Manual, EtherCAT Axia F/T Sensor

Document #: 9610-05-EtherCAT Axia

Engineered Products for Robotic Productivity
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Foreword

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

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FCC Compliance-Class A

This devices complies with Part 15 Subpart B of the FCC Title 47. Operation is subject to the following two conditions: (1) this device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

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

"Electromagnetic Compatibility"

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

RoHS Compliance

This product conforms to EU Directive CE 2015/863 (RoHS).

Note:

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

1. Serial number (e.g., FT01234)
2. Model (e.g., Axia80-M20)
3. Calibration (e.g., US-15-50, SI-65-6, etc.)
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 (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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Statement of Compliance

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

Test Report Details

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

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

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

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

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Glossary

Term	Definition
Active Configuration	The configuration that the system is currently using.
ADC	Analog-to-digital converter.
Calibration	The factory-supplied data used by the EtherCAT Axia sensor so it can report accurate sensor readings. Calibrations apply to a specific loading range.
CoE	CANopen over EtherCAT is the preferred embedded protocol for configuring EtherCAT devices. Used within SDO to encode the configuration data.
Complex Loading	Any force or torque load that is not purely in one axis.
Configuration	User-defined settings that include which force and torque units are reported and which calibration is to be used.
Coordinate Frame	See Point of Origin.
Data Rate	How fast data can be output over a network.
DINT	Signed double integer (32 bit)
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	The push or pull exerted on an object.
FS	Full-Scale.
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 MAP or TAP doesn’t match the bolt pattern on the robot arm or customer tooling. The interface plate has two bolt patterns on either side of the plate. One side is for the MAP or TAP. The other side is for the robot arm or customer tooling.
IP64	Ingress protection rating “64” designates protection against dust and splashing of water. An IP64 rating does not guarantee protection when a user submerges a device in water or any type of fluid.
ISR	Interrupt service routine
Mounting Adapter Plate | MAP	The surface of the sensor that attaches to a fixed surface like an interface plate or robot arm.
N/A	Not Applicable
Overload	The condition where more load is applied to the sensor than the rated measurement range that can be applied to the sensor. Overloads result in reduced accuracy and potentially reduced sensor life.
PDO	Process Data Object, a protocol for reading and writing real-time process information cyclically.
P/N	Part Number
Point of Origin	The location on the sensor from which all forces and torques are measured. Also known as the Coordinate Frame.

Term	Definition
Power Cycle	When a user removes and then restores power to a device.
Resolution	The smallest change in load that can be measured.
Sample Rate	How fast the ADCs are sampling inside the unit.
SDO	Service Data Object, a protocol for reading and writing configuration information acyclically.
Sense loads	The ATI F/T sensor detects sense loads that are a cumulation of forces and torques acted upon the customer tooling.
Sensor	The component that converts a detected load into electrical signals.
SINT	Signed short integer (8 bit)
Status Bit	A unit of computer data sent from the ATI F/T sensor.
STRING*n*	Sting 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.
Tool Adapter Plate | TAP	The surface of the sensor that attaches to a fixed surface like an interface plate or the customer tooling.
Torque	The measurement of force exerted on an object causing it to rotate. Mathematically, torque is expressed as: Torque = Force x Moment Arm Distance.
Transducer	Every transducer is also (or has) a sensor but every sensor isn’t a transducer. A transducer is more than a sensor. It consists of a sensor/actuator along with signal conditioning circuits.
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 declaration of the robot, be aware of the dynamic loads caused by the robot.

1.3 Safety Precautions

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

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

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

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

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

2. Product Overview

The EtherCAT Axia F/T sensor system measures six components of force and torque ($F_x \backslash F_y \backslash F_z \backslash T_x \backslash T_y \backslash T_z$) and streams this data to customer devices via EtherCAT fieldbus (refer to *Section 5.1—PDO Interface*). To user EtherCAT, the user needs a software interface and computer hardware that it compatible with EtherCAT. Free, downloadable software such as TwinCAT is available online for users with a Windows® operating system.

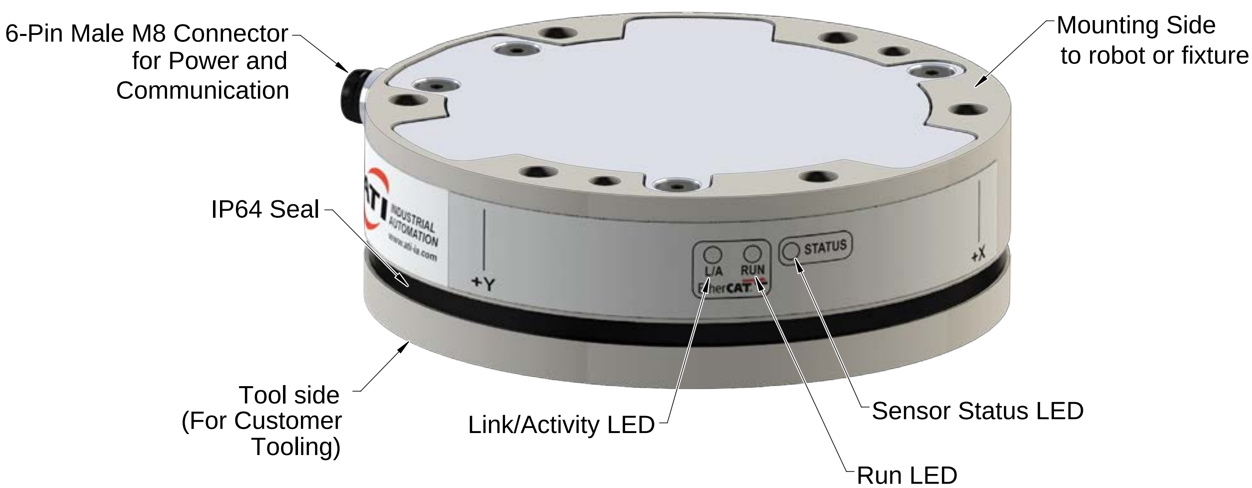
The sensor's mounting side attaches to a mounting interface plate, which mounts to the customer robot. The tool side attaches to the customer tooling. Both the mounting and tool sides have a 71.12 mm bolt circle pattern with (6) M5 tapped holes and (2) slip fit dowel holes (refer to the *customer drawing* on the ATI website). The sensor is IP64 rated. An M8 6-pin male connector is for power and Ethernet. For the pin assignments, refer to *Section 3.5—Pin Assignment for the EtherCAT and Power Connection*.

The customer drawing, ATI P/N 9230-05-1543, is available on the ATI website: *https://www.ati-ia.com/app_content/Documents/9230-05-1543.auto.pdf*.

The Axia sensor provides the following features:

- Set bias and clear bias
- Programmable low-pass filtering
- LED indicator for Run, EtherCAT Link, and Sensor Status (refer to *Section 4.2—LED Self-Test Sequence and Functions* for more information)

Figure 2.1—EtherCAT Axia F/T Sensor



2.1 Overview of Axia Models

The Axia sensor is available in three different models. An overview of each model is summarized in the following table:

Table 2.1—Axia Models

Model	Part Number	Number of Identifying Grooves[1]	Material
Axia80-M8	9105-ECAT-Axia80-M8	3	Aluminum
Axia80-M20	9105-ECAT-Axia80-M20[2]	0	
Axia80-M50	9105-ECAT-Axia80-M50	2	Stainless Steel

Notes:

1. Identifying grooves are physical indentations in the sensor body (refer to *Figure 2.2*). These grooves provide users a quick visual method to differentiate the sensor models.
2. This part number used to be 9105-ECAT-Axia80.
3. For calibration ranges, refer to *Section 8.3—Calibration Ranges*.

Figure 2.2—Identifying Grooves (Axia80-M8 shown as a reference)

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.

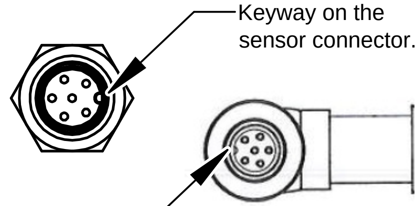
CAUTION: Modification or disassembly of the sensor could cause damage and void the warranty. Use the supplied mounting bolt pattern and the provided tool side mounting bolt pattern to mount the sensor to the robot and customer tooling to the sensor (refer to the *customer drawing* on the ATI website).

CAUTION: Using fasteners that exceed the customer interface depth penetrates the body of the sensor, damages the electronics, and voids the warranty (refer to the *customer drawing* on the ATI website).

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

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

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



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

3.1 Interface Plates

The sensor's mounting side attaches to the robot arm, and the sensor's tool side attaches to the customer tooling. If interface plate(s) are required, ATI can supply custom robot mounting and tool interface plates. For technical information on the sensor's mounting features refer to the *customer drawing* on the ATI website.

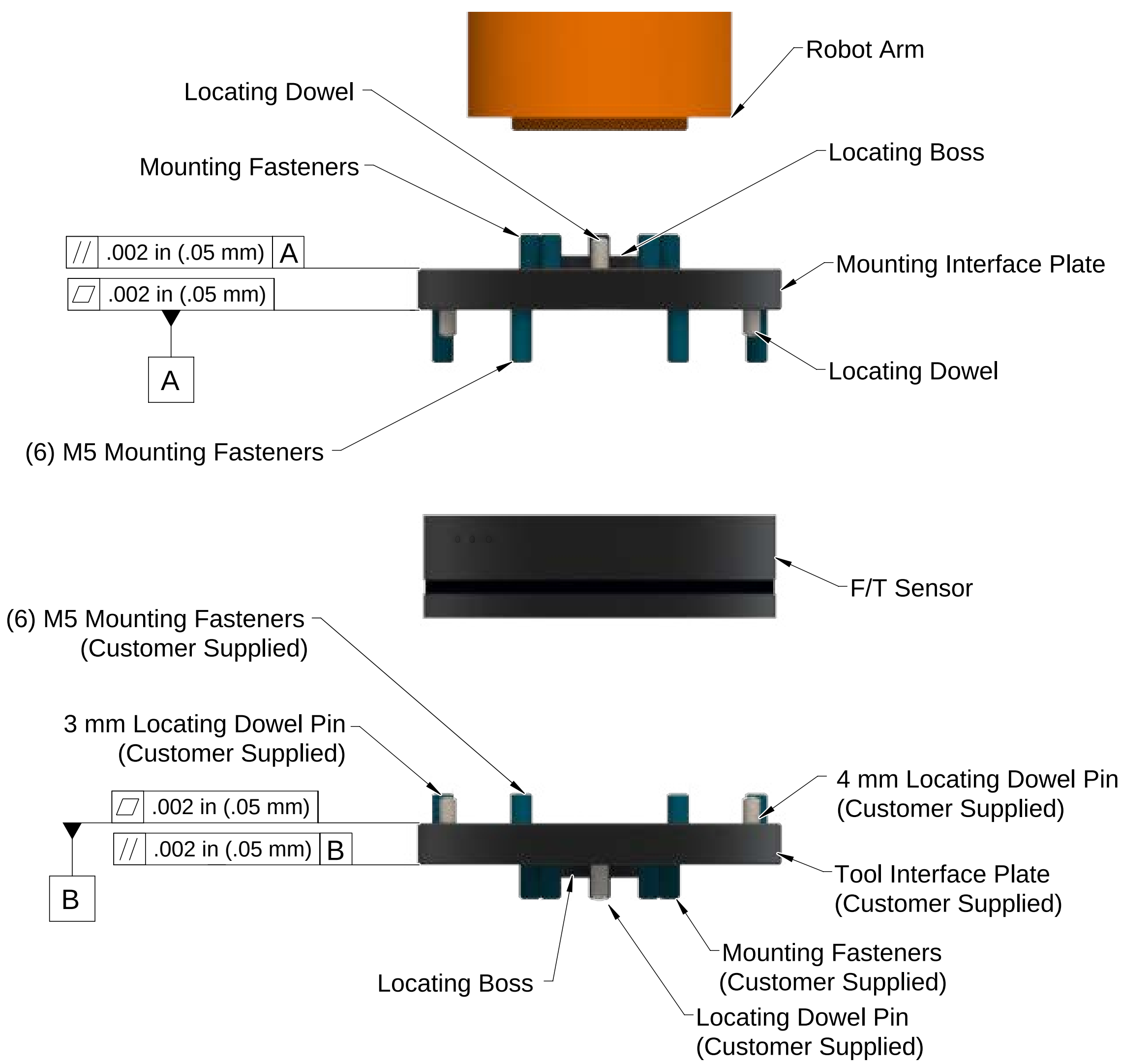
CAUTION: Incorrect installation of robot mounting and tool interface plates will result in the failure of the F/T sensor to function properly. Because the mounting and tool sides of the sensor have identical bolt patterns, verify the robot mounting and tool interface plates are installed correctly.

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

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

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

Figure 3.1—Adapter Plate(s)

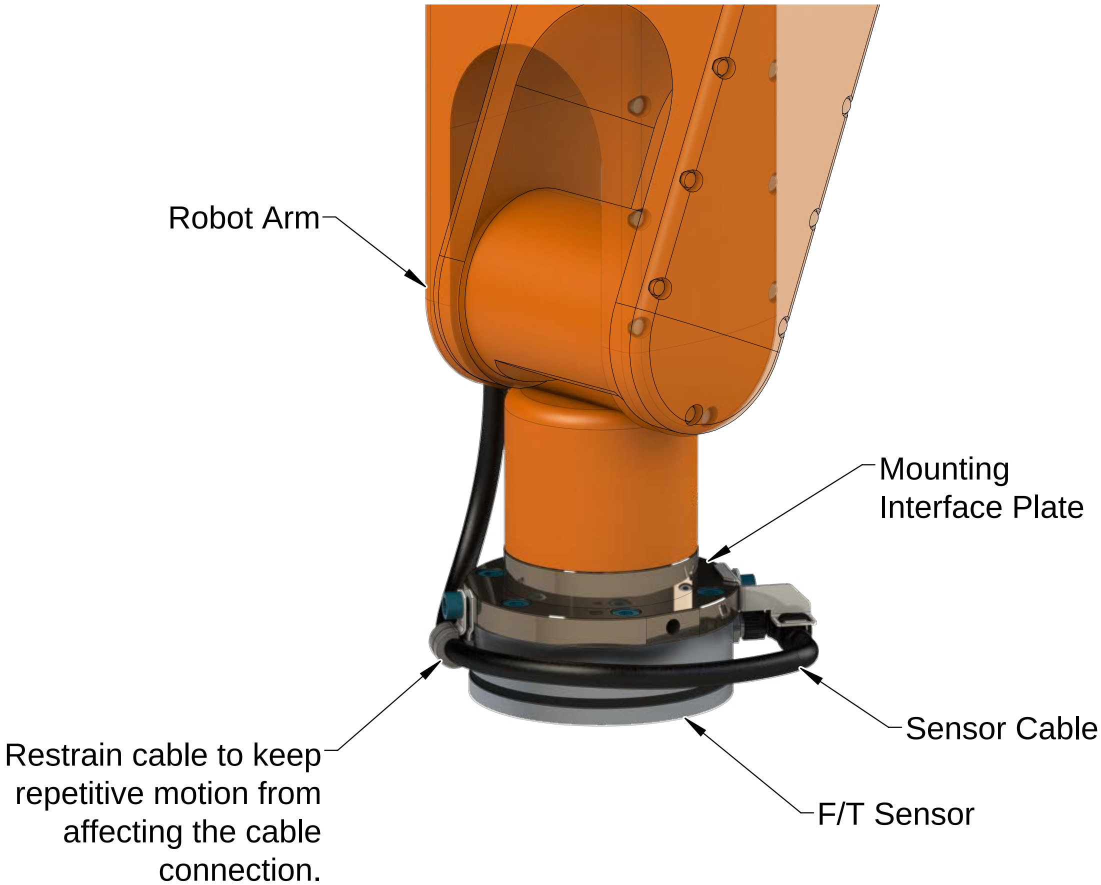


3.2 Routing the Cable

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

NOTICE: The maximum supported cable length is 25 m.

Figure 3.2—Routing of the Sensor Cable



CAUTION: 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.

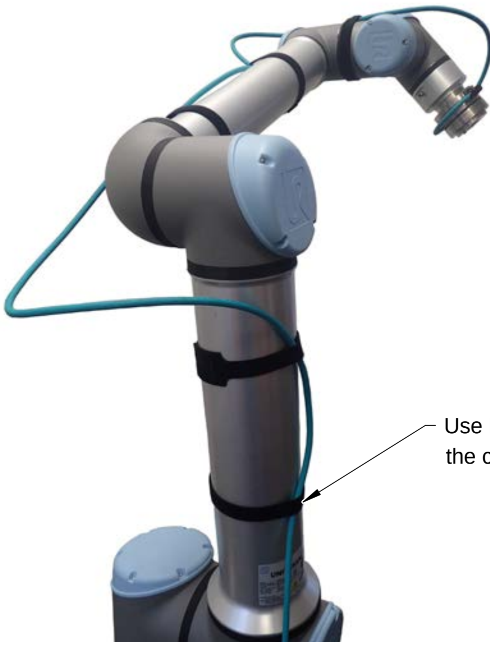
For added stability, zip ties can be used to secure the cable to a mounting bracket (refer to the following figure). The zip ties should never contact the cable jacket.

Figure 3.3—Use Zip Ties on the Connector

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 senor'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.

Route the sensor cable so that it is not stressed, pulled, kinked, cut, or otherwise damaged throughout the full range of motion. Affix the cable by using hook and loop straps or Velcro® straps; do not use cable ties or zip ties.

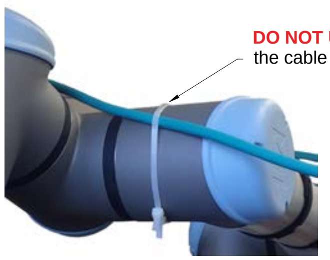
Figure 3.4—Use Hook and Loop or Velcro® Straps on the Cable

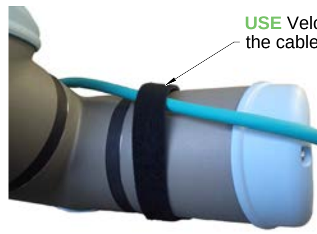


CAUTION: Do not cable ties or zip ties to bundle cables or restrain the cable to the robot arm. Directly affixing cable ties or zip ties to the cable jacket will prevent power and signal communication between the F/T sensor and robot controller. Use hook and loop or Velcro straps on the cable jacket 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 cables do not bend less than the minimum bending radius specified in *Table 3.1*. A bend radius too small causes the cable to fail from fatigue of the robot's repetitive motion.

Table 3.1—Sensor Cable Bending Radius and Dynamic Twist Angle

Cable Part Number	Spliced Cable Branch Description	Cable Diameter mm (in)	Static Bending Radius (at room temperature)		Dynamic Bending Radius (at room temperature)		Dynamic Cable Twist Angle per Unit Length
			mm	in	mm	in	
9105-C-ZC22-ZC28-X	N/A	6 (.24)	25	1	50	2	180°/m or 55°/ft
9105-C-ZC28-U-RJ45S-X	Branch 1, Power						
	Branch 2, EtherCAT						

Notes:

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

3.3 Installing the Sensor to the Robot

Parts required: *Refer to Figure 3.5 and (the customer drawing on the ATI website).*

Tools required: *4 mm hex key*

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

1. Clean the mounting surfaces.
2. Attach the mounting interface plate to the robot arm with the mounting fasteners.

> **NOTICE:** When mounting the sensor to the mounting interface plate, mounting the customer tooling or interface plate to the sensor, consider the following points:
>
> - Screws must have a minimum thread engagement length of 4.5 mm and a maximum thread engagement less than the threaded depth that is listed the *customer drawing* on the ATI website.
> - Unless otherwise specified, apply Loctite 242 to the (6) M5 socket head cap screws (class 12.9) so that the fasteners secure the sensor to the mounting plate.

3. Attach the sensor to the mounting adapter plate.
   a. Using a 4 mm hex key, secure the sensor to the mounting adapter plate with the (6) M5 socket head cap screws, class 12.9. Tighten the fasteners per the specifications in the following table.

Table 3.2—Torque Values for Axia Models

Model	Torque
Axia80-M8	52 in-lbs (5.88 Nm)
Axia80-M20	
Axia80-M50	75 in-lbs (8.47 Nm)

4. Once the sensor is installed on the robot, the customer tooling or tool interface plate can be installed.

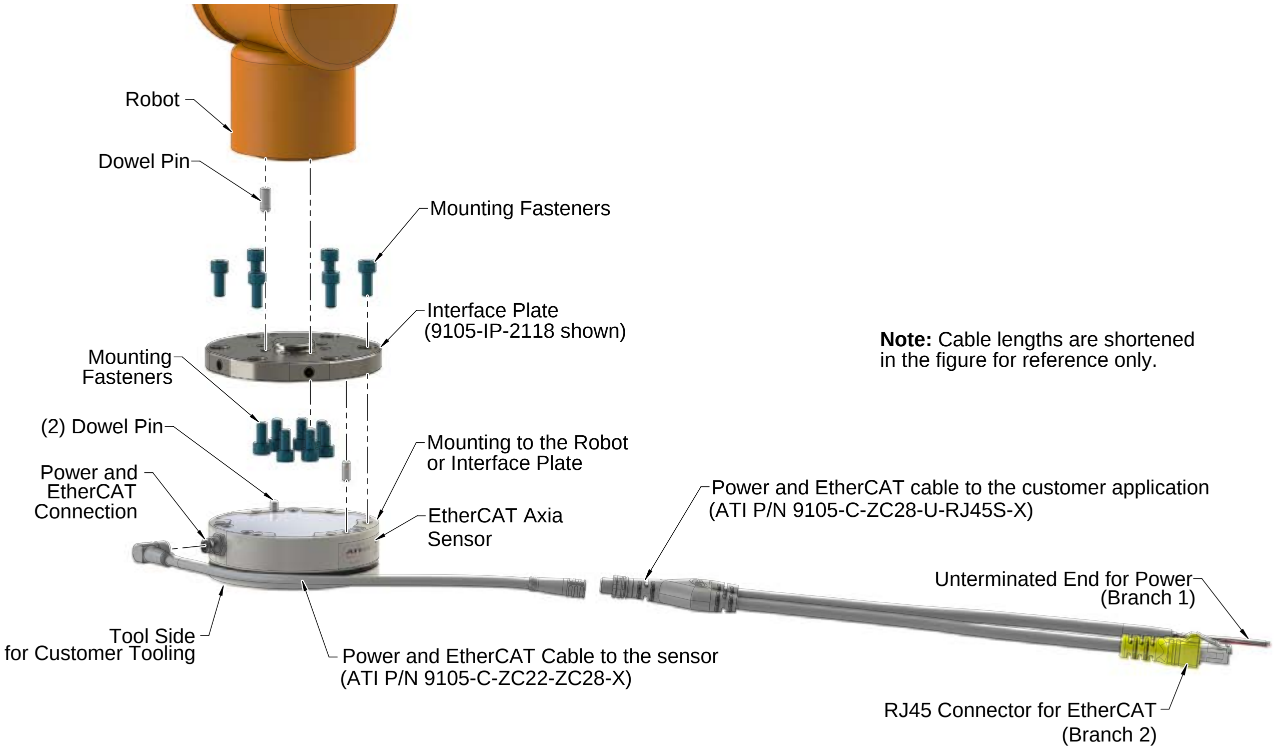
> **NOTICE:** The tool must not touch any other part of the sensor except the tool side; otherwise, the sensor does not properly detect loads.

5. Connect the cable(s) to the sensor and customer application.
   a. Connect a power and EtherCAT cable (ATI P/N 9105-C-ZC22-ZC28-X) to the sensor's connection. Tighten to 4.43 in-lbs (0.5 Nm).
   b. Connect the branched cable (ATI P/N 9105-C-ZC28-U-RJ45S-X) to the cable from step *a*. Tighten to 7.08 in-lbs (0.8 Nm).
   c. Connect the RJ45 and power connections to the customer application.

> **NOTICE:** For the LED outputs that occur whenever power is applied to the sensor, refer to *Section 4.2.1—LED Self-Test Sequence*.

6. Properly restrain and route the power and EtherCAT cable; refer to *Section 3.2—Routing the Cable*.
7. After installation is complete, the sensor is ready for an accuracy check (refer to *Section 3.6—Accuracy Check Procedure*).
8. Safely start normal operation.

Figure 3.5—Installation of the Sensor to the Robot



3.4 Removing the Sensor from the Robot

Tools required: *4 mm hex key*

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

3.5 Pin Assignment for the EtherCAT and Power Connection

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

Pin assignments for the power and EtherCAT connection on the sensor and cables are in the following sections. For supply voltage ratings, refer to the following table or *Section 8.2—Electrical Specifications*.

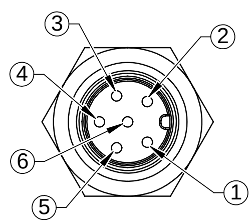
Table 3.3—Power Supply[1]				
Power Source	**Voltage**			**Power Consumption**
	Minimum	**Nominal**	**Maximum**	**Maximum**
DC Power	12 V	24 V	30 V	1.5 W

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.

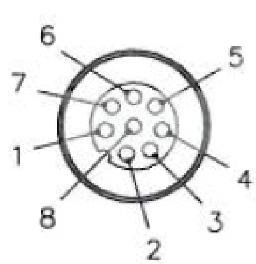
3.5.1 Pin Assignment : 6-pin Male M8 Connector

Signals and corresponding pin numbers on the M8 connector are in the following table:

Table 3.4—Pin Assignment for the 6-pin, Male, M8 Connector (Power and EtherCAT)		
Connector Schematic	**Pin Number**	**Signal**
	1	TX+
	2	TX-
	3	RX+
	4	RX-
	5	V +
	6	V -

3.5.2 Pin Assignment : 8-Pin Male M12 ZC28 Connector

For the 8-pin male M12 ZC28 connector on cable P/N 9105-C-ZC22-ZC28-X that connects to cable P/N 9105-C-ZC28-U-RJ45S-X, the signals and corresponding pin numbers are in the following table:

Table 3.5—Pin Assignment for the 8-pin, Male, M12 Connector (Power and Ethernet)		
Connector Schematic	**Pin Number**	**Signal**
	1	No Connection
	2	V +
	3	V -
	4	TX-
	5	RX+
	6	TX+
	7	No Connection
	8	RX-
	Shield	Shell

3.5.3 Pin Assignment for 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. For the signals and corresponding pin numbers/wire color, refer to the following sections.

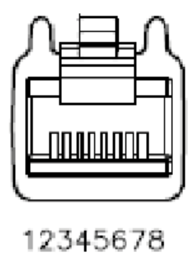
3.5.3.1 Branch 1, Unterminated End for Power Connection

The signals and corresponding wire jacket color for the unterminated wires which connect to the customer's device are in the following table:

Table 3.6—Branch 1, Unterminated End: Wire Jacket Color, and Signal	
Wire Jacket Color	**Signal**
-	Shield
Brown	V+
Brown/White	V-
Blue/White (TP1+)[1]	Sync
Blue (TP1-)[1]	Sync Ground
Note: 1. Reserved-not used.	

3.5.3.2 Branch 2, RJ45 Connection for EtherCAT

The signals and corresponding pin numbers for the 8-pin RJ45 connect which connect to the customer device are in the following table:

Table 3.7—Cable P/N 9105-C-ZC28-X Pin Assignment for the 8-pin, RJ45 Connector			
Connector Schematic	**Pin Number**	**Wire Color**	**Signal**
	1	White/Orange	TX+
	2	Orange	TX-
	3	White/Green	RX+
	4	-	No Connection
	5	-	No Connection
	6	Green	RX-
	7	-	No Connection
	8	-	No Connection

3.6 Accuracy Check Procedure

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

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.
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 $F_{x,\text{ average}}$ \ $F_{y,\text{ average}}$ \ $F_{z,\text{ average}}$:
   a. Use the following equations, to complete the calculations:

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

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

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

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

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

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

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

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

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 Axia80-M20 sensor's rated accuracy is 2% the range on all axes. For a 500 N F_{xy} range and a 900 N F_z range, the allowable errors of any single data point would be ± 10 N F_xy and ± 18 N F_z respectively. Since F_z has the larger tolerance, then one data point could be + 18 N and another data point could be–18 N, for a total range (max-min) of 36 N error.
- In addition, the tooling mass should be within 36 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

4. Operation

Information required when using software to operate the EtherCAT Sensor is provided in the following sections. Knowledge of EtherCAT standards and operation is required to communicate with the EtherCAT sensor.

4.1 Sensor Environment

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

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

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

4.2 LED Self-Test Sequence and Functions

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

4.2.1 LED Self-Test Sequence

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

Sequence Order	LED	State	Duration
1	Sensor Status	Red	Approximately one second for each LED.
2	Run	Red	
3	EtherCAT Link/Activity	Red	
4	Sensor Status	Green	
5	EtherCAT Link/Activity	Green	

Note:

1. The Green Run LED is not tested in the self-test sequence.

4.2.2 EtherCAT Link/Activity LED

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

LED State	Link	Activity	Condition
Off	No	No	No EtherCAT connection.
Green	Yes	No	EtherCAT link/activity is detected.
		Yes[1]	

Note:

1. This LED behavior is different from the standard EtherCAT device Link/Activity LED behavior, which is a flashing green LED.

4.2.3 Run LED

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

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

4.2.4 Sensor Status LED

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

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

4.3 Sample Rate

The "Sample Rate" field in *Section 5.2.1.11—Object 0x7010: Control Codes* controls how fast the ADCs are sampling inside the sensor. Rounded and exact sample rates are in the following table.

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

4.3.1 Sample Rate Versus Data Rate

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

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

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

4.4 Low-pass Filter

The power-on default selection is no filtering. The “Filter Selection” field in *Section 5.2.1.11—Object 0x7010: Control Codes* controls the current filter selection. The cutoff frequency (for example: -3 dB frequency) is dependent on the sample rate selection which is defined in *Section 4.3—Sample Rate*. The cutoff frequencies for the different sampling rates are listed in the following table and graphs:

Table 4.2—Low-Pass Filtering

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

Figure 4.1—Filter Attenuation at 0.5 kHz Sample Rate

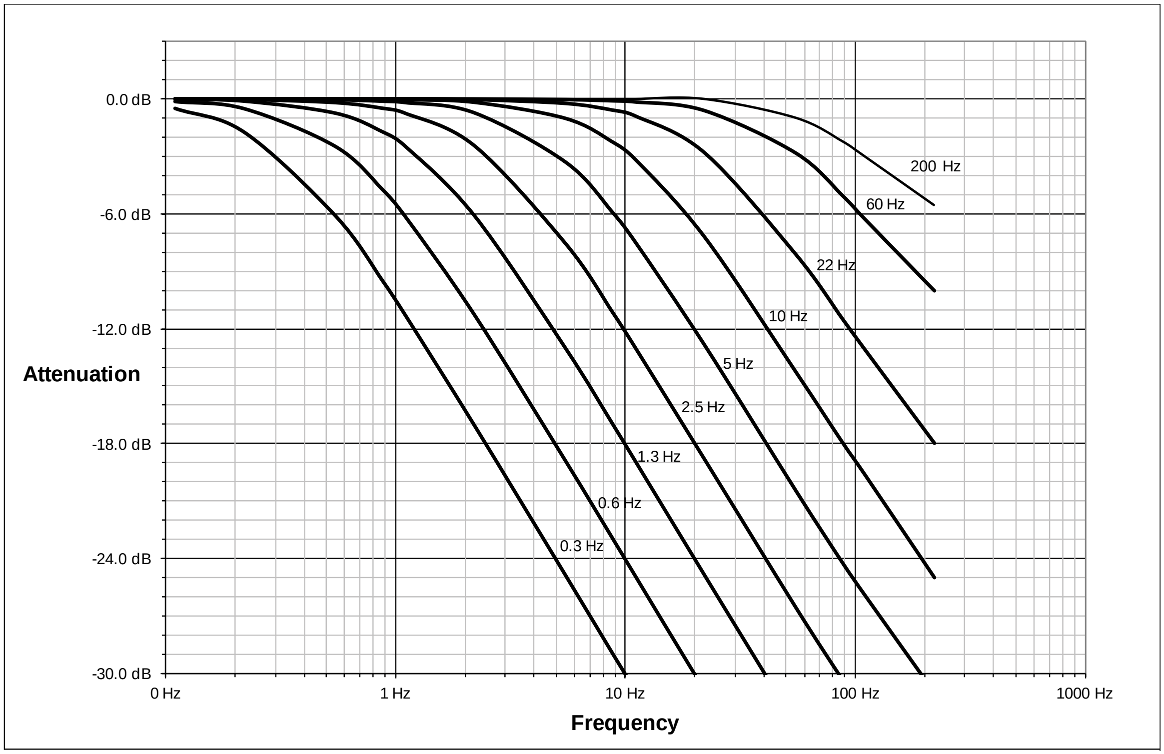


Figure 4.2—Filter Attenuation at 1 kHz Sample Rate

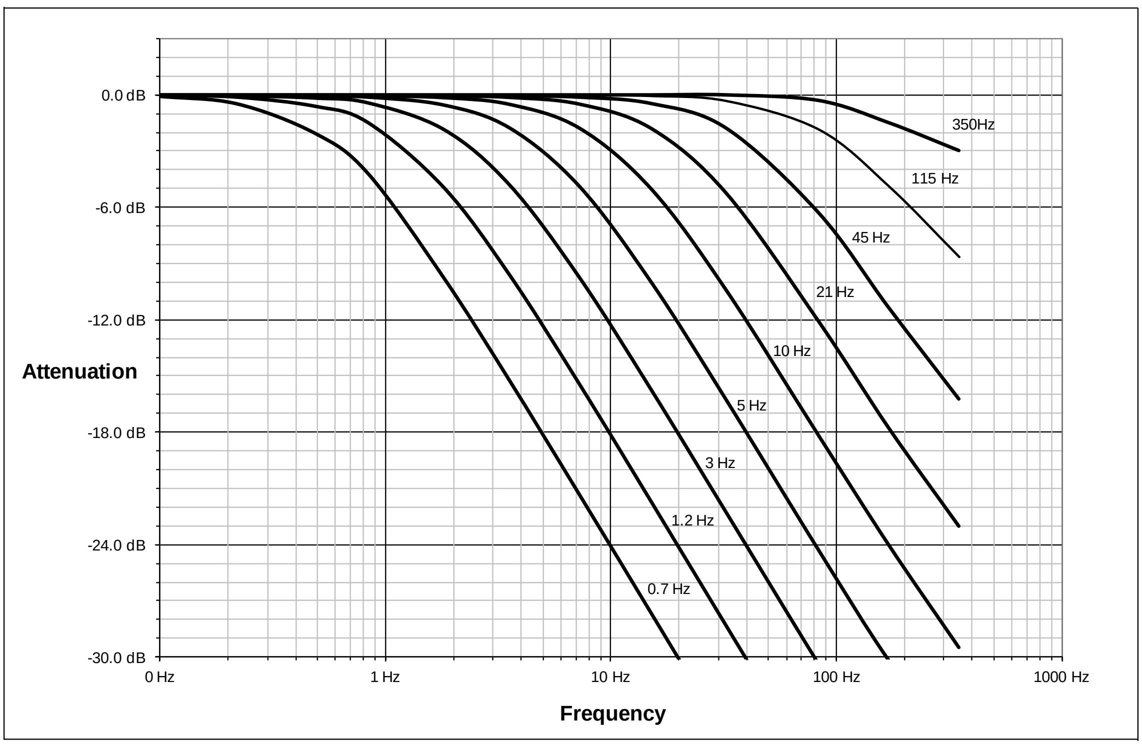


Figure 4.3—Filter Attenuation at 2 kHz Sample Rate

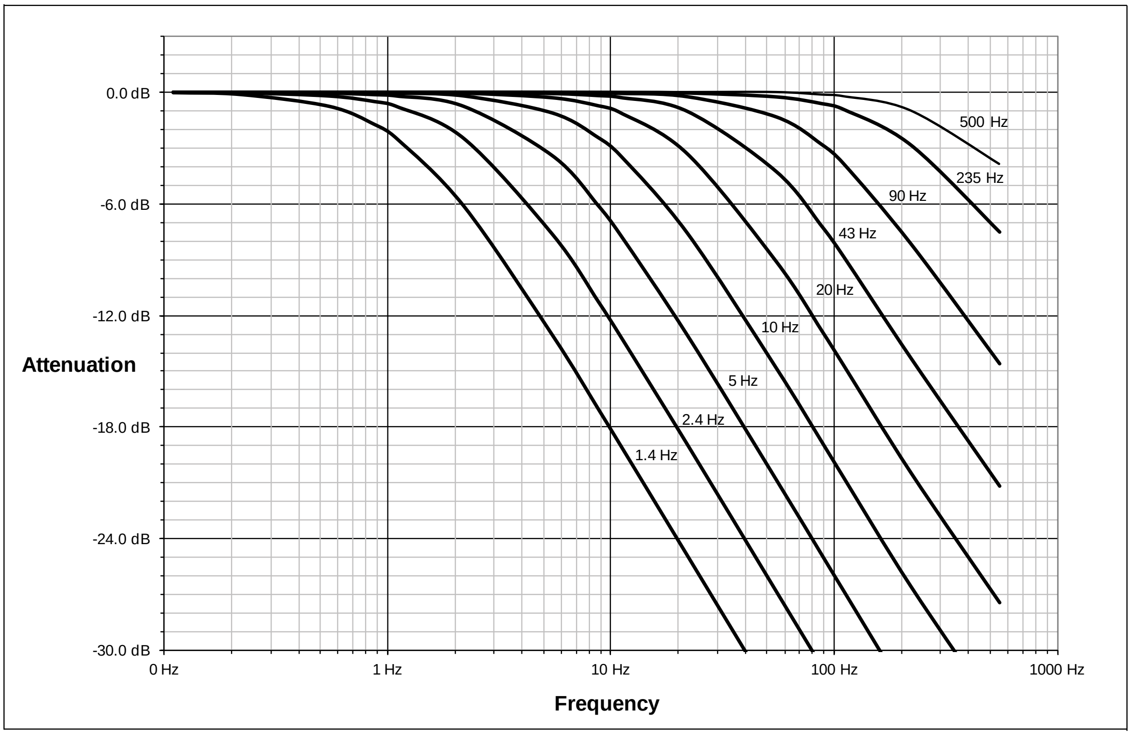
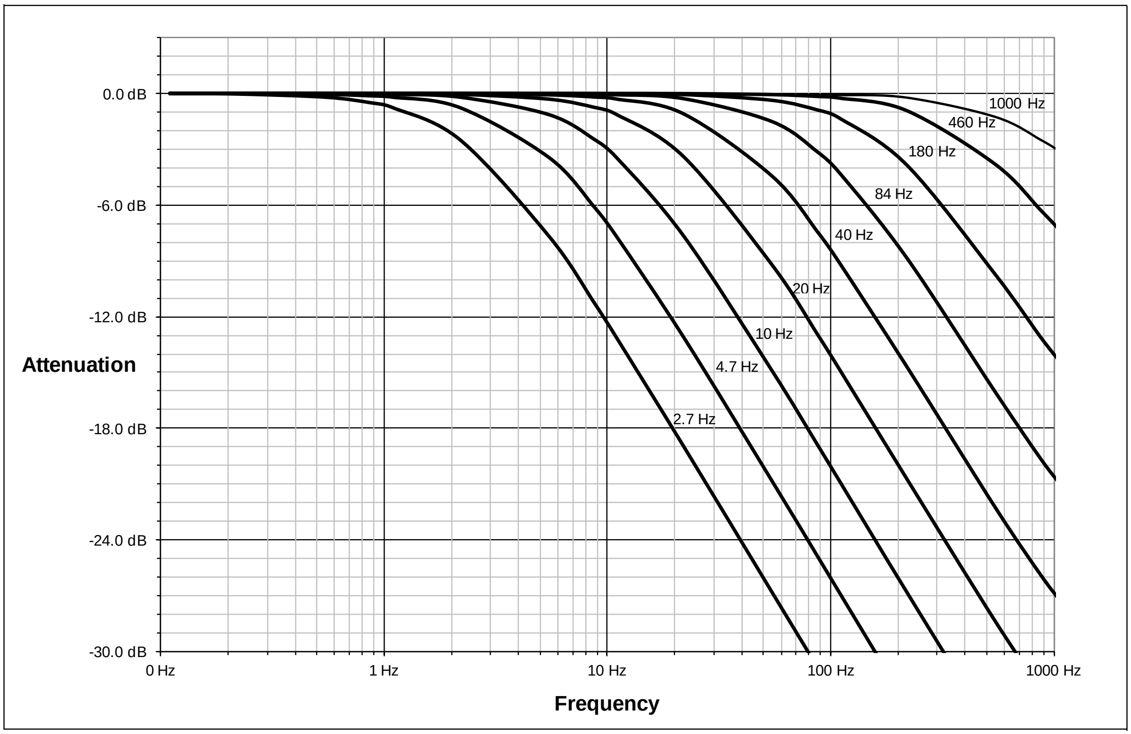


Figure 4.4—Filter Attenuation at 4 kHz Sample Rate



4.5 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 *customer drawing* on the ATI website.. 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 4.5.1—Avoid Overloading the Sensor During Tool Transformation*). Therefore, when evaluating overloading conditions, use the sensor's point of origin as the reference point.

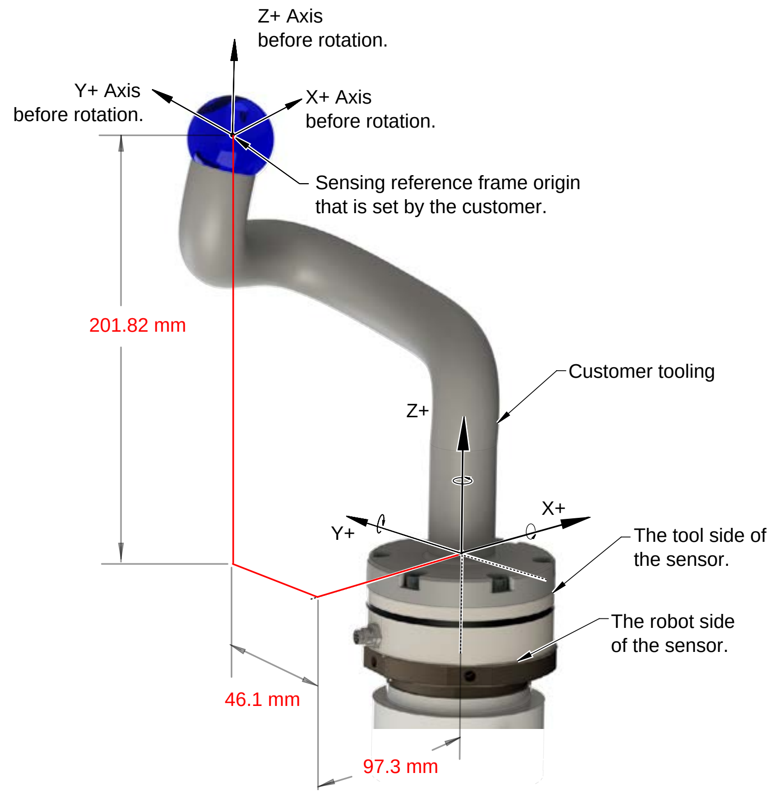
The user defines a reference point by inputting a parameter set that is a series of (3) displacements (D_x \ D_y \ D_z) and (3) rotations (R_x \ R_y \ R_z), for example:

D_x = -97.3 mm D_y = 46.1 mm D_z = 201.82 mm R_x = +90° rotation R_y = +180° rotation R_z = 0° 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.

Figure 4.5—Tool Transformation : Distances

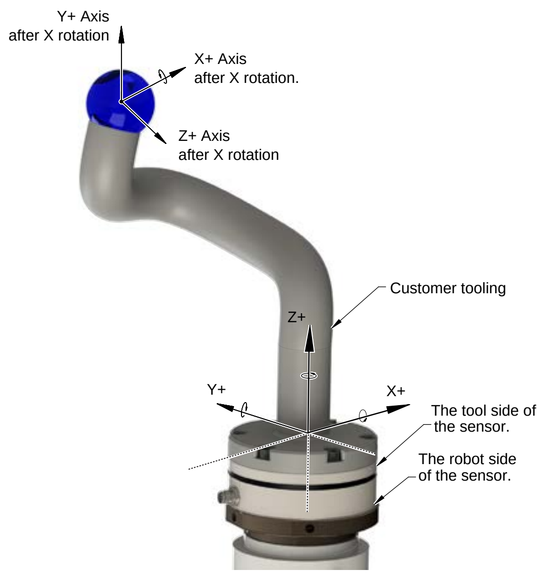


After the displacements, the user point of origin rotates in the following order:

1. The first rotation is about the X-axis.

- Recall in this example R_x = +90° rotation. The user point of origin rotates +90° about the X-axis, in the following figure.

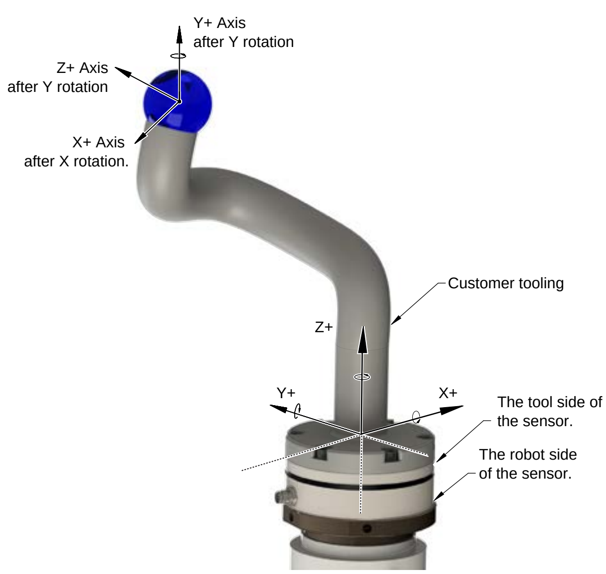
Figure 4.6—Tool Transformation : Rotation About the X-Axis



2. The second rotation is about the Y-axis of the new user output reference frame.

- In this example R_y = +180° rotation. The user point of origin rotates +180° about the Y-axis of the new user output reference frame, in the following figure.

Figure 4.7—Tool Transformation: Rotation About the Y-Axis



3. The third and final rotation is about the Z-axis of the new user output reference frame.

- In this example R_Z = 0° 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.

A user can issue tool transformation commands through EtherCAT dictionary Object 0x2020 (refer to *Section 5.2.1.2—Object 0x2020: Tool Transformation*).

4.5.1 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.

5. EtherCAT Bus Interface

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

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

5.1 PDO Interface

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

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

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

5.2 EtherCAT Dictionary Objects (SDO Data)

The SDO data configures the sensor and reads the manufacturing and calibration data. This section lists dictionary Objects specific to the EtherCAT F/T sensor application and some Objects that are a required part of the EtherCAT standard. Dictionary Objects (covered in this section) can be found in the ECAT Axia80 ESI File (ATI P/N 9030-05-1021) that is located at *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 32-bit binary number (refer to *Section 5.2.3—How to Interpret Hexadecimal Output*).

5.2.1 ATI Specific Area Objects

The structure of these Objects are defined by ATI.

5.2.1.1 Object 0x2019: Product Description

CAUTION: Most users should not edit the fields in Object 0x2019. Changing these fields results in the ATI-provided EtherCAT Axia ESI/XML file not working. Therefore, this Object is not visible with the standard EtherCAT Axia ESI/XML file. To change these fields, contact *ft_support@ati-ia.com* for support

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. Instead, the same information can be found in *Section 5.2.2—EtherCAT Communication Area Objects*.

<table>
<tr><th colspan="7">Table 5.1—Object Index (hex) 0x2019: Product Description</th></tr>
<tr><th rowspan="2">Subindex (Hex)</th><th rowspan="2">Name</th><th rowspan="2">Description</th><th rowspan="2">Type</th><th colspan="3">Default Value</th></tr>
<tr><th>Hexadecimal Format</th><th>Decimal Format</th><th>String</th></tr>
<tr><td>0x01</td><td>Vendor ID</td><td>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).</td><td>UDINT</td><td>0x00000732</td><td>1842</td><td>-</td></tr>
<tr><td>0x02</td><td>Product Code</td><td>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).</td><td>UDINT</td><td>0x26483053</td><td>642265171</td><td>-</td></tr>
<tr><td>0x03</td><td>Product Name</td><td>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).</td><td>String(32)</td><td>-</td><td>-</td><td>“ATI Axia F/T Sensor”</td></tr>
<tr><td>0x04</td><td>Product Revision</td><td rowspan="2">This field is not used by ATI.</td><td>UDINT</td><td colspan="3" rowspan="2">N/A</td></tr>
<tr><td>0x05</td><td>Product Serial Number</td><td>UDINT</td></tr>
<tr><td>0x06</td><td>Manufacturer</td><td>A field to identify ATI or a company that has integrated the ATI sensor into their branded system.</td><td>String(32)</td><td>-</td><td>-</td><td>“ATI Industrial Automation”</td></tr>
<tr><td>0x07</td><td>Commit</td><td>To use this field, the user must have an ATI-provided password. This field accepts changes to other fields within this Object.</td><td>UDINT</td><td>0x00000000</td><td>0</td><td>-</td></tr>
</table>

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:

1. This field identifies an individual sensor. A sensor may have more than one FTxxxxx calibration serial number; each F/T calibration serial number identifies a separate calibration. No two sensors share an F/T calibration serial number.
2. This field identifies the calibration size. A sensor model may have more than one calibration size/ part number.

<table>
<tr><th colspan="5">Table 5.3— Object Index (hex) 0x2021: Calibration</th></tr>
<tr><th>Subindex</th><th>Name</th><th>Type</th><th colspan="2">Description</th></tr>
<tr><td rowspan="6">0x2f</td><td rowspan="6">Force Units</td><td rowspan="6">USINT</td><th>Value</th><th>Unit</th></tr>
<tr><td>0</td><td>Lbf</td></tr>
<tr><td>1</td><td>N</td></tr>
<tr><td>2</td><td>Klbf</td></tr>
<tr><td>3</td><td>kN</td></tr>
<tr><td>4</td><td>Kg</td></tr>
<tr><td rowspan="7">0x30</td><td rowspan="7">Torque Units</td><td rowspan="7">USINT</td><th>Value</th><th>Unit</th></tr>
<tr><td>0</td><td>lbf-in</td></tr>
<tr><td>1</td><td>lbf-ft</td></tr>
<tr><td>2</td><td>Nm</td></tr>
<tr><td>3</td><td>Nmm</td></tr>
<tr><td>4</td><td>Kgf-cm</td></tr>
<tr><td>5</td><td>kNm</td></tr>
<tr><td>0x31</td><td>Max Fx Counts</td><td rowspan="6">DINT</td><td rowspan="6" colspan="2">The maximum rated value for this axis, in counts.</td></tr>
<tr><td>0x32</td><td>Max Fy Counts</td></tr>
<tr><td>0x33</td><td>Max Fz Counts</td></tr>
<tr><td>0x34</td><td>Max Tx Counts</td></tr>
<tr><td>0x35</td><td>Max Ty Counts</td></tr>
<tr><td>0x36</td><td>Max Tz Counts</td></tr>
<tr><td>0x37</td><td>Counts Per Force</td><td>DINT</td><td colspan="2">The calibration counts per force unit.</td></tr>
<tr><td>0x38</td><td>Counts Per Torque</td><td>DINT</td><td colspan="2">The calibration counts per torque unit.</td></tr>
<tr><td>0x39 through 0x56</td><td>Reserved</td><td>UINT</td><td colspan="2">Reserved</td></tr>
<tr><td>0x57</td><td>PeakLoadsPosFx</td><td rowspan="6">DINT</td><td rowspan="6" colspan="2">Peak Loads Positive. All-time peak positive force/torque loads in counts per unit.</td></tr>
<tr><td>0x58</td><td>PeakLoadsPosFy</td></tr>
<tr><td>0x59</td><td>PeakLoadsPosFz</td></tr>
<tr><td>0x5a</td><td>PeakLoadsPosTx</td></tr>
<tr><td>0x5b</td><td>PeakLoadsPosTy</td></tr>
<tr><td>0x5c</td><td>PeakLoadsPosTz</td></tr>
<tr><td>0x5d</td><td>PeakLoadsNegFx</td><td rowspan="6">DINT</td><td rowspan="6" colspan="2">Peak Loads Negative. All-time peak negative force/torque loads in counts per unit.</td></tr>
<tr><td>0x5e</td><td>PeakLoadsNegFy</td></tr>
<tr><td>0x5f</td><td>PeakLoadsNegFz</td></tr>
<tr><td>0x60</td><td>PeakLoadsNegTx</td></tr>
<tr><td>0x61</td><td>PeakLoadsNegTy</td></tr>
<tr><td>0x62</td><td>PeakLoadsNegTz</td></tr>
<tr><td>0x63 through 0x97</td><td colspan="4">Reserved</td></tr>
</table>

5.2.1.4 Object 0x2080: Diagnostic Readings

This read-only Object provides firmware version information. In this version 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	Calibration checksum error
4	Gage(s) disconnected: <*list*>
5	Gage(s) out-of-range: <*list*>
6	Force/torque out of range
7	Hardware or stack error
8	Simulated error
9	Spare
10	Error (unspecified)
11	No status code errors

5.2.1.5 Object 0x2090: Version

This read-only Object provides firmware version information. In this version 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	Boatloader Version	UDINT	Bootloader Version
0x05	SensorHwVer	UINT	Sensor Hardware Version
0x06	SensorInstrument	UINT	Sensor Instrument

5.2.1.6 Object 0x6000: Reading Data

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

<table>
<tr><th colspan="4">Table 5.7— Object Index (hex) 0x6000: Reading Data</th></tr>
<tr><th>Subindex</th><th>Name</th><th>Type</th><th>Description</th></tr>
<tr><td>0x01</td><td>Fx</td><td rowspan="6">DINT</td><td rowspan="6">These fields contain the 32-bit F/T result data, in counts per unit.</td></tr>
<tr><td>0x02</td><td>Fy</td></tr>
<tr><td>0x03</td><td>Fz</td></tr>
<tr><td>0x04</td><td>Tx</td></tr>
<tr><td>0x05</td><td>Ty</td></tr>
<tr><td>0x06</td><td>Tz</td></tr>
</table>

5.2.1.7 Object 0x6010: Status Code

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

Bit Number	Description	Indicates an Error?
0	Internal Temperature Out of Range: This bit is active (high) if the temperature is outside the range -5 to 70°C.	Yes
1	Supply Voltage Out of Range: This bit is active (high) if the input voltage is outside the range of 12 V to 30 V.	Yes
2	Broken Gage: This bit is active whenever any gage reads positive full scale and indicates that the electrical connection to the gage is open or disconnected. This bit stays high for 32 samples, after the last such sample, to allow time for the sample's effect on the data to abate.	Yes
3	Busy Bit. The sensor is performing (1) or more of the following activities that may temporarily affect the F/T data: • Committing a change to Object 0x2021. • Changing the filter time constant. • Changing the calibration in use. • Changing the ADC sampling rate. • Writing to flash memory. • Any ADC ISR overrun.	Yes
4	Reserved.	No
5	Hardware or stack error.	Yes
6-25	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 holdTime (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[1]: This bit is set whenever a F/T reading exceeds the calibrated range. This check occurs before digital filtering.	Yes
31	Error: This bit is set whenever any status code bit that indicates an error is set.	Yes

Table 5.8— Object Index (hex) 0x6010: Status Code

Note:
1. Sensing Range Exceeded is comparable to what previous F/T sensor manuals identified as saturation.

5.2.1.8 Status Code: Force/Torque Out of Range

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 the calibrated ranges that are used in the preceding equations, refer to *Section 8.3—Calibration Ranges*. For Example:

An Axia80-M20 sensor that uses calibration range 0 is subjected to the following loads and has the following calibration ranges:

Table 5.9—Example of Force/Torque Out of Range		
Axis	**Applied Load**	**Calibration Range 0** *Table 8.3* **Value**
F_x	87.5 N	500 N
F_y	-151.6 N	500 N
F_z	-500.0 N	900 N
T_x	1.0 Nm	20 Nm
T_y	2.0 Nm	20 Nm
T_z	-17.5 Nm	20 Nm

The F_{xy} T_z equation simplifies as follows:

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

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

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

$$122.5\% > 105\%$$

$$\text{TRUE}$$

The F_z T_{xy} equation simplifies as follows:

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

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

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

$$64.3\% > 105\%$$

$$\mathrm{FALSE}$$

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>
<tr><th colspan="5">Table 5.11— Object Index (hex) 0x7010: Control Codes</th></tr>
<tr><th>Subindex</th><th>Name</th><th>Type</th><th colspan="2">Description</th></tr>
<tr><td rowspan="9">0x01</td><td rowspan="9">Control 1</td><td rowspan="9">DINT</td><th>Bit</th><th>Function</th></tr>
<tr><td>0</td><td>1 = Set bias against current load
0 = Use last set bias[1]</td></tr>
<tr><td>1</td><td>Reserved</td></tr>
<tr><td>2</td><td>1 = clear bias
0 = leave bias unchanged</td></tr>
<tr><td>3</td><td>Reserved</td></tr>
<tr><td>4-7</td><td>The low-pass filter selection.
0 = No filtering
1–8 = Refer to Section 4.4—Low-pass Filter for details.</td></tr>
<tr><td>8-11</td><td>Active calibration.
Calibration slot 0, refer to Table 8.3.
Calibration slot 1, refer to Table 8.3.
2 through 15 = Reserved.</td></tr>
<tr><td>12-15</td><td>Sample Rate
0 = 487 Hz
1 = 975 Hz
2 = 1990 Hz
3 = 3900 Hz</td></tr>
<tr><td>16-31</td><td>Reserved</td></tr>
<tr><td rowspan="3">0x02</td><td rowspan="3">Control 2</td><td rowspan="3">DINT</td><th>Bit</th><th>Function</th></tr>
<tr><td>0-30</td><td>Reserved</td></tr>
<tr><td>31</td><td>Simulated Error Control</td></tr>
<tr><td colspan="5">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.</td></tr>
</table>

5.2.2 EtherCAT Communication Area 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 EtheCAT 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>
<tr><th colspan="6">Table 5.14—Object Index (hex) 0x1018: Identity Object</th></tr>
<tr><th>Subindex (Hex)</th><th>Name</th><th>Functionality</th><th>Type</th><th>Default Value (hex)</th><th>Default Value (decimal)</th></tr>
<tr><td>0x01</td><td>Vendor ID</td><td>This Vendor ID number is assigned by EtherCAT® Technology Group uniquely to ATI. [1]</td><td>UDINT</td><td>0x00000732</td><td>1842</td></tr>
<tr><td>0x02</td><td>Product Code</td><td>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]</td><td>UDINT</td><td>0x26483053</td><td>642265171</td></tr>
<tr><td>0x03</td><td>Revision Number</td><td>This field is subject to change and should not be used for identification purposes. [3]</td><td rowspan="2">UDINT</td><td rowspan="2" colspan="2">N/A</td></tr>
<tr><td>0x04</td><td>Serial Number</td><td>This field is subject to change and should not be used for identification purposes. [4]</td></tr>
<tr><td colspan="6">Note:
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).</td></tr>
</table>

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 Area Objects*. To know what ATI Objects should be reference, refer to the following table:

<table>
<tr><th colspan="6">Table 5.15—Unused EtherCAT Objects</th></tr>
<tr><th>Object Index (Hex)</th><th>Object Name</th><th>Type</th><th>Cross-Reference to the ATI Specific Area Objects</th><th>Default Value (hex)</th><th>Default Value (decimal)</th></tr>
<tr><td>0x1001</td><td>Error Register</td><td>USINT</td><td>To monitor the F/T sensor status code, refer to Section 5.2.1.7—Object 0x6010: Status Code.</td><td>0x00</td><td>0</td></tr>
<tr><td>0x1009</td><td>Hardware Version</td><td>STRING</td><td>To view the F/T sensor hardware version, refer to Section 5.2.1.5—Object 0x2090: Version.</td><td colspan="2" rowspan="2">N/A</td></tr>
<tr><td>0x100A</td><td>Software Version</td><td>STRING</td><td>To view the sensor software version, refer to Section 5.2.1.5—Object 0x2090: Version.</td></tr>
</table>

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.

Table 5.16—Bit Pattern Examples		
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 your application.

1. Attach the sensor to the EtherCAT and power cables. Refer to *Section 3.3—Installing the Sensor to the Robot* and *Section 3.5—Pin Assignment for the EtherCAT and Power Connection*.
2. Import the ECAT Axia80 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 varies among the different EtherCAT master software and hardware available to the customer.
3. Configure the EtherCAT master device to communicate with the EtherCAT sensor.
4. In the software for the EtherCAT master, read the calibration data at system start by using a SDO read to Object 0x2021, the Calibration Object (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:

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

6. Maintenance

6.1 Periodic Inspection

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

6.2 Periodic Calibrating

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

7. Troubleshooting

This section includes answers to some issues that might arise when setting up and using the EtherCAT Axia. The question or concern is listed followed by its probable answer or solution. They are categorized for easy reference.

The information in this section should answer many questions that might arise in the field. Customer service is available to users who have 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., Axia80-M20)
3. Calibration (e.g., US-15-50, SI-65-6, etc.)
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 (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@ati-ia.com*

7.1 Errors with Force and Torque Readings

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

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

8. Specifications

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

8.1 Storage and Operating Conditions

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

8.2 Electrical Specifications

Table 8.2—Power Supply[1]				
Power Source	**Voltage**			**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.

8.3 Calibration Ranges

Table 8.3—Calibration Range 0 and Calibration Range 1									
Model	**Axia80-M8**			**Axia80-M20**			**Axia80-M50**		
Parameter	Fxy	Fz	Txyz	Fxy	Fz	Txyz	Fxy	Fz	Txyz
Calibration Range 0	150 N	470 N	8 Nm	500 N	900 N	20 Nm	1200 N	2000 N	50 Nm
Calibration Range 1	75 N	235 N	4 Nm	200 N	360 N	8 Nm	480 N	800 N	20 Nm

Notes:

1. Each Axia80 sensor is calibrated with both of these calibration ranges.

9. 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.

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

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

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