



Force/Torque (F/T) Manual

Introduction

This manual is a compilation of several modular manual sections for an F/T sensor system. The modular manual sections are in the following order and provide the following information:

A. Introduction

This section includes contact information to reach an ATI representative, general safety guidelines, and terms and conditions of sale. The ATI document number for this modular manual section is: 9620-05-A-Introduction.

A comprehensive glossary of terms is here: https://www.ati-ia.com/library/Glossary_of_Robotic_Terminology.aspx.

B. Sensor

This section contains information about the sensor mechanical body.

Content includes a product overview, installation instructions, operation information, preventative maintenance guidance, troubleshooting guidelines, and specifications.

The ATI document number for this modular manual section is: 9620-05-B-XX (XX = sensor model name).

C. Communication Interface Version

This section contains information about the electrical and software features of a specific communication interface version. Examples of communication interface versions are EtherCAT, Ethernet, and RS422. This section also includes cable information.

The ATI document number for this modular manual section is: 9620-05-C-XX (XX = communication interface version).

D. Custom Application

This section contains additional information needed for the sensor system to work within a custom application.

The ATI document number for this modular manual section is: 9620-05-D-XX (XX = custom application).

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A. Introduction

Please contact ATI Industrial Automation with any questions concerning a particular model.



WARNING: Only use ATI products for applications approved by the manufacturer. Using ATI products in applications other than what was intended by the manufacturer could result in damage to equipment and injury to personnel.



CAUTION: This manual describes the function, application, and safety considerations of this product. This manual must be read and understood before any attempt is made to install or operate the product, otherwise damage to the product or unsafe conditions may occur.

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Note:

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

1. Serial number, for example: FT01234
2. Model, for example: Axia130-M125
3. Calibration, for example: SI-800-50 or SI-2000-125
4. Accurate and complete description of the question or concern
5. Computer and software information, for example: operating system, PC type, drivers, and application software

Be near the F/T system when calling (if possible).

Please contact an ATI representative for assistance, if needed:

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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. Product specific notifications are imbedded within the sections of this manual (where they apply).

1.1 Explanation of Notifications

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



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



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



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

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

1.2 General Safety Guidelines

The customer should verify that the 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 deceleration of the robot, be aware of the dynamic loads caused by the robot.

2. Terms and Conditions of Sale

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Axia90 F/T Sensor Manual



Document #: 9620-05-B-Axia90

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Note:

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

1. Serial number (e.g., FT01234)
2. Sensor model (e.g., Axia90-M50)
3. Calibration (e.g., US-15-50, SI-65-6, etc.)
4. Accurate and complete description of the question or problem
5. Computer and software information (operating system, PC type, drivers, application software, and other relevant information about the application's configuration)

Be near the F/T system when calling (if possible).

Please contact an ATI representative for assistance, if needed:

Sale, Service and Information about ATI products:

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Glossary

Term	Definition
Bias	Biasing is useful for eliminating the effects of gravity (tool weight) or other acting forces. When the bias function is used, the software collects data for the forces and torques that are currently acting on the sensor and use these readings as a reference for future readings. Future readings will have this reference subtracted from them before they are transmitted. Bias may also be referred to as “zero out” or “tare” the sensor.
Calibration	Defines a specific measurement or sensing range for a given sensor. Calibration is also the process of measuring a transducer’s raw response to loads and creating data used in converting the response to forces and torques.
Complex Loading	Any load that is not purely in one axis.
Communication Interface Versions	The software standard that the customer device uses to apply features to the sensor and for the sensor to report data, for example: EtherCAT, RS422, and Ethernet.
Coordinate Frame	See Sensing Reference Frame Origin.
Data Rate	How fast data can be output over a network.
Force	A force is a push or pull action on an object caused by an interaction with another object. Force = mass x acceleration.
FS	Full-Scale, refers to the limits of a given calibration or sensing range.
F/T	Force/Torque.
F_{xy}	The resultant force vector comprised of components F_x and F_y .
Hysteresis	A source of measurement error caused by the residual effects of previously applied loads.
Interface Plate	A separate plate that attaches the sensor to another surface. Interface plates are often used if the bolt pattern on the sensor doesn’t match the bolt pattern on the robot arm or customer tooling. The interface plate has two bolt patterns, one on either side of the plate. One side is for the sensor. The other side is for the robot arm or customer tooling.
IP67	Ingress protection rating “67” designates protection against dust and submersion under 1 m of fresh water.
Master Device	A customer supplied device such as a personal computer, robot, or programmable logic controller (PLC) that is compatible a specific communication interface.
Measurement Uncertainty	Commonly referred to as “accuracy”, “measurement uncertainty” is the worst-case error between the measured value and the true load. The measurement uncertainty is specified as a percentage of the full-scale measurement range for a given sensor model and calibration size. This value takes into account multiple sources of error. The sensor’s calibration certificate lists the measurement uncertainty percentage. For more information, refer to <i>Section 2.2: Measurement Uncertainty</i> in the Frequently Asked Questions (FAQ) document located at: https://www.ati-ia.com/library/documents/FT_FAQ.pdf .
Mechanical Coupling	When an external object such as customer tooling or utilities contacts a sensor’s surface between the sensor’s mounting side and tool side.
Mounting Interface Plate	An interface plate that attaches the sensor to a fixed surface like a robot arm.
N/A	Not Applicable
Overload	The condition where more load is applied to the transducer than it can measure. This will result in saturation.

Term	Definition
P/N	Part Number
Power Cycle	When a user removes and then restores power to a device.
Resolution	The smallest change in load that can be measured. Resolution is usually much smaller than accuracy.
Sample Rate	How fast the ADCs are sampling inside the unit.
Saturation	The condition where the transducer or data acquisition hardware has a load or signal outside of its sensing range.
Sensing Reference Frame Origin	The point on the sensor from which all forces and torques are measured.
Sensor	The component that converts a detected load into electrical signals.
Sensor System (or configuration)	The entire assembly consisting of a sensor body and a system interface to translate force and torque signals into a specific communication interface/protocol.
Tool Interface Plate	An interface plate that attaches the customer's tooling to the tooling side (sensing side) of the sensor.
Torque	The application of a force through a lever or moment arm that causes something to want to turn. For example, a user applies torque to a screw to make it turn. Torque = force x moment arm length.
T_{xy}	The resultant torque vector comprised of components T_x and T_y .

1. Safety

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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 is rated for the maximum load and torque expected during operation. Because static forces are less than the dynamic forces from the acceleration or deceleration 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. Use the supplied mounting interface plate and the provided tool side mounting bolt pattern to mount the sensor to the robot and customer tooling to the sensor. For more information, refer to the customer drawings.



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



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



CAUTION: The sensor should be protected from impact and shock loads that exceed rated ranges during transportation as the impacts can damage the sensor's performance. Refer to [Section 7—Specifications](#) for more information about rated ranges.

2. Product Overview

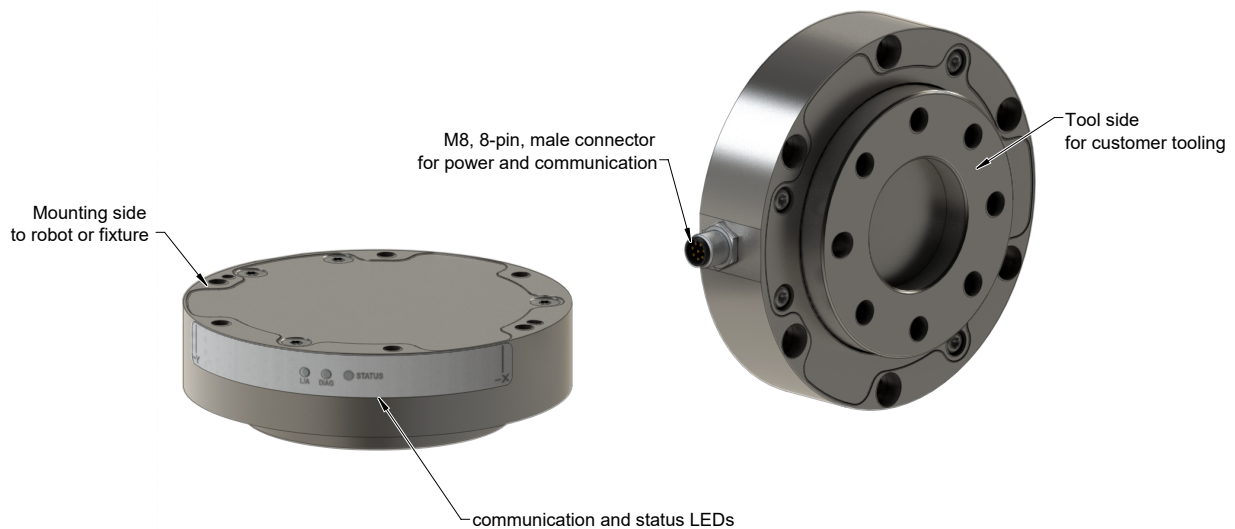
The Axia90 Force/Torque (F/T) sensor detects six components of force and torque ($F_x \setminus F_y \setminus F_z \setminus T_x \setminus T_y \setminus T_z$) that are applied to the tool side of the sensor. The sensor communicates this data to a device (such as a personal computer, robot, or PLC). The ATI Axia-series product line differs from the other (non-Axia) ATI F/T sensor models. Thus, the Axia sensors have different options and available features. The Axia-series force/torque sensors are available in several different payload and communication interface versions. For more information about the communication interface, refer to the applicable ATI Axia sensor manual in [Table 2.1](#).

The sensor's mounting side attaches to a rigid fixture or robot. The robot mounting side of the sensor has a 81.065 mm diameter bolt circle (BC) for (6) M4 socket head cap screws and (2) 3 mm slip-fit dowel pin holes. The tool side attaches to the customer tooling. The tool side has a 50 mm BC pattern with (7) M6 tapped holes, 6 mm slip-fit dowel pin hole, and a 31.5 mm recess. For more information on the mounting patterns, refer to the [ATI Axia90 sensor customer drawing](#). If the sensor does not have the same bolt pattern as the mounting or tool sides, use interface plates; refer to [Section 3.1—Interface Plates](#). The sensor is IP67 rated.

An M8 8-pin male connector is for power and communication. On the side of the sensor, LEDs indicate the sensor's operational state. For the connector pin assignments on the sensor and cables and more information about the LEDs, refer to the applicable ATI communication interface manual in [Table 2.1](#).

The ATI Axia90 sensor customer drawing is available on the ATI website: https://www.ati-ia.com/app_content/Documents/9630-05-0007.auto.pdf.

Figure 2.1—Axia90 F/T Sensor



For more information on the electrical and software features of a specific communication interface version and the applicable cable, refer to the ATI manual in the following table:

Table 2.1—ATI Communication/Software Manual Reference			
Sensor Model ATI P/N	Communication Type	ATI Cable P/N	Refer to the ATI Manual
9105-NET- Axia90-M50	Ethernet	9105-C-ZC27-ZC28-4 ¹ 9105-C-ZC28-U-RJ45S-x	ATI F/T Ethernet Axia manual (ATI document # 9620-05-C-Ethernet Axia)
9105-ECAT- Axia90-M50	EtherCAT	9105-C-ZC27-ZC28-4 ¹ 9105-C-ZC28-U-RJ45S-x	ATI F/T EtherCAT Axia manual (ATI document # 9620-05-C-EtherCAT Axia)
9105-RS422- Axia90-M50	RS422	9105-C-ZC27-ZC28-4 ¹ 9105-C-ZC28-MS-ZC35-4 ²	ATI F/T RS422 Axia manual (ATI document # 9620-05-C-RS422 Axia)
Note: 1. Included in 9105-CKIT-ZC27-ZC28-X refer to Table 3.2 . 2. Customers must use either the 9105-C-ZC28-MS-ZC35-X DB9 serial cable or their own RS422 serial cable with a DB9 or USB connector to the ATI sensor cable. 3. This ATI manual references the Axia80 sensor, but the software interface concepts still apply to the Axia90 sensor.			

3. Installation



WARNING: Performing maintenance or repair on the sensor when circuits (for example: 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: Using fasteners that exceed the customer interface depth penetrates the body of the sensor, damages the electronics, and voids the warranty. For more information, refer to the customer drawings.



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



CAUTION: Avoid damage to the sensor from electrostatic 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.

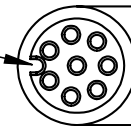


CAUTION: Do not apply excessive force to the sensor and cable connector during installation, or damage will occur to the connectors. Align the keyway on the sensor and cable connector during installation to avoid applying excessive force to the connectors.



Keyway on the
sensor connector.

Keyway on the
cable connector.



3.1 Interface Plates

The sensor's mounting side attaches to a surface like the robot arm, and the sensor's tool side attaches to the customer tooling. The pattern on the Axia90 tool side is compatible with ISO 9409-1-50-4-M6 bolt pattern. Therefore, if customer tooling mounts to the sensor's tool side with a 50 mm bolt circle and (4) or (7) M6 bolts, an interface plate on the tool side of the sensor is not required. ATI can supply robot mounting kits that include a mounting interface plate and fasteners; for more information, contact ATI (refer to [page B-2](#)). If the customer chooses to supply their own interface plates, refer to the following design guidelines and the [ATI Axia sensor customer drawing](#).

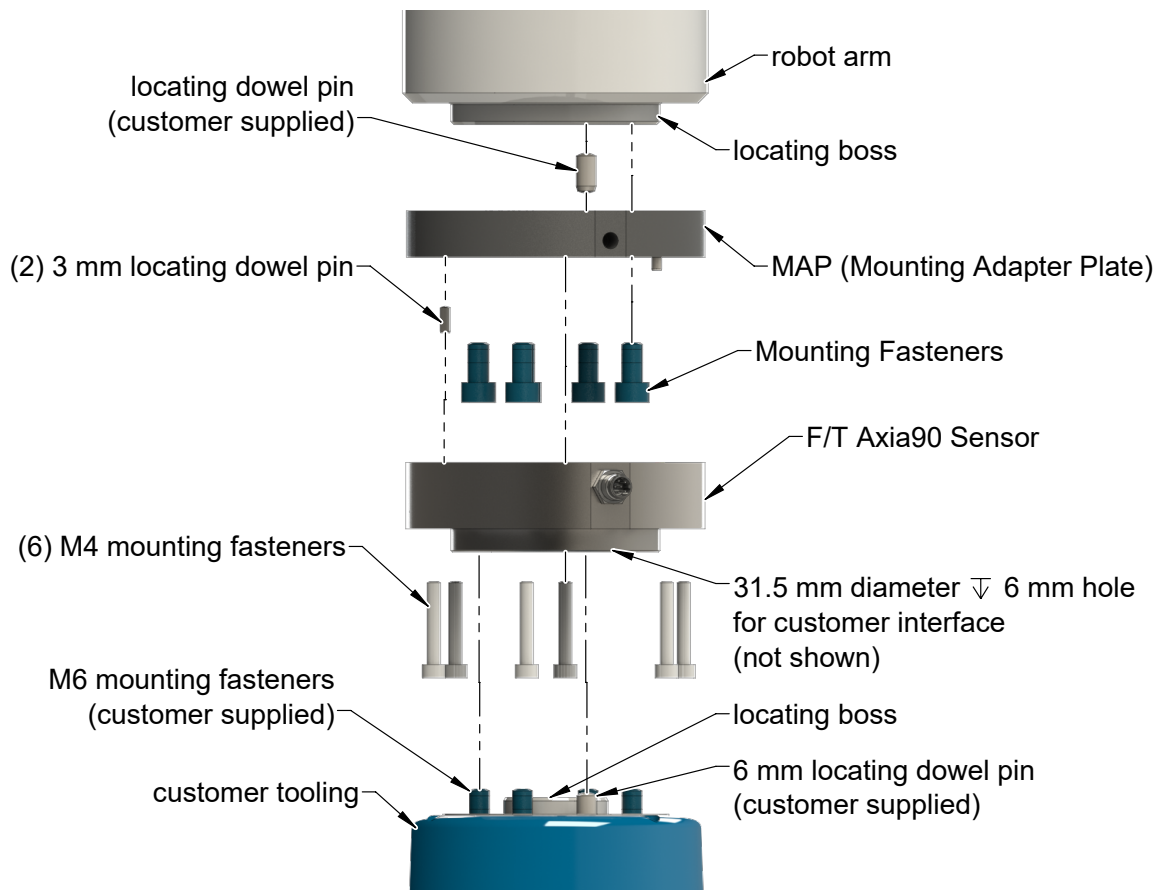


CAUTION: Incorrect installation of interface plates can prevent the F/T sensor from functioning properly.

If the customer chooses to design and build an interface plate, consider the following points:

- The interface plate should include bolt holes for mounting fasteners as well as a dowel pin and boss for accurate positioning to the robot.
- The thickness of the interface plate must provide sufficient thread engagement for the mounting fasteners.
- The mounting fasteners should not interfere with the internal electronics of the sensor. For thread depth, mounting patterns, and other details, refer to the [ATI Axia sensor customer drawing](#).
- Do not use dowel pins that exceed length requirements and prevent interface plate from mating flush with the robot. Fasteners that exceed length requirements create a gap between the interfacing surfaces and cause damage.
- The interface plate must be as strong or stronger than the sensor so that maximum force and torque values applied to the sensor do not distort the interface plate. For these force and torque values, refer to [Section 7—Specifications](#).
- The interface plate must provide a flat and parallel mounting surface for the sensor.

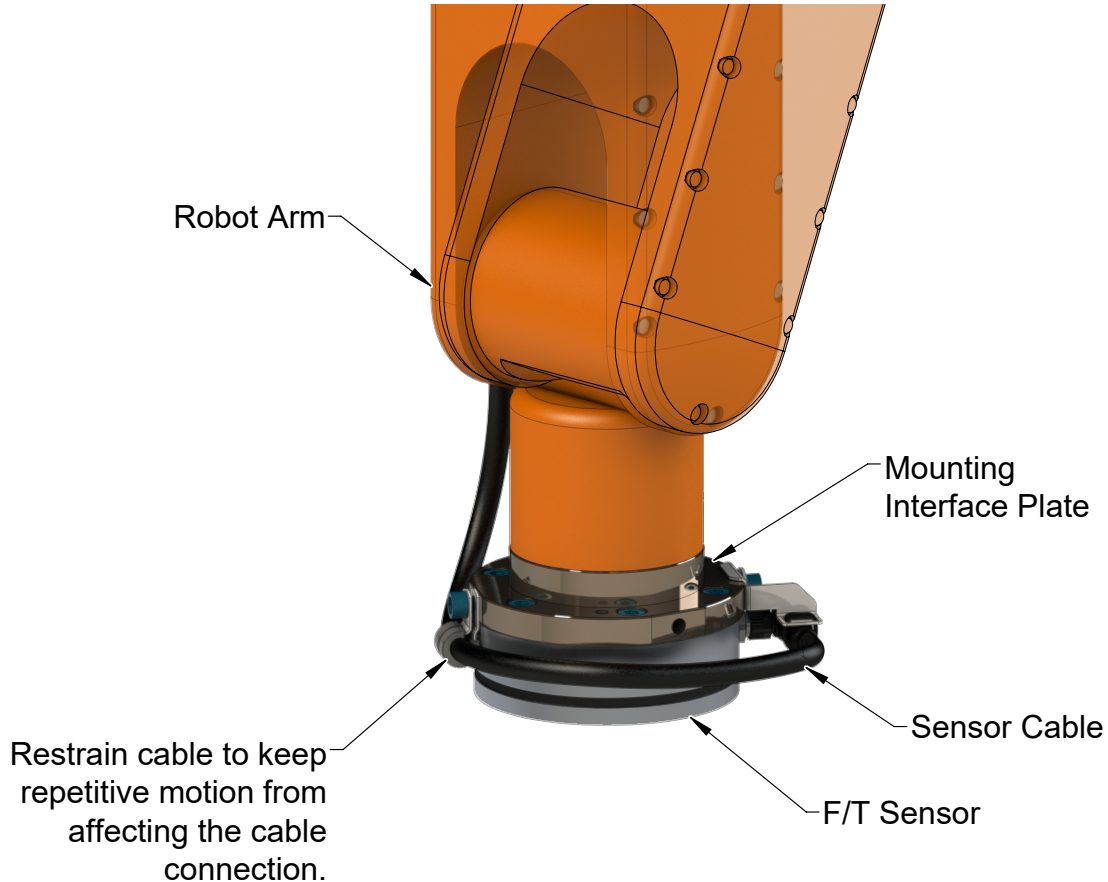
Figure 3.1 —Interface Plate(s)



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.

Figure 3.2—Routing of the Sensor Cable



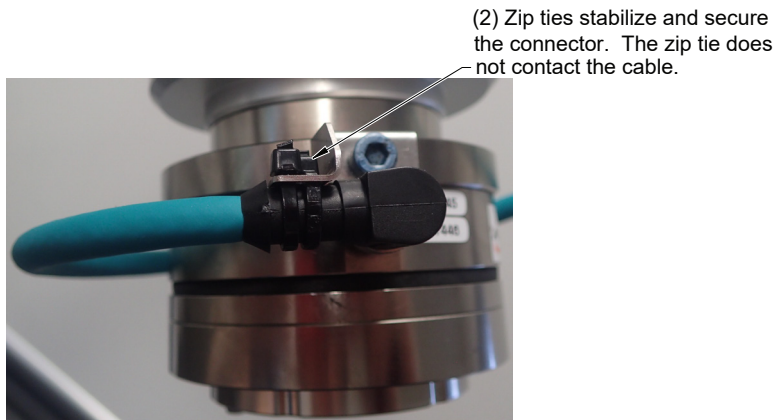
CAUTION: Subjecting the connector to the repetitive motion will cause damage to the connector. Restrain the cable close to the connector so that the repetitive motion of the robot does not interfere with the cable connector.



CAUTION: Improper cable routing may cause injury to personnel, poor functionality of critical electrical lines, or damage to the equipment. 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. Damage to the sensor or cable from improper routing will void the warranty.

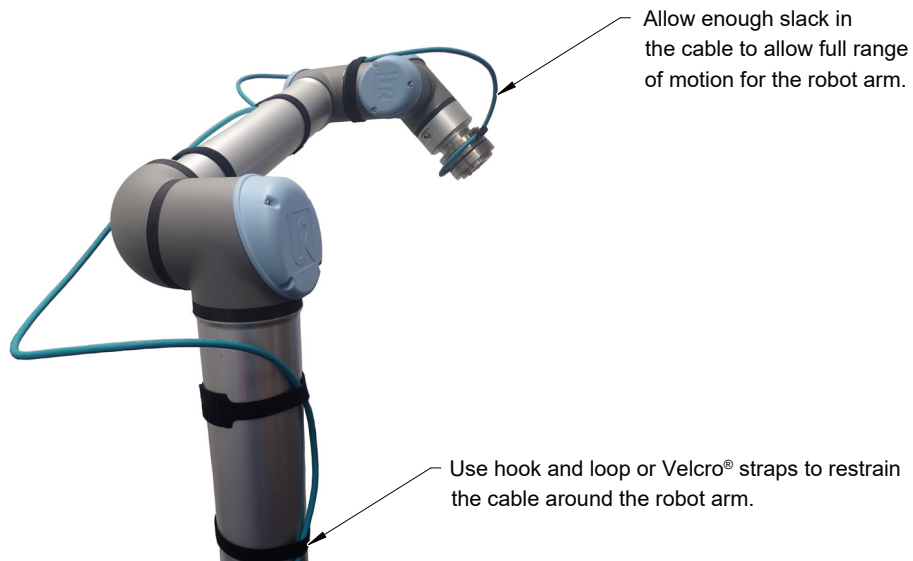
For added stability, zip ties can be used to secure the cable to a mounting bracket (refer to the following figure). The zip ties should never contact the cable jacket.

Figure 3.3—Use Zip Ties on the Connector (sensor shown for reference only)



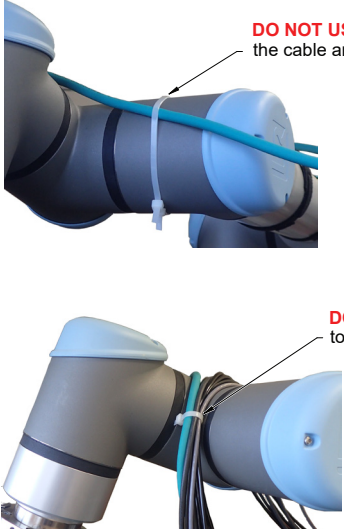
Route the sensor cable so that it is not stressed, pulled, kinked, cut, or otherwise damaged throughout the full range of motion. Use a robot dresspack solution, if possible. Examples of how to route the cable, if a dresspack is not available, are shown in the following figures and descriptions. Affix the cable by using hook and loop straps or Velcro® straps; do not use cable ties or zip ties.

Figure 3.4—Use Hook and Loop or Velcro® Straps on the Cable (sensor shown for reference only)

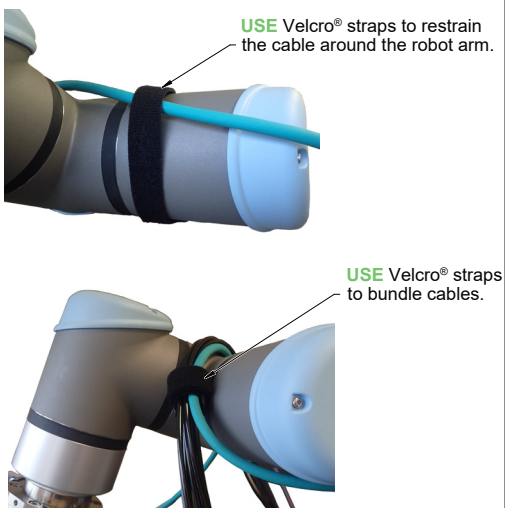


CAUTION: Do not use cable ties or zip ties to bundle cables or restrain the cable to the robot arm. Directly affixing cable ties or zip ties to the cable jacket will damage the cable. Use hook and loop or Velcro straps on the cable jacket surfaces. Examples of the incorrect and correct methods to restrain or bundle cables are in the following pictures:

INCORRECT



CORRECT



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

CAUTION: When routing the 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	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-ZC27-ZC28-X ^{2,3}	6 (0.24)	25	1	50	2	180°/m or 55°/ft
9105-C-ZC28-U-RJ45S-X ²						

Notes:

- Temperature affects cable flexibility. ATI recommends increasing the minimum dynamic bending radius for lower temperatures.
- The X in the part number represents the cable length. For more information, contact ATI.
- Available in an ATI kit; refer to [Table 3.2](#).
- For information specific to the cable part number, refer to the applicable manual in [Table 2.1](#).

3.3 Cable Kits

For images of the sensor support bracket and P-clip, refer to [Figure 3.2](#) and [Figure 3.5](#).

Table 3.2—Cable Kit 9105-CKIT-ZC27-ZC28-X		
Part Number	Description	Quantity
9105-C-ZC27-ZC28-4	8-pin M12 connector to 8-pin M12 connector with a 4 m cable	1
9005-05-1078	(1) bracket, (1) M5 x 10 socket head cap screw, (1) M5 flat washer, and (1) tie	1
9005-05-1079	(1) P-clamp and (1) M5 x 10 socket head cap screw	1

3.4 Install the Sensor

Parts required: Refer to [Figure 3.5](#) and [ATI Axia sensor customer drawing](#)

Tools required: 3 mm and 4 mm hex key

Supplies required: Clean cloth, Loctite® 242

1. Clean the mounting surfaces.
2. Use the mounting fasteners to attach the interface plate to the mounting surface.

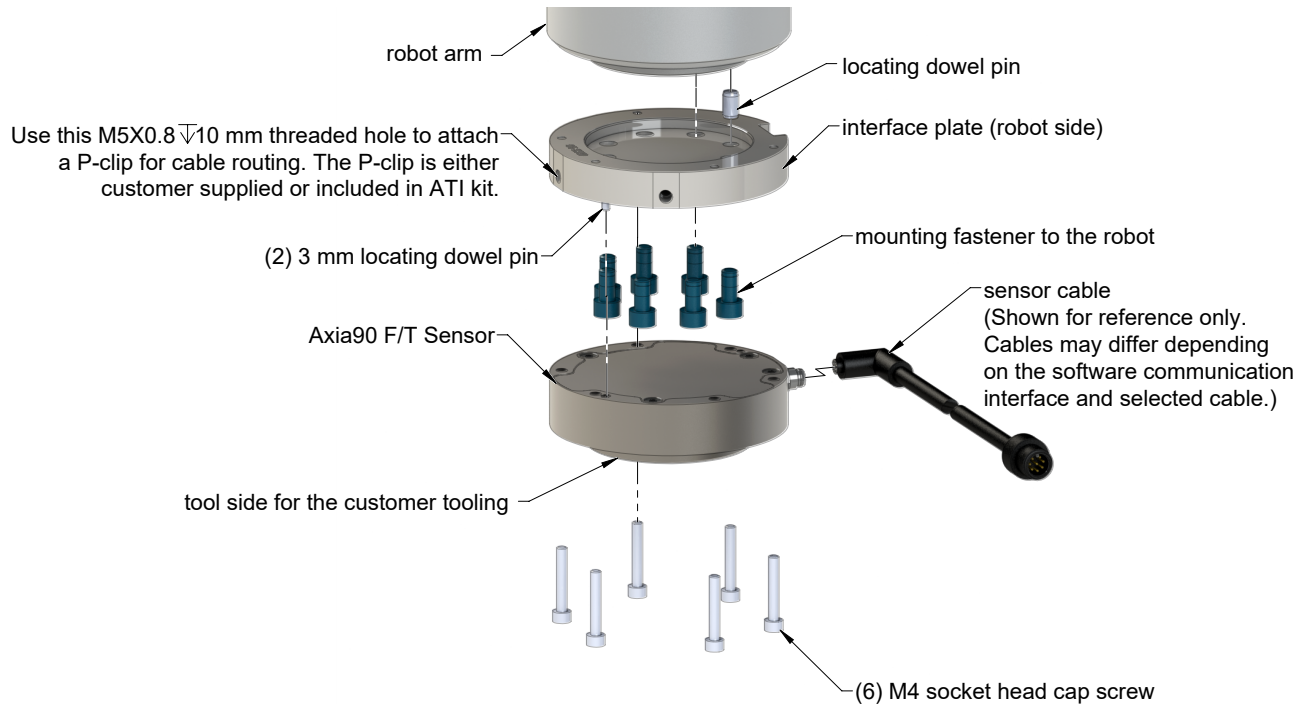
NOTICE: When installing an interface plate:

- Screws must have a minimum thread engagement length of 4.5 mm. Maximum screw thread engagement shall not exceed the threaded depth listed on the [ATI Axia sensor customer drawing](#).
- Unless otherwise specified, apply Loctite 242 to the (6) M4 socket head cap screws (class 12.9) so that the fasteners secure the sensor to the mounting plate.

3. Attach the mounting side of the sensor to the interface plate.
 - a. Secure the mounting side of the sensor to the interface plate with (6) M4 socket head cap screws (class 12.9). Use a 3 mm hex key to tighten the fasteners 45 in-lbs (5.08 Nm).
4. Once the sensor is installed on the robot, the customer tooling can be installed.

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

Figure 3.5—Installation of the Sensor to the Robot



NOTICE: For the LED outputs that indicate the sensor's operational condition, refer to the applicable manual listed in [Table 2.1](#).

5. Connect the cable(s) to the sensor and customer application. For the sensor and cable connector pinout information, refer to the applicable manual in [Table 2.1](#).
6. After connecting the cable to the customer interface, set up the sensor communication interface software; for additional information about the software communication interface, refer to the applicable manual in [Table 2.1](#).
7. Properly restrain and route the cable (refer to [Section 3.2—Routing the Cable](#)). If using an ATI cable kit:
 - a. Above the sensor connector, secure the bracket to the interface plate. Insert the M5 screw through the flat washer. Use a 4 mm hex key to tighten the M5 socket head cap screw.
 - b. Use the tie in the kit to secure the connector to the bracket (refer to [Figure 3.3](#)).
 - c. Secure the P-clip to the interface plate (refer to [Figure 3.2](#)). Use a 4 mm hex key to tighten the M5 socket head cap screw.
 - d. Route the cable (refer to [Section 3.2—Routing the Cable](#)).
8. After installation is complete, the sensor is ready for an accuracy check (refer to [Section 3.6—Accuracy Check Procedure](#)).
9. Safely start normal operation.

3.5 Remove the Sensor

Tools required: 3 mm hex key

1. Turn off all energized circuits, for example: electrical.
2. Remove the cable from the sensor.
3. Supporting the customer tooling, remove the customer supplied screws that attach the customer tooling to the sensor.
4. Supporting the sensor, use a 3 mm hex key to remove the (6) M4 socket head cap screws that secure to the sensor to the mounting interface plate or surface.
5. Remove the sensor

3.6 Accuracy Check Procedure

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

NOTICE: The mass on the tool side can be the weight of the tooling used in the application.

1. Attach a fixed mass to the tool side of the F/T sensor:
 - a. Remove cables that form bridges between the sensor's mounting and tool sides.
2. Power on the sensor. Allow a 30 minute warm-up time. Minimize external sources of temperature change.

NOTICE: For optimal results, write a robot program to move the sensor and mass to each of the following positions sequentially. At each position, the robot should pause to record the sensor's output. Avoid jogging the robot and waiting several minutes between each position.

3. Move the robot so that the sensor is in the following positions:
 - a. Record the sensor's output, $F_{x, \text{point } n}$, $F_{y, \text{point } n}$, $F_{z, \text{point } n}$, 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
4. Calculate $F_{x, \text{average}}$, $F_{y, \text{average}}$, and $F_{z, \text{average}}$:
 - a. Use the following equations, to complete the calculations:

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

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

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

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

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

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

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

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

6. The calculated tooling masses for all (6) points should deviate from each other by less than twice the worst accuracy rating of the sensor.
 - For example: the Axia90-M50 sensor's rated accuracy is 2% the range on all axes. For a 1000 N F_{xy} range and a 2000 N F_z range, the allowable errors of any single data point would be ± 20 N F_{xy} and ± 40 N F_z respectively. Since F_z has the larger tolerance, then one data point could be + 40 N and another data point could be - 40 N, for a total range (max-min) of 80 N error.
 - In addition, the tooling mass should be within 80 N of the results of this test when it was performed with a new sensor.
7. If this test fails, then the sensor should be returned to ATI for diagnosis or recalibration.

3.7 Detecting Sensitivity Changes

Sensitivity checking of the sensor can also be used to measure the Axia sensor's health. Apply known loads to the sensor and verifying the system output matches the known loads. For example, a sensor mounted to a robot arm may have an end-effector attached to it. Use the following process to set a sensitivity value:

1. If the end-effector has moving parts, they must be moved in a known position.
 - a. Place the robot arm in an orientation that allows the gravity load from the end-effector to exert load on many sensor output axes.
2. Record the output readings.
3. Position the robot arm to apply another load, this time causing the outputs to move far from the earlier readings.
4. Record the second set of output readings.
5. Find the differences from the first and second set of readings.
6. Use the differences as a sensitivity value.

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

4. Operation

Information that applies generally to all Axia90 sensors is in the following section. For more information specific to the communication protocol of the sensor, such as sampling rate, LEDs, operation commands, refer to the applicable manual in [Table 2.1](#).

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 has not deteriorated to prevent sensor damage.

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

The user must ensure that the water in the environment does not exceed the IP67 rating of the sensor. With an IP67 rating, the sensor is dustproof and water resistant up to 1 m of submersion in fresh water for up to 30 minutes as well as when exposed to high pressure spray. While the Axia90 sensor is IP67 rated, keep debris and dust from accumulating on or in the sensor.

4.2 Tool Transformation

By default, the forces and torques are reported with respect to a point of origin on the sensor that is set by ATI. For the sensor's point of origin, refer to the [ATI Axia sensor customer drawing](#). The tool transformation function allows measurement of the forces and torques at a reference point other than the sensor's point of origin.



CAUTION: If the customer sets a reference point that is at the same location to which a force is applied, there will be no report of a torque applied to the sensor. As a result, the sensor could be overloaded (refer to [Section 4.2.1—Avoid Overloading the Sensor During Tool Transformation](#)). Therefore, when evaluating overloading conditions, use the sensor's point of origin as the reference point.

The user defines a reference point by inputting a parameter set that is a series of (3) displacements ($D_x \setminus D_y \setminus D_z$) and (3) rotations ($R_x \setminus R_y \setminus R_z$), for example:

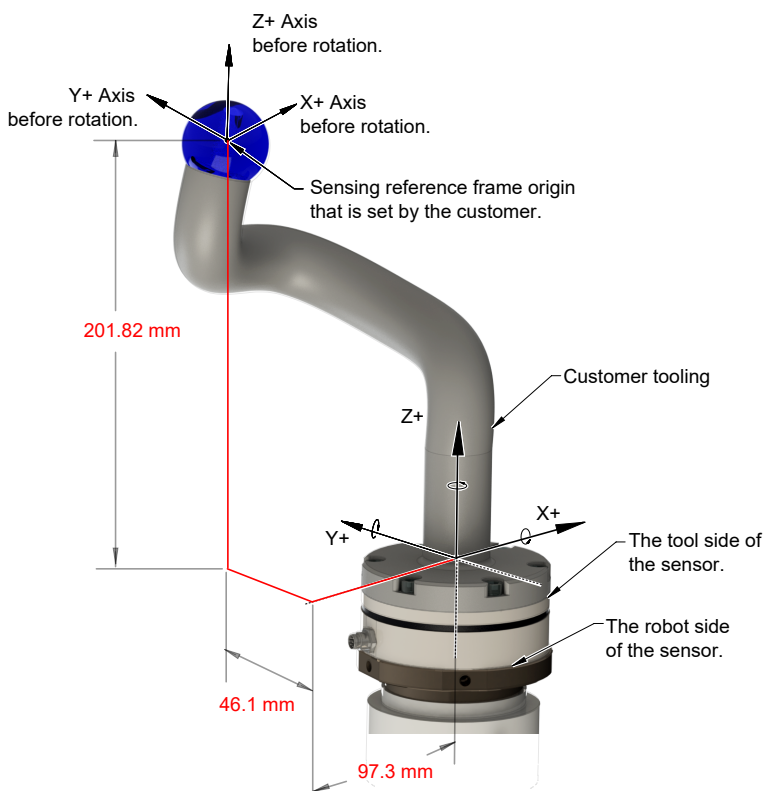
$D_x = -97.3 \text{ mm}$ $D_y = 46.1 \text{ mm}$ $D_z = 201.82 \text{ mm}$ $R_x = +90^\circ \text{ rotation}$ $R_y = +180^\circ \text{ rotation}$ $R_z = 0^\circ \text{ rotation}$

If zeros are entered for any of the parameter set values, the tool transformation is not performed for that particular parameter. Entering zero for all of the parameters, turns the tool transformation feature off. Once a new parameter set is entered and saved, previously entered parameter sets are no longer in effect.

Once a user enters a parameter set, the displacements are performed first. The displacements of the user reference frame of origin from the sensor point of origin is shown in the following figure. In this figure, the user reference frame of origin has not yet rotated relative to the sensor point of origin.

NOTICE: In the following figures, the sensor model is shown for reference only. The connector and sensor axes may align differently between sensor models. To determine the location of the default sensor axes, refer to the ATI sensor drawing or the axes labels on the sensor.

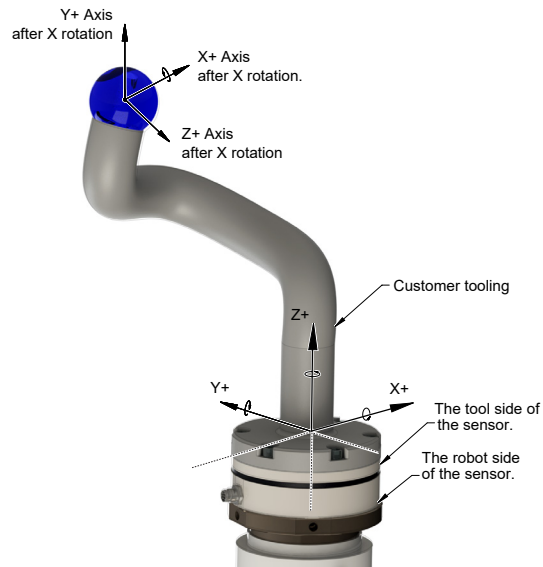
**Figure 4.1—Tool Transformation : Distances
 (sensor shown for reference only)**



After the displacements, the user point of origin rotates in the following order:

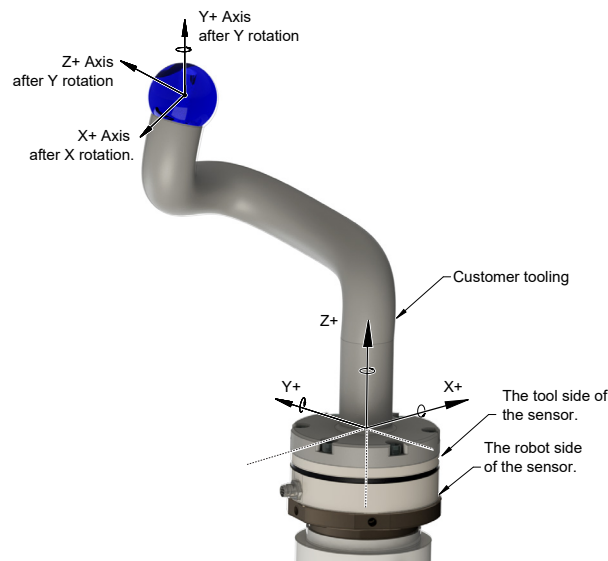
1. The first rotation is about the X-axis.
 - Recall in this example $R_x = +90^\circ$ rotation. The user point of origin rotates $+90^\circ$ about the X-axis, in the following figure.

**Figure 4.2—Tool Transformation : Rotation About the X-Axis
(sensor shown for reference only)**



2. The second rotation is about the Y-axis of the new user output reference frame.
 - In this example $R_y = +180^\circ$ rotation. The user point of origin rotates $+180^\circ$ about the Y-axis of the new user output reference frame, in the following figure.

**Figure 4.3—Tool Transformation: Rotation About the Y-Axis
(sensor shown for reference only)**



3. The third and final rotation is about the Z-axis of the new user output reference frame.
 - In this example $R_z = 0^\circ$ rotation. Therefore, the user point of origin does not rotate any more.
- After, the rotations are complete, the final user reference frame of origin is set.

4.2.1 Avoid Overloading the Sensor During Tool Transformation

It is possible for the user to set a reference point of origin that does not detect that a torque is applied to the customer tooling, and by extension, the sensor. Torque is the force multiplied by the distance of that force from a reference point of origin. If the customer reference point of origin is at the same point at which a force is applied, the distance from that force to the customer reference point of origin is zero. Any force that is multiplied by a distance of zero yields zero torque. The software tool transformation reports that no torque is applied to the sensor. However, the sensor's point of origin has not changed, and the force is still applied at a distance from the sensor's point of origin. Therefore, if the customer is evaluating overloading conditions, the customer should use the sensor's point of origin as the reference point.

4.2.2 Tool Transformation Functionality Through a Communication Interface

The user defines a reference point by inputting a parameter set that is a series of (3) displacements ($D_x \setminus D_y \setminus D_z$) and (3) rotations ($R_x \setminus R_y \setminus R_z$). For commands that write a parameter set and units, refer to the appropriate manual in [Table 2.1](#).

5. Maintenance

5.1 Periodic Inspection

With industrial-type applications that frequently move the system's cabling, inspect the cable jacket for signs of wear. While the Axia sensor is IP67 rated, keep debris and dust from accumulating on or in the sensor. Clean the surface of the sensor with isopropyl alcohol.

5.2 Periodic Calibrating

Periodic calibration of the sensor and its electronics is required to maintain traceability to national standards. The sensor cannot be calibrated in the field; return the sensor to ATI for recalibration. Contact an ATI account manager or rma-admin@ati-ia.com to request a Returned Materials Authorization (RMA) for recalibration. ATI recommends annual accuracy checks (refer to [Section 3.6—Accuracy Check Procedure](#)). If the sensor does not meet the performance requirements of the user application and fails the accuracy check, return the sensor to ATI for recalibration.

6. Troubleshooting

This section includes solutions to some issues that might arise when setting-up and using the sensor. For questions and troubleshooting assistance with software, refer to the appropriate manual in [Table 2.1](#). Answers to frequently asked questions are available from the ATI website: https://www.ati-ia.com/library/documents/FT_FAQ.pdf.

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

Note

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

1. Serial number (e.g., FT01234)
2. Sensor model (e.g., Axia90-M50)
3. Calibration (e.g., US-15-50, SI-65-6, etc.)
4. Accurate and complete description of the question or problem
5. Computer and software information (operating system, PC type, drivers, application software, and other relevant information about the application's configuration)

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

For additional troubleshooting information or to speak with a customer service representative, please contact ATI at:

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Application Engineering

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Fax: +1.919.772.8259
E-mail: ft.support@novanta.com
24/7 Support: +1 855 ATI-IA 00 (+1 855-284-4200)

6.1 Basic Guidance for Troubleshooting

Basic symptoms of inaccurate data and errors are listed in the following section. For each symptom, causes and appropriate solutions are suggested.

Symptom: Noise — jumps in force torque readings greater than 0.05% of full-scale counts.

Cause: Noise can be caused by mechanical vibrations and electrical disturbances that are possibly from a poor ground. Electrical interference can also come from a high noise output device such as a motor.

Solution: Make sure that the DC supply voltage for the Axia sensor has little to no noise superimposed. Ground the sensor by connecting the cable's shield to ground. In most setups, 0 V is also connected to ground. Connect the robot or other fixture to the same ground.

Verify that sensor cables do not cross over other cables or are within close proximity to other equipment that could generate electrical noise.

Avoid sources of mechanical noise. If not possible, apply a filter to the data as described in the applicable communication interface ATI manual in [Table 2.1](#).

Cause: Noise can also indicate component failure within the system.

Solution: Check the status code of the sensor; refer to the applicable communication interface ATI manual in [Table 2.1](#).

Perform an accuracy check; refer to [Section 3.6—Accuracy Check Procedure](#) or refer to [Section 4.5: How do I evaluate the accuracy of health of the sensor?](#) in the Frequently Asked Questions (FAQ) ATI document located at: https://www.ati-ia.com/library/documents/FT_FAQ.pdf.

To return the sensor to ATI for inspection, contact ATI for a Returned Materials Authorization (RMA); refer to [Section 5.2—Periodic Calibrating](#).

Symptom: Drift — when the force torque data continues to increase or decrease after a load is removed.

Cause: Some drift from a change in temperature is normal. Drift is observed more easily in the Z axis, compared to the X and Y axes.

Solution: For approximately thirty minutes, allow the sensor to warm up until it is at a steady state with the air and other objects touching the sensor.

Use the bias command to shift the readings back to zero. Bias regularly.

Use an insulator between the sensor and any tooling or fixtures which are at a different temperature. Avoid creating a temperature gradient across the sensor. Shield the sensor from excessive air flow.

For more information about how to avoid drift from temperature change, refer to the following ATI document: <https://www.ati-ia.com/Library/Documents/DriftExplanation.pdf>.

Symptom: Hysteresis — when the sensor is loaded from a zeroed or biased state and then the load is removed, sensor output does not immediately return to zero.

Cause: Mechanical coupling or internal failure can cause Hysteresis which is outside of the sensor's specified and acceptable measurement uncertainty (error) range.

Solution: Verify the sensor is properly installed, fasteners are tightened, and the customer tooling is securely installed per [Section 3—Installation](#).

Use the bias command to shift the readings back to zero.

Symptom: The initial F/T values are non-zero and no load is applied.

Normal. Bias the sensor to bring all the F/T values back to zero.

Symptom: The sensor does not report accurate F/T data.

Cause: The sensor may be in an error state.

Solution: Check the sensor status code. For how to read and interpret the status code, refer to the appropriate manual in [Table 2.1](#)). If there are no error bits ON, continue troubleshooting.

Cause: The sensor is not properly installed or not mounted to a flat, stiff surface.

Solution: Verify the sensor is correctly installed per [Section 3—Installation](#).

Cause: The mounting fasteners are not properly secured.

Solution: Verify the fasteners are secured per the installation procedures in [Section 3.4—Install the Sensor](#).

If fasteners are customer supplied, do not use fasteners that are too long. For maximum fastener penetration depth into the sensor, refer to the [ATI sensor drawing](#). When selecting fasteners: use a high quality, high strength screw or bolt and ensure the fastener's material type, fastener head, and fastener grade are proper for the application.

Cause: Mechanical coupling — an external object such as customer tooling or utilities contacts a sensor's surface between the mounting side and tool side.

Solution: Remove any debris between the tool side and interface plate. Use proper cable management for cables and hoses; do not connect them tightly between the mounting and tool side of the sensor.

Anything that contacts surfaces such as the through hole in the sensor or cover plates on either side of the sensor induces loading or movement that could result in inaccurate F/T data.

Symptom: The F/T values do not match expected values, for example: the F/T values are fluctuating but are higher than a known applied load.

Cause: The sensor may be in a mode that reports gage data instead of F/T data.

Solution: Gage data is not a 1:1 correlation to F/T axis data. View F/T data instead of gage data; refer to the applicable communication interface ATI manual in [Table 2.1](#).

Cause: The sensor outputs data in counts. The user must convert the counts to calibration units.

Solution: Counts must be divided by the Counts per Force (CpF) or Counts per Torque (CpT) in order to convert them to calibration units such as N and Nm.

In addition to CpF and CpT, depending on the communication protocol, the values may be further scaled by a 16-bit scale factor. 16-bit counts must be divided by (CpF or CpT ÷ 16-bit scale factor) in order to convert to calibration units.

Cause: If once the F/T readings are converted to calibration units and exceed the sensor's calibration range per [Section 7.3—Calibration Range](#), the reported values are inaccurate and the sensor may be overloaded.

Solution: Check the status code. For information on how to read and interpret the sensor's status code, refer to the applicable communication interface ATI manual in [Table 2.1](#).

Unmount the sensor. Improper mounting methods can induce high loads in the sensor.

After reinstalling the sensor and without applying a load, if errors such as "Sensing Range Exceeded", "Gage Out of Range", or "Gage Broken" persist, the sensor is likely permanently damaged due to overload.

7. Specifications

Some requirements and specifications for the Axia90 sensor are covered in the following sections. For more information, refer to the customer drawing.

7.1 Environmental Conditions

Table 6.1—Environmental Conditions	
Parameter	Value
Storage Temperature, °C	-20 to +85
Operating Temperature, °C	0 to +65
Relative Humidity	<95%, non-condensing

7.2 Electrical Specifications

Table 6.2—Power Supply ¹				
Power Source	Voltage			Power Consumption
	Minimum	Nominal	Maximum	Maximum
DC Power	12 V	24 V	30 V	1.5 W

Notes:

- The power supply input is reverse polarity protected. If the power and ground to the power supply inputs are plugged in reverse, then the reverse polarity protection stops the incorrectly wired supply input from damaging or powering on the sensor.

7.3 Calibration Range

Table 6.3—Calibration Range			
Model	Axia90-M50		
Parameter	Fxy	Fz	Txyz
Calibration Range 0 (SI-1000-50)	1000 N	2000 N	50 Nm

7.4 Default Peak Values

When powered on, the sensor records the peak values seen on any single axis. The following values are the default values programmed at the factory during calibration. If the sensor shows peak values higher than these defaults, the sensor has been loaded past the intended calibrated sensing range.

Table 6.4—Default Peak Values in Counts						
Sensor Model	Axia90-M50					
Parameter	Fx	Fy	Fz	Tx	Ty	Tz
Positive Default Value	6.24999 x 10 ⁸		1.249998 x 10 ⁹			3.124995 x 10 ⁷
Negative Default Value	-6.24999 x 10 ⁸		-1.249998 x 10 ⁹			-3.124995 x 10 ⁷

8. 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.

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EtherCAT Axia Manual



Document #: 9620-05-C-EtherCAT Axia

Engineered Products for Robotic Productivity

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Note:

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

1. Serial number, for example: FT01234
2. Model, for example: Axia130-M125
3. Calibration, for example: SI-800-50 or SI-2000-125
4. Accurate and complete description of the question or concern
 - For the status code; refer to [Section 5.2.1.7—Object 0x6010: Status Code](#).
5. Computer and software information, for example: operating system, PC type, drivers, and application software

Be near the F/T system when calling (if possible).

Please contact an ATI representative for assistance, if needed:

Sale, Service and Information about ATI products:

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Glossary

Term	Definition
ADC	Analog-to-digital converter.
Bias	Bias may also be referred to as “zero out” or “tare” the sensor. Biasing is useful for eliminating the effects of gravity (tool weight) or other acting forces, as well as the effects of drift. When the bias function is used, the software collects data for the forces and torques that are currently acting on the sensor and use these readings as a reference for future readings. Future readings will have this reference subtracted from them before they are transmitted.
Calibration	Defines a specific measurement or sensing range for a given sensor. Calibration is also the process of measuring a transducer’s raw response to loads and creating data used in converting the response to forces and torques.
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. Complex loading may reduce measurement range in a given axis.
Coordinate Frame	See Point of Origin.
Data Rate	How fast data can be output over a network.
DINT	Signed double integer (32 bit)
EEPROM	Electrically Erasable Programmable Read-Only Memory—a type of non-volatile memory integrated in the sensor electronics.
ESI	EtherCAT Slave Information is a file type.
EtherCAT	An industrial automation fieldbus.
FoE	File access over EtherCAT, the preferred embedded protocol for uploading new firmware to EtherCAT devices.
Force	A force is a push or pull action on an object caused by an interaction with another object. Force = mass X acceleration
FS	Full-Scale, refers to the limits of a given calibration or sensing range.
F/T	Force/Torque.
F_{xy}	The resultant force vector comprised of components F_x and F_y .
Hysteresis	A source of measurement error caused by the residual effects of previously applied loads.
INT	Signed integer (16 bit)
Interface Plate	A separate plate that attaches the sensor to another surface. Interface plates are often used if the bolt pattern on the sensor doesn’t match the bolt pattern on the robot arm or customer tooling. The interface plate has two bolt patterns, one on either side of the plate. One side is for the sensor. The other side is for the robot arm or customer tooling.
IP64	Ingress protection rating “64” designates complete protection against dust and protection against splash water from any direction (limited ingress permitted).
IP67	Ingress protection rating “67” designates protection against dust and submersion under 1 m of fresh water.
ISR	Interrupt service routine
Master Device	A customer supplied device such as a personal computer, robot, or programmable logic controller (PLC) that is compatible with a specific communication interface.

Term	Definition
Measurement Uncertainty	Commonly referred to as “accuracy”, “measurement uncertainty” is the worst-case error between the measured value and the true load. The measurement uncertainty is specified as a percentage of the full-scale measurement range for a given sensor model and calibration size. This value takes into account multiple sources of error. The sensor’s calibration certificate lists the measurement uncertainty percentage. For more information, refer to <i>Section 2.2: Measurement Uncertainty</i> in the Frequently Asked Questions (FAQ) document located at: https://www.ati-ia.com/library/documents/FT_FAQ.pdf .
Mechanical Coupling	When an external object such as customer tooling or utilities contacts a sensor’s surface between the sensor’s mounting side and tool side.
N/A	Not Applicable
Overload	The condition where more load is applied to the transducer than it can measure. Overload results in saturation.
PDO	Process Data Object, a protocol for reading and writing real-time process information cyclically.
P/N	Part Number
Point of Origin	The point on the sensor from which all forces and torques are measured.
Power Cycle	When a user removes and then restores power to a device.
Resolution	The smallest change in load that can be measured. Resolution is usually much smaller than accuracy. Resolution specifications for specific ATI F/T sensors are available on the ATI F/T product web page.
Sample Rate	How fast the ADCs are sampling inside the unit.
Saturation	The condition where the transducer or data acquisition hardware has a load or signal outside of its sensing range.
SDO	Service Data Object, a protocol for reading and writing configuration information acyclically.
Sensor	The component that converts a detected load into electrical signals.
Sensor System (or configuration)	The entire assembly consisting of a sensor body and a system interface to translate force and torque signals into a specific communication interface/protocol.
SINT	Signed short integer (8 bit)
Status Bit	A unit of computer data sent from the ATI F/T sensor.
STRING n	String of n characters
STRING(8)	A data type representing (8) characters, using (8) bytes.
STRING(30)	A data type representing (30) characters, using (30) bytes.
Torque	The application of a force through a lever or moment arm that causes something to want to turn. For example, a user applies torque to a screw to make it turn. Torque = force x moment arm length
T _{xy}	The resultant torque vector comprised of components T _x and T _y .
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. Product specific notifications are imbedded within the sections of this manual (where they apply).

1.1 Explanation of Notifications

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



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



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



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

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

1.2 General Safety Guidelines

The customer should verify that the 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 deceleration 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: 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. For more information about rated ranges, refer to the appropriate sensor manual in [Table 2.1](#).

2. Product Overview

The EtherCAT Axia Force/Torque (F/T) sensor system measures six components of force and torque ($F_x \setminus F_y \setminus F_z \setminus T_x \setminus T_y \setminus T_z$) and streams this data to customer devices via EtherCAT fieldbus (refer to [Section 5—EtherCAT Bus Interface](#)). To use EtherCAT, the user needs a software interface and device (such as a personal computer, robot, or PLC) that is compatible with EtherCAT. Free, downloadable software such as TwinCAT is available online for users with a Windows® operating system. The ATI Axia-series product line differs from the other (non-Axia) ATI F/T sensor models. Thus, the Axia sensors have different options and available features. The Axia-series F/T sensors are available in several different payload and communication interface versions.

This manual covers the following topics:

- Electrical specifications and wire information for cables
- Sensor and cable connector pin numbers and descriptions
- Operation (LEDs, filter rates, and sampling rates)
- EtherCAT Objects dictionary.

For additional sensor information, such as installation on a robot, operation, and general troubleshooting, refer to the appropriate sensor manual listed in the following table:

Table 2.1—ATI Axia F/T Sensor Manual	
ATI Axia Sensor Model	Refer to the ATI Axia F/T Sensor Manual: (ATI Manual P/N)
Axia80	ATI F/T Axia80 Sensor Manual (ATI Document #9620-05-B-Axia80)
Axia90	ATI F/T Axia90 Sensor Manual (ATI Document #9620-05-B-Axia90)
Axia130	ATI F/T Axia130 Sensor Manual (ATI Document #9620-05-B-Axia130)

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.



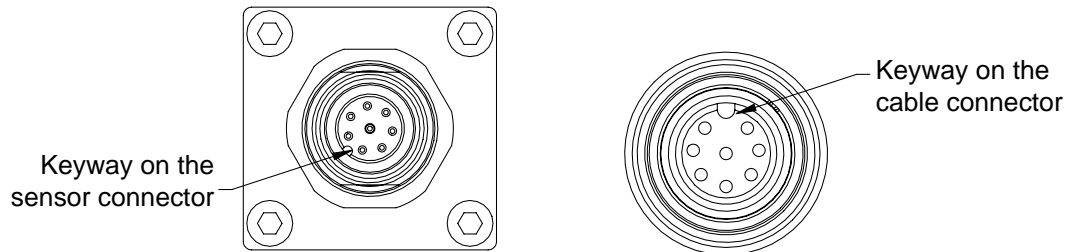
CAUTION: Modification or disassembly of the sensor could cause damage and void the warranty. Use the supplied mounting bolt pattern and the provided tool side mounting bolt pattern to mount the sensor to the robot and customer tooling to the sensor (refer to the customer drawing).



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 Cable Configuration

Cables can be configured a number of ways; however, the most common configurations are presented in the following:

Figure 3.1—Axia80/Axia90 Cable Configuration

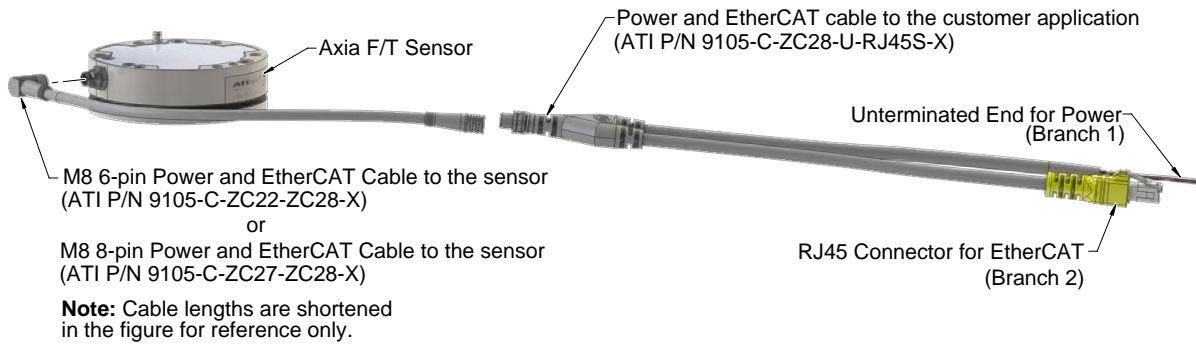
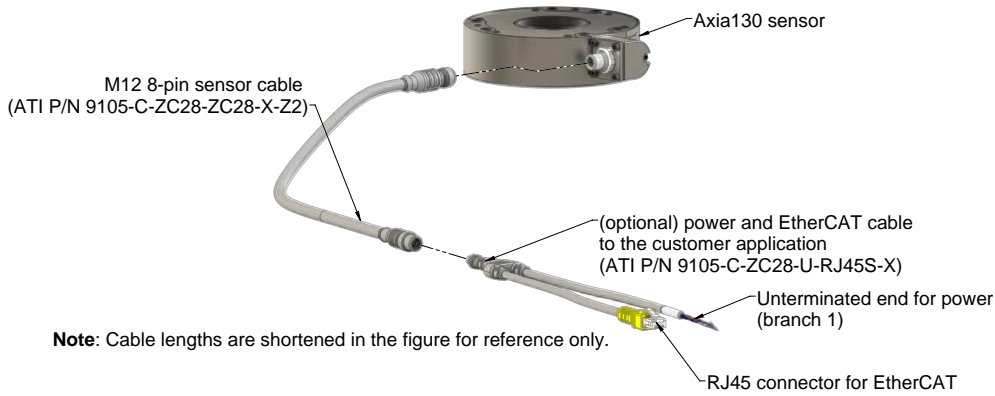



Figure 3.2—Axia130 Cable Configuration



3.2 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 connector on the Axia sensor and applicable connectors on the cables. For cable technical specifications, refer to [Section 7.2—Cable Specifications](#).

Power Source	Voltage			Power Consumption
	Minimum	Nominal	Maximum	Maximum
DC Power	12 V	24 V	30 V	1.5 W

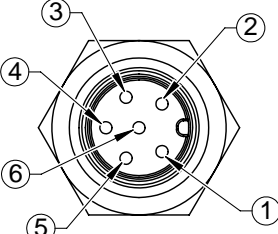
Notes:

- The power supply input is reverse polarity protected. If the power and ground to the power supply inputs are plugged in reverse, then the reverse polarity protection stops the incorrectly wired supply input from damaging or powering on the sensor.

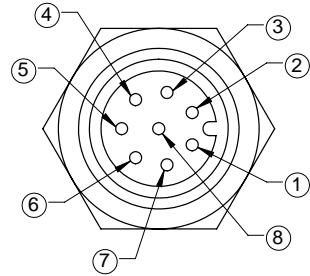
3.2.1 Axia F/T Sensor

Signals and corresponding pin numbers for the Axia models are listed in the following sections.

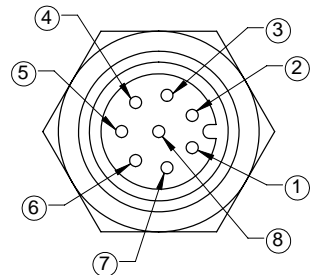
3.2.1.1 Axia80 Pin Assignment for the 6-Pin, M8 Male Sensor Connector

Table 3.2—Axia80 Sensor Connector, M8, 6-pin, Male		
Connector Schematic	Pin Number	Signal
	1	Tx +
	2	Tx -
	3	Rx +
	4	RX -
	5	V +
	6	V - / 0 V / Ground
	Shell	Shield

3.2.1.2 Axia80 and Axia90 Pin Assignment for the 8-pin M8 Male Sensor Connector

Table 3.3—Axia80 and Axia90 Sensor Connector, M12, 8-pin, Male		
Connector Schematic	Pin Number	Signal
	1	Reserved
	2	V +
	3	V - / Ground
	4	TX -
	5	RX +
	6	TX+
	7	Reserved
	8	RX -
	Shell	Shield

3.2.1.3 Axia130 Pin Assignment for the 8-Pin M12 Sensor Connector

Table 3.4—Axia130 Sensor Connector, M8, 8-pin, Male		
Connector Schematic	Pin Number	Signal
	1	Reserved
	2	V +
	3	V - / Ground
	4	TX -
	5	RX +
	6	X+
	7	Reserved
	8	RX -
	Shell	Shield

3.2.2 Axia80 Sensor Cable (P/N 9105-C-ZC22-ZC28)

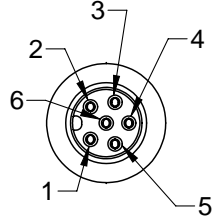
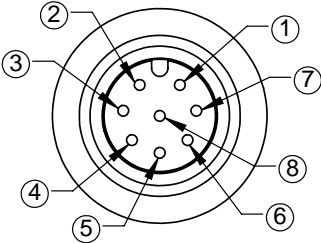
Table 3.5—ZC22 Connector, M8, 6-pin, Female		
Connector Schematic	Pin Number	Signal
	1	TX +
	2	TX -
	3	RX +
	4	RX -
	5	V +
	6	V -
	Shell	Shield

Table 3.6—ZC28 Connector, M12, 8-pin, Male		
Connector Schematic	Pin Number	Signal
	1	Reserved
	2	V +
	3	V -
	4	TX -
	5	RX +
	6	Tx +
	7	Reserved
	8	RX -
Shell	Shield	

3.2.3 Axia80 and Axia90 Sensor Cable (P/N 9105-C-ZC27-ZC28)

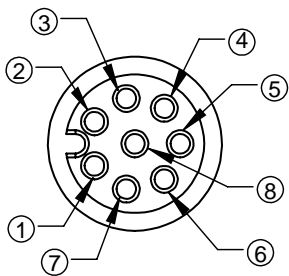
Table 3.7—ZC27 Connector, M8, 8-pin, Female		
Connector Schematic	Pin Number	Signal
	1	Reserved
	2	V +
	3	V -
	4	TX -
	5	RX +
	6	TX +
	7	Reserved
	8	RX -
Shell	Shield	

Table 3.8—ZC28 Connector, M12, 8-pin, Male

Connector Schematic	Pin Number	Signal
	1	Reserved
	2	V +
	3	V -
	4	TX -
	5	RX +
	6	Tx +
	7	Reserved
	8	RX -
	Shell	Shield

3.2.4 Axia130 Sensor Cable (P/N 9105-C-ZC28-ZC28)

Table 3.9—ZC28 Connector, M12, 8-pin, Female

Connector Schematic	Pin Number	Signal
	1	Reserved
	2	V +
	3	V -
	4	TX -
	5	RX +
	6	TX +
	7	Reserved
	8	RX -
	Shell	Shield

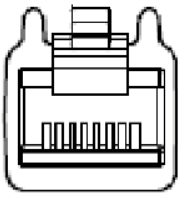
Table 3.10—ZC28 Connector, M12, 8-pin, Male

Connector Schematic	Pin Number	Signal
	1	Reserved
	2	V +
	3	V -
	4	TX -
	5	RX +
	6	TX +
	7	Reserved
	8	RX -
	Shell	Shield

3.2.5 EtherCAT Cable (P/N 9105-C-ZC28-U-RJ45S-X)

This cable has (2) branches: an unterminated end for power and a RJ45 connection for EtherCAT. Both of these connections connect to the customer's device. For the signals and corresponding pin numbers/wire color, refer to the following sections.

Table 3.11—Branch 1, Unterminated End For Power	
Wire Jacket Color	Signal
Braided Metal Shield	Shield (Connect to Ground)
Brown	V+
Brown/White	V-
Blue/White (TP1+)	Reserved
Blue (TP1-) ¹	Reserved

Table 3.12—EtherCAT Connector, RJ45, 8-pin, Female			
Connector Schematic	Pin Number	Wire Color	Signal
 12345678	1	White/Orange	TX+
	2	Orange	TX-
	3	White/Green	RX+
	4	-	No Connection
	5	-	
	6	Green	RX-
	7	-	No Connection
	8	-	

4. Operation

For general operation information about the sensor, refer to the appropriate sensor manual in [Table 2.1](#).

4.1 LED Self-Test Sequence

The EtherCAT Axia sensor has three LEDs: Link/Activity, Run, and Sensor Status. When the user applies power, the sensor completes a self-test, during which the LEDs under firmware control turn-on individually.

Table 4.1—LED Self Test Sequence			
Sequence Order	LED	State	Duration
0	All	At power on, some transient activity may be seen for only a few milliseconds.	
1	All	Off	Approximately one second for each state.
2	Status	Red	
3	Error	Red	
4	EtherCAT Link/Activity	Red	
5	Status	Green	
6	Run	Green	
7	EtherCAT Link/Activity	Green	
8	All	Off	
9	All	Normal Operation	

Figure 4.1—LED Label on the Sensor



4.2 LED Normal Operation

4.2.1 Sensor Status LED

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

Table 4.2—Status LED		
LED Color	State	Description
Off	No power	Electricity not supplied to the sensor.
Green	Normal operation	The sensor's electronics are functioning and communicating.
Amber ¹	Sensing range exceeded	Forces and torques applied to the sensor exceed the ranges listed in the applicable sensor manual; refer to Table 2.1 .
Red (flash at 10 Hz speed)	Communication error	The sensor is not able to communicate data over the communication protocol.
Red (flash at 1 Hz speed)	Calibration error	Calibration was not stored in the EEPROM.
Red (Solid)	Status code error	For more information on the error set, refer to Table 5.8 .
Note:		
1. Amber is when both green and red LEDs are on.		

4.2.2 Run (Error) LED

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

Table 4.3—Error/Run LED		
LED Color	State	Description
Off	No power	Electricity not supplied to the sensor.
Green Blinking	Pre-operational	Defined in the communication/protocol standard set by the EtherCAT® Technology Group.
Green Single Flash	Safe-operational	
Green On	Operational	
Red	Error	Indicates any error reported by the sensor. It stays red for five seconds after any error.

4.2.3 EtherCAT L/A (Link/Activity) LED

One LED signals the communication status of the Axia130 sensor interface as follows:

Table 4.4—EtherCAT L/A Activity LED		
LED Color	State	Description
Off	No power or no link activity	Either no link activity has occurred within 5 seconds or electricity is not supplied to the sensor.
Green	Link activity	Stays green for five seconds after link activity.

4.3 Sample Rate

The user can set Sample Rate to control how fast the ADCs are sampling inside the sensor. Sensors with older electronics (SensorHwVer < 2) cannot achieve simultaneous max data rate and ADC sample rate. Rounded and exact sample rates are in the following table.

Table 4.5—Sample Rate					
Rounded Sample Rate	0.5 kHz	1 kHz	2 kHz	4 kHz	8 kHz
Exact Sample Rate	488 Hz	976 Hz	1953 Hz	3906 Hz	7812 Hz

4.3.1 Sample Rate Versus Data Rate

The data rate is how fast data can be output over the network. Sometimes the data rate can be referred to as communication rate or network data communication rate, for example TwinCAT® references it as cycle time.

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 necessarily sampling internally at that rate.

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.

4.4 Low-pass Filter

The power-on default selection is no filtering. Users can configure the filter setting to reduce the signal noise. The cutoff frequency (for example: -3 dB frequency) is dependent on the selected sample rate which is listed in the following table. The cutoff frequencies for the different sampling rates are listed in the following table and graphs:

Table 4.6—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	at 8 kHz Sample Rate
0	200	350	500	1000	2000
1	58	115	235	460	935
2	22	45	90	180	364
3	10	21	43	84	170
4	5	10	20	40	81
5	2.5	5	10	20	40
6	1.3	3	5	10	20
7	0.6	1.2	2.4	4.7	9
8	0.3	0.7	1.4	2.7	5

Figure 4.2—Filter Attenuation at 0.5 kHz Sample Rate

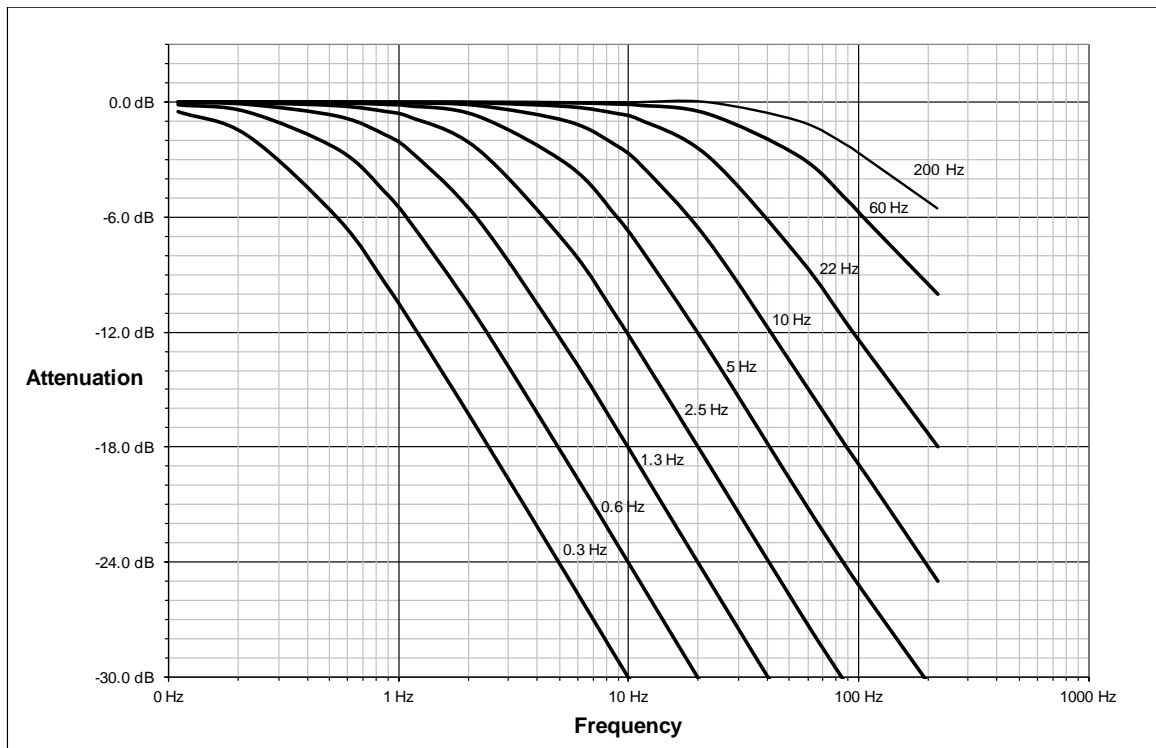


Figure 4.3—Filter Attenuation at 1 kHz Sample Rate

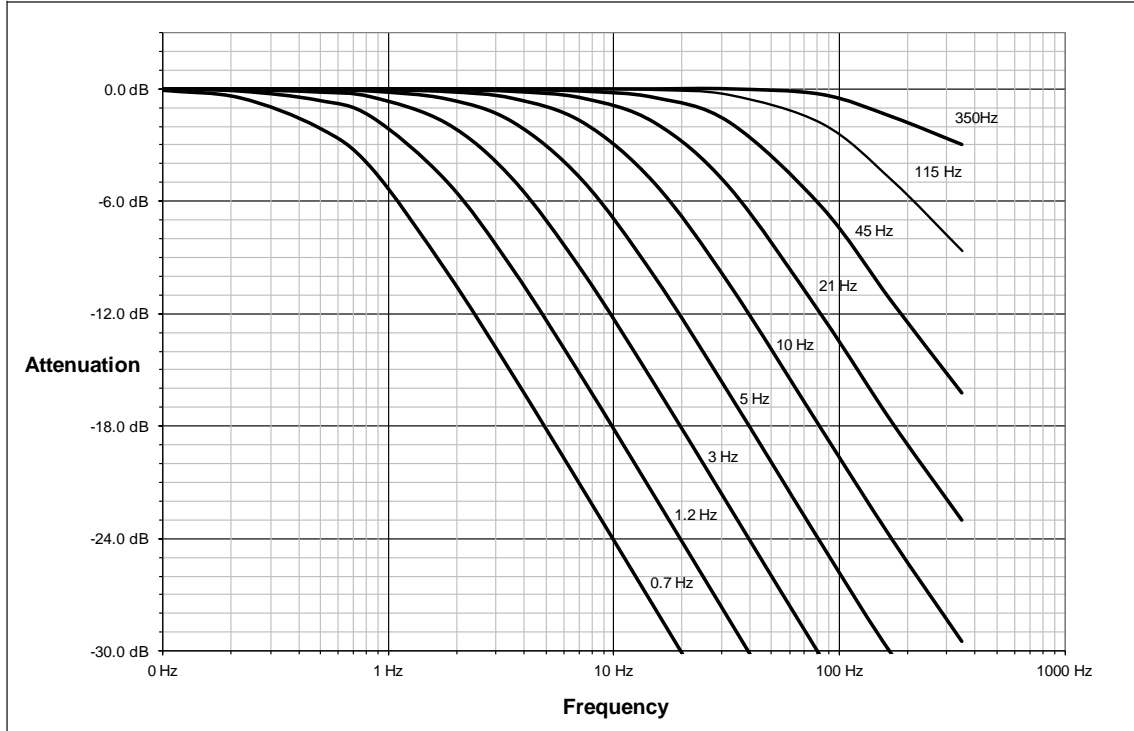


Figure 4.4—Filter Attenuation at 2 kHz Sample Rate

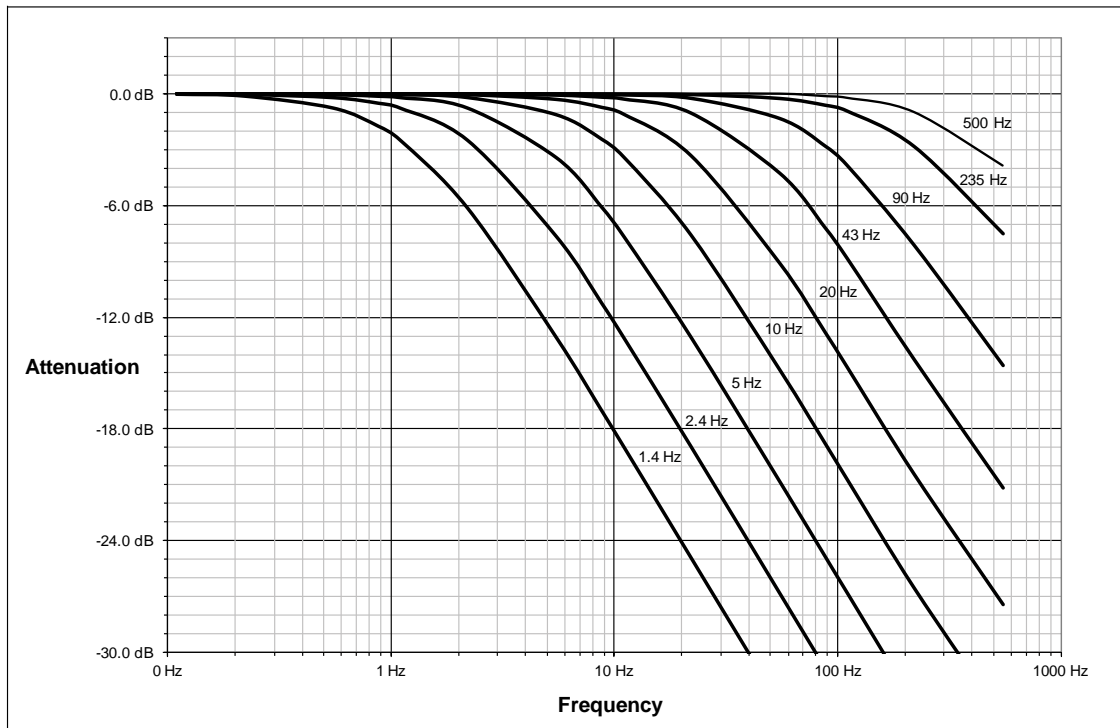


Figure 4.5—Filter Attenuation at 4 kHz Sample Rate

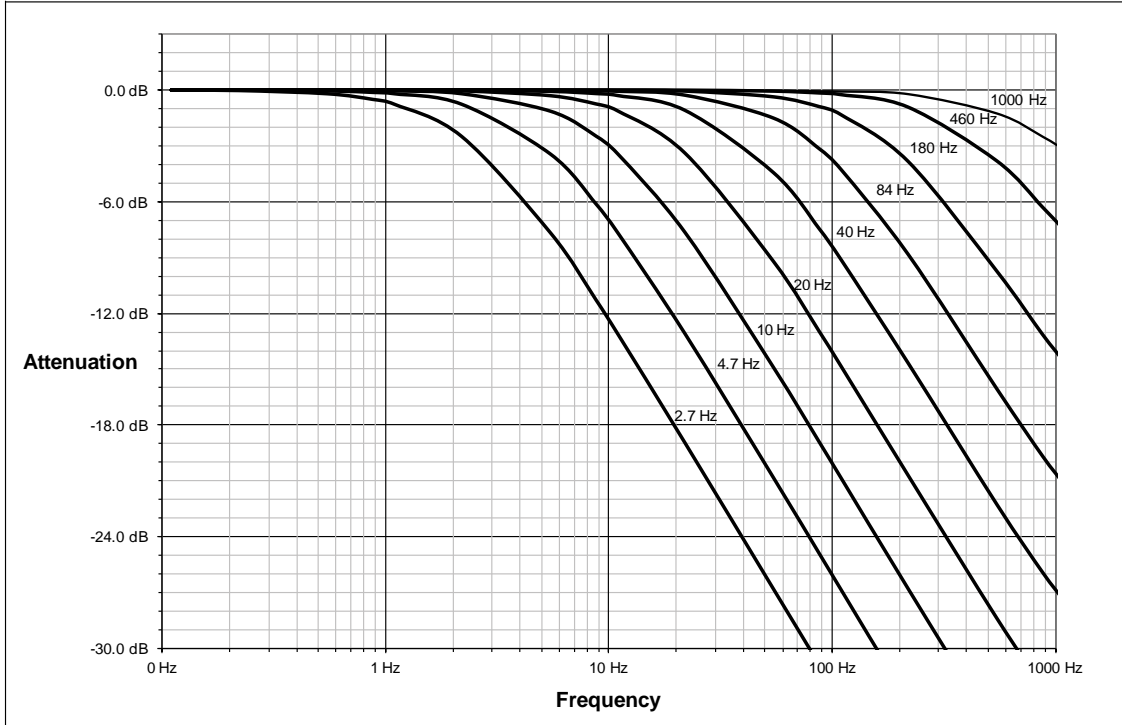
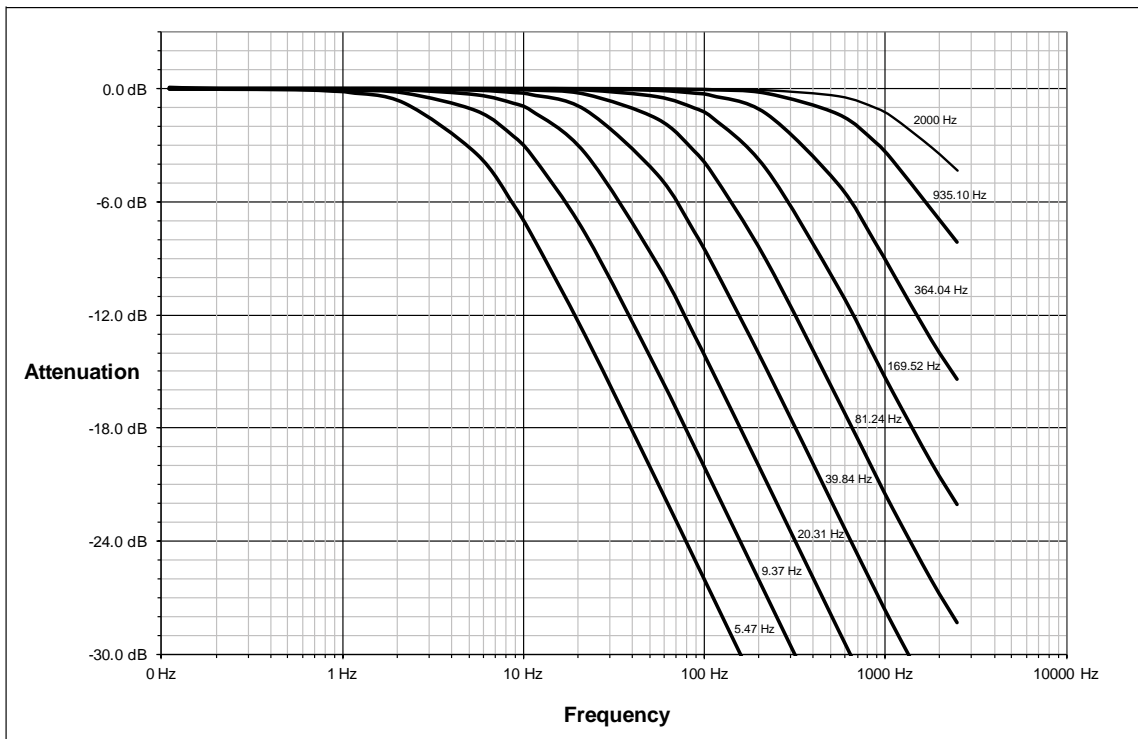


Figure 4.6—Filter Attenuation at 8 kHz Sample Rate



5. EtherCAT Bus Interface

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

- Read the active calibration information, and serial number
- Read the firmware version
- Read F/T 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 *Object 0x6010: Status Code*.
- 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 and some objects that are a required part of the standard defined by the set by the EtherCAT® Technology Group. Dictionary objects (covered in this section) can be found in the **ECAT AXIA ESI File (ATI P/N 9030-05-1021)** that is available to download from the ATI webpage: https://www.ati-ia.com/Products/ft/software/axia_software.aspx.

While using some dictionary objects, the user may need to convert a code from hexadecimal to a binary number (refer to *Section 5.2.3—How to Interpret Hexadecimal Output*).

5.2.1 ATI Specific Objects

The structure of these objects is defined by ATI.

5.2.1.1 Object 0x2019: Product Description

This read/write object allows a user to change this field in order to brand the sensor as part of their own system. This object is not visible to most users. To change these fields, contact ft.support@novanta.com for assistance. Note that the same information can be found in [Section 5.2.2—EtherCAT Communication Objects](#).

Table 5.1—Object Index (hex) 0x2019: Product Description

Subindex (Hex)	Name	Description	Type	Default Value		
				Hexadecimal Format	Decimal Format	String
0x01	Vendor ID	The value written to this field will be read into Object 0x1018, Subindex 0x01: Vendor ID (refer to Section 5.2.2.3—Object 0x1018: Identity).	UDINT	0x00000732	1842	-
0x02	Product Code	The value written to this field will be read into Object 0x1018, Subindex 0x02: Product Code (refer to Section 5.2.2.3—Object 0x1018: Identity).	UDINT	0x26483053	642265171	-
0x03	Product Name	The value written to this field will be read into Object 0x1008: Device Name (refer to Section 5.2.2.2—Object 0x1008: Device Name).	String(32)	-	-	“ATI Axia F/T Sensor”
0x04	Product Revision	This field is not used by ATI.	UDINT	N/A		
0x05	Product Serial Number		UDINT			
0x06	Manufacturer	This field identifies ATI or a company that has integrated the ATI sensor into their branded system.	String(32)	-	-	“ATI Industrial Automation”
0x07	Commit	To use this field, the user must have an ATI-provided password. This field accepts changes to other fields within this object.	UDINT	0x00000000	0	-

5.2.1.2 Object 0x2020: Tool Transformation

This object allows the settings for the function tool transformation to be viewed or changed. After entering the changes, commit to the changes by entering “123” into the “Commit” field at the bottom of the object. To turn off this feature, set the three displacements and rotations to zero. This object contains the following fields:

Table 5.2— Object Index (hex) 0x2020: Tool Transformation			
Subindex	Name	Type	Description
0x01	Dx	STRING(12) Enter each element as a floating-point number in text form.	Displacement along the X axis in units of ttDistUnits.
0x02	Dy		Displacement along the Y axis in units of ttDistUnits.
0x03	Dz		Displacement along the Z axis in units of ttDistUnits.
0x04	Rx		Rotation about the X axis in units of ttAngUnits.
0x05	Ry		Rotation about the Y axis in units of ttAngUnits.
0x06	Rz		Rotation about the Z axis in units of ttAngUnits.
0x07	ttDistUnits	UINT8	Distance units: 0 = inches 1 = feet 2 = mm 3 = cm 4 = m
0x08	ttAngUnits	UINT8	Rotation units: 0 = degrees 1 = radians
0x09	Commit	UINT8	Write “123” here to set the changes.

5.2.1.3 Object 0x2021: Calibration

This read-only object contains information about the currently active calibration selected by the “Calibration Selection” field in [Section 5.2.1.11—Object 0x7010: Control Codes](#). This object contains the following fields:

Table 5.3— Object Index (hex) 0x2021: Calibration			
Subindex	Name	Type	Description
0x01	FT Serial	STRING(8)	The F/T Serial Number, e.g. “FT01234”. ¹
0x02	Calibration Part Number	STRING(30)	The calibration part number e.g. “SI-500-20”. ²
0x03	Calibration Family	STRING(8)	Always reads “ECAT”.
0x04	Calibration Time	STRING(30)	The date the sensor was calibrated.
0x05 through 0x2e	Reserved	DINT	Reserved
Notes:			
<ol style="list-style-type: none"> 1. This field identifies an individual sensor. A sensor may have more than one FTxxxx calibration serial number; each F/T calibration serial number identifies a separate calibration. No two sensors share a F/T calibration serial number. 2. This field identifies the calibration size. A sensor model may have more than one calibration size/part number. To change the active calibration, use the control codes; refer to Section 5.2.1.11—Object 0x7010: Control Codes. 3. When powered on, the sensor records the peak values detected on any single axis. If the sensor detects all-time peak values higher than the ATI factory defaults, the sensor has been loaded past the intended calibrated sensing range/ For the ATI factory default all-time peak values (listed in counts), refer to the applicable Axia F/T sensor manual in Table 2.1. 			

Table 5.3— Object Index (hex) 0x2021: Calibration				
Subindex	Name	Type	Description	
0x2f	Force Units	USINT	Value	Unit
			0	Lbf
			1	N
			2	Klbf
			3	kN
0x30	Torque Units	USINT	Value	Unit
			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	Reserved		
0x57	PeakLoadsPosFx ³	DINT	Peak Loads ³ Positive. All-time peak positive F/T loads in counts.	
0x58	PeakLoadsPosFy ³			
0x59	PeakLoadsPosFz ³			
0x5a	PeakLoadsPosTx ³			
0x5b	PeakLoadsPosTy ³			
0x5c	PeakLoadsPosTz ³			
Notes: <ol style="list-style-type: none"> 1. This field identifies an individual sensor. A sensor may have more than one FTxxxx calibration serial number; each F/T calibration serial number identifies a separate calibration. No two sensors share a F/T calibration serial number. 2. This field identifies the calibration size. A sensor model may have more than one calibration size/part number. To change the active calibration, use the control codes; refer to Section 5.2.1.11— Object 0x7010: Control Codes. 3. When powered on, the sensor records the peak values detected on any single axis. If the sensor detects all-time peak values higher than the ATI factory defaults, the sensor has been loaded past the intended calibrated sensing range/ For the ATI factory default all-time peak values (listed in counts), refer to the applicable Axia F/T sensor manual in Table 2.1. 				

Table 5.3— Object Index (hex) 0x2021: Calibration			
Subindex	Name	Type	Description
0x5d	PeakLoadsNegFx ³	DINT	Peak Loads ³ Negative. All-time peak negative F/T loads in counts.
0x5e	PeakLoadsNegFy ³		
0x5f	PeakLoadsNegFz ³		
0x60	PeakLoadsNegTx ³		
0x61	PeakLoadsNegTy ³		
0x62	PeakLoadsNegTz ³		
0x63 through 0x97	Reserved		
Notes:			
<ol style="list-style-type: none"> 1. This field identifies an individual sensor. A sensor may have more than one FTxxxx calibration serial number; each F/T calibration serial number identifies a separate calibration. No two sensors share a F/T calibration serial number. 2. This field identifies the calibration size. A sensor model may have more than one calibration size/part number. To change the active calibration, use the control codes; refer to Section 5.2.1.11—Object 0x7010: Control Codes. 3. When powered on, the sensor records the peak values detected on any single axis. If the sensor detects all-time peak values higher than the ATI factory defaults, the sensor has been loaded past the intended calibrated sensing range/ For the ATI factory default all-time peak values (listed in counts), refer to the applicable Axia F/T sensor manual in Table 2.1. 			

5.2.1.4 Object 0x2080: Diagnostic Readings

This read-only object provides diagnostic information. In this object, the following fields are available:

Table 5.4—Object Index (hex) 0x2080: 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 5.5)

Table 5.5—Errors in the Diagnostic Readings Status Message	
Priority	Text Error Messages
1	Supply voltage out of range
2	Gage temperature out of range
3	Error (unspecified)
4	Gage(s) disconnected: <list>
5	Gage(s) out-of-range: <list>
6	F/T out of range
7	Common error
8	Simulated error
9	Spare
10	No status code errors

5.2.1.5 Object 0x2090: Version

This read-only object provides firmware version information. In this object, the following fields are available:

Table 5.6—Object Index (hex) 0x2090: Version			
Subindex	Name	Type	Description
0x01	Major	UINT	Major Version
0x02	Minor	UINT	Minor Version
0x03	Revision	UINT	Revision
0x04	Bootloader Version	UDINT	Bootloader Version
0x05	SensorHwVer	UINT	Sensor Hardware Version
0x06	SensorInstrument	UINT	Instrumentation Version
Note:			
1. SensorHWVer = 2 indicates the electronics are part of the ATI Axia F/T Gen-2 series. SensorHWVer < 2 indicates the electronics are part of the ATI Axia F/T Gen-1 series.			

5.2.1.6 Object 0x6000: Reading Data

This read-only object represents the current F/T and is mapped into the TxPDO input data. In the reading data, the following fields are present:

Table 5.7—Object Index (hex) 0x6000: Reading Data			
Subindex	Name	Type	Description
0x01	Fx	DINT	These fields contain the 32-bit F/T resolved data, in counts. For the force data to be in units, divide the force counts values by the counts per force field from the calibration object. For the torque data to be in units, divide the torque counts values by the counts per torque field from the calibration object.
0x02	Fy		
0x03	Fz		
0x04	Tx		
0x05	Ty		
0x06	Tz		

5.2.1.7 Object 0x6010: Status Code

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

Table 5.8—Object Index (hex) 0x6010: 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 (high): <ul style="list-style-type: none"> A gage reads positive full scale and indicates that the electrical connection to a gage is open or disconnected. The sensor reports loads significantly higher than its sensing range. It self resets 32 sample periods after the condition clears.	Yes
3	Busy Bit. The sensor is performing (1) or more of the following activities that may temporarily affect the F/T data: <ul style="list-style-type: none"> 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
6-25	Reserved.	No
26	Gage Out of Range Warning: This bit is active if a strain gage warning range (gageMinRangeWam to gageMaxRangeWam) has been exceeded in any of the past hold time (normally 32) samples.	Yes
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 5.2.1.11—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!: 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.		

5.2.1.8 Status Code: Sensing Range Exceeded

Bit 30 in [Table 5.8](#) 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 greater than 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 greater than 105%. Refer to the following F_z T_{xy} equation.

$$\frac{|F_z|}{F_z\text{CalibratedRange}} + \frac{\sqrt{T_x^2 + T_y^2}}{T_{XY}\text{CalibratedRange}} > 105\%$$

For Example:

An Axia130-M125 sensor that is subjected to the following loads and has the following calibration range (for the calibrated ranges of a sensor, refer to the applicable manual in [Table 2.1](#)):

Axis	Applied Load	Calibration Range
F_x	475 N	2000 N
F_y	-300 N	2000 N
F_z	-1000 N	4000 N
T_x	10 Nm	125 Nm
T_y	20 Nm	125 Nm
T_z	-105 Nm	125 Nm

The F_{xy} T_z equation simplifies as follows:

$$\frac{\sqrt{(475\text{N})^2 + (-300\text{N})^2}}{2000\text{N}} + \frac{|-105\text{Nm}|}{125\text{Nm}} > 105\%$$

$$\frac{561.8\text{N}}{2000\text{N}} + \frac{105\text{Nm}}{125\text{Nm}} > 105\%$$

$$28.1\% + 84\% > 105\%$$

$$112.1\% > 105\%$$

TRUE

The $F_z T_{xy}$ equation simplifies as follows:

$$\frac{|-1000N|}{4000N} + \frac{\sqrt{(10Nm)^2 + (20Nm)^2}}{125Nm} > 105\%$$

$$\frac{1000N}{4000N} + \frac{22.4Nm}{125Nm} > 105\%$$

$$25\% + 17.9\% > 105\%$$

$$42.9\% > 105\%$$

FALSE

Because the $F_{xy} T_z$ equation simplified to TRUE, bit 30 in [Table 5.8](#) is set.

5.2.1.9 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.

5.2.1.10 Object 0x6030: Gage Data

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

Table 5.10—Object Index (hex) 0x6030: 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		

5.2.1.11 Object 0x7010: Control Codes

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

Table 5.11—Object Index (hex) 0x7010: Control Codes				
Subindex	Name	Type	Description	
0x01	Control 1	DINT	Bit	Function
			0	1 = Set bias (tare) 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 = for details on the types of filters, refer to Table 4.6 .
			8-11	Active calibration. 0 = use the calibration in slot 0 ² 1 = use the calibration in slot 1 ² 2 through 15 = Reserved. For calibration ranges, refer to the specifications section in the applicable manual in Table 2.1 .
			12-15	Sample Rate 0 = 488 Hz 1 = 976 Hz 2 = 1953 Hz 3 = 3906 Hz 4 = 7812 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. 2. For the calibration ranges, refer to the applicable F/T sensor manual in Table 2.1 .				

5.2.2 EtherCAT Communication Objects

The structure of these 0x1000 Objects are defined by the EtherCAT® Technology Group. ATI does not use all fields.

5.2.2.1 Object 0x1000: Device Type

This read-only object describes the type of EtherCAT device.

Table 5.12—Object Index (hex) 0x1000: Device Type			
Type	Description	Default Value (hex)	Default Value (decimal)
UDINT	The EtherCAT device category under which the ATI EtherCAT Axia is categorized.	0x00000192	402

5.2.2.2 Object 0x1008: Device Name

This read-only object describes the name of the device. The EtherCAT® Technology Group defines the structure of this object but leaves it as optional. ATI programs in a default name, and this name may change. ATI can provide support to users who want to change this field. Sometimes users may want to change this field so they can brand the ATI sensor as part of their system.

Table 5.13—Object Index (hex) 0x1008: Device Name		
Type	Description	Default Value (string)
STRING	The name of the device as a non-zero terminated string. Do not use for product identification. ¹	“ATI Axia F/T Sensor”
Note: 1. Because this field can change, do not use this field for product identification. For fields that can be used for product identification, refer to Section 5.2.2.3—Object 0x1018: Identity .		

5.2.2.3 Object 0x1018: Identity

This read-only object contains information about the connected EtherCAT device (in this case, the ATI EtherCAT Axia sensor). The EtherCAT® Technology Group defines the structure of this object, and ATI defines the values for each ATI product. ATI can provide support to users who want to change this field. Sometimes users may want to change this field so they can brand the ATI sensor as part of their system.

Table 5.14—Object Index (hex) 0x1018: Identity Object					
Subindex (Hex)	Name	Functionality	Type	Default Value (hex)	Default Value (decimal)
0x01	Vendor ID	This Vendor ID number is assigned by EtherCAT® Technology Group uniquely to ATI. ¹	UDINT	0x00000732	1842
0x02	Product Code	This Product Code is assigned by ATI uniquely to the EtherCAT Axia sensors (ATI part numbers 9105-ECAT-Axiax-x where x indicates the Axia model). ²	UDINT	0x26483053	642265171
0x03	Revision Number	This field is subject to change and should not be used for identification purposes. ³	UDINT	N/A	
0x04	Serial Number	This field is subject to change and should not be used for identification purposes. ⁴			
Note: <ol style="list-style-type: none"> 1. Because this field does not change among ATI products, use Vendor ID for product identification. 2. For EtherCAT Axia sensors, this field does not change and can be used for product identification. 3. To identify a sensor model and calibration size, refer to Section 5.2.1.3—Object 0x2021: Calibration, subindex 0x02 (calibration part number). 4. To identify an individual sensor, refer to Section 5.2.1.3—Object 0x2021: Calibration, subindex 0x01 (F/T Serial). 					

5.2.2.4 Unused EtherCAT Objects

The EtherCAT® Technology Group defines the structure of these object but leaves them as optional. Currently, ATI does not use these fields. Instead, the information is included in [Section 5.2.1—ATI Specific Objects](#). To know what ATI objects should be referenced, refer to the following table:

Table 5.15—Unused EtherCAT Objects					
Object Index (Hex)	Object Name	Type	Cross-Reference to the ATI Specific Area Objects	Default Value (hex)	Default Value (decimal)
0x1001	Error Register	USINT	To monitor the F/T sensor status code, refer to Section 5.2.1.7—Object 0x6010: Status Code .	0x00	0
0x1009	Hardware Version	STRING	To view the F/T sensor hardware version, refer to Section 5.2.1.5—Object 0x2090: Version .	N/A	
0x100A	Software Version	STRING	To view the sensor software version, refer to Section 5.2.1.5—Object 0x2090: Version .		

5.2.3 How to Interpret Hexadecimal Output

The user converts hexadecimal outputs to a 32-bit binary number that correlates to a code in a dictionary object. An example of bit patterns are in the following table.

Bit Number	Simple Description (refer to Table 5.8)	Bit Pattern
0	Temperature	0x80000001
1	Supply voltage	0x80000002
2	Broken gage	0x80000004
3	Busy bit	0x80000008
4	Reserved	N/A
5	Other	0x80000020
6 to 25	Reserved	N/A
26	Gage Out of Range Warning	0x84000000
27	Gage out of range	0x88000000
28	Simulated error	0x10000000
29	Calibration checksum error	0xA0000000
30	F/T out of range	0xC0000000
31	Any error	0x80000000
—	Healthy	0x00000000

The bit pattern can be different if more than one error is present. For example, if the status code is 80000005 then the user must convert the hexadecimal number to a binary number.

Using a free online calculator, convert the hexadecimal number to a binary number:

Hex	8	0	0	0	0	0	0	5
Binary	1000	0000	0000	0000	0000	0000	0000	0101

The binary number has 32-bits total. The least significant bit is on the right end of the following table. “1” means the bit is on. “0” means the bit is off.

Binary Number	1	0	0	0	0	0	00 0000 0000 0000 0000 00	0	0	0	1	0	1
Bit Position	31	30	29	28	27	26	25 to 6	5	4	3	2	1	0

So in this example, bit number 0, 2 and 31 are on. According to the preceding table, the sensor has a “temperature”, “broken gage error”, and “any error” status codes (refer to [Table 5.8](#)).

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 the application. If using a PC, be sure that the PC's network adapter is compatible with EtherCAT communication using the customer's EtherCAT master software.

1. Attach the sensor to the EtherCAT and power cables (refer to [Section 3.2—Pin Assignment for the EtherCAT and Power Connection](#) and the applicable F/T sensor manual in [Table 2.1](#)).
2. Import the **ECAT AXIA ESI File (ATI P/N 9030-05-1021)** that is located at https://www.ati-ia.com/Products/ft/software/axia_software.aspx.
 - Specific steps to import the ESI file vary 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 (refer to [Section 5.2.1.3—Object 0x2021: Calibration](#)).
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:

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

6. Troubleshooting

This section includes solutions to some issues that might arise when setting-up and using the sensor. For more troubleshooting guidance, refer to the sensor model manual listed in [Table 2.1](#). Answers to frequently asked questions are available from the ATI website: https://www.ati-ia.com/library/documents/FT_FAQ.pdf.

Note:

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

1. Serial number, for example: FT01234
2. Sensor model, for example: Axia130-M125
3. Calibration, for example: SI-800-50 or SI-2000-125
4. Accurate and complete description of the question or concern
 - For the status code; refer to [Section 5.2.1.7—Object 0x6010: Status Code](#).
5. Computer and software information. for example: operating system, PC type, drivers, and application software.

Be near the F/T system when calling (if possible).

Please contact an ATI representative for assistance, if needed:

ATI Industrial Automation

1031 Goodworth Drive
 Apex, NC 27539 USA
www.ati-ia.com

Application Engineering

Tel: +1.919.772.0115, Extension 511
 Fax: +1.919.772.8259
 E-mail: ft.support@novanta.com
 24/7 Support: +1.855.ATI.IA 00 (+1.855.284.4200)

6.1 LED Errors

Symptom	Resolution
Status LED stays red after the (20) second power up phase.	Check the sensor cable connections. Verify the sensor cable is not damaged. There may be an internal error in the sensor. Check the status code, refer to Section 5.2.1.7—Object 0x6010: Status Code .
Status LED is red for the first (20) seconds, after power up, and then turns green.	Normal.
The EtherCAT Link/Activity LED is not green or flashing green.	Check the sensor and EtherCAT cables' connections. Verify the EtherCAT Master device has the correct ECAT ESI file; refer to Section 5.3—Establishing Communication with the EtherCAT Axia Sensor .
The EtherCAT Link/Activity LED is not illuminated (no activity and power is supplied to the sensor).	Verify the proper port (on the EtherCAT Master or junction) is ON and permits communication.

6.2 Basic Guidance for Troubleshooting

Basic symptoms of inaccurate data and system errors are listed in the following section. For each symptom, causes and appropriate solutions are suggested.

Symptom: Noise — jumps in F/T readings greater than 0.05% of full-scale counts.

Cause: Noise can be caused by mechanical vibrations and electrical disturbances that are possibly from a poor ground. Electrical interference can also come from a high noise output device such as a motor.

Solution: Make sure that the DC supply voltage for the Axia sensor has little to no noise superimposed. Ground the sensor by connecting the cable's shield to ground. In most setups, 0 V is also connected to the ground. Connect the robot or other fixture to the same ground.

Verify that the sensor cables do not cross over other cables. Verify the sensor cables are not within close proximity to other equipment that could generate electrical noise.

Avoid sources of mechanical noise. If not possible, apply a filter to the data as described in [Section 4.4—Low-pass Filter](#). For more information about Noise, refer to [Section 6.3—Reducing Noise](#).

Cause: Noise can also indicate component failure within the system.

Solution: Check the status code of the sensor; refer to [Section 5.2.1.7—Object 0x6010: Status Code](#).

Perform an accuracy check as described in the applicable ATI sensor manual in [Table 2.1](#) or in [Section 4.5: How do I evaluate the accuracy of health of the sensor?](#) in the Frequently Asked Questions (FAQ) ATI document located at: https://www.ati-ia.com/library/documents/FT_FAQ.pdf.

If the sensor fails the accuracy check, return the sensor to ATI for inspection. Contact ATI at rma-admin@ati-ia.com for a Returned Materials Authorization (RMA).

Symptom: Drift — when the F/T data continues to increase or decrease after a load is removed.

Cause: Some drift from a change in temperature is normal. Drift is observed more easily in the Z axis, compared to the X and Y axes.

Solution: For approximately thirty minutes, allow the sensor to warm-up until it is at a steady state with the air and other objects touching the sensor. Use the bias command to shift the readings back to zero. Bias regularly.

Use an insulator between the sensor and any tooling or fixtures that are at a different temperature. Avoid creating a temperature gradient across the sensor. Shield the sensor from excessive air flow.

For more information about how to avoid drift from temperature change, refer to the following ATI document: <https://www.ati-ia.com/Library/Documents/DriftExplanation.pdf>.

Symptom: Hysteresis — when the sensor is loaded from a zeroed or biased state and then the load is removed, the sensor output does not immediately return to zero.	Cause: Mechanical coupling or internal failure can cause Hysteresis which is outside of the sensor’s specified and acceptable measurement uncertainty (error) range. Solution: Verify the sensor is properly installed, fasteners are tightened, and the customer tooling is securely installed; refer to the <i>Installation Section</i> in the applicable ATI F/T sensor manual in <i>Table 2.1</i> . Use the bias command to shift the readings back to zero.
Symptom: <i>Object 0x6010: Status Code; Bit 1 - Supply voltage is out of range.</i>	Cause: If the supply voltage is out of range, the bit is active which indicates a potential system fault or failure. Solution: Power cycle the system. Verify the power supply is within range per <i>Section 7—Specifications</i> .
Symptom: <i>Object 0x6010: Status Code; Bit 3 - Busy Bit</i>	Cause: While the sensor is busy, the Busy Bit will be ON = 1. The sensor is busy applying a change such as an ADC rate change, filter, or an active calibration. Solution: After applying changes, wait until the Busy Bit is OFF = 0. Then read data or make any other changes.
Symptom: <i>Object 0x6010: Status Code; Bit 2, 26, 27, or 30 - Out of Range</i>	Cause: The Axia sensor may have been overloaded, and now the gages are in a saturated state. Solution: Remove applied loads. If the errors do not go away, continue troubleshooting. Unmount the sensor. Improper mounting methods can induce high loads in the sensor. Switch to a larger calibration size, if the application requires loads outside the range of the smaller calibration size. After using the larger calibration size and without applying a load, if errors such as “Sensing Range Exceeded”, “Gage Out of Range”, or “Gage Broken” persist, the sensor is likely permanently damaged due to overload. Perform an accuracy check (refer to the applicable ATI sensor manual in <i>Table 2.1</i>) or refer to <i>Section 4.5: How do I evaluate the accuracy of health of the sensor?</i> in the Frequently Asked Questions (FAQ) ATI document located at: https://www.ati-ia.com/library/documents/FT_FAQ.pdf . If the sensor fails the accuracy check, return the sensor to ATI for inspection. Contact ATI at rma-admin@ati-ia.com for a Returned Materials Authorization (RMA).

<p>Symptom: The sensor and/or EtherCAT program is not responsive.</p>	<p>Cause: The sensor has insufficient power supply. Solution: Verify the power supply meets the requirements listed in Section 7—Specifications. Verify the cables are not damaged and are properly routed per the <i>Installation Section</i> in the applicable ATI manual in Table 2.1.</p> <p>Cause: The software ESI file is not properly installed or not current. Solution: ATI offers multiple EtherCAT products which use different ESI files. Download the latest EtherCAT Axia ESI file from the ATI website. Load this ESI file into the EtherCAT Master. The way to download the file depends on the Master. ESI files are also referred to as .XML files or Device Description Files. For more information, refer to Section 5.3—Establishing Communication with the EtherCAT Axia Sensor.</p> <p>Cause: Third party hardware is not compatible with EtherCAT. Solution: Verify that the Robot/PLC/PC acts as an EtherCAT Master. Use EtherCAT junctions to split signals, because standard Ethernet switches do not work with EtherCAT. If the Master device has multiple ports, verify that the sensor is connected to the correct port. Some PC EtherCAT Masters require specific drivers to be installed on the correct port so that the system may properly work with EtherCAT.</p> <p>Cause: The sensor has a hardware or software failure. Solution: Observe the Axia sensor LEDs; refer to Section 4.2—LED Normal Operation.</p>
<p>Symptom: The actual data output rate of the sensor is less than expected.</p>	<p>Cause: The ADC and EtherCAT data rate may be set too high on an older version of the EtherCAT Axia sensor; refer to Section 4.3—Sample Rate. Solution: Check the sensor’s calibration certificate. If the “Electronics” field on the calibration certificate is listed as “Axia EtherCAT F/T”, reduce the ADC sample rate and the EtherCAT data rate. Only the EtherCAT Axia Gen-2 series can maximize both of these rates at the same time.</p>
<p>Symptom: The sensor is connected but not streaming data</p>	<p>Cause: The user’s devices are not compatible with real time EtherCAT communication. Solution: Confirm the sensor system is compatible with real time EtherCAT communication.</p> <p>Cause: The connection from the user’s device to the sensor is interrupted. Solution: Try a direct connection from the user’s EtherCAT device to the Axia sensor. Standard Ethernet network switches can not be used in EtherCAT systems. If needed, use an EtherCAT junction device instead of Ethernet switches.</p> <p>Cause: The sensor has had a hardware or software failure. Solution: Observe the Axia sensor LEDs; refer to Section 4.2—LED Normal Operation.</p>

Symptom: The sensor does not report accurate F/T data.

Cause: The sensor may have been overloaded beyond its calibration limits. For calibration limits, refer to the applicable ATI manual listed in [Table 2.1](#).

Solution: Check the status code. Error bits related to overload are: 2, 26, 27, and 30. See solution for [Symptom—Object 0x6010: Status Code; Bit 2, 26, 27, or 30 - Out of Range](#).

Cause: The sensor system configuration is not set-up correctly.

Solution: Verify the installation is correct; refer to [Section 3—Installation](#) or contact ATI for assistance.

Cause: The user enabled Tool Transformation.

A Tool Transformation moves the origin and coordinates of the sensor data. If the Tool Transformation is incorrectly applied, the F/T data is skewed.

Solution: Check if a Tool Transformation is applied, and adjust it if needed. If all fields are 0, Tool Transformation is not applied; refer to [Section 5.2.1.2—Object 0x2020: Tool Transformation](#).

For more information on the concept of Tool Transformation, refer to the applicable ATI manual in [Table 2.1](#).

Cause: The sensor is not properly installed, for example: improper fasteners are used, or the sensor is not mounted to a flat, stiff surface.

Solution: Verify the sensor is correctly installed; refer to the [Installation](#) and [Troubleshooting Sections](#) in the appropriate ATI F/T sensor manual listed in [Table 2.1](#).

Cause: Mechanical coupling — an external object such as customer tooling or utilities is contacting a sensor's surface between the mounting side and tool side.

Solution: Remove any debris between the tool side and interface plate. Use proper cable management for cables and hoses; do not connect them tightly between the mounting and tool side of the sensor.

Anything that contacts surfaces such as the through hole in the sensor or cover plates on either side of the sensor induces loading or movement that could result in inaccurate F/T data.

Symptom: The values do not match expected values, for example: the F/T values are fluctuating but are higher than a known applied load.	<p>Cause: The user may be viewing gage data instead of F/T data.</p> <p>Solution: <i>Object 0x6030: Gage Data</i> reports strain gage data. Gage data is not a 1:1 correlation to F/T axis data. To view F/T data, refer to <i>Object 0x6000: Reading Data</i>.</p> <p>Cause: The sensor outputs data in counts. Counts must be divided by the Counts per Force (CpF) or Counts per Torque (CpT) in order to convert them to Calibration units (such as N and Nm).</p> <p>Solution: Verify if the user or user's software is scaling the F/T values to convert into units. Use the CpF and CpT to convert the raw F/T values into units. For the CpF and CpT values, refer to <i>Section 5.2.1.3—Object 0x2021: Calibration</i>.</p> <p>Cause: If the raw F/T values are already converted into units and the values are high or nonsensical, verify that the sensor is not in one of these conditions: saturation, gage out of range, or F/T out of range. Check the status code of the sensor; refer to <i>Section 5.2.1.7—Object 0x6010: Status Code</i>.</p> <p>Solution: If the values exceed the ATI sensor's calibration range per the ATI manual in <i>Table 2.1</i>, the reported values are incorrect. For more information, refer to <i>Section 2.1: Measurement Range & Overload Limits</i> in the Frequently Asked Questions (FAQ) ATI document located at: https://www.ati-ia.com/library/documents/FT_FAQ.pdf.</p>
Symptom: The initial F/T values are non-zero and no load is applied.	Normal. Bias the sensor to bring all the F/T values back to zero.

6.3 Reducing Noise

6.3.1 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 Axia sensor offers digital low-pass filters that can dampen frequencies above a certain threshold. If digital low-pass filters are insufficient, a digital filter may be added to the application software.

6.3.2 Electrical Interference

To reduce the effects of electrical noise on the sensor, do the following:

- If interference by motors or other noise-generating equipment is observed, check the sensor's ground connections.
- If sufficient grounding is not possible or does not reduce noise, consider using the sensor's digital low-pass filters.
- Verify the power supply is Class 1 which has an earth ground connection.

7. Specifications

The requirements for the EtherCAT sensor interface are covered in the following sections. For ATI F/T sensor model specifications, refer to the applicable manual in [Table 2.1](#).

7.1 Electrical Specifications

Table 7.1—Power Supply ¹				
Power Source	Voltage			Power Consumption
	Minimum	Nominal	Maximum	Maximum
DC Power	12 V	24 V	30 V	1.5 W
Notes:				
1. The power supply input is reverse polarity protected. If the power and ground to the power supply inputs are plugged in reverse, then the reverse polarity protection stops the incorrectly wired supply input from damaging or powering on the sensor.				

7.2 Cable Specifications

7.2.1 9105-C-ZC22-ZC28

Table 7.2—9105-C-ZC27-ZC28 M8, 6-pin, Female Connector to M12 A-Coded, 8-pin, Male Connector	
Parameter	Value
Voltage Rating	> 30 V
Current Rating	> 0.25 A
IP Rating (when connectors are attached at both ends)	IP64
Operating Temperature Range (Min-Max)	-5°C to 70°C

7.2.2 9105-C-ZC27-ZC28

Table 7.3—9105-C-ZC27-ZC28 M8, 8-pin, Female Connector to M12 A-Coded, 8-pin, Male Connector	
Parameter	Value
Voltage Rating	> 30 V
Current Rating	> 0.25 A
IP Rating (when connectors are attached at both ends)	IP64
Operating Temperature Range (Min-Max)	-5°C to 70°C

7.2.3 9105-C-ZC28-ZC28

Table 7.4—9105-C-ZC28-ZC28-X-Z2 8-pin Female and Male M12 Connector	
Parameter	Value
Voltage Rating	60 V
Current Rating	> 0.25 A
IP Rating (when connectors are attached at both ends)	IP64
Operating Temperature Range (Min-Max)	-5°C to 70°C

7.2.4 9105-C-ZC28-U-RJ45S-X

Table 7.5—9105-C-ZC28-U-RJ45S-X 8-pin Female M12 Connector to Unterminated Wires and RJ45 Connector	
Parameter	Value
Voltage Rating	> 40 V
Current Rating	> 0.25 A
IP Rating (when connectors are attached at both ends)	IP64
Operating Temperature Range (Min-Max)	-5°C to 70°C

8. 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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D. Custom Application

This modular manual section does not apply to this sensor system.

Please contact an ATI representative for assistance, if needed:

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