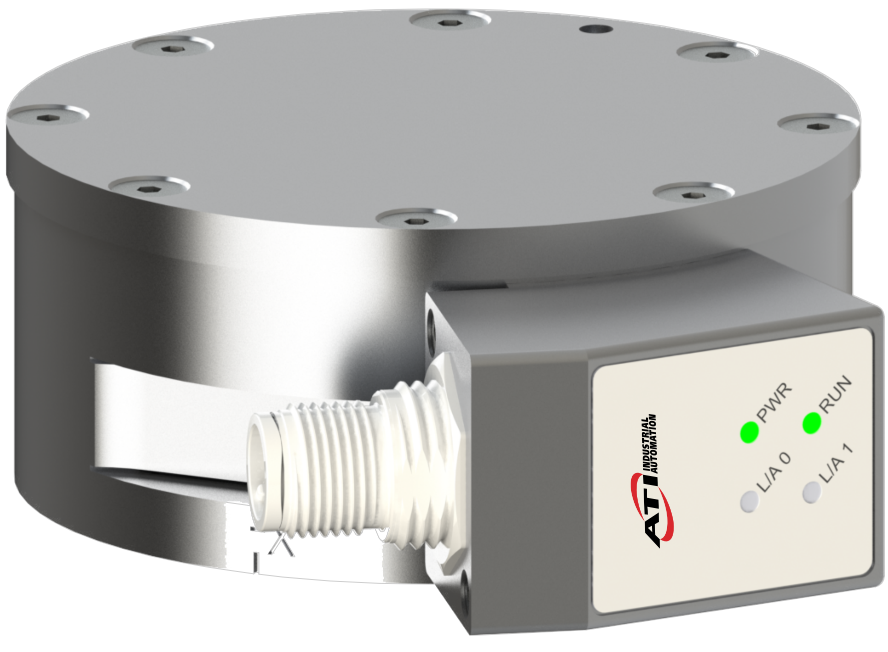
Manual

EtherCAT Generation 3 (ECAT3) Force/Torque Interface



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Foreword

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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. Transducer model; for example, Nano17, Gamma, Theta.
3. Calibration; for example, US-15-50, SI-65-6.
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 configuration)

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

Please contact an ATI representative for assistance, if needed:

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Glossary

Term	Definition
Accelerometer	A device provided within ATI's Varo sensors that measures acceleration. ATI's Varo sensors use a Micro Electronic Mechanical System (MEMS) accelerometer.
ADC	Analog to Digital Converter
CEB	Communications Electronics Box is a component of the ATI Network RS422/485 Force/Torque systems that houses additional electronics for power or additional network capability
CoE	CANopen over EtherCAT, the preferred embedded protocol for configuring EtherCAT devices. Used within SDO to encode the configuration data.
DINT	A data type representing a signed integer with 32 bits.
EtherCAT	An industrial automation fieldbus.
FoE	File access over EtherCAT, the preferred embedded protocol for uploading new firmware to EtherCAT devices.
F/T	Force/Torque.
F/T Transducer	Converts force and torque into an electrical signal.
g	G-force or gravitational force equivalent is a mass-specific force expressed in units of standard gravity.
Gyroscope	device provided within ATI's Varo sensors that measures orientation and angular velocity. ATI's Varo sensors use a Micro Electronic Mechanical System (MEMS) gyroscope.
IMU	Inertial measurement unit (IMU) is a device that detects acceleration and angular velocity (gyroscopic data).
MAP	The Mounting Adapter Plate (MAP) is the transducer plate that attaches to the fixed surface or robot arm.
PDO	Process Data Object, a protocol for reading and writing real-time process information cyclically.
SDO	Service Data Object, a protocol for reading and writing configuration information acyclically.
STG	Strain Gage
TAP	Tool Adapter Plate (TAP) is the transducer surface that attaches to the load to be measured.
Transducer	Transducer is the component that converts the sensed load into electrical signals.
UDINT	A data type representing an unsigned integer with 32 bits.
UINT	A data type representing an unsigned integer with 16 bits.
USINT	A data type representing an unsigned integer with 8 bits.

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 transducer selected is rated for maximum loads and moments expected during operation. Refer to the *ATI F/T Transducer Section* manual or contact ATI Industrial Automation for assistance. Particular attention should be paid to dynamic loads caused by robot acceleration and deceleration. These forces can be many times the value of static forces in high acceleration or deceleration situations.

1.3 Safety Precautions

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

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

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

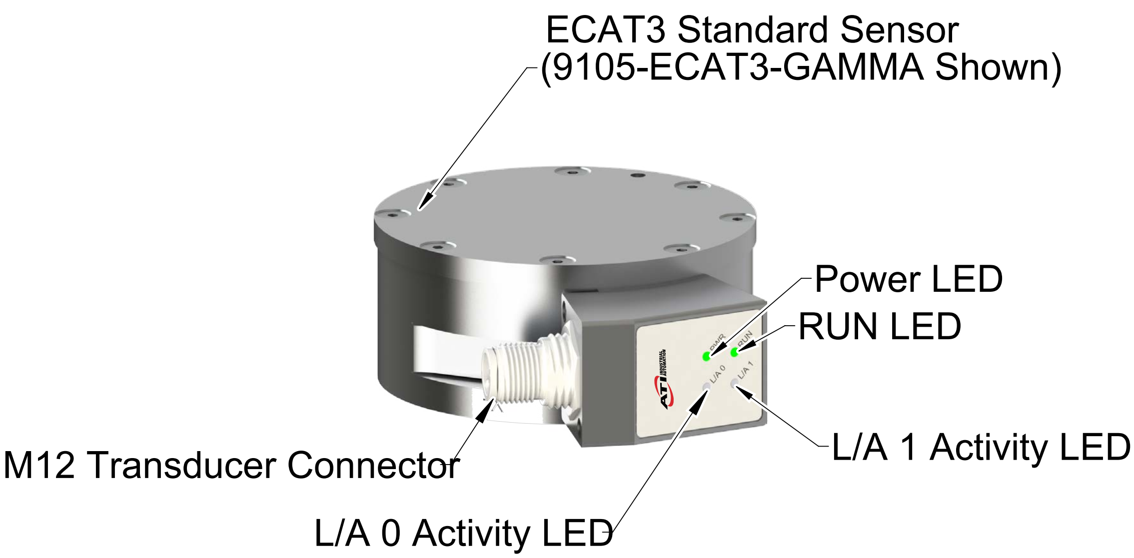
2. Product Overview

The EtherCAT Third Generation Force/Torque (ECAT3) sensor system measures six components of force and torque (Fx, Fy, Fz, Tx, Ty, Tz) and seamlessly streams data to devices that use EtherCAT fieldbus. Integrated signal conditioning, data acquisition, and a two-port EtherCAT interface are all contained in a small rugged enclosure.

ATI sensors with EtherCAT3 interface provide the following features:

- Two-port EtherCAT connection allows daisy chaining for multiple devices
- Resolved force and torque data with an update rate of 8 kHz
- Console commands available either over EtherCAT network or serial connection. (refer to *Section 4.7.3—Object 0x2023: Console Over EtherCAT* and *Section 5—Console Operation)*
- Adjustable Digital low-pass filters
- Up to three different calibrations (measurement ranges) can be stored and selected (refer to *Section 4.7.2—Object 0x2021: Calibration*)
- Tool transformation programmable over EtherCAT (refer to *Section 4.5—Tool Transformation)* or console commands (refer to *Section 5.2—Cal Command*)
- Condition monitoring functionality. (refer to *Section 4.3—Threshold Monitoring* and *Section 5.2—Cal Command*)
- LED indicator for Power status, RUN status, port 0 link/activity, port 1 link/activity (refer to *Section 4.8—LED Functions* for more information)

Figure 2.1—EtherCAT3 Sensor



2.1 System Overview

ATI's standard ECAT3 system offerings can be categorized into two groups: standard transducers communicating only via EtherCAT, and standard transducers communicating via EtherCAT and console over a serial connection. The components for each of these set-ups are outlined in *Table 2.1* below.

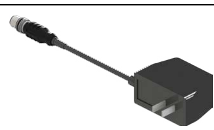
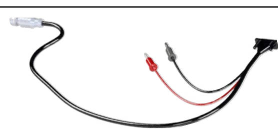
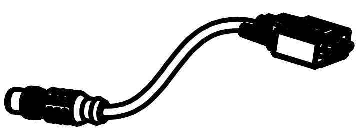
Table 2.1—ECAT3 System Components		
Image	**Description**	**Part Number**
Standard Transducer Communicating EtherCAT Only		
	Standard Transducer	9105-ECAT3-*SensorModel*
	Transducer Cable	9105-C-MA12F1-MA12M1-01-1.0 9105-C-MA12F1-MA12M1-01-5.0 9105-C-MA12F1-MA12M1-01-10.0
	Splitter Box	9105-GEN3-SPLIT-001
	Power Supply	9105-CBL-S-G1-Q5F-WWPS1-1.5
	M12 to RJ45 Ethernet Adapter	9105-C-R08F1-MD04M1-01-0.2 (x2) *(Default)* [1]
Standard Transducer Communicating EtherCAT and Console Over Serial		
	Standard Transducer	9105-ECAT3-*SensorModel*
	Transducer Cable	9105-C-MA12F1-MA12M1-01-1.0 9105-C-MA12F1-MA12M1-01-5.0 9105-C-MA12F1-MA12M1-01-10.0
	Splitter Box	9105-GEN3-SPLIT-001
	Power and Serial Cable	9105-CF-MTS-DB9-5
	M12 to RJ45 Ethernet Adapter	9105-C-R08F1-MD04M1-01-0.2 (x2) *(Default)* [1]
Note: 1. Additional cable lengths available.		

Table 2.1—ECAT3 System Components		
Image	**Description**	**Part Number**
MIni or Nano Transducer Communicating EtherCAT		
	Transducer with integral cable	9105-TW-*SensorModel*
	ECAT3 Communications Electronics Box (CEB)	9105-ECAT3-CEB-001
	Power Supply	9105-CBL-S-G1-Q5F-WWPS1-1.5
	M12 to RJ45 Ethernet Adapter	9105-C-R08F1-MD04M1-01-0.2 (*Default*)[1]
Note: 1. Additional cable lengths available.		

- **ECAT3 F/T Transducer:** converts the force and torque loads into electrical signals and transmits them over the transducer cable. ATI's ECAT3 sensors send digital signals. For more information, refer to the F/T Transducer Manual (*9620-05-Transducer Section*).
- **Transducer Cable:** delivers power to the transducer and transmits the transducer's strain gage data. Transducers with on-board electronics connect to a splitter box. Any DeviceNet compatible cable with correct gender M12 Micro connectors can be used, but non IP rated transducers are not compatible with right angled connectors. ATI Industrial Automation supplies a robotic grade high flex transducer cable with each ECAT3 F/T system.
- **Splitter Box:** splits the transducer cable into connections for EtherCAT port 0, EtherCAT port 1, and power/ RS485. The splitter box is necessary for any application using a standard transducer.
- **ECAT3 CEB:** processes and communicates the transducer's force and torque readers to the user's equipment. The ECAT3 CEB (9105-ECAT3-CEB-001) is specific to customers using a Nano or Mini series transducer
- **Power Cable:** provides power to the transducer via splitter box**.**
- **Communication Cable:** transmits signals over EtherCAT.
- **ATI Industrial Automation software, calibration documents, and manuals** (including this manual). This information is on the ATI website (*https://www.ati-ia.com/Products/ft/sensors.aspx*) or sent as an e-mail upon purchase of the system.
- Other optional components include:
    - Power supply that plugs into a 100–240 VAC (50–60 Hz) power outlet and provides power to the sensor via splitter box
    - Power supply that also includes DB9 connector for serial connection
    - M12 to RJ45 Ethernet cable adapter
    - Robot-grade transducer cables of different lengths

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.

The following section provides information for installing the EtherCAT3 F/T sensor system. The installation of the transducer to the robot or other device is covered in the (*9620-05-Transducer Section* manual).

3.1 Connecting Standard Transducer System

> **CAUTION:** The Splitter Box should be grounded through at least one of the two mounting tabs. Ground the shield pin of the power supply cable to earth and power supply (-) for best noise performance.

ATI's selection of ECAT3 standard transducers include the Gamma series, Delta series, and Omega series. the following process outlines how to connect the ECAT3 system.

Supplies required:

- *Transducer (9105-ECAT3-SENSORMODEL)*
- *Transducer Cable (9105-C-MA12F1-MA12M1-01-X)*
- *Splitter Box (9105-GEN3-SPLIT-001)*
- *(2) M12 to RJ45 Ethernet Adapter (9105-C-R08F1-MD04M1-01-0.2)*
- *(2) Standard RJ45 ethernet cable (customer supplied)*
- *Power Supply: ECAT only: 9105-CBL-S-G1-Q5F-WWPS1-1.5*
  Serial and ECAT: 9105-CF-MTS-DB9-LENGTH

1. Connect transducer to splitter box using transducer cable.
   a. Align the female M12 socket of the transducer cable into the male M12 connector of the transducer. Use the key to ensure pins are aligned correctly. Refer to ***Section 8—Specifications*** for detailed pinout information.
   b. Tighten cable sleeve clockwise to lock the connector at a recommended torque value of 0.8 Nm to 1.0 Nm.
   c. Align the male M12 connector of the transducer cable to the female M12 socket of the splitter box. Splitter box should be clearly labeled "Transducer" to identify correct placement, refer to *Figure 3.1.* Refer to ***Section 8—Specifications*** for detailed splitter box pinout information.

Figure 3.1—Splitter Box

   d. Tighten the sleeve clockwise to lock the connector at a recommended torque value of 0.8 Nm to 1.0 Nm.

2. Connect EtherCAT port0:
   a. Locate ECAT port 0 (ECAT0 on label) on the splitter box. Refer to *Figure 3.1.*
   b. Connect the M12 to RJ45 adapter to the splitter box. Tighten the sleeve fully to lock the connector at a recommended torque of 0.8 Nm to 1.0 Nm.
   c. Connect a standard RJ45 cable (customer-supplied) to the adapter.
   d. Plug the other end of the RJ45 cable into customer EtherCAT device.

3. Connect EtherCAT port 1:
   a. Locate ECAT port 1 (ECAT1 on label) on the splitter box. Refer to *Figure 3.1.*
   b. Connect the M12 to RJ45 adapter to the splitter box. Tighten the sleeve fully to lock the connector

at a recommended torque of 0.8 Nm to 1.0 Nm.

c. Connect a standard RJ45 cable (customer-supplied) to the adapter.

d. Plug the other end of the RJ45 cable into customer EtherCAT device.

4. Connect power to splitter box

a. Locate the power input on the splitter box. Refer to *Figure 3.1.*

b. Connect the power supply cable to the splitter box connector.

c. Connect power supply to customer power source.

d. Optional: If using 9105-CF-MTS-DB9-X, plug DB9 serial connector into customer equipment.

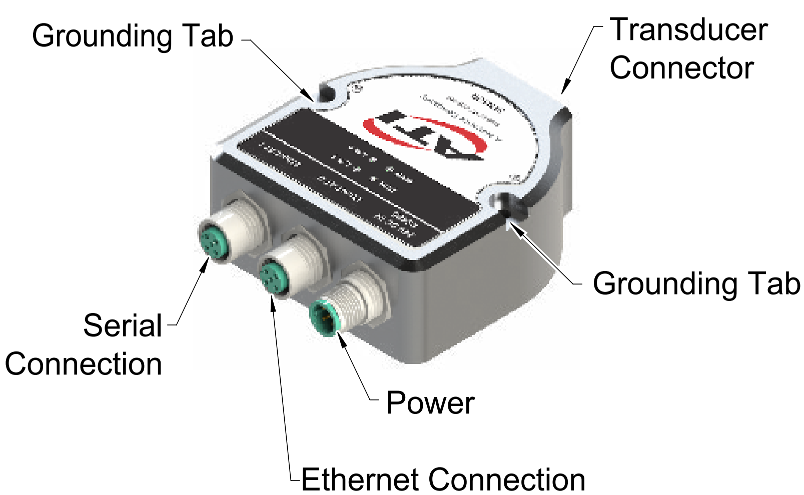
3.2 Connecting a Mini or Nano Transducer

ATI offers a selection of smaller transducers that require the use of the ECAT3 Communications Electronics Box (CEB), which houses an additional electronic board. Those sensors include the Nano series and Mini series. These sensors include an attached transducer cable.

Supplies required:

- ECAT3 CEB (9105-ECAT3-CEB-001)
- (2) M12 to RJ45 Ethernet Adapter (9105-C-R08F1-MD04M1-01-0.2)
- (2) Standard RJ45 ethernet cable (customer supplied)
- Power Supply: ECAT only: 9105-CBL-S-G1-Q5F-WWPS1-1.5
  Serial and ECAT: 9105-CF-MTS-DB9-*LENGTH*

Figure 3.2—ECAT3 CEB Inputs



1. Connect transducer cable to the ECAT3 CEB.

a. Align M12 male transducer cable connector with M12 female transducer socket on ECAT3 CEB.

b. Tighten cable sleeve clockwise to lock the connector at a recommended torque value of 0.7 Nm.

2. Connect EtherCAT port0:

a. Locate ECAT port 0 (ECAT0 on label) on the ECAT3 CEB. Refer to *Figure 3.2.*

b. Connect the M12 to RJ45 adapter to the CEB. Tighten the sleeve fully to lock the connector at a recommended torque of 0.8 Nm to 1.0 Nm.

c. Connect a standard RJ45 cable (customer-supplied) to the adapter.

d. Plug the other end of the RJ45 cable into customer EtherCAT device.

3. Connect EtherCAT port 1:
    a. Locate ECAT port 1 (ECAT1 on label) on the CEB. Refer to *Figure 3.2.*
    b. Connect the M12 to RJ45 adapter to the CEB. Tighten the sleeve fully to lock the connector at a recommended torque of 0.8 Nm to 1.0 Nm.
    c. Connect a standard RJ45 cable (customer-supplied) to the adapter.
    d. Plug the other end of the RJ45 cable into customer EtherCAT device.
4. Connect power to CEB
    a. Locate the power input on the splitter box. Refer to *Figure 3.2.*
    b. Connect the power supply cable to the CEB.
    c. Connect power supply to customer power source.
    d. *Optional*: If using 9105-CF-MTS-DB9-X, plug DB9 serial connector into customer equipment.

4. EtherCAT Bus Interface Operation

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

The EtherCAT bus interface allows a user to:

- Read force/torque data
- Read strain gage data and status information
- Configure tool transformation
- Set monitor conditions
- Set low pass filter cutoff frequency
- Bias transducer
- Determine which calibration is active
- Select a calibration to be active
- Read the active calibration information matrix, serial number, etc.
- Read the firmware revision

4.1 F/T Raw Data Output

F/T data output from the sensor and into the EtherCAT interface is in counts. The user must convert the value from counts to units (refer to *Section 4.7.7.1—Converting Force/Torque Counts to Units*).

4.2 Sample Rate

The firmware samples internally at 1000 Hz by default. This rate can be configured by the user. Reference *Section 4.7.11—Object 0x7010: Control Codes* and *Section 5.2—Cal Command.*

4.3 Threshold Monitoring

The EtherCAT3 FT system allows the user to configure thresholds. To activate a threshold, first write the appropriate values from *Section 4.7.4—Object 0x2060: Monitor Condition*, then set the bit corresponding to that threshold in the "Monitor Condition Enable Bitmap" in *Section 4.7.11—Object 0x7010: Control Codes*.

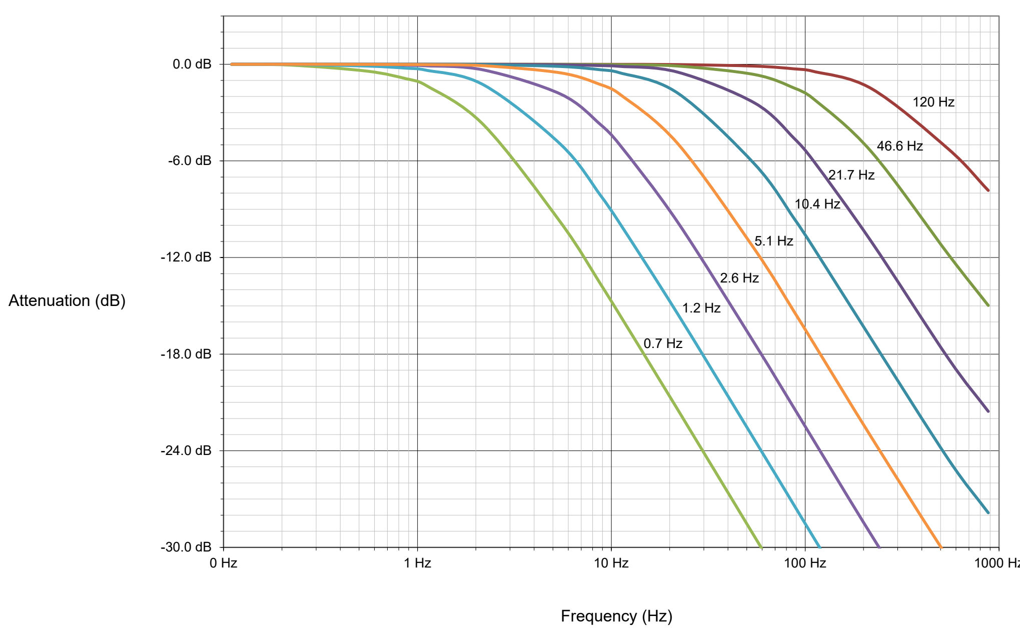
The software currently supports one monitor condition.

4.4 Filtering

The “Filter Selection” field in *Section 4.7.11—Object 0x7010: Control Codes* controls the coefficient used in the internal IIR filter. The cutoff frequency is dependent on the internal sample rate, which is defined in *Section 4.2—Sample Rate*. The relative cutoff frequencies for different values of this coefficient are:

Table 4.1—Filtering		
Coefficient	**Cutoff Frequency (Percent of Internal Sample Rate)**	**Frequency[1]**
0	No filter	15.9 kHz
1	11.97%	120 Hz
2	4.66%	46.6 Hz
3	2.17%	21.7 Hz
4	1.04%	10.4 Hz
5	0.51%	5.1 Hz
6	0.26%	2.6 Hz
7	0.12%	1.2 Hz
8	0.07%	0.7 Hz
Note: 1. Values are displayed based on a 1 kHz ADC rate, which is the default for ATI ECAT3 sensors.		

Figure 4.1—Filter Attenuation at 1 kHz Sample Rate



4.5 Tool Transformation

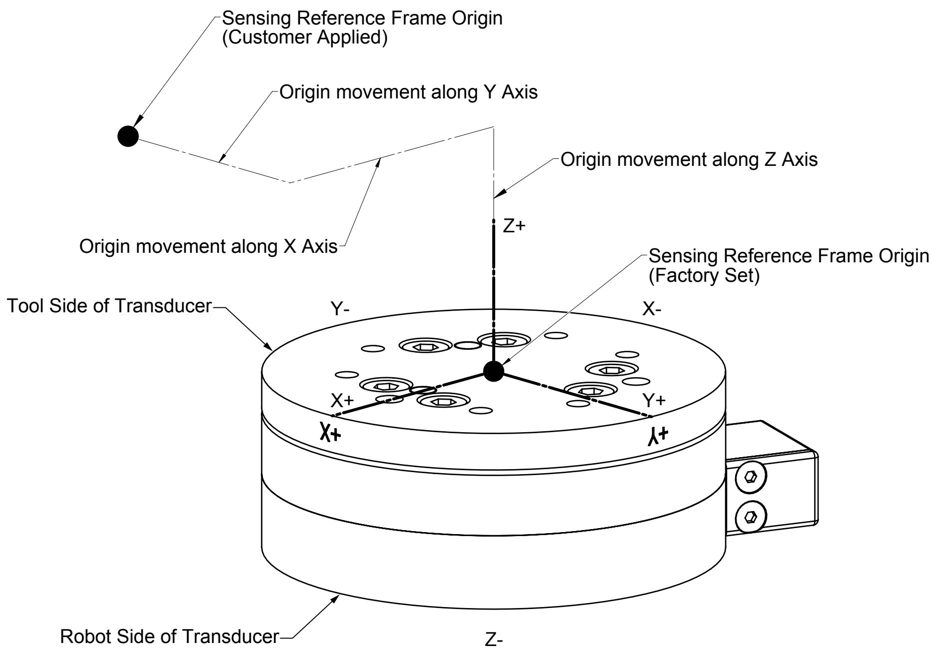
To activate a tool transformation, first write the appropriate transform coefficients from *Section 4.7.1—Object 0x2020: Tool Transformation*, then set the "Tool Transform Index Selection" bits in *Section 4.7.11—Object 0x7010: Control Codes* to activate that condition. The software supports one tool transformation.

The tool transformation function allows measurement of the forces and torques at a reference point other than the sensor's point of origin. If both rotations and displacements are specified within a particular tool transformation, displacements are performed first, in the order DX, DY, DZ, then rotations are performed, in the order RX, RY, RZ.

- Displacement DX, DY, and DZ: the displacement along each axis is measured in the distance component of the calibration's torque units, so if the sensor was calibrated to use Newton-meters as the torque unit, the displacement is measured in meters.
- Rotations RX, RY, and RZ: the rotation about each axis, in radians.

Displacement allows the customer to move the sensing reference frame origin along the X, Y, and Z axes. Displacement should be calculated and values should be entered before rotation. Displacement is measured in units which are set as either Nm or in-lbs.

Figure 4.2—Displacement of Sensing Reference Frame Origin



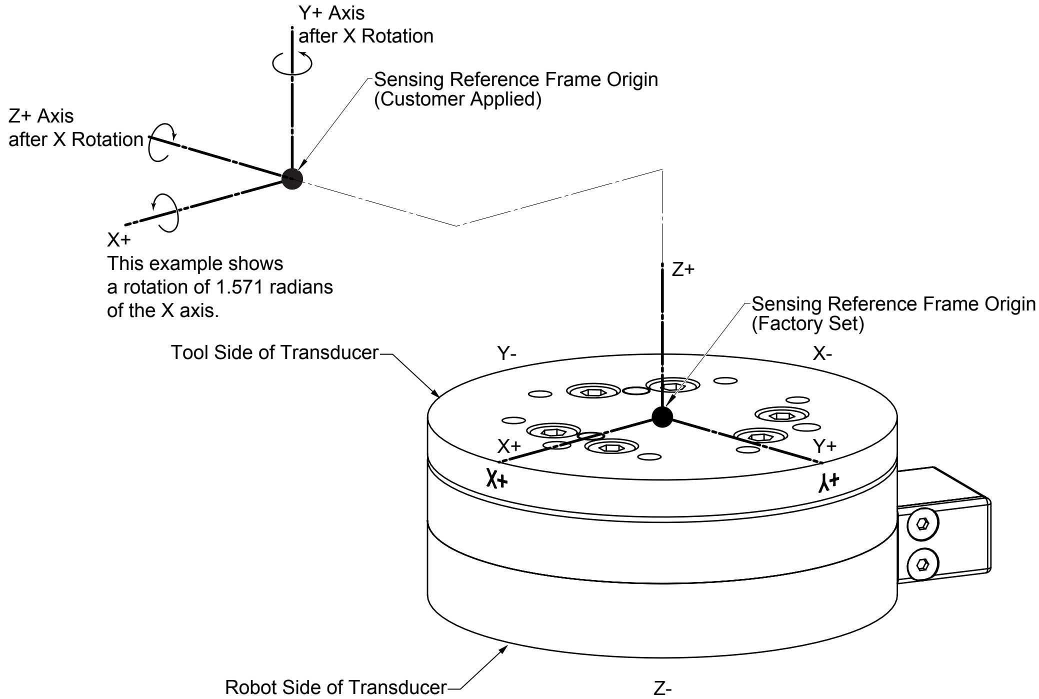
Rotation allows the customer to rotate the axes while maintaining the frame origin. *Figure 4.3* shows the direction of rotation about the axis. Rotation is measured in radians.

When a value is entered for RX, RY, or RZ the following will result:

- RX value will rotate Y and Z about X in the direction shown (see *Figure 4.3*).
- RY value will rotate X and Z about Y in the direction shown.
- RZ value will rotate X and Y about Z in the direction shown.

In a tool transformation, the order of the rotations matters. The X-rotation occurs first, followed by rotation about Y (in its new orientation), then Z. Therefore, rotations MUST be expressed in this order.

Figure 4.3—Rotating Reference Frame



4.6 Process Data Object (PDO) Interface

The PDO interface is used to exchange data in real-time with the F/T sensor.

e. TxPDO Map / Output Data
The TxPDO combines *Object 0x6000: Reading Data*, *Object 0x6010: Status Code*, and *Object 0x6020: Sample Counter*.

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

4.7 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.*

4.7.1 Object 0x2020: Tool Transformation

This writable object contains the following 32-bit signed integer fields:

Table 4.2—Tool Transformation

Subindex	Name	Description
0x01	Dx	The displacement along the x axis, in units of 0.01 calibration length units. E.g. if the distance component of the torque is meters, a Dx value of 100 = 1 meter.
0x02	Dy	The displacement along the y axis, in units of 0.01 calibration length units.
0x03	Dz	The displacement along the z axis, in units of 0.01 calibration length units.
0x04	Rx	The rotation about the X axis, in units of 0.1 degrees, e.g. an Rx value of 900 = 90 degrees.
0x05	Ry	The rotation about the Y axis, in units of 0.1 degrees.
0x06	Rz	The rotation about the Z axis, in units of 0.1 degrees.
0x07	ttDistUnits	0=in, 1=ft, 2=mm, 3=cm, 4=m
0x08	ttAngUnits	0=degrees, 1=radians
0x09	Commit	Use to send the command.

4.7.2 Object 0x2021: Calibration

This object allows the user to view the currently active calibration, as defined by the "Calibration Selection" field in *Section 4.7.11—Object 0x7010: Control Codes*. The calibration object contains the following fields:

<table>
<tr><th colspan="5">Table 4.3—Calibration</th></tr>
<tr><th>Subindex</th><th>Name</th><th>Type</th><th colspan="2">Description</th></tr>
<tr><td>0x01</td><td>FT Serial</td><td>STRING(8)</td><td colspan="2">The FT Serial Number, e.g. "FT01234."</td></tr>
<tr><td>0x02</td><td>Calibration Part Number</td><td>STRING(30)</td><td colspan="2">The calibration part number e.g. "SI-120-95."</td></tr>
<tr><td>0x03</td><td>Calibration Family</td><td>STRING(8)</td><td colspan="2">Always reads "ECAT"</td></tr>
<tr><td>0x04</td><td>Calibration Time</td><td>STRING(30)</td><td colspan="2">The date the sensor was calibrated</td></tr>
<tr><td>0x05-0x28</td><td>Internal Matrix</td><td>STRING(16)</td><td colspan="2">Internal calibration matrix</td></tr>
<tr><td rowspan="6">0x29</td><td rowspan="6">Force Units</td><td rowspan="6">USINT8</td><td>Value</td><td>Unit</td></tr>
<tr><td>1</td><td>Lbf</td></tr>
<tr><td>2</td><td>N</td></tr>
<tr><td>3</td><td>Klbf</td></tr>
<tr><td>4</td><td>kN</td></tr>
<tr><td>5</td><td>Kg</td></tr>
<tr><td rowspan="7">0x2a</td><td rowspan="7">Torque Units</td><td rowspan="7">USINT8</td><td>Value</td><td>Unit</td></tr>
<tr><td>1</td><td>Lbf-in</td></tr>
<tr><td>2</td><td>Lbf-ft</td></tr>
<tr><td>3</td><td>N-m</td></tr>
<tr><td>4</td><td>N-mm</td></tr>
<tr><td>5</td><td>Kg-cm</td></tr>
<tr><td>6</td><td>kN-m</td></tr>
<tr><td>0x2b</td><td>Max Fx Counts</td><td rowspan="6">DINT</td><td colspan="2" rowspan="6">The maximum rated value for this axis, in counts.</td></tr>
<tr><td>0x2c</td><td>Max Fy Counts</td></tr>
<tr><td>0x2d</td><td>Max Fz Counts</td></tr>
<tr><td>0x2e</td><td>Max Tx Counts</td></tr>
<tr><td>0x2f</td><td>Max Ty Counts</td></tr>
<tr><td>0x30</td><td>Max Tz Counts</td></tr>
<tr><td>0x31</td><td>Counts Per Force</td><td>DINT</td><td colspan="2">The calibration counts per force unit.</td></tr>
<tr><td>0x32</td><td>Counts Per Torque</td><td>DINT</td><td colspan="2">The calibration counts per torque unit.</td></tr>
<tr><td>0x33-0x3a</td><td>Internal Data</td><td>UINT16</td><td colspan="2">Internal Data</td></tr>
<tr><td>0x3b-0x40</td><td>Internal Data</td><td>DINT</td><td colspan="2">Internal Data</td></tr>
<tr><td>0x41</td><td>Gage Max Range</td><td rowspan="2">DINT</td><td colspan="2">Any gage strain of this level and higher are considered out of range.</td></tr>
<tr><td>0x42</td><td>Gage Min. Range</td><td colspan="2">Any gage strain of this level and lower are considered out of range.</td></tr>
<tr><td>0x43</td><td>Peak Loads Positive Fx</td><td rowspan="6">DINT</td><td colspan="2">All-time peak positive force load in x axis</td></tr>
<tr><td>0x44</td><td>Peak Loads Positive Fy</td><td colspan="2">All-time peak positive force load in y axis</td></tr>
<tr><td>0x45</td><td>Peak Loads Positive Fz</td><td colspan="2">All-time peak positive force load in z axis</td></tr>
<tr><td>0x46</td><td>Peak Loads Positive Tx</td><td colspan="2">All-time peak positive torque load in x axis</td></tr>
<tr><td>0x47</td><td>Peak Loads Positive Ty</td><td colspan="2">All-time peak positive torque load in y axis</td></tr>
<tr><td>0x48</td><td>Peak Loads Positive Tz</td><td colspan="2">All-time peak positive torque load in z axis</td></tr>
</table>

Table 4.3—Calibration			
Subindex	**Name**	**Type**	**Description**
0x49	Peak Loads Negative Fx	DINT	All-time peak negative force load in x axis
0x4a	Peak Loads Negative Fy		All-time peak negative force load in y axis
0x4b	Peak Loads Negative Fz		All-time peak negative force load in z axis
0x4c	Peak Loads Negative Tx		All-time peak negative torque load in x axis
0x4d	Peak Loads Negative Ty		All-time peak negative torque load in y axis
0x4e	Peak Loads Negative Tz		All-time peak negative torque load in y axis
0x4f	Gage Max Warning	DINT	Any gage strain of this level is nearing the maximum range limit.
0x50	Gage Min. Warning		Any gage strain of this level is nearing the minimum range limit.
0x51	Hold Time	UINT	Holds time in ADC ticks after detecting gage correction overflow, gage out of range, gage disconnect, or FT out of range.
0x52	Internal Calibration Data	Float	Internal Calibration Data

4.7.3 Object 0x2023: Console Over EtherCAT

This object allows the user to enter console commands and read responses without converting to a serial interface. Reference *Table 5.1* for a full list of console commands.

The following fields are available in console over EtherCAT:

Table 4.4—Diagnostic Readings

Subindex	Name	Type	Description
0x01	Command	STRING(100)	Command to send to console.
0x02	Response	STRING(100)	Latest line printed to the console.
0x03	Commit	UINT16	Write "1" to execute the command.

Note:

1. See *Section 4.2—Sample Rate* for strain gage sampling rate.

4.7.4 Object 0x2060: Monitor Condition

This user-writable object allows the user to configure an axis, a threshold value, and direction to continuously evaluate against the current F/T data. When an enabled condition becomes true, the monitor output becomes active and stays active until reset via setting the "Reset Monitor Condition" bit in *Section 4.7.11—Object 0x7010: Control Codes*, which is also mapped into the TxPDO data.

The following fields are available in the monitor condition:

<table>
<tr><th colspan="5">Table 4.5—Monitor Condition</th></tr>
<tr><th>Subindex</th><th>Name</th><th>Type</th><th colspan="2">Description</th></tr>
<tr><td>0x01</td><td>Threshold Value</td><td>DINT</td><td colspan="2">The threshold value to compare against, in counts.</td></tr>
<tr><td rowspan="7">0x02</td><td rowspan="7">Axis</td><td rowspan="7">USINT</td><th>Value</th><th>Axis</th></tr>
<tr><td>0</td><td>Fx</td></tr>
<tr><td>1</td><td>Fy</td></tr>
<tr><td>2</td><td>Fz</td></tr>
<tr><td>3</td><td>Tx</td></tr>
<tr><td>4</td><td>Ty</td></tr>
<tr><td>5</td><td>Tz</td></tr>
<tr><td>0x03</td><td>CompareGreaterThan</td><td>BOOL</td><td colspan="2">If TRUE (1): the monitor condition is true when the selected axis is greater than the selected threshold value.
If FALSE (0), the monitor condition is true when the selected axis is less than the selected threshold value.</td></tr>
<tr><td>0x04</td><td>Commit</td><td>UINT16</td><td colspan="2">Write "123" to commit a command.</td></tr>
</table>

4.7.5 Object 0x2080: Diagnostic Readings

This read-only object provides access to diagnostic values. These values may be useful when troubleshooting the system.

The following fields are available in the Diagnostic Readings object:

Table 4.6—Diagnostic Readings					
Subindex	**Name**	**Type**	**Description**	**Limits**	**Sampling Rate**
0x01	Supply Sense	UINT16	The supply voltage * 10.	12V to 32V	Background loop [1]
0x02	Temperature degrees C * 10	INT16	Internal sensor temperature in Celsius *10.	-5°C to 70°C	Background loop. [1]
0x03	Status Message	STRING (40)	Current highest priority error message.	N/A	N/A
Note: 1. See *Section 4.2—Sample Rate* for strain gage sampling rate.					

4.7.6 Object 0x2090: Version

This read-only object provides firmware version information.

The following fields are available in the version object:

Table 4.7—Version			
Subindex	**Name**	**Type**	**Description**
0x01	Major	UINT16	Major Version
0x02	Minor	UINT16	Minor Version
0x03	Revision	UINT16	Revision
0x04	Boot Loader Version	UINT32	Boot Loader Version
0x05	sensorHW Ver	UINT16	Sensor Hardware Version
0x06	sensorInstrument	UINT16	Internal manufacturing data

4.7.7 Object 0x6000: Reading Data

This read-only object represents the current force/torque or gage data. It is mapped into the TxPDO input data.

The following fields are present in the reading data:

Table 4.8—Reading Data			
Subindex	**Name**	**Type**	**Description**
0x01	Fx/Gage0	DINT	If the "Gage Data" bit in *Section 4.7.11—Object 0x7010: Control Codes* is set, these fields contain the 16-bit gage data. If the "Gage Data" bit is cleared, these fields contain the 32-bit F/T result data, in counts.
0x02	Fy/Gage1		
0x03	Fz/Gage2		
0x04	Tx/Gage3		
0x05	Ty/Gage4		
0x06	Tz/Gage5		

4.7.7.1 Converting Force/Torque Counts to Units

The data in the register for this object is in counts. Therefore, the F/T counts must be converted to a value in units.

To convert the SDO counts into units, complete the following steps:

1. Read the Counts per Force SDO register (refer to *Section 4.7.2—Object 0x2021: Calibration* subindex 0x31).
2. Read the Counts per Torque SDO register (refer to *Section 4.7.2—Object 0x2021: Calibration* subindex 0x32).
3. Verify the units of force (refer to *Section 4.7.2—Object 0x2021: Calibration* subindex 0x29).
4. Verify the units of torque (refer to *Section 4.7.2—Object 0x2021: Calibration* subindex 0x2a).
5. Read the F/T counts for force (refer to *Section 4.7.7—Object 0x6000: Reading Data*).
6. Read the F/T counts for torque (refer to *Section 4.7.7—Object 0x6000: Reading Data*).
7. Convert the counts to units.
   a. For force, divide the register from step *5* by the register from step *1*.
   b. For torque, divide the register from step *6* by the register from step *2*.

For example, a user wants the F/T counts for Fx and Tx in units.

First, the user reads the registers for the applicable SDO subindexes and finds the following:

Table 4.9—Example of Registers for SDO Subindexes

SDO	Subindex	Register	Description[1]
0x2021	0x31	1, 000, 000	Counts Per Force
0x2021	0x32	1, 000, 000	Counts Per Torque
0x2021	0x29	1	The force units are Lbf.
0x2021	0x2a	2	The torque units are Lbf-ft.
0x6000	0x01	5, 214, 777	Fx data in raw counts
0x6000	0x04	4, 214, 777	Tx data in raw counts

Note:

1. The description is not provided in the user's EtherCAT interface but is provided in this table for reference.

Then, the user converts counts to units for Fx and Tx.

For Fx: 5, 214, 777 counts ÷ 1, 000, 000 N/counts = 5.21 N

For Tx: 4, 214, 777 counts ÷ 1, 000, 000 Nm/counts = 4.21 Nm

4.7.8 Object 0x6010: Status Code

This object contains a single DINT value (at subindex 0), that displays the status code bit pattern. Reference *Section 6.2—System Status Code.*

4.7.9 Object 0x6020: Sample Counter

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

4.7.10 Object 0x6030: Gage Data

This object contains eight 32-bit unsigned integers that are the latest 24-bit raw gage data for gages 0 to 7.

Table 4.10—Gage Data

Subindex	Name	Type	Description
0x01	Gage0	DINT	These fields contain the 32-bit gage data.
0x02	Gage1		
0x03	Gage2		
0x04	Gage3		
0x05	Gage4		
0x06	Gage5		
0x07	Gage6		
0x08	Gage7		

4.7.11 Object 0x6050: IMU Data

This read-only object contains six 16-bit signed integers that contain the latest accelerometer and gyroscopic data.

Resolved data can be extracted from the counts using the formula:

$$Resolved\ data\ = counts\ \times\ 2^{-q}$$

where q is the Qpoint of that data.

Table 4.11—Object Index (hex) 0x6030: Raw Unbiased Gage Data			
Subindex	**Name**	**Type**	**Description**
0x01	CalAccelX	INT16	These fields contain the raw 16-bit accelerometer data in counts. Qpoint = 8, scaled value in m/s^2.
0x02	CalAccelY		
0x03	CalAccelZ		
0x04	CalGyroX	INT16	These fields contain the raw 16-bit gyroscope data in counts. Qpoint = 9, scaled value in rad/s.
0x05	CalGyroY		
0x06	CalGyroZ		

4.7.12 IMU Accuracy Checking Procedure

The IMU contains a self-accuracy check, which monitors the output of the accelerometer. The accuracy of the accelerometer is reported to the end user with the following definitions:

Table 4.12—IMU Accelerometer Accuracy Bits			
Status Bit 18	**Status Bit 17**	**Decimal Value**	**Description**
0	0	0	Unreliable
0	1	1	Accuracy Low
1	0	2	Accuracy Medium
1	1	3	Accuracy High

Bits 17 and 18 of the Status Code communicate the accelerometer accuracy. For more information, refer to *Section 6.2—Status Code.*

While the end user must decide the exact performance accuracy that is needed for an application, the datasheet specifications correspond to operating the sensor at a high accuracy status. If the current, reported accuracy status is below the level that is desired by the end user, a calibration procedure can be performed as described the *ATI F/T Transducer Section* manual

4.7.13 Object 0x7010: Control Codes

This object, mapped into the RxPDO for real-time control of the F/T system, contains these fields:

<table>
<tr><th colspan="6">Table 4.13—Control Codes</th></tr>
<tr><th>Subindex</th><th>Name</th><th>Type</th><th colspan="3">Description</th></tr>
<tr><td rowspan="24">0x01</td><td rowspan="24">Control 1</td><td rowspan="24">DINT</td><th>Bit</th><th colspan="2">Function</th></tr>
<tr><td>0</td><td colspan="2">1 = Set bias against current load.
0 = Use last set bias.</td></tr>
<tr><td>1</td><td colspan="2">1 = Clear monitor condition status.
0 = Leave monitor condition status as-is</td></tr>
<tr><td>2</td><td colspan="2">1 = Clear bias
0 = Leave bias as-is</td></tr>
<tr><td>3</td><td colspan="2">1 = Output gages 0-5 in PDO
0 = Output F/T in PDO</td></tr>
<tr><td>4-7</td><td colspan="2">Filter selection</td></tr>
<tr><td>8-11</td><td colspan="2">Calibration Selection:
0 = Calibration 0
1 = Calibration 1
2 = Calbration 2
All other values are reserved.</td></tr>
<tr><td>12-15</td><td colspan="2">ADC Sampling Rate:
0 = 500 Hz
1= 1000 Hz (default)
2 = 2000 Hz
3 = 4000 Hz
4 = 8000 Hz
All other values are reserved</td></tr>
<tr><td>16</td><td colspan="2">IMU calibration save.</td></tr>
<tr><td>17-19</td><td colspan="2">Reserved</td></tr>
<tr><td rowspan="7">20-23</td><td colspan="2">IMU accelerometer gain selection. Refer to Section 4.7.13.1—IMU Accelerometer and Gyroscope</td></tr>
<tr><th>Value</th><th>Gain</th></tr>
<tr><td>0</td><td>Last Set Gain Value[1]</td></tr>
<tr><td>1</td><td>2 g</td></tr>
<tr><td>2</td><td>4 g</td></tr>
<tr><td>3</td><td>8 g</td></tr>
<tr><td>4</td><td>16 g</td></tr>
<tr><td rowspan="6">24-27</td><td colspan="2">IMU gyroscope gain selection. Refer to Section 4.7.13.1—IMU Accelerometer and Gyroscope</td></tr>
<tr><th>Value</th><th>Gain</th></tr>
<tr><td>0</td><td>Last Set Gain Value[1]</td></tr>
<tr><td>2</td><td>250 DPS</td></tr>
<tr><td>3</td><td>500 DPS</td></tr>
<tr><td>5</td><td>2000 DPS</td></tr>
<tr><td>28-31</td><td colspan="2">Reserved</td></tr>
</table>

Table 4.13—Control Codes				
Subindex	Name	Type	Description	
			Bit	Function
0x02	Control 2	DINT	0	Enable checking of Monitor Condition 0
			1-30	Reserved
			31	Simulated Error Control
Note: 1. After changing the tool transform index, it is recommended to not update the control codes for a period of 500 milliseconds to allow the sensor to fully apply the transformation.				

4.7.13.1 IMU Accelerometer and Gyroscope

NOTICE: Prior to streaming or setting up IMU data, the user needs to complete an IMU calibration as outlined the *9620-05-Transducer Section manual*.

The Sano74 IMU accelerometer and gyroscope can be configured via bits 20-27. The following six combinations outlined in *Table 4.14* are available for the user. Any other combination of accelerometer and gyroscope gain selections will result in an error.

Table 4.14—Allowed IMU Configurations	
Accelerometer Gain	Gyroscope Gain
2g	2000 DPS
4g	2000 DPS
8g	2000 DPS
8g	250 DPS
8g	500 DPS
16g	2000 DPS

To stream IMU data, reference *Section 4.7.11—Object 0x6050: IMU Data.*

4.8 LED Functions

The EtherCAT3 F/T includes four LEDs: EtherCAT0 link activity, EtherCAT1 link activity, power, and run. Each of these LEDs can be off, red, green, or both red and green, which may appear as orange.

Figure 4.4—ECAT3 LEDs

At power up, the LEDs cycle through the following sequence once:

- All LEDS off
- LA0 LED flash red
- LA0 flash green
- LA1 flash red
- LA1 flash green
- RUN flash red
- PWR flash red
- PWR flash green.
- All LEDs off

Table 4.12 outlines LED behavior during normal operation.

Table 4.15—ECAT3 Sensor LED Descriptions

LED	Label	LED State	Description
Link Activity 0	LA0	Off	No LA0 activity
		Green	LED will light green for five seconds following any activity to LA0.
Link Activity 1	LA1	Off	No LA1 activity
		Green	LED will light green for five seconds following any activity to LA1.
Network Status	RUN	Blinking Green	Pre-Operational State
		Single Green Flash	Safe-Operational State
		Solid Green	Operational State
		Red	Error
Power	PWR	Solid Green	No errors
		Slow Blinking Red	Calibration or checksum error.
		Fast Blinking Red	ECAT communication error.
		Solid Orange (Red and Green)	Axis out of range error.
		Solid Red	Serious status error. Reference ***Section 7.2—Status Word.***

5. Console Operation

When the sensor is attached to the serial interface of the customer's computer or robot, the computer assigns the sensor a COM port. Then by using a console on the computer, the user can communicate with the sensor. A full list of serial commands is outlined in *Table 5.1*

<table>
<tr><th colspan="3">Table 5.1—Serial Commands</th></tr>
<tr><th>Command</th><th>Command with Operands</th><th>Description</th></tr>
<tr><td rowspan="3">Help</td><td>h</td><td rowspan="3">Prints help</td></tr>
<tr><td>H</td></tr>
<tr><td>?</td></tr>
<tr><td rowspan="4">Bias</td><td>bias</td><td>Displays current bias status</td></tr>
<tr><td>bias on</td><td>Turns bias on</td></tr>
<tr><td>bias off</td><td>Turns bias off</td></tr>
<tr><td>bias [value]</td><td>Sets bias to particular value in F/T counts</td></tr>
<tr><td rowspan="3">Peak</td><td>peak</td><td>Displays the run-time and all-time F/T data peaks in units.</td></tr>
<tr><td>peak c</td><td>Displays the run-time and all-time F/T data peaks in counts.</td></tr>
<tr><td>peak reset</td><td>Resets run-time F/T data peaks.</td></tr>
<tr><td rowspan="2">C/S</td><td>c</td><td>Continuous flow of values. Reference 5.1.1.</td></tr>
<tr><td>s</td><td>Stingle strand of values. Reference 5.1.1.</td></tr>
<tr><td rowspan="4">Set</td><td>set</td><td>Prints all setting field values. Reference Section 4.1.2—Cal Command</td></tr>
<tr><td>set [field]</td><td>Prints specific setting field value.</td></tr>
<tr><td>set [field] [value]</td><td>Sets specific setting field with value entered.</td></tr>
<tr><td>set *</td><td>Prints fields that have changed from default.</td></tr>
<tr><td rowspan="2">Simerr</td><td>simerr on</td><td>Turns the simulated error status bit on. Refer to Table 7.1</td></tr>
<tr><td>simerr off</td><td>Turns the simulated error status bit on. Refer to Table 7.1</td></tr>
<tr><td>Reset</td><td>reset</td><td>Resets the processor, returning all parameters and settings to their defaults.</td></tr>
<tr><td>Saveall</td><td>saveall</td><td>Writes all settings to non-volatile memory. This is typically used if any settings have been updated.</td></tr>
<tr><td>Status</td><td>status</td><td>Prints a status report on the various components of the sensor</td></tr>
<tr><td>MC</td><td>mc</td><td>Prints all global monitor condition status information.</td></tr>
<tr><td rowspan="4">View</td><td>view</td><td>Prints calibration report properties such as F/T part number, serial number, units, calibration date, and calibration family.</td></tr>
<tr><td>view 0</td><td>Prints calibration properties for Calibration 0.</td></tr>
<tr><td>view 1</td><td>Prints calibration properties for Calibration 1.</td></tr>
<tr><td>view a</td><td>Prints calibration properties for active calibration.</td></tr>
<tr><td>Diag</td><td>diag</td><td>Prints a diagnostic report of gage number, gage readings in counts, and a gage status indicator. Indicators include:
"w" gage in warning range
"!" gage in error range
"x" gage disconnected</td></tr>
<tr><td>Sysver</td><td>Sysver</td><td>Prints firmware version.</td></tr>
<tr><td>WHOAMI</td><td>whoami</td><td>Prints console input source.</td></tr>
</table>

Table 5.1—Serial Commands		
Command	**Command with Operands**	**Description**
IMUSAVE	(none)	Saves IMU calibration data following procedure outlined in the *Transducer Section* manual
ACCLCAL	ACCLCAL 2g	Sets the IMU accelerometer sensing range between +/- 2g and the gyroscope to 2000 DPS. Refer to *Section 5.3—IMU Data*
	ACCLCAL 4g	Sets the IMU accelerometer sensing range between +/- 4g and the gyroscope to 2000 DPS. Refer to *Section 5.3—IMU Data*
	ACCLCAL 8g	Sets the IMU accelerometer sensing range between +/- 8g and the gyroscope to 2000 DPS. Refer to *Section 5.3—IMU Data*
	ACCLCAL 16g	Sets the IMU accelerometer sensing range between +/- 16g and the gyroscope to 2000 DPS. Refer to *Section 5.3—IMU Data*
	ACCLCAL 8g250	Sets the IMU accelerometer sensing range between +/- 8g and the gyroscope to 250 DPS. Refer to *Section 5.3—IMU Data*
	ACCLCAL 8g500	Sets the IMU accelerometer sensing range between +/- 8g and the gyroscope to 500 DPS. Refer to *Section 5.3—IMU Data*

5.1 Query Commands: “s” or “c”

The query command starts the high-speed data transmission of FT data. The “s” command reports a single line of FT data that is scaled by the counts per force or counts per torque. The “c” command reports continuous lines of FT data that stop when the user holds another key, for example: “enter”, until the output of data ceases. The “c” command reports data at the rate specified in the rdtRate.

The following are examples of an “S” or “C” command with specifiers:

1. Example: S c0123

user: S c0123

response: fd6b02 ff240d fe2b34 fe273d

   a. S: prints a single line of data.
   b. c: prints data in counts.
   c. 0123: a number 0 through 6 specifies to print the data for the corresponding gage number. So 0 will print data for gage 0, and 3 will print data for gage four. In this example, the response will print gage data for gages one, two, three, and four.
   d. Data is displayed in hexidecimal by default.

2. Example: s >012345du

user: s >012345du

response: fd6afd ff2407 fe2b2a fe272f fdb571 fec16b

   a. S: a command for reporting a single line of data.
   b. >: will print the data in a compressed output, intended for highspeed applications.
   c. 012345: will print the data for the corresponding gages zero through six.
   d. D: any data following prints in decimal format.
   e. U: any data following will prints in units.

Table 5.2—S or C command specifiers		
Category	**Specifier**	**Description**
Gage number(s)	0123456	Specifies active ADC channels 0 to 6. Raw values are printed in counts only.
Axis	XYZ	Specifies z, y, or z force or torque data
	M	Specifies force or torque Magnitude data
Force and/or torque	F	The following XYZM data specifies force (default)
	T	The following XYZM data specifies torque
Counts or units	C	Data is printed in counts
	U	Data is printed in units (default)
Numeric system	D	Data is printed in decimal
	H	Data is printed in hexadecimal, except any data always printed in decimal (default)
Format	<	Data is printed in human-readable form with lined-up columns (default)
	>	Data is printed in compressed format, intended for high-speed automated applications.
Additional inputs to aid in development of customer software program	#	Specifies a sample counter that prints for every new C or S line.
	@	Specifies an ADC read counter that prints for every time the ADC is read.
	;	Uses a comma between fields instead of blanks
	S	Specifies a 16-bit CRC.
	$	$ is a long specifier tag that indicates the IMU specifier. Refer to *Section 5.3—IMU Data*
Troubleshooting	!	Specifies a 32-bit Status Code. Reference *Table 6.1.*

5.2 Set Command

The set command allows users to either view or set specific settings, which are outlined in *Table 5.3—Set Commands.* The following are examples of a set command with specifiers:

1. Example: set baud

user: set baud

response:baud rate 115200

- By entering the set command with the operand “baud”, the sensor will print the current baud rate

user: *set baud 1000000*

response: *baud rate was 115200, now 1000000*

user: *saveall*

response: *Parameters saved to NVM bank 0*
Parameters saved to NVM bank 1

- By entering a value after the baud rate set command, the user can set a new baud rate.
- Remember to send a saveall command to ensure all changes are saved to non-volitile memory.

2. Example: set ttdx

user: set ttdx

response:

Field	*Value*
-----	-----
ttdx	*0*

- By entering the set command with the operand “ttdx”, the sensor will print the current tool transformation distance in the X axis.

user: *set ttdx 1*

response: *set ttdx 1*
ttdx was “0” now “1”

user: *saveall*

response: *Parameters saved to NVM bank 0*
Parameters saved to NVM bank 1

- By default, tool transformation units are millimeters for distance and radians for angle. These units can be changed using the ttdu (distance units) and ttau (angle units) commands. Reference *Table 5.3.*

- Remember to send a saveall command to ensure all changes are saved to non-volitile memory.

Table 5.3—Set Commands

Field	Read/Edit	Example	Data Type	Description
SerialNum	Read	FT00123	STRING(8)	Calibrated F/T serial number
partNum	Read	Num-4	STRING(30)	Calibration part number
calFamily	Read	ENET	STRING(8)	Calibration family
CalTime	Read	1970-01-01 00:00	STRING(30)	Date and time sensor was calibrated
max0	Read	2147483647	32-bit unsigned integer	Maximum rated force value in counts for the that axis.
max1				
max2				
max3				Maximum rated torque value in counts for that axis.
max4				
max5				
forceUnits	Read	1	8-bit unsigned integer	Force units. 0=Lbf, 1=N, 2=Klbf, 3=kN, 4=Kg
torqueUnits		2		Torque units. 0=Lbf-in, 1=Lbf-ft, 2=Nm, 3=Nmm, 4=Kg-cm, 5=kN-m
cpf	Read	100000	32-bit unsigned integer	Calibration counts per force unit.
cpt		100000		Calibration counts per torque unit.
peakPos0	Read	2395927	32-bit unsigned integer	Peak Loads Positive. All-time peak positive force and torque loads in F/T counts
peakPos1		624576		
peakPos2		35521		
peakPos3		721632		
peakPos4		159210		
peakPos5		74910		
PeakNeg0	Read	-988570	32-bit unsigned integer	Peak Loads Negative. All-time peak negative force and torque loads in F/T counts
PeakNeg1		-2008525		
PeakNeg2		-9148784		
PeakNeg3		-46851		
PeakNeg4		-12383		
PeakNeg5		0		

Table 5.3—Set Commands				
Field	**Read/Edit**	**Example**	**Data Type**	**Description**
sensorHwVer	Read	0	16-bit unsigned integer	Active version of the sensor hardware
sensorInstr		1		Internal Manufacturing Data
paramWrites		4		Number of times the sensor wrote the parameters to NVM
adcRate	Read and Edit	1000 (default)	16-bit unsigned integer	ADC rate in Hz. Must be 500, 1000 (default), 2000, 4000, or 8000.
rdtRate		40		RDT transmission rate in serial continuous mode in Hz. This number can range from 1 to the ADC Rate.
filTc		0 (default)		(IIR) filter code This setting changes the parameter that determines data filtering.
calib		1	8-bit unsigned integer	Three calibrations to use. Either 0, 1, or 2.
location		Bench	STRING(40)	Shows physical location.
hwRev	Read	04	16-bit unsigned integer	Hardware revision number
ttdu	Read and Edit	0	8-bit unsigned integer	Tool Transform distance units 0=in, 1=ft, 2=mm, 3=cm, 4=m
ttau		0		Tool Transform angle units. 0=degrees, 1=radians
ttdx	Read and edit	0 (default)	float	Tool Transform distances
ttdy		0 (default)		
ttdz		0 (default)		
ttrx		0 (default)		Tool Transform rotation angles
ttry		0 (default)		
ttrz		0 (default)		
baud	Read and edit	115200 (default)	32-bit unsigned integer	UART baud rate. Must be between 300 and 3M. All baud rates are temporary until saveall command is sent.
msg		0	8-bit unsigned integer	0=print only prompted messages 1=print all messages
serial	Read	0		0= EtherCAT and serial 1=Serial-only mode.

Table 5.3—Set Commands				
Field	**Read/Edit**	**Example**	**Data Type**	**Description**
mcEnabled	Read and edit	1	8-bit unsigned integer	1 = enabled, 0 = disabled. Global monitor conditions enabled or disabled.
mcOutMomen		1		0: Monitor Conditions Momentary. Valid output code will only be active while threshold is met. If conditions change and threshold is no longer met, output code will no longer be displayed. 1: Latching: Valid output code will be active after a threshold is met, even if conditions change and threshold was only met briefly.
mcOutDelay		20		Global monitor conditions momentary delay. How long monitor condition will remain latched after it trips. This value is displayed in tenths of a second.
mcAndCodes		1		0: Uses the AND bitwise. If all set thresholding conditions are met, monitor condition will trip. 1: Uses OR bitwise. If any set thresholding condition is met, monitor condition will trip.

5.2.1 Counts Per Force/Torque to FT Values

To obtain the real force and torque values, each force value must be divided by the counts per force (cpf) factor, and each torque value must divided by the counts per torque (cpt) factor. The cpf and cpt factors can be obtained using the set commands. Refer to *Section 5.2—Set Command*. For example: if a calibration reports 1,000,000 counts per N and the Fz reports 4,500,000 counts, then the force applied in the Z axis is 4.5 N.

5.3 IMU Data

5.3.1 Configuring Accelerometer and Gyroscope

The Sano74 IMU accelerometer and gyroscope can be configured by using the `acclcal` command (reference *Table 5.1).* The following six combinations are available for the user:

- *`acclcal 2g`*: sets the accelerometer sensing range to +/- 2g, and the gyroscope to 2000 DPS
- `acclcal 4g`: sets the accelerometer sensing range to +/- 4g, and the gyroscope to 2000 DPS
- *`acclcal 8g`*: sets the accelerometer sensing range to +/- 8g, and the gyroscope to 2000 DPS
- *`acclcal 16g`*: sets the accelerometer sensing range to +/- 16g, and the gyroscope to 2000 DPS
- `acclcal 8g250`: sets the accelerometer sensing range to +/- 8g, and the gyroscope to 250 DPS
- *`acclcal 8g500`*: sets the accelerometer sensing range to +/- 8g, and the gyroscope to 500 DPS

5.3.2 Streaming IMU Data

Accelerometer and gyroscope IMU data is streamed via C/S commands using long specifiers. The Accelerometer performance is 0.3 m/s and the gyroscope is 3.1 dps After a specifier tag **$** from *Table 5.2*, long specifiers outline IMU steaming data. Additional modifiers may be used to control the type of data. Reference *Table 5.5——IMU Specifiers* for IMU data streaming options.

Table 5.4—IMU Specifiers

Specifier	Name	Modifiers[1]	Units	Type	Axes
$A	Accelerometer	C	counts	16-bit	XYZ
		U	m/s^2		
$G	Gyro	C	counts		
		U	radian/s		
$LA	Linear Acceleration	C	counts		
		U	m/s^2		
$GV	Gravity Vector	C	counts		
		U	m/s^2		
$AV	Angular Velocity	C	counts		
		U	radian/s		
$ACL	Linear Acceleration Accuracy Level[2]	Bits 76	0: Unreliable 1: Low Accuracy 2: Medium Accuracy 3: High Accuracy	8-bit	N/A
	Accelerometer Accuracy Level[2]	Bits 54			
	Gyro Accuracy Level[2]	Bits 32			
$US	MicroSecond (us) counter	None	counts	32-bit	N/A

Notes:

1. Modifiers
   C: Prints the raw IMU data.
   U: Prints the calibrated IMU data. If a field allows modifiers but a modifier is not present, calibrated IMU data prints by default.
2. Refer to *Section 5.3.3—IMU Accuracy Checking Procedure*.

Table 5.4—IMU Specifiers					
Specifier	**Name**	**Modifiers[1]**	**Units**	**Type**	**Axes**
$HDR	Send 0x1234 for packet synchronization	None	N/A	16-bit	N/A
$TW	Enable two-way Continuous Mode communication	N/A: No data returned			

Notes:
1. Modifiers
   C: Prints the raw IMU data.
   U: Prints the calibrated IMU data. If a field allows modifiers but a modifier is not present, calibrated IMU data prints by default.
2. Refer to *Section 5.3.3—IMU Accuracy Checking Procedure*.

Examples:

1. Accelerometer

user: `s $axyz`

response: `s $axyz`

`-0.527 0.488 -9.965`

- By entering the `s` command with the operand `$axyz`, the sensor will print the acceleration data in the X, Y, and Z axis.
- Values will be printed in calibrated IMU data by default.

2. Gyroscope

user: `s $gxyz`

response: `s $gxy`

`-0.004 -0.111 -0.045`

- By entering the `s` command with the operand `$gxyz`, the sensor will print the gyroscope data in the X, Y, and Z axis.
- Values will be printed in calibrated IMU data by default.

5.3.3 IMU Accuracy Checking Procedure

The IMU contains a self-accuracy check, which monitors the output of the accelerometer. The accuracy of the accelerometer is reported to the end user with the following definitions:

Table 5.5—IMU Accelerometer Accuracy Bits		
Description	**Bit**	**Decimal**
Unreliable	76	0
Accuracy Low	54	1
Accuracy Medium	32	2
Accuracy High	10	3

For more information, refer to bits 17 and 18 of *Section 6.2—System Status Code*

While the end user must decide the exact performance accuracy that is needed for an application, the datasheet specifications correspond to operating the sensor at a high accuracy status. If the current, reported accuracy status is below the level that is desired by the end user, a calibration procedure can be performed as described in the *Transducer Section manual*.

6. Troubleshooting

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

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

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, Nano17, Gamma, Theta.
3. Calibration; for example, US-15-50, SI-65-6.
4. Accurate and complete description of the question or problem.

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

How to Reach Us

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

6.1 Errors with Force and Torque Readings

Incorrect data from the transducer's strain gages can cause errors in force/torque readings. These errors can result in problems with transducer biasing and accuracy. In the following table, basic conditions of incorrect data are listed and described. Use this table for troubleshooting guidance.

Question/Problem	Answer/Solution
Noise	Jumps in raw strain gage readings (with transducer unloaded) greater than 250 counts is considered abnormal. Noise can be caused by mechanical vibrations and electrical disturbances, possibly from a poor ground. It can also indicate component failure within the system. Make sure that the DC supply voltage for the EtherCAT sensor has little to no noise superimposed.
Drift	After a load is removed or applied, the raw gage reading does not stabilize, but continues to increase or decrease. This may be observed more easily in resolved data mode using the bias command. Drift is caused by temperature change, mechanical coupling, or internal failure. Mechanical coupling is caused when a physical connection is made between the tool plate and the transducer body (i.e., filings between the tool adapter plate and the transducer body). Some mechanical coupling is common, such as hoses and wires attached to a tool.
Hysteresis	When the transducer is loaded and then unloaded, gage readings do not return quickly and completely to their original readings. Hysteresis is caused by mechanical coupling (explained in Drift section) or internal failure.
Sensor is giving unexpected values.	Complete an accuracy check. Refer to *Section 7.6—Accuracy Check* If symptoms continue, contact ATI customer service at *ft.support@novanta.com.*

6.2 System Status Code

The ECAT3 F/T performs many diagnostic checks during operation and reports results in a 32-bit system status code. Each F/T record includes this system status code. The bit patterns for all present error conditions are or'ed together to form the system status code. If any error condition is present then bit 31 of the system status code is set.

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

The system status code should be:

0x00000000 if no errors and no Condition statements are breached

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

Any other code signals means there is a serious error. Possible errors and bit assignments are in *Table 8.1*.

<table>
<tr><th colspan="7">Table 6.1—Status Code</th></tr>
<tr><th>Bit</th><th>Bit Pattern</th><th colspan="4">Description</th><th>Indicates Error?</th></tr>
<tr><td>0</td><td>00000001</td><td colspan="4">Gage Temperature Out of Range. This bit is active if the gage temperature is outside the expected -5 to 70 degrees C.</td><td>Yes</td></tr>
<tr><td>1</td><td>00000002</td><td colspan="4">Supply Voltage Out of Range. This bit is active if the supply voltage reading is outside the expected range of 12V to 32V.</td><td>Yes</td></tr>
<tr><td>2</td><td>00000004</td><td colspan="4">Broken Gage. This bit is active whenever any gage reads positive full scale. This indicates the electrical connection to the gage is open or disconnected.</td><td>Yes</td></tr>
<tr><td>3</td><td>00000008</td><td colspan="4">Busy bit. The firmware is performing one or more of the follwing activities that may affect the F/T data temporarily:
1. Commiting a change to Object 0x2021
2. Changing calibration in use
3. Any ADC Interrupt Service Routine (ISR) overrun
4. Changing the ADC sampling rate
5. Changing the filter time constant
6. Writing to the flash memory</td><td>No</td></tr>
<tr><td>4</td><td>00000010</td><td colspan="4">Reserved</td><td>Yes.</td></tr>
<tr><td>5</td><td>00000020</td><td colspan="4">Common error bit. This bit indicates an internal error has occurred.</td><td>Yes.</td></tr>
<tr><td>6-15</td><td>0000FFC0</td><td colspan="4">Reserved</td><td>Yes.</td></tr>
<tr><td>16</td><td>00010000</td><td colspan="4">Monitor Condition 0 Output</td><td>No</td></tr>
<tr><td rowspan="5">17-18</td><td rowspan="5">00060000</td><th>Status Bit 18</th><th>Status Bit 17</th><th>Decimal Value</th><th>Description</th><td rowspan="5">No</td></tr>
<tr><td>0</td><td>0</td><td>0</td><td>Unreliable</td></tr>
<tr><td>0</td><td>1</td><td>1</td><td>Accuracy Low</td></tr>
<tr><td>1</td><td>0</td><td>2</td><td>Accuracy Medium</td></tr>
<tr><td>1</td><td>1</td><td>3</td><td>Accuracy High</td></tr>
<tr><td>19</td><td>00080000</td><td colspan="4">IMU not present</td><td>Yes</td></tr>
<tr><td>20-25</td><td>07FE0000</td><td colspan="4">Reserved</td><td>Yes</td></tr>
<tr><td>26</td><td>04000000</td><td colspan="4">Gage Out of Range Warning. This bit is active if gage is outside of the range gageMinRangeWarn to gageMaxRangeWarn.</td><td>No</td></tr>
<tr><td>27</td><td>08000000</td><td colspan="4">Gage Out of Range. This bit is active if gage is outside of the range gageMinRange to gageMaxRange.</td><td>Yes.</td></tr>
</table>

Table 6.1—Status Code			
Bit	**Bit Pattern**	**Description**	**Indicates Error?**
28	10000000	Simulated Error. This bit mirrors Simulated Error Control bit in Object 0x7010: Control Codes. This is used to test user error handling	No
29	20000000	Calibration checksum error. This bit is active if calibrations do not have a valid checksum when read from EEPROM.	Yes
30	40000000	F/T Out of Range.This bit is active whenever a force/torque sample is out of range or mathematically saturated.	Yes
31	80000000	Error: This bit is active whenever any other status code that indicates an erroris set.	Yes

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 ECAT3 F/T system offers digital low-pass filters that can dampen frequencies above a certain Condition. If this is not sufficient, add a digital filter to the application software.

6.3.2 Electrical Interference

If observing interference by motors or other noise-generating equipment, check the ECAT3 F/T's ground connections. If sufficient grounding is not possible or does not reduce the noise, consider using the ECAT3 F/T's digital low pass filters. Verify the use of Class 1 power supply which has an earth ground connection.

6.4 Accuracy Check

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

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

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

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

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

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

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

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

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

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.

6. If this test fails, then the sensor should be returned to ATI for diagnosis or recalibration.

7. Specifications

The specification specifically for the EtherCAT sensor interface are covered in this section. Specifications for the different EtherCAT Sensor models such as weight, dimensions, operating and storage temperature are covered in the *9620-05-Transducer Section* manual.

7.1 Storage and Operating Conditions

Table 7.1—Temperature		
Component	**Storage Temperature, °C**	**Operating Temperature, °C**
EtherCAT3 Electronics	-40 to +100	-20 to +70
ECAT3 CEB	-40 to +100	- 20 to +70

7.2 Electrical Specifications

Table 7.2—Power Supply		
Power Source[1]	**Voltage**	**Maximum Power Consumption**
DC Power Connector	12V min. to 30V max.	3.0 W

Notes:

1. The EtherCAT3 sensor power supply input is protected against incorrect polarity.

7.2.1 Mating Connectors

Table 7.3—Mechanical Specifications of Mating Connectors			
Connector	**Mating Type**	**Recommended Torque**	**Maximum Torque**
Standard Transducer	M12 5-Pin, Male	0.8 Nm to 1.0 Nm	3.0 Nm
Splitter Box Input: Transducer Cable	M12 5-Pin Female	0.8 Nm to 1.0 Nm	3.0 Nm
Splitter Box Output: ECAT0	M12 D-Coded, 4-Pin Male	0.8 Nm to 1.0 Nm	3.0 Nm
Splitter Box Output: ECAT1	M12 D-Coded, 4-Pin Male	0.8 Nm to 1.0 Nm	3.0 Nm
Splitter Box Power / RS485	M12 5-Pin Female	0.8 Nm to 1.0 Nm	3.0 Nm

7.3 Connector Pin-Out Assignments

7.3.1 Splitter Box

Pinout information for the Splitter Box (9105-GEN3-SPLIT-001) is outlined below.

Table 7.4—Splitter Box Transducer Cable Connector

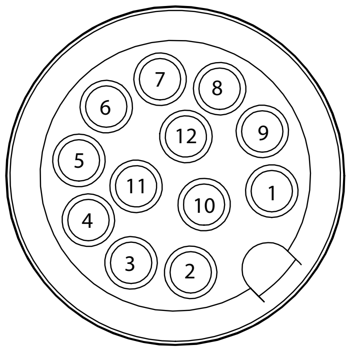
Connector	Pin	Assignment
	1	ECAT-OUT TX+
	2	ECAT-OUT TX-
	3	ECAT-OUT RX+
	4	ECAT-OUT RX-
	5	RS485-
	6	RS485+
	7	V- (GND)
	8	V+
	9	ECAT-IN TX+
	10	ECAT IN TX-
	11	ECATIN RX+
	12	ECAT IN RX-
	Shell	Drain

Table 7.5—Splitter Box Power/RS485 Connector

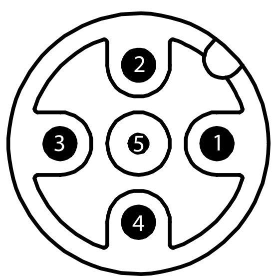
Connector	Pin	Assignment
	1	Drain
	2	V+
	3	V- (GND)
	4	RS485+
	5	RS485-

Table 7.6—Splitter Box ECAT Port 0 Connector

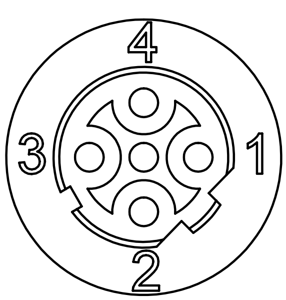
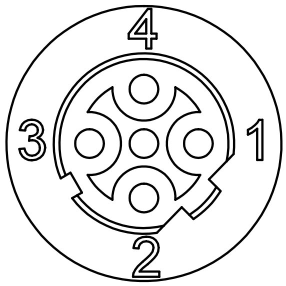
Connector	Pin	Assignment
	1	ECAT-IN TX+
	2	ECAT-IN RX+
	3	ECAT-IN TX-
	4	ECAT-IN RX-

Table 7.7—Splitter Box ECAT Port 1 Connector		
Connector	**Pin**	**Assignment**
	1	ECAT-OUT TX+
	2	ECAT-OUT RX+
	3	ECAT-OUT TX-
	4	ECAT-OUT RX-

7.3.2 ECAT3 CEB

Pinout information for the ECAT3 CEB (9105-ECAT3-CEB-001) is outlined below.

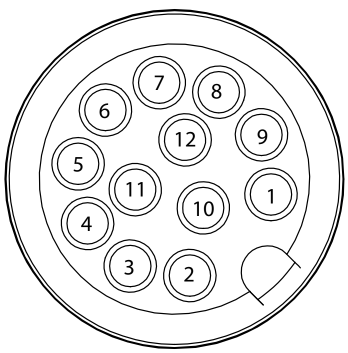
Table 7.8—ECAT3 CEB Transducer Connector		
Connector	**Pin**	**Assignment**
	1	ECAT-OUT TX+
	2	ECAT-OUT TX-
	3	ECAT-OUT RX+
	4	ECAT-OUT RX-
	5	RS485-
	6	RS485+
	7	V- (GND)
	8	V+
	9	ECAT-IN TX+
	10	ECAT IN TX-
	11	ECATIN RX+
	12	ECAT IN RX-
	Shell	Drain

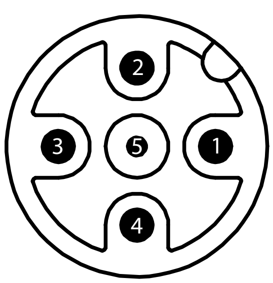
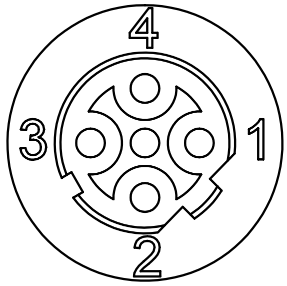
Table 7.9—ECAT3 CEB Power/RS485 Connector		
Connector	**Pin**	**Assignment**
	1	Drain
	2	V+
	3	V- (GND)
	4	RS485+
	5	RS485-

Table 7.10—ECAT3 CEB ECAT Port 0/ECAT Port 1 Connector		
Connector	**Pin**	**Assignment**
	1	ECAT-IN TX+
	2	ECAT-IN RX+
	3	ECAT-IN TX-
	4	ECAT-IN RX-

8. Drawings

Drawings are available on the *ATI website* or by contacting an ATI representative.

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

ATI will in no event be liable for incidental, consequential, or special damages of any kind, even if 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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