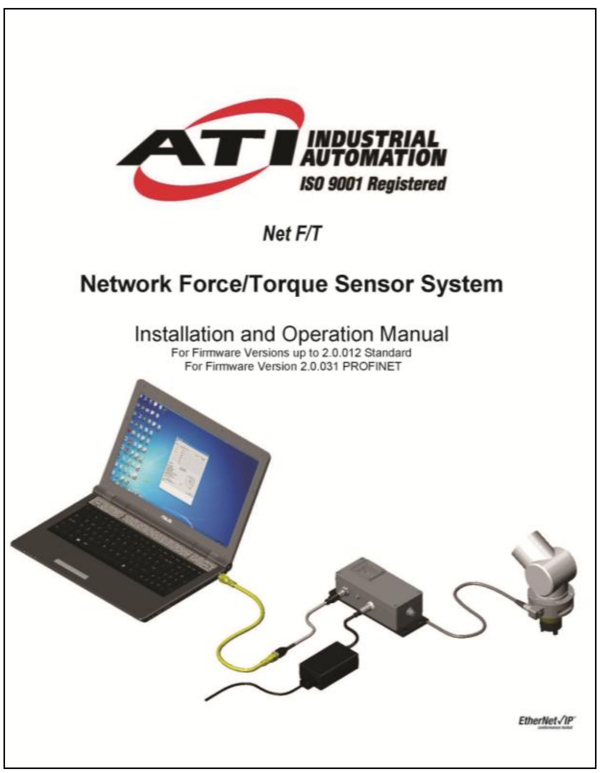
Net F/T

Network Force/Torque Sensor System

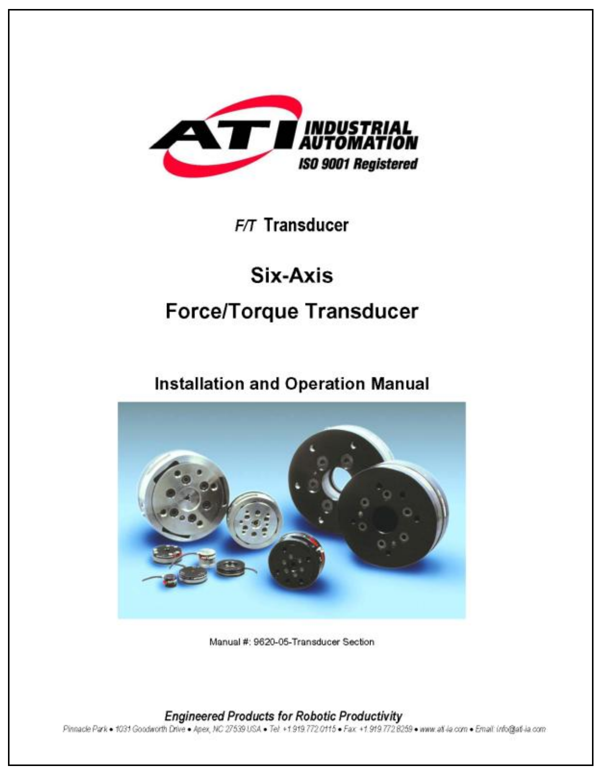
Compilation of Manuals


ATI INDUSTRIAL AUTOMATION
ISO 9001 Registered

Net F/T

Network Force/Torque Sensor System

Installation and Operation Manual
For Firmware Versions up to 2.0.012 Standard
For Firmware Version 2.0.031 PROFINET


ATI INDUSTRIAL AUTOMATION
ISO 9001 Registered

F/T **Transducer**

Six-Axis
Force/Torque Transducer

Installation and Operation Manual

Manual #: 9620-05-Transducer Section

Engineered Products for Robotic Productivity

Document #: 9610-05-1022

Engineered Products for Robotic Productivity

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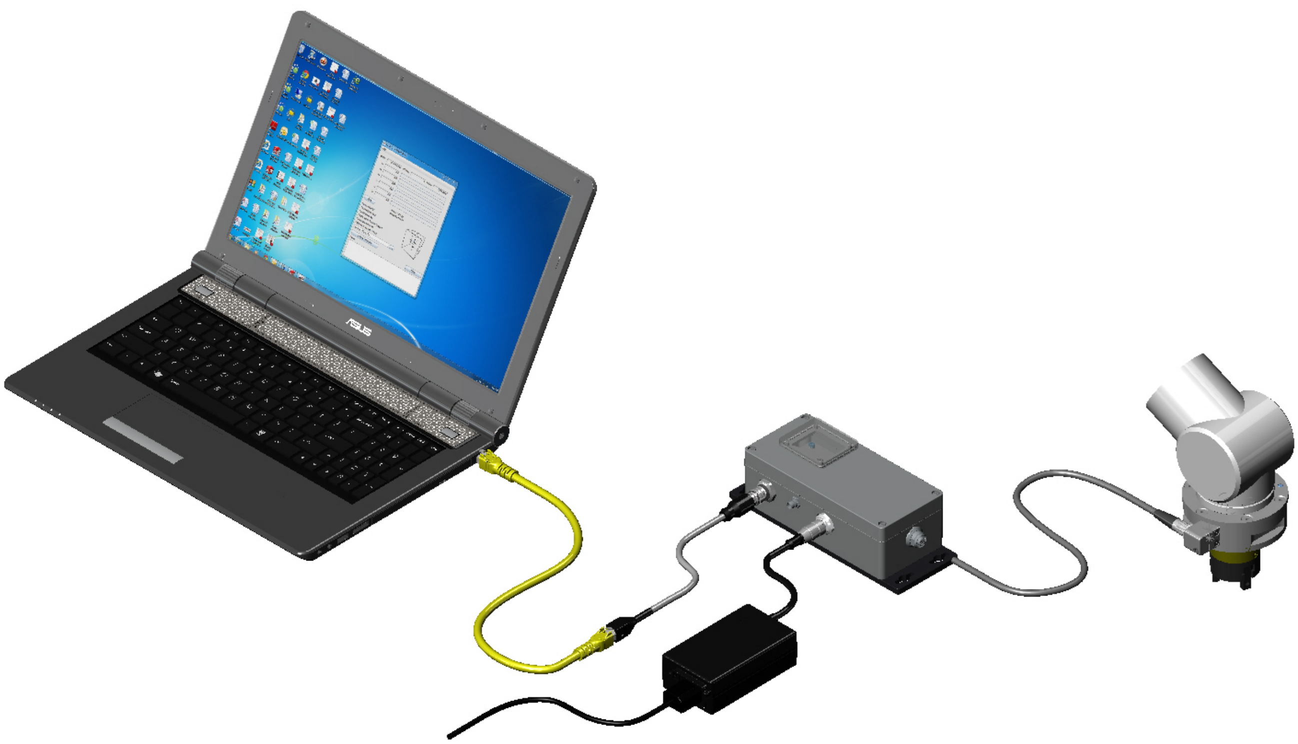

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Foreword

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

NOTICE: 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.

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.

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

200094-0	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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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.
Fieldbus	A generic term referring to any one of a number of industrial computer networking standards. Examples include: CAN, Modbus, and PROFINET.
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.

Terms	Definitions
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.
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.
PROFINET	An Ethernet-based fieldbus used in factory automation.
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 Notifications

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

or

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

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

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

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

1.3 Precautions

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

CAUTION: Do not probe any opening in the transducer. Touching internal electronics or instrumentation could damage the transducer and void the warranty.

CAUTION: Do not exceed the transducer's overload ratings. Smaller Nano and Mini transducers can easily be irreparably damaged by apply small loads using tools (moment arm increases applied loads) when mounting the transducer. Always monitor the transducer using the demo application for gage saturation errors during installation.

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. Optional fieldbus interfaces are also available. 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 18.2—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.

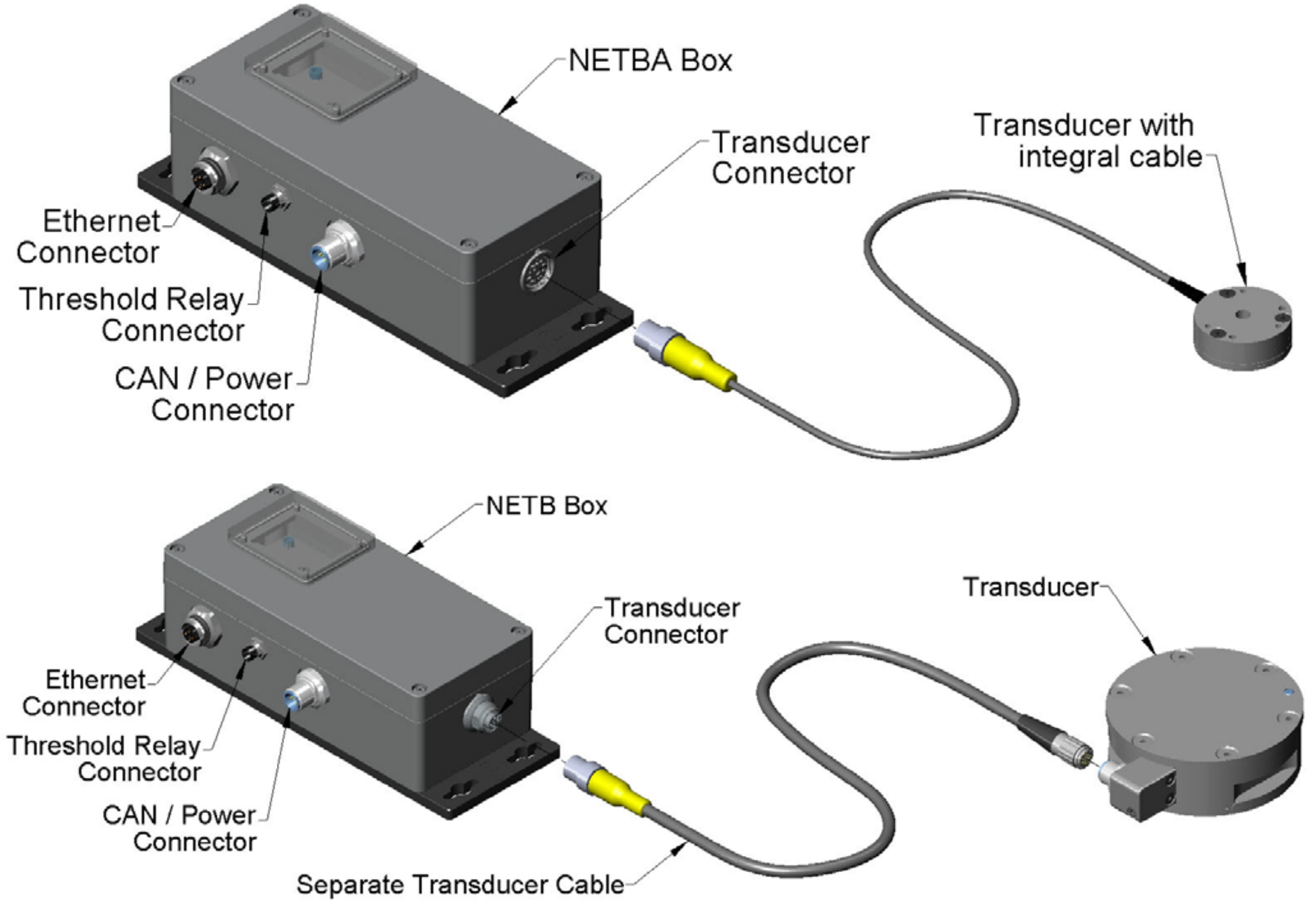
In *Figure 3.1*, the main components of the Net F/T system are displayed.

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 3.1—Net F/T System Components



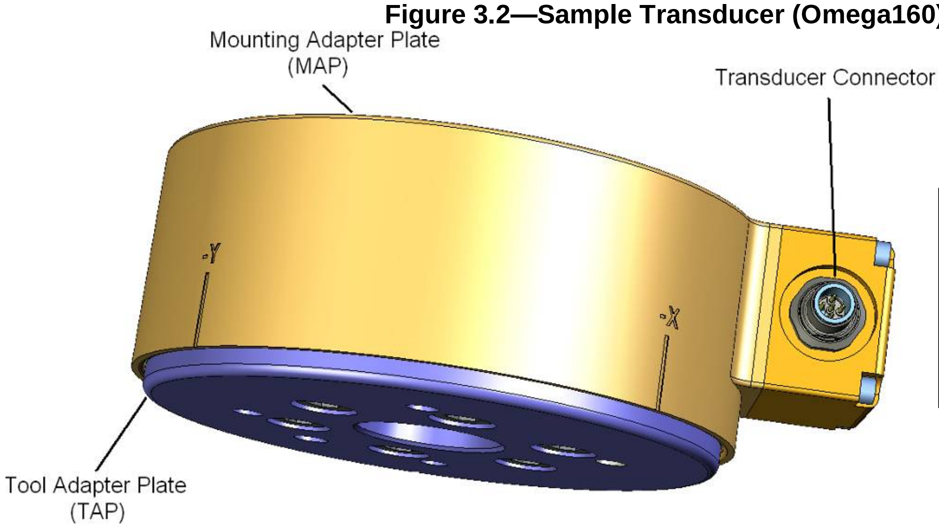
3.3.1 F/T Transducer

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 3.2* 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 3.2—Sample Transducer (Omega160)



NOTICE: The transducer is designed to withstand extremely high overloading because of its construction using strong materials and quality silicon strain gages.

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.

NOTICE: 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.

The transducer can be used in a variety of applications that will affect how best to route the cable and determine the proper bending radius to use. Some applications will allow the transducer and the cable to remain in a static condition, other applications require the transducer to be in a dynamic condition that requires the cable to be subjected to repetitive motion. It is important not to expose the transducer cable connectors to this repetitive motion, and properly restrain the cable close the transducer connection. Refer to (*9620-05 Transducer Section*) manual for proper cable routing and bending radius instructions.

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

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 19.1—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.

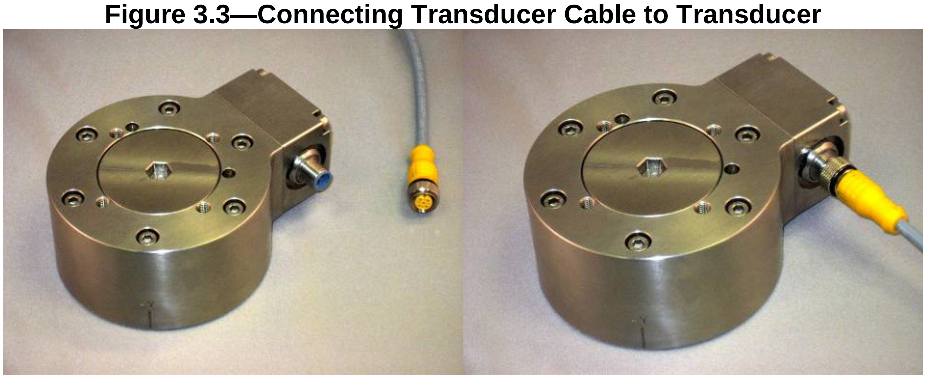
3.4 Connecting the System Components

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.

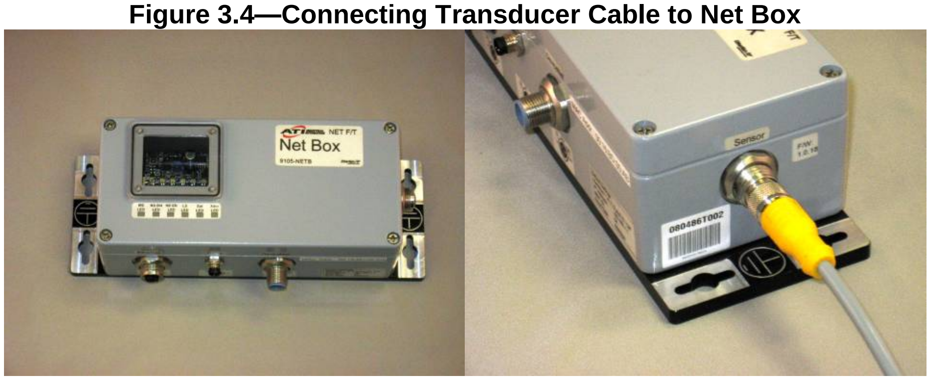
Plug the female M12 connector of this cable into the male M12 socket of the transducer. Then tighten its sleeve clockwise to lock the connector. See *Section 19.3.3–Mating Connectors* for recommended connector torque levels.

Figure 3.3—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 19.3.3—Mating Connectors* for recommended connector torque levels.

Figure 3.4—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 a standard Net F/T. Net F/Ts with an optional fieldbus interface do not support PoE and must use an external power source (Method 2).

3.4.2.1 Method 1: Providing Power with PoE

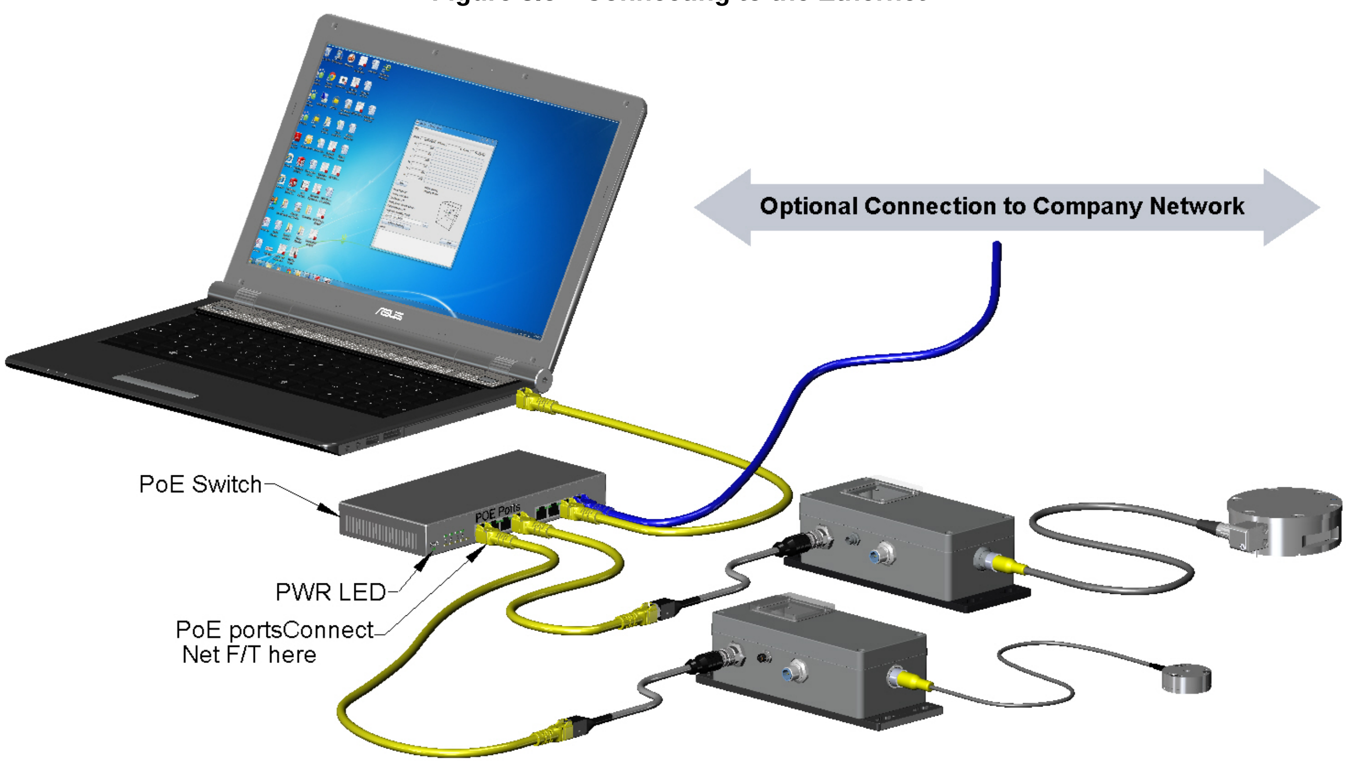
> **NOTICE:** Power-over-Ethernet is not supported by Net F/Ts that have an optional fieldbus.

The Net F/T's Power over Ethernet input is compatible with IEEE 802.3af (Power over Ethernet) specification and uses Mode A to receive power. Mode B requires eight Ethernet conductors and is not supported.

The Net F/T system optionally ships with a PoE Ethernet switch. ATI Industrial Automation part number 9105-POESWITCH-1 (see Figure 3.5—*Connecting to the Ethernet*), 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.

- 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 3.5—Connecting to the Ethernet



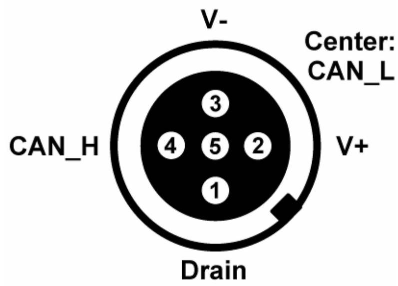
Once the Net Box is connected to the PoE switch, it should start up, first with red and green blinking LEDs. After approximately 20 seconds all LEDs should be green.

> **NOTICE:** 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 Method 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 19.3.3—Mating Connectors* for recommended connector torque levels.

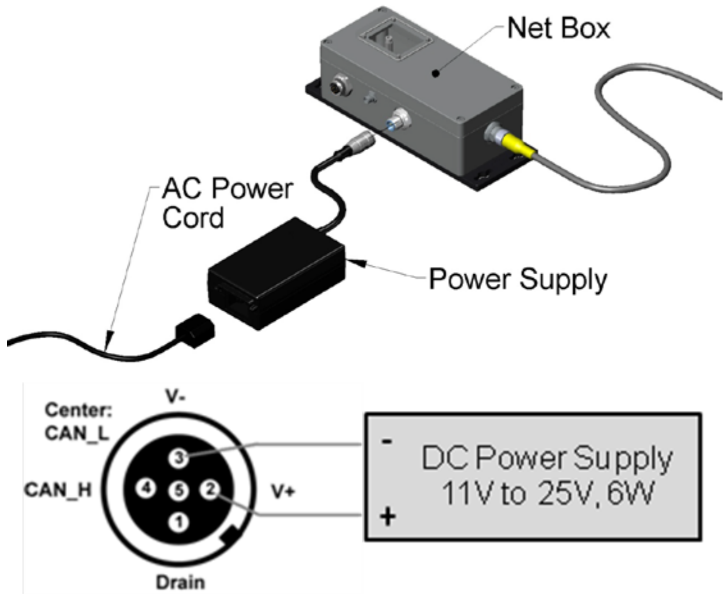
Figure 3.6—*Pwr/CAN* Micro Connector (view from male pin side)



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 19.3.3—Mating 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 3.7—DC Power Source Connection (Using *Pwr/CAN* Connector)

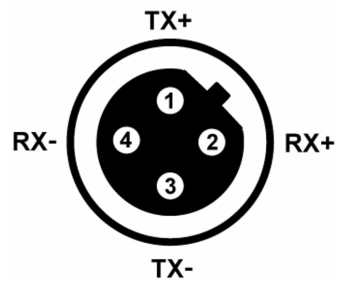


3.4.3 Connecting to Ethernet

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 19.3.3—Mating 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 3.8—Ethernet M12-4, Type-D Connector (view from female pin side)



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

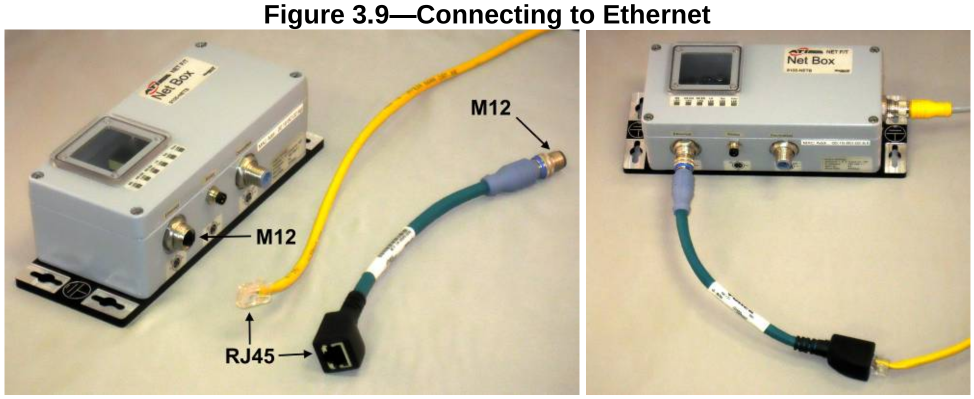
> **NOTICE:** To achieve the best Ethernet performance (and to reduce the likelihood of loosing data), we recommend connecting the Net Box directly to the host computer, as described in Option 2.

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 3.8—Connecting to Ethernet* for a proposed setup.

Figure 3.9—Connecting to Ethernet

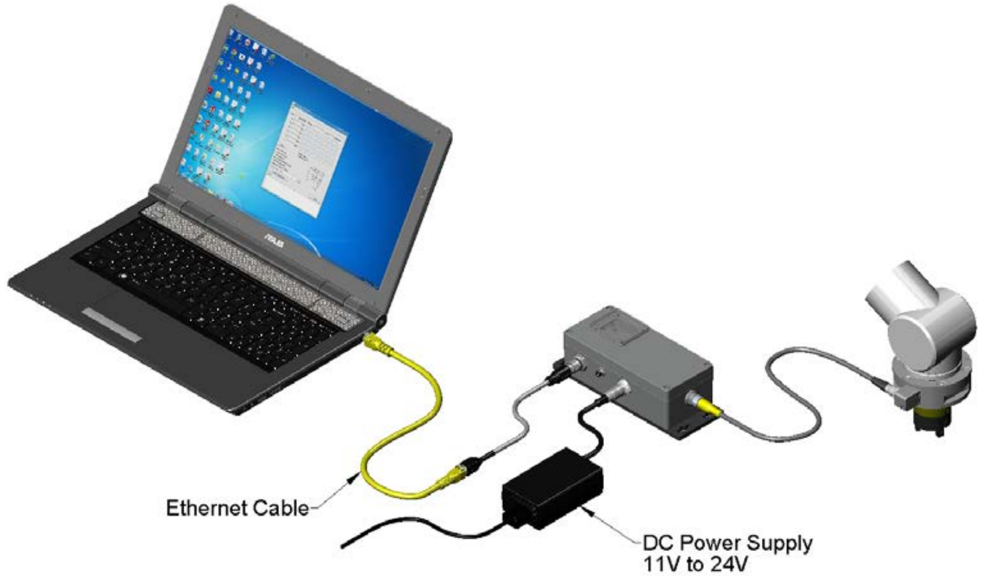


3.4.3.2 Option 2: Connect directly to a Computer's Ethernet Interface

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 3.9—Point-to-Point Ethernet Connection*). In this case, power has to be provided via the *Pwr/CAN* connector (see *Section 3.4.2.2—Method 2: Providing Power to 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 3.10—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.

> **NOTICE** 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.

3.6.1 Windows Vista and Windows 7

a. From the Start menu, select *Control Panel*.

b. For Vista, click on *Control Panel Home*.

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

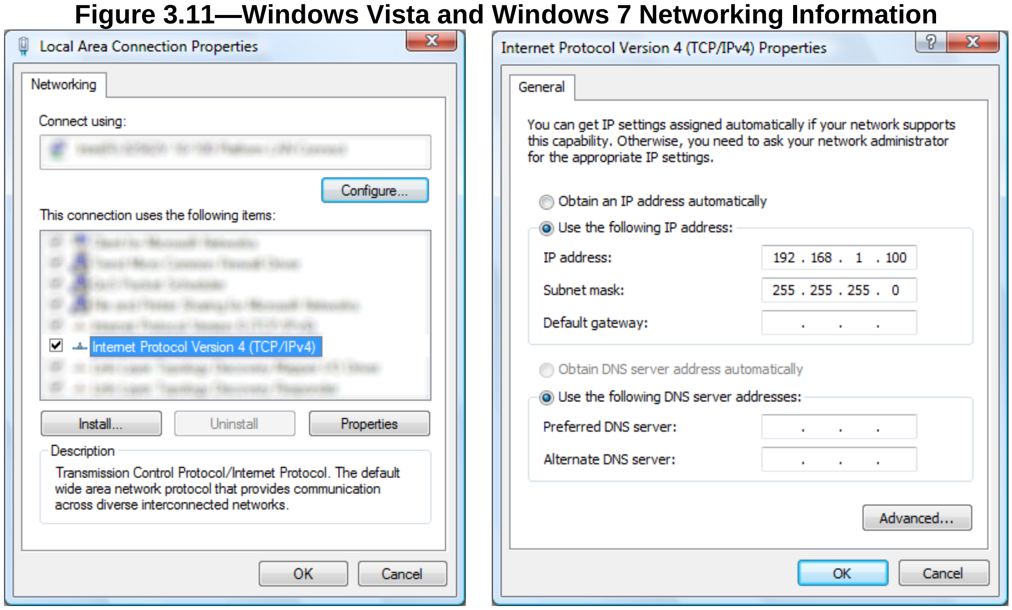
d. Click on the *Network and Sharing Center* icon.

e. For Vista, click on the *Manage Network Connections* task link. For Windows 7, click on the *Local Area Connection* link.

f. For Vista, right-click on *Local Area Connection* and select the *Properties* button. For Windows 7, click on the *Properties* button.

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

Figure 3.11—Windows Vista and Windows 7 Networking Information



3.6.2 Windows XP

a. From the Start menu, select Control Panel.

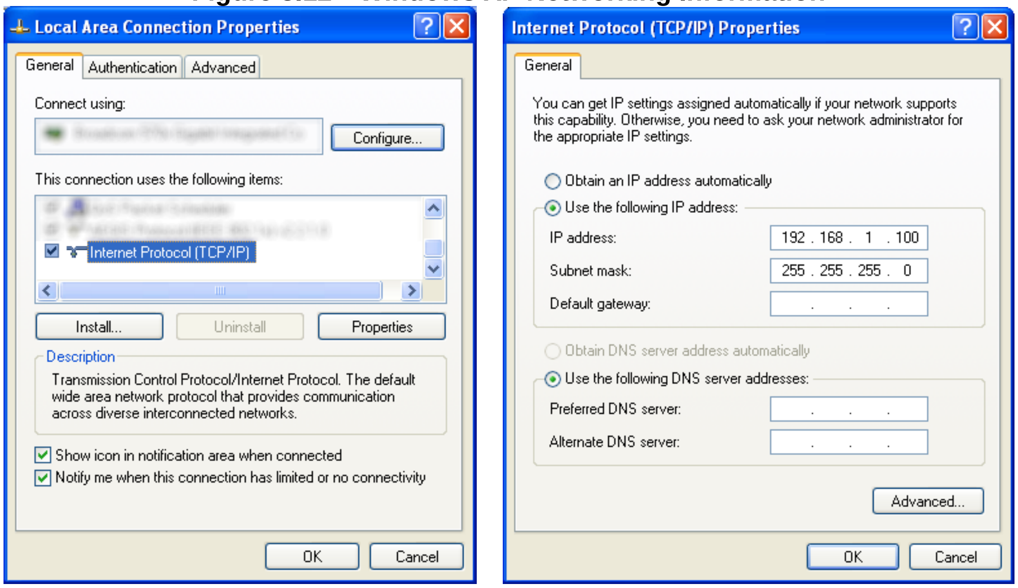
b. Open the *Network Connections* icon from within the Control Panel. If your Control Panel says *Pick a category* at the top, you will need to first click on the *Network and Internet Connections* icon.

c. Click on the *Network Connections* icon.

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

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

Figure 3.12—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*.

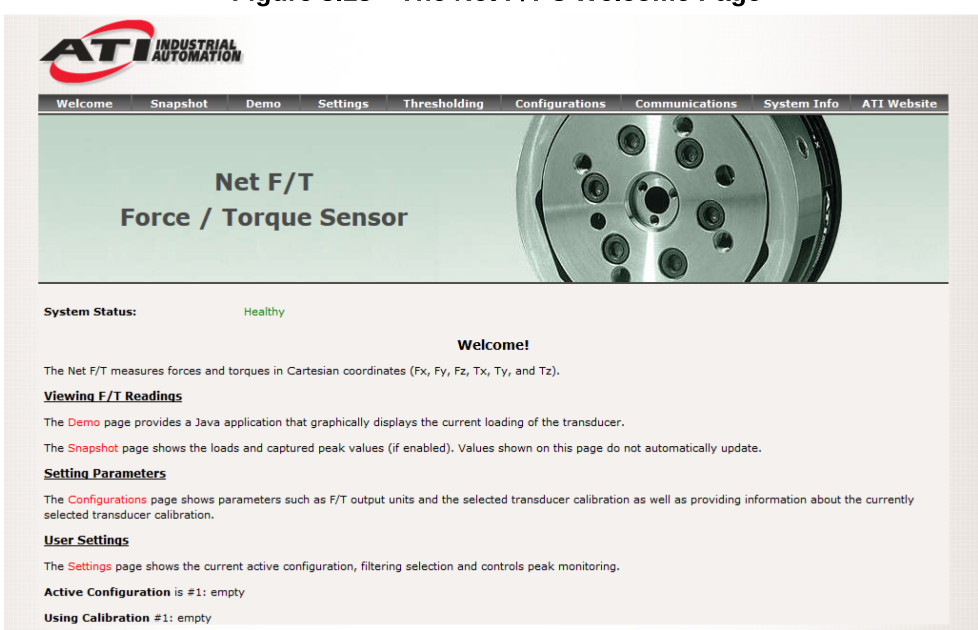
Step 7: Click on the *OK* button.

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.

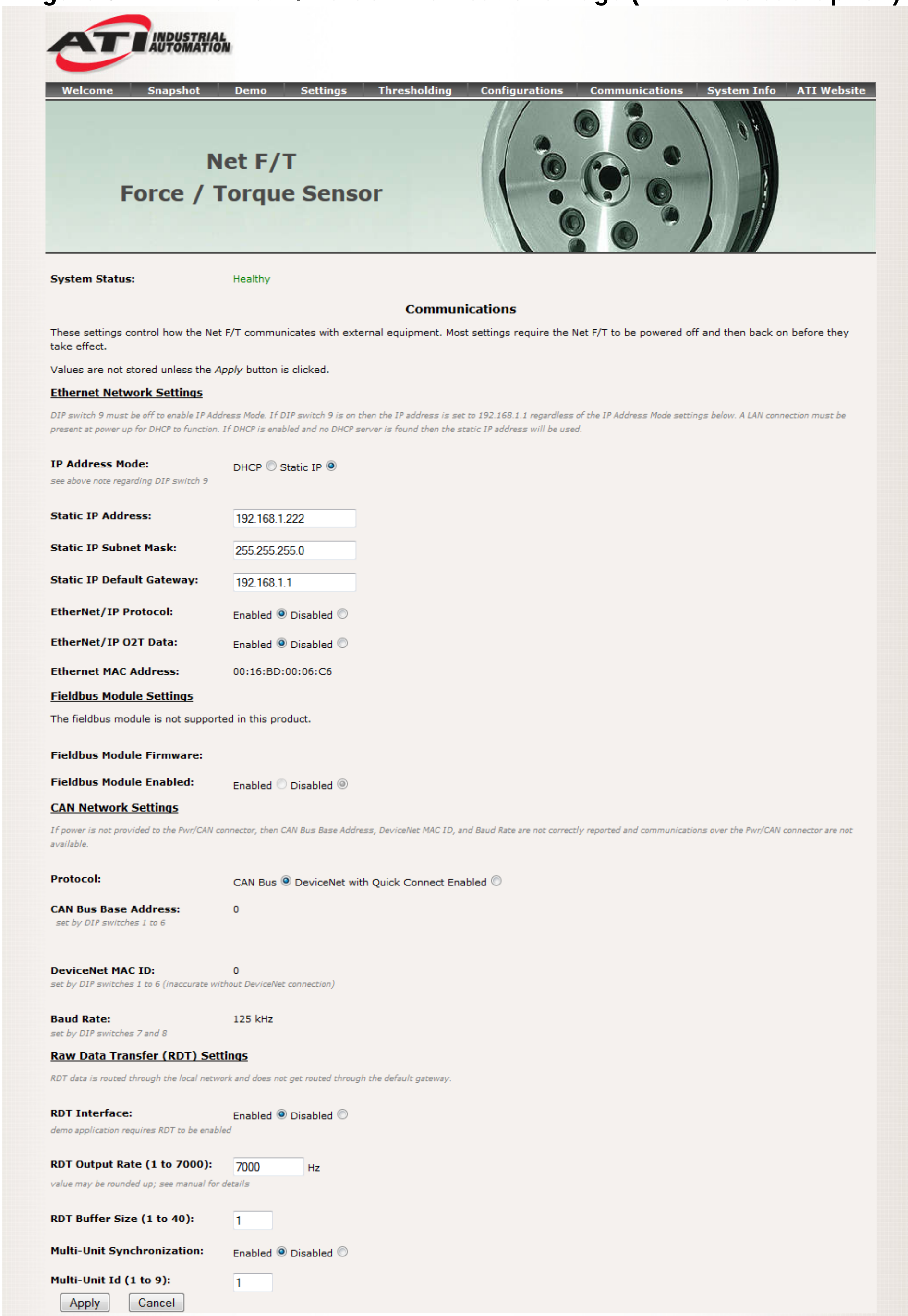
Step 10: Enter the address [192.168.1.1](192.168.1.1) in your browser to view the Net F/T's *Welcome* page.

Figure 3.13—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 3.14—The Net F/T's Communications Page (with Fieldbus Option)



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*.

NOTICE: 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.

NOTICE: 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 an Ethernet-based Fieldbus

Net F/Ts with an optional fieldbus module connect to the fieldbus via the Net F/T's standard Ethernet connection. Although the fieldbus uses the same Ethernet connection as the Net F/T uses for its standard communications, the fieldbus option has its own MAC address and its own IP address. The fieldbus's MAC address is shown as *MAC ID 2* on the connector side of the Net Box.

To be used, the fieldbus module option must be enabled on the Net F/T's *Communications* page.

3.8 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 3.10—DIP Switches and Termination Resistor*. For protocol information, refer to *Section 13—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.

3.9 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 3.10—DIP Switches and Termination Resistor*. For protocol information refer to *Section 15—CAN Bus Operation.*

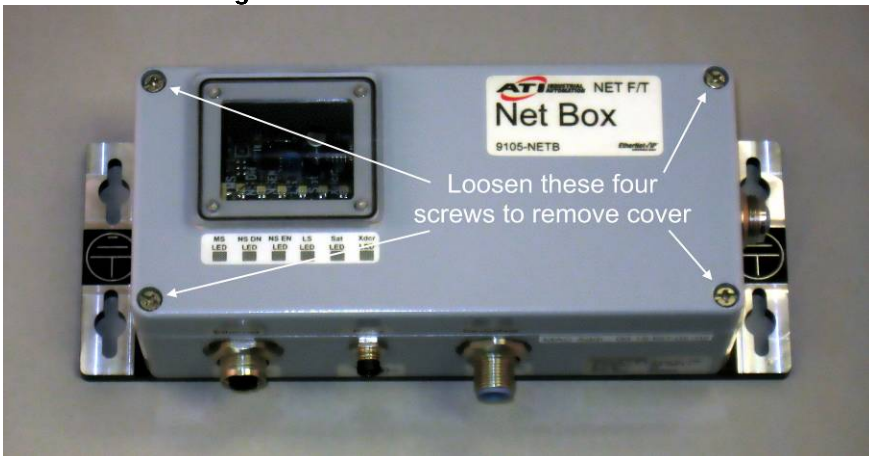
3.10 DIP Switches and Termination Resistor

The configuration DIP switches and termination resistor are located inside of the Net Box where they are safely protected from 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.

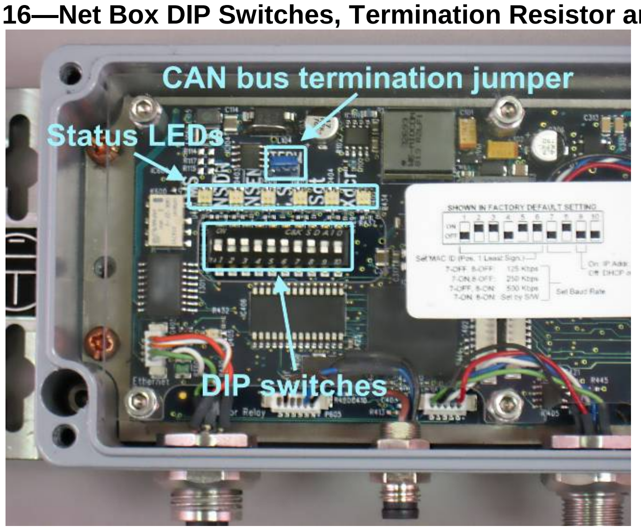
To remove the cover, fully loosen each of the four screws that fasten the cover to the Net Box chassis. The cover can then be removed by lifting it straight up and off of the chassis.

Figure 3.15—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 3.16—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.

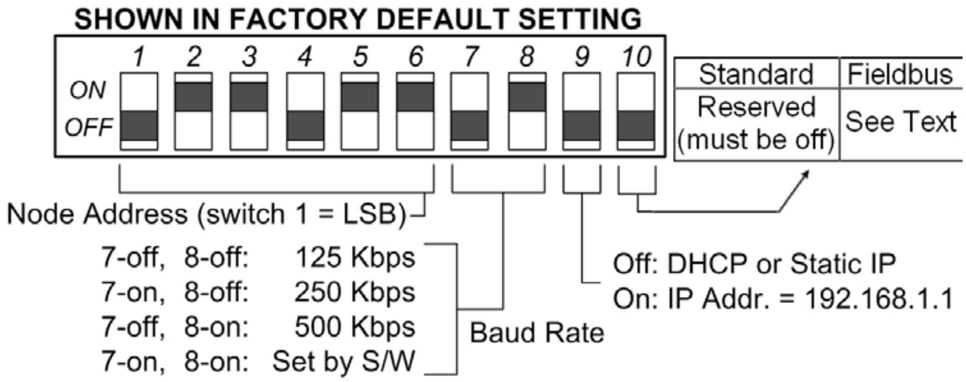
3.10.1 Termination Resistor

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.

3.10.2 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 3.16—DIP Switch Settings* for details).

Figure 3.17—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.

NOTICE: 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.

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	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 3.2—DeviceNet MAC ID 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

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.

3.10.3 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 3.16—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.

Table 3.3—Baud Rate Switch Settings

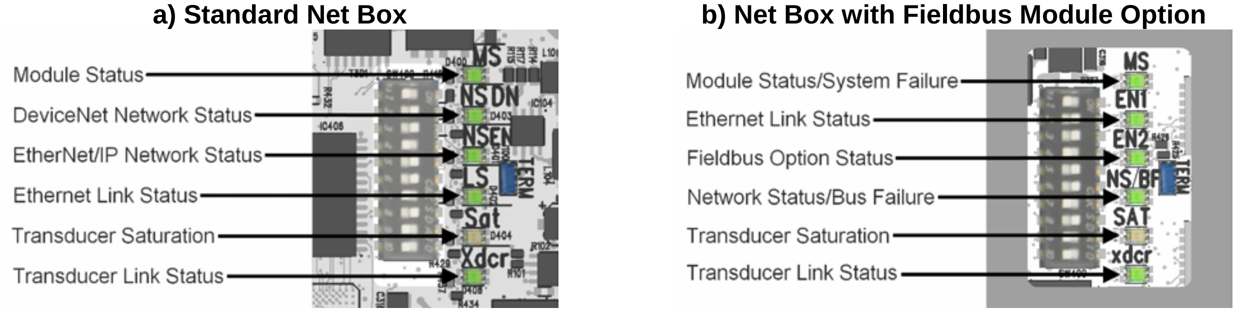
Baud Rate	7 8
125 Kbps:	00
250 Kbps:	10
500 Kbps:	01
Selected by software:	11

3.11 Status LEDs

The status LEDs indicate the general health and connectedness of the Net F/T. *Table 3.4—Standard Net Box Status LED Descriptions* and *Table 3.5—Fieldbus Net Box Status LED Descriptions* describe the possible LED states and meanings.

Figure 3.18—Status LEDs

a) Standard Net Box **b) Net Box with Fieldbus Module Option**



3.12 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:

- For the standard Net Box, all status LEDs blink green then red once in this order: *MS*, *NS DN*, *NS EN*, *LS EN*, *Sat*, and *Xdcr*. For the fieldbus Net Box, the LEDs blink green once then red once in this order: *MS*, *EN1*, *NS/BF*, *Sat*, and *Xdcr*. The *EN2* LED does not blink in the sequence.
- Next the *Xdcr* LED glows red and the *MS* LED blinks red. The *LS EN* LED blinks green if the Net Box is connected to the Ethernet network.
- Approximately 20 seconds after power up, the *MS* and *Xdcr* LEDs should display green. This signals that the data acquisition system is now functioning.
- Refer to *Section 18—Troubleshooting* if the Net F/T does not power up as described above.

Table 3.4—Standard Net Box Status LED Descriptions

Status LED Function	Name on PCB	LED State	Description
Module Status	**MS**	Off	No power
		Green	Correct operation
		Flashing Red	Minor fault such as incorrect or inconsistent configuration
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
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
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 load is appropriate (or no power)
		Red	Transducer has too much load and is saturated. This causes system load outputs to be invalid.
Sensor Link Status	**Xdcr**	Green	Data acquisition system functioning properly.
		Red	Data acquisition system error or power-up sequence is being executed.

<table>
<tr><th colspan="4">Table 3.5—Fieldbus Net Box Status LED Descriptions</th></tr>
<tr><th>Status LED Function</th><th>Name on PCB</th><th>LED State</th><th>Description</th></tr>
<tr><td rowspan="3">Module Status</td><td rowspan="3">MS</td><td>Off</td><td>No power</td></tr>
<tr><td>Green</td><td>Correct Operation</td></tr>
<tr><td>Flashing Red</td><td>Minor fault such as incorrect or inconsistent configuration</td></tr>
<tr><td rowspan="3">Ethernet Link Status</td><td rowspan="3">EN1</td><td>Off</td><td>No Ethernet link (or no power)</td></tr>
<tr><td>Green</td><td>Ethernet link established</td></tr>
<tr><td>Flashing Green</td><td>Ethernet activity</td></tr>
<tr><td rowspan="4">Fieldbus Option Status</td><td rowspan="4">EN2</td><td>Off</td><td>Fieldbus disabled (or no power)</td></tr>
<tr><td>Green</td><td>Fieldbus connected</td></tr>
<tr><td>Flashing Amber</td><td rowspan="2">Fieldbus activity</td></tr>
<tr><td>Amber</td></tr>
<tr><td rowspan="6">Network Status/Bus Failure</td><td rowspan="6">NS/BF</td><td colspan="2">The NS/BF LED displays only the status of the highest priority bus connected. The priorities are as follows, in order of highest to lowest: Fieldbus, EtherNet/IP, DeviceNet.</td></tr>
<tr><td>Off</td><td><table><tr><th>Bus</th><th>Description</th></tr><tr><td>Fieldbus</td><td rowspan="2">No IP address assigned or network disabled (or no power)</td></tr><tr><td>EtherNet/IP</td></tr><tr><td>DeviceNet</td><td>Pending duplicate MAC ID test or network disabled (or no power)</td></tr></table></td></tr>
<tr><td>Green</td><td><table><tr><th>Bus</th><th>Description</th></tr><tr><td>Fieldbus</td><td rowspan="2">Network connected</td></tr><tr><td>EtherNet/IP</td></tr><tr><td>DeviceNet</td><td>DeviceNet master connected</td></tr></table></td></tr>
<tr><td>Flashing Green</td><td><table><tr><th>Bus</th><th>Description</th></tr><tr><td>Fieldbus</td><td rowspan="2">IP address assigned without connecting to network</td></tr><tr><td>EtherNet/IP</td></tr><tr><td>DeviceNet</td><td>No connection to network</td></tr></table></td></tr>
<tr><td>Flashing Red</td><td>Connection(s) timed out</td></tr>
<tr><td>Red</td><td><table><tr><th>Bus</th><th>Description</th></tr><tr><td>Fieldbus</td><td>Duplicate IP address found</td></tr><tr><td>EtherNet/IP</td><td>Duplicate IP address found or EtherNet/IP network</td></tr><tr><td>DeviceNet</td><td>Network error</td></tr></table></td></tr>
<tr><td rowspan="2">Transducer Saturation</td><td rowspan="2">Sat</td><td>Off</td><td>Transducer load is appropriate (or no power)</td></tr>
<tr><td>Red</td><td>Transducer has too much load and is saturated. This causes system load outputs to be invalid</td></tr>
<tr><td rowspan="2">Transducer Link Status</td><td rowspan="2">Xdcr</td><td>Green</td><td>Data acquisition system functioning properly</td></tr>
<tr><td>Red</td><td>Data acquisition system error or power-up sequence is being executed</td></tr>
</table>

4. Web Pages

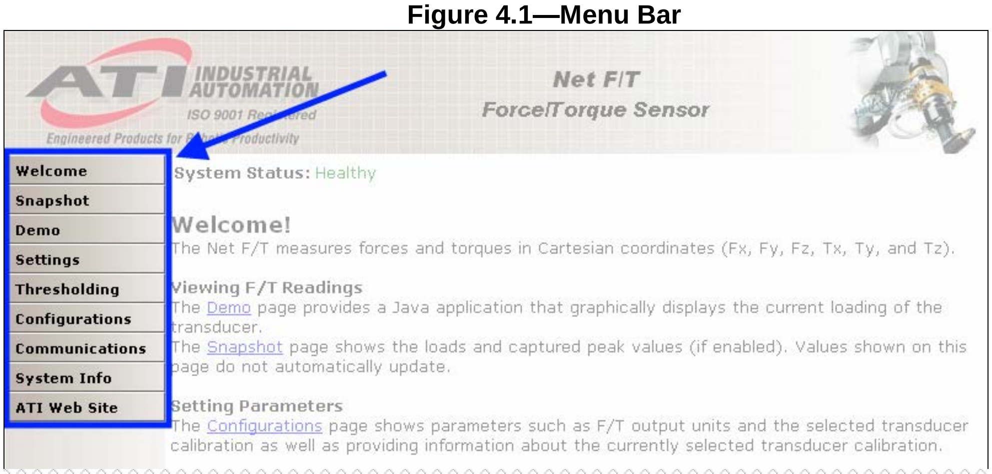
4.1 Introduction

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 18.2—System Status Code.*

Figure 4.1—Menu Bar

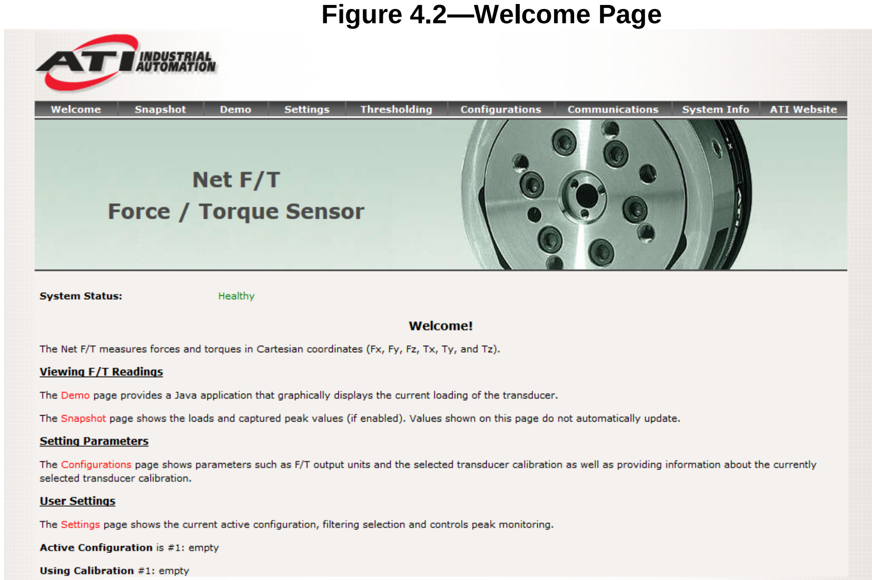


4.2 Welcome Page (index.htm)

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—Welcome Page

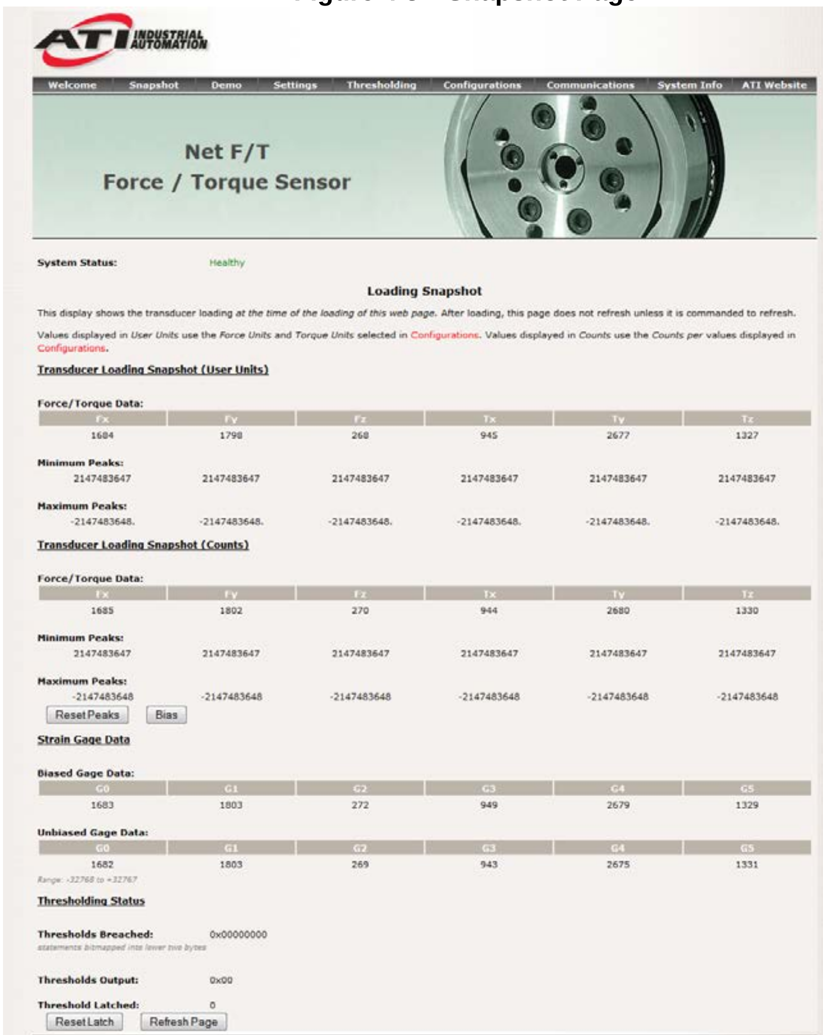


4.3 Snapshot Page (rundata.htm)

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—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:

Biased Gage Data: Displays the transducer's strain gages minus the software bias vector.

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

NOTICE: When saturation occurs, the reported force and torque values are invalid.

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

NOTICE: 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 since the last reset latch function execution. 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 the result of or'ing the bit patterns for all true statements together. The *Thresholds Breached* value is cleared to zero by the reset latch function.

Table 4.1—Bit Patterns for Thresholds Breached

#:	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

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.

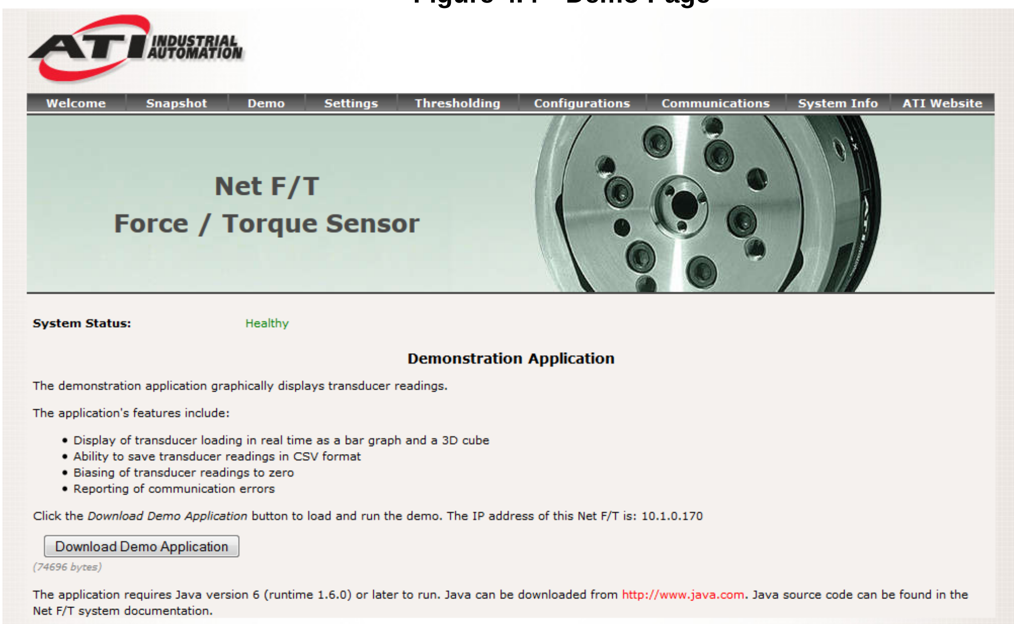
Reset Latch button: Clears any threshold latching and reloads the *Snapshot* page. If no threshold conditions remain true then *Thresholds Breached*, *Thresholds Output*, and *Threshold Latched* will all be set to zero and the System Status: Threshold Level Latched condition will be cleared.

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*.

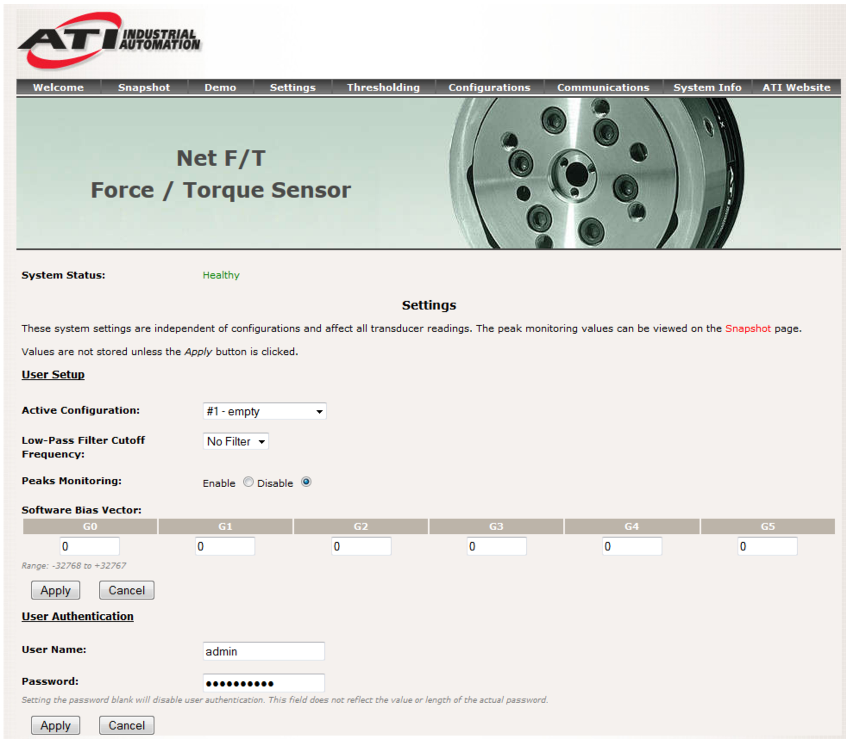
Figure 4.4—Demo Page



4.5 Settings Page (setting.htm)

This page allows you to choose 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—Settings Page



Active Configuration:

Selects one of sixteen configurations to be applied to the force and torque readings. 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 19.2—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.

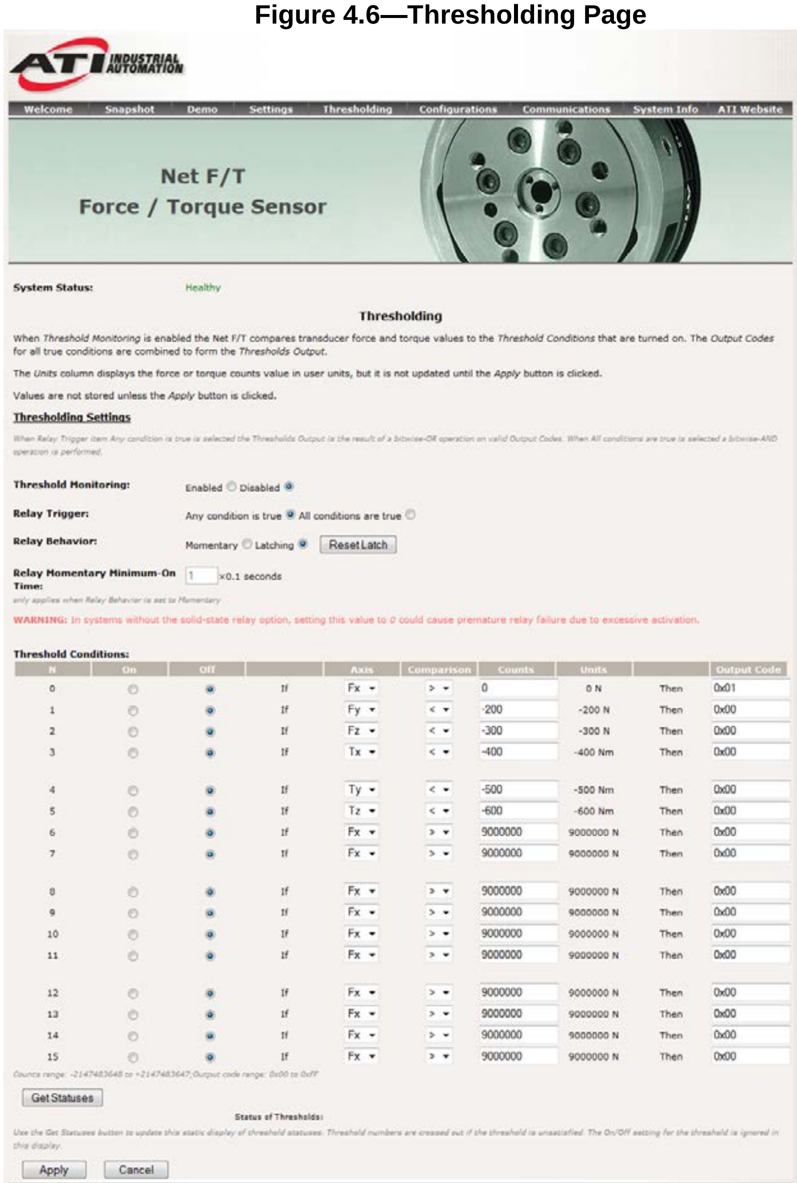
4.6 Thresholding Page (moncon.htm)

This page allows you to set up threshold conditions. Threshold conditions compare the transducer readings to simple user-defined threshold statements. When threshold monitoring is enabled and a sample is read that satisfies one or more of the active threshold conditions, the user-defined output code for all threshold conditions satisfied by that sample are bitwise or'ed together to form the threshold output (in practice, it is very unlikely that more than one threshold sample will be satisfied in a single sample). The threshold monitoring latch is then set, and threshold monitoring is then paused until a command to reset the threshold monitoring latch is received. 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—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 18.2— 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 4.7—Standard Net Box 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:

Table 4.2—Thresholding Statement Axis Selections

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

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

Table 4.3—Thresholding Statement Comparison Selections

Menu Value	Description
>	Greater Than
<	Less Than

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 value1000000(from *Configurations* page)

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

> **NOTICE:** 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.

Relay operation is determined by the *Relay Trigger*, *Relay Behavior*, and *Relay Momentary Minimum-On Time* settings.

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.

The threshold relay contacts (NC, NO, and COM) are protected against overload by a resettable fuse, see *Section 19.3.4—Standard Threshold Relay* for electrical specifications.

4.6.1.1 Standard Net Box Threshold Relay

The standard Net Box threshold relay is a mechanical relay. (The fieldbus Net Box has the solid-state relay described in *Section 4.6.1.2—Fieldbus Net Box and Optional Solid State Threshold Relay).*

Figure 4.7—Standard Net Box Threshold Relay Connector Pin Assignment (Male-pin side view)

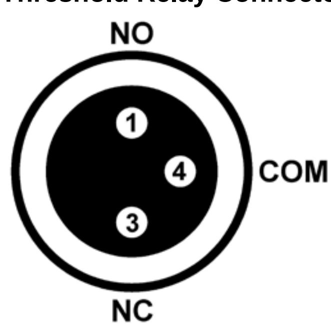


Table 4.4—Solid-State Relay Connector Pin Descriptions

Pin	Name	Description
1	NO	Normally open connection
3	NC	Normally closed connection
4	Com	Common

CAUTION: The solid-state relay connections are polarity dependent. A reverse-polarity connection could cause high current flow and damage the Net Box or user equipment.

Figure 4.8—Example Circuit for Standard Net Box Threshold Relay Monitoring

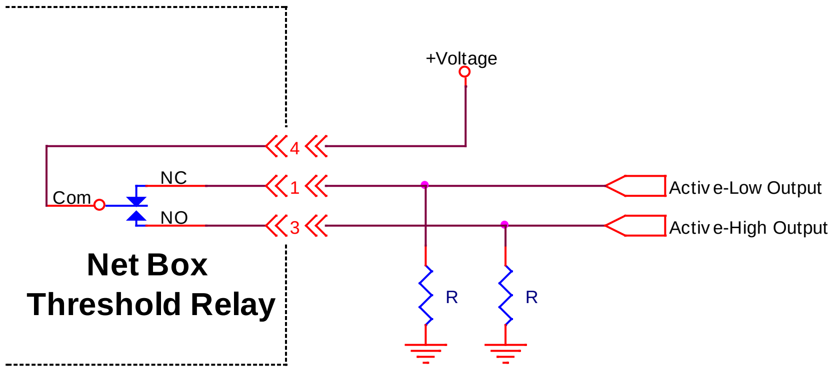
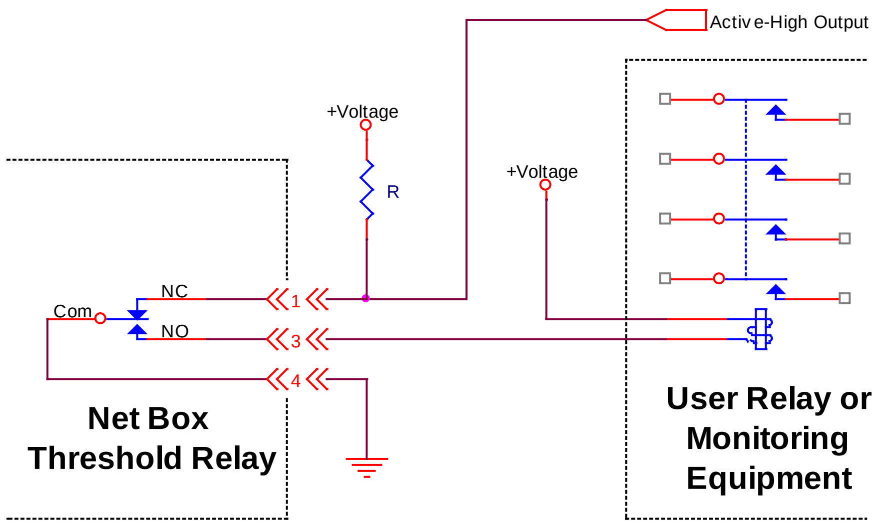


Figure 4.9—Example Circuit for a Relay Interface



The standard 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.

4.6.1.2 Fieldbus Net Box and Optional Solid State Threshold Relay

The solid-state relay is standard on the fieldbus Net Box.

The optional solid-state threshold relay has a quicker activation time than the standard threshold relay and no moving parts to wear out.

Figure 4.10—Optional Solid State Relay Connector Pin Assignments (male-pin side view)

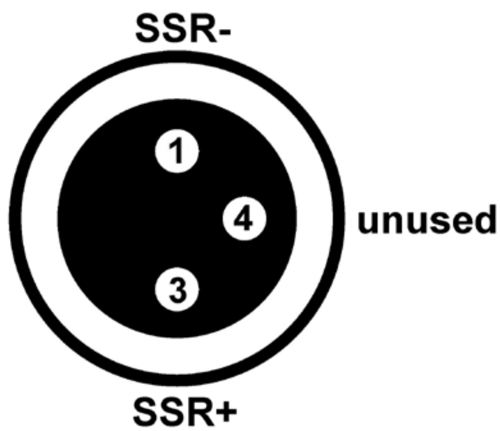


Figure 4.11—Solid-State Relay Equivalent Output Circuit

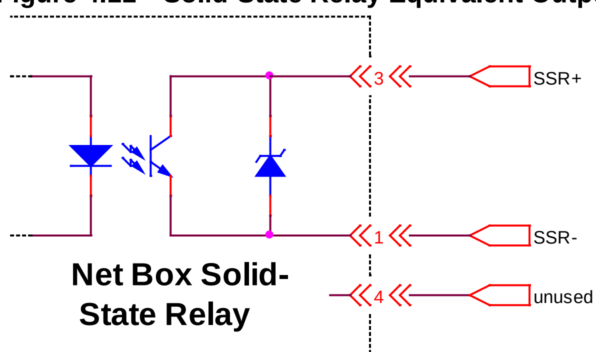
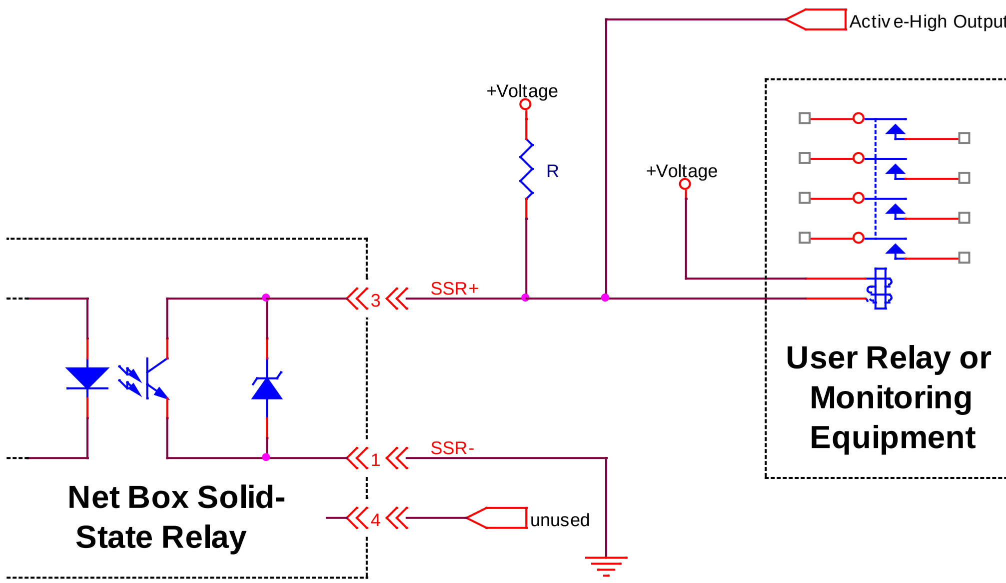


Table 4.5—Solid-State Relay Connector Pin Descriptions		
Pin	**Name**	**Description**
1	SSR-	Solid-State Relay negative connection
3	SSR+	Solid-State Relay positive connection
4	–	unused

The solid-state relay can operate at up to 30VDC and at a maximum current of 35mA. The relay can turn on within 500µs of a trigger load. The output is reverse polarity protected to up to 1A (V_r = 1.5V), 47V. The maximum delay from threshold condition trigger to relay conduction is 500µs.

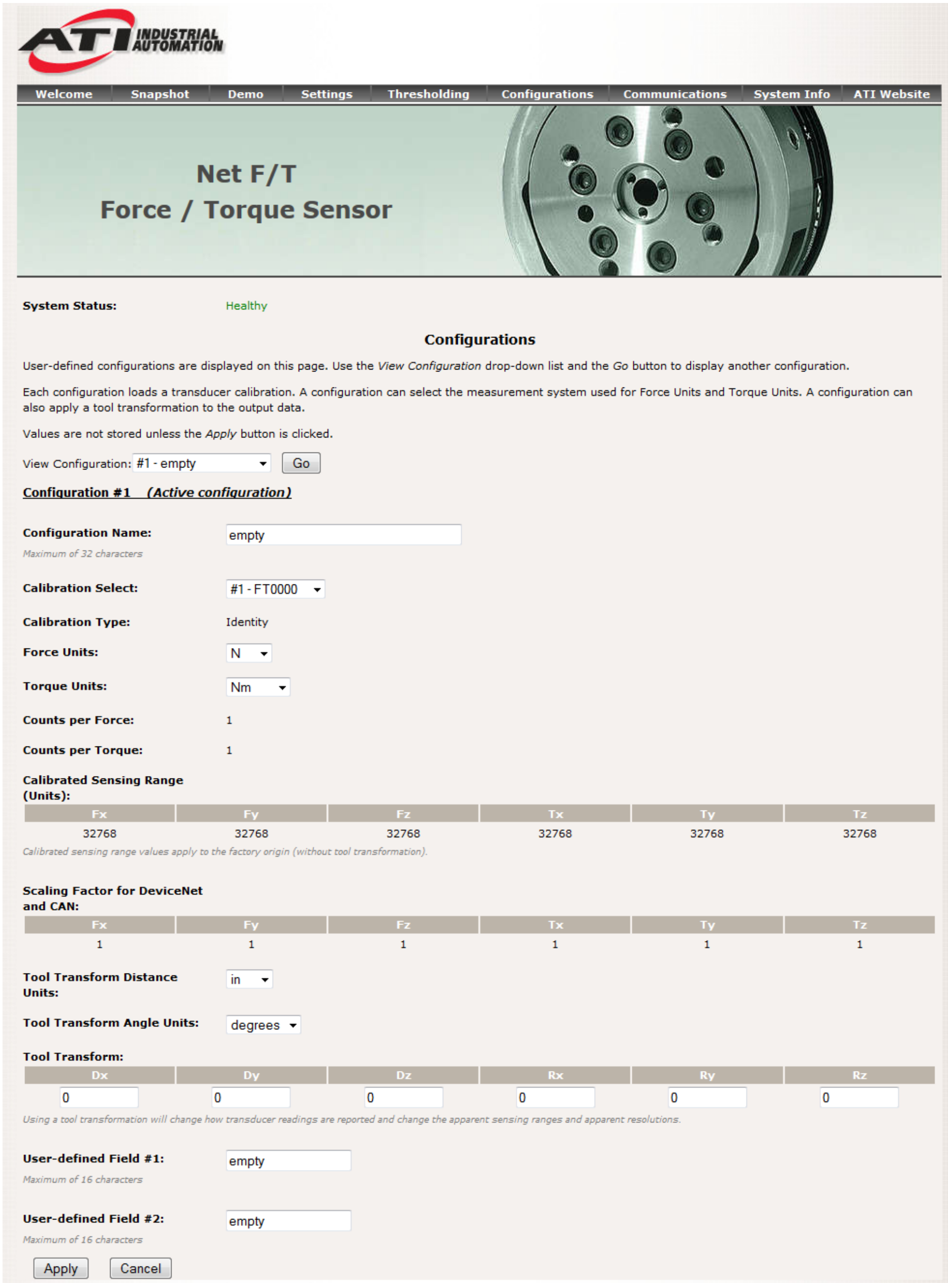
Figure 4.12—Example Connections to Solid-State Relay



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 4.13—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; an *Empty Calibration Selected* error will occur if an invalid calibration is selected.)

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:

Table 4.6—Force Unit Selections

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

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:

Table 4.7—Torque Unit Selections

Menu Value	Description
lbf-in	Pound-force-inch
lbf-ft	Pound-force-feet
Nm	Newton-meter
Nmm	Newton-millimeter
kgf-cm	Kilogram-force-centimeter
kNm	Kilonewton-meter

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 10.2—Calculating F/T Values for RDT* information and *Section 14.2—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 10.2—Calculating F/T Values for RDT* information and *Section 14.2—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 14.2.2—DeviceNet* and *Section 15.5—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:

Table 4.8—Tool Transform Distance Unit Selections

Menu Value	Description
In	inch
ft	foot
mm	millimeter
cm	centimeter
m	meter

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:

Table 4.9—Tool Transform Angle Unit Selections

Menu Value	Description
degrees	degrees (°)
radians	radians

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:

Table 4.10—Tool Transform Values and Execution Order

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

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.

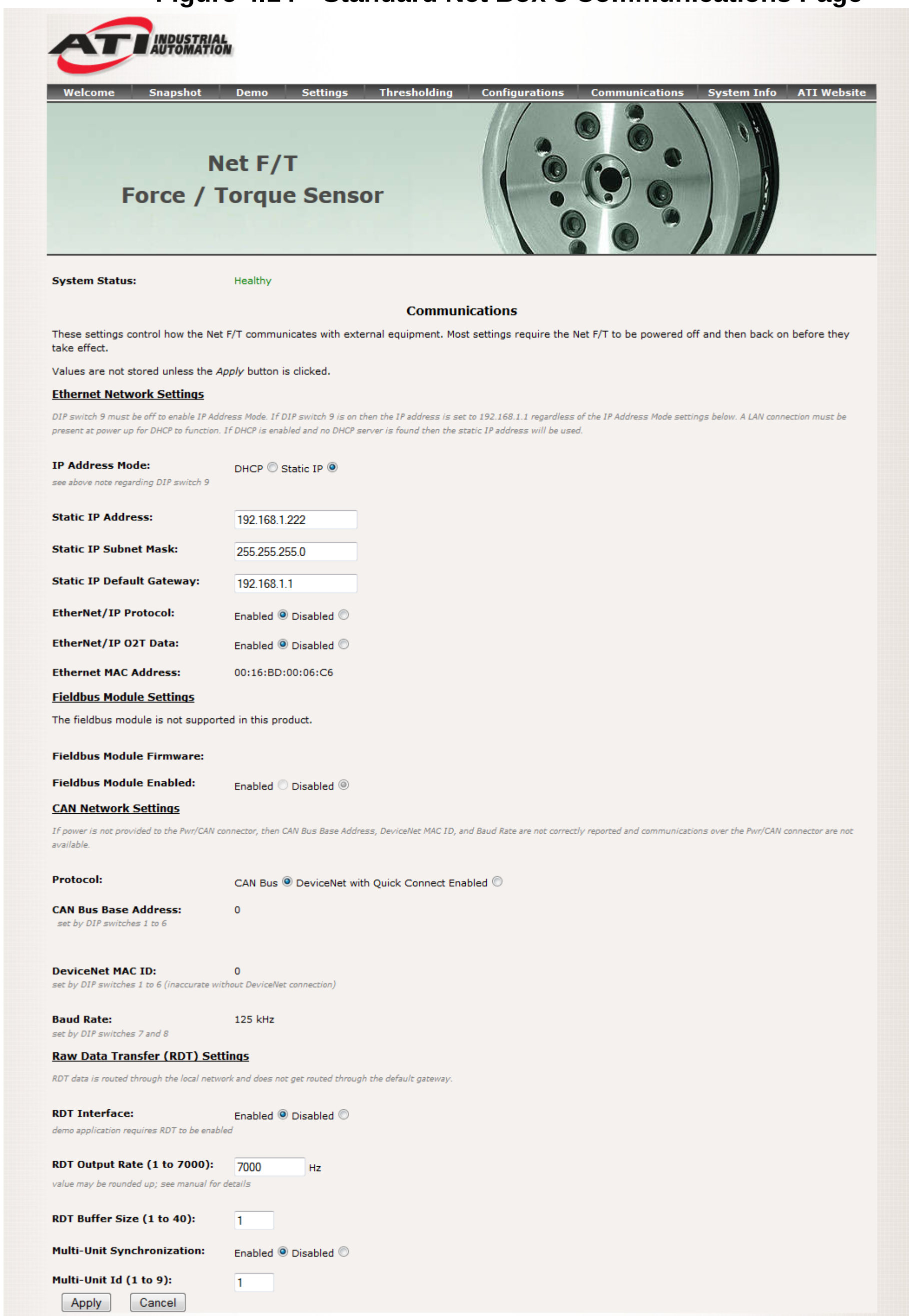
[1] The factory point of origin places the X, Y, and Z axes as shown on the transducer drawings in the F/T Transducer Manual (*9620-05-Transducer Section—Installation and Operation Manual*).

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*.

Figure 4.14—Standard Net Box's Communications Page



> **NOTICE:** The *Ethernet Network* Settings only applies to the standard Ethernet and EtherNet/IP interfaces included in all Net Boxes. The *Ethernet Network Settings* do not apply to the additional fieldbus interface included in fieldbus Net Boxes.

Ethernet Network Settings:

Ethernet/IP O2T Data: When enabled, the Net F/T accepts 4 bytes of output from the Ethernet/IP master. When disabled, the Net F/T does not accept any output over the Ethernet/IP interface.

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.

NOTICE: 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. DeviceNet protocol must be disabled when EtherNet/IP protocol is enabled.

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.

Fieldbus Module Settings (only displays on fieldbus Net Boxes):

Fieldbus Module Firmware: Displays the type of fieldbus protocol supported by the fieldbus Net Box.

Fieldbus Module Enabled: If enabled, the Net Box will support the fieldbus protocol listed in *Fieldbus Module Firmware*. If disabled, then that fieldbus protocol is unavailable to the network.

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 15—CAN Bus Operation* is used. When *DeviceNet* is selected the DeviceNet-compatibility mode protocol described in *Section 13—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. EtherNet/IP protocol must be disabled when DeviceNet protocol is enabled.

CAN Bus Base Address: Displays the base address to be used by the CAN bus protocol. See *Section 3.10.2—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 3.10.2—Node Address* for information on setting this address.

Baud Rate: Displays the CAN bus baud rate used by the CAN network. See *Section 3.10.3—Baud Rate* for information on setting the baud rate.

> **NOTICE:** 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 10—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 10.3—Multi-Unit Mode* for details. Multi-Unit IDs must be assigned for this to work correctly.

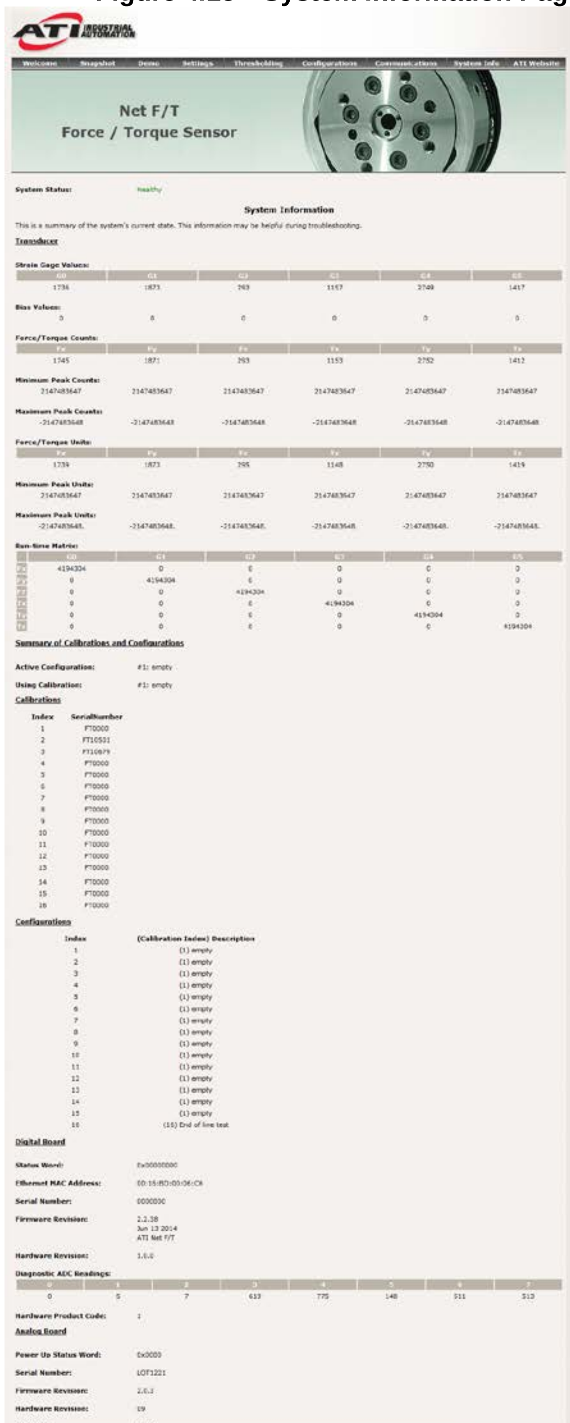
Multi-Unit ID: If *Multi-Unit Synchronization* is enabled, each Net F/T using multi-unit synchronization needs to have a unique ID assigned to it.

Ethernet/IP O2T Data: If enabled, the Net F/T accepts a 4-byte output bitmap which is identical to the Profinet bitmap in table 15.3. If disabled, the Net F/T does not accept any Ethernet/IP output data (the same as the current version of the product).

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. For status codes refer to *Section 18.2.*

Figure 4.15—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.

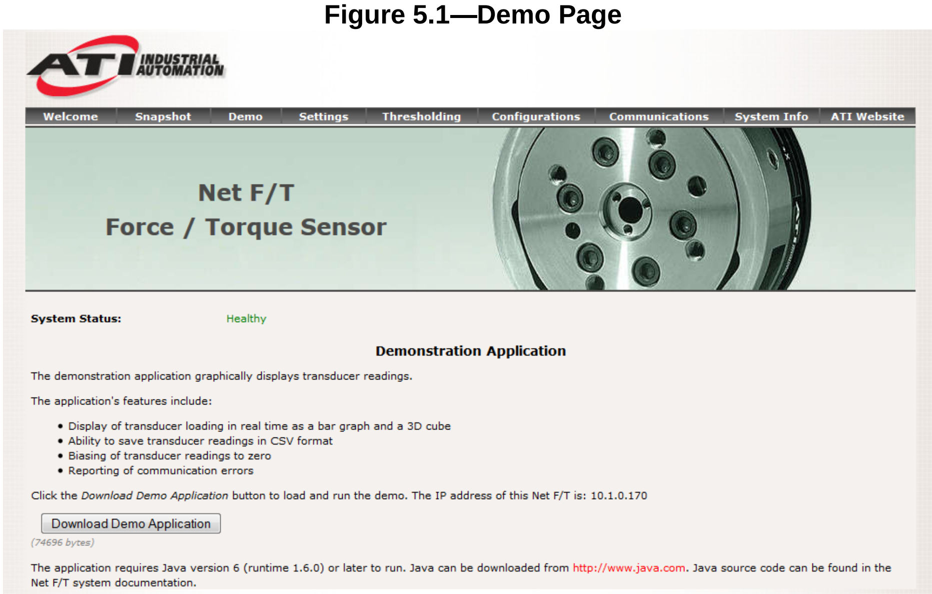
5. Java Demo Application

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.

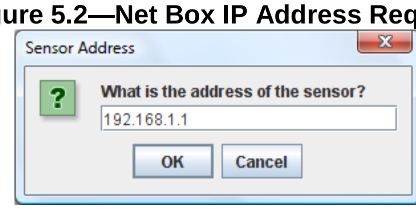
Figure 5.1—Demo Page



> **NOTICE** The Java Demo requires the Net F/T to have its RDT Interface enabled. RDT is enabled in the Net F/T by default. See *Section 4.8—Communication Settings Page (comm.htm)* for information on RDT settings.

The demo program opens with the following window:

Figure 5.2—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 5.3—Windows Vista Firewall Alert

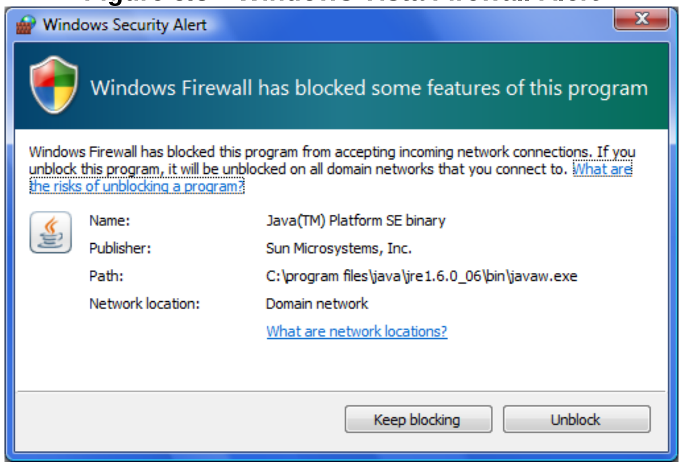
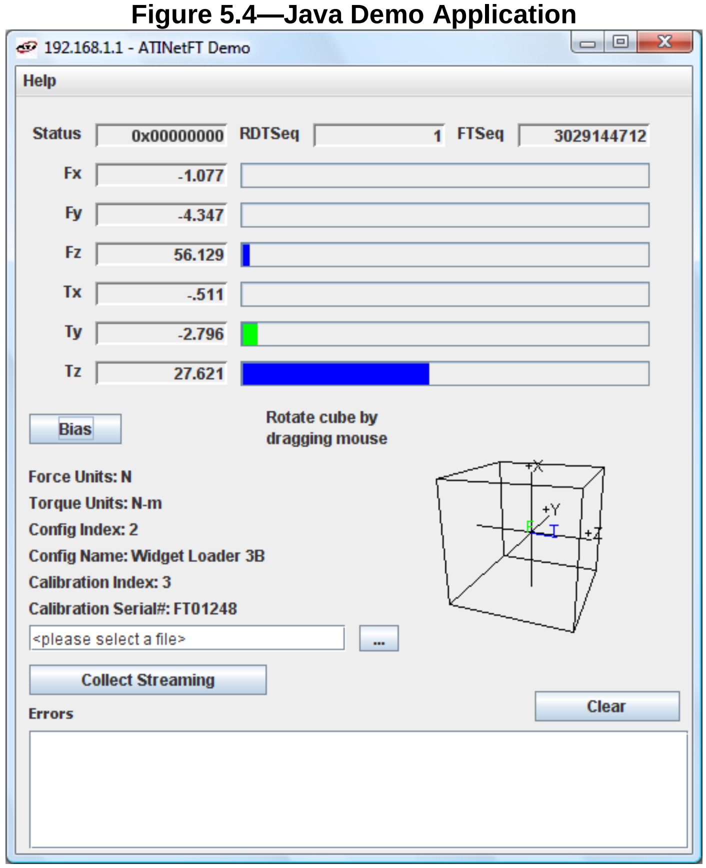


Figure 5.4—Java Demo Application



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.

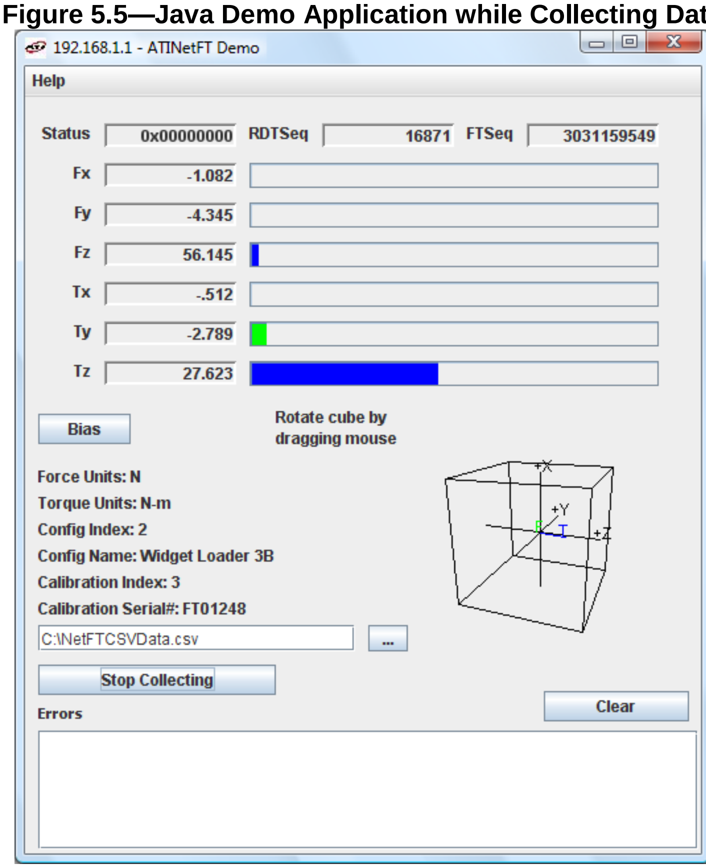
5.3 Collecting Data with the Demo

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 5.5—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.

Note: If the sample rate is changed after start of the demo program, this value will not be updated.

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.

Table 5.1—CSV File Column Headings

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

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 18.2—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:

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

Missing sequences indicate that data packages were lost. To avoid lost samples, see *Section 17.1—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.

Figure 5.6—Sample Data Opened in Spreadsheet

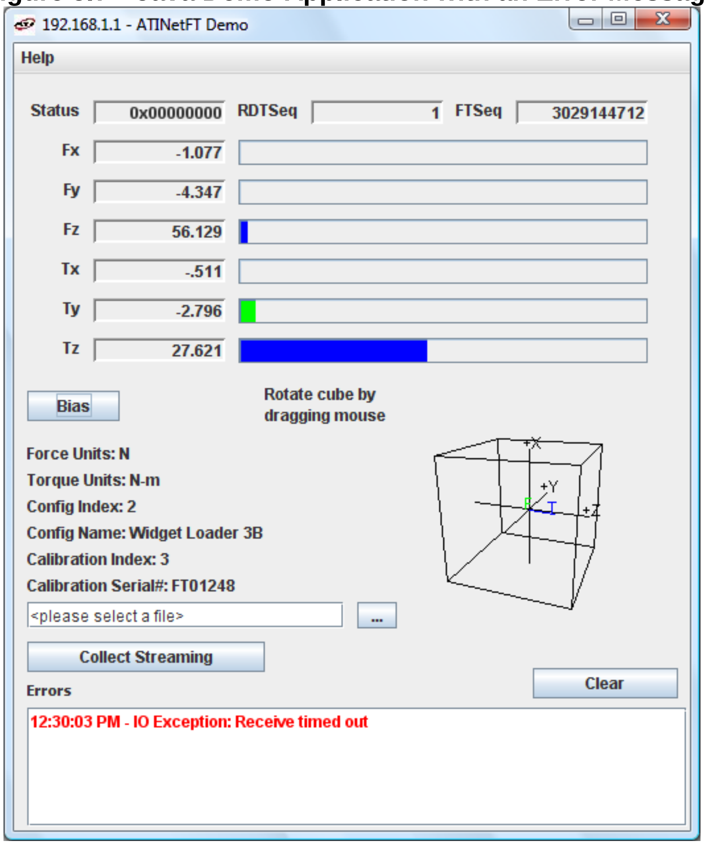
	A	B	C	D	E	F	G	H	I	J
1	Start Time: 10/28/08 4:45 PM									
2	RDT Sample Rate: 7000									
3	Force Units: N									
4	Counts per Unit Force: 1000000.0									
5	Torque Units: N-m									
6	Counts per Unit Torque: 1000000.0									
7	Status (hex)	RDTSequence	F/T Sequence	Fx	Fy	Fz	Tx	Ty	Tz	Time
8	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

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 5.7* for an example). Refer to *Section 18.3.3—Java Demo* if you need help with error messages. See *Section 17.1—Improving Ethernet Throughput* if there is excessive *IO Exception: Receive timed out* errors.

Figure 5.7—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

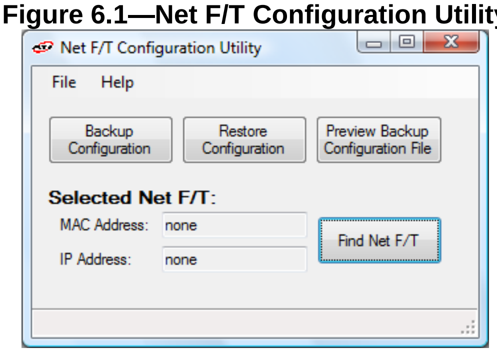
The Net F/T Configuration Utility is a Windows program that can find Net F/Ts on an Ethernet network, back up configurations to a computer, restore configurations, and display saved configuration files.

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

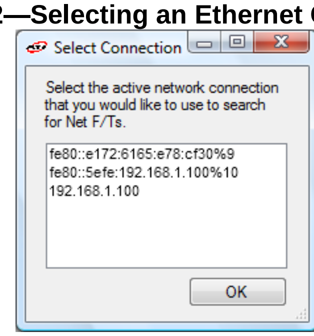
Launch *Net F/T Configuration Utility*. Click the Find Net F/T button.

Figure 6.1—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*.

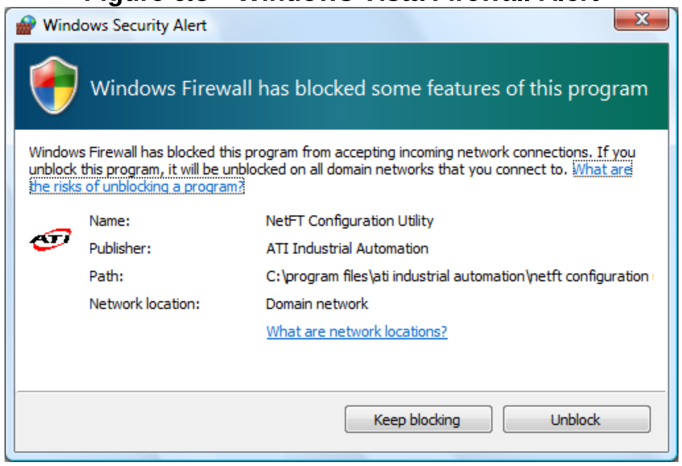
Figure 6.2—Selecting an Ethernet Connection



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.

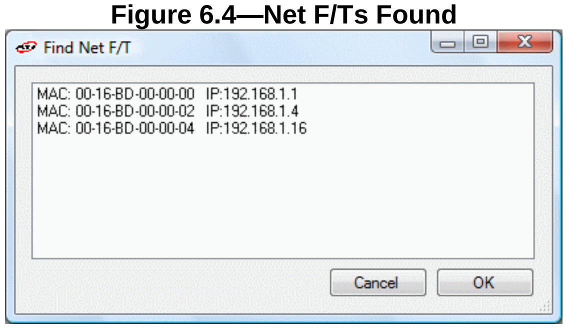
Figure 6.3—Windows Vista Firewall Alert



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 6.4—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*.

NOTICE: 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.

NOTICE: 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

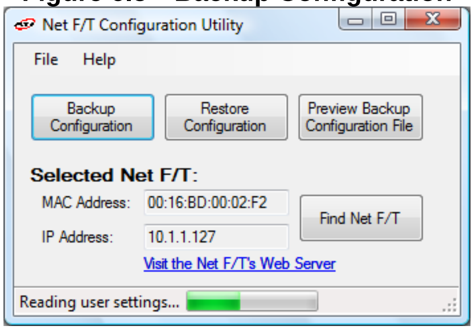
The Net F/T Configuration Utility can read the configurations stored in a Net F/T and store them on the local computer. A replacement Net F/T can be easily be set up to replace a damaged Net F/T by restoring a previously backed up configuration file to the new Net F/T. The configuration file contains 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 6.5—Backup Configuration



NOTICE: 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

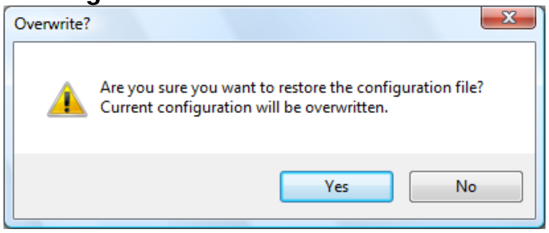
A previously-saved configuration file can be loaded into a Net F/T using the restore configuration feature.

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*.

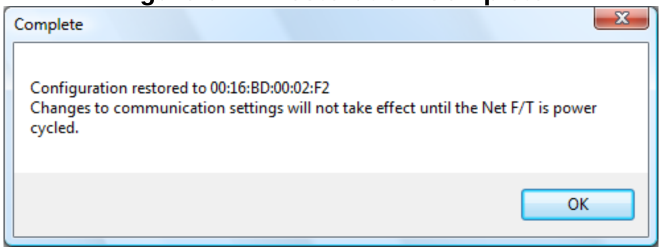
A confirmation message will appear before the configuration file is loaded into the Net F/T.

Figure 6.6—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 6.7—Restoration Complete



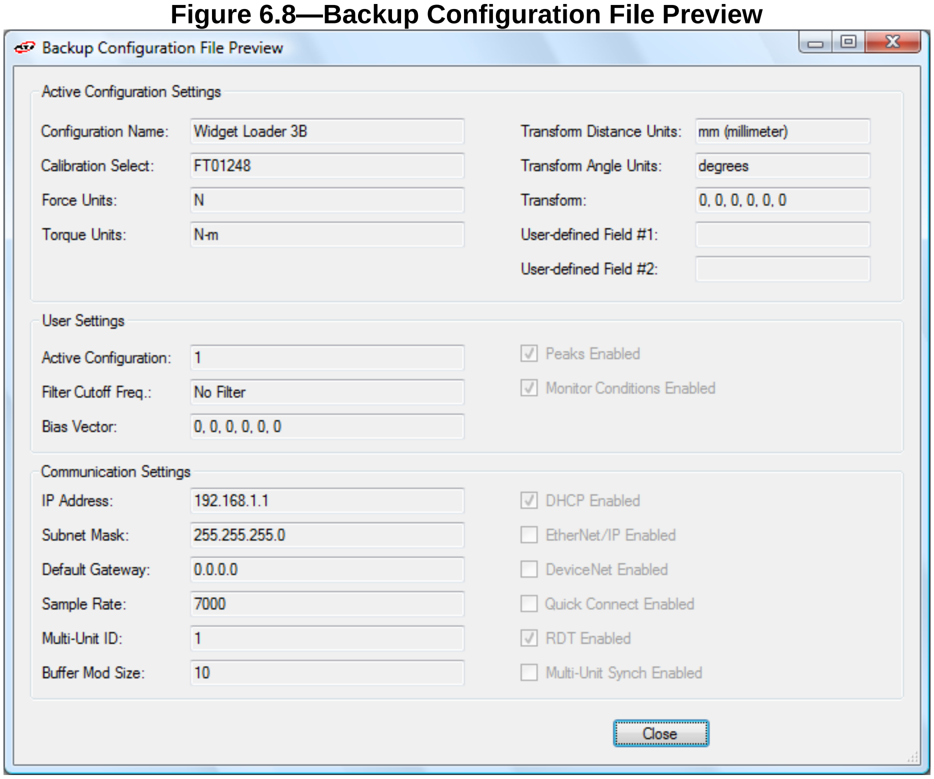
6.4 Inspecting a Saved Configuration File

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 6.8—Backup Configuration File Preview

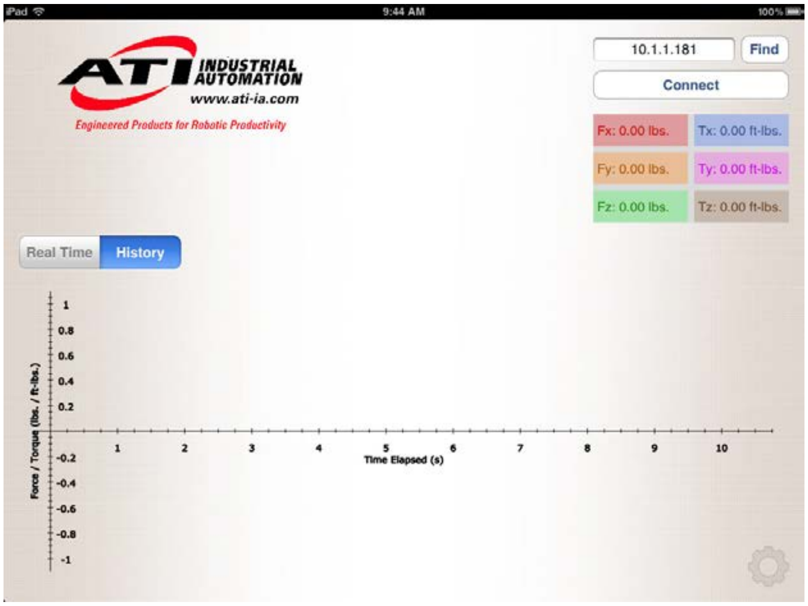


7. Net F/T iPad Application

The Net F/T iPad application can be down loaded from the App Store. Type in Net F/T iPad in the search field and search to find the application. Then install the application on your device.

The Net F/T iPad Application allows the users to connect to transducers in their network. The application will display 10 seconds of recorded the F/T readings in numeric and waveform line graph and can record that data to a file for additional processing.

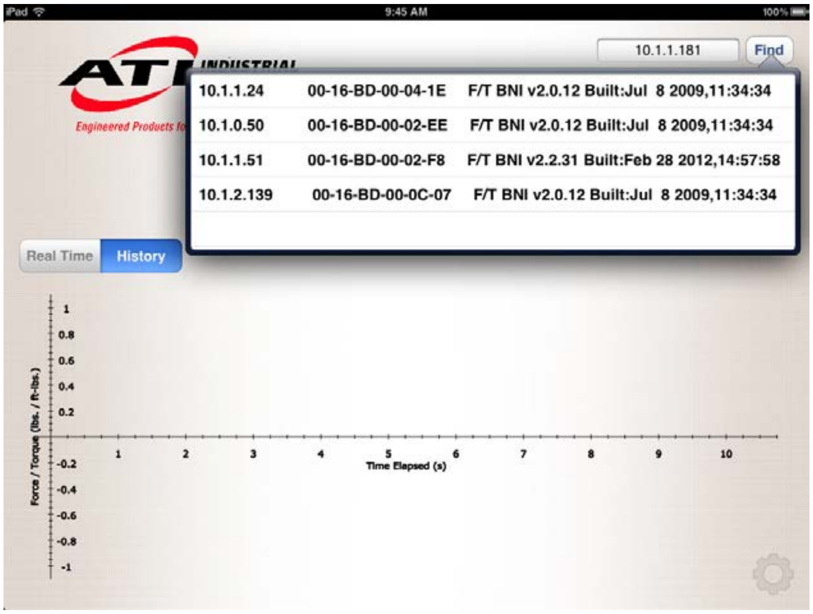
Figure 7.1—Initial Screen



7.1 Monitoring and Data Collection

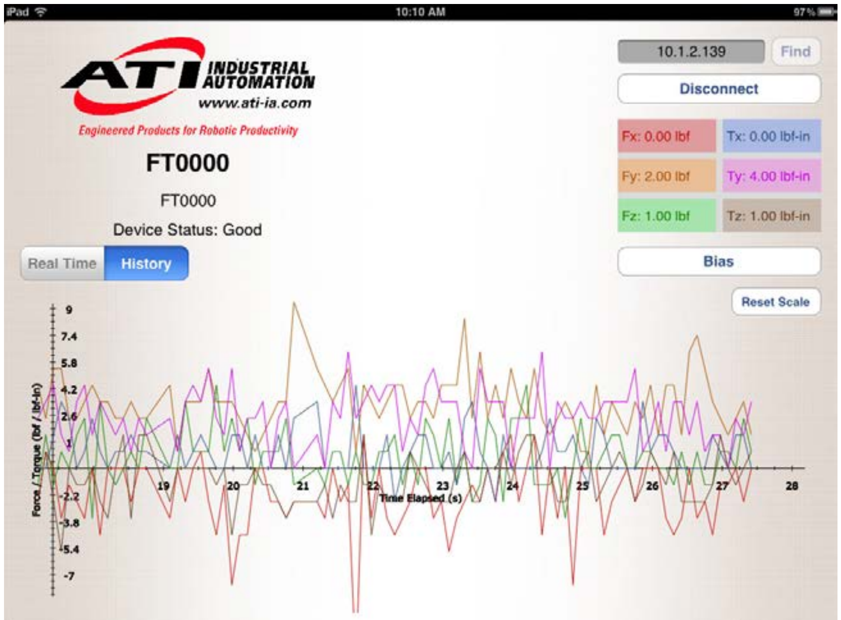
To find a Transducer connected to the network click the **Find** button a list of all available transducer will be displayed with the IP and MAC addresses in the listed. Select the desired transducer from the displayed list. The IP address of the transducer selected will be displayed to the left of the **Find** button.

Figure 7.2—Find Transducer's Connected to the Network



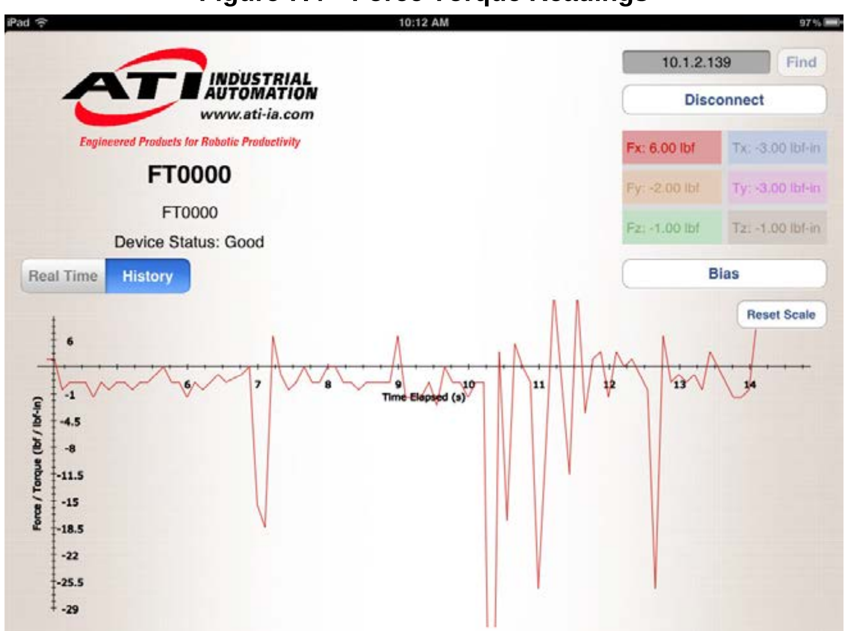
Select the **Connect** button to connect to the selected transducer. The iPad application will begin collecting and displaying data immediately. In the upper left corner of the display under the ATI logo the device status of the transducer will be displayed and show if there are any errors. The History view will display a waveform line graph of the data being collected. The **Bias** button will set the current load level as the new zero point. The **Reset Scale** button adjusts the display to capture the current minimum and maximum reading.

Figure 7.3—History View



Force and torque reading can be turned on and off as desired by clicking on the Fx, Fy, Fz, Tx, Ty, and Tz buttons below the Disconnect button. *Figure 7.4* shows the display with only Fx active.

Figure 7.4—Force Torque Readings



The Real Time view will display numerical values of the F/T readings.

Figure 7.5—Real Time View

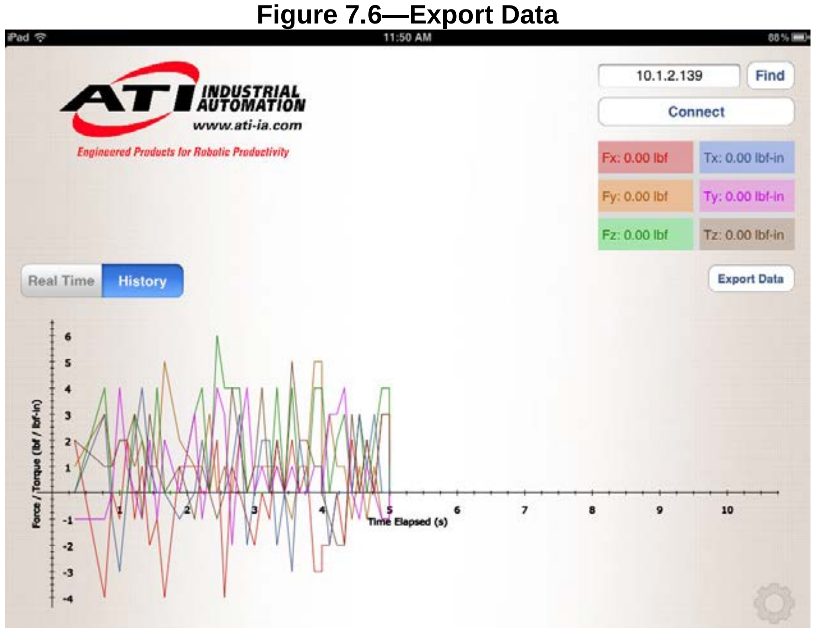
7.2 Exporting Data

Once you have the data desired, click the **Disconnect** button in the upper right corner under the Find button. Click the **Export Data** Button to open the data file on your device. A pop up window will appear with a list of apps that can open the spread sheet file (CSV).

> **NOTICE:** You must have an app loaded on you iPad in order for the pop up window to appear. If no pop up window appears, go to the App Store and download an app that can open a spread sheet file.

Select the app you wish to use to open the spread sheet. From the app you may be able to save the file to a network directory or email the file.

Figure 7.6—Export Data



The measurement data is 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. 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 7.7—Sample CSV Data File Opened in a Spread Sheet

	A	B	C	D	E	F	G	H	I	J
1	Start Time: 1/28/2013 4:24 PM									
2	RDT Sample Rate: 7000									
3	Force Units: N									
4	Counts Per Unit Force: 0.224809									
5	Torque Units: N-m									
6	Counts Per Unit Torque: 8.85075									
7										
8	Status (hex)	RDTSequence	F/T Sequence	Fx	Fy	Fz	Tx	Ty	Tz	Time
9	0x0	41	17433244	209.0664	0	62.27509	1.129848	12.54131	-1.12985	16:24:46.654
10	0x0	42	17433261	209.0664	0	62.27509	1.016863	12.54131	-1.12985	16:24:46.656
11	0x0	43	17433278	209.0664	0	62.27509	1.016863	12.54131	-1.12985	16:24:46.658
12	0x0	44	17433295	209.0664	0	57.82687	1.016863	12.42833	-1.12985	16:24:46.661
13	0x0	45	17433312	209.0664	0	62.27509	1.016863	12.54131	-1.12985	16:24:46.663
14	0x0	46	17433329	213.5146	0	62.27509	1.016863	12.65429	-1.01686	16:24:46.666
15	0x0	47	17433346	213.5146	0	62.27509	1.016863	12.54131	-1.12985	16:24:46.668
16	0x0	48	17433363	213.5146	0	62.27509	1.016863	12.54131	-1.12985	16:24:46.671
17	0x0	49	17433380	213.5146	0	62.27509	1.016863	12.54131	-1.12985	16:24:46.673
18	0x0	50	17433397	209.0664	-4.44822	57.82687	1.016863	12.42833	-1.12985	16:24:46.675
19	0x0	51	17433414	204.6181	0	53.37864	1.016863	12.42833	-1.24283	16:24:46.678
20	0x0	52	17433431	209.0664	0	57.82687	0.903878	12.54131	-1.12985	16:24:46.680
21	0x0	53	17433448	209.0664	0	62.27509	1.016863	12.54131	-1.12985	16:24:46.683
22	0x0	54	17433465	209.0664	0	62.27509	1.016863	12.65429	-1.12985	16:24:46.685
23	0x0	55	17433482	213.5146	4.44822	62.27509	1.016863	12.65429	-1.12985	16:24:46.688
24	0x0	56	17433499	213.5146	0	66.7233	1.129848	12.54131	-1.01686	16:24:46.690
25	0x0	57	17433516	209.0664	0	57.82687	1.016863	12.42833	-1.12985	16:24:46.692

DataValues

7.3 Data Collection Settings

Data Collection – Data collection can be turned ON or OFF if desired.

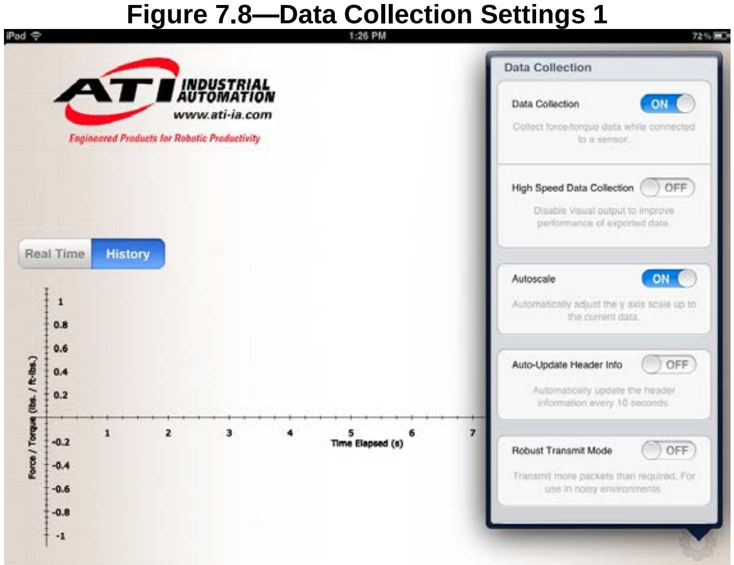
High Speed Data Collection – When high speed data collection is turned on the visual output is disabled. Use this function when only interested in collecting F/T data reading and not monitoring the transducer.

Autoscale - The autoscale function can be turned ON or OFF. The autoscale function adjusts the waveform line graph to capture the current minimum and maximum reading from the transducer.

Auto-Update Header Info – Automatically updates the header information every 10 seconds.

Robust Transmit Mode – Transmitts more packets than required. For use on noisy networks where packet loss occurs frequently.

Figure 7.8—Data Collection Settings 1



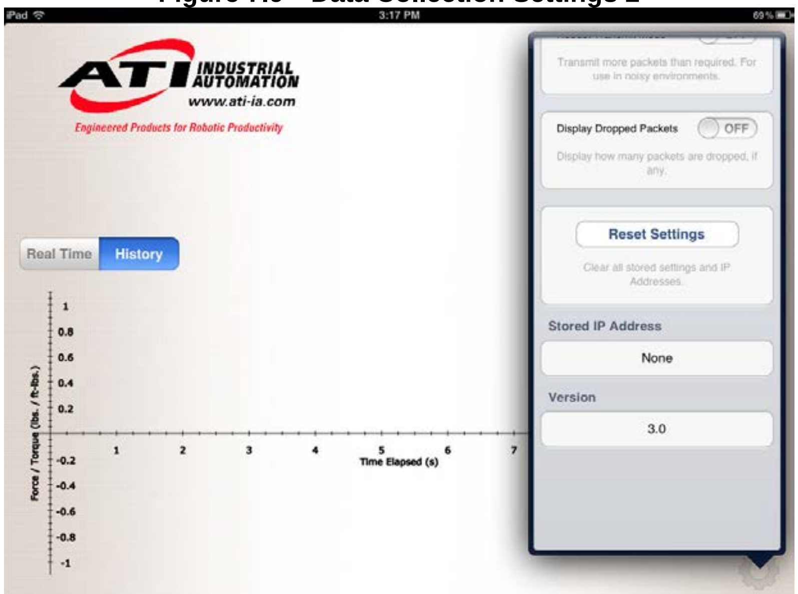
Display Dropped Packets – Displays how many packets are dropped.

Reset Settings – Clears all stored settings and IP addresses.

Stored IP Address – Displays the stored IP address.

Version – Displays the Net F/T iPad application software version.

Figure 7.9—Data Collection Settings 2



8. 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.

8.1 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 colspan="3">Table 8.1—setting.cgi Variables</th></tr>
<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>

8.2 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.

<table>
<tr><th colspan="3">Table 8.2—moncon.cgi Variables</th></tr>
<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>

8.3 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.

Table 8.3—config.cgi Variables		
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 colspan="3">Table 8.3—config.cgi Variables</th></tr>
<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>Nm</td></tr>
<tr><td>4</td><td>Newton-millimeter</td><td>Nmm</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>kNm</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</td></tr>
<tr><td>2</td><td>foot</td><td>ft</td></tr>
<tr><td>3</td><td>millimeter</td><td>mm</td></tr>
<tr><td>4</td><td>centimeter</td><td>cm</td></tr>
<tr><td>5</td><td>meter</td><td>m</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>

Table 8.3—config.cgi Variables		
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.

8.4 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 colspan="3">Table 8.4—comm.cgi Variables</th></tr>
<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. Basic CAN protocol must be selected when EtherNet/IP protocol is enabled.</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>EtherNet/IP protocol must be disabled when DeviceNet protocol is selected.</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 4.8–Communications Settings Page (comm.htm) 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>

9. 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:

Table 9.1—Types Used by XML Elements	
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)

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.

9.1 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 9.2— 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 8–Common Gateway Interface (CGI)* for related information.

Table 9.2—XML Elements in netftapi2.xml			
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
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

<table>
<tr><th colspan="4">Table 9.2—XML Elements in netftapi2.xml</th></tr>
<tr><th>XML Element</th><th>Data Type</th><th>Description</th><th>Reference</th></tr>
<tr><td>cfgusra</td><td>STRING16</td><td>User-defined field #1 for the active configuration</td><td>config</td></tr>
<tr><td>cfgusrb</td><td>STRING16</td><td>User-defined field #2 for the active configuration</td><td>config</td></tr>
<tr><td>comnetdhcp</td><td>ENABL</td><td>DHCP behavior setting</td><td>comm</td></tr>
<tr><td>comnetip</td><td>STRING15</td><td>Static IP address</td><td>comm</td></tr>
<tr><td>comnetmsk</td><td>STRING15</td><td>Static IP subnet mask</td><td>comm</td></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>

9.2 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*.

Table 9.3—XML Elements in netftcalapi.xml

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

10. 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.

NOTICE: Multi-byte values must be transferred to the network high byte first and with the correct number of bytes. Some compilers align structures to large field sizes, such as 32- or 64-bit fields, and send an incorrect number of bytes. C compilers usually provide the functions *htons(), htonl(), ntohs(),* and *ntohl()* that can automatically handle these issues.

10.1 RDT Protocol

There are six commands in the RDT protocol. These are listed in *Table 10.1—RDT Commands*. Any command received by the Net F/T will take precedence over any previously-received commands.

Table 10.1—RDT 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

The three streaming modes are further described in *Table 10.2—Streaming Modes*.

Table 10.2—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 4.8—Communications Settings Page (comm..htm).*
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.

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 10.1*—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—Communication Settings Page (comm.htm)* for a description of RDT Buffer Size.

10.2 Extended RDT Requests

Extended RDT requests have the following structure:

```
{
uint16 hdr  ;       /* Always set to 0x1234 */
uint16 cmd  ;       /* The command code, with high bit set to '1'. */
uint32 count;       /* The number of samples to send in response. */
uint32 ipaddr_dest; /* The ip address to send the response to. */
uint16 port_dest;   /* The port to send the response to. */
}
```

The extended RDT request format is used when you want the Net F/T to send the UDP F/T data to a different IP address than the IP address the request comes from. This is useful, for example, if you wish to have the Net F/T stream data to a multicast address so multiple clients can receive the stream at once.

The command codes used in the Extended RDT format are the same as the command codes in normal RDT requests, except that the high bit is set to a '1'. For example, the command code 2, for high-speed streaming, is changed to 0x8002 for use with the Extended RDT request packet structure.

```
For example, to request high speed streaming to the multicast address
224.0.5.128, port 28250, you would send a UDP packet with the following
data:
```

```
{ 0x12, 0x34, 0x80, 0x02, 0x00, 0x00, 0x00, 0x00, 224, 0, 5, 128, 0x6e, 0x5a };
```

Your clients can then subscribe to the UDP multicast IP address 224.0.5.128, and receive the streaming data on port 28250. Consult your client system's documentation for information on how to subscribe to a multicast IP address.

10.3 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 9.1—System and Configuration Information (netftapi2.xml).*

10.4 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.

10.5 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.)

10.6 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 rollover 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 17.1—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 28□s.

The Net F/T only supports one UDP connection at a time.

10.7 Example Code

Example C code can be found on the ATI website at http://www.ati-ia.com/Products /ft/software/net_ft_software.aspx and on the product CD.

11. TCP Interface

11.1 General

The TCP interface listens on TCP port 49151. All commands are 20 bytes in length. All responses begin with the two byte header 0x12, 0x34.

11.2 Command Codes

```
READFT          =     0,     /* Read F/T values. */
READCALINFO     =     1,     /* Read calibration info. */
WRITETRANSFORM  =     2,     /* Write tool transformation. */
WRITETHRESHOLD  =     3,     /* Write monitor condition. */
```

11.3 Read F/T Command

```
{
uint8       command;         /* Must be READFT (0) . */
uint8       reserved[15];    /* Should be all 0s. */
uint16      MCEnable;        /* Bitmap of MCs to enable. */
uint16      sysCommands;     /* Bitmap of system commands. */
}
```

Each bit position 0-15 in MCEnable corresponds to the monitor condition at that index. If the bit is a ‘1’, that monitor condition is enabled. If the bit is a ‘0’, that monitor condition is disabled.

Bit 0 of sysCommands controls the Bias. If bit 0 is a ‘1’, the system is biased. If bit 0 is a ‘0’, no action is taken.

Bit 1 of sysCommands controls the monitor condition latch. If bit 1 is a ‘1’, the monitor condition latch is cleared, and monitor condition evaluation begins again. If bit 1 is a ‘0’, no action is taken.

11.4 Read F/T Response

```
{
   uint16 header;      /* always 0x1234. */
   uint16 status;      /* Upper 16 bits of status code. */
   uint16 ForceX;      /* 16-bit Force X counts. */
   uint16 ForceY;      /* 16-bit Force Y counts. */
   uint16 ForceZ;      /* 16-bit Force Z counts. */
   uint16 TorqueX;     /* 16-bit Torque X counts. */
   uint16 TorqueY;     /* 16-bit Torque Y counts. */
   uint16 TorqueZ;     /* 16-bit Torque Z counts. */
}
```

The status code is the upper 16 bits of the 32-bit status code described in the Net F/T user manual.

The force and torque values in the response are equal to (actual ft value * calibration counts per unit / 16-bit scaling factor). The counts per unit and scaling factor are read using the read calibration information command.

11.5 Read Calibration Info Command

```
{
   uint8 command;          /* Must be READCALINFO (1). */
   uint8 reserved[19];     /* Should be all 0s. */
}
```

11.6 Read Calibration Info Response

```
{
   uint16 header;          /* always 0x1234. */
   uint8  forceUnits;      /* Force Units. */
   uint8  torqueUnits;     /* Torque Units. */
   uint32 countsPerForce;  /* Calibration Counts per force unit. */
   uint32 countsPerTorque; /* Calibration Counts per torque unit. */
   uint16 scaleFactors[6]; /* Further scaling for 16-bit counts. */
}
```

The force unit codes are:

1: Pound
2: Newton
3: Kilopound
4: Kilonewton
5: Kilogram
6: Gram

The torque unit codes are:

1: Pound-inch
2: Pound-foot
3: Newton-meter
4: Newton-millimeter
5: Kilogram-centimeter
6: Kilonewton-meter

11.7 Write Tool Transform Command

```
{
   uint8 command;             /* Must be WRITETRANSFORM (2). */
   uint8 transformDistUnits;  /* Units of dx,dy,dz */
   uint8 transformAngleUnits; /* Units of rx,ry,rz */
   int16 transform[6];        /* dx, dy, dz, rx, ry, rz */
   uint8 reserved[5];         /* Should be all zeroes. */
}
```

The ‘transform’ elements are multiplied by 100 to provide good granularity with integer numbers.

The distance unit codes are:

1: Inch
2: Foot
3: Millimeter
4: Centimeter
5: Meter

The angle unit codes are:

1: Degrees
2: Radians.

The response is a standard Write Response.

11.8 Write Monitor Condition Command

```
{
   uint8 command;             /* Must be WRITETHRESHOLD. */
   uint8 index;               /* Index of monitor condition. 0-31. */
   uint8 axis;                /* 0 = fx, 1 = fy, 2 = fz, 3 = tx, 4 = ty,
                              5 = tz. */
   uint8 outputCode;          /* Output code of monitor condition. */
   int8  comparison;          /* Comparison code.  1 for "greater than"
                              (>), -1    for "less than" (<). */
   int16 compareValue;        /* Comparison value, divided by 16 bit
                              Scaling factor. */
}
```

The response is a standard Write Response.

11.9 Write Response

```
{
   uint16 header;              /* Always 0x1234. */
   uint8  commandEcho;         /* Echoes command. */
   uint8  status;              /* 0 if successful, nonzero if not. */
}
```

12. EtherNet/IP Operation

12.1 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. It supports one input-only connection and does not support a listen-only connection. 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.

Table 12.1—Class 1 Connection Information Parameters

	Instance	Size (bytes)	RT Transfer Format	Connection Type
Configuration	128	0	n/a	n/a
Input *(Target to Originator)*	100	28	Modeless	Point-to-Point
Output *(Originator to Target)* Ethernet/IP O2T Data Disabled	102	0	Modeless	Point-to-Point
Output *(Originator to Target)* Ethernet/IP O2T Data Disabled	102	4	Run/Idle	Point-to-Point

12.2 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 3.17—Status LEDs* and *Table 3.4—Standard Net Box Status LED Descriptions* for an outline of the LED operation.

13. DeviceNet-Compatibility Mode Operation

13.1 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 14—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.

13.2 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 3.10.2—Node Address* and *Table 3.2—DeviceNet MAC ID Address Switch Settings.* The factory set MAC ID is 54.

13.3 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 3.10.3—Baud Rate* and *Table 3.3—Baud Rate Switch Settings*. The factory set baud rate is 500Kbps.

13.4 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 3.17—Status LEDs* and *Table 3.4—Standard Net Box Status LED Descriptions* for an outline of the LED operation.

13.5 EDS File

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

14. EtherNet/IP and DeviceNet CIP Model

14.1 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.

EtherNet/IP and DeviceNet protocols cannot be enabled at the same time.

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

Table 14.1—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)

Table 14.2—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)

There is no output data if the Ethernet/IP O2T Data option on the Communications page (Section 4.8) is disabled.

Table 14.3—Ethernet/IP Output Mapping

Byte	Bit	Name	Description/Function
0	0	Bias	Perform tare function to zero out any load reading
	1	Reset Latch	Reset threshold latch
	2	reserved	
	3	reserved	
	4	reserved	
	5	reserved	
	6	reserved	
	7	reserved	
1	0	Config Select bit 0	Selects a Net F/T configuration, from 0 to 15
	1	Config Select bit 1	
	2	Config Select bit 2	
	3	Config Select bit 3	
	4	reserved	
	5	reserved	
	6	reserved	
	7	reserved	
2	0-7	Threshold high	Threshold enable mask, high byte
3	0-7	Threshold low	Threshold enable mask, low byte

14.2 Calculating F/T Values for CIP

14.2.1 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.

14.2.2 DeviceNet

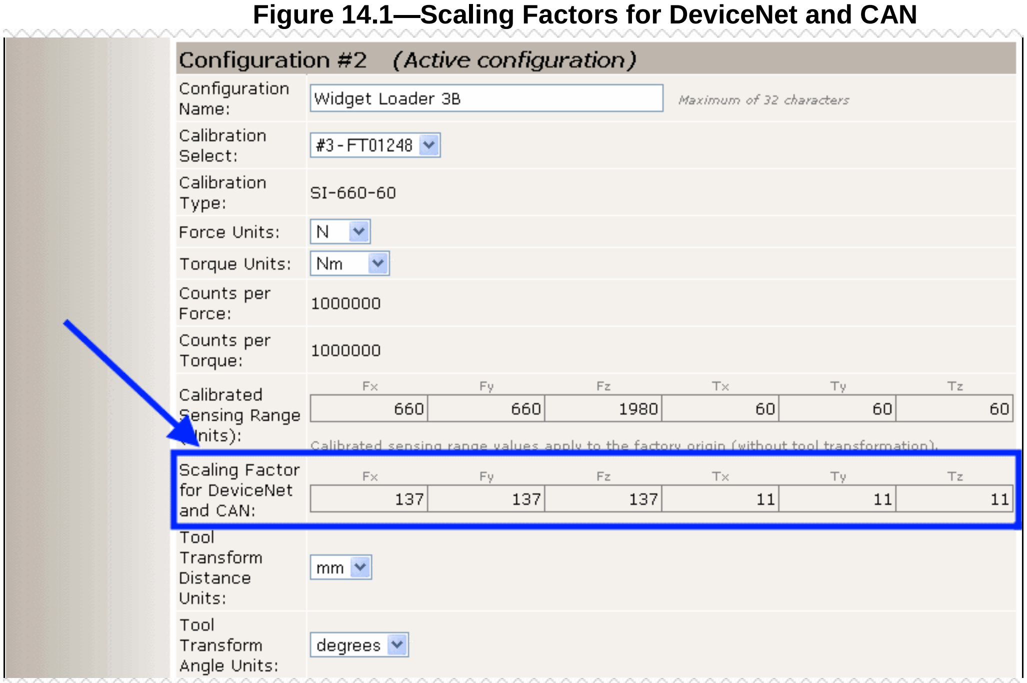
In order to reduce the amount of data transmitted over DeviceNet, the force and torque values are reduced to 16 bits using the *Scaling Factor for DeviceNet and CAN* values (*Figure 14.1—Scaling Factors for DeviceNet and CAN*) before they are transmitted.

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.

NOTICE: Be sure to use the scaling factors from the appropriate configuration. This is usually the active configuration.

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 14.1—Scaling Factors for DeviceNet and CAN



14.3 Object Model

14.3.1 Data Types

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

Table 14.4—Data Types	
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)

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

Table 14.5—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.

Table 14.6—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.

Table 14.7—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.

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

Table 14.8—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
3	Number of Instances	UINT	6	Get

Table 14.9—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.

Table 14.10—Common Services			
Service Codes	**Implemented for**		**Service Name**
	Class Level	**Instance Level**	
0x0E	Yes	Yes	Get_Attribute_Single
0x10	No	Yes	Set_Attribute_Single

14.3.4 Thresholding Output Object (0x66—1 Instance)

Table 14.11—Class Attributes (Instance 0)				
Attribute ID	**Name**	**Data Type**	**Default Data Value**	**Access Rule**
1	Revision	UINT	1	Get

Table 14.12—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*.

Table 14.13—Common Services			
Service Codes	**Implemented for**		**Service Name**
	Class Level	**Instance Level**	
0x0E	Yes	Yes	Get_Attribute_Single
0x10	No	Yes	Set_Attribute_Single

14.3.5 System Status Object (0x67—1 Instance)

Table 14.14—Class Attributes (Instance 0)				
Attribute ID	**Name**	**Data Type**	**Default Data Value**	**Access Rule**
1	Revision	UINT	1	Get

Table 14.15—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.

Table 14.16—Common Services			
Service Codes	**Implemented for**		**Service Name**
	Class Level	**Instance Level**	
0x0E	Yes	Yes	Get_Attribute_Single

14.3.6 Configurations Object (0x71—16 Instances)

Table 14.17—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

Table 14.18—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

Table 14.18—Instance Attributes (Instance 1–16)				
Attribute ID	**Name**	**Data Type**	**Default Data Value**	**Access Rule**
15	User Counts per Unit Torque	UINT	N/A	Get
16	User Max Rating – Fx	REAL	N/A	Get
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.

Table 14.19—Common Services			
Service Codes	**Implemented for**		**Service Name**
	Class Level	**Instance Level**	
0x0E	Yes	Yes	Get_Attribute_Single
0x10	No	Yes	Set_Attribute_Single

14.3.7 Settings Object (0x72—1 Instance)

Table 14.20—Class Attributes (Instance 0)				
Attribute ID	**Name**	**Data Type**	**Default Data Value**	**Access Rule**
1	Revision	UINT	1	Get

Table 14.21—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

Table 14.22—Common Services			
Service Codes	**Implemented for**		**Service Name**
	Class Level	**Instance Level**	
0x0E	Yes	Yes	Get_Attribute_Single
0x10	No	Yes	Set_Attribute_Single

14.3.8 Thresholding Settings Object (0x73—32 Instances)

Table 14.23—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

Table 14.24—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.

Table 14.25—Common Services

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

15. CAN Bus Operation

15.1 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 3.10—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.

15.2 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.

15.3 Base Address and Communication Format

The CAN Bus base address is set by DIP switches 1 through 6. For more information refer to *Section 3.10.2—Node Address* and *Table 3.1—CAN Bus Base Address Switch Settings.* The factory set base address is 432.

Table 15.1—Request Long Data

Message to Net F/T	Response from Net F/T	CAN Identifier	Data length in bytes	1^{st}–4^{th} data bytes	5^{th}–8^{th} data bytes	Comment
Request Long Data		Base Address	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	Base Address +1	8	Fx value (DINT)	Tx value (DINT)	X-axis force and torque values in long format
	Fy and Ty data	Base Address +2	8	Fy value (DINT)	Ty value (DINT)	Y-axis force and torque values in long format.
	Fz and Tz data	Base Address +3	8	Fz value (DINT)	Tz value (DINT)	Z-axis force and torque values in long format.
	Status and sample number	Base Address +4	8	system status (DINT)	sample number (DINT)	System status word and sample number in long format.

Table 15.2—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		Base Address	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	Base Address +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	Base Address +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.

Table 15.3—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		Base Address	1	0x04 (BYTE)	N/A	Zeros the force and torque readings at the current loading level.

Table 15.4—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		Base Address	1	0x08 (BYTE)	N/A	Clears the threshold latch so it can respond to subsequent conditions.

15.4 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 3.10.3—Baud Rate* and *Table 3.3—Baud Rate Switch Settings*. The factory set baud rate is 500Kbps.

15.5 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 *Table 14.1—DeviceNet Input Bitmap* for 16-bit data handling and *Table 14.2—EtherNet/IP Input Bitmap* for 32-bit data handling.

16. Fieldbus Operation

Operational information about the additional fieldbus included in some Net Boxes is described below.

16.1 PROFINET Fieldbus Interface

A Net Box with the -PN option provides a PROFINET interface for access to the F/T data and for control of certain functions. The standard EtherNet/IP and DeviceNet interfaces may be used simultaneously while using the PROFINET interface.

Although the Net Box's PROFINET interface shares the standard Ethernet port, it has its own MAC address and IP address. The fieldbus's MAC address is shown as *MAC ID 2* on the connector side of the Net Box.

NOTICE: The PROFINET interface does not support DHCP. The Net Box's GSDML file details the PROFINET capabilities of the Net Box.

Unlike the Net F/T's other interfaces to tool transformations, the TCP interface uses scaled integer values to define distances and rotations.

The following table lists the PROFINET interface parameters employed in the –PN Net Box:

Table 16.1—PROFINET Interface Parameters

Parameter	Description
DCP	supported
Used Protocols (subset)	UDP, IP, ARP, ICMP (Ping)
Topology recognition	LLDP, SNMP V1, MIB2, physical device
VLAN- and priority tagging	yes
Context Management	by CL-RPC
Minimum cycle time	2ms
Minimum F/T data update rate	20Hz
Baud rate	100 MBit/s
Data transport layer	Ethernet II, IEEE 802.3

A GSDML file is available for the ATI website at http://www.ati-ia.com/Products/ft/software/net_ft_software.aspx or can be requested via email at info@ati-ia.com. The ATI part number for the GSDML file is 9031-05-1021 and has the description "Net F/T PROFINET GSDML.file."

16.1.1 Enabling the PROFINET Interface

The PROFINET fieldbus interface can be enabled and disabled using the *Communications* web page. See the *Fieldbus Module Settings* portion of *Section 4.8—Communication Settings Page (comm.htm)* for details.

Table 16.2—Input Mapping			
16-bit Word	**Data Type**	**Name**	**Description/Function**
0	INT	Status	Status word, bits 16 through 31
1	INT	Fx	Force in X-direction, 16-bit format
2	INT	Fy	Force in Y-direction, 16-bit format
3	INT	Fz	Force in Z-direction, 16-bit format
4	INT	Tx	Torque about X-axis, 16-bit format
5	INT	Ty	Torque about Y-axis, 16-bit format
6	INT	Tz	Torque about Z-axis, 16-bit format
7	UINT	Sequence	Incremented each time a dataset is sent

Input word 0, *Status*, contains bits 16 through 31 of the Net F/T's System Status Code. See *Section 18.2—System Status Code* for more details on the contents.

Input words 1–6 contain values representing force and torque vectors Fx, Fy, Fz, Tx, Ty, and Tz. In order to reduce the amount of data transmitted over PROFINET, they are reduced to 16 bits using the *Scaling Factor for DeviceNet and CAN* values (see *Figure 14.1—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).*

Table 16.3—Output Mapping			
Byte	**Bit**	**Name**	**Description/Function**
0	0	Bias	Perform tare function to zero out any load reading
	1	Reset Latch	Reset threshold latch
	2	reserved	
	3	reserved	
	4	reserved	
	5	reserved	
	6	reserved	
	7	reserved	
1	0	Config Select bit 0	Selects a Net F/T configuration, from 0 to 15
	1	Config Select bit 1	
	2	Config Select bit 2	
	3	Config Select bit 3	
	4	reserved	
	5	reserved	
	6	reserved	
	7	reserved	
2	0-7	Threshold high	Threshold enable mask, high byte
3	0-7	Threshold low	Threshold enable mask, low byte

Output byte 0, bit 0 performs a bias function when it is set to one. See the bias button information in *Section 4.3—Snapshot Page (rundata.htm)* for details on this function. Bit 0 should be set to one for at least 100ms to ensure the bias is executed. Then it should be returned to zero.

Output byte 0, bit 1 performs a reset threshold latch function when it is set to one. See the reset latch button information in *Section 4.6—Thresholding Page (moncon.htm)* for details on this function. Bit 1 should be set to one for at least 100ms to ensure a reset latch is executed. Then it should be returned to zero.

Output byte 0, bits 2–7 are reserved and should not be used.

Output byte 1, bits 0–3 select the active configuration (0 through 15) to be used. There is a delay of up to one second before the newly-selected configuration becomes usable. During the change of configuration s, the Net F/T does not supply valid force and torque data. See the active configuration information in *Section 4.5—Settings Page (setting.htm)* for details on active configuration.

Output byte 1, bits 4–7 are reserved and should not be used.

Output bytes 2 and 3 form a 16-bit threshold enable mask that enables and disables threshold conditions. Each bit, 0–15, of the threshold enable mask maps directly to its corresponding threshold condition number *N*. A value of one enables the corresponding condition while a value of zero disables the condition. See *Section 4.6—Thresholding Page (moncon.htm)* for more information on thresholding.

NOTICE: When Fieldbus Module Enabled is set to Enabled (on the Communications Settings page), active configuration selection and thresholding statement selection is controlled by the PROFINET output data. While enabled, these values are not controlled by Net Box web pages or CGI interface.

16.1.2 Communications CGI (comm.cgi) Options

The PROFINET Fieldbus Net Box can have the PROFINET function enabled and disabled via CGI. The following function is available in the comm.cgi in addition to those shown in *Table 8.4—comm.cgi Variables:*

Table 16.4—Additional comm.cgi Variable		
Variable Name	**Allowed Values**	**Description**
fieldbusenabled	Integers: 0 or 1	Enable (value=1) or disable (value=0) the PROFINET fieldbus interface.

16.1.3 XML Page Elements

The PROFINET Fieldbus Net Box has two additional XML elements included in the netftapi2.xml page output. The following elements are available in the netftapi2.xml page in addition to those shown in *Table 9.2—XML Elements in netftapi2.xml*:

Table 16.5—Additional netftapi2.xml XML Elements			
XML Element	**Data Type**	**Description**	**Reference**
fieldbusenabled	ENABL	PROFINET interface setting	comm
fieldbusfirmware	STRING64	PROFINET interface firmware version	comm

16.1.4 Returning Default Settings

The PROFINET Station Name and the PROFINET IP address can be cleared to default settings. This is useful when already-configured devices need to be moved or replaced in the PROFINET network. To return the PROFINET fieldbus Net Box to default PROFINET settings, the power must be on and the fieldbus module must already be enabled (see *Section 4.8—Communication Settings Page (comm.htm)).* The PROFINET network connection should be disconnected to ensure the Net Box does not automatically get recommissioned. The steps are:

1. Remove the Net Box cover (see *Section 3.10—DIP Switches and Termination Resistor).*
2. Move DIP switch 10 to the ON position.
3. Once the MS LED is blinking red, return DIP switch 10 to the OFF position.
4. Replace the Net Box cover.
5. Disconnect power. The PROFINET Station Name and IP address will be reset when power is reapplied.

NOTICE: Returning to the PROFINET default settings does not affect the standard Ethernet and EtherNet/IP settings.

16.1.5 Replacing and Installed PROFINET Fieldbus Net Box

Replacing an installed PROFINET Fieldbus Net Box can easily be done if the Topology of the PROFINET network was properly defined with the PROFIN
ET engineering tool and the PROFINET controller supports automatic device replacement.

16.1.5.1 Replacement with an Uncommissioned Fieldbus Net Box

1. Remove the power and network connections of the PROFINET Fieldbus Net Box that is to be replaced. Mechanically unmount the Net Box if necessary.
2. Mount the replacement PROFINET Fieldbus Net Box and connect the power and PROFINET network connections to it.
3. The new Net Box will automatically be assigned the name and IP address of the former Net Box.

4. After a few seconds, the *NS/BF* LED will turn solid green and the Net Box will be correctly operating on the network.

16.1.5.2 Replacement with Previously Commissioned Fieldbus Net Box

1. Remove the power and network connections of the PROFINET Fieldbus Net Box that is to be replaced. Mechanically unmount the Net Box if necessary.
2. Mount the replacement PROFINET Fieldbus Net Box and connect the power to it. **Do not make the network connection.**
3. Follow the steps in *Section 16.1.4—Returning Default Settings* to remove the previous commission.
4. Connect the PROFINET Fieldbus Net Box to the PROFINET network.
5. The new Net Box will automatically be assigned the name and IP address of the former Net Box.
6. After a few seconds, the *NS/BF* LED will turn solid green and the Net Box will be correctly operating on the network.

17. Advanced Topics

17.1 Improving Ethernet Throughput

In an optimum network setup, the Net F/T's 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:

17.1.1 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.

17.1.2 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.

17.1.3 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.

17.1.4 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.

17.1.5 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.

17.2 Reducing Noise

17.2.1 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.

17.2.2 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.

17.3 Detecting Failures (Diagnostics)

17.3.1 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).

17.4 Scheduled Maintenance

17.4.1 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 17.3—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.

17.5 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*).

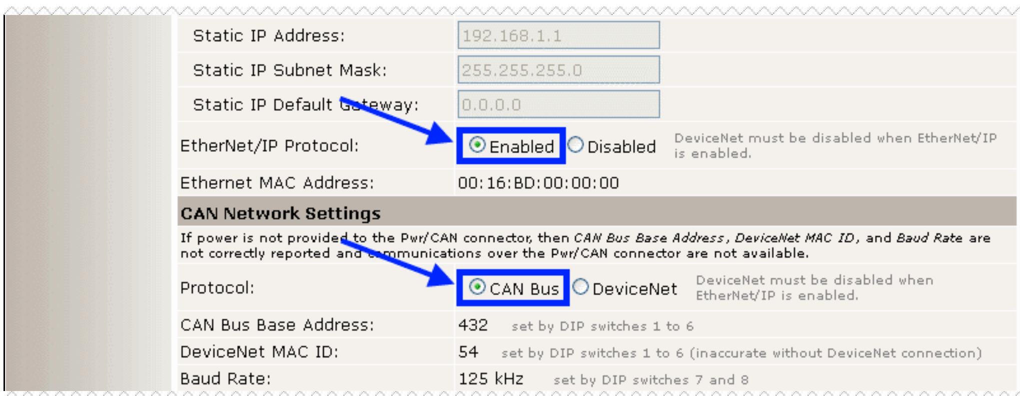
The resolution of each transducer axis depends on how the applied load is spread among the sensing beams. The best resolution occurs in the scenario when the quantization of the gages is evenly distributed as load is applied. In the worst case scenario, the discrete value of all involved gages increases 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.

17.6 Connecting to Specific Industrial Robots

Many industrial robots connect to the Net F/T over its EtherNet/IP connection. When connecting to the Net F/T using EtherNet/IP, the Net F/T's EtherNet/IP protocol must be enabled and its DeviceNet protocol must be disabled (by enabling CAN bus protocol). This can be done on the Net F/T's Communications page (comm.htm).

Figure 17.1—Enabling EtherNet/IP on the Communications Page (comm.htm)



The following information will be necessary to configure the connection to the Net F/T:

Table 17.1—Net F/T EtherNet/IP Configuration Information

Item	Decimal Value	Hexadecimal Value
Vendor Code	555	0x022B
Product Type	0	0x0
Product Code	1	0x1
Major Revision	1	0x1
Minor Revision	20	0x14
Configuration Instance	128	0x80
Target to Originator (input) Instance	100	0x64
Originator to Target (output) Instance	102	0x66
Input Size (bytes)	28	0x1C
Output Size (byte) *I/O Output is unused*	0	0x0

17.6.1 ABB Robotics

ABB robot controller firmware versions 5.14 and later support EtherNet/IP connections to the Net F/T.

17.6.2 Denso Robotics

Denso RC7 robot controllers with EtherNet/IP support connections to the Net F/T.

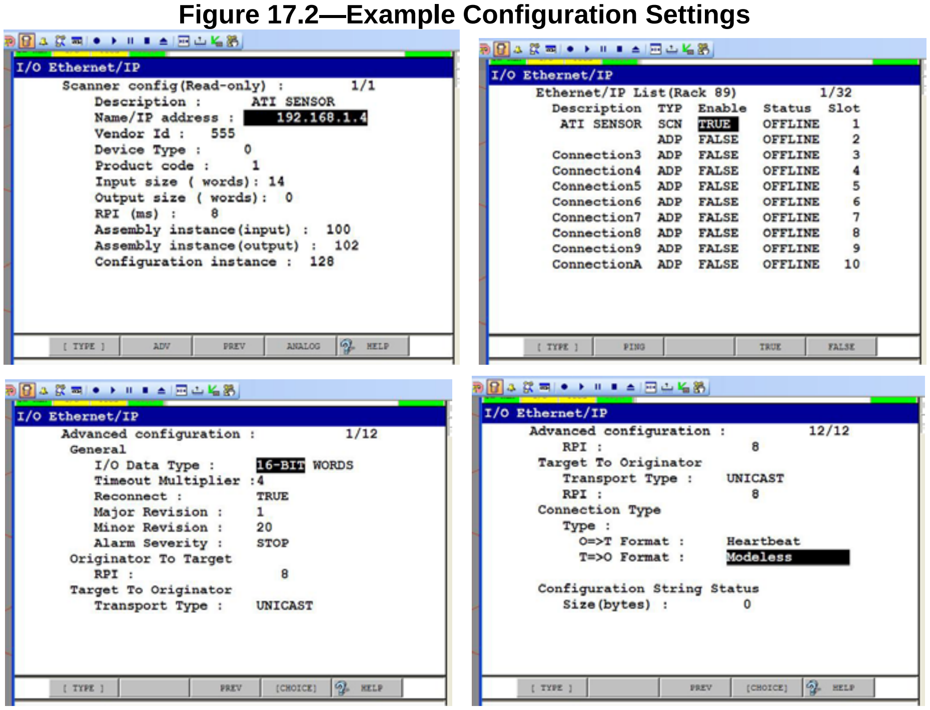
17.6.3 Fanuc Robotics

Fanuc robot controllers with an EtherNet/IP scanner installed can communicate with the Net F/T. Details about the Fanuc EtherNet/IP scanner can be found in the Fanuc manual *FANUC Robotics SYSTEM R-30iA EtherNet/IP Setup and Operations Manual MAROCENTET04081E REV B Version 7.40.*

Fanuc R30iA robot controller configuration. See *Section 4.2.4—Advanced EtherNet/IP Scanner Configuration* in the Fanuc manual for additional information:

- Set the robot as the EtherNet/IP scanner (Client).
- In the robot controller's scan list, set the *Connection Type* for the Net F/T to *Input-Only*.
- For TCP communications, set the *Transport Type* to *UNICAST* in order to use the Socket Messaging. For UDP communications, set the robot controller's *Transport Type* to *MULTICAST*.
- If the controller's word size is set to *16-BIT WORDS*, then set the input size to 14 or for *8-BIT BYTES*, then set the input size to 28. Pages 4–7 and 4–8 of the Fanuc manual discuss input and output sizes and how to set 8-bit or 16-bit words.
- The Output Run/Idle header must be turned off (set to *Heartbeat*).

Figure 17.2—Example Configuration Settings



Some Karel programming is because the Fanuc robot controller does not support the following types of data:

- DINT (Double Integer)

- EtherNet/IP data of 32 bits. Two words of 16 bits (high and low) will need to be combined to use 32 bits.
- Two's complement.

17.6.4 Kuka Robotics

Kuka robots with the KUKA.ForceTorqueControl package connect to the Net F/T and provide the robot with real-time force control.

17.6.5 Motoman Robotics

A Motoman robot controller with an EtherNet/IP add-on board is required for connections to the Net F/T.

18. Troubleshooting

18.1 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

NOTICE: Please read the F/T manuals before calling customer service. When calling, have the following information available:

6. Serial number(s).
7. Transducer type (e.g., Nano17, Gamma, Theta).
8. Calibration (e.g., US-15-50, SI-130-10).
9. An accurate and complete description of the question or problem.
10. 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.

18.2 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 16.1–System Status Code Bit Assignments describes possible errors and their bit assignments.

Table 18.1—System Status Code 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

18.3 Questions and Answers

18.3.1 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.

18.3.2 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 3.10—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.

18.3.3 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 cannot 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.

18.3.4 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.

18.3.5 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 15.2—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.

18.3.6 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.

19. General Specifications

19.1 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.

19.1.1 Storage and Operating Temperatures

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

Table 19.1—Net Box Storage and Operating Temperatures	
Storage Temperature, °C	**Operating Temperature, °C**
-40 to +100	-20 to +70

NOTICE: 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.

19.2 Transducer Data Filtering

Figure 19.1—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 19.1—Data Acquisition Subsystem Frequency Response (typical)

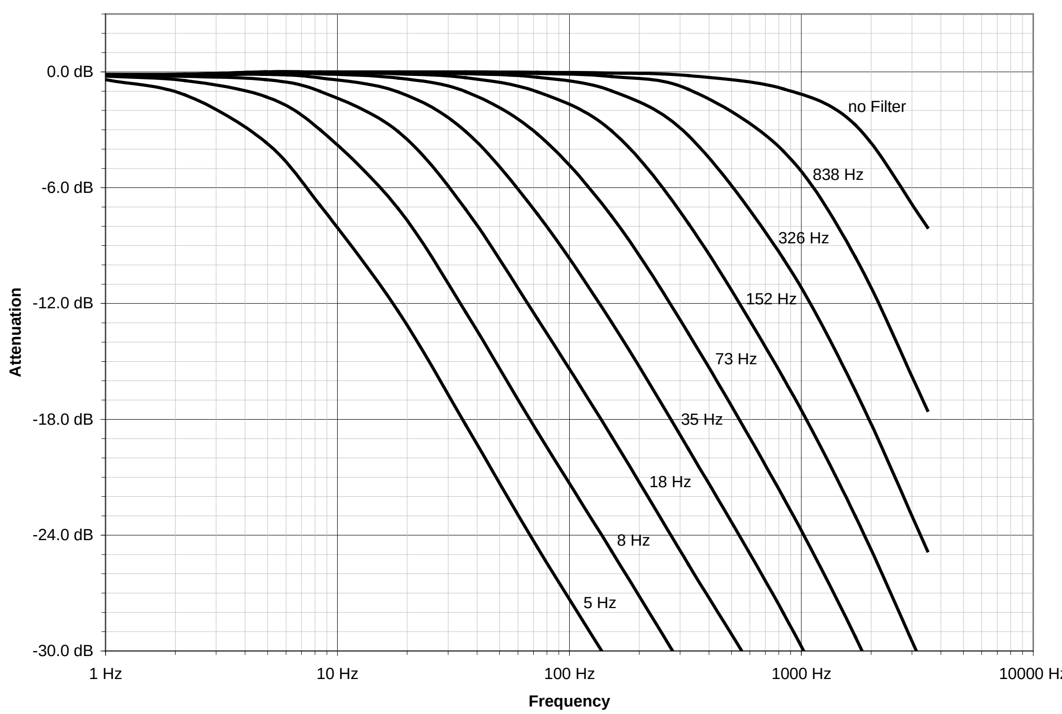
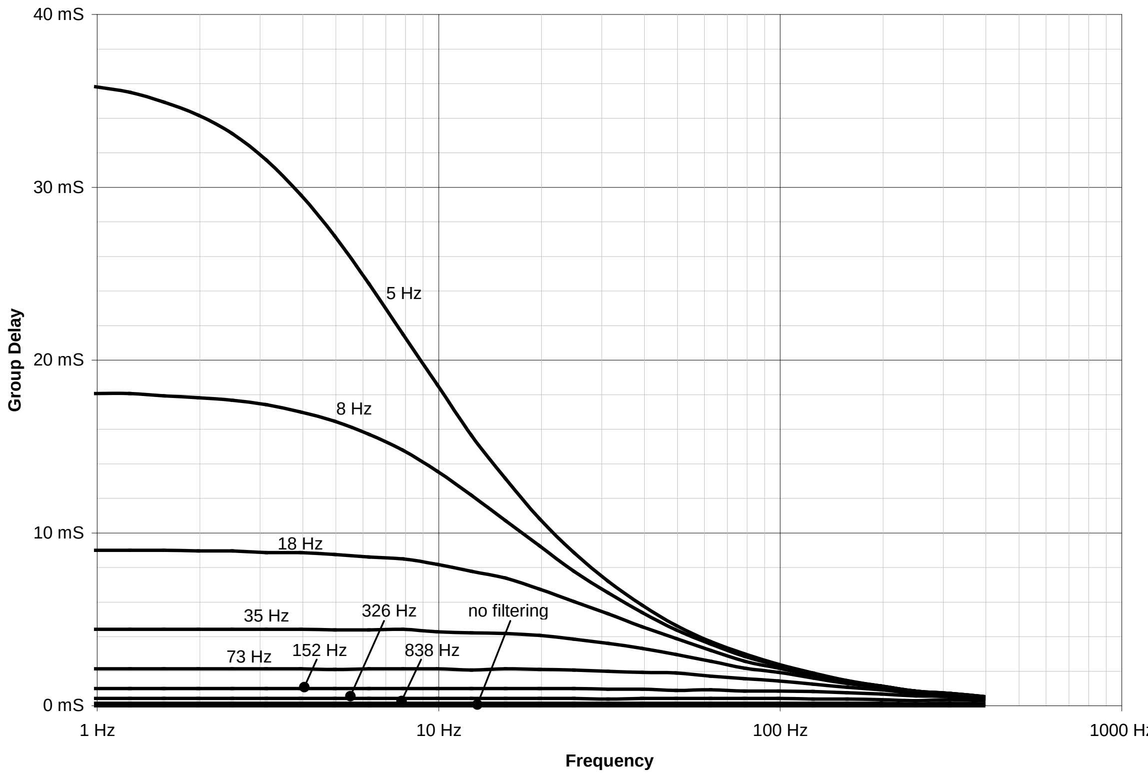


Figure 19.2—Filtering Group Delays (calculated) shows the group delays that various levels of low-pass filtering add to the signals. These delays do not show the Ethernet delays in your network or computer. With no filtering enabled, the Net F/T delivers F/T data to its Ethernet port with a delay of 286µS.

Figure 19.2—Filtering Group Delays (calculated)



19.3 Electrical Specifications

19.3.1 Power Supply

Table 19.2—Power Requirements			
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. Uses Mode A to receive power. Mode B is not supported.

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.

19.3.2 Communications

19.3.2.1 Ethernet Interface

The Ethernet interface is 10/100 Mbit and features both negotiation and auto crossover. It can support up to four TCP connections and one UDP connection.

The EtherNet/IP interface supports one input-only connection and does not support a listen-only connection. It does not support any Client functionality.

19.3.2.2 CAN Interface

The CAN interface supports 125 Kbps, 250 Kbps, and 500 Kbps (see *Section 3.10.3—Baud Rate*). A switchable termination resistor is available (see *Section 3.10.1—Termination Resistor*).

19.3.3 Mating Connectors

Table 19.3—Mechanical Specifications of Mating Connectors			
Connector	**Mating Type**	**Recommended Torque**	**Maximum Torque**
Ethernet	M12 D-Coded, 4-Pin, male	0.8 Nm to 1.0 Nm	3.0 Nm
Threshold Relay	M8 3-Pin, female	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	

19.3.4 Standard Threshold Relay

The standard threshold relay contacts (NC, NO, or COM) are protected against overload by a resettable fuse. The relay will turn on within 6ms.

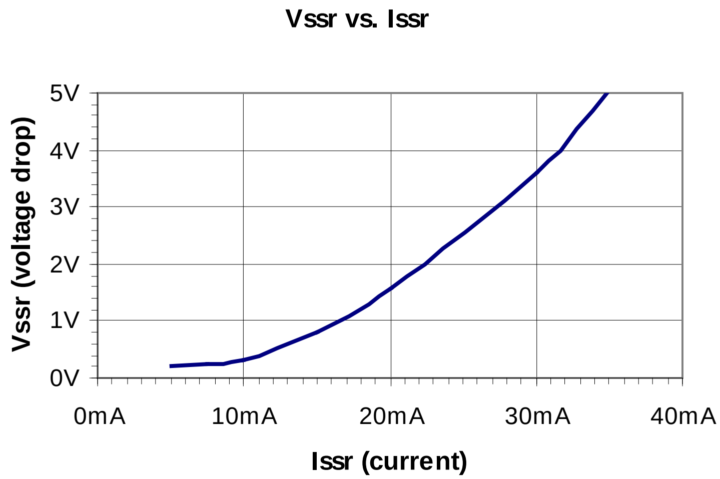
Table 19.4—Standard Threshold Relay Specifications		
	Maximum Rating	**Maximum Load**
Current	50mA	10µA
Voltage	42VDC, 30VAC	10mVDC

19.3.5 Solid-State Threshold Relay

The optional solid state threshold relay contacts (SSR+ and SSR-) are protected against reverse voltage by a zener diode. The relay will turn on within 500µs.

Table 19.5—Solid-State Relay Specifications	
	Maximum Load
Current	35mA
Voltage	30VDC

Figure 19.3—Solid-State Relay Voltage Drop vs. Current



19.3.6 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.

Figure 19.4—Netbox's Transducer Cable Connector (female Pins)

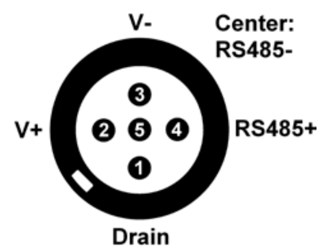
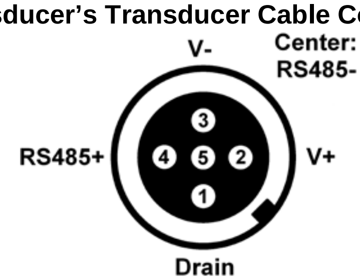


Figure 19.5—Transducer's Transducer Cable Connector (male pins)

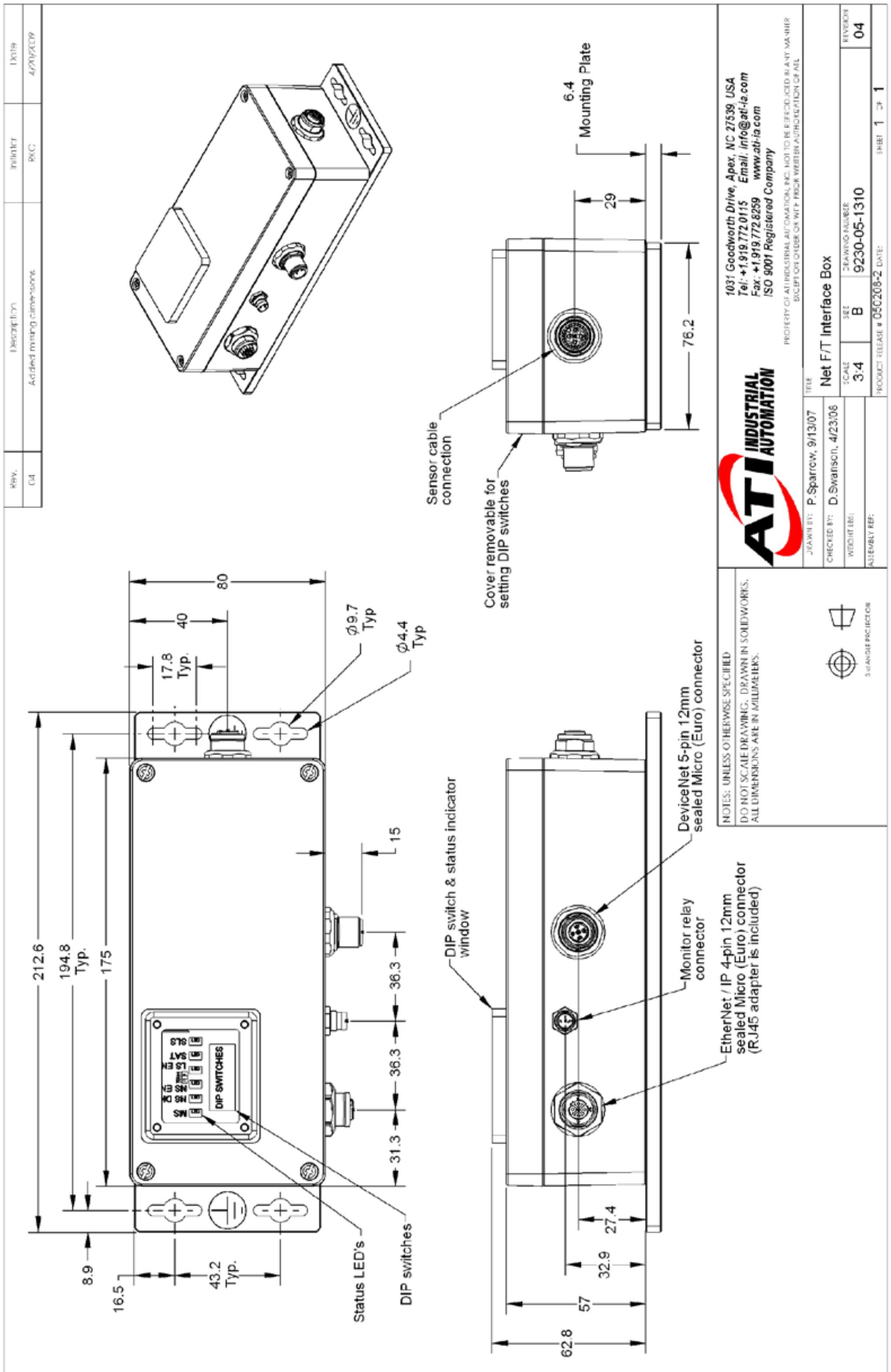


19.4 Net Box Weight

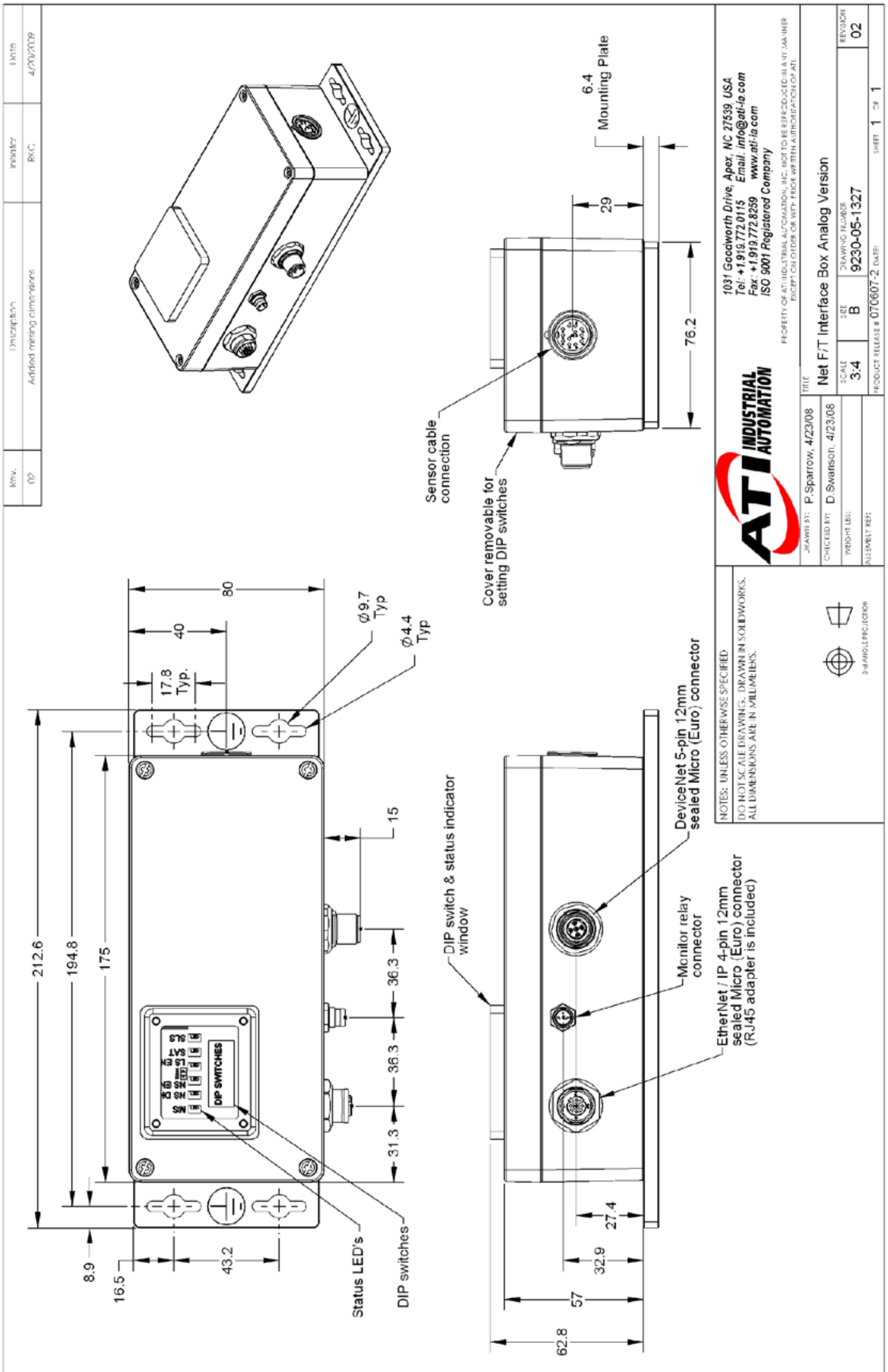
Table 19.6—Net Box Weight	
Condition	**Weight**
Without Mounting Plate	0.8 kg (1.8 lbs)
With Mounting Plate	1.1 kg (2.4 lbs)

20. Drawings

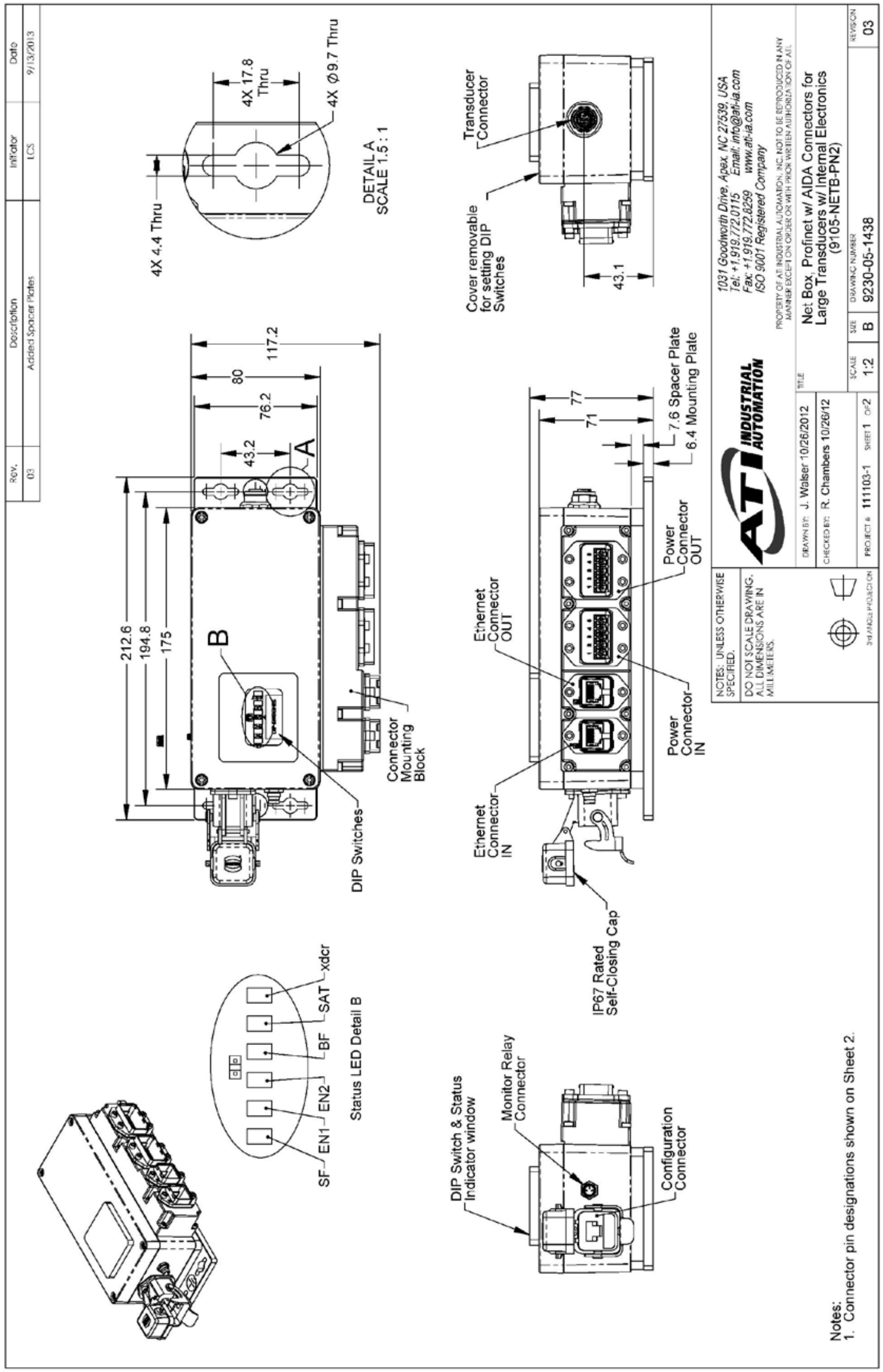
20.1 9105-NETB Drawing

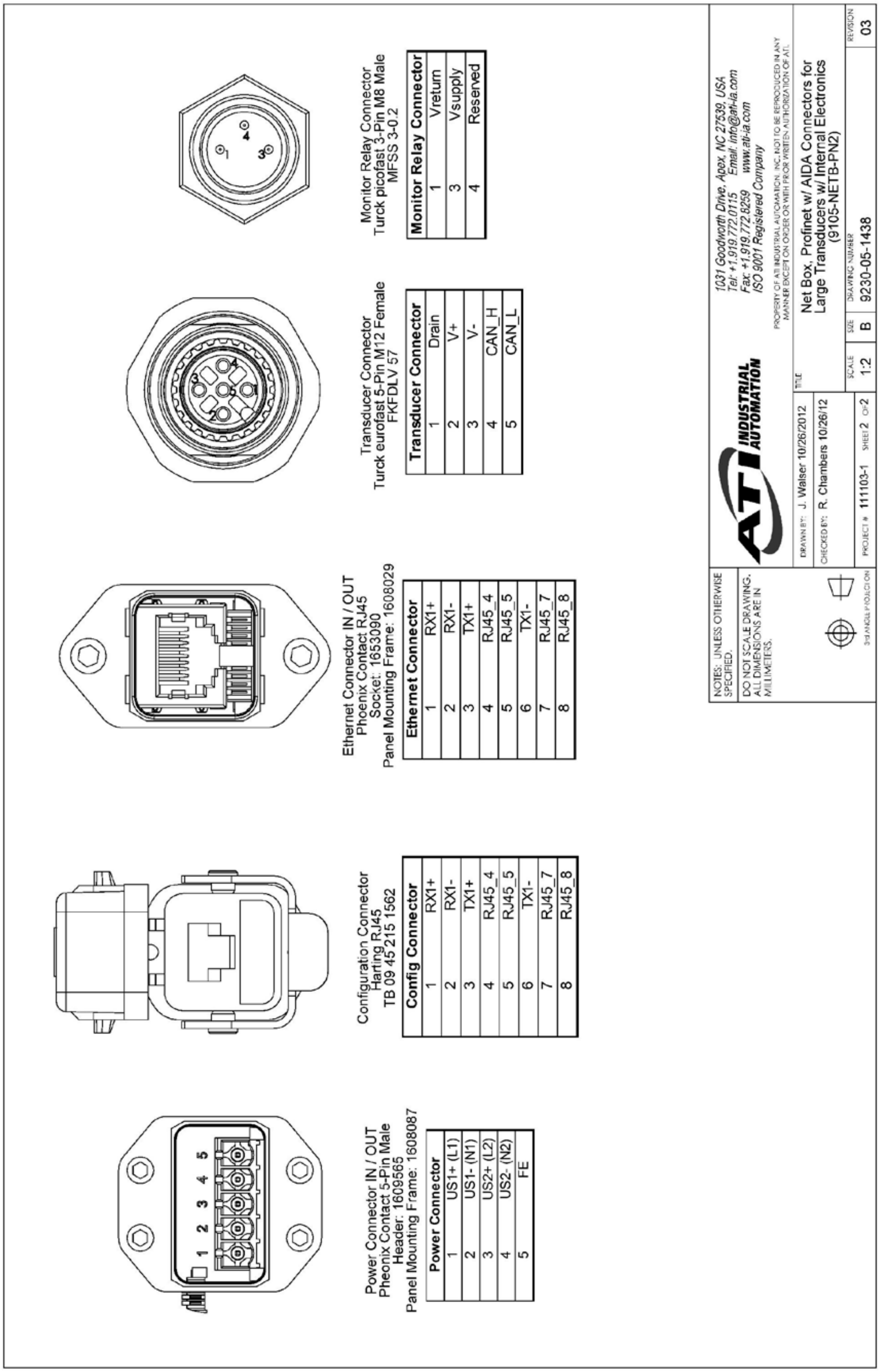


20.2 9105-NETBA Drawing



20.3 9105-NETB-PN2 Drawing




Power Connector IN / OUT
Pheonix Contact 5-Pin Male
Header: 1609565
Panel Mounting Frame: 1608087
Power Connector
1 US1+ (L1)
2 US1- (N1)
3 US2+ (L2)
4 US2- (N2)
5 FE
Configuration Connector
Harting RJ45
TB 09 45 215 1562
Config Connector
1 RX1+
2 RX1-
3 TX1+
4 RJ45_4
5 RJ45_5
6 TX1-
7 RJ45_7
8 RJ45_8
Ethernet Connector IN / OUT
Phoenix Contact RJ45
Socket: 1653090
Panel Mounting Frame: 1608029
Ethernet Connector
1 RX1+
2 RX1-
3 TX1+
4 RJ45_4
5 RJ45_5
6 TX1-
7 RJ45_7
8 RJ45_8
Transducer Connector
Turck eurofast 5-Pin M12 Female
FKFDLV 57
Transducer Connector
1 Drain
2 V+
3 V-
4 CAN_H
5 CAN_L
Monitor Relay Connector
Turck picofast 3-Pin M8 Male
MFSS 3-0.2
Monitor Relay Connector
1 Vreturn
3 Vsupply
4 Reserved
NOTES: UNLESS OTHERWISE SPECIFIED.
DO NOT SCALE DRAWING.
ALL DIMENSIONS ARE IN MILLIMETERS.
ATI INDUSTRIAL AUTOMATION
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DRAWN BY: J. Walser 10/26/2012
CHECKED BY: R. Chambers 10/26/12
TITLE Net Box, Profinet w/ AIDA Connectors for Large Transducers w/ Internal Electronics (9105-NETB-PN2)
3rd ANGLE PROJECTION
PROJECT # 111103-1
SHEET 2 OF 2
SCALE 1:2
SIZE B
DRAWING NUMBER 9230-05-1438
REVISION 03

21. Terms and Conditions of Sale

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

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

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

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

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

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

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

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

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

F/T Transducer

Six-Axis Force/Torque Sensor System

Installation and Operation Manual

Document #: 9620-05-Transducer Section
March 2016

Engineered Products for Robotic Productivity
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Foreword

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

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

FCC Compliance - Class A

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

CE Conformity CE

CTL Transducers

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

DAQ Transducers

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

Net F/T Transducers

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

TWE Transducers

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

Note

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

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

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

How to Reach Us

Sale, Service and Information about ATI products:

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

Technical support and questions:

Application Engineering
Tel: +1.919.772.0115, Option 2, Option 2
Fax: +1.919.772.8259
E-mail: *ft_support@ati-ia.com*

Table of Contents

Glossary of Terms

Accuracy	See Measurement Uncertainty.
ActiveX Component	A reusable software component for the Windows applications.
Calibration	The act of measuring a transducer's raw response to loads and creating data used in converting the response to forces and torques.
Calibration Certificate	A statement that says the equipment measures correctly. These statements usually mean the equipment has been tested against national standards. The statements are produced as a result of calibration or re-calibration.
Compound Loading	Any load that is not purely in one axis.
Coordinate Frame	See Point of Origin
DAQ	Data Acquisition device.
DAQ F/T	An F/T Sensor System that uses industry standard data acquisition fasteners (usually computer cards) to convert the transducer signals into digital data.
DoF	Degrees of Freedom. See Six Degrees of Freedom.
Force	The push or pull exerted on an object.
FS	Full-Scale
F/T	Force and Torque.
F/T Controller	The electronics that connect to mux transducers.
Fxy	The resultant force vector comprised of components Fx and Fy.
Full-Scale Error	A measurement of sensing error. For example, if the calibrated measurement range of a sensor is 100 Newtons and the sensor is accurate to within 1 Newton, that sensor will have a Full-Scale Error of 1% (1% = 0.01 = 1 N / 100 N).
HTC	Fasteners Temperature Compensation. This is a method of improving the temperature performance of transducers. Usually this refers to span temperature compensation. Sometimes it also includes offset temperature compensation. HTC is better than STC.
Hysteresis	A source of measurement error caused by the residual effects of previously applied loads.
IP60	Ingress Protection Rating "60" designates protection against dust
IP65	Ingress Protection Rating "65" designates protection against water spray
IP68	Ingress Protection Rating "68" designates submergibility in fresh water, in this case, to a depth of 10 meters
LabVIEW	A graphical programming environment created for data acquisition tasks by National Instruments.
Max. Single-Axis Overload	The largest amount of load in a single axis (all other axes are unloaded) that the transducer can withstand without damage.
MAP	Mounting Adapter Plate. The transducer's MAP attaches to the fixed surface or robot arm.
Measurement Uncertainty	The maximum expected error in measurements, as specified on the calibration certificate.
Moment	When something receives a torque, we say a moment is applied to it.

Mux	Short for multiplexer. F/T Controller Sensor Systems use mux electronics to interface to the transducer signals.
Mux Box	A box that holds mux electronics for transducers that are too small for on-board electronics.
Net F/T	An F/T Sensor System that connects to the customer's monitoring equipment via Ethernet or CAN bus or DeviceNet.
NI	National Instruments Corporation, the owner of the National Instruments and LabVIEW trademarks. (www.ni.com) Maker of Data Acquisition Cards used by ATI in force sensors.
Offset Compensation	Correction of errors that change the zero point of a transducer's readings.
Overload	The condition where more load is applied to the transducer than it can measure. This will result in saturation.
Point of Origin	The point on the transducer from which all forces and torques are measured.
Quantization	The way the continuously variable transducer signal is converted into discreet digital values. Usually used when describing the change from one digital value to the next.
Reaction Torque	Torque applied that does not result in movement. Think of the twisting you attempt to put on a screw or bolt when it does not move. Our transducers sense reaction torque.
Re-calibration	The periodic verification of measurement equipment, like transducers, calipers and voltmeters, to prove it still measures correctly. The equipment may be adjusted if it doesn't measure correctly.
Resolution	The smallest change in load that can be measured. This is usually much smaller than accuracy.
Rotary Torque	Torque resulting in something moving. Generally this refers to the torque on things like drive shafts. Our transducers cannot sense rotational torque.
Saturation	The condition where the transducer or data acquisition fasteners has a load or signal outside of its sensing range.
Sensor System	The entire assembly consisting of parts from transducer to data acquisition card.
Six-axis Force/Torque Sensor	A device that measures the outputting forces and torques from all three Cartesian coordinates (x, y and z). A six-axis force/torque transducer is also known as a multi-axis force/torque transducer, multi-axis load cell, F/T sensor, or six-axis load cell.
Six Degrees of Freedom	Fx, Fy, Fz, Tx, Ty and Tz.
Span Compensation	Correction of errors that affect the sensitivity of a transducer.
STC	Software Temperature Compensation. A method of improving temperature performance of transducers. This method is not as good as HTC.
TAP	Tool Adapter Plate. The TAP part of the transducer is attached to the load that is to be measured.
Tool Transformation	Mathematically changing the measurement coordinate system by translating the origin and/or rotating the axes.
Torque	The measurement of force exerted on an object causing it to rotate.
Transducer	The component that converts the sensed load into electrical signals.
Txy	The resultant torque vector comprised of components Tx and Ty.
Visual Basic	A Microsoft programming environment for developing Windows-based applications.

1. Safety

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

1.1 Explanation of Notifications

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

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

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

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

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

1.2 General Safety Guidelines

The customer should verify that the transducer selected is rated for maximum loads and moments expected during operation. Refer to transducer specifications in *Section 5—Transducer Specifications* of this manual or contact ATI for assistance. Particular attention should be paid to dynamic loads caused by robot acceleration and deceleration. These forces can be many times the value of static forces in high acceleration or deceleration situations.

1.3 Safety Precautions

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

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

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

2. Product Overview

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

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

3. Installing the Transducer

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

3.1 Transducer Environment

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

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

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

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

3.2 Mounting the Transducer

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

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

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

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

3.2.1 Interface Plate Design

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

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

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

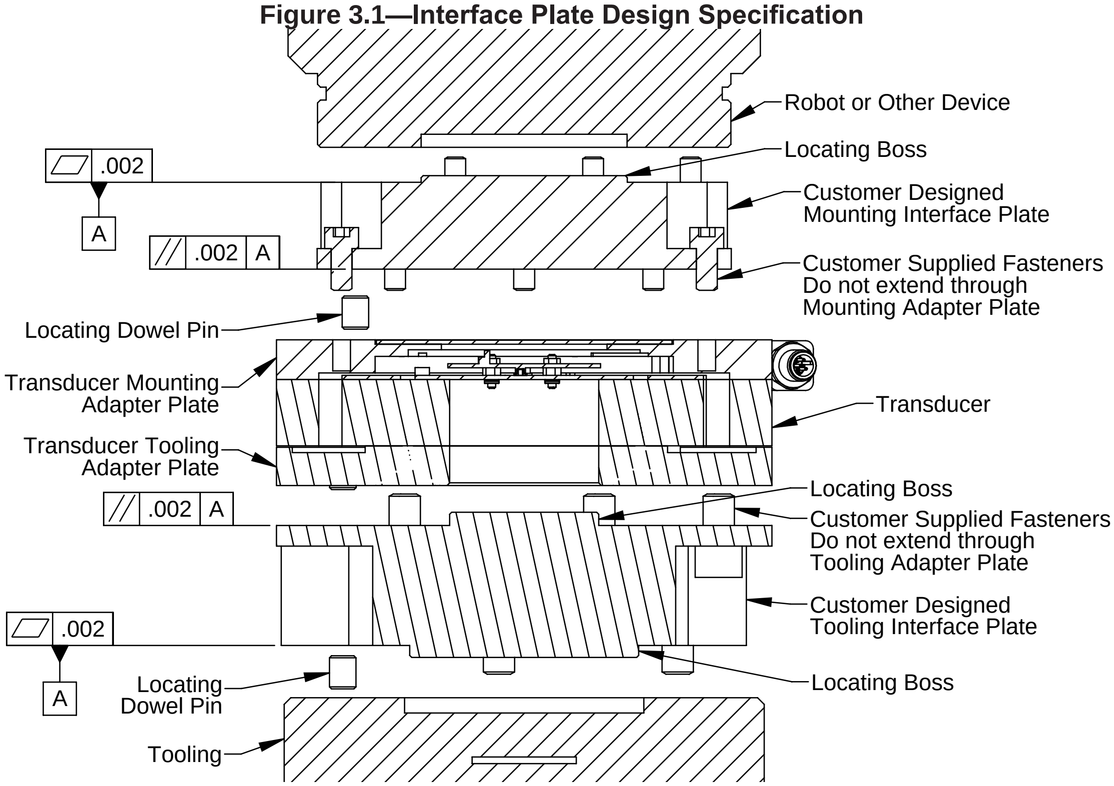
The transducer tooling adapter plate is factory installed and the bolt circle is shown with the transducer in *Section 5—Transducer Specifications*. Most large F/T tool adapters follow the ISO 9409-1 mounting pattern. Machine the tooling interface plate to attach to this bolt circle.

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

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

- The interface plate should be designed to include bolt holes for mounting, dowel pins, and a boss for accurate positioning on the robot or other devices and to the adapter plate. These locating features should orient the X and Y axis of the Transducer to the X and Y axis of the robot.
- The thickness of the interface plate must be great enough to provide the necessary thread engagement for the mounting fasteners.
- Mounting fasteners must not be too long. They should not extend through the adapter plate to avoid interference with the electronics inside the transducer. Refer to *Section 5—Transducer Specifications* for thread depth, mounting patterns, and other details.
- The interface plate must be properly designed to provide rigid mounting for the transducer. The interface plate should not distort under maximum sensor range of the transducer. Refer to *Section 5—Transducer Specifications* for specifications.
- The interface plate design must provide a flat and parallel mounting surface for the transducer. Refer to *Figure 3.1*.

Figure 3.1—Interface Plate Design Specification



3.2.2 Mounting the Transducer with a Removable Mounting Adapter Plate

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

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

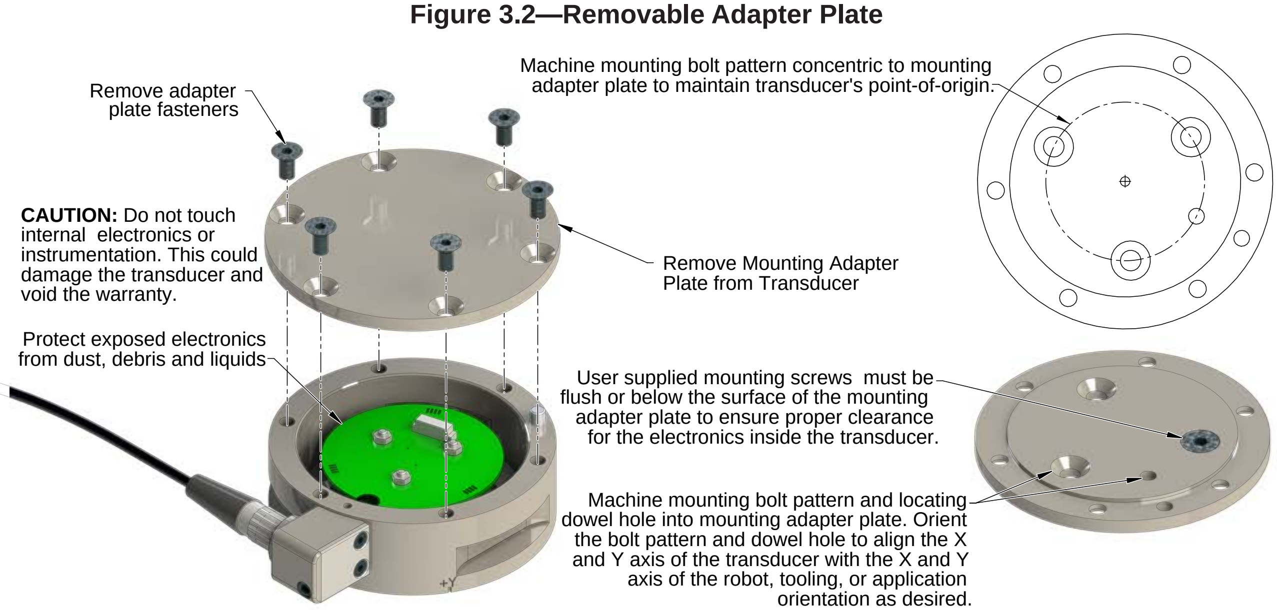
CAUTION: Do not touch internal electronics or instrumentation. This could damage the transducer and void the warranty. When the adapter plate is removed protect the exposed electronics from dust, debris, liquids, and other foreign objects.

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

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

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

Figure 3.2—Removable Adapter Plate



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

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

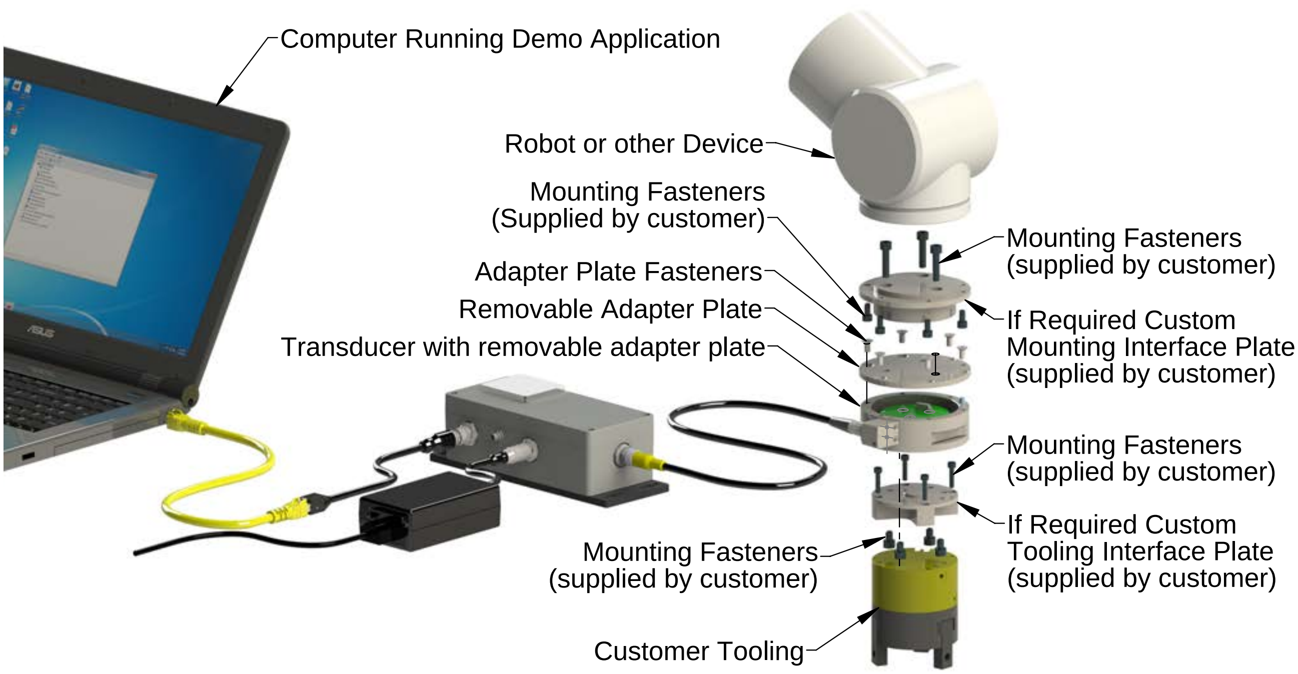
5. Attach the transducer to the removable adapter plate, hand tighten fasteners.

6. Connect power to the transducer and wait until demo application displays load data when applying force on the transducer.

> **CAUTION:** Do not exceed the transducer's overload ratings. Smaller transducers can be easily be irreparably damaged by applying small loads using tools (moment arm increases applied loads) when mounting the transducer. Always monitor the transducer using the demo application for gage saturation errors during installation. Stop applying force to the transducer and wait until the error clears to continue installation. If error does not clear, it may indicate loss of power or the overload value has been exceeded.

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

Figure 3.3—Installing Transducers with Removable Mounting Adapter Plates



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

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

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

3.2.3 Mounting the Transducer with a Non-removable Adapter Plate

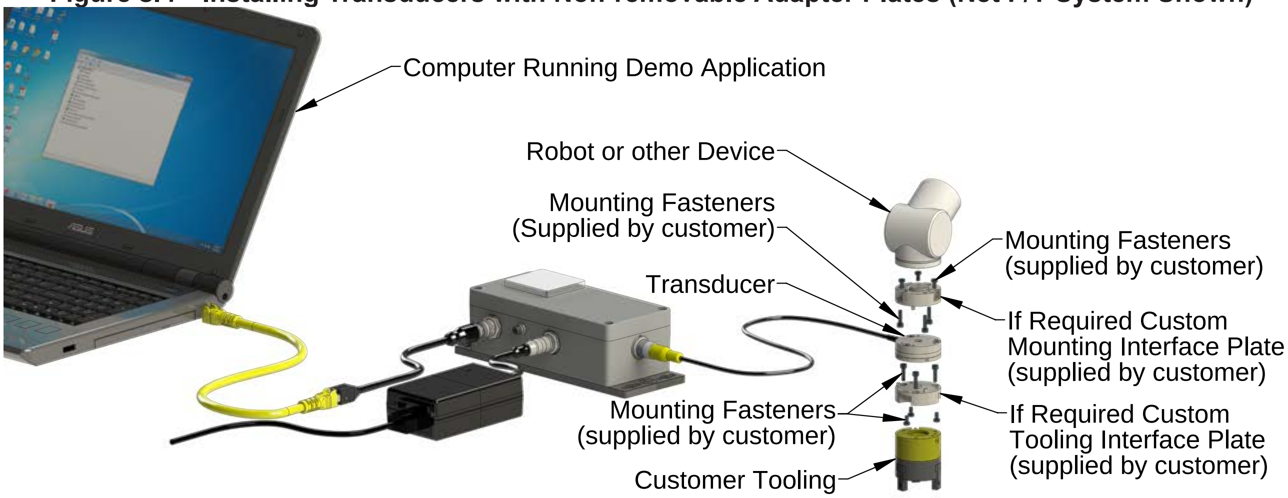
CAUTION: Do not attempt to drill, tap, machine, or otherwise modify or disassemble the transducer. This could damage the transducer and will void the warranty. Use the mounting bolt pattern provided to attach the transducer to the robot or other device and to mount the tool to the transducer. See the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

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

CAUTION: Do not exceed the single-axis overload value of the transducer. Smaller transducers can easily be irreparably damaged by applying small loads using tools (moment arm increases applied loads) when mounting the transducer. Always monitor the transducer using the demo application for gage saturation errors during installation. Stop applying force to the transducer and wait until the error clears to continue installation. If error does not clear, it may indicate loss of power or the overload value has been exceeded.

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

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



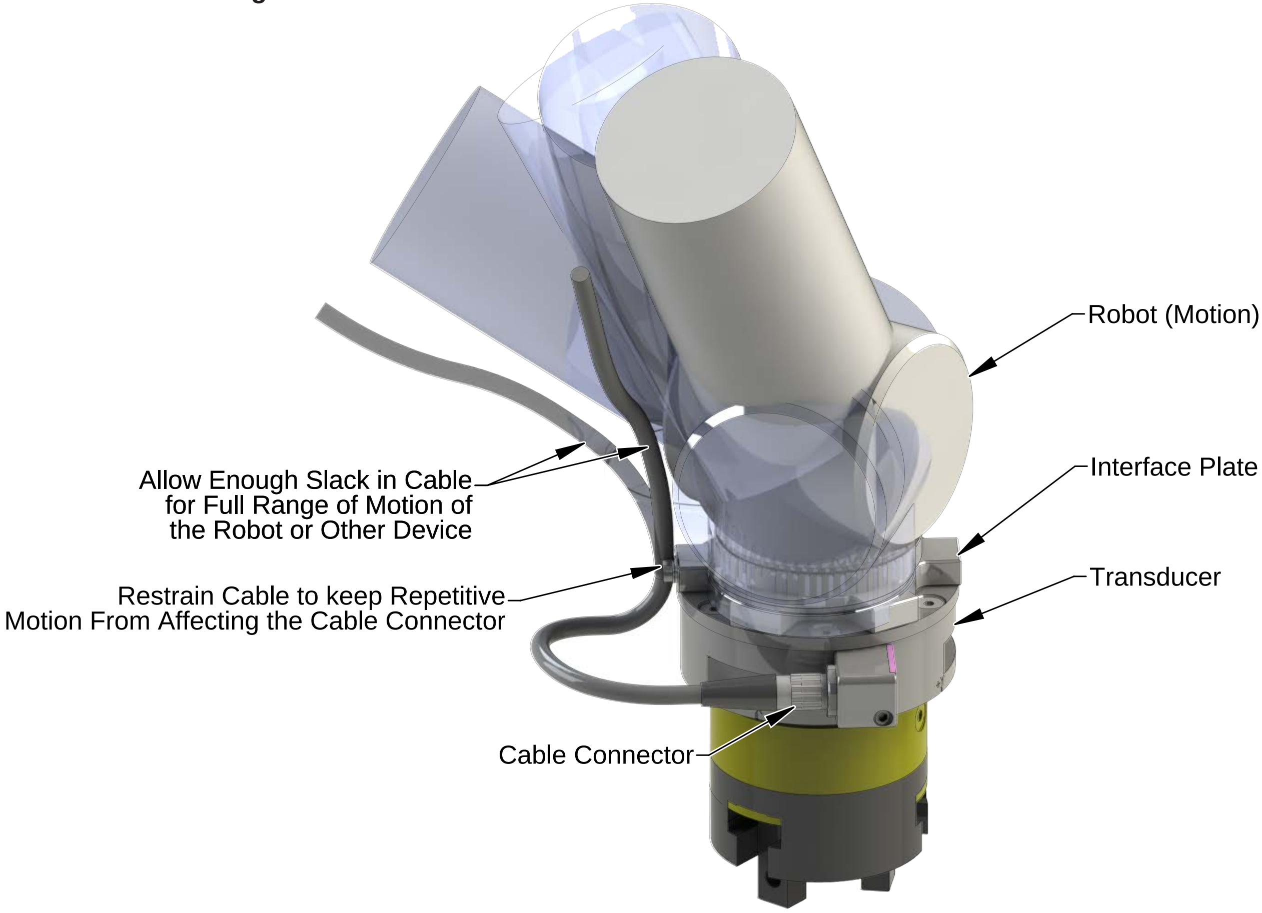
NOTICE: The tool may not touch any other part of the transducer except the tool mounting surface. If the tool touches any other part of the transducer it will not properly sense loads. Make sure the tool mounts to the tool mounting surface and does not touch any other part of the transducer.

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

3.3 Routing the Transducer Cable

The transducer can be used in a variety of applications that will affect how best to route the cable and determine the proper bending radius to use. Some applications will allow the transducer and the cable to remain in a static condition. Some applications require the transducer to be in a dynamic condition that requires the cable to be subjected to repetitive motion. It is important not to expose the transducer cable connectors to this repetitive motion, and properly restrain the cable close to the transducer connection

Figure 3.5—Restrain Transducer Cable Close to Cable Connector



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

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

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

Figure 3.6—Transducer Bending Radius

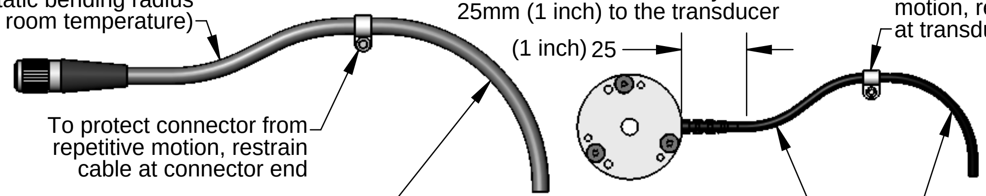


Table 3.1—Transducer Cable Bending Radius

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

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

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

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

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

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

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

4. Topics

4.1 Accuracy over Temperature

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

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

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

Note:

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

Table 4.2—Error Introduced Over Temperature for Gamma Transducers

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

Note:

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

4.2 Tool Transformation Effects

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

4.3 Environmental

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

Table 4.3—Transducer Temperature Ranges - Non-IP-Rated

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

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

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

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

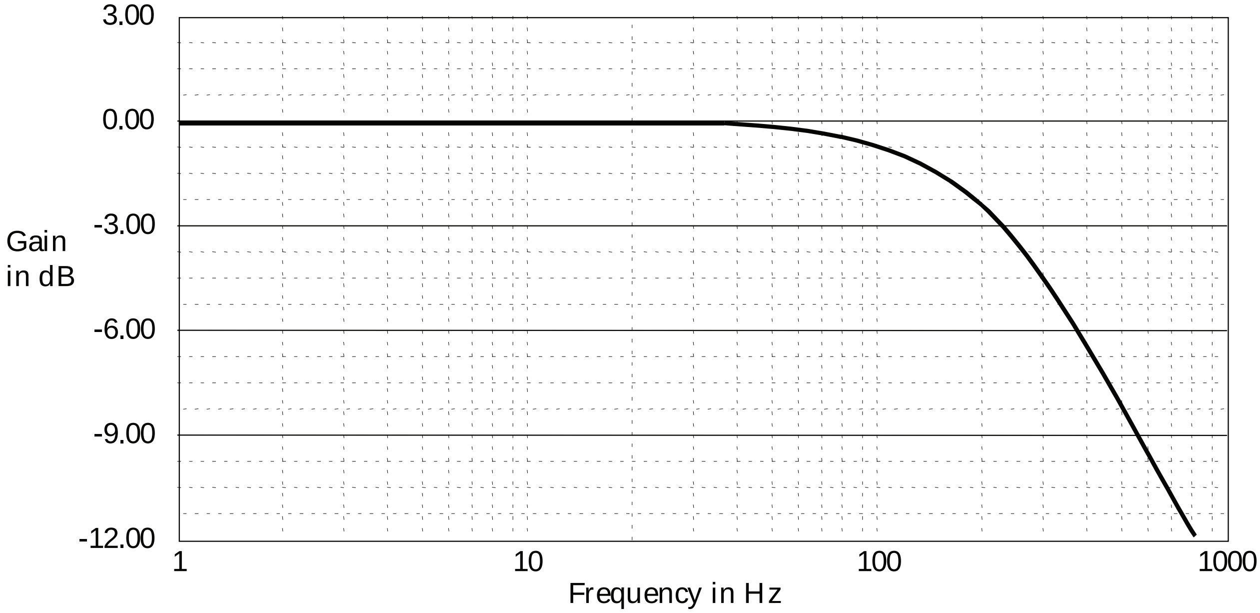
Note: These temperature ranges specify the storage and operation ranges in which the transducer can survive without damage. They do not take accuracy into account.

4.4 Mux Transducer Input Filter Frequency Response

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

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

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



4.5 Transducer Strain Gage Saturation

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

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

5. Transducer Specifications

5.1 Notes

5.1.1 About CTL Calibration Specifications

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

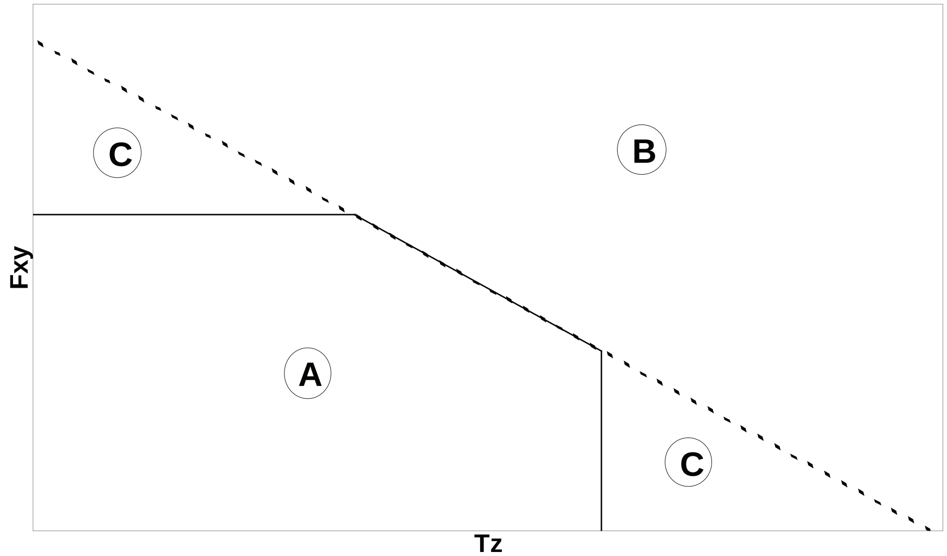
5.1.2 Complex Loading Graph Description

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

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

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

Figure 5.1—Complex Loading Sample Graph



5.2 Nano17 Titanium

5.2.1 Nano17 Titanium Physical Properties

Table 5.1—Nano17 Titanium Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±35 lbf	±160 N
Fz	±70 lbf	±310 N
Txy	±8.9 inf-lb	±1 Nm
Tz	±10 inf-lb	±1.2 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	2.7×10^{4} lb/in	4.8×10^{6} N/m
Z-axis force (Kz)	3.8×10^{4} lb/in	6.6×10^{6} N/m
X-axis & Y-axis torque (Ktx, Kty)	1.2×10^{3} lbf-in/rad	1.4×10^{2} Nm/rad
Z-axis torque (Ktz)	2.0×10^{3} lbf-in/rad	2.2×10^{2} Nm/rad
Resonant Frequency		
Fx, Fy, Tz	3000 Hz	3000 Hz
Fz, Tx, Ty	3000 Hz	3000 Hz
Physical Specifications		
Weight[1]	0.0223 lb	0.0101 kg
Diameter[1]	0.669 in	17 mm
Height[1]	0.571 in	14.5 mm

Note:
1. Specifications include standard interface plates.

5.2.2 Calibration Specifications (excludes CTL calibrations)

Table 5.2— Nano17 Titanium Calibrations (excludes CTL calibrations)[1, 2]									
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**	**Fx,Fy (lbf)**	**Fz (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**
Nano17 Titanium	US-1.8-0.4	1.8	3.15	0.4	0.4	1/3400	1/2720	7/92800	1/18560
Nano17 Titanium	US-3.6-0.8	3.6	6.3	0.8	0.8	1/1700	1/1360	7/46400	1/9280
Nano17 Titanium	US-7.2-1.6	7.2	12.6	1.6	1.6	1/850	1/680	7/23200	1/4640
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**	**Fx,Fy (N)**	**Fz (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**
Nano17 Titanium	SI-8-0.05	8	14.1	50	50	1/682	1/682	3/364	5/728
Nano17 Titanium	SI-16-0.1	16	28.2	100	100	1/341	1/341	3/182	5/364
Nano17 Titanium	SI-32-0.2	32	56.4	200	200	1/171	1/171	3/92	5/184
		Sensing Ranges				**Resolution (DAQ, Net F/T)[3]**			

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

5.2.3 CTL Calibration Specifications

Table 5.3— Nano17 Titanium CTL Calibrations[1, 2]									
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**	**Fx,Fy (lbf)**	**Fz (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**
Nano17 Titanium	US-1.8-0.4	1.8	3.15	0.4	0.4	1/1700	1/1360	7/46400	1/9280
Nano17 Titanium	US-3.6-0.8	3.6	6.3	0.8	0.8	1/850	1/680	7/23200	1/4640
Nano17 Titanium	US-7.2-1.6	7.2	12.6	1.6	1.6	1/425	1/340	7/11600	1/2320
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**	**Fx,Fy (N)**	**Fz (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**
Nano17 Titanium	SI-8-0.05	8	14.1	50	50	1/341	1/341	3/182	5/364
Nano17 Titanium	SI-16-0.1	16	28.2	100	100	2/341	2/341	3/91	5/182
Nano17 Titanium	SI-32-0.2	32	56.4	200	200	2/171	2/171	3/46	5/92
		Sensing Ranges				**Resolution (Controller)**			

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

5.2.4 Analog Output

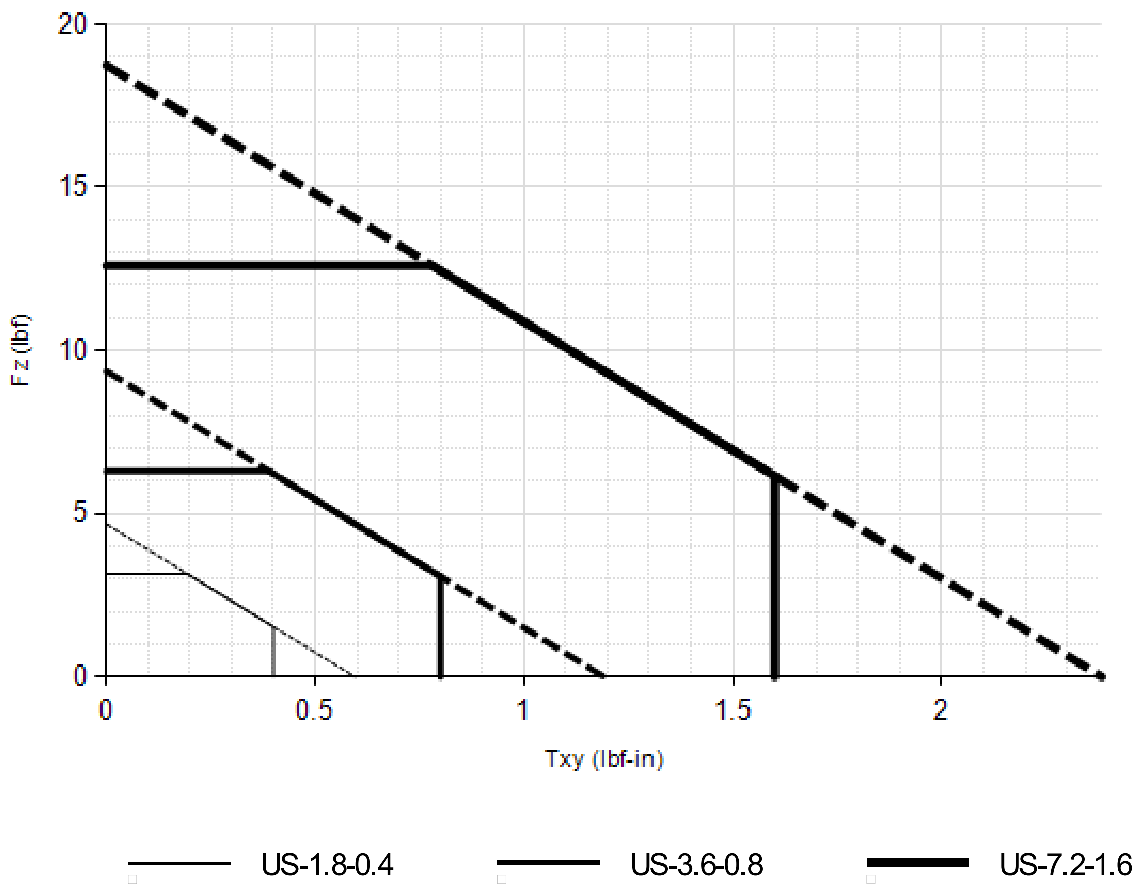
Table 5.4— Nano17 Titanium Analog Output							
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz (lbf)**	**Tx,Ty,Tz (lbf-in)**	**Fx,Fy (lbf/V)**	**Fz (lbf/V)**	**Tx,Ty,Tz (lbf-in/V)**
Nano17 Titanium	US-1.8-0.4	±1.8	±3.15	±0.4	0.18	0.315	0.04
Nano17 Titanium	US-3.6-0.8	±3.6	±6.3	±0.8	0.36	0.63	0.08
Nano17 Titanium	US-7.2-1.6	±7.2	±12.6	±1.6	0.72	1.26	0.16
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz (N)**	**Tx,Ty,Tz (Nmm)**	**Fx,Fy (N/V)**	**Fz (N/V)**	**Tx,Ty,Tz (Nm/V)**
Nano17 Titanium	SI-8-0.05	±8	±14.1	±50	0.8	1.41	5
Nano17 Titanium	SI-16-0.1	±16	±28.2	±100	1.6	2.82	10
Nano17 Titanium	SI-32-0.2	±32	±56.4	±200	3.2	5.64	20
		Analog Output Range			**Analog ±10V Sensitivity[1]**		

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

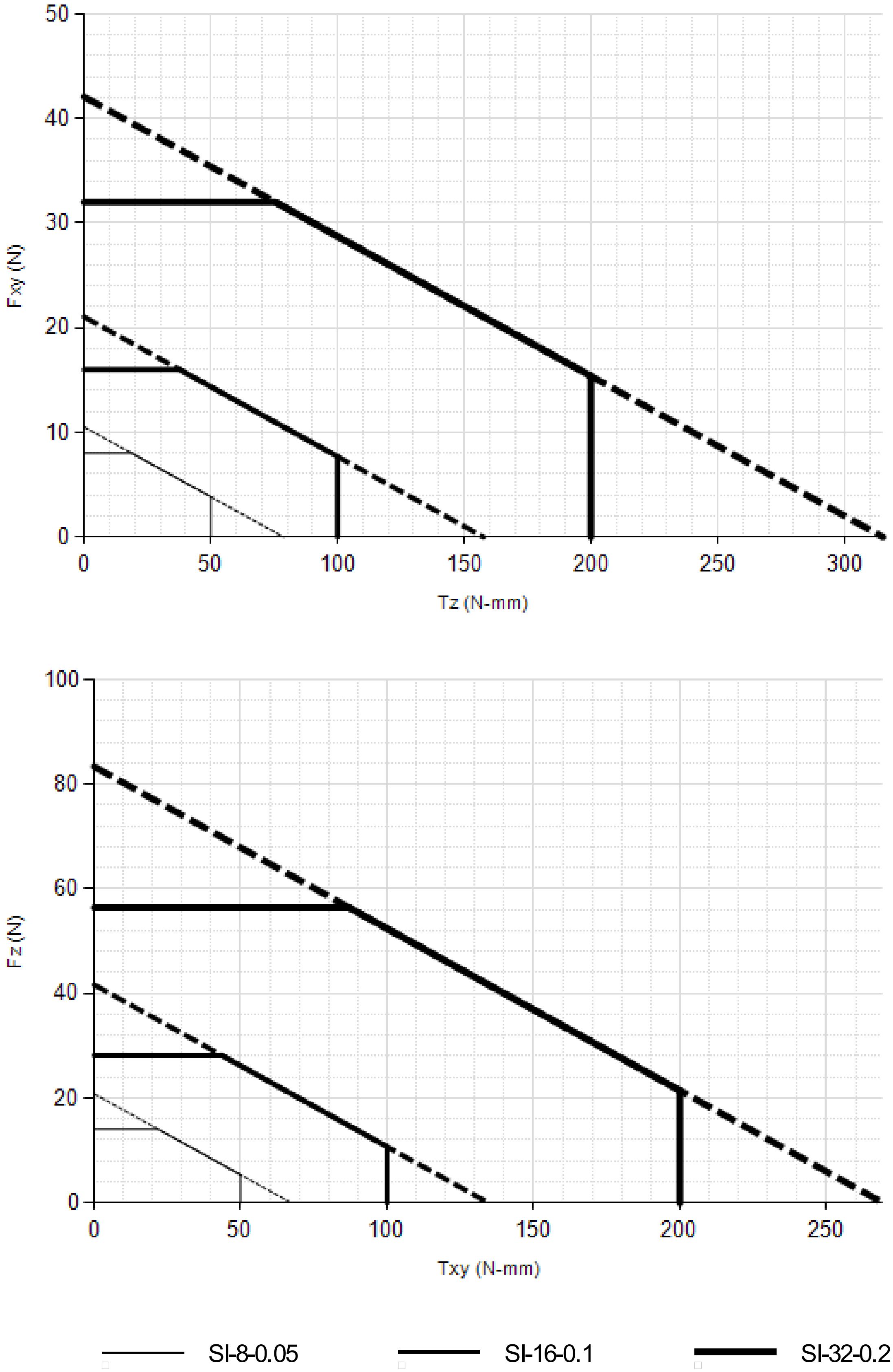
5.2.5 Counts Value

Table 5.5—Counts Value					
Sensor	**Calibration**	**Fx, Fy, Fz (/ lbf)**	**Tx, Ty, Tz (/ lbf-in)**	**Fx, Fy, Fz (/ N)**	**Tx, Ty, Tz (/ Nmm)**
Nano17 Titanium	US-1.8–0.4 / SI-8–0.05	54400	371200	1280	256
Nano17 Titanium	US-3.6–0.8 / SI-16–0.1	27200	185600	640	128
Nano17 Titanium	US-7.2–1.6 / SI-32–0.2	13600	82800	320	64
Nano17 Titanium	Tool Transform Factor	0.0022 in/lbf		0.0375 mm/N	
		Counts Value – Standard (US)		**Counts Value – Metric (SI)**	

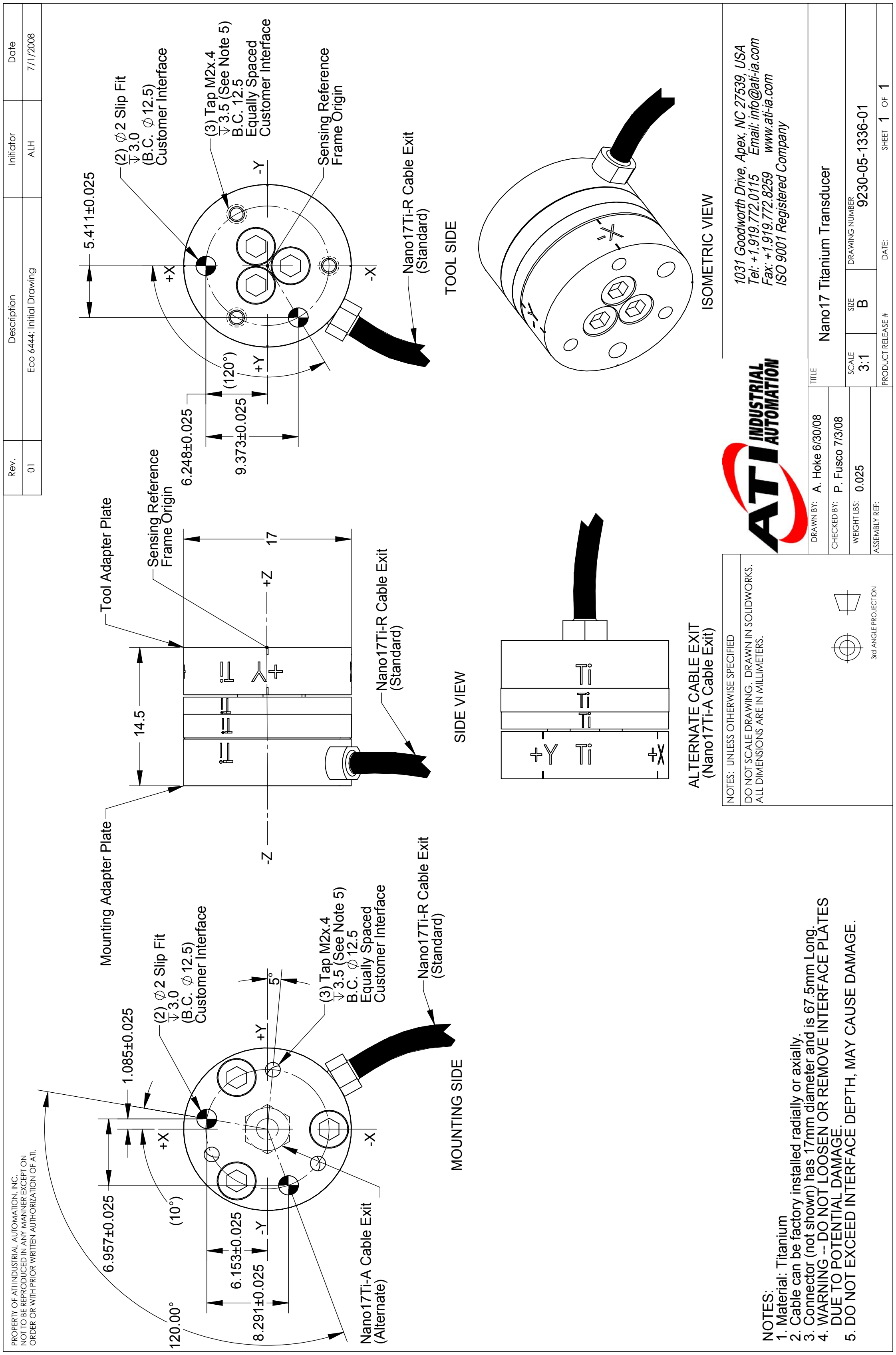
5.2.6 Nano17 Titanium (US Calibration Complex Loading)



5.2.7 Nano17 Titanium (SI Calibration Complex Loading)



5.2.8 Nano17 Titanium Transducer Drawing



5.3 Nano17 Specifications (Includes IP65/IP68 Versions)

5.3.1 Nano17 Physical Properties

Table 5.6—Nano17 Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±56 lbf	±250 N
Fz	±110 lbf	±480 N
Txy	±14 inf-lb	±1.6 Nm
Tz	±16 inf-lb	±1.8 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	4.7×10^{4} lb/in	8.2×10^{6} N/m
Z-axis force (Kz)	6.5×10^{4} lb/in	1.1×10^{7} N/m
X-axis & Y-axis torque (Ktx, Kty)	2.1×10^{3} lbf-in/rad	2.4×10^{2} Nm/rad
Z-axis torque (Ktz)	3.4×10^{3} lbf-in/rad	3.8×10^{2} Nm/rad
Resonant Frequency		
Fx, Fy, Tz	7200 Hz	7200 Hz
Fz, Tx, Ty	7200 Hz	7200 Hz
Physical Specifications		
Weight[1]	0.02 lb	0.00907 kg
Diameter[1]	0.669 in	17 mm
Height[1]	0.571 in	14.5 mm
Note: 1. Specifications include standard interface plates.		

5.3.2 Nano17 IP65/IP68 Physical Properties

Table 5.7—Nano17 IP65/IP68 Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±56 lbf	±250 N
Fz	±110 lbf	±480 N
Txy	±14 inf-lb	±1.6 Nm
Tz	±16 inf-lb	±1.8 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	4.7×10^{4} lb/in	8.2×10^{6} N/m
Z-axis force (Kz)	6.5×10^{4} lb/in	1.1×10^{7} N/m
X-axis & Y-axis torque (Ktx, Kty)	2.1×10^{3} lbf-in/rad	2.4×10^{2} Nm/rad
Z-axis torque (Ktz)	3.4×10^{3} lbf-in/rad	3.8×10^{2} Nm/rad
Resonant Frequency		
Fx, Fy, Tz	2200 Hz	2200 Hz
Fz, Tx, Ty	2200 Hz	2200 Hz
Physical Specifications		
Weight[1]	0.09 lb	0.0408 kg
Diameter[1]	0.79 in	20.1 mm
Height[1]	0.873 in	22.2 mm
Note: 1. Specifications include standard interface plates.		

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

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

5.3.3 Calibration Specifications (excludes CTL calibrations)

Table 5.8— Nano17 Calibrations (excludes CTL calibrations)[1, 2]

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

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

5.3.4 CTL Calibration Specifications

Table 5.9— Nano17 CTL Calibrations[1, 2]									
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz[3] (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**	**Fx,Fy (lbf)**	**Fz[3] (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**
Nano17	US-3-1	3	4.25	1	1	1/640	1/640	1/4000	1/4000
Nano17	US-6-2	6	8.5	2	2	1/320	1/320	1/2000	1/2000
Nano17	US-12-4	12	17	4	4	1/160	1/160	1/1000	1/1000
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**
Nano17	SI-12-0.12	12	17	120	120	1/160	1/160	1/32	1/32
Nano17	SI-25-0.25	25	35	250	250	1/80	1/80	1/16	1/16
Nano17	SI-50-0.5	50	70	500	500	1/40	1/40	1/8	1/8
		Sensing Ranges				**Resolution (Controller)**			

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

5.3.5 Analog Output

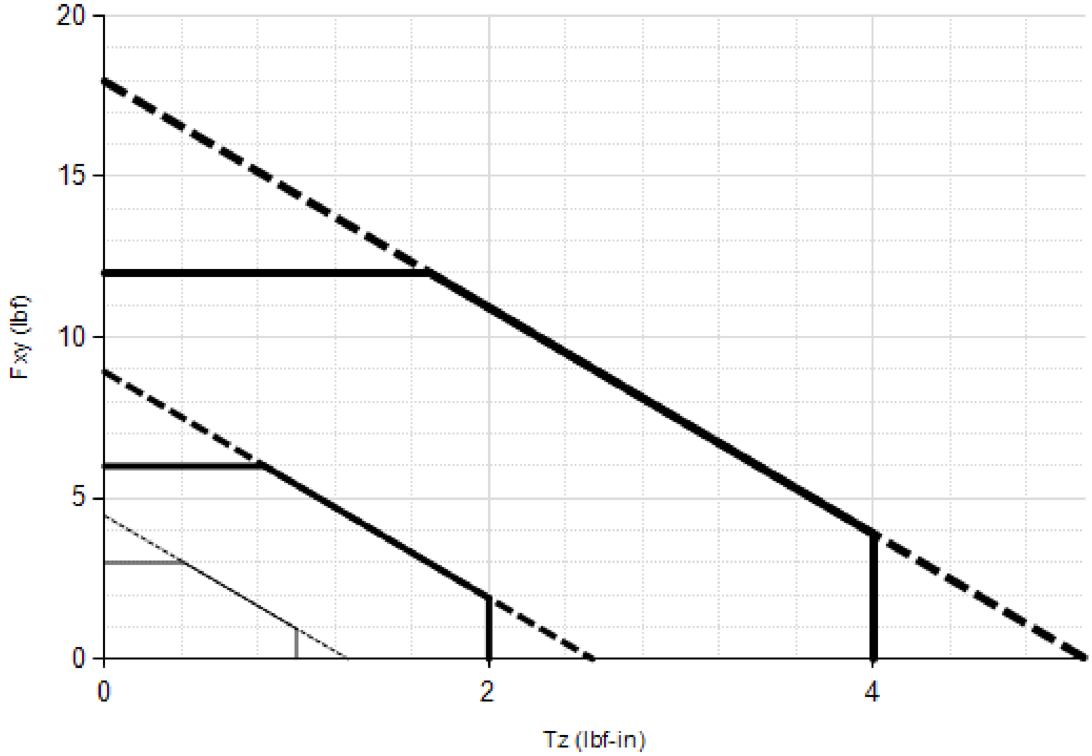
Table 5.10— Nano17 Analog Output							
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz[2] (lbf)**	**Tx,Ty,Tz (lbf-in)**	**Fx,Fy (lbf/V)**	**Fz[2] (lbf/V)**	**Tx,Ty,Tz (lbf-in/V)**
Nano17	US-3-1	±3	±4.25	±1	0.3	0.425	0.1
Nano17	US-6-2	±6	±8.5	±2	0.6	0.85	0.2
Nano17	US-12-4	±12	±17	±4	1.2	1.7	0.4
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz[2] (N)**	**Tx,Ty,Tz (Nmm)**	**Fx,Fy (N/V)**	**Fz[2] (N/V)**	**Tx,Ty,Tz (Nm/V)**
Nano17	SI-12-0.12	±12	±17	±120	1.2	1.7	12
Nano17	SI-25-0.25	±25	±35	±250	2.5	3.5	25
Nano17	SI-50-0.5	±50	±70	±500	5	7	50
		Analog Output Range			**Analog ±10V Sensitivity[1]**		

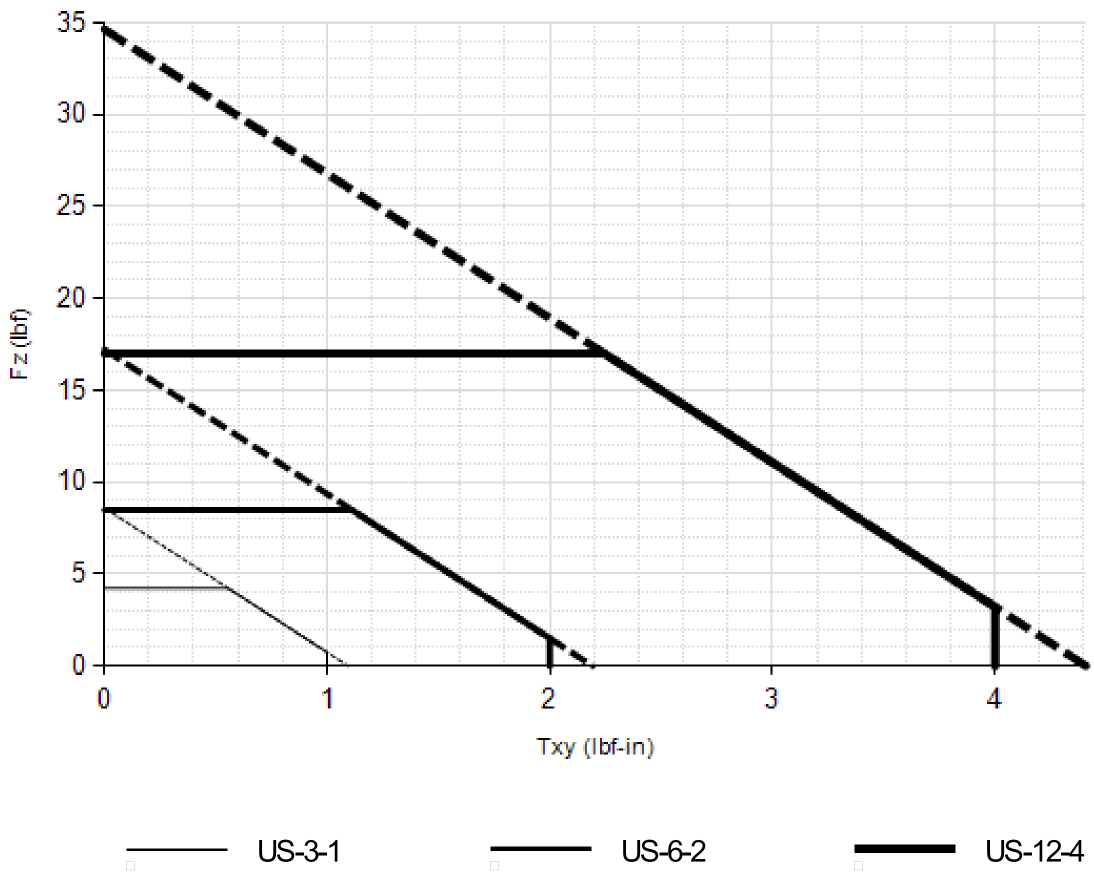
Notes:
1. ±5V Sensitivity values are double the listed ±10V Sensitivity values.
2. For IP68 version see caution on physical properties page.

5.3.6 Counts Value

Table 5.11—Counts Value					
Sensor	**Calibration**	**Fx, Fy, Fz (/ lbf)**	**Tx, Ty, Tz (/ lbf-in)**	**Fx, Fy, Fz (/ N)**	**Tx, Ty, Tz (/ Nmm)**
Nano17	US-3–1 / SI-12–0.25	5120	32000	1280	256
Nano17	US-6–2 / SI-25–0.25	2560	16000	640	128
Nano17	US-12–4 / SI-50–0.5	1280	8000	320	64
Nano17	Tool Transform Factor	0.0016 in/lbf		0.05 mm/N	
		Counts Value – Standard (US)		**Counts Value – Metric (SI)**	

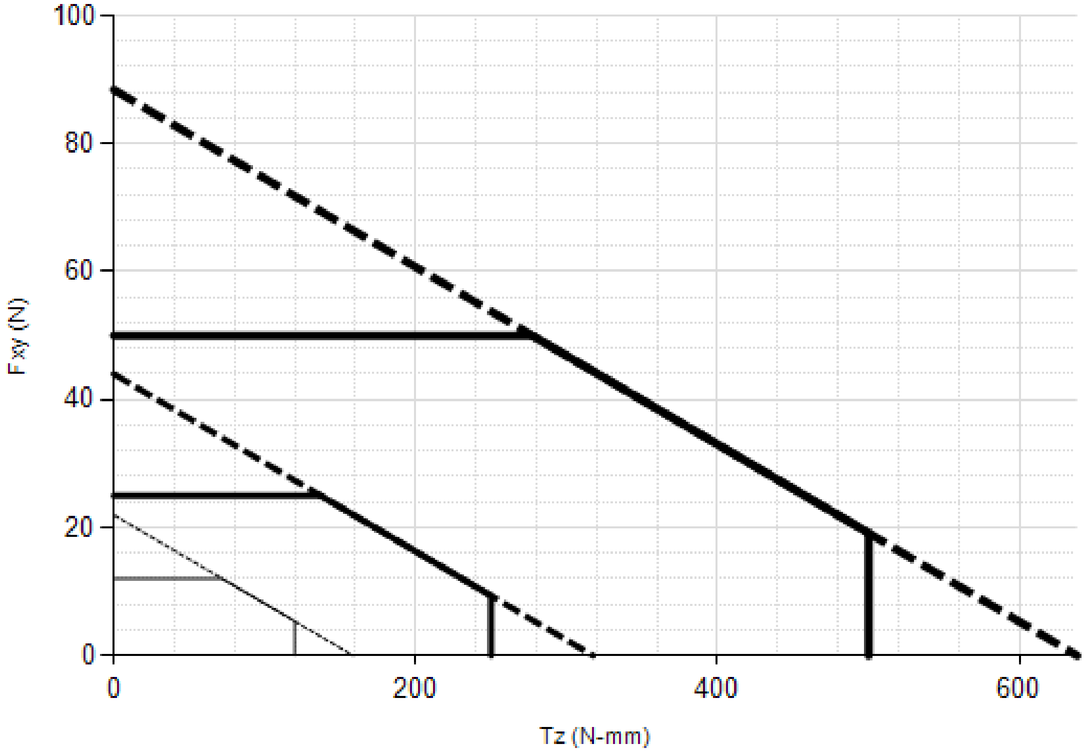
5.3.7 Nano17 (US Calibration Complex Loading)(Includes IP65/IP68)[1]

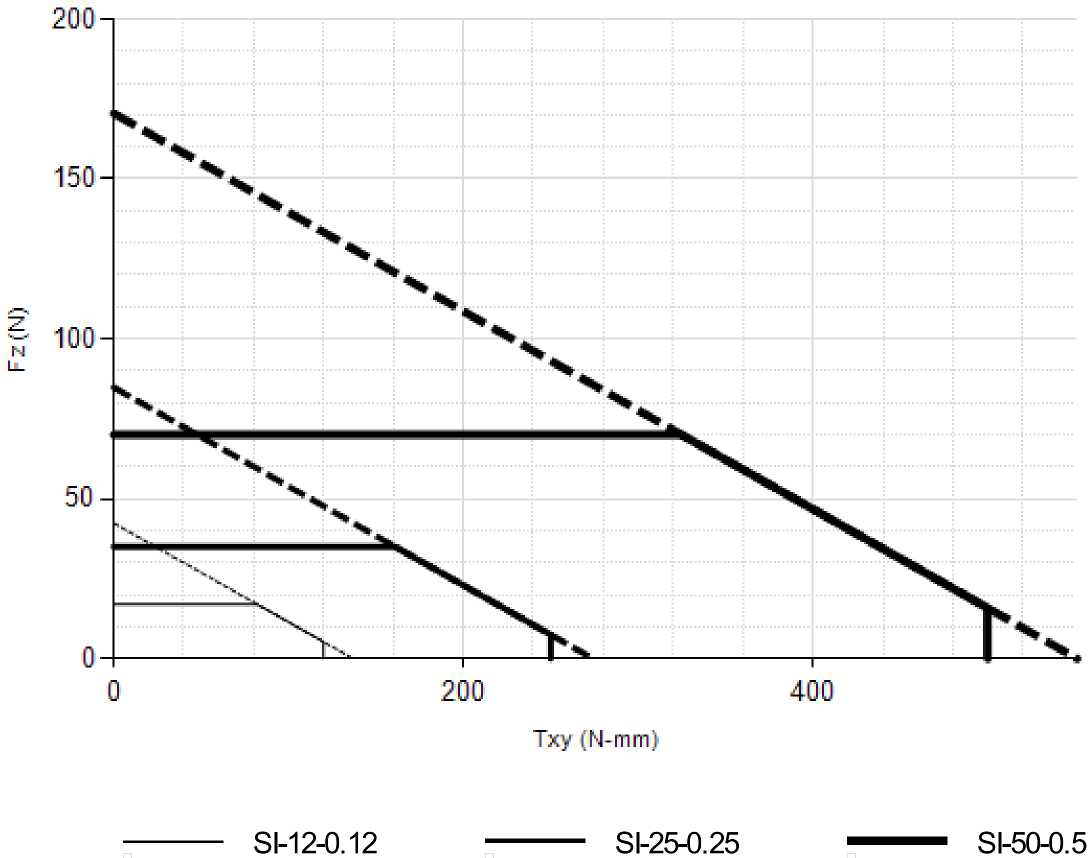




Note: 1. For IP68 version see caution on physical properties page.

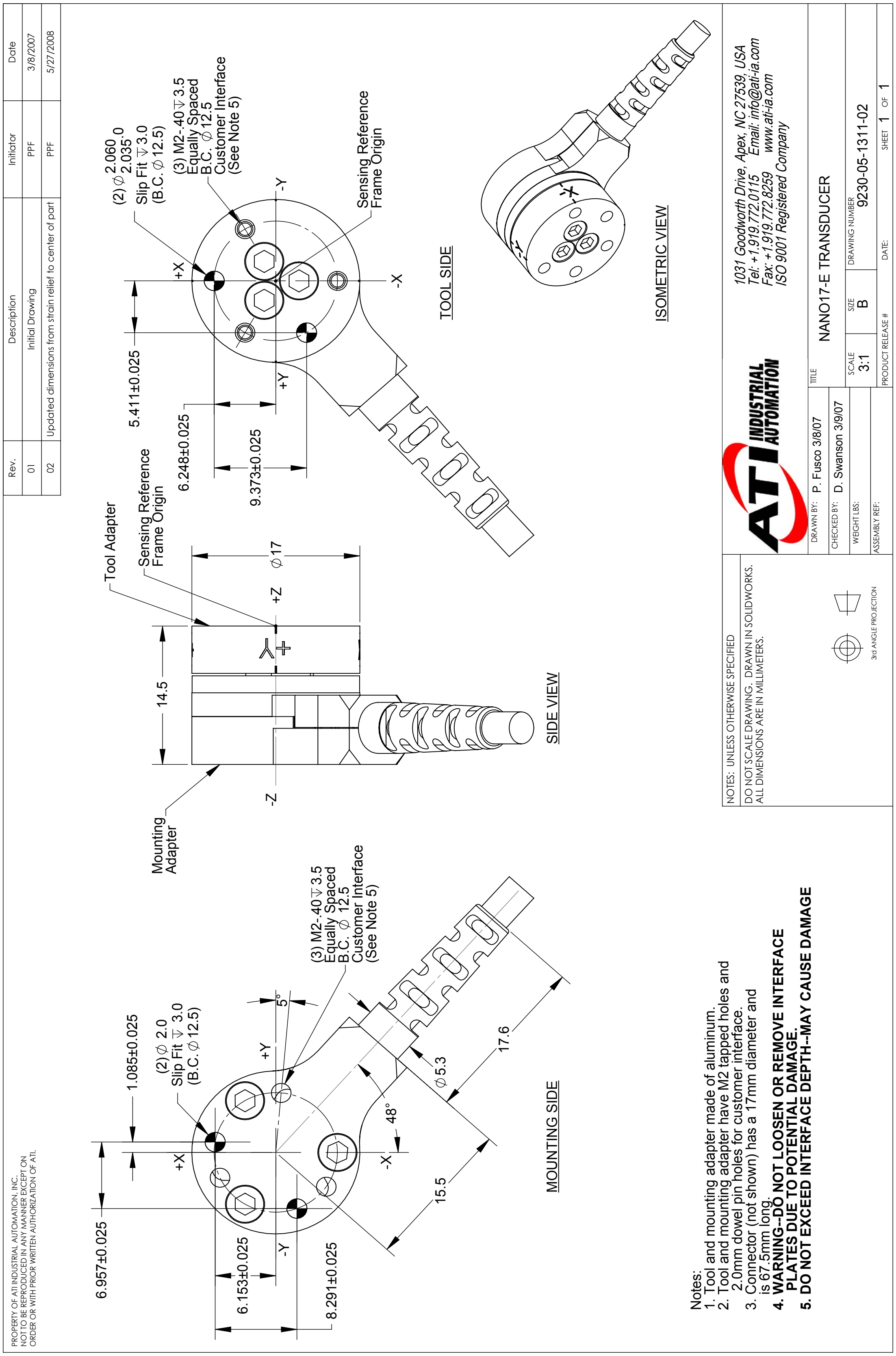
5.3.8 Nano17 (SI Calibration Complex Loading)(Includes IP65/IP68)[1]



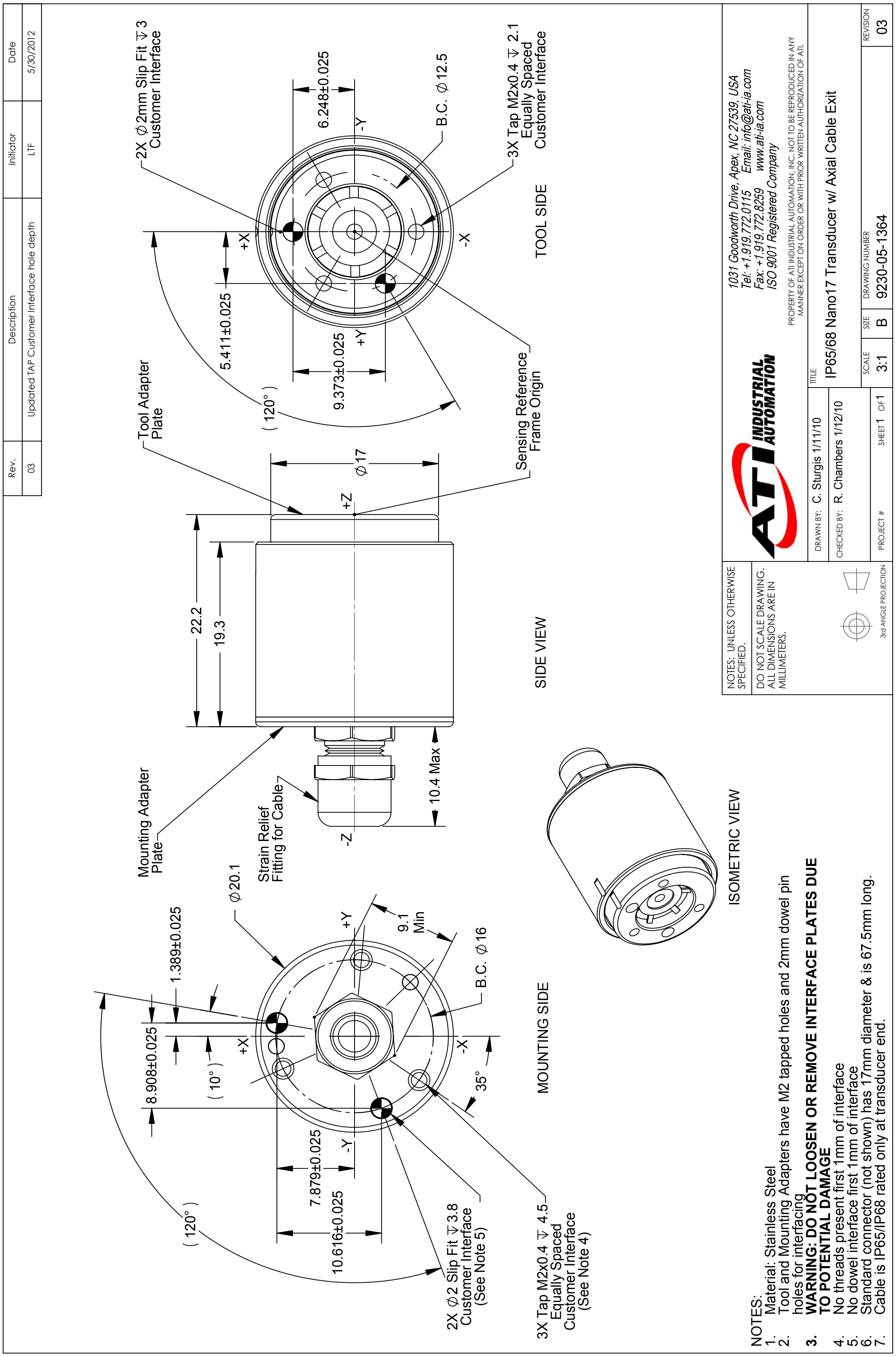


Note: 1. For IP68 version see caution on physical properties page.

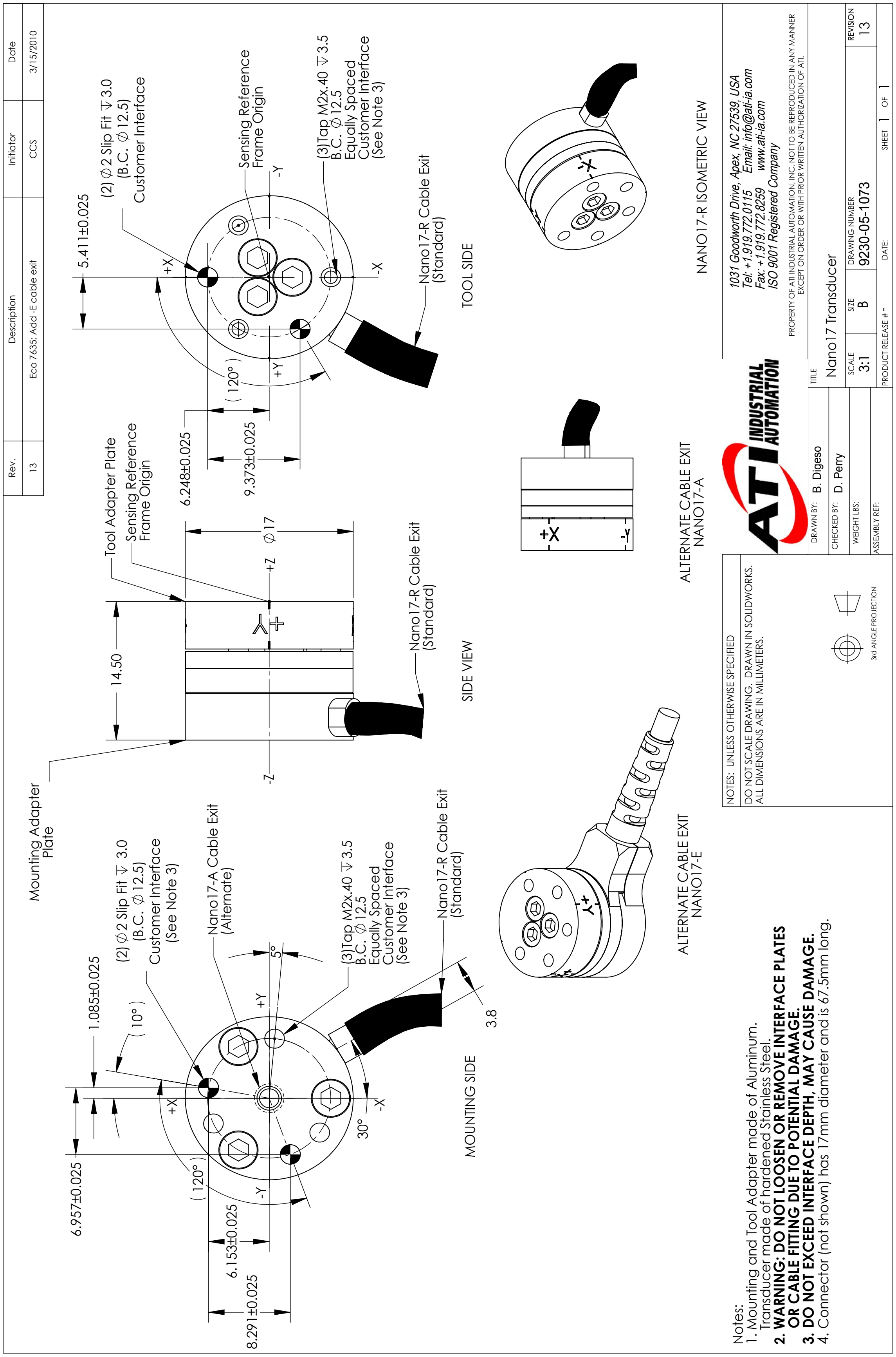
5.3.9 Nano17-E Transducer Drawing



5.3.10 Nano17 IP65/IP68 Transducer with Axial Cable Exit Drawing



5.3.11 Legacy Nano17 Transducer Drawing



5.4 Nano25 Specifications (Includes IP65/IP68 Versions)

5.4.1 Nano25 Physical Properties

Table 5.12—Nano25 Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±520 lbf	±2300 N
Fz	±1600 lbf	±7300 N
Txy	±380 inf-lb	±43 Nm
Tz	±560 inf-lb	±63 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	3.0×10^{5} lb/in	5.3×10^{7} N/m
Z-axis force (Kz)	6.3×10^{5} lb/in	1.1×10^{8} N/m
X-axis & Y-axis torque (Ktx, Kty)	5.7×10^{4} lbf-in/rad	6.5×10^{3} Nm/rad
Z-axis torque (Ktz)	8.1×10^{4} lbf-in/rad	9.2×10^{3} Nm/rad
Resonant Frequency		
Fx, Fy, Tz	3600 Hz	3600 Hz
Fz, Tx, Ty	3800 Hz	3800 Hz
Physical Specifications		
Weight[1]	0.14 lb	0.0634 kg
Diameter[1]	0.984 in	25 mm
Height[1]	0.85 in	21.6 mm
Note: 1. Specifications include standard interface plates.		

5.4.2 Nano25 IP65/IP68 Physical Properties

Table 5.13—Nano25 IP65/IP68 Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±520 lbf	±2300 N
Fz	±1600 lbf	±7300 N
Txy	±380 inf-lb	±43 Nm
Tz	±560 inf-lb	±63 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	3.0×10^{5} lb/in	5.3×10^{7} N/m
Z-axis force (Kz)	6.3×10^{5} lb/in	1.1×10^{8} N/m
X-axis & Y-axis torque (Ktx, Kty)	5.7×10^{4} lbf-in/rad	6.5×10^{3} Nm/rad
Z-axis torque (Ktz)	8.1×10^{4} lbf-in/rad	9.2×10^{3} Nm/rad
Resonant Frequency		
Fx, Fy, Tz	3400 Hz	3400 Hz
Fz, Tx, Ty	3500 Hz	3500 Hz
Physical Specifications		
Weight[1]	0.3 lb	0.136 kg
Diameter[1]	1.1 in	28 mm
Height[1]	1.08 in	27.5 mm
Note: 1. Specifications include standard interface plates.		

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

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

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

5.4.3 Calibration Specifications (excludes CTL calibrations)

Table 5.14— Nano25 Calibrations (excludes CTL calibrations)[1, 2, 4]

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

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

5.4.4 CTL Calibration Specifications

Table 5.15— Nano25 CTL Calibrations[1, 2, 4]									
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz[3] (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**	**Fx,Fy (lbf)**	**Fz[3] (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**
Nano25	US-25-25	25	100	25	25	1/112	3/112	1/80	1/160
Nano25	US-50-50	50	200	50	30	1/56	3/56	1/40	1/80
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**
Nano25	SI-125-3	125	500	3	3	1/24	1/8	1/660	1/1320
Nano25	SI-250-6	250	1000	6	3.4	1/12	1/4	1/330	1/660
		Sensing Ranges				**Resolution (Controller)**			

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

5.4.5 Analog Output

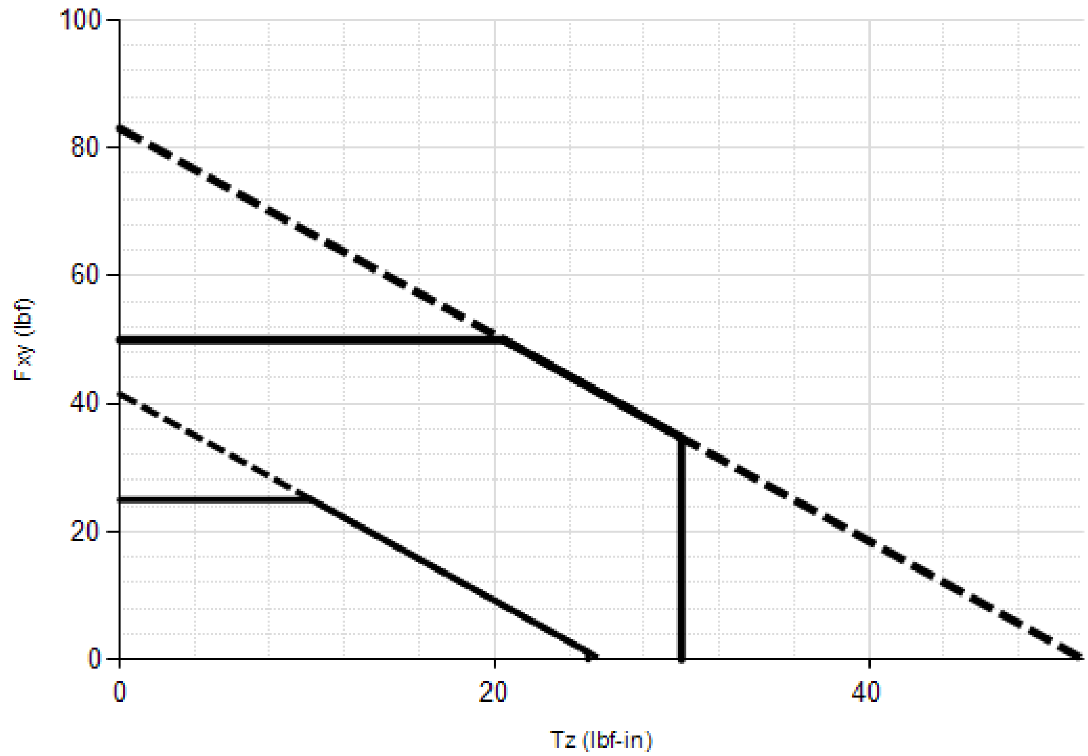
Table 5.16— Nano25 Analog Output							
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz[2] (lbf)**	**Tx,Ty,Tz (lbf-in)**	**Fx,Fy (lbf/V)**	**Fz[2] (lbf/V)**	**Tx,Ty,Tz (lbf-in/V)**
Nano25	US-25-25	±25	±100	±25	2.5	10	2.5
Nano25	US-50-50	±50	±200	±50	5	20	5
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz[2] (N)**	**Tx,Ty,Tz (Nmm)**	**Fx,Fy (N/V)**	**Fz[2] (N/V)**	**Tx,Ty,Tz (Nm/V)**
Nano25	SI-125-3	±125	±500	±3	12.5	50	0.3
Nano25	SI-250-6	±250	±1000	±6	25	100	0.6
		Analog Output Range			**Analog ±10V Sensitivity[1]**		

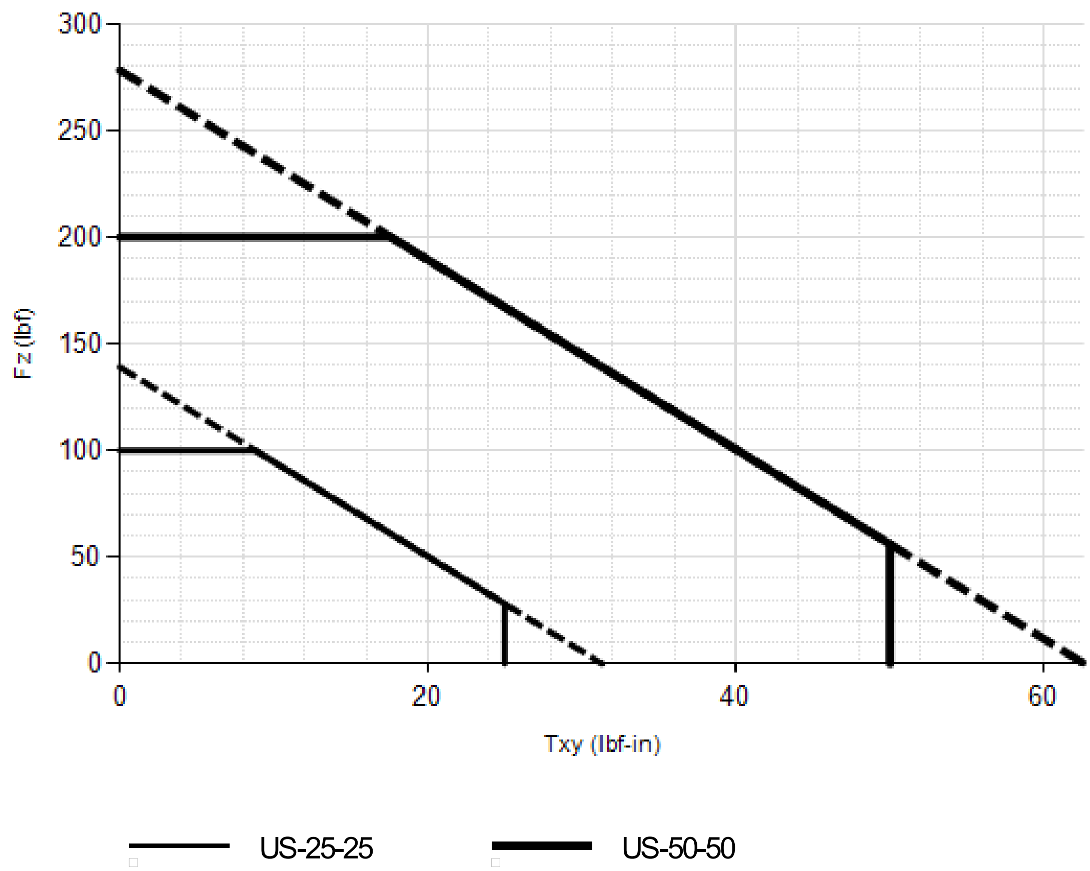
Notes:
1. ±5V Sensitivity values are double the listed ±10V Sensitivity values.
2. For IP68 version see caution on physical properties page.

5.4.6 Counts Value

Table 5.17—Counts Value					
Sensor	**Calibration**	**Fx, Fy, Fz (/ lbf)**	**Tx, Ty, Tz (/ lbf-in)**	**Fx, Fy, Fz**	**Tx, Ty, Tz**
Nano25	US-25–25 / SI-125–3	896	1280	192 / N	10560 / N
Nano25	US-50–50 / SI-250–6	448	640	96 / Nm	5280 / Nm
Nano25	Tool Transform Factor	0.007 in/lbf		0.18182 mm/N	
		Counts Value – Standard (US)		**Counts Value – Metric (SI)**	

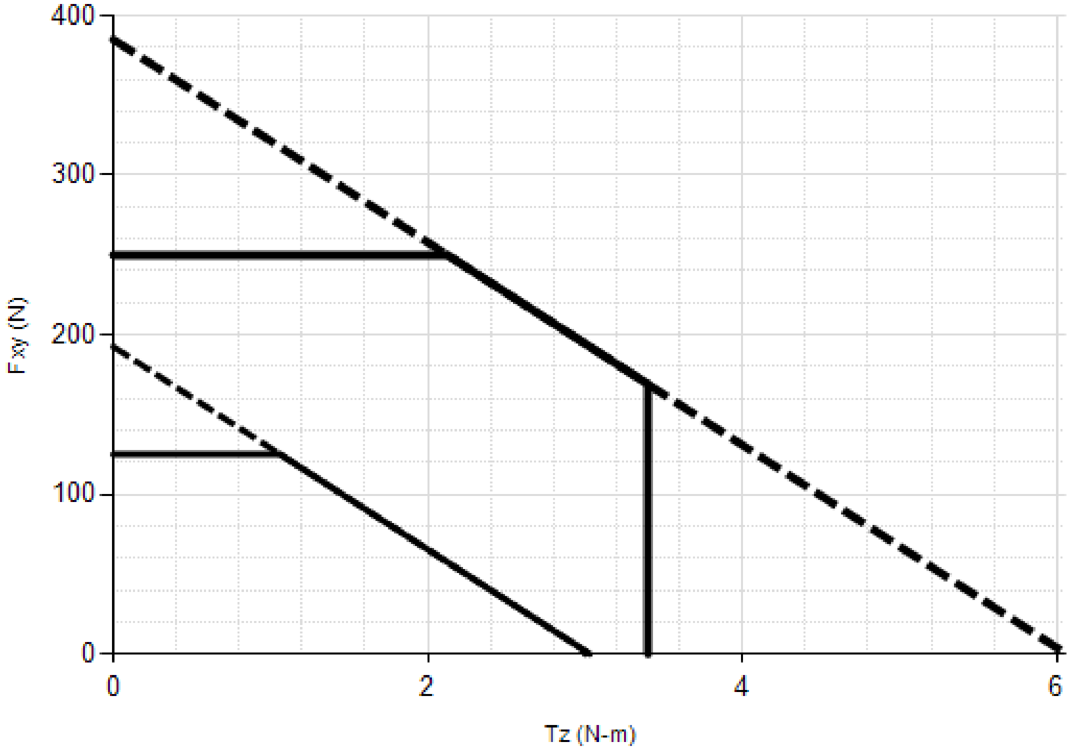
5.4.7 Nano25 (US Calibration Complex Loading)(Includes IP65/IP68)[1]

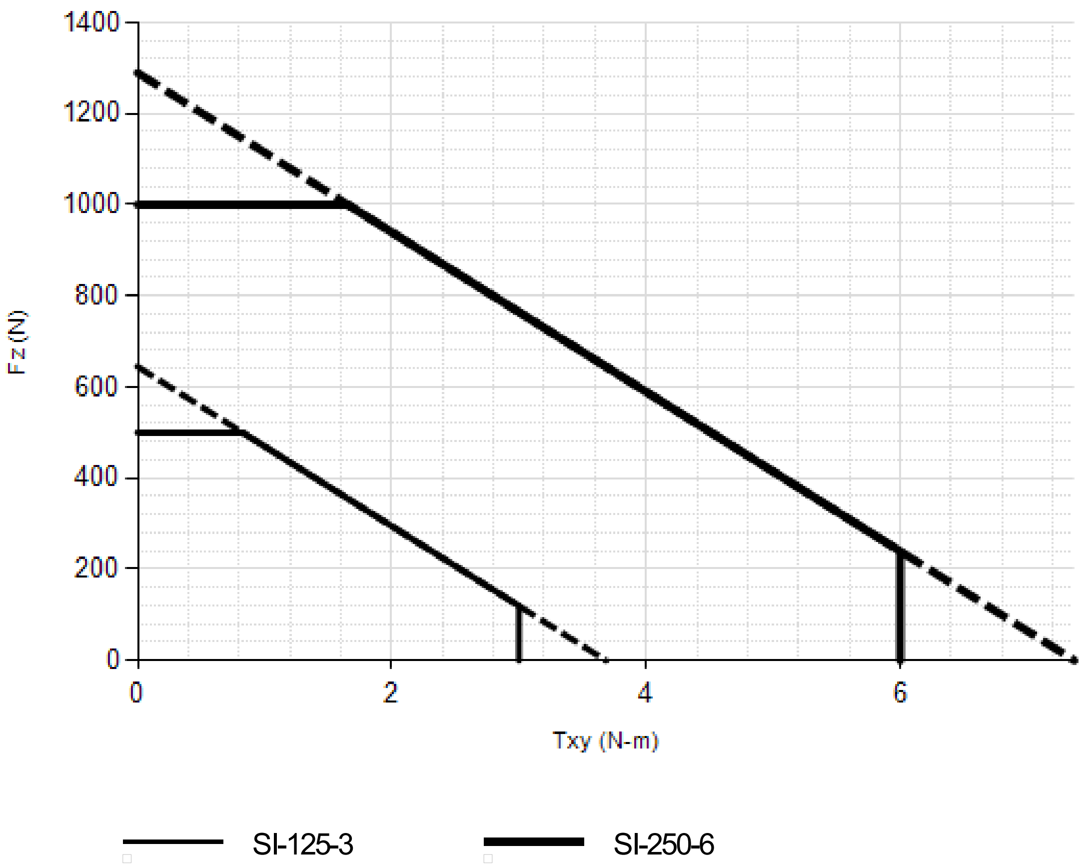




Note: 1. For IP68 version see caution on physical properties page.

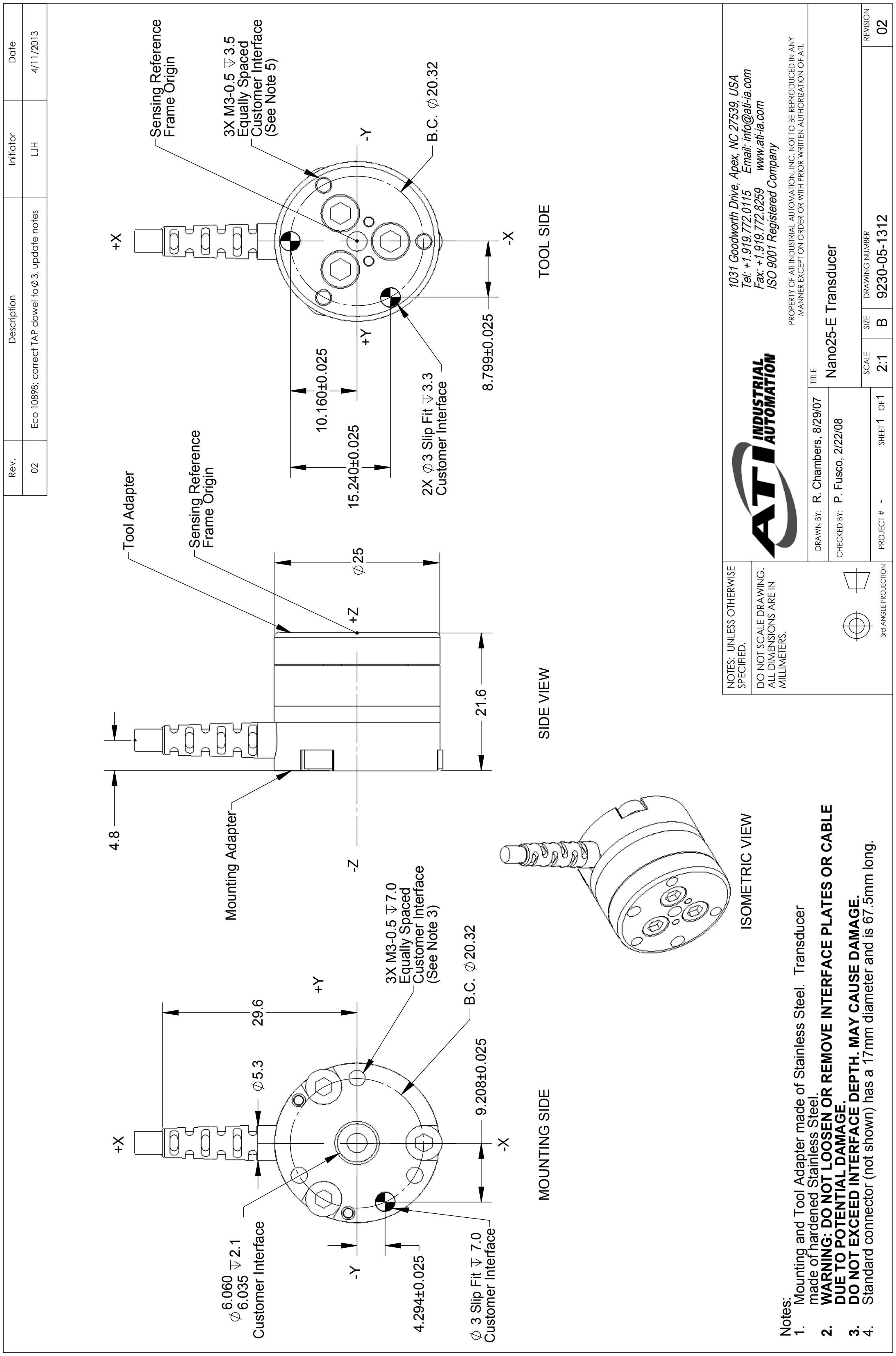
5.4.8 Nano25 (SI Calibration Complex Loading)(Includes IP65/IP68)[1]



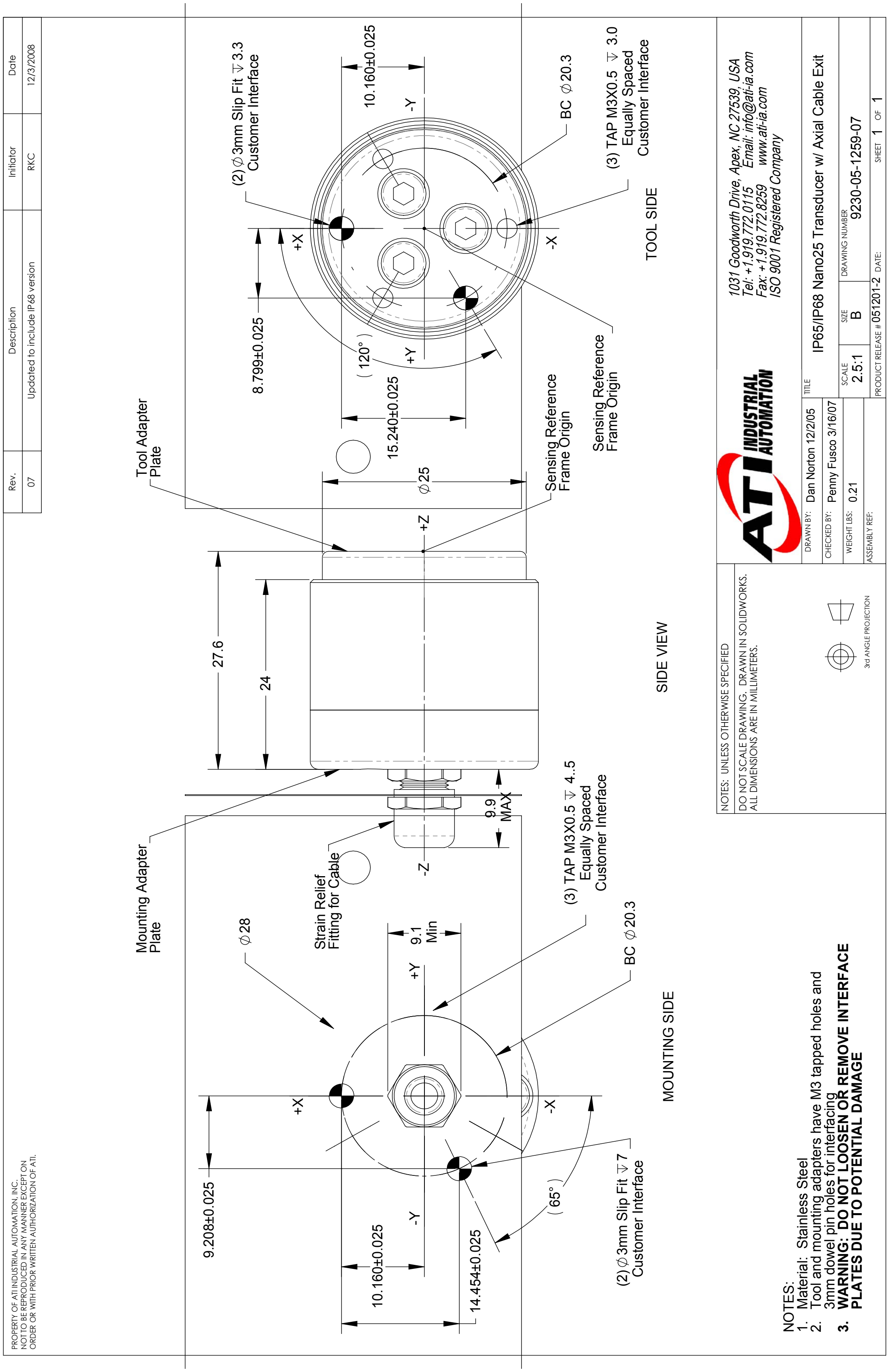


Note: 1. For IP68 version see caution on physical properties page.

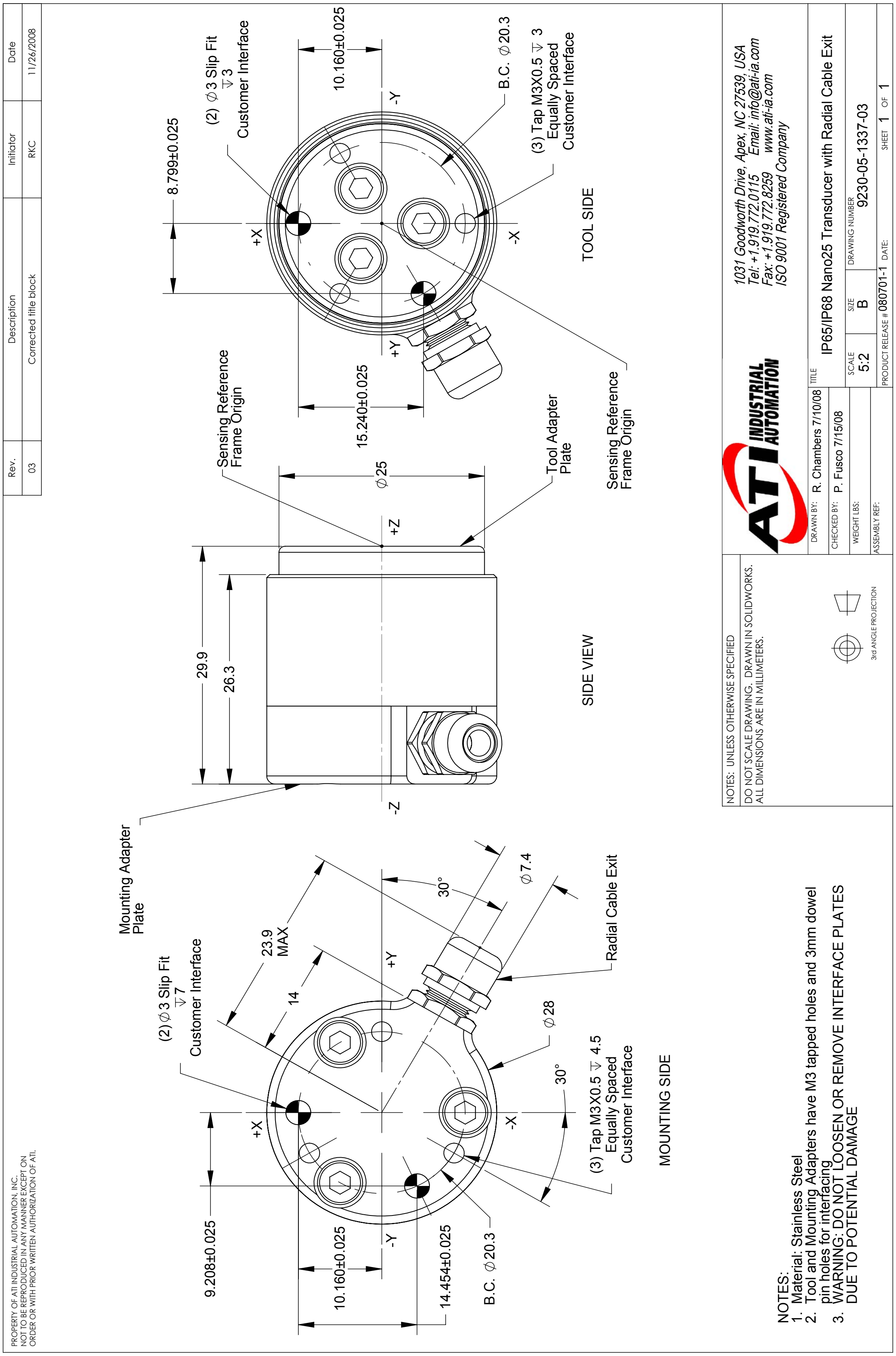
5.4.9 Nano25-E Transducer Drawing



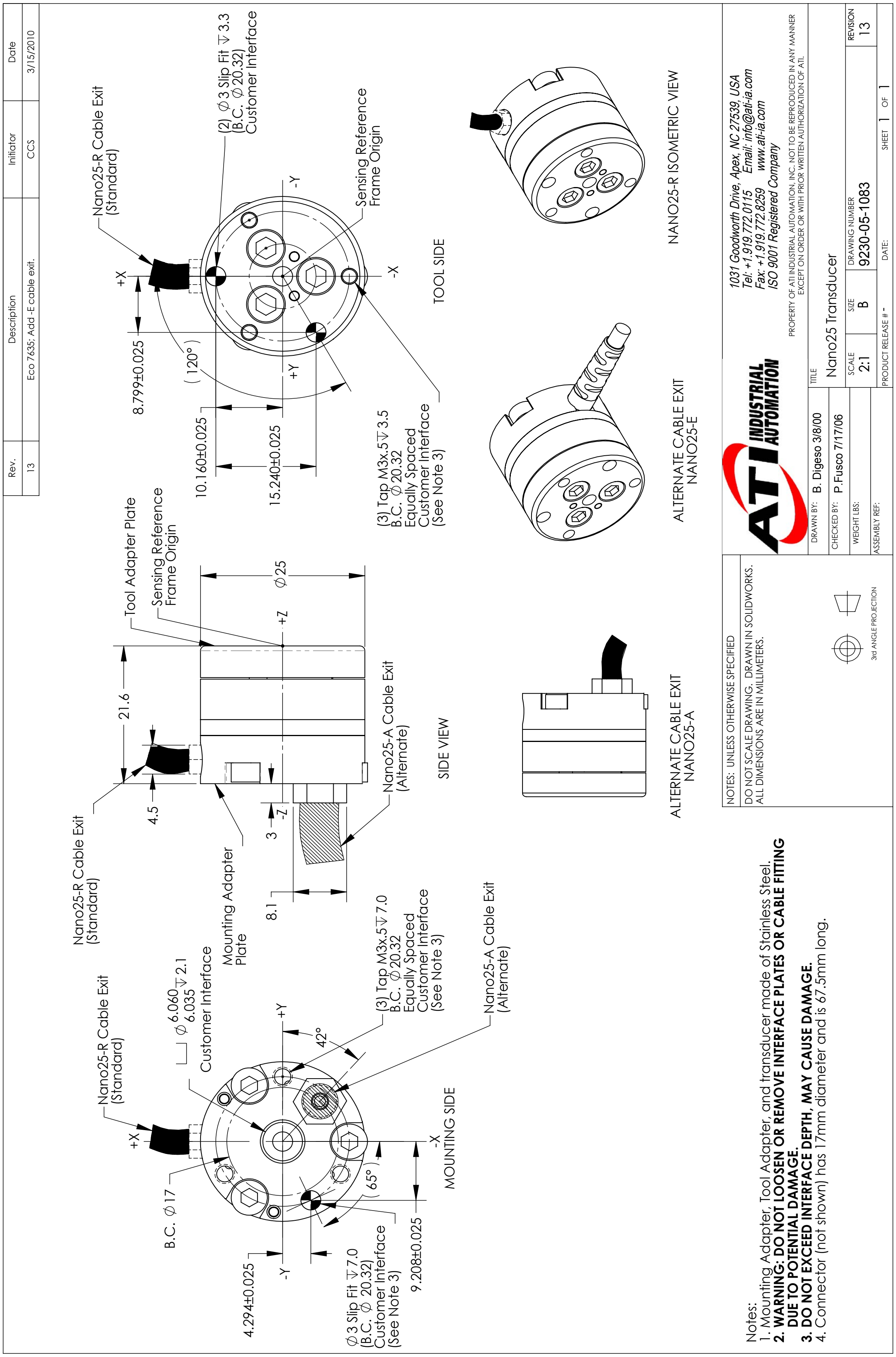
5.4.10 Nano25 IP65/IP68 Transducer with Axial Cable Exit Drawing



5.4.11 Nano25 IP65/IP68 Transducer with Radial Cable Exit Drawing



5.4.12 Legacy Nano25 Transducer Drawing



5.5 Nano43 Specifications

5.5.1 Nano43 Physical Properties

Table 5.18—Nano43 Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±68 lbf	±300 N
Fz	±86 lbf	±380 N
Txy	±29 inf-lb	±3.2 Nm
Tz	±41 inf-lb	±4.6 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	$2.9x10^4$ lb/in	$5.2x10^6$ N/m
Z-axis force (Kz)	$2.9x10^4$ lb/in	$5.2x10^6$ N/m
X-axis & Y-axis torque (Ktx, Kty)	$6.8x10^3$ lbf-in/rad	$7.7x10^2$ Nm/rad
Z-axis torque (Ktz)	$1.0x10^4$ lbf-in/rad	$1.1x10^3$ Nm/rad
Resonant Frequency		
Fx, Fy, Tz	2800 Hz	2800 Hz
Fz, Tx, Ty	2300 Hz	2300 Hz
Physical Specifications		
Weight[1]	0.0854 lb	0.0387 kg
Diameter[1]	1.69 in	43 mm
Height[1]	0.454 in	11.5 mm
Note: 1. Specifications include standard interface plates.		

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

5.5.2 Calibration Specifications (excludes CTL calibrations)

Table 5.19— Nano43 Calibrations (excludes CTL calibrations)[1, 2]									
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**	**Fx,Fy (lbf)**	**Fz (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**
Nano43	US-2-1	2	2	1	1	1/2320	1/2320	1/4640	1/4640
Nano43	US-4-2	4	4	2	2	1/1160	1/1160	1/2320	1/2320
Nano43	US-8-4	8	8	4	4	1/580	1/580	1/1160	1/1160
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**	**Fx,Fy (N)**	**Fz (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**
Nano43	SI-9-0.125	9	9	125	125	1/512	1/512	1/40	1/40
Nano43	SI-18-0.25	18	18	250	250	1/256	1/256	1/20	1/20
Nano43	SI-36-0.5	36	36	500	500	1/128	1/128	1/10	1/10
		Sensing Ranges				**Resolution (DAQ, Net F/T)[3]**			

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

5.5.3 CTL Calibration Specifications

Table 5.20— Nano43 CTL Calibrations[1, 2]

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

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

5.5.4 Analog Output

Table 5.21— Nano43 Analog Output

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

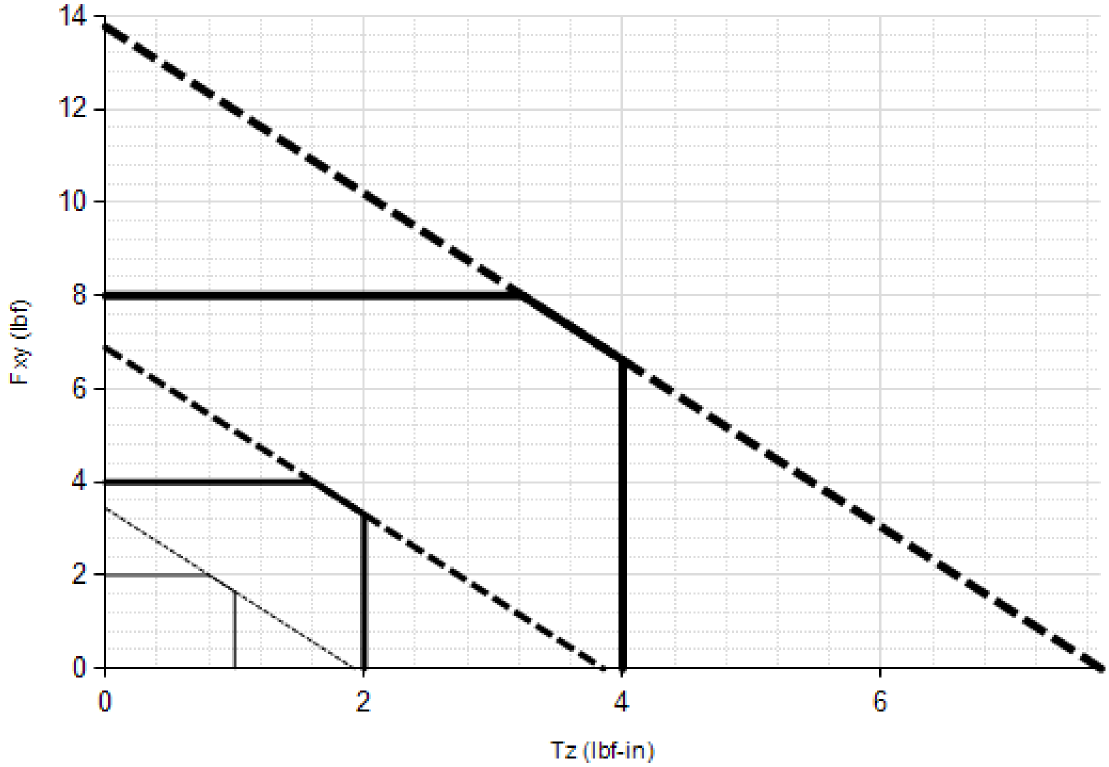
Notes:
1. ±5V Sensitivity values are double the listed ±10V Sensitivity values.

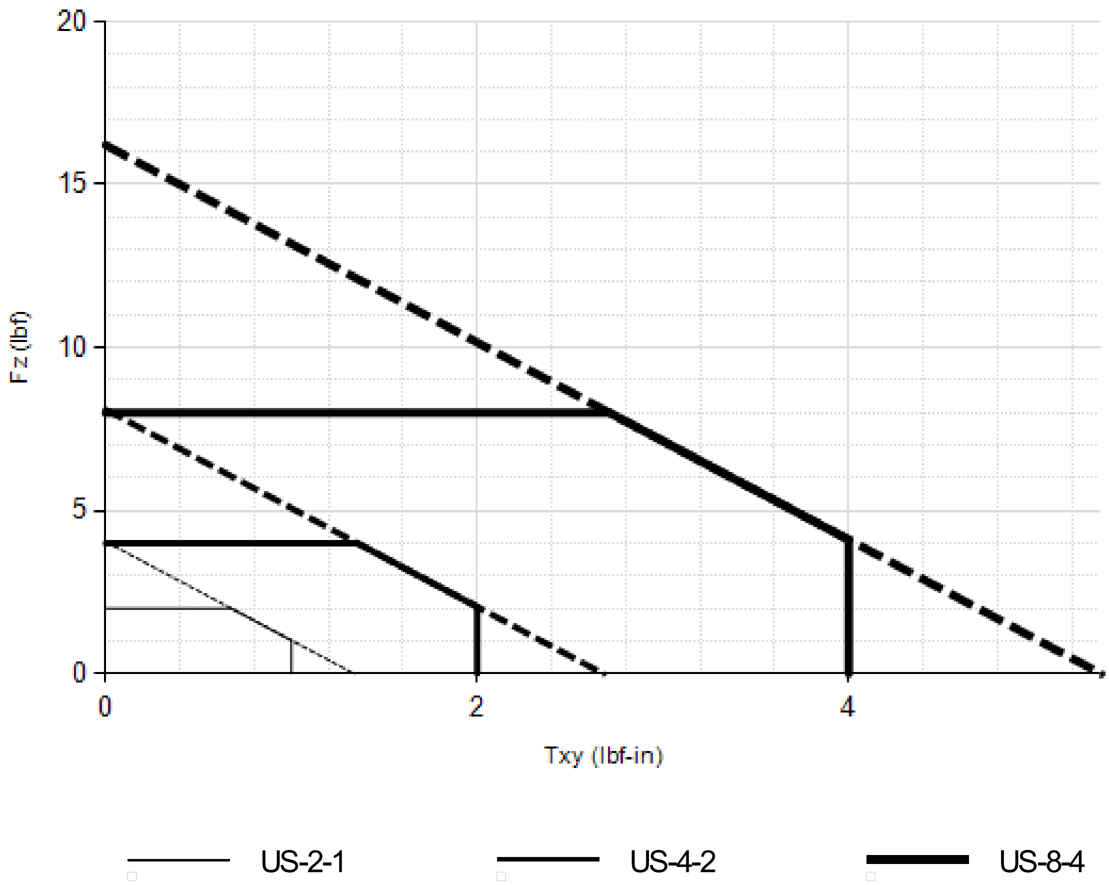
5.5.5 Counts Value

Table 5.22—Counts Value

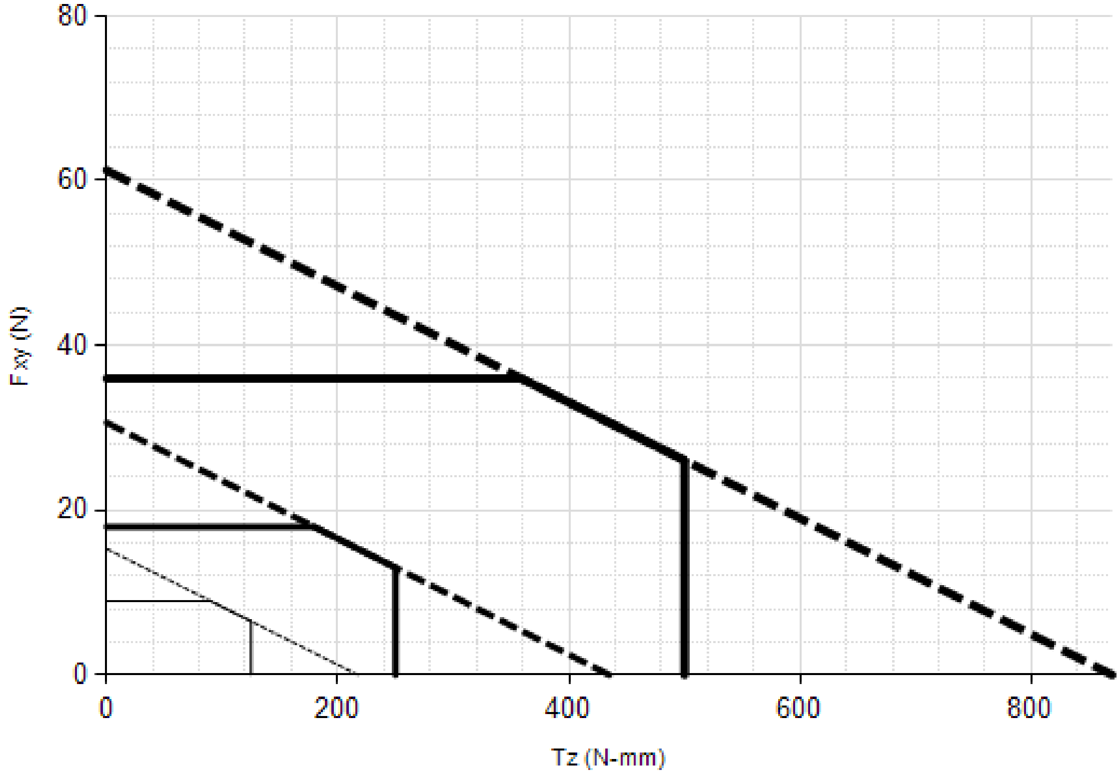
Sensor	Calibration	Fx, Fy, Fz (/ lbf)	Tx, Ty, Tz (/ lbf-in)	Fx, Fy, Fz (/ N)	Tx, Ty, Tz (/ Nmm)
Nano43	US-2-1 / SI-9-0.125	N/A	N/A	N/A	N/A
Nano43	US-4–2 / SI-18–0.25	4640	9280	1024	80
Nano43	US-8–4 / SI-36–0.5	2320	4640	512	40
Nano43	Tool Transform Factor	0.005 in/lbf		0.128 mm/N	
		Counts Value – Standard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

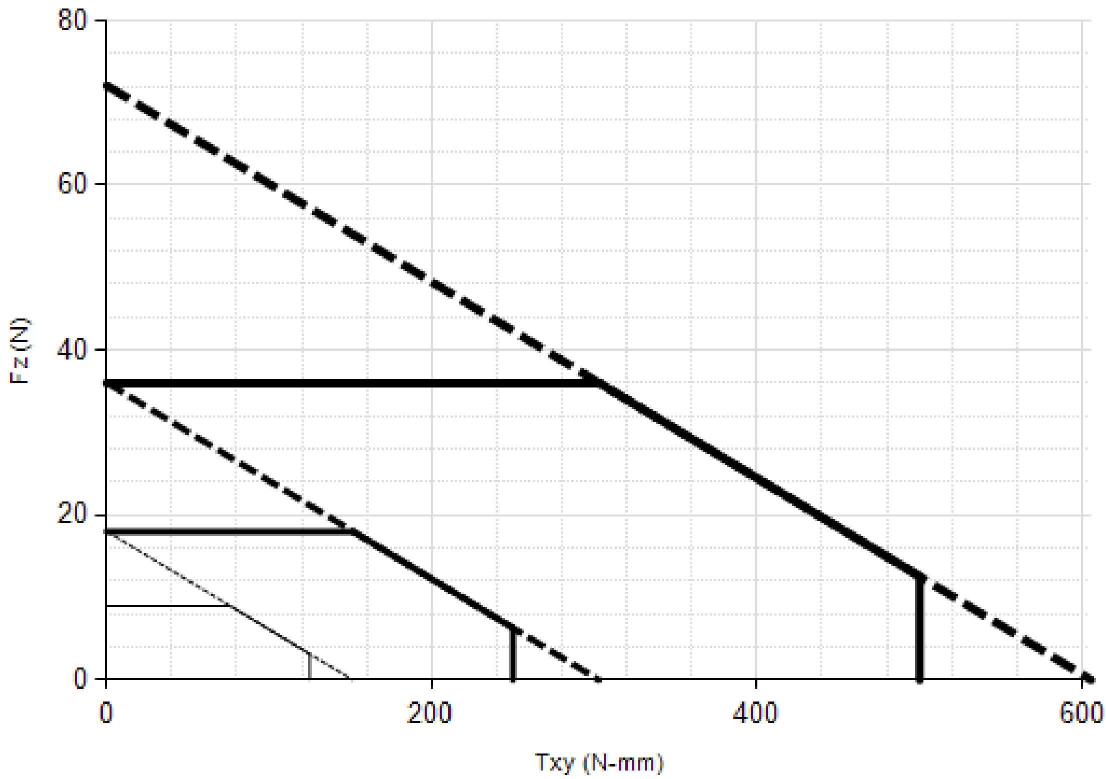
5.5.6 Nano43 (US Calibration Complex Loading)

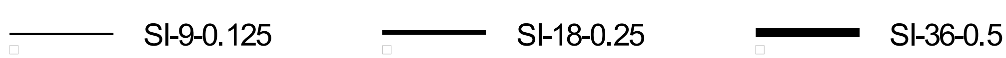




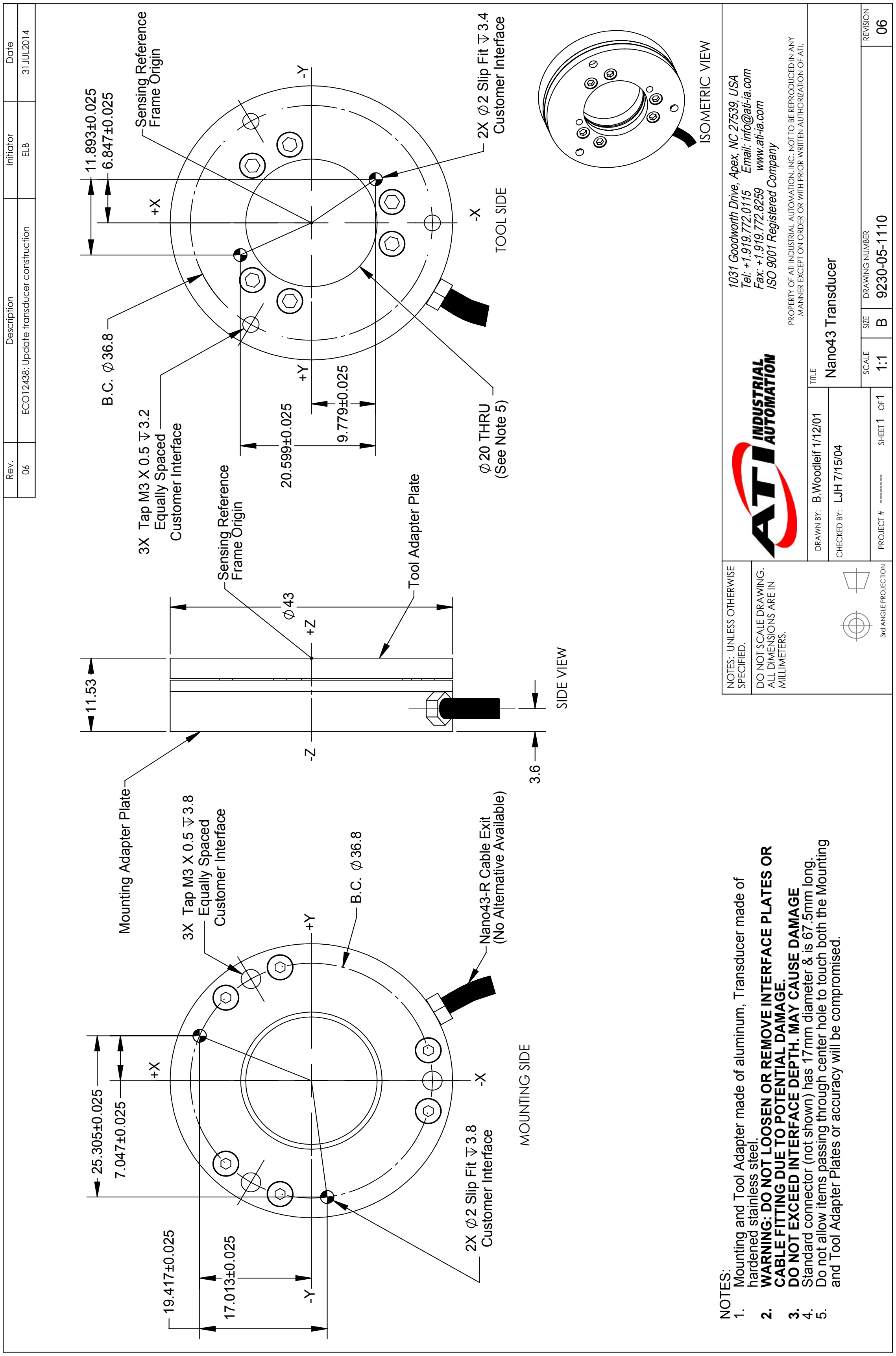
5.5.7 Nano43 (SI Calibration Complex Loading)







5.5.8 Nano43 Transducer Drawing



5.6 Mini27 Titanium Specifications

5.6.1 Mini27 Titanium Physical Properties

Table 5.23—Mini27 Titanium Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±330 lbf	±1500 N
Fz	±1000 lbf	±4600 N
Txy	±270 inf-lb	±30 Nm
Tz	±360 inf-lb	±40 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	1.8×10^{5} lb/in	3.1×10^{7} N/m
Z-axis force (Kz)	3.6×10^{5} lb/in	6.4×10^{7} N/m
X-axis & Y-axis torque (Ktx, Kty)	4.0×10^{4} lbf-in/rad	4.5×10^{3} Nm/rad
Z-axis torque (Ktz)	5.8×10^{4} lbf-in/rad	6.5×10^{3} Nm/rad
Resonant Frequency		
Fx, Fy, Tz	N/A	N/A
Fz, Tx, Ty	N/A	N/A
Physical Specifications		
Weight[1]	0.0736 lb	0.0334 kg
Diameter[1]	1.06 in	27 mm
Height[1]	0.715 in	18.2 mm
Note: 1. Specifications include standard interface plates.		

5.6.2 Calibration Specifications (excludes CTL calibrations)

Table 5.24— Mini27 Titanium Calibrations (excludes CTL calibrations)[1, 2]									
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**	**Fx,Fy (lbf)**	**Fz (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**
Mini27 Titanium	US-10-18	10	20	18	10	1/400	3/400	1/400	1/800
Mini27 Titanium	US-20-36	20	40	36	20	1/200	3/200	1/200	1/400
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**	**Fx,Fy (N)**	**Fz (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**
Mini27 Titanium	SI-40-2	40	80	2	1	3/200	3/100	3/8000	1/4000
Mini27 Titanium	SI-80-4	80	160	4	2	3/100	3/50	3/4000	1/2000
		Sensing Ranges				**Resolution (DAQ, Net F/T)[3]**			

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

5.6.3 CTL Calibration Specifications

Table 5.25— Mini27 Titanium CTL Calibrations[1, 2]									
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**	**Fx,Fy (lbf)**	**Fz (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**
Mini27 Titanium	US-10-18	10	20	18	10	1/200	3/200	1/200	1/400
Mini27 Titanium	US-20-36	20	40	36	20	1/100	3/100	1/100	1/200
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**	**Fx,Fy (N)**	**Fz (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**
Mini27 Titanium	SI-40-2	40	80	2	1	3/100	3/50	3/4000	1/2000
Mini27 Titanium	SI-80-4	80	160	4	2	3/50	3/25	3/2000	1/1000
		Sensing Ranges				**Resolution (Controller)**			

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

5.6.4 Analog Output

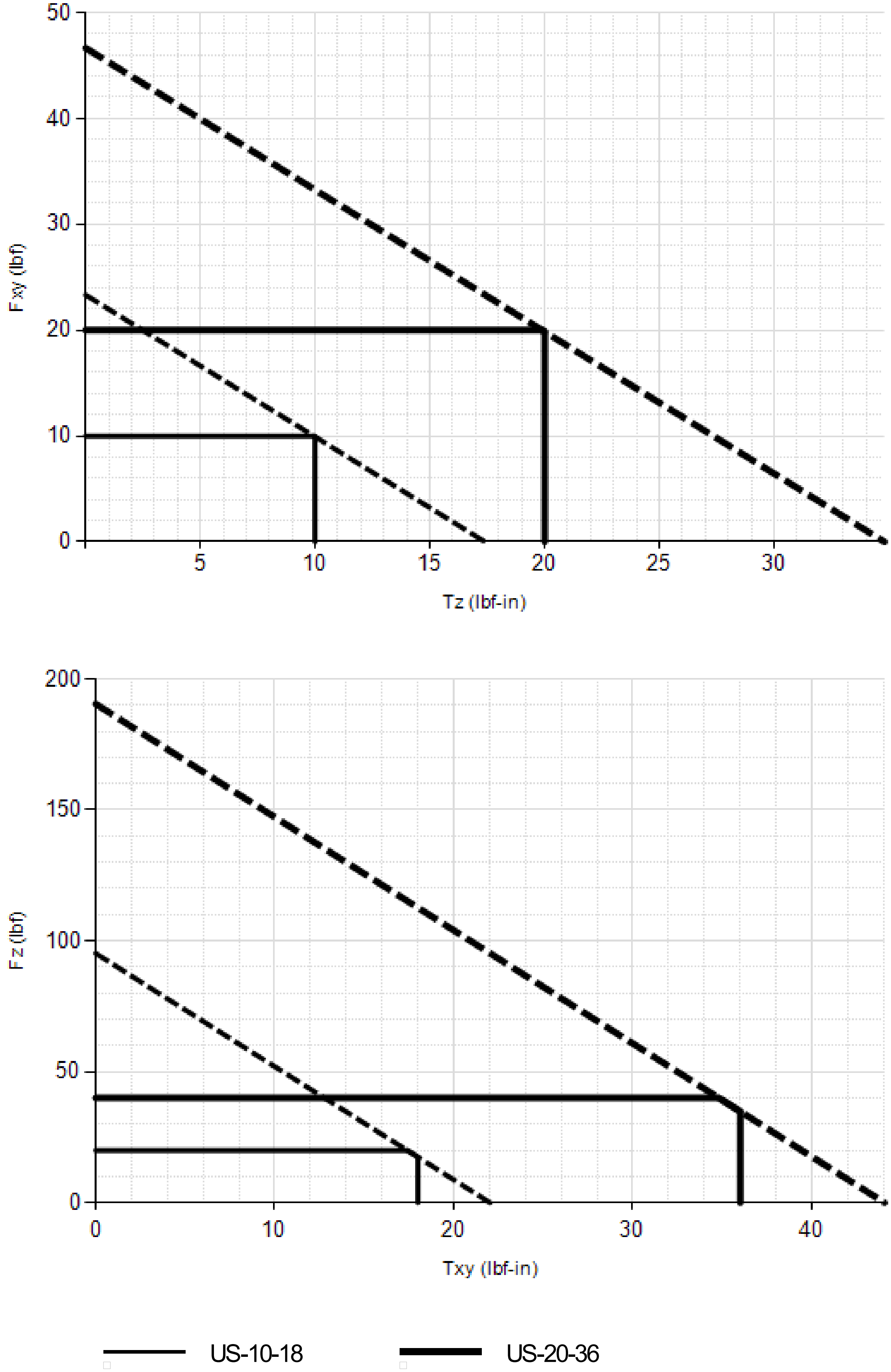
Table 5.26— Mini27 Titanium Analog Output							
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz (lbf)**	**Tx,Ty,Tz (lbf-in)**	**Fx,Fy (lbf/V)**	**Fz (lbf/V)**	**Tx,Ty,Tz (lbf-in/V)**
Mini27 Titanium	US-10-18	±10	±20	±18	1	2	1.8
Mini27 Titanium	US-20-36	±20	±40	±36	2	4	3.6
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz (N)**	**Tx,Ty,Tz (Nmm)**	**Fx,Fy (N/V)**	**Fz (N/V)**	**Tx,Ty,Tz (Nm/V)**
Mini27 Titanium	SI-40-2	±40	±80	±2	4	8	0.2
Mini27 Titanium	SI-80-4	±80	±160	±4	8	16	0.4
		Analog Output Range			**Analog ±10V Sensitivity[1]**		

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

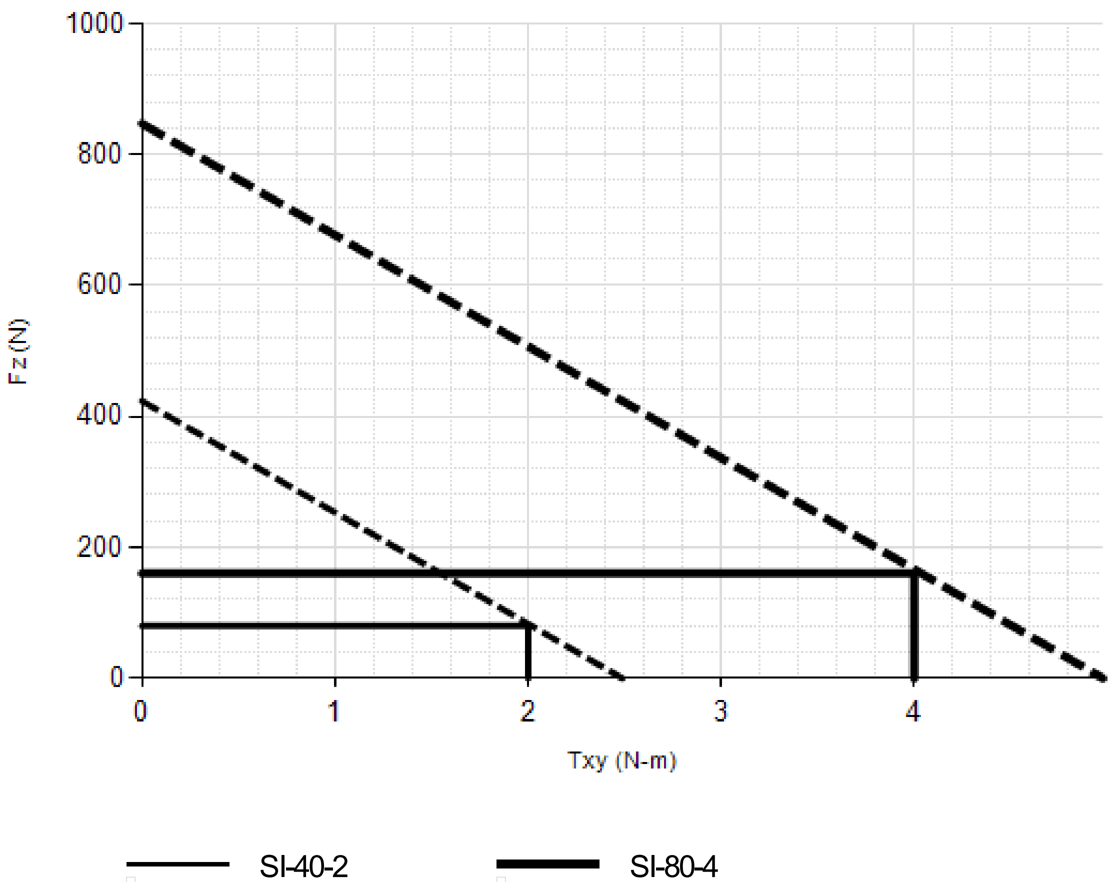
5.6.5 Counts Value

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

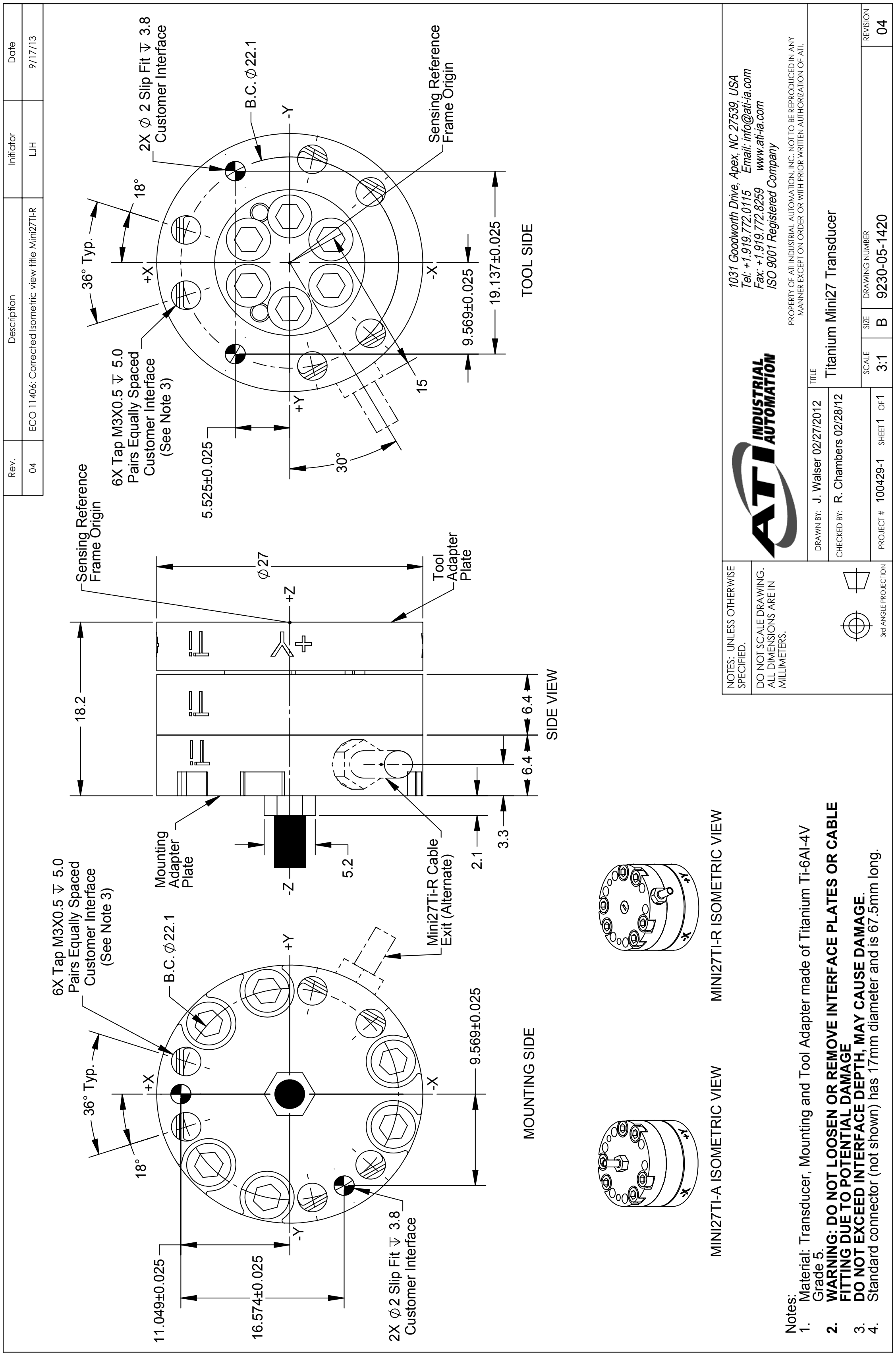
5.6.6 Mini27 Titanium (US Calibration Complex Loading)



5.6.7 Mini27 Titanium (SI Calibration Complex Loading)



5.6.8 Mini27 Titanium Transducer Drawing



5.7 Mini40 Specifications (Includes IP65/IP68 Versions)

5.7.1 Mini40 Physical Properties

Table 5.28—Mini40 Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±180 lbf	±810 N
Fz	±530 lbf	±2400 N
Txy	±170 inf-lb	±19 Nm
Tz	±180 inf-lb	±20 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	6.1×10^{4} lb/in	1.1×10^{7} N/m
Z-axis force (Kz)	1.2×10^{5} lb/in	2.0×10^{7} N/m
X-axis & Y-axis torque (Ktx, Kty)	2.5×10^{4} lbf-in/rad	2.8×10^{3} Nm/rad
Z-axis torque (Ktz)	3.6×10^{4} lbf-in/rad	4.0×10^{3} Nm/rad
Resonant Frequency		
Fx, Fy, Tz	3200 Hz	3200 Hz
Fz, Tx, Ty	4900 Hz	4900 Hz
Physical Specifications		
Weight[1]	0.11 lb	0.0499 kg
Diameter[1]	1.57 in	40 mm
Height[1]	0.482 in	12.2 mm
Note: 1. Specifications include standard interface plates.		

5.7.2 Mini40 IP65/IP68 Physical Properties

Table 5.29—Mini40 IP65/IP68 Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±180 lbf	±810 N
Fz	±530 lbf	±2400 N
Txy	±170 inf-lb	±19 Nm
Tz	±180 inf-lb	±20 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	6.1×10^{4} lb/in	1.1×10^{7} N/m
Z-axis force (Kz)	1.2×10^{5} lb/in	2.0×10^{7} N/m
X-axis & Y-axis torque (Ktx, Kty)	2.5×10^{4} lbf-in/rad	2.8×10^{3} Nm/rad
Z-axis torque (Ktz)	3.6×10^{4} lbf-in/rad	4.0×10^{3} Nm/rad
Resonant Frequency		
Fx, Fy, Tz	1400 Hz	1400 Hz
Fz, Tx, Ty	1300 Hz	1300 Hz
Physical Specifications		
Weight[1]	0.6 lb	0.272 kg
Diameter[1]	2.1 in	53.3 mm
Height[1]	0.83 in	21.1 mm
Note: 1. Specifications include standard interface plates.		

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

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

5.7.3 Calibration Specifications (excludes CTL calibrations)

Table 5.30— Mini40 Calibrations (excludes CTL calibrations)[1, 2]

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

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

5.7.4 CTL Calibration Specifications

Table 5.31— Mini40 CTL Calibrations[1, 2]

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

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

5.7.5 Analog Output

Table 5.32— Mini40 Analog Output

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

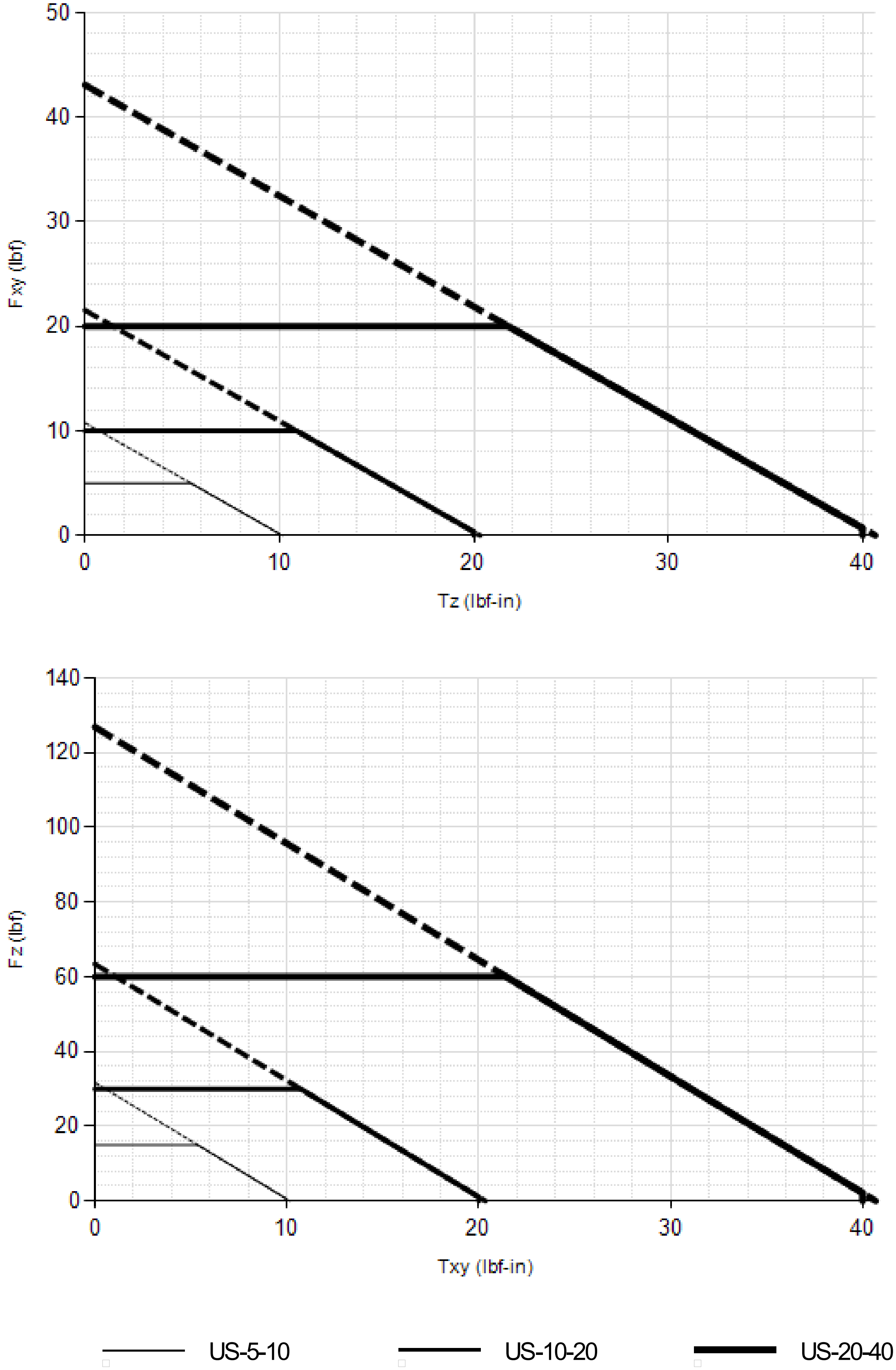
Notes:
1. ±5V Sensitivity values are double the listed ±10V Sensitivity values.
2. For IP68 version see caution on physical properties page.

5.7.6 Counts Value

Table 5.33—Counts Value

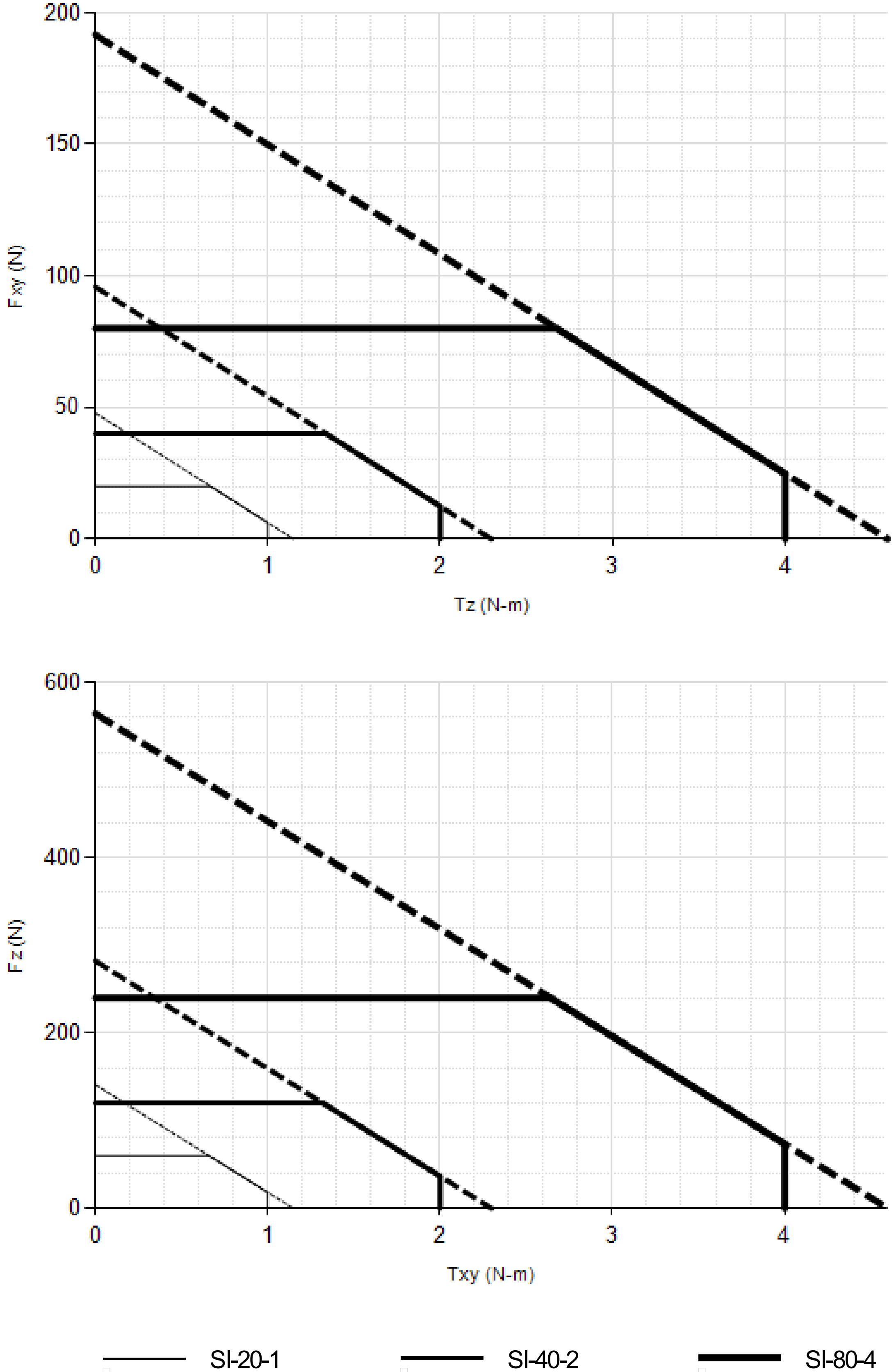
Sensor	Calibration	Fx, Fy, Fz (/ lbf)	Tx, Ty, Tz (/ lbf-in)	Fx, Fy, Fz (/ N)	Tx, Ty, Tz (/ Nm)
Mini40	US-5–10 / SI-20–1	3200	3200	800	32000
Mini40	US-10–20 / SI-40–2	1600	1600	400	16000
Mini40	US-20–40 / SI-80-4	800	800	200	8000
Mini40	Tool Transform Factor	0.01 in/lbf		0.25 mm/N	
		Counts Value – Standard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

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



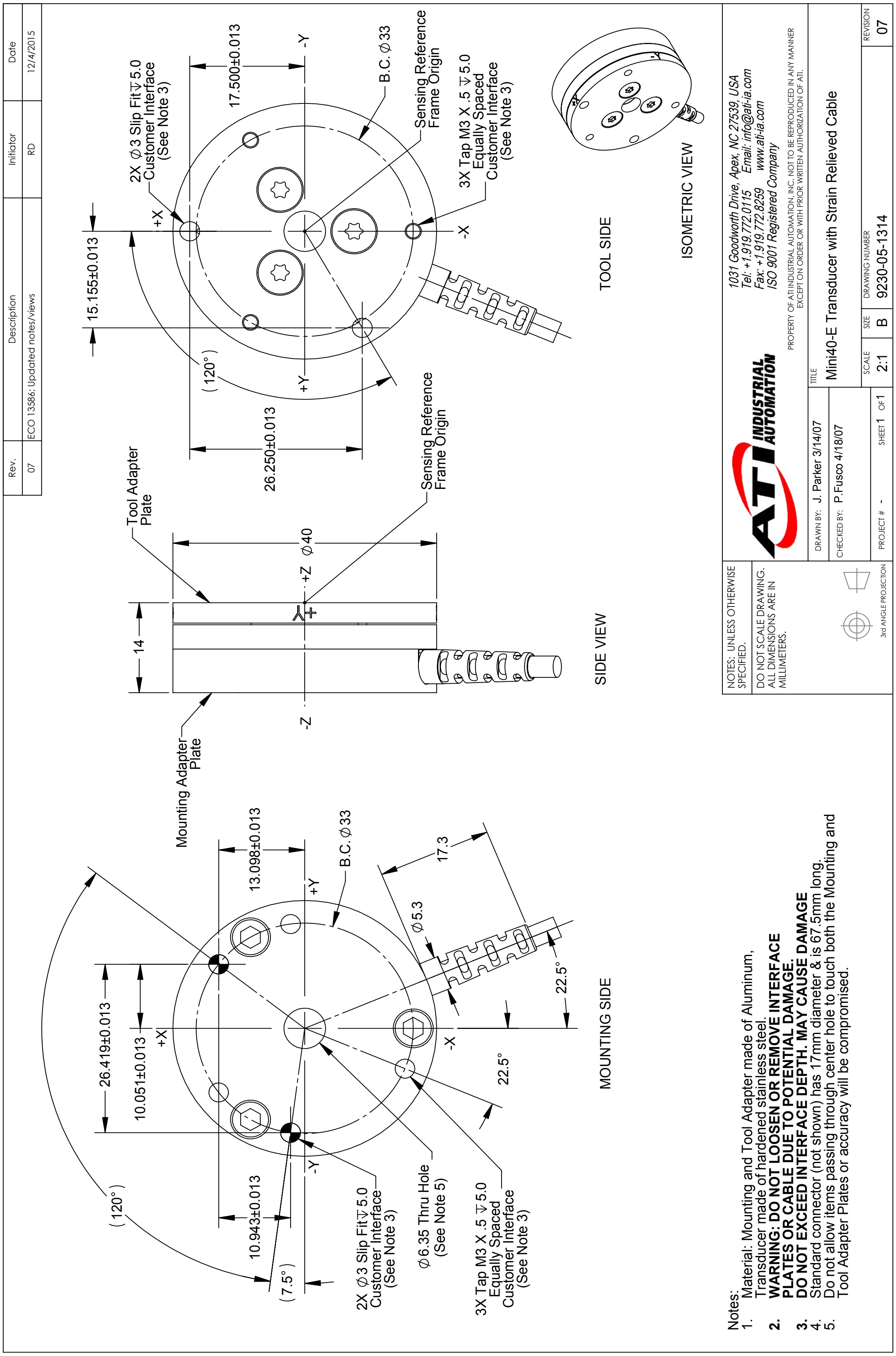
Note: 1. For IP68 version see caution on physical properties page.

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

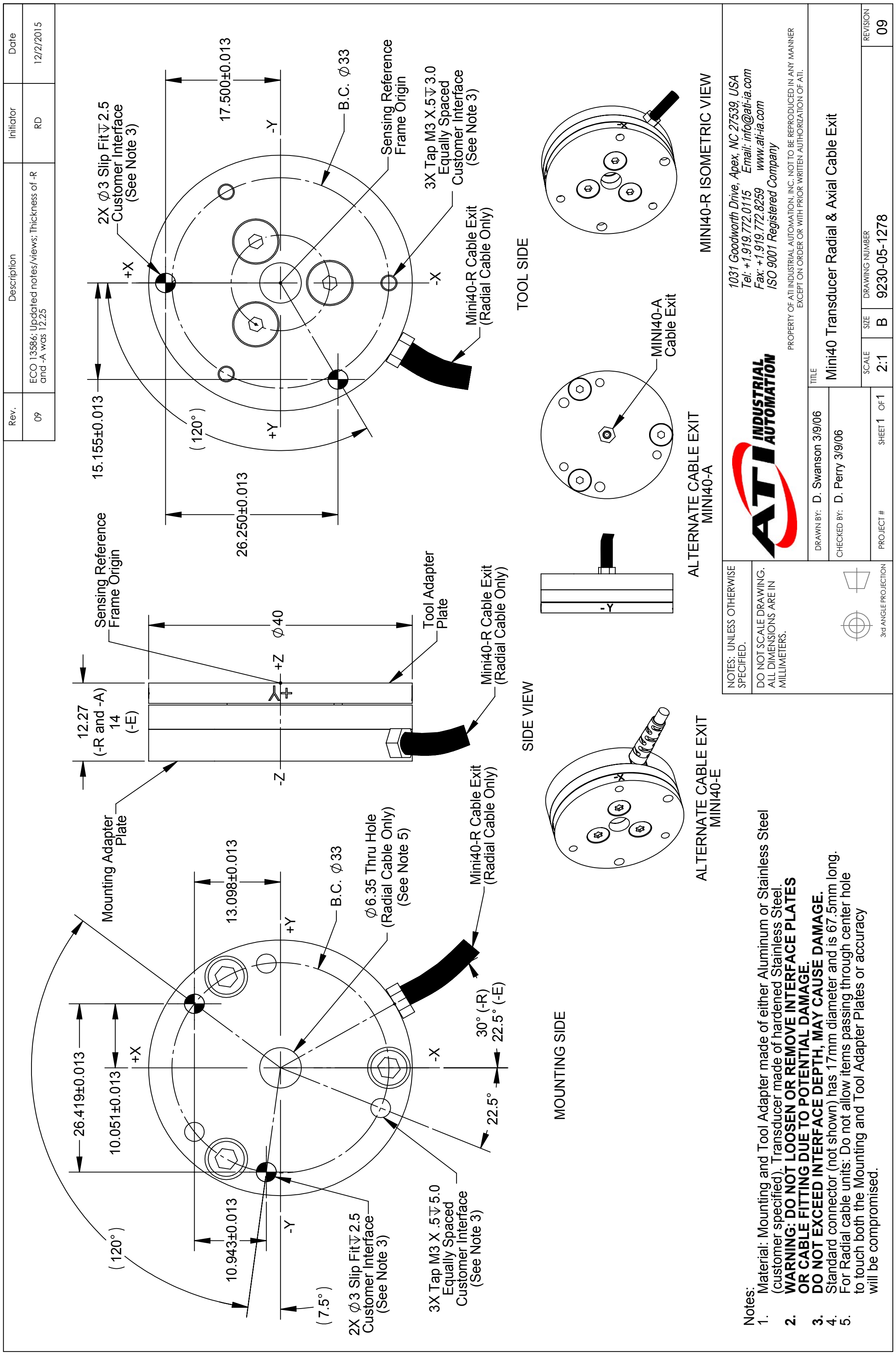


Note: 1. For IP68 version see caution on physical properties page.

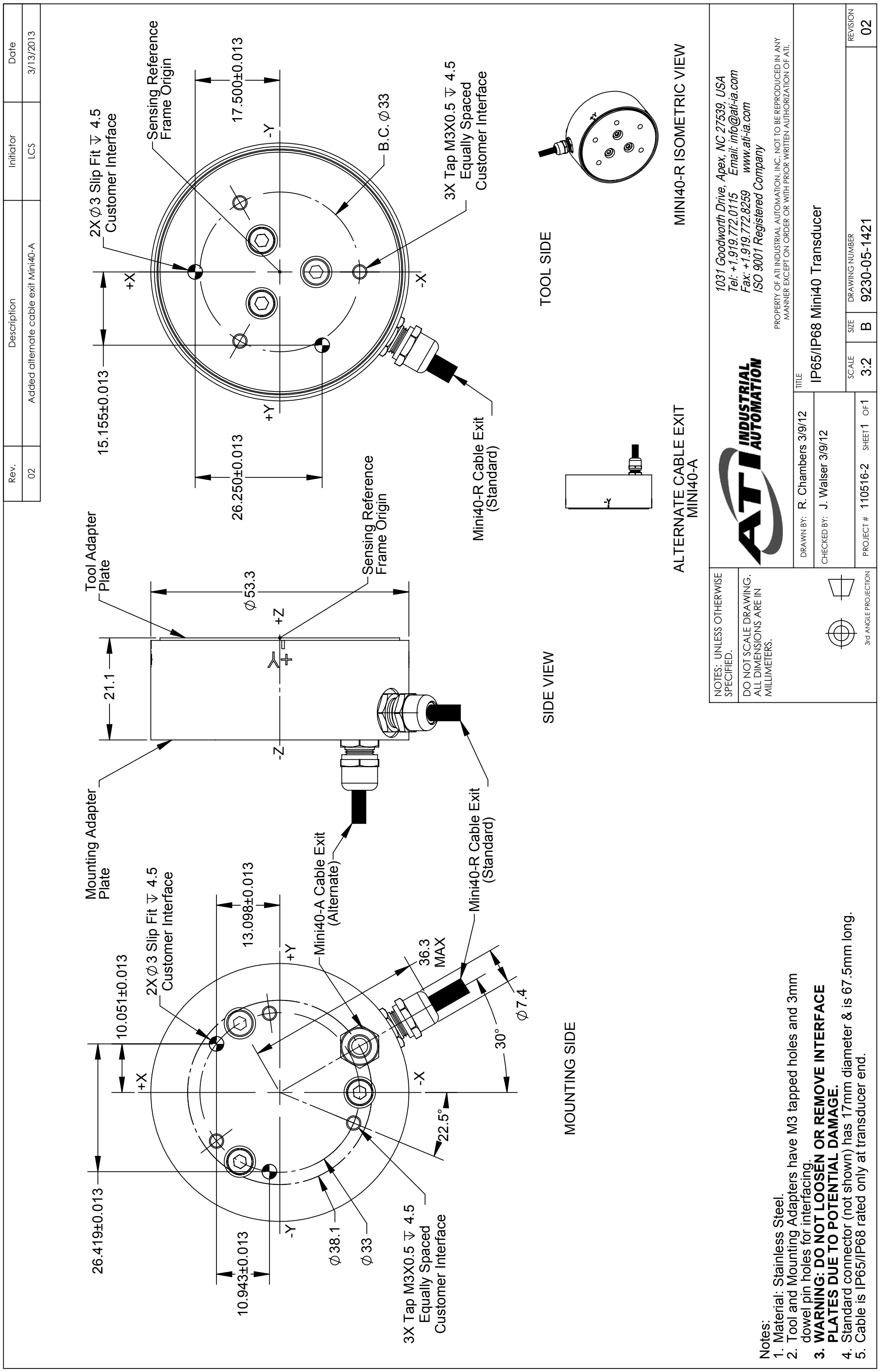
5.7.9 Mini40-E Transducer Drawing



5.7.10 Legacy Mini40 Transducer Drawing



5.7.11 Mini40 IP65/IP68 Transducer Drawing



5.8 Mini45 Titanium Specifications

5.8.1 Mini45 Titanium Physical Properties

Table 5.34—Mini45 Titanium Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±670 lbf	±3000 N
Fz	±1400 lbf	±6400 N
Txy	±590 inf-lb	±67 Nm
Tz	±720 inf-lb	±81 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	2.5×10^5 lb/in	4.3×10^7 N/m
Z-axis force (Kz)	3.3×10^5 lb/in	5.7×10^7 N/m
X-axis & Y-axis torque (Ktx, Kty)	8.6×10^4 lbf-in/rad	9.7×10^3 Nm/rad
Z-axis torque (Ktz)	1.8×10^5 lbf-in/rad	2.0×10^4 Nm/rad
Resonant Frequency		
Fx, Fy, Tz	5800 Hz	5800 Hz
Fz, Tx, Ty	4600 Hz	4600 Hz
Physical Specifications		
Weight[1]	0.22 lb	0.0998 kg
Diameter[1]	1.77 in	45 mm
Height[1]	0.69 in	17.5 mm
Note: 1. Specifications include standard interface plates.		

5.8.2 Calibration Specifications (excludes CTL calibrations)

Table 5.35— Mini45 Titanium Calibrations (excludes CTL calibrations)[1, 2]									
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**	**Fx,Fy (lbf)**	**Fz (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**
Mini45 Titanium	US-15-25	15	30	25	25	3/800	1/160	1/300	1/400
Mini45 Titanium	US-30-50	30	60	50	50	3/400	1/80	1/150	1/200
Mini45 Titanium	US-60-100	60	120	100	100	3/200	1/40	1/75	1/100
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**	**Fx,Fy (N)**	**Fz (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**
Mini45 Titanium	SI-60-3	60	120	3	3	1/60	7/240	3/8000	1/3200
Mini45 Titanium	SI-120-6	120	240	6	6	1/30	7/120	3/4000	1/1600
Mini45 Titanium	SI-240-12	240	480	12	12	1/15	7/60	3/2000	1/800
		Sensing Ranges				**Resolution (DAQ, Net F/T)[3]**			

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

5.8.3 CTL Calibration Specifications

Table 5.36— Mini45 Titanium CTL Calibrations[1, 2]									
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**	**Fx,Fy (lbf)**	**Fz (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**
Mini45 Titanium	US-15-25	15	30	25	25	3/400	1/80	1/150	1/200
Mini45 Titanium	US-30-50	30	60	50	50	3/200	1/40	1/75	1/100
Mini45 Titanium	US-60-100	60	120	100	100	3/100	1/20	2/75	1/50
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**	**Fx,Fy (N)**	**Fz (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**
Mini45 Titanium	SI-60-3	60	120	3	3	1/30	7/120	3/4000	1/1600
Mini45 Titanium	SI-120-6	120	240	6	6	1/15	7/60	3/2000	1/800
Mini45 Titanium	SI-240-12	240	480	12	12	2/15	7/30	3/1000	1/400
		Sensing Ranges				**Resolution (Controller)**			

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

5.8.4 Analog Output

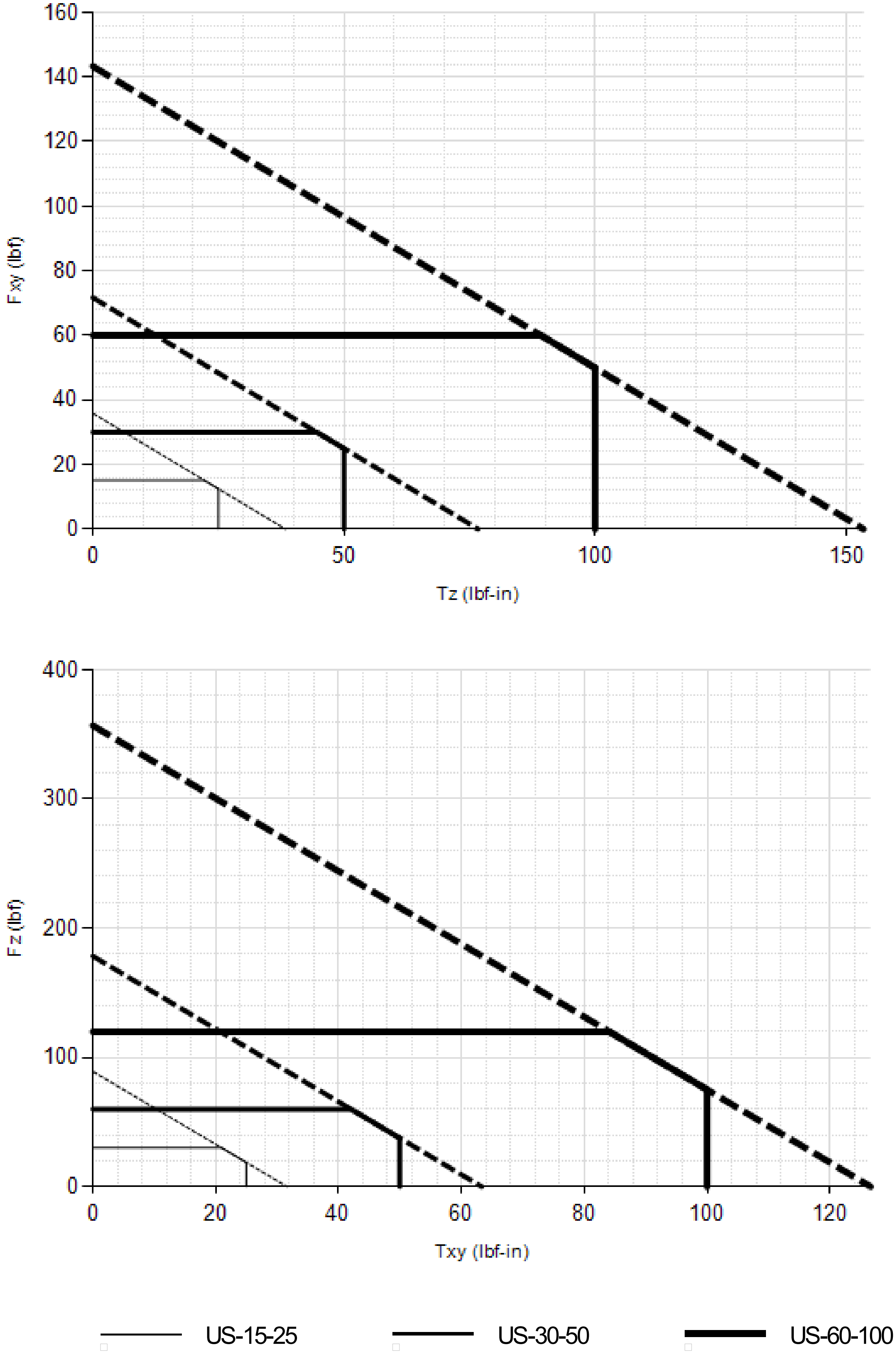
Table 5.37— Mini45 Titanium Analog Output							
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz (lbf)**	**Tx,Ty,Tz (lbf-in)**	**Fx,Fy (lbf/V)**	**Fz (lbf/V)**	**Tx,Ty,Tz (lbf-in/V)**
Mini45 Titanium	US-15-25	±15	±30	±25	1.5	3	2.5
Mini45 Titanium	US-30-50	±30	±60	±50	3	6	5
Mini45 Titanium	US-60-100	±60	±120	±100	6	12	10
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz (N)**	**Tx,Ty,Tz (Nmm)**	**Fx,Fy (N/V)**	**Fz (N/V)**	**Tx,Ty,Tz (Nm/V)**
Mini45 Titanium	SI-60-3	±60	±120	±3	6	12	0.3
Mini45 Titanium	SI-120-6	±120	±240	±6	12	24	0.6
Mini45 Titanium	SI-240-12	±240	±480	±12	24	48	1.2
		Analog Output Range			**Analog ±10V Sensitivity[1]**		

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

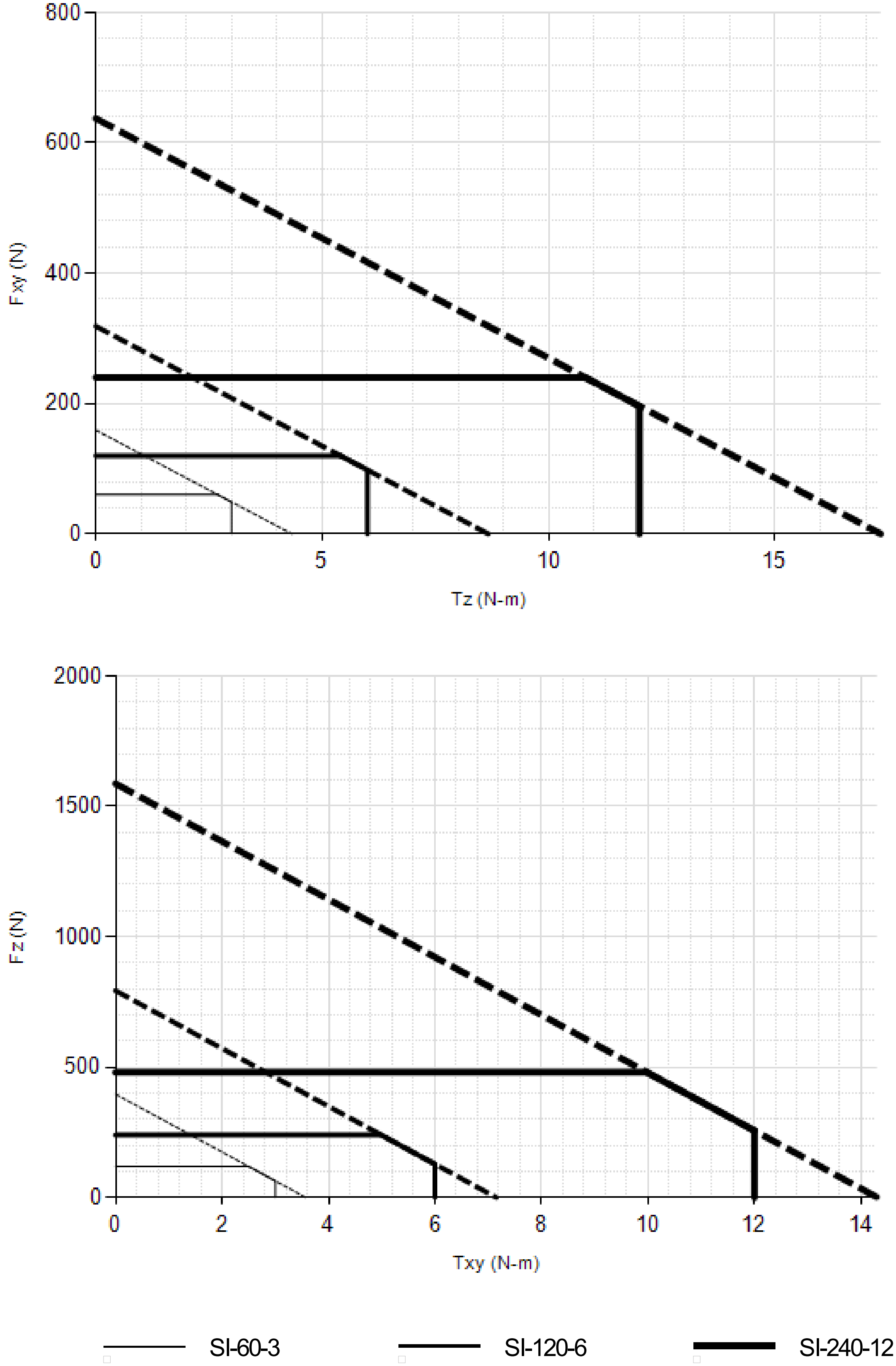
5.8.5 Counts Value

Table 5.38—Counts Value					
Sensor	**Calibration**	**Fx, Fy, Fz (/ lbf)**	**Tx, Ty, Tz (/ lbf-in)**	**Fx, Fy, Fz (/ N)**	**Tx, Ty, Tz (/ Nm)**
Mini45 Titanium	US-15-25 / SI-60-3	640	704	128	6016
Mini45 Titanium	US-30-50 / SI-120-6	320	352	64	3008
Mini45 Titanium	US-60-100 / SI-240-12	160	176	32	1504
Mini45 Titanium	Tool Transform Factor	0.009091 in/lbf		0.21277 mm/N	
		Counts Value – Standard (US)		**Counts Value – Metric (SI)**	

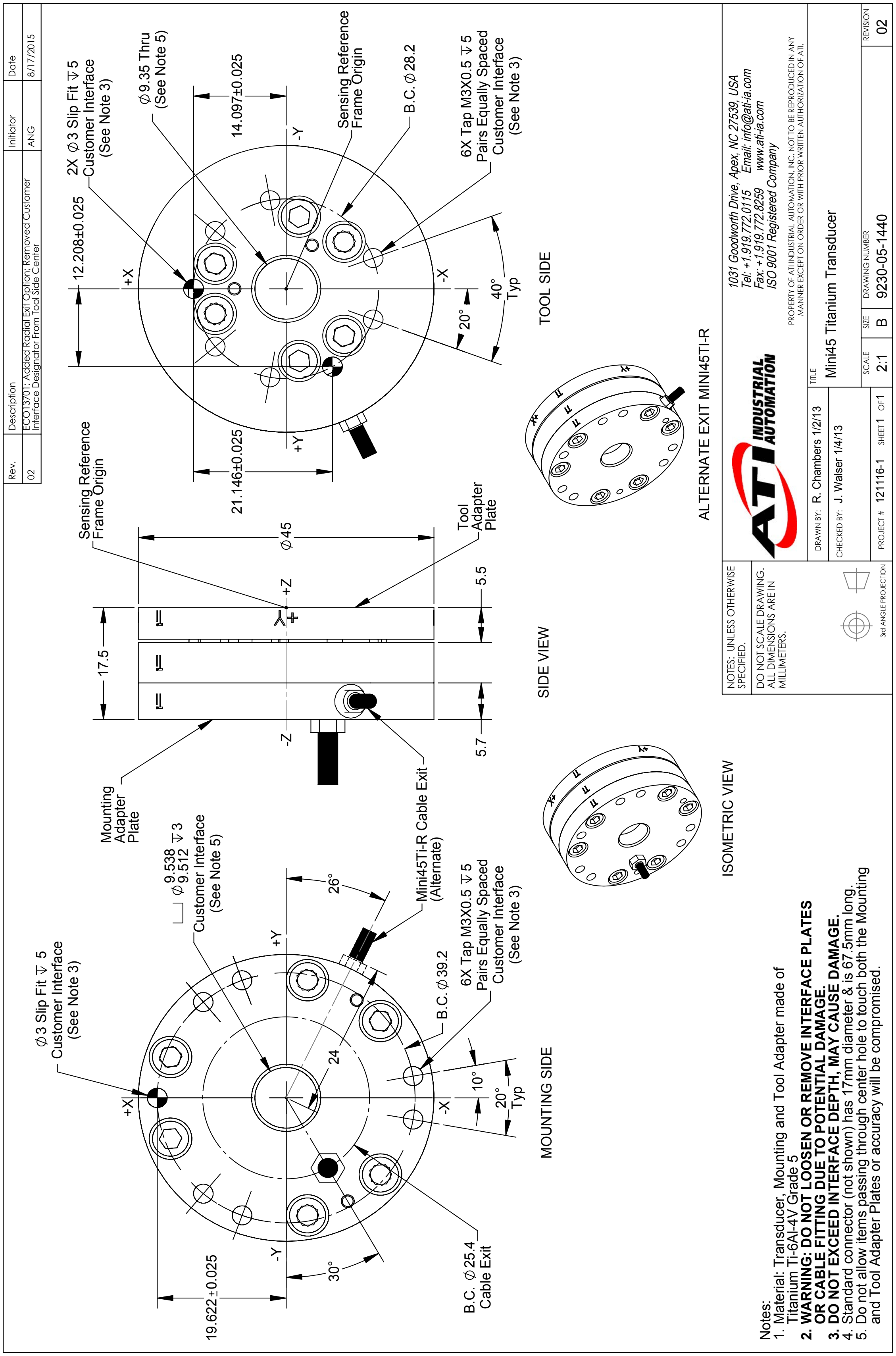
5.8.6 Mini45 Titanium (US Calibration Complex Loading)



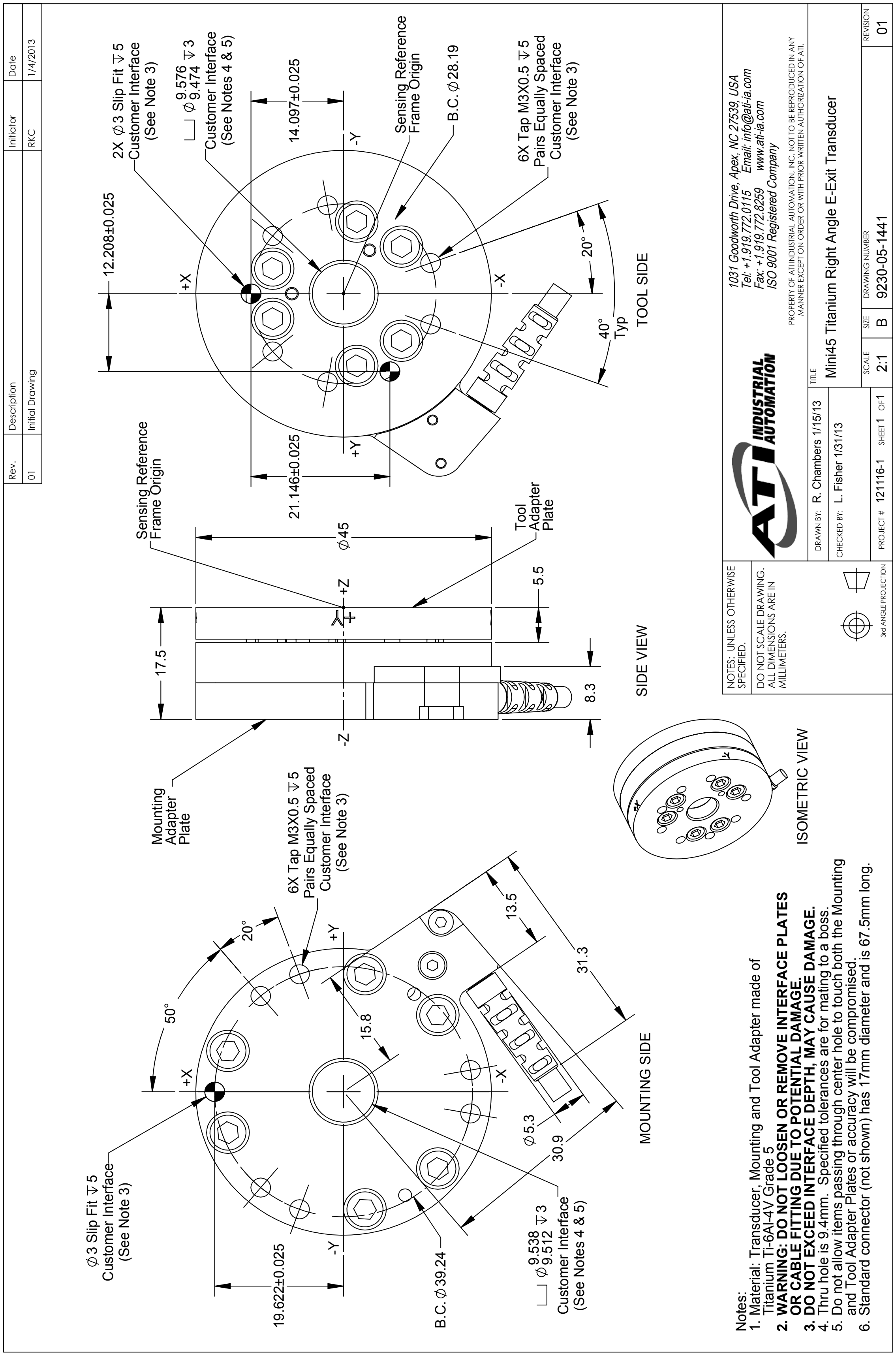
5.8.7 Mini45 Titanium (SI Calibration Complex Loading)



5.8.8 Mini45 Titanium Axial Exit Transducer Drawing



5.8.9 Mini45 Titanium Right Angle E-Exit Transducer Drawing



5.9 Mini45 Specifications (Includes IP65/IP68 Versions)

5.9.1 Mini45 Physical Properties

Table 5.39—Mini45 Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±1100 lbf	±5100 N
Fz	±2300 lbf	±10000 N
Txy	±1000 inf-lb	±110 Nm
Tz	±1200 inf-lb	±140 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	$4.2x10^{5}$ lb/in	$7.4x10^{7}$ N/m
Z-axis force (Kz)	$5.6x10^{5}$ lb/in	$9.8x10^{7}$ N/m
X-axis & Y-axis torque (Ktx, Kty)	$1.5x10^{5}$ lbf-in/rad	$1.7x10^{4}$ Nm/rad
Z-axis torque (Ktz)	$3.1x10^{5}$ lbf-in/rad	$3.5x10^{4}$ Nm/rad
Resonant Frequency		
Fx, Fy, Tz	5600 Hz	5600 Hz
Fz, Tx, Ty	5400 Hz	5400 Hz
Physical Specifications		
Weight[1]	0.202 lb	0.0917 kg
Diameter[1]	1.77 in	45 mm
Height[1]	0.618 in	15.7 mm
Note: 1. Specifications include standard interface plates.		

5.9.2 Mini45 IP65/IP68 Physical Properties

Table 5.40—Mini45 IP65/IP68 Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±1100 lbf	±5100 N
Fz	±2300 lbf	±10000 N
Txy	±1000 inf-lb	±110 Nm
Tz	±1200 inf-lb	±140 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	$4.2x10^{5}$ lb/in	$7.4x10^{7}$ N/m
Z-axis force (Kz)	$5.6x10^{5}$ lb/in	$9.8x10^{7}$ N/m
X-axis & Y-axis torque (Ktx, Kty)	$1.5x10^{5}$ lbf-in/rad	$1.7x10^{4}$ Nm/rad
Z-axis torque (Ktz)	$3.1x10^{5}$ lbf-in/rad	$3.5x10^{4}$ Nm/rad
Resonant Frequency		
Fx, Fy, Tz	5200 Hz	5200 Hz
Fz, Tx, Ty	4200 Hz	4200 Hz
Physical Specifications		
Weight[1]	0.861 lb	0.391 kg
Diameter[1]	2.28 in	57.9 mm
Height[1]	0.988 in	25.1 mm
Note: 1. Specifications include standard interface plates.		

CAUTION: When submerged, IP68 transducers exhibit a decrease in Fz range related to the submersion depth. This loss is the result of pressure-induced preloading on the transducer. The preload can be masked by biasing the transducer at the depth prior to applying the load to be measured. The following estimates are for room temperature fresh water at sea level.		
Submersion Depth		
IP68 Mini45	**US**	**Metric**
Fz preload at 4 m depth	17.0 lb	75.5 N
Fz preload at other depths	-1.29 lb/ft × depthInFeet	-18.9 N/m × depthInMeters

5.9.3 Calibration Specifications (excludes CTL calibrations)

Table 5.41— Mini45 Calibrations (excludes CTL calibrations)[1, 2]									
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz[3] (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**	**Fx,Fy (lbf)**	**Fz[3] (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**
Mini45	US-30-40	30	60	40	40	1/80	1/80	1/88	1/176
Mini45	US-60-80	60	120	80	80	1/40	1/40	1/44	1/88
Mini45	US-120-160	120	240	160	160	1/20	1/20	1/22	1/44
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**
Mini45	SI-145-5	145	290	5	5	1/16	1/16	1/752	1/1504
Mini45	SI-290-10	290	580	10	10	1/8	1/8	1/376	1/752
Mini45	SI-580-20	580	1160	20	20	1/4	1/4	1/188	1/376
		Sensing Ranges				**Resolution (DAQ, Net F/T)[4]**			

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

5.9.4 CTL Calibration Specifications

Table 5.42— Mini45 CTL Calibrations[1, 2]									
Sensor	(US) Standard Calibration	Fx,Fy (lbf)	Fz[3] (lbf)	Tx,Ty (lbf-in)	Tz (lbf-in)	Fx,Fy (lbf)	Fz[3] (lbf)	Tx,Ty (lbf-in)	Tz (lbf-in)
Mini45	US-30-40	30	60	40	40	1/40	1/40	1/44	1/88
Mini45	US-60-80	60	120	80	80	1/20	1/20	1/22	1/44
Mini45	US-120-160	120	240	160	160	1/10	1/10	1/11	1/22
Sensor	(SI) Metric Calibration	Fx,Fy (N)	Fz[3] (N)	Tx,Ty (Nm)	Tz (Nm)	Fx,Fy (N)	Fz[3] (N)	Tx,Ty (Nm)	Tz (Nm)
Mini45	SI-145-5	145	290	5	5	1/8	1/8	1/376	1/752
Mini45	SI-290-10	290	580	10	10	1/4	1/4	1/188	1/376
Mini45	SI-580-20	580	1160	20	20	1/2	1/2	1/94	1/188
		Sensing Ranges				Resolution (Controller)			

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

5.9.5 Analog Output

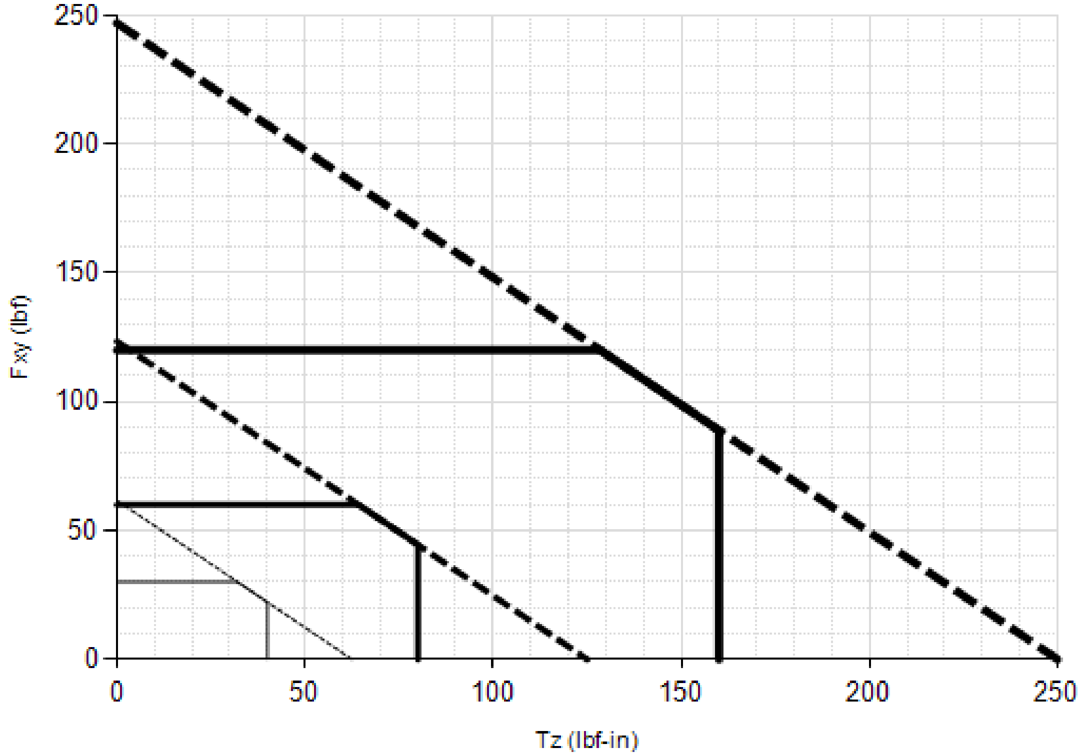
Table 5.43— Mini45 Analog Output							
Sensor	(US) Standard Calibration	Fx,Fy (lbf)	Fz[2] (lbf)	Tx,Ty,Tz (lbf-in)	Fx,Fy (lbf/V)	Fz[2] (lbf/V)	Tx,Ty,Tz (lbf-in/V)
Mini45	US-30-40	±30	±60	±40	3	6	4
Mini45	US-60-80	±60	±120	±80	6	12	8
Mini45	US-120-160	±120	±240	±160	12	24	16
Sensor	(SI) Metric Calibration	Fx,Fy (N)	Fz[2] (N)	Tx,Ty,Tz (Nmm)	Fx,Fy (N/V)	Fz[2] (N/V)	Tx,Ty,Tz (Nm/V)
Mini45	SI-145-5	±145	±290	±5	14.5	29	0.5
Mini45	SI-290-10	±290	±580	±10	29	58	1
Mini45	SI-580-20	±580	±1160	±20	58	116	2
		Analog Output Range			Analog ±10V Sensitivity[1]		

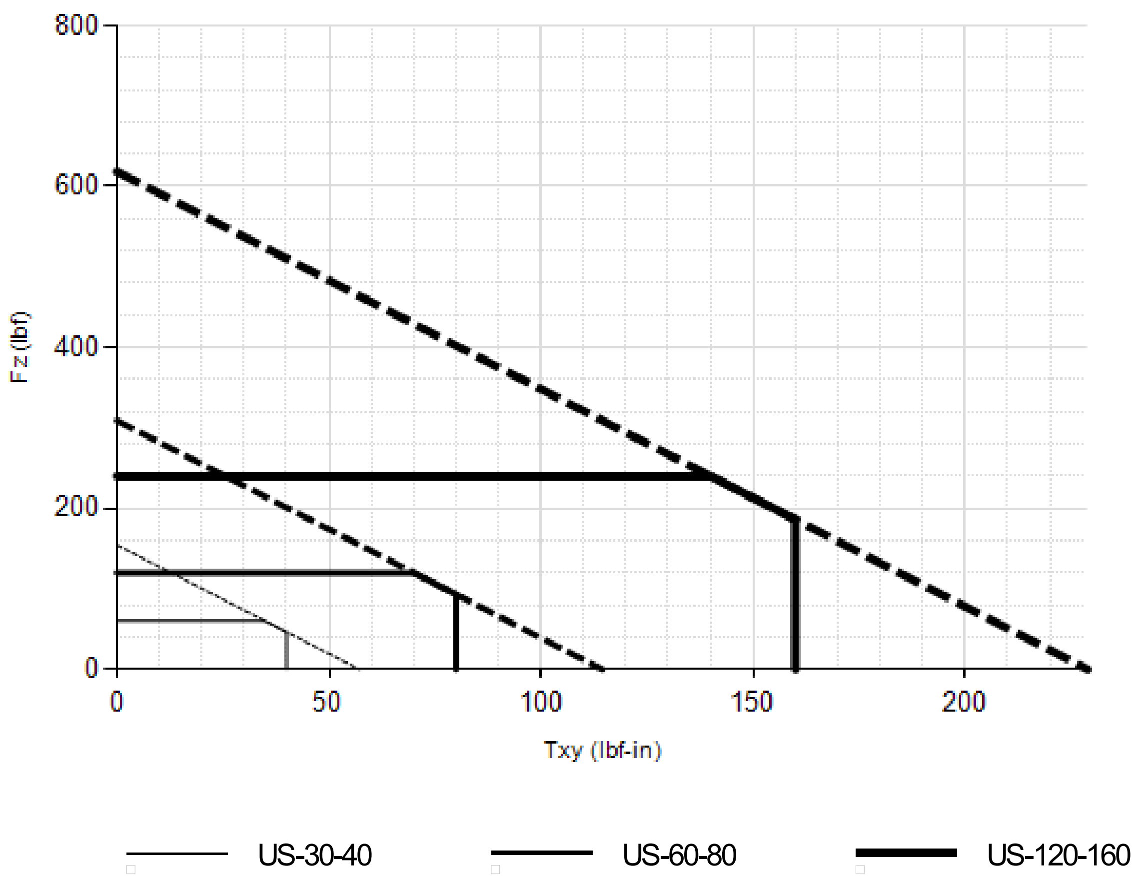
Notes:
1. ±5V Sensitivity values are double the listed ±10V Sensitivity values.
2. For IP68 version see caution on physical properties page.

5.9.6 Counts Value

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

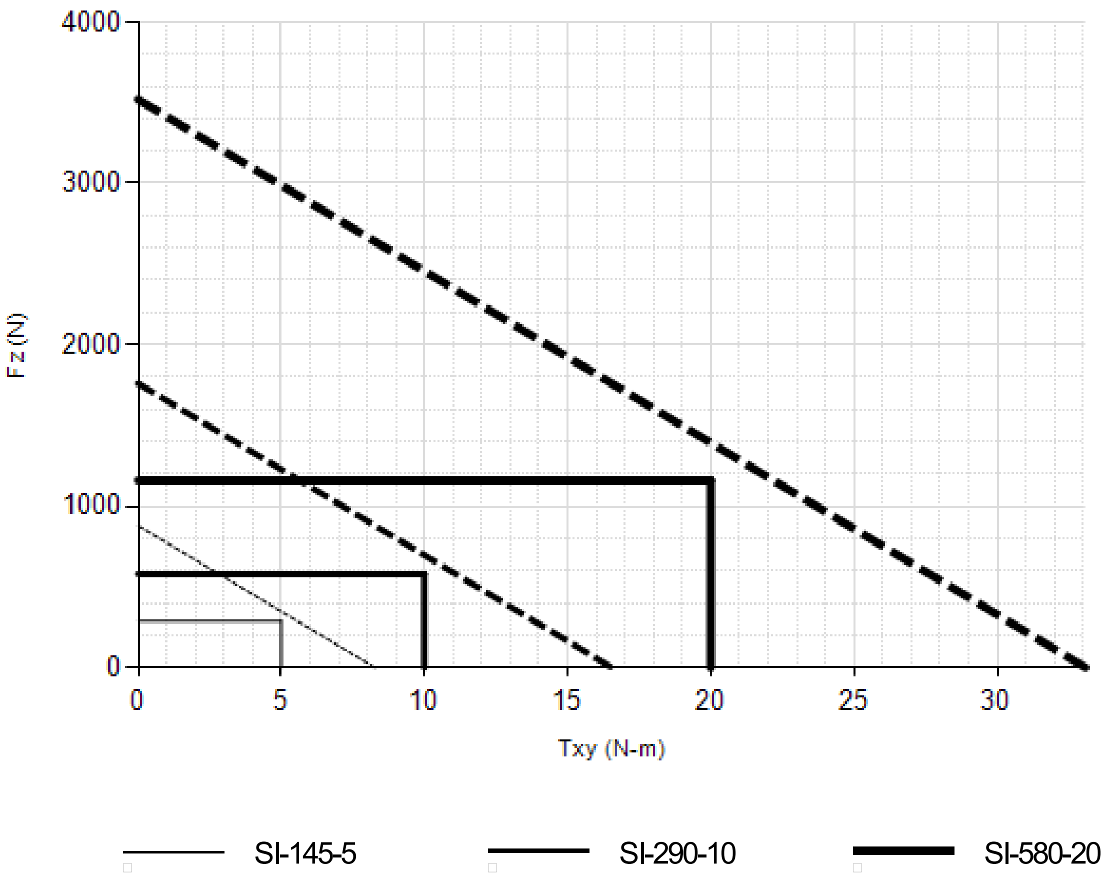
5.9.7 Mini45 (US Calibration Complex Loading)(Includes IP65/IP68)[1]





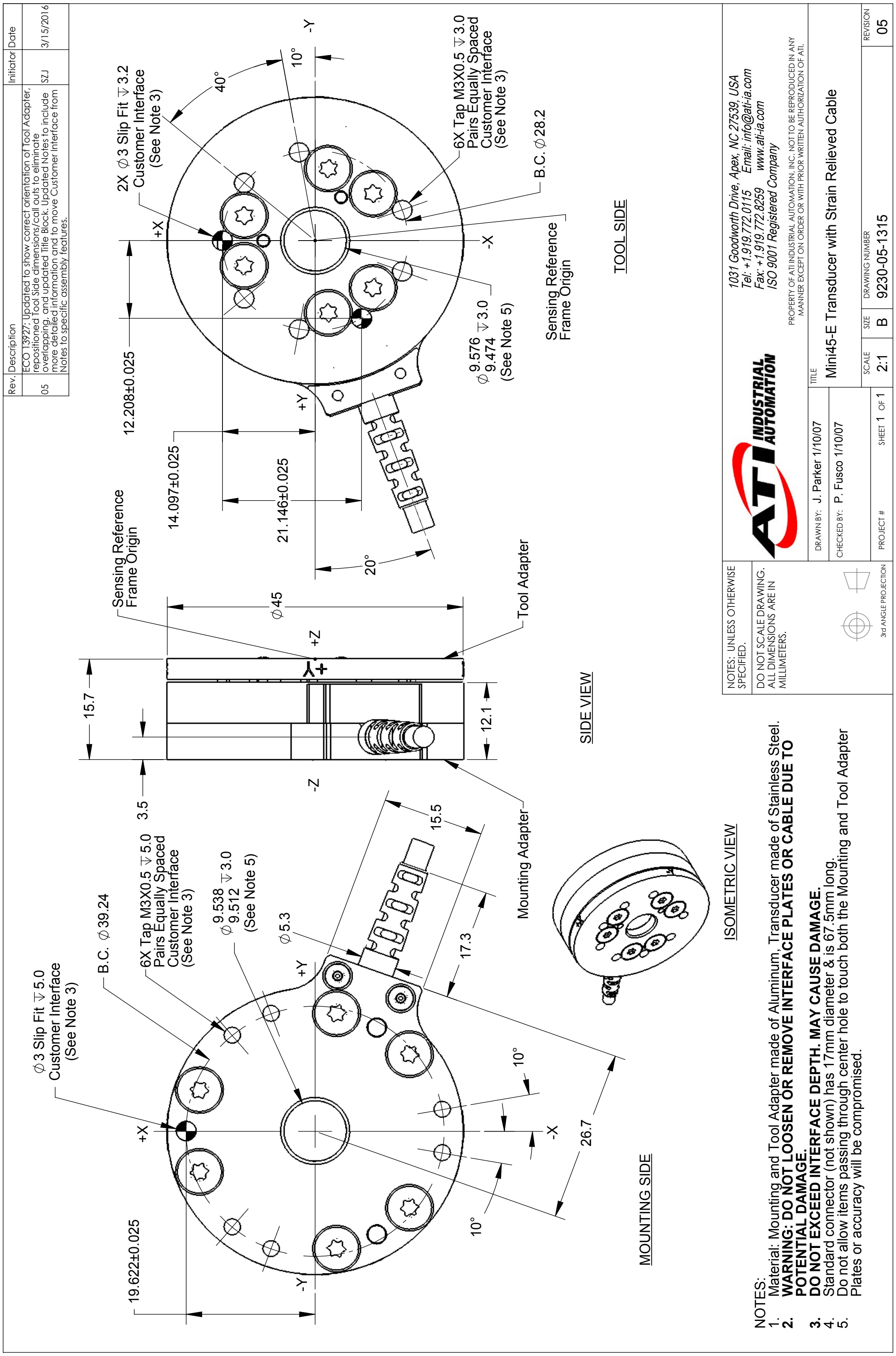
Note: 1. For IP68 version see caution on physical properties page.

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

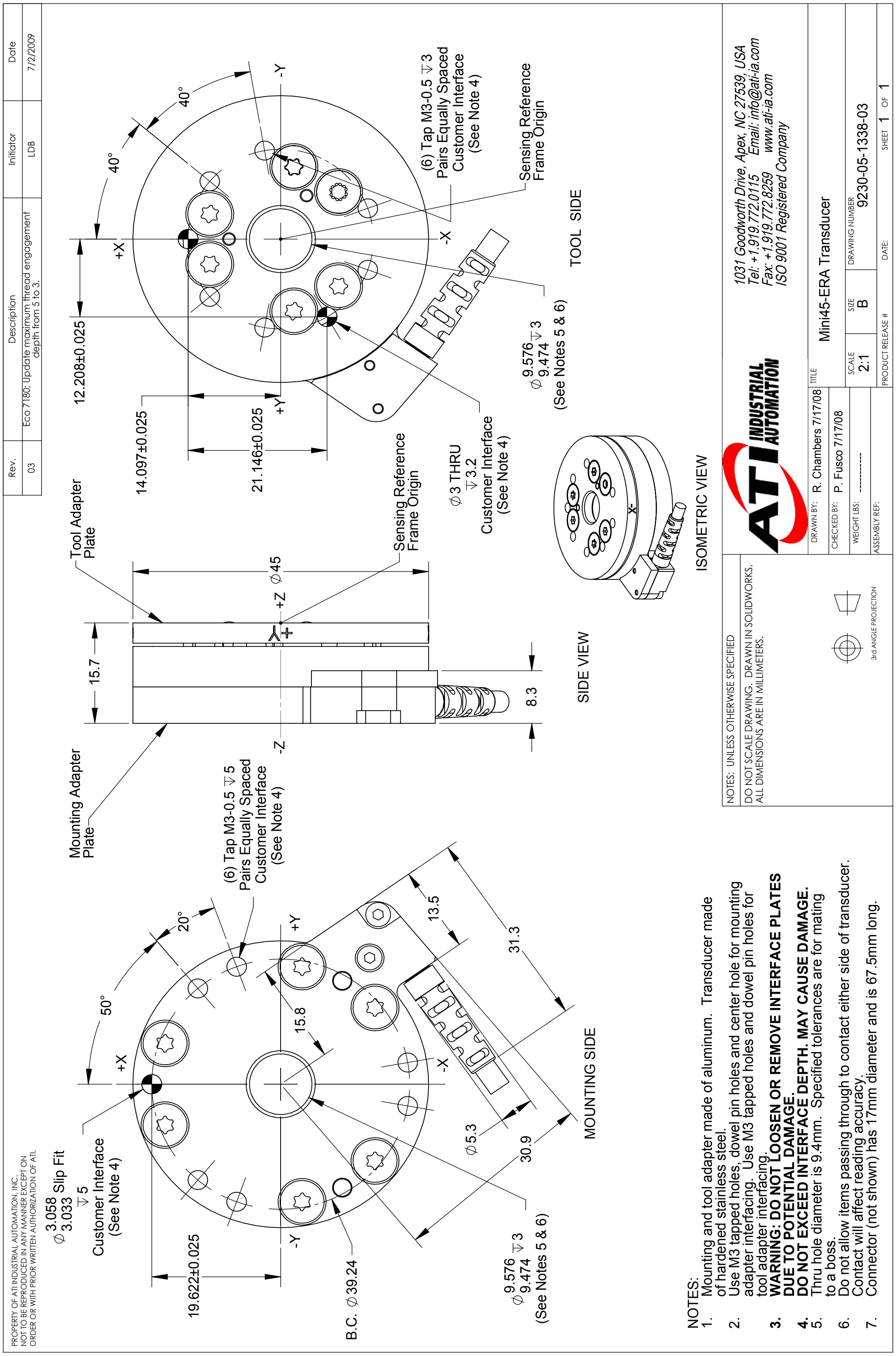


Note: 1. For IP68 version see caution on physical properties page.

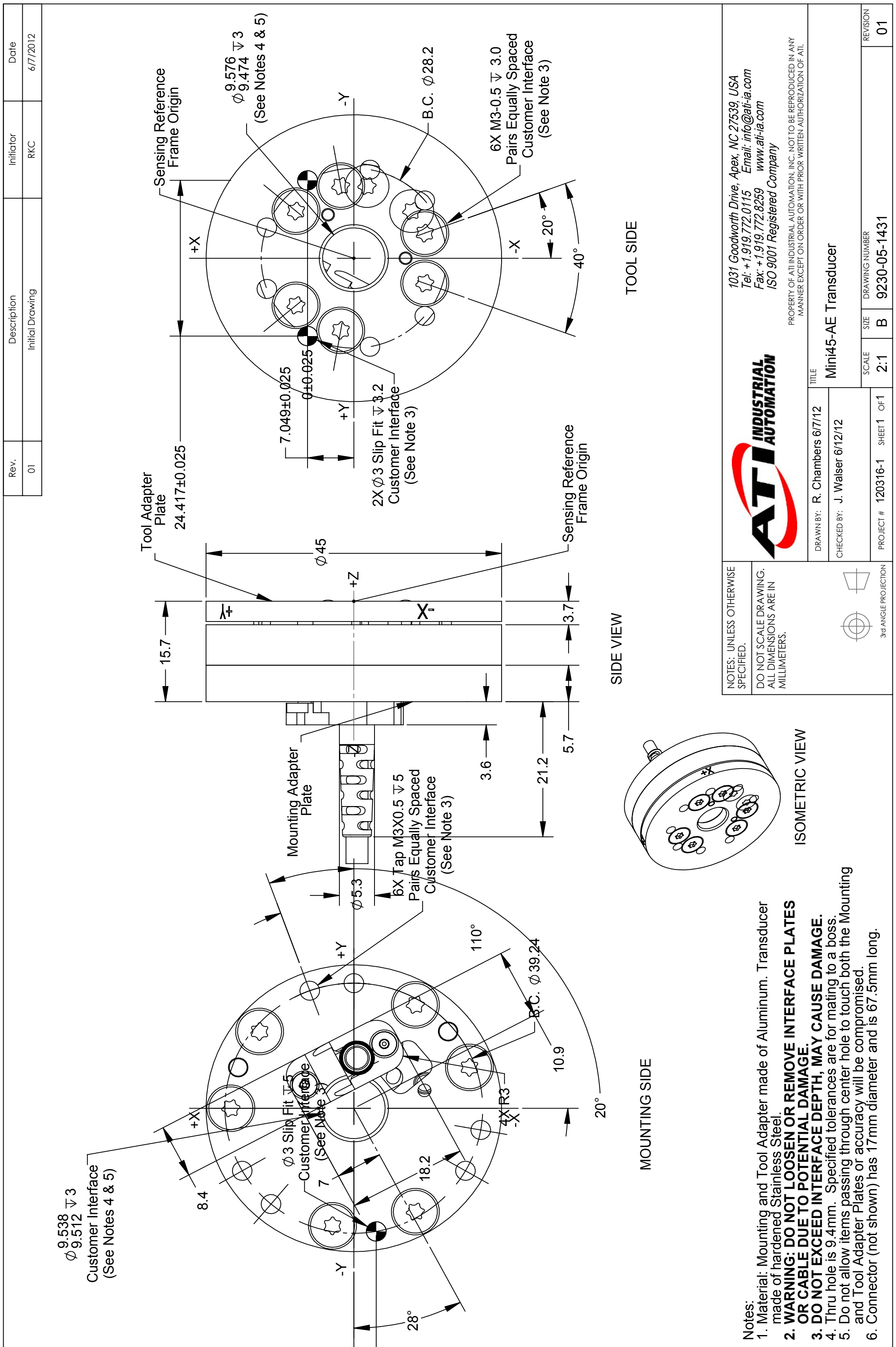
5.9.9 Mini45-E Transducer Drawing



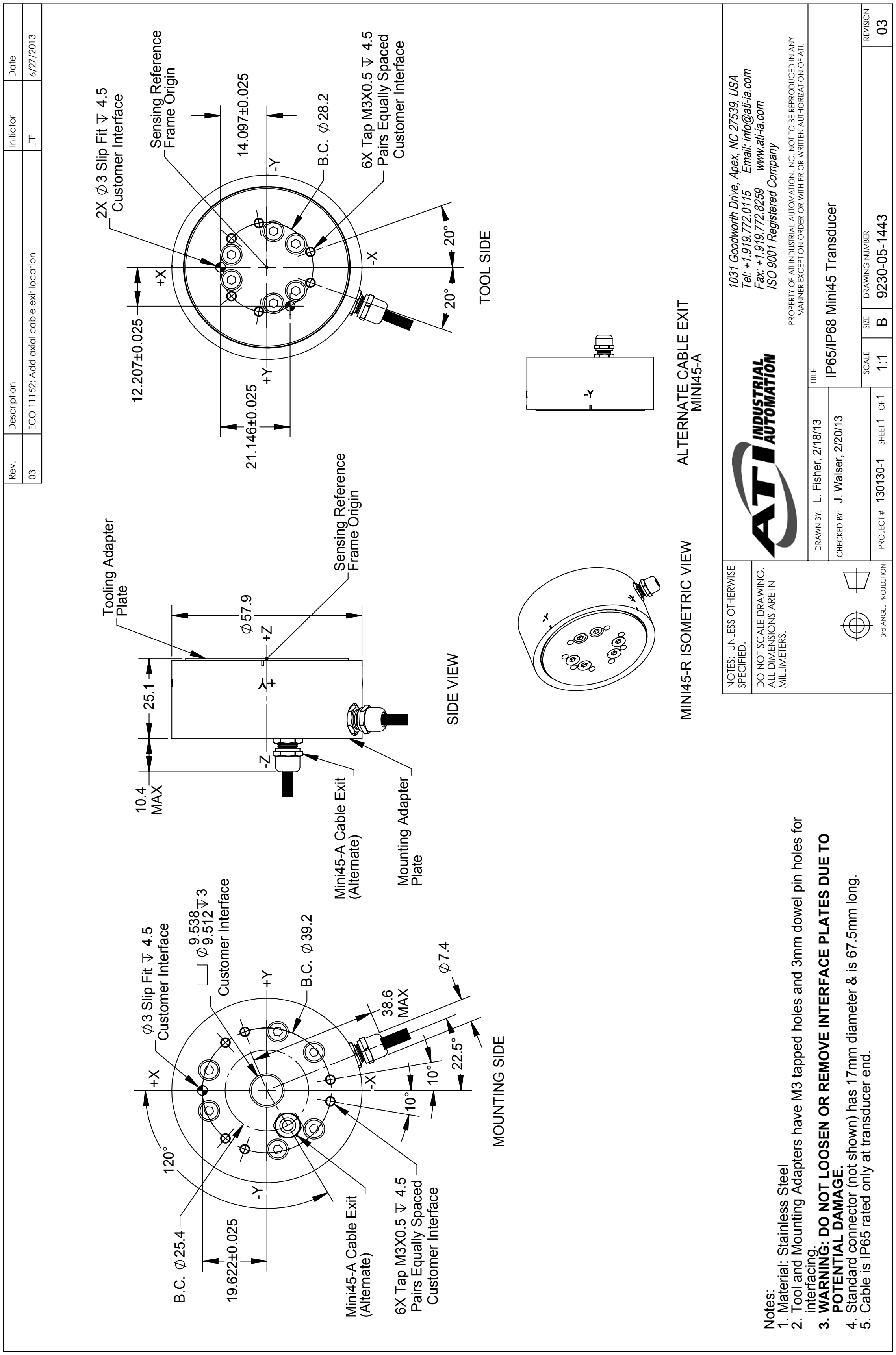
5.9.10 Mini45-ERA Transducer Drawing



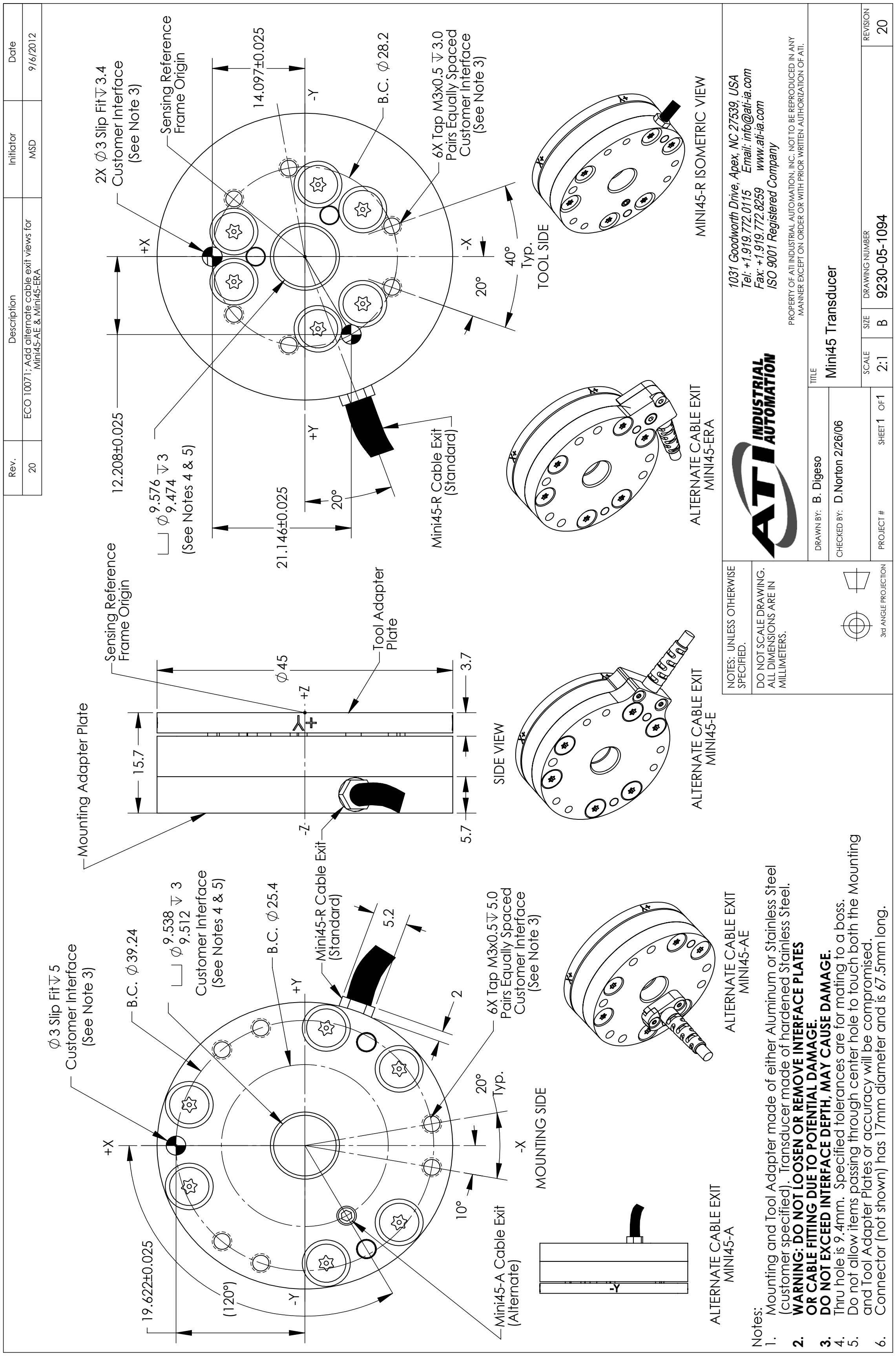
5.9.11 Mini45-AE Transducer Drawing



5.9.12 Mini45 IP65/IP68 Transducer Drawing



5.9.13 Legacy Mini45 Transducer Drawing



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

5.10.1 Mini58 Physical Properties

Table 5.45—Mini58 Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±4800 lbf	±21000 N
Fz	±11000 lbf	±48000 N
Txy	±5300 inf-lb	±590 Nm
Tz	±7100 inf-lb	±800 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	$1.4x10^6$ lb/in	$2.5x10^8$ N/m
Z-axis force (Kz)	$2.1x10^6$ lb/in	$3.7x10^8$ N/m
X-axis & Y-axis torque (Ktx, Kty)	$9.3x10^5$ lbf-in/rad	$1.1x10^5$ Nm/rad
Z-axis torque (Ktz)	$1.8x10^6$ lbf-in/rad	$2.0x10^5$ Nm/rad
Resonant Frequency		
Fx, Fy, Tz	3000 Hz	3000 Hz
Fz, Tx, Ty	5700 Hz	5700 Hz
Physical Specifications		
Weight[1]	0.76 lb	0.345 kg
Diameter[1]	2.28 in	58 mm
Height[1]	1.18 in	30 mm
Note: 1. Specifications include standard interface plates.		

5.10.2 Mini58 IP60 Physical Properties

Table 5.46—Mini58 IP60 Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±4800 lbf	±21000 N
Fz	±11000 lbf	±48000 N
Txy	±5300 inf-lb	±590 Nm
Tz	±7100 inf-lb	±800 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	$1.4x10^6$ lb/in	$2.5x10^8$ N/m
Z-axis force (Kz)	$2.1x10^6$ lb/in	$3.7x10^8$ N/m
X-axis & Y-axis torque (Ktx, Kty)	$9.3x10^5$ lbf-in/rad	$1.1x10^5$ Nm/rad
Z-axis torque (Ktz)	$1.8x10^6$ lbf-in/rad	$2.0x10^5$ Nm/rad
Resonant Frequency		
Fx, Fy, Tz	N/A	N/A
Fz, Tx, Ty	N/A	N/A
Physical Specifications		
Weight[1]	1.15 lb	0.522 kg
Diameter[1]	3.23 in	82 mm
Height[1]	1.42 in	36.2 mm
Note: 1. Specifications include standard interface plates.		

5.10.3 Mini58 IP65/IP68 Physical Properties

Table 5.47—Mini58 IP65/IP68 Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±4800 lbf	±21000 N
Fz	±11000 lbf	±48000 N
Txy	±5300 inf-lb	±590 Nm
Tz	±7100 inf-lb	±800 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	1.4×10^{6} lb/in	2.5×10^{8} N/m
Z-axis force (Kz)	2.1×10^{6} lb/in	3.7×10^{8} N/m
X-axis & Y-axis torque (Ktx, Kty)	9.3×10^{5} lbf-in/rad	1.1×10^{5} Nm/rad
Z-axis torque (Ktz)	1.8×10^{6} lbf-in/rad	2.0×10^{5} Nm/rad
Resonant Frequency		
Fx, Fy, Tz	N/A	N/A
Fz, Tx, Ty	N/A	N/A
Physical Specifications		
Weight[1]	1.77 lb	0.804 kg
Diameter[1]	2.58 in	65.4 mm
Height[1]	1.48 in	37.6 mm
Note: 1. Specifications include standard interface plates.		

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

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

5.10.4 Calibration Specifications (excludes CTL calibrations)

Table 5.48— Mini58 Calibrations (excludes CTL calibrations)[1, 2]

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

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

5.10.5 CTL Calibration Specifications

Table 5.49— Mini58 CTL Calibrations[1, 2]

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

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

5.10.6 Analog Output

Table 5.50— Mini58 Analog Output							
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz[2] (lbf)**	**Tx,Ty,Tz (lbf-in)**	**Fx,Fy (lbf/V)**	**Fz[2] (lbf/V)**	**Tx,Ty,Tz (lbf-in/V)**
Mini58	US-150-250	±150	±375	±250	15	37.5	25
Mini58	US-300-500	±300	±750	±500	30	75	50
Mini58	US-600-1000	±600	±1500	±1000	60	150	100
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz[2] (N)**	**Tx,Ty,Tz (Nmm)**	**Fx,Fy (N/V)**	**Fz[2] (N/V)**	**Tx,Ty,Tz (Nm/V)**
Mini58	SI-700-30	±700	±1700	±30	70	170	3
Mini58	SI-1400-60	±1400	±3400	±60	140	340	6
Mini58	SI-2800-120	±2800	±6800	±120	280	680	12
		Analog Output Range			**Analog ±10V Sensitivity[1]**		

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

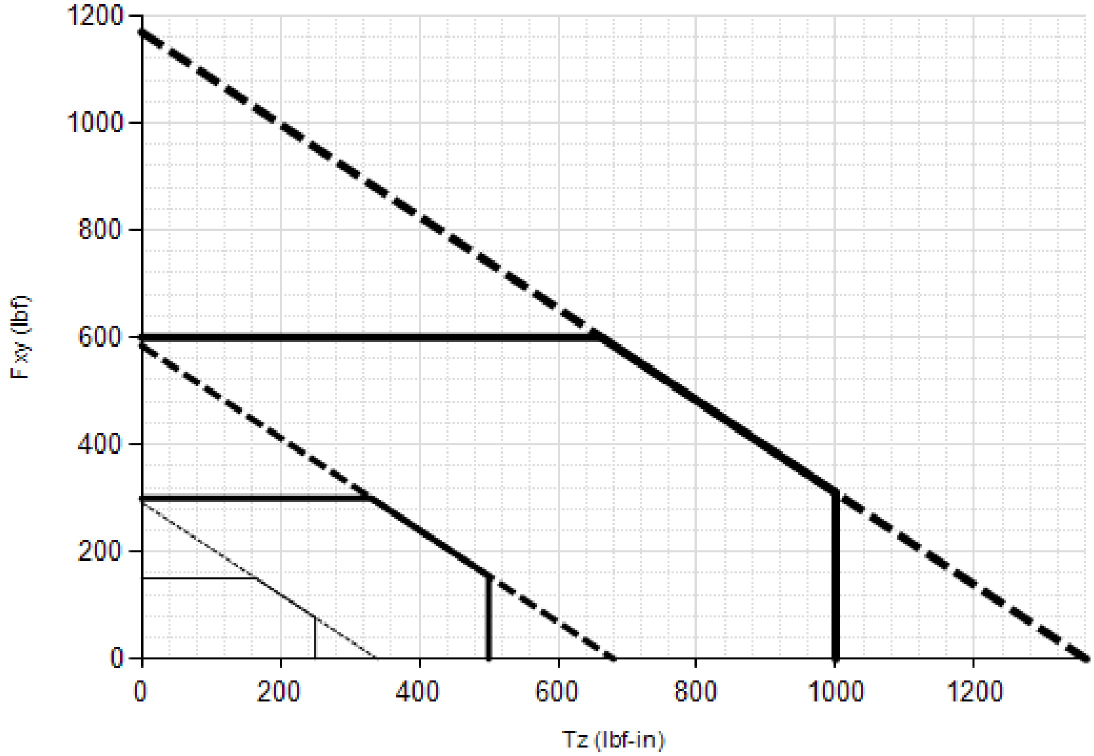
5.10.7 Counts Value

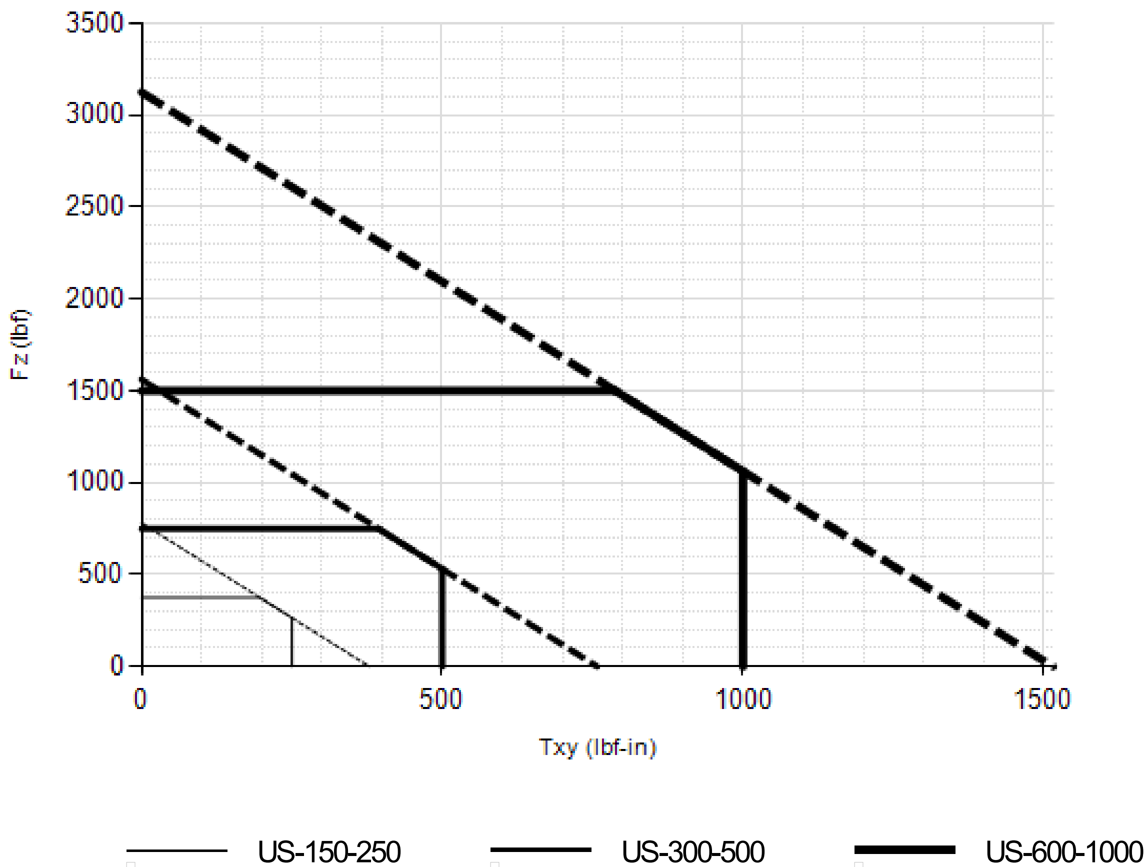
Table 5.51—Counts Value					
Sensor	**Calibration**	**Fx, Fy, Fz (/ lbf)**	**Tx, Ty, Tz (/ lbf-in)**	**Fx, Fy, Fz (/ N)**	**Tx, Ty, Tz (/ Nm)**
Mini58	US-150-250 / SI-700-30	448	960	96	6400
Mini58	US-300-500 / SI-1400-60	224	480	48	3200
Mini58	US-600-1000 / SI-2800-120	112	240	16	1600
Mini58	Tool Transform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

5.10.8 Tool Transform Factor

Table 5.52—Tool Transform Factor			
Sensor	**Calibration**	**US (English)**	SI (Metric)
Mini58	US-150-250 / SI-700-30	0.00467 in/lbf	0.150 mm/N
Mini58	US-300-500 / SI-1400-60	0.00467 in/lbf	0.150 mm/N
Mini58	US-600-1000 / SI-2800-120	0.00467 in/lbf	0.150 mm/N

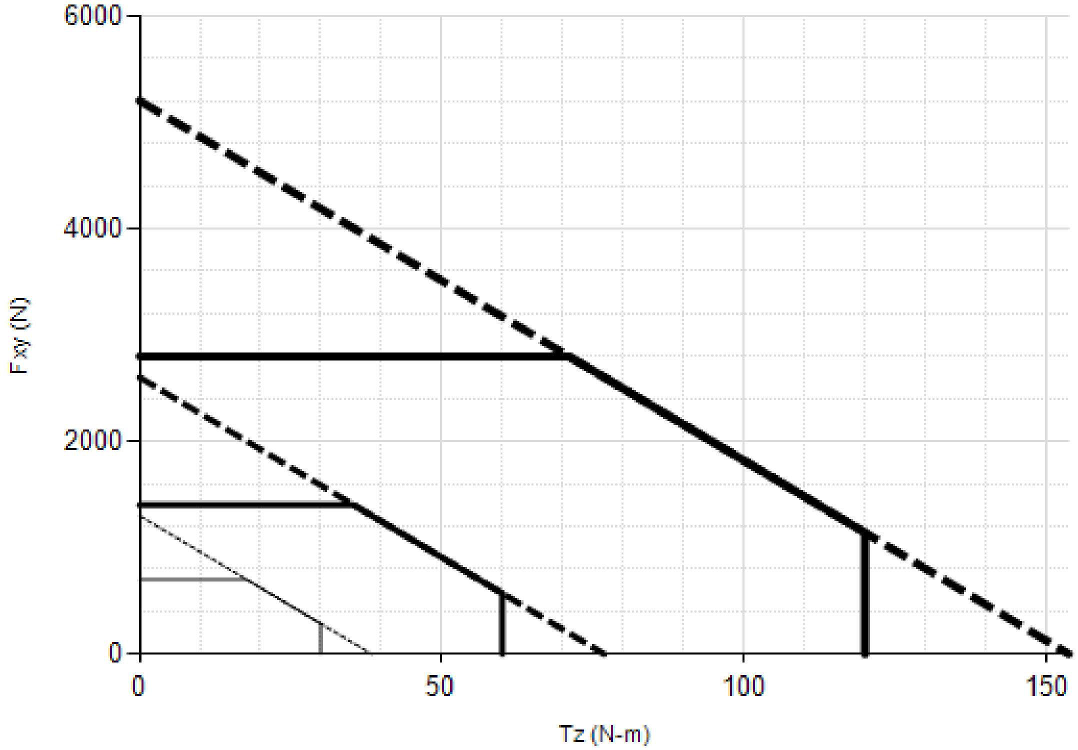
5.10.9 Mini58 (US Calibration Complex Loading)(Includes IP60/IP65/IP68)[1]

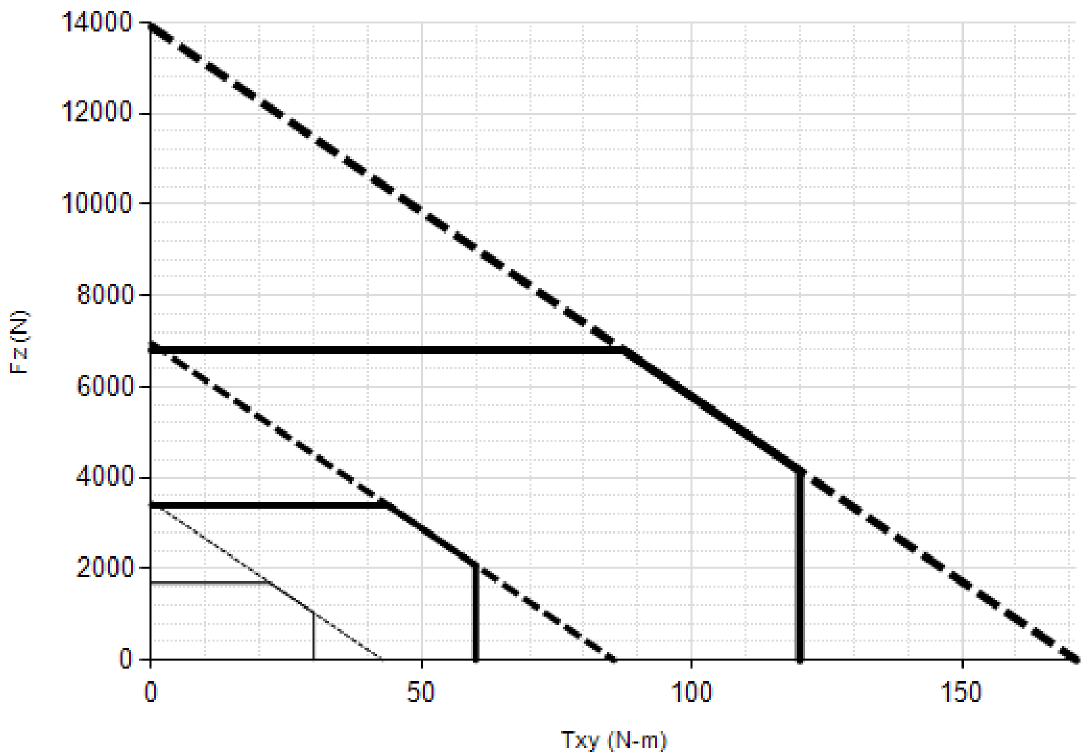




Note: 1. For IP68 version see caution on physical properties page.

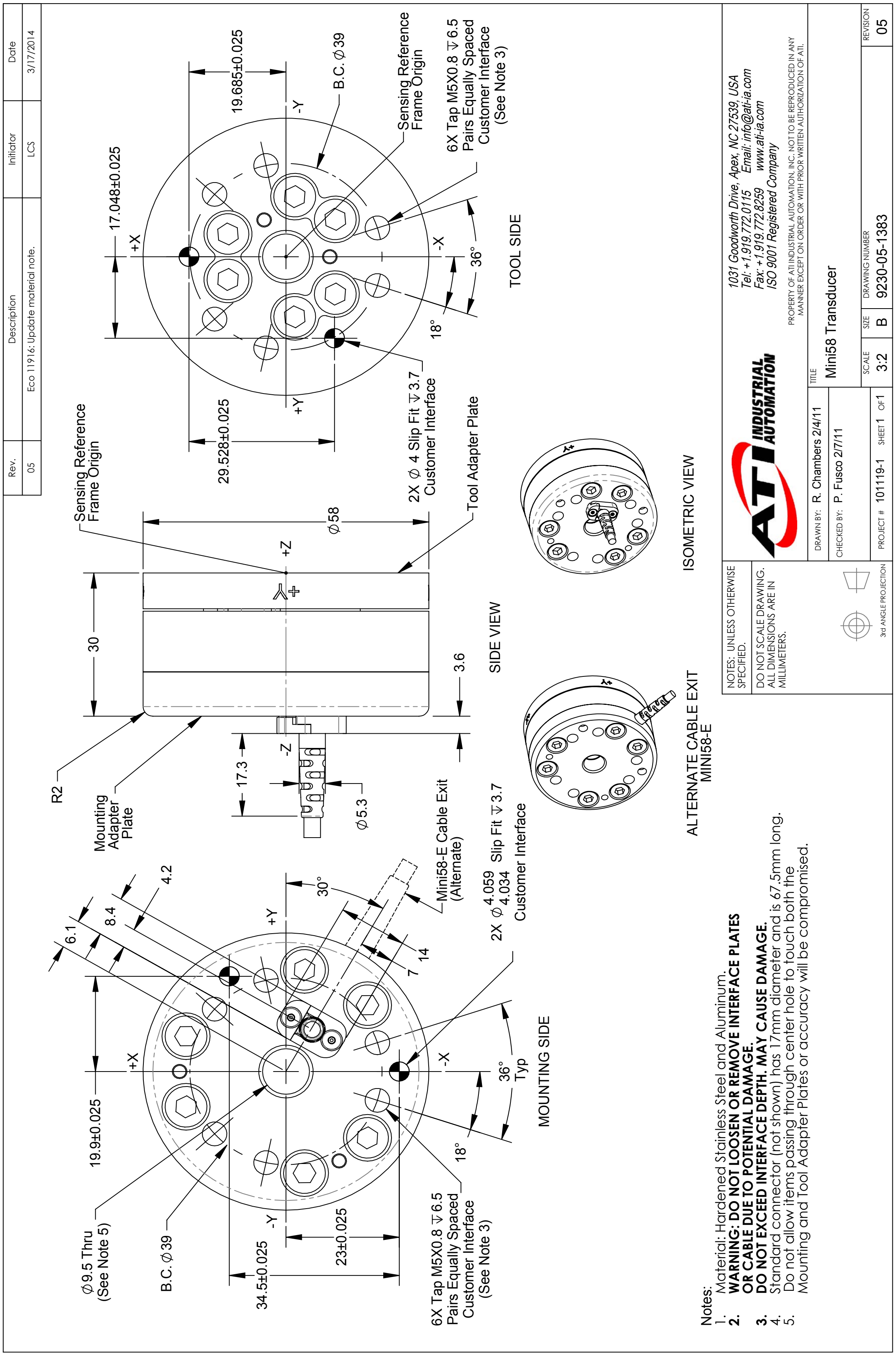
5.10.10 Mini58 (SI Calibration Complex Loading)(Includes IP60/IP65/IP68)[1]



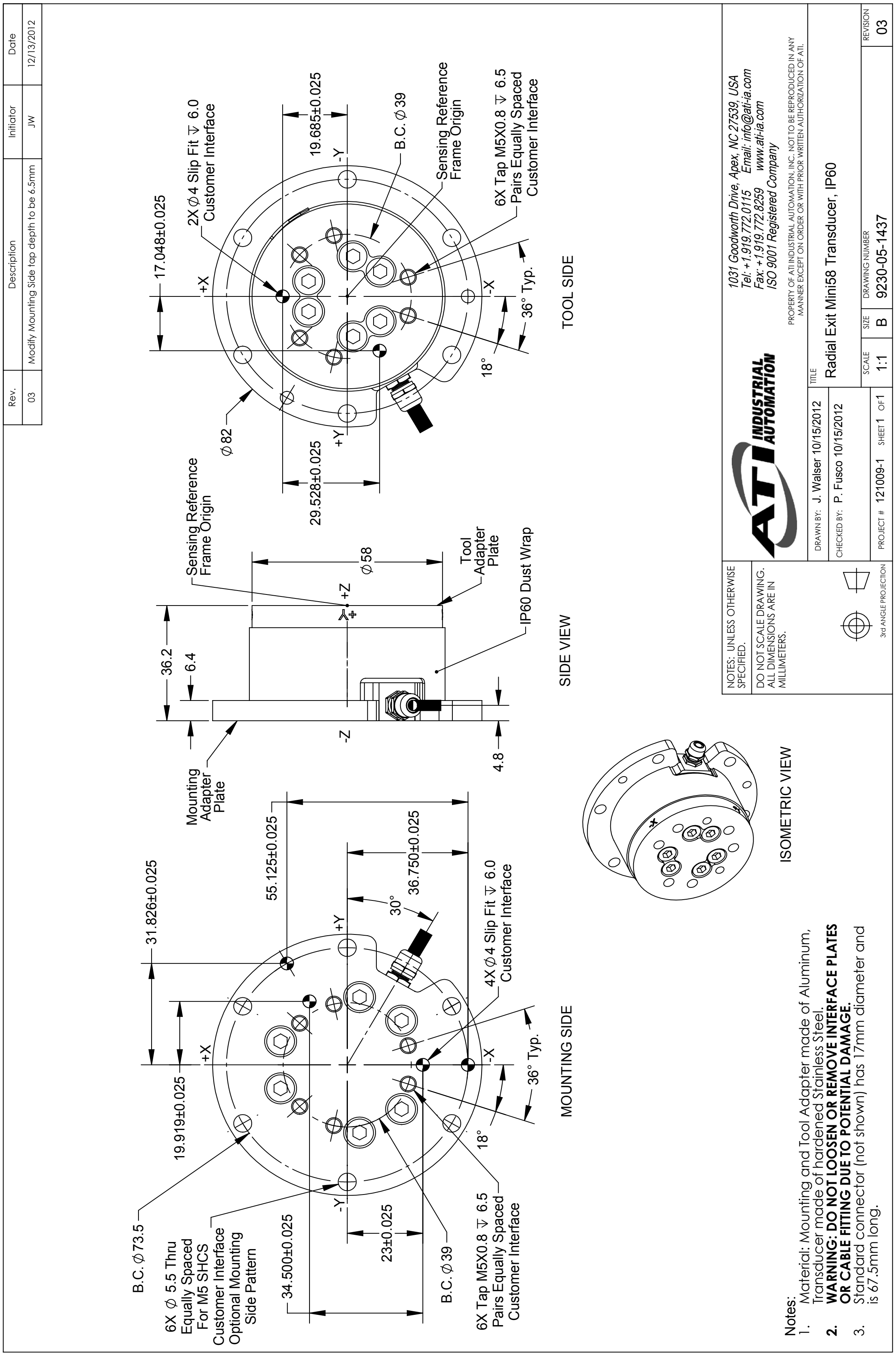


Note: 1. For IP68 version see caution on physical properties page.

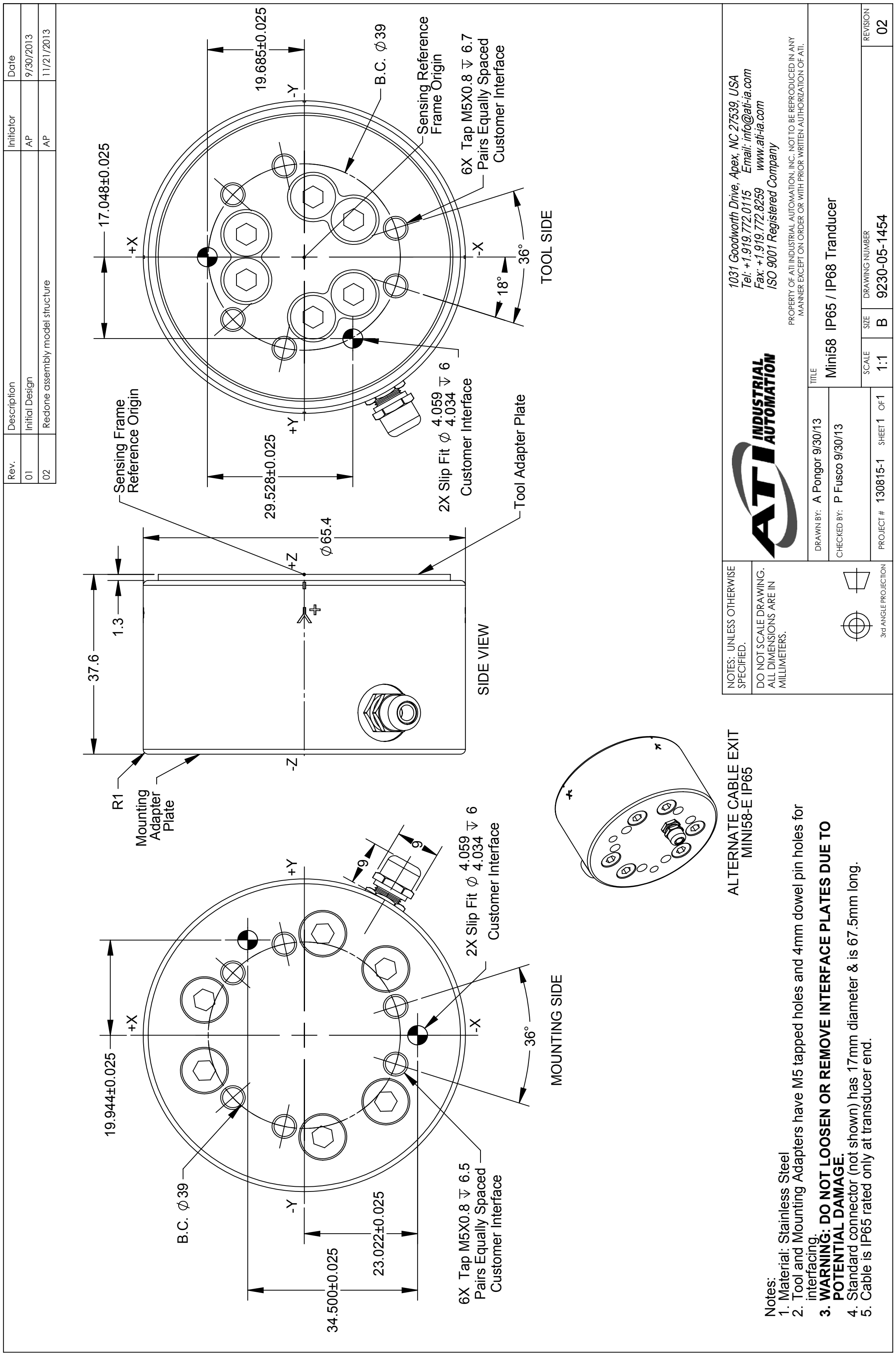
5.10.11 Mini58 Transducer Drawing



5.10.12 Mini58 IP60 Transducer Drawing



5.10.13 Mini58 IP65/IP68 Transducer Drawing



5.11 Mini85 Specifications (Includes IP60 Versions)

5.11.1 Mini85 Physical Properties

Table 5.53—Mini85 Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±2800 lbf	±13000 N
Fz	±6100 lbf	±27000 N
Txy	±4400 inf-lb	±500 Nm
Tz	±5400 inf-lb	±610 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	4.4×10^5 lb/in	7.7×10^7 N/m
Z-axis force (Kz)	6.8×10^5 lb/in	1.2×10^8 N/m
X-axis & Y-axis torque (Ktx, Kty)	7.2×10^5 lbf-in/rad	8.1×10^4 Nm/rad
Z-axis torque (Ktz)	1.2×10^6 lbf-in/rad	1.3×10^5 Nm/rad
Resonant Frequency		
Fx, Fy, Tz	2400 Hz	2400 Hz
Fz, Tx, Ty	3100 Hz	3100 Hz
Physical Specifications		
Weight[1]	1.4 lb	0.635 kg
Diameter[1]	3.35 in	85.1 mm
Height[1]	1.17 in	29.8 mm

Note:
1. Specifications include standard interface plates.

5.11.2 Calibration Specifications (excludes CTL calibrations)

Table 5.54— Mini85 Calibrations (excludes CTL calibrations)[1, 2]									
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**	**Fx,Fy (lbf)**	**Fz (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**
Mini85	US-105-185	105	210	185	185	1/52	7/260	5/168	1/48
Mini85	US-210-370	210	420	370	370	5/128	3/64	5/84	1/24
Mini85	US-420-740	420	840	740	740	5/64	3/32	5/42	1/12
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**	**Fx,Fy (N)**	**Fz (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**
Mini85	SI-475-20	475	950	20	20	9/112	3/28	5/1496	7/2992
Mini85	SI-950-40	950	1900	40	40	9/56	3/14	5/748	7/1496
Mini85	SI-1900-80	1900	3800	80	80	9/28	3/7	5/374	7/748
		Sensing Ranges				**Resolution (DAQ, Net F/T)[3]**			

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

5.11.3 CTL Calibration Specifications

Table 5.55— Mini85 CTL Calibrations[1, 2]									
Sensor	(US) Standard Calibration	Fx,Fy (lbf)	Fz (lbf)	Tx,Ty (lbf-in)	Tz (lbf-in)	Fx,Fy (lbf)	Fz (lbf)	Tx,Ty (lbf-in)	Tz (lbf-in)
Mini85	US-105-185	105	210	185	185	1/26	7/130	5/84	1/24
Mini85	US-210-370	210	420	370	370	5/64	3/32	5/42	1/12
Mini85	US-420-740	420	840	740	740	5/32	3/16	5/21	1/6
Sensor	(SI) Metric Calibration	Fx,Fy (N)	Fz (N)	Tx,Ty (Nm)	Tz (Nm)	Fx,Fy (N)	Fz (N)	Tx,Ty (Nm)	Tz (Nm)
Mini85	SI-475-20	475	950	20	20	9/56	3/14	5/748	7/1496
Mini85	SI-950-40	950	1900	40	40	9/28	3/7	5/374	7/748
Mini85	SI-1900-80	1900	3800	80	80	9/14	6/7	5/187	7/374
		Sensing Ranges				Resolution (Controller)			

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

5.11.4 Analog Output

Table 5.56— Mini85 Analog Output							
Sensor	(US) Standard Calibration	Fx,Fy (lbf)	Fz (lbf)	Tx,Ty,Tz (lbf-in)	Fx,Fy (lbf/V)	Fz (lbf/V)	Tx,Ty,Tz (lbf-in/V)
Mini85	US-105-185	±105	±210	±185	10.5	21	18.5
Mini85	US-210-370	±210	±420	±370	21	42	37
Mini85	US-420-740	±420	±840	±740	42	84	74
Sensor	(SI) Metric Calibration	Fx,Fy (N)	Fz (N)	Tx,Ty,Tz (Nmm)	Fx,Fy (N/V)	Fz (N/V)	Tx,Ty,Tz (Nm/V)
Mini85	SI-475-20	±475	±950	±20	47.5	95	2
Mini85	SI-950-40	±950	±1900	±40	95	190	4
Mini85	SI-1900-80	±1900	±3800	±80	190	380	8
		Analog Output Range			Analog ±10V Sensitivity[1]		

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

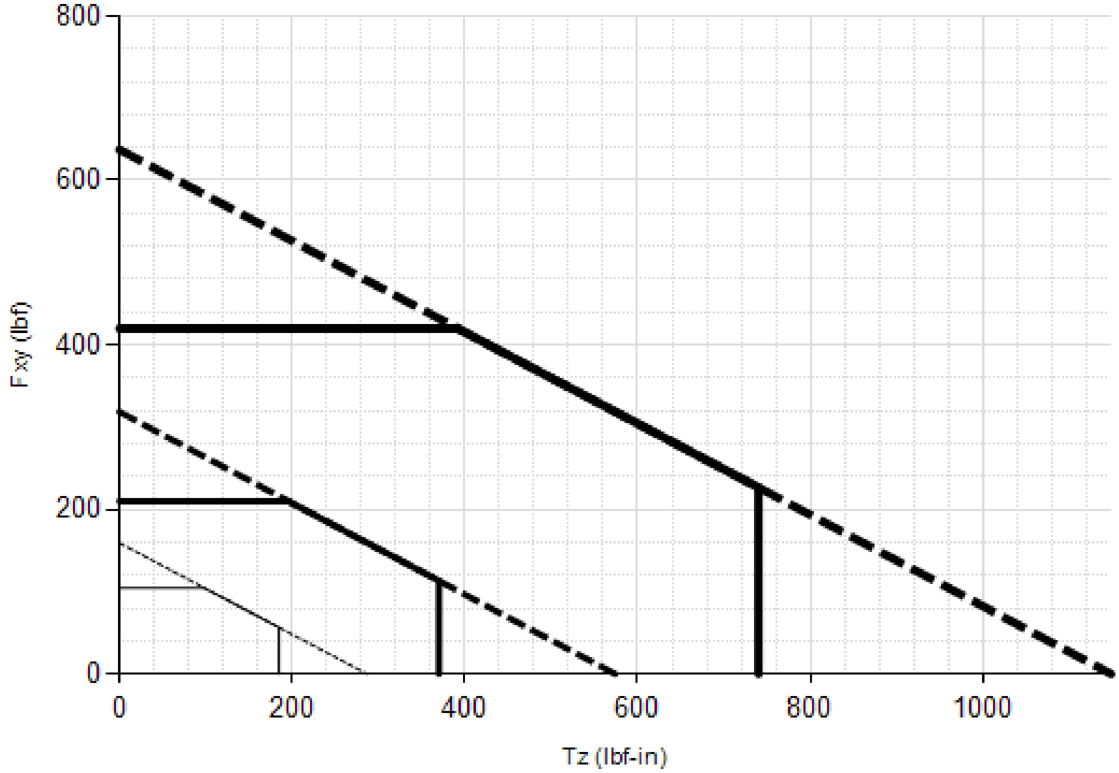
5.11.5 Counts Value

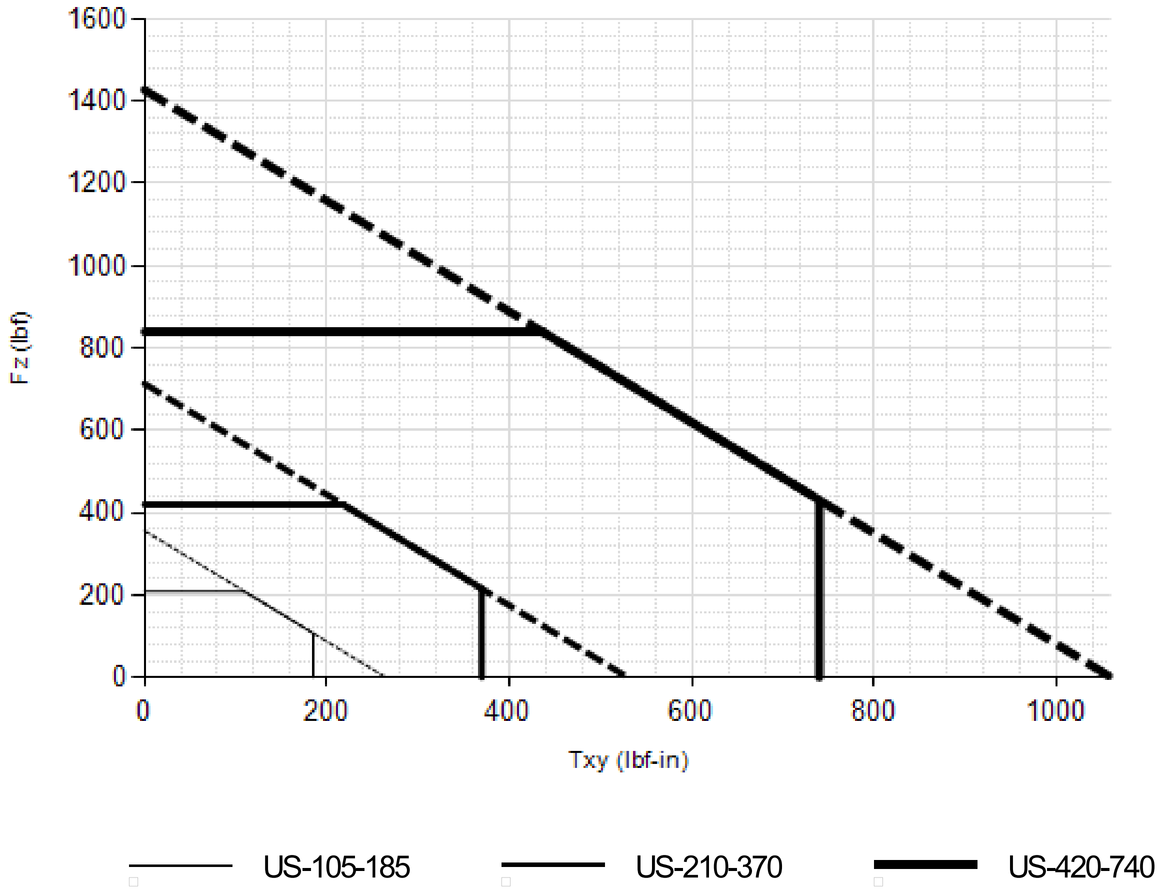
Table 5.57—Counts Value					
Sensor	Calibration	Fx, Fy, Fz (/ lbf)	Tx, Ty, Tz (/ lbf-in)	Fx, Fy, Fz (/ N)	Tx, Ty, Tz (/ Nm)
Mini85	US-105-185 / SI-475-20	1040	1344	448	11968
Mini85	US-210-370 / SI-950-40	512	672	224	5984
Mini85	US-420-740 / SI-1900-80	256	336	112	2992
Mini85	Tool Transform Factor	See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

5.11.6 Tool Transform Factor

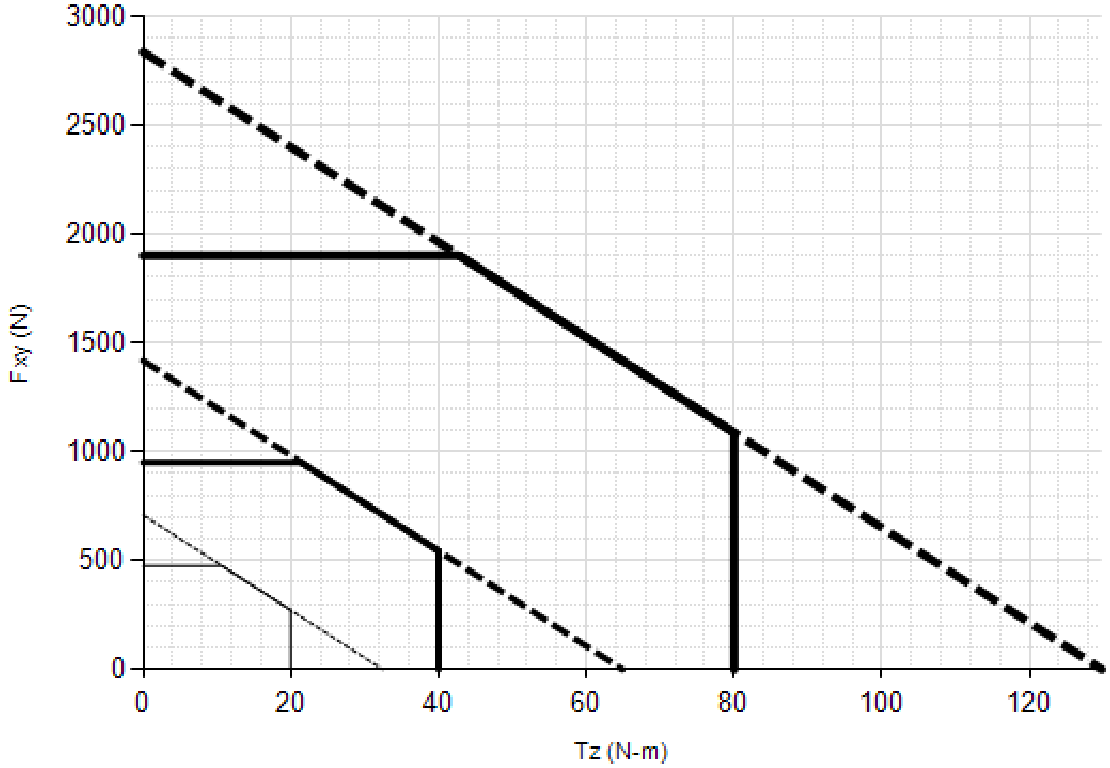
Table 5.58—Tool Transform Factor			
Sensor	**Calibration**	**US (English)**	SI (Metric)
Mini85	US-105-185 / SI-475-20	0.00774 in/lbf	0.374 mm/N
Mini85	US-210-370 / SI-950-40	0.00762 in/lbf	0.374 mm/N
Mini85	US-420-740 / SI-1900-80	0.00762 in/lbf	0.374 mm/N

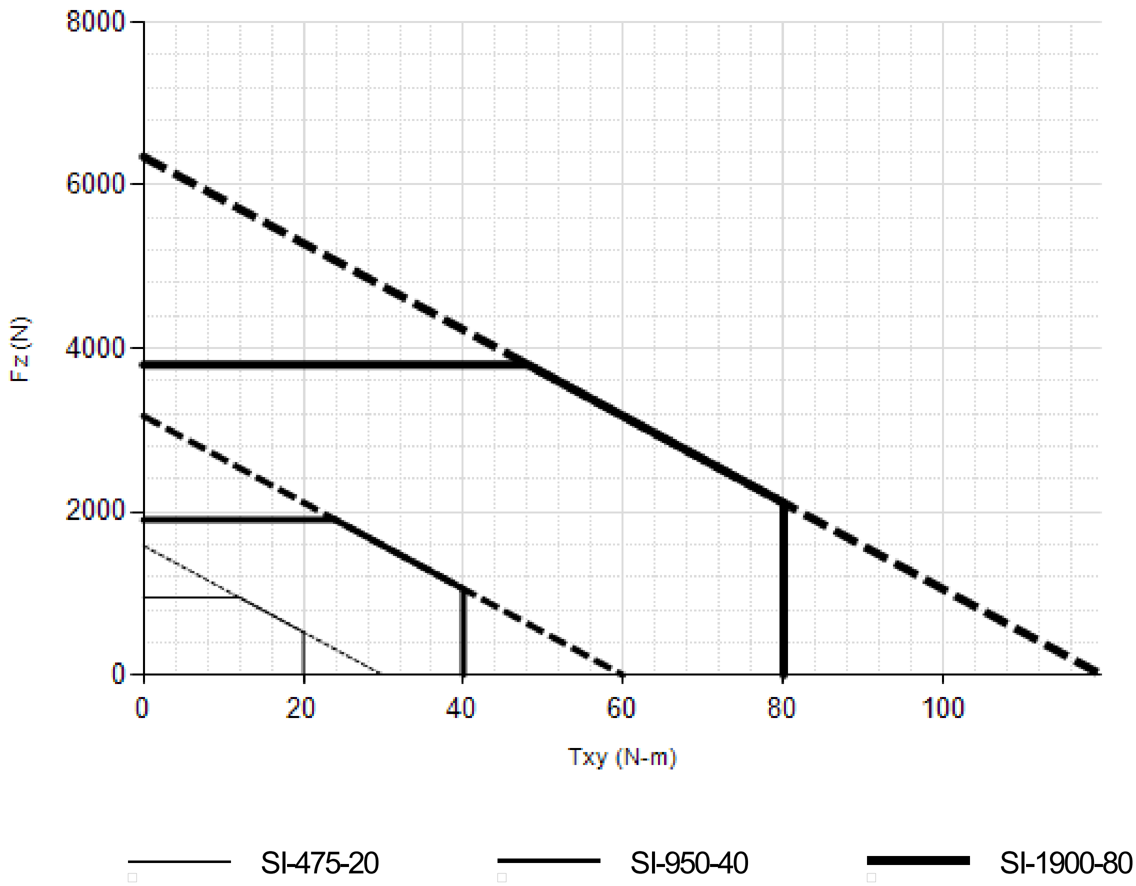
5.11.7 Mini85 (US Calibration Complex Loading)(Includes IP60)



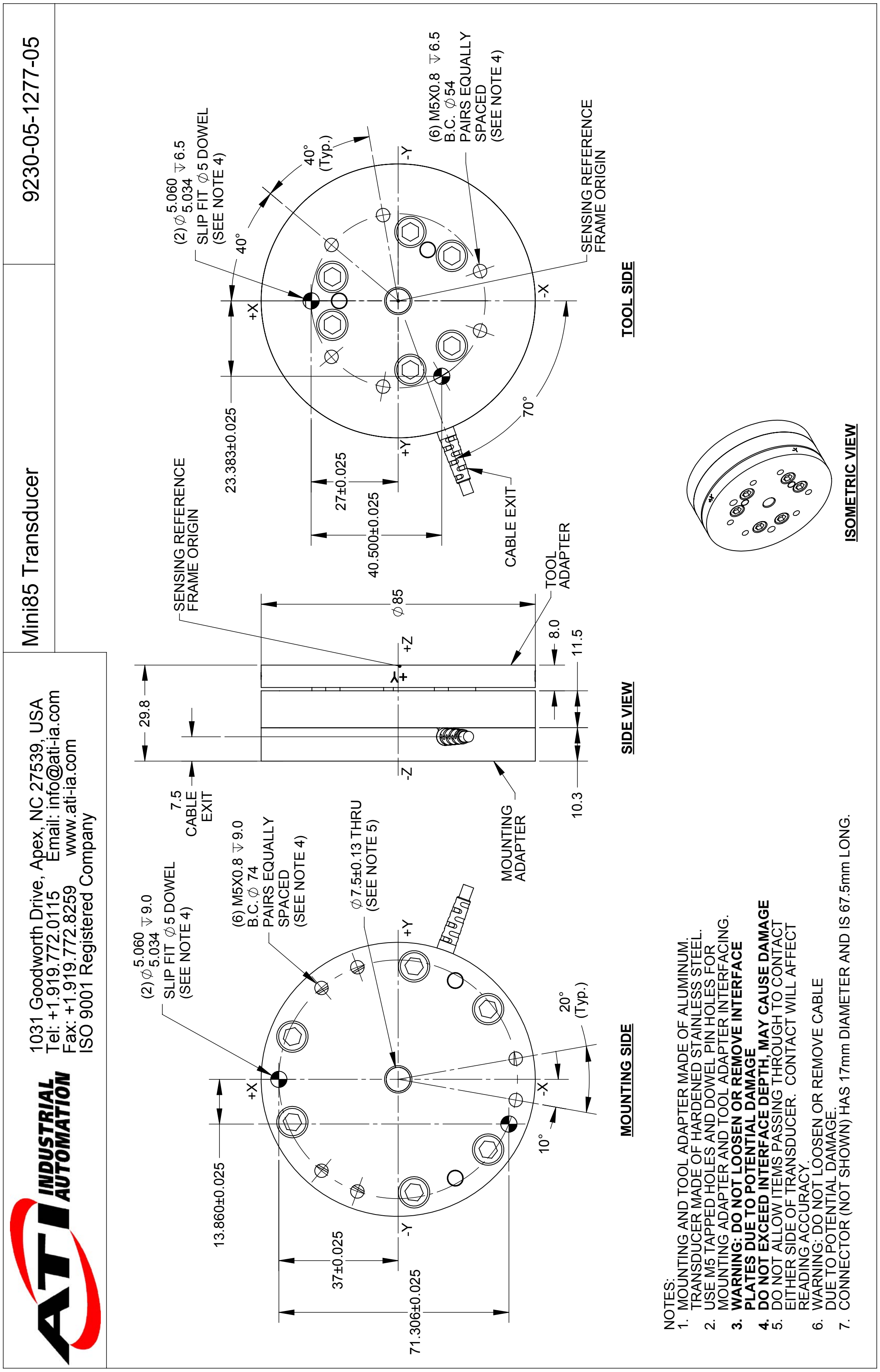


5.11.8 Mini85 (SI Calibration Complex Loading)(Includes IP60)

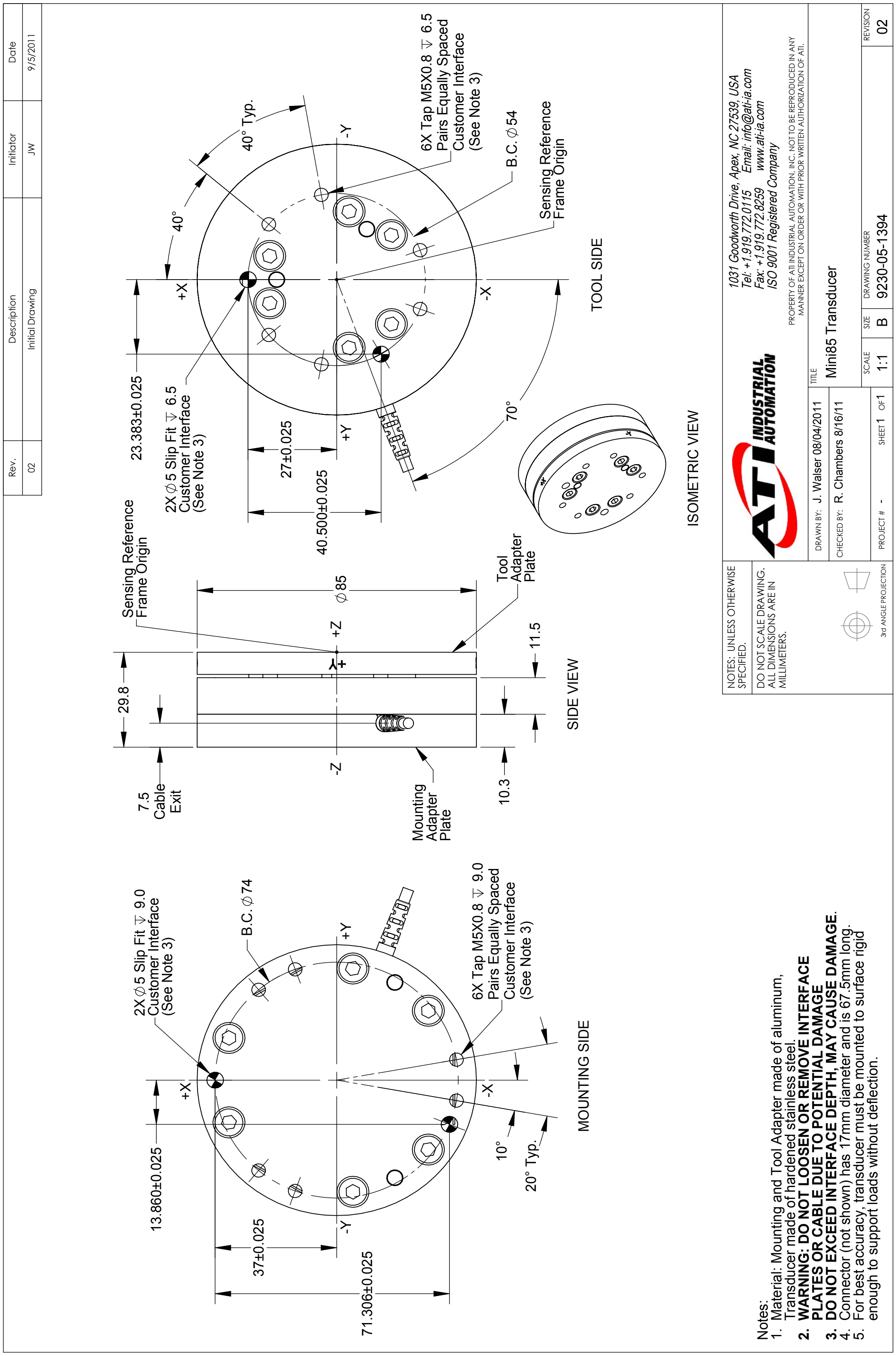




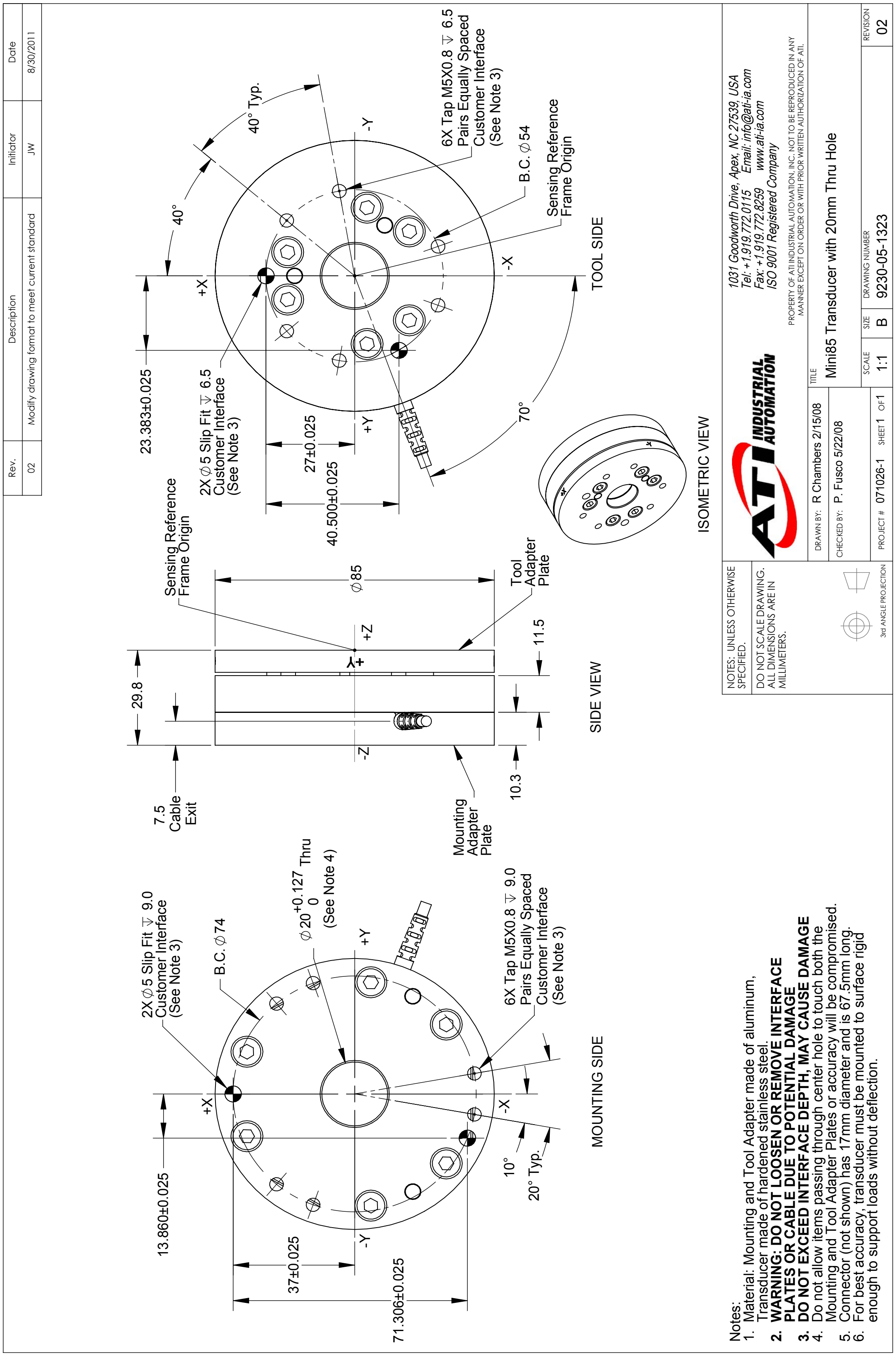
5.11.9 Mini85 Transducer Drawing



5.11.10 Mini85-E Transducer Drawing



5.11.11 Mini85 IP60 Transducer with 20mm Through-Hole Drawing



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

5.12.1 Gamma Physical Properties

Table 5.59—Gamma Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±280 lbf	±1200 N
Fz	±930 lbf	±4100 N
Txy	±700 inf-lb	±79 Nm
Tz	±730 inf-lb	±82 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	5.2×10^4 lb/in	9.1×10^6 N/m
Z-axis force (Kz)	1.0×10^5 lb/in	1.8×10^7 N/m
X-axis & Y-axis torque (Ktx, Kty)	9.3×10^4 lbf-in/rad	1.1×10^4 Nm/rad
Z-axis torque (Ktz)	1.4×10^5 lbf-in/rad	1.6×10^4 Nm/rad
Resonant Frequency		
Fx, Fy, Tz	1400 Hz	1400 Hz
Fz, Tx, Ty	2000 Hz	2000 Hz
Physical Specifications		
Weight[1]	0.562 lb	0.255 kg
Diameter[1]	2.97 in	75.4 mm
Height[1]	1.31 in	33.3 mm
Note: 1. Specifications include standard interface plates.		

5.12.2 Gamma IP60 Physical Properties

Table 5.60—Gamma IP60 Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±280 lbf	±1200 N
Fz	±930 lbf	±4100 N
Txy	±700 inf-lb	±79 Nm
Tz	±730 inf-lb	±82 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	5.2×10^4 lb/in	9.1×10^6 N/m
Z-axis force (Kz)	1.0×10^5 lb/in	1.8×10^7 N/m
X-axis & Y-axis torque (Ktx, Kty)	9.3×10^4 lbf-in/rad	1.1×10^4 Nm/rad
Z-axis torque (Ktz)	1.4×10^5 lbf-in/rad	1.6×10^4 Nm/rad
Resonant Frequency		
Fx, Fy, Tz	1200 Hz	1200 Hz
Fz, Tx, Ty	1200 Hz	1200 Hz
Physical Specifications		
Weight[1]	1.03 lb	0.467 kg
Diameter[1]	3.9 in	99.1 mm
Height[1]	1.56 in	39.6 mm
Note: 1. Specifications include standard interface plates.		

5.12.3 Gamma IP65 Physical Properties

Table 5.61—Gamma IP65 Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±280 lbf	±1200 N
Fz	±930 lbf	±4100 N
Txy	±700 inf-lb	±79 Nm
Tz	±730 inf-lb	±82 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	5.2×10^4 lb/in	9.1×10^6 N/m
Z-axis force (Kz)	1.0×10^5 lb/in	1.8×10^7 N/m
X-axis & Y-axis torque (Ktx, Kty)	9.3×10^4 lbf-in/rad	1.1×10^4 Nm/rad
Z-axis torque (Ktz)	1.4×10^5 lbf-in/rad	1.6×10^4 Nm/rad
Resonant Frequency		
Fx, Fy, Tz	1000 Hz	1000 Hz
Fz, Tx, Ty	970 Hz	970 Hz
Physical Specifications		
Weight[1]	2.4 lb	1.09 kg
Diameter[1]	4.37 in	111 mm
Height[1]	2.06 in	52.3 mm
Note: 1. Specifications include standard interface plates.		

5.12.4 Gamma IP68 Physical Properties

Table 5.62—Gamma IP68 Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±280 lbf	±1200 N
Fz	±930 lbf	±4100 N
Txy	±700 inf-lb	±79 Nm
Tz	±730 inf-lb	±82 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	5.2×10^4 lb/in	9.1×10^6 N/m
Z-axis force (Kz)	1.0×10^5 lb/in	1.8×10^7 N/m
X-axis & Y-axis torque (Ktx, Kty)	9.3×10^4 lbf-in/rad	1.1×10^4 Nm/rad
Z-axis torque (Ktz)	1.4×10^5 lbf-in/rad	1.6×10^4 Nm/rad
Resonant Frequency		
Fx, Fy, Tz	1250 Hz	1250 Hz
Fz, Tx, Ty	940 Hz	940 Hz
Physical Specifications		
Weight[1]	4.37 lb	1.98 kg
Diameter[1]	4.37 in	111 mm
Height[1]	2.06 in	52.3 mm
Note: 1. Specifications include standard interface plates.		

CAUTION: When submerged, IP68 transducers exhibit a decrease in Fz range related to the submersion depth. This loss is the result of pressure-induced preloading on the transducer. The preload can be masked by biasing the transducer at the depth prior to applying the load to be measured. The following estimates are for room temperature fresh water at sea level.		
Submersion Depth		
IP68 Gamma	**US**	**Metric**
Fz preload at 4 m depth	-42.9 lb	-191 N
Fz preload at other depths	-3.27 lb/ft × depthInFeet	-47.4 N/m × depthInMeters

5.12.5 Calibration Specifications (excludes CTL calibrations)

Table 5.63— Gamma Calibrations (excludes CTL calibrations)[1, 2]									
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz[3] (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**	**Fx,Fy (lbf)**	**Fz[3] (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**
Gamma	US-7.5-25	7.5	25	25	25	1/640	1/320	1/320	1/320
Gamma	US-15-50	15	50	50	50	1/320	1/160	1/160	1/160
Gamma	US-30-100	30	100	100	100	1/160	1/80	1/80	1/80
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**
Gamma	SI-32-2.5	32	100	2.5	2.5	1/160	1/80	1/2000	1/2000
Gamma	SI-65-5	65	200	5	5	1/80	1/40	10/13333	10/13333
Gamma	SI-130-10	130	400	10	10	1/40	1/20	1/800	1/800
		Sensing Ranges				**Resolution (DAQ, Net F/T)[4]**			

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

5.12.6 CTL Calibration Specifications

Table 5.64— Gamma CTL Calibrations[1, 2]

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

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

5.12.7 Analog Output

Table 5.65— Gamma Analog Output

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

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

5.12.8 Counts Value

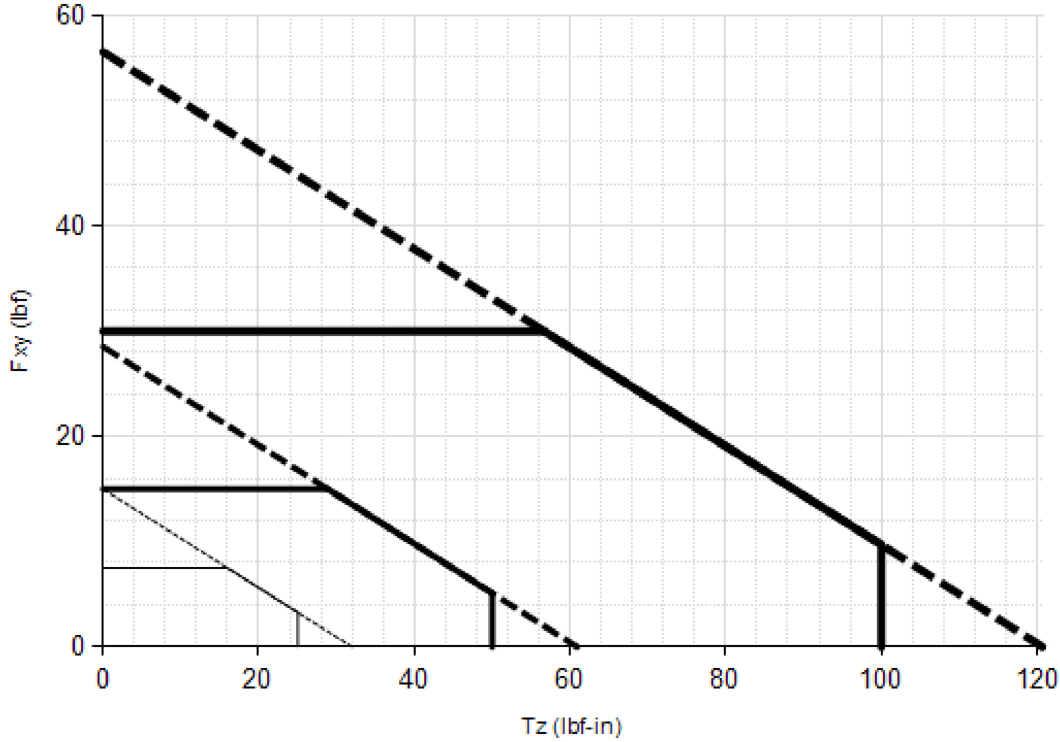
Table 5.66—Counts Value					
Sensor	**Calibration**	**Fx, Fy, Fz (/ lbf)**	**Tx, Ty, Tz (/ lbf-in)**	**Fx, Fy, Fz (/ N)**	**Tx, Ty, Tz (/ Nm)**
Gamma	US-7.5–25 / SI-32–2.5	2560	2560	640	8000
Gamma	US-15–50 / SI-65–5	1280	1280	320	5333.33
Gamma	US-30–100 / SI-130–10	640	640	160	3200
Gamma	Tool Transform Factor	See Tool Transform Factor table			
		Counts Value – Standard (US)		**Counts Value – Metric (SI)**	

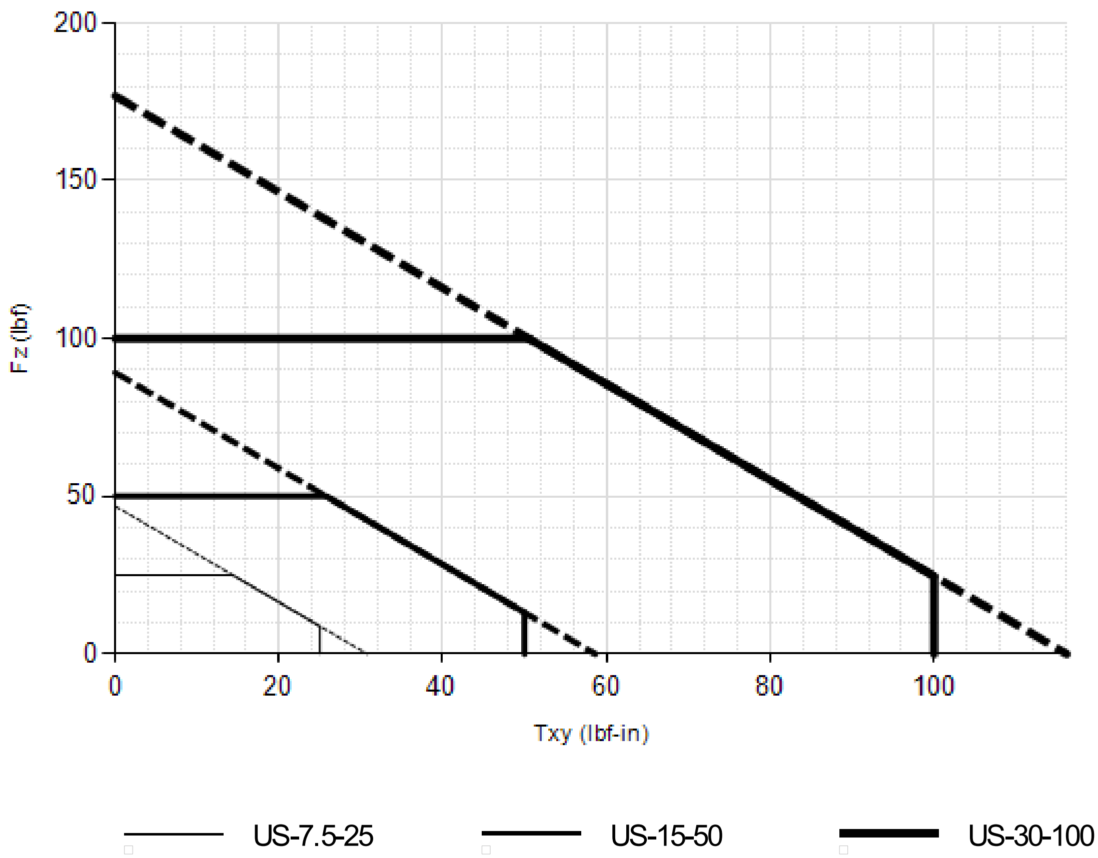
5.12.9 Tool Transform Factor

Table 5.67—Tool Transform Factor			
Sensor	**Calibration**	**US (English)**	SI (Metric)
Gamma	US-7.5–25 / SI-32–2.5	0.01 in/lbf	0.8 mm/N
Gamma	US-15–50 / SI-65–5	0.01 in/lbf	0.6 mm/N
Gamma	US-30–100 / SI-130–10	0.01 in/lbf	0.y h5 mm/N

.

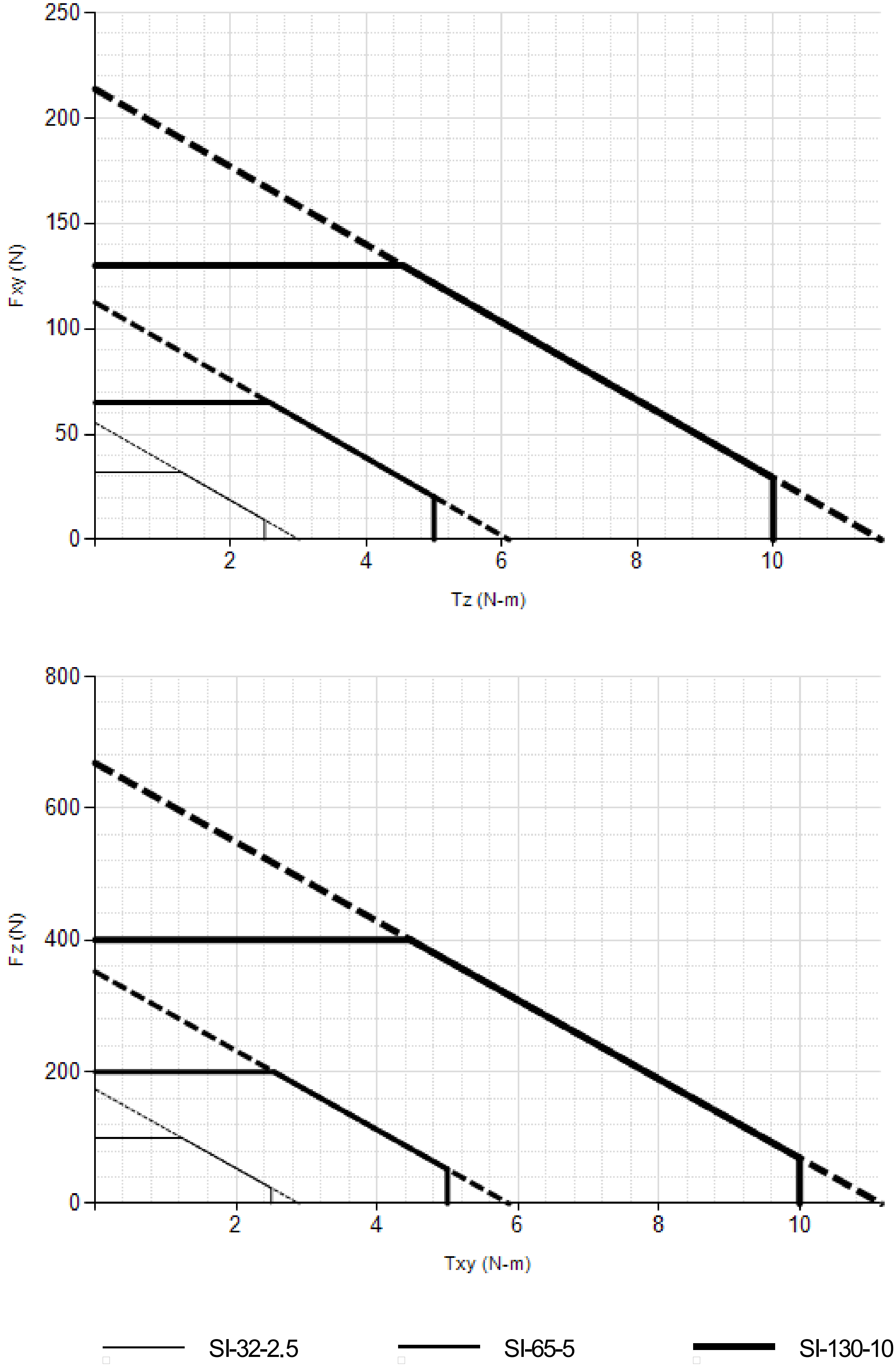
5.12.10 Gamma (US Calibration Complex Loading)(Includes IP60/IP65/IP68)[1]





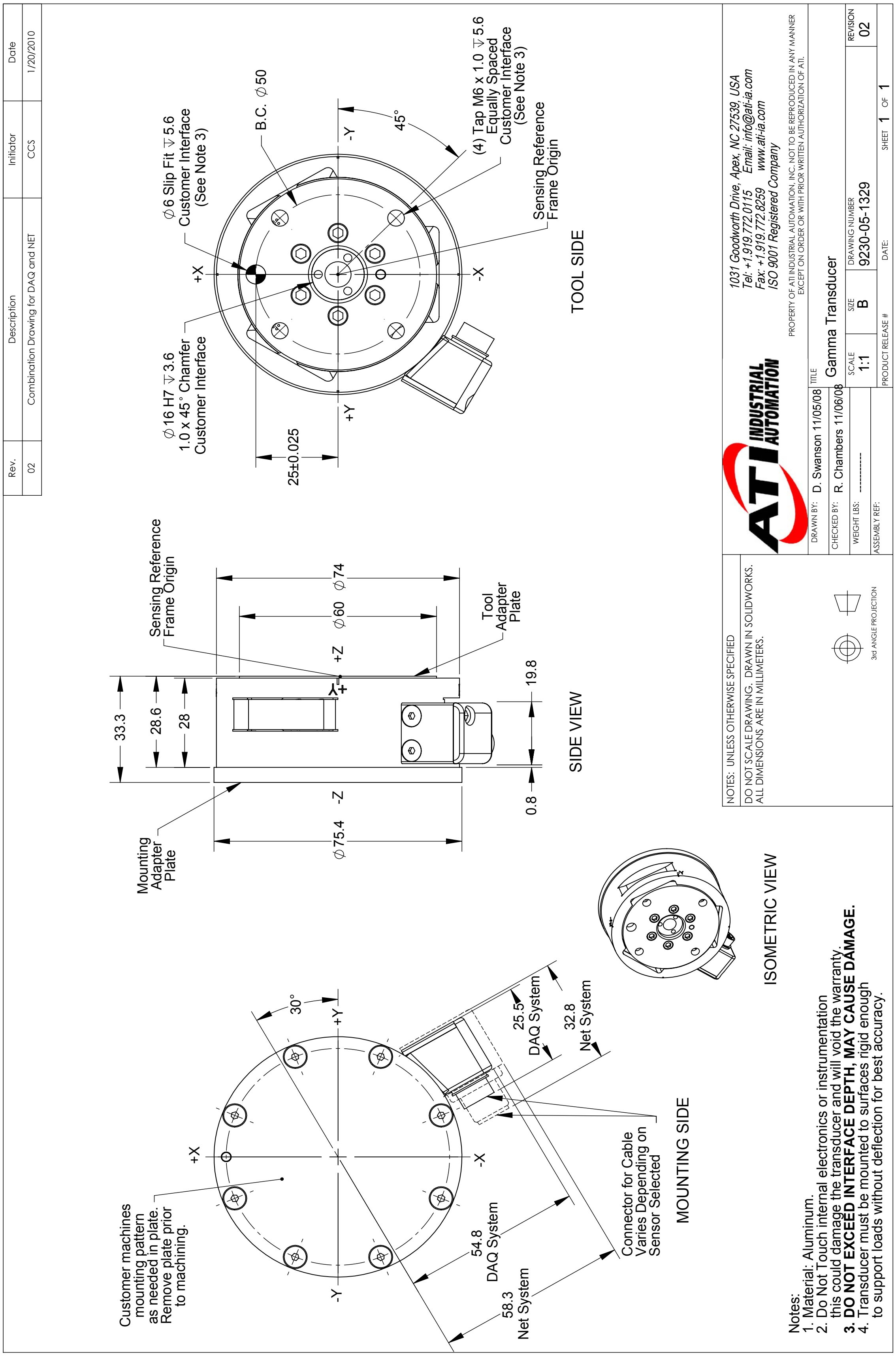
Note: 1. For IP68 version see caution on physical properties page.

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

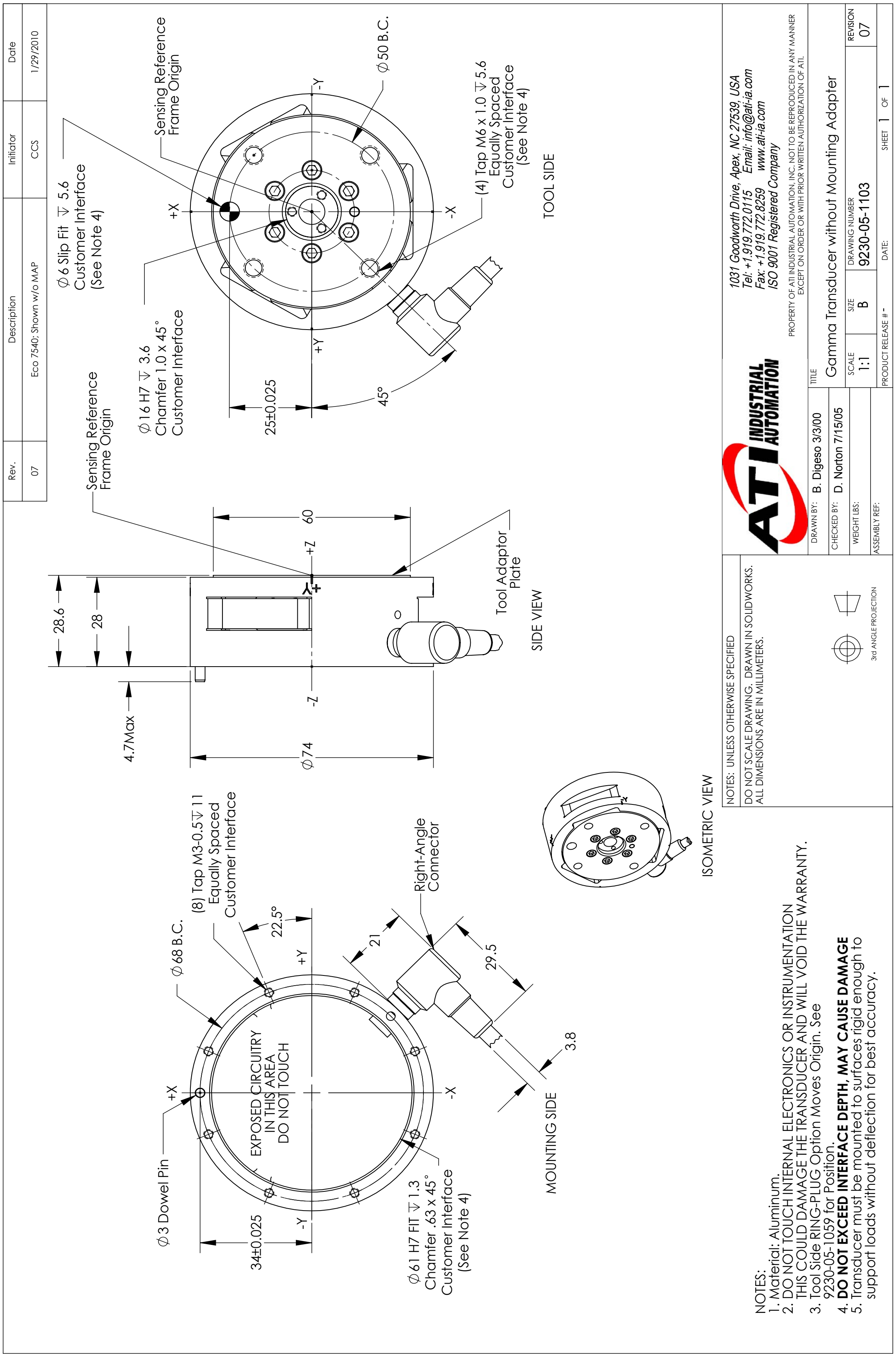


Note: 1. For IP68 version see caution on physical properties page.

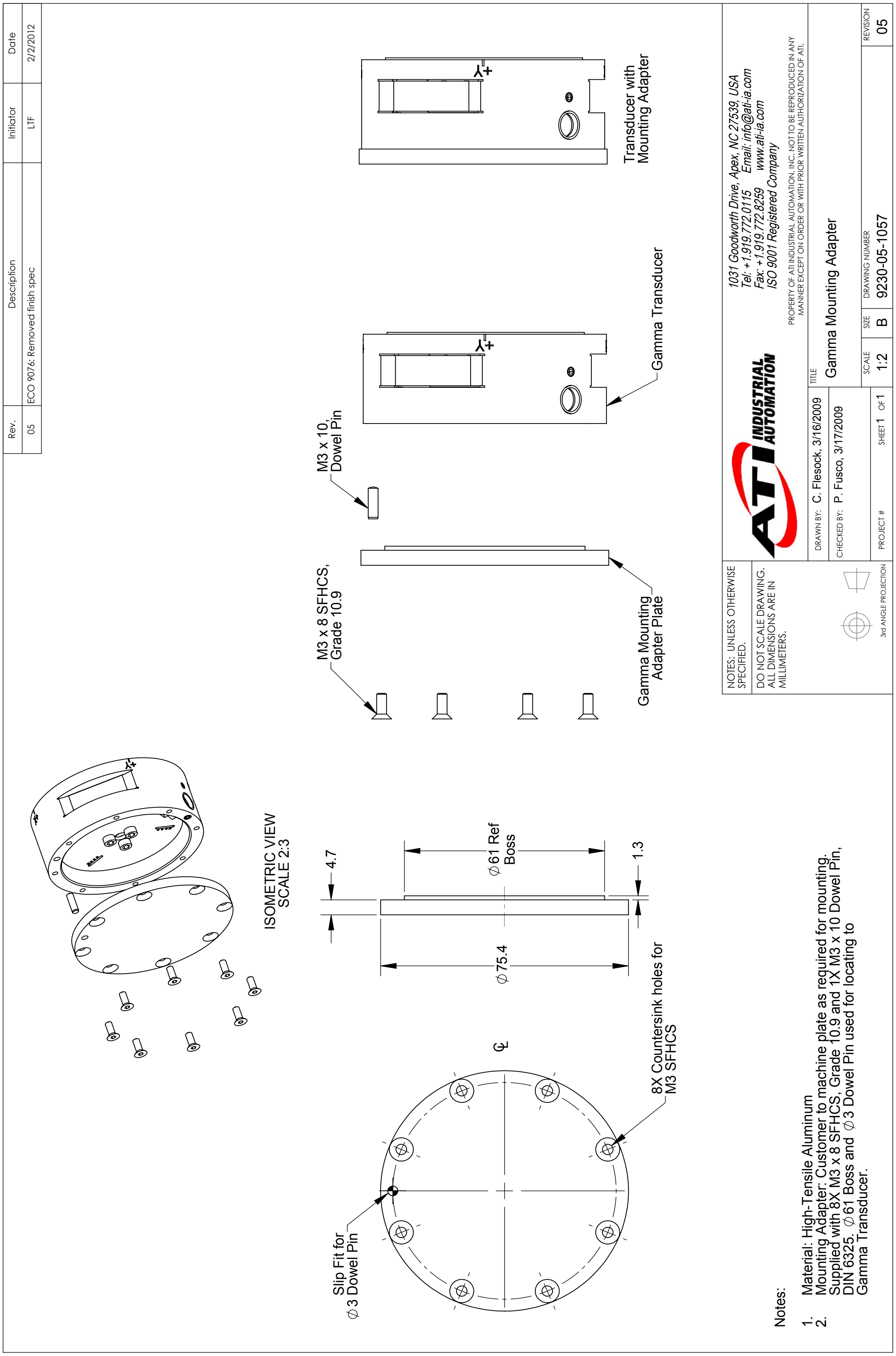
5.12.12 Gamma DAQ/Net Transducer Drawing



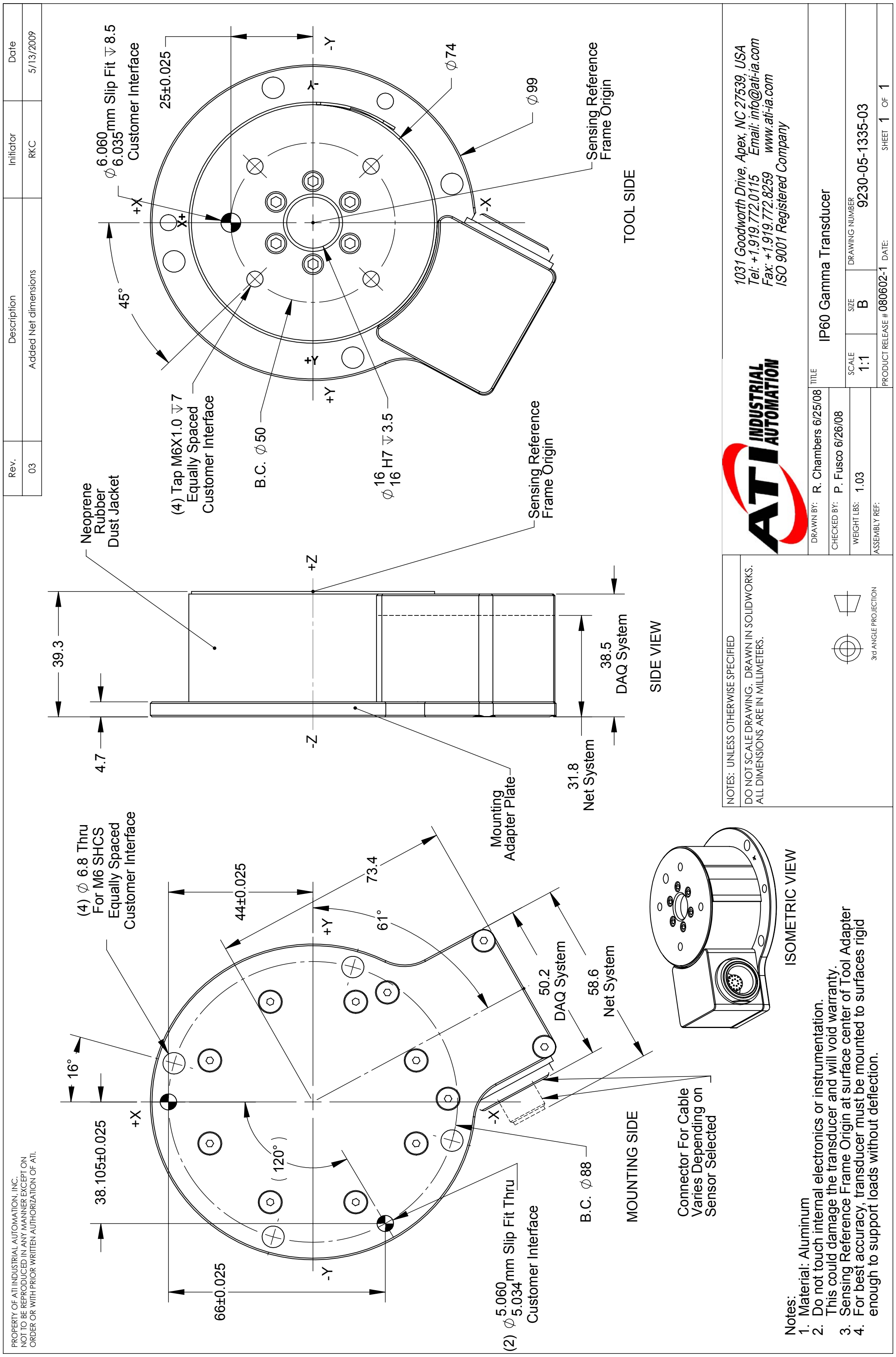
5.12.13 9105-T-Gamma Transducer without Mounting Adapter Drawing



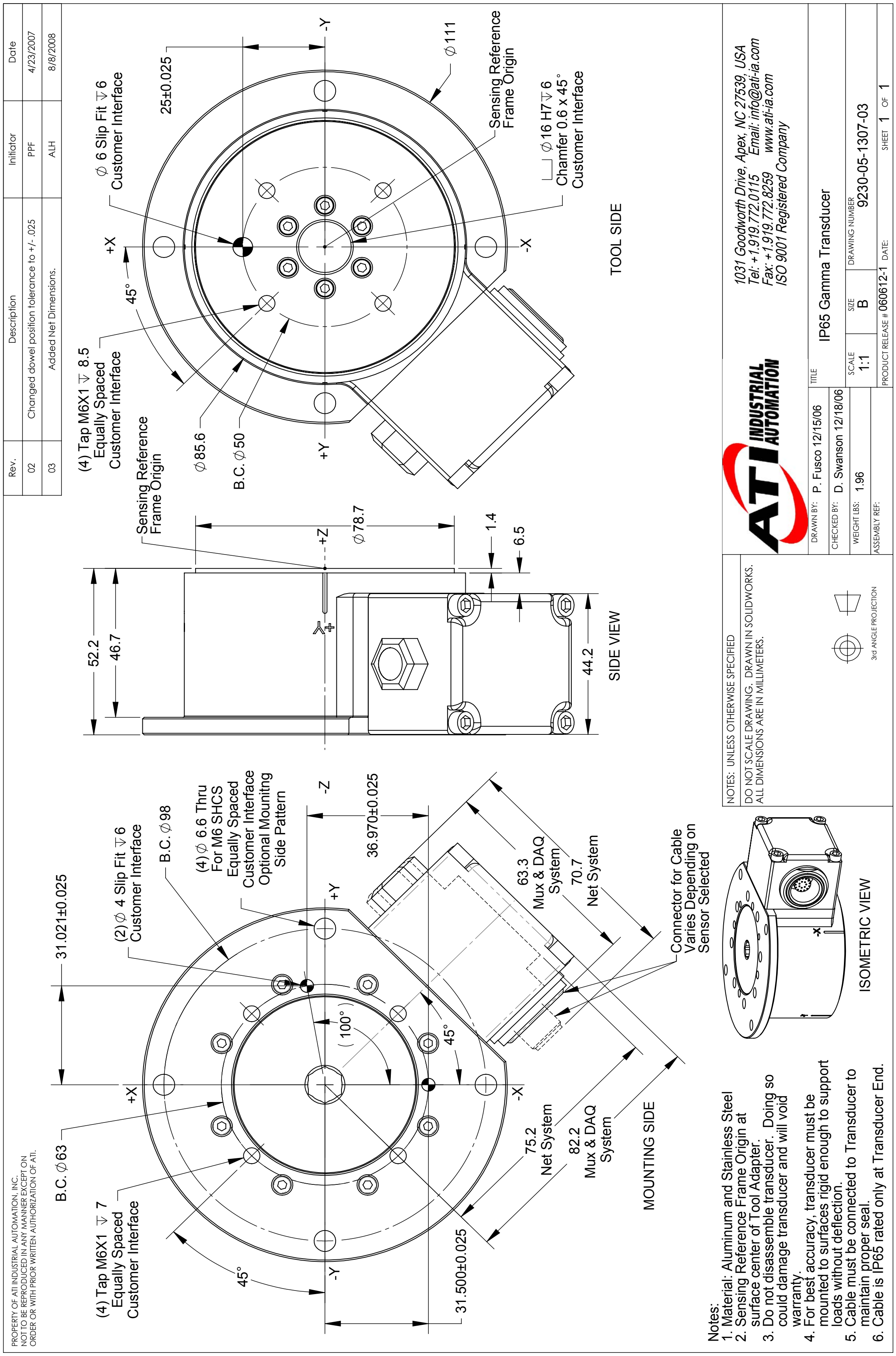
5.12.14 Gamma Mounting Adapter Plate Drawing



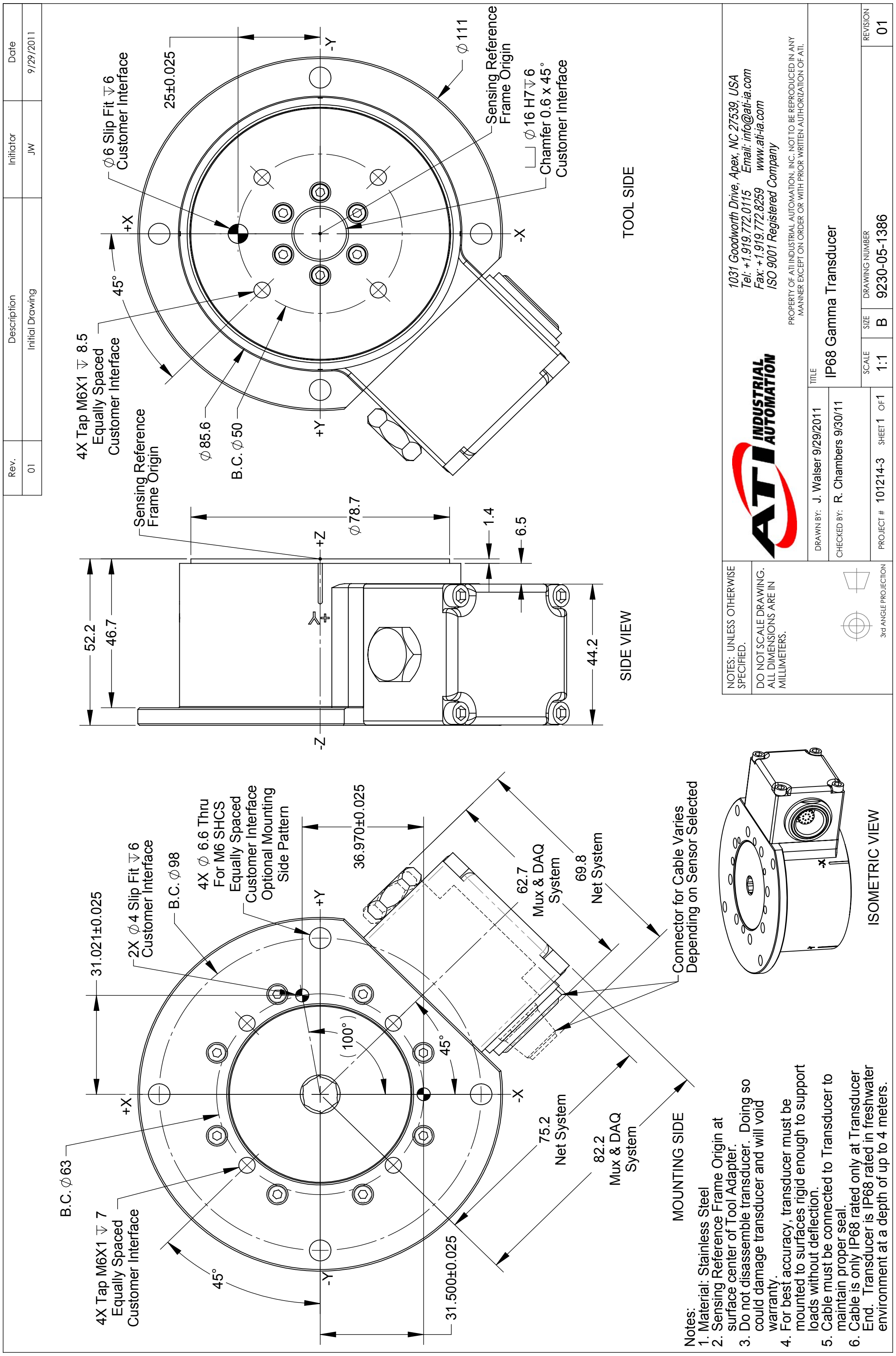
5.12.15 Gamma IP60 Transducer Drawing



5.12.16 Gamma IP65 Transducer Drawing



5.12.17 Gamma IP68 Transducer Drawing



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

5.13.1 Delta Physical Properties

Table 5.68—Delta Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±840 lbf	±3700 N
Fz	±2300 lbf	±10000 N
Txy	±2500 inf-lb	±280 Nm
Tz	±3600 inf-lb	±400 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	2.0×10^5 lb/in	3.6×10^7 N/m
Z-axis force (Kz)	3.4×10^5 lb/in	5.9×10^7 N/m
X-axis & Y-axis torque (Ktx, Kty)	4.6×10^5 lbf-in/rad	5.2×10^4 Nm/rad
Z-axis torque (Ktz)	8.1×10^5 lbf-in/rad	9.1×10^4 Nm/rad
Resonant Frequency		
Fx, Fy, Tz	1500 Hz	1500 Hz
Fz, Tx, Ty	1700 Hz	1700 Hz
Physical Specifications		
Weight[1]	2.01 lb	0.913 kg
Diameter[1]	3.72 in	94.5 mm
Height[1]	1.31 in	33.3 mm
Note: 1. Specifications include standard interface plates.		

5.13.2 Delta IP60 Physical Properties

Table 5.69—Delta IP60 Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±840 lbf	±3700 N
Fz	±2300 lbf	±10000 N
Txy	±2500 inf-lb	±280 Nm
Tz	±3600 inf-lb	±400 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	2.0×10^5 lb/in	3.6×10^7 N/m
Z-axis force (Kz)	3.4×10^5 lb/in	5.9×10^7 N/m
X-axis & Y-axis torque (Ktx, Kty)	4.6×10^5 lbf-in/rad	5.2×10^4 Nm/rad
Z-axis torque (Ktz)	8.1×10^5 lbf-in/rad	9.1×10^4 Nm/rad
Resonant Frequency		
Fx, Fy, Tz	1100 Hz	1100 Hz
Fz, Tx, Ty	1100 Hz	1100 Hz
Physical Specifications		
Weight[1]	4 lb	1.81 kg
Diameter[1]	4.6 in	117 mm
Height[1]	1.85 in	47.1 mm
Note: 1. Specifications include standard interface plates.		

5.13.3 Delta IP65 Physical Properties

Table 5.70—Delta IP65 Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±840 lbf	±3700 N
Fz	±2300 lbf	±10000 N
Txy	±2500 inf-lb	±280 Nm
Tz	±3600 inf-lb	±400 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	2.0×10^{5} lb/in	3.6×10^{7} N/m
Z-axis force (Kz)	3.4×10^{5} lb/in	5.9×10^{7} N/m
X-axis & Y-axis torque (Ktx, Kty)	4.6×10^{5} lbf-in/rad	5.2×10^{4} Nm/rad
Z-axis torque (Ktz)	8.1×10^{5} lbf-in/rad	9.1×10^{4} Nm/rad
Resonant Frequency		
Fx, Fy, Tz	880 Hz	880 Hz
Fz, Tx, Ty	920 Hz	920 Hz
Physical Specifications		
Weight[1]	3.91 lb	1.77 kg
Diameter[1]	4.96 in	126 mm
Height[1]	2.06 in	52.2 mm
Note: 1. Specifications include standard interface plates.		

5.13.4 Delta IP68 Physical Properties

Table 5.71—Delta IP68 Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±840 lbf	±3700 N
Fz	±2300 lbf	±10000 N
Txy	±2500 inf-lb	±280 Nm
Tz	±3600 inf-lb	±400 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	2.0×10^{5} lb/in	3.6×10^{7} N/m
Z-axis force (Kz)	3.4×10^{5} lb/in	5.9×10^{7} N/m
X-axis & Y-axis torque (Ktx, Kty)	4.6×10^{5} lbf-in/rad	5.2×10^{4} Nm/rad
Z-axis torque (Ktz)	8.1×10^{5} lbf-in/rad	9.1×10^{4} Nm/rad
Resonant Frequency		
Fx, Fy, Tz	950 Hz	950 Hz
Fz, Tx, Ty	960 Hz	960 Hz
Physical Specifications		
Weight[1]	5.8 lb	2.63 kg
Diameter[1]	4 in	102 mm
Height[1]	2.06 in	52.2 mm
Note: 1. Specifications include standard interface plates.		

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

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

5.13.5 Calibration Specifications (excludes CTL calibrations)

Table 5.72— Delta Calibrations (excludes CTL calibrations)[1, 2]

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

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

5.13.6 CTL Calibration Specifications

Table 5.73— Delta CTL Calibrations[1, 2]									
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz[3] (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**	**Fx,Fy (lbf)**	**Fz[3] (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**
Delta	US-50-150	50	150	150	150	1/64	1/32	3/64	1/32
Delta	US-75-300	75	225	300	300	1/32	1/16	3/32	1/16
Delta	US-150-600	150	450	600	600	1/16	1/8	3/16	1/8
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**
Delta	SI-165-15	165	495	15	15	1/16	1/8	1/264	1/264
Delta	SI-330-30	330	990	30	30	1/8	1/4	10/1333	10/1333
Delta	SI-660-60	660	1980	60	60	1/4	1/2	5/333	5/333
		Sensing Ranges				**Resolution (Controller)**			

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

5.13.7 Analog Output

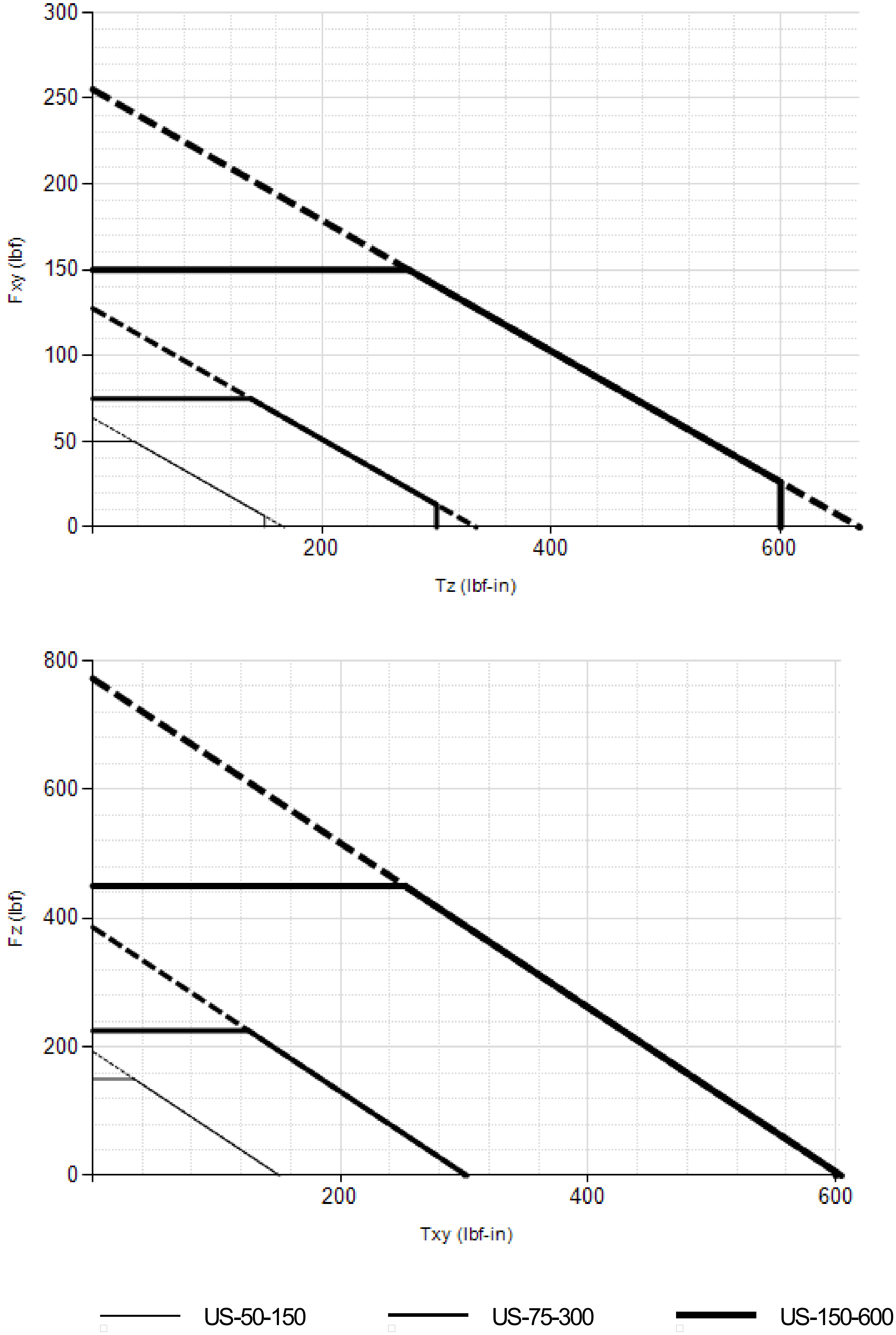
Table 5.74— Delta Analog Output							
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz[2] (lbf)**	**Tx,Ty,Tz (lbf-in)**	**Fx,Fy (lbf/V)**	**Fz[2] (lbf/V)**	**Tx,Ty,Tz (lbf-in/V)**
Delta	US-50-150	±50	±150	±150	5	15	15
Delta	US-75-300	±75	±225	±300	7.5	22.5	30
Delta	US-150-600	±150	±450	±600	15	45	60
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz[2] (N)**	**Tx,Ty,Tz (Nmm)**	**Fx,Fy (N/V)**	**Fz[2] (N/V)**	**Tx,Ty,Tz (Nm/V)**
Delta	SI-165-15	±165	±495	±15	16.5	49.5	1.5
Delta	SI-330-30	±330	±990	±30	33	99	3
Delta	SI-660-60	±660	±1980	±60	66	198	6
		Analog Output Range			**Analog ±10V Sensitivity[1]**		

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

5.13.8 Counts Value

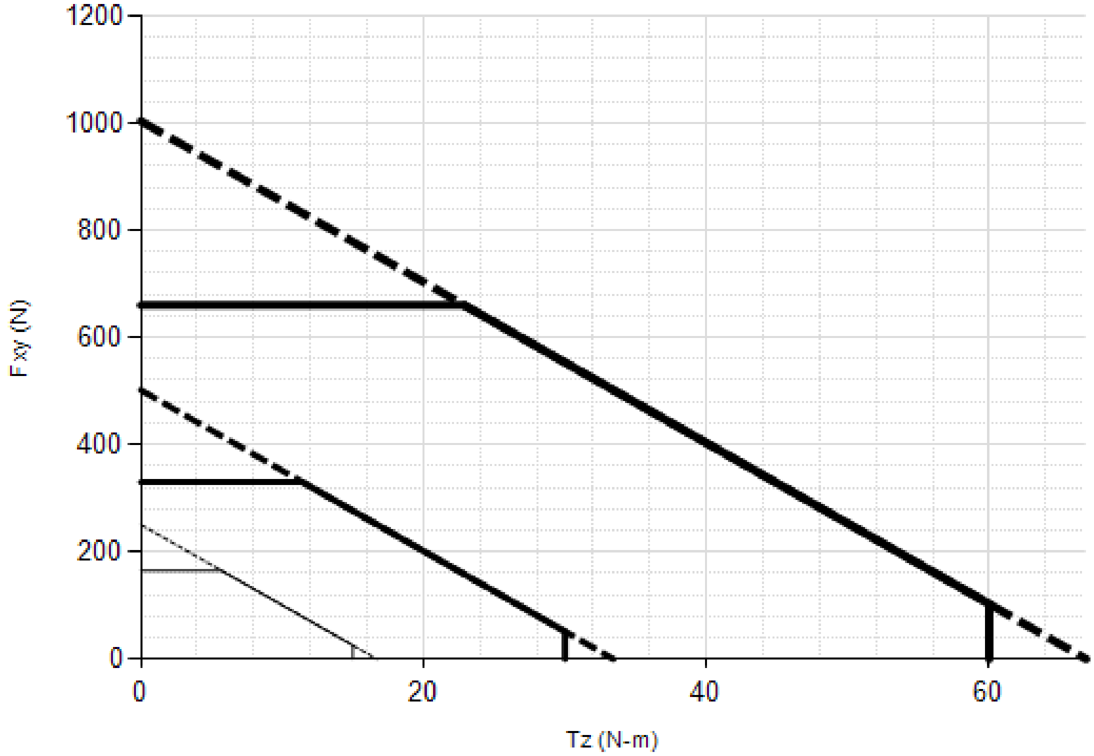
Table 5.75—Counts Value					
Sensor	**Calibration**	**Fx, Fy, Fz (/ lbf)**	**Tx, Ty, Tz (/ lbf-in)**	**Fx, Fy, Fz (/ N)**	**Tx, Ty, Tz (/ Nm)**
Delta	US-7.5–25 / SI-32–2.5	512	512	128	2112
Delta	US-15–50 / SI-65–5	256	256	64	1066.67
Delta	US-30–100 / SI-130–10	128	128	32	533.333
Delta	Tool Transform Factor	0.01 in/lbf		0.6 mm/N	
		Counts Value – Standard (US)		**Counts Value – Metric (SI)**	

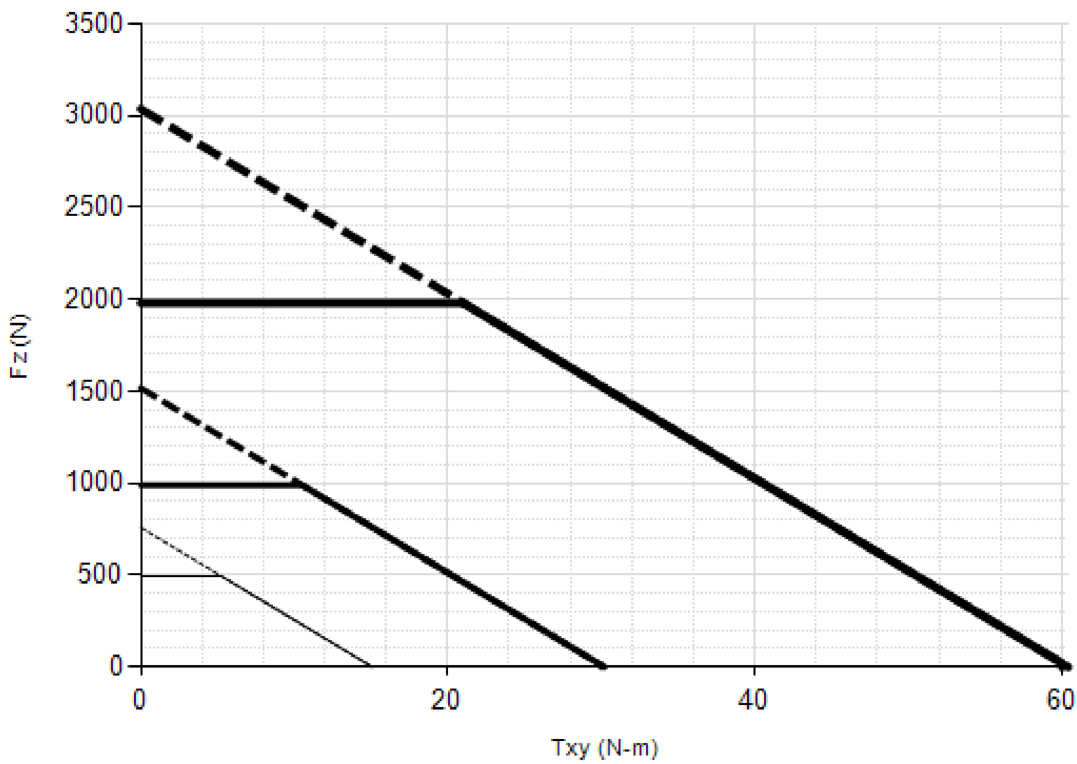
5.13.9 Delta (US Calibration Complex Loading)(Includes IP60/IP65/IP68)[1]

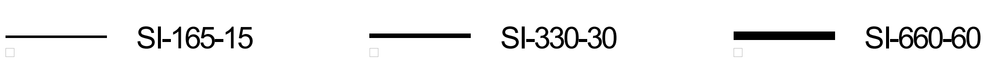


Note: 1. For IP68 version see caution on physical properties page.

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

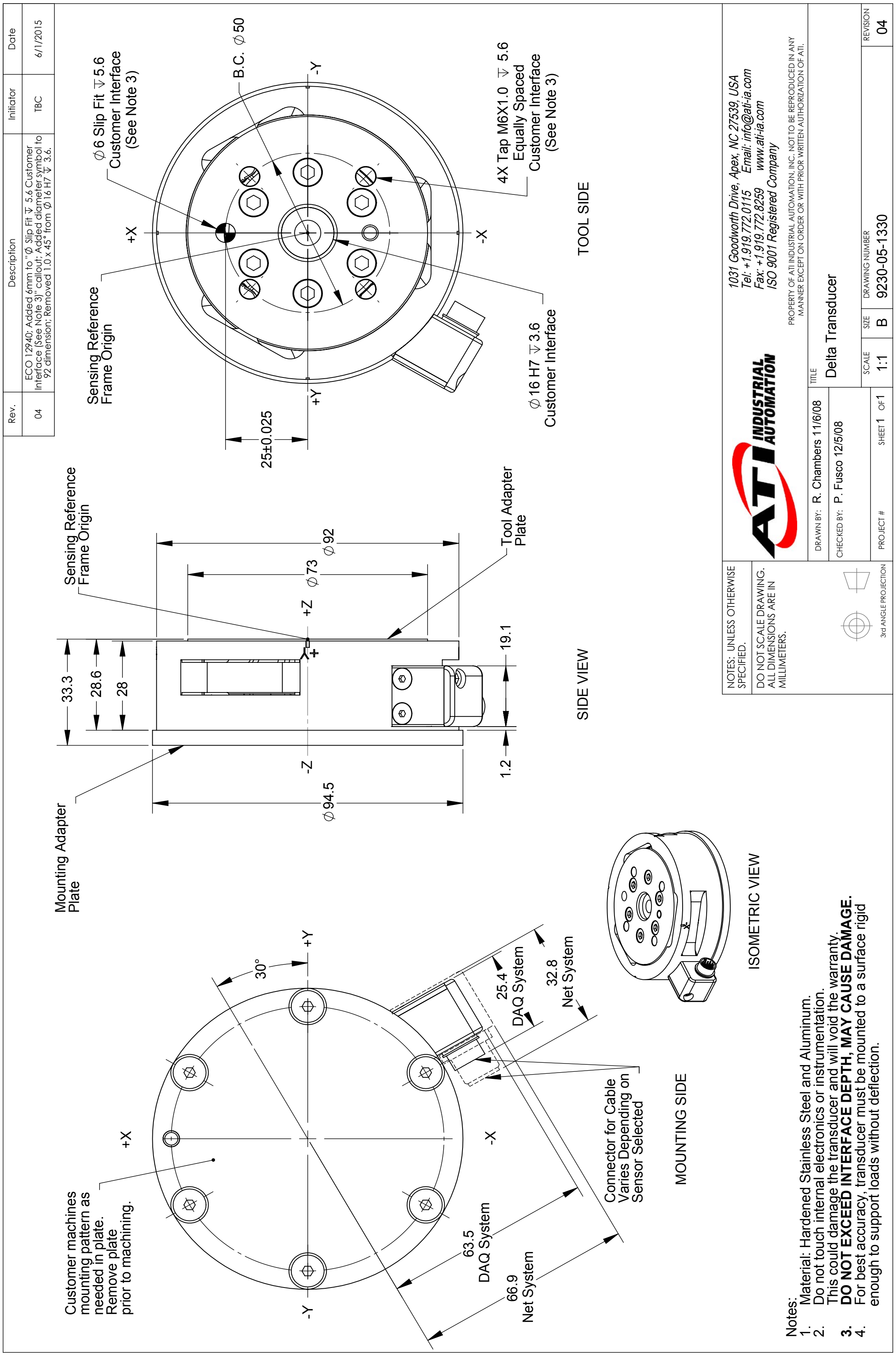




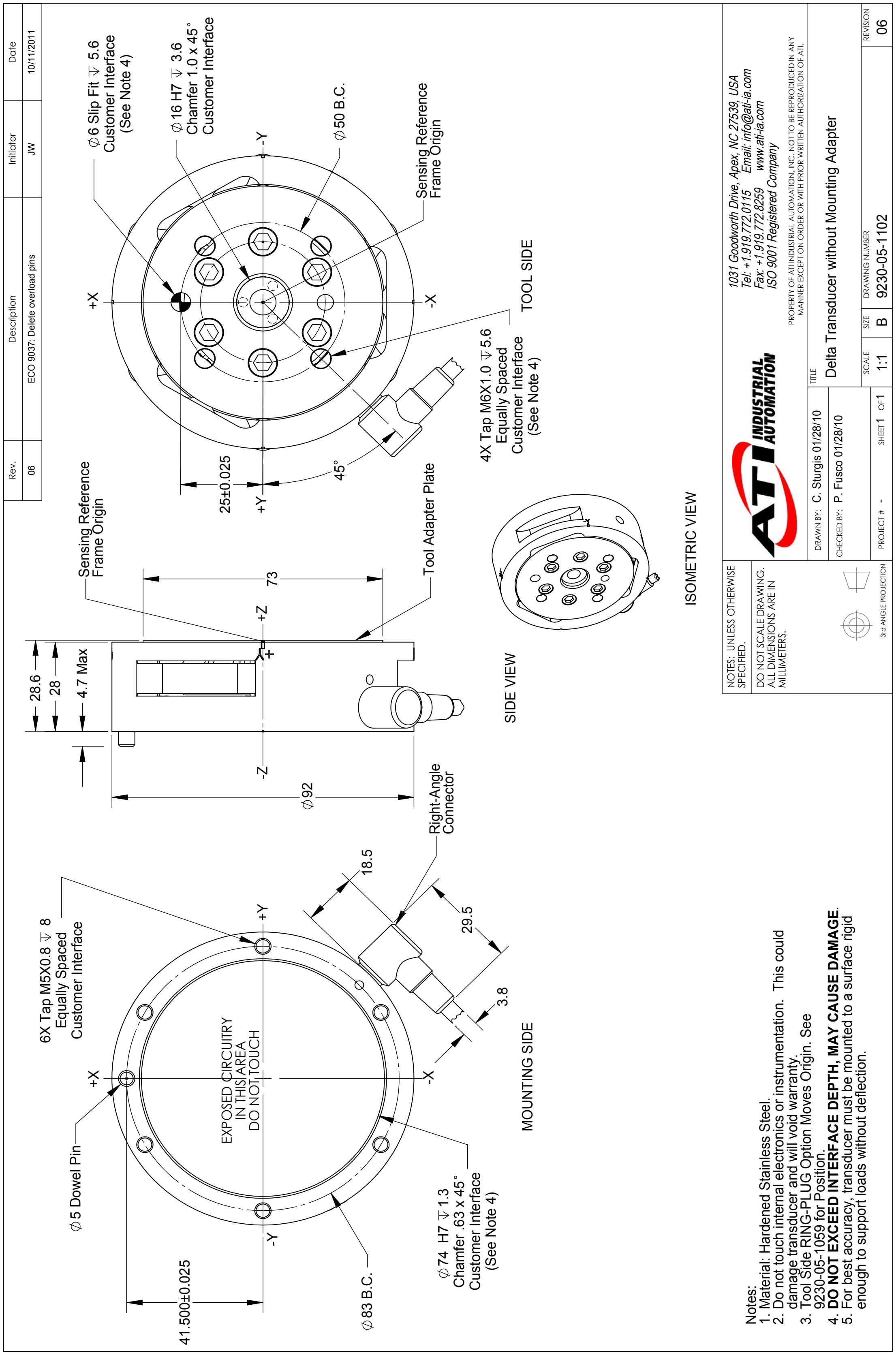


Note: 1. For IP68 version see caution on physical properties page.

5.13.11 Delta DAQ/Net Transducer Drawing

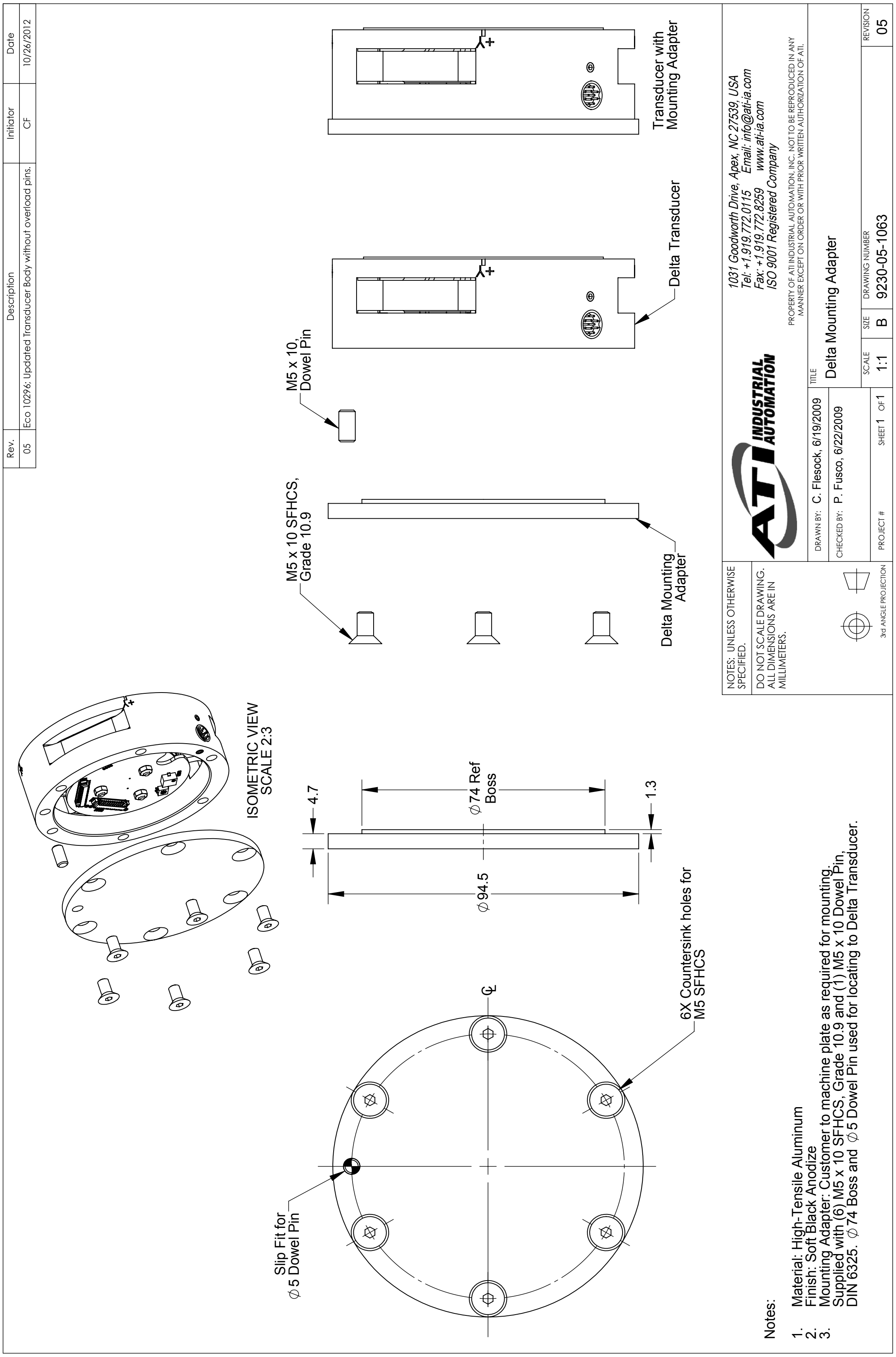


5.13.12 9105-T-Delta Transducer without Mounting Adapter Drawing

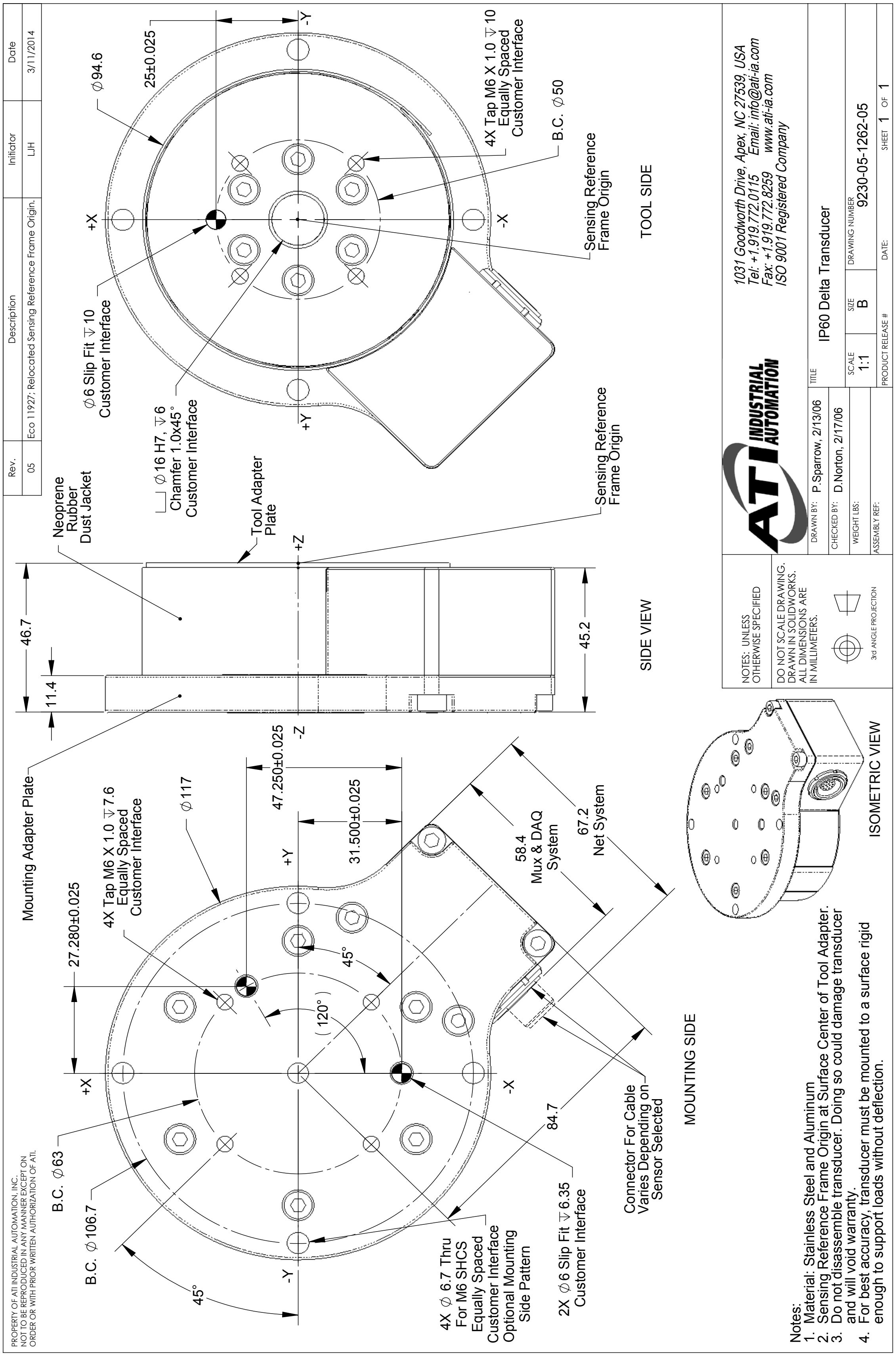


Note: Mux transducers are used in F/T Controller systems.

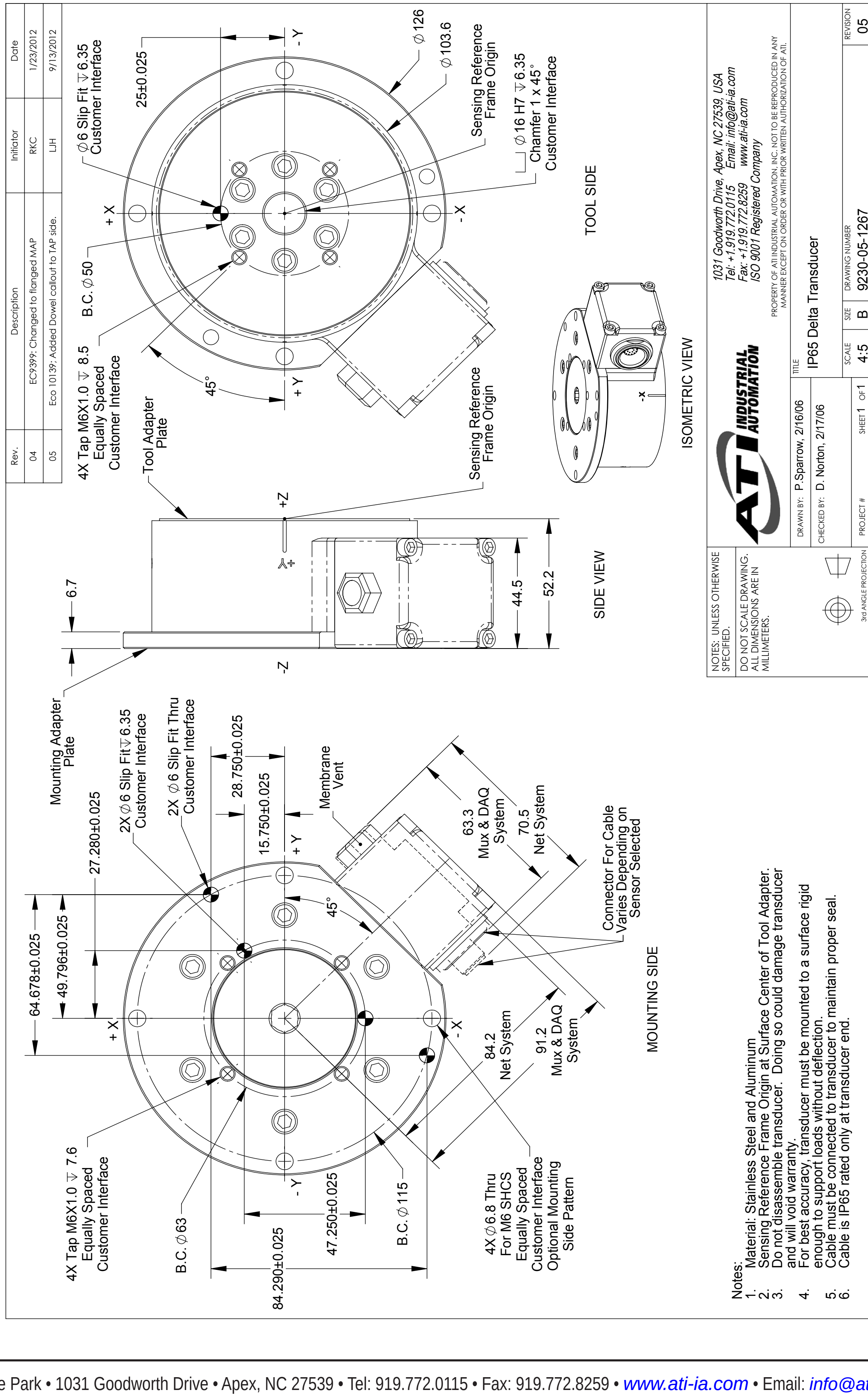
5.13.13 Delta Mounting Adapter Drawing



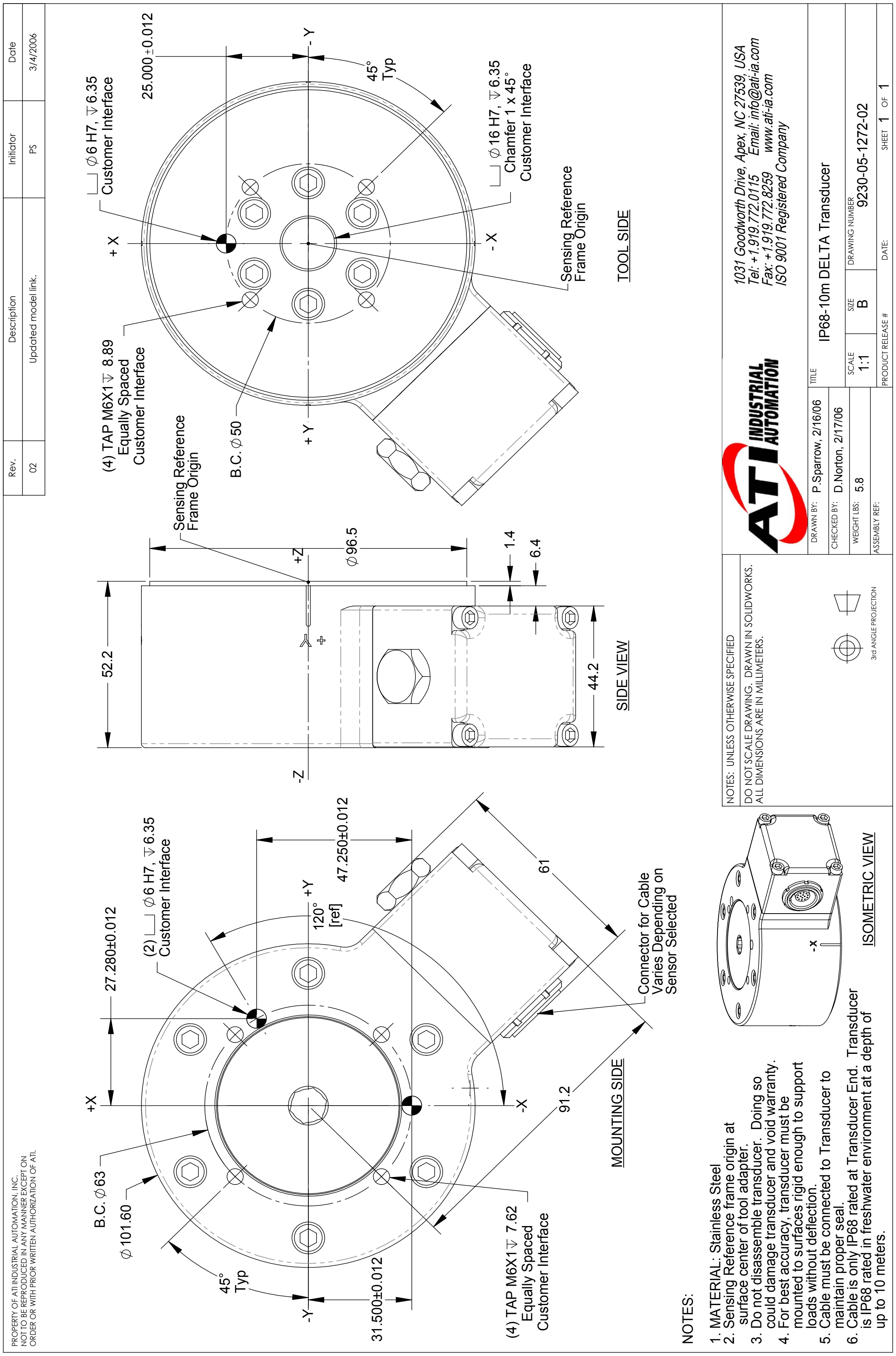
5.13.14 Delta IP60 Transducer Drawing



5.13.15 Delta IP65 Transducer Drawing



5.13.16 Delta IP68 Transducer Drawing



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

5.14.1 Theta Physical Properties

Table 5.76—Theta Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±4500 lbf	±20000 N
Fz	±11000 lbf	±51000 N
Txy	±18000 inf-lb	±2000 Nm
Tz	±18000 inf-lb	±2000 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	4.0×10^5 lb/in	7.1×10^7 N/m
Z-axis force (Kz)	6.9×10^5 lb/in	1.2×10^8 N/m
X-axis & Y-axis torque (Ktx, Kty)	3.0×10^6 lbf-in/rad	3.4×10^5 Nm/rad
Z-axis torque (Ktz)	4.7×10^6 lbf-in/rad	5.3×10^5 Nm/rad
Resonant Frequency		
Fx, Fy, Tz	680 Hz	680 Hz
Fz, Tx, Ty	820 Hz	820 Hz
Physical Specifications		
Weight[1]	11 lb	4.99 kg
Diameter[1]	6.1 in	155 mm
Height[1]	2.41 in	61.1 mm
Note: 1. Specifications include standard interface plates.		

5.14.2 Theta IP60 Physical Properties

Table 5.77—Theta IP60 Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±4500 lbf	±20000 N
Fz	±11000 lbf	±51000 N
Txy	±18000 inf-lb	±2000 Nm
Tz	±18000 inf-lb	±2000 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	4.0×10^5 lb/in	7.1×10^7 N/m
Z-axis force (Kz)	6.9×10^5 lb/in	1.2×10^8 N/m
X-axis & Y-axis torque (Ktx, Kty)	3.0×10^6 lbf-in/rad	3.4×10^5 Nm/rad
Z-axis torque (Ktz)	4.7×10^6 lbf-in/rad	5.3×10^5 Nm/rad
Resonant Frequency		
Fx, Fy, Tz	N/A	N/A
Fz, Tx, Ty	N/A	N/A
Physical Specifications		
Weight[1]	19 lb	8.62 kg
Diameter[1]	7.63 in	194 mm
Height[1]	2.91 in	74 mm
Note: 1. Specifications include standard interface plates.		

5.14.3 Theta IP65/IP68 Physical Properties

Table 5.78—Theta IP65/IP68 Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±4500 lbf	±20000 N
Fz	±11000 lbf	±51000 N
Txy	±18000 inf-lb	±2000 Nm
Tz	±18000 inf-lb	±2000 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	4.0×10^5 lb/in	7.1×10^7 N/m
Z-axis force (Kz)	6.9×10^5 lb/in	1.2×10^8 N/m
X-axis & Y-axis torque (Ktx, Kty)	3.0×10^6 lbf-in/rad	3.4×10^5 Nm/rad
Z-axis torque (Ktz)	4.7×10^6 lbf-in/rad	5.3×10^5 Nm/rad
Resonant Frequency		
Fx, Fy, Tz	N/A	N/A
Fz, Tx, Ty	N/A	N/A
Physical Specifications		
Weight[1]	19.8 lb	9 kg
Diameter[1]	6.41 in	163 mm
Height[1]	2.95 in	74.8 mm
Note: 1. Specifications include standard interface plates.		

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

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

5.14.4 Calibration Specifications (excludes CTL calibrations)

Table 5.79— Theta Calibrations (excludes CTL calibrations)[1, 2]

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

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

5.14.5 CTL Calibration Specifications

Table 5.80— Theta CTL Calibrations[1, 2]

Sensor	(US) Standard Calibration	Fx,Fy (lbf)	Fz[3] (lbf)	Tx,Ty (lbf-in)	Tz (lbf-in)	Fx,Fy (lbf)	Fz[3] (lbf)	Tx,Ty (lbf-in)	Tz (lbf-in)
Theta	US-200-1000	200	500	1000	1000	1/16	1/8	1/4	1/4
Theta	US-300-1800	300	875	1800	1800	5/34	5/17	5/8	5/8
Theta	US-600-3600	600	1500	3600	3600	1/4	1/2	1	1
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**
Theta	SI-1000-120	1000	2500	120	120	1/2	1/2	1/20	1/40
Theta	SI-1500-240	1500	3750	240	240	1	1	1/10	1/20
Theta	SI-2500-400	2500	6250	400	400	1	2	1/10	1/10
		Sensing Ranges				**Resolution (Controller)**			

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

5.14.6 Analog Output

Table 5.81— Theta Analog Output							
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz[2] (lbf)**	**Tx,Ty,Tz (lbf-in)**	**Fx,Fy (lbf/V)**	**Fz[2] (lbf/V)**	**Tx,Ty,Tz (lbf-in/V)**
Theta	US-200-1000	±200	±500	±1000	20	50	100
Theta	US-300-1800	±300	±875	±1800	30	87.5	180
Theta	US-600-3600	±600	±1500	±3600	60	150	360
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz[2] (N)**	**Tx,Ty,Tz (Nmm)**	**Fx,Fy (N/V)**	**Fz[2] (N/V)**	**Tx,Ty,Tz (Nm/V)**
Theta	SI-1000-120	±1000	±2500	±120	100	250	12
Theta	SI-1500-240	±1500	±3750	±240	150	375	24
Theta	SI-2500-400	±2500	±6250	±400	250	625	40
		Analog Output Range			**Analog ±10V Sensitivity[1]**		

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

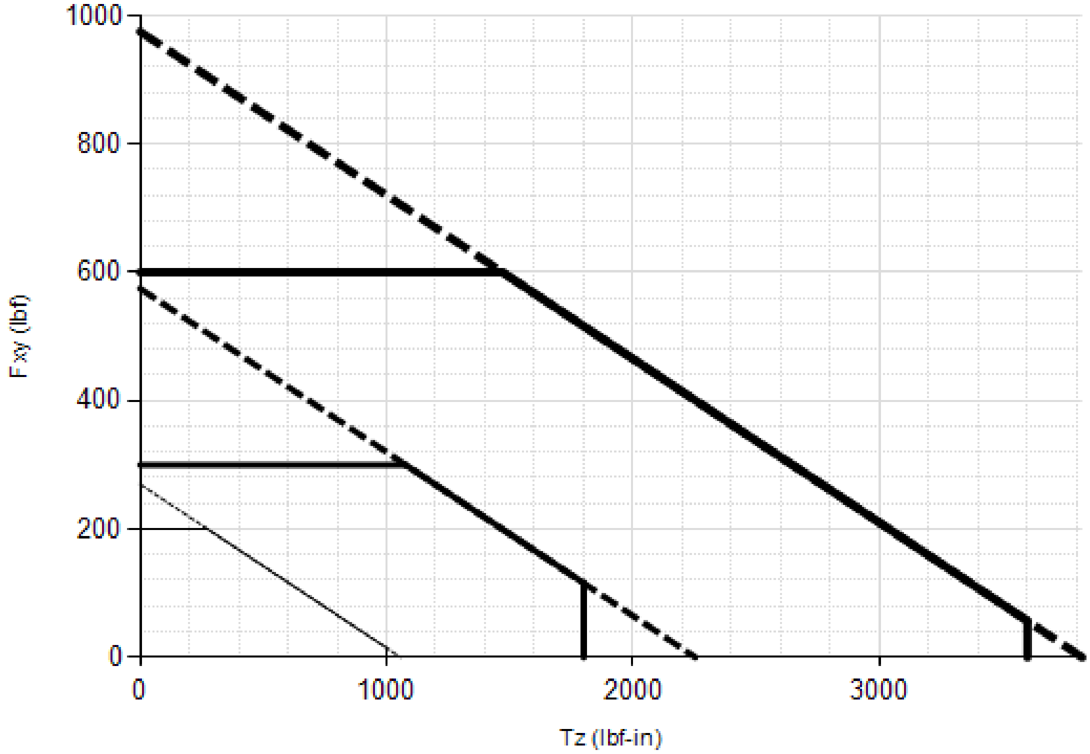
5.14.7 Counts Value

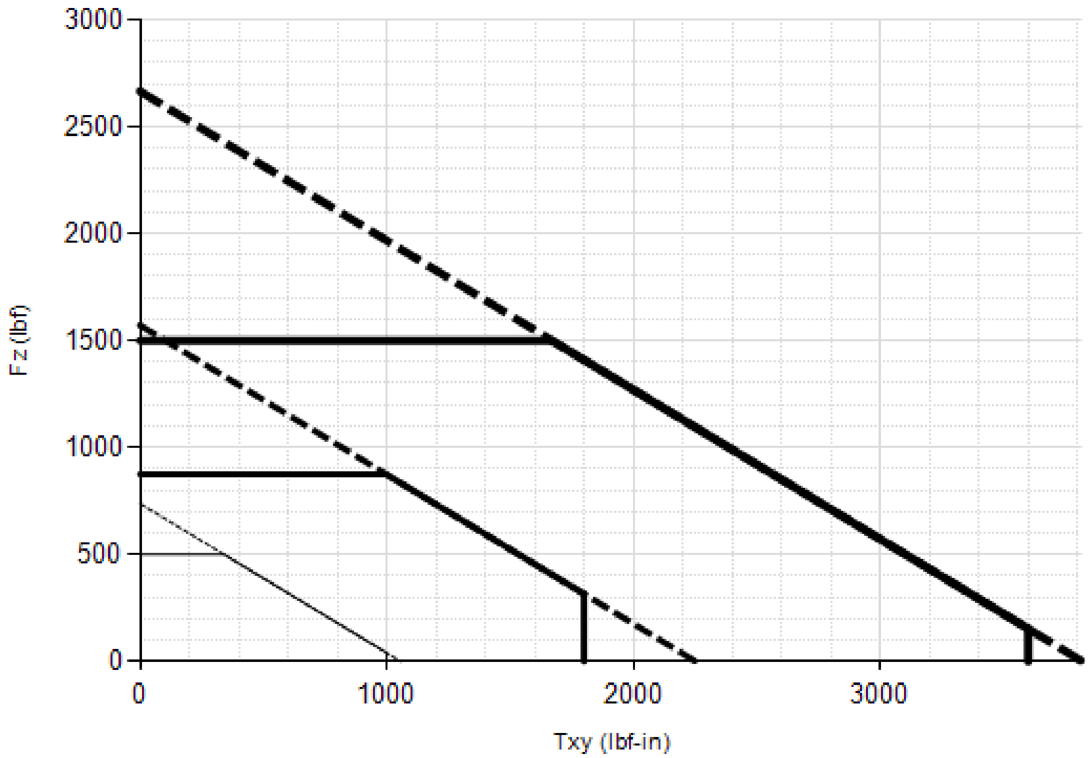
Table 5.82—Counts Value					
Sensor	**Calibration**	**Fx, Fy, Fz (/ lbf)**	**Tx, Ty, Tz (/ lbf-in)**	**Fx, Fy, Fz (/ N)**	**Tx, Ty, Tz (/ Nm)**
Theta	US-200–1000 / SI-1000–120	128	64	32	320
Theta	US-300–1800 / SI-1500–240	54.4	12.8	16	160
Theta	US-600–3600 / SI-2500–400	32	16	16	80
Theta	Tool Transform Factor	See Tool Transform Factor table			
		Counts Value – Standard (US)		**Counts Value – Metric (SI)**	

5.14.8 Tool Transform Factor

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

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

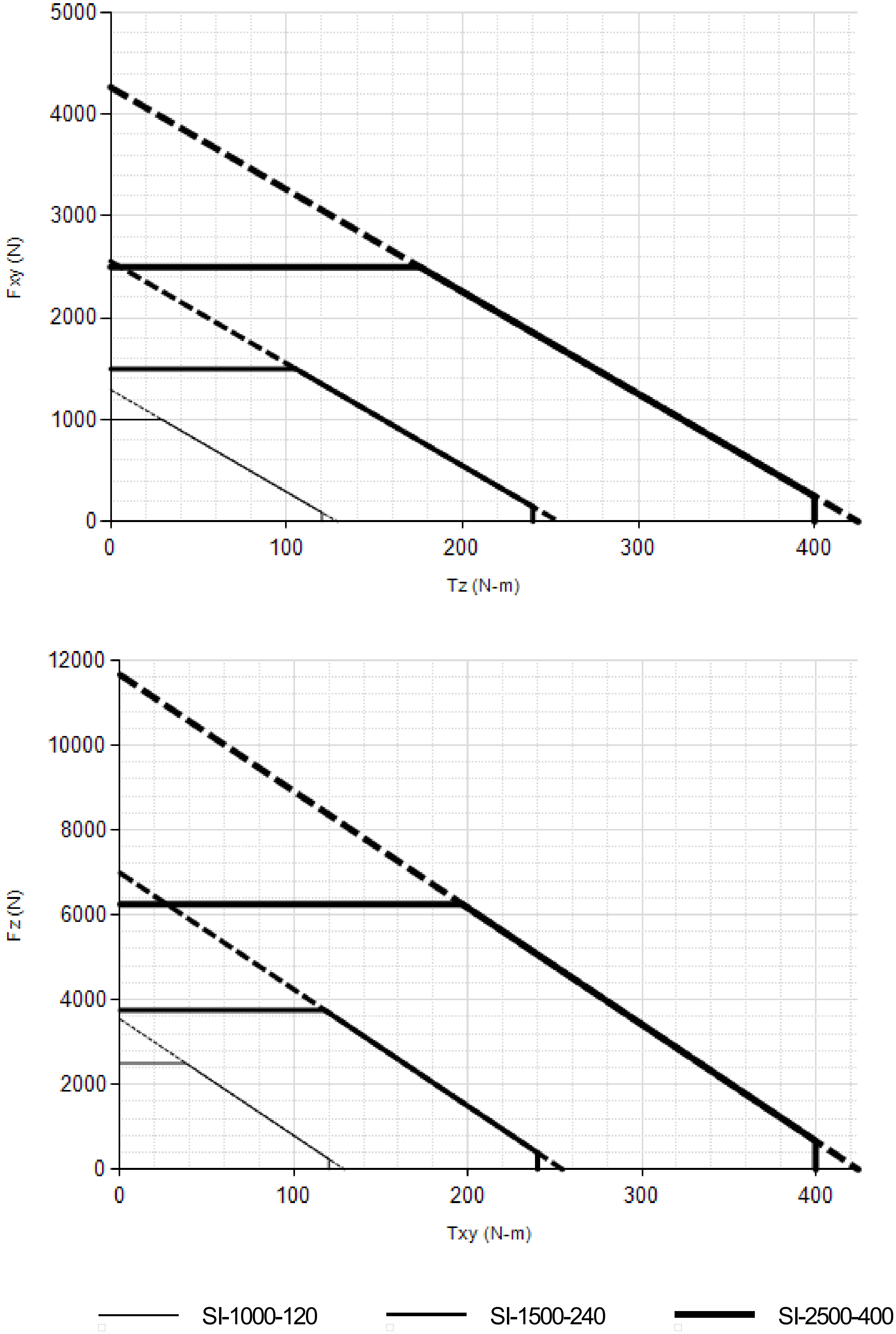




US-200-1000 US-300-1800 US-600-3600

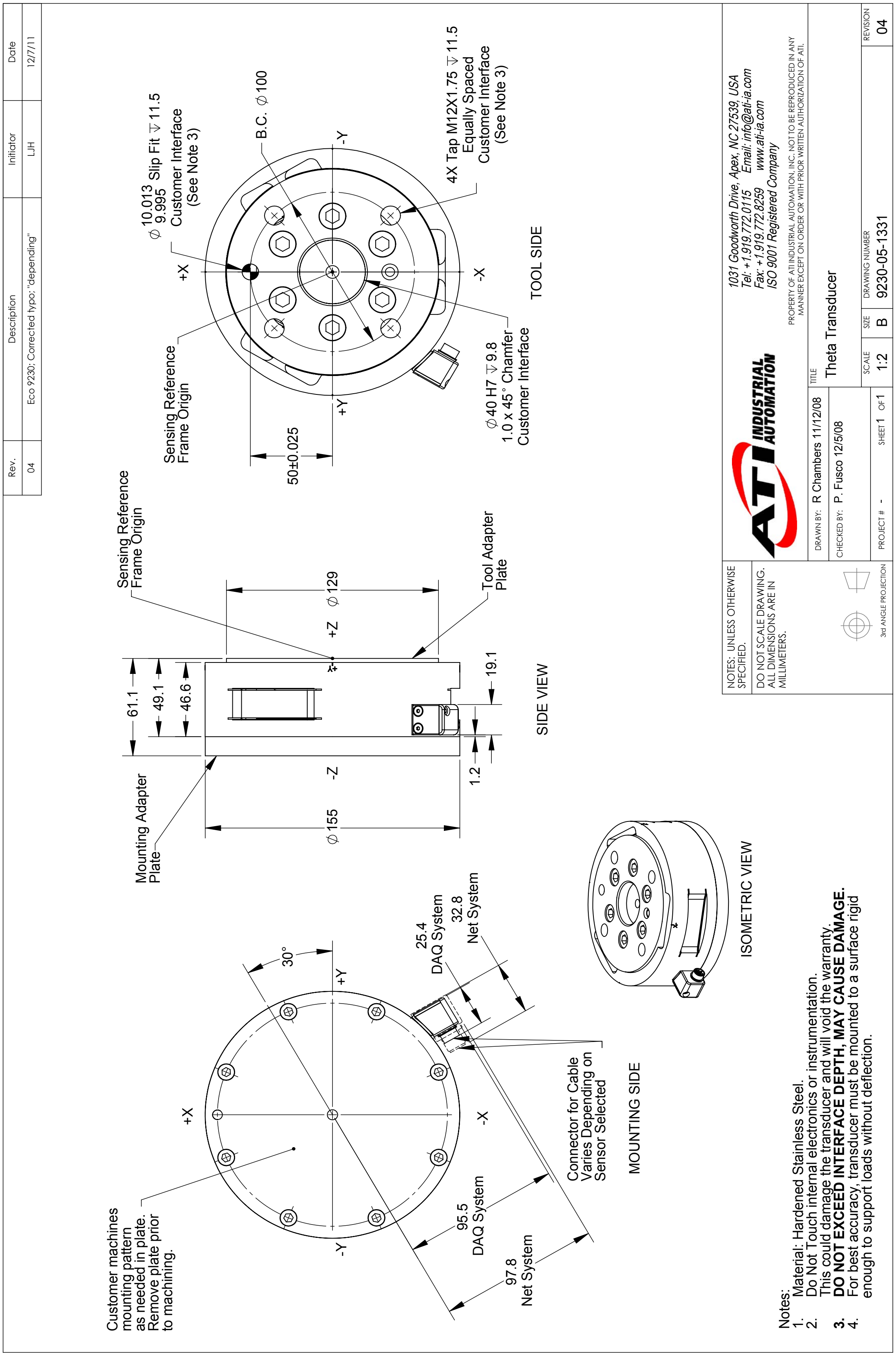
Note: 1. For IP68 version see caution on physical properties page.

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

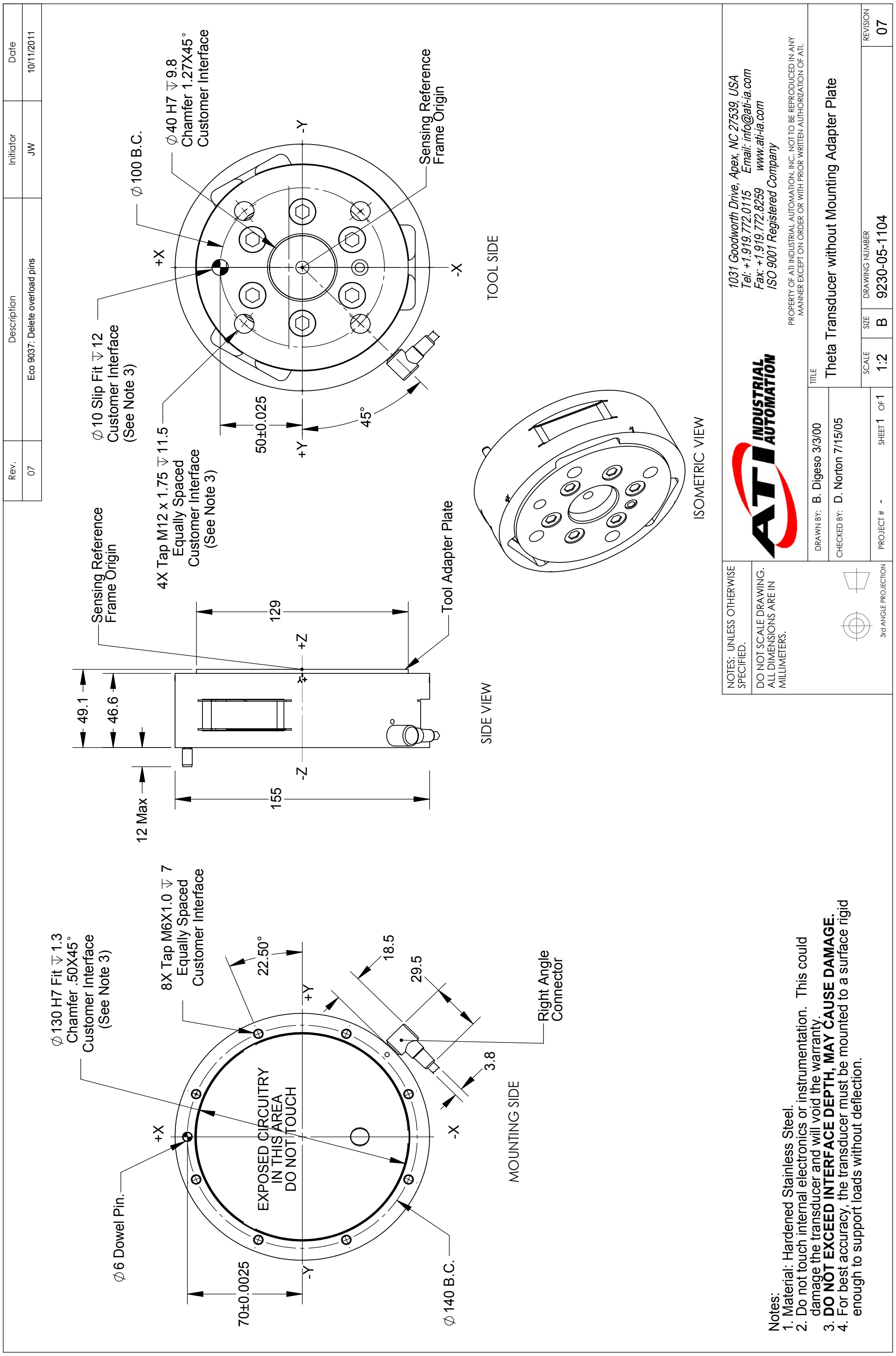


Note: 1. For IP68 version see caution on physical properties page.

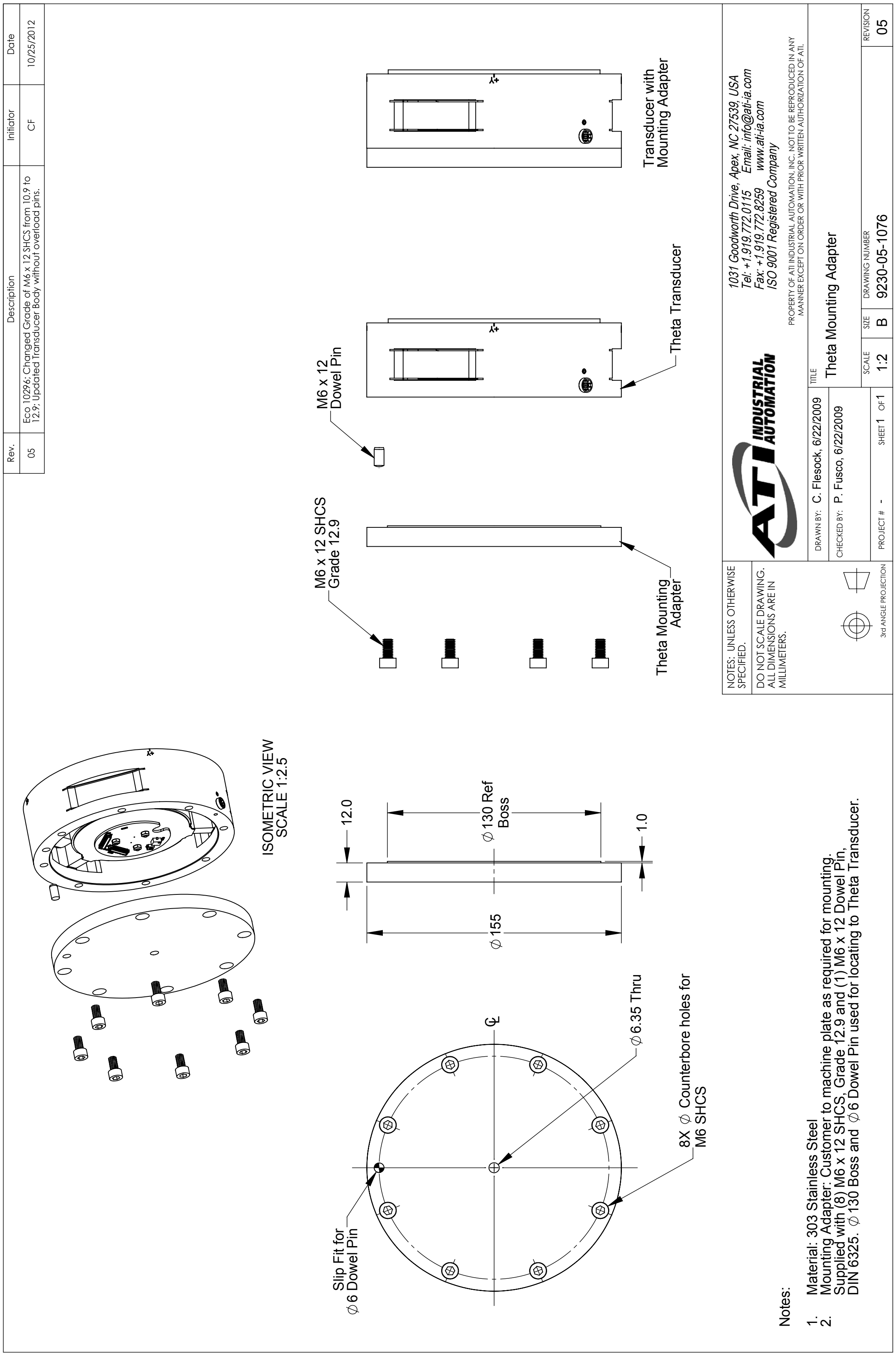
5.14.11 Theta DAQ/Net Transducer Drawing



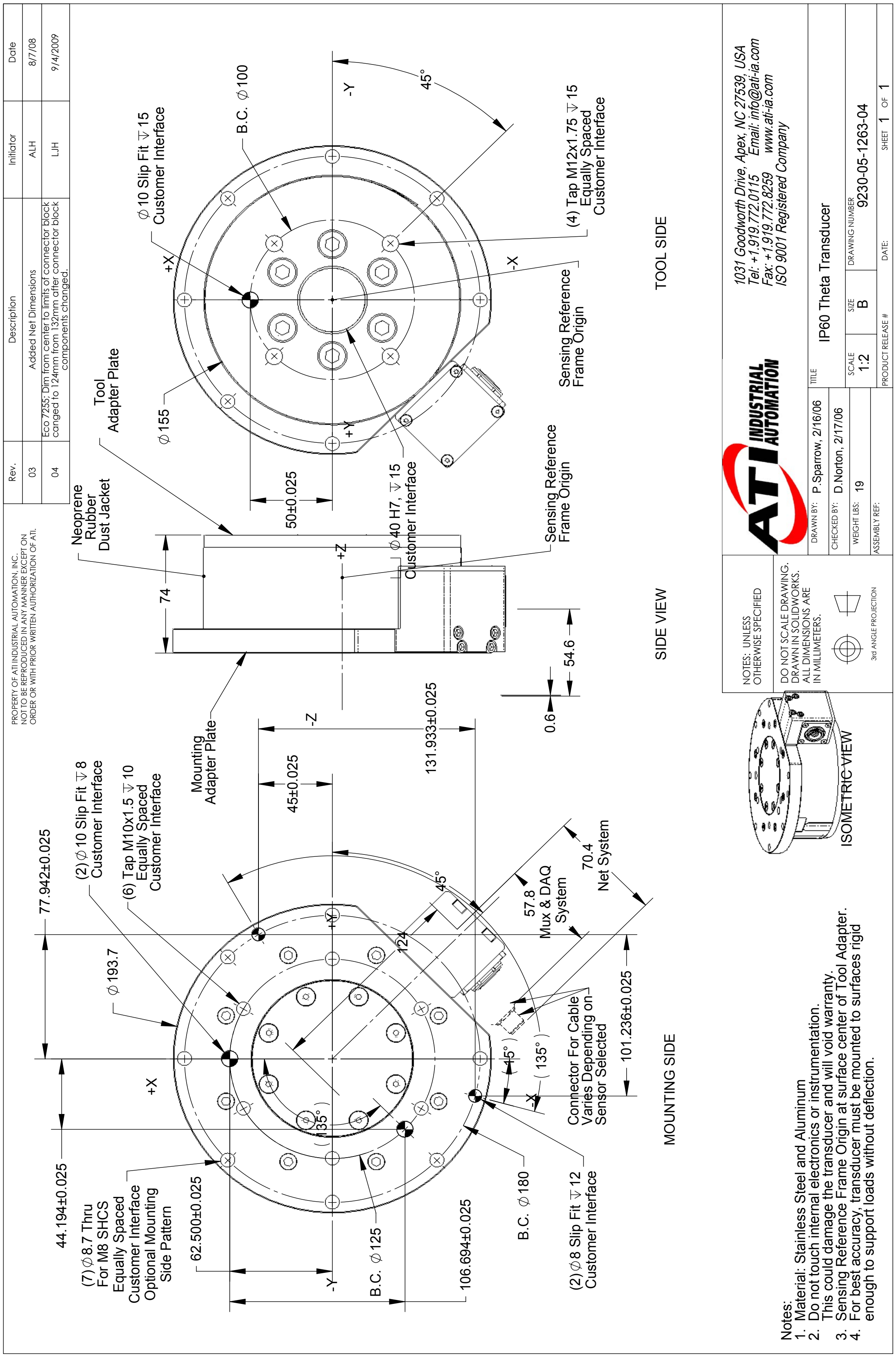
5.14.12 9105-T-Theta Transducer without Mounting Adapter Drawing



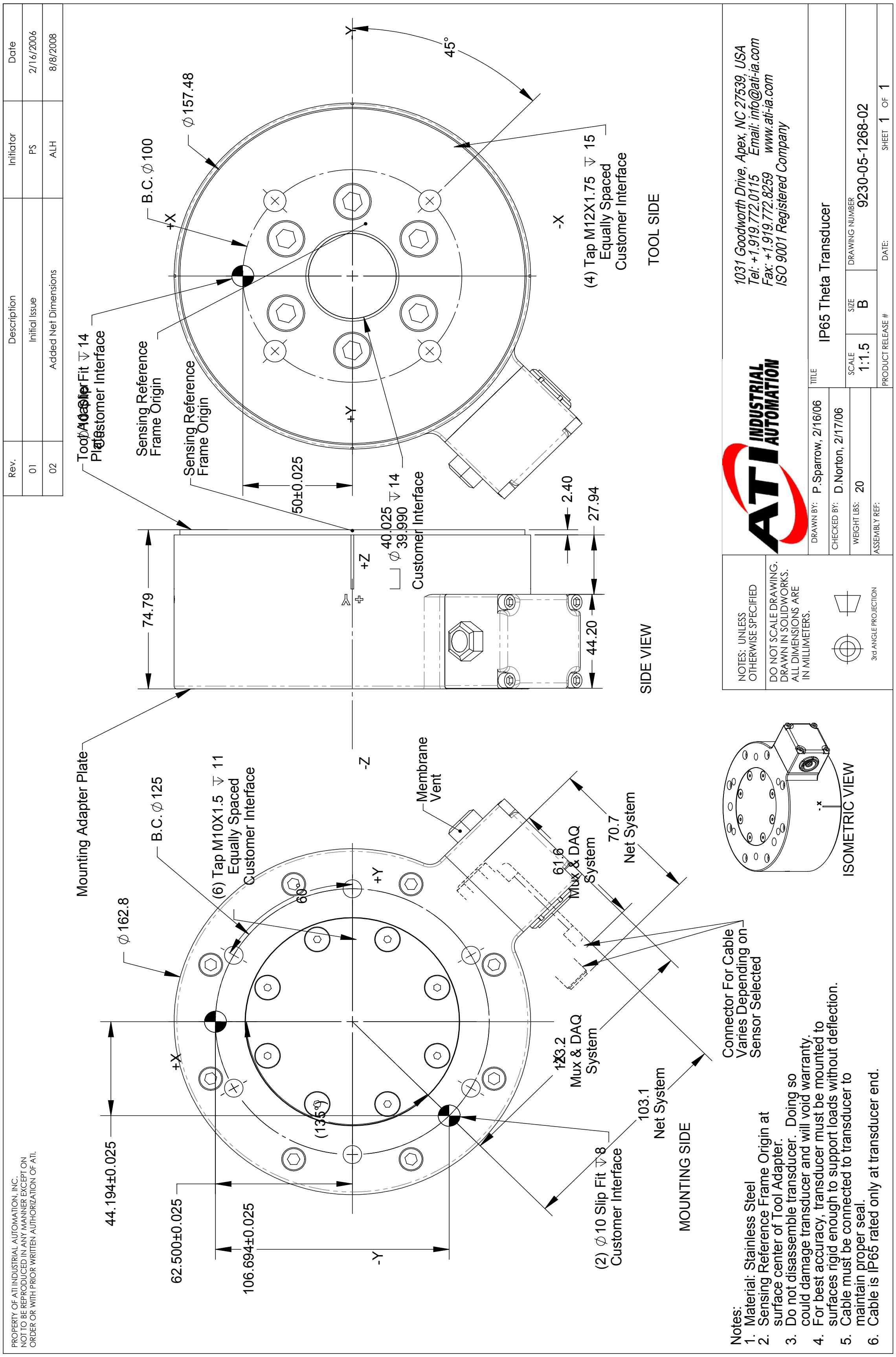
5.14.13 Theta Mounting Adapter Plate Drawing



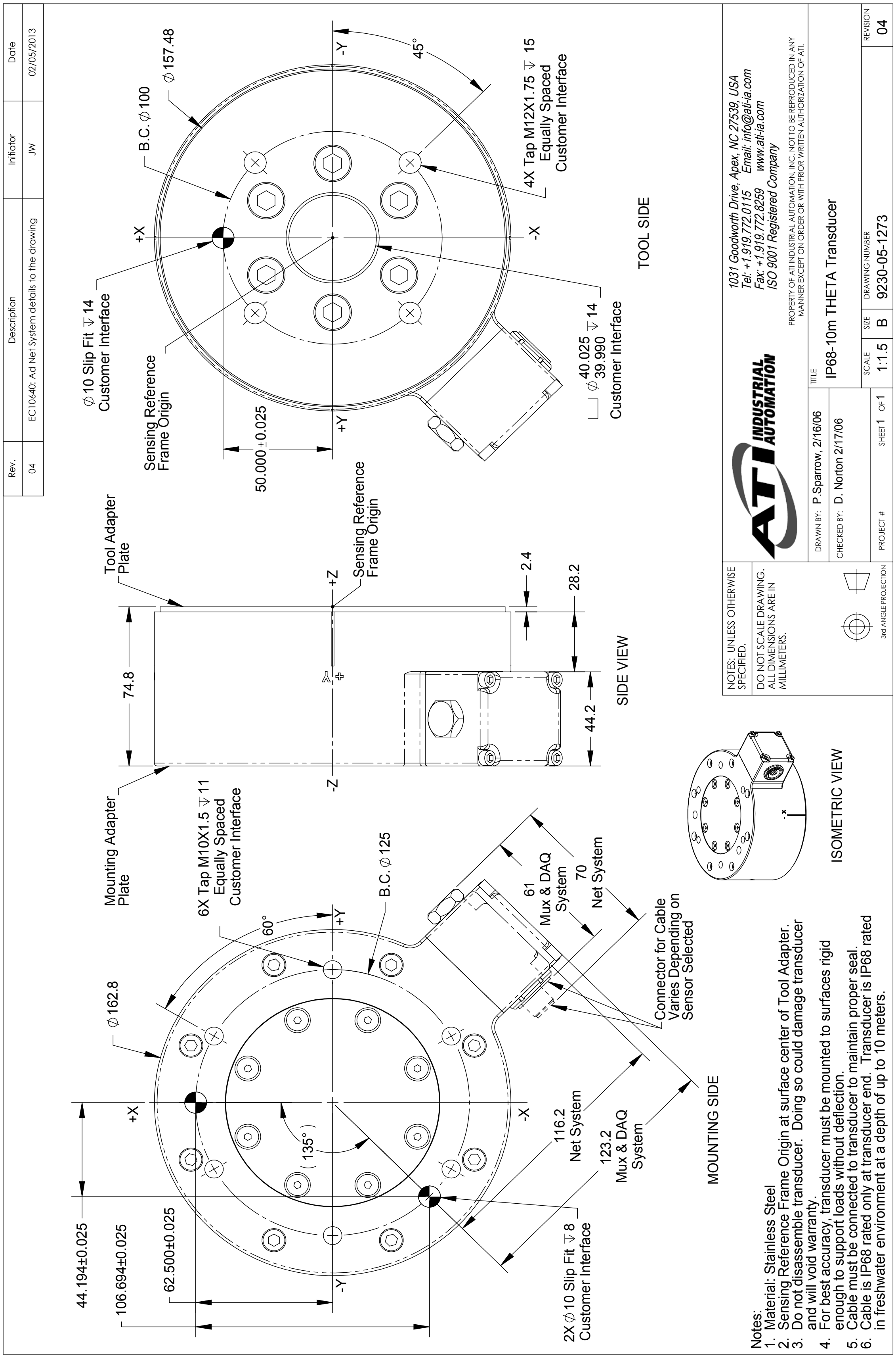
5.14.14 Theta IP60 Transducer Drawing



5.14.15 Theta IP65 Transducer Drawing



5.14.16 Theta IP68 Transducer Drawing



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

5.15.1 Omega85 Physical Properties

Table 5.84—Omega85 Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±2800 lbf	±13000 N
Fz	±6100 lbf	±27000 N
Txy	±4400 inf-lb	±500 Nm
Tz	±5400 inf-lb	±610 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	$4.4x10^5$ lb/in	$7.7x10^7$ N/m
Z-axis force (Kz)	$6.8x10^5$ lb/in	$1.2x10^8$ N/m
X-axis & Y-axis torque (Ktx, Kty)	$7.2x10^5$ lbf-in/rad	$8.1x10^4$ Nm/rad
Z-axis torque (Ktz)	$1.2x10^6$ lbf-in/rad	$1.3x10^5$ Nm/rad
Resonant Frequency		
Fx, Fy, Tz	2100 Hz	2100 Hz
Fz, Tx, Ty	3000 Hz	3000 Hz
Physical Specifications		
Weight[1]	1.45 lb	0.658 kg
Diameter[1]	3.35 in	85.1 mm
Height[1]	1.32 in	33.4 mm
Note: 1. Specifications include standard interface plates.		

5.15.2 Omega85 IP65/IP68 Physical Properties

Table 5.85—Omega85 IP65/IP68 Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±2800 lbf	±13000 N
Fz	±6100 lbf	±27000 N
Txy	±4400 inf-lb	±500 Nm
Tz	±5400 inf-lb	±610 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	$4.4x10^5$ lb/in	$7.7x10^7$ N/m
Z-axis force (Kz)	$6.8x10^5$ lb/in	$1.2x10^8$ N/m
X-axis & Y-axis torque (Ktx, Kty)	$7.2x10^5$ lbf-in/rad	$8.1x10^4$ Nm/rad
Z-axis torque (Ktz)	$1.2x10^6$ lbf-in/rad	$1.3x10^5$ Nm/rad
Resonant Frequency		
Fx, Fy, Tz	N/A	N/A
Fz, Tx, Ty	N/A	N/A
Physical Specifications		
Weight[1]	4.2 lb	1.91 kg
Diameter[1]	3.65 in	92.7 mm
Height[1]	1.52 in	38.7 mm
Note: 1. Specifications include standard interface plates.		

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

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

5.15.3 Calibration Specifications (excludes CTL calibrations)

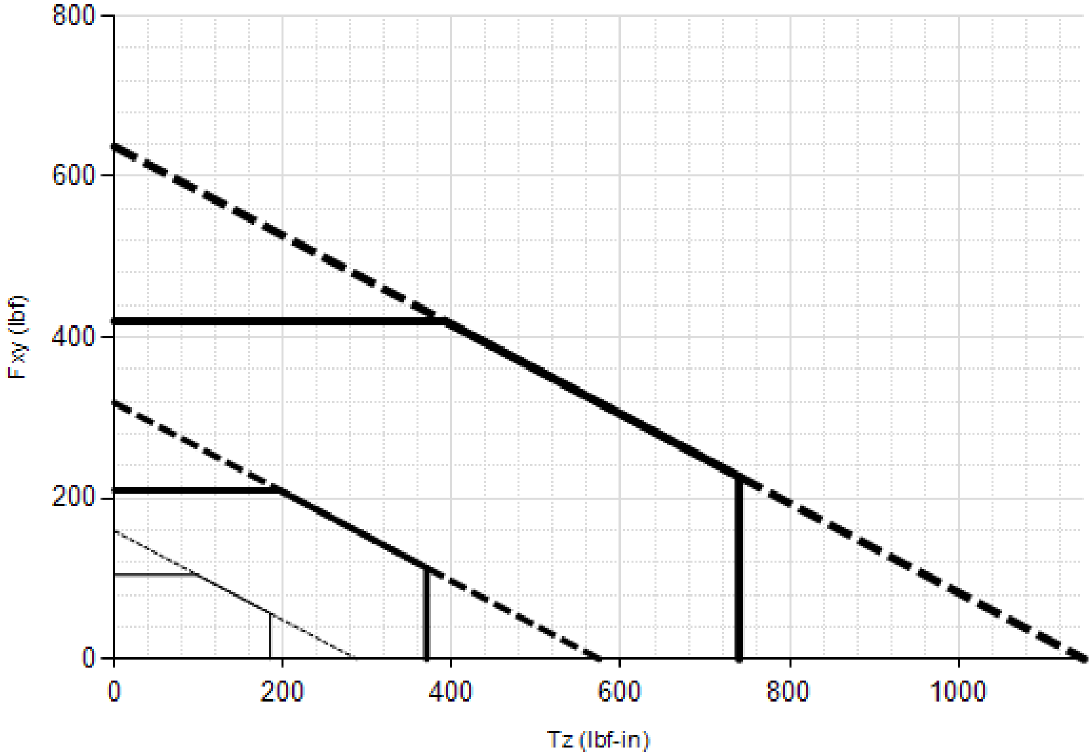
Table 5.86— Omega85 Calibrations (excludes CTL calibrations)[1, 2]

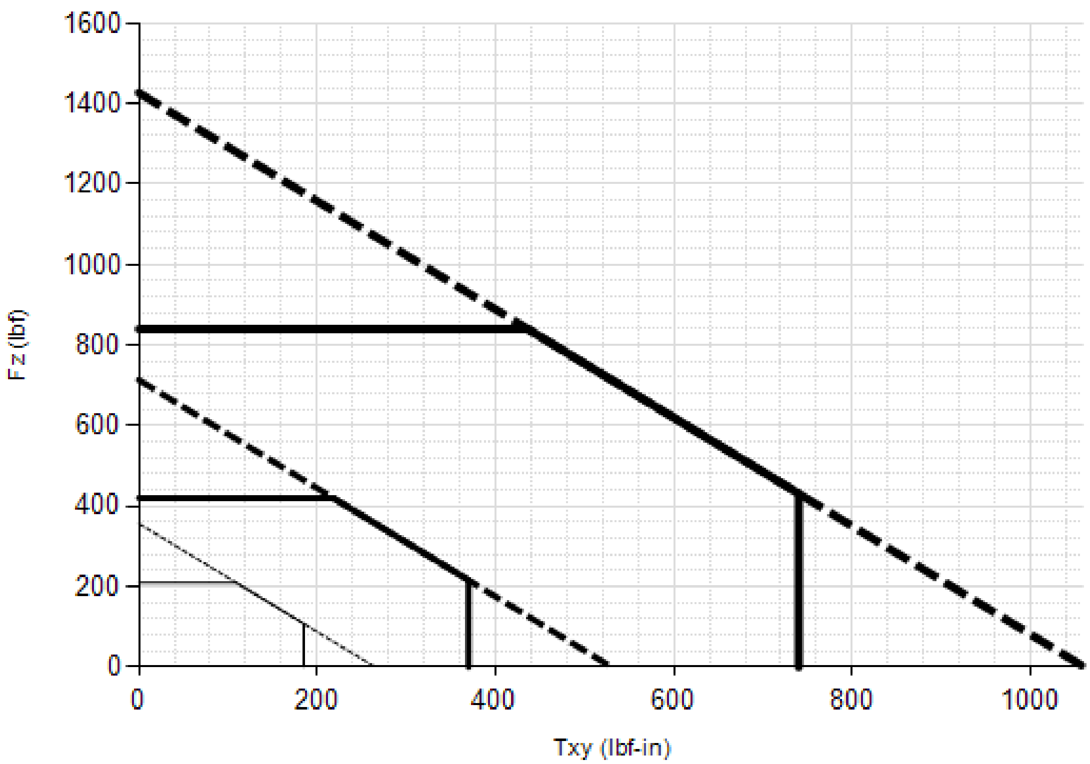
Sensor	(US) Standard Calibration	Fx,Fy (lbf)	Fz[3] (lbf)	Tx,Ty (lbf-in)	Tz (lbf-in)	Fx,Fy (lbf)	Fz[3] (lbf)	Tx,Ty (lbf-in)	Tz (lbf-in)
Omega85	US-105-185	105	210	185	185	1/52	3/130	3/112	1/48
Omega85	US-210-370	210	420	370	370	5/128	3/64	3/56	1/24
Omega85	US-420-740	420	840	740	740	5/64	3/32	3/28	1/12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

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

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

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

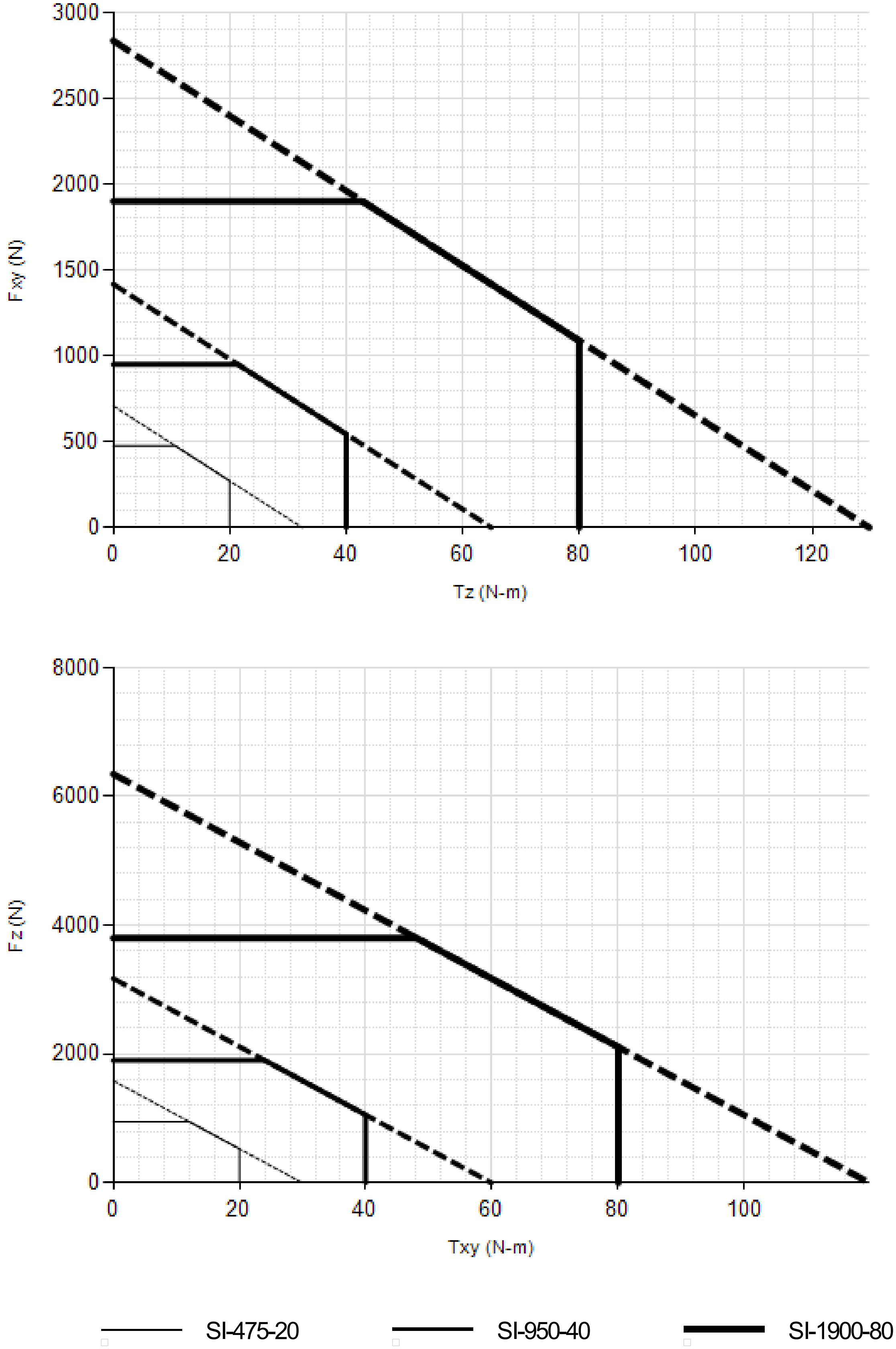




US-105-185 US-210-370 US-420-740

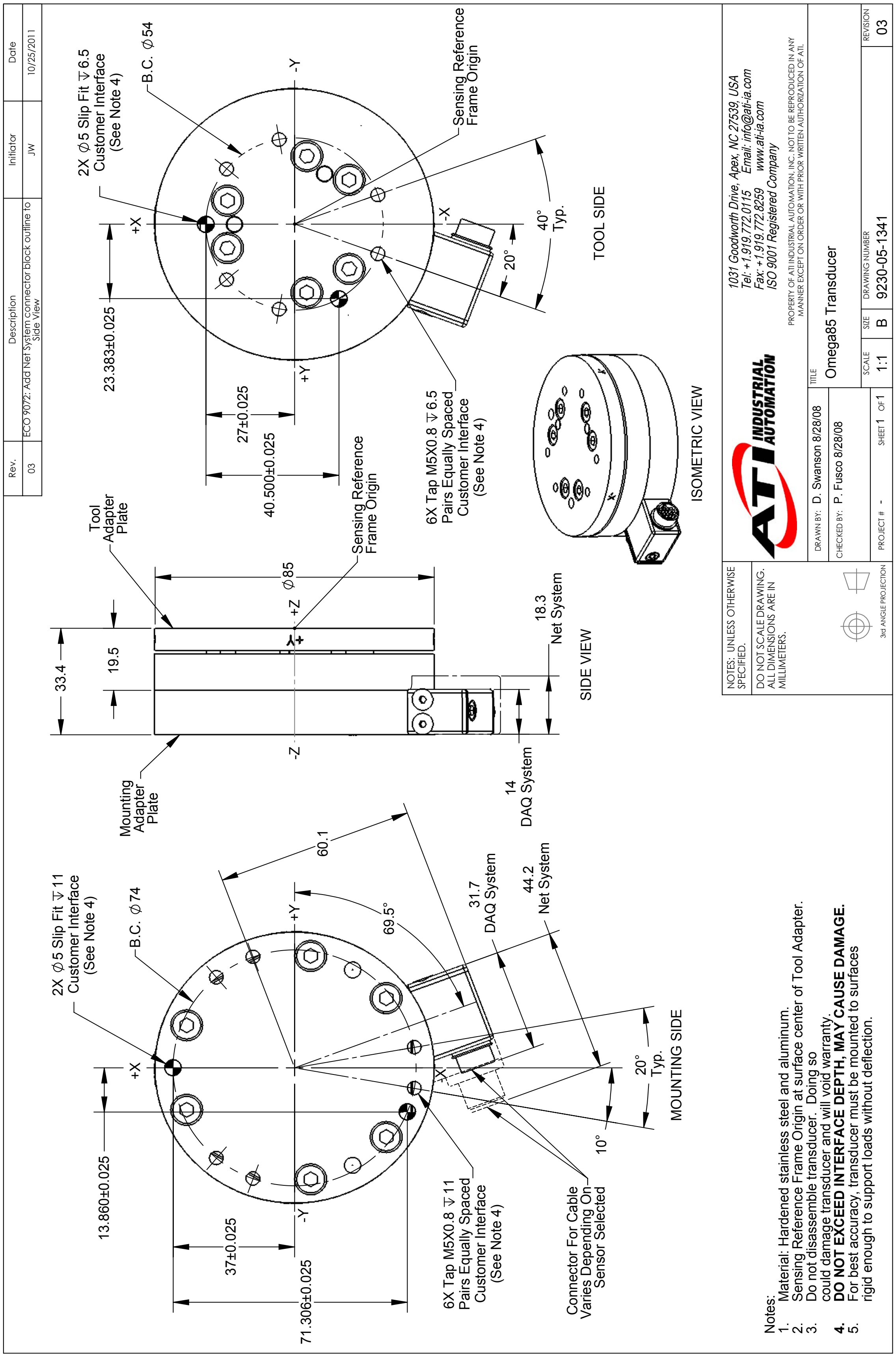
Note: 1. For IP68 version see caution on physical properties page.

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

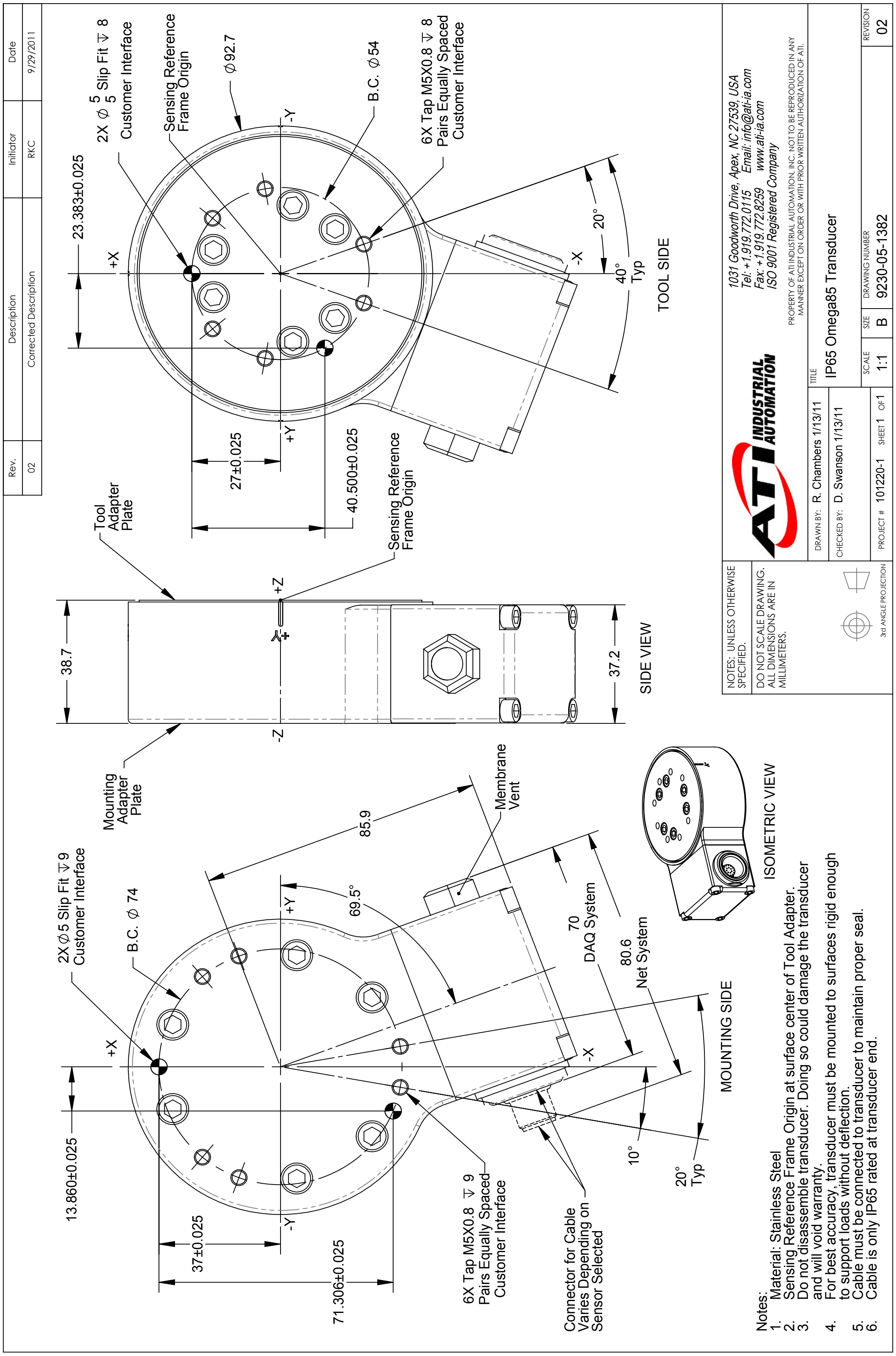


Note: 1. For IP68 version see caution on physical properties page.

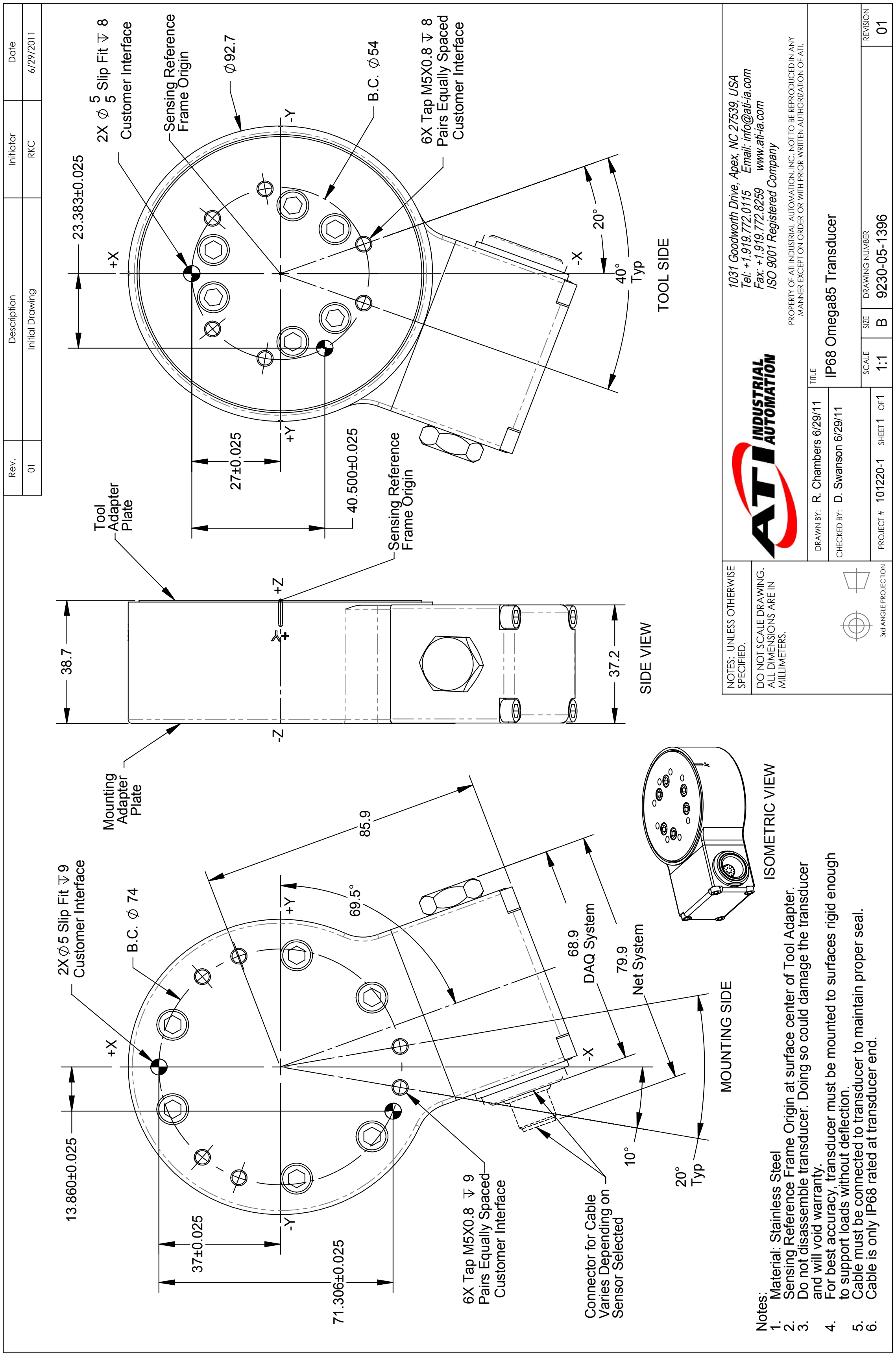
5.15.6 Omega85 Transducer Drawing



5.15.7 Omega85 IP65 Transducer Drawing



5.15.8 Omega85 IP68 Transducer Drawing



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

5.16.1 Omega160 Physical Properties

Table 5.87—Omega160 Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±3900 lbf	±18000 N
Fz	±11000 lbf	±48000 N
Txy	±15000 inf-lb	±1700 Nm
Tz	±17000 inf-lb	±1900 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	4.0×10^{5} lb/in	7.0×10^{7} N/m
Z-axis force (Kz)	6.8×10^{5} lb/in	1.2×10^{8} N/m
X-axis & Y-axis torque (Ktx, Kty)	2.9×10^{6} lbf-in/rad	3.3×10^{5} Nm/rad
Z-axis torque (Ktz)	4.6×10^{6} lbf-in/rad	5.2×10^{5} Nm/rad
Resonant Frequency		
Fx, Fy, Tz	1300 Hz	1300 Hz
Fz, Tx, Ty	1000 Hz	1000 Hz
Physical Specifications		
Weight[1]	6 lb	2.72 kg
Diameter[1]	6.16 in	157 mm
Height[1]	2.2 in	55.9 mm
Note: 1. Specifications include standard interface plates.		

5.16.2 Omega160 IP160 Physical Properties (Includes ECAT)

Table 5.88—Omega160 IP160 Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±3900 lbf	±18000 N
Fz	±11000 lbf	±48000 N
Txy	±15000 inf-lb	±1700 Nm
Tz	±17000 inf-lb	±1900 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	4.0×10^{5} lb/in	7.0×10^{7} N/m
Z-axis force (Kz)	6.8×10^{5} lb/in	1.2×10^{8} N/m
X-axis & Y-axis torque (Ktx, Kty)	2.9×10^{6} lbf-in/rad	3.3×10^{5} Nm/rad
Z-axis torque (Ktz)	4.6×10^{6} lbf-in/rad	5.2×10^{5} Nm/rad
Resonant Frequency		
Fx, Fy, Tz	1100 Hz	1100 Hz
Fz, Tx, Ty	1000 Hz	1000 Hz
Physical Specifications		
Weight[1]	16.9 lb	7.67 kg
Diameter[1]	7.63 in	194 mm
Height[1]	2.27 in	57.7 mm
Note: 1. Specifications include standard interface plates.		

5.16.3 Omega160 IP65/IP68 Physical Properties

Table 5.89—Omega160 IP65/IP68 Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±3900 lbf	±18000 N
Fz	±11000 lbf	±48000 N
Txy	±15000 inf-lb	±1700 Nm
Tz	±17000 inf-lb	±1900 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	4.0×10^{5} lb/in	7.0×10^{7} N/m
Z-axis force (Kz)	6.8×10^{5} lb/in	1.2×10^{8} N/m
X-axis & Y-axis torque (Ktx, Kty)	2.9×10^{6} lbf-in/rad	3.3×10^{5} Nm/rad
Z-axis torque (Ktz)	4.6×10^{6} lbf-in/rad	5.2×10^{5} Nm/rad
Resonant Frequency		
Fx, Fy, Tz	1200 Hz	1200 Hz
Fz, Tx, Ty	900 Hz	900 Hz
Physical Specifications		
Weight[1]	16 lb	7.26 kg
Diameter[1]	6.5 in	165 mm
Height[1]	2.59 in	65.9 mm
Note: 1. Specifications include standard interface plates.		

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

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

5.16.4 Calibration Specifications (excludes CTL calibrations)

Table 5.90— Omega160 Calibrations (excludes CTL calibrations)[1, 2]									
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz[3] (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**	**Fx,Fy (lbf)**	**Fz[3] (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**
Omega160	US-200-1000	200	500	1000	1000	1/32	1/16	1/8	1/8
Omega160	US-300-1800	300	875	1800	1800	5/68	5/34	5/16	5/16
Omega160	US-600-3600	600	1500	3600	3600	1/8	1/4	1/2	1/4
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**
Omega160	SI-1000-120	1000	2500	120	120	1/4	1/4	1/40	1/80
Omega160	SI-1500-240	1500	3750	240	240	1/4	1/2	1/20	1/40
Omega160	SI-2500-400	2500	6250	400	400	1/2	3/4	1/20	1/20
		Sensing Ranges				**Resolution (DAQ, Net F/T)[4]**			

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

5.16.5 CTL Calibration Specifications

Table 5.91— Omega160 CTL Calibrations[1, 2]									
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz[3] (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**	**Fx,Fy (lbf)**	**Fz[3] (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**
Omega160	US-200-1000	200	500	1000	1000	1/16	1/8	1/4	1/4
Omega160	US-300-1800	300	875	1800	1800	5/34	5/17	5/8	5/8
Omega160	US-600-3600	600	1500	3600	3600	1/4	1/2	1	1/2
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**
Omega160	SI-1000-120	1000	2500	120	120	1/2	1/2	1/20	1/40
Omega160	SI-1500-240	1500	3750	240	240	1/2	1	1/10	1/20
Omega160	SI-2500-400	2500	6250	400	400	1	1 1/2	1/10	1/10
		Sensing Ranges				**Resolution (Controller)**			

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

5.16.6 Analog Output

Table 5.92— Omega160 Analog Output							
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz[2] (lbf)**	**Tx,Ty,Tz (lbf-in)**	**Fx,Fy (lbf/V)**	**Fz[2] (lbf/V)**	**Tx,Ty,Tz (lbf-in/V)**
Omega160	US-200-1000	±200	±500	±1000	20	50	100
Omega160	US-300-1800	±300	±875	±1800	30	87.5	180
Omega160	US-600-3600	±600	±1500	±3600	60	150	360
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz (N)**	**Tx,Ty,Tz (Nmm)**	**Fx,Fy (N/V)**	**Fz[2] (N/V)**	**Tx,Ty,Tz (Nm/V)**
Omega160	SI-1000-120	±1000	±2500	±120	100	250	12
Omega160	SI-1500-240	±1500	±3750	±240	150	375	24
Omega160	SI-2500-400	±2500	±6250	±400	250	625	40
		Analog Output Range			**Analog ±10V Sensitivity[1]**		

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

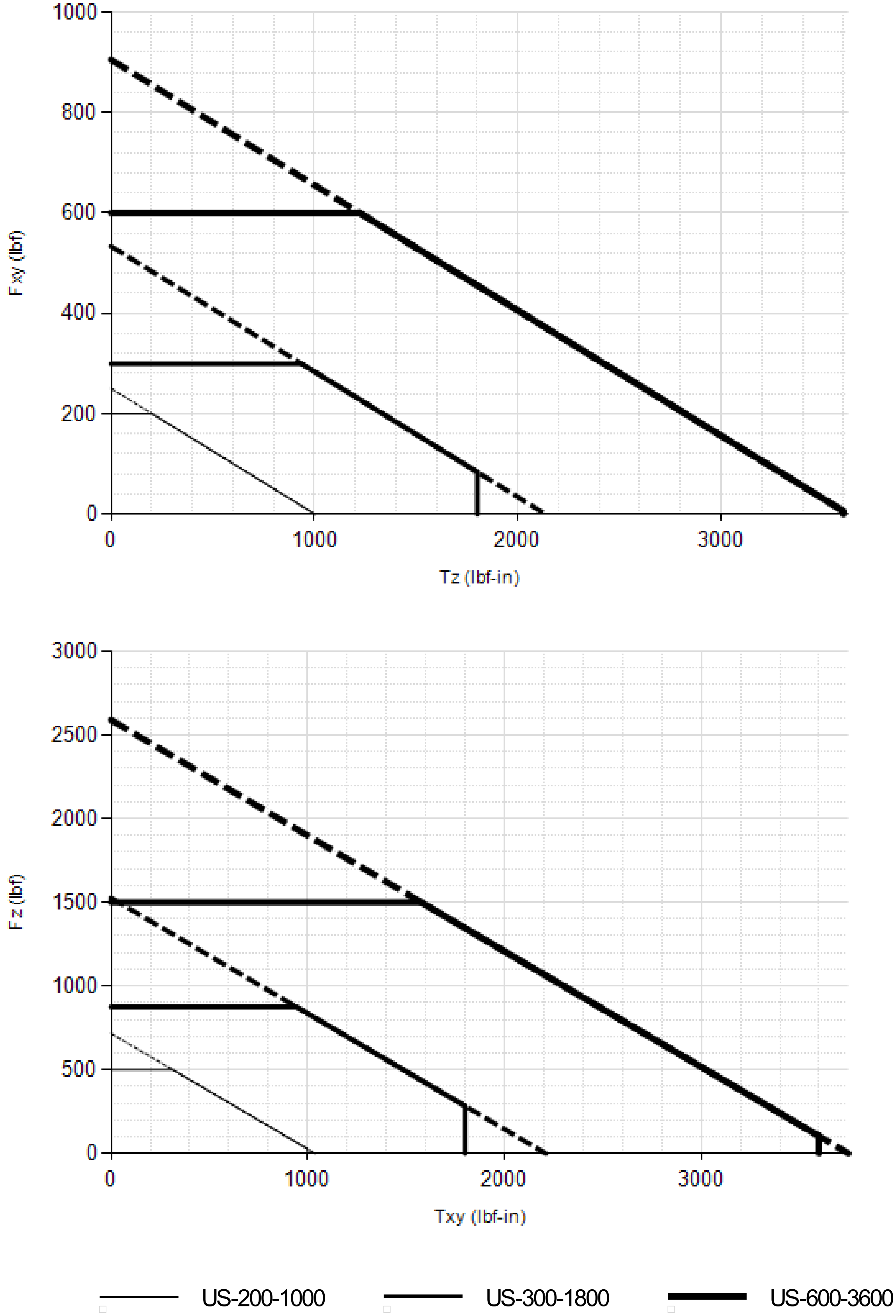
5.16.7 Counts Value

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

5.16.8 Tool Transform Factor

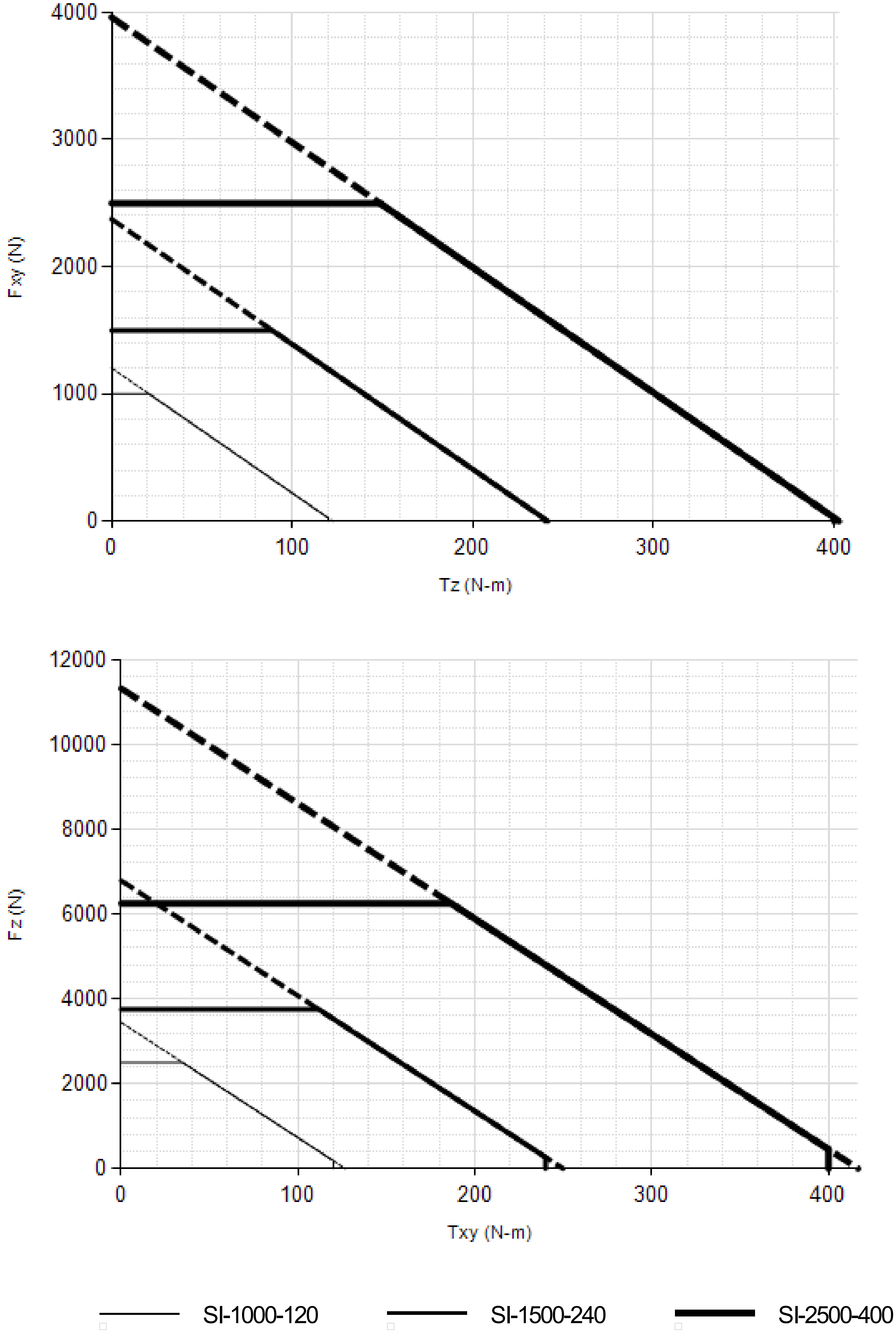
Table 5.94—Tool Transform Factor			
Sensor	**Calibration**	**US (English)**	SI (Metric)
Omega160	US-200–1000 / SI-1000–120	0.02 in/lbf	1 mm/N
Omega160	US-300–1800 / SI-1500–240	0.0425 in/lbf	1 mm/N
Omega160	US-600–3600 / SI-2500–400	0.02 in/lbf	2 mm/N

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



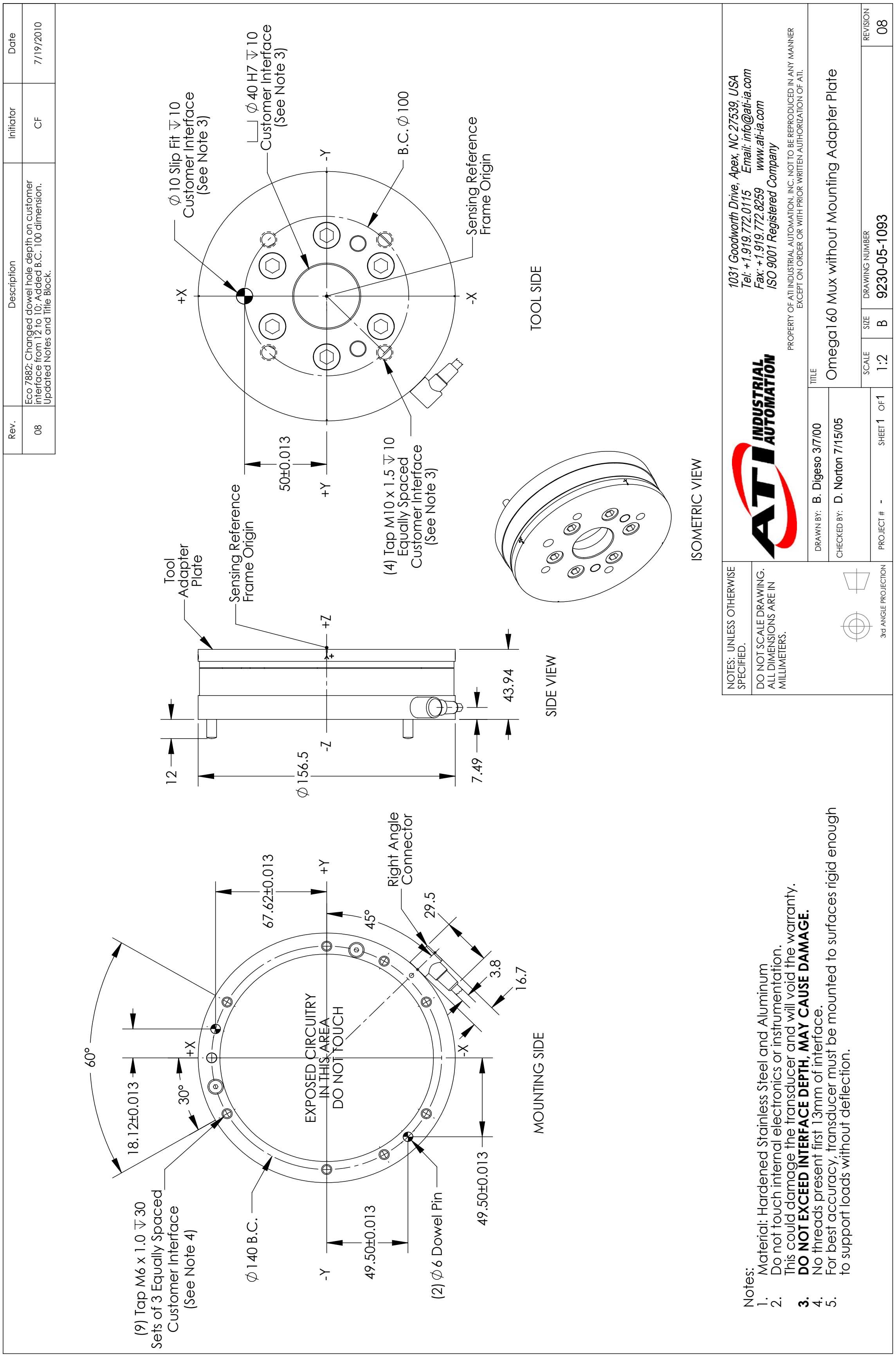
Note: 1. For IP68 version see caution on physical properties page.

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

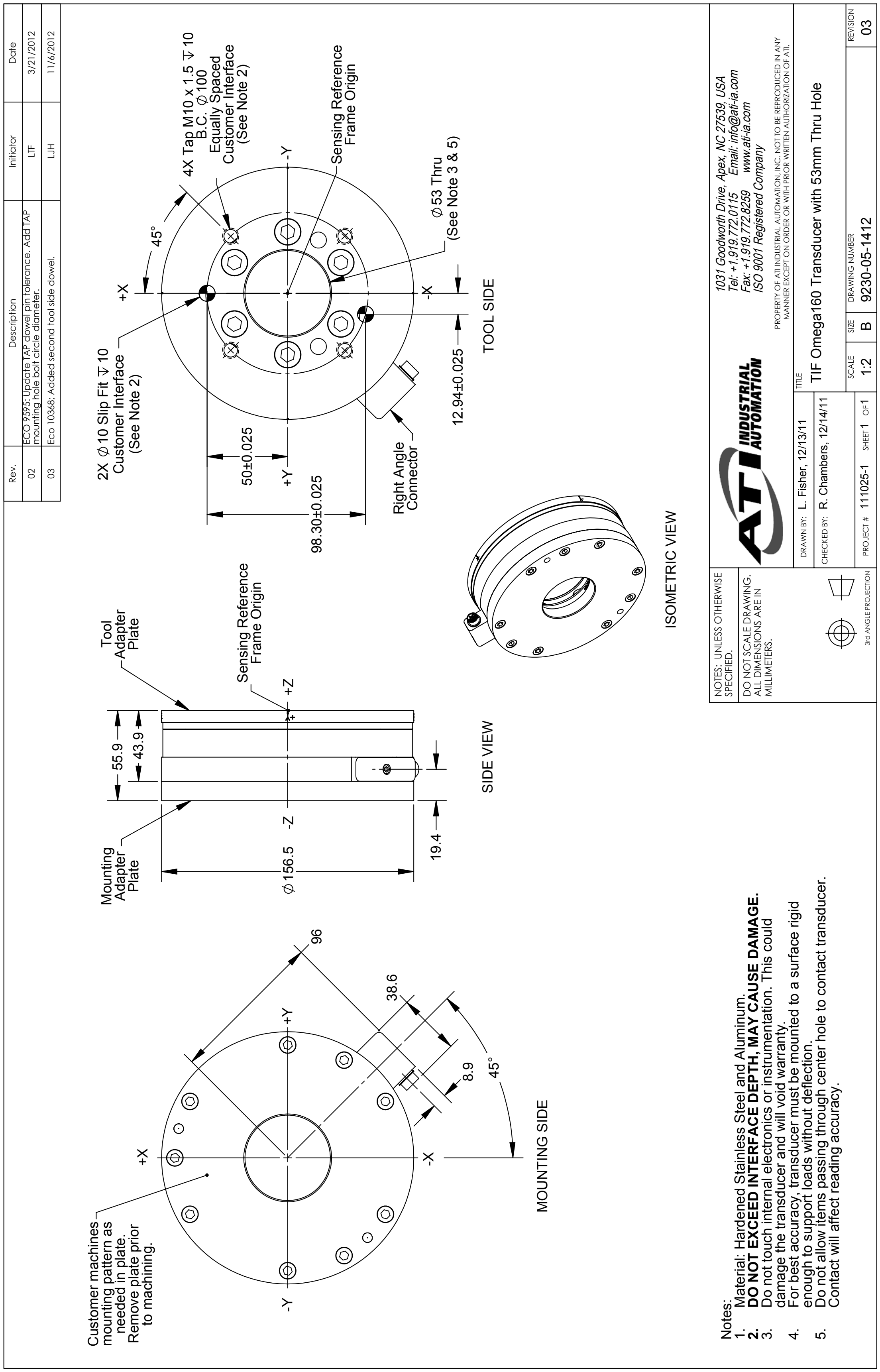


Note: 1. For IP68 version see caution on physical properties page.

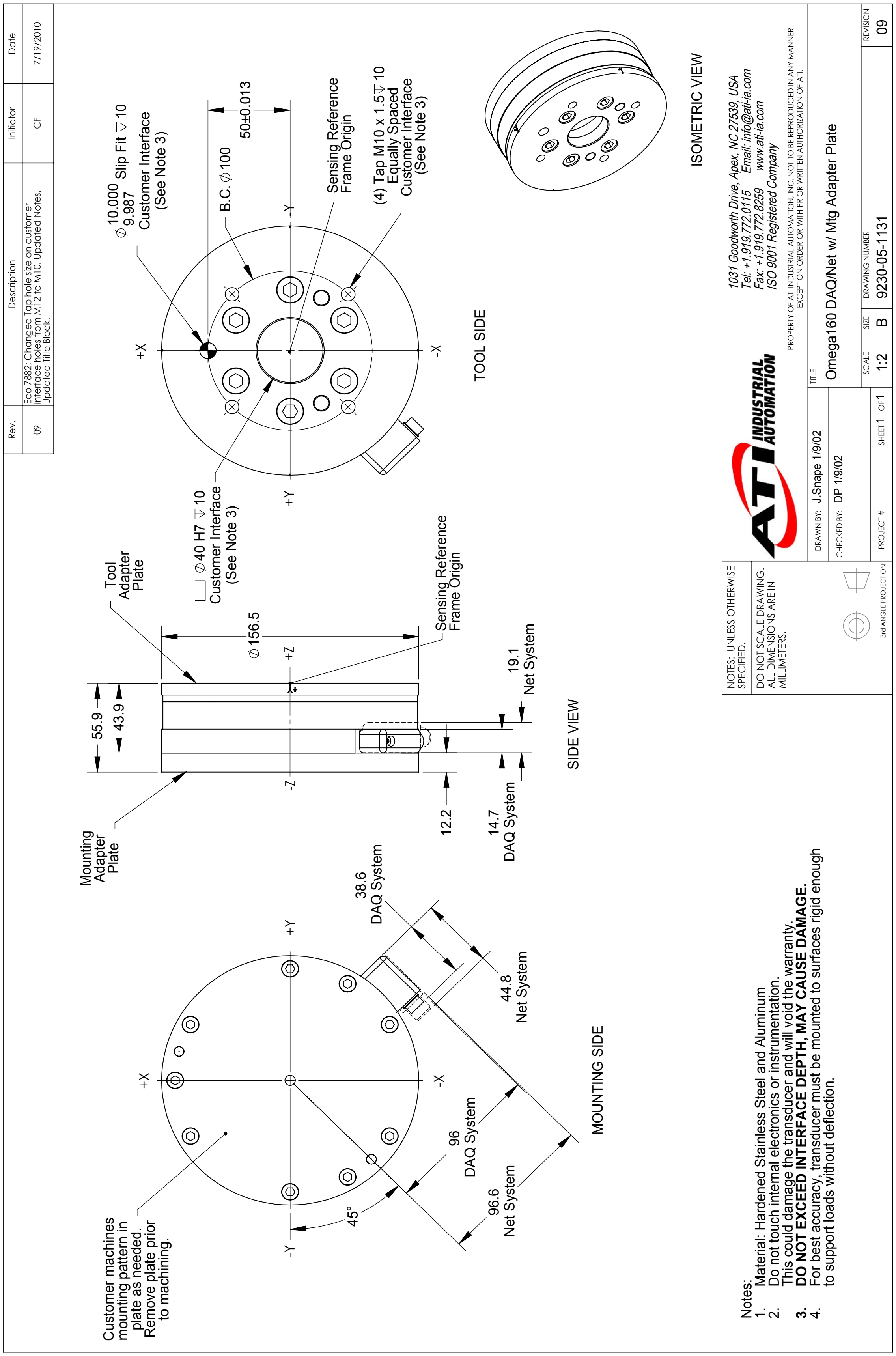
5.16.11 Omega160 Transducer without Mounting Adapter Drawing



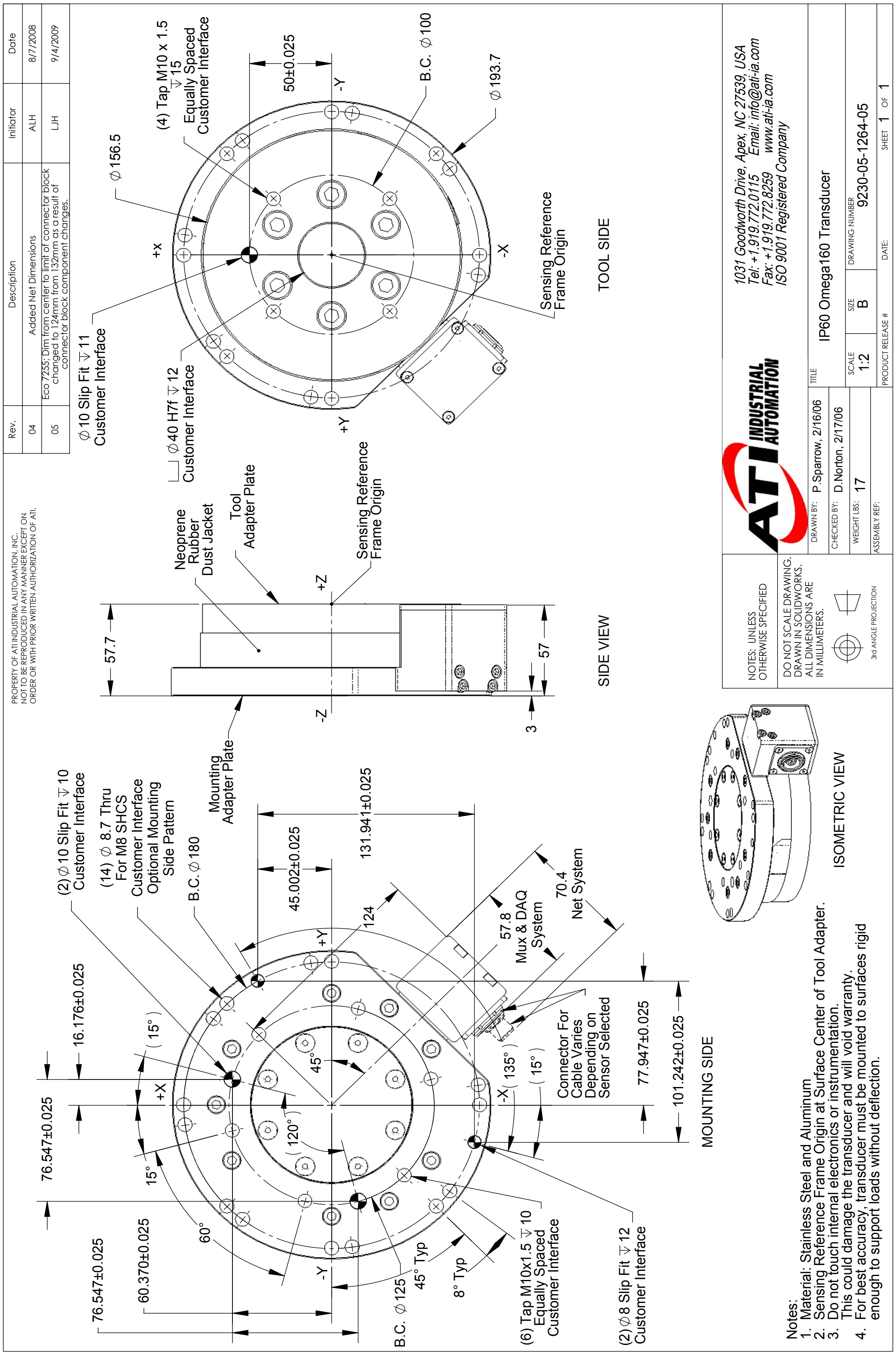
5.16.12 Omega160 Transducer with 53mm Through Hole



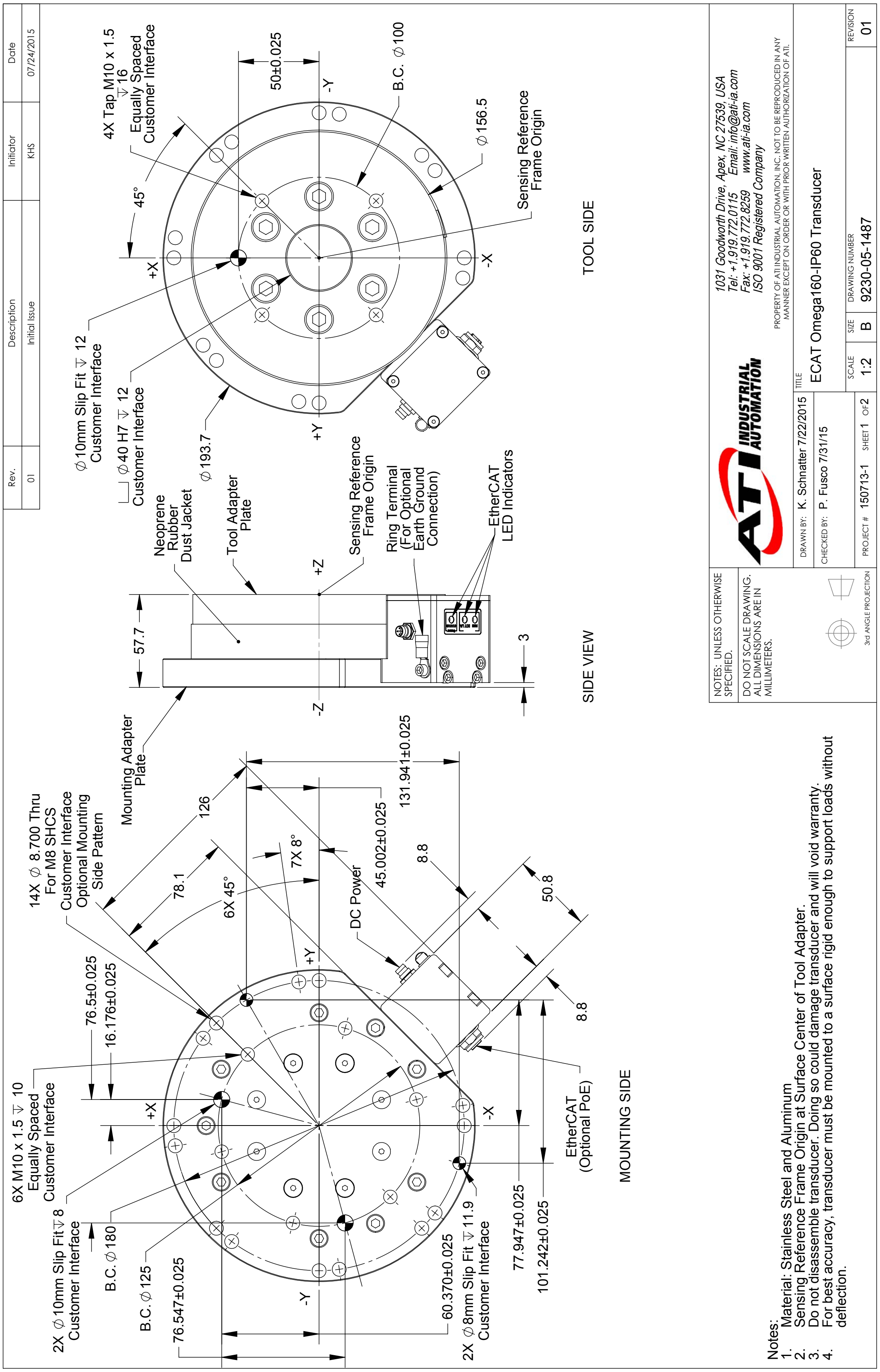
5.16.13 Omega160 Transducer with Mounting Adapter Drawing

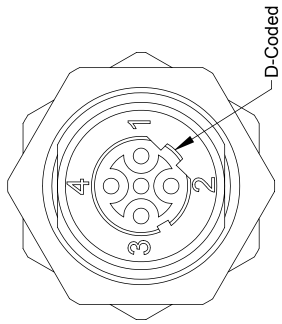


5.16.14 Omega160 IP60 Transducer Drawing



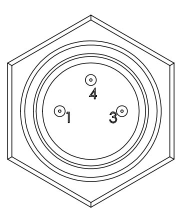
5.16.15 ECAT Omega160 IP60 Transducer Drawing





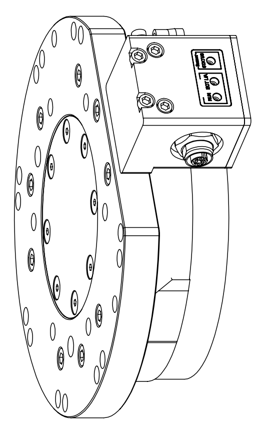
Pin No.	Signal
1	TX+
2	RX+
3	TX-
4	RX-
Shell	Connector Block Housing

EtherCAT Connector
4 pin Female M12 D-Coded



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

DC Power Connector
3 pin Male M8



ISOMETRIC VIEW

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

3rd ANGLE PROJECTION

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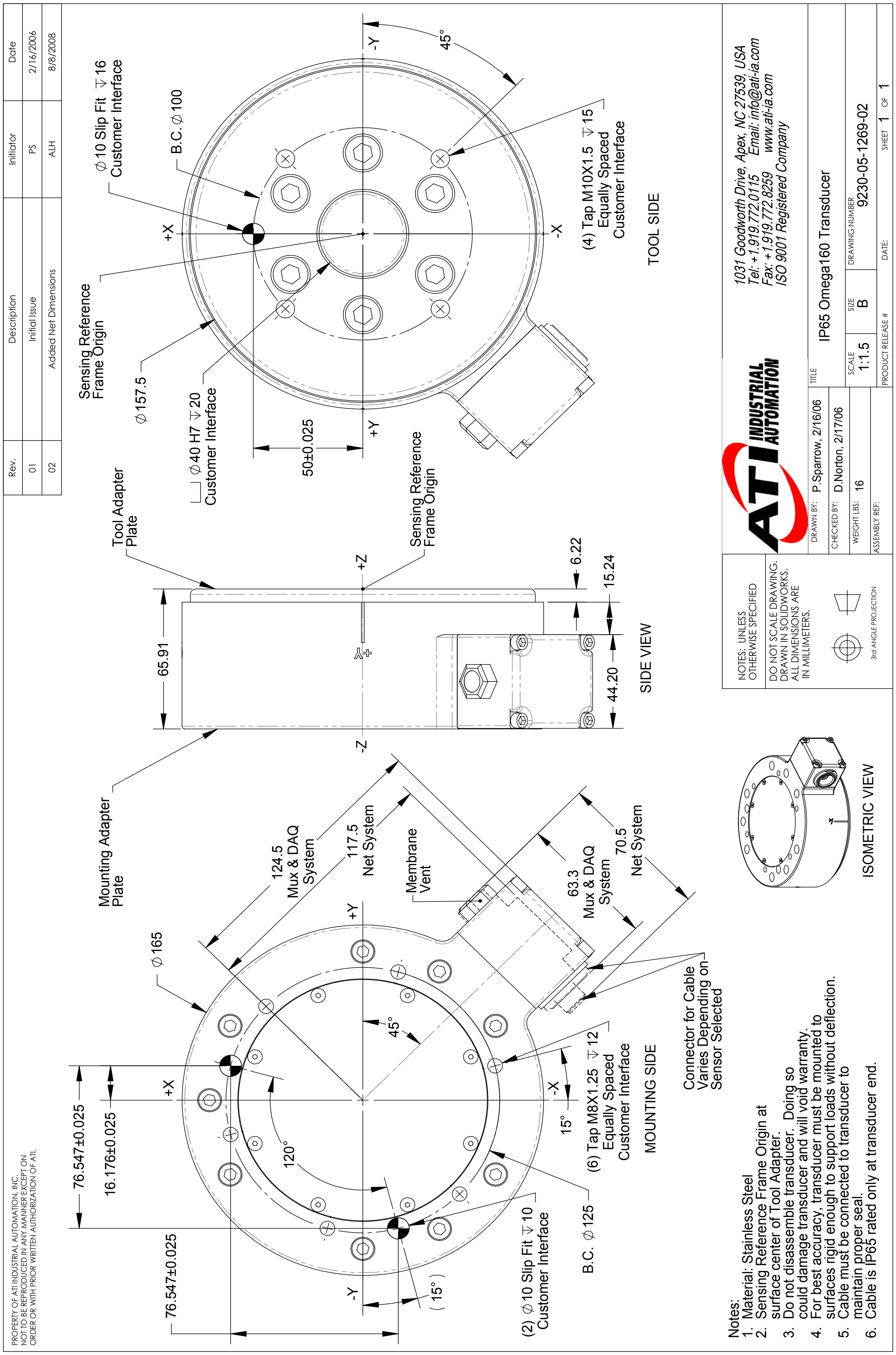
DRAWN BY: K. Schnatter 7/22/2015
CHECKED BY: P. Fusco 7/31/15
PROJECT # 150713-1 SHEET 2 OF 2

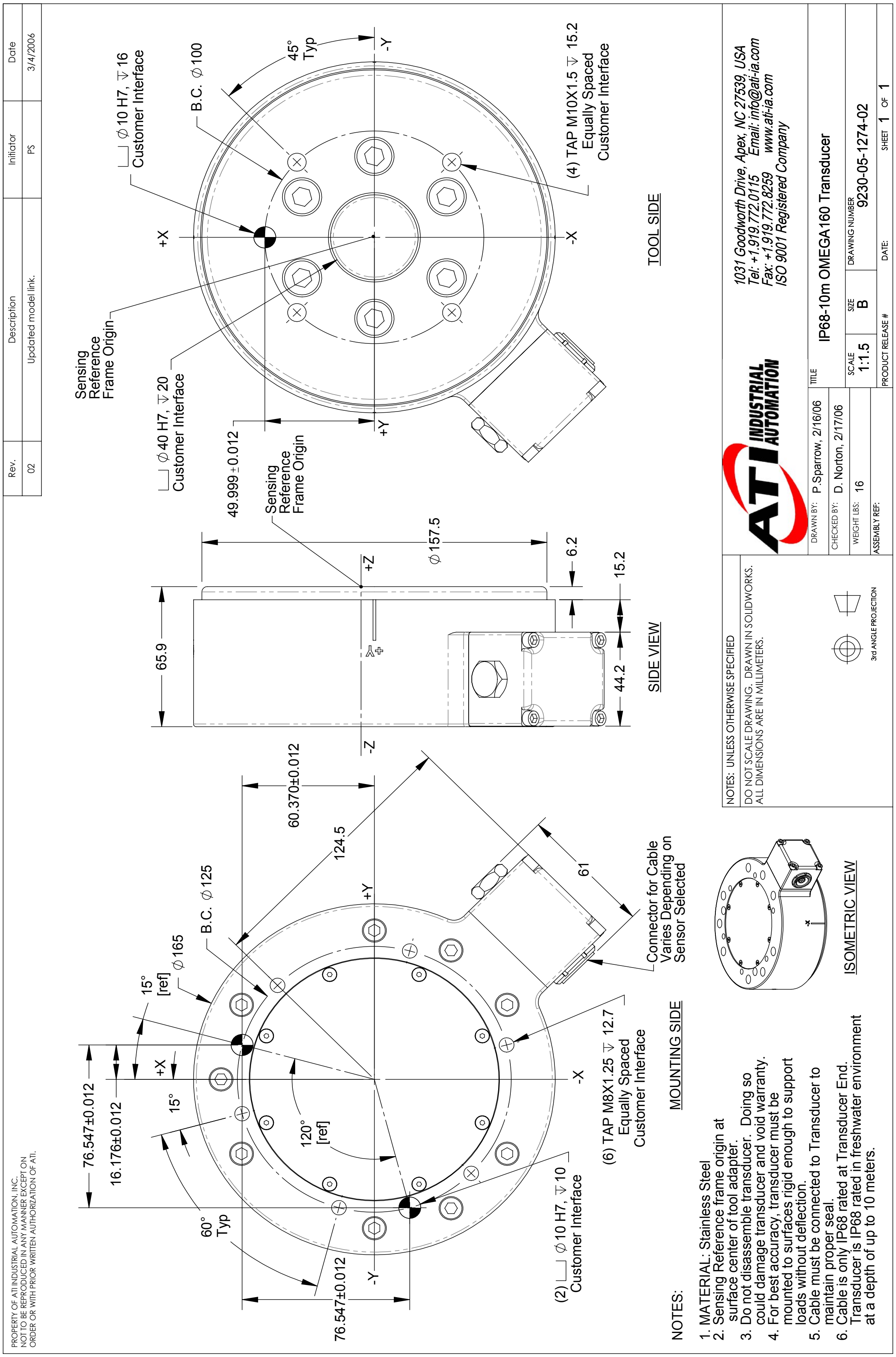
TITLE: ECAT Omega160-IP60 Transducer

SCALE 5:1 | SIZE B | DRAWING NUMBER 9230-05-1487 | REVISION 01

5.16.16 Omega160 IP65 Transducer Drawing



5.16.17 Omega160 IP68 Transducer Drawing



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

5.17.1 Omega190 Physical Properties

Table 5.95—Omega190 Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±8000 lbf	±36000 N
Fz	±25000 lbf	±110000 N
Txy	±60000 lbf-in	±6800 Nm
Tz	±60000 lbf-in	±6800 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	$1.4\text{x}10^6$ lb/in	$2.4\text{x}10^8$ N/m
Z-axis force (Kz)	$2.1\text{x}10^6$ lb/in	$3.6\text{x}10^8$ N/m
X-axis & Y-axis torque (Ktx, Kty)	$1.4\text{x}10^7$ lbf-in/rad	$1.5\text{x}10^6$ Nm/rad
Z-axis torque (Ktz)	$2.8\text{x}10^7$ lbf-in/rad	$3.2\text{x}10^6$ Nm/rad
Resonant Frequency		
Fx, Fy, Tz	N/A	N/A
Fz, Tx, Ty	N/A	N/A
Physical Specifications		
Weight[1]	14 lb	6.35 kg
Diameter[1]	7.48 in	190 mm
Height[1]	2.2 in	55.9 mm
Note: *1. Specifications include standard interface plates.*		

5.17.2 Omega190 IP60 Physical Properties

Table 5.96—Omega190 IP60 Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±8000 lbf	±36000 N
Fz	±25000 lbf	±110000 N
Txy	±60000 lbf-in	±6800 Nm
Tz	±60000 lbf-in	±6800 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	$1.4\text{x}10^6$ lb/in	$2.4\text{x}10^8$ N/m
Z-axis force (Kz)	$2.1\text{x}10^6$ lb/in	$3.6\text{x}10^8$ N/m
X-axis & Y-axis torque (Ktx, Kty)	$1.4\text{x}10^7$ lbf-in/rad	$1.5\text{x}10^6$ Nm/rad
Z-axis torque (Ktz)	$2.8\text{x}10^7$ lbf-in/rad	$3.2\text{x}10^6$ Nm/rad
Resonant Frequency		
Fx, Fy, Tz	1200 Hz	1200 Hz
Fz, Tx, Ty	1200 Hz	1200 Hz
Physical Specifications		
Weight[1]	31 lb	14.1 kg
Diameter[1]	9.37 in	238 mm
Height[1]	2.9 in	73.7 mm
Note: *1. Specifications include standard interface plates.*		

5.17.3 Omega190 IP65/IP68 Physical Properties

Table 5.97—Omega190 IP65/IP68 Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±8000 lbf	±36000 N
Fz	±25000 lbf	±110000 N
Txy	±60000 lbf-in	±6800 Nm
Tz	±60000 lbf-in	±6800 Nm)
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	1.4×10^{6} lb/in	2.4×10^{8} N/m)
Z-axis force (Kz)	2.1×10^{6} lb/in	3.6×10^{8} N/m
X-axis & Y-axis torque (Ktx, Kty)	1.4×10^{7} lbf-in/rad	1.5×10^{6} Nm/rad
Z-axis torque (Ktz)	2.8×10^{7} lbf-in/rad	3.2×10^{6} Nm/rad
Resonant Frequency		
Fx, Fy, Tz	1400 Hz	1400 Hz
Fz, Tx, Ty	980 Hz	980 Hz
Physical Specifications		
Weight[1]	29 lb	13.2 kg
Diameter[1]	8.03 in	204 mm
Height[1]	2.94 in	74.8 mm
Note: *1. Specifications include standard interface plates.*		

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

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

5.17.4 Calibration Specifications (excludes CTL calibrations)

Table 5.98— Omega190 Calibrations (excludes CTL calibrations)[1, 2]									
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz[3] (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**	**Fx,Fy (lbf)**	**Fz[3] (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**
Omega190	US-400-3000	400	1000	3000	3000	5/64	5/32	15/32	5/16
Omega190	US-800-6000	800	2000	6000	6000	5/32	5/16	15/16	5/8
Omega190	US-1600-12000	1600	4000	12000	12000	5/16	5/8	1 7/8	1 1/4
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**
Omega190	SI-1800-350	1800	4500	350	350	3/8	3/4	5/96	5/144
Omega190	SI-3600-700	3600	9000	700	700	3/4	1 1/2	5/48	5/72
Omega190	SI-7200-1400	7200	18000	1400	1400	1 1/2	3	5/24	5/36
		Sensing Ranges				**Resolution (DAQ, Net F/T)[4]**			

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

5.17.5 CTL Calibration Specifications

Table 5.99— Omega190 CTL Calibrations[1, 2]									
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz[3] (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**	**Fx,Fy (lbf)**	**Fz[3] (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**
Omega190	US-400-3000	400	1000	3000	3000	5/32	5/16	15/16	5/8
Omega190	US-800-6000	800	2000	6000	6000	5/16	5/8	1 7/8	1 1/4
Omega190	US-1600-12000	1600	4000	12000	12000	5/8	1 1/4	3 3/4	2 1/2
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**
Omega190	SI-1800-350	1800	4500	350	350	3/4	1 1/2	5/48	5/72
Omega190	SI-3600-700	3600	9000	700	700	1 1/2	3	5/24	5/36
Omega190	SI-7200-1400	7200	18000	1400	1400	3	6	5/12	5/18
		Sensing Ranges				**Resolution (Controller)**			

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

5.17.6 Analog Output

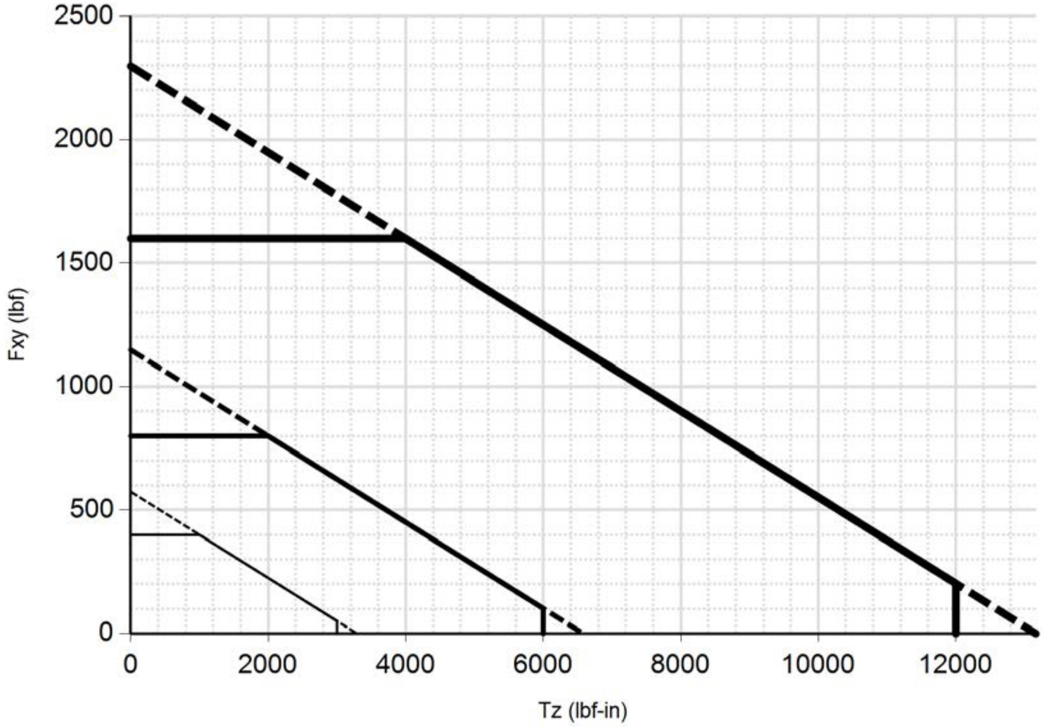
Table 5.100— Omega190 Analog Output							
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz[2] (lbf)**	**Tx,Ty,Tz (lbf-in)**	**Fx,Fy (lbf/V)**	**Fz[2] (lbf/V)**	**Tx,Ty,Tz (lbf-in/V)**
Omega190	US-400-3000	±400	±1000	±3000	40	100	300
Omega190	US-800-6000	±800	±2000	±6000	80	200	600
Omega190	US-1600-12000	±1600	±4000	±12000	160	400	1200
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz[2] (N)**	**Tx,Ty,Tz (Nmm)**	**Fx,Fy (N/V)**	**Fz[2] (N/V)**	**Tx,Ty,Tz (Nm/V)**
Omega190	SI-1800-350	±1800	±4500	±350	180	450	35
Omega190	SI-3600-700	±3600	±9000	±700	360	900	70
Omega190	SI-7200-1400	±7200	±18000	±1400	720	1800	140
		Analog Output Range			**Analog ±10V Sensitivity[1]**		

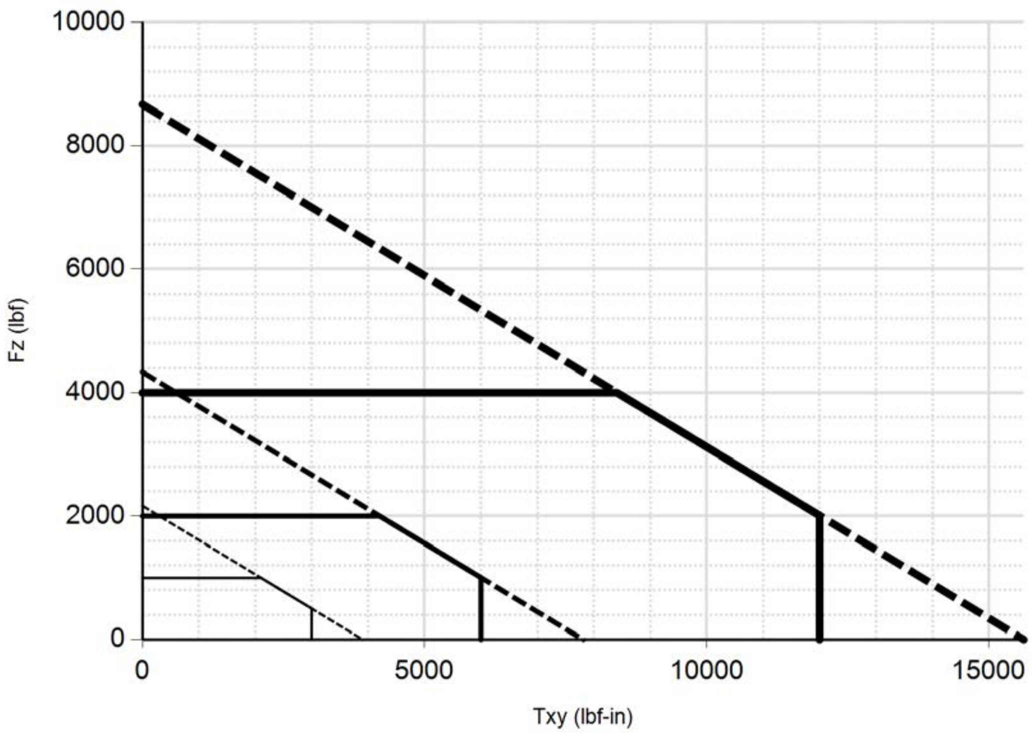
Notes:
1. ±5V Sensitivity values are double the listed ±10V Sensitivity values.
2. For IP68 version see caution on physical properties page.

5.17.7 Counts Value

Table 5.101—Counts Value					
Sensor	**Calibration**	**Fx, Fy, Fz (/ lbf)**	**Tx, Ty, Tz (/ lbf-in)**	**Fx, Fy, Fz (/ N)**	**Tx, Ty, Tz (/ Nm)**
Omega190	US-400-3000 / SI-1800-350	153.6	307.2	32	230.4
Omega190	US-800-6000 / SI-3600-700	76.8	153.6	16	115.2
Omega190	US-1600-12000 / SI-7200-1400	38.4	76.8	8	57.6
Omega190	Tool Transform Factor	0.005 in/lbf		1.3889 mm/N	
		Counts Value – Standard (US)		**Counts Value – Metric (SI)**	

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

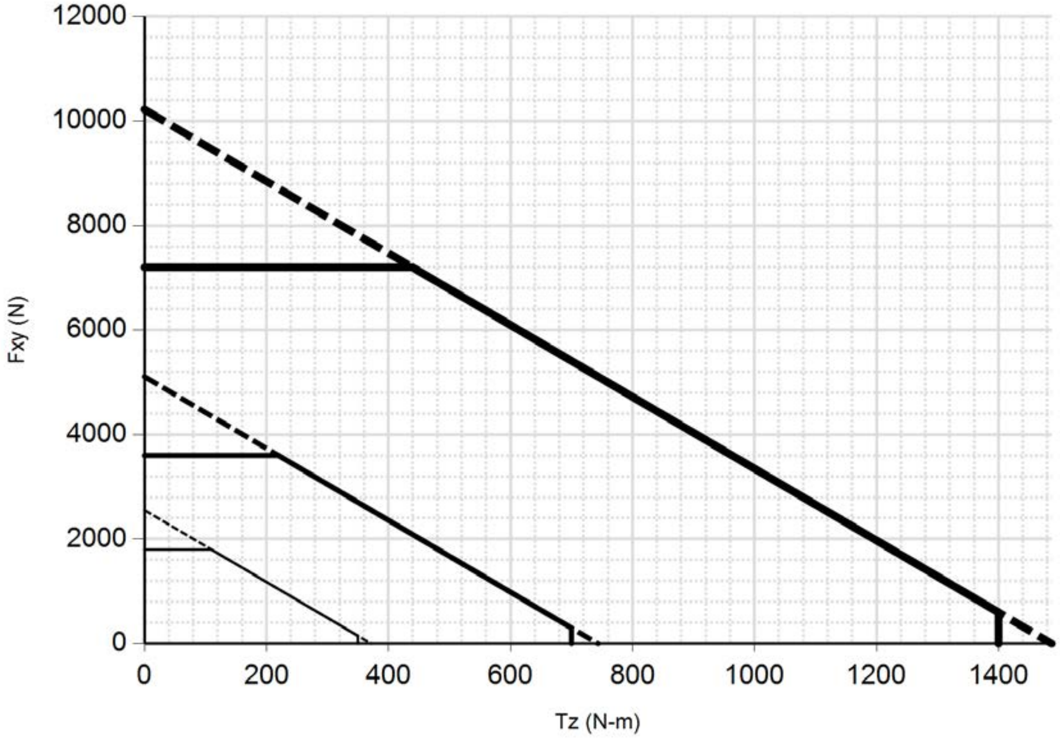


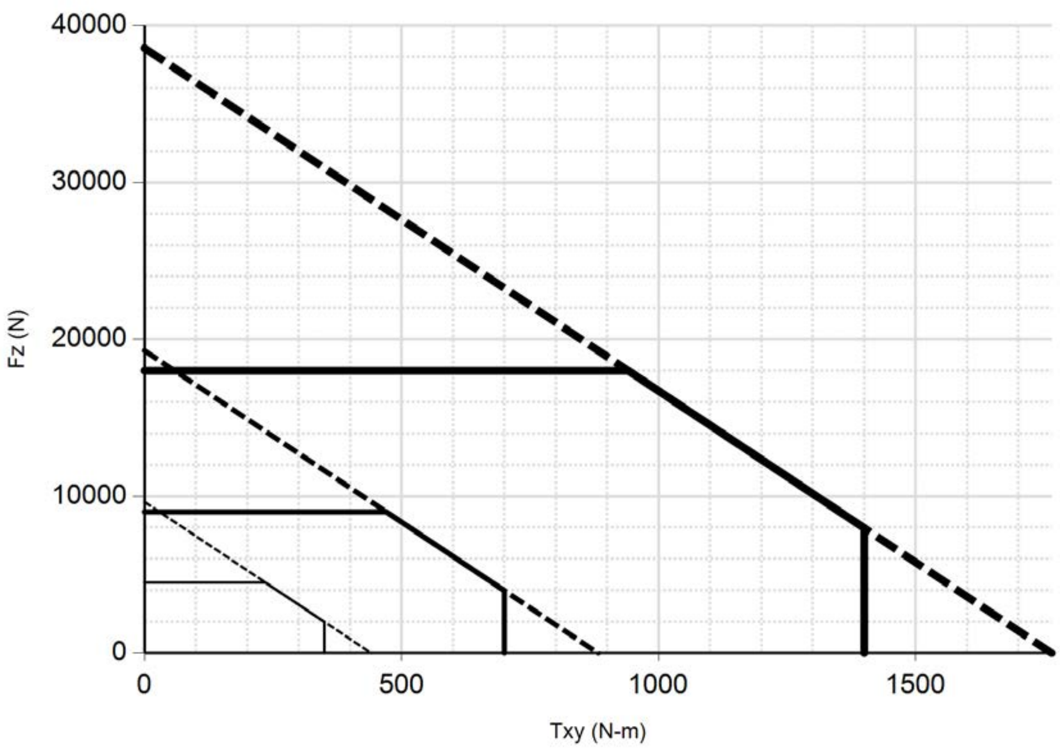


US-400-3000 US-800-6000 US-1600-12000

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

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

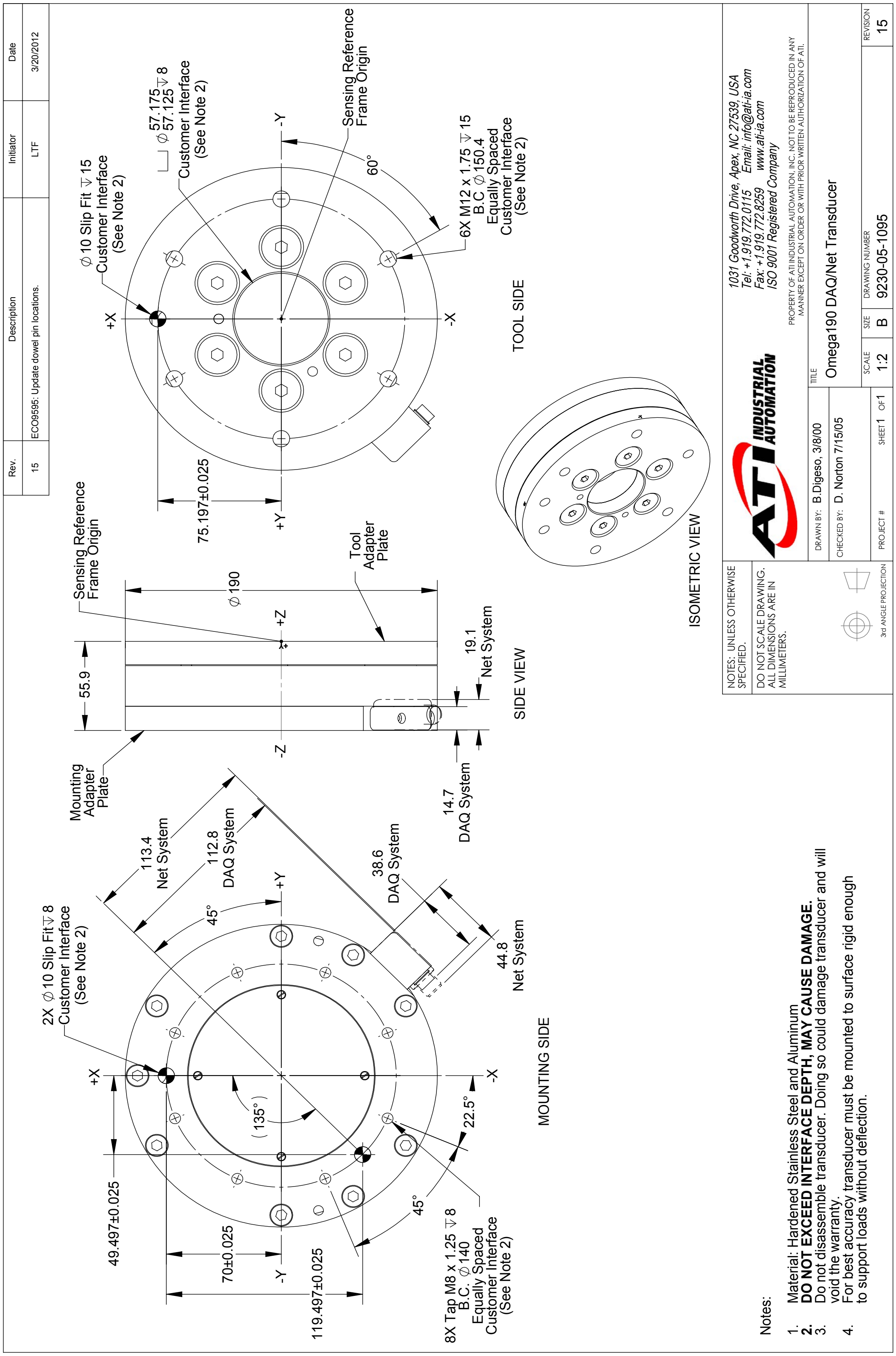




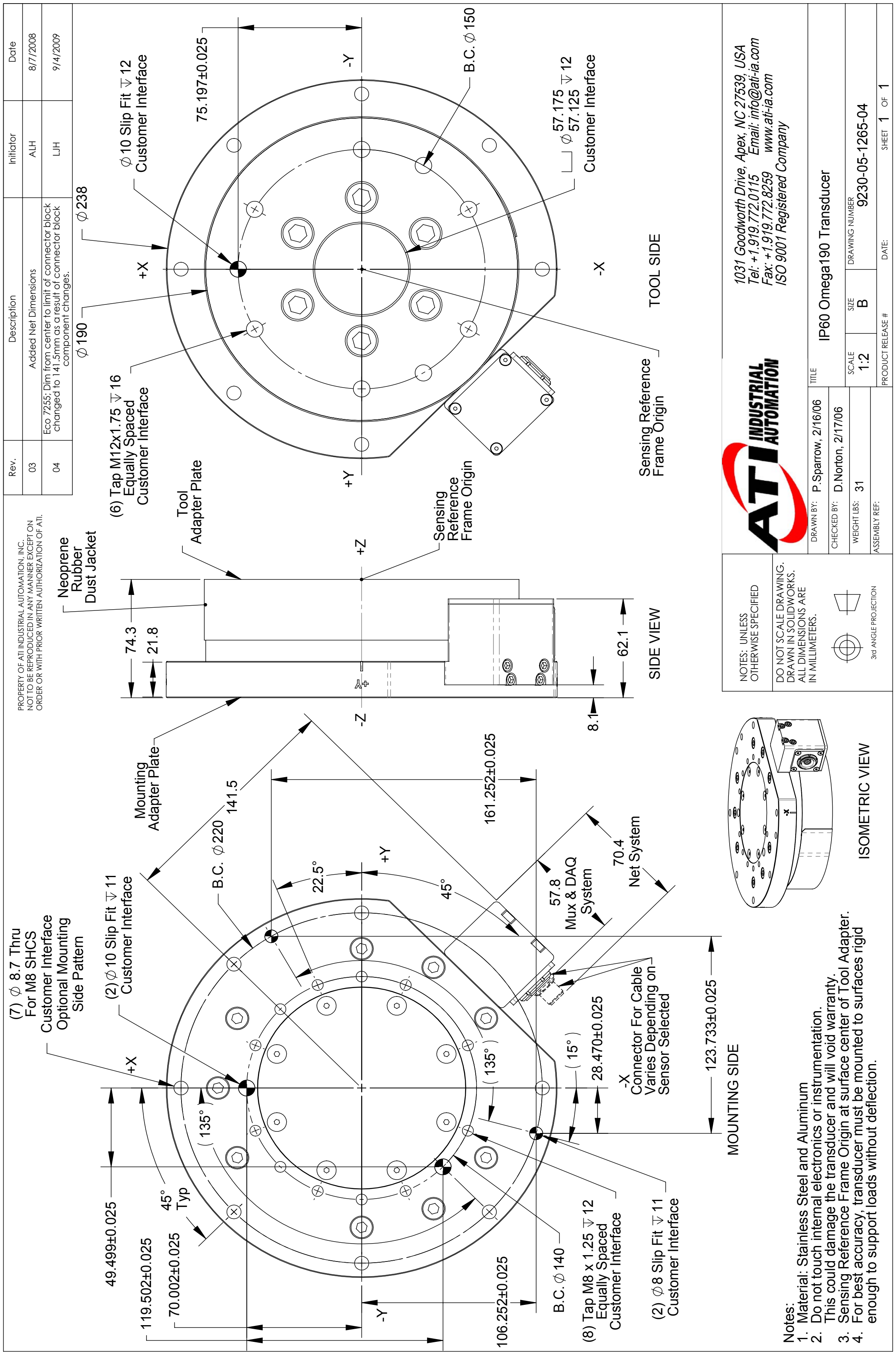
SI-1800-350 SI-3600-700 SI-7200-1400

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

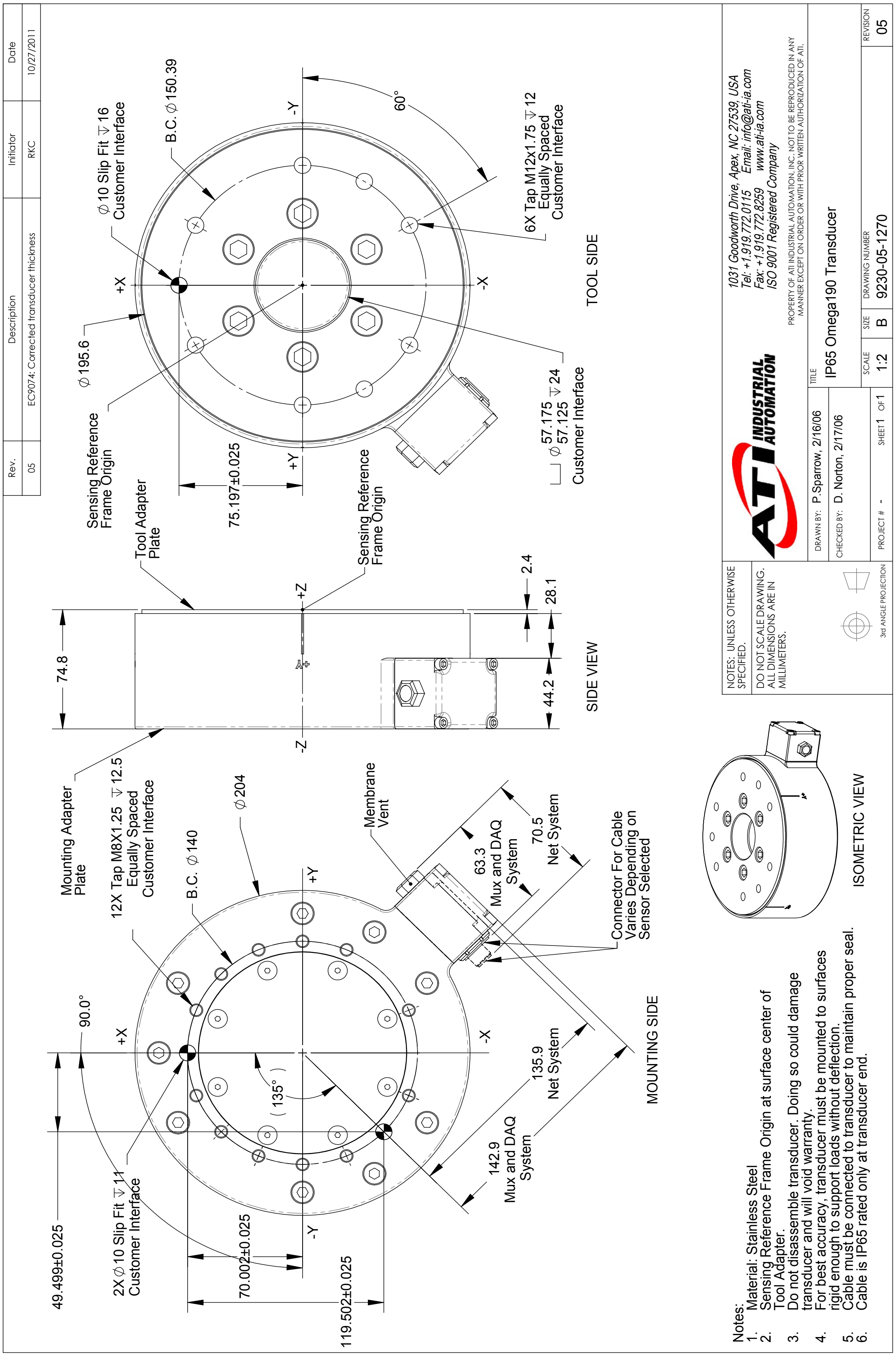
5.17.10 Omega190 DAQ/Net Transducer Drawing



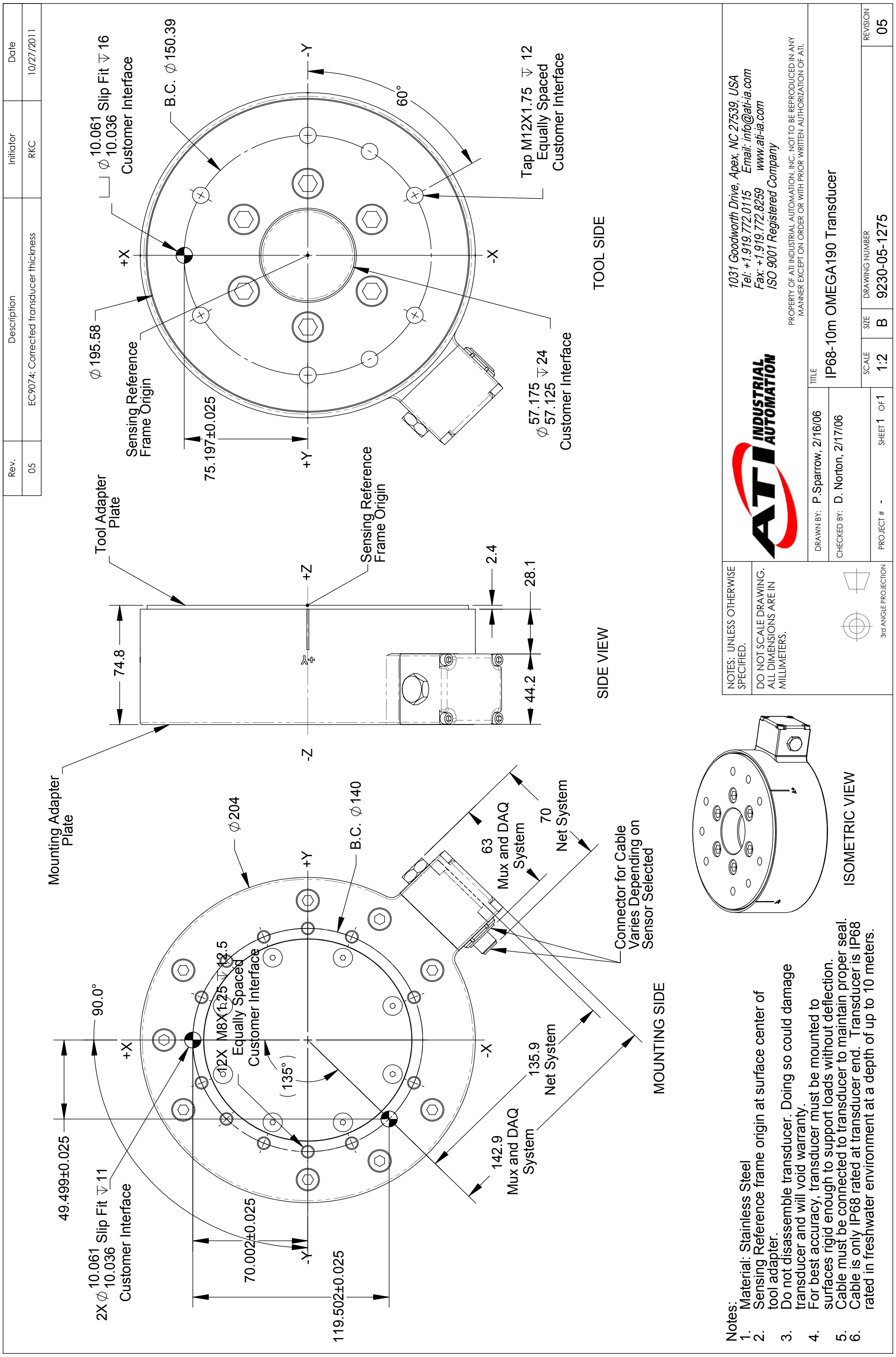
5.17.11 Omega190 IP60 Transducer Drawing



5.17.12 Omega190 IP65 Transducer Drawing



5.17.13 Omega190 IP68 Transducer Drawing



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

5.18.1 Omega191 Physical Properties

Table 5.102—Omega191 Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±8000 lbf	±36000 N
Fz	±25000 lbf	±110000 N
Txy	±60000 inf-lb	±6800 Nm
Tz	±60000 inf-lb	±6800 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	1.4×10^6 lb/in	2.4×10^8 N/m
Z-axis force (Kz)	2.1×10^6 lb/in	3.6×10^8 N/m
X-axis & Y-axis torque (Ktx, Kty)	1.4×10^7 lbf-in/rad	1.5×10^6 Nm/rad
Z-axis torque (Ktz)	2.8×10^7 lbf-in/rad	3.2×10^6 Nm/rad
Resonant Frequency		
Fx, Fy, Tz	N/A	N/A
Fz, Tx, Ty	N/A	N/A
Physical Specifications		
Weight[1]	20.8 lb	9.41 kg
Diameter[1]	7.48 in	190 mm
Height[1]	2.52 in	64 mm
Note: 1. Specifications include standard interface plates.		

5.18.2 Omega191 IP60 Physical Properties

Table 5.103—Omega191 IP60 Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±8000 lbf	±36000 N
Fz	±25000 lbf	±110000 N
Txy	±60000 inf-lb	±6800 Nm
Tz	±60000 inf-lb	±6800 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	1.4×10^6 lb/in	2.4×10^8 N/m
Z-axis force (Kz)	2.1×10^6 lb/in	3.6×10^8 N/m
X-axis & Y-axis torque (Ktx, Kty)	1.4×10^7 lbf-in/rad	1.5×10^6 Nm/rad
Z-axis torque (Ktz)	2.8×10^7 lbf-in/rad	3.2×10^6 Nm/rad
Resonant Frequency		
Fx, Fy, Tz	1200 Hz	1200 Hz
Fz, Tx, Ty	1200 Hz	1200 Hz
Physical Specifications		
Weight[1]	31 lb	14.1 kg
Diameter[1]	9.37 in	238 mm
Height[1]	2.9 in	73.7 mm
Note: 1. Specifications include standard interface plates.		

5.18.3 Omega191 IP65/IP68 Physical Properties

Table 5.104—Omega191 IP65/IP68 Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±8000 lbf	±36000 N
Fz	±25000 lbf	±110000 N
Txy	±60000 inf-lb	±6800 Nm
Tz	±60000 inf-lb	±6800 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	1.4×10^{6} lb/in	2.4×10^{8} N/m
Z-axis force (Kz)	2.1×10^{6} lb/in	3.6×10^{8} N/m
X-axis & Y-axis torque (Ktx, Kty)	1.4×10^{7} lbf-in/rad	1.5×10^{6} Nm/rad
Z-axis torque (Ktz)	2.8×10^{7} lbf-in/rad	3.2×10^{6} Nm/rad
Resonant Frequency		
Fx, Fy, Tz	1400 Hz	1400 Hz
Fz, Tx, Ty	980 Hz	980 Hz
Physical Specifications		
Weight[1]	29 lb	13.2 kg
Diameter[1]	8.03 in	204 mm
Height[1]	2.94 in	74.8 mm
Note: 1. Specifications include standard interface plates.		

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

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

5.18.4 Calibration Specifications (excludes CTL calibrations)

Table 5.105— Omega191 Calibrations (excludes CTL calibrations)[1, 2]									
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz[3] (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**	**Fx,Fy (lbf)**	**Fz[3] (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**
Omega191	US-400-3000	400	1000	3000	3000	5/64	5/32	15/32	5/16
Omega191	US-800-6000	800	2000	6000	6000	5/32	5/16	15/16	5/8
Omega191	US-1600-12000	1600	4000	12000	12000	5/16	5/8	1 7/8	1 1/4
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**
Omega191	SI-1800-350	1800	4500	350	350	3/8	3/4	5/96	5/144
Omega191	SI-3600-700	3600	9000	700	700	3/4	1 1/2	5/48	5/72
Omega191	SI-7200-1400	7200	18000	1400	1400	1 1/2	3	5/24	5/36
		Sensing Ranges				**Resolution (DAQ, Net F/T)[4]**			

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

5.18.5 CTL Calibration Specifications

Table 5.106— Omega191 CTL Calibrations[1, 2]									
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz[3] (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**	**Fx,Fy (lbf)**	**Fz[3] (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**
Omega191	US-400-3000	400	1000	3000	3000	5/32	5/16	15/16	5/8
Omega191	US-800-6000	800	2000	6000	6000	5/16	5/8	1 7/8	1 1/4
Omega191	US-1600-12000	1600	4000	12000	12000	5/8	1 1/4	3 3/4	2 1/2
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**
Omega191	SI-1800-350	1800	4500	350	350	3/4	1 1/2	5/48	5/72
Omega191	SI-3600-700	3600	9000	700	700	1 1/2	3	5/24	5/36
Omega191	SI-7200-1400	7200	18000	1400	1400	3	6	5/12	5/18
		Sensing Ranges				**Resolution (Controller)**			

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

5.18.6 Analog Output

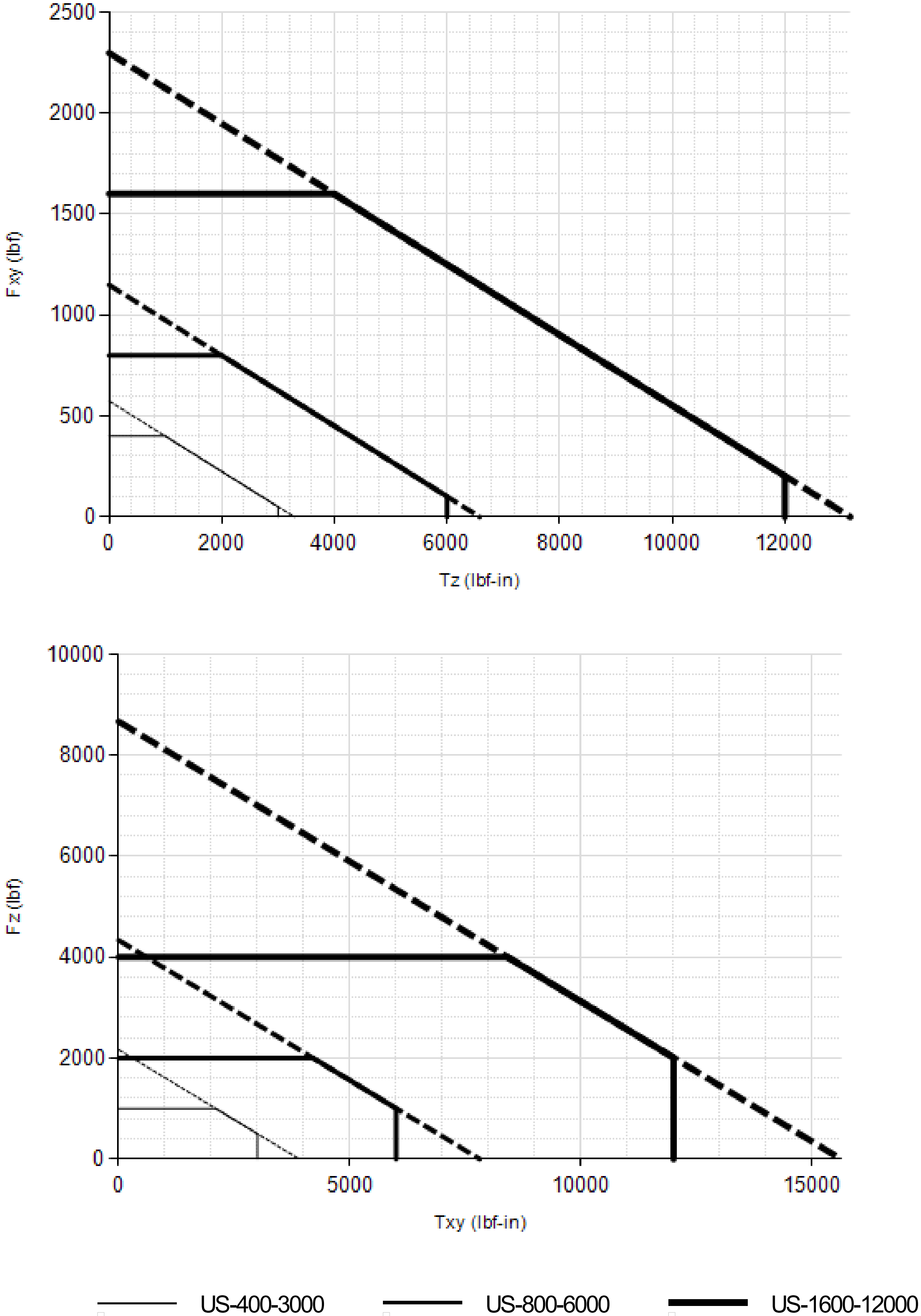
Table 5.107— Omega191 Analog Output							
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz[2] (lbf)**	**Tx,Ty,Tz (lbf-in)**	**Fx,Fy (lbf/V)**	**Fz[2] (lbf/V)**	**Tx,Ty,Tz (lbf-in/V)**
Omega191	US-400-3000	±400	±1000	±3000	40	100	300
Omega191	US-800-6000	±800	±2000	±6000	80	200	600
Omega191	US-1600-12000	±1600	±4000	±12000	160	400	1200
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz[2] (N)**	**Tx,Ty,Tz (Nmm)**	**Fx,Fy (N/V)**	**Fz[2] (N/V)**	**Tx,Ty,Tz (Nm/V)**
Omega191	SI-1800-350	±1800	±4500	±350	180	450	35
Omega191	SI-3600-700	±3600	±9000	±700	360	900	70
Omega191	SI-7200-1400	±7200	±18000	±1400	720	1800	140
		Analog Output Range			**Analog ±10V Sensitivity[1]**		

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

5.18.7 Counts Value

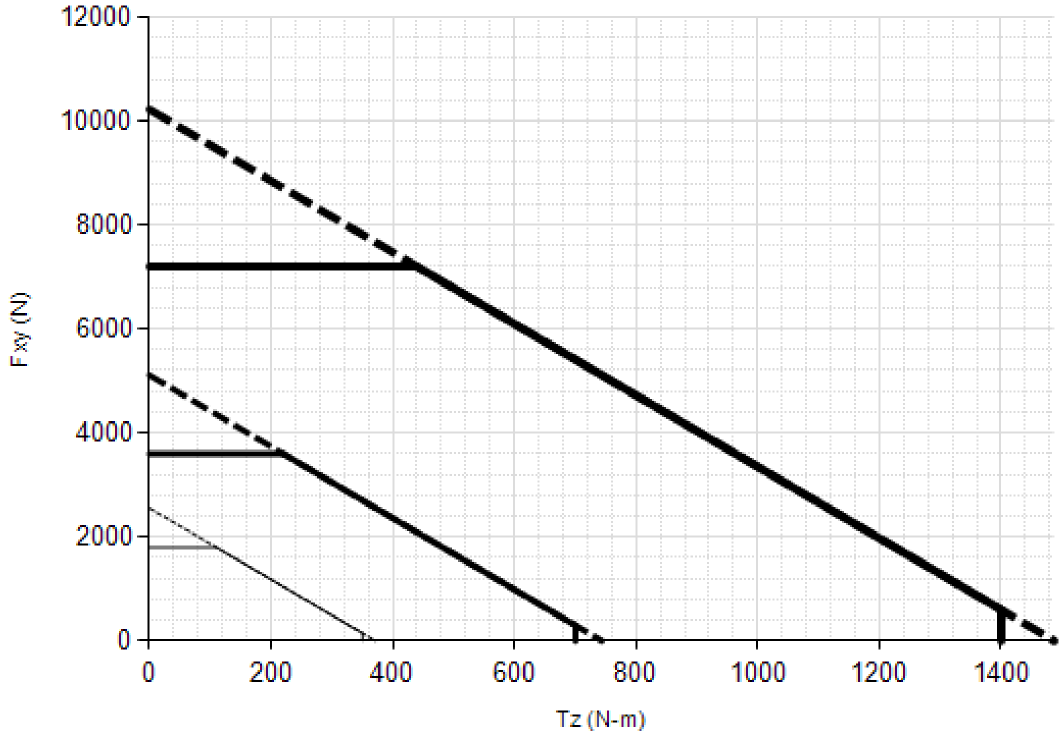
Table 5.108—Counts Value					
Sensor	**Calibration**	**Fx, Fy, Fz (/ lbf)**	**Tx, Ty, Tz (/ lbf-in)**	**Fx, Fy, Fz (/ N)**	**Tx, Ty, Tz (/ Nm)**
Omega191	US-400-3000 / SI-1800-350	153.6	307.2	32	230.4
Omega191	US-800-6000 / SI-3600-700	76.8	153.6	16	115.2
Omega191	US-1600-12000 / SI-7200-1400	38.4	76.8	8	57.6
Omega191	Tool Transform Factor	0.005 in/lbf		1.3889 mm/N	
		Counts Value – Standard (US)		**Counts Value – Metric (SI)**	

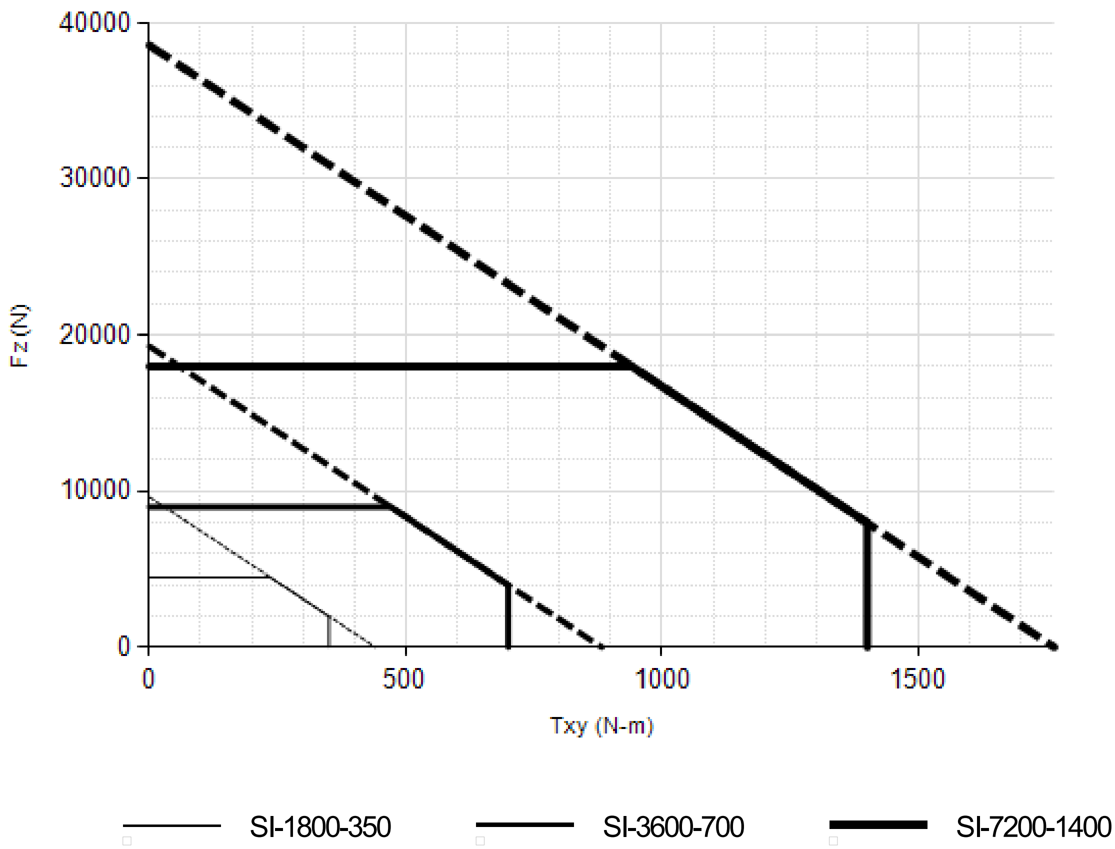
5.18.8 Omega191 (US Calibration Complex Loading) (Includes IP60/IP65/IP68)[1]



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

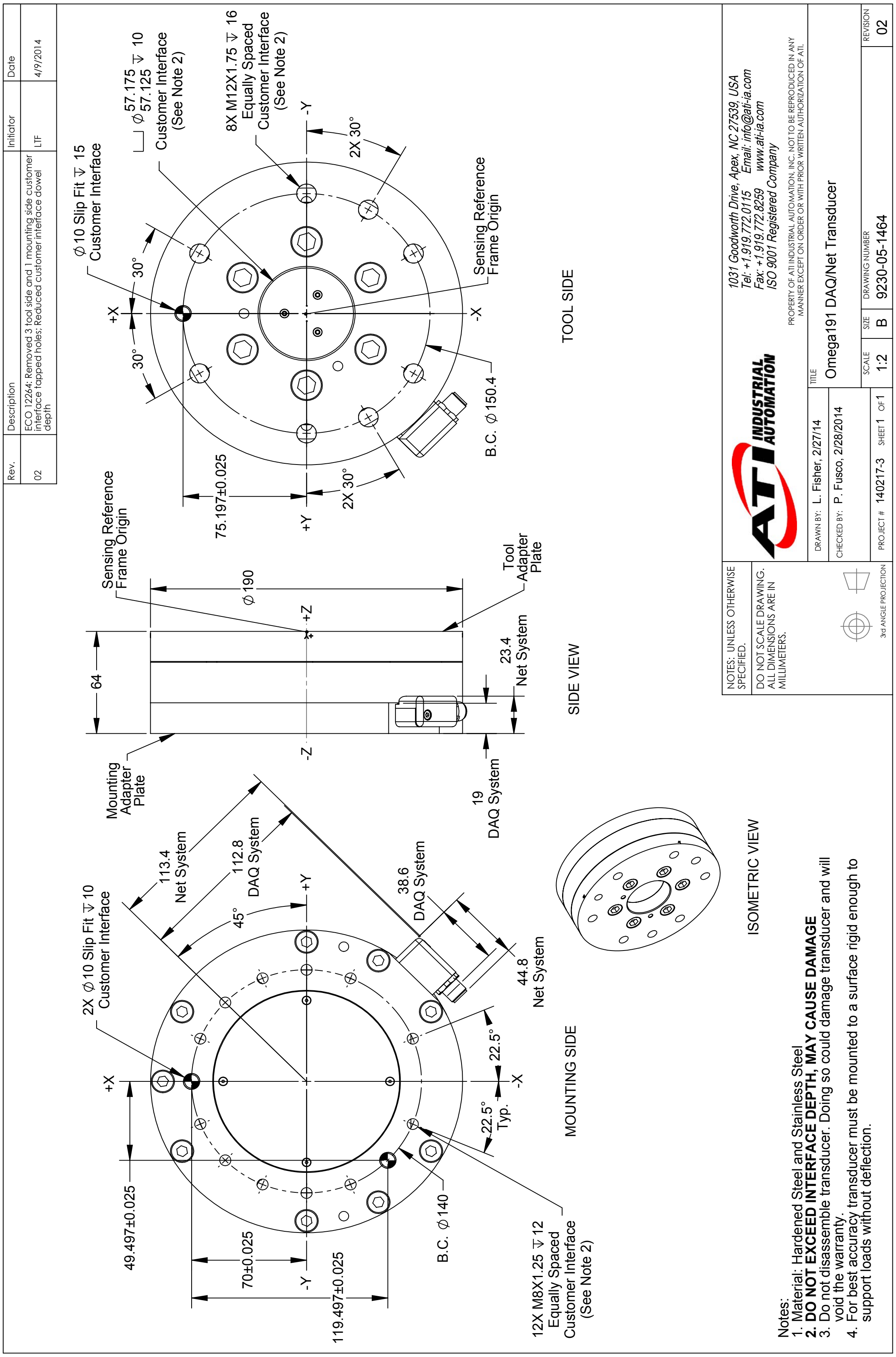
5.18.9 Omega191 (SI Calibration Complex Loading) (Includes IP60/IP65/IP68)[1]



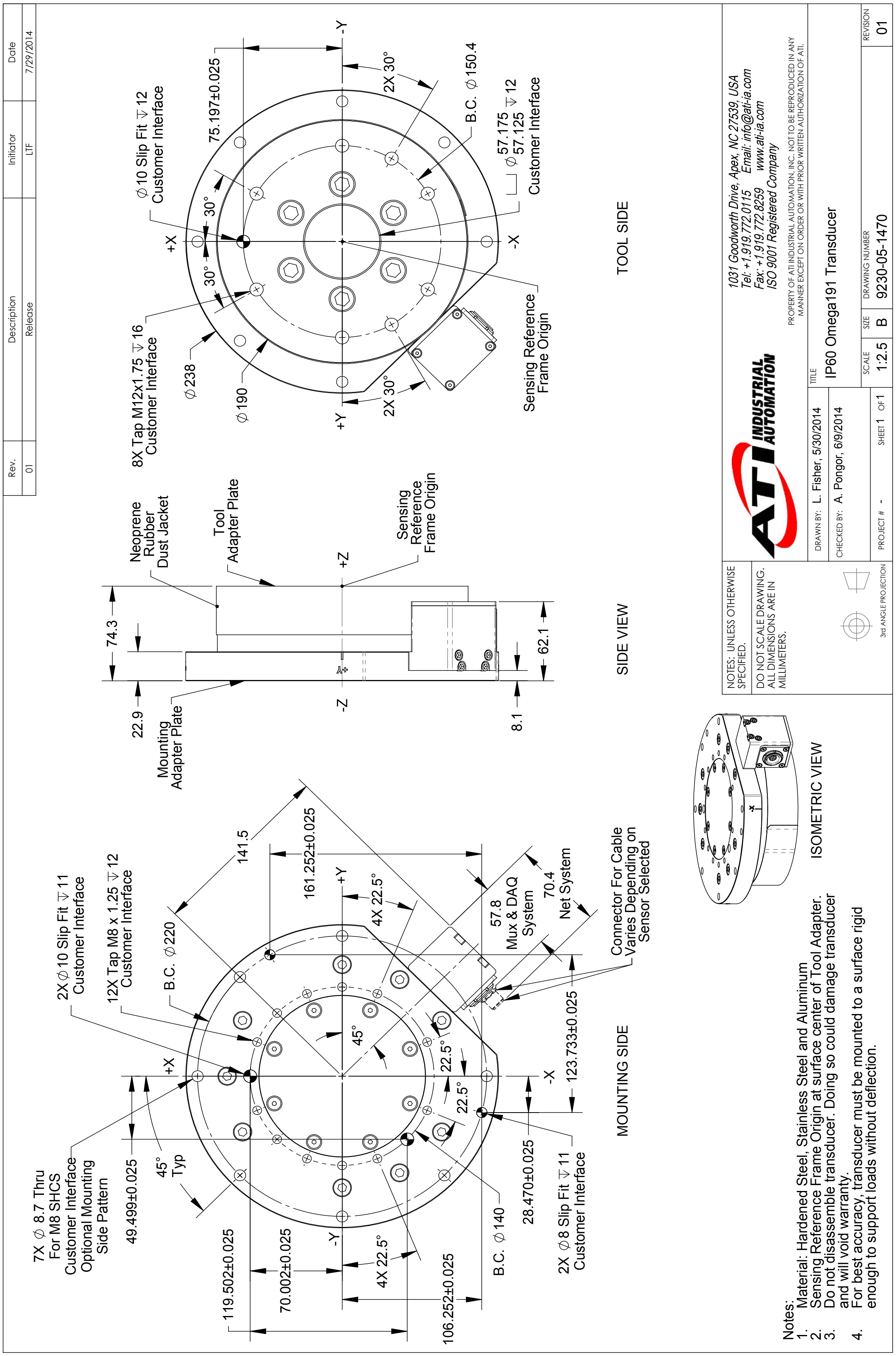


Note: 1. For IP68 version see caution on physical properties page.

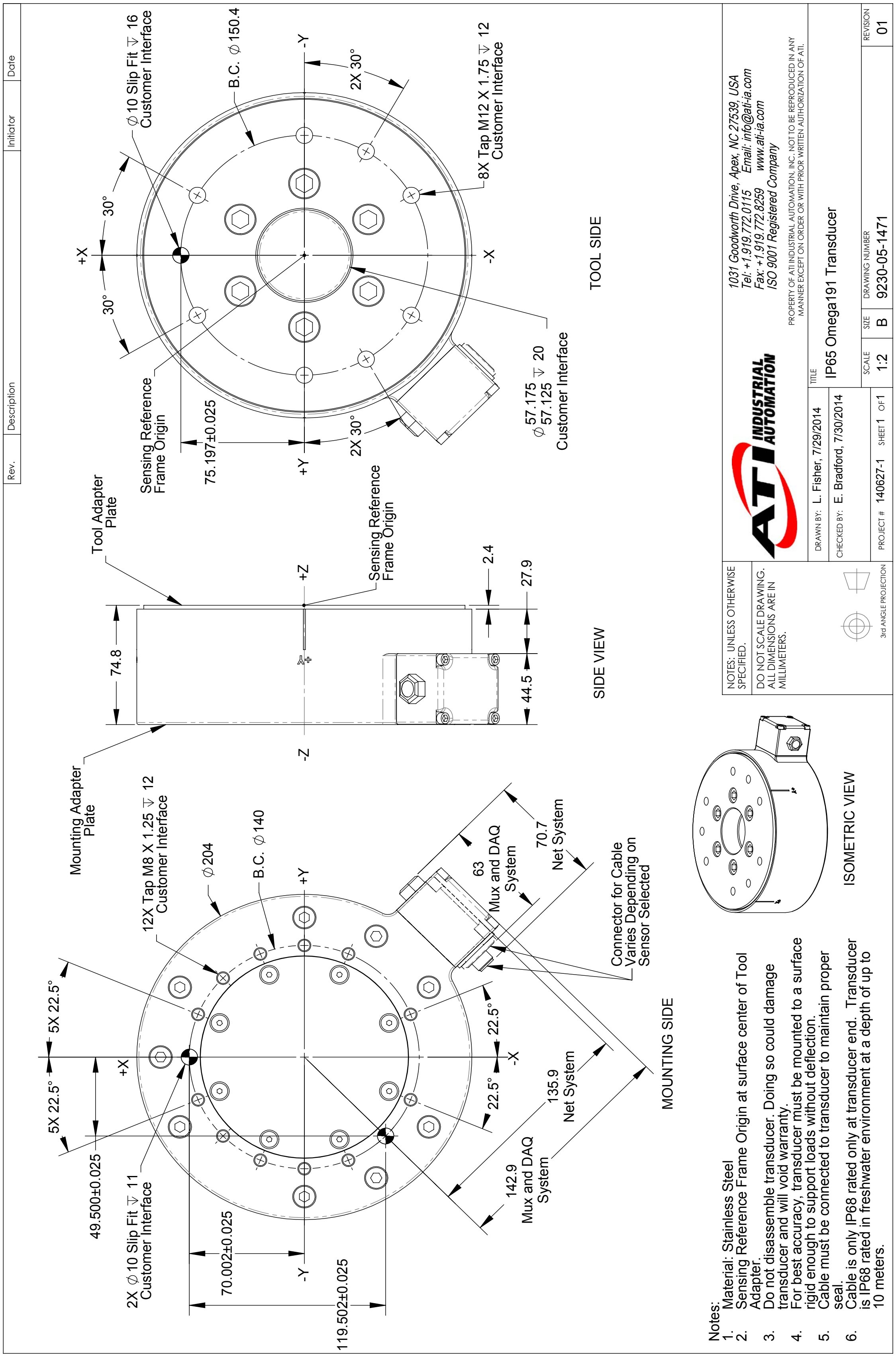
5.18.10 Omega191 DAQ/Net Transducer Drawing



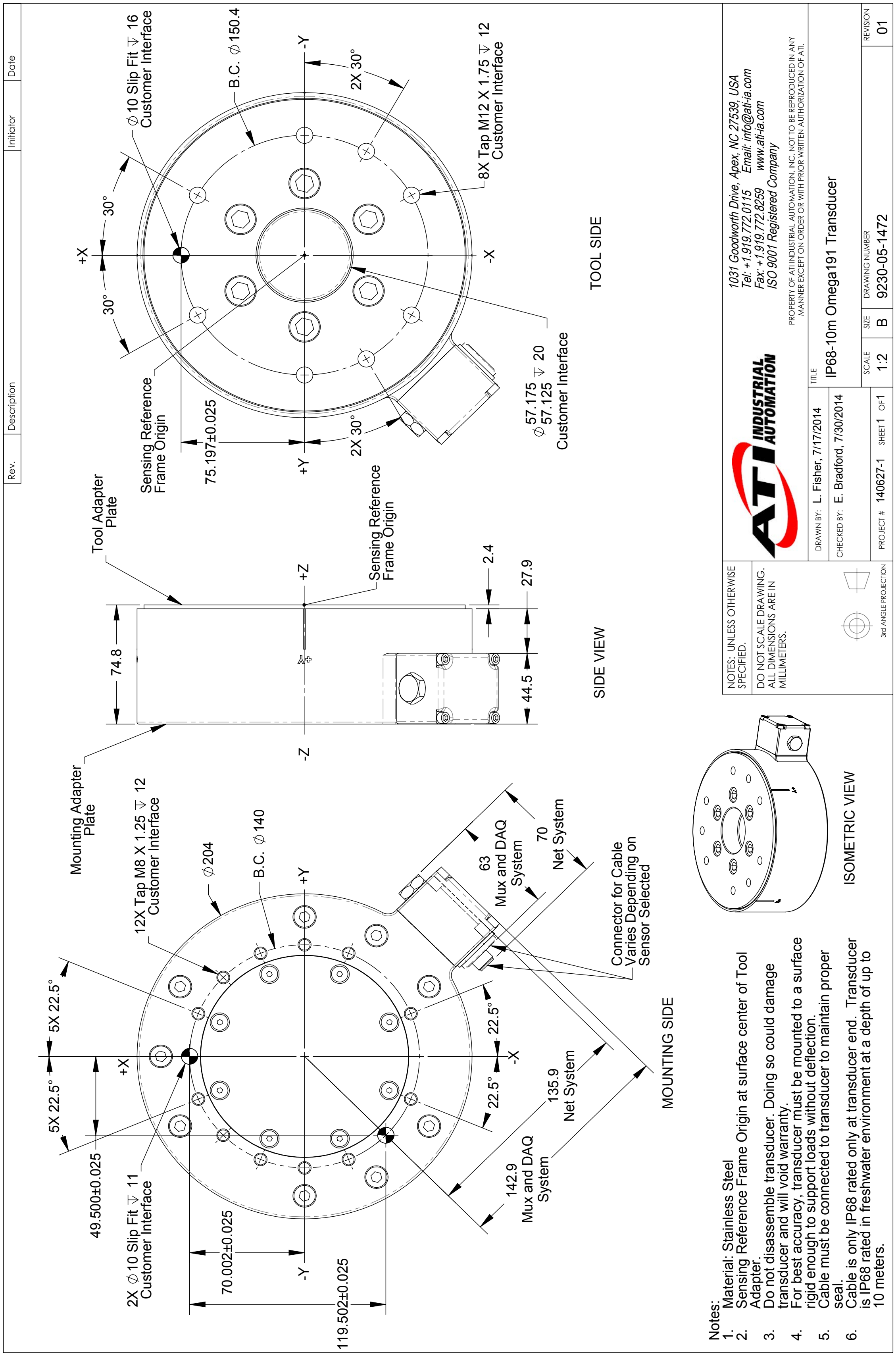
5.18.11 Omega191 IP60 Transducer Drawing



5.18.12 Omega191 IP65 Transducer Drawing



5.18.13 Omega191 IP68 Transducer Drawing



5.19 Omega250 Specifications (Includes IP60/IP65/IP68)

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

Table 5.109—Omega250 Physical Properties (Includes IP60/IP65/IP68)

Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±37000 lbf	±160000 N
Fz	±74000 lbf	±330000 N
Txy	±180000 inf-lb	±21000 Nm
Tz	±220000 inf-lb	±25000 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	$2.4\text{x}10^{6}$ lb/in	$4.2\text{x}10^{8}$ N/m
Z-axis force (Kz)	$3.2\text{x}10^{6}$ lb/in	$5.6\text{x}10^{8}$ N/m
X-axis & Y-axis torque (Ktx, Kty)	$2.7\text{x}10^{7}$ lbf-in/rad	$3.0\text{x}10^{6}$ Nm/rad
Z-axis torque (Ktz)	$5.5\text{x}10^{7}$ lbf-in/rad	$6.2\text{x}10^{6}$ Nm/rad
Resonant Frequency		
Fx, Fy, Tz	780 Hz	780 Hz
Fz, Tx, Ty	770 Hz	770 Hz
Physical Specifications		
Weight[1]	70 lb	31.8 kg
Diameter[1]	11.6 in	295 mm
Height[1]	3.74 in	94.9 mm

Note:
1. Specifications include standard interface plates.

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

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

5.19.2 Calibration Specifications (excludes CTL calibrations)

Table 5.110— Omega250 Calibrations (excludes CTL calibrations)[1, 2]									
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz[3] (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**	**Fx,Fy (lbf)**	**Fz[3] (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**
Omega250	US-900-4500	900	1800	4500	4500	1/2	1/2	1	1
Omega250	US-1800-9000	1800	3600	9000	9000	1	1	2	2
Omega250	US-3600-18000	3600	7200	18000	18000	2	2	5	5
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**
Omega250	SI-4000-500	4000	8000	500	500	1	2	1/8	1/8
Omega250	SI-8000-1000	8000	16000	1000	1000	2	4	1/4	1/4
Omega250	SI-16000-2000	16000	32000	2000	2000	4	8	1/2	1/2
		Sensing Ranges				**Resolution (DAQ, Net F/T)[4]**			

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

5.19.3 CTL Calibration Specifications

Table 5.111— Omega250 CTL Calibrations[1, 2]									
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz[3] (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**	**Fx,Fy (lbf)**	**Fz[3] (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**
Omega250	US-900-4500	900	1800	4500	4500	1	1	2	2
Omega250	US-1800-9000	1800	3600	9000	9000	2	2	5	5
Omega250	US-3600-18000	3600	7200	18000	18000	5	5	10	10
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**
Omega250	SI-4000-500	4000	8000	500	500	2	4	1/4	1/4
Omega250	SI-8000-1000	8000	16000	1000	1000	4	8	1/2	1/2
Omega250	SI-16000-2000	16000	32000	2000	2000	8	16	1	1
		Sensing Ranges				**Resolution (Controller)**			

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

5.19.4 Analog Output

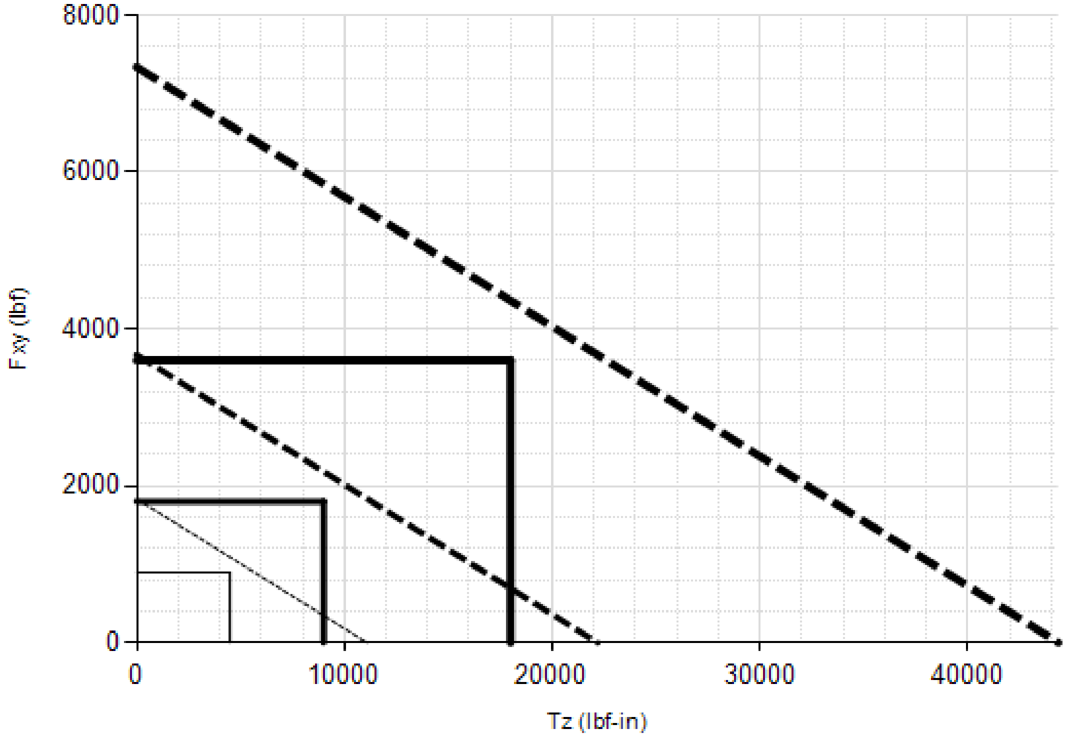
Table 5.112— Omega250 Analog Output							
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz[2] (lbf)**	**Tx,Ty,Tz (lbf-in)**	**Fx,Fy (lbf/V)**	**Fz[2] (lbf/V)**	**Tx,Ty,Tz (lbf-in/V)**
Omega250	US-900-4500	±900	±1800	±4500	90	180	450
Omega250	US-1800-9000	±1800	±3600	±9000	180	360	900
Omega250	US-3600-18000	±3600	±7200	±18000	360	720	1800
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz[2] (N)**	**Tx,Ty,Tz (Nmm)**	**Fx,Fy (N/V)**	**Fz[2] (N/V)**	**Tx,Ty,Tz (Nm/V)**
Omega250	SI-4000-500	±4000	±8000	±500	400	800	50
Omega250	SI-8000-1000	±8000	±16000	±1000	800	1600	100
Omega250	SI-16000-2000	±16000	±32000	±2000	1600	3200	200
		Analog Output Range			**Analog ±10V Sensitivity[1]**		

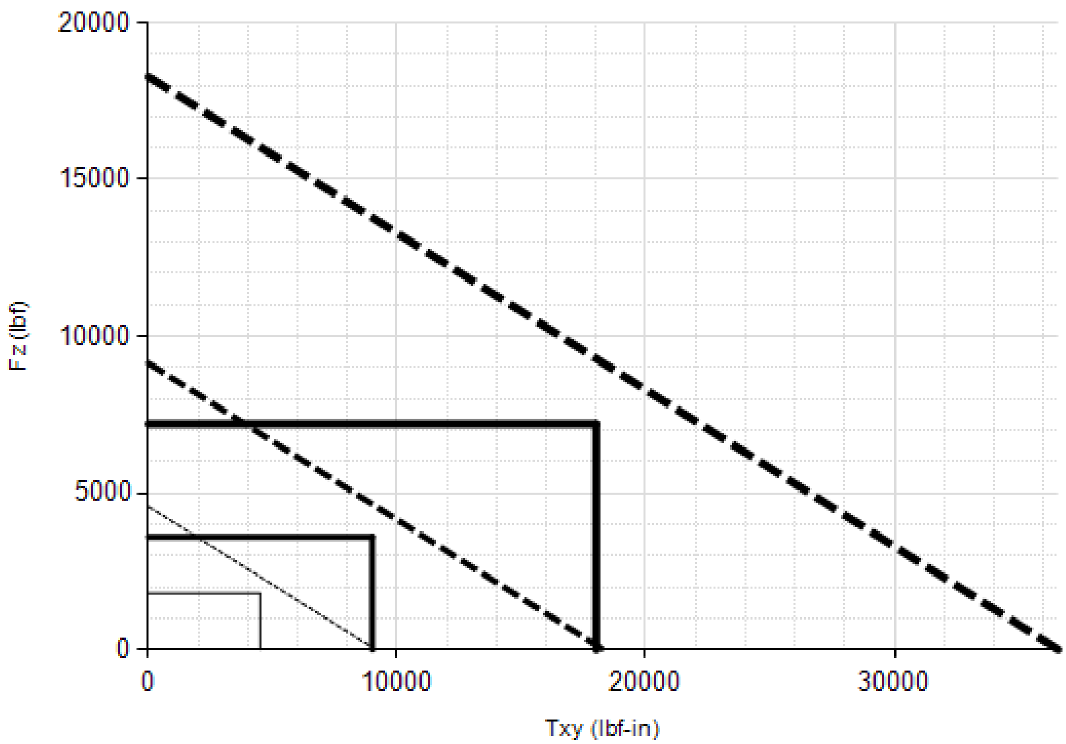
Notes:
1. ±5V Sensitivity values are double the listed ±10V Sensitivity values.
2. For IP68 version see caution on physical properties page.

5.19.5 Counts Value

Table 5.113—Counts Value					
Sensor	**Calibration**	**Fx, Fy, Fz (/ lbf)**	**Tx, Ty, Tz (/ lbf-in)**	**Fx, Fy, Fz (/ N)**	**Tx, Ty, Tz (/ Nm)**
Omega250	US-900–4500 / SI-4000–500	8	4	4000	32000
Omega250	US-1800–9000 / SI-8000–1000	4	2	2000	16000
Omega250	US-3600–18000 / SI-16000-2000	2	1	1000	8000
Omega250	Tool Transform Factor	0.02 in/lbf		1.25 mm/N	
		Counts Value – Standard (US)		**Counts Value – Metric (SI)**	

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

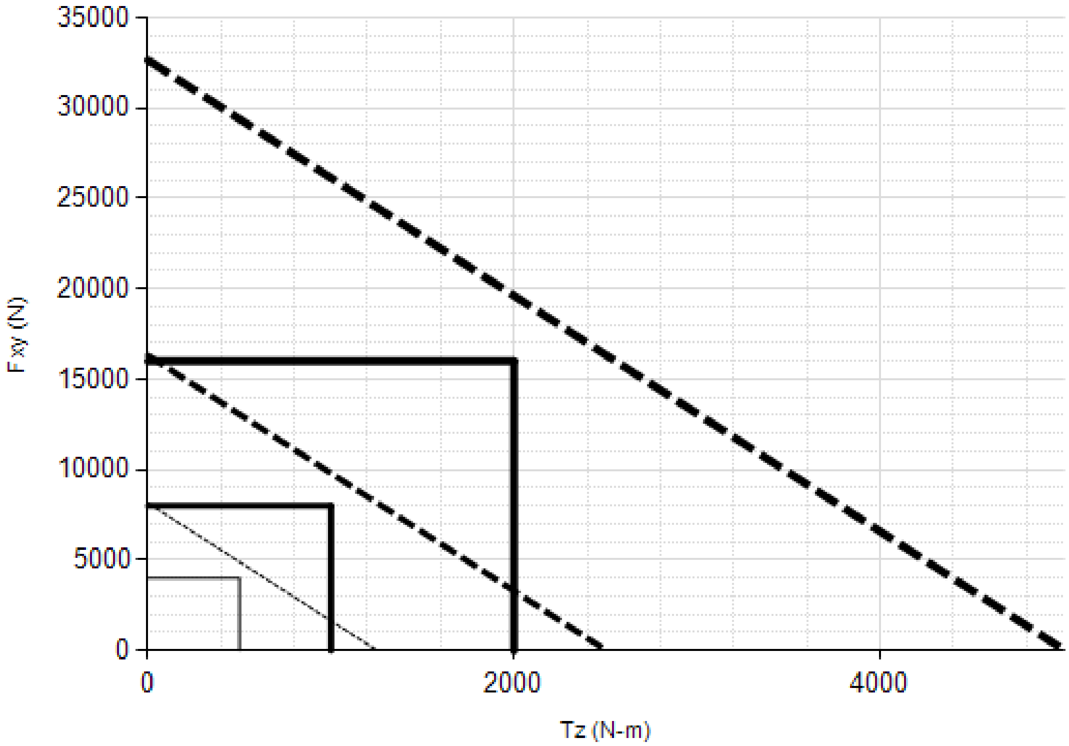


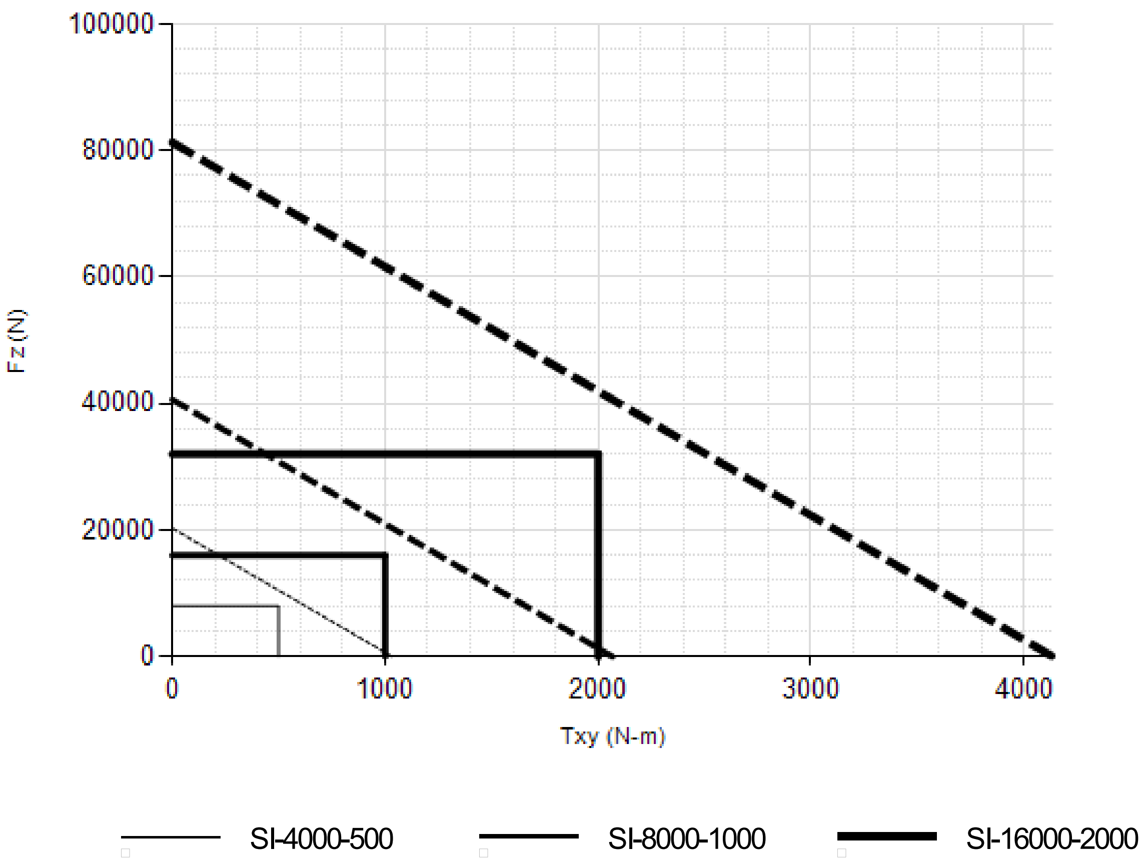


US-900-4500 US-1800-9000 US-3600-18000

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

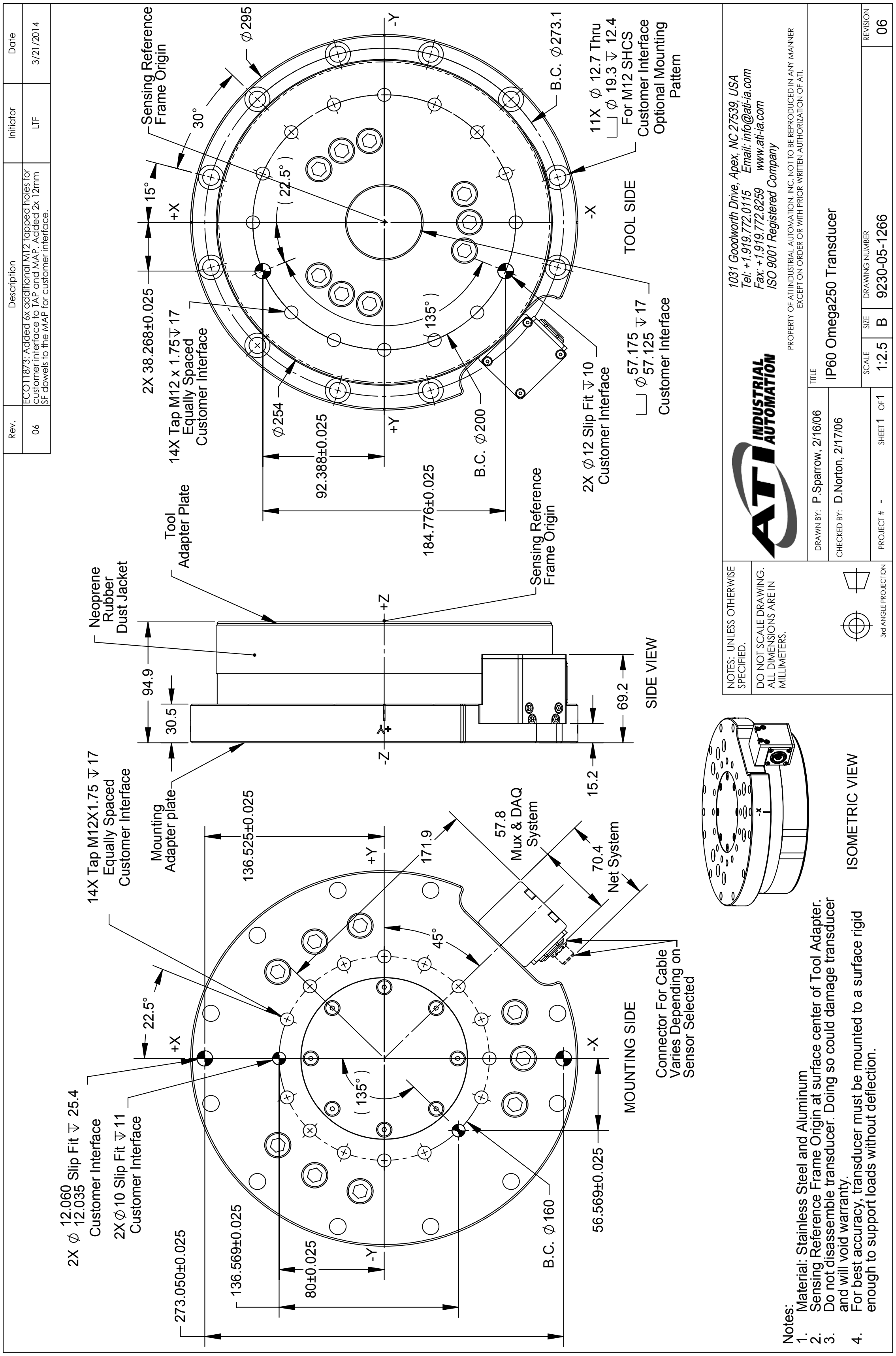
5.19.7 Omega250 (SI Calibration Complex Loading) (Includes IP60/IP65/IP68)[1]



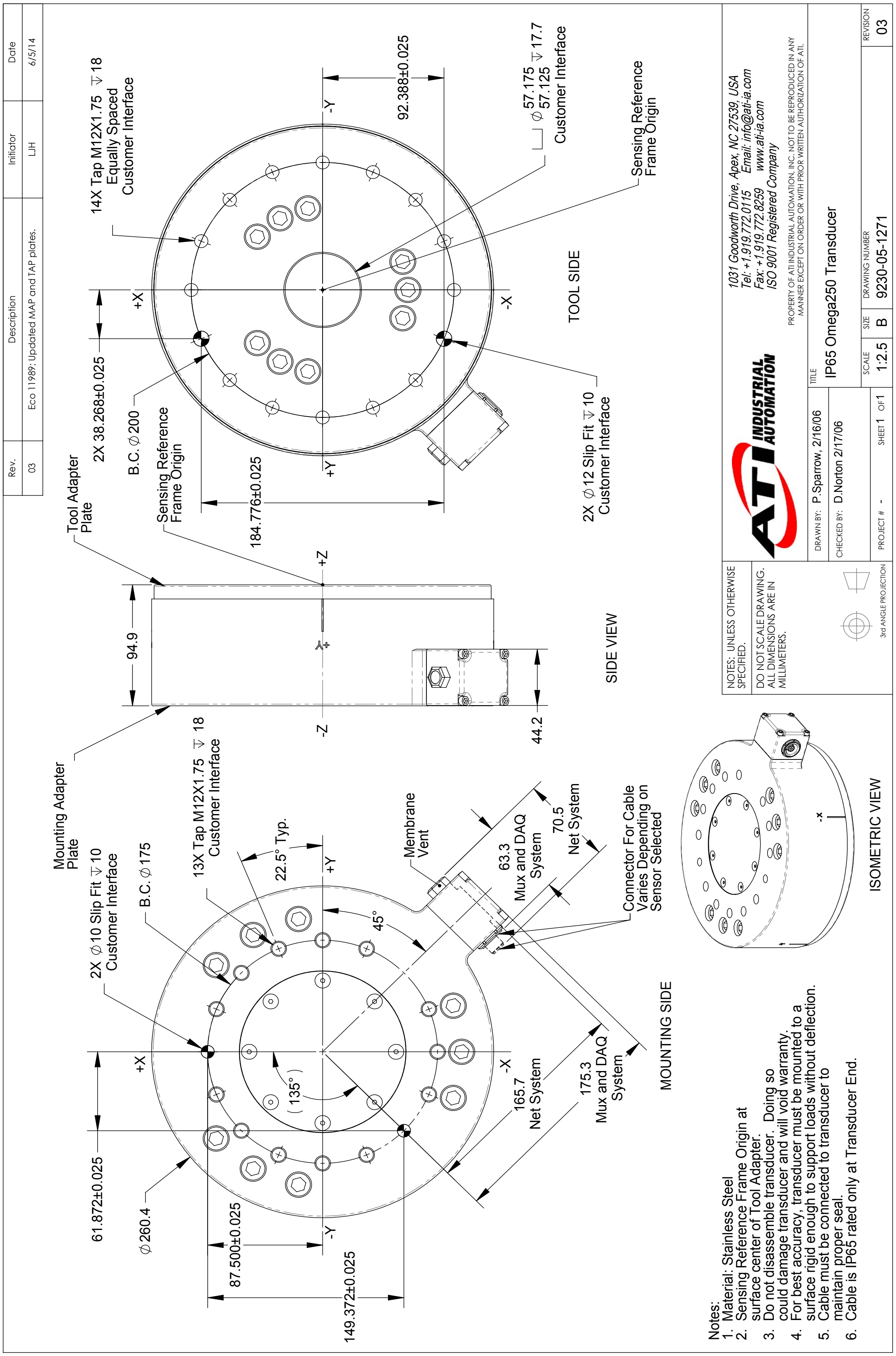


Note: 1. For IP68 version see caution on physical properties page.

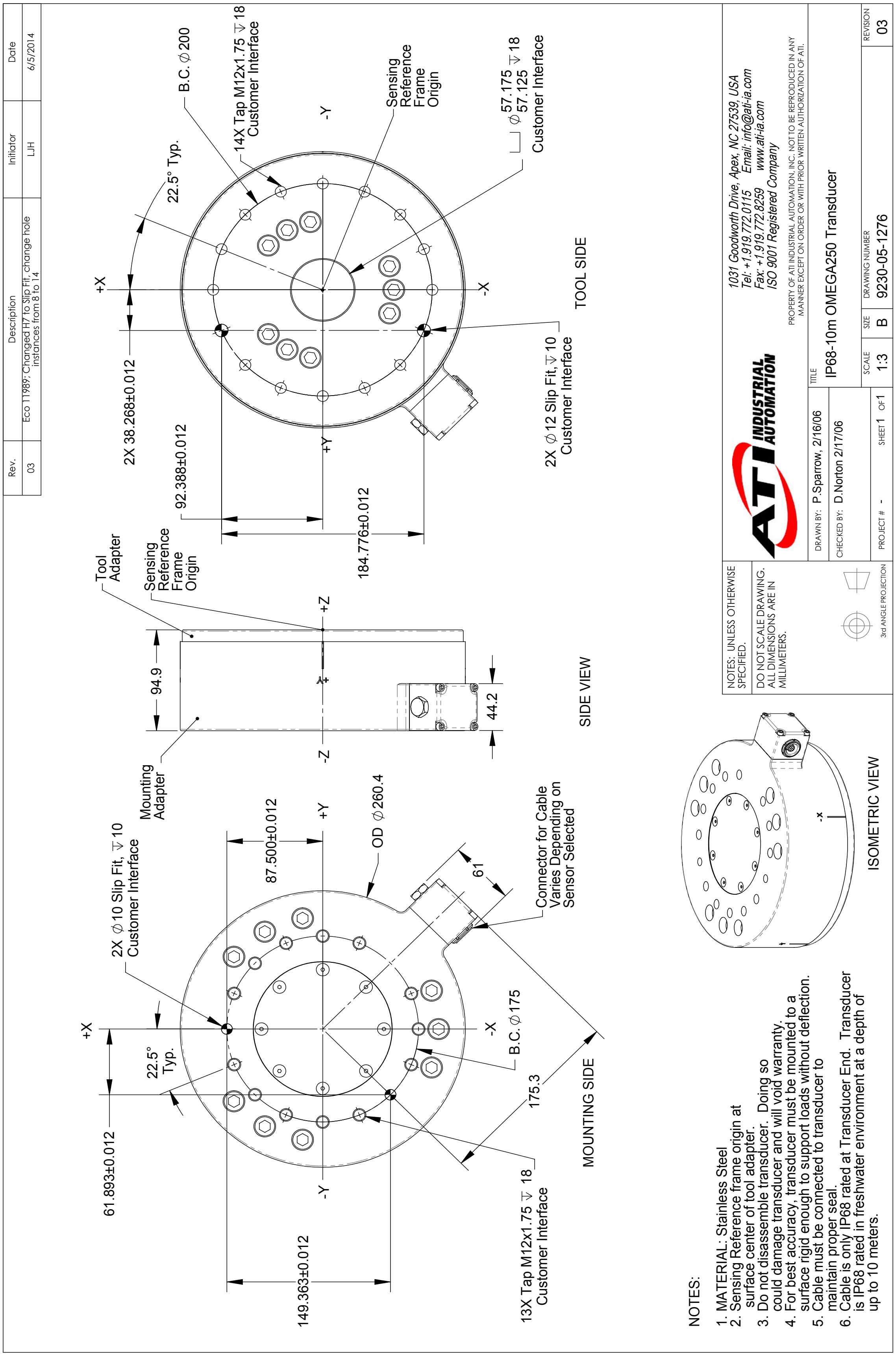
5.19.8 Omega250 IP60 Transducer Drawing



5.19.9 Omega250 IP65 Transducer Drawing



5.19.10 Omega250 IP68 Transducer Drawing



5.20 Omega331 Specifications (Includes IP65)

5.20.1 Omega331 Physical Properties (Includes IP65)

Table 5.114—Omega331 Physical Properties (Includes IP60/IP65)

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

5.20.2 Calibration Specifications (excludes CTL calibrations)

Table 5.115— Omega331 Calibrations (excludes CTL calibrations)[1, 2]

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

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

5.20.3 CTL Calibration Specifications

Table 5.116— Omega331 CTL Calibrations[1, 2]

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

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

5.20.4 Analog Output

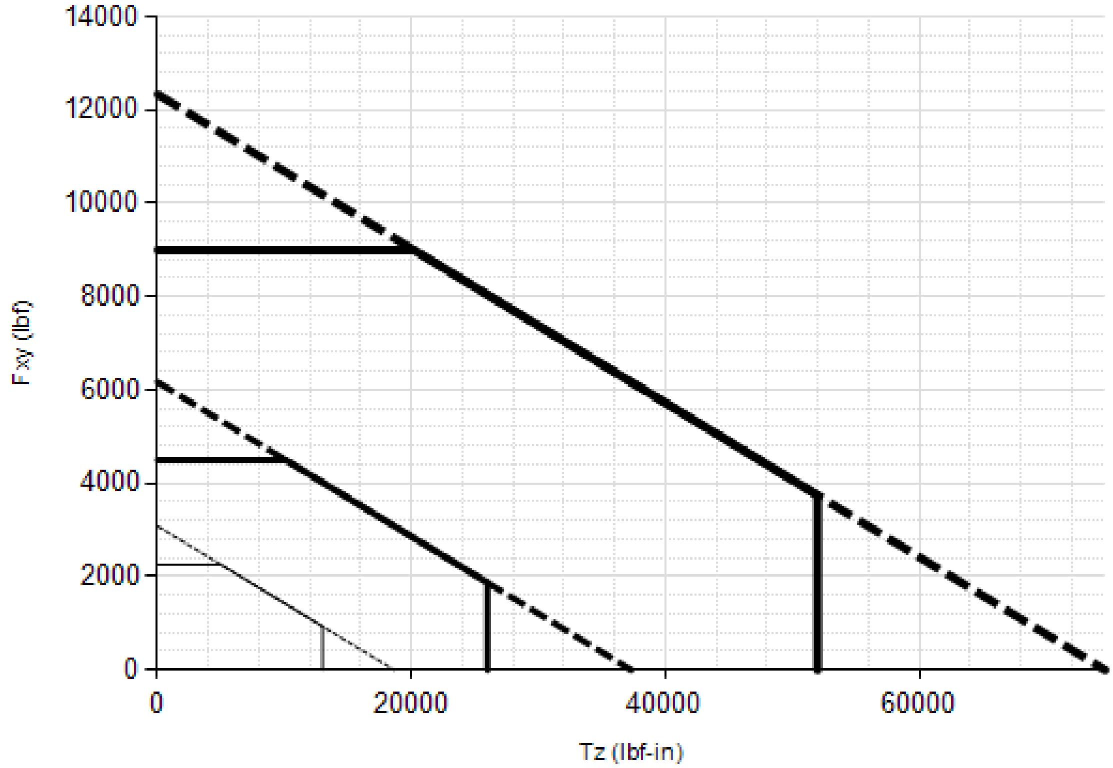
Table 5.117— Omega331 Analog Output							
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz (lbf)**	**Tx,Ty,Tz (lbf-in)**	**Fx,Fy (lbf/V)**	**Fz (lbf/V)**	**Tx,Ty,Tz (lbf-in/V)**
Omega331	US-2250-13000	±2250	±5250	±13000	225	525	1300
Omega331	US-4500-26000	±4500	±10500	±26000	450	1050	2600
Omega331	US-9000-52000	±9000	±21000	±52000	900	2100	5200
Sensor	**(SI) Metric Calibration**	**Fx,Fy (kN)**	**Fz (kN)**	**Tx,Ty,Tz (kNm)**	**Fx,Fy (kN/V)**	**Fz (kN/V)**	**Tx,Ty,Tz (kNm/V)**
Omega331	SI-10000-1500	±10	±22	±1.5	1	2.2	0.15
Omega331	SI-20000-3000	±20	±44	±3	2	4.4	0.3
Omega331	SI-40000-6000	±40	±88	±6	4	8.8	0.6
		Analog Output Range			**Analog ±10V Sensitivity[1]**		

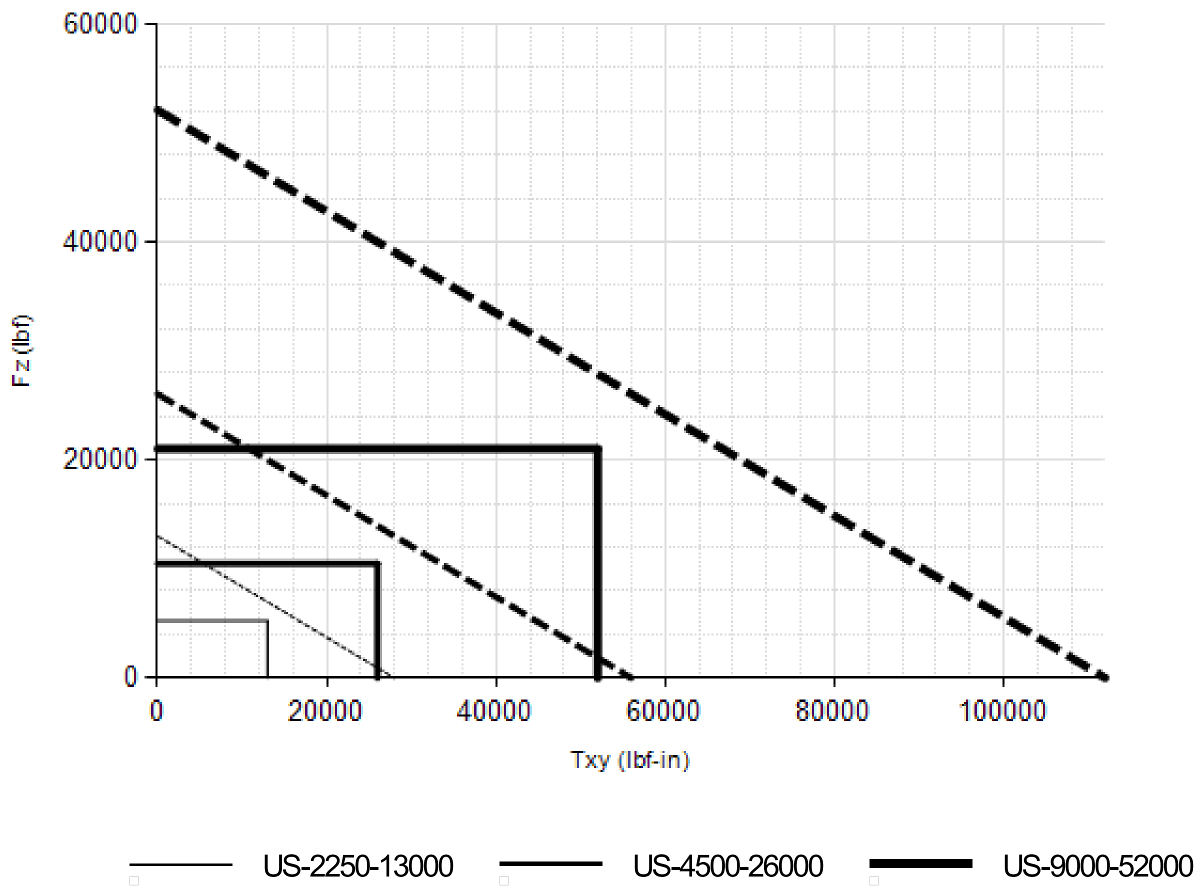
Notes:
1. ±5V Sensitivity values are double the listed ±10V Sensitivity values.

5.20.5 Counts Value

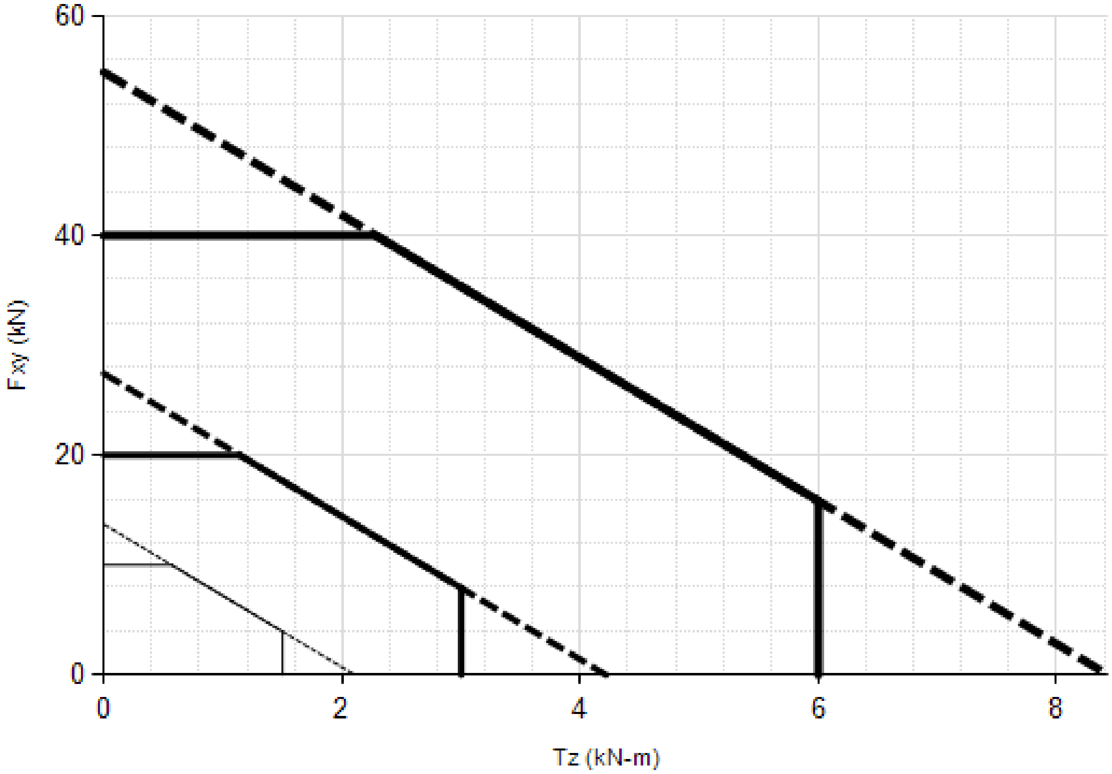
Table 5.118—Counts Value					
Sensor	**Calibration**	**Fx, Fy, Fz (/ lbf)**	**Tx, Ty, Tz (/ lbf-in)**	**Fx, Fy, Fz (/ kN)**	**Tx, Ty, Tz (/ kNm)**
Omega331	US-2250–13000 / SI-10000–1500	32	6.4	7680	64000
Omega331	US-4500–26000 / SI-20000–3000	16	3.2	3840	32000
Omega331	US-9000–52000 / SI-40000–6000	8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

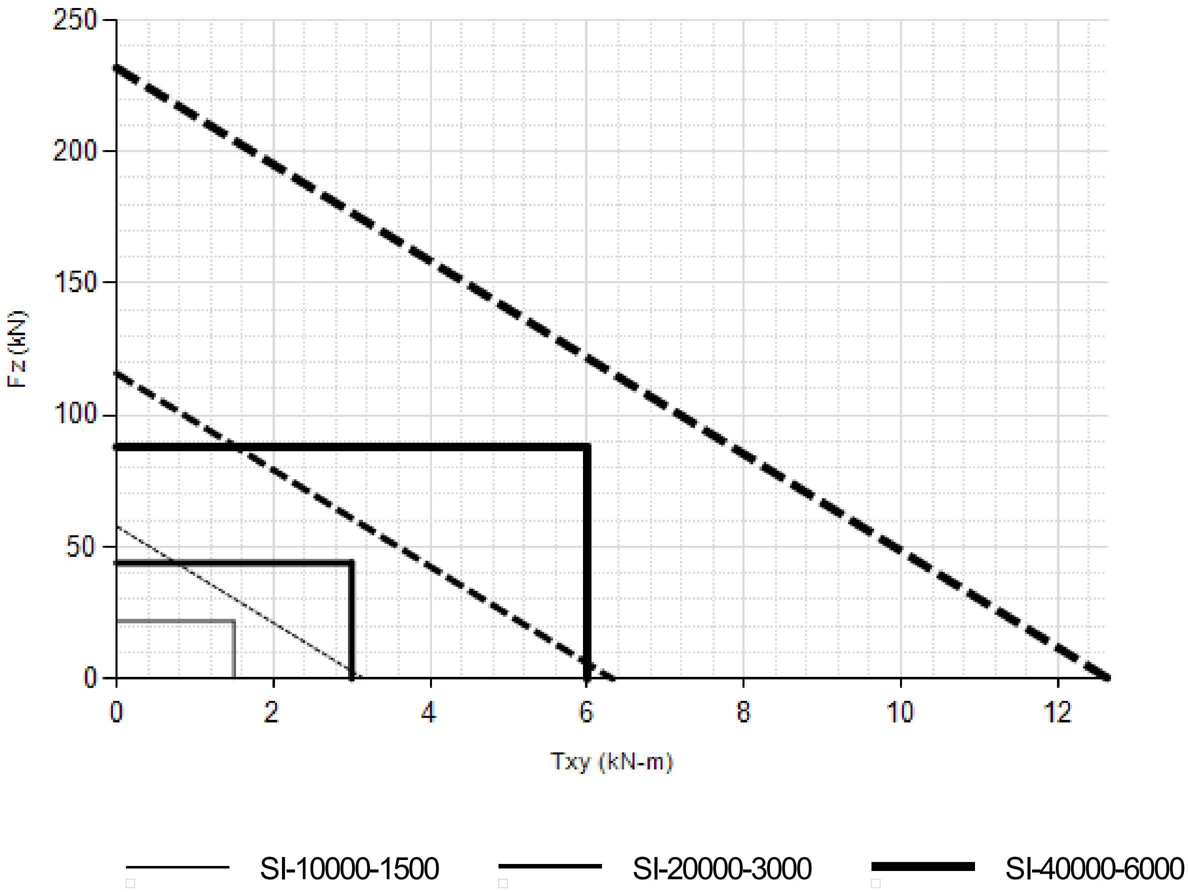
5.20.6 Omega331 (US Calibration Complex Loading) (Includes IP65)



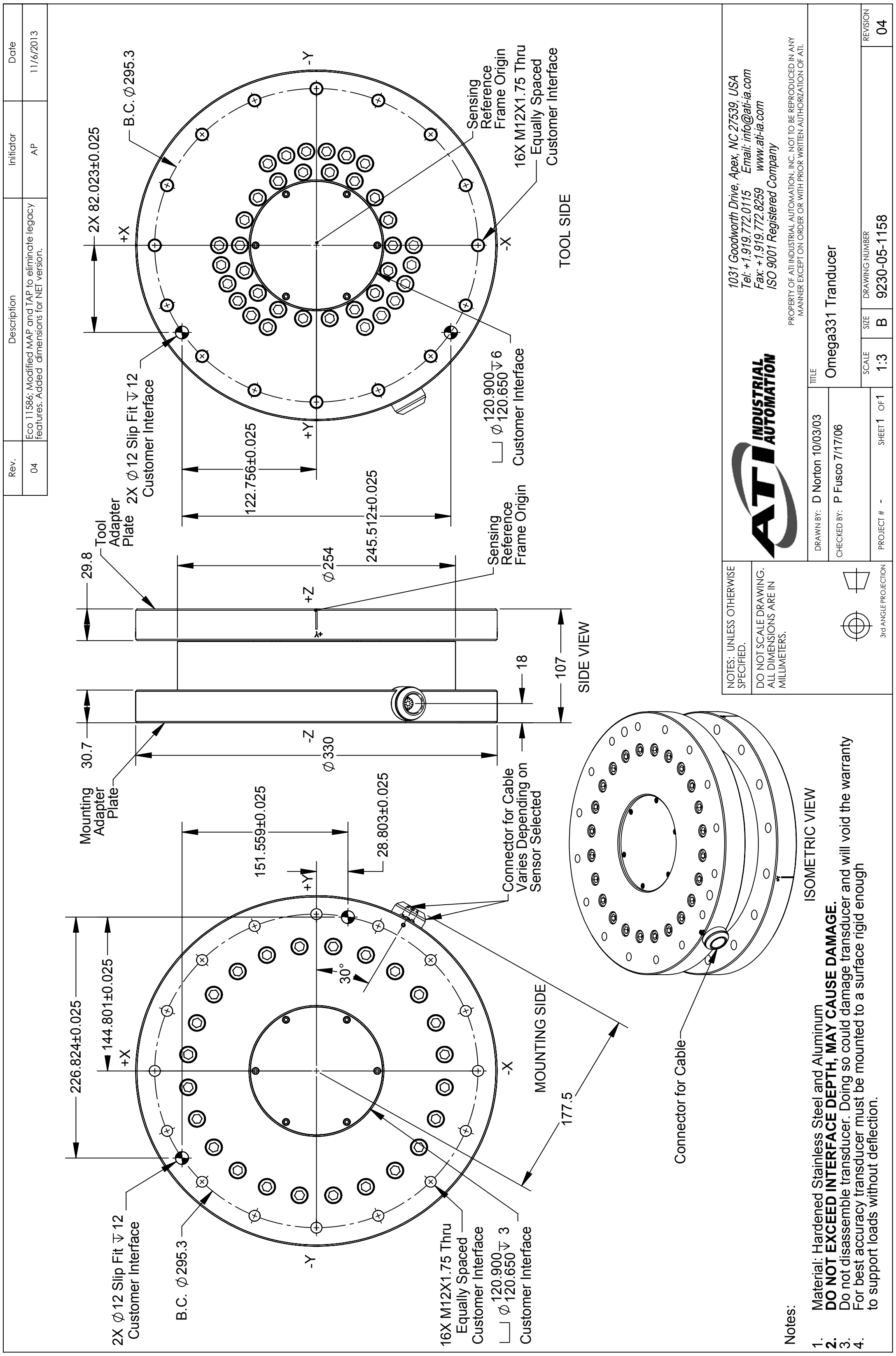


5.20.7 Omega331 (SI Calibration Complex Loading) (Includes IP65)

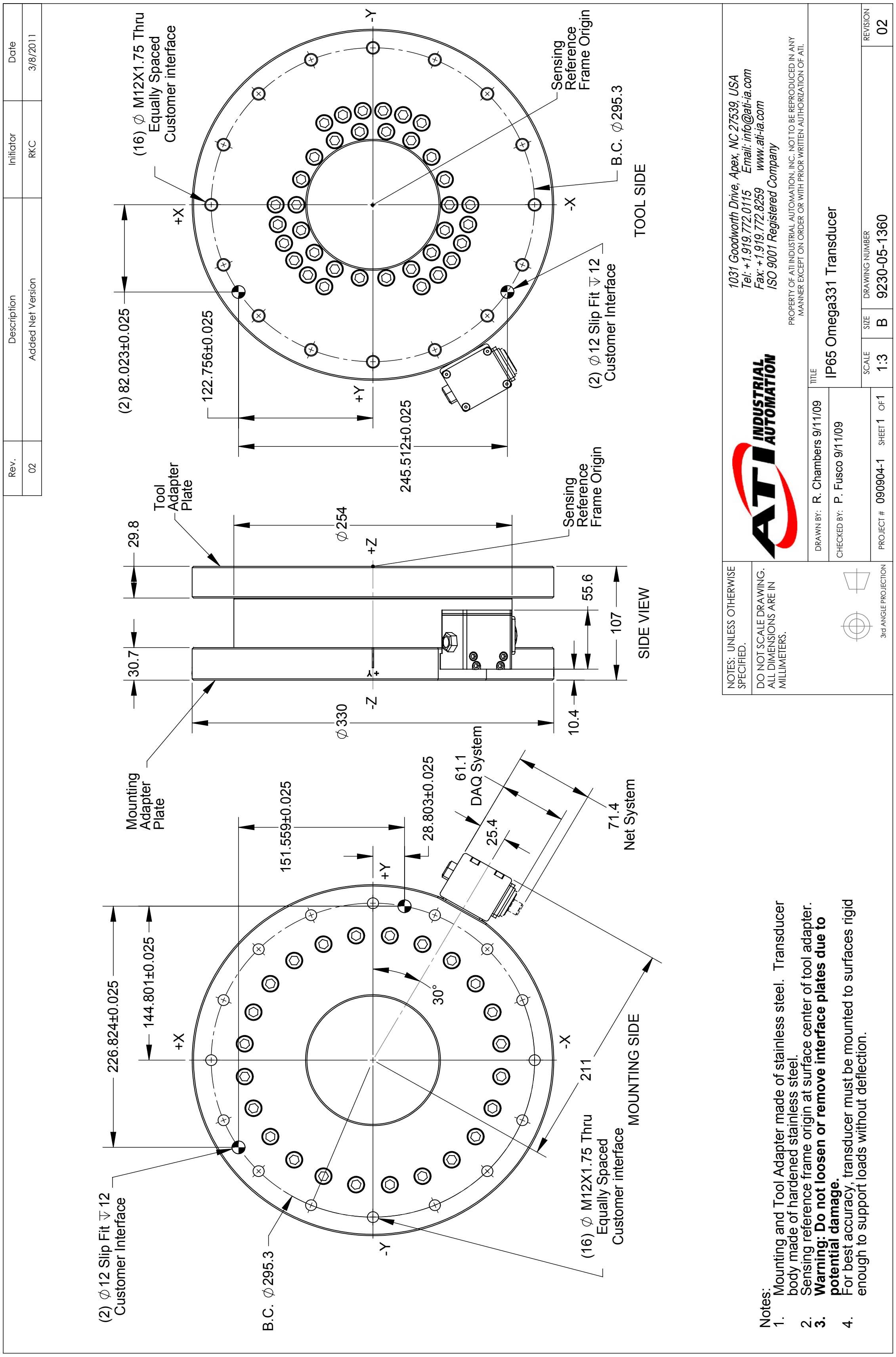




5.20.8 Omega331 Transducer Drawing



5.20.9 Omega331 IP65 Transducer Drawing



6. Advanced Topics

6.1 Reducing Noise

6.1.1 Mechanical Vibration

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

6.1.2 Electrical Interference

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

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

6.2 Detecting Failures (Diagnostics)

6.2.1 Detecting Sensitivity Changes

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

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

Record the output readings.

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

Record the second set of output readings.

Find the differences from the first and second set of readings and use it as your sensitivity value.

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

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

6.3 Scheduled Maintenance

6.3.1 Periodic Inspection

For most applications, there are no parts that need to be replaced during normal operation. With industrial-type applications that continuously or frequently move the system's cabling, you should periodically check the cable jacket for signs of wear. These applications should implement the procedures discussed in Section 5.2—Detecting Failures (Diagnostics) to detect any failures.

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

6.3.2 Periodic Calibration

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

6.4 Transducer Cabling

6.4.1 Calibrations

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

6.4.2 Cabling and Connectors

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

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

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

6.5 Resolution

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

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

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

7. Terms and Conditions of Sale

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

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

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

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

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

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

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

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