Manual, EtherCAT Axia F/T Sensor

Document #: 9610-05-EtherCAT Axia

Engineered Products for Robotic Productivity
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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.

FCC Compliance-Class A

This devices 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.

Any modifications to the device could impact compliance. It is the user's responsibility to certify the device remains compliant after modifications.

"Electromagnetic Compatibility"

This device complies with EMC Directive 2014/30/EU and conforms to the following standards: EN61000-6-4 CISPR 16-2-3, IEC/EN61000-4-2, IEC/EN61000-4-3, IEC/EN61000-4-4, IEC/EN61000-4-5, IEC/EN61000-4-6, IEC/EN61000-4-8, IEC/EN61000-4-11.

RoHS Compliance

This product conforms to EU Directive CE 2011/65/EU (RoHS).

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., Axia, etc.)
3. Calibration (e.g., US-120-95, etc.)
4. Accurate and complete description of the question or problem
5. Computer and software information. Operating system, PC type, drivers, application software, and other relevant information about your configuration.

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

How to Reach Us

Sale, Service and Information about ATI products:

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Statement of Compliance

Order Number: 11910248 Project Number: R11910248-EMC Page 2 of 69
Model Number: 9105-ECAT-AXIA80
Client Name: ATI Industrial Automation Issued: 2017-08-30

Test Report Details

Tests Performed By:	**UL LLC** **12 Laboratory Dr.** **Research Triangle Park, NC 27709**
Tests Performed For:	**ATI Industrial Automation** **1031 Goodworth Drive** **Apex, NC, 27539, USA**
Applicant Contact: Phone: E-mail:	**Michael Coyle** **919-772-0115** **mcoyle@ati-ia.com**
Test Report Date:	**2017-08-30**
Product Type:	**Force/Torque Transducer**
Product standards	**EN61000-6-4, EN61000-6-2, CFR 47 FCC Part 15 Subpart B**
Model Number:	**9105-ECAT-AXIA80**
Sample Serial Number:	**Non-serialized**
EUT Category:	**Industrial Control - Heavy Industry**
Testing Start Date:	**2017-08-16**
Date Testing Complete:	**2017-08-18**
Overall Results:	**Compliant**

UL LLC reports apply only to the specific samples tested under stated test conditions. All samples tested were in good operating condition throughout the entire test program. It is the manufacturer's responsibility to assure that additional production units of this model are manufactured with identical electrical and mechanical components. UL LLC shall have no liability for any deductions, inferences or generalizations drawn by the client or others from UL LLC issued reports. This report must not be used by the client to claim product certification, approval, or endorsement by NVLAP, NIST, or any agency of the U.S. Government.

This report may contain test results that are not covered by the NVLAP or A2LA accreditation. The scope of accreditation is limited to the specific tests that are listed on the NVLAP and/or A2LA websites referenced at the end of this report.

UL LLC | 12 Laboratory Dr. | Research Triangle Park, NC 27709 USA | Tel.: 919 549-1400 | Rev. No 1.0
EMC Report 2012-87-EM-F0042

Table of Contents

Glossary

Term	Definition
Accuracy	See Measurement Uncertainty.
ADC	Analog-to-digital converter.
Calibration	The factory-supplied data that is used by the EtherCAT Axia sensor so that it can report accurate sensor readings. Calibrations are specific to a given loading range.
Calibration Certificate	A statement that says the equipment measures correctly. These statements mean the equipment has been tested against national standards. The statements are produced as a result of calibration or re-calibration.
CoE	CANopen over EtherCAT is the preferred embedded protocol for configuring EtherCAT devices. Used within SDO to encode the configuration data.
Complex Loading	Any load that is not purely in one axis.
Coordinate Frame	See point of origin.
Data Rate	How fast data can be output over a network.
DINT	A 32-bit data type representing a signed integer.
DoF	Degrees of freedom. See six degrees of freedom.
EtherCAT	An industrial automation fieldbus.
FoE	File access over EtherCAT, the preferred embedded protocol for uploading new firmware to EtherCAT devices.
Force	The push or pull exerted on an object.
FS	Full-Scale.
F/T	Force/Torque.
F/T Sensor	The device that converts force and torque into an electrical signal.
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).
Hysteresis	A source of measurement error caused by the residual effects of previously applied loads.
IP64	Ingress protection rating “64” designates protection against dust and splashing of water.
ISR	Interrupt service routine.
Maximum Single-Axis Overload	The largest amount of load in a single axis (all other axes are unloaded) that the sensor can withstand without damage.
Measurement Uncertainty	The maximum expected error in measurements, as specified on the calibration certificate.
Moment	An object that receives a torque has a moment applied to that object.
Offset Compensation	Correction of errors that change the zero point of a sensor’s readings.
Overload	The condition where more load is applied to the sensor than the rated measurement range. Overloads result in reduced accuracy and potentially reduced sensor life.

Term	Definition
PDO	Process Data Object, a protocol for reading and writing real-time process information cyclically.
Point of Origin	The physical location from which the sensor measures all forces and torques.
Quantization	The way the continuously variable sensor signal is converted into discrete 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. For example, if a user twists a screw or bolt but the fastener does not move. ATI sensors detect reaction torque.
Re-Calibration	The periodic verification of measurement equipment, like sensors, 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 that results in something moving. Generally this refers to the torque on things like drive shafts. ATI sensors cannot detect rotational torque.
Sample Rate	How often the sensor reads the applied forces and torques.
SDO	Service Data Object, a protocol for reading and writing configuration information acyclically.
Sensor	The sensor is the component that converts the detected load into electrical signals.
Six Degrees of Freedom	Fx, Fy, Fz, Tx, Ty, and Tz.
SG	Strain Gage.
STRING(8)	A data type representing (8) characters, using (8) bytes.
STRING(30)	A data type representing (30) characters, using (30) bytes.
Torque	The measurement of force exerted on an object causing it to rotate.
Txy	The resultant torque vector comprised of components Tx and Ty.
UDINT	A (32) bit data type representing an unsigned integer.
UINT	A (16) bit data type representing an unsigned integer.
USINT	An (8) bit data type representing an unsigned integer.

1. Safety

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

1.1 Explanation of Notifications

The following notifications 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, installing, or setting up the product that if not followed could result in damage to equipment. The notification can emphasize, but is not limited to: specific grease types, best operating practices, and maintenance tips.

1.2 General Safety Guidelines

The customer should verify that the sensor selected is rated for maximum loads and torques expected during operation. Because static forces are less than the dynamic forces from the acceleration or declaration of the robot, be aware of the dynamic loads caused by the robot.

1.3 Safety Precautions

CAUTION: Modifying or disassembly of the sensor could cause damage and void the warranty.

CAUTION: Probing openings in the sensor causes damage to the instrumentation. Avoid prying into openings of the sensor.

CAUTION: Do not overload the sensor. Exceeding the single-axis overload values of the sensor, causes irreparable damage.

CAUTION: Do not contact the IP64 seal. Contacting the seal can cause the sensor to malfunction.

CAUTION: The sensor should be protected from impact and shock loads that exceed rated ranges during transport as the impacts can damage the sensor's performance. Refer to *Section 8—Specifications* for more information about rated ranges.

2. Product Overview

The EtherCAT Axia F/T sensor system measures (6) components of force and torque (Fx, Fy, Fz, Tx, Ty, Tz) and streams data to customer devices that use EtherCAT fieldbus. Refer to *Section 5.1—PDO Interface*.

The mounting side attaches to a mounting interface plate, which mounts to the customer robot. The tool side attaches to the customer tooling. Both the mounting and tool sides have a 71.12 mm bolt circle pattern with (6) M5 tapped holes. Refer *Section 9—Drawings* for more information. The sensor is IP64 rated. A M8 6-pin male connector is for power and EtherCAT. For the pin assignments, refer to *Section 3.5—Pin Assignment for the EtherCAT and Power Connection*.

The Axia sensor provides the following features:

- Resolved force and torque data (refer to *Section 5.1—PDO Interface*).
- Set bias and clear bias.
- Programmable low-pass filtering.
- LED indicator for Run, EtherCAT Link, and Sensor Status. Refer to *Section 2.1—LED Self-Test Sequence and Functions* for more information.

Figure 2.1—EtherCAT Axia F/T Sensor

2.1 LED Self-Test Sequence and Functions

The EtherCAT F/T provides (3) LEDs for EtherCAT Link, Run, and Sensor Status. When the user applies power, the sensor completes a self-test, during which the LEDs under firmware control individually turn on.

2.1.1 LED Self-Test Sequence

When the user applies power to the sensor, the sensor completes a self-test, during which the LEDs under firmware control individually turn on in the following sequence:

Sequence Order	LED	State	Duration
1	Sensor Status	Red	Approximately one second for each LED.
2	Run	Red	
3	EtherCAT Link/Activity	Red	
4	Sensor Status	Green	
5	EtherCAT Link/Activity	Green	
Note: 1. The Green Run LED is not tested in the self-test sequence.			

2.1.2 EtherCAT Link/Activity LED

One LED signals link/activity on the EtherCAT port as follows:

LED State	Link	Activity	Condition
Off	No	No	No EtherCAT connection.
Green	Yes	No	EtherCAT link/activity is detected.
		Yes[1]	
Note: 1. This LED behavior is different from the standard EtherCAT device Link/Activity LED behavior, which is a flashing green LED.			

2.1.3 Run LED

One LED signals the communication status of the EtherCAT sensor interface as follows:

LED State	Description
Off	EtherCAT interface is in the state “INIT”.
Flashing green	EtherCAT interface is in the state “Preoperational”.
Green	EtherCAT interface is in the state “Operational”.

2.1.4 Sensor Status LED

One LED signals the health status of the sensor as follows:

LED State	Description
Off	No power.
Green	Normal operation. The sensor’s electronics are functioning and communicating.
Flashing green	Power-up self testing. At power-up, the sensor completes diagnostic testing to verify internal electronics are functioning.
Amber	Sensing range exceeded.
Red	System error.

3. Installation

WARNING: Performing maintenance or repair on the sensor when circuits (e.g. power, water, and air) are energized could result in death or serious injury. Discharge and verify all energized circuits are de-energized in accordance with the customer's safety practices and policies.

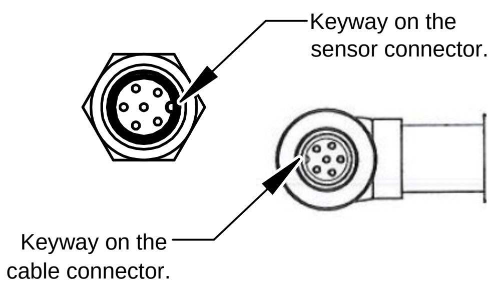
CAUTION: Modification or disassembly of the sensor could cause damage and void the warranty. Use the supplied mounting bolt pattern and the provided tool side mounting bolt pattern to mount the sensor to the robot and customer tooling to the sensor. Refer to *Section 9—Drawings* for more information.

CAUTION: Using fasteners that exceed the customer interface depth penetrates the body of the sensor, damages the electronics, and voids the warranty. Refer to *Section 9—Drawings* for more information.

CAUTION: Thread locker applied to fasteners must not be used more than once. Fasteners may become loose and cause equipment damage. Always apply new thread locker when reusing fasteners.

CAUTION: Avoid damage to the sensor from Electro-Static Discharge. Ensure proper grounding procedures are followed when handling the sensor or cables connected to the sensor. Failure to follow proper grounding procedures could damage the sensor.

CAUTION: Do not apply excessive force to the sensor and cable connector during installation, or damage will occur to the connectors. Align the keyway on the sensor and cable connector during installation to avoid applying excessive force to the connectors.



NOTICE: Depending on the maintenance or repair being performed, utilities to the sensor may not need to be disconnected.

3.1 Interface Plates

The sensor's mounting side attaches to the robot arm, and the sensor's tool side attaches to the customer tooling. If interface plate(s) are required, ATI can supply custom robot mounting and tool interface plates. Refer to *Section 9—Drawings* of this manual for technical information on the sensor's mounting features.

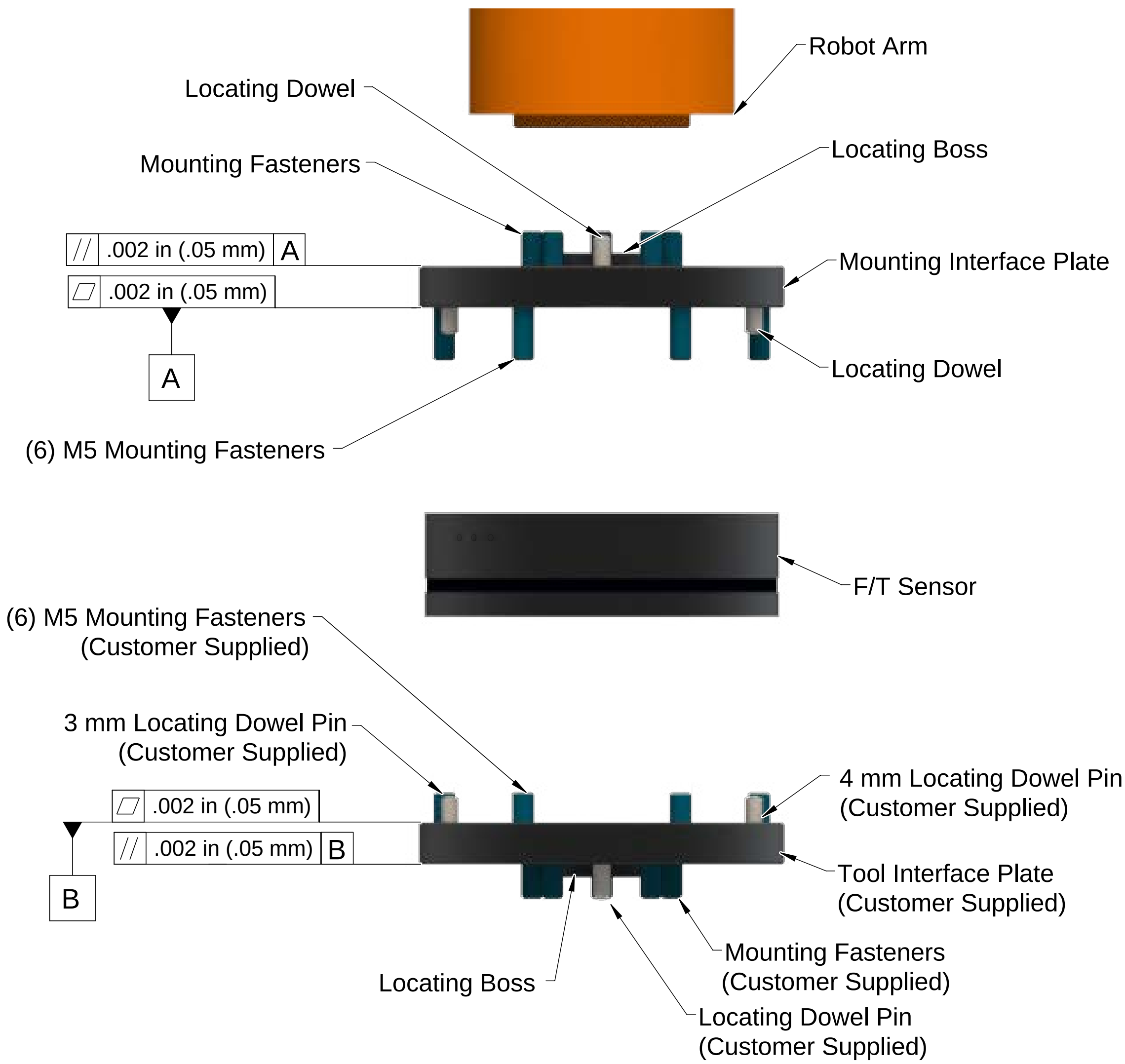
CAUTION: Incorrect installation of robot mounting and tool interface plates will result in the failure of the F/T sensor to function properly. Because the mounting and tool sides of the sensor have identical bolt patterns, verify the robot mounting and tool interface plates are installed correctly.

CAUTION: The customer tool should only touch the tool interface plate. If the customer tool touches any other part of the sensor, it will not properly sense loads.

If the customer chooses to design and build an adapter plate(s), the following points should be considered:

- The interface plate(s) should include bolt holes for mounting fasteners as well as dowel pin(s) and a boss for accurate positioning to the robot or customer's device.
- The thickness of the interface plate(s) must provide sufficient thread engagement for the mounting fasteners.
- The mounting fasteners should not extend through the sensor's housing or interfere with the internal electronics. Refer to *Section 9—Drawings* for thread depth, mounting patterns, and other details.
- Do not use dowel pin(s) that exceed length requirements and prevent the interface plate(s) from mating flush with the robot and customer tooling. Fasteners that exceed length requirements create a gap between the interfacing surfaces and cause damage.
- The interface plate(s) must not distort from the maximum force and torque values that can be applied to the sensor. For these values, refer to *Section 8—Specifications*.
- The interface plate(s) must provide a flat and parallel mounting surface for the sensor.

Figure 3.1 —Adapter Plate(s)

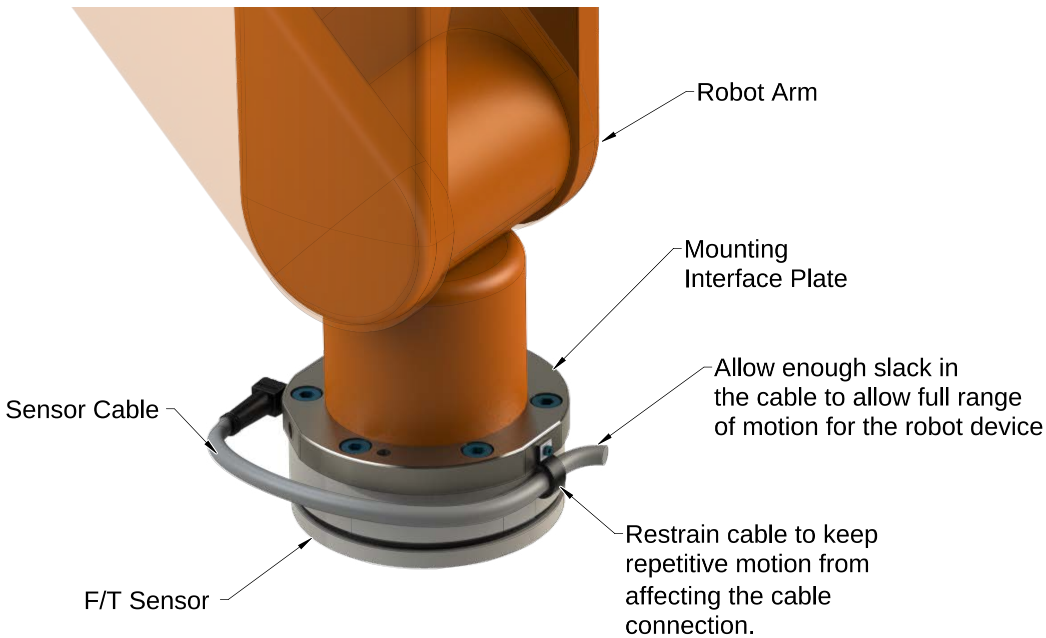


3.2 Routing the Cable

The routing and bending radius of the cable depends upon the customer application. Unlike motionless applications, where the cable is in a static condition, dynamic applications subject the cable to a repetitive motion. For dynamic applications, restrain the cable at a distance that does not expose and damage the sensor's cable connection from the robot's repetitive motion.

NOTICE: The maximum supported cable length is 25 m.

Figure 3.2—Routing of the Sensor Cable



CAUTION: Do not subject the sensor's 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 so that the repetitive motion of the robot does not interfere with the cable connector.

CAUTION: The cable must withstand the repetitive motions of the robot without failing. The electrical line, especially where attached to the sensor's connector, must be routed to avoid stress failure, sharp bends, or a disconnection from the equipment. Improper routing may cause poor functionality of critical electrical lines, injury to personnel, or damage to equipment. Damage to the sensor or cable from improper routing will void the warranty. If the application results in cable rubbing, use a loose, plastic spiral wrap for protection.

CAUTION: When routing cables do not bend less than the minimum bending radius specified in *Table 3.1*. A bend radius too small causes the cable to fail from fatigue of the robot's repetitive motion.

Table 3.1—Sensor Cable Bending Radius and Dynamic Twist Angle							
Cable Part Number	**Spliced Cable Branch Description**	**Cable Diameter mm (in)**	**Static Bending Radius (at room temperature)**		**Dynamic Bending Radius (at room temperature)**		**Dynamic Cable Twist Angle per Unit Length**
			mm	**in**	**mm**	**in**	
9105-C-ZC22-ZC26-X	N/A	6.2 (.24)	31	1.2	62	2.4	180°/m or 55°/ft
9105-C-ZC26-U-RJ45S-X	Branch 1, Power	5.1 (.20)	25.5	1	51	2	
	Branch 2, EtherCAT	5.7 (.22)	28.5	1.1	57	2.2	

Notes:

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

The 6-pin connector on the 9105-C-ZC22-ZC26-X power and EtherCAT cable attaches to the sensor's connector. The 9105-C-ZC26-U-RJ45S-X 8-pin connector attaches to the 9105-C-CZ22-ZC26-X power and EtherCAT cable, of which branch 1 is an unterminated end for connection to power and branch 2 has a RJ45 connection for EtherCAT.

Route the sensor cable so that it is not stressed, pulled, kinked, cut, or otherwise damaged throughout the full range of motion. If the application causes cable abrasion, use a loose plastic, spiral wrap to protect the outer cable jacket material.

CAUTION: Do not damage or crush the cable by over tightening tie wraps on the cable.

3.3 Installing the Sensor to the Robot

Parts required: *Refer to Figure 3.3 and Section 9—Drawings.*

Tools required: *4 mm hex wrench*

Supplies required: *Clean rag, Loctite® 242 (if applicable, refer to step 3 and 4)*

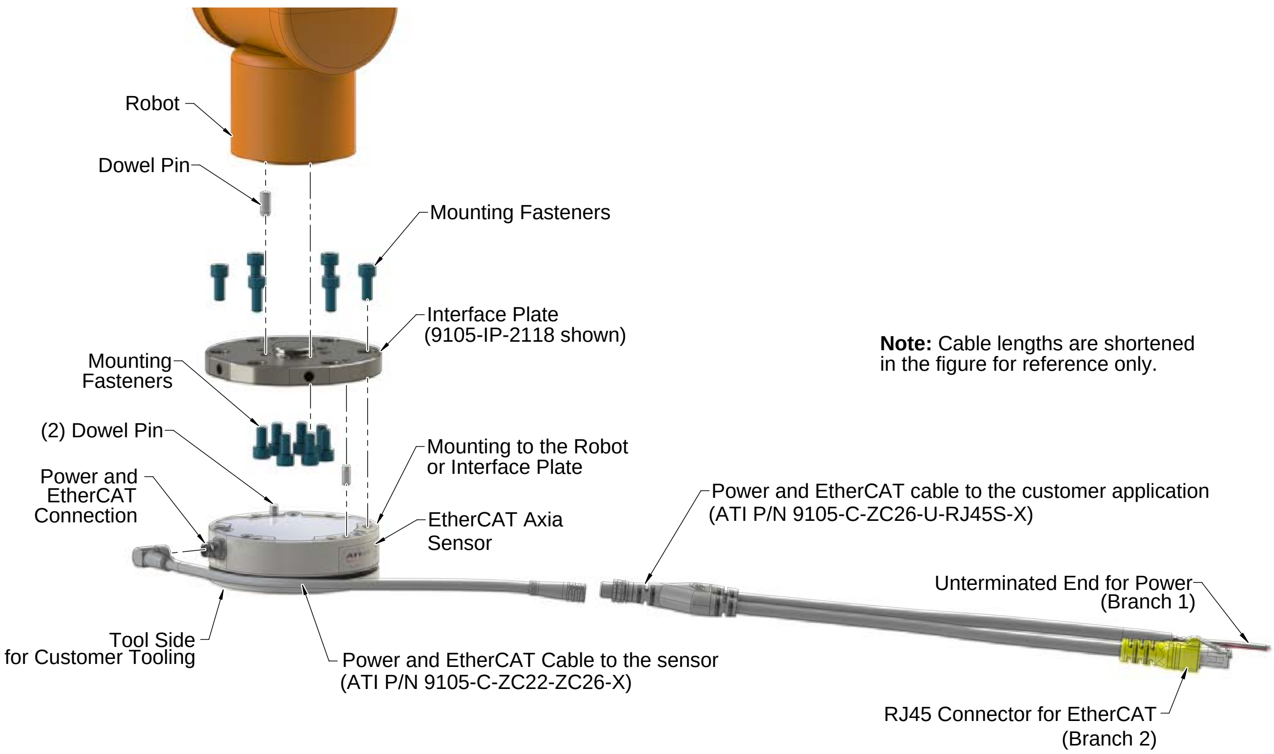
1. Ensure the mounting surface of the mounting adapter plate and robot are clean and free of debris.
2. Attach the mounting interface plate to the robot arm with the mounting fasteners.
3. Attach the sensor to the mounting adapter plate.
    - Screws to have a minimum thread engagement length of 4.5 mm with a maximum thread engagement less than the threaded depth listed in the customer drawing *Section 9—Drawings*.
    - If the sensor is to be used in a high-vibration environment, Loctite 242 should be applied to the (6) M5 socket head cap screws, class 12.9 so that the fasteners secure the sensor to the mounting plate.

    a. Using a 4 mm Allen wrench, secure the sensor to the mounting adapter plate with the (6) M5 socket head cap screws, class 12.9. Tighten to 52 in-lbs (5.88 Nm).
4. Once the sensor is installed on the robot, the customer tooling or tool interface plate can be installed.
    - Screws to have a minimum thread engagement length of 4.5 mm with a maximum thread engagement less than the threaded depth listed in the customer drawing *Section 9—Drawings*.
    - If the sensor is to be used in a high-vibration environment, Loctite 242 should be applied to the fasteners so that the fasteners secure the customer tooling to the sensor.

NOTICE: The tool must not touch any other part of the sensor except the tool side; otherwise, the sensor does not properly detect loads.

5. Connect the cable(s) to the sensor and customer application.
   a. Connect a power and EtherCAT cable (ATI P/N 9105-C-ZC22-ZC26-X) to the sensor's connection. Tighten to 4.43 in-lbs (0.5 Nm).
   b. Connect the branched cable (ATI P/N 9105-C-ZC26-U-RJ45S-X) to the cable from step *a*. Tighten to 7.08 in-lbs (0.8 Nm).
   c. Connect the RJ45 and power connections to the customer application. Refer to *Section 2.1.1—LED Self-Test Sequence* for the LED outputs that occur whenever power is supplied to the sensor.
6. Properly restrain and route the power and EtherCAT cable; refer to *Section 3.2—Routing the Cable*.
7. After installation is complete, the sensor is ready for an accuracy check as described in *Section 3.6—Accuracy Check Procedure* and then normal use.

Figure 3.3—Installation of the Sensor to the Robot



3.4 Removing the Sensor from the Robot

Tools required: *4 mm hex wrench*

1. Turn off all energized circuits (e.g. electrical).
2. Remove the power and EtherCAT cable from the sensor's connection.
3. Supporting the customer tooling and/or interface plate, remove the customer supplied screws that attach to the customer tooling to the sensor.
4. Supporting the sensor, use a hex wrench to loosen the (6) M5 socket head cap screws that secure to the sensor to the mounting interface plate or robot.
5. Remove the sensor.

3.5 Pin Assignment for the EtherCAT and Power Connection

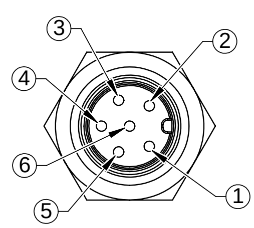
CAUTION: Ensure the cable shield is properly grounded. Improper shielding on the cables can cause communication errors and inoperative sensors.

The following section provides the pin assignment for the power and EtherCAT connection on the sensor, the 8-pin male M12 connector on the power and EtherCAT cable (P/N 9105-C-ZC22-ZC26-X), and the unterminated end on cable (P/N 9105-C-ZC26-U-RJ45S-X) for power. Refer to the following table or *Section 8.2—Electrical Specifications* for supply voltage ratings.

Table 3.2—Power Supply[1]		
Power Source	**Voltage**	**Maximum Power Consumption**
DC Power	12 V min. to 30 V max.	1.5 W
Notes: 1. The power supply input is protected from a reversed polarity circuit.		

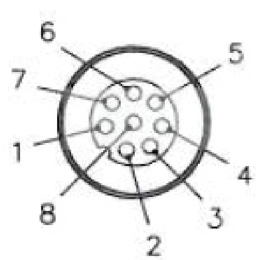
3.5.1 Pin Assignment for the 6-pin M8 Male Connector on the Sensor

The following table details the signals and corresponding pin numbers on the M8 connector (ZC26) for power and EtherCAT.

Table 3.3—Pin Assignment for the 6-pin, M8, Male Sensor Connector (Power and EtherCAT)		
Connector Schematic	**Pin Number**	**Signal**
	1	TX+
	2	TX-
	3	RX+
	4	RX-
	5	V +
	6	V -

3.5.2 Pin Assignment for the 8-Pin M12 Male Connector on Cable P/N 9105-C-ZC22-ZC26-X

The following table details the signals and corresponding pin numbers for the 8-pin M12 connector (ZC22) on cable P/N 9105-C-ZC22-ZC26-X that connects to cable P/N 9105-C-ZC26-U-RJ45S-X.

Table 3.4—Cable P/N 9105-C-ZC22-ZC26-X Pin Assignment for the 8-pin, M12, Male Connector (Power and EtherCAT)		
Connector Schematic	**Pin Number**	**Signal**
	1	Shield
	2	V +
	3	V -
	4	TX-
	5	RX+
	6	TX+
	7	No Connection
	8	RX-

3.5.3 Pin Assignment for Cable P/N 9105-C-ZC26-U-RJ45S-X, Branch 1, Unterminated End for Power Connection

The following table details the signals and corresponding pin numbers for unterminated wires on cable P/N 9105-C-ZC26-U-RJ45S-X that connects to the customer's device.

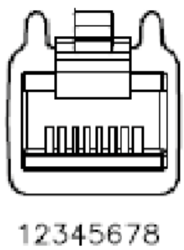
Table 3.5—Cable 9105-C-ZC26-U-RJ45S-X, Branch 1, Unterminated Pin Assignment

Pin Number	Wire Jacket Color	Signal
1	-	Shield
2	Black	V +
3	White	V -

3.5.4 Pin Assignment for Cable P/N 9105-C-ZC26-U-RJ45S-X, Branch 2, RJ45 Connection

The following table details the signals and corresponding pin numbers for the 8-pin RJ45 connector on cable P/N 9105-C-ZC26-U-RJ45S-X that connects to the customer device.

Table 3.6—Cable P/N 9105-C-ZC22-ZC26-X Pin Assignment for the 8-pin, RJ45 Connector

Connector Schematic	Pin Number	Wire Color	Signal
	1	White/Orange	TX+
	2	Orange	TX-
	3	White/Green	RX+
	4	-	No Connection
	5	-	No Connection
	6	Green	RX-
	7	-	No Connection
	8	-	No Connection

3.6 Accuracy Check Procedure

Complete the following procedures after the initial installation of the sensor to the robot and once annually for maintenance.

1. Attach a fixed mass to the tool side of the F/T sensor.
    - The mass on the tool side can be the weight of the tooling used in an application.

    a. Remove cables that form bridges between the sensor's mounting and tool sides.

2. Move the robot so that the sensor is in the following positions.

    a. Record the sensor's output, F_x F_y F_z, at each point without biasing.
    - Point 1: +Z up
    - Point 2: +X up
    - Point 3: +Y up
    - Point 4: -X up
    - Point 5: -Y up
    - Point 6: -Z up

3. Find $F_{x,\ average}$, $F_{y,\ average}$, and $F_{z,\ average}$.

    a. Perform the following equations.

$$F_{x,average} = \frac{F_{x,point\ 1} + F_{x,point\ 2} + \cdots + F_{x,point\ 6}}{6}$$

$$F_{y,average} = \frac{F_{y,point\ 1} + F_{y,point\ 2} + \cdots + F_{y,point\ 6}}{6}$$

$$F_{z,average} = \frac{F_{z,point\ 1} + F_{z,point\ 2} + \cdots + F_{z,point\ 6}}{6}$$

4. For each of the 6 points, complete the following calculation:

$$F_x = F_{x,point\ n} - F_{x,average}$$

$$F_y = F_{y,point\ n} - F_{y,average}$$

$$F_z = F_{z,point\ n} - F_{z,average}$$

$$\text{Tooling Mass} = \sqrt{{F_x}^2 + {F_y}^2 + {F_x}^2}$$

5. The calculated tooling masses for all (6) points should deviate from each other by less than twice the worst accuracy rating of the sensor. The worst accuracy rating for the Axia sensor is 36 N.
    - For example: max (tooling masses) - min (tooling masses) < 36 N
    - In addition, the tooling mass should be within 36 N of the results of this test when it was performed with a new sensor.
    - If this test fails, then the sensor should be returned to ATI for diagnosis or recalibration.

4. Operation

The following section provides information required when using software to operate the EtherCAT Sensor. Communicating with the EtherCAT sensor requires knowledge of EtherCAT standards and operation.

4.1 Sensor Environment

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

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

The user must ensure that the dust and water in the environment does not exceed the IP64 rating of the sensor.

4.2 Sample Rate

The "Sample Rate" field in *Section 5.2.8—Object 0x7010: Control Codes* controls how fast the ADCs are sampling inside the sensor. The following table lists the rounded and exact sample rates.

Table 4.1—Sample Rate				
Rounded Sample Rate	0.5 kHz	1 kHz	2 kHz	4 kHz
Exact Sample Rate	487 Hz	975 Hz	1990 Hz	3900 Hz

4.2.1 Sample Rate Versus Data Rate

The data rate is how fast data can be output over the EtherCAT network.

If the data rate is faster than the sample rate, the customer sees duplicate samples output over the network until the next sample is read internally. A faster data rate could be useful so that the sensor sends data at the same rate that other devices in a customer's system are outputting. For example: if a discrete I/O device on the same network as the Axia is outputting data at 7,000 Hz, the customer may want the Axia to be outputting data to the network at 7,000 Hz as well, even though the sensor is not sampling that quickly internally.

If the sample rate is faster than the data rate, the customer does not receive the data from every internal sample over the network. However, any filters that are enabled work based on the faster internal sample rate, and so, the sensor filters out higher frequency noise sources than if the filter is operating at a slower data rate.

4.3 Low-pass Filter

The power-on default selection is no filtering. The "Filter Selection" field in *Section 5.2.8—Object 0x7010: Control Codes* controls the current filter selection. The cutoff frequency (i.e. -3 dB frequency) is dependent on the sample rate selection, which is defined in *Section 4.2—Sample Rate*. The cutoff frequencies for the different sampling rates are listed in the following table and graphs:

Table 4.2—Low-Pass Filtering

Selected Filter	-3dB Cutoff Frequency (in Hz)			
	at 0.5 kHz Sample Rate	at 1 kHz Sample Rate	at 2 kHz Sample Rate	at 4 kHz Sample Rate
0	200	350	500	1000
1	58	115	235	460
2	22	45	90	180
3	10	21	43	84
4	5	10	20	40
5	2.5	5	10	20
6	1.3	3	5	10
7	0.6	1.2	2.4	4.7
8	0.3	0.7	1.4	2.7

Figure 4.1—Filter Attenuation at 0.5 kHz Sample Rate

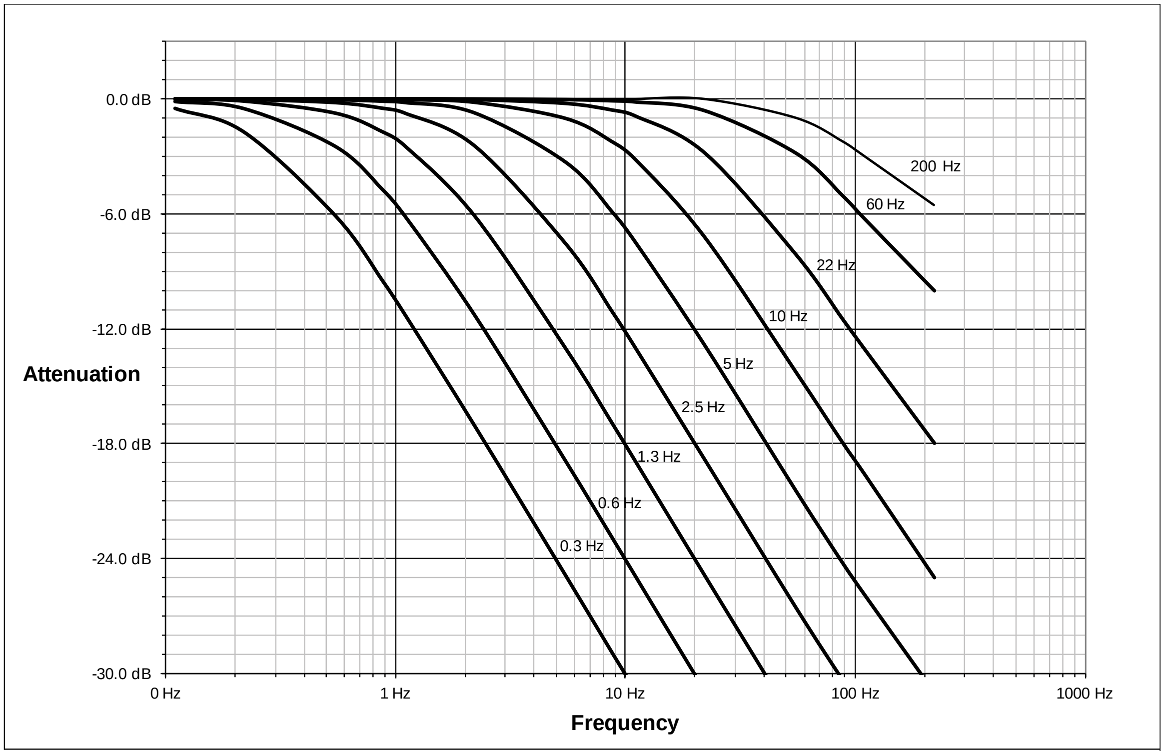


Figure 4.2—Filter Attenuation at 1 kHz Sample Rate

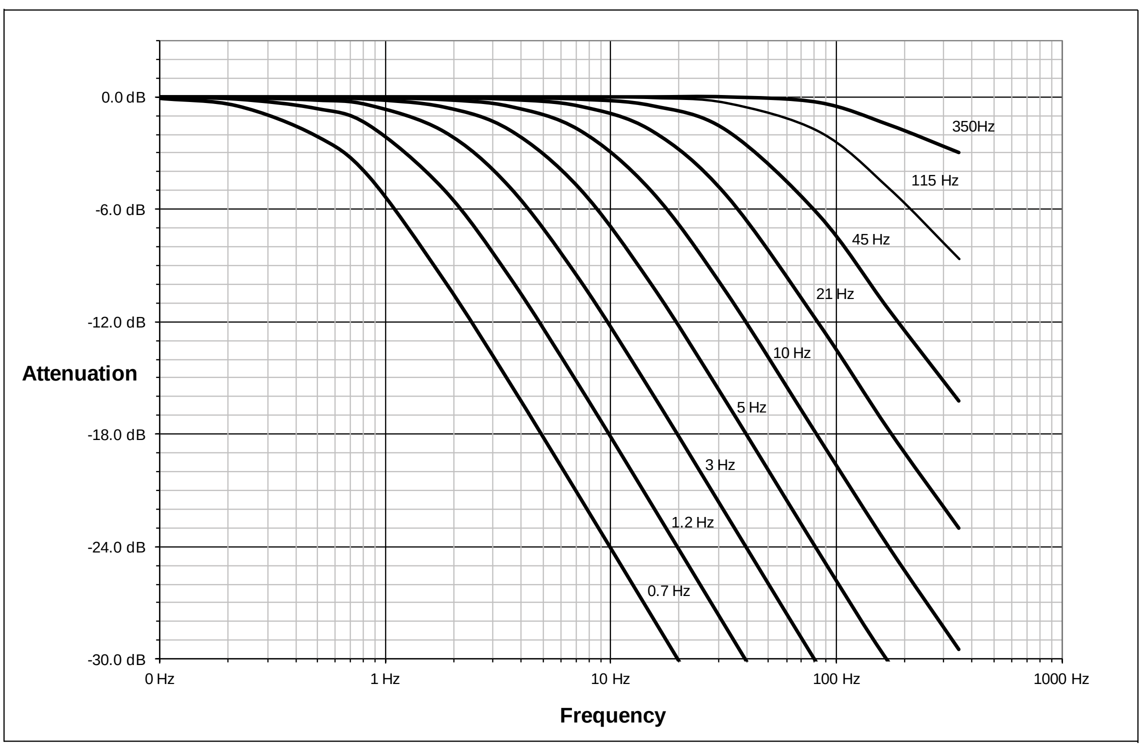


Figure 4.3—Filter Attenuation at 2 kHz Sample Rate

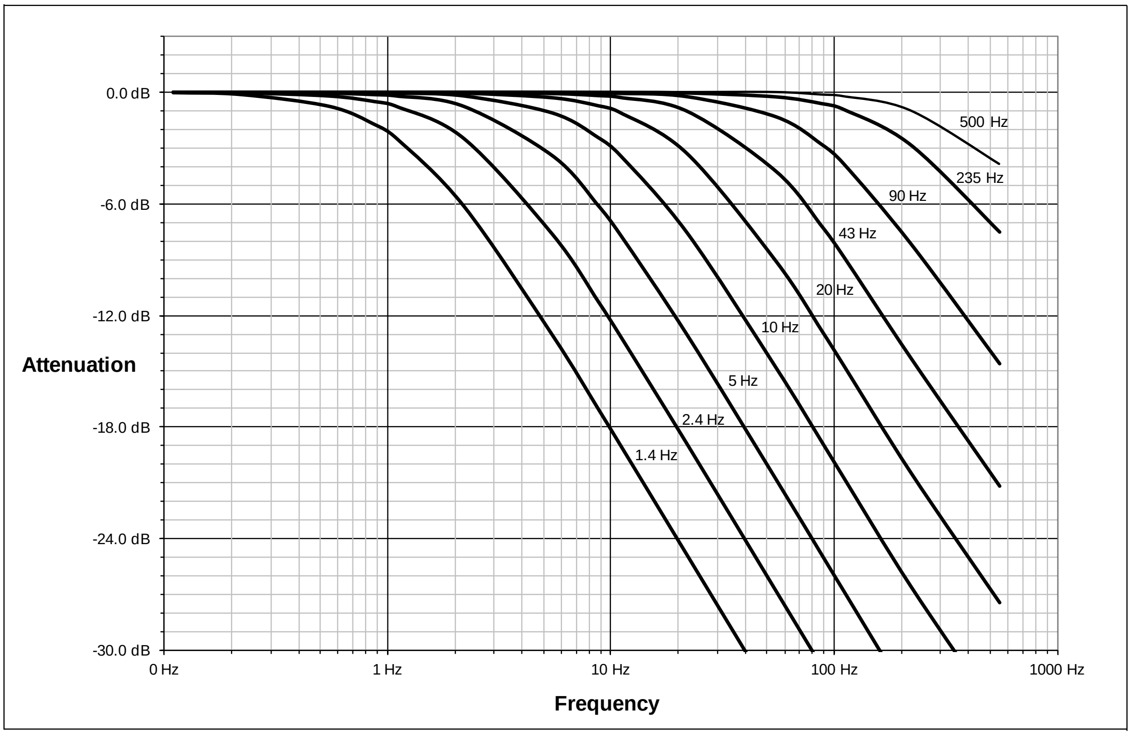
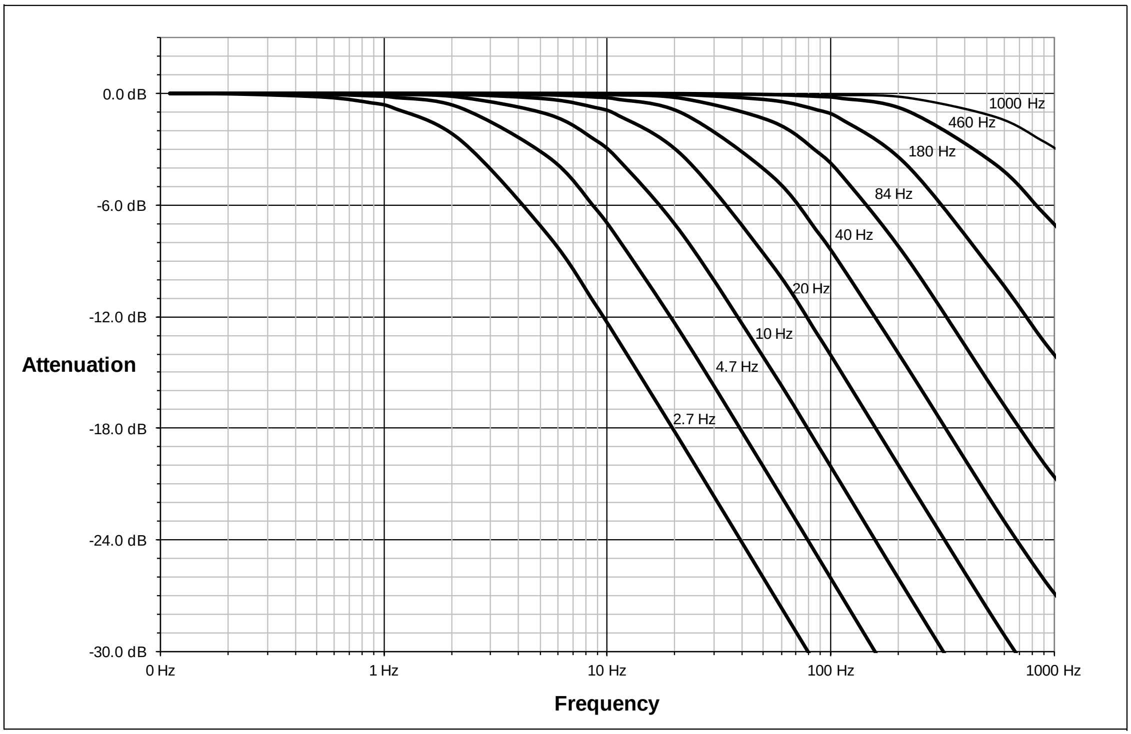


Figure 4.4—Filter Attenuation at 4 kHz Sample Rate



5. EtherCAT Bus Interface

The EtherCAT bus interface enables users to perform the following actions:

- Read the active calibration information matrix, serial number, etc.
- Read the firmware revision.
- Read force/torque data.
- Read strain gage data and status information.
- Set low-pass filter cutoff frequency.
- Bias the sensor.
- Change the sample rate.

5.1 PDO Interface

The PDO interface exchanges data in real time with the F/T sensor.

a. TxPDO Map / Output Data
The TxPDO combines *Object 0x6000: Reading Data*, *Object 0x6010: Status Code*, and *Status Code: Force/Torque Out of Range*.

b. RxPDO Map / Input Data
The RxPDO map consists of *Object 0x7010: Control Codes*.

5.2 EtherCAT Dictionary Objects (SDO Data)

The SDO data configures the sensor and reads the manufacturing and calibration data. This section lists dictionary objects specific to the EtherCAT F/T sensor application; it does not list objects that are a required part of the EtherCAT standard. These dictionary objects can also be found in the ESI file: 9031-05-1049 on the ATI website.

5.2.1 Object 0x2021: Calibration

This read-only object contains information about the currently active calibration selected by the “Calibration Selection” field in *Section 5.2.8—Object 0x7010: Control Codes*. It contains the following fields:

<table>
<tr><th colspan="5">Table 5.1—Calibration</th></tr>
<tr><th>Subindex</th><th>Name</th><th>Type</th><th colspan="2">Description</th></tr>
<tr><td>0x01</td><td>FT Serial</td><td>STRING(8)</td><td colspan="2">The FT Serial Number, e.g. “FT01234”.</td></tr>
<tr><td>0x02</td><td>Calibration Part Number</td><td>STRING(30)</td><td colspan="2">The calibration part number e.g. “SI-500-20”.</td></tr>
<tr><td>0x03</td><td>Calibration Family</td><td>STRING(8)</td><td colspan="2">Always reads “ECAT”.</td></tr>
<tr><td>0x04</td><td>Calibration Time</td><td>STRING(30)</td><td colspan="2">The date the sensor was calibrated.</td></tr>
<tr><td>0x05 through 0x2e</td><td>Reserved</td><td>DINT</td><td colspan="2">Reserved.</td></tr>
<tr><td rowspan="6">0x2f</td><td rowspan="6">Force Units</td><td rowspan="6">USINT</td><th>Value</th><th>Unit</th></tr>
<tr><td>0</td><td>Lbf</td></tr>
<tr><td>1</td><td>N</td></tr>
<tr><td>2</td><td>Klbf</td></tr>
<tr><td>3</td><td>kN</td></tr>
<tr><td>4</td><td>Kg</td></tr>
</table>

Table 5.1—Calibration				
Subindex	**Name**	**Type**	**Description**	
			Value	**Unit**
0x30	Torque Units	USINT	0	lbf-in
			1	lbf-ft
			2	Nm
			3	Nmm
			4	Kgf-cm
			5	kNm
0x31	Max Fx Counts	DINT	The maximum rated value for this axis, in counts.	
0x32	Max Fy Counts			
0x33	Max Fz Counts			
0x34	Max Tx Counts			
0x35	Max Ty Counts			
0x36	Max Tz Counts			
0x37	Counts Per Force	DINT	The calibration counts per force unit.	
0x38	Counts Per Torque	DINT	The calibration counts per torque unit.	
0x39 through 0x56	Reserved	UINT	Reserved.	
0x57	PeakLoadsPosFx	DINT	Peak Loads Positive. All-time peak positive force/torque loads in counts per unit.	
0x58	PeakLoadsPosFy			
0x59	PeakLoadsPosFz			
0x5a	PeakLoadsPosTx			
0x5b	PeakLoadsPosTy			
0x5c	PeakLoadsPosTz			
0x5d	PeakLoadsNegFx	DINT	Peak Loads Negative. All-time peak negative force/torque loads in counts per unit.	
0x5e	PeakLoadsNegFy			
0x5f	PeakLoadsNegFz			
0x60	PeakLoadsNegTx			
0x61	PeakLoadsNegTy			
0x62	PeakLoadsNegTz			
0x63 through 0x7c	Reserved.			

5.2.2 Object 0x2080: Diagnostic Readings

This read-only object provides firmware version information. The following fields are available in the version object:

Table 5.2—Diagnostic Readings

Subindex	Name	Type	Description
0x01	Supply Voltage	UINT16	The voltage of the external power supply x 10.
0x02	Gage Temperature	INT16	The sensor temperature in °C x 10.
0x03	Status Message	STRING(40)	A priority status code error message. Refer to *Table 5.3*.

Table 5.3—Errors in the Diagnostic Readings Status Message

Priority	Text Error Messages
1	Supply voltage out of range.
2	Gage temperature out of range.
3	Calibration checksum error.
4	Gage(s) disconnected: *<list>*
5	Gage(s) out-of-range: *<list>*
6	Force/torque out of range.
7	Hardware or stack error.
8	Simulated error.
9	Error (unspecified).
10	No status code errors.

5.2.3 Object 0x2090: Version

This read-only object provides firmware version information. The following fields are available in the version object:

Table 5.4—Version

Subindex	Name	Type	Description
0x01	Major	UINT	Major Version
0x02	Minor	UINT	Minor Version
0x03	Revision	UINT	Revision
0x04	Boatloader Version	UDINT	Bootloader Version

5.2.4 Object 0x6000: Reading Data

This read-only object represents the current force/torque and is mapped into the TxPDO input data. The following fields are present in the reading data:

Table 5.5—Reading Data

Subindex	Name	Type	Description
0x01	Fx	DINT	These fields contain the 32-bit F/T result data, in counts per unit.
0x02	Fy		
0x03	Fz		
0x04	Tx		
0x05	Ty		
0x06	Tz		

5.2.5 Object 0x6010: Status Code

This object contains a single DINT value (at subindex 0), with the following bitmap:

Table 5.6—Status Code		
Bit Number	**Description**	**Indicates an Error?**
0	Internal Temperature Out of Range: This bit is active (high) if the temperature is outside the range -5 to 70°C.	Yes
1	Supply Voltage Out of Range: This bit is active (high) if the input voltage is outside the range of 12 V to 30 V.	Yes
2	Broken Gage: This bit is active whenever any gage reads positive full scale and indicates that the electrical connection to the gage is open or disconnected. This bit stays high for 32 samples, after the last such sample, to allow time for the sample's effect on the data to abate.	Yes
3	Busy Bit. The sensor is performing (1) or more of the following activities that may temporarily affect the F/T data: • Committing a change to Object 0x2021. • Changing the filter time constant. • Changing the calibration in use. • Changing the ADC sampling rate. • Writing to flash memory. • Any ADC ISR overrun.	Yes
4	Reserved.	No
5	Hardware or stack error.	Yes
6-15	Reserved.	No
16-26	Reserved.	No
27	Gage Out of Range: The bit is active if a strain gage output operating range has been exceeded in any of the past 32 samples.	Yes
28	Simulated Error. This bit mirrors the "Simulated Error Control" bit in *Section 5.2.8—Object 0x7010: Control Codes*. It can be used to test user error handling.	Yes
29	Calibration checksum error: This bit is set if the active calibration has an invalid checksum.	Yes
30	Sensing Range Exceeded[1]: This bit is set whenever a F/T reading exceeds the calibrated range. This check occurs before digital filtering.	Yes
31	Error: This bit is set whenever any status code bit that indicates an error is set.	Yes
Note: 1. Sensing Range Exceeded is comparable to what previous F/T sensor manuals identified as saturation.		

5.2.5.1 Status Code: Force/Torque Out of Range

Bit 30 in *Table 5.6* is set when a F/T load is outside the sensor's detection capability. bit 30 is set when either of the following conditions are TRUE:

- The total percentage of the calibrated range used by F_{xy} and T_z axes is past 105%. Refer to the following F_{xy} T_z equation.

$$\frac{\sqrt{F_X^2 + F_Y^2}}{F_{XY}\text{CalibratedRange}} + \frac{|T_Z|}{T_Z\text{CalibratedRange}} > 105\%$$

- The total percentage of the calibrated range used by F_z and T_{xy} axes is past 105%. Refer to the following F_z T_{xy} equation.

$$\frac{|F_Z|}{F_Z\text{CalibratedRange}} + \frac{\sqrt{T_X^2 + T_Y^2}}{T_{XY}\text{CalibratedRange}} > 105\%$$

Refer to *Section 8.3—Calibration Ranges* for the calibrated ranges that are used in the preceding equations.

For Example:

A sensor that uses calibration range 0 is subjected to the following loads and has the following calibration ranges:

Table 5.7—Example of Force/Torque Out of Range		
Axis	**Applied Load**	**Calibration Range 0 *Table 8.3* Value**
F_x	87.5 N	500 N
F_y	-151.6 N	500 N
F_z	-500.0 N	900 N
T_x	1.0 Nm	20 Nm
T_y	2.0 Nm	20 Nm
T_z	-17.5 Nm	20 Nm

The F_{xy} T_z equation simplifies as follows:

$$\frac{\sqrt{(87.5\text{ N})^2 + (-151.6\text{ N})^2}}{500\text{ N}} + \frac{|-17.5\text{ Nm}|}{20\text{ Nm}} > 105\%$$

$$\frac{175\text{ N}}{500\text{ N}} + \frac{17.5\text{ Nm}}{20\text{ Nm}} > 105\%$$

$$35\% + 87.5\% > 105\%$$

$$122.5\% > 105\%$$

$$\text{TRUE}$$

The F_z T_{xy} equation simplifies as follows:

$$\frac{|-500\ \text{N}|}{900\ \text{N}} + \frac{\sqrt{(1.0\ \text{Nm})^2 + (2.0\ \text{Nm})^2}}{20\ \text{Nm}} > 105\%$$

$$\frac{500\ \text{N}}{900\ \text{N}} + \frac{1.73\ \text{Nm}}{20\ \text{Nm}} > 105\%$$

$$55.6\% + 8.7\% > 105\%$$

$$64.3\% > 105\%$$

$$\text{FALSE}$$

Because the F_{xy} T_z equation simplified to TRUE, bit 30 in *Table 5.6* is set.

5.2.6 Object 0x6020: Sample Counter

This object contains a single 32-bit unsigned integer at subindex 0 that increases by one each time a F/T sample (one complete set of gage data) is read.

This number rolls over from 4 294 967 295 (2^{32}-1) to 0 without signalling an error. The sample counter is reset to zero during power up.

5.2.7 Object 0x6030: Gage Data

This read-only object reads the latest raw gage data.

Table 5.8—Raw Unbiased Gage Data

Subindex	Name	Type	Description
0x01	Gage 0	DINT	These fields contain the latest raw gage values.
0x02	Gage 1		
0x03	Gage 2		
0x04	Gage 3		
0x05	Gage 4		
0x06	Gage 5		
0x07	Gage 6		

5.2.8 Object 0x7010: Control Codes

This object is mapped into the RxPDO for real-time control of the F/T system. It contains the following fields:

Table 5.9—Control Codes

Subindex	Name	Type	Description: Bit	Description: Function
0x01	Control 1	DINT	0	1 = Set bias against current load 0 = Use last set bias[1]
			1	Reserved
			2	1 = clear bias 0 = leave bias unchanged
			3	Reserved
			4-7	The low-pass filter selection. 0 = No filtering 1 - 8 = Refer to *Section 4.3—Low-pass Filter* for details.
			8-11	Active calibration. Calibration slot 0, refer to *Table 8.3*. Calibration slot 1, refer to *Table 8.3*. 2 through 15 = Reserved.
			12-15	Sample Rate 0 = 487 Hz 1 = 975 Hz 2 = 1990 Hz 3 = 3900 Hz
			16-31	Reserved
0x02	Control 2	DINT	**Bit**	**Function**
			0-30	Reserved
			31	Simulated Error Control

Note:

1. This bit must be returned to 0 for the sensor to read properly, after a bias command is entered. If this bit is held at 1, then the sensor will continuously bias and output readings of zero in all axes.

5.3 Establishing Communication with the EtherCAT Axia Sensor

The following steps guides the user through initializing communication between the EtherCAT Axia sensor and the customer's EtherCAT master device. Always refer to the software manual for the EtherCAT master device for instructions best suited for your application.

1. Attach the sensor to the EtherCAT and power cables. Refer to *Section 3.3—Installing the Sensor to the Robot* and *Section 3.5—Pin Assignment for the EtherCAT and Power Connection*.
2. Import the ESI file: 9031-05-1049 from the ATI website into the EtherCAT master software
    - Specific steps to import the ESI file varies among the different EtherCAT master software and hardware available to the customer.
3. Configure the EtherCAT master device to communicate with the EtherCAT sensor.
4. In the software for the EtherCAT master, read the calibration data at system start by using a SDO read to object 0x2021, the calibration object.
5. Upon receipt of each real-time PDO sample, divide the force and torque counts values by the counts per force and counts per torque values from the calibration object to calculate the F/T units values.
    - F/T units are in the units specified in the calibration.
    - For different units, the software for the EtherCAT master device can adjust the counts per force and counts per torque values so that the resulting units are in the desired units.
        - For example: If the calibration outputs 1, 000, 000 counts per Newton (N), to calculate the output in counts per pound force (lbf), perform the following conversion:

$$\frac{1{,}000{,}000 \text{ counts}}{1 \text{ N}} \times \frac{4.4482222 \text{ N}}{1 \text{ lbf}} = 4,448,222 \ {}^{\text{counts}}\!/_{\text{lbf}}$$

6. Maintenance

6.1 Periodic Inspection

With industrial-type applications that frequently move the system's cabling, you should check the cable jacket for signs of wear. The Axia sensor is IP64 rated. Debris and dust should be kept from accumulating on or in the sensor. The surface of the sensor can be cleaned with isopropyl alcohol, if contaminated by its environment. The sensor itself should experience no wear, if used within the operating ranges and fastened to the proper torque specifications. Refer to *Section 8—Specifications* and *Section 3.3—Installing the Sensor to the Robot*.

6.2 Periodic Calibrating

Periodic calibration of the sensor and its electronics is required to maintain traceability to national standards. Follow applicable ISO-9000-type standards for calibration. ATI Industrial Automation recommends annual accuracy checks. Refer to *Section 3.6—Accuracy Check Procedure*.

7. Troubleshooting

The information in this section should answer many questions that might arise in the field. Customer service is available for problems or questions not addressed in the manuals.

7.1 Errors with Force and Torque Readings

Inaccurate data from the sensor's strain gages can cause errors in force/torque readings. These errors can result in problems with sensor biasing and accuracy. Listed in the following table are the basic problems of inaccurate data.

Question/Problem	Answer/Solution
Noise	Jumps in force torque data readings (with the sensor unloaded) greater than 0.05% of full scale counts is abnormal. Noise can be caused by mechanical vibrations and electrical disturbances, possibly from a poor ground. Noise can also indicate component failure within the system. Make sure that the DC supply voltage for the Axia80 sensor has little to no noise superimposed. The sensor should be grounded through installation construction.
Drift	After a load is removed or applied, the raw gage reading does not stabilize but continues to increase or decrease. A shift in the raw gage reading is observed more easily in the resolved data mode using the bias command. Some drift from a change in temperature or mechanical coupling is normal.Mechanical coupling occurs when a tool plate contacts the sensor body, for example, debris between the tool adapter plate and the sensor body or in applications such as hoses and wires attached to a tool.
Hysteresis	When the sensor 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.
Sensor not streaming measurement data to the customer devices that use EtherCAT fieldbus.	Verify the sensor is correctly installed. Ensure the robot mounting and tool adapter plates are installed on the proper side of the sensor. Refer to *Section 3—Installation* for more information.

8. Specifications

The requirements for the EtherCAT sensor interface are covered in the following sections.

8.1 Storage and Operating Conditions

Table 8.1—Environmental Conditions	
Parameter	**Value**
Storage Temperature, °C	-20 to +85
Operating Temperature, °C	0 to +65
Relative Humidity	<95%, non-condensing

8.2 Electrical Specifications

Table 8.2—Power Supply[1]		
Power Source	**Voltage**	**Maximum Power Consumption**
DC Power	12 V min. to 30 V max.	1.5 W

Notes:

1. The power supply input is protected from a reversed polarity circuit.

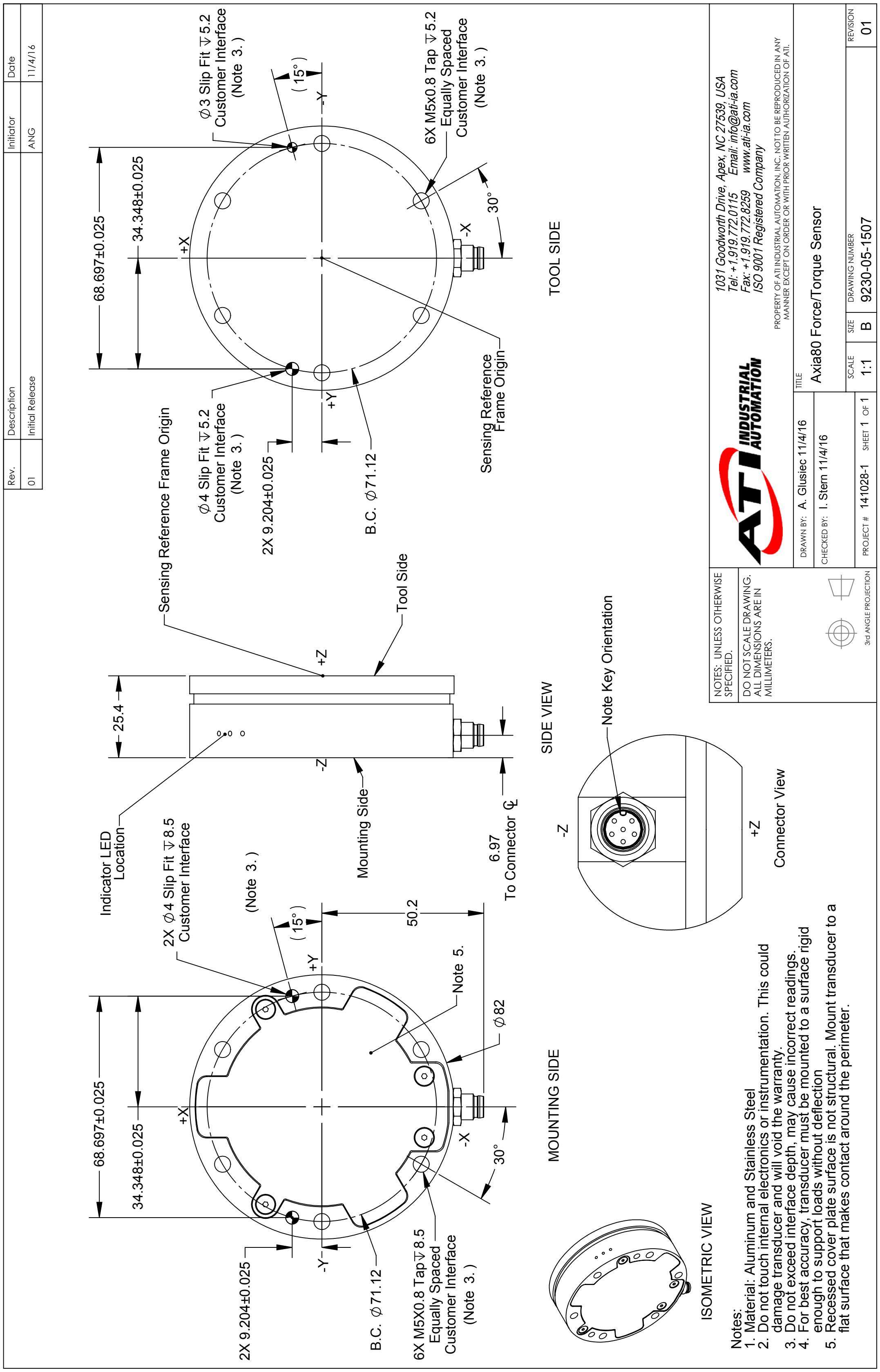
8.3 Calibration Ranges

Table 8.3—Calibration Range 0 and Calibration Range 1		
Parameter	**Calibration Range 0**	**Calibration Range 1**
Fxy	500 N	200 N
Fz	900 N	360 N
Txyz	20 Nm	8 Nm

Notes:

1. Each sensor is calibrated with these values.

9. Drawings


Rev.
Description
Initiator
Date
01
Initial Release
ANG
11/4/16
TOOL SIDE
SIDE VIEW
MOUNTING SIDE
ISOMETRIC VIEW
Connector View
Sensing Reference Frame Origin
Tool Side
Mounting Side
Note Key Orientation
Indicator LED Location
6.97 To Connector ℄
25.4
50.2
68.697±0.025
34.348±0.025
2X 9.204±0.025
B.C. ϕ71.12
ϕ82
Note 5.
ϕ3 Slip Fit ⫟5.2 Customer Interface (Note 3.)
ϕ4 Slip Fit ⫟5.2 Customer Interface (Note 3.)
6X M5x0.8 Tap ⫟5.2 Equally Spaced Customer Interface (Note 3.)
2X ϕ4 Slip Fit ⫟8.5 Customer Interface (Note 3.)
6X M5X0.8 Tap⫟8.5 Equally Spaced Customer Interface (Note 3.)
Notes:
1. Material: Aluminum and Stainless Steel
2. Do not touch internal electronics or instrumentation. This could damage transducer and will void the warranty.
3. Do not exceed interface depth, may cause incorrect readings.
4. For best accuracy, transducer must be mounted to a surface rigid enough to support loads without deflection
5. Recessed cover plate surface is not structural. Mount transducer to a flat surface that makes contact around the perimeter.
NOTES: UNLESS OTHERWISE SPECIFIED.
DO NOT SCALE DRAWING. ALL DIMENSIONS ARE IN MILLIMETERS.
3rd ANGLE PROJECTION
ATI INDUSTRIAL AUTOMATION
1031 Goodworth Drive, Apex, NC 27539, USA
Tel: +1.919.772.0115 Email: info@ati-ia.com
Fax: +1.919.772.8259 www.ati-ia.com
ISO 9001 Registered Company
PROPERTY OF ATI INDUSTRIAL AUTOMATION, INC. NOT TO BE REPRODUCED IN ANY MANNER EXCEPT ON ORDER OR WITH PRIOR WRITTEN AUTHORIZATION OF ATI.
DRAWN BY: A. Glusiec 11/4/16
CHECKED BY: I. Stern 11/4/16
TITLE Axia80 Force/Torque Sensor
PROJECT # 141028-1
SHEET 1 OF 1
SCALE 1:1
SIZE B
DRAWING NUMBER 9230-05-1507
REVISION 01

10. 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 (1) year from the date of shipment. The warranty period for repairs made under a RMA shall be for the duration of the original warranty, or ninety (90) days from the date of repaired product shipment, whichever is longer. ATI will have no liability under this warranty unless: (a) ATI is given written notice of the claimed defect and a description thereof with thirty (30) days after Purchaser discovers the defect and in any event, not later than the last day of the warranty period and (b) the defective item is received by ATI not later than (10) days after the last day of the warranty period. ATI's entire liability and Purchaser's sole remedy under this warranty is limited to repair or replacement, at ATI's election, of the defective part or item or, at ATI's election, refund of the price paid for the item. The foregoing warranty does not apply to any defect or failure resulting from improper installation, operation, maintenance, or repair by anyone other than ATI.

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

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

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

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

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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.

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