in	4 lbf-in	1/160 lbf	1/160 lbf	1/1000 lbf-in	1/1000 lbf-in
	SENSING RANGES				RESOLUTION			

SI (Metric)

Calibration	Fx,Fy	Fz	Tx,Ty	Tz	Fx,Fy	Fz	Tx,Ty	Tz
SI-12–0.12	12 N	17 N	120 Nm	120 Nmm	1/160 N	1/160 N	1/32 Nmm	1/32 Nmm
SI-25–0.25	25 N	35 N	250 Nmm	250 Nmm	1/80 N	1/80 N	1/16 Nmm	1/16 Nmm
SI-50–0.5	50 N	70 N	500 Nmm	500 Nmm	1/40 N	1/40 N	1/8 Nmm	1/8 Nmm
	SENSING RANGES				RESOLUTION			

US (English)

Calibration	Fx,Fy	Fz	Tx,Ty, Tz	Fx,Fy	Fz	Tx,Ty, Tz
US-3–1	±3 lbf	±4.25 lbf	±1 lbf-in	0.3 lbf/V	0.425 lbf/V	0.1 lbf-in/V
US-6–2	±6 lbf	±8.5 lbf	±2 lbf-in	0.6 lbf/V	0.85 lbf/V	0.2 lbf-in/V
US-12–4	±12 lbf	±17 lbf	±4 lbf-in	1.2 lbf/V	1.7 lbf/V	0.4 lbf-in/V
	Analog Output Range			Analog ±10V Sensitivity‡		

SI (Metric)

Calibration	Fx,Fy	Fz	Tx,Ty, Tz	Fx,Fy	Fz	Tx,Ty, Tz
SI-12–0.25	±12 N	±17 N	±120 Nmm	1.2 N/V	1.7 N/V	12 Nmm/V
SI-25–-0.25	±25 N	±35 N	±250 Nmm	2.5 N/V	3.5 N/V	25 Nmm/V
SI-50–0.5	±50 N	±70 N	±500 Nmm	5 N/V	7 N/V	50 Nmm/V
	Analog Output Range			Analog ±10V Sensitivity‡		

Counts Value

Calibration	Fx, Fy, Fz	Tx, Ty, Tz	Fx, Fy, Fz	Tx, Ty, Tz
US-3–1	5120 / lbf	32000 / lbf-in	1280 / N	256 / Nmm
US-6–2	2560 / lbf	16000 / lbf-in	640 / N	128 / Nmm
US-12–4	1280 / lbf	8000 / lbf-in	320 / N	64 / Nmm
Tool Transform Factor	0.0016 in/unit		0.05 mm/unit	
	Counts Value – US (English)		Counts Value – SI (Metric)	

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. NOTE: Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.

‡ *±5V Sensitivity values are double the listed ±10V Sensitivity values.*

CAUTION:
IP68 Nano17 Fz as a Function of Submersion Depth:
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 seal level.

IP68 Nano17	**US**	**Metric**
Fz preload at 1m depth	-0.50 lb	-2.22 N
Fz preload at other depths	-0.15 lb/ft × depthInFeet	-2.22 N/m × depthInMeters

4.3.3 Nano17 Physical Properties

US (English)

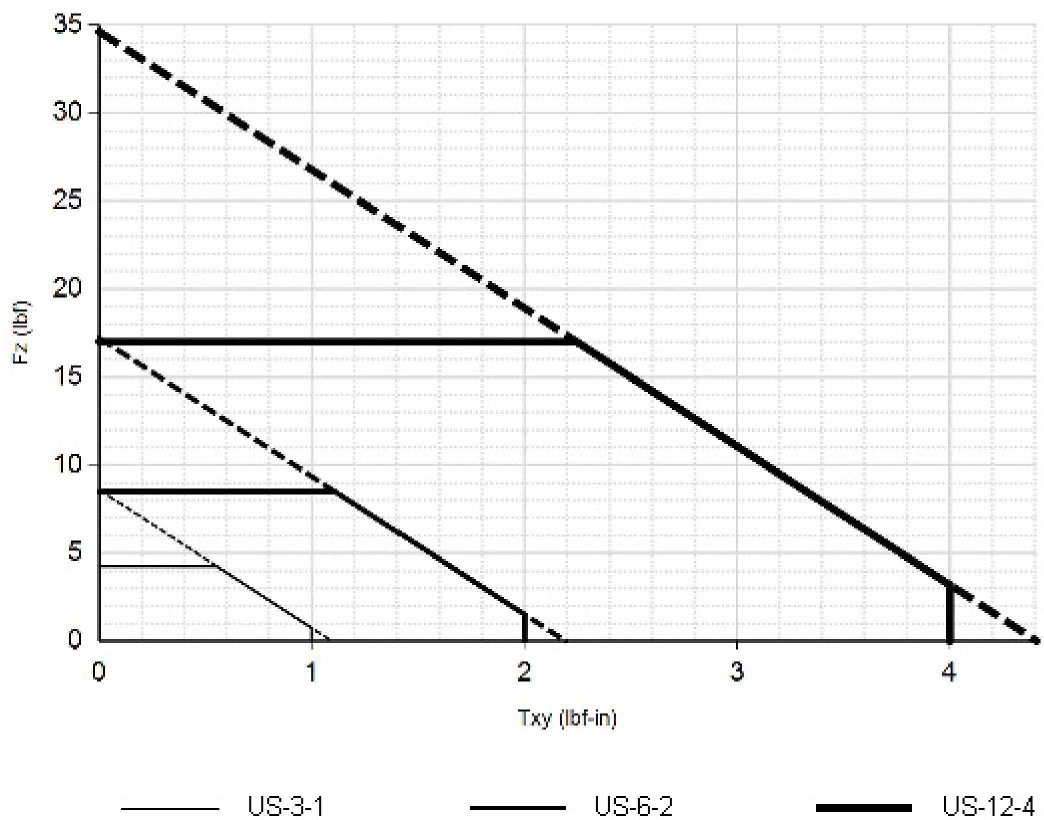
Single-Axis Overload	
Fxy	±56 lbf
Fz	±110 lbf
Txy	±14 lbf-in
Tz	±16 lbf-in
Stiffness (Calculated)	
X-axis & Y-axis forces (Kx, Ky)	4.7×10^4 lb/in
Z-axis force (Kz)	6.5×10^4 lb/in
X-axis & Y-axis torque (Ktx, Kty)	2.1×10^3 lbf-in/rad
Z-axis torque (Ktz)	3.4×10^3 lbf-in/rad
Resonant Frequency (Measured)	
Fx, Fy, Tz	7200 Hz
Fz, Tx, Ty	7200 Hz
Physical Specifications	
Weight*	0.02 lb
Diameter*	0.67 in
Height*	0.57 in

SI (Metric)

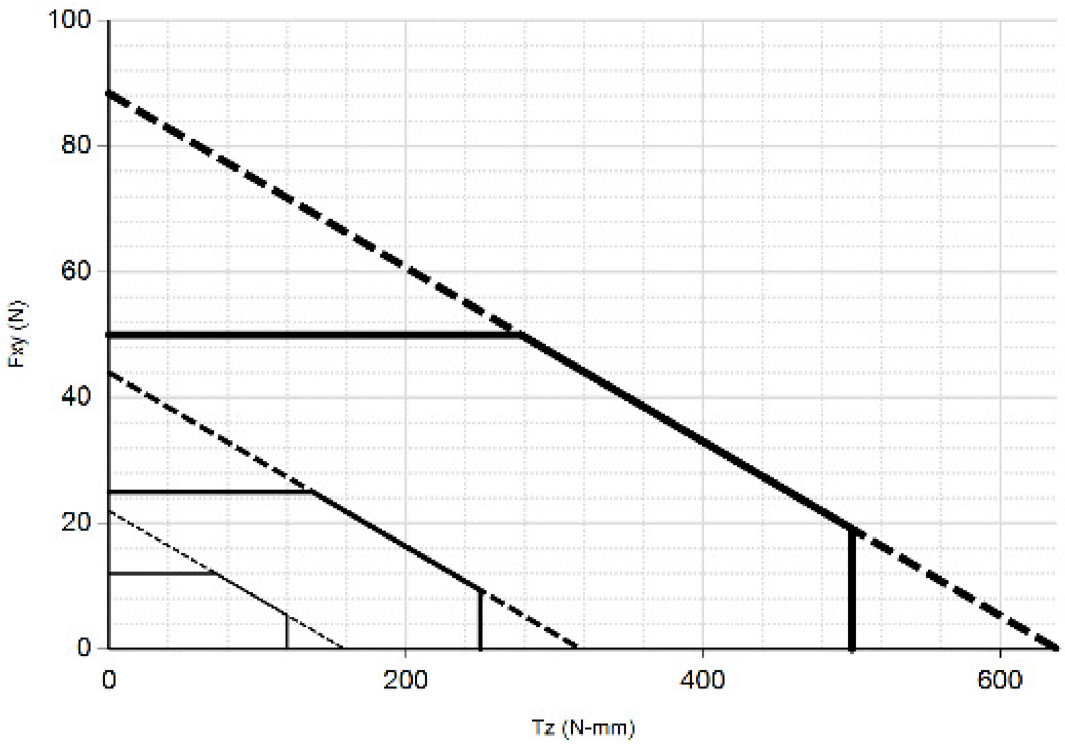
Single-Axis Overload	
Fxy	±250 N
Fz	±480 N
Txy	±1.6 Nm
Tz	±1.8 Nm
Stiffness (Calculated)	
X-axis & Y-axis forces (Kx, Ky)	8.2×10^6 N/m
Z-axis force (Kz)	1.1×10^7 N/m
X-axis & Y-axis torque (Ktx, Kty)	2.4×10^2 Nm/rad
Z-axis torque (Ktz)	3.8×10^2 Nm/rad
Resonant Frequency (Measured)	
Fx, Fy, Tz	7200 Hz
Fz, Tx, Ty	7200 Hz
Physical Specifications	
Weight*	0.00907 kg
Diameter*	17 mm
Height*	15 mm

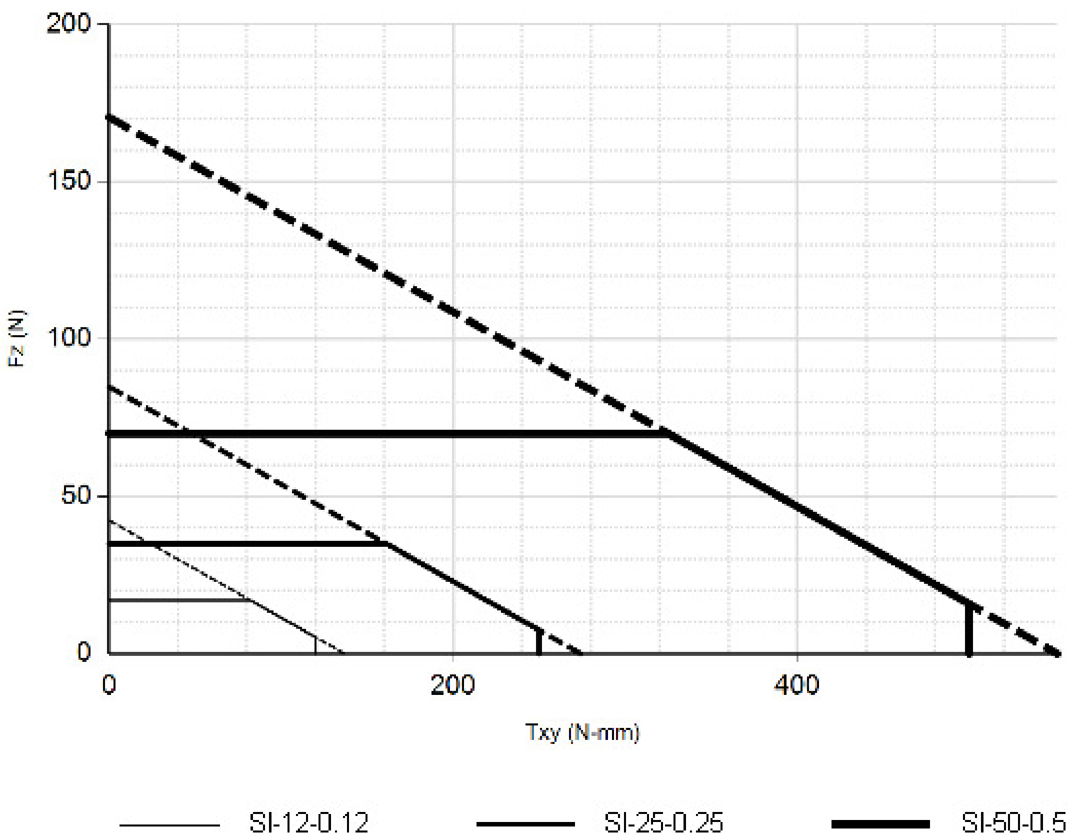
** Specifications include standard interface plate.*

4.3.4 Nano17 (US Calibration Complex Loading)

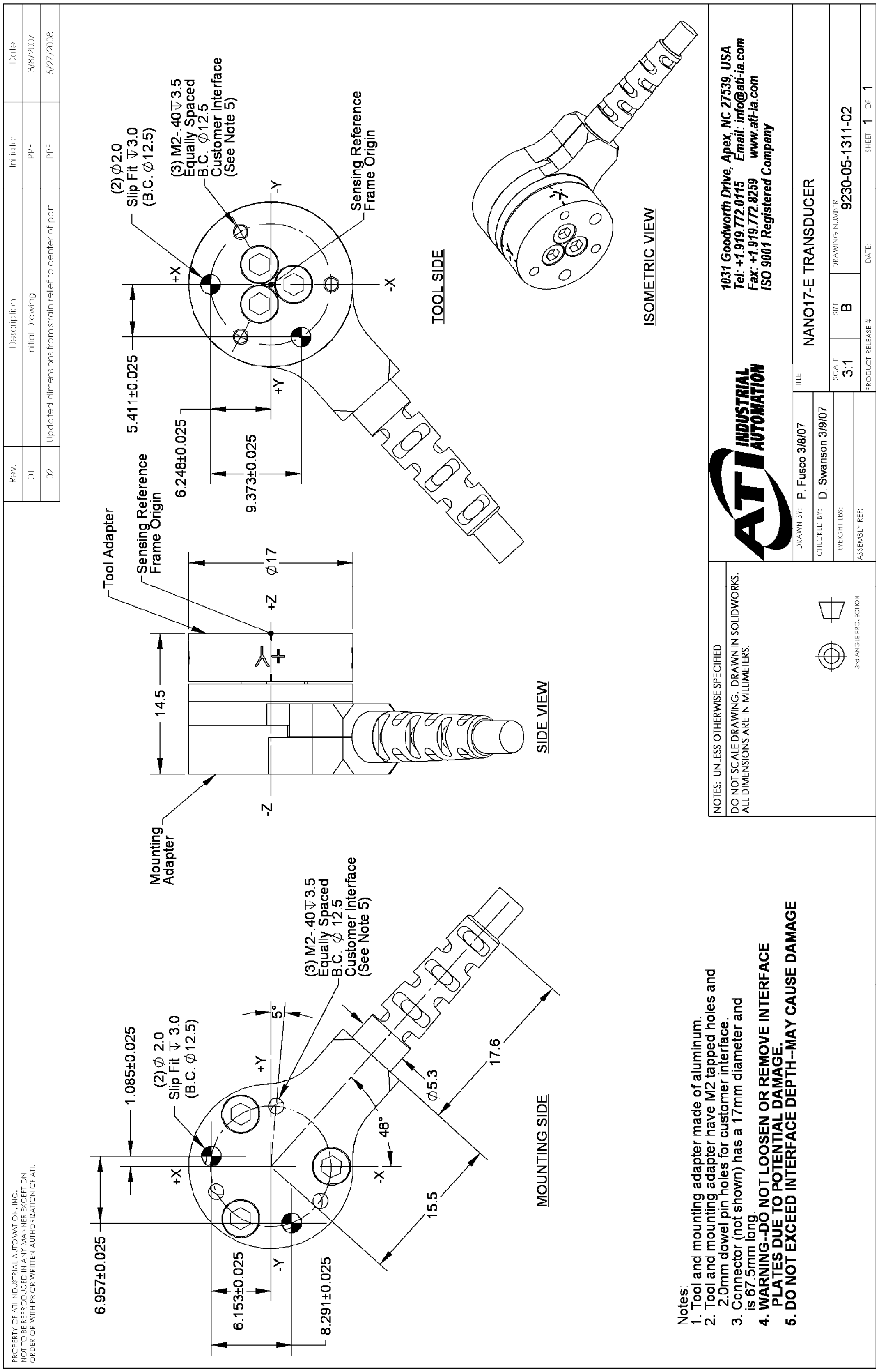


4.3.5 Nano17 (SI Calibration Complex Loading)

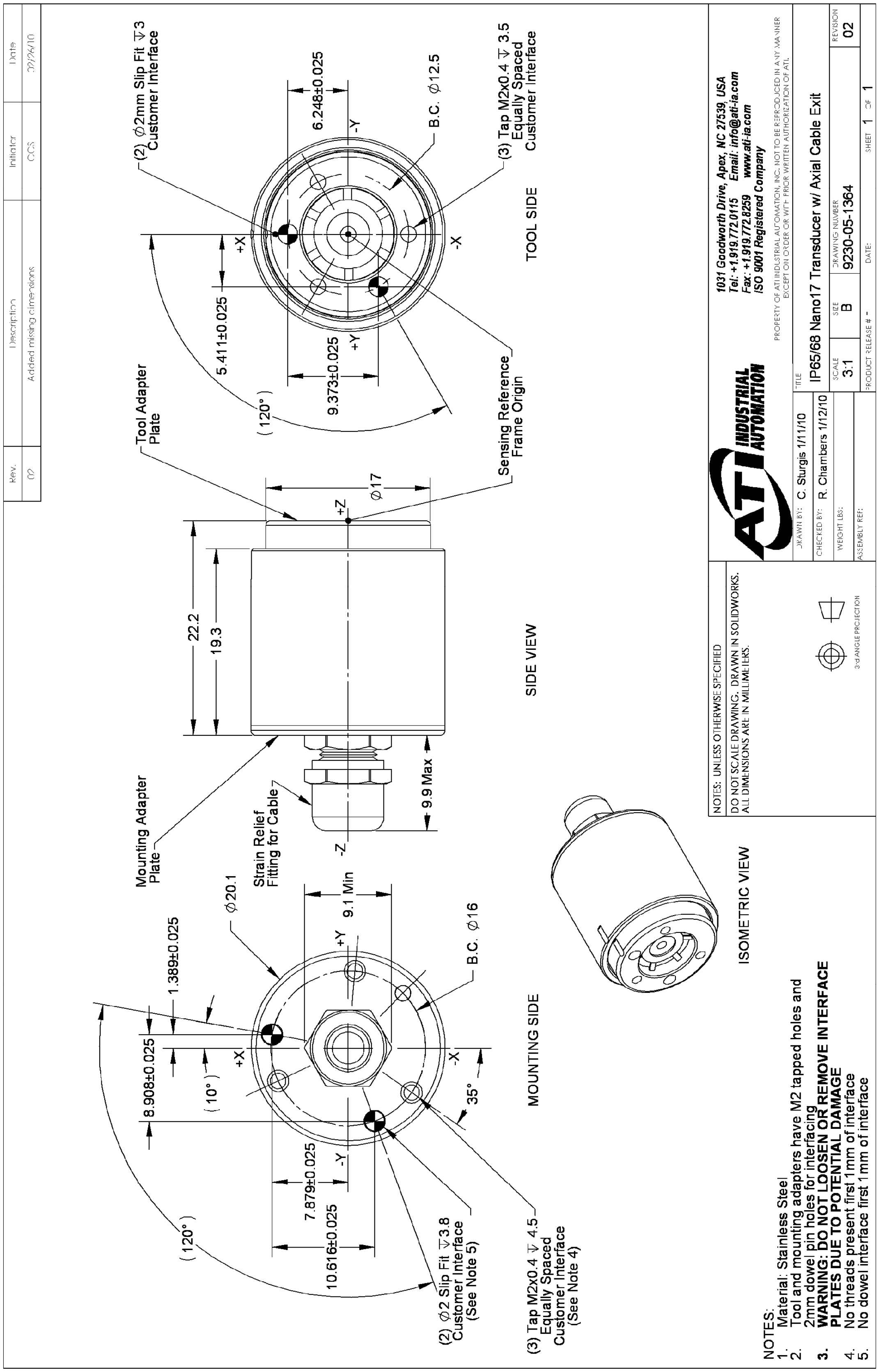




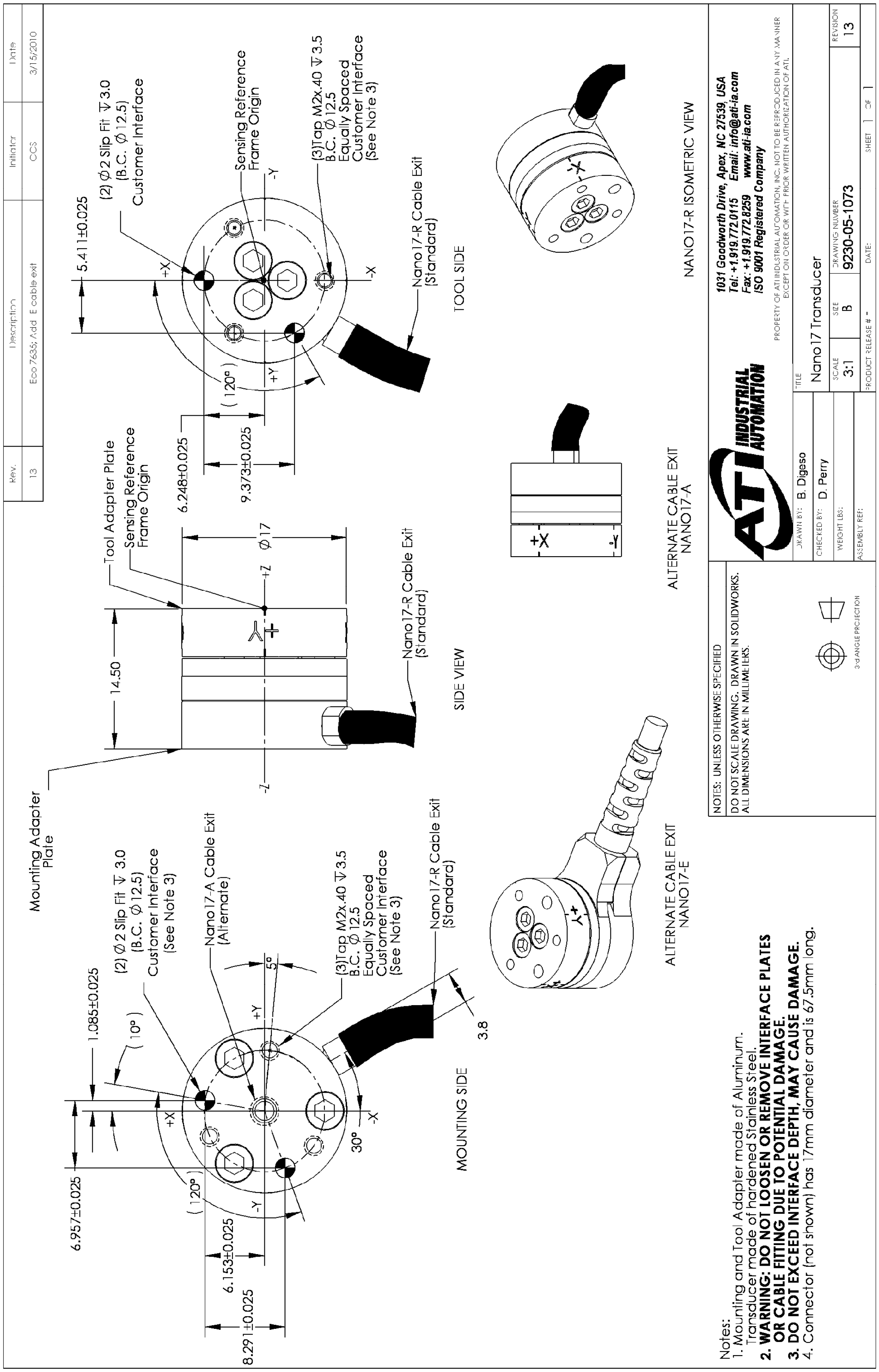
4.3.6 Nano17-E Transducer



4.3.7 Nano17 IP65/IP68 Transducer with Axial Cable Exit



4.3.8 Legacy Nano17 Transducer



4.4 Nano25—(Includes IP65/IP68 Versions)

4.4.1 Calibration Specifications (excludes CTL calibrations)

US (English)

Calibration	Fx,Fy	Fz	Tx,Ty	Tz	Fx,Fy	Fz	Tx,Ty	Tz
US-25–25	25 lbf	100 lbf	25 lbf-in	25 lbf-in	1/224 lbf	3/224 lbf	1/160 lbf-in	1/320 lbf-in
US-50–50	50 lbf	200 lbf	50 lbf-in	30 lbf-in	1/112 lbf	3/112 lbf	1/80 lbf-in	1/160 lbf-in
	SENSING RANGES				RESOLUTION			

SI (Metric)

Calibration	Fx,Fy	Fz	Tx,Ty	Tz	Fx,Fy	Fz	Tx,Ty	Tz
SI-125–3	125 N	500 N	3 Nm	3 Nm	1/48 N	1/16 N	1/1320 Nm	1/2640 Nm
SI-250–6	250 N	1000 N	6 Nm	3.4 Nm	1/24 N	1/8 N	1/660 Nm	1/1320 Nm
	SENSING RANGES				RESOLUTION			

These system resolutions quoted are the effective resolution after dropping four counts of noise. The effective resolution can be improved with filtering. NOTE: Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.

4.4.2 CTL Calibration Specifications

US (English)

Calibration	Fx,Fy	Fz	Tx,Ty	Tz	Fx,Fy	Fz	Tx,Ty	Tz
US-25–25	25 lbf	100 lbf	25 lbf-in	25 lbf-in	1/112 lbf	3/112 lbf	1/80 lbf-in	1/160 lbf-in
US-50–50	50 lbf	200 lbf	50 lbf-in	30 lbf-in	1/56 lbf	3/56 lbf	1/40 lbf-in	1/80 lbf-in
	SENSING RANGES				RESOLUTION			

SI (Metric)

Calibration	Fx,Fy	Fz	Tx,Ty	Tz	Fx,Fy	Fz	Tx,Ty	Tz
SI-125–3	125 N	500 N	3 Nm	3 Nm	1/24 N	1/8 N	1/660 Nm	1/1320 Nm
SI-250–6	250 N	1000 N	6 Nm	3.4 Nm	1/12 N	1/4 N	1/330 Nm	1/660 Nm
	SENSING RANGES				RESOLUTION			

US (English)

Calibration	Fx,Fy	Fz	Tx,Ty, Tz	Fx,Fy	Fz	Tx,Ty, Tz
US-25–25	±25 lbf	±100 lbf	±25 lbf-in	2.5 lbf/V	10 lbf/V	2.5 lbf-in/V
US-50–50	±50 lbf	±200 lbf	±50 lbf-in	5 lbf/V	20 lbf/V	5 lbf-in/V
	Analog Output Range			Analog ±10V Sensitivity‡		

SI (Metric)

Calibration	Fx,Fy	Fz	Tx,Ty, Tz	Fx,Fy	Fz	Tx,Ty, Tz
SI-125–3	±125 N	±500 N	±3 Nm	12.5 N/V	50 N/V	0.3 Nm/V
SI-250–-6	±250 N	1000 N	±6 Nm	25 N/V	100 N/V	0.6 Nm/V
	Analog Output Range			Analog ±10V Sensitivity‡		

Counts Value

Calibration	Fx, Fy, Fz	Tx, Ty, Tz	Fx, Fy, Fz	Tx, Ty, Tz
US-25–25	896 / lbf	1280 / lbf-in	192 / N	10560 / N
US-50–50	448 / lbf	640 / lbf-in	96 / Nm	5280 / Nm
Tool Transform Factor	0.007 in/unit		0.18182 mm/unit	
	Counts Value – US (English)		Counts Value – SI (Metric)	

Note: *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).*

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. NOTE: Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.

† *For IP68 version see caution on physical properties page.*

‡ *±5V Sensitivity values are double the listed ±10V Sensitivity values.*

4.4.3 Nano25 Physical Properties (Includes IP65/IP68 Versions)

US (English)

Single-Axis Overload	
Fxy	±520 lbf
Fz	±1600 lbf
Txy	±380 lbf-in
Tz	±560 lbf-in
Stiffness (Calculated)	
X-axis & Y-axis forces (Kx, Ky)	3.0×10^5 lb/in
Z-axis force (Kz)	6.3×10^5 lb/in
X-axis & Y-axis torque (Ktx, Kty)	5.7×10^4 lbf-in/rad
Z-axis torque (Ktz)	8.1×10^4 lbf-in/rad
Resonant Frequency (Measured)	
Fx, Fy, Tz	3600 Hz
Fz, Tx, Ty	3800 Hz
Physical Specifications	
Weight*	0.14 lb
Diameter*	0.98 in
Height*	0.85 in

SI (Metric)

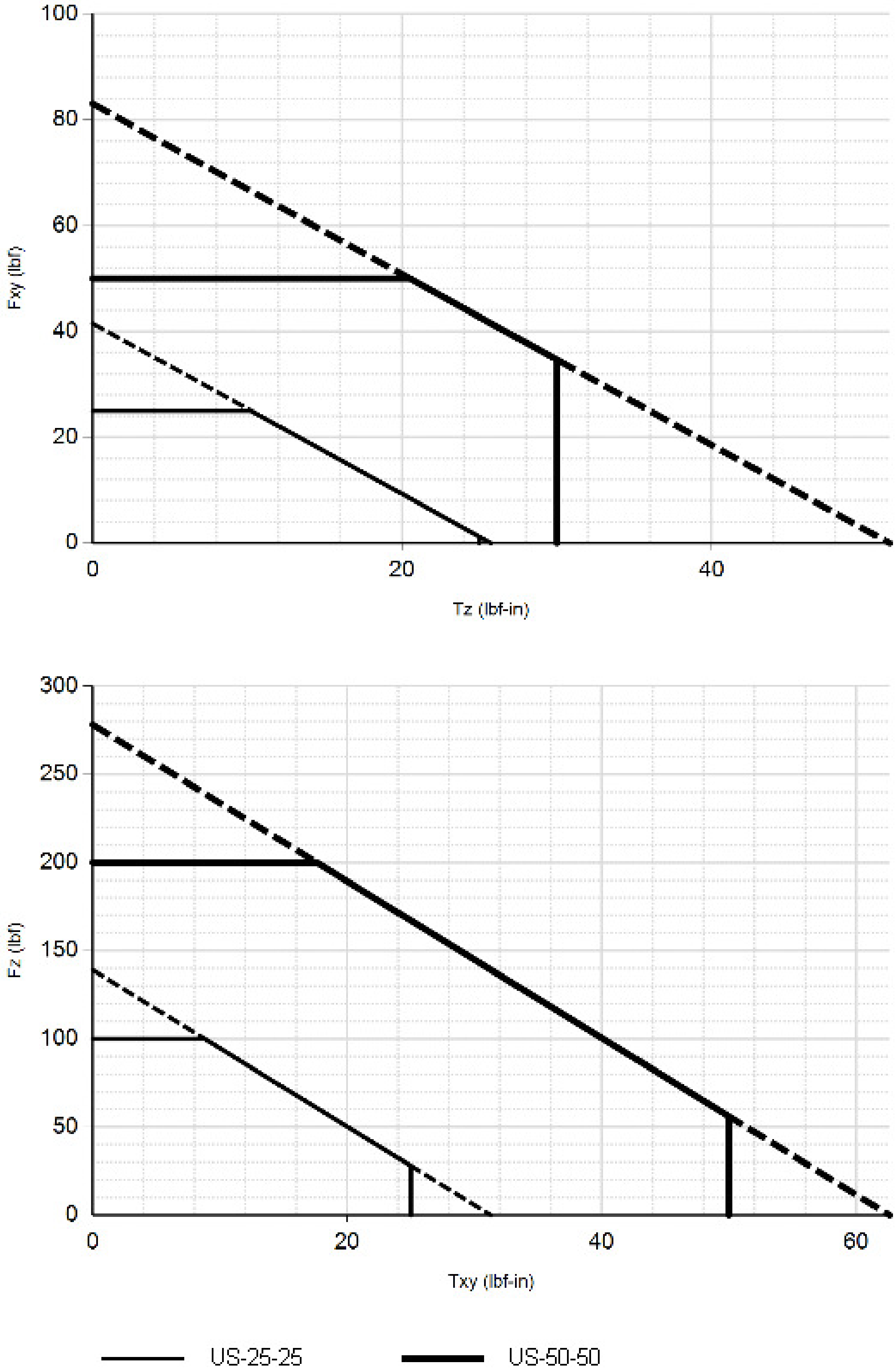
Single-Axis Overload	
Fxy	±2300 N
Fz	±7300 N
Txy	±43 Nm
Tz	±63 Nm
Stiffness (Calculated)	
X-axis & Y-axis forces (Kx, Ky)	5.3×10^7 N/m
Z-axis force (Kz)	1.1×10^8 N/m
X-axis & Y-axis torque (Ktx, Kty)	6.5×10^3 Nm/rad
Z-axis torque (Ktz)	9.2×10^3 Nm/rad
Resonant Frequency (Measured)	
Fx, Fy, Tz	3600 Hz
Fz, Tx, Ty	3800 Hz
Physical Specifications	
Weight*	0.0635 kg
Diameter*	25 mm
Height*	22 mm

** Specifications include standard interface plates.*

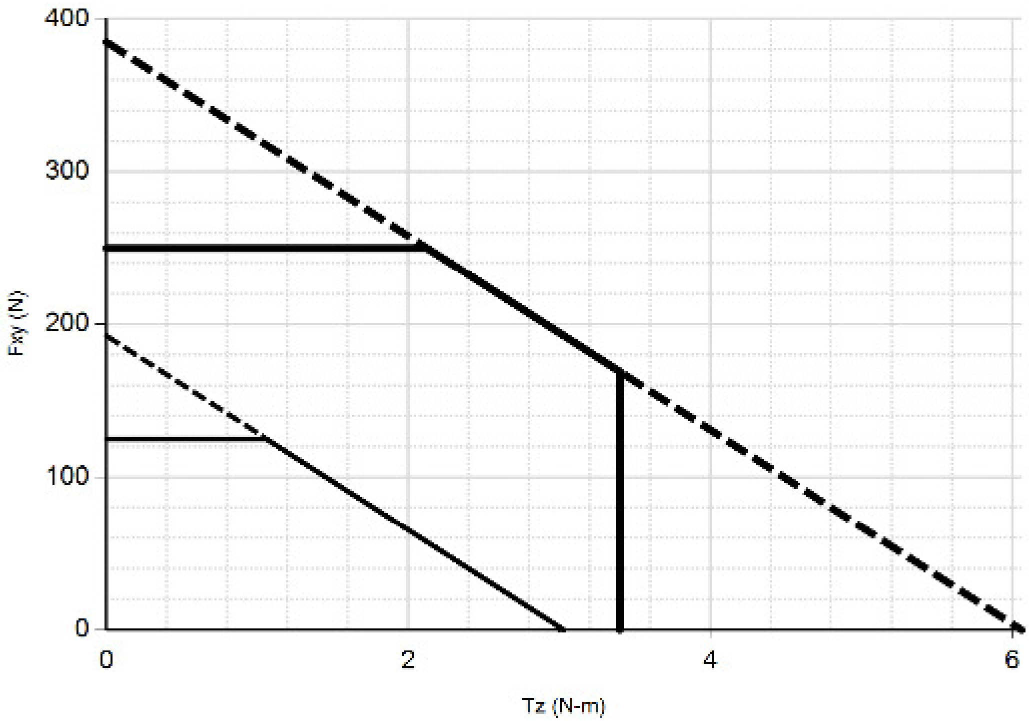
CAUTION:
IP68 Nano25 Fz as a Function of Submersion Depth:
When submerged, IP68 transducers exhibit a decrease in Fz range related to the submersion depth. This loss is the result of pressure-induced preloading on the transducer. The preload can be masked by biasing the transducer at the depth prior to applying the load to be measured. The following estimates are for room temperature fresh water at seal level.

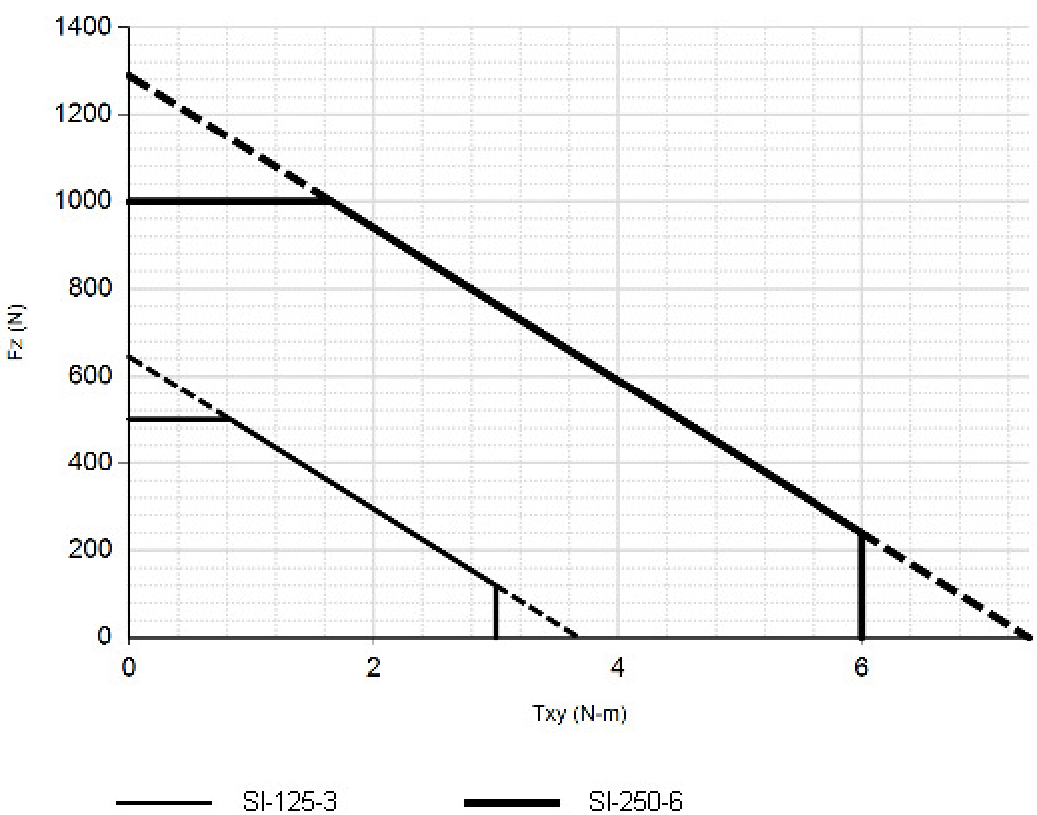
IP68 Nano25	**US**	**Metric**
Fz preload at 4m depth	-4.33 lb	-19.26 N
Fz preload at other depths	-0.33 lb/ft × depthInFeet	-4.81 N/m × depthInMeters

4.4.4 Nano25 (US Calibration Complex Loading) (Includes IP65/IP68 Versions)

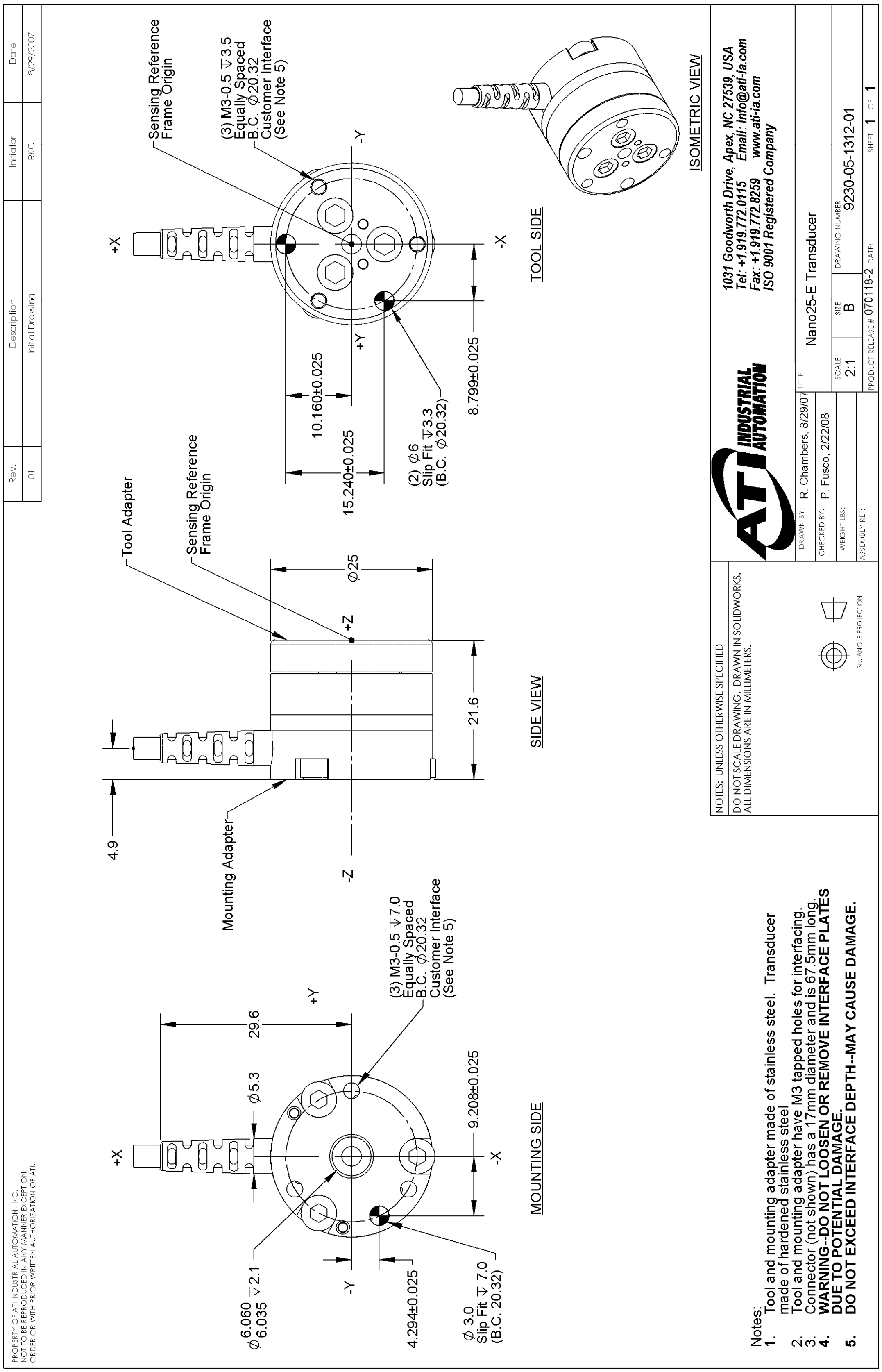


4.4.5 Nano25 (SI Calibration Complex Loading) (Includes IP65/IP68 Versions)

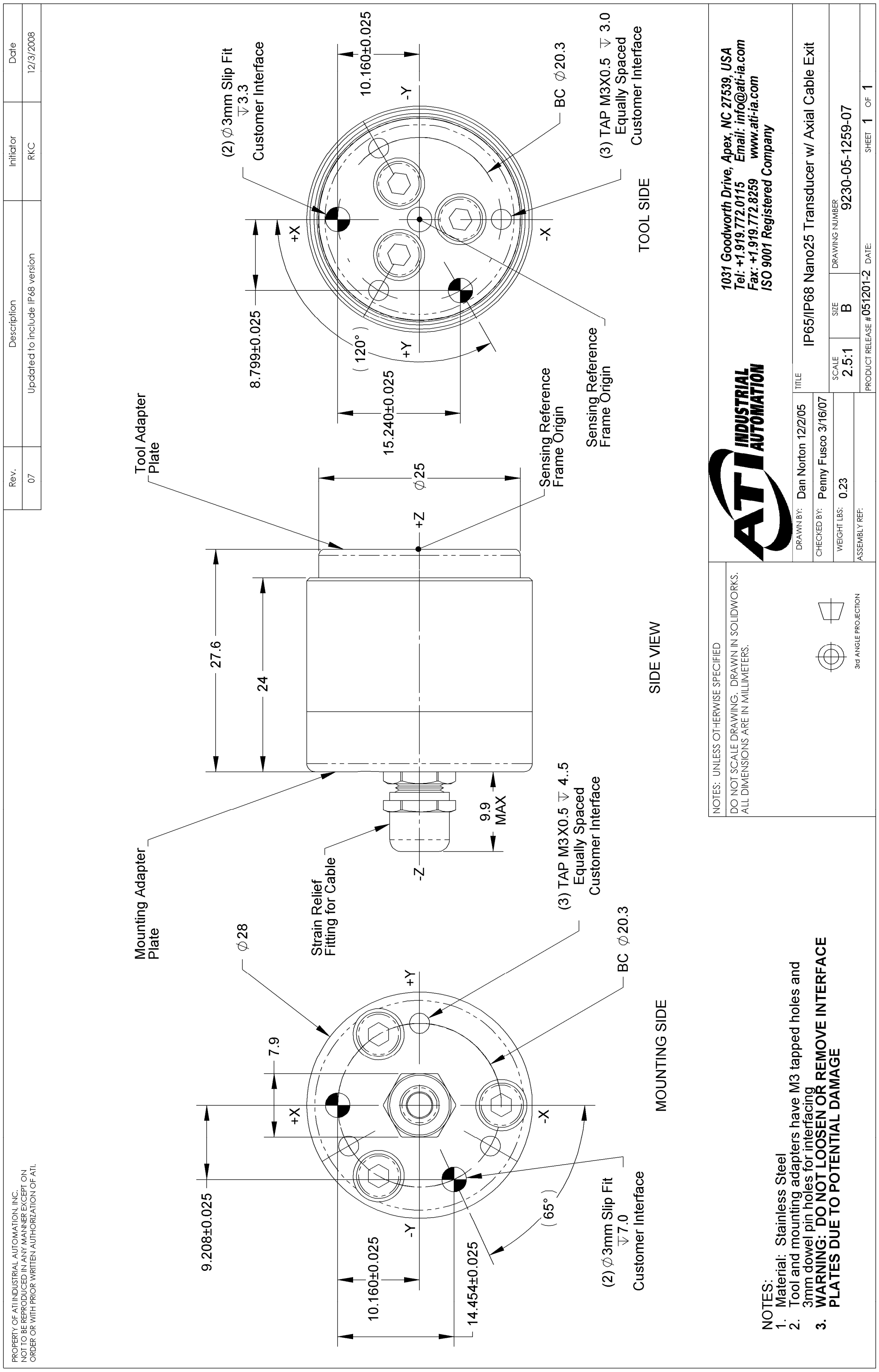




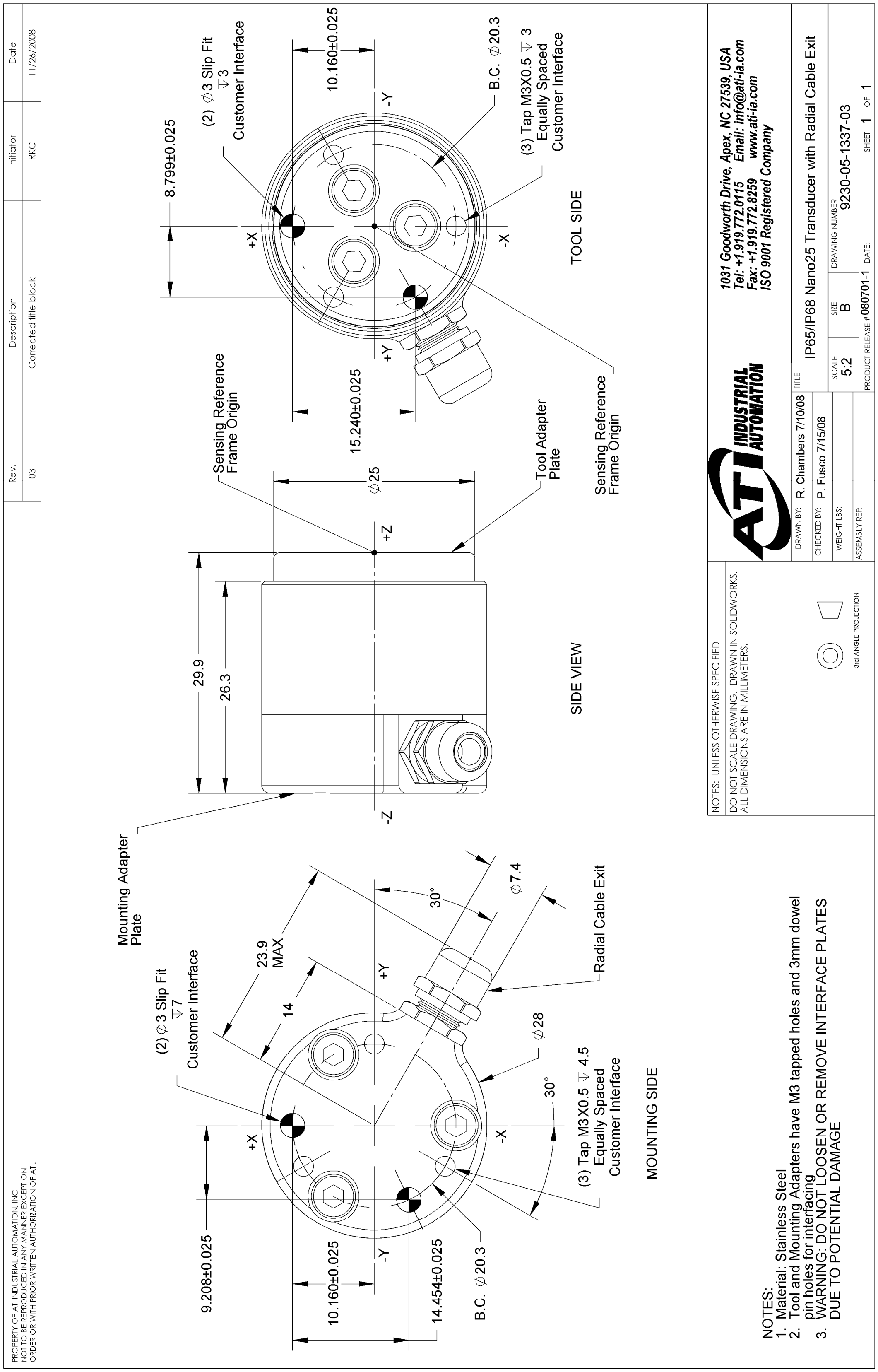
4.4.6 Nano25-E Transducer



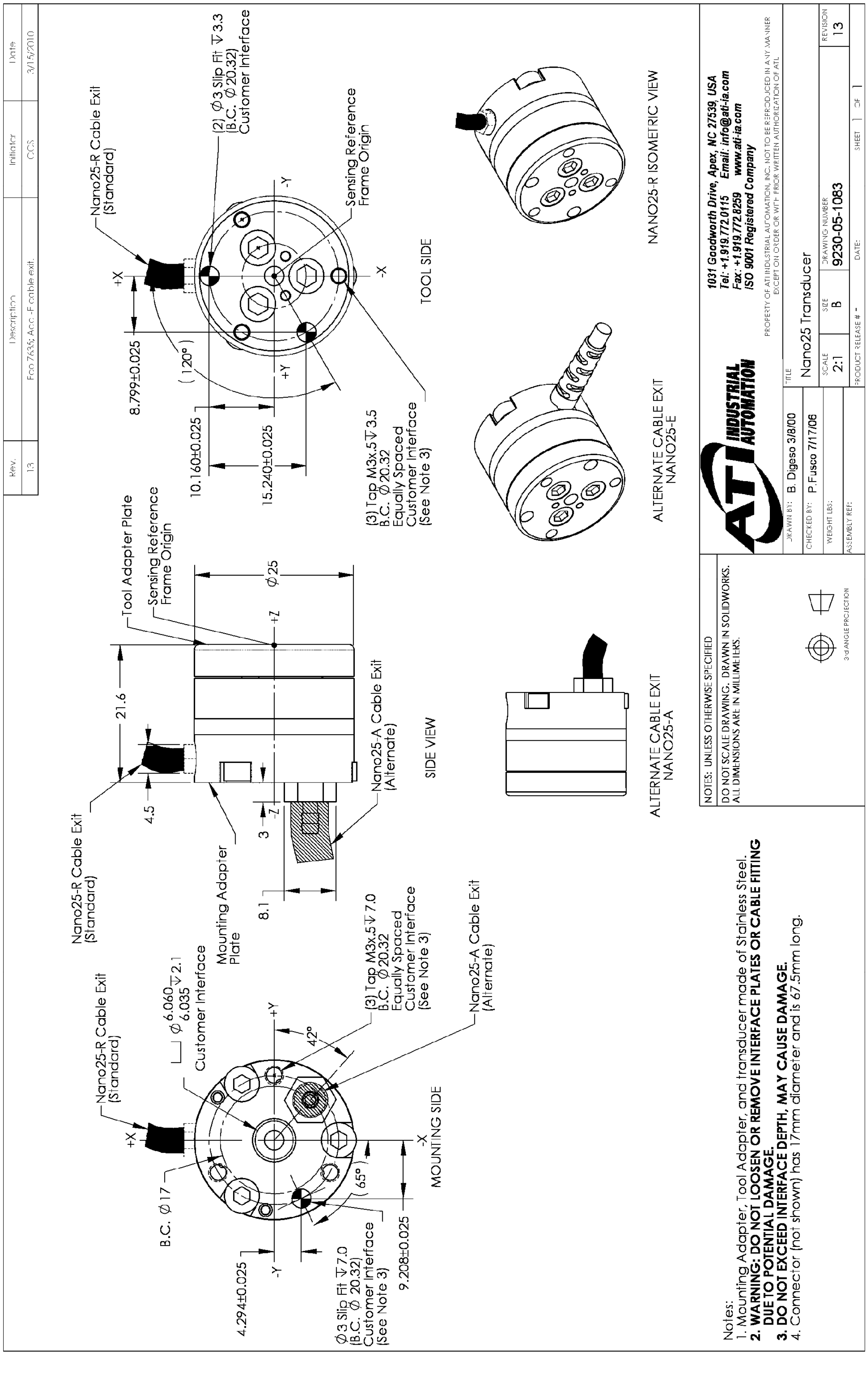
4.4.7 Nano25 IP65/IP68 Transducer with Axial Cable Exit



4.4.8 Nano25 IP65/IP68 Transducer with Radial Cable Exit



4.4.9 Legacy Nano25 Transducer



4.5 Nano43

4.5.1 Calibration Specifications (excludes CTL calibrations)

US (English)

Calibration	Fx,Fy	Fz	Tx,Ty	Tz	Fx,Fy	Fz	Tx,Ty	Tz
US-4–2	4 lbf	4 lbf	2 lbf-in	2 lbf-in	1/1160 lbf	1/1160 lbf	1/2320 lbf-in	1/2320 lbf-in
US-8–4	8 lbf	8 lbf	4 lbf-in	4 lbf-in	1/580 lbf	1/580 lbf	1/1160 lbf-in	1/1160 lbf-in
	SENSING RANGES				RESOLUTION*			

SI (Metric)

Calibration	Fx,Fy	Fz	Tx,Ty	Tz	Fx,Fy	Fz	Tx,Ty	Tz
SI-18–0.25	18 N	18 N	250 Nmm	250 Nmm	1/256 N	1/256 N	1/20 Nmm	1/20 Nmm
SI-36–0.5	36 N	36 N	500 Nmm	500 Nmm	1/128 N	1/128 N	1/10 Nmm	1/10 Nmm
	SENSING RANGES				RESOLUTION*			

** DAQ resolutions are typical for a 16-bit data acquisition system.*

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

4.5.2 CTL Calibration Specifications

US (English)

Calibration	Fx,Fy	Fz	Tx,Ty	Tz	Fx,Fy	Fz	Tx,Ty	Tz
US-4–2	4 lbf	4 lbf	2 lbf-in	2 lbf-in	1/580 lbf	1/580 lbf	1/1160 lbf-in	1/1160 lbf-in
US-8–4	8 lbf	8 lbf	4 lbf-in	4 lbf-in	1/290 lbf	1/290 lbf	1/580 lbf-in	1/580 lbf-in
	SENSING RANGES				**RESOLUTION**			

SI (Metric)

Calibration	Fx,Fy	Fz	Tx,Ty	Tz	Fx,Fy	Fz	Tx,Ty	Tz
SI-18–0.25	18 N	18 N	250 Nmm	250 Nmm	1/128 N	1/128 N	1/10 Nmm	1/10 Nmm
SI-36–0.5	36 N	36 N	500 Nmm	500 Nmm	1/64 N	1/64 N	1/5 Nmm	1/5 Nmm
	SENSING RANGES				**RESOLUTION**			

US (English)

Calibration	Fx,Fy	Fz	Tx,Ty, Tz	Fx,Fy	Fz	Tx,Ty, Tz
US-4–2	±4 lbf	±4 lbf	2 lbf-in	0.4 lbf/V	0.4 lbf/V	0.2 lbf-in/V
US-8–4	±8 lbf	±8 lbf	±4 lbf-in	0.8 lbf/V	0.8 lbf/V	0.4 lbf-in/V
	Analog Output Range			**Analog ±10V Sensitivity‡**		

SI (Metric)

Calibration	Fx,Fy	Fz	Tx,Ty, Tz	Fx,Fy	Fz	Tx,Ty, Tz
SI-18–0.25	±18 N	±18 N	±250 Nmm	1.8 N/V	1.8 N/V	25 Nmm/V
SI-36–0.5	±36 N	±36 N	±500 Nmm	3.6 N/V	3.6 N/V	50 Nmm/V
	Analog Output Range			**Analog ±10V Sensitivity‡**		

Counts Value

Calibration	Fx, Fy, Fz	Tx, Ty, Tz	Fx, Fy, Fz	Tx, Ty, Tz
US-4–2	4640 / lbf	9280 / lbf-in	1024 / N	80 / Nmm
US-8–4	2320 / lbf	4640 / lbf-in	512 / N	40 / Nmm
Tool Transform Factor	0.005 in/unit		0.128 mm/unit	
	Counts Value – US (English)		**Counts Value – SI (Metric)**	

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. NOTE: Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.

‡ *±5V Sensitivity values are double the listed ±10V Sensitivity values.*

4.5.3 Nano43 Physical Properties

US (English)

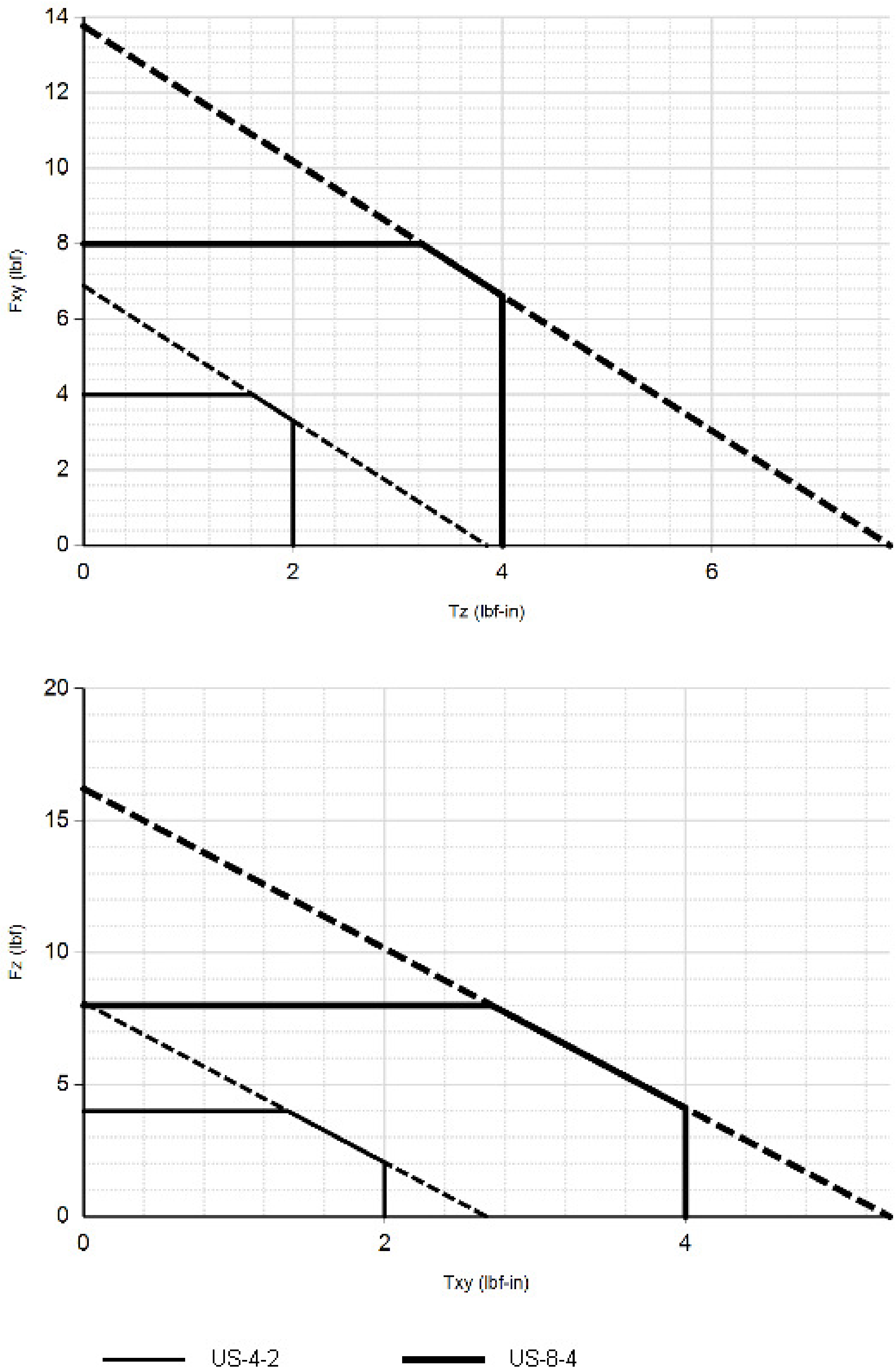
Single-Axis Overload	
Fxy	±68 lbf
Fz	±86 lbf
Txy	±29 lbf-in
Tz	±41 lbf-in
Stiffness (Calculated)	
X-axis & Y-axis forces (Kx, Ky)	$2.9x10^4$ lb/in
Z-axis force (Kz)	$2.9x10^4$ lb/in
X-axis & Y-axis torque (Ktx, Kty)	$6.8x10^3$ lbf-in/rad
Z-axis torque (Ktz)	$1.0x10^4$ lbf-in/rad
Resonant Frequency (Measured)	
Fx, Fy, Tz	2800 Hz
Fz, Tx, Ty	2300 Hz
Physical Specifications	
Weight*	0.085 lb
Diameter*	1.7 in
Height*	0.45 in

SI (Metric)

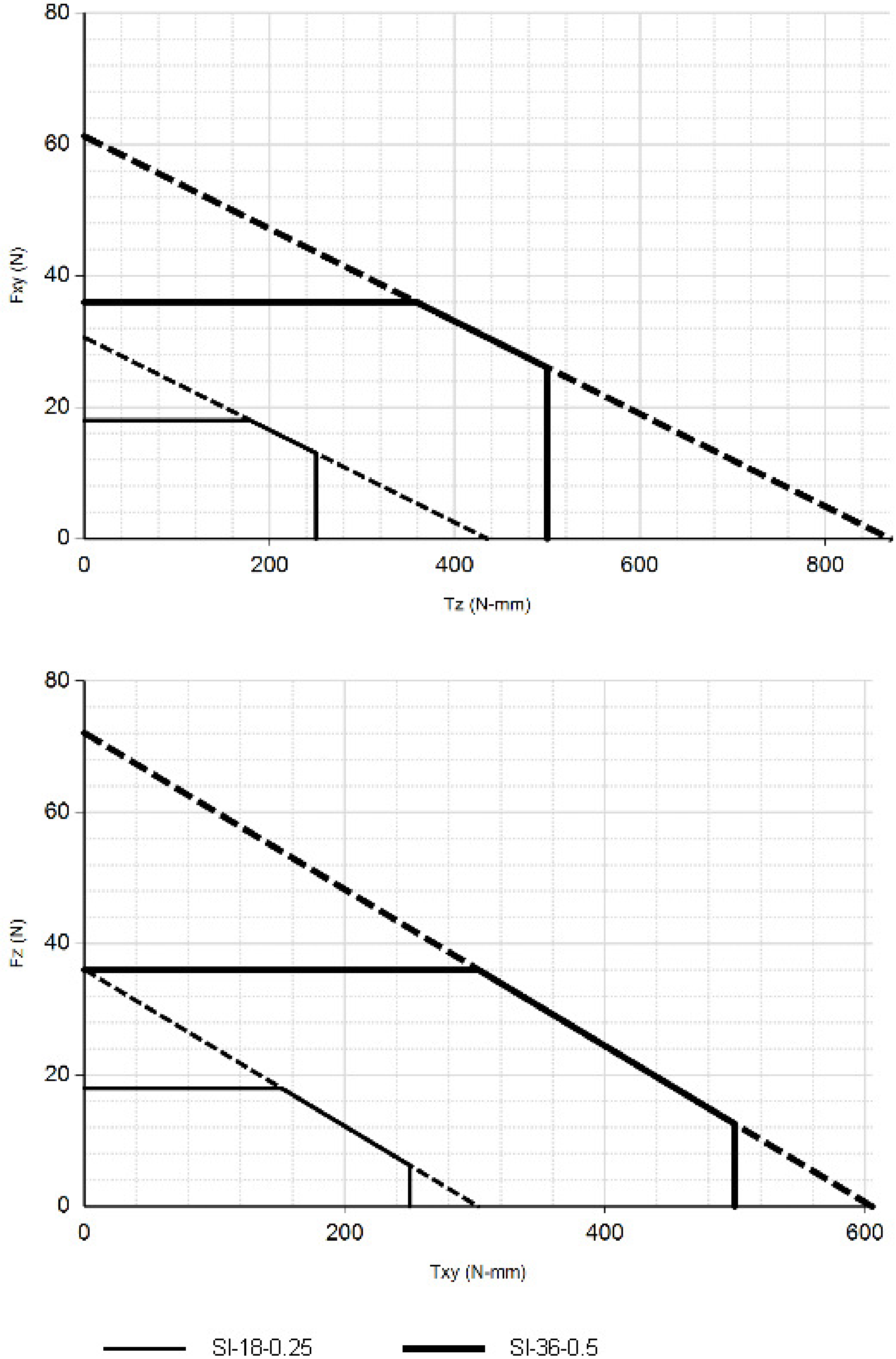
Single-Axis Overload	
Fxy	±300 N
Fz	±380 N
Txy	±3.3 Nm
Tz	±4.6 Nm
Stiffness (Calculated)	
X-axis & Y-axis forces (Kx, Ky)	$5.2x10^6$ N/m
Z-axis force (Kz)	$5.2x10^6$ N/m
X-axis & Y-axis torque (Ktx, Kty)	$7.7x10^2$ Nm/rad
Z-axis torque (Ktz)	$1.1x10^3$ Nm/rad
Resonant Frequency (Measured)	
Fx, Fy, Tz	2800 Hz
Fz, Tx, Ty	2300 Hz
Physical Specifications	
Weight*	0.0386 kg
Diameter*	43 mm
Height*	12 mm

** Specifications include standard interface plates.*

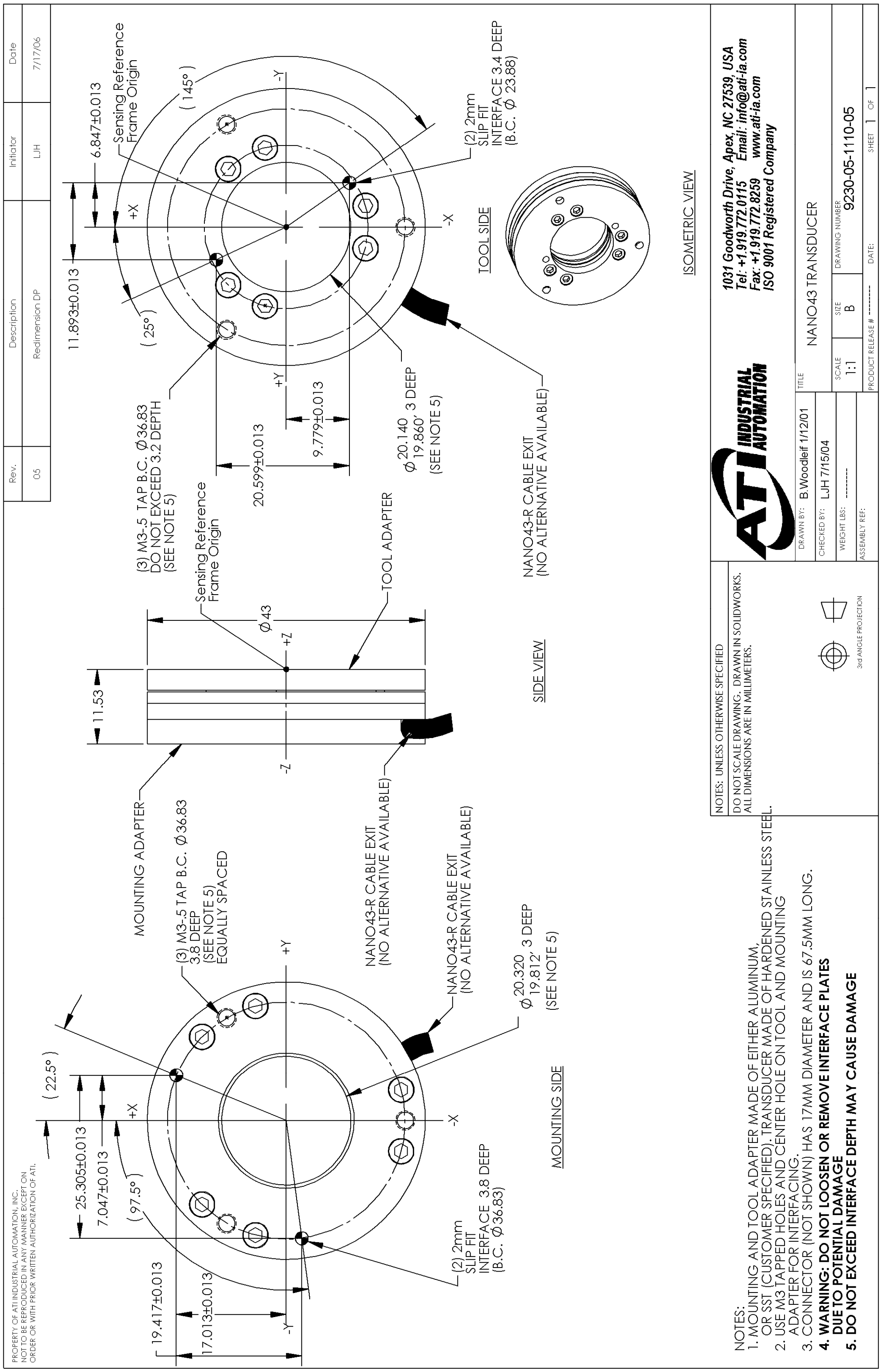
4.5.4 Nano43 (US Calibration Complex Loading)



4.5.5 Nano43 (SI Calibration Complex Loading)



4.5.6 Nano43 Transducer



4.6 Mini40

4.6.1 Calibration Specifications (excludes CTL calibrations)

US (English)

Calibration	Fx,Fy	Fz	Tx,Ty	Tz	Fx,Fy	Fz	Tx,Ty	Tz
US-5–10	5 lbf	15 lbf	10 lbf-in	10 lbf-in	1/800 lbf	1/400 lbf	1/800 lbf-in	1/800 lbf-in
US-10–20	10 lbf	30 lbf	20 lbf-in	20 lbf-in	1/400 lbf	1/200 lbf	1/400 lbf-in	1/400 lbf-in
US-20–40	20 lbf	60 lbf	40 lbf-in	40 lbf-in	1/200 lbf	1/100 lbf	1/200 lbf-in	1/200 lbf-in
	SENSING RANGES				RESOLUTION*			

SI (Metric)

Calibration	Fx,Fy	Fz	Tx,Ty	Tz	Fx,Fy	Fz	Tx,Ty	Tz
SI-20–1	20 N	60 N	1 Nm	1 Nm	1/200 N	1/100 N	1/8000 Nm	1/8000 Nm
SI-40–2	40 N	120 N	2 Nm	2 Nm	1/100 N	1/50 N	1/4000 Nm	1/4000 Nm
SI-80–4	80 N	240 N	4 Nm	4 Nm	1/50 N	1/25 N	1/2000 Nm	1/2000 Nm
	SENSING RANGES				RESOLUTION*			

** DAQ resolutions are typical for a 16-bit data acquisition system.*

These system resolutions quoted are the effective resolution after dropping four counts of noise. The effective resolution can be improved with filtering. NOTE: Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.

4.6.2 CTL Calibration Specifications

US (English)

Calibration	Fx,Fy	Fz	Tx,Ty	Tz	Fx,Fy	Fz	Tx,Ty	Tz
US-5–10	5 lbf	15 lbf	10 lbf-in	10 lbf-in	1/400 lbf	1/200 lbf	1/400 lbf-in	1/400 lbf-in
US-10–20	10 lbf	30 lbf	20 lbf-in	20 lbf-in	1/200 lbf	1/100 lbf	1/200 lbf-in	1/200 lbf-in
US-20–40	20 lbf	60 lbf	40 lbf-in	40 lbf-in	1/100 lbf	1/50 lbf	1/100 lbf-in	1/100 lbf-in
	SENSING RANGES				RESOLUTION			

SI (Metric)

Calibration	Fx,Fy	Fz	Tx,Ty	Tz	Fx,Fy	Fz	Tx,Ty	Tz
SI-20–1	20 N	60 N	1 Nm	1 Nm	1/100 N	1/50 N	1/4000 Nm	1/4000 Nm
SI-40–2	40 N	120 N	2 Nm	2 Nm	1/50 N	1/25 N	1/2000 Nm	1/2000 Nm
SI-80–4	80 N	240 N	4 Nm	4 Nm	1/25 N	2/25 N	1/1000 Nm	1/1000 Nm
	SENSING RANGES				RESOLUTION			

US (English)

Calibration	Fx,Fy	Fz†	Tx,Ty, Tz	Fx,Fy	Fz†	Tx,Ty, Tz
US-5–10	±5 lbf	±15 lbf	±10 lbf-in	0.5 lbf/V	1.5 lbf/V	1 lbf-in/V
US-10–20	±10 lbf	±30 lbf	±20 lbf-in	1 lbf/V	3 lbf/V	2 lbf-in/V
US-20–40	±20 lbf	±60 lbf	±40 lbf-in	2 lbf/V	6 lbf/V	4 lbf-in/V
	Analog Output Range			Analog ±10V Sensitivity‡		

SI (Metric)

Calibration	Fx,Fy	Fz†	Tx,Ty, Tz	Fx,Fy	Fz†	Tx,Ty, Tz
SI-20–1	±20 N	±60 N	±1 Nm	2 N/V	6 N/V	0.1 Nm/V
SI-40–2	±40 N	±120 N	±2 Nm	4 N/V	12 N/V	0.2 Nm/V
SI-80–4	±80 N	±240 N	±4 Nm	8 N/V	24 N/V	0.4 Nm/V
	Analog Output Range			Analog ±10V Sensitivity‡		

Counts Value

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

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. NOTE: Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.

‡ *±5V Sensitivity values are double the listed ±10V Sensitivity values.*

4.6.3 Mini40 Physical Properties

US (English)

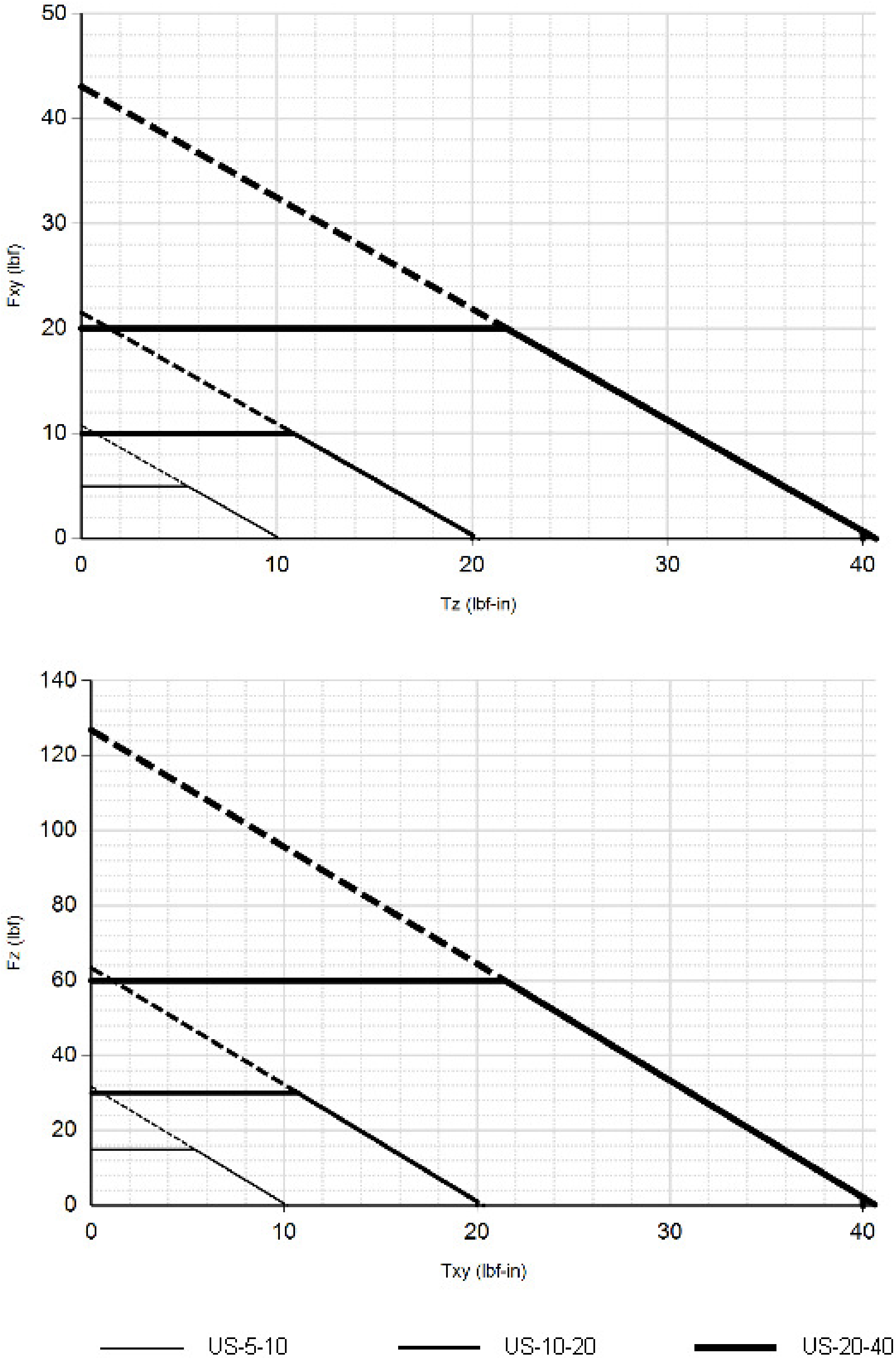
Single-Axis Overload	
Fxy	±180 lbf
Fz	±530 lbf
Txy	±170 lbf-in
Tz	±180 lbf-in
Stiffness (Calculated)	
X-axis & Y-axis forces (Kx, Ky)	6.1×10^4 lb/in
Z-axis force (Kz)	1.2×10^5 lb/in
X-axis & Y-axis torque (Ktx, Kty)	2.5×10^4 lbf-in/rad
Z-axis torque (Ktz)	3.6×10^4 lbf-in/rad
Resonant Frequency (Measured)	
Fx, Fy, Tz	3200 Hz
Fz, Tx, Ty	4900 Hz
Physical Specifications	
Weight*	0.11 lb
Diameter*	1.6 in
Height*	0.48 in

SI (Metric)

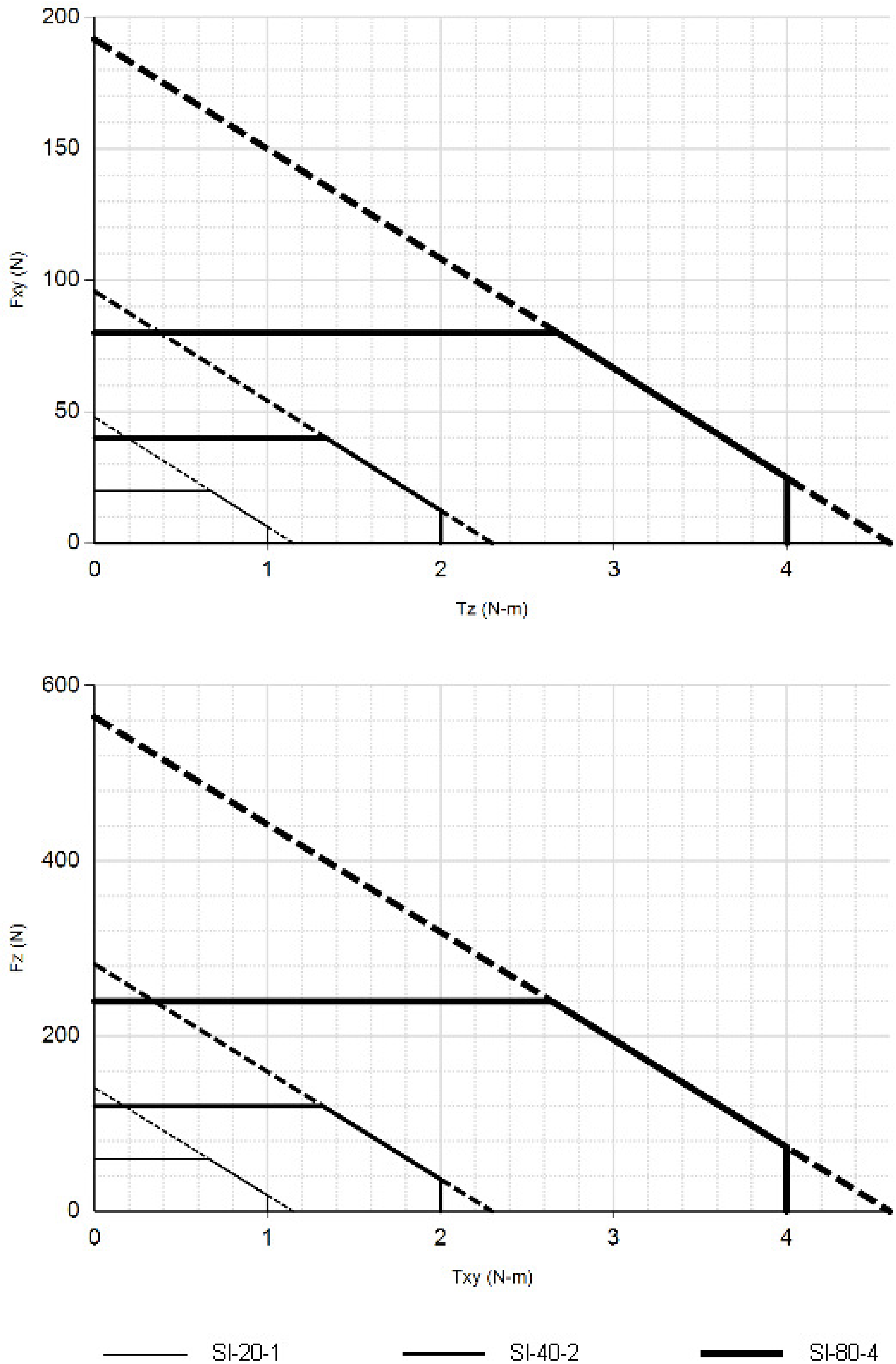
Single-Axis Overload	
Fxy	±810 N
Fz	±2400 N
Txy	±19 Nm
Tz	±20 Nm
Stiffness (Calculated)	
X-axis & Y-axis forces (Kx, Ky)	1.1×10^7 N/m
Z-axis force (Kz)	2.0×10^7 N/m
X-axis & Y-axis torque (Ktx, Kty)	2.8×10^3 Nm/rad
Z-axis torque (Ktz)	4.0×10^3 Nm/rad
Resonant Frequency (Measured)	
Fx, Fy, Tz	3200 Hz
Fz, Tx, Ty	4900 Hz
Physical Specifications	
Weight*	0.0499 kg
Diameter*	40 mm
Height*	12 mm

** Specifications include standard interface plates.*

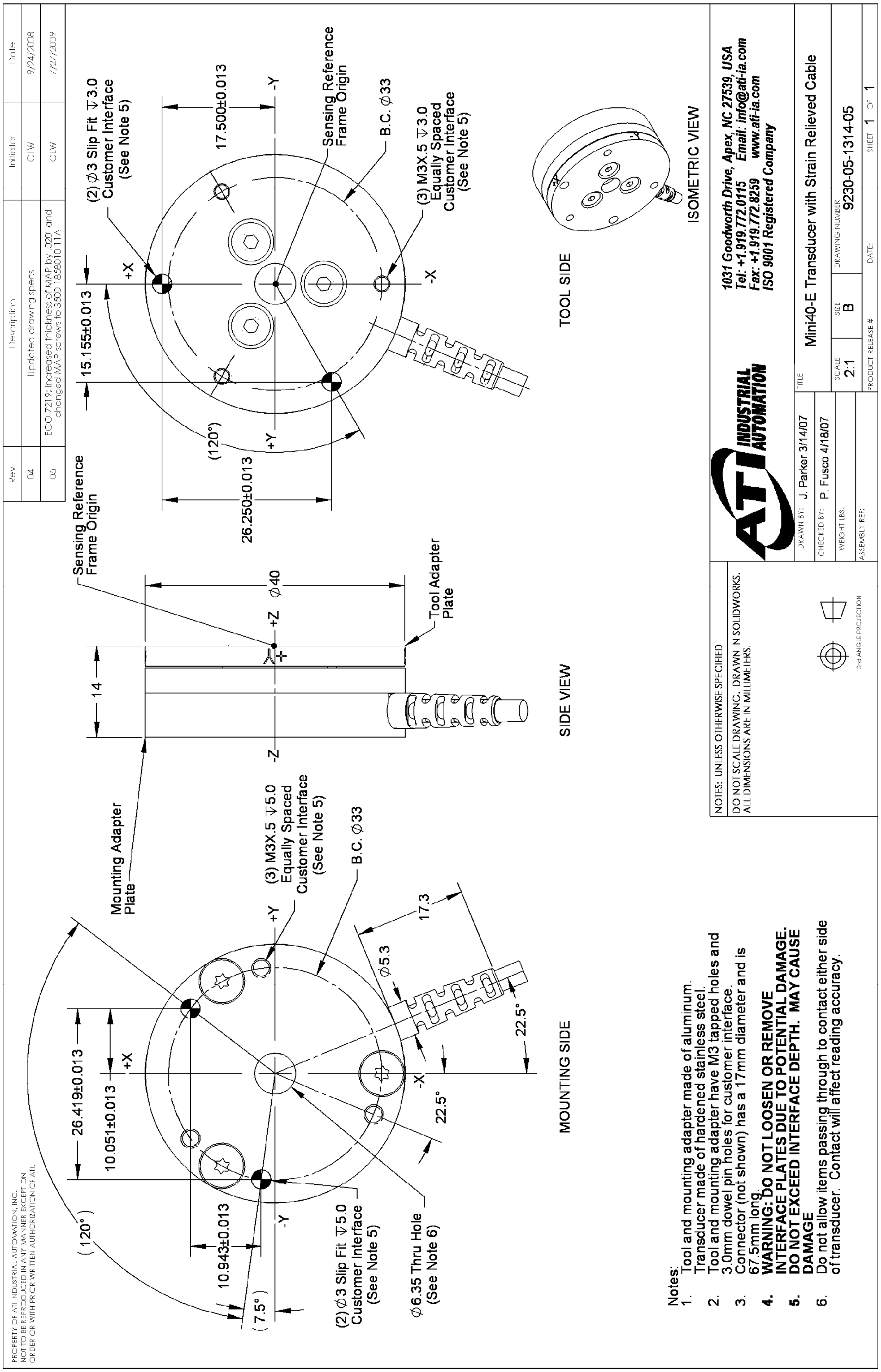
4.6.4 Mini40 (US Calibration Complex Loading)



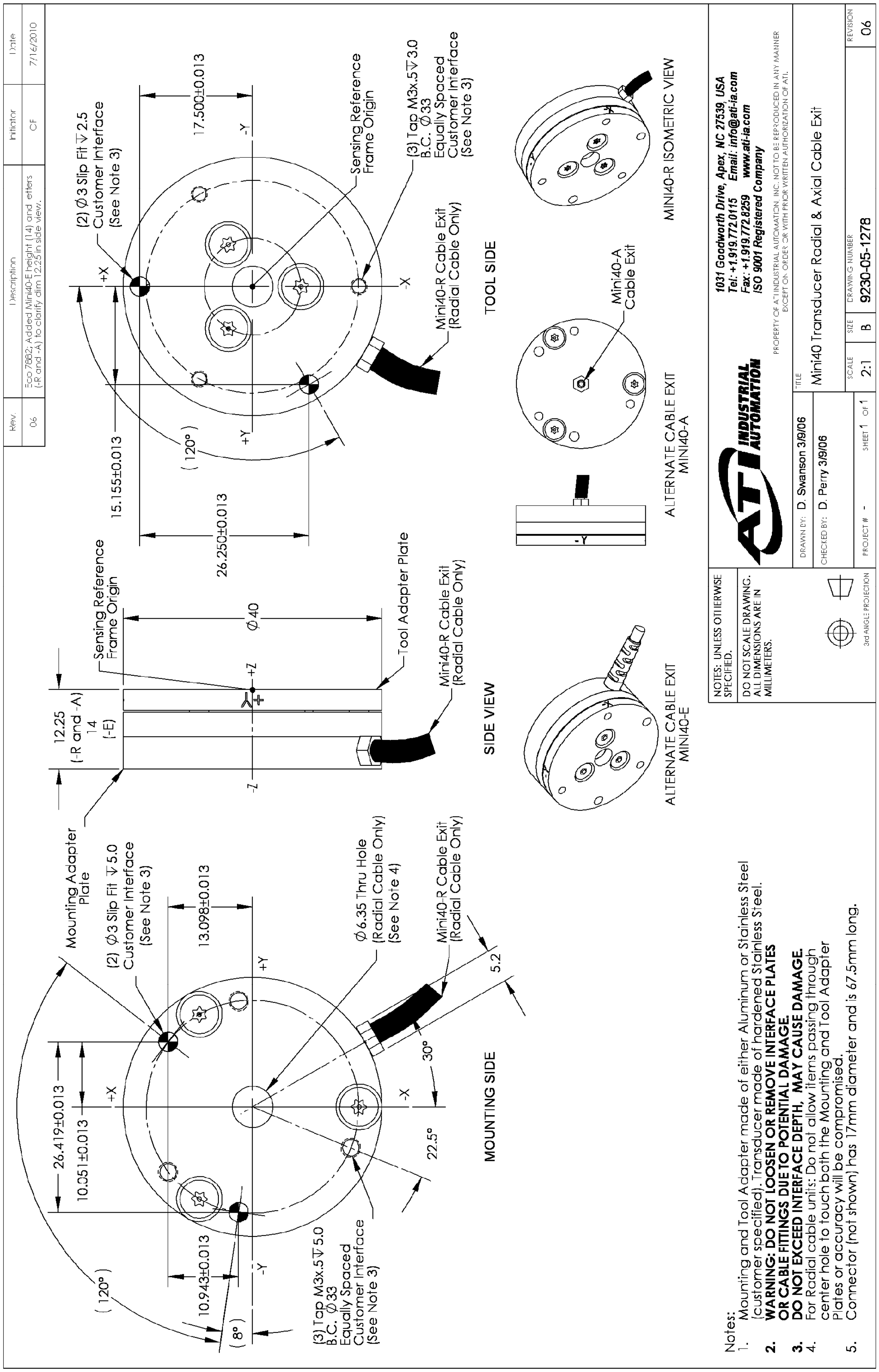
4.6.5 Mini40 (SI Calibration Complex Loading)



4.6.6 Mini40-E Transducer



4.6.7 Legacy Mini40 Transducer



4.7 Mini45

4.7.1 Calibration Specifications (excludes CTL calibrations)

US (English)

Calibration	Fx,Fy	Fz	Tx,Ty	Tz	Fx,Fy	Fz	Tx,Ty	Tz
US-30-–0	30 lbf	60 lbf	40 lbf-in	40 lbf-in	1/80 lbf	1/80 lbf	1/88 lbf-in	1/176 lbf-in
US-60–80	60 lbf	120 lbf	80 lbf-in	80 lbf-in	1/40 lbf	1/40 lbf	1/44 lbf-in	1/88 lbf-in
US-120–160	120 lbf	240 lbf	160 lbf-in	160 lbf-in	1/20 lbf	1/20 lbf	1/22 lbf-in	1/44 lbf-in
	SENSING RANGES				RESOLUTION*			

SI (Metric)

Calibration	Fx,Fy	Fz	Tx,Ty	Tz	Fx,Fy	Fz	Tx,Ty	Tz
SI-145–5	145 N	290 N	5 Nm	5 Nm	1/16 N	1/16 N	1/752 Nm	1/1504 Nm
SI-290–10	290 N	580 N	10 Nm	10 Nm	1/8 N	1/8 N	1/376 Nm	1/752 Nm
SI-580–20	580 N	1160 N	20 Nm	20 Nm	1/4 N	1/4 N	1/188 Nm	1/376 Nm
	SENSING RANGES				RESOLUTION*			

* *DAQ resolutions are typical for a 16-bit data acquisition system.*

These system resolutions quoted are the effective resolution after dropping four counts of noise. The effective resolution can be improved with filtering. NOTE: Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.

4.7.2 CTL Calibration Specifications

US (English)

Calibration	Fx,Fy	Fz	Tx,Ty	Tz	Fx,Fy	Fz	Tx,Ty	Tz
US-30–40	30 lbf	60 lbf	40 lbf-in	40 lbf-in	1/40 lbf	1/40 lbf	1/44 lbf-in	1/88 lbf-in
US-60–80	60 lbf	120 lbf	80 lbf-in	80 lbf-in	1/20 lbf	1/20 lbf	1/22 lbf-in	1/44 lbf-in
US-120–160	120 lbf	240 lbf	160 lbf-in	160 lbf-in	1/10 lbf	1/10 lbf	1/11 lbf-in	1/22 lbf-in
	SENSING RANGES				RESOLUTION			

SI (Metric)

Calibration	Fx,Fy	Fz	Tx,Ty	Tz	Fx,Fy	Fz	Tx,Ty	Tz
SI-145–5	145 N	290 N	5 Nm	5 Nm	1/8 N	1/8 N	1/376 Nm	1/752 Nm
SI-290–10	290 N	580 N	10 Nm	10 Nm	1/4 N	1/4 N	1/188 Nm	1/376 Nm
SI-580–20	580 N	1160 N	20 Nm	20 Nm	1/2 N	1/2 N	1/94 Nm	1/188 Nm
	SENSING RANGES				RESOLUTION			

US (English)

Calibration	Fx,Fy	Fz†	Tx,Ty, Tz	Fx,Fy	Fz†	Tx,Ty, Tz
US-30–40	±30 lbf	±60 lbf	±40 lbf-in	3 lbf/V	6 lbf/V	4 lbf-in/V
US-60–80	±60 lbf	±120 lbf	±80 lbf-in	6 lbf/V	12 lbf/V	8 lbf-in/V
US-120–160	±120 lbf	±240 lbf	±160 lbf-in	12 lbf/V	24 lbf/V	16 lbf-in/V
	Analog Output Range			Analog ±10V Sensitivity‡		

SI (Metric)

Calibration	Fx,Fy	Fz†	Tx,Ty, Tz	Fx,Fy	Fz†	Tx,Ty, Tz
SI-145–5	±145 N	±290 N	±5 Nm	14.5 N/V	29 N/V	0.5 Nm/V
SI-290–10	±290 N	±580 N	±10 Nm	29 N/V	58 N/V	1 Nm/V
SI-580–20	±580 N	±1160 N	±20 Nm	58 N/V	116 N/V	2 Nm/V
	Analog Output Range			Analog ±10V Sensitivity‡		

Counts Value

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

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. NOTE: Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.

‡ *±5V Sensitivity values are double the listed ±10V Sensitivity values.*

4.7.3 Mini45 Physical Properties

US (English)

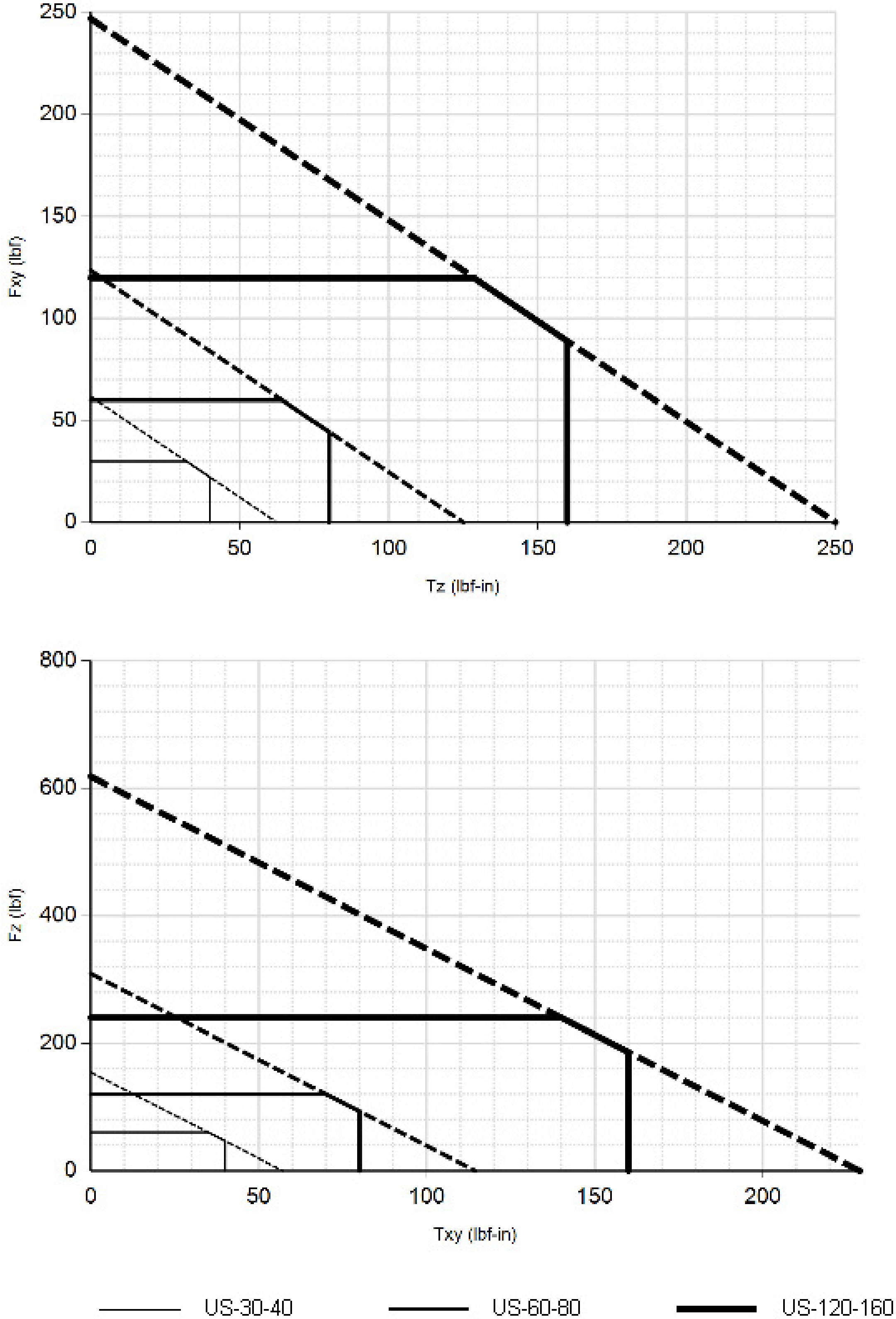
Single-Axis Overload	
Fxy	±1100 lbf
Fz	±2300 lbf
Txy	±1000 lbf-in
Tz	±1200 lbf-in
Stiffness (Calculated)	
X-axis & Y-axis forces (Kx, Ky)	4.2×10^5 lb/in
Z-axis force (Kz)	5.6×10^5 lb/in
X-axis & Y-axis torque (Ktx, Kty)	1.5×10^5 lbf-in/rad
Z-axis torque (Ktz)	3.1×10^5 lbf-in/rad
Resonant Frequency (Measured)	
Fx, Fy, Tz	5600 Hz
Fz, Tx, Ty	5400 Hz
Physical Specifications	
Weight*	0.202 lb
Diameter*	1.8 in
Height*	0.62 in

SI (Metric)

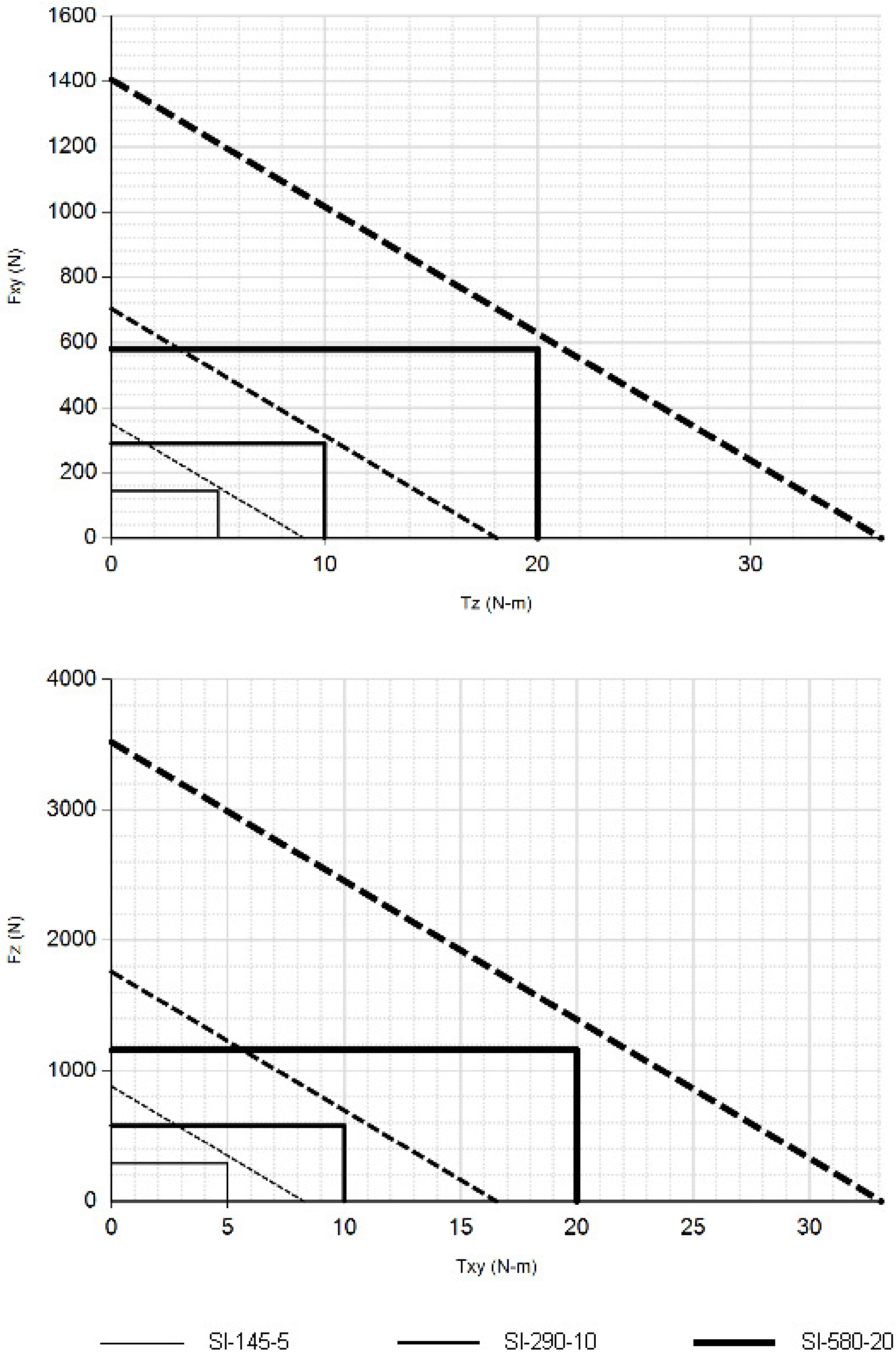
Single-Axis Overload	
Fxy	±5100 N
Fz	±10000 N
Txy	±110 Nm
Tz	±140 Nm
Stiffness (Calculated)	
X-axis & Y-axis forces (Kx, Ky)	7.4×10^7 N/m
Z-axis force (Kz)	9.8×10^7 N/m
X-axis & Y-axis torque (Ktx, Kty)	1.7×10^4 Nm/rad
Z-axis torque (Ktz)	3.5×10^4 Nm/rad
Resonant Frequency (Measured)	
Fx, Fy, Tz	5600 Hz
Fz, Tx, Ty	5400 Hz
Physical Specifications	
Weight*	0.0916 kg
Diameter*	45 mm
Height*	16 mm

** Specifications include standard interface plates.*

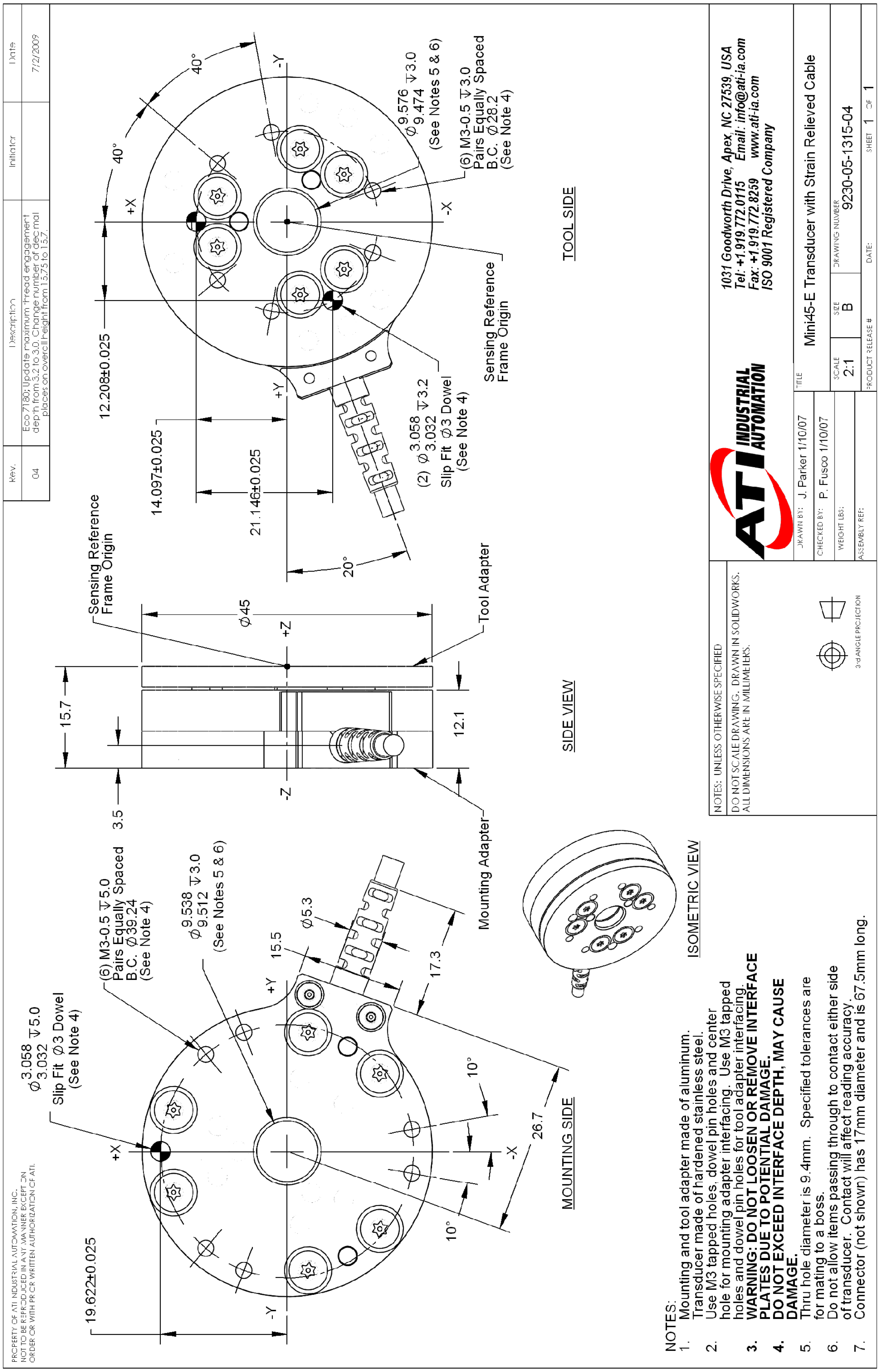
4.7.4 Mini45 (US Calibration Complex Loading)



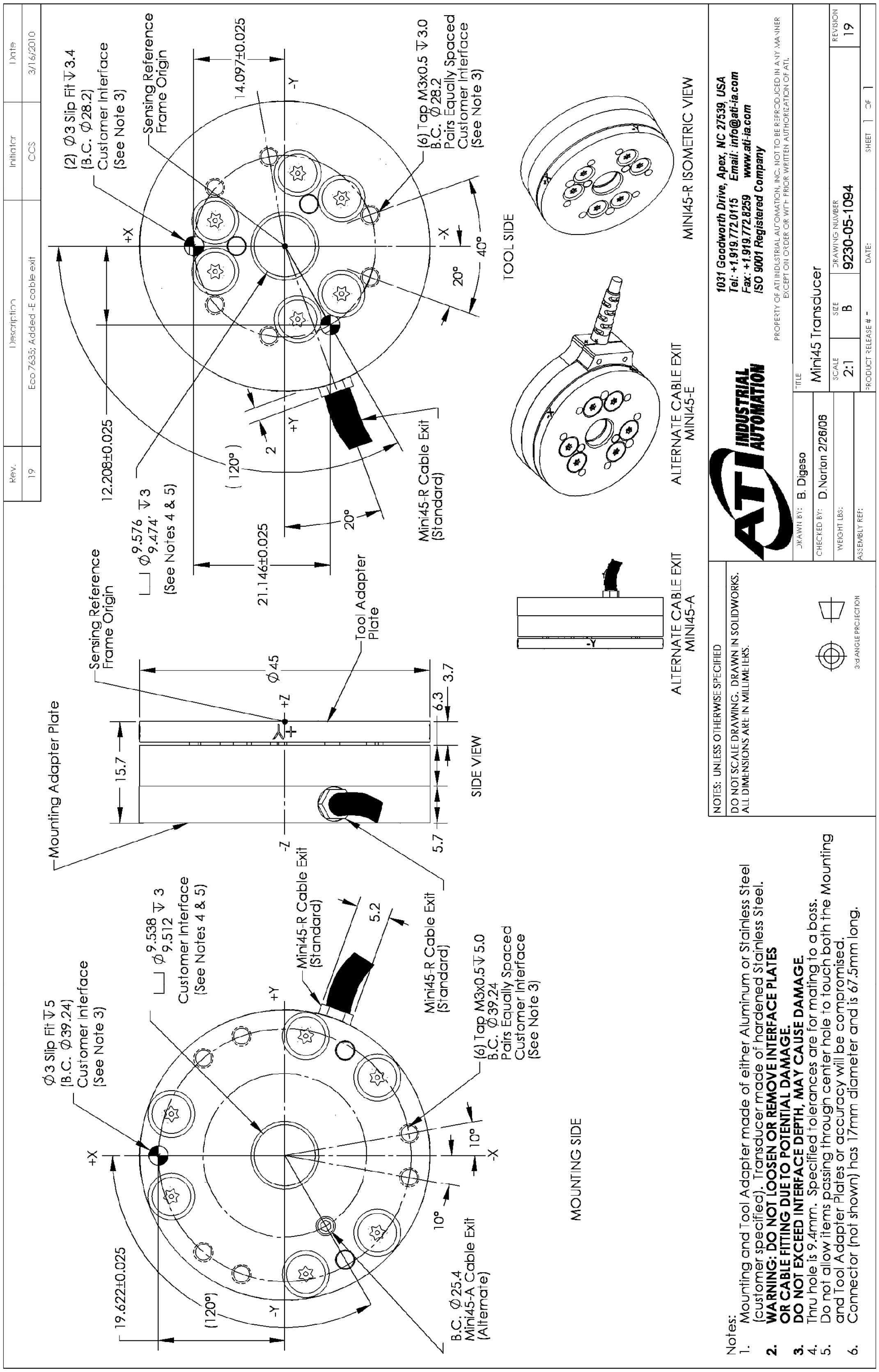
4.7.5 Mini45 (SI Calibration Complex Loading)



4.7.6 Mini45-E Transducer



4.7.7 Legacy Mini45 Transducer



4.8 Mini85

4.8.1 Calibration Specifications (excludes CTL calibrations)

US (English)

Calibration	Fx,Fy	Fz	Tx,Ty	Tz	Fx,Fy	Fz	Tx,Ty	Tz
US-105–185	105 lbf	210 lbf	185 lbf-in	185 lbf-in	13/800 lbf	23/1000 lbf	107/4000 lbf-in	37/2000 lbf-in
US-210–370	210 lbf	420 lbf	370 lbf-in	370 lbf-in	129/4000 lbf	23/500 lbf	107/2000 lbf-in	37/1000 lbf-in
US-420–740	420 lbf	840 lbf	740 lbf-in	740 lbf-in	257/4000 lbf	367/4000 lbf	427/4000 lbf-in	37/500 lbf-in
	SENSING RANGES				RESOLUTION*			

SI (Metric)

Calibration	Fx,Fy	Fz	Tx,Ty	Tz	Fx,Fy	Fz	Tx,Ty	Tz
SI-475–20	475 N	950 N	20 Nm	20 Nm	143/2000 N	51/500 N	13/4000 Nm	9/4000 Nm
SI-950–40	950 N	1900 N	40 Nm	40 Nm	571/4000 N	51/250 N	1/160 Nm	17/4000 Nm
SI-1900–80	1900 N	3800 N	80 Nm	80 Nm	571/2000 N	51/125 N	49/4000 Nm	17/2000 Nm
	SENSING RANGES				RESOLUTION*			

* *DAQ resolutions are typical for a 16-bit data acquisition system.*

These system resolutions quoted are the effective resolution after dropping four counts of noise. The effective resolution can be improved with filtering. NOTE: Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.

4.8.2 CTL Calibration Specifications

US (English)

Calibration	Fx,Fy	Fz	Tx,Ty	Tz	Fx,Fy	Fz	Tx,Ty	Tz
US-105–185	105 lbf	210 lbf	185 lbf-in	185 lbf-in	13/400 lbf	23/500 lbf	107/2000 lbf-in	37/1000 lbf-in
US-210–370	210 lbf	420 lbf	370 lbf-in	370 lbf-in	129/2000 lbf	23/250 lbf	107/1000 lbf-in	37/500 lbf-in
US-420–740	420 lbf	840 lbf	740 lbf-in	740 lbf-in	257/2000 lbf	367/2000 lbf	427/2000 lbf-in	37/250 lbf-in
	SENSING RANGES				RESOLUTION			

SI (Metric)

Calibration	Fx,Fy	Fz	Tx,Ty	Tz	Fx,Fy	Fz	Tx,Ty	Tz
SI-475–20	475 N	950 N	20 Nm	20 Nm	143/1000 N	51/250 N	13/2000 Nm	9/2000 Nm
SI-950–40	950 N	1900 N	40 Nm	40 Nm	571/2000 N	51/125 N	1/80 Nm	17/2000 Nm
SI-1900–80	1900 N	3800 N	80 Nm	80 Nm	571/1000 N	102/125 N	49/2000 Nm	17/1000 Nm
	SENSING RANGES				RESOLUTION			

US (English)

Calibration	Fx,Fy	Fz	Tx,Ty, Tz	Fx,Fy	Fz	Tx,Ty, Tz
US-105–185	±55 lbf	±110 lbf	±110 lbf-in	5.5 lbf/V	11 lbf/V	11 lbf-in/V
US-210–370	±110 lbf	±220 lbf	±220 lbf-in	11 lbf/V	22 lbf/V	22 lbf-in/V
US-420–740	±220 lbf	±440 lbf	±440 lbf-in	22 lbf/V	44 lbf/V	44 lbf-in/V
	Analog Output Range			Analog ±10V Sensitivity‡		

SI (Metric)

Calibration	Fx,Fy	Fz	Tx,Ty, Tz	Fx,Fy	Fz	Tx,Ty, Tz
SI-475–20	±250 N	±500 N	±12.5 Nm	25 N/V	50 N/V	1.25 Nm/V
SI-950–40	±500 N	±1000 N	±25 Nm	50 N/V	100 N/V	2.5 Nm/V
SI-1900–80	±1000 N	±2000 N	±50 Nm	100 N/V	200 N/V	5 Nm/V
	Analog Output Range			Analog ±10V Sensitivity‡		

Counts Value

Calibration	Fx, Fy, Fz	Tx, Ty, Tz	Fx, Fy, Fz	Tx, Ty, Tz
US-105–185 / SI-475–20	2560 / lbf	1280 / lbf-in	576 / N	14400 / Nm
US-210–370 / SI-950–40	1280 / lbf	640 / lbf-in	288 / N	7200 / Nm
US-420–740 /fSI-1900–80	640 / lbf	320 / lbf-in	144 / N	3600 / Nm
Tool Transform Factor	0.02 in/unit		0.4 mm/unit	
	Counts Value – US (English)		Counts Value – SI (Metric)	

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. NOTE: Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.

‡ *±5V Sensitivity values are double the listed ±10V Sensitivity values.*

4.8.3 Mini85 Physical Properties

US (English)

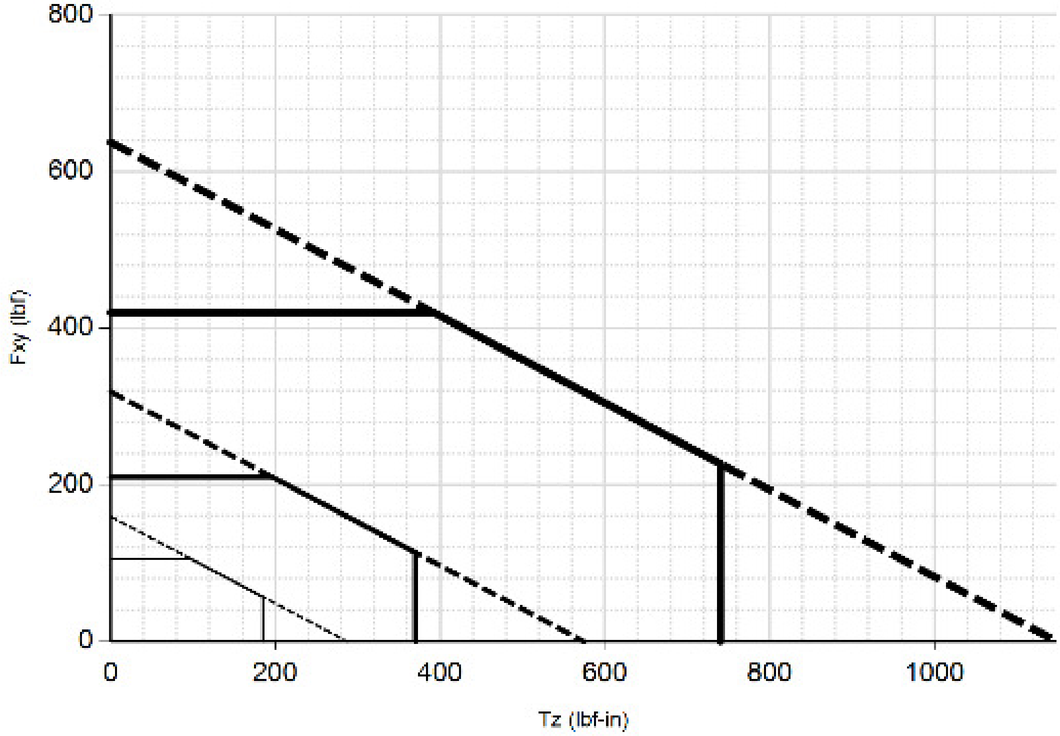
Single-Axis Overload	
Fxy	±2800 lbf
Fz	±6100 lbf
Txy	±4400 lbf-in
Tz	±5400 lbf-in
Stiffness (Calculated)	
X-axis & Y-axis forces (Kx, Ky)	$4.4x10^5$ lb/in
Z-axis force (Kz)	$6.8x10^5$ lb/in
X-axis & Y-axis torque (Ktx, Kty)	$7.2x10^5$ lbf-in/rad
Z-axis torque (Ktz)	$1.2x10^6$ lbf-in/rad
Resonant Frequency (Measured)	
Fx, Fy, Tz	2400 Hz
Fz, Tx, Ty	3100 Hz
Physical Specifications	
Weight*	1.4 lb
Diameter*	3.4 in
Height*	1.2 in

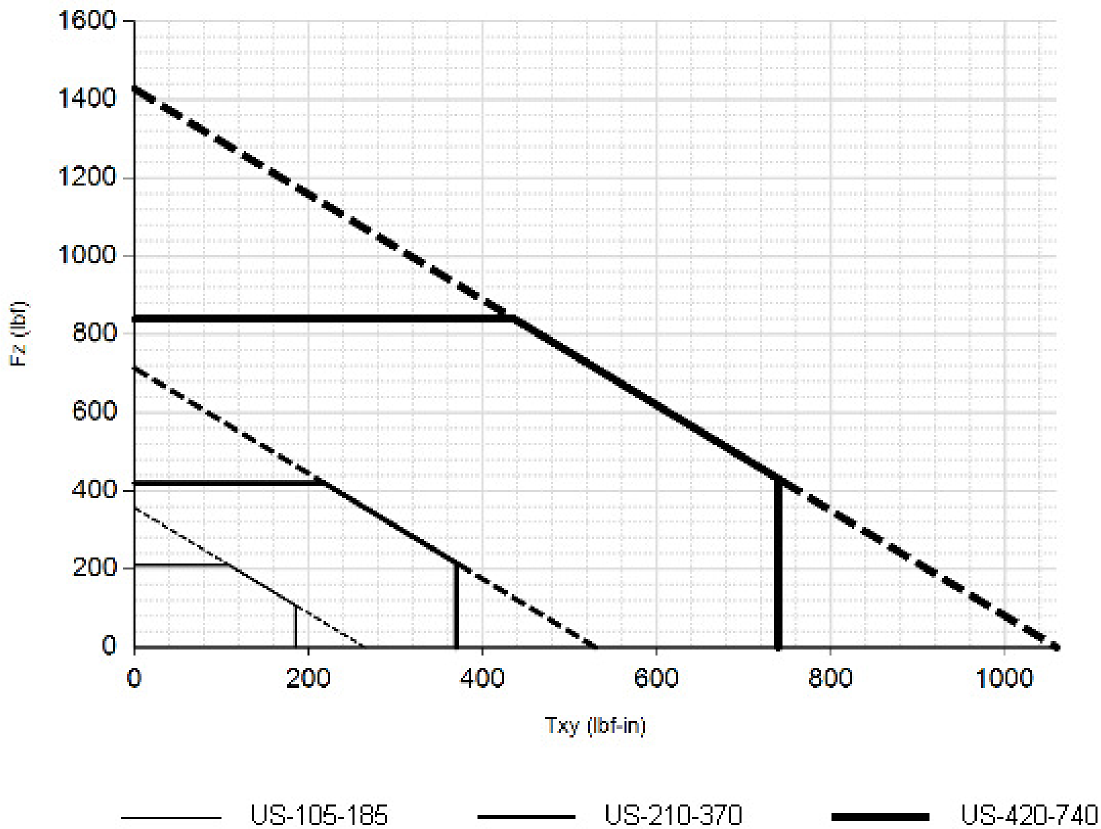
SI (Metric)

Single-Axis Overload	
Fxy	±13000 N
Fz	±27000 N
Txy	±500 Nm
Tz	±610 Nm
Stiffness (Calculated)	
X-axis & Y-axis forces (Kx, Ky)	$7.7x10^7$ N/m
Z-axis force (Kz)	$1.2x10^8$ N/m
X-axis & Y-axis torque (Ktx, Kty)	$8.1x10^4$ Nm/rad
Z-axis torque (Ktz)	$1.3x10^5$ Nm/rad
Resonant Frequency (Measured)	
Fx, Fy, Tz	2400 Hz
Fz, Tx, Ty	3100 Hz
Physical Specifications	
Weight*	0.635 kg
Diameter*	85 mm
Height*	30 mm

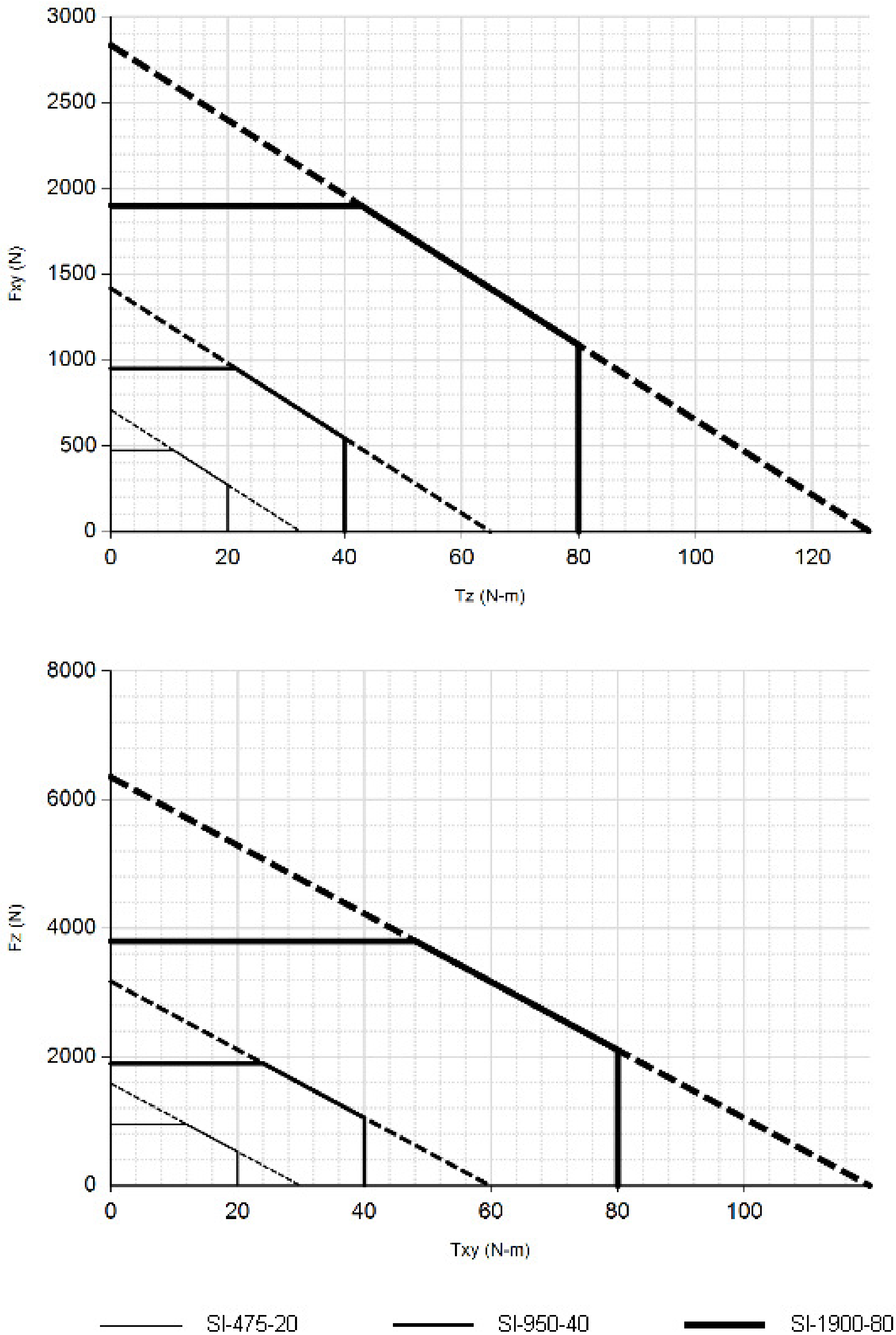
** Specifications include standard interface plates.*

4.8.4 Mini85 (US Calibration Complex Loading)

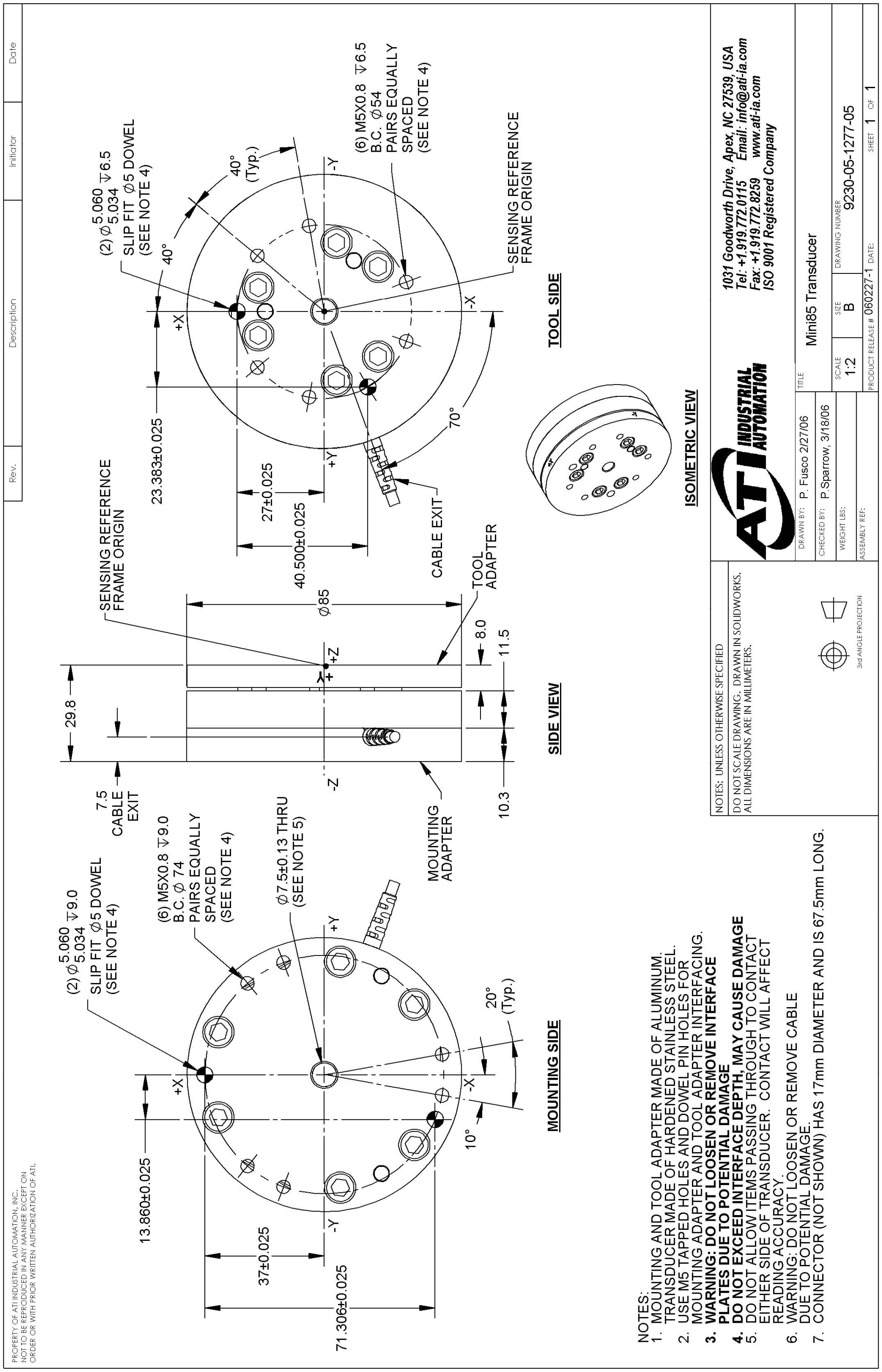




4.8.5 Mini85 (SI Calibration Complex Loading)



4.8.6 Mini85-E Transducer



4.9 Gamma (Includes IP60/IP65 Versions)

4.9.1 Calibration Specifications (excludes CTL calibrations)

US (English)

Calibration	Fx,Fy	Fz	Tx,Ty	Tz	Fx,Fy	Fz	Tx,Ty	Tz
US-7.5–25	7.5 lbf	25 lbf	25 lbf-in	25 lbf-in	1/640 lbf	1/320 lbf	1/320 lbf-in	1/320 lbf-in
US-15–50	15 lbf	50 lbf	50 lbf-in	50 lbf-in	1/320 lbf	1/160 lbf	1/160 lbf-in	1/160 lbf-in
US-30–100	30 lbf	100 lbf	100 lbf-in	100 lbf-in	1/160 lbf	1/80 lbf	1/80 lbf-in	1/80 lbf-in
	SENSING RANGES				RESOLUTION*			

SI (Metric)

Calibration	Fx,Fy	Fz	Tx,Ty	Tz	Fx,Fy	Fz	Tx,Ty	Tz
SI-32–2.5	32 N	100 N	2.5 Nm	2.5 NM	1/160 N	1/80 N	1/2000 Nm	1/2000 Nm
SI-65–5	65 N	200 N	5 Nm	5 Nm	1/80 N	1/40 N	10/13333 Nm	10/13333 Nm
SI-130–10	130 N	400 N	10 Nm	10 Nm	1/40 N	1/20 N	1/800 Nm	1/800 Nm
	SENSING RANGES				RESOLUTION*			

** DAQ resolutions are typical for a 16-bit data acquisition system.*

These system resolutions quoted are the effective resolution after dropping four counts of noise. The effective resolution can be improved with filtering. NOTE: Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.

4.9.2 CTL Calibration Specifications

US (English)

Calibration	Fx,Fy	Fz	Tx,Ty	Tz	Fx,Fy	Fz	Tx,Ty	Tz
US-7.5–25	7.5 lbf	25 lbf	25 lbf-in	25 lbf-in	1/320 lbf	1/160 lbf	1/160 lbf-in	1/160 lbf-in
US-15–50	15 lbf	50 lbf	50 lbf-in	50 lbf-in	1/160 lbf	1/80 lbf	1/80 lbf-in	1/80 lbf-in
US-30–100	30 lbf	100 lbf	100 lbf-in	100 lbf-in	1/80 lbf	1/40 lbf	1/40 lbf-in	1/40 lbf-in
SI (Metric)								
SI-32–2.5	32 N	100 N	2.5 Nm	2.5 Nm	1/80 N	1/40 N	1/1000 Nm	1/1000 Nm
SI-65–5	65 N	200 N	5 Nm	5 Nm	1/40 N	1/20 N	5/3333 Nm	5/3333 Nm
SI-130–10	130 N	400 N	10 Nm	10 Nm	1/20 N	1/10 N	1/400 Nm	1/400 Nm
	SENSING RANGES				RESOLUTION			

US (English)

Calibration	Fx,Fy	Fz†	Tx,Ty, Tz	Fx,Fy	Fz†	Tx,Ty, Tz
US-7.5–25	±7.5 lbf	±25 lbf	±25 lbf-in	0.75 lbf/V	2.5 lbf/V	2.5 lbf-in/V
US-15–50	±15 lbf	±50 lbf	±50 lbf-in	1.5 lbf/V	5 lbf/V	5 lbf-in/V
US-30–100	±30 lbf	±100 lbf	±100 lbf-in	3 lbf/V	10 lbf/V	10 lbf-in/V
SI (Metric)						
SI-32–2.5	±32 N	±100 N	±2.5 Nm	3.2 N/V	10 N/V	0.25 Nm/V
SI-65–5	±65 N	±200 N	±5 Nm	6.5 N/V	20 N/V	0.5 Nm/V
SI-130–10	±130 N	±400 N	±10 Nm	13 N/V	40 N/V	1 Nm/V
	Analog Output Range			Analog ±10V Sensitivity‡		

Counts Value

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

Tool Transform Factor

Calibration	US (English)	SI (Metric)
SI-1000–120	0.01 in/unit	0.8 mm/unit
SI-1500–240	0.01 in/unit	0.6 mm/unit
SI-2500–400	0.01 in/unit	0.5 mm/unit

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. NOTE: Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.

† *For IP68 version see caution on physical properties page.*
‡ *±5V Sensitivity values are double the listed ±10V Sensitivity values.*

4.9.3 Gamma Physical Properties

US (English)

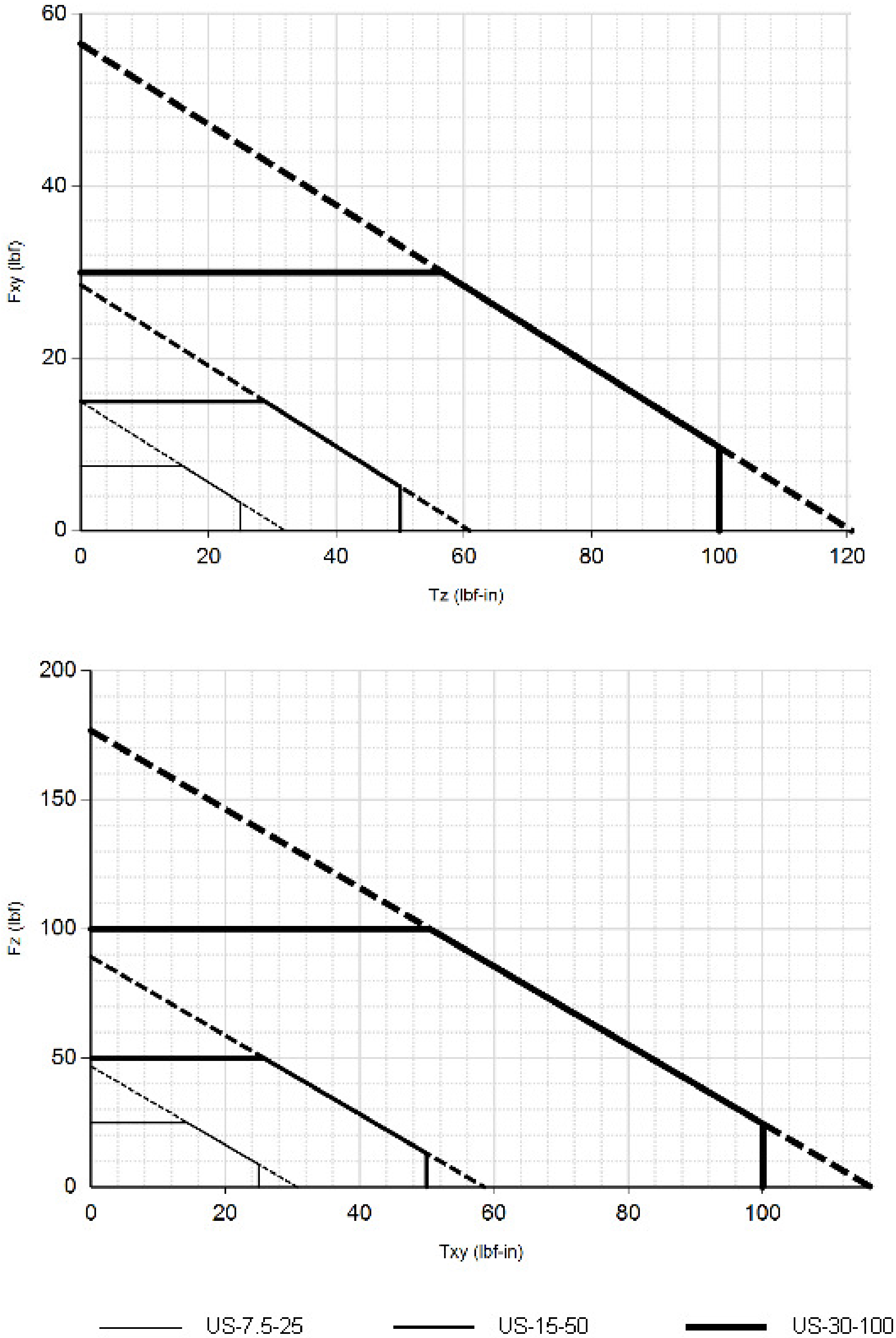
Single-Axis Overload	
Fxy	±280 lbf
Fz	±930 lbf
Txy	±700 lbf-in
Tz	±730 lbf-in
Stiffness (Calculated)	
X-axis & Y-axis forces (Kx, Ky)	5.2×10^{4} lb/in
Z-axis force (Kz)	1.0×10^{5} lb/in
X-axis & Y-axis torque (Ktx, Kty)	9.3×10^{4} lbf-in/rad
Z-axis torque (Ktz)	1.4×10^{5} lbf-in/rad
Resonant Frequency (Measured)	
Fx, Fy, Tz	1400 Hz
Fz, Tx, Ty	2000 Hz
Physical Specifications	
Weight*	0.562 lb
Diameter*	3 in
Height*	1.3 in

SI (Metric)

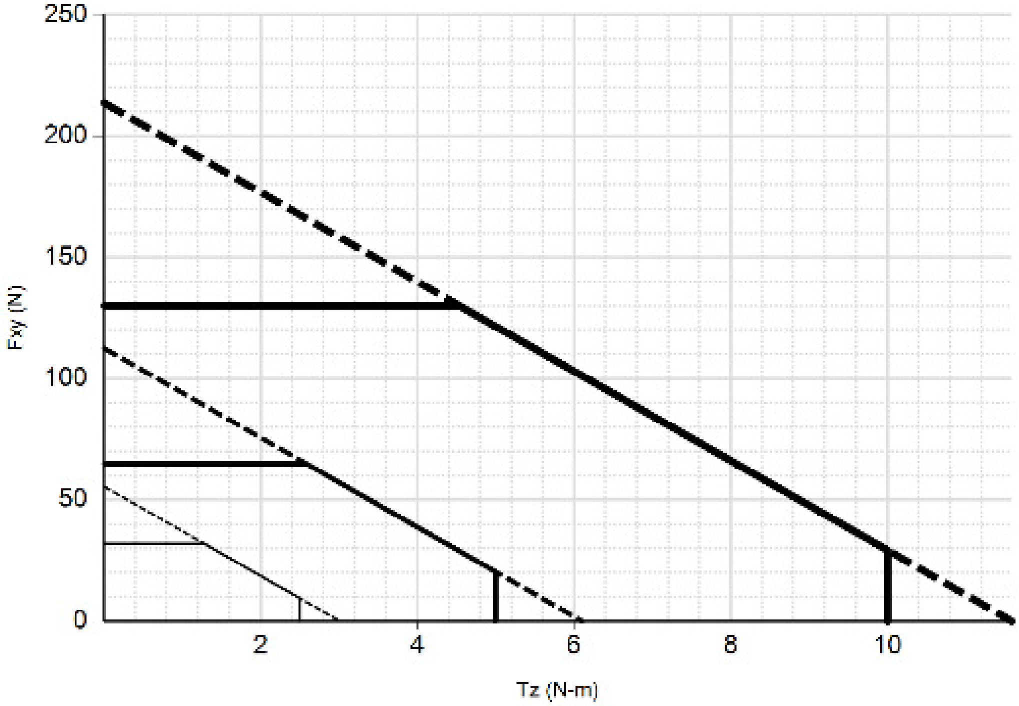
Single-Axis Overload	
Fxy	±1200 N
Fz	±4100 N
Txy	±79 Nm
Tz	±82 Nm
Stiffness (Calculated)	
X-axis & Y-axis forces (Kx, Ky)	9.1×10^{6} N/m
Z-axis force (Kz)	1.8×10^{7} N/m
X-axis & Y-axis torque (Ktx, Kty)	1.1×10^{4} Nm/rad
Z-axis torque (Ktz)	1.6×10^{4} Nm/rad
Resonant Frequency (Measured)	
Fx, Fy, Tz	1400 Hz
Fz, Tx, Ty	2000 Hz
Physical Specifications	
Weight*	0.255 kg
Diameter*	75 mm
Height*	33 mm

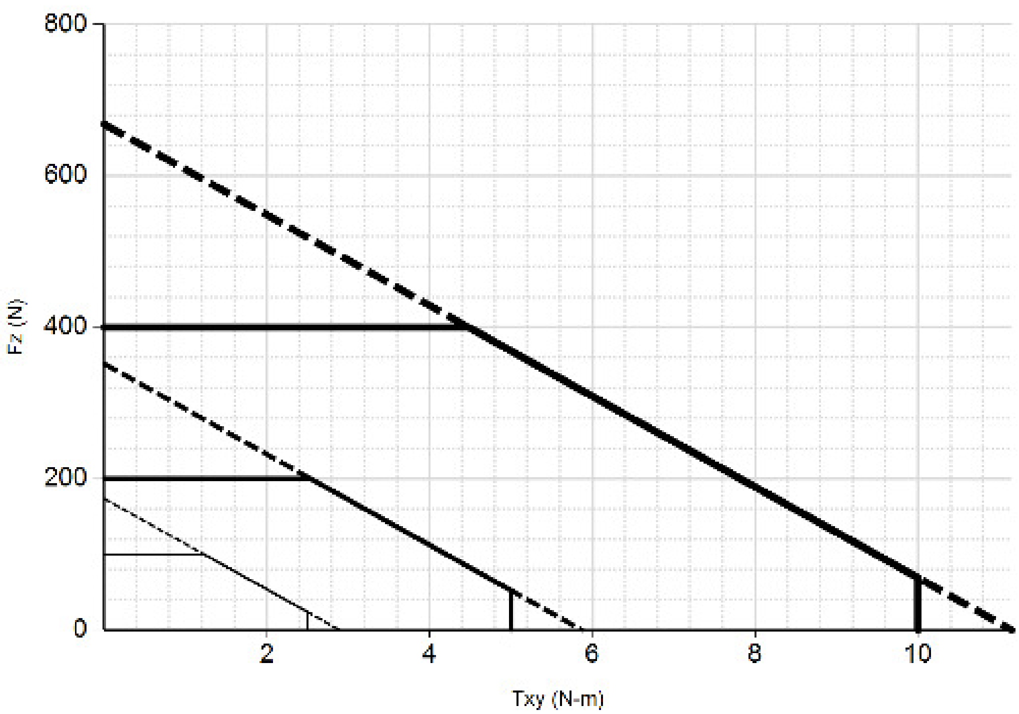
** Specifications include standard interface plates.*

4.9.4 Gamma (US Calibration Complex Loading) (Includes IP60/IP65 Version)



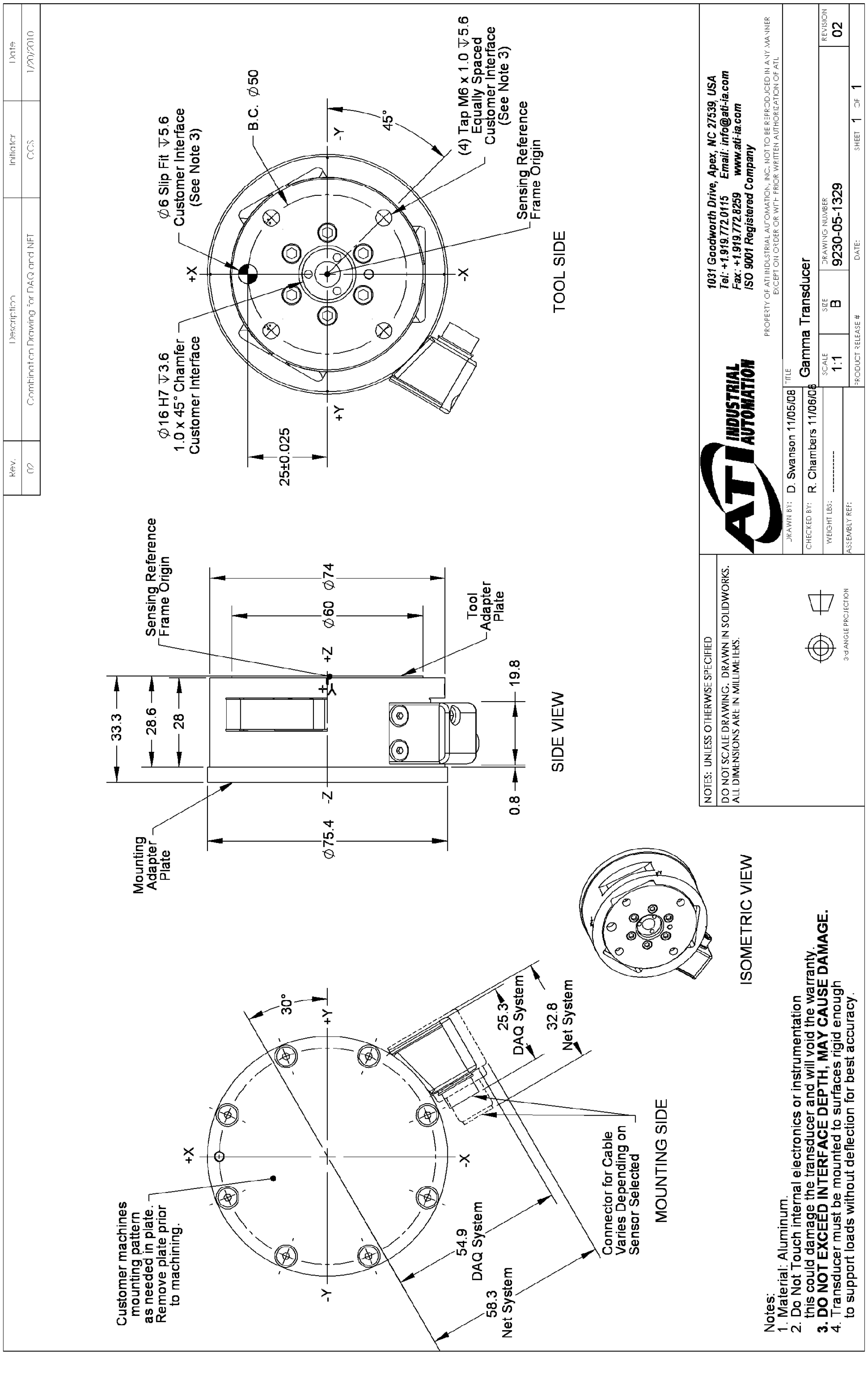
4.9.5 Gamma (SI Calibration Complex Loading) (Includes IP60/IP65 Version)



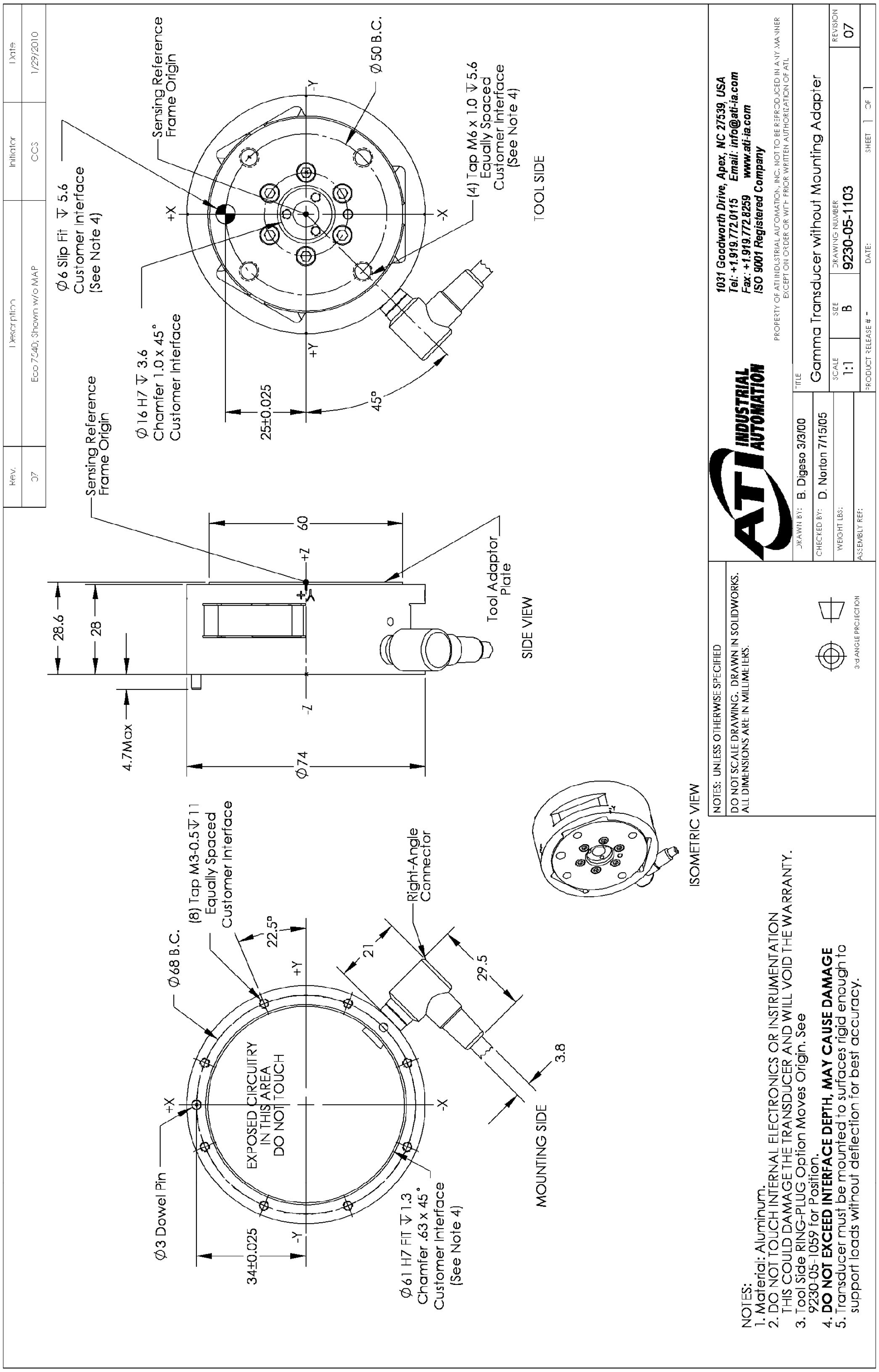


SI-32-2.5 SI-65-5 SI-130-10

4.9.6 Gamma DAQ/Net Transducer

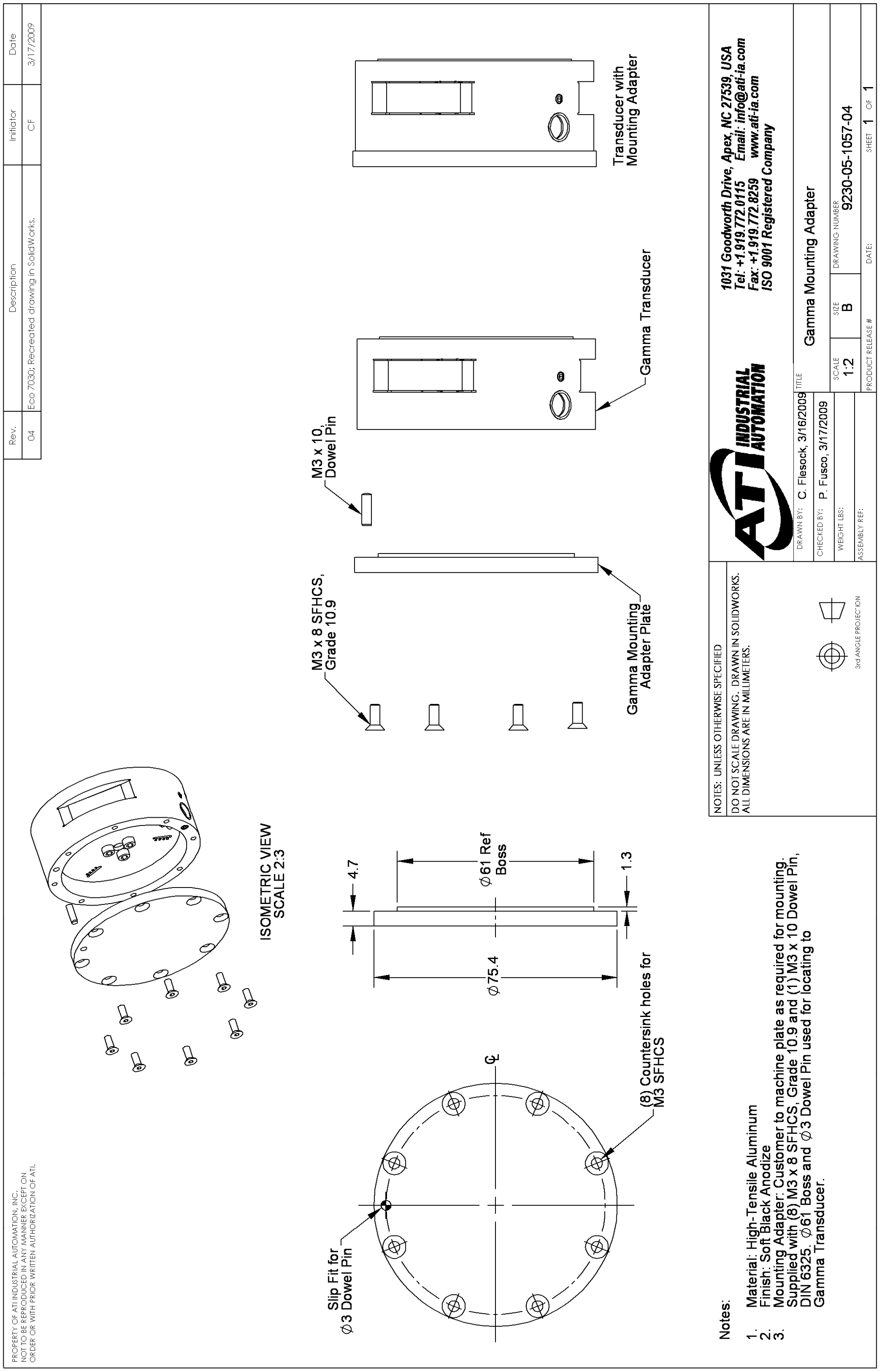


4.9.7 9105-T-Gamma Transducer without Mounting Adapter

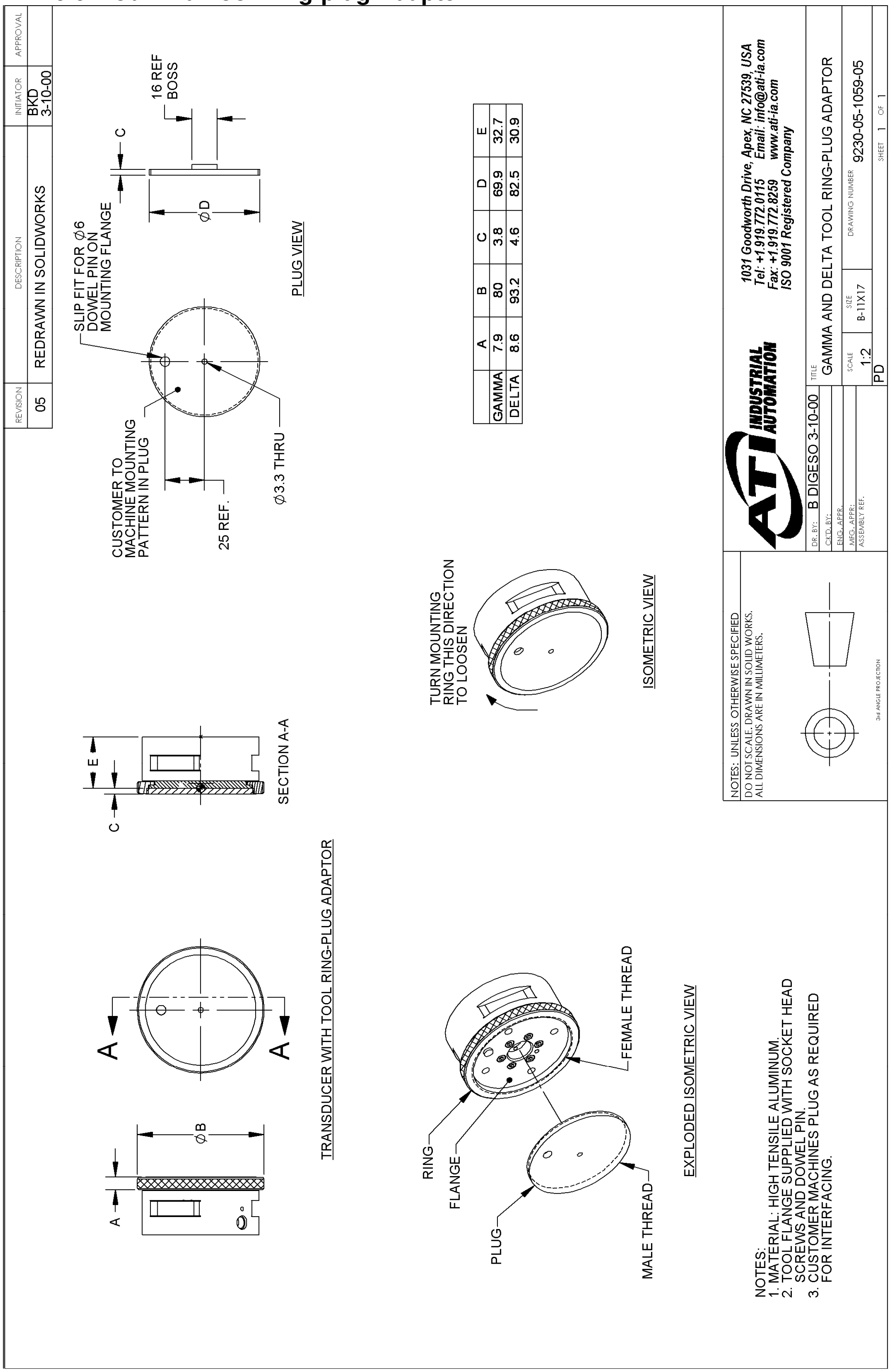


Note: Mux transducers are used in F/T Controller systems.

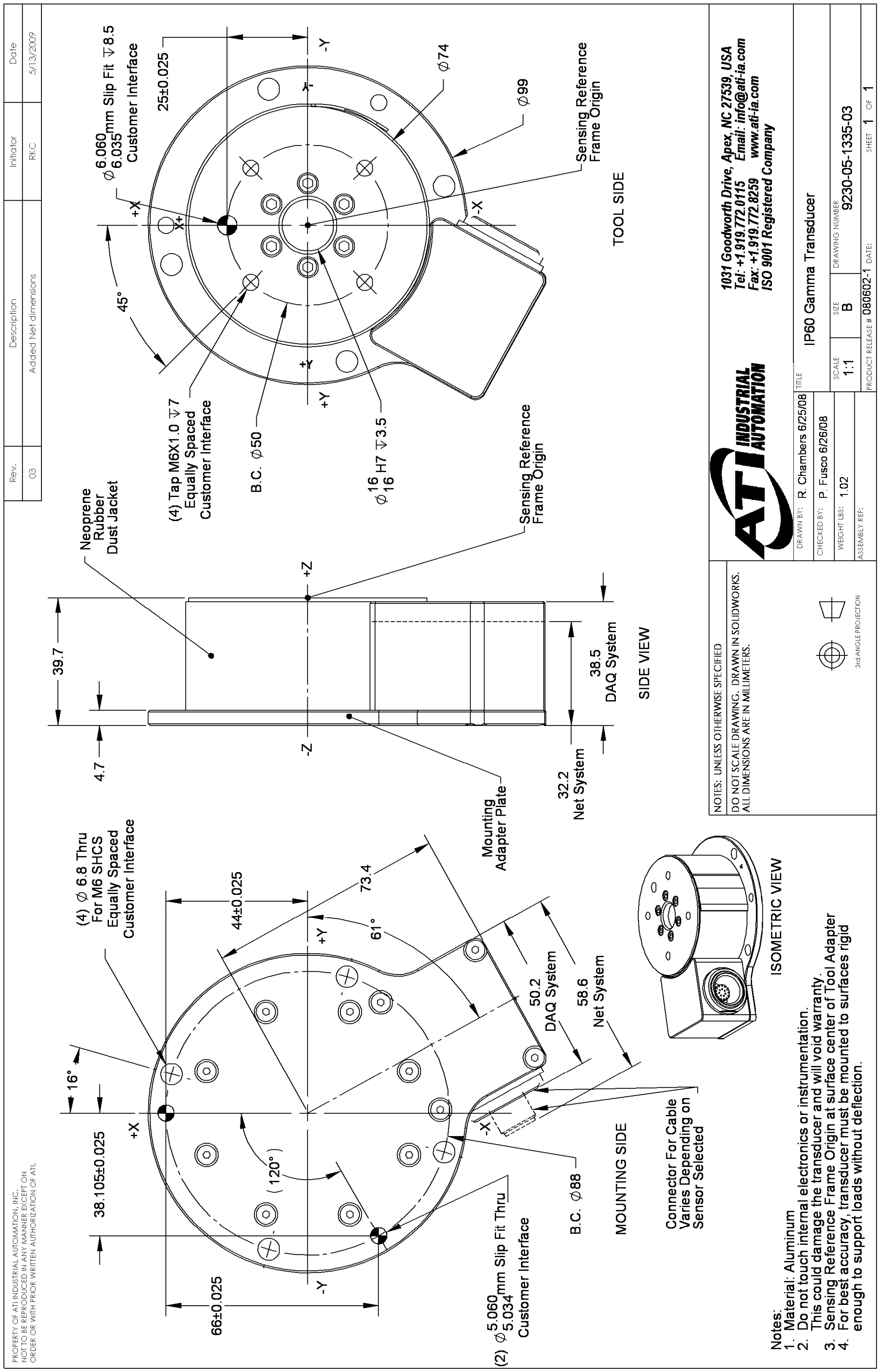
4.9.8 Gamma Mounting Adapter Plate



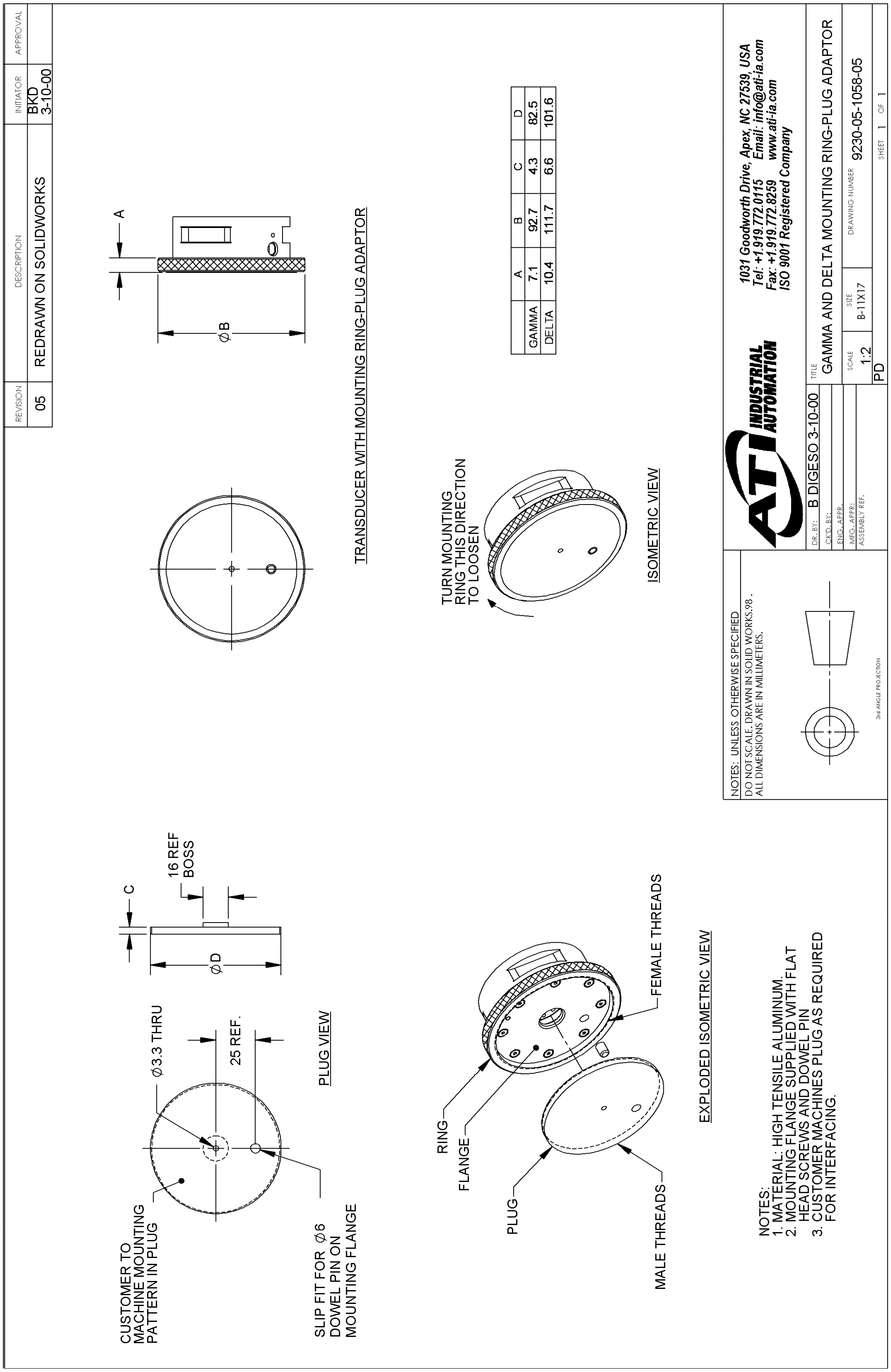
4.9.9 Gamma Tool Ring-plug Adapter



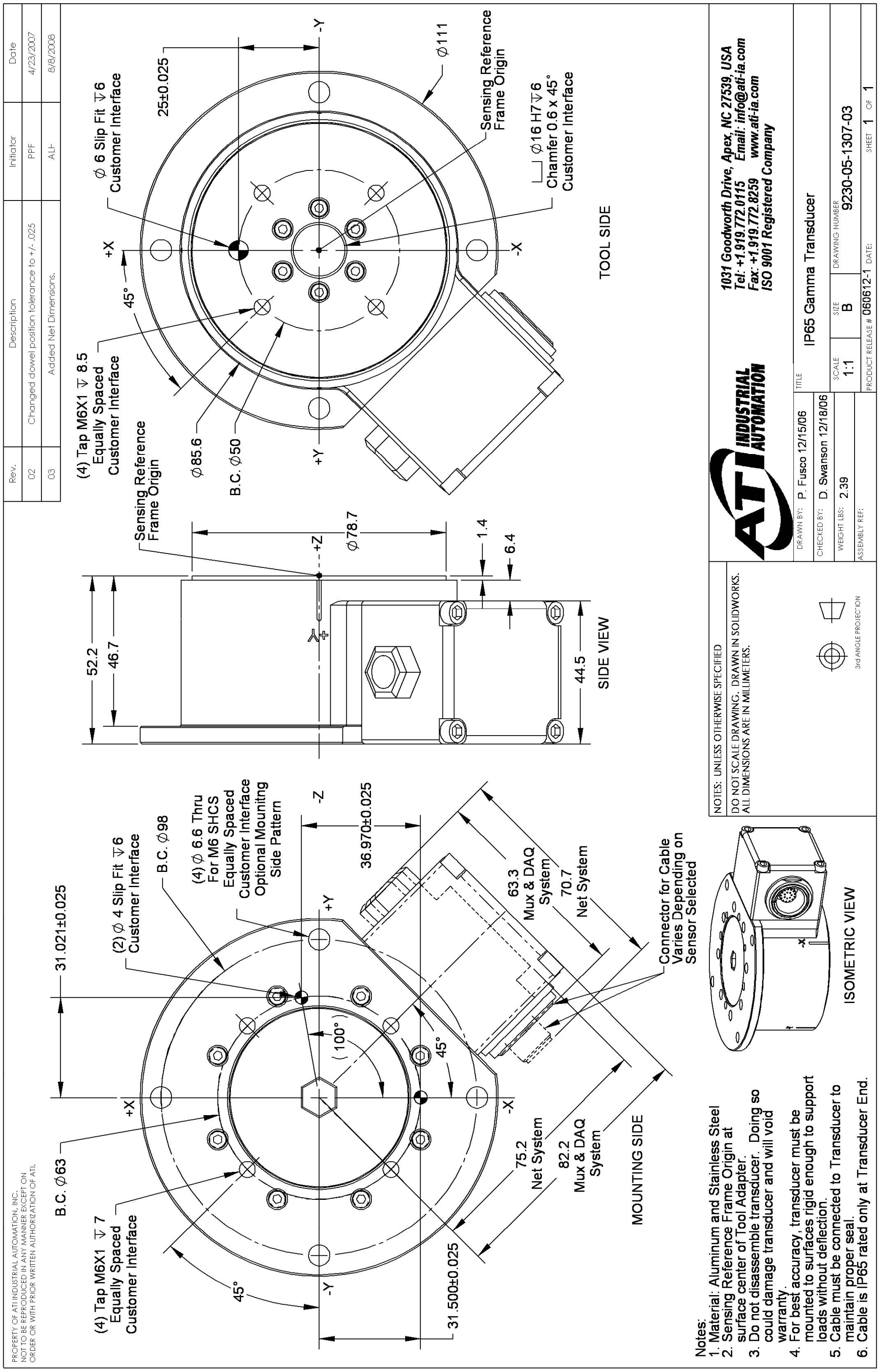
4.9.10 Gamma IP60 Transducer



4.9.11 Gamma Mounting Ring-plug Adapter



4.9.12 Gamma IP65 Transducer



4.10 Delta (Includes IP60/IP65/IP68 Versions)

4.10.1 Calibration Specifications (excludes CTL calibrations)

US (English)

Calibration	Fx,Fy	Fz***	Tx,Ty	Tz	Fx,Fy	Fz***	Tx,Ty	Tz
US-50–150	50 lbf	150 lbf	150 lbf-in	150 lbf-in	1/128 lbf	1/64 lbf	3/128 lbf-in	1/64 lbf-in
US-75–300	75 lbf	225 lbf	300 lbf-in	300 lbf-in	1/64 lbf	1/32 lbf	3/64 lbf-in	1/32 lbf-in
US-150–600	150 lbf	450 lbf	600 lbf-in	600 lbf-in	1/32 lbf	1/16 lbf	3/32 lbf-in	1/16 lbf-in
	SENSING RANGES				RESOLUTION*			

SI (Metric)

Calibration	Fx,Fy	Fz***	Tx,Ty	Tz	Fx,Fy	Fz***	Tx,Ty	Tz
SI-165–15	165 N	495 N	15 Nm	15 Nm	1/32 N	1/16 N	1/528 Nm	1/528 Nm
SI-330–30	330 N	990 N	30 Nm	30 Nm	1/16 N	1/8 N	5/1333 Nm	5/1333 Nm
SI-660–60	660 N	1980 N	60 Nm	60 Nm	1/8 N	1/4 N	10/1333 Nm	10/1333 Nm
	SENSING RANGES				RESOLUTION*			

** DAQ resolutions are typical for a 16-bit data acquisition system.*

These system resolutions quoted are the effective resolution after dropping four counts of noise. The effective resolution can be improved with filtering. NOTE: Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.

4.10.2 CTL Calibration Specifications

US (English)

Calibration	Fx,Fy	Fz†	Tx,Ty	Tz	Fx,Fy	Fz†	Tx,Ty	Tz
US-50–150	50 lbf	150 lbf	150 lbf-in	150 lbf-in	1/64 lbf	1/32 lbf	3/64 lbf-in	1/32 lbf-in
US-75–300	75 lbf	225 lbf	300 lbf-in	300 lbf-in	1/32 lbf	1/16 lbf	3/32 lbf-in	1/16 lbf-in
US-150–600	150 lbf	450 lbf	600 lbf-in	600 lbf-in	1/16 lbf	1/8 lbf	3/16 lbf-in	1/8 lbf-in
	SENSING RANGES				RESOLUTION			

SI (Metric)

Calibration	Fx,Fy	Fz†	Tx,Ty	Tz	Fx,Fy	Fz†	Tx,Ty	Tz
SI-165–15	165 N	495 N	15 Nm	15 Nm	1/16 N	1/8 N	1/264 Nm	1/264 Nm
SI-330–30	330 N	990 N	30 Nm	30 Nm	1/8 N	1/4 N	10/1333 Nm	10/1333 Nm
SI-660–60	660 N	1980 N	60 Nm	60 Nm	1/4 N	1/2 N	5/333 Nm	5/333 Nm
	SENSING RANGES				RESOLUTION			

US (English)

Calibration	Fx,Fy	Fz†	Tx,Ty, Tz	Fx,Fy	Fz†	Tx,Ty, Tz
US-50–150	±50 lbf	±150 lbf	±150 lbf-in	5 lbf/V	15 lbf/V	15 lbf-in/V
US-75–300	±75 lbf	±225 lbf	±300 lbf-in	7.5 lbf/V	22.5 lbf/V	30 lbf-in/V
US-150–600	±150 lbf	±450 lbf	±600 lbf-in	15 lbf/V	45 lbf/V	60 lbf-in/V
	Analog Output Range			Analog ±10V Sensitivity‡		

SI (Metric)

Calibration	Fx,Fy	Fz†	Tx,Ty, Tz	Fx,Fy	Fz†	Tx,Ty, Tz
SI-165–15	±165 N	±495 N	±15 Nm	16.5 N/V	49.5 N/V	1.5 Nm/V
SI-330–30	±330 N	±990 N	±30 Nm	33 N/V	99 N/V	3 Nm/V
SI-660–60	±660 N	±1980 N	±60 Nm	66 N/V	198 N/V	6 Nm/V
	Analog Output Range			Analog ±10V Sensitivity‡		

Counts Value

Calibration	Fx, Fy, Fz	Tx, Ty, Tz	Fx, Fy, Fz	Tx, Ty, Tz
US-50–150 / si-165–15	512 / lbf	512 / lbf-in	128 / N	2112 / Nm
US-75–300 / SI-330–30	256 / lbf	256 / lbf-in	64 / N	1066.67 / Nm
US-150–600 / SI-660–60	128 / lbf	128 / lbf-in	32 / N	533.333 / Nm
Tool Transform Factor	0.01 in/unit		0.6 mm/unit	
	Counts Value – US (English)		Counts Value – SI (Metric)	

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. NOTE: Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.

† For IP68 version see caution on physical properties page.

‡ ±5V Sensitivity values are double the listed ±10V Sensitivity values.

4.10.3 Delta Physical Properties (Includes IP60/IP65/IP68 Versions)

US (English)

Single-Axis Overload	
Fxy	±580 lbf
Fz	±1900 lbf
Txy	±2500 lbf-in
Tz	±3600 lbf-in
Stiffness (Calculated)	
X-axis & Y-axis forces (Kx, Ky)	2.0×10^5 lb/in
Z-axis force (Kz)	3.4×10^5 lb/in
X-axis & Y-axis torque (Ktx, Kty)	4.6×10^5 lbf-in/rad
Z-axis torque (Ktz)	8.1×10^5 lbf-in/rad
Resonant Frequency (Measured)	
Fx, Fy, Tz	1500 Hz
Fz, Tx, Ty	1700 Hz
Physical Specifications	
Weight*	2.01 lb
Diameter*	3.7 in
Height*	1.3 in

SI (Metric)

Single-Axis Overload	
Fxy	±2600 N
Fz	±8600 N
Txy	±290 Nm
Tz	±400 Nm
Stiffness (Calculated)	
X-axis & Y-axis forces (Kx, Ky)	3.6×10^7 N/m
Z-axis force (Kz)	5.9×10^7 N/m
X-axis & Y-axis torque (Ktx, Kty)	5.2×10^4 Nm/rad
Z-axis torque (Ktz)	9.1×10^4 Nm/rad
Resonant Frequency (Measured)	
Fx, Fy, Tz	1500 Hz
Fz, Tx, Ty	1700 Hz
Physical Specifications	
Weight*	0.913 kg
Diameter*	94 mm
Height*	33 mm

** Specifications include standard interface plates.*

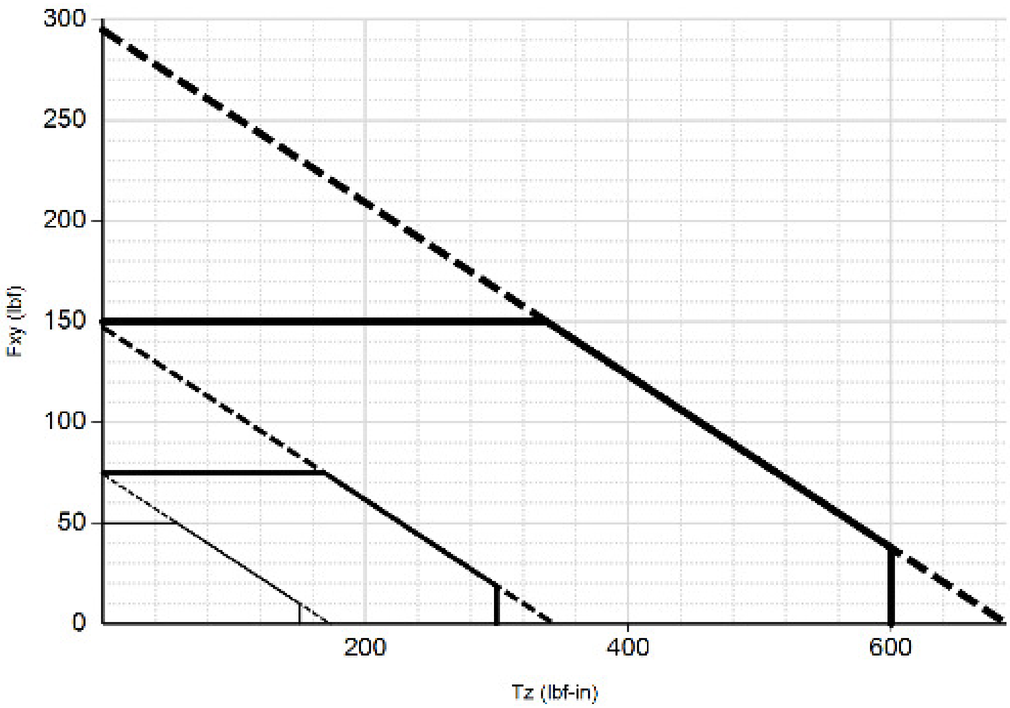
CAUTION:

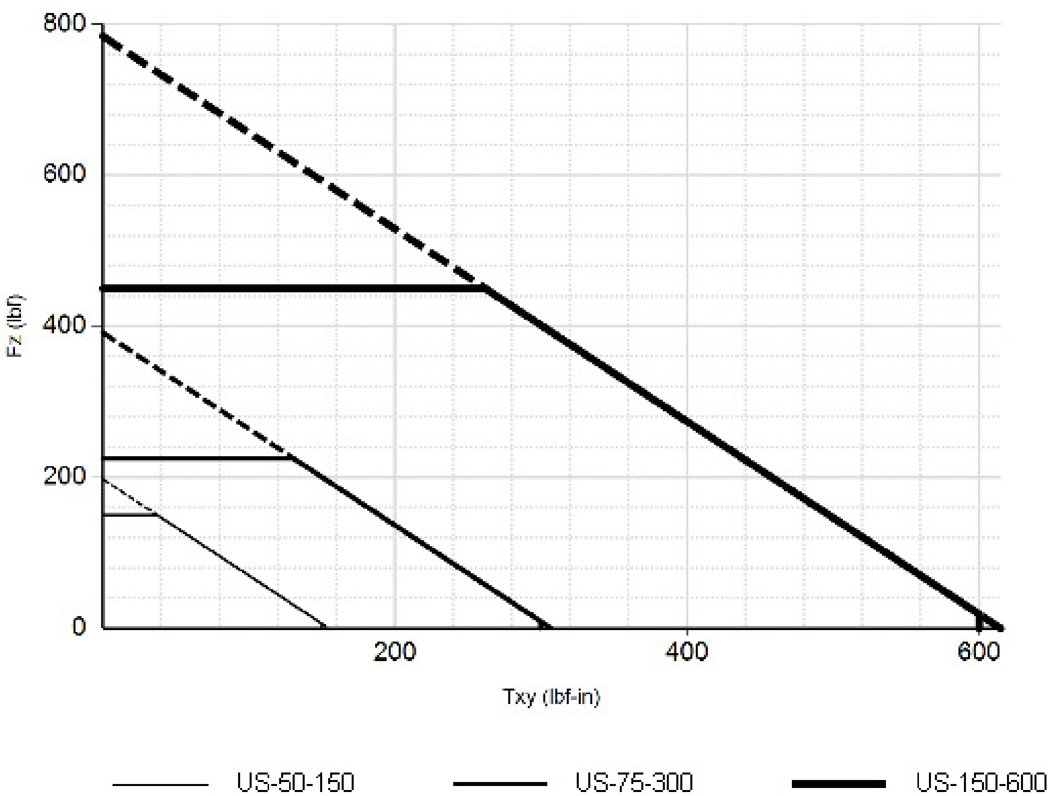
IP68 Delta Fz as a Function of Submersion Depth:

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 seal level.

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

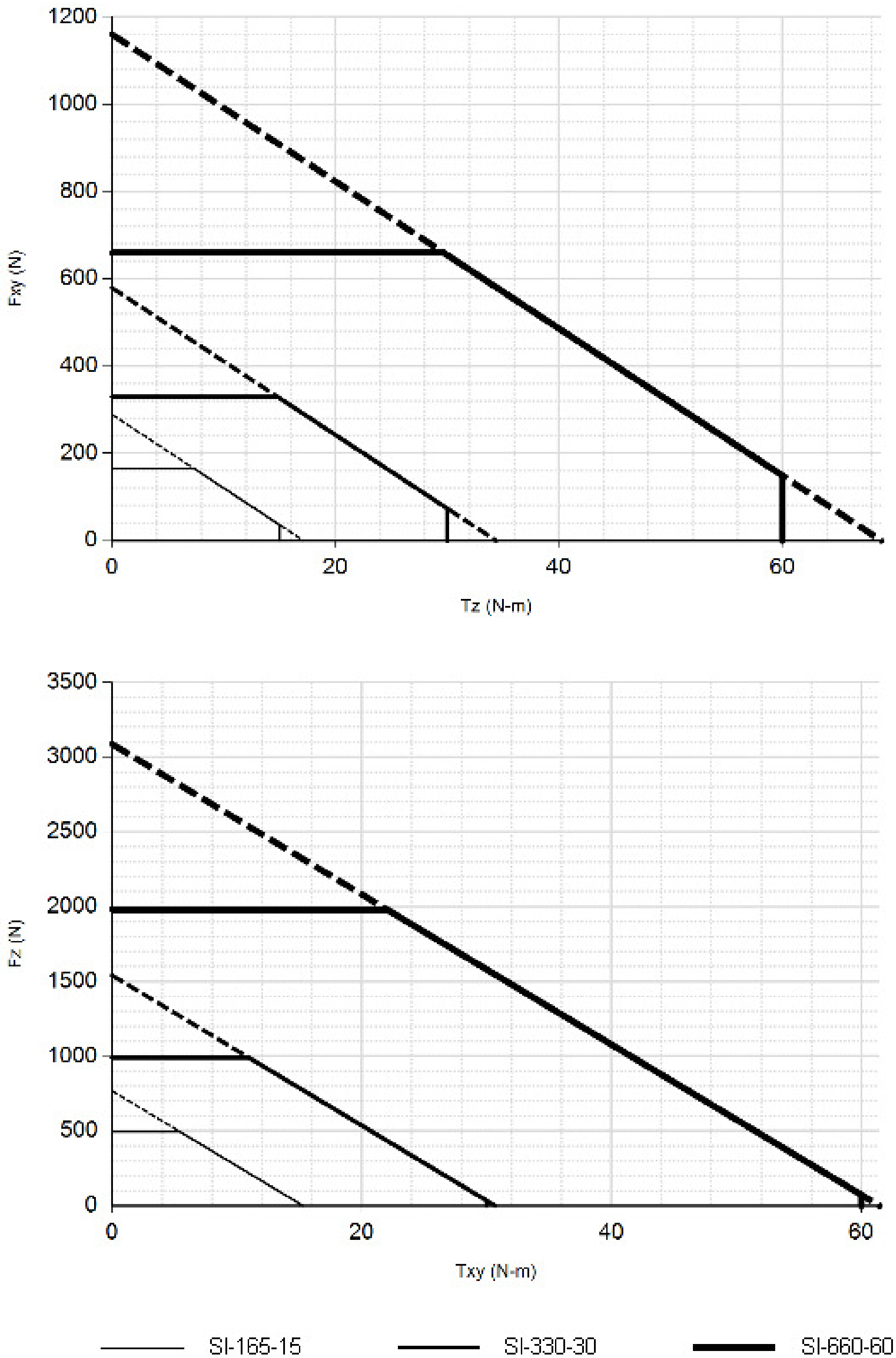
4.10.4 Delta (US Calibration Complex Loading) (Includes IP60/IP65/IP68 Versions)





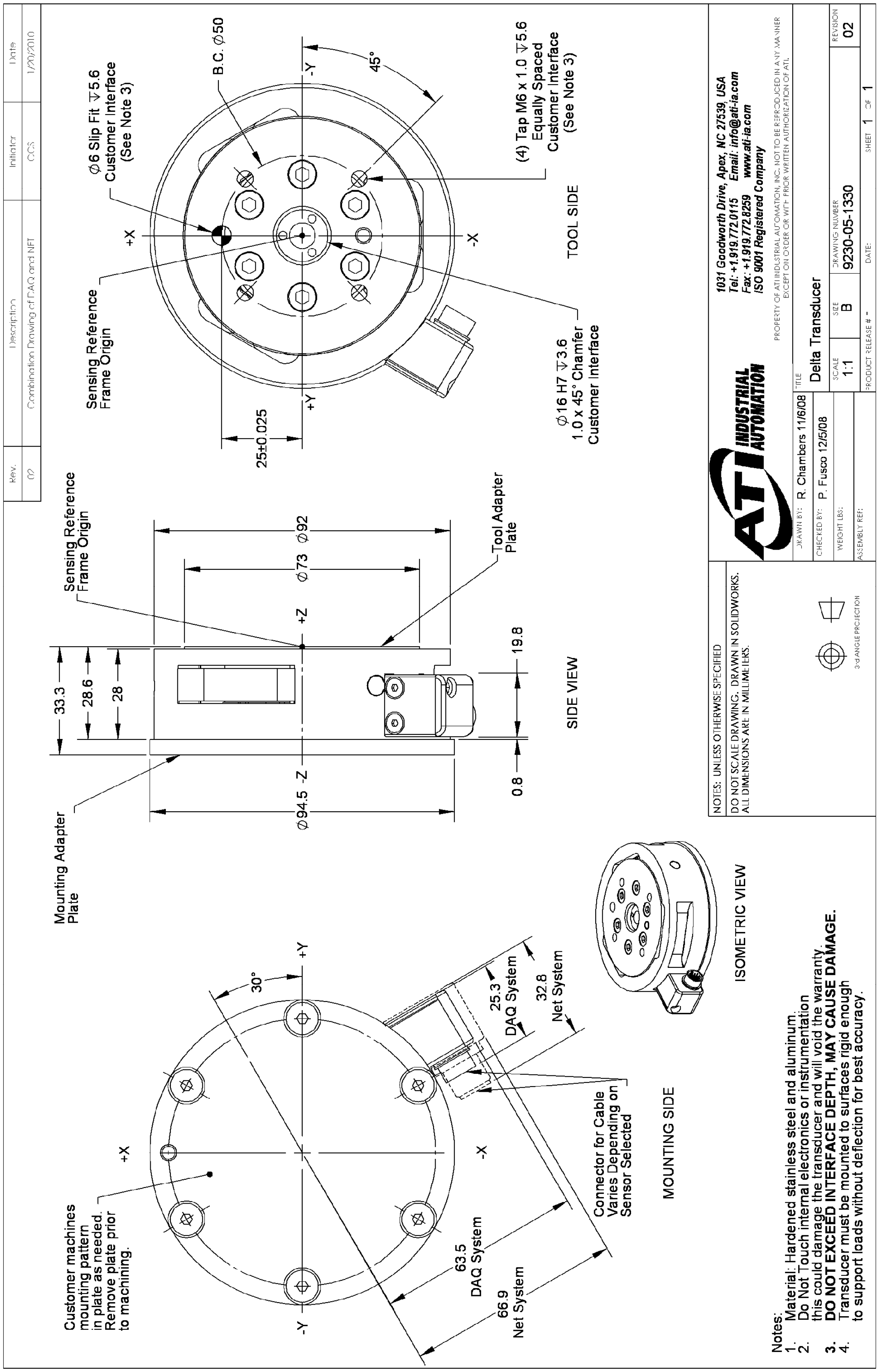
*** For IP68 version see caution on physical properties page.

4.10.5 Delta (SI Calibration Complex Loading) (Includes IP60/IP65/IP68 Versions)

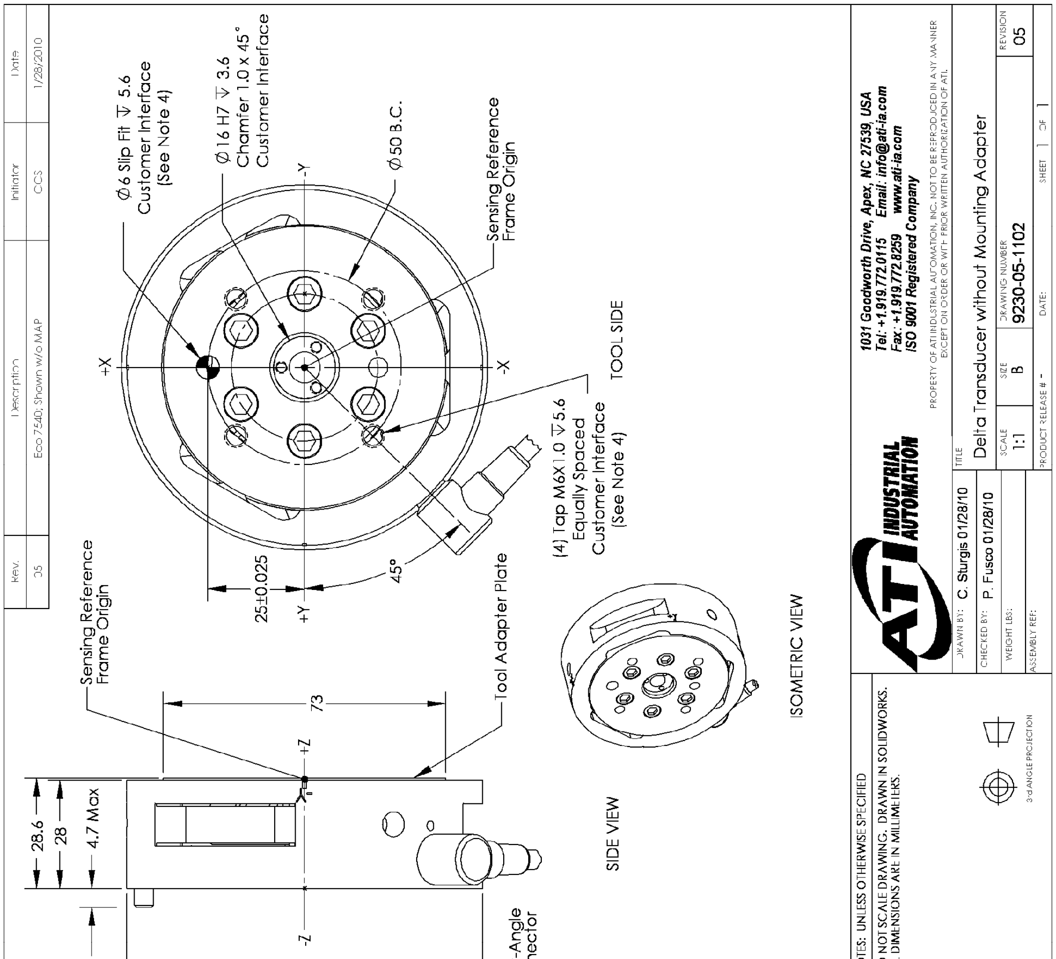


*** For IP68 version see caution on physical properties page.

4.10.6 Delta DAQ/Net Transducer

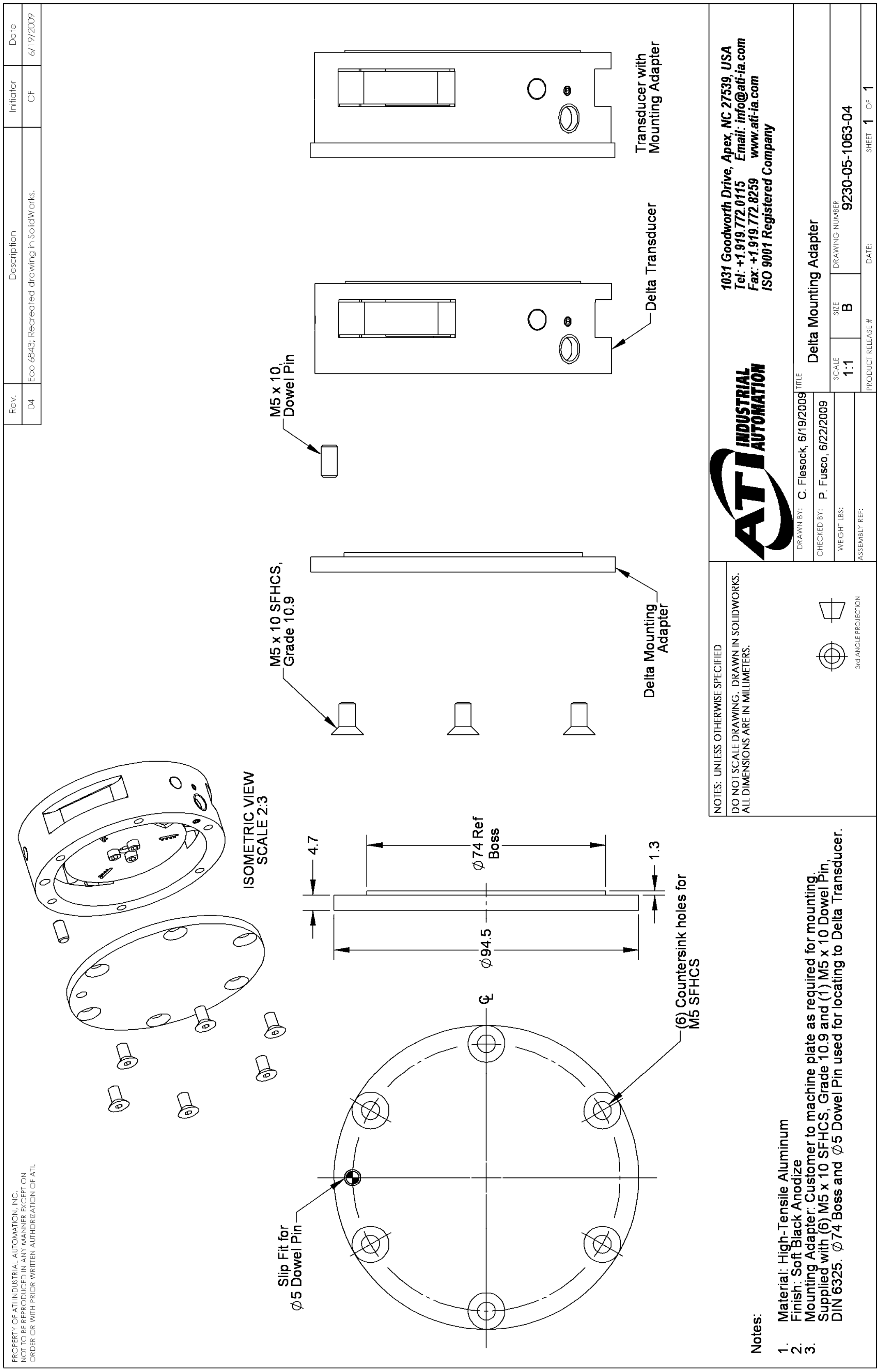


4.10.7 9105-T-Delta Transducer without Mounting Adapter

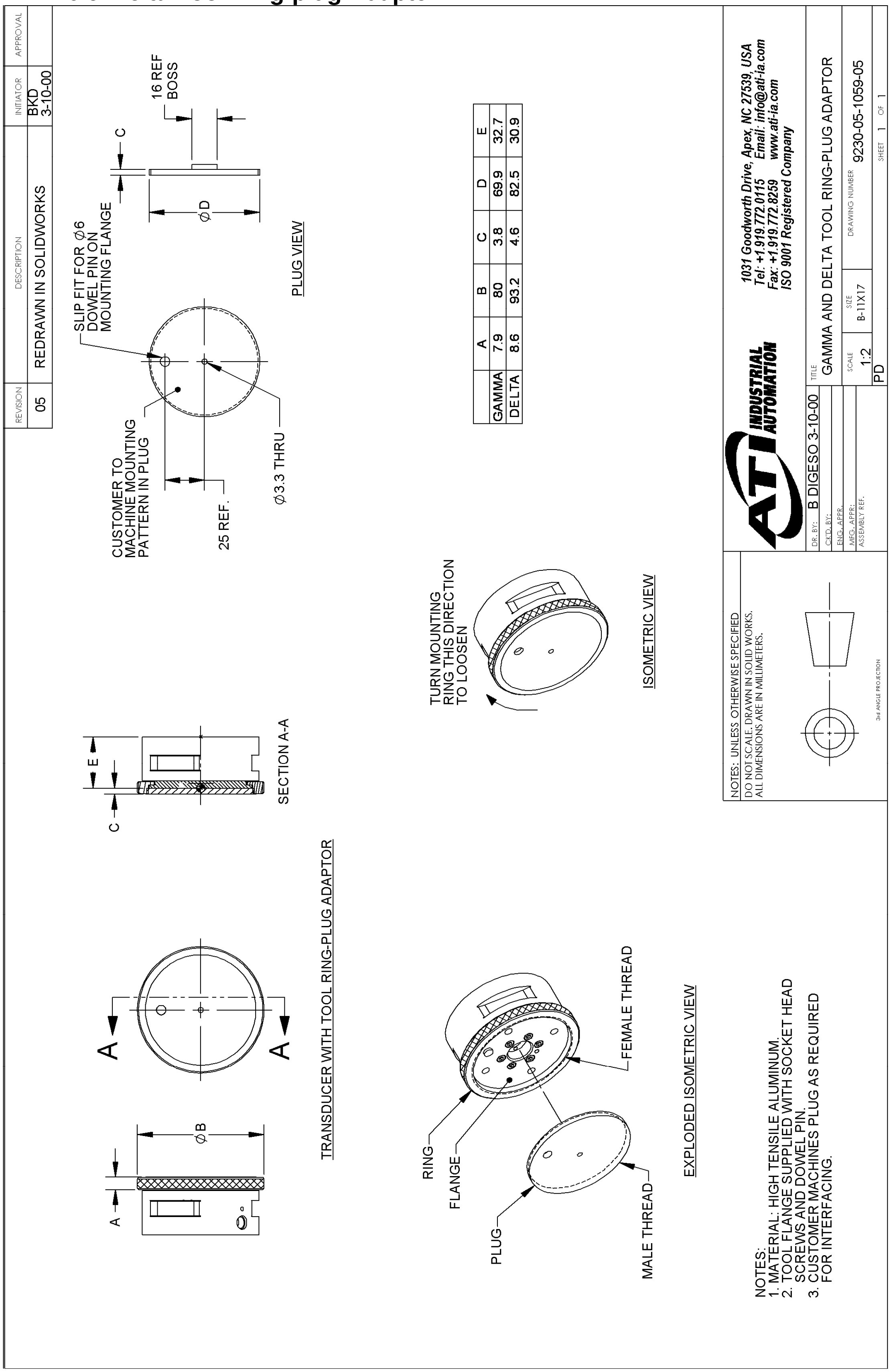


Note: Mux transducers are used in F/T Controller systems.

4.10.8 Delta Mounting Adapter

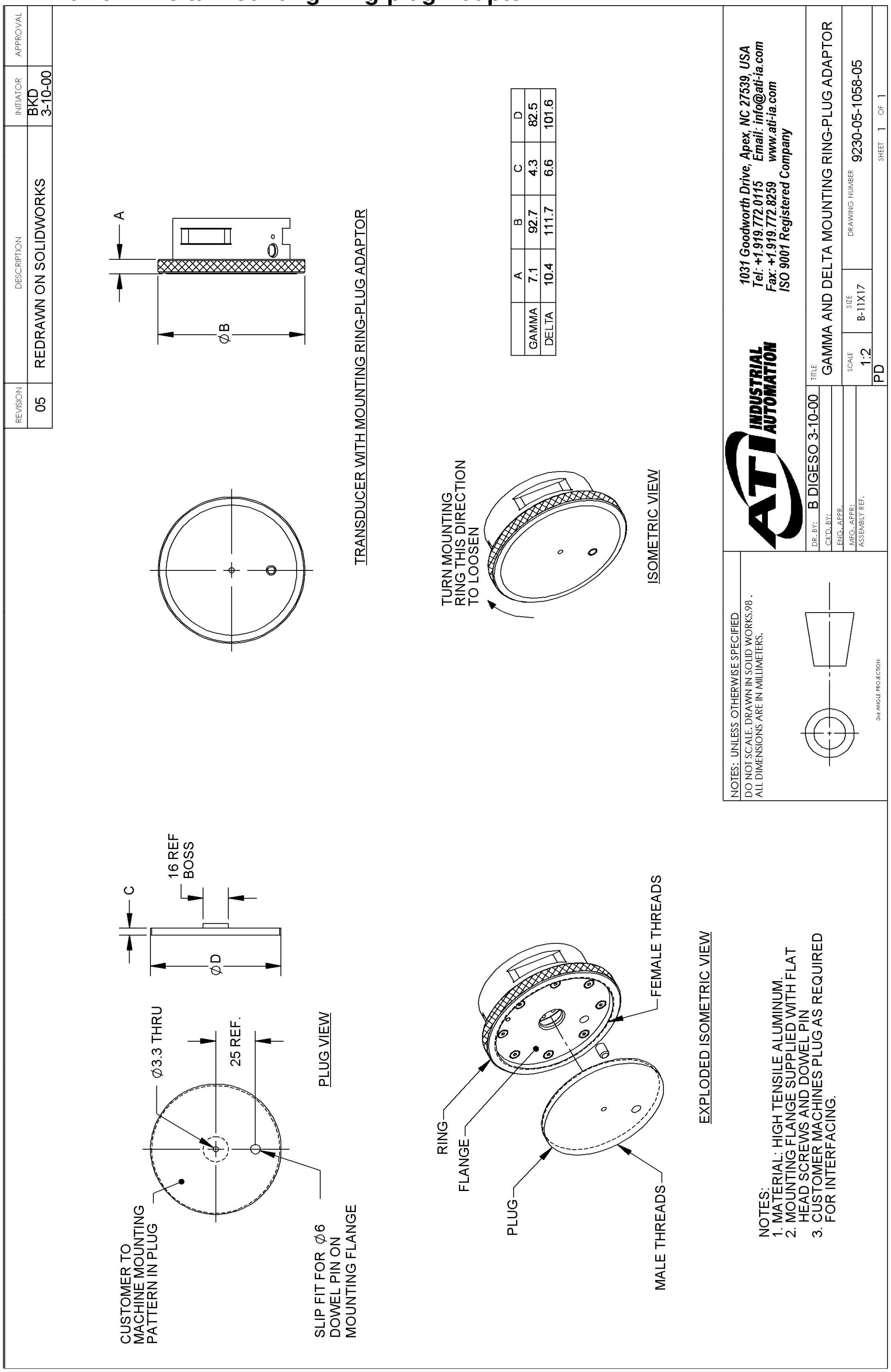


4.10.9 Delta Tool Ring-plug Adapter

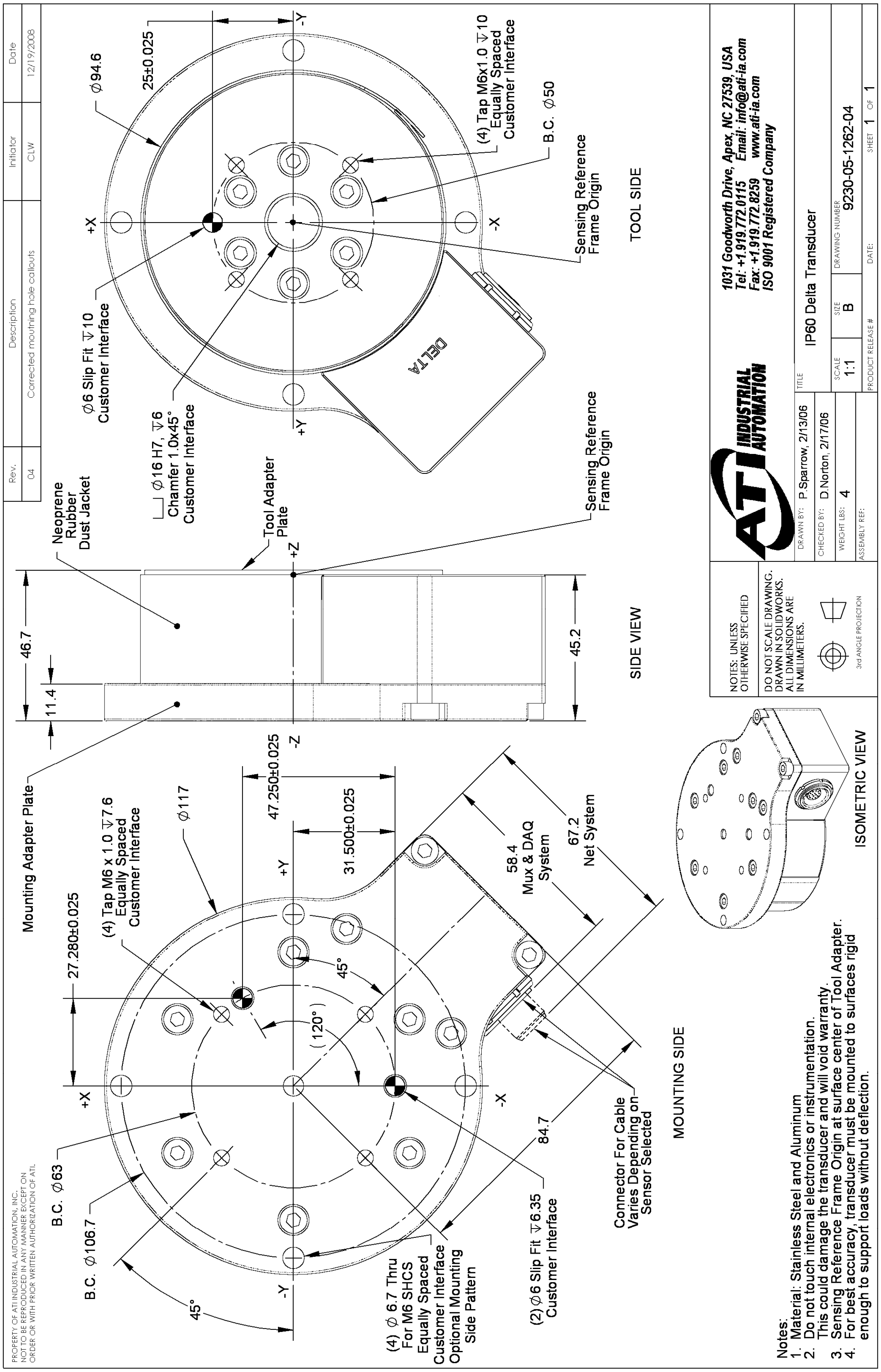


	A	B	C	D	E
GAMMA	7.9	80	3.8	69.9	32.7
DELTA	8.6	93.2	4.6	82.5	30.9

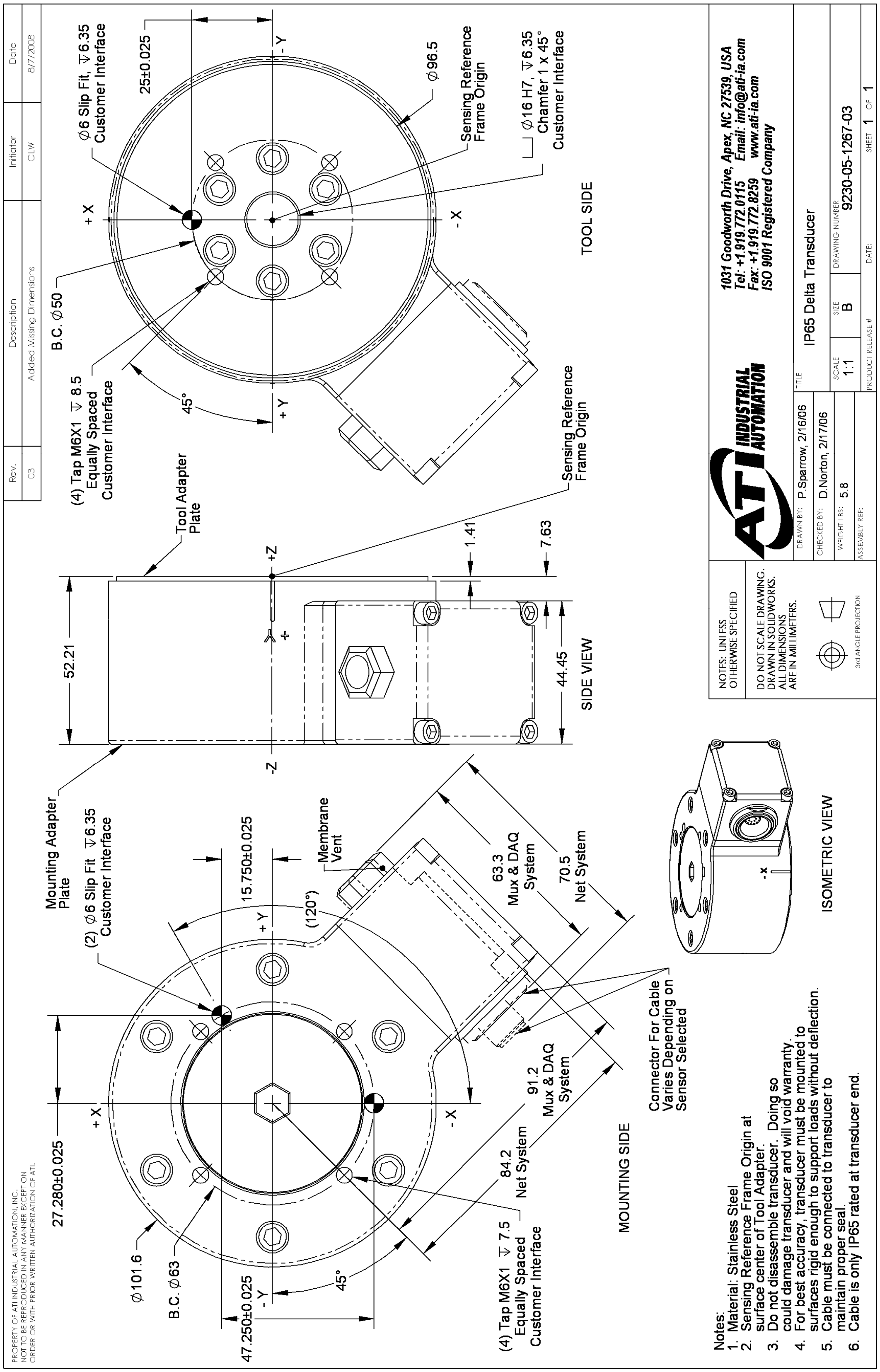
4.10.10 Delta Mounting Ring-plug Adapter



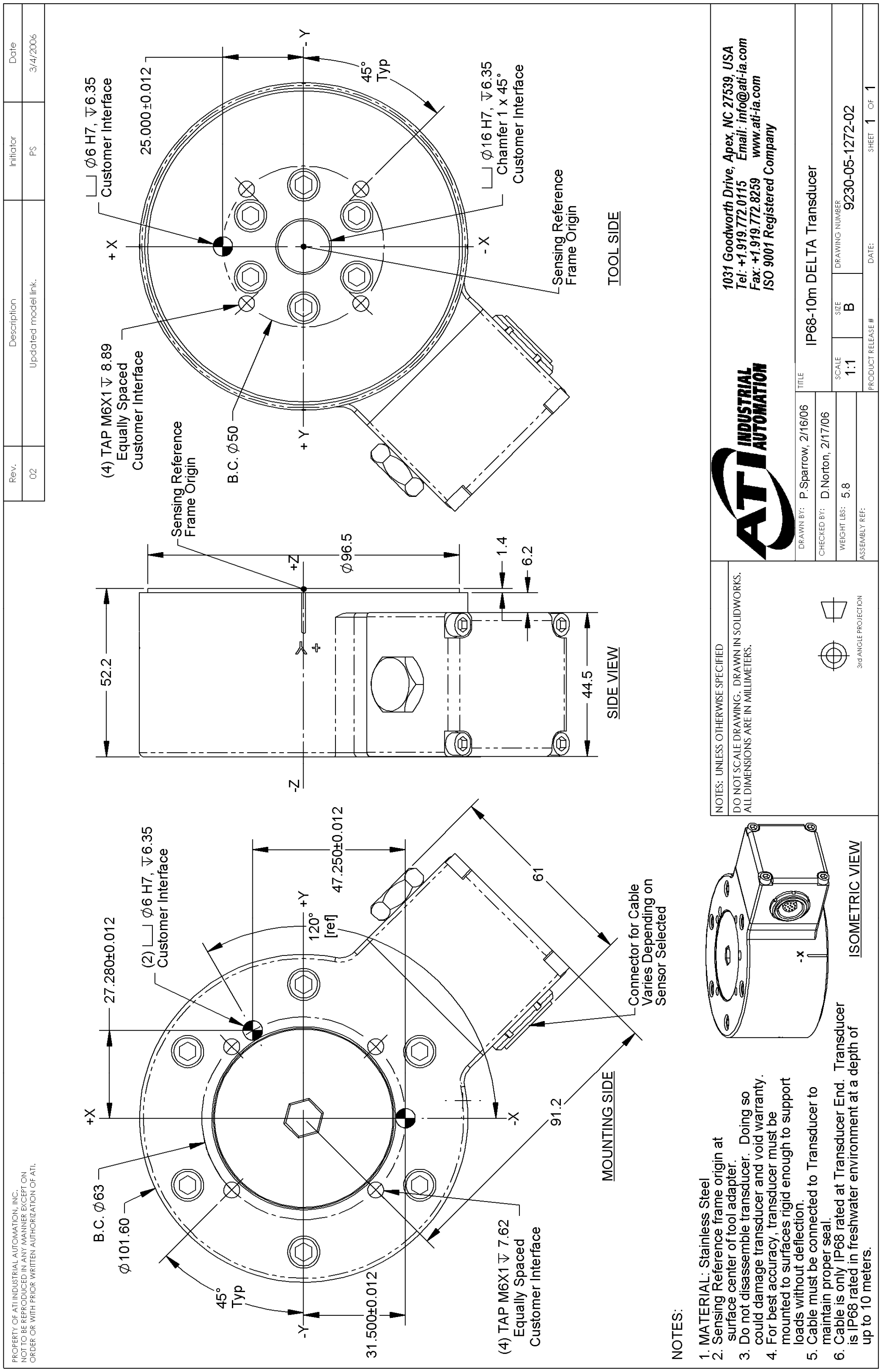
4.10.11 Delta IP60 Transducer



4.10.12 Delta IP65 Transducer



4.10.13 Delta IP68 Transducer



4.11 Theta (Includes IP60/IP65/IP68 Versions)

4.11.1 Calibration Specifications (excludes CTL calibrations)

US (English)

Calibration	Fx,Fy	Fz***	Tx,Ty	Tz	Fx,Fy	Fz***	Tx,Ty	Tz
US-200–1000	200 lbf	500 lbf	1000 lbf-in	1000 lbf-in	1/32 lbf	1/16 lbf	1/8 lbf-in	1/8 lbf-in
US-300–1800	300 lbf	875 lbf	1800 lbf-in	1800 lbf-in	5/68 lbf	5/34 lbf	5/16 lbf-in	5/16 lbf-in
US-600–3600	600 lbf	1500 lbf	3600 lbf-in	3600 lbf-in	1/8 lbf	1/4 lbf	1/2 lbf-in	1/2 lbf-in
	SENSING RANGES				RESOLUTION*			

SI (Metric)

Calibration	Fx,Fy	Fz***	Tx,Ty	Tz	Fx,Fy	Fz***	Tx,Ty	Tz
SI-1000–120	1000 N	2500 N	120 Nm	120 Nm	1/4 N	1/4 N	1/40 Nm	1/80 Nm
SI-1500–240	1500 N	3750 N	240 Nm	240 Nm	1/2 N	1/2 N	1/20 Nm	1/40 Nm
SI-2500–400	2500 N	6250 N	400 Nm	400 Nm	1/2 N	1 N	1/20 Nm	1/20 Nm
	SENSING RANGES				RESOLUTION*			

** DAQ resolutions are typical for a 16-bit data acquisition system.*

These system resolutions quoted are the effective resolution after dropping four counts of noise. The effective resolution can be improved with filtering. NOTE: Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.

4.11.2 CTL Calibration Specifications

US (English)

Calibration	Fx,Fy	Fz†	Tx,Ty	Tz	Fx,Fy	Fz†	Tx,Ty	Tz
US-200–1000	200 lbf	500 lbf	1000 lbf-in	1000 lbf-in	1/16 lbf	1/8 lbf	1/4 lbf-in	1/4 lbf-in
US-300–1800	300 lbf	875 lbf	1800 lbf-in	1800 lbf-in	5/34 lbf	5/17 lbf	5/8 lbf-in	5/8 lbf-in
US-600–3600	600 lbf	1500 lbf	3600 lbf-in	3600 lbf-in	1/4 lbf	1/2 lbf	1 lbf-in	1 lbf-in
SI (Metric)								
SI-1000–120	1000 N	2500 N	120 Nm	120 Nm	1/2 N	1/2 N	1/20 Nm	1/40 Nm
SI-1500–240	1500 N	3750 N	240 Nm	240 Nm	1 N	1 N	1/10 Nm	1/20 Nm
SI-2500–400	2500 N	6250 N	400 Nm	400 Nm	1 N	2 N	1/10 Nm	1/10 Nm
	SENSING RANGES				RESOLUTION			

US (English)

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

Counts Value

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

Tool Transform Factor

Calibration	US (English)	SI (Metric)
SI-1000–120	0.02 in/unit	1 mm/unit
SI-1500–240	0.0425 in/unit	1 mm/unit
SI-2500–400	0.02 in/unit	2 mm/unit

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. NOTE: Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.

† For IP68 version see caution on physical properties page.
‡ ±5V Sensitivity values are double the listed ±10V Sensitivity values.

4.11.3 Theta Physical Properties (Includes IP60/IP65/IP68 Versions)

US (English)

Single-Axis Overload	
Fxy	±4100 lbf
Fz	±11000 lbf
Txy	±22000 lbf-in
Tz	±20000 lbf-in
Stiffness (Calculated)	
X-axis & Y-axis forces (Kx, Ky)	4.0×10^5 lb/in
Z-axis force (Kz)	6.9×10^5 lb/in
X-axis & Y-axis torque (Ktx, Kty)	3.0×10^6 lbf-in/rad
Z-axis torque (Ktz)	4.7×10^6 lbf-in/rad
Resonant Frequency (Measured)	
Fx, Fy, Tz	680 Hz
Fz, Tx, Ty	820 Hz
Physical Specifications	
Weight*	11 lb
Diameter*	6.1 in
Height*	2.4 in

SI (Metric)

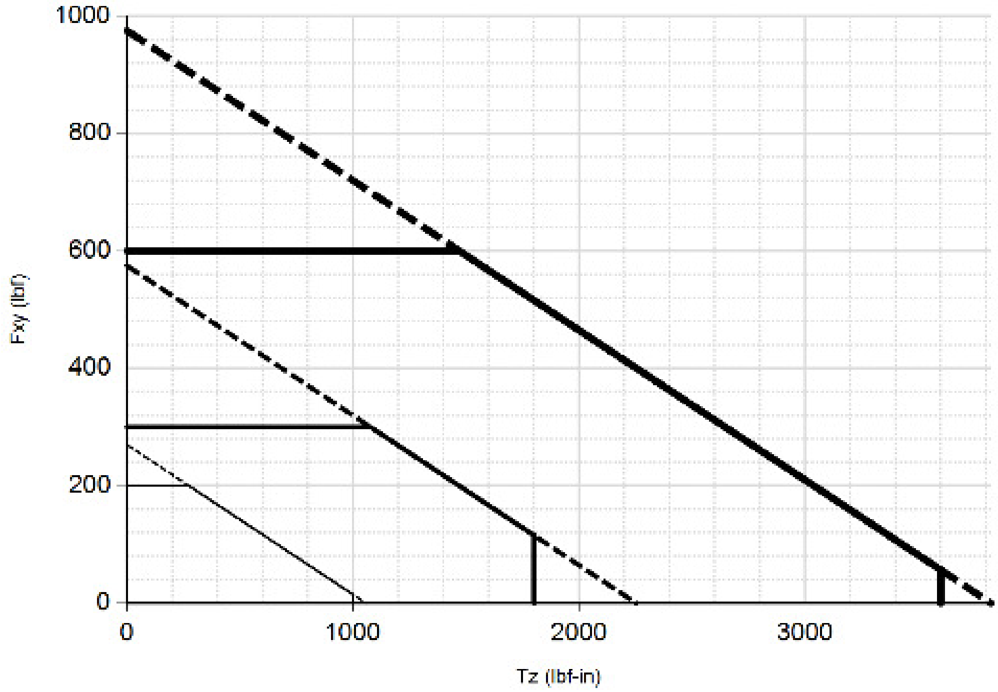
Single-Axis Overload	
Fxy	±18000 N
Fz	±49000 N
Txy	±2500 Nm
Tz	±2300 Nm
Stiffness (Calculated)	
X-axis & Y-axis forces (Kx, Ky)	7.1×10^7 N/m
Z-axis force (Kz)	1.2×10^8 N/m
X-axis & Y-axis torque (Ktx, Kty)	3.4×10^5 Nm/rad
Z-axis torque (Ktz)	5.3×10^5 Nm/rad
Resonant Frequency (Measured)	
Fx, Fy, Tz	680 Hz
Fz, Tx, Ty	820 Hz
Physical Specifications	
Weight*	4.99 kg
Diameter*	150 mm
Height*	61 mm

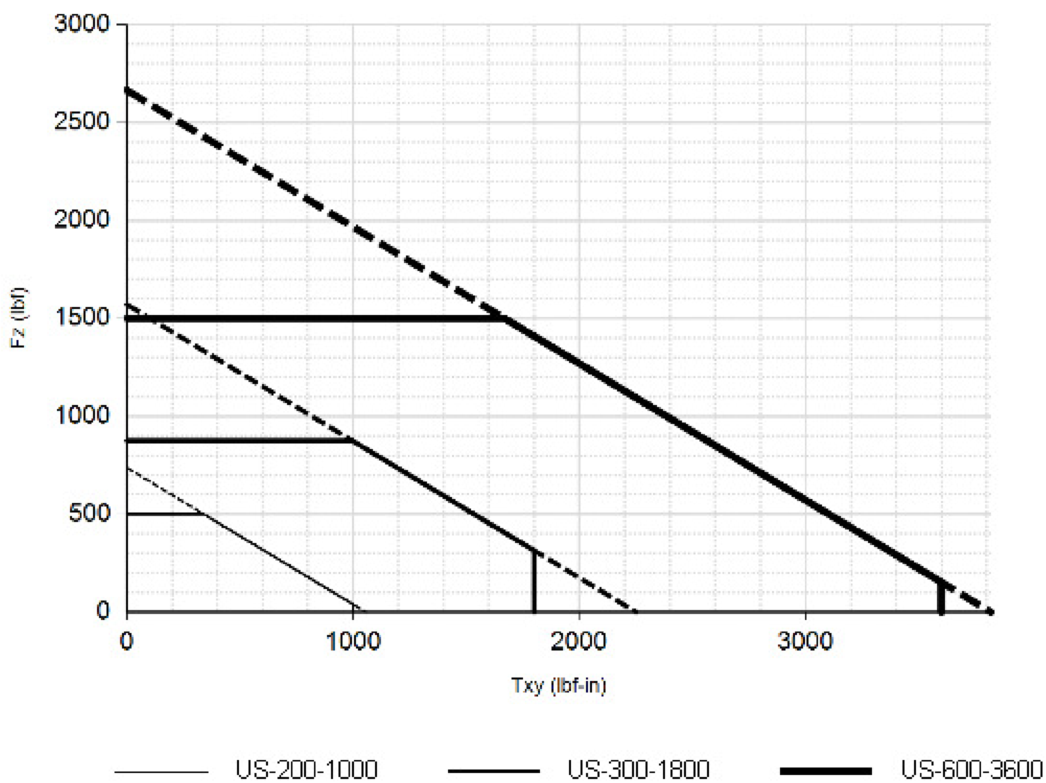
** Specifications include standard interface plates.*

⚠ **CAUTION:**
IP68 Theta Fz as a Function of Submersion Depth:
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 seal level.

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

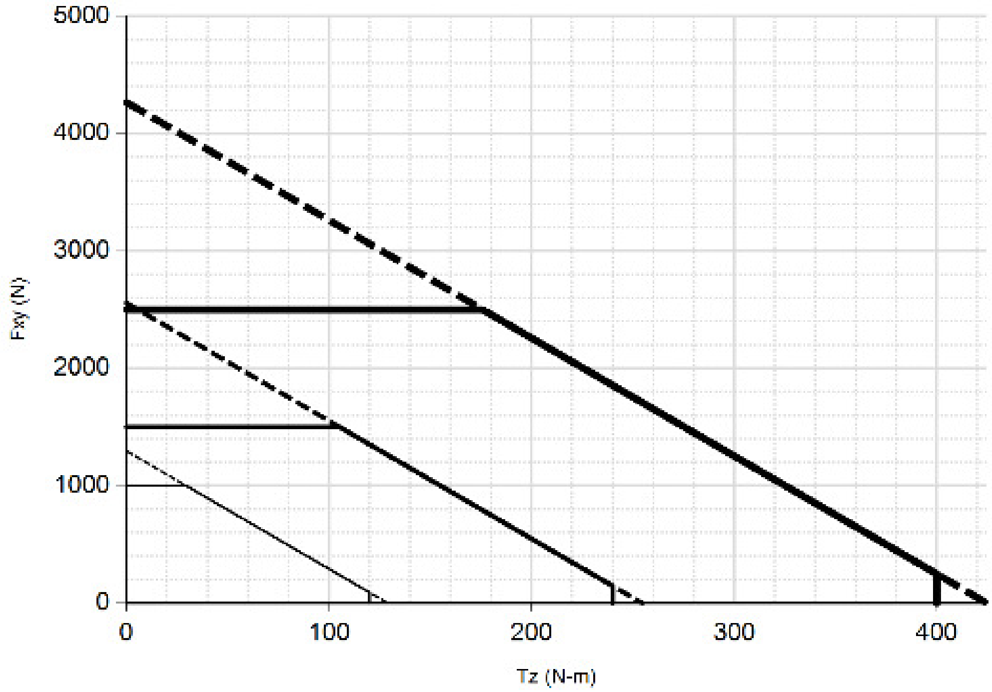
4.11.4 Theta (US Calibration Complex Loading) (Includes IP60/IP65/IP68 Versions)

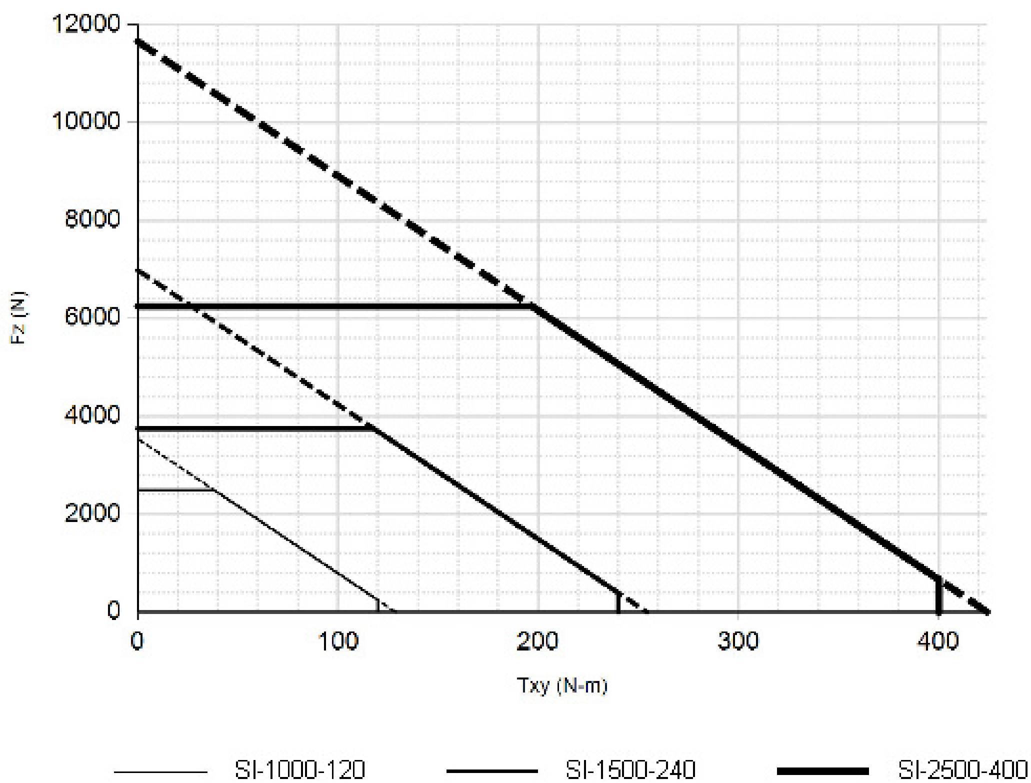




*** For IP68 version see caution on physical properties page.

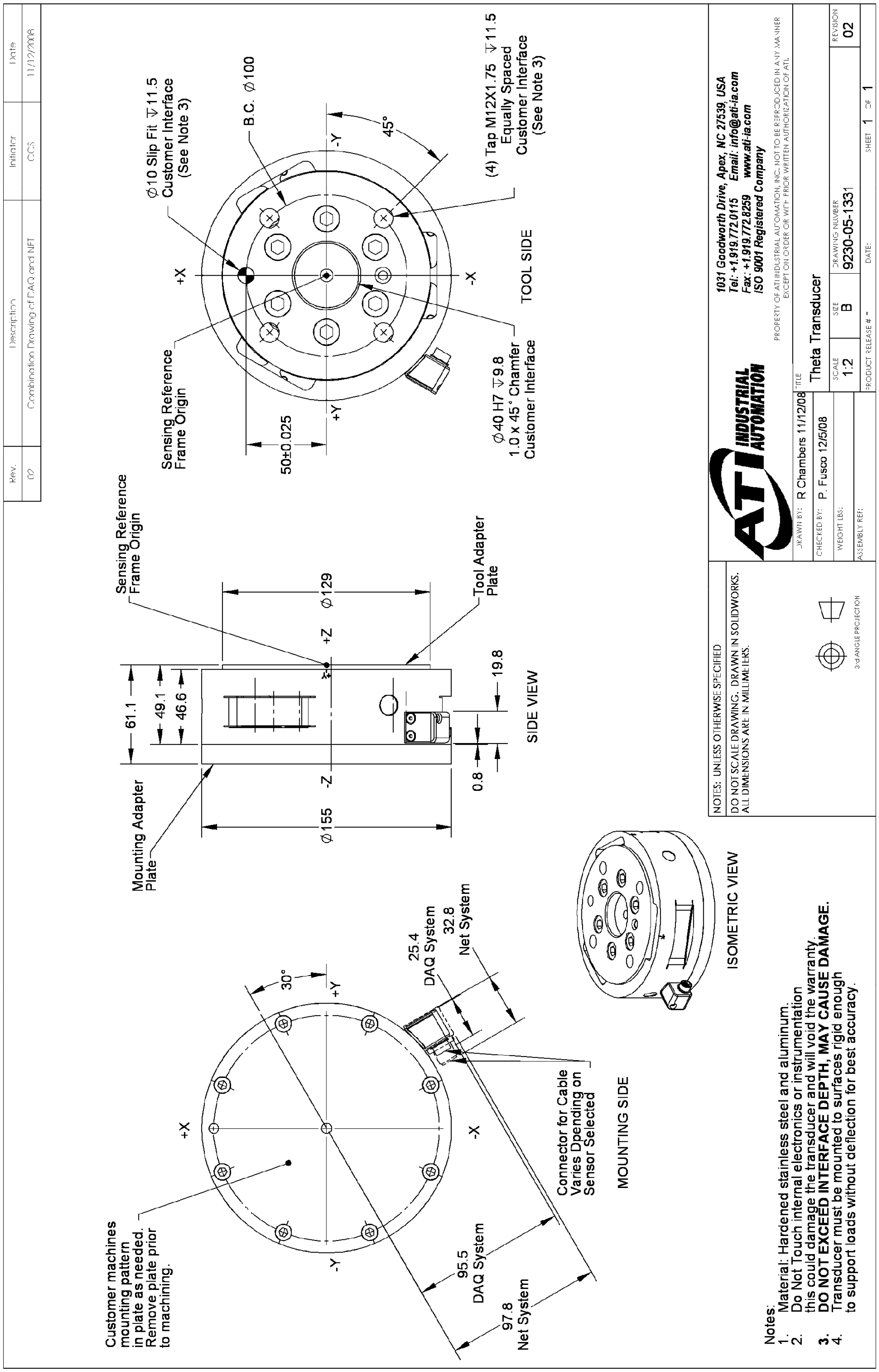
4.11.5 Theta (SI Calibration Complex Loading) (Includes IP60/IP65/IP68 Versions)



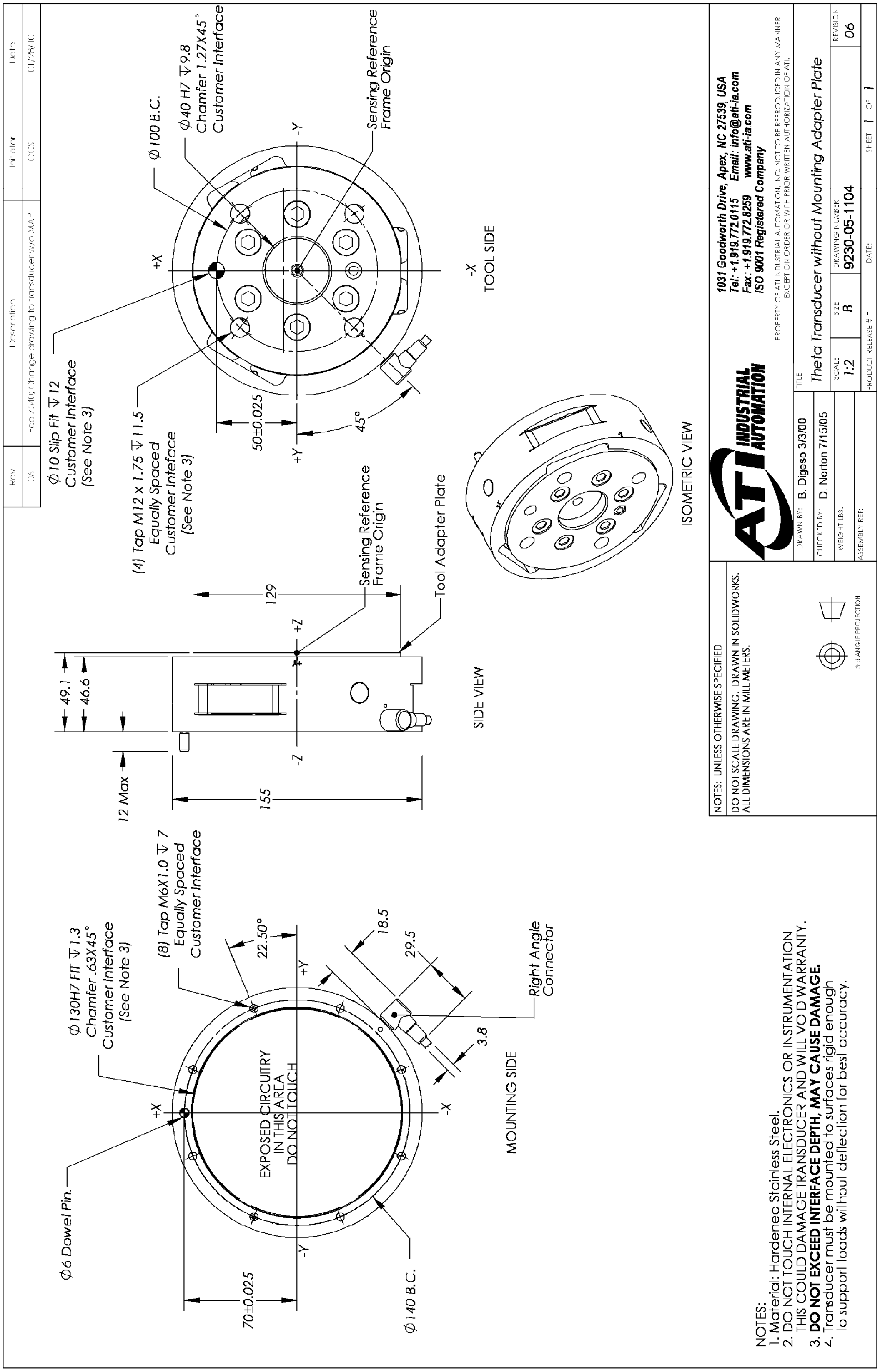


*** For IP68 version see caution on physical properties page.

4.11.6 Theta DAQ/Net Transducer

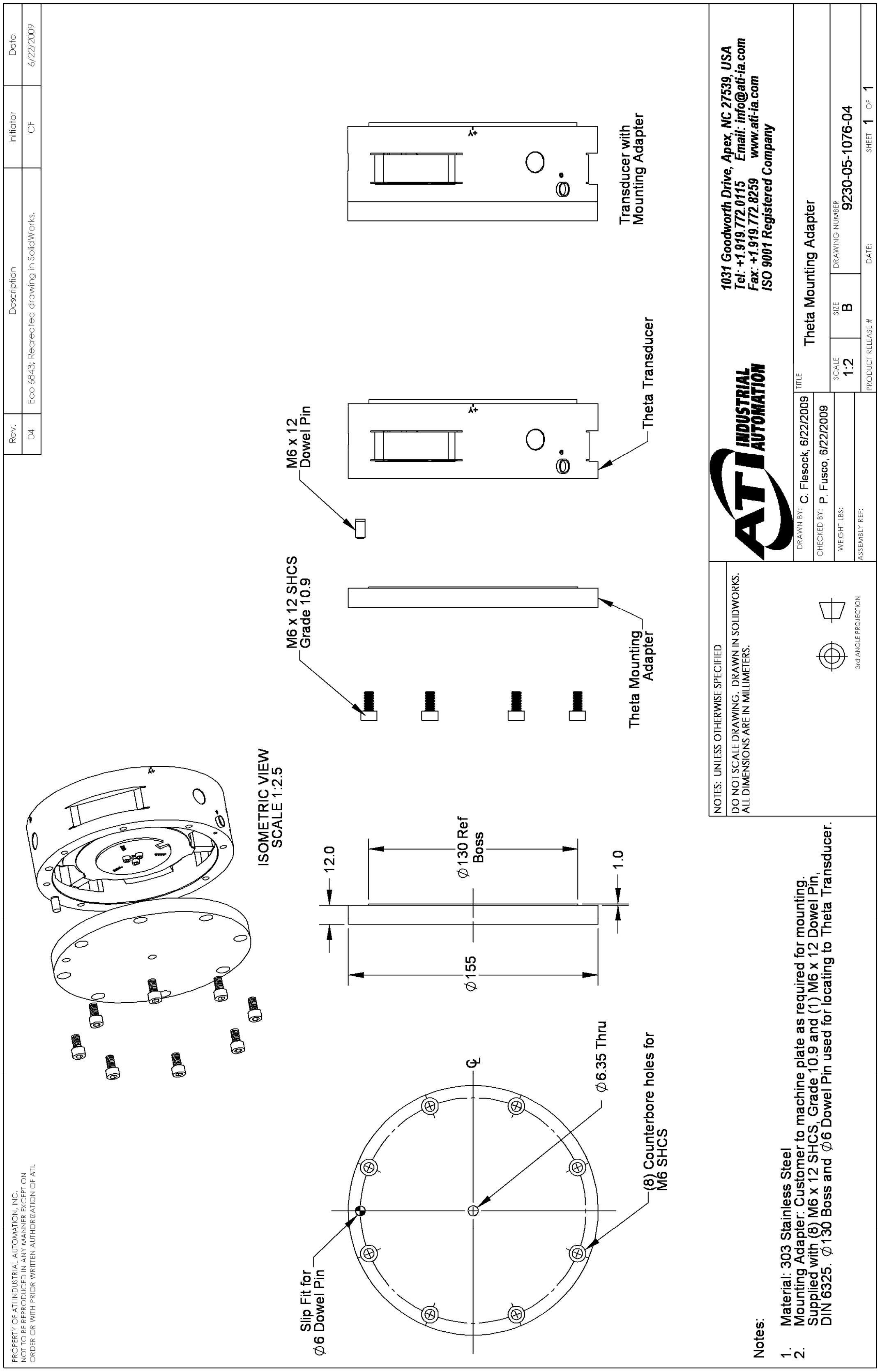


4.11.7 9105-T-Theta Transducer without Mounting Adapter Plate

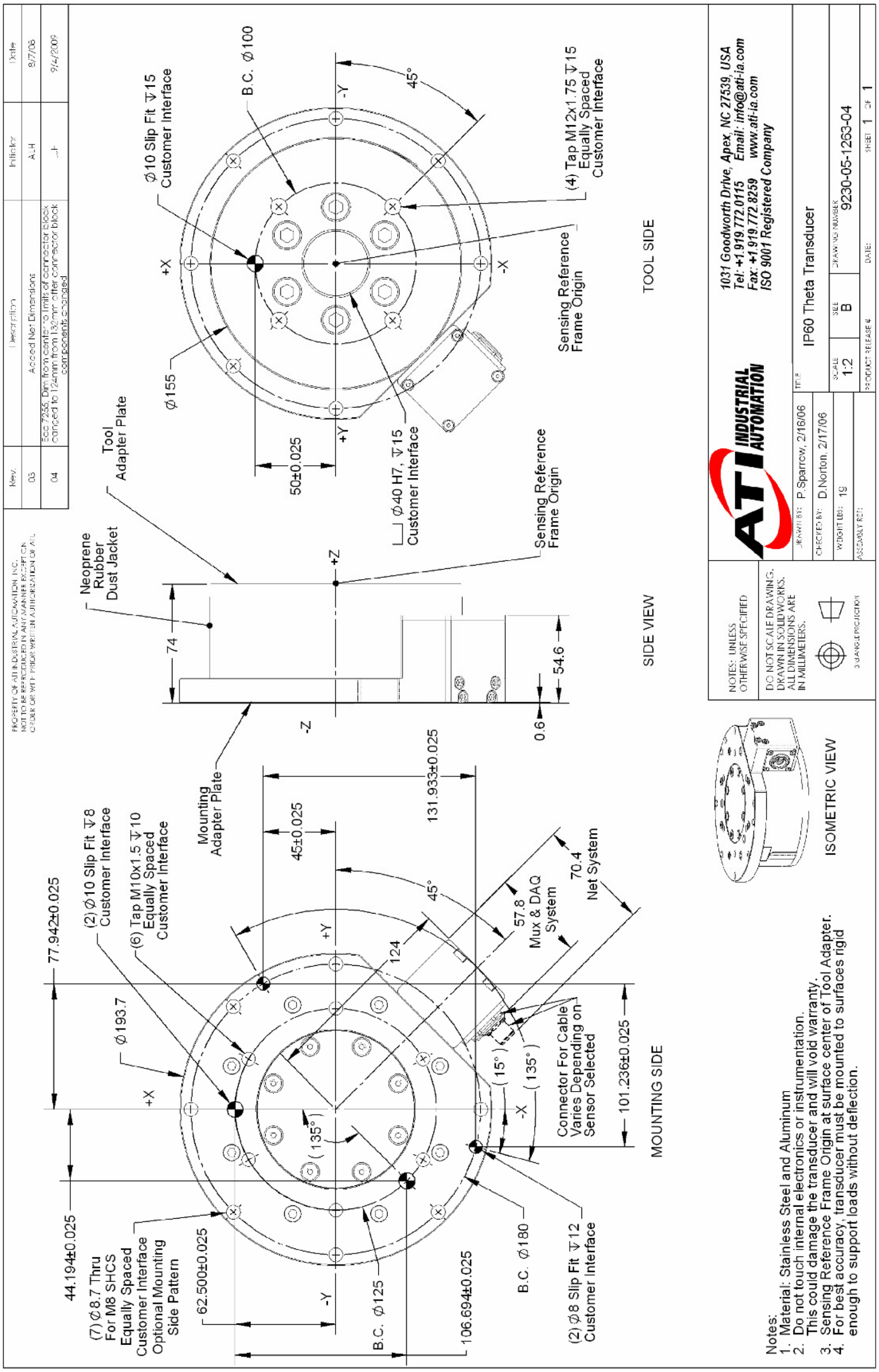


Note: Mux transducers are used in F/T Controller systems.

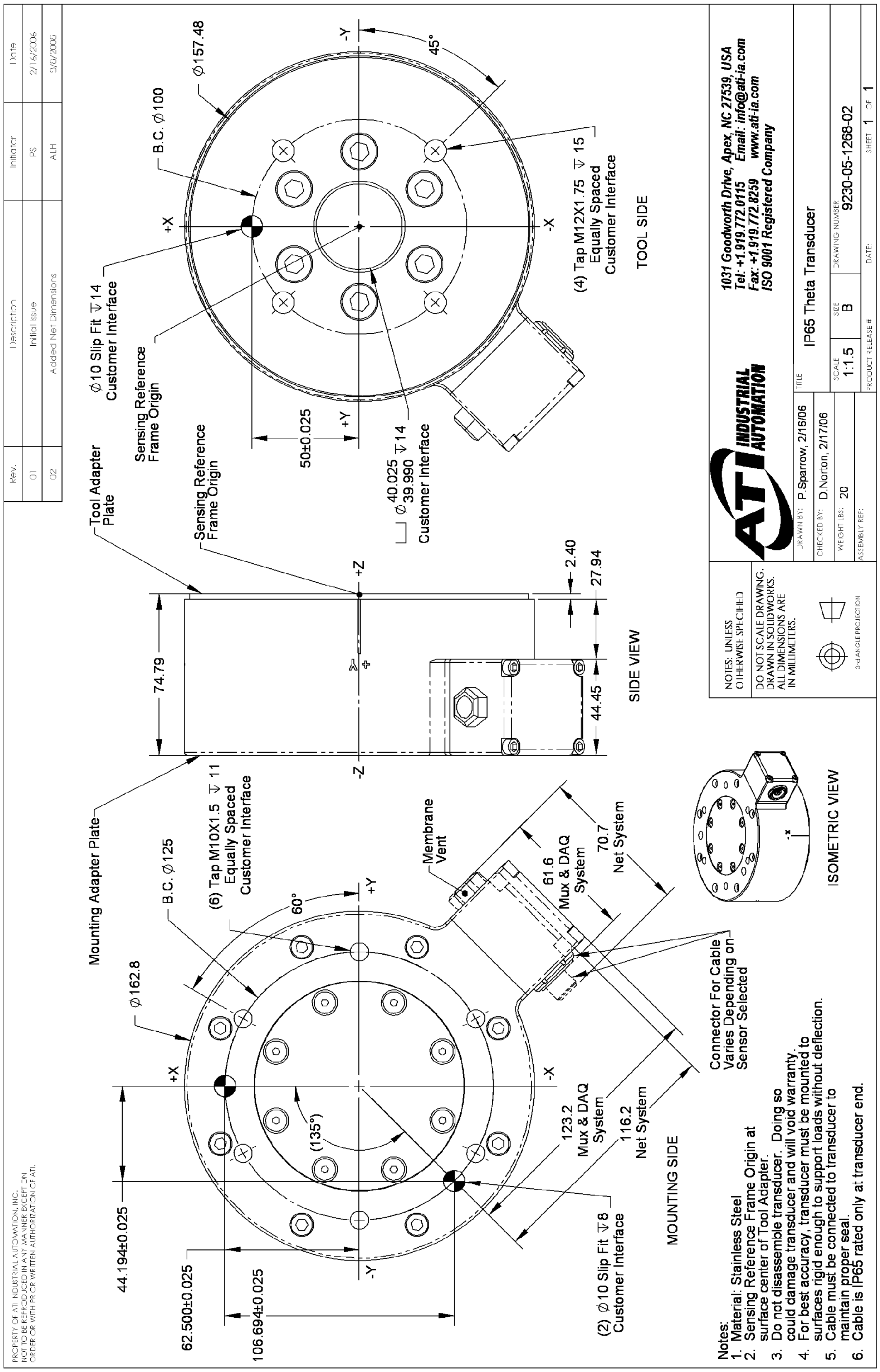
4.11.8 Theta Mounting Adapter Plate



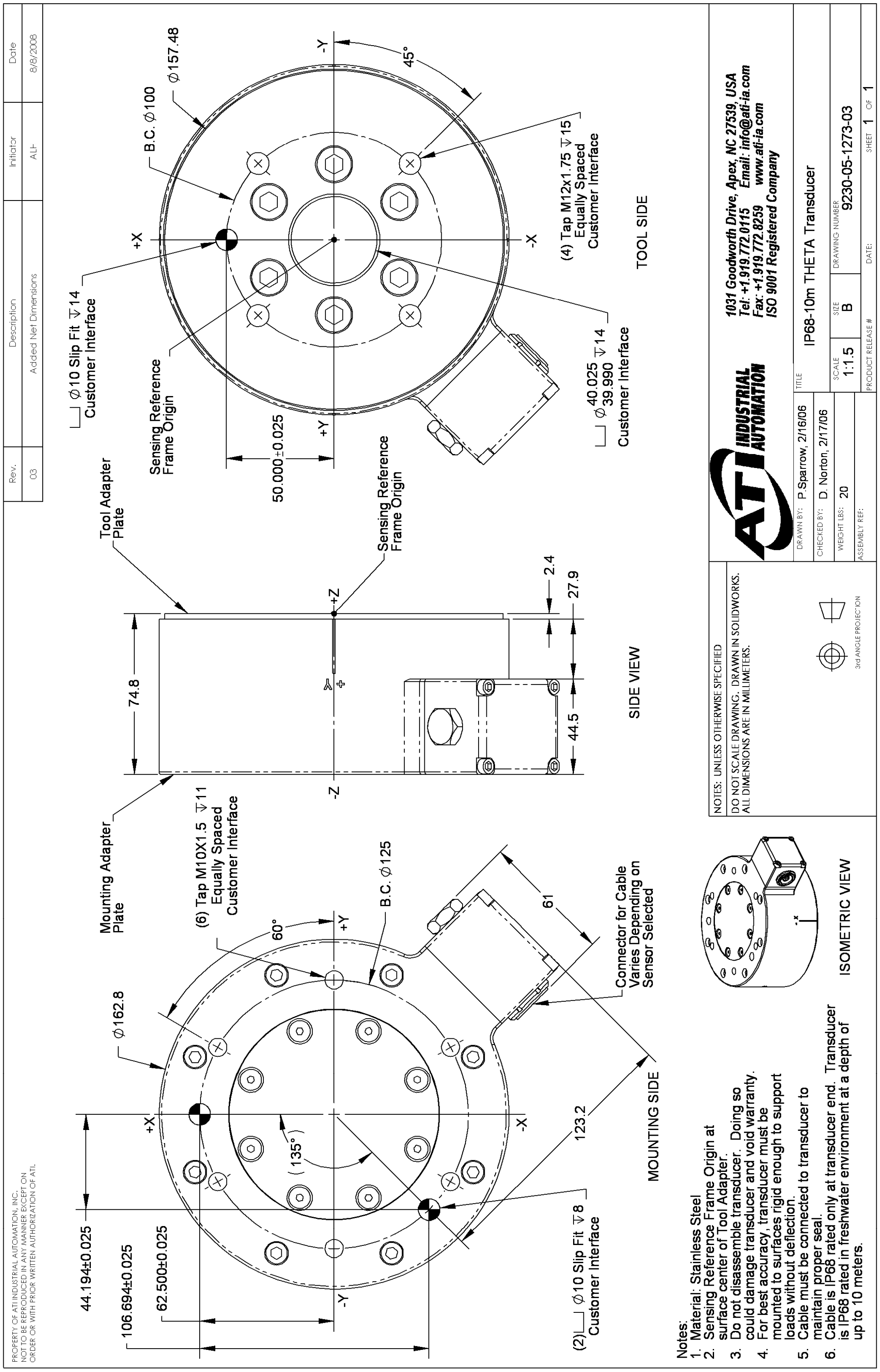
4.11.9 Theta IP60 Transducer



4.11.10 Theta IP65 Transducer



4.11.11 Theta IP68 Transducer



4.12 Omega160 (Includes IP60/IP65/IP68 Versions)

4.12.1 Calibration Specifications (excludes CTL calibrations)

US (English)

Calibration	Fx,Fy	Fz†	Tx,Ty	Tz	Fx,Fy	Fz†	Tx,Ty	Tz
US-200–1000	200 lbf	500 lbf	1000 lbf-in	1000 lbf-in	1/32 lbf	1/16 lbf	1/8 lbf-in	1/8 lbf-in
US-300–1800	300 lbf	875 lbf	1800 lbf-in	1800 lbf-in	5/68 lbf	5/34 lbf	5/16 lbf-in	5/16 lbf-in
US-600–3600	600 lbf	1500 lbf	3600 lbf-in	3600 lbf-in	1/8 lbf	1/4 lbf	1/2 lbf-in	1/4 lbf-in

SI (Metric)

Calibration	Fx,Fy	Fz†	Tx,Ty	Tz	Fx,Fy	Fz†	Tx,Ty	Tz
SI-1000–120	1000 N	2500 N	120 Nm	120 Nm	1/4 N	1/4 N	1/40 Nm	1/80 Nm
SI-1500–240	1500 N	3750 N	240 Nm	240 Nm	1/4 N	1/2 N	1/20 Nm	1/40 Nm
SI-2500–400	2500 N	6250 N	400 Nm	400 Nm	1/2 N	3/4 N	1/20 Nm	1/20 Nm
	SENSING RANGES				RESOLUTION*			

* *DAQ resolutions are typical for a 16-bit system.*

These system resolutions quoted are the effective resolution after dropping four counts of noise. The effective resolution can be improved with filtering. NOTE: Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.

4.12.2 CTL Calibration Specifications

US (English)

Calibration	Fx,Fy	Fz†	Tx,Ty	Tz	Fx,Fy	Fz†	Tx,Ty	Tz
US-200–1000	200 lbf	500 lbf	1000 lbf-in	1000 lbf-in	1/16 lbf	1/8 lbf	1/4 lbf-in	1/4 lbf-in
US-300–1800	300 lbf	875 lbf	1800 lbf-in	1800 lbf-in	5/34 lbf	5/17 lbf	5/8 lbf-in	5/8 lbf-in
US-600–3600	600 lbf	1500 lbf	3600 lbf-in	3600 lbf-in	1/4 lbf	1/2 lbf	1 lbf-in	1/2 lbf-in
SI (Metric)								
SI-1000-120	1000 N	2500 N	120 Nm	120 Nm	1/2 N	1/2 N	1/20 Nm	1/40 Nm
SI-1500-240	1500 N	3750 N	240 Nm	240 Nm	1/2 N	1 N	1/10 Nm	1/20 Nm
SI-2500-400	2500 N	6250 N	400 Nm	400 Nm	1 N	1 1/2 N	1/10 Nm	1/10 Nm
	SENSING RANGES				RESOLUTION			

US (English)

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

Counts Value

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

Tool Transform Factor

Calibration	US (English)	SI (Metric)
US-200–1000	0.02 in/unit	1 mm/unit
US-300–1800	0.0425 in/unit	1 mm/unit
US-600–3600	0.02 in/unit	2 mm/unit

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. NOTE: Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.

† For IP68 version see caution on physical properties page.
‡ ±5V Sensitivity values are double the listed ±10V Sensitivity values.

4.12.3 Omega160 Physical Properties (Includes IP60/IP65/IP68 Versions)

US (English)

Single-Axis Overload	
Fxy	±3900 lbf
Fz	±11000 lbf
Txy	±15000 lbf-in
Tz	±17000 lbf-in
Stiffness (Calculated)	
X-axis & Y-axis forces (Kx, Ky)	4.0×10^5 lb/in
Z-axis force (Kz)	6.8×10^5 lb/in
X-axis & Y-axis torque (Ktx, Kty)	2.9×10^6 lbf-in/rad
Z-axis torque (Ktz)	4.6×10^6 lbf-in/rad
Resonant Frequency (Measured)	
Fx, Fy, Tz	1300 Hz
Fz, Tx, Ty	1000 Hz
Physical Specifications	
Weight*	6 lb
Diameter*	6.1 in
Height*	2.2 in

SI (Metric)

Single-Axis Overload	
Fxy	±18000 N
Fz	±48000 N
Txy	±1700 Nm
Tz	±1900 Nm
Stiffness (Calculated)	
X-axis & Y-axis forces (Kx, Ky)	7.0×10^7 N/m
Z-axis force (Kz)	1.2×10^8 N/m
X-axis & Y-axis torque (Ktx, Kty)	3.3×10^5 Nm/rad
Z-axis torque (Ktz)	5.2×10^5 Nm/rad
Resonant Frequency (Measured)	
Fx, Fy, Tz	1300 Hz
Fz, Tx, Ty	1000 Hz
Physical Specifications	
Weight*	2.72 kg
Diameter*	160 mm
Height*	56 mm

** Specifications include standard interface plates.*

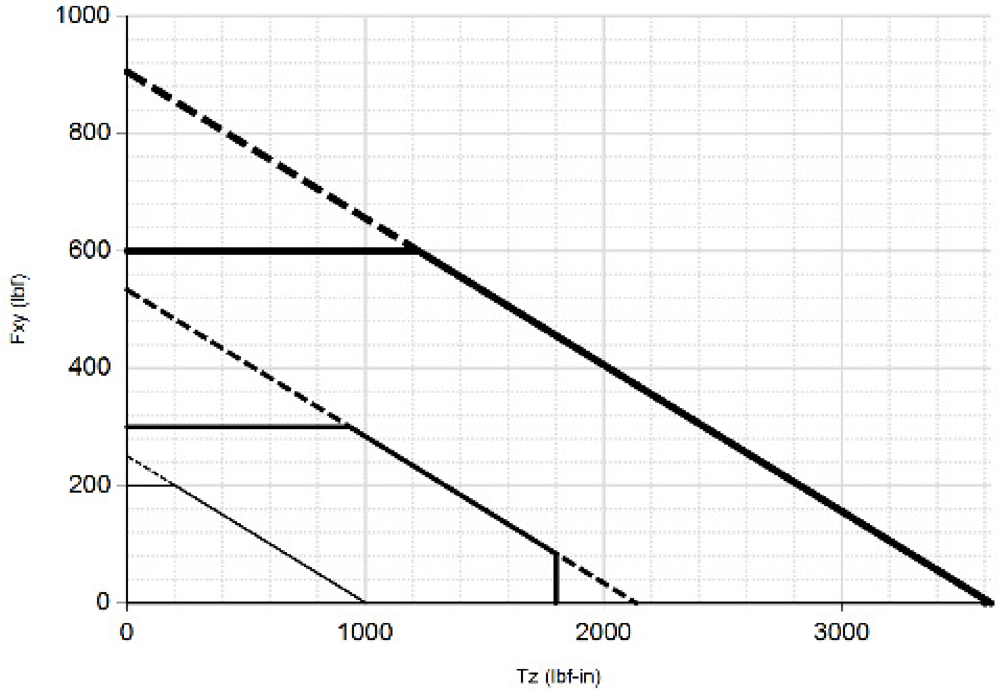
CAUTION:

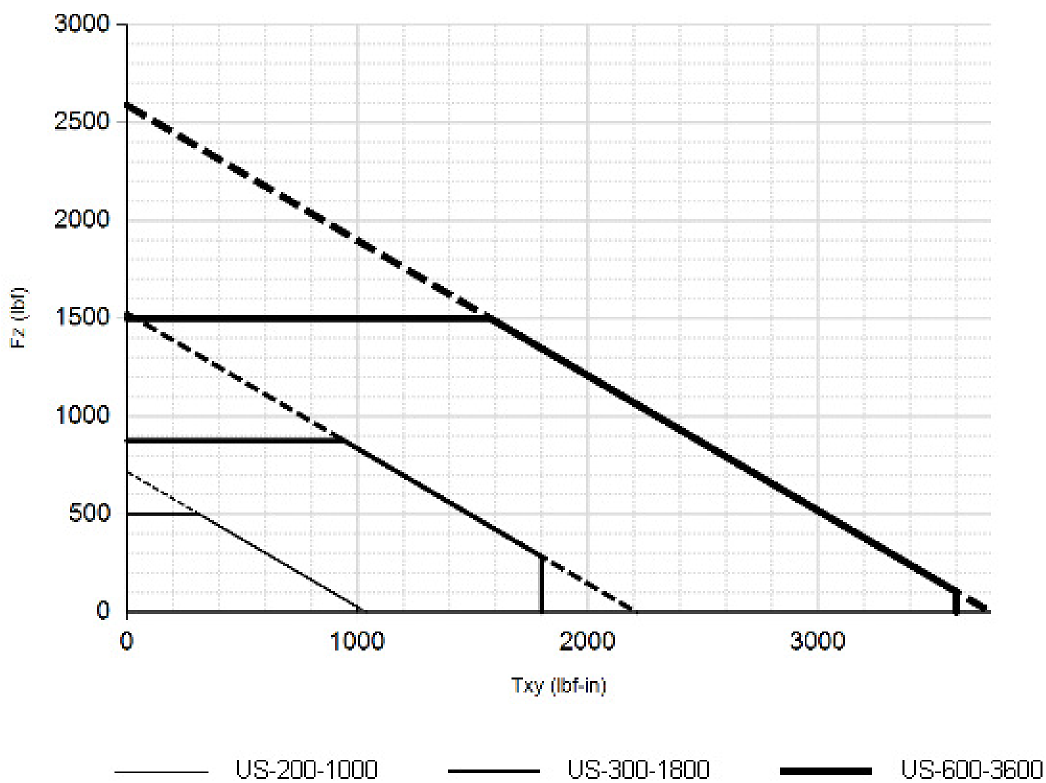
IP68 Omega160 Fz as a Function of Submersion Depth:

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 seal level.

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

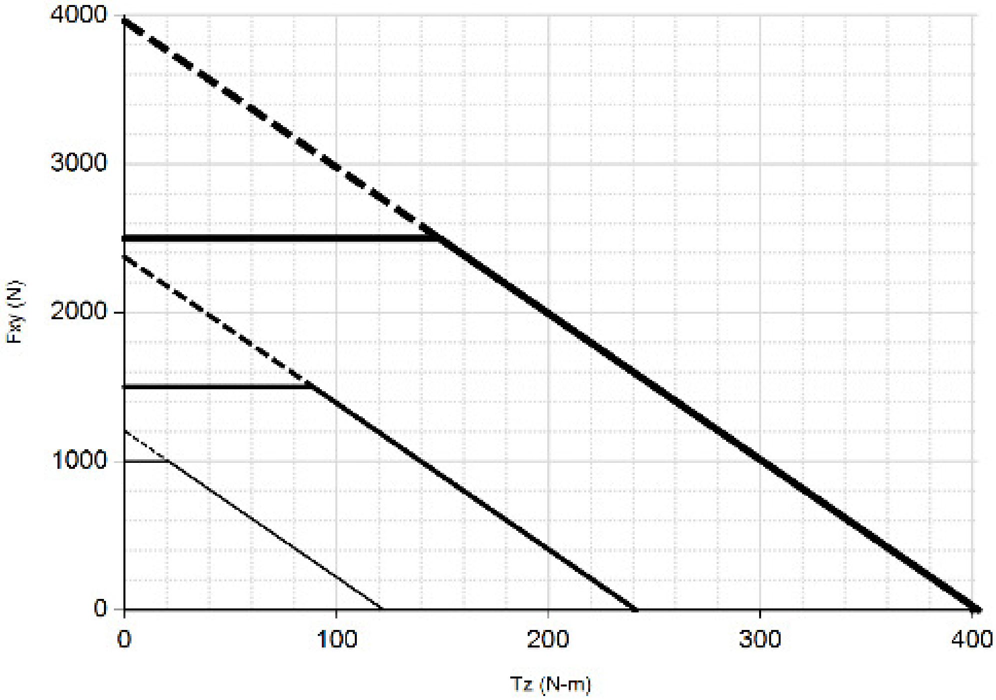
4.12.4 Omega160 (US Calibration Complex Loading) (Includes IP60/IP65/IP68 Versions)

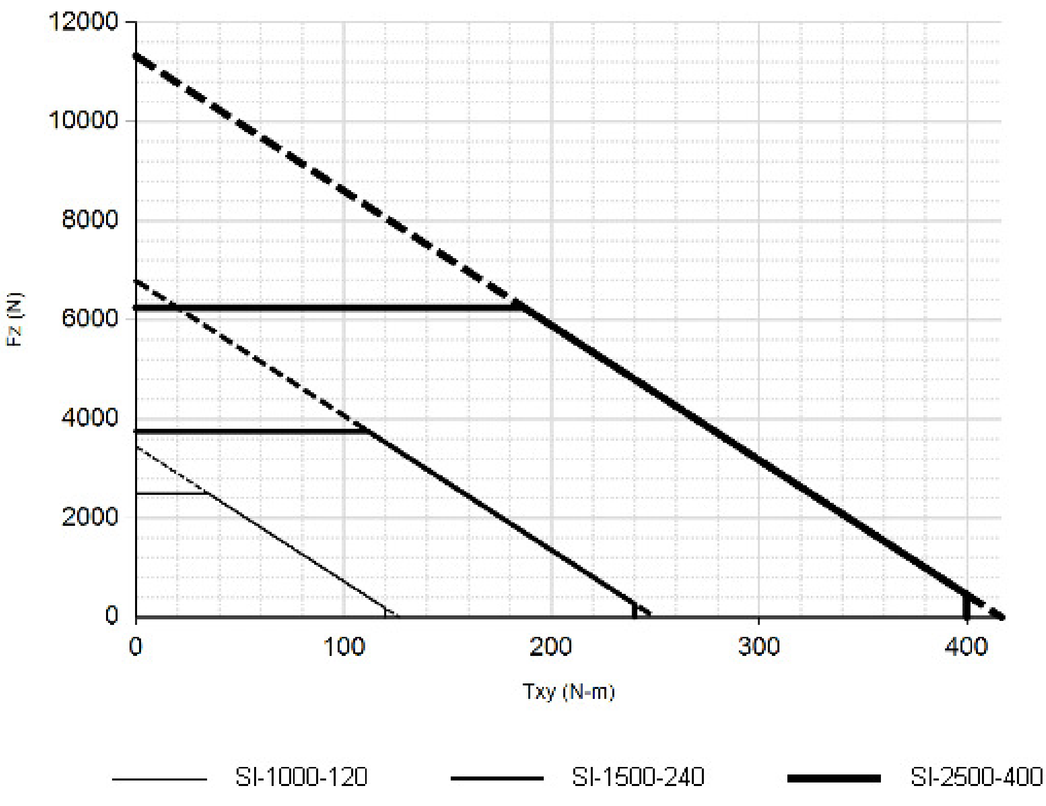




*** For IP68 version see caution on physical properties page.

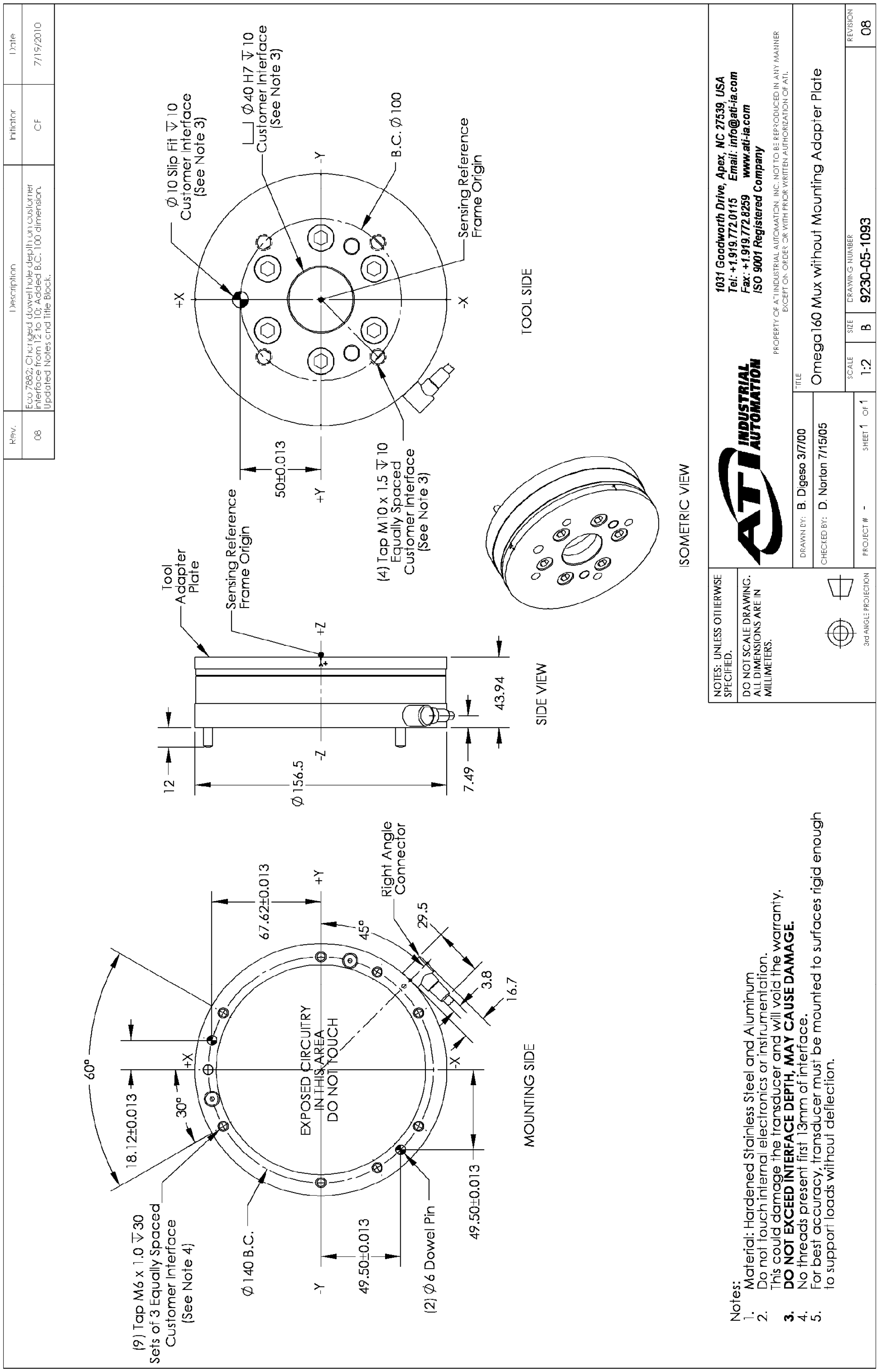
4.12.5 Omega160 (SI Calibration Complex Loading) (Includes IP60/IP65/IP68 Versions)



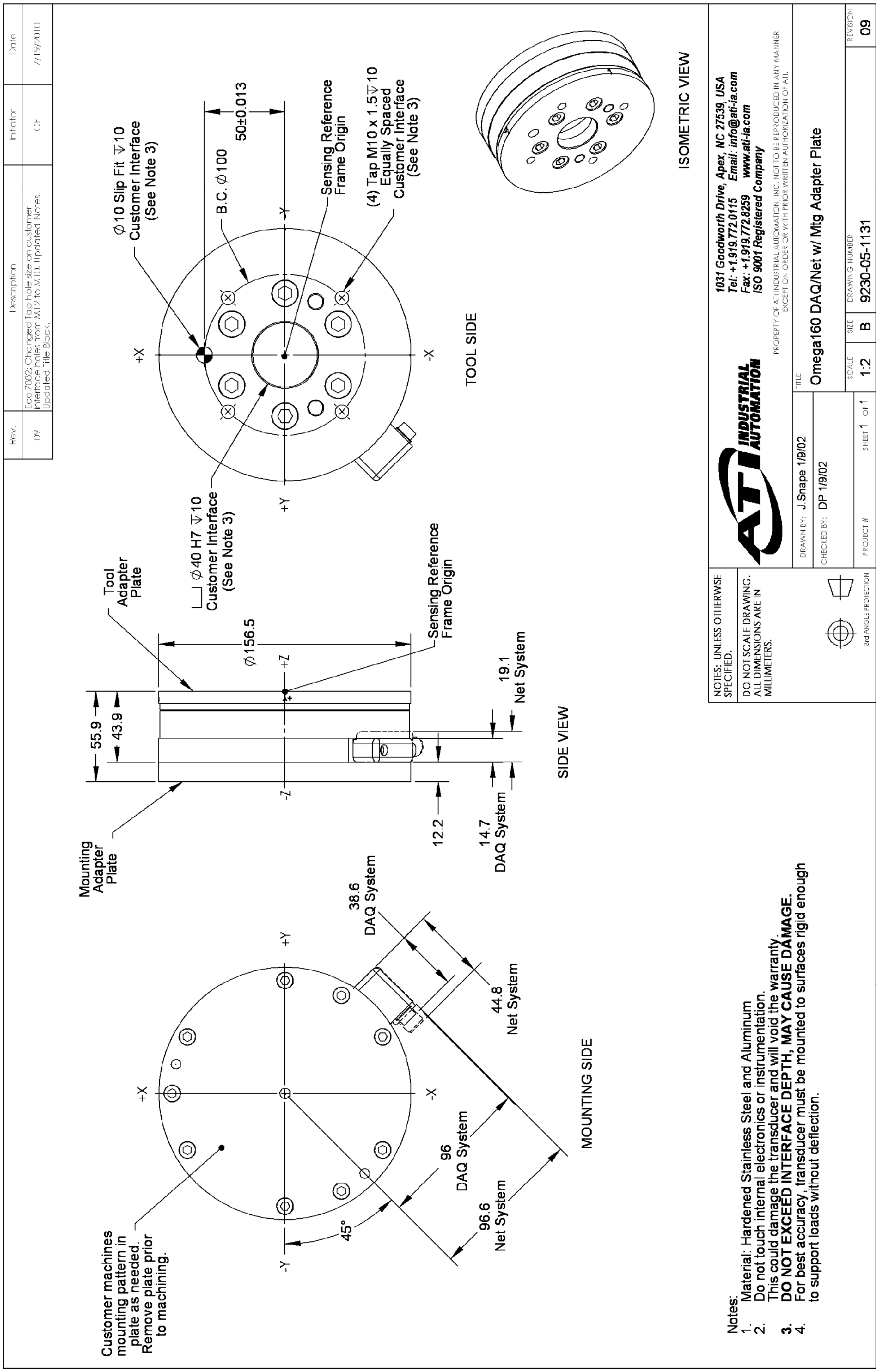


*** For IP68 version see caution on physical properties page.

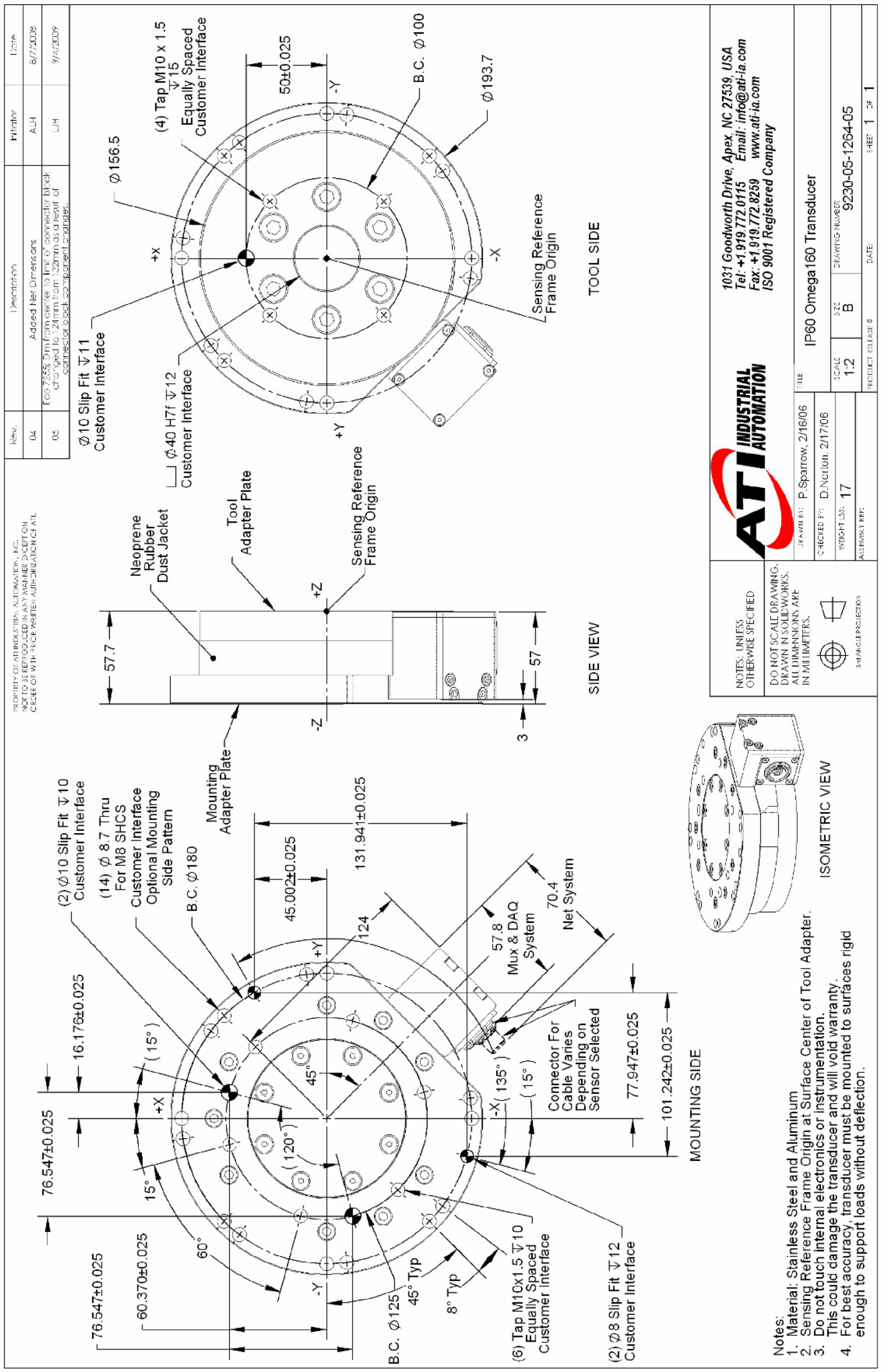
4.12.6 Omega160 Transducer with Mounting Adapter Plate



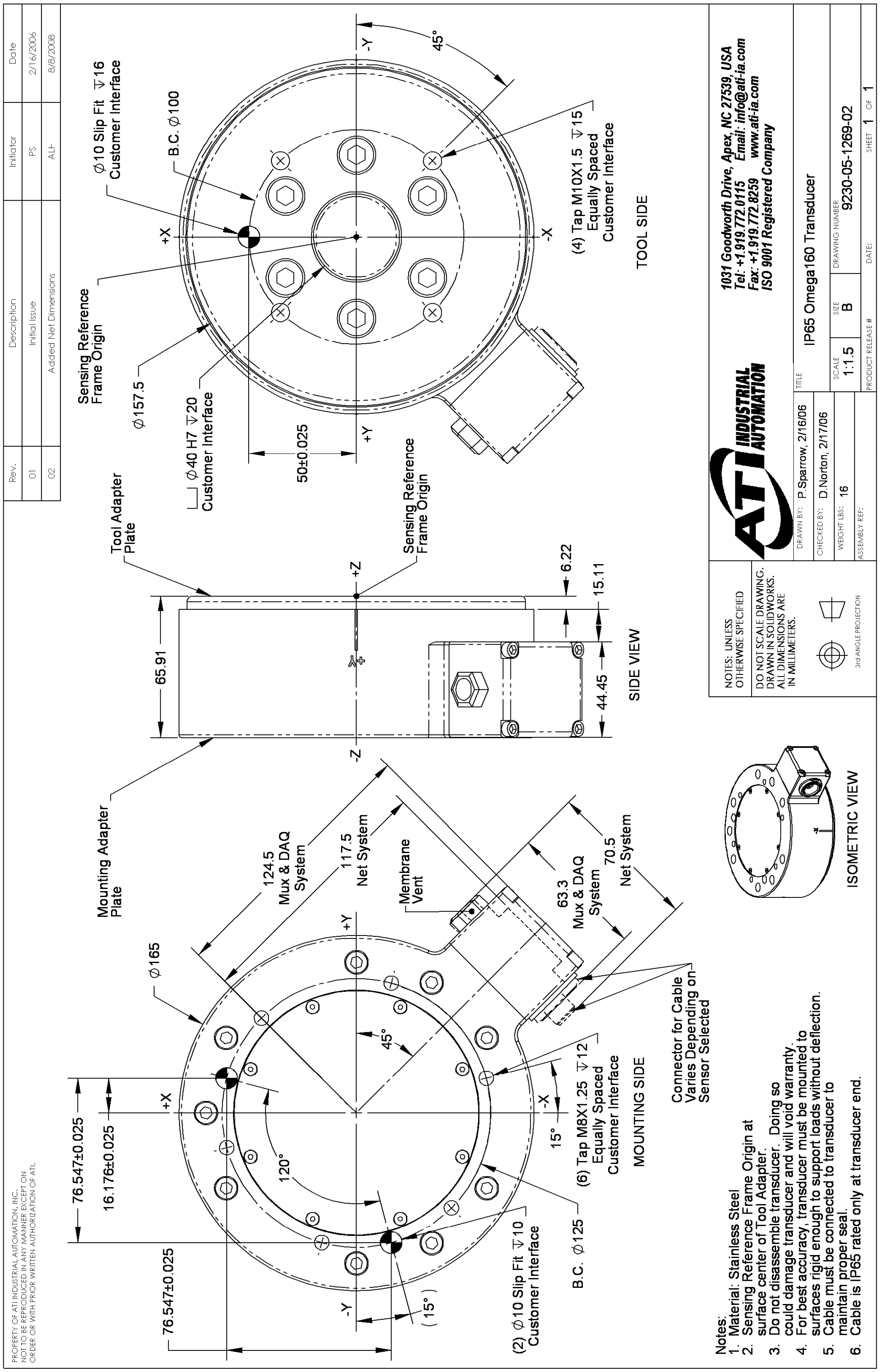
4.12.7 Omega160 DAQ/Net with Mounting Adapter Plate



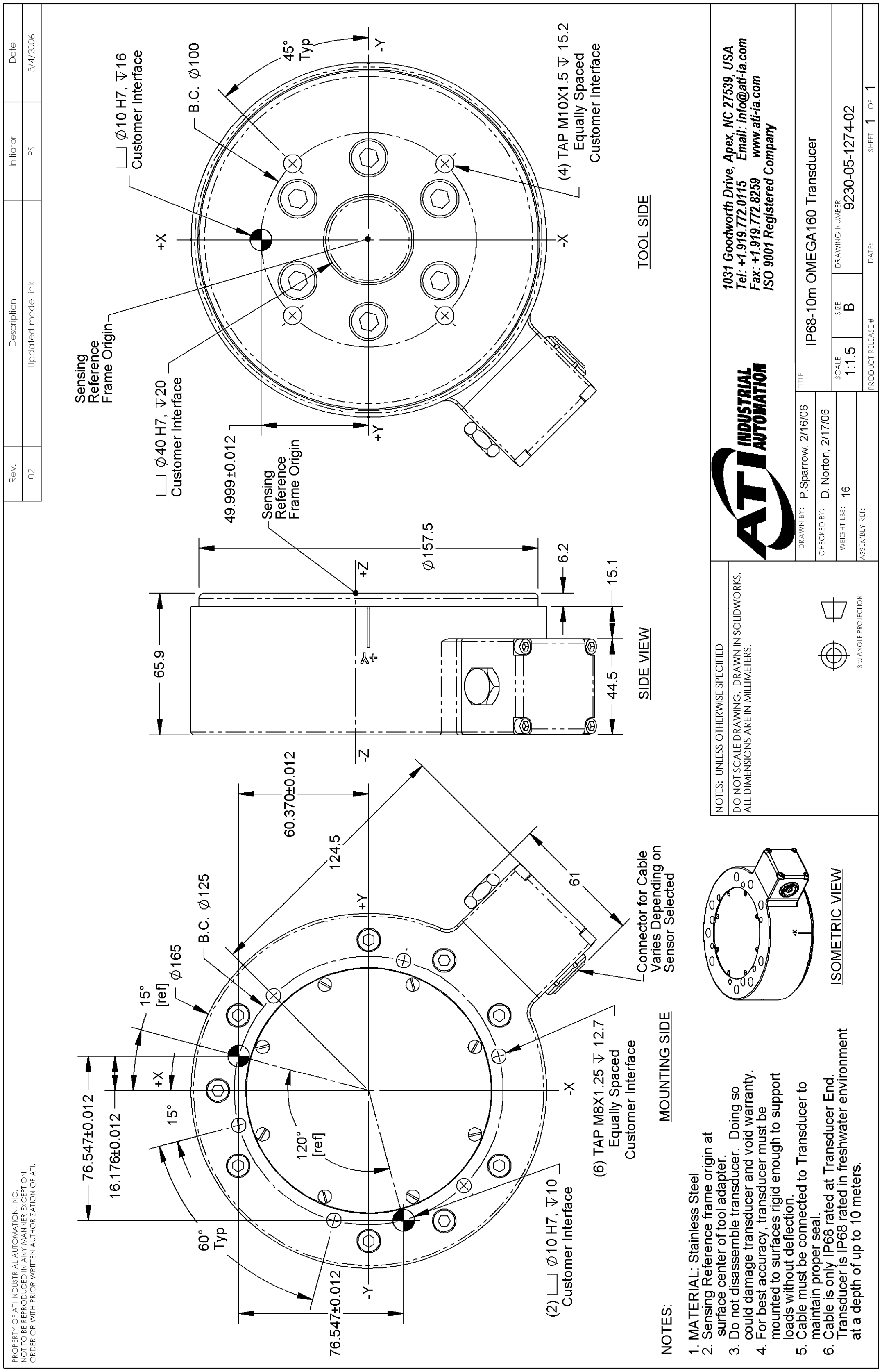
4.12.8 Omega160 IP60 Transducer



4.12.9 Omega160 IP65 Transducer



4.12.10 Omega160 IP68 Transducer



4.13 Omega190 (Includes IP60/IP65/IP68 Versions)

4.13.1 Calibration Specifications (excludes CTL calibrations)

US (English)

Calibration	Fx,Fy	Fz†	Tx,Ty	Tz	Fx,Fy	Fz†	Tx,Ty	Tz
US-400-3000	400 lbf	1000 lbf	3000 lbf-in	3000 lbf-in	5/64 lbf	5/32 lbf	15/32 lbf-in	5/16 lbf-in
US-800-6000	800 lbf	2000 lbf	6000 lbf-in	6000 lbf-in	5/32 lbf	5/16 lbf	15/16 lbf-in	5/8 lbf-in
US-1600-12000	1600 lbf	4000 lbf	12000 lbf-in	12000 lbf-in	5/16 lbf	5/8 lbf	1 7/8 lbf-in	1 1/4 lbf-in

SI (Metric)

SI-1800-350	1800 N	4500 N	350 Nm	350 Nm	3/8 N	3/4 N	5/96 Nm	5/144 Nm
SI-3600-700	3600 N	9000 N	700 Nm	700 Nm	3/4 N	1 1/2 N	5/48 Nm	5/72 Nm
SI-7200-1400	7200 N	18000 N	1400 Nm	1400 Nm	1 1/2 N	3 N	5/24 Nm	5/36 Nm
	Sensing Ranges				Resolution*			

* *DAQ resolutions are typical for a 16-bit data acquisition system.*

These system resolutions quoted are the effective resolution after dropping four counts of noise. The effective resolution can be improved with filtering. NOTE: Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.

4.13.2 CTL Calibration Specifications

US (English)

Calibration	Fx,Fy	Fz†	Tx,Ty	Tz	Fx,Fy	Fz†	Tx,Ty	Tz
US-400-3000	400 lbf	1000 lbf	3000 lbf-in	3000 lbf-in	5/32 lbf	5/16 lbf	15/16 lbf-in	5/8 lbf-in
US-800-6000	800 lbf	2000 lbf	6000 lbf-in	6000 lbf-in	5/16 lbf	5/8 lbf	1 7/8 lbf-in	1 1/4 lbf-in
US-1600-12000	1600 lbf	4000 lbf	12000 lbf-in	12000 lbf-in	5/8 lbf	1 1/4 lbf	3 3/4 lbf-in	2 1/2 lbf-in
	SENSING RANGES				RESOLUTION			

SI (Metric)

Calibration	Fx,Fy	Fz†	Tx,Ty	Tz	Fx,Fy	Fz†	Tx,Ty	Tz
SI-1800-350	1800 N	4500 N	350 Nm	350 Nm	3/4 N	1 1/2 N	5/48 Nm	5/72 Nm
SI-3600-700	3600 N	9000 N	700 Nm	700 Nm	1 1/2 N	3 N	5/24 Nm	5/36 Nm
SI-7200-1400	7200 N	18000 N	1400 Nm	1400 Nm	3 N	6 N	5/12 Nm	5/18 Nm
	SENSING RANGES				RESOLUTION			

US (English)

Calibration	Fx,Fy	Fz†	Tx,Ty, Tz	Fx,Fy	Fz†	Tx,Ty, Tz
US-105–185	±400 lbf	±1000 lbf	±3000 lbf-in	40 lbf/V	100 lbf/V	300 lbf-in/V
US-210–370	±800 lbf	±2000 lbf	±6000 lbf-in	80 lbf/V	200 lbf/V	600 lbf-in/V
US-420–740	±1600 lbf	±4000 lbf	±12000 lbf-in	160 lbf/V	400 lbf/V	1200 lbf-in/V
	Analog Output Range			Analog ±10V Sensitivity‡		

SI (Metric)

Calibration	Fx,Fy	Fz†	Tx,Ty, Tz	Fx,Fy	Fz†	Tx,Ty, Tz
SI-475–20	±1800 N	±4500 N	±350 Nm	180 N/V	450 N/V	35 Nm/V
SI-950–40	±3600 N	±9000 N	±700 Nm	360 N/V	900 N/V	70 Nm/V
SI-1900–80	±7200 N	±18000 N	±1400 Nm	720 N/V	1800 N/V	140 Nm/V
	Analog Output Range			Analog ±10V Sensitivity‡		

Counts Value

Calibration	Fx, Fy, Fz	Tx, Ty, Tz	Fx, Fy, Fz	Tx, Ty, Tz
US-105–185 / SI-475–20	153.6 / lbf	307.2 / lbf-in	32 / N	230.4 / Nm
US-210–370 / SI-950–40	76.8 / lbf	153.6 / lbf-in	16 / N	115.2 / Nm
US-420–740 /fSI-1900–80	38.4 / lbf	76.8 / lbf-in	8 / N	57.6 / Nm
Tool Transform Factor	0.005 in/unit		1.3889 mm/unit	
	Counts Value – US (English)		Counts Value – SI (Metric)	

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. NOTE: Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.

† For IP68 version see caution on physical properties page.

‡ ±5V Sensitivity values are double the listed ±10V Sensitivity values.

4.13.3 Omega190 Physical Properties (Includes IP60/IP65/IP68 Versions)

US (English)

Single-Axis Overload	
Fxy	±8000 lbf
Fz	±25000 lbf
Txy	±60000 lbf-in
Tz	±60000 lbf-in
Stiffness (Calculated)	
X-axis & Y-axis forces (Kx, Ky)	1.4×10^{6} lb/in
Z-axis force (Kz)	2.1×10^{6} lb/in
X-axis & Y-axis torque (Ktx, Kty)	1.4×10^{7} lbf-in/rad
Z-axis torque (Ktz)	2.8×10^{7} lbf-in/rad
Resonant Frequency (Measured)	
Fx, Fy, Tz	N/A
Fz, Tx, Ty	N/A
Physical Specifications	
Weight*	14 lb
Diameter*	7.5 in
Height*	2.2 in

SI (Metric)

Single-Axis Overload	
Fxy	±36000 N
Fz	±110000 N
Txy	±6800 Nm
Tz	±6800 Nm
Stiffness (Calculated)	
X-axis & Y-axis forces (Kx, Ky)	2.4×10^{8} N/m
Z-axis force (Kz)	3.6×10^{8} N/m
X-axis & Y-axis torque (Ktx, Kty)	1.5×10^{6} Nm/rad
Z-axis torque (Ktz)	3.2×10^{6} Nm/rad
Resonant Frequency (Measured)	
Fx, Fy, Tz	N/A
Fz, Tx, Ty	N/A
Physical Specifications	
Weight*	6.35 kg
Diameter*	190 mm
Height*	56 mm

** Specifications include standard interface plates.*

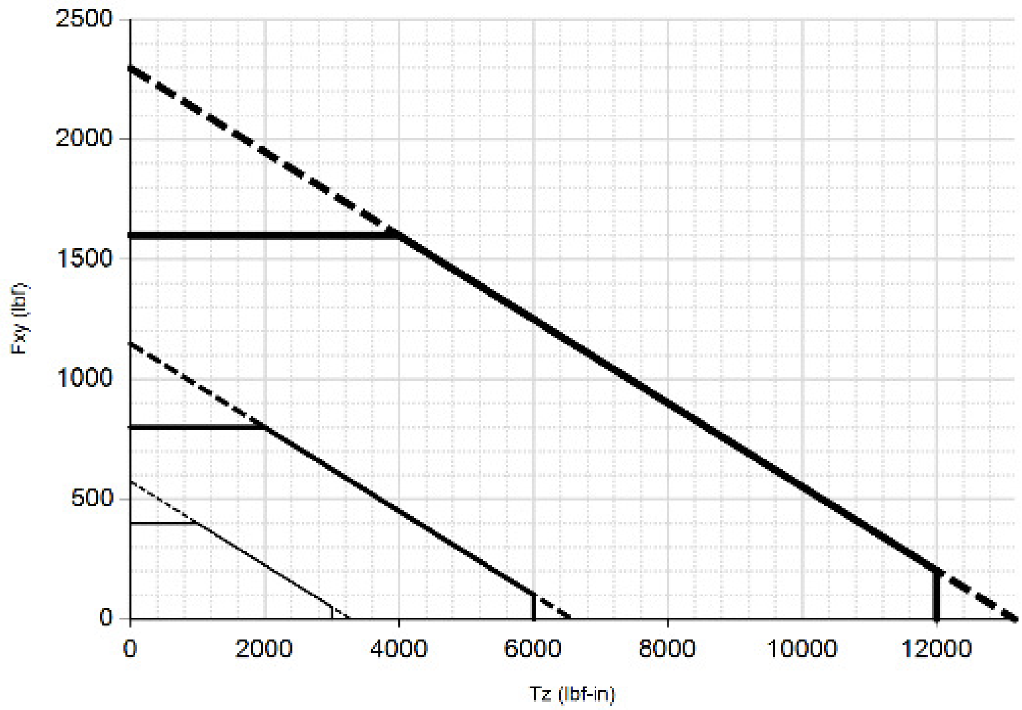
CAUTION:

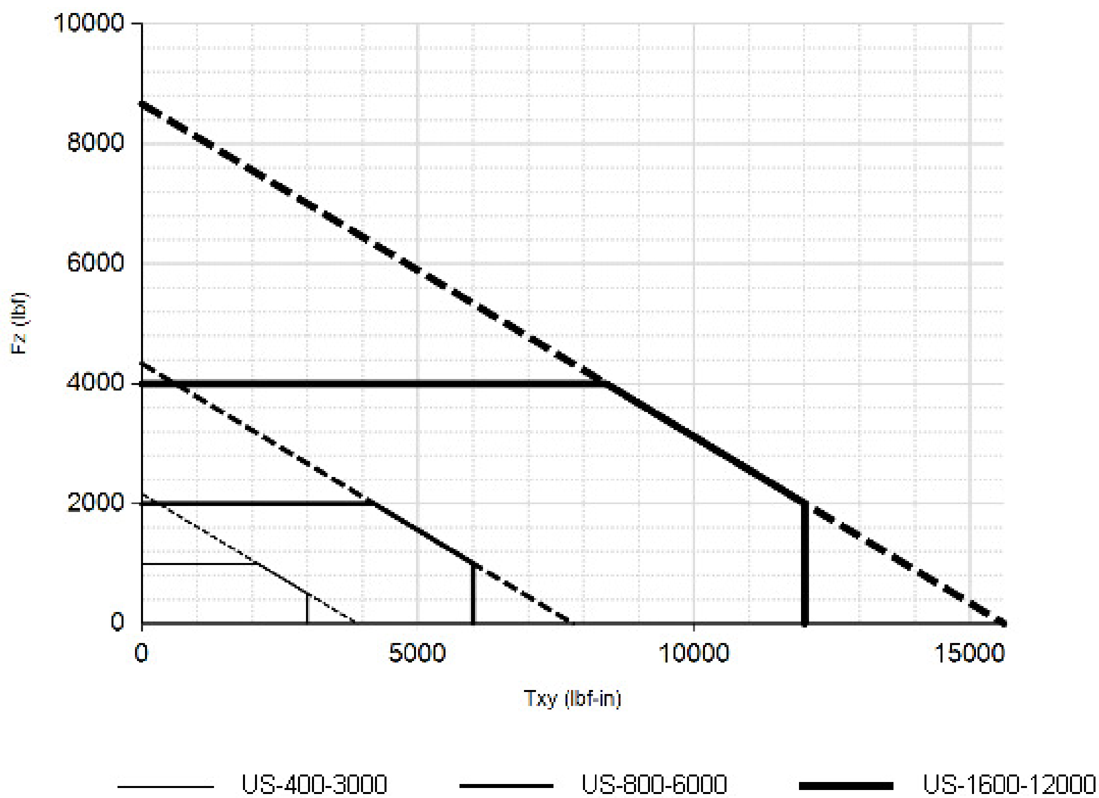
IP68 Omega190 Fz as a Function of Submersion Depth:

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 seal level.

IP68 Omega190	**US**	**Metric**
Fz preload at 10m depth	-661 lb	-2941 N
Fz preload at other depths	-20 lb/ft × depthInFeet	-294 N/m × depthInMeters

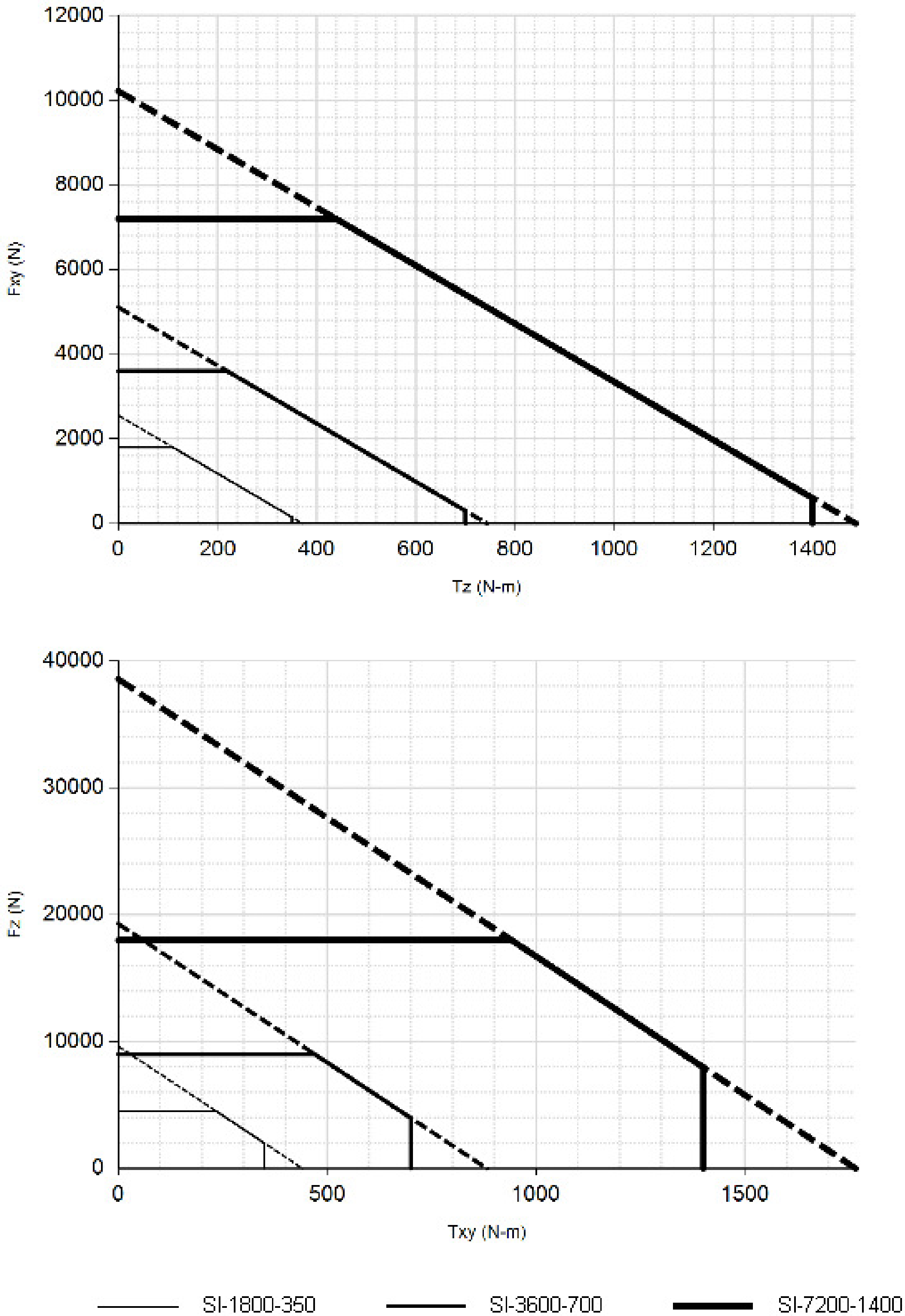
4.13.4 Omega190 (US Calibration Complex Loading) (Includes IP60/IP65/IP68 Versions)





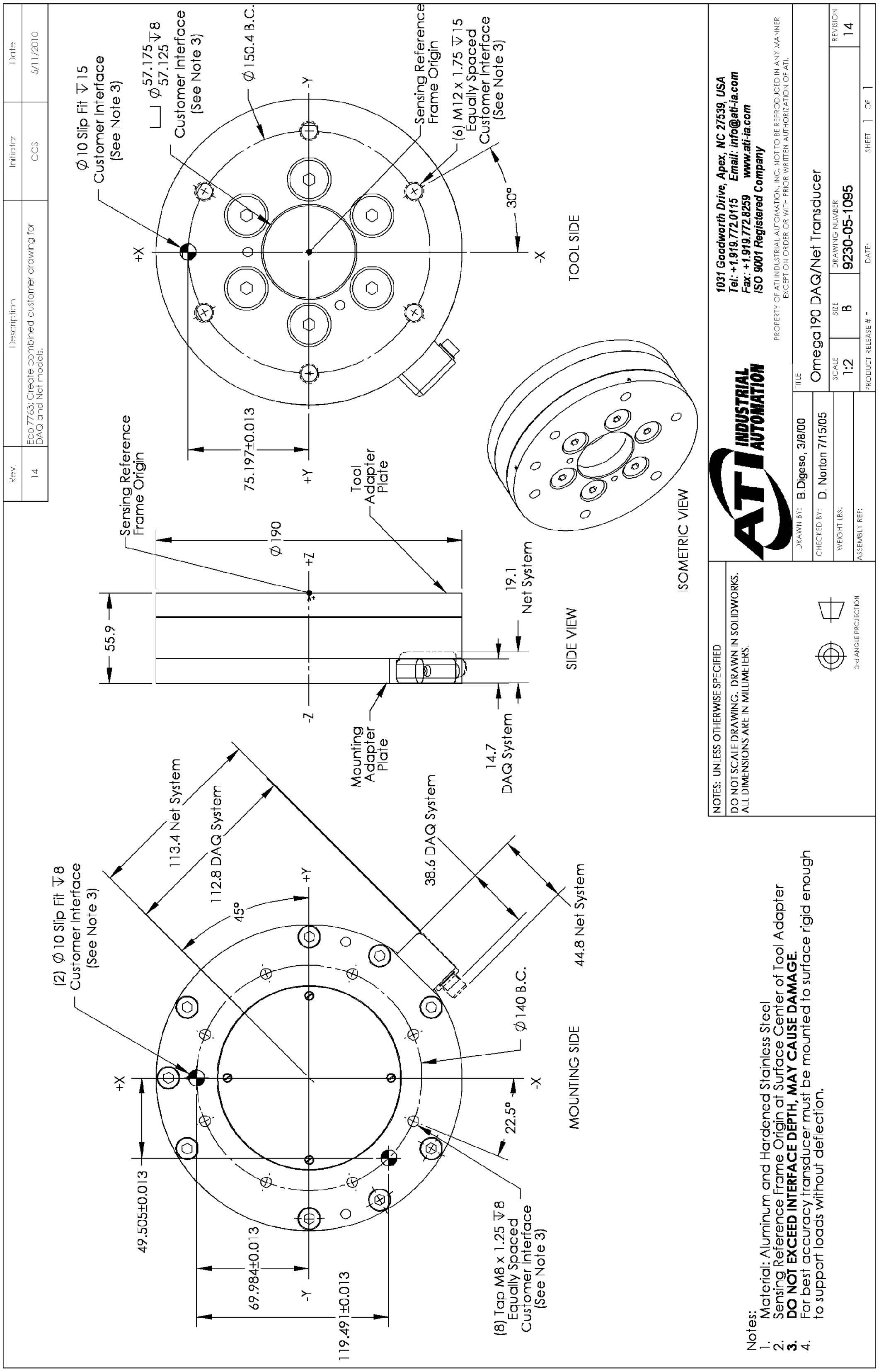
*** For IP68 version see caution on physical properties page.

4.13.5 Omega190 (SI Calibration Complex Loading) (Includes IP60/IP65/IP68 Versions)

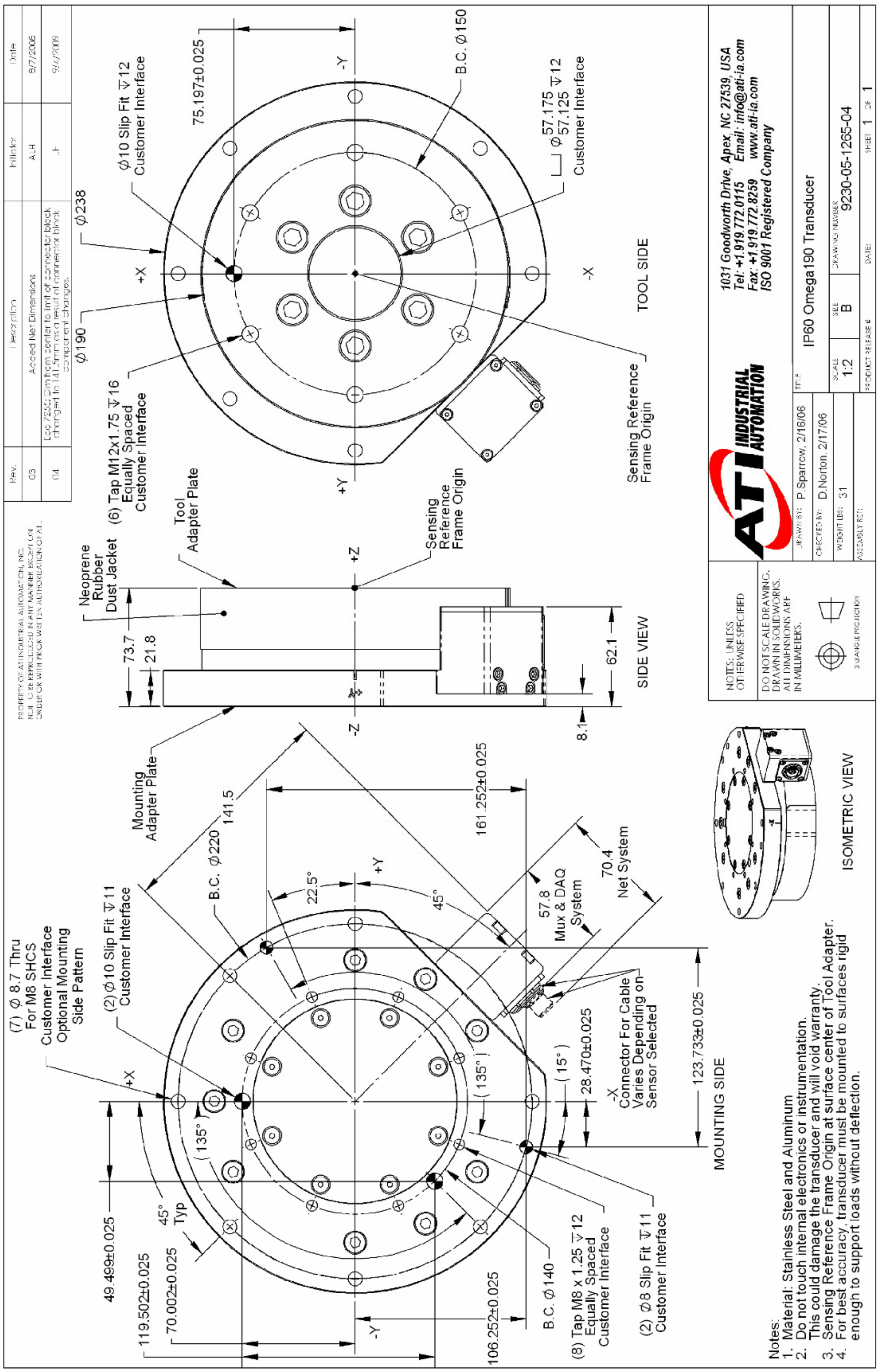


*** For IP68 version see caution on physical properties page.

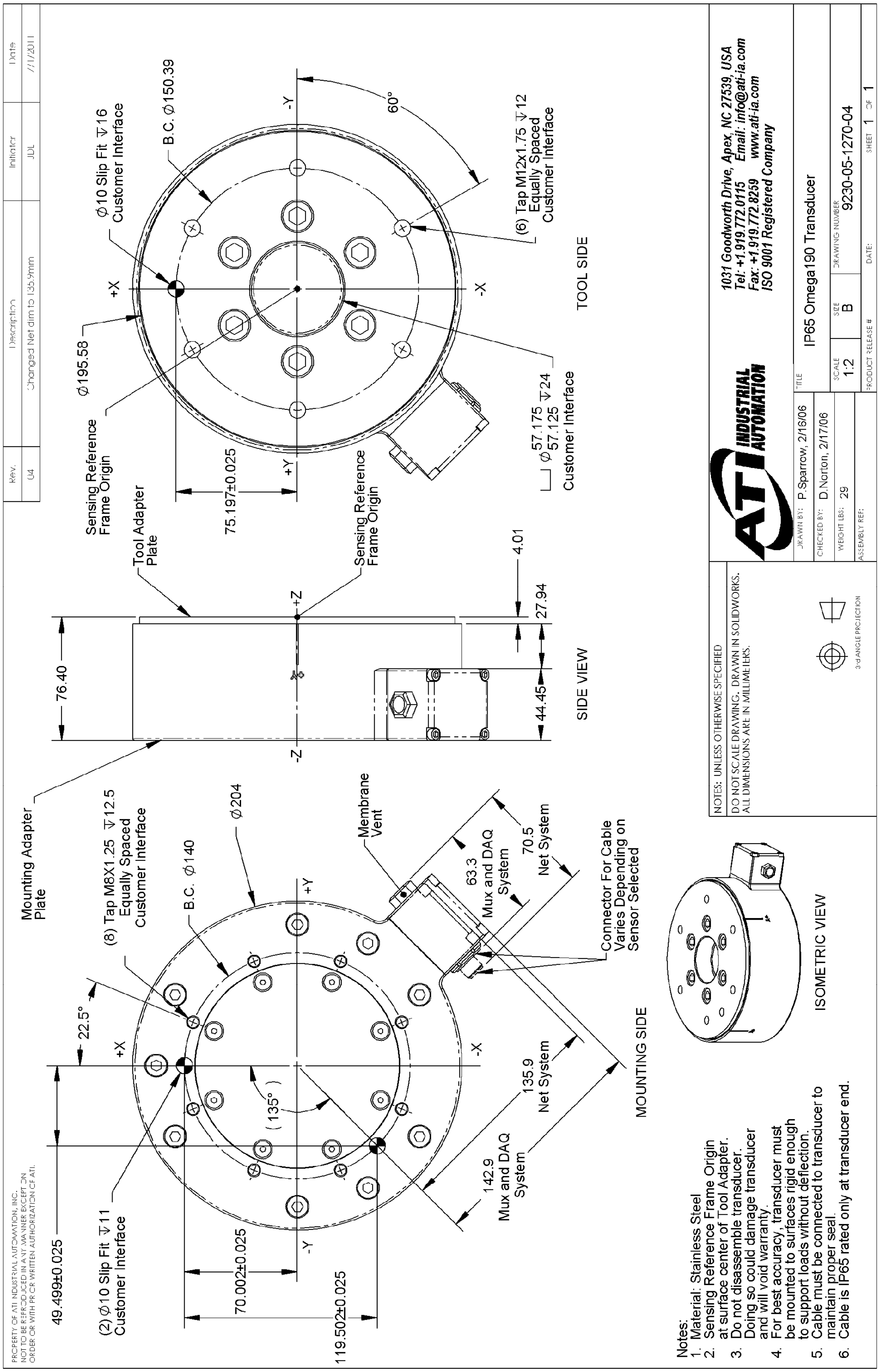
4.13.6 Omega190 Transducer



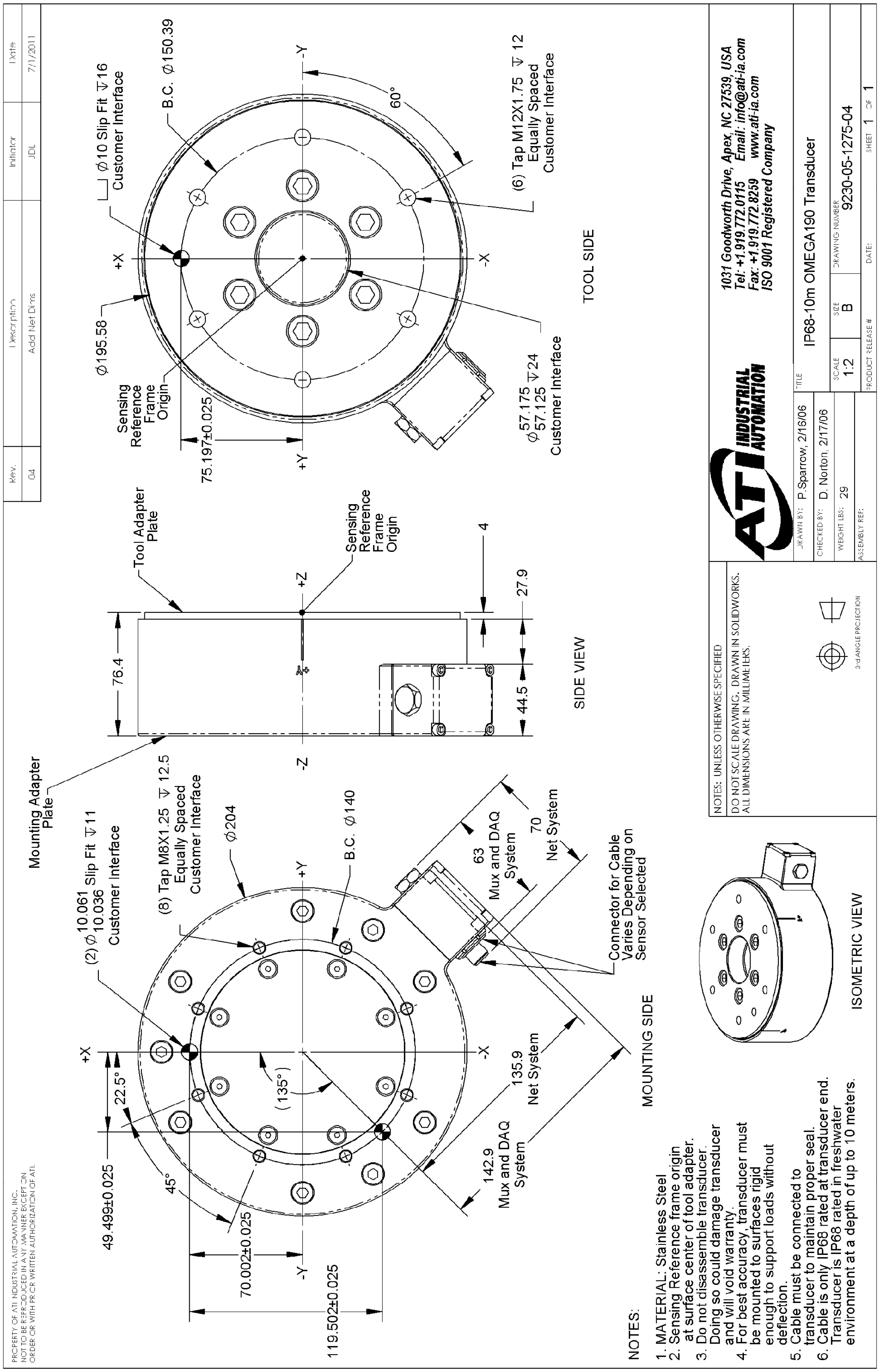
4.13.7 Omega190 IP60 Transducer



4.13.8 Omega190 IP65 Transducer



4.13.9 Omega190 IP68 Transducer



4.14 Omega250 (Includes IP60/IP65/IP68 Versions)

4.14.1 Calibration Specifications (excludes CTL calibrations)

US (English)

Calibration	Fx,Fy	Fz***	Tx,Ty	Tz	Fx,Fy	Fz***	Tx,Ty	Tz
US-900–4500	900 lbf	1800 lbf	4500 lbf-in	4500 lbf-in	1/2 lbf	1/2 lbf	1 lbf-in	1 lbf-in
US-1800–9000	1800 lbf	3600 lbf	9000 lbf-in	9000 lbf-in	1 lbf	1 lbf	2 lbf-in	2 lbf-in
US-3600–18000	3600 lbf	7200 lbf	18000 lbf-in	18000 lbf-in	2 lbf	2 lbf	5 lbf-in	5 lbf-in
	SENSING RANGES				RESOLUTION*			

SI (Metric)

Calibration	Fx,Fy	Fz***	Tx,Ty	Tz	Fx,Fy	Fz***	Tx,Ty	Tz
SI-4000–500	4000 N	8000 N	500 Nm	500 Nm	1 N	2 N	1/8 Nm	1/8 Nm
SI-8000–1000	8000 N	16000 N	1000 Nm	1000 Nm	2 N	4 N	1/4 Nm	1/4 Nm
SI-16000–2000	16000 N	32000 N	2000 Nm	2000 Nm	5 N	10 N	1/2 Nm	1/2 Nm
	SENSING RANGES				RESOLUTION*			

** DAQ resolutions are typical for a 16-bit data acquisition system.*

These system resolutions quoted are the effective resolution after dropping four counts of noise. The effective resolution can be improved with filtering. NOTE: Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.

4.14.2 CTL Calibration Specifications

US (English)

Calibration	Fx,Fy	Fz***	Tx,Ty	Tz	Fx,Fy	Fz***	Tx,Ty	Tz
US-900–4500	900 lbf	1800 lbf	4500 lbf-in	4500 lbf-in	1 lbf	1 lbf	2 lbf-in	2 lbf-in
US-1800–9000	1800 lbf	3600 lbf	9000 lbf-in	9000 lbf-in	2 lbf	2 lbf	5 lbf-in	5 lbf-in
US-3600–18000	3600 lbf	7200 lbf	18000 lbf-in	18000 lbf-in	5 lbf	5 lbf	10 lbf-in	10 lbf-in
	SENSING RANGES				RESOLUTION			

SI (Metric)

Calibration	Fx,Fy	Fz***	Tx,Ty	Tz	Fx,Fy	Fz***	Tx,Ty	Tz
SI-4000–500	4000 N	8000 N	500 Nm	500 Nm	2 N	4 N	1/4 Nm	1/4 Nm
SI-8000–1000	8000 N	16000 N	1000 Nm	1000 Nm	5 N	10 N	1/2 Nm	1/2 Nm
SI-16000–2000	16000 N	32000 N	2000 Nm	2000 Nm	10 N	20 N	1 Nm	1 Nm
	SENSING RANGES				RESOLUTION			

US (English)

Calibration	Fx,Fy	Fz†	Tx,Ty, Tz	Fx,Fy	Fz†	Tx,Ty, Tz
US-900–4500	±900 lbf	±1800 lbf	±4500 lbf-in	90 lbf/V	180 lbf/V	450 lbf-in/V
US-1800–9000	±1800 lbf	±3600 lbf	±9000 lbf-in	180 lbf/V	360 lbf/V	900 lbf-in/V
US-3600–18000	±3600 lbf	±7200 lbf	±18000 lbf-in	360 lbf/V	720 lbf/V	1800 lbf-in/V
	Analog Output Range			Analog ±10V Sensitivity‡		

SI (Metric)

Calibration	Fx,Fy	Fz†	Tx,Ty, Tz	Fx,Fy	Fz†	Tx,Ty, Tz
SI-4000–500	±4000 N	±8000 N	±500 Nm	400 N/V	900 N/V	50 Nm/V
SI-8000–1000	±8000 N	±16000 N	±1000 Nm	800 N/V	1600 N/V	100 Nm/V
SI-16000–2000	±16000 N	±32000 N	±2000 Nm	1600 N/V	3200 N/V	200 Nm/V
	Analog Output Range			Analog ±10V Sensitivity‡		

Counts Value

Calibration	Fx, Fy, Fz	Tx, Ty, Tz	Fx, Fy, Fz	Tx, Ty, Tz
US-900–4500 / SI-4000–500	8 / lbf	4 / lbf-in	4 / N	32 / Nm
US-1800–9000 / SI-8000–1000	4 / lbf	2 / lbf-in	2 / N	16 / Nm
US-3600–18000 / SI-16000-2000	2 / lbf	1 / lbf-in	1 / N	8 / Nm
Tool Transform Factor	0.02 in/unit		1.25 mm/unit	
	Counts Value – US (English)		Counts Value – SI (Metric)	

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. NOTE: Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.

† For IP68 version see caution on physical properties page.

‡ ±5V Sensitivity values are double the listed ±10V Sensitivity values.

4.14.3 Omega250 Physical Properties (Includes IP60/IP65/IP68 Versions)

US (English)

Single-Axis Overload	
Fxy	±37000 lbf
Fz	±74000 lbf
Txy	±180000 lbf-in
Tz	±220000 lbf-in
Stiffness (Calculated)	
X-axis & Y-axis forces (Kx, Ky)	2.4×10^{6} lb/in
Z-axis force (Kz)	3.2×10^{6} lb/in
X-axis & Y-axis torque (Ktx, Kty)	2.7×10^{7} lbf-in/rad
Z-axis torque (Ktz)	5.5×10^{7} lbf-in/rad
Resonant Frequency (Measured)	
Fx, Fy, Tz	N/A
Fz, Tx, Ty	N/A
Physical Specifications	
Weight*	70 lb
Diameter*	10 in
Height*	3.7 in

SI (Metric)

Single-Axis Overload	
Fxy	±160000 N
Fz	±330000 N
Txy	±21000 Nm
Tz	±25000 Nm
Stiffness (Calculated)	
X-axis & Y-axis forces (Kx, Ky)	4.2×10^{8} N/m
Z-axis force (Kz)	5.6×10^{8} N/m
X-axis & Y-axis torque (Ktx, Kty)	3.0×10^{6} Nm/rad
Z-axis torque (Ktz)	6.2×10^{6} Nm/rad
Resonant Frequency (Measured)	
Fx, Fy, Tz	N/A
Fz, Tx, Ty	N/A
Physical Specifications	
Weight*	31.8 kg
Diameter*	260 mm
Height*	95 mm

** Specifications include standard interface plates.*

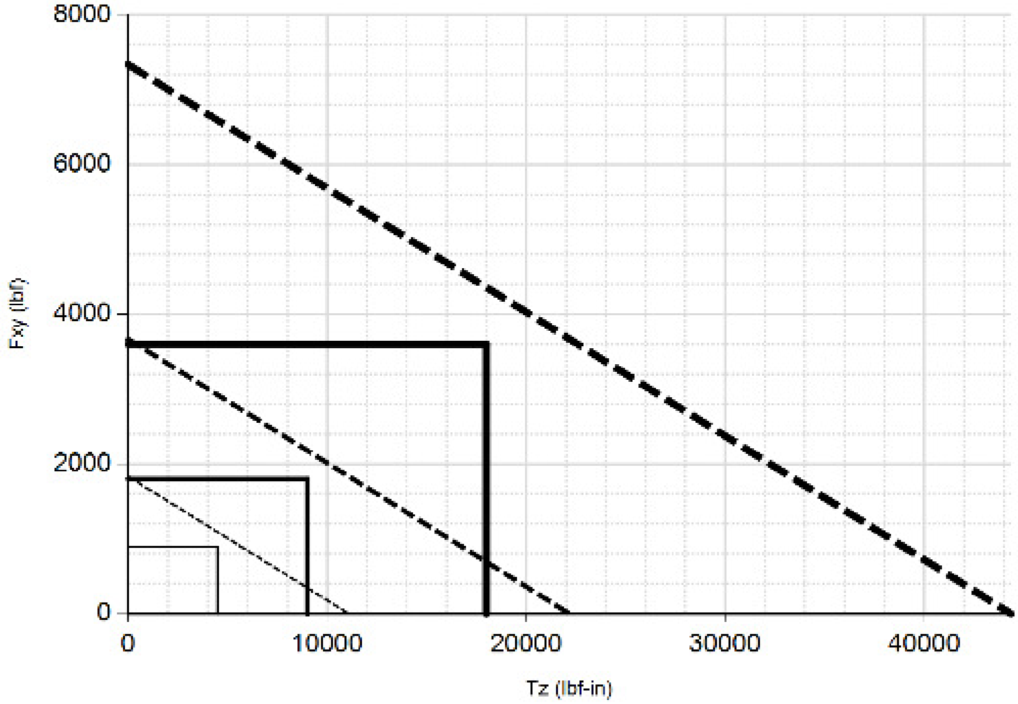
CAUTION:

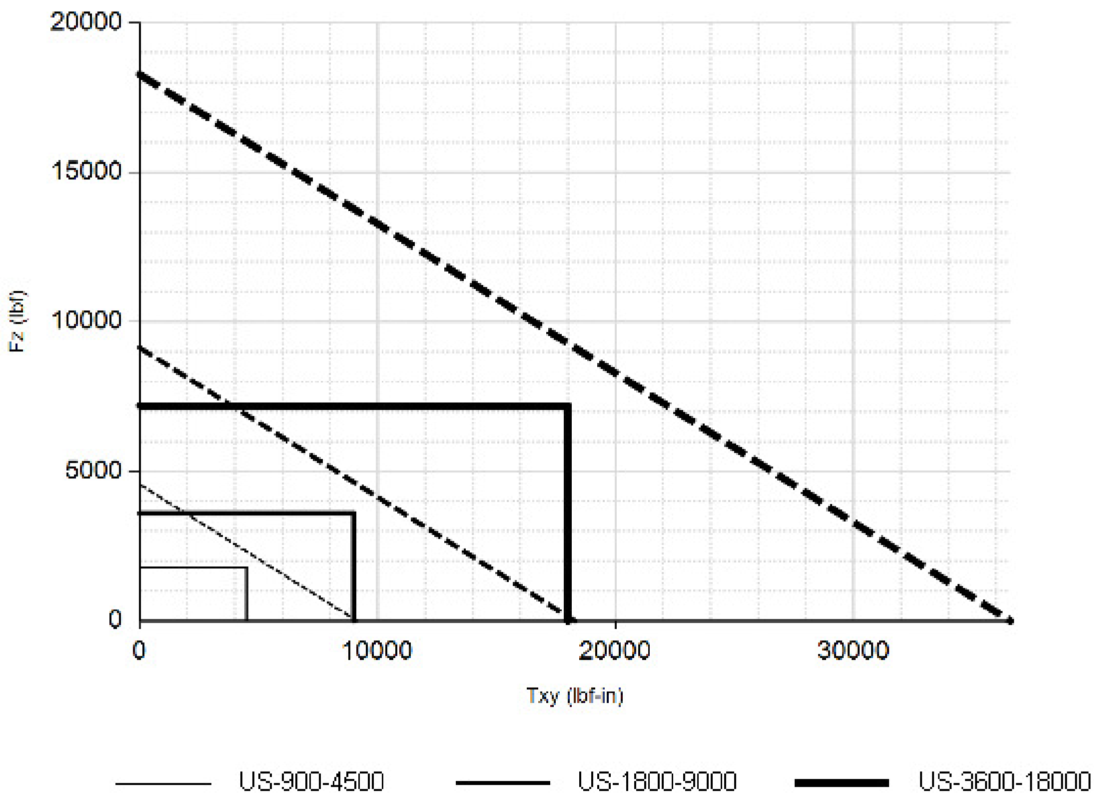
IP68 Omega250 Fz as a Function of Submersion Depth:

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 seal level.

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

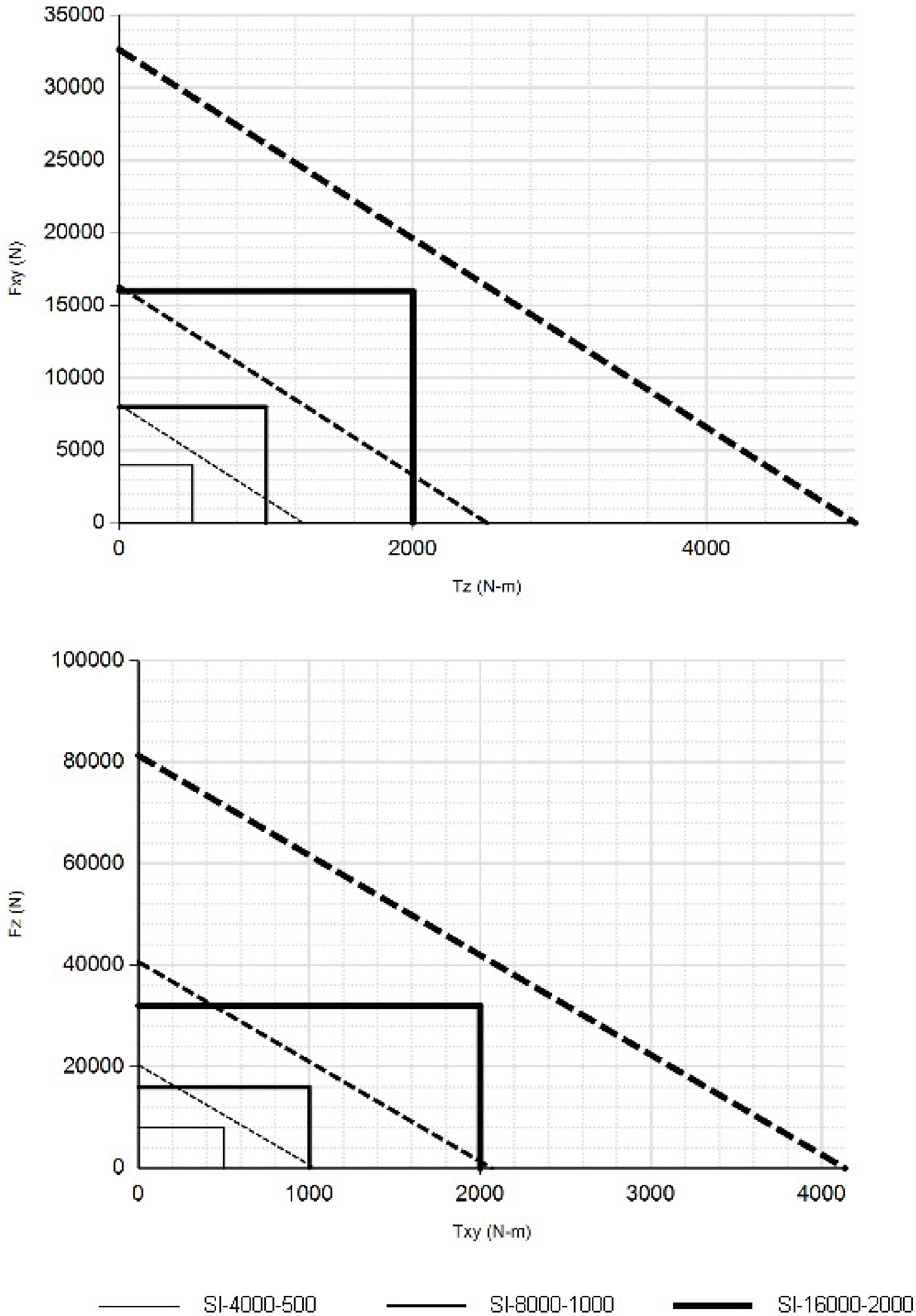
4.14.4 Omega250 (US Calibration Complex Loading) (Includes IP60/IP65/IP68 Versions)





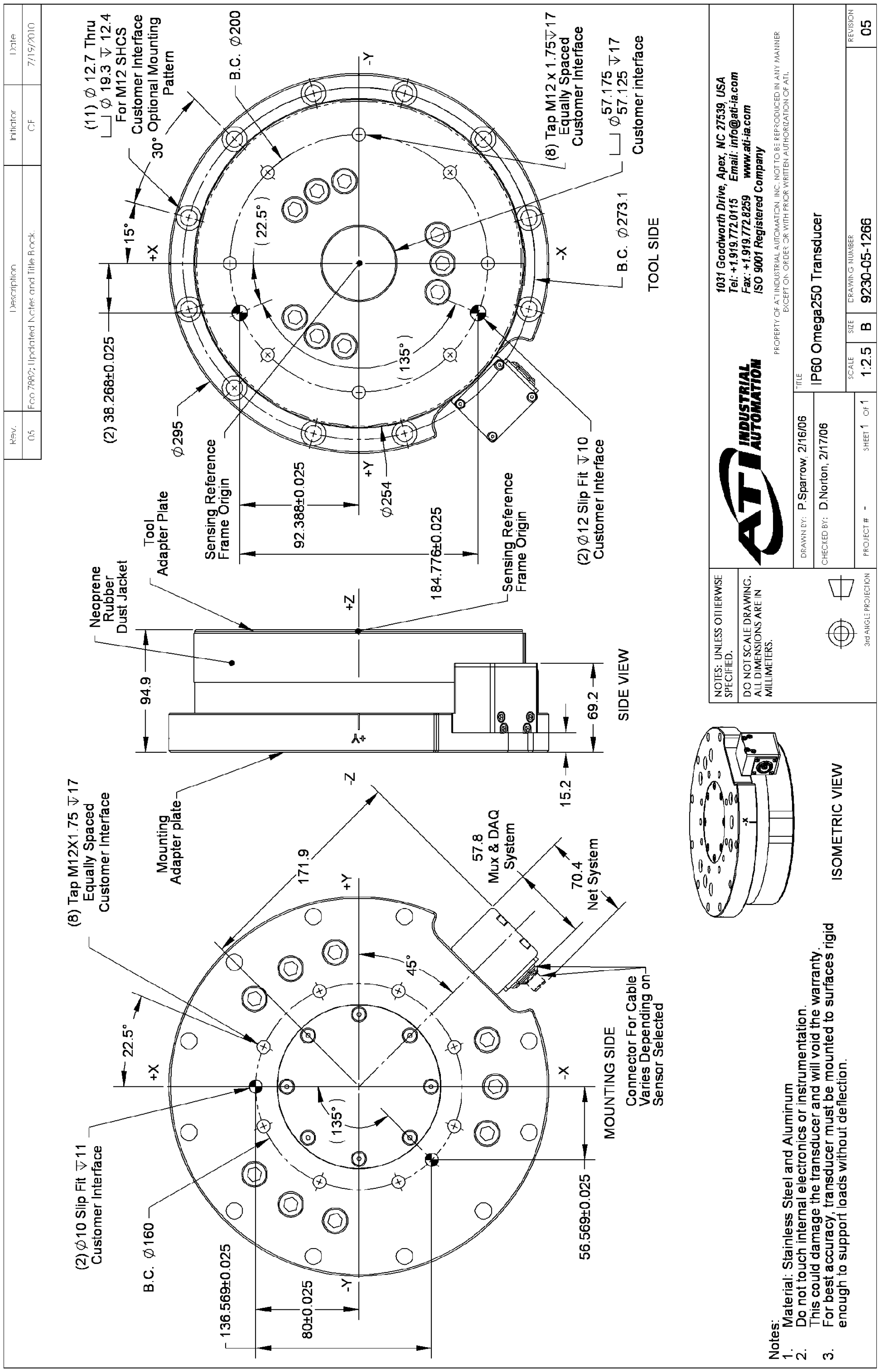
*** For IP68 version see caution on physical properties page.

4.14.5 Omega250 (SI Calibration Complex Loading) (Includes IP60/IP65/IP68 Versions)

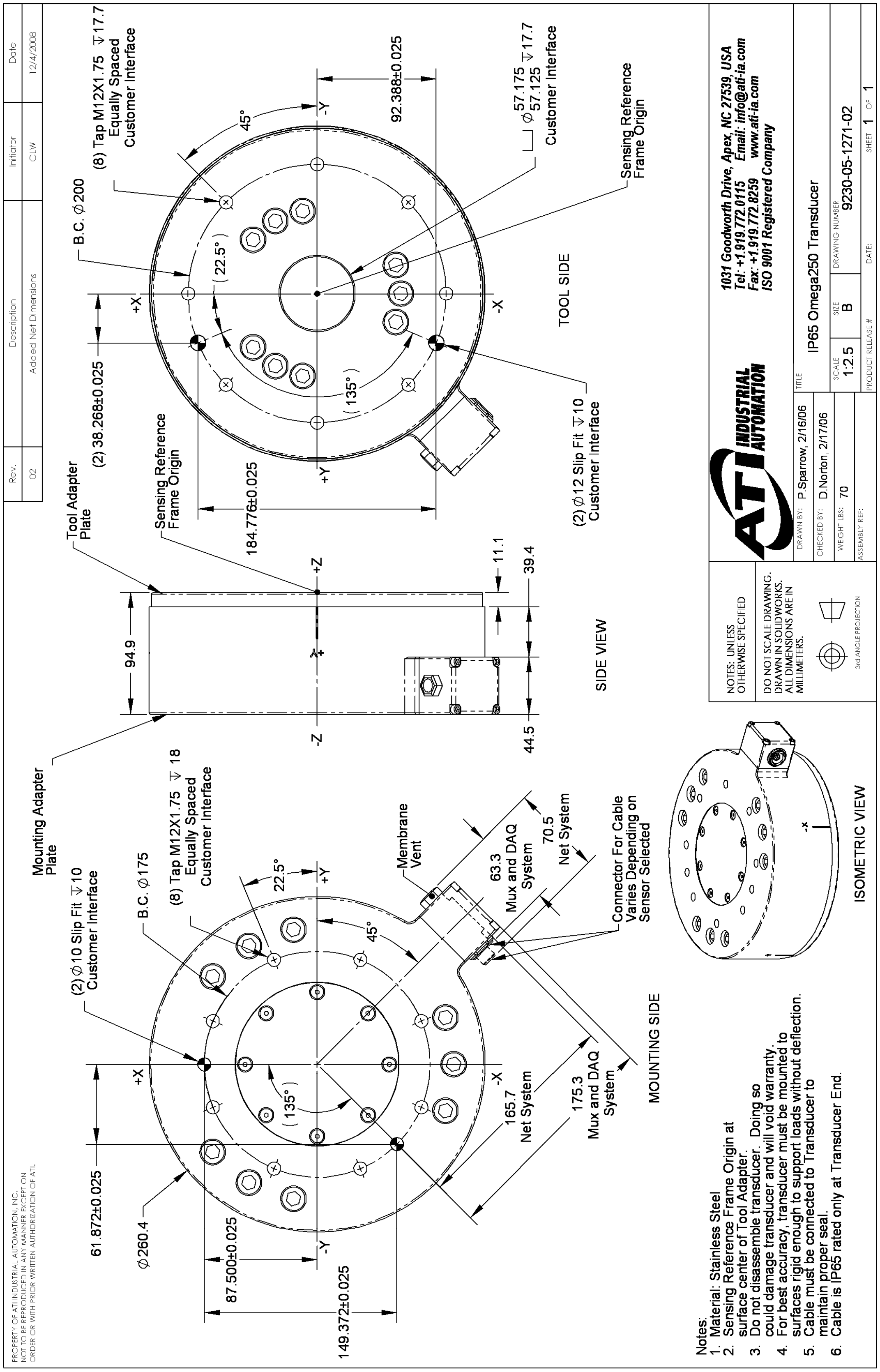


*** For IP68 version see caution on physical properties page.

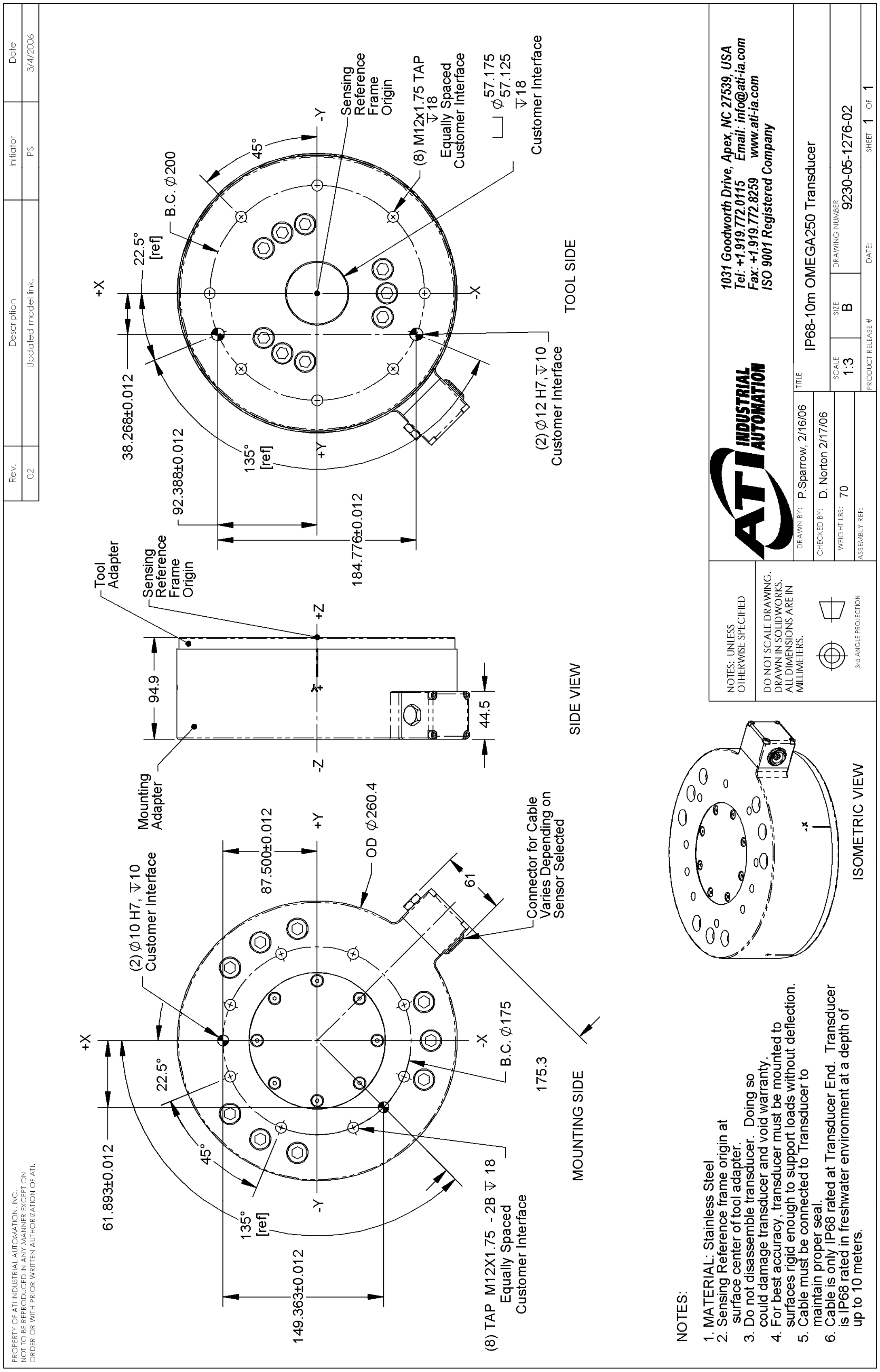
4.14.6 Omega250 IP60 Transducer



4.14.7 Omega250 IP65 Transducer



4.14.8 Omega250 IP68 Transducer



4.15 Omega331

4.15.1 Calibration Specifications (excludes CTL calibrations)

US (English)

Calibration	Fx,Fy	Fz	Tx,Ty	Tz	Fx,Fy	Fz	Tx,Ty	Tz
US-2250–13000	2250 lbf	5250 lbf	13000 lbf-in	13000 lbf-in	1/2 lbf	1 lbf	3 3/4 lbf-in	1 7/8 lbf-in
US-4500–26000	4500 lbf	10500 lbf	26000 lbf-in	26000 lbf-in	1 lbf	2 lbf	7 1/2 lbf-in	3 3/4 lbf-in
US-9000–52000	9000 lbf	21000 lbf	52000 lbf-in	52000 lbf-in	2 lbf	4 lbf	15 lbf-in	7 1/2 lbf-in
	SENSING RANGES				RESOLUTION*			

SI (Metric)

Calibration	Fx,Fy	Fz	Tx,Ty	Tz	Fx,Fy	Fz	Tx,Ty	Tz
SI-10000–1500	10 kN	22 kN	1.5 kNm	1.5 kNm	1/480 kN	1/240 kN	3/8000 kNm	3/16000 kNm
SI-20000–3000	20 kN	44 kN	3 kNm	3 kNm	1/240 kN	1/120 kN	3/4000 kNm	3/8000 kNm
SI-40000–6000	40 kN	88 kN	6 kNm	6 kNm	1/120 kN	1/60 kN	3/2000 kNm	3/4000 kNm
	SENSING RANGES				RESOLUTION*			

**   DAQ resolutions are typical for a 16-bit data acquisition system.*

These system resolutions quoted are the effective resolution after dropping four counts of noise. The effective resolution can be improved with filtering. NOTE: Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.

4.15.2 CTL Calibration Specifications

US (English)

Calibration	Fx,Fy	Fz	Tx,Ty	Tz	Fx,Fy	Fz	Tx,Ty	Tz
US-2250–13000	2250 lbf	5250 lbf	13000 lbf-in	13000 lbf-in	1 lbf	2 lbf	7 1/2 lbf-in	3 3/4 lbf-in
US-4500–26000	4500 lbf	10500 lbf	26000 lbf-in	26000 lbf-in	2 lbf	4 lbf	15 lbf-in	7 1/2 lbf-in
US-9000–52000	9000 lbf	21000 lbf	52000 lbf-in	52000 lbf-in	4 lbf	8 lbf	30 lbf-in	15 lbf-in
	SENSING RANGES				RESOLUTION			

SI (Metric)

Calibration	Fx,Fy	Fz	Tx,Ty	Tz	Fx,Fy	Fz	Tx,Ty	Tz
SI-10000–1500	10 kN	22 kN	1.5 kNm	1.5 kNm	1/240 kN	1/120 kN	3/4000 kNm	3/8000 kNm
SI-20000–3000	20 kN	44 kN	3 kNm	3 kNm	1/120 kN	1/60 kN	3/2000 kNm	3/4000 kNm
SI-40000–6000	40 kN	88 kN	6 kNm	6 kNm	1/60 kN	1/30 kN	3/1000 kNm	3/2000 kNm
	SENSING RANGES				RESOLUTION			

US (English)

Calibration	Fx,Fy	Fz	Tx,Ty, Tz	Fx,Fy	Fz	Tx,Ty, Tz
US-2250–13000	±2250 lbf	±5250 lbf	±13000 lbf-in	225 lbf/V	525 lbf/V	1300 lbf-in/V
US-4500–26000	±4500 lbf	±10500 lbf	±26000 lbf-in	450 lbf/V	1050 lbf/V	2600 lbf-in/V
US-9000–52000	±9000 lbf	±21000 lbf	±52000 lbf-in	900 lbf/V	2100 lbf/V	5200 lbf-in/V
	Analog Output Range			Analog ±10V Sensitivity‡		

SI (Metric)

Calibration	Fx,Fy	Fz	Tx,Ty, Tz	Fx,Fy	Fz	Tx,Ty, Tz
SI-10000–1500	±10 kN	±22 kN	±1.5 kNm	1 kN/V	2.2 kN/V	0.15 kNm/V
SI-20000–3000	±20 kN	±44 kN	±3 kNm	2 kN/V	4.4 kN/V	0.3 kNm/V
SI-40000–6000	±40 kN	±88 kN	±6 kNm	4 kN/V	8.8 kN/V	0.6 kNm/V
	Analog Output Range			Analog ±10V Sensitivity‡		

Counts Value

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

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. NOTE: Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.

‡ *±5V Sensitivity values are double the listed ±10V Sensitivity values.*

4.15.3 Omega331 Physical Properties (Includes IP60/IP65/IP68 Versions)

US (English)

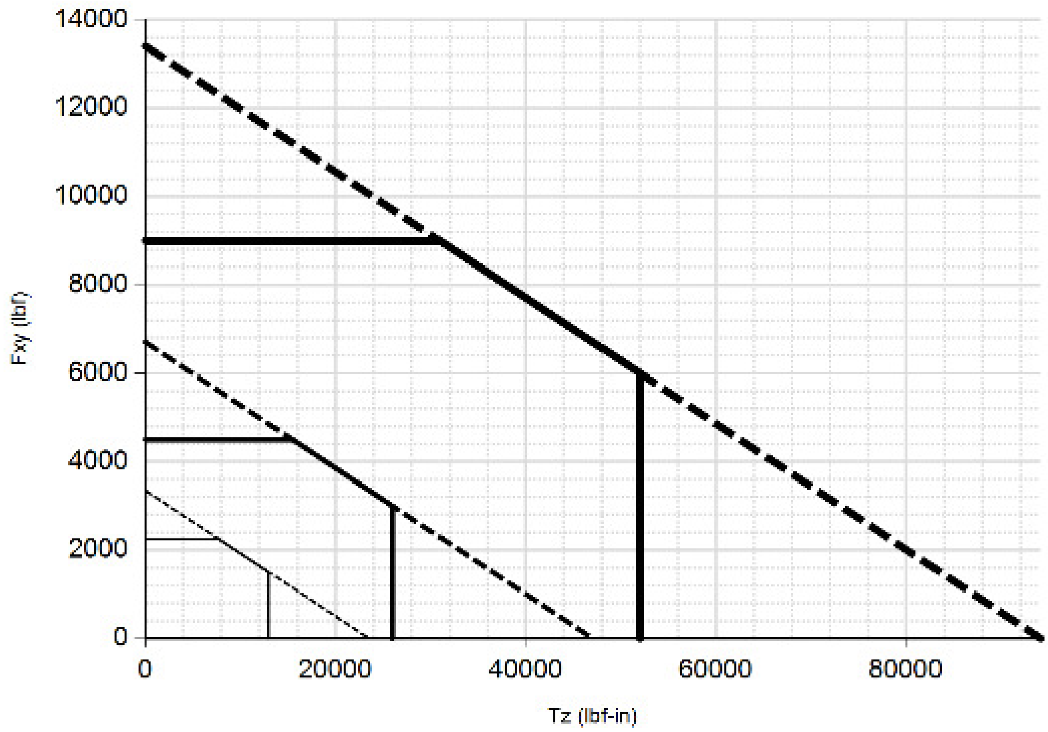
Single-Axis Overload	
Fxy	±58000 lbf
Fz	±120000 lbf
Txy	±280000 lbf-in
Tz	±410000 lbf-in
Stiffness (Calculated)	
X-axis & Y-axis forces (Kx, Ky)	$6.9x10^6$ lb/in
Z-axis force (Kz)	$7.3x10^6$ lb/in
X-axis & Y-axis torque (Ktx, Kty)	$8.1x10^7$ lbf-in/rad
Z-axis torque (Ktz)	$2.1x10^8$ lbf-in/rad
Resonant Frequency (Measured)	
Fx, Fy, Tz	N/A
Fz, Tx, Ty	N/A
Physical Specifications	
Weight*	104 lb
Diameter*	13 in
Height*	4.3 in

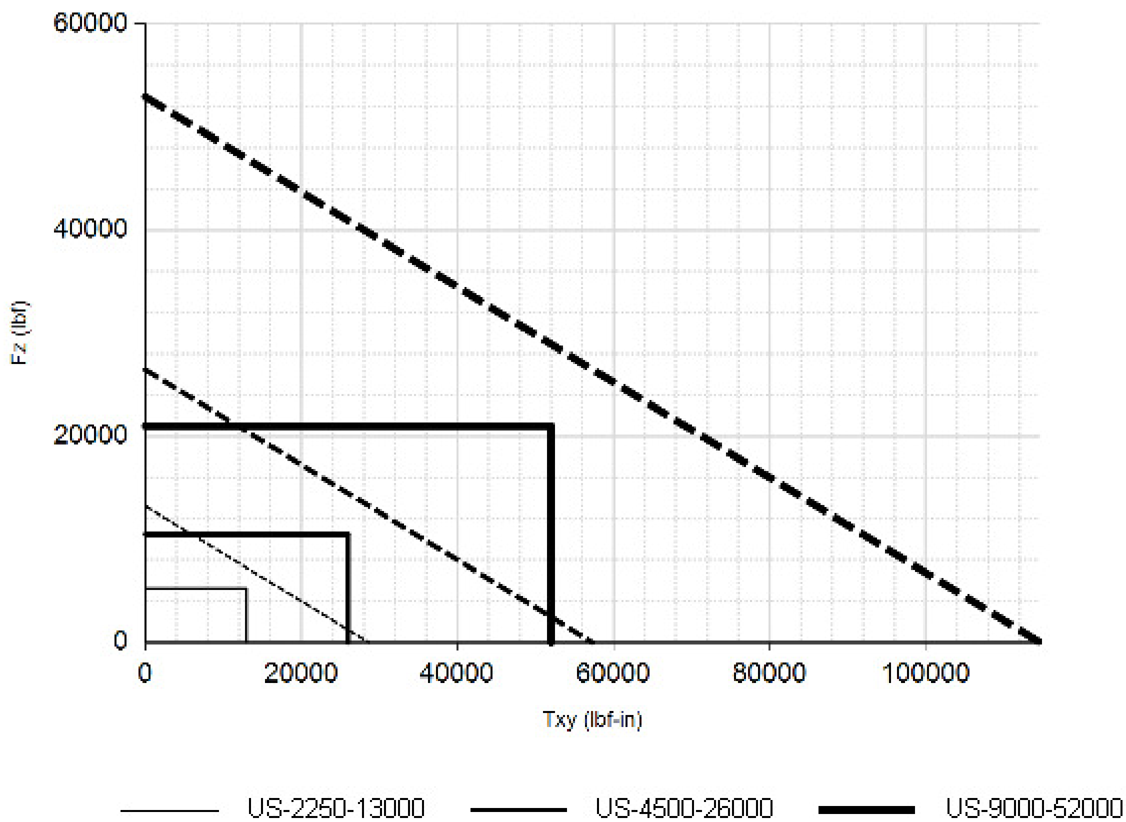
SI (Metric)

Single-Axis Overload	
Fxy	±260000 N
Fz	±520000 N
Txy	±32000 Nm
Tz	±46000 Nm
Stiffness (Calculated)	
X-axis & Y-axis forces (Kx, Ky)	$1.2x10^9$ N/m
Z-axis force (Kz)	$1.3x10^9$ N/m
X-axis & Y-axis torque (Ktx, Kty)	$9.2x10^6$ Nm/rad
Z-axis torque (Ktz)	$2.4x10^7$ Nm/rad
Resonant Frequency (Measured)	
Fx, Fy, Tz	N/A
Fz, Tx, Ty	N/A
Physical Specifications	
Weight*	47 kg
Diameter*	330 mm
Height*	110 mm

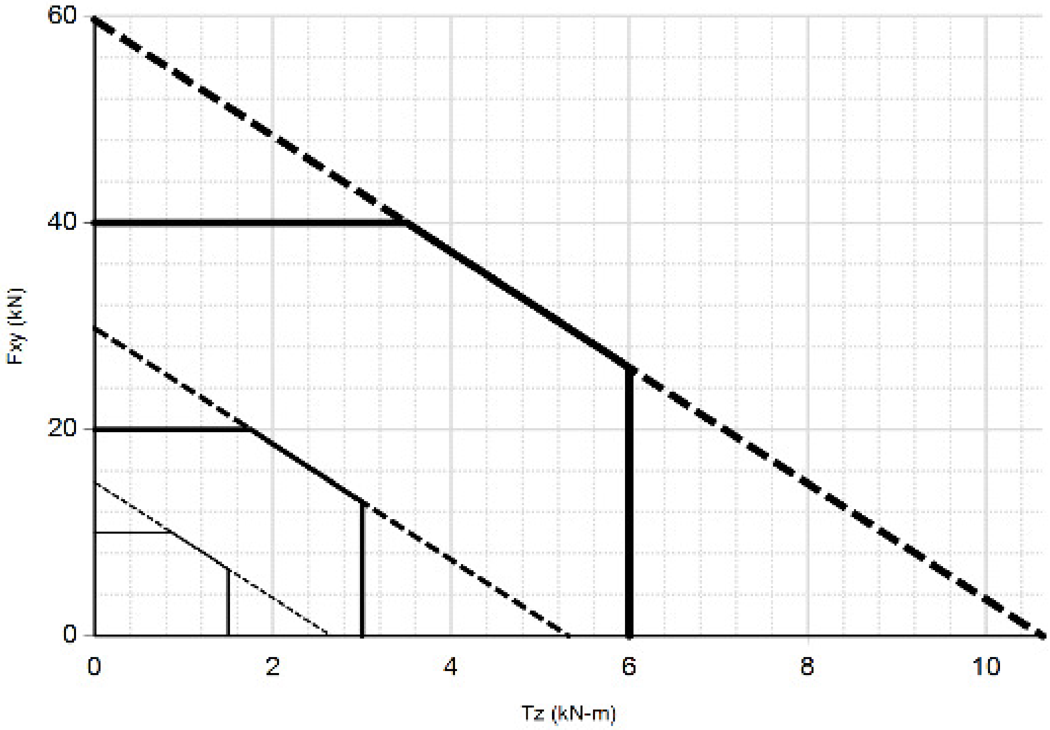
** Specifications include standard interface plates.*

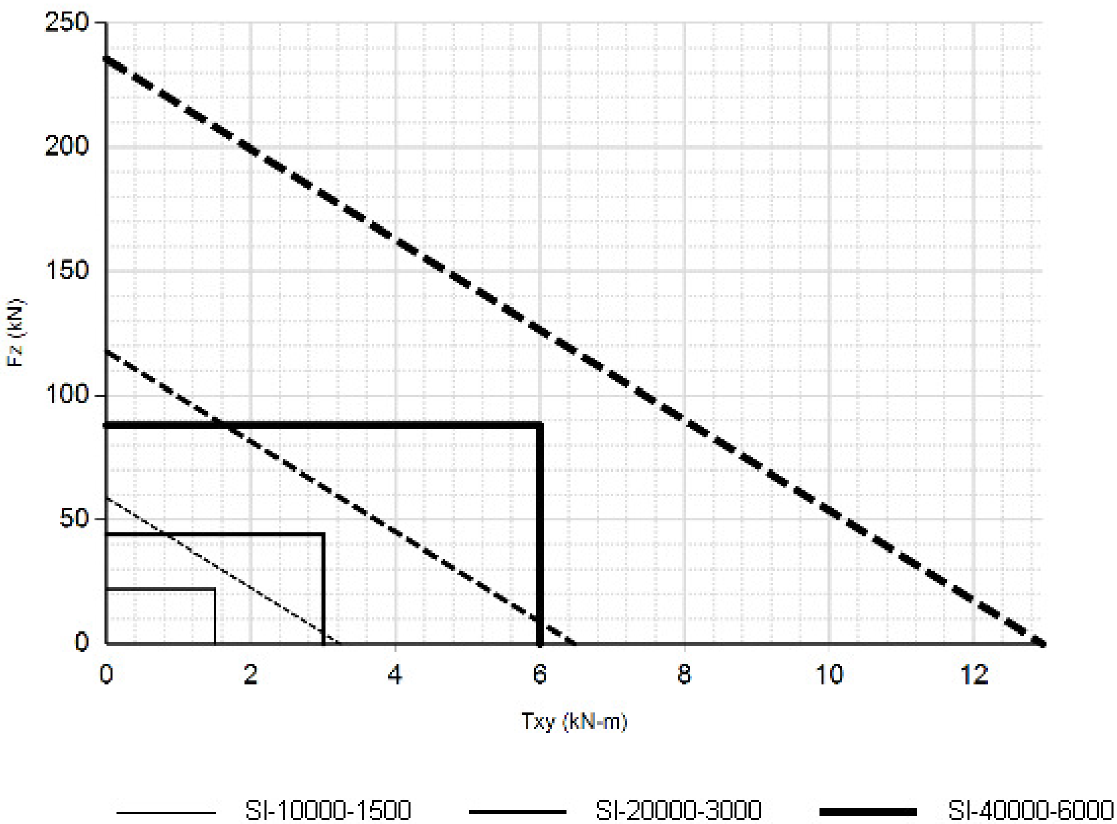
4.15.4 Omega331 (US Calibration Complex Loading)



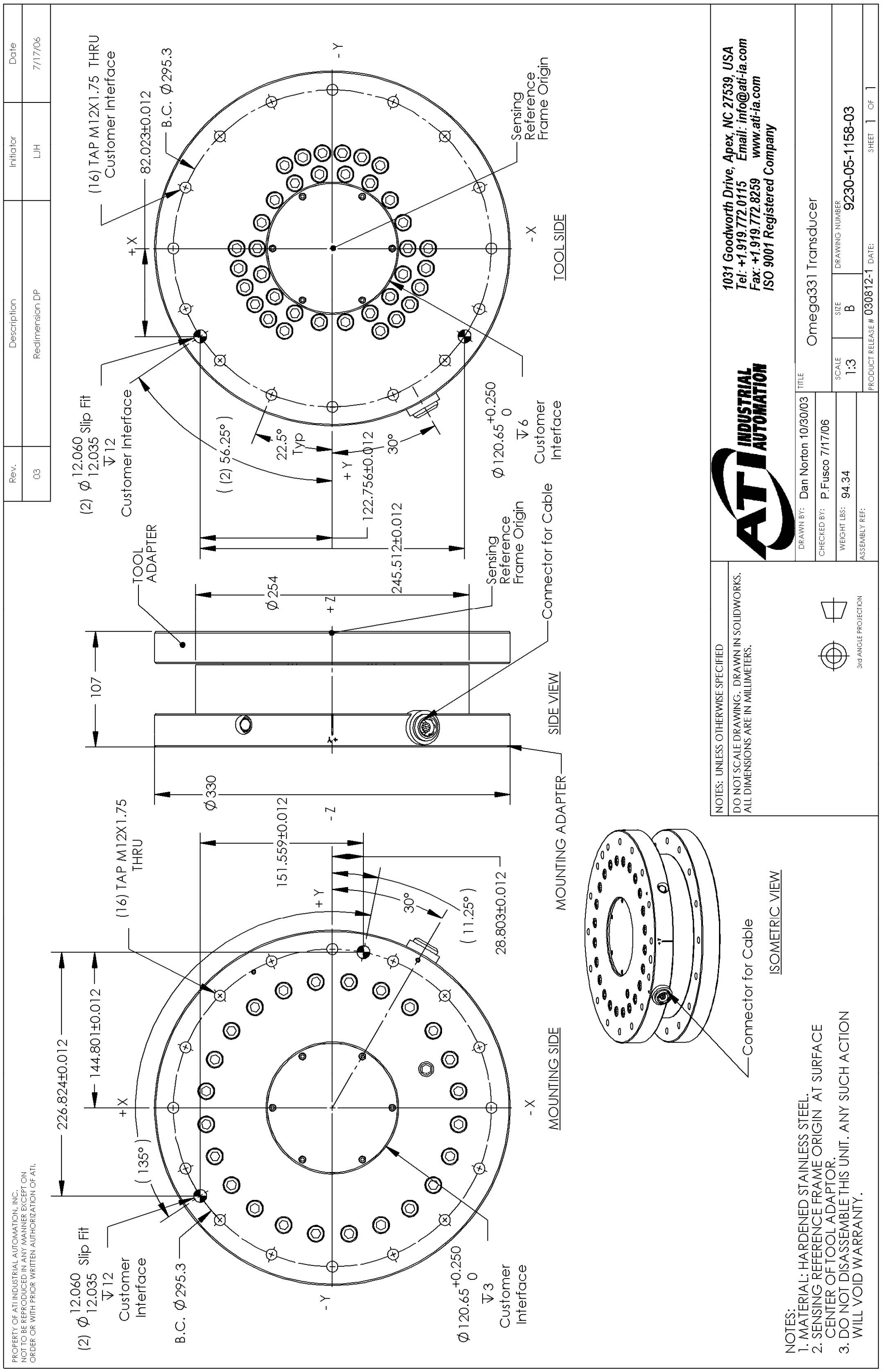


4.15.5 Omega331 (SI Calibration Complex Loading)





4.15.6 Omega331 Transducer



5. Advanced Topics

5.1 Reducing Noise

5.1.1 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.

5.1.2 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.

5.2 Detecting Failures (Diagnostics)

5.2.1 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:

1. 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.
2. Record the output readings.
3. Position the robot arm to apply another load, this time causing the outputs to move far from the earlier readings.
4. Record the second set of output readings.
5. Find the differences from the first and second set of readings and use it as 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 output is saturated or otherwise inoperable, **all transducer F/T readings are invalid**. Therefore, it is vitally important to monitor for these conditions.

5.3 Scheduled Maintenance

5.3.1 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.

5.3.2 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.

5.4 Transducer Cabling

5.4.1 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.

5.4.2 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.

5.5 A Word about Resolution

ATI's transducers have a three sensing beam configuration where the three beams are equally spaced around a central hub and attached to the outside wall of the transducer. This design transfers applied loads to multiple sensing beams and allows the transducer to increase its sensing range in a given axis if a counterpart axis has reduced.

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

F/T resolutions are specified as *typical resolution*, defined as the average of the worst and best case scenarios. Because both multi-gage effects can be modeled as a normal distribution, this value represents the most commonly perceived, average resolution. Although this misrepresents the actual performance of the transducers, it results in a close (and always conservative) estimate.

6. Terms and Conditions of Sale

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

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

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

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

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

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

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

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

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