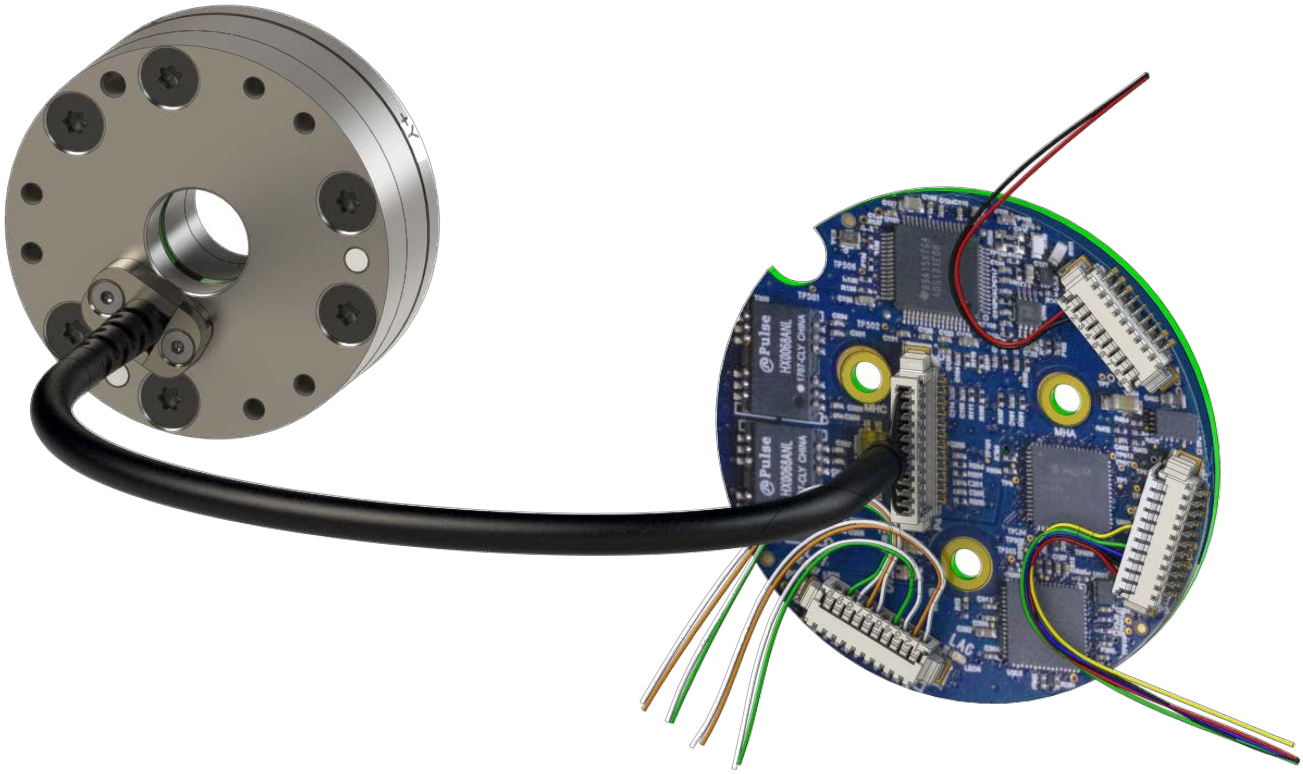
Manual

EtherCAT F/T Interface for OEM2



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RoHS Compliance

This product conforms to EU Directive 2015/65/EU (RoHS).

Indicator and Labeling Compliance

This product conforms to ETG.1300 S (R) V1.1.0 indicator and labeling standard.

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
Baud Rate	A number that is related to the speed of data transmission in a system. The data indicates the number of electrical oscillations per second that occurs within a data transmission.
Chassis Ground	The chassis is connected to earth ground.
DINT	A data type representing a signed integer with 32 bits.
Drain Wire	A shielded, grounded wire in an electrical cable that reduces signal interference from other electrical sources.
Earth Ground	Functional Earth (FE) or Protective Earth (PE)
EMC	Electromagnetic compatibility (EMC) is the ability of an electrical device to limit unintended electromagnetic energy that causes interference or physical damage.
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.
MOLEX® PicoBlade®	Product series from the connector manufacturer Molex.
PCB	Printed Circuit Board
PDO	Process Data Object, a protocol for reading and writing real-time process information cyclically.
P/N	Part Number
SDO	Service Data Object, a protocol for reading and writing configuration information acyclically.
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. For assistance finding this information, refer to the *ATI F/T Transducer 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. For specific transducer overload values, refer to the *F/T Transducer manual*.

2. Product Overview

The EtherCAT F/T Interface for OEM System consists of an ATI transducer and a F/T-to-EtherCAT interface board (ECATOEM2) that has the functionality of the *ATI F/T ECATEOEM* board and dual EtherCAT ports. The ATI transducer has a hard wired cable that includes a Molex PicoBlade connector. The ECATOEM2 interface board mounts within a customer's enclosure. The customer provides 20 to 30 V DC power supply. The ECATOEM2 supports three calibrations. The number of calibration ranges available to the user depends on the ATI F/T transducer connected to the board. For more information about the transducer, refer to *F/T Transducer manual*.

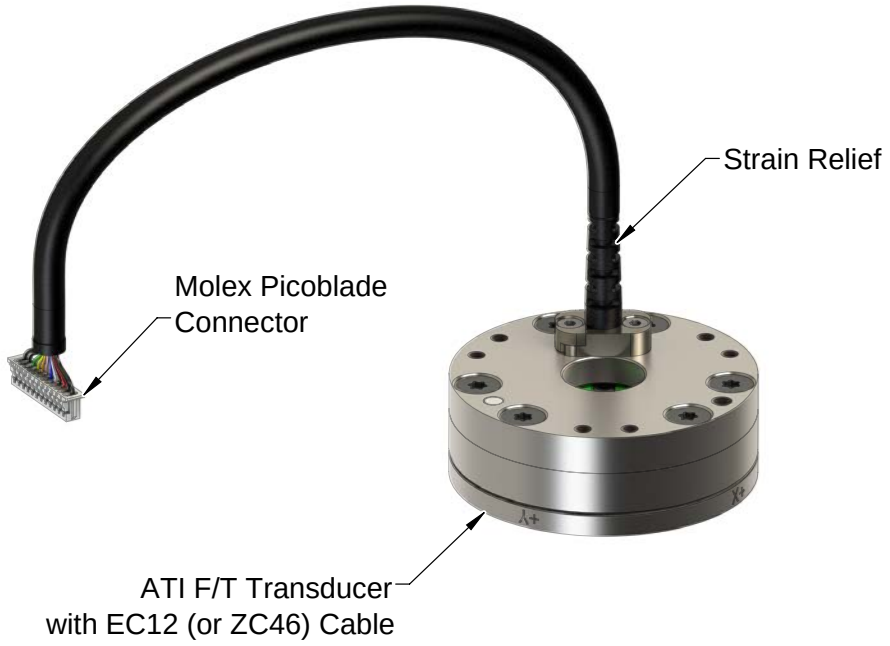
Figure 2.1 shows a sample application that uses the ECATOEM2 mounted in a segment of a light weight arm and a Mini45 transducer mounted on the arm.

Figure 2.1—Sample Application

3. Compatible Transducer

Transducers with part numbers ending in EC12 or ZC46 are custom designed for use with ECATOEM2. ZC46 cables are for transducers that have eight channels. These transducers are unlike standard Nano or Mini transducers in that the connector contacts are crimped to the wires of the transducer cable. Note that unlike the cable represented in the following figure, the actual cable has a longer length of unjacketed wire (and drain wire) that leads up to the connector from the transducer. A cable with a shorter strain relief can be purchased from ATI; a shorter strain relief allows the static bend of the cable to be closer to the transducer.

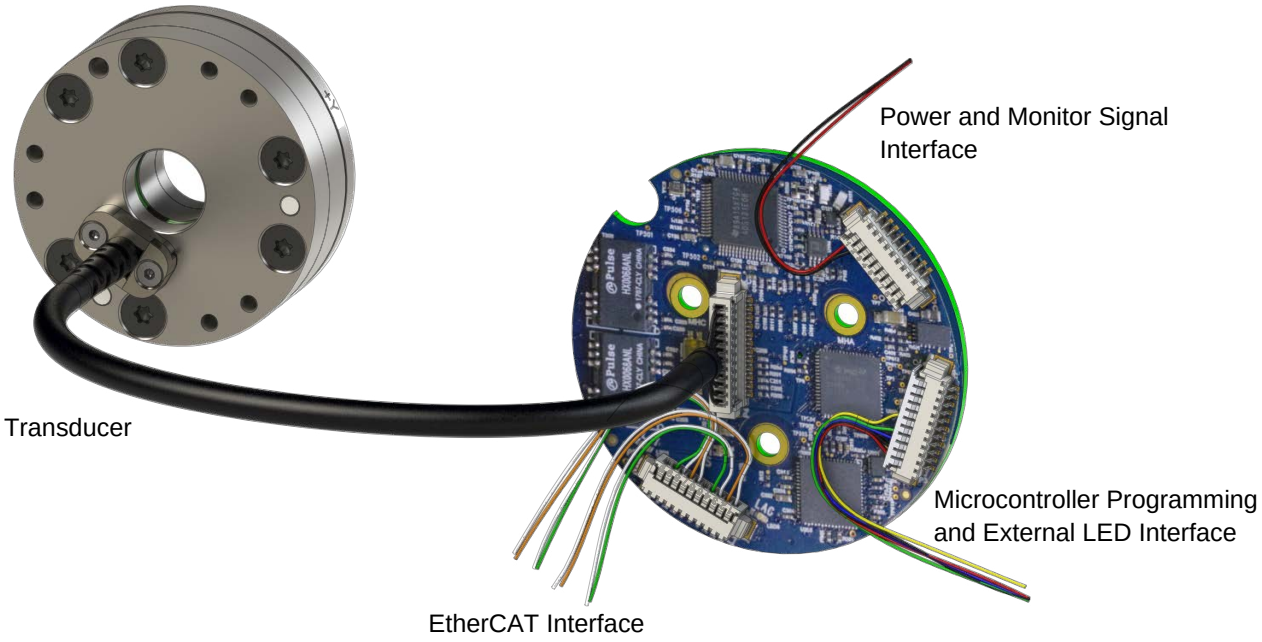
Figure 3.1—Transducer with Strain Relieved EC12 or ZC46 Cable



4. ECATOEM2 Interface Board

The ECATOEM2 provides an EtherCAT bus interface for ATI's F/T transducers. Transducer equipped with a compatible 8 or 12-pin connector can be plugged directly into the ECATOEM2 interface board.

Figure 4.1—ECATOEM2 System



The 9105-ECATOEM2 interfaces with the transducer's strain gages via connector P4 (*Figure 4.3*). The strain gage signals are digitized with a 24 bit resolution on the strain gage A/D converter, multiplied with the selected calibration matrix and the resulting force/torque data are then transmitted over an EtherCAT bus interface. Up to three transducer calibrations can be stored in the on-board EEPROM. The ECATOEM2 can be supplied with 20 V to 30 V DC power.

Figure 4.2—ECATOEM2 Block Diagram

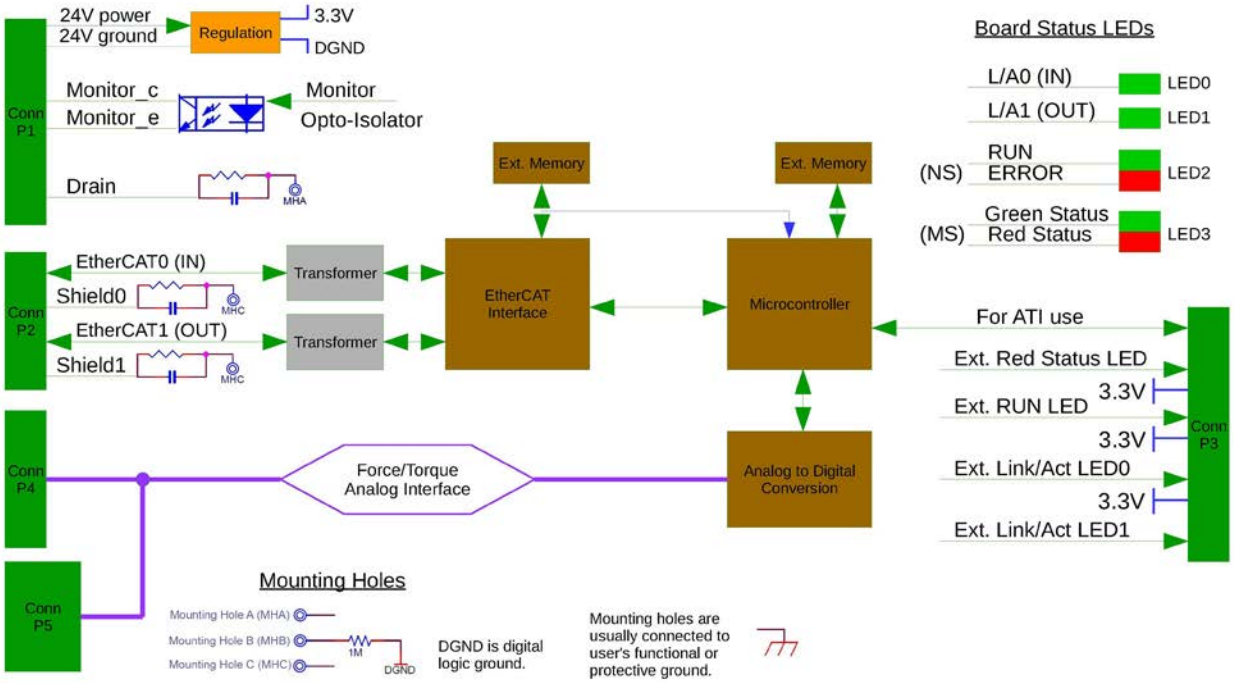
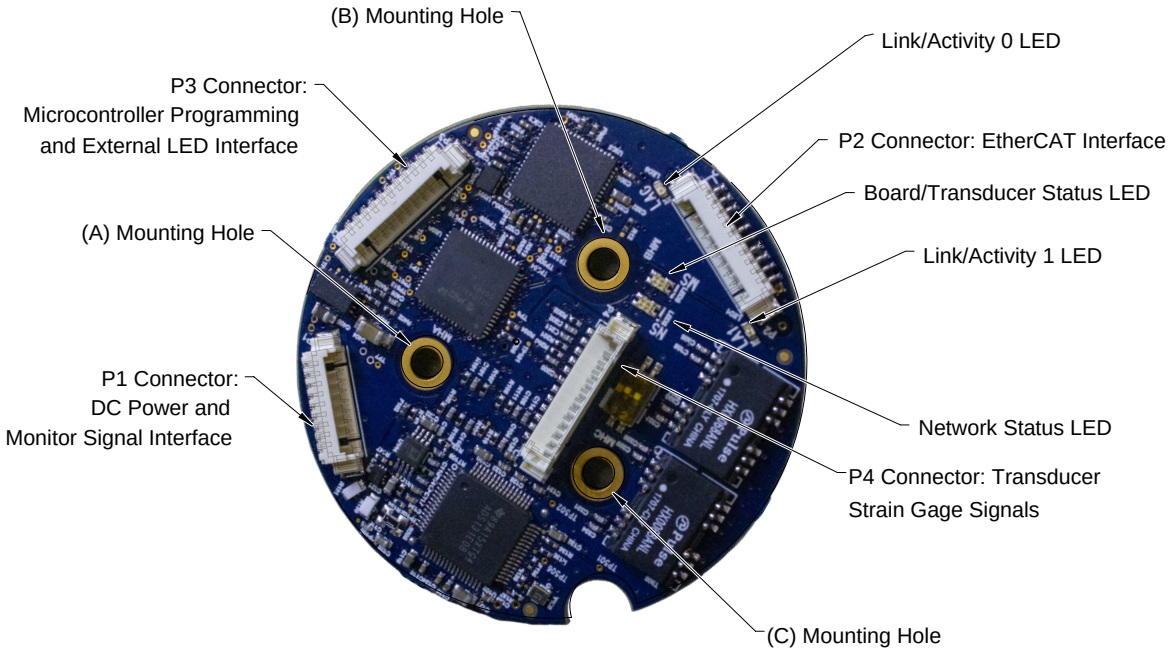
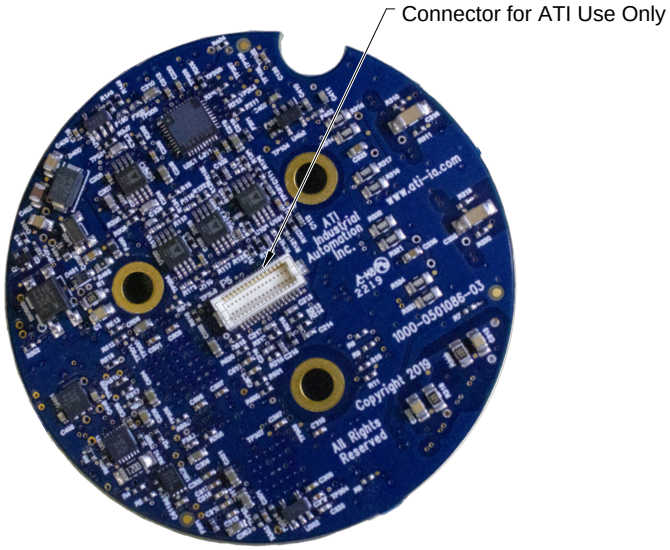


Figure 4.3—ECATOEM2 Board Components

Top View



Bottom View



4.1 LEDs

The following LEDs are available on the ECATOEM2 PCB Assembly (for a visual reference, refer to *Figure 4.3*):

4.1.1 LEDs LA0/LA1: EtherCAT Link/Activity

Two green LEDs signal activity on EtherCAT port 0 (LED0) and port 1 (LED1), in the following ways:

Table 4.1—LEDs LA0/LA1

LED State	Link	Activity	Condition
Green LED0 Off	No	No	Port 0 closed
Green LED0 Blinking	Yes	Yes	Communicating
Green LED0 On	Yes	No	Port 0 open
Green LED1 Off	No	No	Port 1 closed
Green LED1 Blinking	Yes	Yes	Communicating
Green LED1 On	Yes	No	Port 1 open

4.1.2 LED NS: EtherCAT Network Status

One dual-color (green/red) LED (LED2) signals the status of the EtherCAT Network in the following way.

Table 4.2—LED NS

LED State	RUN State	ERROR State	Description
GREEN/ RED OFF	INIT	N/A	Device is in state INIT
GREEN Blinking	PRE-OP		Device is in state PRE-OPERATIONAL
GREEN Single Flash	SAFE-OP		Device is in state SAFE-OPERATIONAL
GREEN ON	OP		Device is in state OPERATIONAL
RED Blinking	N/A	Invalid Configuration Error	General configuration error For example: State change commanded by master is impossible due to register or object settings, or invalid hardware configuration (pin sharing violation detected by ESC)
RED Single Flash		Local Error	Slave device application has changed the EtherCAT state autonomously, due to local error. For example: device changes its EtherCAT state from OP to SAFE-OP due to a synchronization error
RED Double Flash		Process Data Watchdog Timeout	An application watchdog timeout has occurred. For example: ECAT Sync Manager Watchdog timeout

4.1.3 LED MS: Board/Transducer Status

One dual-color (red/green) LED (LED3) signals the status of the EtherCAT board/transducer in the following way.

Table 4.3—LED MS

LED State	Status	Description
OFF	No Power	The board doesn't have sufficient power.
Green ON	All OK	Fully operational and no errors
Orange (Amber)	Saturation	Transducer input is saturated. One of the strain gage input voltages is too high, and all force and torque data is invalid. Resolve by using a less sensitive calibration, if available.
Red ON	Diagnostic voltage error	One of the internal diagnostic voltages is outside the acceptable range.
Red Blinking (1 Hz)	No calibration loaded	Active calibration slot is empty or has a checksum error.
Red Blinking (10 Hz)	Communication error with ECAT ASIC	No or faulty SPI communication between uC and EtherCAT ASIC

5. Installation

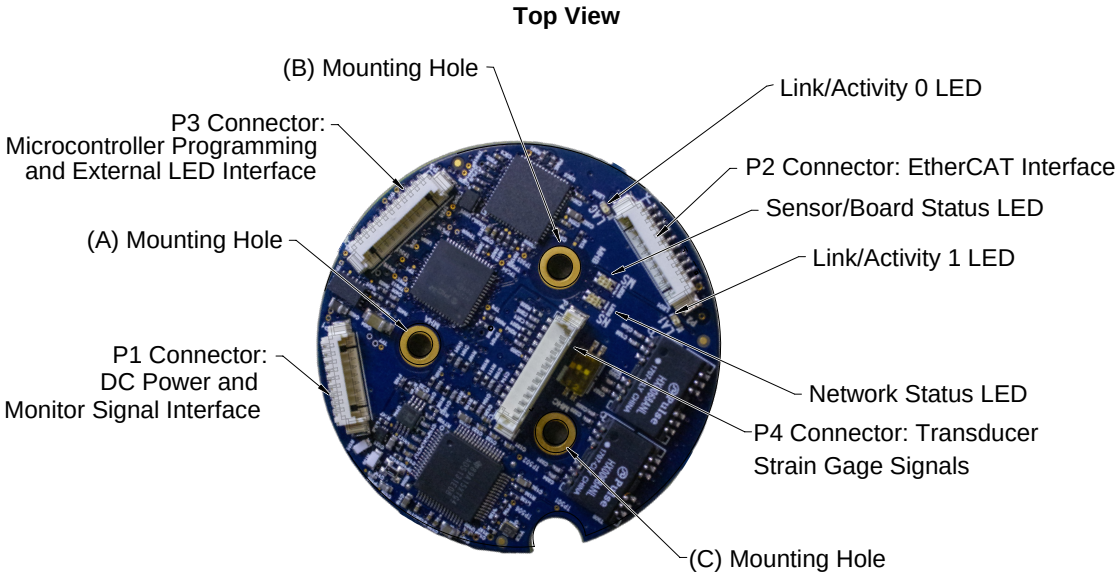
Information for installing the ECATOEM2 PCB into an application is in the following section.

5.1 Chassis Grounding

The ECATOEM2 interface board has three mounting holes: A, B, and C. For best EMC performance connect all three mounting holes to the chassis that is connected to earth ground. Earth ground is often referred to as either functional earth (FE) or protective earth (PE). Many times grounding is achieved by installing a metal screw in the mounting hole.

NOTICE: To minimize PCB vibration, use all three mounting holes.

Figure 5.1—ECATOEM2 Interface Board Mounting

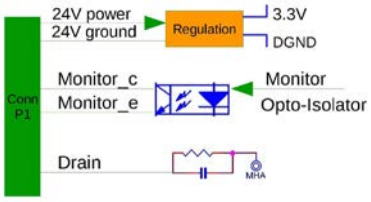
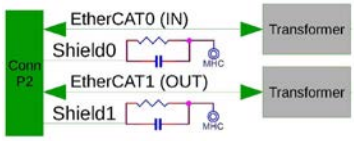


For particular applications, a user may opt to not ground all three mounting holes. Circumstances for grounding one mounting hole compared to another are described generally in *Table 5.1*.

CAUTION: Users must have an understanding of electromagnetic energy within the application in order to determine how to use one of the following grounding options in the following table. Failure to understand the electrical environment, could result in unintended electrical shock to personnel and/or damage to equipment.

If an energy source like an arc welder is nearby and the chassis, surrounding the ECATOEM2 board, is not grounded, energy can build-up and create a potential shock hazard condition. To prevent this build-up of electrical energy, coupling from the environment onto the chassis, the following optional paths for dissipating energy are available:

Table 5.1—Chassis Grounding Options

Grounding Option	Schematic[1]	Description
Mounting Hole A		Mounting hole A is connected (usually through a metal screw) to the chassis ground. If the shield/drain wire of a shielded cable is connected to the Drain pin of connector P1, it provides a slow energy dissipation path from mounting hole A.
Mounting Hole B		Mounting hole B is connected (usually through a metal screw) to the chassis ground. By grounding mounting hole B, the energy build-up slowly dissipates to the digital ground (DGND) and eventually out through the 24 V ground.
Mounting Hole C		Mounting hole C is connected (usually through a metal screw) to the chassis ground. If the shield/drain wire of a shielded Ethernet cable is connected to shield0 or shield1 of connector P2, it provides a slow energy dissipation path from mounting hole C to the shield or drain wire of the EtherCAT cable.

Notes:
1. These schematics are taken from *Figure 4.1*.

5.2 Transducer Handling

In addition to the standard transducer handling instructions (see *F/T Transducer manual* for details), observe the following points:

- The transducer calibration label FTxxxx must not be removed or painted over. If a transducer gets returned to ATI for calibration or repair, it is important that this number is present.
- The transducer cable male connector to the P4 connector on the board is not strain relieved. To protect the fragile crimp contacts provide a suitable strain relief (refer to *Figure 5.2*). Do not use zip ties.

5.3 Ground and Cable Shield Considerations

There are several options for connecting the transducer cable shield:

1. If the transducer is connected to chassis ground, then don't connect the cable shield (since the shield is connected to the transducer body).
2. If the transducer is isolated, then complete one of the following:
    - Connect the cable shield to chassis ground
    - (or) connect the cable shield to system Ground P1 pin 9.

Some experimentation is necessary to find the best solution for EMC compliance and best noise performance.

5.4 Power Supply Considerations

The ECATOEM2 interface board can be supplied with a DC voltage of 20 V to 30 V on the P1 connector.

5.5 Installation

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 board's cable connection from the robot's repetitive motion (refer to *Figure 5.2*). Do not use cable ties or zip ties. For proper cable restraint and bending radius methods, refer to the *F/T Transducer manual*.

1. Attach the ECATOEM2 interface board to the mounting using customer supplied M3 fasteners; use all three mounting holes to secure the board (refer to *Figure 5.2*).

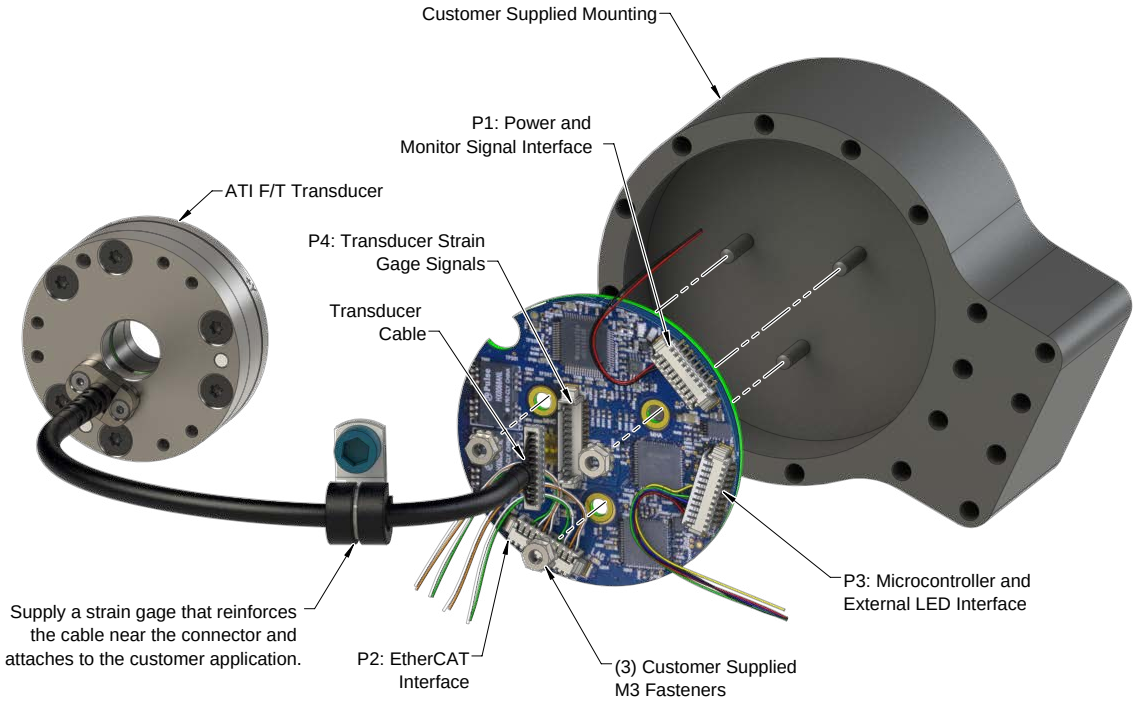
NOTICE: Verify all mounting holes are connected to chassis ground. Not connecting the "A", "B", and "C" mounting holes to chassis ground may cause unpredictable behavior (refer to *Figure 5.1*).

NOTICE: The pin number and signals for the P1, P2, P3, and P4 connectors are in *Section 5.6—Connector Pin Numbers and Signals*. When installing the cables to the connectors, refer to the applicable subsection in *Section 5.6—Connector Pin Numbers and Signals*.

2. Route and connect the EtherCAT wires to the P2 connector on the ECATOEM2 interface board.
3. Route and connect the Transducer cable to the P4 connector on the ECATOEM2 interface board.

NOTICE: Make sure to route the Transducer cable away from the Power Transformer on the ECATOEM2 interface board. Routing the Transducer cable close to the power transformer can cause noise problems.

Figure 5.2—ECATOEM2 Interface Board Installation



4. Route and connect power wires to the P1 connector.
5. If using the Optional External LED cable route the wires to the P3 connector. For connector signals, refer to *Section 5.6.3—P3 Connector for Microcontroller Programming and External LED Interface*.

5.6 Connector Pin Numbers and Signals

The ECATOEM2 PCB assembly has the following connections:

5.6.1 P1 Connector for DC Power and Monitor Signal

Mating connector housing: Molex 51021-0900
Mating connector contact: Molex 50058-8000 (28-32 AWG) or Molex 50079-8000 (26-28 AWG)

Table 5.2—P1 Pin Numbers and Signals

Pin No.	Signal Name	Description
1	SL0_VP	+24 (20 -30 V) VDC Power Supply
2	SL0_GND	Ground for +24 (20 -30 V) VDC Power Supply
3 to 4	Reserved (used by ATI). Do not connect to these pins.	
5	MONITOR_E	Monitor signal: emitter contact of opto-coupler
6	MONITOR_C	Monitor signal: collector contact of opto-coupler
7 to 9	Reserved (used by ATI). Do not connect to these pins.	

5.6.2 P2 Connector for EtherCAT Interface

Mating connector housing: Molex 51021-1000
Mating connector contact: Molex 50058-8000 (28-32 AWG) or Molex 50079-8000 (26-28 AWG)

Table 5.3—P2 Pin Numbers and Signals

Pin No.	Signal Name	Description
1	TX0+	Port 0 Ethernet Transmit +
2	TX0-	Port 0 Ethernet Transmit -
3	RX0+	Port 0 Ethernet Receive +
4	RX0-	Port 0 Ethernet Receive -
5	Shield0	Port 0 Ethernet cable shield
6	TX1+	Port 1 Ethernet Transmit +
7	TX1-	Port 1 Ethernet Transmit -
8	RX1+	Port 1 Ethernet Receive +
9	RX1-	Port 1 Ethernet Receive -
10	Shield1	Port 1 Ethernet cable shield

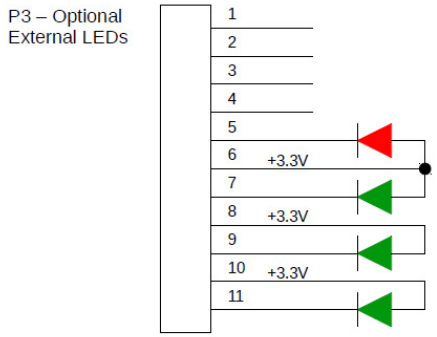
5.6.3 P3 Connector for Microcontroller Programming and External LED Interface

Mating connector housing: Molex 51021-1100
Mating connector contact: Molex 50058-8000 (28-32 AWG) or Molex 50079-8000 (26-28 AWG)

Table 5.4—P3 Pin Numbers and Signals

Pin No.	Signal Name	Description
1 to 4	Reserved (used by ATI). Do not connect to these pins.	
5	RED_STATUS_LED	For cathode of optional external red Board Status LED
6	+3.3 V	For anode of optional external LED
7	RUN_LED	For cathode of optional external EtherCAT OP status LED
8	+3.3 V	For anode of optional external LED
9	ACTIVITY_LED0	For cathode of optional external ACTIVITY LED – Port 0
10	+3.3 V	For anode of optional external LED
11	ACTIVITY_LED1	For cathode of optional external ACTIVITY LED – Port 1

Figure 5.3—P3 LED Wiring Diagram



5.6.4 P4 Connector for Transducer Strain Gage Signals

Mating connector housing: Molex 51021-1200
Mating connector contact: Molex 50058-8000 (28-32 AWG) or Molex 50079-8000 (26-28 AWG)

Table 5.5—P4: Pin Numbers and Signals

Pin No.	Signal Name	Description
1	+VSG	1.2V/2.4V, Positive strain gage bridge supply voltage
2	-VSG	0V, Negative strain gage bridge supply voltage
3	G0	Strain gage 0 voltage
4	G1	Strain gage 1 voltage
5	G2	Strain gage 2 voltage
6	G3	Strain gage 3 voltage
7	G4	Strain gage 4 voltage
8	G5	Strain gage 5 voltage
9 to 11	Reserved	
12	Sensor_Mid_ Vbr	Optional feedback for future sensor noise reduction / drift perform

6. Operation

Information required when using software to operate the EtherCATOEM2 is provided in the following sections. Knowledge of EtherCAT standards and operation is required to communicate with the EtherCAT devices.

6.1 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 7.2.6.1—Converting Force/Torque Counts to Units*).

6.2 Sample Rate

The firmware can be configured to sample internally for 1000, 2000, 4000, or 8000 Hz.

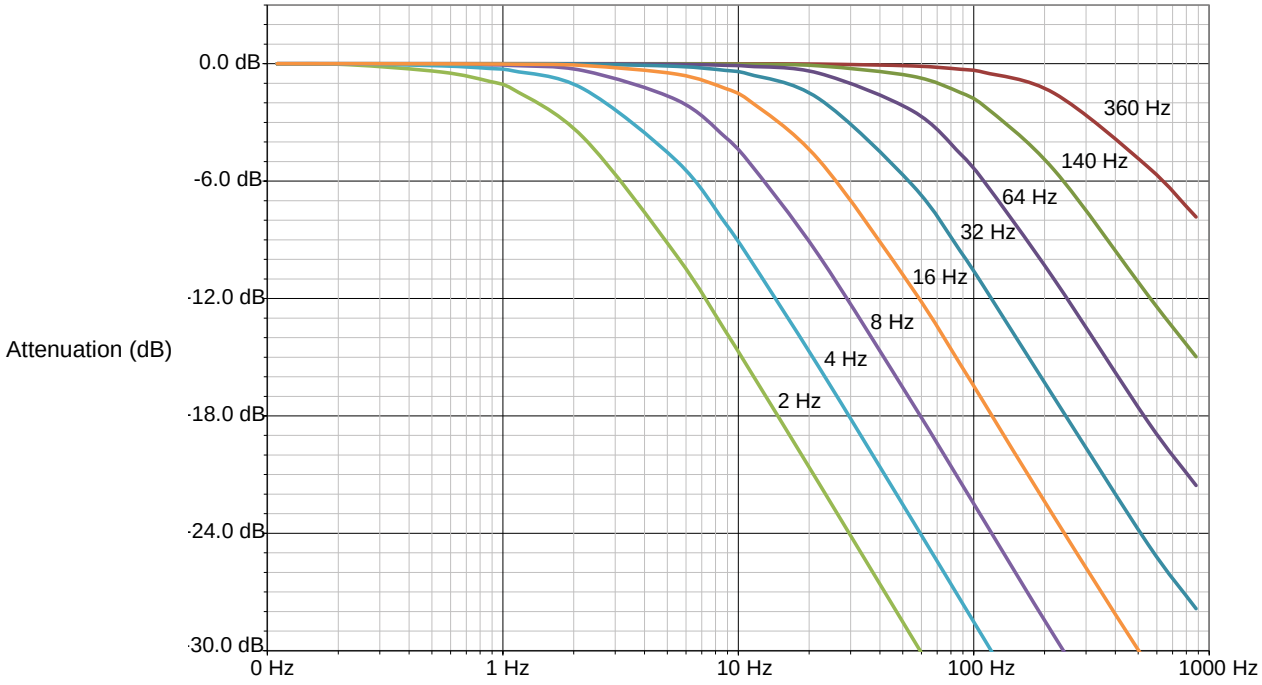
6.3 Filtering

The "Filter Selection" field in Object 0x7010 subindex 0x01 (*Section 7.2.10—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 6.2—Sample Rate*. The relative cutoff frequencies for different values of this coefficient are:

Table 6.1—Filtering Frequency

Coefficient	Cutoff Frequency (Percent of Internal Sample Rate)	Frequency
0	No filter	N/A
1	11.97%	360 Hz
2	4.66%	140 Hz
3	2.17%	64 Hz
4	1.04%	32 Hz
5	0.51%	16 Hz
6	0.26%	8 Hz
7	0.12%	4 Hz
8	0.07%	2 Hz

Figure 6.1—Filter Attenuation at 3 kHz Sample Rate



6.4 ECATOEM2 LEDs on the PCB

For the ECATOEM2 LED behavior, refer to *Section 4.1—LEDs*.

6.5 Threshold Monitoring

The EtherCAT OEM2 F/T system allows the user to configure thresholds. To activate a threshold, first write the appropriate values in Object 0x2060 subindex 0x01 (*Section 7.2.3—Object 0x2060: Monitor Condition*), then in Object 0x7010 subindex 0x02 set Bit 0 “Enable checking of Monitor Condition” (*Section 7.2.10—Object 0x7010: Control Codes*).

The software currently supports one monitor condition.

6.6 Diagnostic Monitoring

During operation, the firmware monitors the hardware. When the user first applies power, the firmware waits five seconds before evaluating the supply voltage for errors. The user can read status messages in the Object 0x2080 subindex 0x03 (refer to *Section 7.2.4—Object 0x2080: Diagnostic Readings*). For a priority list of status error messages and a list of monitored safety indicators, refer to *Section 8.2—Diagnostic Monitoring* for more information.

6.7 Discrete Output

The discrete output will turn on whenever any active monitor condition becomes true.

6.8 Bias

Biasing is useful for eliminating the effects of gravity (tool weight) or other acting forces. When the bias function is used, the software collects data for the forces and torques that are currently acting on the sensor and use these readings as a reference for future readings. Future readings will have this reference subtracted from them before they are transmitted. Bias may also be referred to as “zero out” or “tare” the sensor.

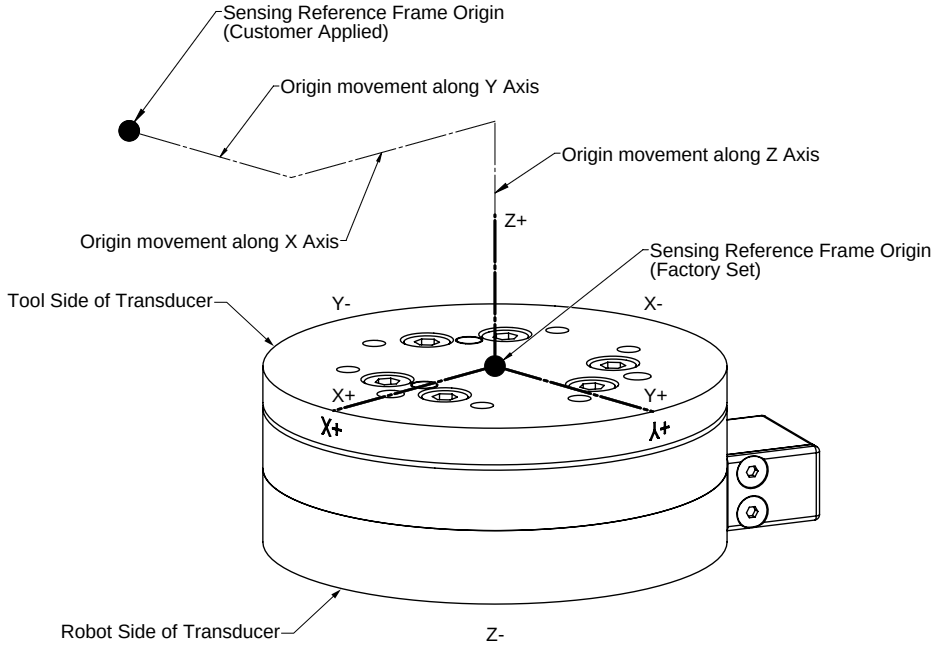
6.9 Tool Transformation

Through the tool transformation functionality, a user may enter a series of tool transformations in order to measure the forces and torques acting at a point other than the origin of the sensor. The tool transformations are applied in the order entered, for example: rotations could occur before displacements, if tool transformation with only rotations are entered before the rotation with displacements. 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 F/T 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 user 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 6.2—Displacement of Sensing Reference Frame Origin



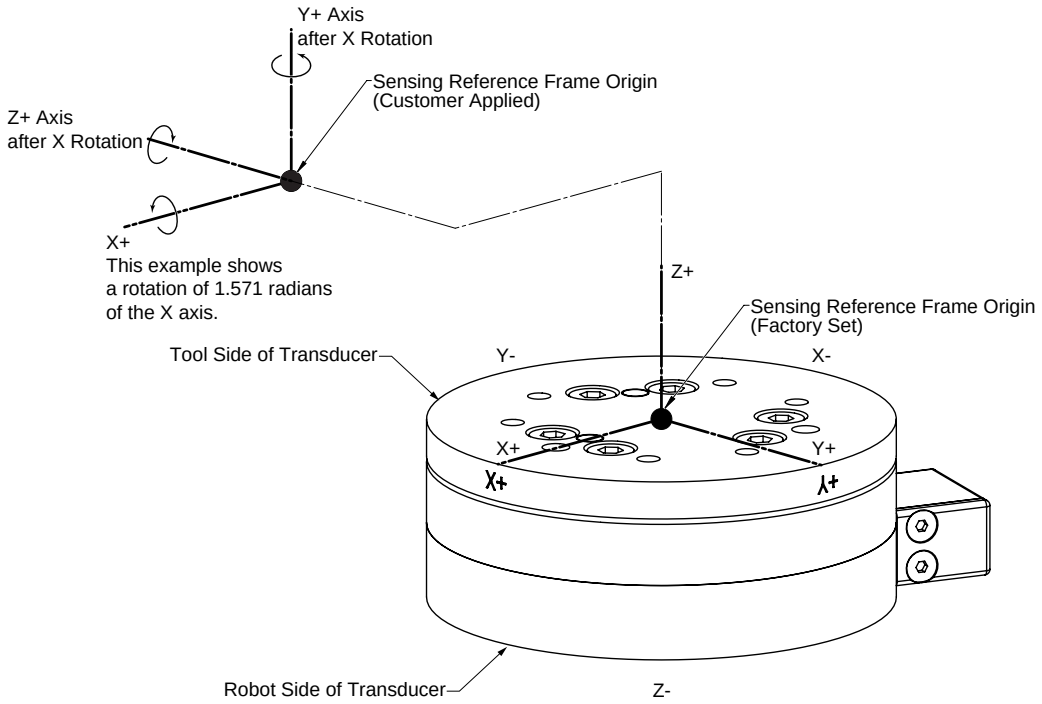
Rotation allows the customer to rotate the axes while maintaining the frame origin. *Figure 6.3* shows the direction of rotation about the axis. Rotation is measured in radians.

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 6.3*)
- 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 6.3—Rotating Reference Frame



To activate a tool transformation, first type the appropriate transform coefficients to Object 0x2020 (*Section 7.2.1—Object 0x2020: Tool Transformation*), then set the "Tool Transform Index Selection" bits in Object 0x7010 subindex 0x02 (*Section 7.2.10—Object 0x7010: Control Codes*) to activate that condition. The software currently only supports one tool transformation.

7. EtherCAT Bus Interface

The EtherCAT bus interface allows a user to:

- Determine which calibration is active
- Select a calibration to be active
- Read the active calibration information matrix, serial number, etc.
- Read the firmware revision of the ECATOEM2
- 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

7.1 PDO Interface

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

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

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

7.2 EtherCAT Dictionary Objects (SDO Data)

The SDO data is used to configure the sensor and read manufacturing and calibration information. This section documents dictionary objects that are specific to the EtherCAT F/T sensor application; it does not list objects which are a required part of the EtherCAT standard.

7.2.1 Object 0x2020: Tool Transformation

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

Table 7.1—Object 0x2020: Tool Transformation

Subindex	Name	Description
0x01	Rx	The rotation about the X axis, in units of 0.1 degrees, e.g. an Rx value of 900 = 90 degrees.
0x02	Ry	The rotation about the Y axis, in units of 0.1 degrees.
0x03	Rz	The rotation about the Z axis, in units of 0.1 degrees.
0x04	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.
0x05	Dy	The displacement along the y axis, in units of 0.01 calibration length units.
0x06	Dz	The displacement along the z axis, in units of 0.01 calibration length units.

7.2.2 Object 0x2021: Calibration

This read-only object contains information about the currently active calibration selected through the “Active Calibration”bits in Object 0x7010 subindex 0x01 (*Section 7.2.10—Object 0x7010: Control Codes*). The active calibration contains the following fields:

Table 7.2—Object 0x2021: Calibration

Subindex	Name	Type	Description
0x01	FT Serial	STRING(8)	The FT Serial Number, for example: “FT01234”
0x02	Calibration Part Number	STRING(30)	The calibration part number, for example: “SI-120-95”
0x03	Calibration Family	STRING(8)	Always reads “ECAT”
0x04	Calibration Time	STRING(30)	The date the sensor was calibrated

Table 7.2—Object 0x2021: Calibration			
Subindex	**Name**	**Type**	**Description**
0x05	Matrix FxG0	STRING(12)	These 36 elements contain the matrix used for the force/torque calculation. Each element is entered as a floating-point number in text form. Matrix coefficients are calculated from calibration data.
0x06	Matrix FxG1		
0x07	Matrix FxG2		
0x08	Matrix FxG3		
0x09	Matrix FxG4		
0x0a	Matrix FxG5		
0x0b	Matrix FyG0		
0x0c	Matrix FyG1		
0x0d	Matrix FyG2		
0x0e	Matrix FyG3		
0x0f	Matrix FyG4		
0x10	Matrix FyG5		
0x11	Matrix FzG0		
0x12	Matrix FzG1		
0x13	Matrix FzG2		
0x14	Matrix FzG3		
0x15	Matrix FzG4		
0x16	Matrix FzG5		
0x17	Matrix TxG0		
0x18	Matrix TxG1		
0x19	Matrix TxG2		
0x1a	Matrix TxG3		
0x1b	Matrix TxG4		
0x1c	Matrix TxG5		
0x1d	Matrix TyG0		
0x1e	Matrix TyG1		
0x1f	Matrix TyG2		
0x20	Matrix TyG3		
0x21	Matrix TyG4		
0x22	Matrix TyG5		
0x23	Matrix TzG0		
0x24	Matrix TzG1		
0x25	Matrix TzG2		
0x26	Matrix TzG3		
0x27	Matrix TzG4		
0x28	Matrix TzG5		

Table 7.2—Object 0x2021: Calibration				
Subindex	**Name**	**Type**	**Description**	
0x29	Max Fx Counts	DINT	The maximum rated value for this axis, in counts.[1]	
0x2A	Max Fy Counts			
0x2B	Max Fz Counts			
0x2C	Max Tx Counts			
0x2D	Max Ty Counts			
0x2E	Max Tz Counts			
0x2F	Force Units	USINT	**Value**	**Unit**
			1	Lbf
			2	N
			3	Klbf
			4	kN
			5	Kg
0x30	Torque Units	USINT	**Value**	**Unit**
			1	Lbf-in
			2	Lbf-ft
			3	N-m
			4	N-mm
			5	Kg-cm
			6	kN-m
0x31	Counts Per Force	DINT	The calibration counts per force unit.	
0x32	Counts Per Torque	DINT	The calibration counts per torque unit.	
0x33	Gain G0	UINT16	The ADC gain multiplier. Valid values are 1, 2, 4, 8, 16, and 32.	
0x34	Gain G1			
0x35	Gain G2			
0x36	Gain G3			
0x37	Gain G4			
0x38	Gain G5			
0x39	Gain G6			
0x3a	Gain G7			
0x3b	GageMaxRange	DINT	Gage strain levels of this and higher are considered out of range.	
0x3c	GageMinRange	DINT	Gage strain levels of this and lower are considered out of range.	

Table 7.2—Object 0x2021: Calibration			
Subindex	**Name**	**Type**	**Description**
0x3d	PeakLoadsPosFx	DINT	Peak Loads Positive. All-time peak negative force/torque loads.
0x3e	PeakLoadsPosFy		
0x3f	PeakLoadsPosFz		
0x40	PeakLoadsPosTx		
0x41	PeakLoadsPosTy		
0x42	PeakLoadsPosTz		
0x43	PeakLoadsNegFx	DINT	Peak Loads Negative. All-time peak negative force/torque loads.
0x44	PeakLoadsNegFy		
0x45	PeakLoadsNegFz		
0x46	PeakLoadsNegTx		
0x47	PeakLoadsNegTy		
0x48	PeakLoadsNegTz		
0x49 to 0xcd	Reserved		

7.2.3 Object 0x2060: Monitor Condition

This 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. To reset the monitor output, set the "Clear Monitor Condition" bit in Object 0x7010 subindex 0x01 (*Section 7.2.10—Object 0x7010: Control Codes*) which is also mapped into the TxPDO data.

In a monitor condition, the following fields are available:

Table 7.3—Object 0x2060: Monitor Condition

Subindex	Name	Type	Description	
0x01	Threshold Value	DINT	The threshold value to compare against, in counts.	
0x02	Axis	USINT	**Value**	**Axis**
			0	Fx
			1	Fy
			2	Fz
			3	Tx
			4	Ty
			5	Tz
0x03	CompareGreaterThan	BOOL	If TRUE, the monitor condition is true when the selected axis is greater than the selected threshold value. If FALSE, the monitor condition is true when the selected axis is less than the selected threshold value.	

7.2.4 Object 0x2080: Diagnostic Readings

This read-only object provides access to diagnostic values. These values may be useful when troubleshooting the system. All diagnostic voltages are filtered with the filter coefficient set to "8" (refer to *Section 6.3—Filtering* for details).

The following fields are available in the Diagnostic Readings object:

Table 7.4—Object 0x2080: Diagnostic Readings

Subindex	Name	Type	Description	Limits	Sampling Rate
0x01	Supply Voltate	UINT16	The external power supply Voltage x 10 (based on the ADC reading)	12V to 32 V	background loop[1]
0x02	Gage Temperature	INT16	The average gage temperature in °C	-5 to 70°C	background loop[1]
0x03	Status Message	STRING(40)	The highest priority status code error message.[2]	n/a	n/a

Note:
1. See *Section 6.2—Sample Rate* for strain gage sampling rate.
2. Status error code messages are ranked according to priority in *Table 8.2*.

7.2.5 Object 0x2090: Version

This read-only object provides firmware version information.

The following fields are available in the version object:

Table 7.5—Object 0x2090: Version			
Subindex	**Name**	**Type**	**Description**
0x01	Major	UINT16	Major Version
0x02	Minor	UINT16	Minor Version
0x03	Revision	UINT16	Revision
0x04	Boot Loader Version	UNIT32	Boot Loader Version
0x05	SensorHwVer	UNIT16	Sensor Hardware Version
0x06	SensorInstrument	UNIT16	Sensor Instrument 1=Micron 2=Microgage All values are reserved.

7.2.6 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 7.6—Object 0x6000: Reading Data			
Subindex	**Name**	**Type**	**Description**
0x01	Fx	DINT	These fields contain the 32-bit F/T result data, in counts.
0x02	Fy		
0x03	Fz		
0x04	Tx		
0x05	Ty		
0x06	Tz		

7.2.6.1 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 7.2.2—Object 0x2021: Calibration* subindex 0x31).
2. Read the Counts per Torque SDO register (refer to *Section 7.2.2—Object 0x2021: Calibration* subindex 0x32).
3. Verify the units of force (refer to *Section 7.2.2—Object 0x2021: Calibration* subindex 0x2f).
4. Verify the units of torque (refer to *Section 7.2.2—Object 0x2021: Calibration* subindex 0x30).
5. Read the F/T counts for force (refer to *Section 7.2.6—Object 0x6000: Reading Data*).
6. Read the F/T counts for torque (refer to *Section 7.2.6—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 counts for Fx and Tx in units. First, the user reads the registers for the applicable SDO subindexes and finds the following:

Table 7.7—Example of Registers for SDO Subindexes

SDO	Subindex	Register	Description[1]
0x2040	0x31	1, 000, 000	Counts Per Force
0x2040	0x32	1, 000, 000	Counts Per Torque
0x2040	0x2f	2	The force units are N.
0x2040	0x30	3	The torque units are Nm.
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

7.2.7 Object 0x6010: Status Code

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

Table 7.8—Object 0x6010: Status Code

Bit Number	Description	Indicates Error?
0	Gage Temperature Out of Range: This bit becomes active is the gage temperature is outside the expected range of -5 to 70 °C; this bit could indicate a system fault.	Yes
1	Supply Out of Range: This bit becomes active if the supply voltage reading in *Section 7.2.4—Object 0x2080: Diagnostic Readings* is out of the expected range of 12 to 32 V. This bit remains set until power cycle.	Yes
2	Broken Gage: This bit becomes active whenever any gage reads positive full scale. This 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 firmware is performing one 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	No
4	Reserved	Yes[1]
5	Common error bit. This bit indicates that one or more of the following errors has occurred: • LAN9252 PHY issue • ADC Write Register Verify error • MCU Parameters-RAM CRC error • I2C EEPROM Verify error • MCU Image 0 CRC error • MCU RAM error • MCU Stack critically low error • MCU part number or version is wrong • MCU Watchdog reset • MCU registers error • MCU Program Counter error • ADC No interrupt seen lately • MCU Stuck GPIO output bits	Yes

Notes:
1. In the rare event that a Reserved Bit indicates an error, contact ATI for assistance.

Table 7.8—Object 0x6010: Status Code		
Bit Number	**Description**	**Indicates Error?**
6-15	Reserved	Yes[1]
16	Monitor Condition Tripped: This bit becomes active when an active monitor condition becomes true, and remains set until cleared with the “Reset Monitor Conditions” bit in *Section 7.2.10—Object 0x7010: Control Codes*.	No
17-26	Reserved	Yes[1]
27	Gage Out Of Range. This bit is set whenever a gage sample is outside of the range gageMinRange to gageMaxRange. 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
28	Simulated Error. This bit mirrors the “Simulated Error Control” bit in *Section 7.2.10—Object 0x7010: Control Codes*.	No, but can be used to test user error handling if treated as such.
29	Calibration checksum error. This bit is set if the active calibration did not have a valid checksum when read from EEPROM.	Yes
30	Force/Torque Out Of Range. This bit is set whenever a force/torque sample is out of range or mathematically saturated. 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.
31	Error: This bit is set whenever any status code bit that indicates an error is set.	Yes

Notes:
1. In the rare event that a Reserved Bit indicates an error, contact ATI for assistance.

7.2.8 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.

7.2.9 Object 0x6030: Gage Data

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

Table 7.9—Object 0x2060: Monitor Condition

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		

7.2.10 Object 0x7010: Control Codes

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

Table 7.10—Object 0x2060: Monitor Condition

Subindex	Name	Type	Description	
			Bit	**Function**
0x01	Control 1	DINT	0	1 = Set bias against current load. 0 = leave bias unchanged
			1	Clear Monitor Condition 0: 1 = clear monitor condition status 2 = leave monitor condition status as-is
			2	1 = clear bias 0 = leave bias condition as-is
			3	Reserved
			4-7	Filter selection
			8-11	Active Calibration: 0 = Calibration 0 1 = Calibration 1 2 = Calibration 2 All other values are reserved.
			12-15	ADC Sampling Rate: 0 = 1000 Hz 1 = 2000 Hz 2 = 4000 Hz 3 = 8000 Hz All other values are reserved.
			16-31	Reserved
0x02	Control 2	DINT	**Bit**	**Function**
			0	Enable checking of Monitor Condition 0
			1-15	Reserved
			16-19	Tool transform index selection.[1]
			20-30	Reserved
			31	Simulated Error Control

Note:

1. After changing the tool transform index, do not update the control codes for a period of 500 milliseconds so that the sensor has time to fully apply the transformation.

8. Troubleshooting

This section includes answers to some issues that might arise when setting up and using the ECATOEM2 F/T. The question or problem is listed followed by its probable answer or solution. They are categorized for easy reference.

> 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
> 5. Description of the third party hardware and software used to connect and supply power to the ECATOEM2 F/T system.
>
> If possible, be near the F/T system when calling.

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*

8.1 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. Listed below are the basic conditions of incorrect data. To troubleshoot problems, refer to the following table:

Table 8.1—Troubleshooting

Symptom	Cause	Resolution
Saturation	When the data from a raw decimal strain gage reads the positive or negative maximums, that gage is saturated. Saturation occurs if the sensor is loaded beyond its rated maximum or in the event of an electrical failure within the system.	Stop applying force to the transducer and wait until the error clears to continue. If error does not clear, it may indicate the overload value has been exceeded or a loss of power.
Noise	Excessive 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 the unit is grounded properly and the area is isolated from electrical disturbances.
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 while viewing resolved F/T data. 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 sensor body (i.e., plastic filings between the tool adapter plate and the transducer body). Some mechanical coupling is common, such as hoses and wires attached to a tool.	Make sure the tool, tool adapter plate and the transducer body are isolated from each other and no debris lies between the transducer body and tool plate.
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.	Make sure the tool, tool adapter plate and the transducer body are isolated from each other and no debris lies between the transducer body and tool plate.

8.2 Diagnostic Monitoring

During operation, the firmware monitors the hardware. When the user first applies power, the firmware waits five seconds before evaluating the supply voltage for errors. A status message displays as text in SDO-0x2080 subindex 0x03 (refer to *Section 7.2.4—Object 0x2080: Diagnostic Readings*). The status message with the highest priority or seriousness appears in subindex 0x03. The Status messages are in the following table are ranked in order of priority, where 1 is the highest or most serious and 11 is the lowest.

Table 8.2—Text Error Messages (in order of priority)

Priority	Message
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	Common error
8	Simulated error
9	Monitor condition latched
10	Error (unspecified)
11	Good (no status code errors)

System health indicators that the firmware monitors are in the following table.

Table 8.3—Network Health System

Indicator	Description
Stack Usage	The maximum amount of the stack usage is continuously monitored. An error message is generated if the available stack is too low.
MCU Program Memory CRC	The CRC of the MCU program flash memory is continuously monitored. An error message is generated, if an error is found.
Parameter Memory CRC	The CRC of the MCU RAM Parameter Memory, which is used to store the calibration, is continuously monitored. An error message is generated, if an error is found.
MCU Data Memory Test	The MCU Data Memory (RAM) is continuously tested. An error message is generated, if an error is found.

9. Specifications

9.1 Storage and Operating Conditions

Table 9.1—Temperature		
Component	**Storage Temperature, °C**	**Operating Temperature, °C**
ECATOEM2	-40 to +85	-20 to +70
Transducer Model	Refer to the *F/T Transducer manual*.	

9.2 Electrical Specifications

Table 9.2—Power Supply		
Power Source	**Voltage**	**Maximum Power Consumption[1]**
DCIN through P1	24 V (20 to 30 V)	3.0 W

Notes:

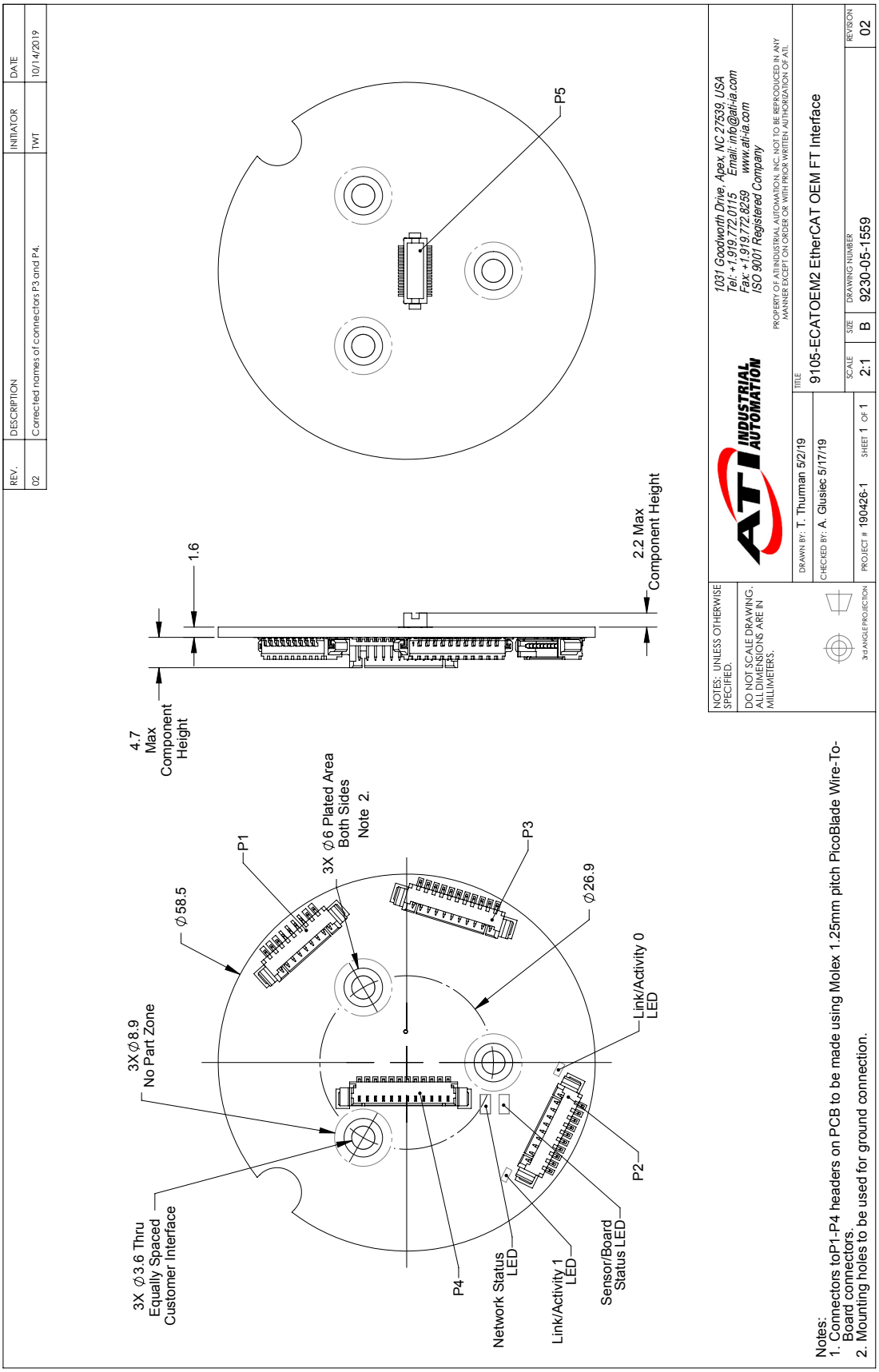
1. Actual power consumption depends on the transducer model connected to the ECATOEM2 interface board assembly.

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 the sensor.

9.3 Weights and Dimensions

Table 9.3—Weights and Dimensions		
Component	**Weight (approx.)**	**Dimensions**
ECATOEM2 PCB Assembly	17 g (0.6 oz)	Refer to *Section 10—Drawings*.
Transducer	Refer to the *F/T Transducer manual*.	

10. Drawings


REV. | DESCRIPTION | INITIATOR | DATE
02 | Corrected names of connectors P3 and P4. | TWT | 10/14/2019
P5
1.6
2.2 Max Component Height
4.7 Max Component Height
P1
3X ⌀6 Plated Area Both Sides Note 2.
P3
⌀58.5
⌀26.9
3X⌀8.9 No Part Zone
Link/Activity 0 LED
3X ⌀3.6 Thru Equally Spaced Customer Interface
P4
Network Status LED
Link/Activity 1 LED
Sensor/Board Status LED
P2
NOTES: UNLESS OTHERWISE SPECIFIED.
DO NOT SCALE DRAWING. ALL DIMENSIONS ARE IN MILLIMETERS.
DRAWN BY: T. Thurman 5/2/19
CHECKED BY: A. Glusiec 5/17/19
3rd ANGLE PROJECTION
PROJECT # 190426-1
SHEET 1 OF 1
TITLE
9105-ECATOEM2 EtherCAT OEM FT Interface
SCALE 2:1
SIZE B
DRAWING NUMBER 9230-05-1559
REVISION 02
1031 Goodworth Drive, Apex, NC 27539 USA
Tel: +1.919.772.0115 Email: info@ati-ia.com
Fax: +1.919.772.8259 www.ati-ia.com
ISO 9001 Registered Company
PROPERTY OF ATI INDUSTRIAL AUTOMATION, INC. NOT TO BE REPRODUCED IN ANY MANNER EXCEPT ON ORDER OK WITH PRIOR WRITTEN AUTHORIZATION OF ATI.
Notes:
1. Connectors toP1-P4 headers on PCB to be made using Molex 1.25mm pitch PicoBlade Wire-To-Board connectors.
2. Mounting holes to be used for ground connection.

11. Terms and Conditions of Sale

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

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

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

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

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

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

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

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