Force/Torque (F/T) Manual

Introduction

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

A. Introduction

This section includes contact information to reach an ATI representative, general safety guidelines, and terms and conditions of sale. The ATI document number for this modular manual section is: 9620-05-A-Introduction.
A comprehensive glossary of terms is here: *https://www.ati-ia.com/library/Glossary_of_Robotic_Terminology.aspx*.

B. Sensor

This section contains information about the sensor mechanical body.

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

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

C. Communication Interface Version

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

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

D. Custom Application

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

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

A. Introduction

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

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

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

Note:

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

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

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

Please contact an ATI representative for assistance, if needed:

Sale, Service and Information about ATI products:

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24/7 Support: +1 855 ATI-IA 00 (+1 855-284-4200)

1. Safety

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

1.1 Explanation of Notifications

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

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

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

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

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

1.2 General Safety Guidelines

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

2. 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 robotic Tool Changer products purchased hereunder will be free from defects in material and workmanship under normal use for a period of three (3) years from the date of shipment. The warranty period for repairs made under a Return Merchandise Authorization (RMA) shall be for the duration of the original warranty, or ninety (90) days from the date of repaired product shipment, whichever is longer. ATI will have no liability under this warranty unless: (a) ATI is given written notice of the claimed defect and a description thereof within 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 ten (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.

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Sano74
F/T Sensor Manual

Document #: 9620-05-B-Sano74

Engineered Products for Robotic Productivity

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Foreword

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ATI Industrial Automation, Inc. assumes no responsibility for any errors or omissions in this document.

ATI F/T Sensing Systems are considered components/ semi-finished goods intended for use in larger system/ device/ finished good.

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

Note:

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

1. Serial number, for example: FT01234.
2. Sensor model, for example: Sano74.
3. Calibration, for example: SI-130-10.
4. Accurate and complete description of the question or problem.
5. Computer and software information (operating system, PC type, drivers, application software, and other relevant information about the application's configuration).

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

Please contact an ATI representative for assistance, if needed:

Sale, Service and Information about ATI products:

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24/7 Support: +1 855 ATI-IA 00 (+1 855-284-4200)

Table of Contents

Glossary

Term	Definition
Accelerometer	A device within ATI's Sano sensors that measures acceleration. ATI's Sano sensors use a Micro Electronic Mechanical System (MEMS) accelerometer.
Bias	Biasing is useful for eliminating the effects of gravity (tool weight) or other acting forces. When the bias function is used, the software collects data for the forces and torques that are currently acting on the sensor and use these readings as a reference for future readings. Future readings will have this reference subtracted from them before they are transmitted. Bias may also be referred to as “zero out” or “tare” the sensor.
Calibration	Defines a specific measurement or sensing range for a given sensor. Calibration is also the process of measuring a transducer’s raw response to loads and creating data used in converting the response to forces and torques.
Complex Loading	Any load that is not purely in one axis.
Communication Interface Versions	The software standard that the customer device uses to apply features to the sensor and for the sensor to report data, for example: EtherCAT, RS422, and Ethernet.
Coordinate Frame	See Sensing Reference Frame Origin.
Cube Method	A method of accelerometer dynamic calibration where the end user orients a device in four to six unique positions and holds the device in each position for at least one second.
Data Rate	How fast data can be output over a network.
Force	A force is a push or pull action on an object caused by an interaction with another object. Force = mass x acceleration.
FS	Full-Scale, refers to the limits of a given calibration or sensing range.
F/T	Force/Torque.
F_{xy}	The resultant force vector comprised of components F_x and F_y.
g	G-force or gravitational force equivalent is a mass-specific force expressed in units of standard gravity.
Gyroscope	A device within ATI's Sano sensors that measures orientation and angular velocity. ATI's Sano sensors use a Micro Electronic Mechanical System (MEMS) gyroscope.
Hysteresis	A source of measurement error caused by the residual effects of previously applied loads.
Interface Plate	A separate plate that attaches the sensor to another surface. Interface plates are often used if the bolt pattern on the sensor doesn’t match the bolt pattern on the robot arm or customer tooling. The interface plate has two bolt patterns, one on either side of the plate. One side is for the sensor. The other side is for the robot arm or customer tooling.
IMU	Inertial measurement unit (IMU) is a device that detects acceleration and angular velocity (gyroscopic data).
Ingress Protection Rating (IP2X)	The sensor has an IP2X classification, which prevents foreign objects less than 0.49 in or 12.5 mm in size from entering the device. The end user should protect the sensor from ingress of water or other liquids.
Master Device	A customer-supplied device such as a personal computer, robot, or programmable logic controller (PLC) that is compatible a specific communication interface.

Term	Definition
Measurement Uncertainty	Commonly referred to as "accuracy", "measurement uncertainty" is the worst-case error between the measured value and the true load. The measurement uncertainty is specified as a percentage of the full-scale measurement range for a given sensor model and calibration size. This value takes into account multiple sources of error. The sensor's calibration certificate lists the measurement uncertainty percentage. For more information, refer to *Section 2.2: Measurement Uncertainty* in the Frequently Asked Questions (FAQ) document located at: *https://www.ati-ia.com/library/documents/FT_FAQ.pdf*.
Mechanical Coupling	When an external object such as customer tooling or utilities contacts a sensor's surface between the sensor's mounting side and tool side.
N/A	Not Applicable
Overload	The condition where more load is applied to the transducer than it can measure. This will result in saturation.
P/N	Part Number
Power Cycle	When a user removes and then restores power to a device.
Resolution	The smallest change in load that can be measured. Resolution is usually much smaller than accuracy.
Sample Rate	How quickly the analog gage data is converted into digital samples by the ADC.
Saturation	The condition where the transducer or data acquisition hardware has a load or signal outside of its sensing range.
Sensing Reference Frame Origin	The point on the sensor from which all F/T and IMU data are measured.
Sensor	The component that converts a detected load into electrical signals.
Sensor System (or configuration)	The entire assembly consisting of a sensor body and a system interface to translate force and torque signals into a specific communication interface/protocol.
Tool Adapter Plate (or TAP)	The surface component that attaches the customer's tooling to the tooling side (sensing side) of the sensor.
Torque	The application of a force through a lever or moment arm that causes something to want to turn. For example, a user applies torque to a screw to make it turn. Torque = force x moment arm length.
T_{xy}	The resultant torque vector comprised of components T_x and T_y.

1. Safety

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1.2 General Safety Guidelines

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

1.3 Safety Precautions

CAUTION: Modifying or disassembly of the sensor could cause damage and void the warranty. Use the provided bolt patterns on the mounting and tool sides of the sensor to install the sensor to the robot and customer tooling to the sensor. For more information, refer to the customer drawings.

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

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

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

2. Product Overview

The Sano74 Force/Torque (F/T) sensor is for use with surgical robotics and ideal for orthopedic applications such as hand-guided robotic navigation and force-controlled cutting or drilling. The Sano74 measures six components of force and torque (F_x \ F_y \ F_z \ T_x \ T_y \ T_z). An onboard Inertial Measurement Unit (IMU) provides triaxial acceleration and angular velocity measurements. The sensor communicates this data to a device such as a personal computer, robot, or PLC. For more information about the communication interface, refer to the applicable manual in *Table 2.1*. For product specifications, refer to *Section 7—Specifications*.

The sensor's mounting adapter plate (MAP) attaches to a rigid fixture or robot. The tool adapter plate (TAP) attaches to the customer tooling. For specific MAP and TAP bolting patterns and dimensions, refer to *Section 8—Drawings.* If the sensor does not have the same bolt pattern as the mounting or tool sides, refer to *Section 3.1—Interface Plates*.

Before installation, end users must remove the cover plate, which protects the internal instrumentation during storage and shipment. Customers supply and attach cables to the connectors on the main board of the sensor. A slot on the side of the housing provides visibility to the communication and status LEDs on the main board. Through the center of the sensor is a 20 mm hole for passing cables and accommodating integration. For more information about the connections and LEDs, refer to the applicable manual in *Table 2.1*.

Figure 2.1—Sano74 F/T Sensor

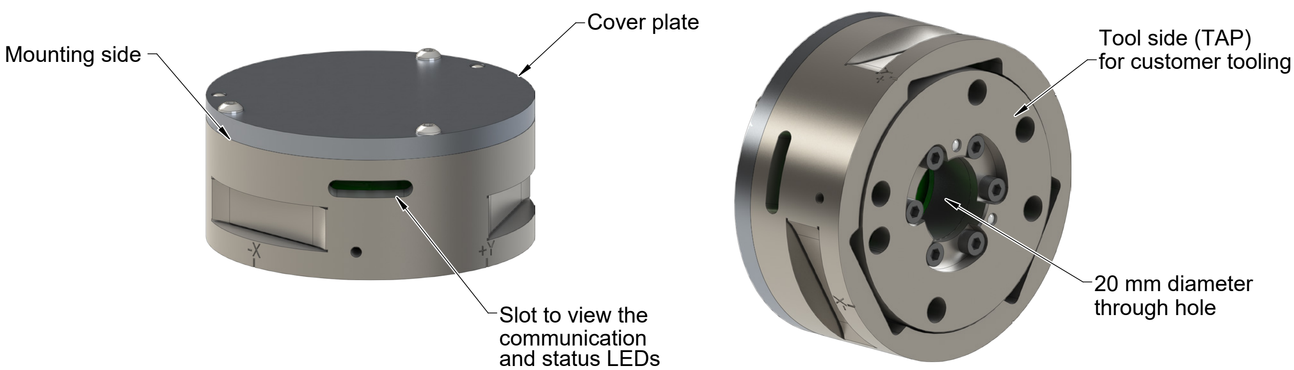


Table 2.1—Sano Communication Manuals		
Sensor Model P/N	**Communication Type**	**ATI Manual**
9105-ECAT3-SANO74-M12	EtherCAT	*9620-05-C-EtherCAT3 Sano*

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: Provide sufficient overvoltage protection to avoid damage to the sensor. The customer should not expose the sensor to ESD voltages out side the range ±8 kV.

CAUTION: To avoid electrical interference with nearby applications, minimize the connection distance from the sensor to the host system where EMC filtering is performed.

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

3.1 Interface Plates

The sensor's mounting side attaches to a surface like the robot arm, and the sensor's Tool Adapter Plate (TAP) attaches to the customer tooling. If the end user chooses to supply their own interface plates, refer to the following design guidelines and the Sano74 drawing (refer to *Section 8—Drawings)*.

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

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

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

- The interface plate should include bolt holes for mounting fasteners as well as a dowel pin and boss for accurate positioning to the robot.
- The thickness of the interface plate must provide sufficient thread engagement for the mounting fasteners.
- The mounting fasteners should not interfere with the internal electronics of the sensor. For thread depth, mounting patterns, and other details, refer to *Section 8—Drawings*
- Do not use dowel pins that exceed length requirements and prevent interface plate from mating flush with the robot. Fasteners that exceed length requirements create a gap between the interfacing surfaces and cause damage.
- The interface plate must be as strong or stronger than the sensor so that maximum force and torque values applied to the sensor do not distort the interface plate. For these force and torque values, refer to *Section 7—Specifications*.
- The interface plate must provide a flat and parallel mounting surface for the sensor.

3.2 Sensor Installation

Supplies required:

- *Clean Rag*
- *Loctite 222® threadlocker*
- *Loctite 242® threadlocker*
- *Loctite 7649® or equivalent threadlocker/primer*
- *Torque Wrench*

Parts required:

- *(8x) Mounting Screws, Sensor to Robot:*
  - Sano74-M12: M3
- *(4x) Mounting Screws, Sensor to Tooling*
  - Sano74-M12: M6
- *(Optional) 8-Pin Flat Flex Cable. See Table 3.1.*
- *(Optional) 6-Pin Flat Flex Cable. See Table 3.1.*
- *(Optional) 8-Pin SM Connector Cable). See Table 3.1.*

Tools required:

- *Hex Keys.*
  - Sano74-M12: 2 mm, 2.5 mm, and 5mm hex keys
- *Torque wrench*

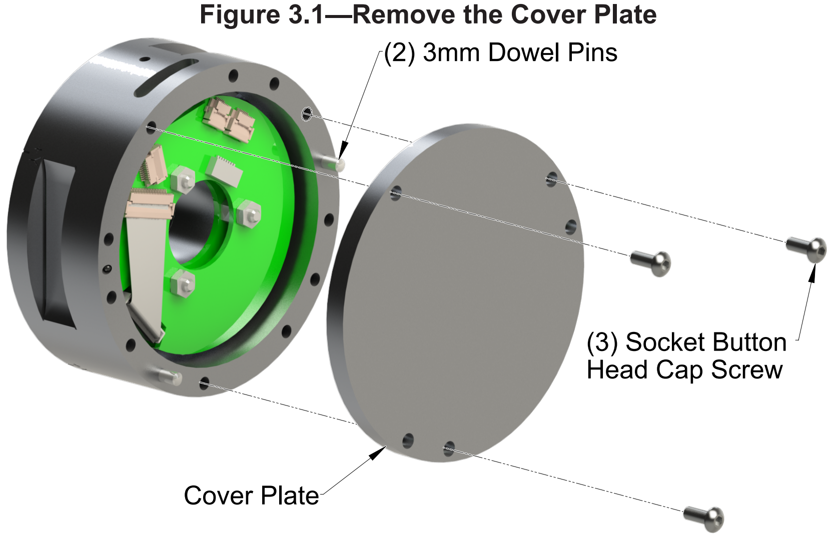
CAUTION: Do not apply excessive force to the sensor and connector during installation, or damage will occur.

CAUTION: Using fasteners that exceed the customer interface depth penetrates the body of the sensor, damages the electronics, and voids the warranty.

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.

1. Remove the cover plate:
   a. Use 2mm hex key to remove (3) M3 button socket head cap screws.
   b. Lift the cover plate off the sensor.

Figure 3.1—Remove the Cover Plate



2. Attach the customer-supplied cable(s) to the connector(s) as outlined in *Table 3.1*. Reference *Figure 3.2* to identify location of connectors.

Figure 3.2—Sano74 Sensor Connectors

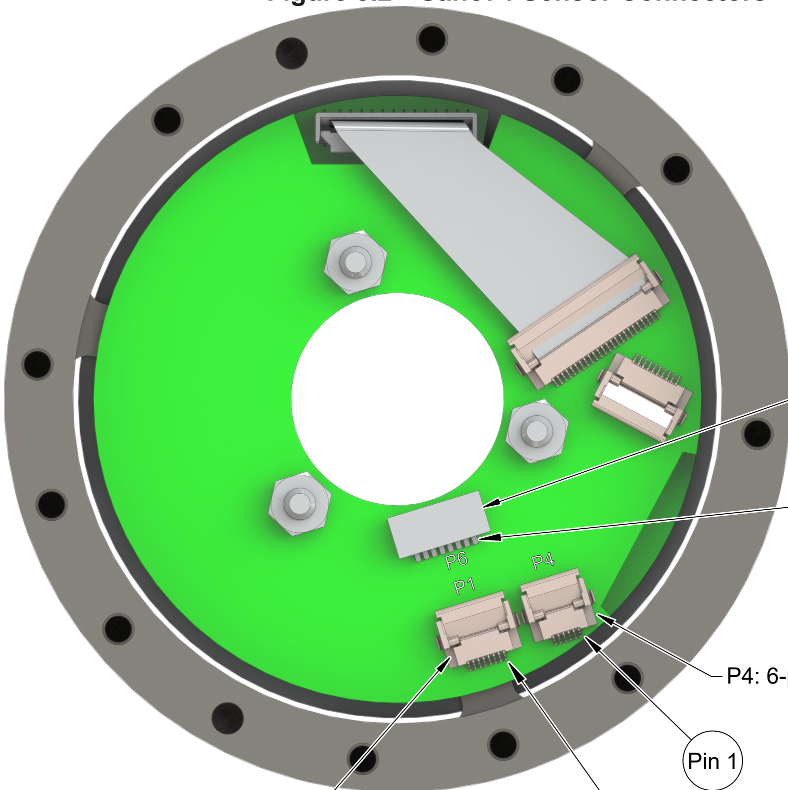


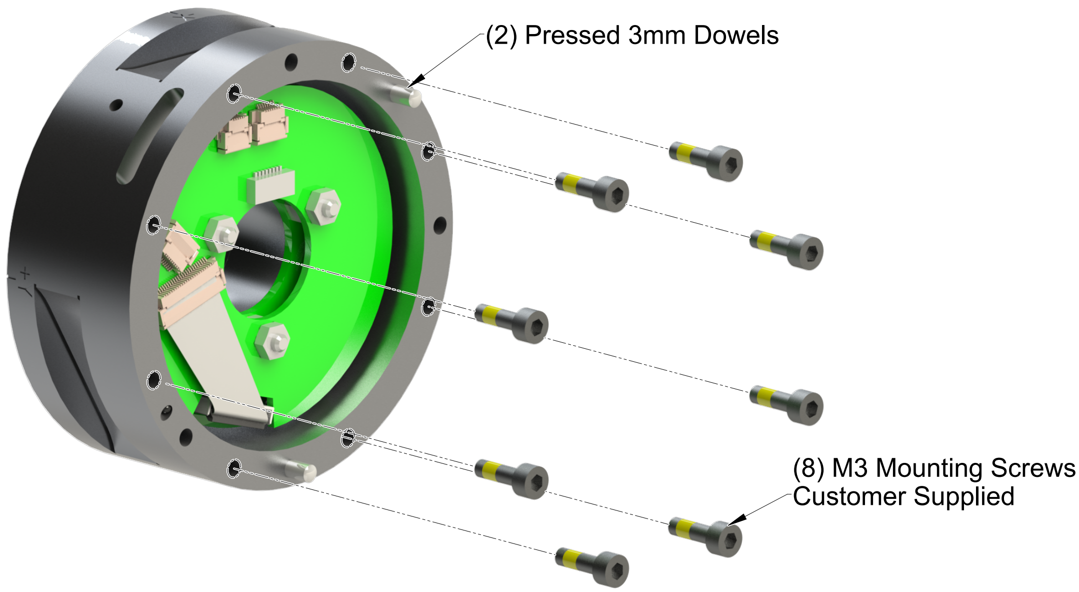
Table 3.1—Connector Pinouts and Signals					
P1: 8-Pin, Male, FFC Connector		**P4: 6-Pin, Male, FFC Connector**		**P6: 8-Pin, Male, SM Connector**	
Pin Number	**Signal**	**Pin Number**	**Signal**	**Pin Number**	**Signal**
1	SL0_VP	1	SL0_VP_Fused	1	SL0_VP
2	RS485 +	2	TX1 +	2	RS485 +
3	RS485 -	3	TX1 -	3	RS485 -
4	TX0 +	4	RX1 +	4	TX0 +
5	TX0 -	5	RX1 -	5	TX0 -
6	RX0 +	6	SL0_Ground	6	RX0 +
7	RX0 -	N/A	N/A	7	RX0 -
8	SL0_Ground	N/A	N/A	8	SL0_Ground

3. Clean the mounting surfaces with clean rag.

NOTICE: The customer's mounting interface should have (2) 3 mm holes for locating the dowel pins in the sensor's MAP side.

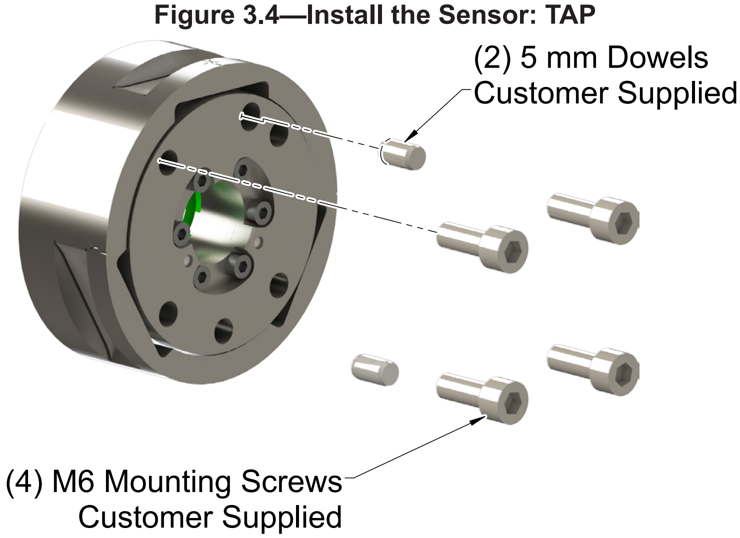
4. Secure the sensor's mounting side to customer's interface. Refer to *Figure 3.3.*
    a. Align sensor with customer interface using (2) pressed 3 mm dowels
    b. Apply Loctite 222 and Loctite 7649 (or equivalent) thread locker to the threads of the (8) customer-supplied mounting screws, sensor to robot.
    c. Use hex key to tighten the fasteners to 15 in-lb (1.7 Nm).

Figure 3.3—Install the Sensor: Mounting Side



5. Secure the customer's tool to the sensor's TAP. Refer to *Figure 3.4.*
    a. Align sensor with customer tooling using (2) customer-supplied 5 mm dowels
    a. Apply Loctite 242 and Loctite 7649 (or equivalent) thread locker to the threads of the (4) customer-supplied mounting screws, sensor to tooling.
    b. Use hex key to tighten the fasteners to 60 in-lb (6.8 Nm).

Figure 3.4—Install the Sensor: TAP



6. Set up the sensor communication interface software. Refer to applicable manual in *Table 2.1*
7. Complete accuracy checks in *Section 3.3—F/T Accuracy Check* and *Section 3.4—IMU Accuracy Check*
8. Safely start normal operation.

3.3 F/T 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:

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

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

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

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

6. The calculated tooling masses for all (6) points should deviate from each other by less than twice the worst accuracy rating of the sensor.

- For example: the Sano74 sensor's rated accuracy is 2% the range on all axes. For a 130 N F_{xy} range and a 400 N F_z range, the allowable errors of any single data point would be ± 2.6 N F_{xy} and ± 8 N F_z respectively. Since F_z has the larger tolerance, then one data point could be + 8 N and another data point could be - 8 N, for a total range (max-min) of 16 N error.
- In addition, the tooling mass should be within 16 N of the results of this test when it was performed with a new sensor.

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

3.4 IMU Accuracy Check

The sensor's IMU contains a self-accuracy check, which monitors the output of the accelerometer. The end user can read the results of the check from the sensor's status code. For the bits and description of the reported results, refer to the communication protocol manual in *Table 2.1*. To improve the level of accuracy, complete a dynamic calibration.

3.5 IMU Dynamic Calibration Procedure

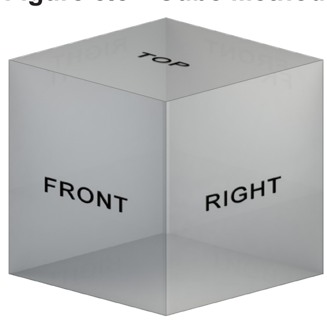
The sensor's IMU hardware requires the zero offsets for each axis to be updated occasionally. The accelerometer at rest should only report gravity, and any deviation is the zero offset. Similarly, while at rest, the gyroscope should only report zero for the angular rate, on every axis. These zero offsets are time dependent and account for temperature characteristics of the sensor's hardware as well as other time varying effects. The zero offsets can be set through a dynamic calibration process, which is always active on the sensor.

3.5.1 Accelerometer Dynamic Calibration

As the sensor moves through various orientations during operation, the accelerometer automatically calibrates because the motions along each sensor's axis are at least partially aligned with the gravity vector. If the sensor is more static during operation, then the user should perform the following calibration:

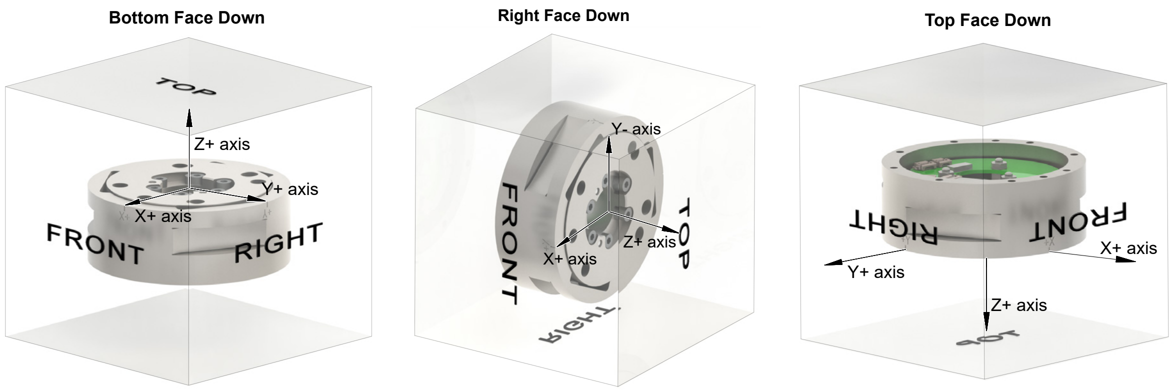
1. Think of the sensor as a standard cube with six faces: front, back, left, right, top, and bottom.

Figure 3.5—Cube Method



2. Orient the sensor so that it is sitting on a face of the cube, for example: start with the sensor positioned top face up and the bottom face down.
3. Hold the device stable in the orientation for at least one second.
4. Continue through the rest of the faces of the cube, for example: next orient the sensor so that the right side of the cube is facing down.

Figure 3.6—Example Calibration Motions



5. Verify the accuracy status:
   a. Monitor the accelerometer accuracy through the status code. Refer to the applicable manual in *Table 2.1*.
   b. When accuracy status code reports high, the calibration process is complete.
6. Save the calibration to the sensor's memory with the command **IMU Calibrate Save**. Refer to the applicable manual in *Table 2.1*.

NOTICE: For the calibration motions, consider the following points:

- Not all six faces of the cube must be used. If one of the orientations is difficult to achieve, four or five orientations are enough.
- The orientations do not need to be perfectly aligned with the cube faces. The important part is that the sensor is positioned into four to six unique orientations.
- Any order of the orientations can be used.

3.5.2 Gyroscope Dynamic Calibration

The sensor automatically completes a gyroscope dynamic calibration anytime it is powered on and at rest for two to three seconds.

To check the zero offsets, verify the reported values are equal to zero when the sensor is not in motion.

3.5.3 Saving a Calibration

For the sensor to not lose dynamic calibrations through a power cycle, save the calibration to the software's memory. More information is found in the applicable communication manual linked in *Table 2.1*.

3.6 Detecting Sensitivity Changes

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

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

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

4. Operation

Information that applies generally to all Sano74 sensors is in the following section. For information specific to the communication protocol of the sensor, such as sampling rate, LEDs, operation commands, refer to the appropriate manual in *Table 2.1*.

4.1 Sensor Environment

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

The sensor has an IP2X classification, which prevents foreign objects less than 0.49 in or 12.5 mm in size from entering the device. The end user should protect the sensor from ingress of water or other liquids. In case of incidental contact such as a light spraying with the following chemicals, the Sano74 sensor should continue to function and maintain its calibration accuracy:

- Cidex
- Hypochlorite Solution
- Hydrogen Peroxide Solution
- 70% Isopropyl Alcohol
- Asepti-HB Solution
- Enzol Solution

For other environmental specifications such as operating and storage temperature, refer to *Section 7—Specifications*.

4.2 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. For information on using this functionality, refer to the appropriate communications manual linked in *Table 2.1*.

4.3 Monitoring Conditions

During operation, the firmware monitors the hardware. For status codes, monitoring conditions, and diagnostic readings, refer to the appropriate communications manual linked in *Table 2.1*.

4.4 LED Behavior

During operation, LEDs on the main board of the sensor are visible through a slot in the Sano74 sensor’s housing. For information, refer to the appropriate manual linked in *Table 2.1*.

5. Maintenance

5.1 Periodic Inspection

While the Sano sensor is IP2X rated, keep debris and dust from accumulating on or in the sensor. Clean the surface of the sensor with isopropyl alcohol.

5.2 Periodic Calibrating of F/T Sensing Ranges

Periodic calibration of the sensor and its electronics is required to maintain traceability to national standards. The sensing ranges cannot be calibrated in the field. To return the sensor to ATI for recalibration, contact an ATI account manager or *ati-rma-admin@novanta.com* to request a Returned Materials Authorization (RMA) for recalibration. ATI recommends annual accuracy checks (refer to *Section 3.3—F/T Accuracy Check*). If the sensor does not meet the performance requirements of the user application and fails the accuracy check, return the sensor to ATI for recalibration.

6. Troubleshooting

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

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

Note

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

1. Serial number , for example: FT01234.
2. Sensor model , for example: Sano74.
3. Calibration , for example: SI-130-10.
4. Accurate and complete description of the question or problem
5. Computer and software information (operating system, PC type, drivers, application software, and other relevant information about the application's configuration)

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

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

Sale, Service and Information about ATI products:

ATI Industrial Automation
1031 Goodworth Drive
Apex, NC 27539 USA
Tel: +1 919-772-0115 • Fax: +1 919-772-8259 • *www.ati-ia.com*

Application Engineering
E-mail: *ft.support@novanta.com*

24/7 Support: +1 855 ATI-IA 00 (+1 855-284-4200)

6.1 Basic Guidance for Troubleshooting

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

Symptom: Noise — jumps in force torque readings greater than 0.05% of full-scale counts.	**Cause:** Noise can be caused by mechanical vibrations and electrical disturbances that are possibly from a poor ground. Electrical interference can also come from a high noise output device such as a motor. **Solution:** Make sure that the DC supply voltage for the Sano sensor has little to no noise superimposed. Ground the sensor by connecting the cable's shield to ground. In most setups, 0 V is also connected to ground. Connect the robot or other fixture to the same ground. Verify that sensor cables do not cross over other cables or are within close proximity to other equipment that could generate electrical noise. Avoid sources of mechanical noise. If not possible, apply a filter to the data as described in the appropriate communications manual linked in *Table 2.1*. **Cause:** Noise can also indicate component failure within the system. **Solution:** Check the status code of the sensor; refer to the communication manual linked in *Table 2.1*. Perform an accuracy check; refer to *Section 3.3—F/T Accuracy Check* or refer to *Section 4.5: How do I evaluate the accuracy of health of the sensor?* in the Frequently Asked Questions (FAQ) ATI document located at: *https://www.ati-ia.com/library/documents/FT_FAQ.pdf*. To return the sensor to ATI for inspection, contact ATI for a Returned Materials Authorization (RMA); refer to *Section 5.2—Periodic Calibrating of F/T Sensing Ranges*.
Symptom: Drift — when the force torque data continues to increase or decrease after a load is removed.	**Cause:** Some drift from a change in temperature is normal. Drift is observed more easily in the Z axis, compared to the X and Y axes. **Solution:** For approximately thirty minutes, allow the sensor to warm up until it is at a steady state with the air and other objects touching the sensor. Use the bias command to shift the readings back to zero. Bias regularly. Use an insulator between the sensor and any tooling or fixtures which are at a different temperature. Avoid creating a temperature gradient across the sensor. Shield the sensor from excessive air flow. For more information about how to avoid drift from temperature change, refer to the following ATI document: *https://www.ati-ia.com/Library/Documents/DriftExplanation.pdf*.

Symptom: Hysteresis — when the sensor is loaded from a zeroed or biased state and then the load is removed, sensor output does not immediately return to zero.	**Cause:** Mechanical coupling or internal failure can cause Hysteresis which is outside of the sensor's specified and acceptable measurement uncertainty (error) range. **Solution:** Verify the sensor is properly installed, fasteners are tightened, and the customer tooling is securely installed per *Section 3—Installation*. Use the bias command to shift the readings back to zero.
Symptom: The initial F/T values are non-zero and no load is applied.	Normal. Bias the sensor to bring all the F/T values back to zero.
Symptom: The sensor does not report accurate F/T data.	**Cause:** The sensor may be in an error state. **Solution:** Check the sensor status code. For how to read and interpret the status code, refer to appropriate communications manual linked in *Table 2.1*. If there are no error bits ON, continue troubleshooting. **Cause:** The sensor is not properly installed or not mounted to a flat, stiff surface. **Solution:** Verify the sensor is correctly installed per *Section 3—Installation*. **Cause:** The mounting fasteners are not properly secured. **Solution:** Verify the fasteners are secured per the installation procedures in *Section 3.2—Install the Sensor*. If fasteners are customer supplied, do not use fasteners that are too long. For maximum fastener penetration depth into the sensor, refer to the sensor drawing. When selecting fasteners: use a high quality, high strength screw or bolt and ensure the fastener's material type, fastener head, and fastener grade are proper for the application. **Cause:** Mechanical coupling—an external object such as customer tooling or utilities contacts a sensor's surface between the mounting side and tool side. **Solution:** Remove any debris between the tool side and interface plate. Use proper cable management for cables and hoses; do not connect them tightly between the mounting and tool side of the sensor. Anything that contacts surfaces such as the through hole in the sensor or interface plates on either side of the sensor induces loading or movement that could result in inaccurate F/T data.

Symptom: The F/T values do not match expected values, for example: the F/T values are fluctuating but are higher than a known applied load.	**Cause:** The sensor may be in a mode that reports gage data instead of F/T data. **Solution:** Gage data is not a 1:1 correlation to F/T axis data. View F/T data instead of gage data; refer to the appropriate communications manual linked in *Table 2.1*. **Cause:** The sensor outputs data in counts. The user must convert the counts to calibration units. **Solution:** Counts must be divided by the Counts per Force (CpF) or Counts per Torque (CpT) in order to convert them to calibration units such as N and Nm. In addition to CpF and CpT, depending on the communication protocol, the values may be further scaled by a 16-bit scale factor. 16-bit counts must be divided by (CpF or CpT ÷ 16-bit scale factor) in order to convert to calibration units. **Cause:** If once the F/T readings are converted to calibration units and exceed the sensor's calibration range per *Section 7—Specifications*, the reported values are inaccurate and the sensor may be overloaded. **Solution:** Check the status code. For information on how to read and interpret the sensor's status code, refer to appropriate communications manual linked in *Table 2.1*. Unmount the sensor. Improper mounting methods can induce high loads in the sensor. If errors such as "F/T Out of Range", "Gage Out of Range", or "Gage Broken" persist, the sensor is likely permanently damaged due to overload

7. Specifications

Some requirements and specifications for the Sano74 sensor are covered in the following sections. For more information, refer to the customer drawing.

Table 7.1—Sano74 Specifications

Parameter	Value			
Weight[1]	0.2 kg			
Power Supply	24 V (Nominal) (12 V to 30 V)			
Storage Temperature	0 to +85 °C			
Operating Temperature	0 to +70 °C			
Relative Humidity	<95%, non-condensing			
Vibration Resistance	Levels up to 20 G_{rms} for 20 minutes			
Calibration[2]	SI-130-12			
Measurement Uncertainty	1.5% in any force or torque axis			
Fatigue Life (within sensing range)	10,000,000 fully-reserved cycles			
	Fxy	Fz	Txy	Tz
Resolution	0.015 N	0.0325 N	0.000715 Nm	0.000525 Nm
Sensing Range[2]	130 N	400 N	12 Nm	
Extended Range[3]	130 N	400 N	20 Nm	
Single-axis Overload	1200 N	4100 N	67 Nm	69 Nm
Thermally-induced Offset Drift[4]	0.2 N/°C	0.6 N/°C	0.015 Nm/°C	

Notes:

1. This weight does not include the cover plate, which is shipped on the sensor and removed before installation.
2. The F/T sensor shall be calibrated to the following sensing ranges per ATI's standard calibration procedure.
3. The F/T sensor can safely operate within the extended sensing range for up to 250,000 cycles.
4. The offset drift shall not exceed these values over the temperature range of +15°C to +85°C for any ambient temperature change of 5°C or greater.

Table 7.2—IMU Specifications				
Parameter	**Value**			
IMU Manufacturer and P/N	CEVA VNO085			
Accelerometer Range	± 16 g			
Composite Sensor	**Calibration**	**Measurement**	**Performance Metric**	**Value**
Rotation Vector	Nominal	Dynamic	Rotation Error	3.5 °
		Static	Rotation Error	2.0 °
Gaming Rotation Vector	Nominal	Dynamic	Non-heading Error	2.5 °
		Static	Non-heading Error	1.5 °
		Dynamic	Heading Drift	0.5 °min
Geomagnetic Rotation Vector	Nominal	Dynamic	Rotation Error	4.5 °
		Static	Rotation Error	3.0 °
Gravity	Nominal	Static	Angle Error	1.5 °
Linear Acceleration	Nominal	Dynamic	Accuracy	0.35 m/s^2
Accelerometer	Nominal	Dynamic	Accuracy	0.3 m/s^2
Gyroscope	Nominal	Dynamic	Accuracy	3.1 °s
Magnetometer	Either	Dynamic	Accuracy	1.4uT

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

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

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

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

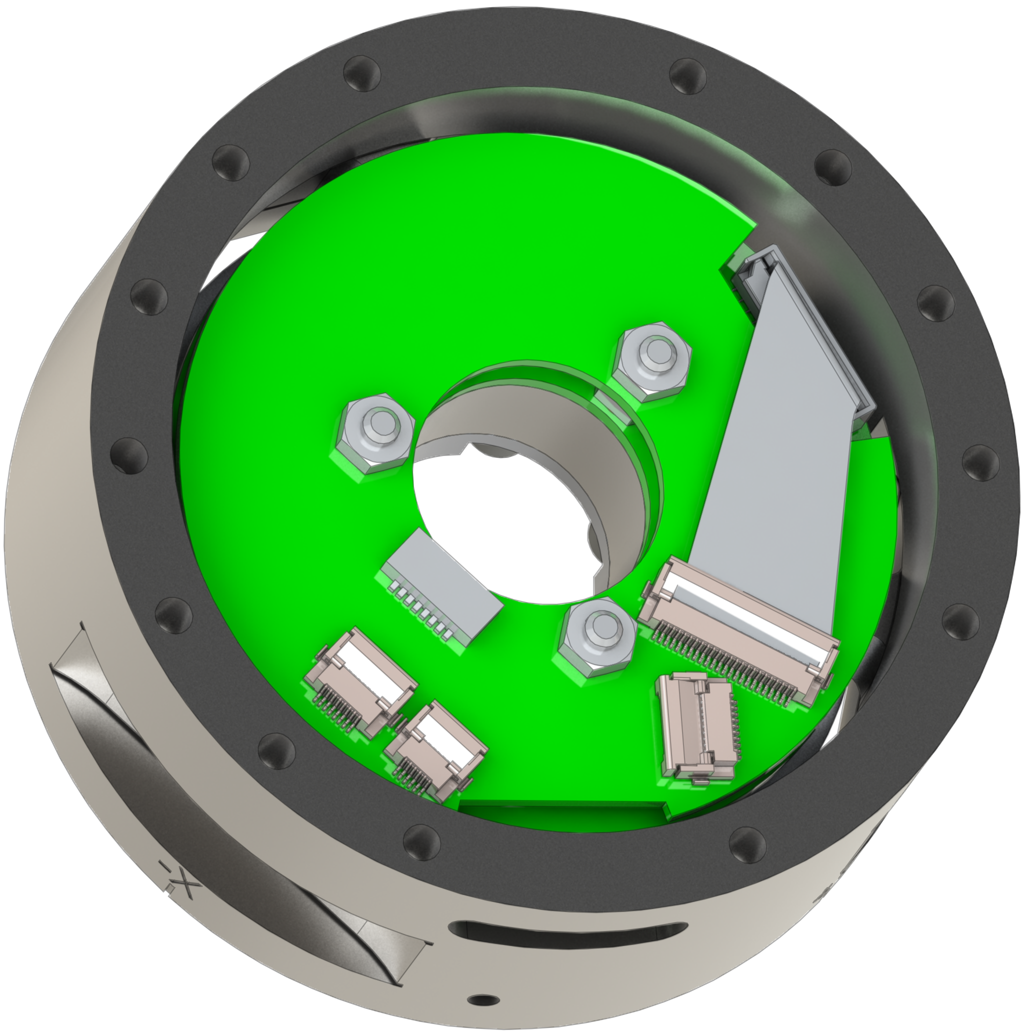
Unless otherwise agreed in writing by ATI, all designs, drawings, data, inventions, software, and other technology made or developed by ATI in the course of providing products and services hereunder, and all rights therein under any patent, copyright, or other law protecting intellectual property, shall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

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

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

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.

EtherCAT3 Sano
F/T Sensor Manual



Document #: 9620-05-C-EtherCAT3 Sano

Engineered Products for Robotic Productivity
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Foreword

ATI Force/Torque Sensing Systems are considered components/ semi-finished goods intended for use in larger system/ device/ finished good.

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

Note:

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

1. Serial number, for example: FT01234.
2. Model, for example: Sano74.
3. Calibration, for example: SI-130-10.
4. Accurate and complete description of the question or concern.
   For the status code, refer to *Section 5.2.8—Object 0x6010: Status Code*.
5. Computer and software information, for example: operating system, PC type, drivers, and application software.

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

Please contact an ATI representative for assistance, if needed:

Sale, Service and Information about ATI products:

ATI Industrial Automation, a *Novanta* company
1031 Goodworth Drive
Apex, NC 27539 USA
Tel: +1 919-772-0115 • Fax: +1 919-772-8259 • *www.ati-ia.com*

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24/7 Support: +1 855 ATI-IA 00 (+1 855-284-4200)

Table of Contents

Glossary

Term	Definition
Accelerometer	A device within ATI's Sano sensors that measures acceleration. ATI's Sano sensors use a Micro Electronic Mechanical System (MEMS) accelerometer.
ADC	Analog-to-digital converter.
Bias	Bias may also be referred to as “zero out” or “tare” the sensor. Biasing is useful for eliminating the effects of gravity (tool weight) or other acting forces. 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.
BOOL	A boolean data type that takes values TRUE or FALSE.
Calibration	Defines a specific measurement or sensing range for a given sensor. Calibration is also the process of measuring a transducer’s raw response to loads and creating data used in converting the response to forces and torques.
CoE	CANopen over EtherCAT is the preferred embedded protocol for configuring EtherCAT devices. Used within SDO to encode the configuration data.
Complex Loading	Any load that is not purely in one axis. Complex loading may reduce measurement range in a given axis.
Coordinate Frame	See Point of Origin.
Data Rate	How quickly data can be output over a network. For more information, refer to *Section 4.3.1—Sample Rate Versus Data Rate*.
DINT	Signed double integer (32 bit)
DPS	Degrees Per Second. This is the unit of value used by the IMU gyroscope.
EEPROM	Electrically Erasable Programmable Read-Only Memory-a type of non-volatile memory integrated in the sensor electronics.
EtherCAT	An industrial automation fieldbus. At times, this is abbrevriated as ECAT.
EtherCAT3 or ECAT3	ATI’s third-generation EtherCAT force/torque system interface.
Force	A force is a push or pull action on an object caused by an interaction with another object. Force = mass X acceleration
FS	Full-Scale, refers to the limits of a given calibration or sensing range.
F/T	Force/Torque.
F_{xy}	The resultant force vector comprised of components F_x and F_y.
g	G-force or gravitational force equivalent is a mass-specific force expressed in units of standard gravity.
Gyroscope	A device within ATI's Sano sensors that measures orientation and angular velocity. ATI's Sano sensors use a Micro Electronic Mechanical System (MEMS) gyroscope.
Hysteresis	A source of measurement error caused by the residual effects of previously applied loads.
IMU	Inertial measurement unit (IMU) is a device that detects acceleration and angular velocity (gyroscopic data).
INT	Signed integer (16 bit)
Interface Plate	A separate plate that attaches the sensor to another surface. Interface plates are often used if the bolt pattern on the sensor doesn’t match the bolt pattern on the robot arm or customer tooling. The interface plate has two bolt patterns, one on either side of the plate. One side is for the sensor. The other side is for the robot arm or customer tooling.
ISR	Interrupt service routine

Term	Definition
Master Device	A customer supplied device such as a personal computer, robot, or programmable logic controller (PLC) that is compatible with a specific communication interface.
Measurement Uncertainty	Commonly referred to as "accuracy", "measurement uncertainty" is the worst-case error between the measured value and the true load. The measurement uncertainty is specified as a percentage of the full-scale measurement range for a given sensor model and calibration size. This value takes into account multiple sources of error. The sensor's calibration certificate lists the measurement uncertainty percentage. For more information, refer to *Section 2.2: Measurement Uncertainty* in the Frequently Asked Questions (FAQ) document located at: *https://www.ati-ia.com/library/documents/FT_FAQ.pdf*.
Mechanical Coupling	When an external object such as customer tooling or utilities contacts a sensor's surface between the sensor's mounting side and tool side.
N/A	Not Applicable
Overload	The condition where more load is applied to the transducer than it can measure. Overload results in saturation.
PDO	Process Data Object, a protocol for reading and writing real-time process information cyclically.
P/N	Part Number
Point of Origin	The point on the sensor from which all forces and torques are measured.
Power Cycle	When a user removes and then restores power to a device.
Q (number) format	A method of coding for fractional numbers. This format is used to output IMU data.
Resolution	The smallest change in load that can be measured. Resolution is usually much smaller than accuracy.
Sample Rate	How quickly the analog gage data is converted into digital samples by the ADC.
Saturation	The condition where the transducer or data acquisition hardware has a load or signal outside of its sensing range.
SDO	Service Data Object, a protocol for reading and writing configuration information acyclically.
Sensor	The component that converts a detected load into electrical signals.
Sensor System (or configuration)	The entire assembly consisting of a sensor body and a system interface to translate force and torque signals into a specific communication interface/protocol.
SINT	Signed short integer (8 bit)
Status Bit	A unit of computer data sent from the ATI F/T sensor.
STRING*n*	String of *n* characters, using *n* btes, for example: String(8) is a data type of characters that uses 8 bytes.
Torque	The application of a force through a lever or moment arm that causes something to want to turn. For example, a user applies torque to a screw to make it turn. Torque = force x moment arm length
T_{xy}	The resultant torque vector comprised of components T_x and T_y.
UDINT	A (32) bit data type representing an unsigned integer.
UINT*n*	A (*n*) bit data type representing an unsigned integer, where *n* is the number of bits.
USINT	An (8) bit data type representing an unsigned integer.

1. Safety

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

1.1 Explanation of Notifications

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

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

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

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

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

1.2 General Safety Guidelines

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

1.3 Safety Precautions

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

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

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

CAUTION: The sensor should be protected from impact and shock loads that exceed rated ranges during transport as the impacts can damage the sensor's performance. For more information about rated ranges, refer to the *9620-05-B-Sano74* manual.

2. Product Overview

The EtherCAT3 Sano Force/Torque (F/T) sensor is for use with surgical robotics and ideal for orthopedic applications such as hand-guided robotic navigation and force controlled cutting or drilling. The Sano measures six components of force and torque (F_x \ F_y \ F_z \ T_x \ T_y \ T_z). An onboard Inertial Measurement Unit (IMU) provides triaxial acceleration and angular velocity measurements. Customer devices can receive F/T and IMU data through EtherCAT fieldbus (refer to *Section 5—EtherCAT Bus Interface*). To use EtherCAT, the user needs a software interface and device, such as a personal computer, robot, or PLC, that is compatible with EtherCAT. Free, downloadable software such as TwinCAT® is available online for users with a Windows® operating system.

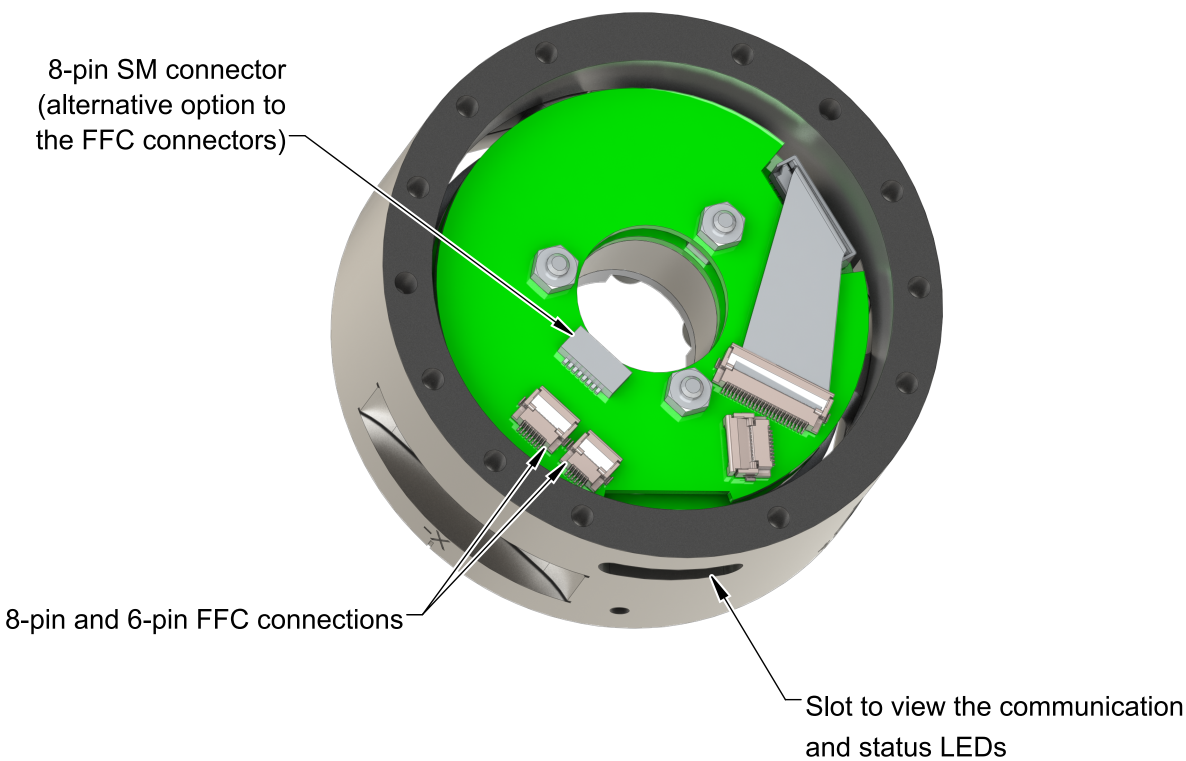
Customers can either use the (2) Flat Flex Cable (FFC) connectors or the single wire-to-wire (SM) connector. The Sano sensor has power pass through and EtherCAT ports so that network devices may be configured as a daisychain.

This manual covers the following topics:

- Electrical specifications and pinout information for the connectors
- Operation (LEDs, filter rates, and sampling rates)
- EtherCAT dictionary objects

For additional sensor information, such as installation on a robot, operation, and general troubleshooting, refer to the *9620-05-B-Sano74* manual.

Figure 2.1—Sano74 F/T Sensor



3. Installation

Specific instructions on mounting the Sano74 sensor into the customer application can be found in the *9620-05-B-Sano74* manual.

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: Provide sufficient overvoltage protection to avoid damage to the sensor. The customer should not expose the sensor to ESD voltages out side the range ±8 kV.

CAUTION: To avoid electrical interference with nearby applications, minimize the connection distance from the sensor to the host system where EMC filtering is performed.

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

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

3.1 Pin Assignment for the EtherCAT and Power Connection

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

Pinouts and their descriptions of the connections are in the following section. The sensor requires the following power supply:

Table 3.1—Power Supply[1]

Power Source	Voltage		
	Minimum	Nominal	Maximum
DC Power	12 V	24 V	30 V

Notes:

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

Customers can either use the (2) FFC connectors or the single SM connector. Signals and corresponding pin numbers are listed in the following table.

Figure 3.1—Sano74 Sensor Connectors

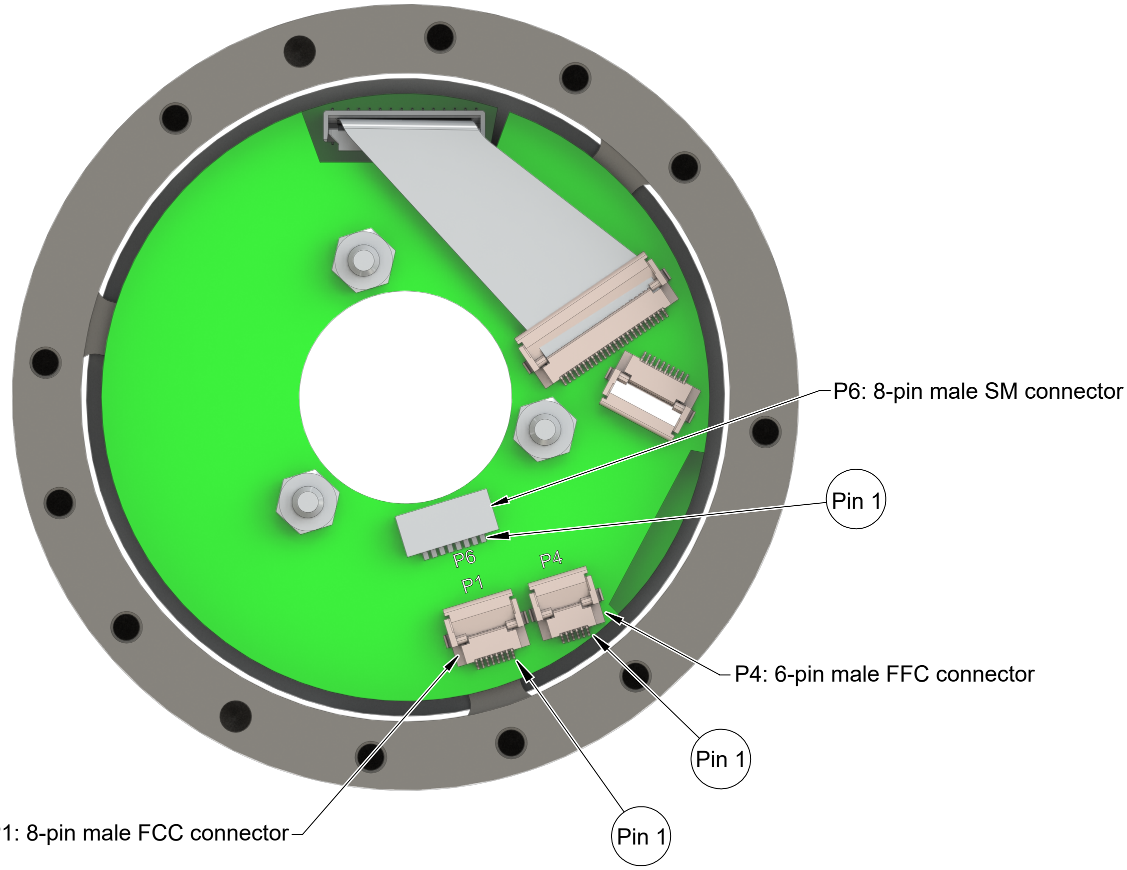


Table 3.2—Connectors' Pinouts and Signals					
P1: 8-Pin, Male, FFC Connector		**P4: 6-Pin, Male, FFC Connector**		**P6: 8-Pin, Male, SM Connector**	
Pin Number	**Signal**	**Pin Number**	**Signal**	**Pin Number**	**Signal**
1	SL0_VP	1	SL0_VP_Fused	1	SL0_VP
2	RS485 +	2	TX1 +	2	RS485 +
3	RS485 -	3	TX1 -	3	RS485 -
4	TX0 +	4	RX1 +	4	TX0 +
5	TX0 -	5	RX1 -	5	TX0 -
6	RX0 +	6	SL0_Ground	6	RX0 +
7	RX0 -	N/A	N/A	7	RX0 -
8	SL0_Ground	N/A	N/A	8	SL0_Ground

3.2 Establishing Communication with the EtherCAT Sano Sensor

The following steps guides the user through initializing communication between the EtherCAT Sano sensor and the customer's EtherCAT master device. Always refer to the software manual for the EtherCAT master device for instructions best suited for the application. If using a PC, be sure that the PC's network adapter is compatible with EtherCAT communication using the customer's EtherCAT master software.

1. Attach the sensor to the EtherCAT and power cables (refer to *Section 3.1—Pin Assignment for the EtherCAT and Power Connection* and the *9620-05-B-Sano74* manual).
2. Import the **ECAT3 Sano ESI File (ATI P/N 9031-05-1100)** that is found on the ATI website.
   - Specific steps to import the ESI file vary among the different EtherCAT master software and hardware available to the customer.
3. Configure the EtherCAT master device to communicate with the EtherCAT sensor.
4. In the software for the EtherCAT master, read the calibration data at system start by using a SDO read to Object 0x2021, the Calibration Object (refer to *Section 5.2.2—Object 0x2021: Calibration*).

3.3 Set-up RS485 Communication Interface

The RS485 Sano sensor is a serial device that is used programmatically with the user's application.

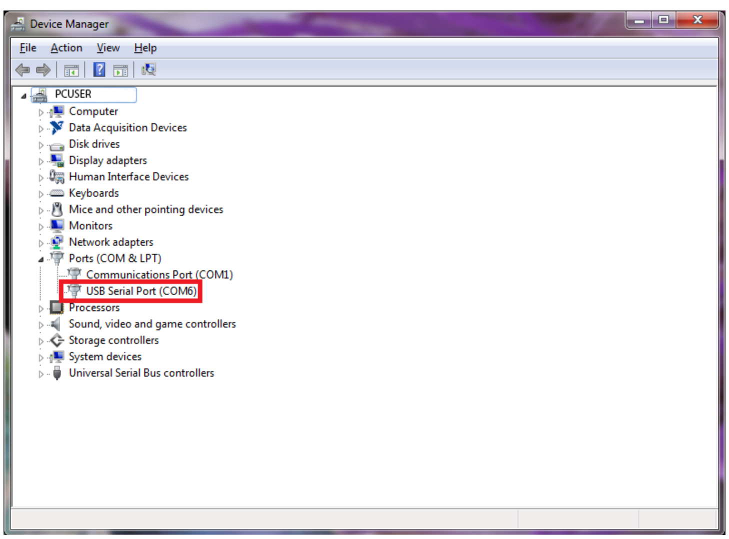
When the sensor is attached via cable to the customer's device, such as a personal computer or robot, the computer assigns the sensor a COM port. Then by using a console on the computer, the user can communicate with the sensor. Free console software, such as PuTTY, is available online. Commands are covered in *Section 5—Serial Commands*.

For additional instructions on setting up a console like PuTTY, refer to the following procedure:

1. If an RS485 serial port is not on the customer device, use a third party serial device to add the port.
2. Connect the RS485 cable from the sensor configuration to the RS485 serial port.
3. Find the COM port that is assigned to the Sano sensor device. This can be achieved via the Device Manager.

NOTICE: The name of the device may differ based on the name of the PC's RS485 port or name of the third-party RS485 device.

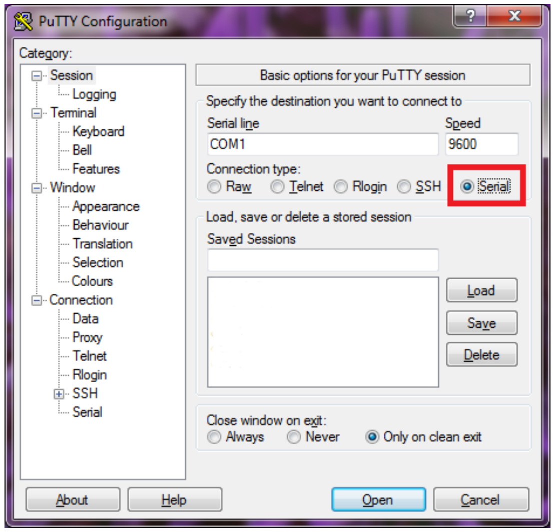
Figure 3.2—Device Manager, Port Assignment



4. Open the console, for example: PuTTY. A window opens that allows the user to set the configuration for the session.

5. Set the configuration:
    a. Under **Connection type:** select the radio button for **Serial**.

Figure 3.3—Set the Connection Type to Serial

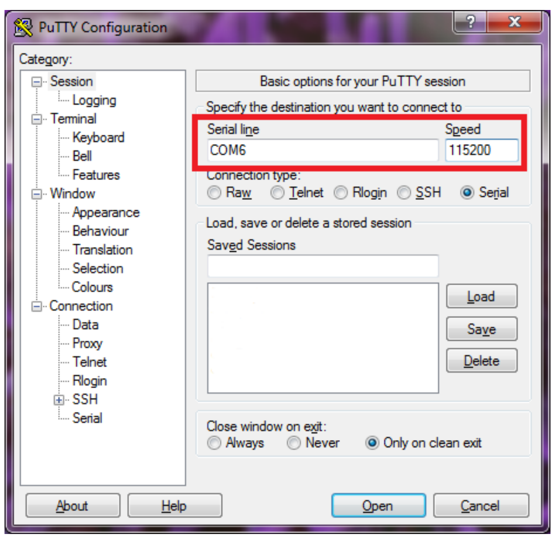


    b. In the **Serial Line** field, enter the assigned COM port from step *3*.

    c. In the **Speed** field, enter the default baud rate of 115200 or the baud rate to which the user has set the RS485 Sano sensor: refer to *Section 5.3—CAL or SET Operands*.

NOTICE: If the baud rate that is set on the console configuration does not match the baud rate set on the RS485 Sano sensor, then the console terminal window will open but commands cannot be sent. The factory default baud rate is 115200.

Figure 3.4—Set the COM port and the Baud Rate



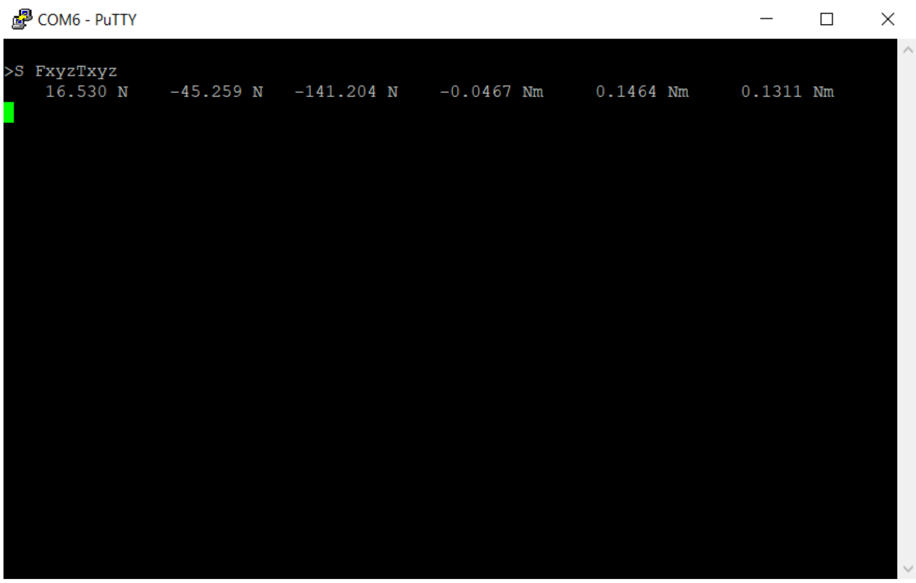
    d. Select **Open**.

e. After a terminal window opens, the user can then start entering commands.

f. After a serial command is typed into the console, press the (enter) key to send the command.

NOTICE: Commands which are entered are not case sensitive.

Figure 3.5—PuTTY Terminal Window



4. Operation

For general operation information about the sensor, also refer to the *9620-05-B-Sano74* manual.

4.1 LED Self-Test Sequence

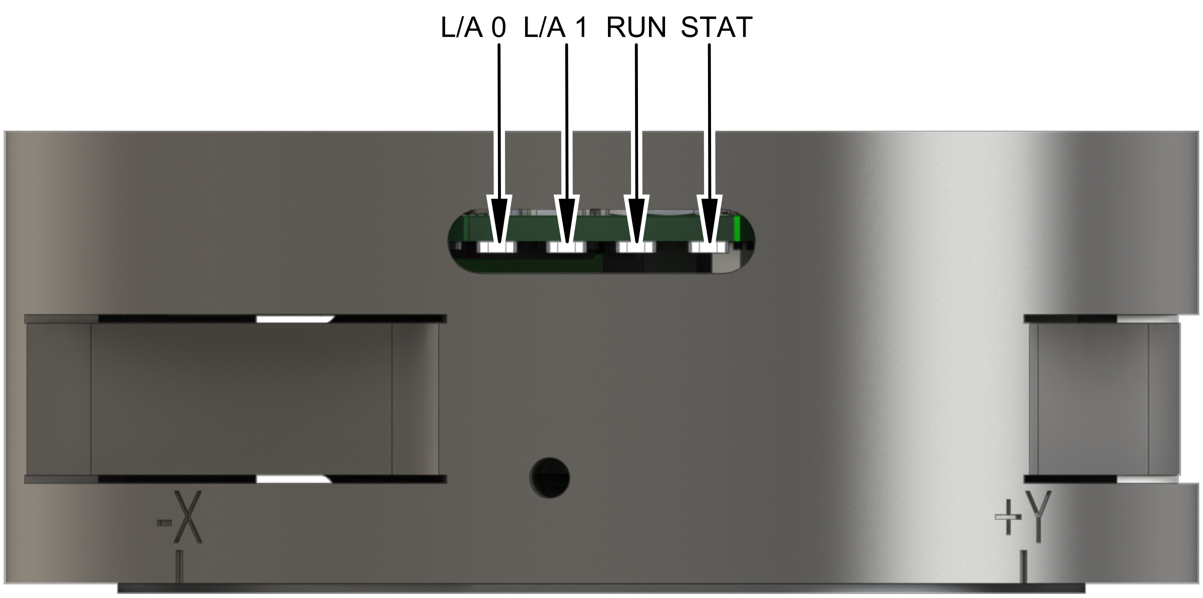
The EtherCAT Sano sensor has four LEDs:

- (2) EtherCAT Link/Activity (L/A): L/A 0 and L/A 1
- (1) Run
- (1) Status

When the user applies power, the sensor completes a self-test, during which the LEDs under firmware control turn on individually.

<table>
<tr><th colspan="4">Table 4.1—LED Self Test Sequence</th></tr>
<tr><th>Sequence Order</th><th>LED</th><th>Color</th><th>Duration</th></tr>
<tr><td>0</td><td>All</td><td colspan="2">At power on, some transient activity may be seen for only a few milliseconds.</td></tr>
<tr><td>1</td><td>All</td><td>Off</td><td rowspan="8">For each step in the sequence, the LED’s color displays approximately one second.</td></tr>
<tr><td>2</td><td>L/A 0</td><td>Green</td></tr>
<tr><td>3</td><td>L/A 1</td><td>Green</td></tr>
<tr><td>4</td><td>Run</td><td>Red</td></tr>
<tr><td>5</td><td>Status</td><td>Red</td></tr>
<tr><td>6</td><td>Status</td><td>Green</td></tr>
<tr><td>7</td><td>Status</td><td>Blue</td></tr>
<tr><td>8</td><td>All</td><td>Off</td></tr>
</table>

Figure 4.1—LEDs on the Sensor



4.2 LED Normal Operation

4.2.1 Status LED

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

Table 4.2—Status LED

LED Color	State	Description
Off	No power	Power not supplied to the sensor.
Green	Normal operation	The sensor's electronics are functioning and communicating.
Orange[1]	F/T out of range	Forces and torques supplied to the sensor exceed ranges in the *9620-05-B-Sano74* manual.
Fast Blinking Red	Communication error	The sensor is not able to communicate data over the communication protocol.
Slow Blinking Red	Calibration error	Calibration was not stored in the EEPROM.
Red (Solid)	Status code error	For more information on the error set, refer to *Table 7.2*.

Note:
1. Orange is when both green and red LEDs are on.

4.2.2 Run LED

One LED signals the EtherCAT run state as follows:

Table 4.3—Run LED

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

4.2.3 EtherCAT L/A (Link/Activity) LEDs: L/A 0 and L/A 1

Two LEDs signal the communication status of each EtherCAT port as follows:

Table 4.4—L/A 0 and L/A 1

LED Color	State	Description
Off	No power or no link activity	Either no link activity has occurred within 5 seconds or power is not supplied to the sensor.
Green	Link activity	Stays green for five seconds after link activity. LA0 will illuminate for any activity in ECAT link 0 or any console activity in serial-only mode. LA1 will illuminate for any activity in ECAT link 1.

4.3 F/T Sample Rate

The user can set the sample rate to control how quickly the ADC is sampling gage data inside the sensor. Rounded and exact sample rates are in the following table.

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

4.3.1 Sample Rate Versus Data Rate

The sample rate is how quickly andalog gage data is converted into digital samples by the ADC. Similarly, the data rate is how quickly F/T and IMU data can be output over the network. Sometimes the data rate can be referred to as communication rate or network data communication rate, for example TwinCAT references it as cycle time.

NOTICE: The IMU data can be transmitted at a max rate of 400 Hz. If the overall data rate is greater than 400 Hz, the sensor reports the same IMU sample for several data packets in a row.

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

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

4.4 Low-Pass Filter

The power-on default selection is no filtering. Users can configure the filter setting to reduce the signal noise. A normalized cutoff frequency (at a sample rate of 1 Hz) for a filter coefficient is listed in the following table. The rise time is how long the system takes at a given filter coefficient to output 90% of the final sample.

Table 4.6—Low-Pass Filtering

Filter Coefficient	Cutoff Frequency (Percent of ADC sample rate)	Rise Time (Samples)
0	none	1
1	11.97%	3
2	4.66%	8
3	2.17%	16
4	1.04%	34
5	0.51%	69
6	0.26%	140
7	0.12%	280
8	0.07%	561

5. EtherCAT Bus Interface

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

- Read the active calibration information and serial number
- Read the firmware version
- Read F/T and IMU data
- Read strain gage data and status information
- Set low-pass filter cutoff frequency
- Bias the sensor
- Change the sample rate
- Monitor the sensor's health

5.1 PDO Interface

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

a. TxPDO Map / Output Data
The TxPDO combines *Object 0x6000: Reading Data*, *Object 0x6010: Status Code*, *Object 0x6020: Sample Counter*, and *Object 0x6050: IMU Data*.

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

5.2 EtherCAT Dictionary Objects (SDO Data), ATI Specific

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 Sano ESI File (ATI P/N 9031-05-1100)** that is available to download from the ATI webpage: *https://www.ati-ia.com/Products/ft/software/Sano74_software.aspx*.

While using some dictionary objects, the user may need to convert a code from hexadecimal to a binary number (refer to *Section 5.2.14—How to Interpret Hexadecimal Output*).

5.2.1 Object 0x2020: Tool Transformation

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

<table>
<tr><th colspan="5">Table 5.1—Object Index (hex) 0x2020: Tool Transformation</th></tr>
<tr><th>Subindex</th><th>Name</th><th>Type</th><th colspan="2">Description</th></tr>
<tr><td>0x01</td><td>Dx</td><td rowspan="6">STRING(16)</td><td colspan="2">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.</td></tr>
<tr><td>0x02</td><td>Dy</td><td colspan="2">The displacement along the y axis, in units of 0.01 calibration length units.</td></tr>
<tr><td>0x03</td><td>Dz</td><td colspan="2">The displacement along the z axis, in units of 0.01 calibration length units.</td></tr>
<tr><td>0x04</td><td>Rx</td><td colspan="2">The rotation about the X axis, in units of 0.1 degrees, e.g. an Rx value of 900 = 90 degrees.</td></tr>
<tr><td>0x05</td><td>Ry</td><td colspan="2">The rotation about the Y axis, in units of 0.1 degrees.</td></tr>
<tr><td>0x06</td><td>Rz</td><td colspan="2">The rotation about the Z axis, in units of 0.1 degrees.</td></tr>
<tr><td rowspan="6">0x07</td><td rowspan="6">ttDistUnits</td><td rowspan="10">USINT</td><th>Value</th><th>Unit</th></tr>
<tr><td>0</td><td>in</td></tr>
<tr><td>1</td><td>ft</td></tr>
<tr><td>2</td><td>mm</td></tr>
<tr><td>3</td><td>cm</td></tr>
<tr><td>4</td><td>m</td></tr>
<tr><td rowspan="3">0x08</td><td rowspan="3">ttAngUnits</td><th>Value</th><th>Unit</th></tr>
<tr><td>0</td><td>degrees</td></tr>
<tr><td>1</td><td>radians</td></tr>
<tr><td>0x09</td><td>Commit</td><td colspan="2">Use to send the command.</td></tr>
</table>

5.2.2 Object 0x2021: Calibration

This read-only object contains information about the currently active calibration selected by the “Calibration Selection” field in *Section 5.2.13—Object 0x7010: Control Codes*. This object contains the following fields:

<table>
<tr><th colspan="5">Table 5.2— Object Index (hex) 0x2021: Calibration</th></tr>
<tr><th colspan="2">Subindex</th><th>Name</th><th>Type</th><th>Description</th></tr>
<tr><td>1.</td><td>01</td><td>FT Serial</td><td>STRING(8)</td><td>The F/T Serial Number, e.g. “FT01234”.[1]</td></tr>
<tr><td colspan="5">Notes:
1. This field identifies an individual sensor. A sensor may have more than one FTxxxxx calibration serial number; each F/T calibration serial number identifies a separate calibration. No two sensors share a F/T calibration serial number.
2. This field identifies the calibration. For sensing ranges, refer to the 9620-05-B-Sano74 manual.
3. When powered on, the sensor records the peak values detected on any single axis. If the sensor detects all-time peak values higher than the ATI factory defaults, the sensor has been loaded past the intended calibrated sensing range.</td></tr>
</table>

<table>
<tr><th colspan="5">Table 5.2— Object Index (hex) 0x2021: Calibration</th></tr>
<tr><th colspan="2">Subindex</th><th>Name</th><th>Type</th><th>Description</th></tr>
<tr><td>2.</td><td>02</td><td>Calibration Part Number</td><td>STRING(30)</td><td>The calibration part number e.g. “SI-130-13.4”.[2]</td></tr>
<tr><td>3.</td><td>03</td><td>Calibration Family</td><td>STRING(8)</td><td>Always reads “ECAT”.</td></tr>
<tr><td>4.</td><td>04</td><td>Calibration Time</td><td>STRING(30)</td><td>The date the sensor was calibrated.</td></tr>
<tr><td>5. to 40.</td><td>05 to 28</td><td>Reserved</td><td colspan="2">Reserved</td></tr>
<tr><td>41</td><td>29</td><td>Force Units</td><td>USINT</td><td><table><tr><th>Value</th><th>Unit</th></tr><tr><td>0</td><td>Lbf</td></tr><tr><td>1</td><td>N</td></tr><tr><td>2</td><td>Klbf</td></tr><tr><td>3</td><td>kN</td></tr><tr><td>4</td><td>Kg</td></tr></table></td></tr>
<tr><td>42.</td><td>2A</td><td>Torque Units</td><td>USINT</td><td><table><tr><th>Value</th><th>Unit</th></tr><tr><td>0</td><td>lbf-in</td></tr><tr><td>1</td><td>lbf-ft</td></tr><tr><td>2</td><td>Nm</td></tr><tr><td>3</td><td>Nmm</td></tr><tr><td>4</td><td>Kgf-cm</td></tr><tr><td>5</td><td>kNm</td></tr></table></td></tr>
<tr><td>43.</td><td>2B</td><td>Max Fx Counts</td><td rowspan="6">DINT</td><td rowspan="6">The maximum rated value for this axis, in counts.</td></tr>
<tr><td>44.</td><td>2C</td><td>Max Fy Counts</td></tr>
<tr><td>45.</td><td>2D</td><td>Max Fz Counts</td></tr>
<tr><td>46.</td><td>2E</td><td>Max Tx Counts</td></tr>
<tr><td>47.</td><td>2F</td><td>Max Ty Counts</td></tr>
<tr><td>48.</td><td>30</td><td>Max Tz Counts</td></tr>
<tr><td>49.</td><td>31</td><td>Counts Per Force</td><td>DINT</td><td>The calibration counts per force unit.</td></tr>
<tr><td>50.</td><td>32</td><td>Counts Per Torque</td><td>DINT</td><td>The calibration counts per torque unit.</td></tr>
<tr><td>51. to 66.</td><td>33 to 42</td><td>Reserved</td><td colspan="2">Reserved</td></tr>
<tr><td colspan="5">Notes:
1. This field identifies an individual sensor. A sensor may have more than one FTxxxxx calibration serial number; each F/T calibration serial number identifies a separate calibration. No two sensors share a F/T calibration serial number.
2. This field identifies the calibration. For sensing ranges, refer to the *9620-05-B-Sano74* manual.
3. When powered on, the sensor records the peak values detected on any single axis. If the sensor detects all-time peak values higher than the ATI factory defaults, the sensor has been loaded past the intended calibrated sensing range.</td></tr>
</table>

Table 5.2— Object Index (hex) 0x2021: Calibration				
Subindex		**Name**	**Type**	**Description**
67.	43	PeakLoadsPosFx[3]	DINT	Peak Loads[3] Positive. All-time peak positive F/T loads in counts.
68.	44	PeakLoadsPosFy[3]		
69.	45	PeakLoadsPosFz[3]		
70.	46	PeakLoadsPosTx[3]		
71.	47	PeakLoadsPosTy[3]		
72.	48	PeakLoadsPosTz[3]		
73.	49	PeakLoadsNegFx[3]	DINT	Peak Loads[3] Negative. All-time peak negative F/T loads in counts.
74.	4A	PeakLoadsNegFy[3]		
75.	4B	PeakLoadsNegFz[3]		
76.	4C	PeakLoadsNegTx[3]		
77.	4D	PeakLoadsNegTy[3]		
78.	4E	PeakLoadsNegTz[3]		
79. to 106.	4F to 6A	Reserved		
107	6B	Max Fx Counts ER	UINT32	Extended Range Value for Fx in FT Counts
108	6C	Max Fy Counts ER		Extended Range Value for Fy in FT Counts
109	6D	Max Fz Counts ER		Extended Range Value for Fz in FT Counts
110	6E	Max Tx Counts ER		Extended Range Value for Tx in FT Counts
111	6F	Max Ty Counts ER		Extended Range Value for Ty in FT Counts
112	70	Max Tz Counts ER		Extended Range Value for Tz in FT Counts
113	71	ftOorCountMr		Number of times the unit exceeded the normal sensing range.
114	72	ftOorCountEr		Number of times the unit exceeded the extended sensing range.

Notes:

1. This field identifies an individual sensor. A sensor may have more than one FTxxxxx calibration serial number; each F/T calibration serial number identifies a separate calibration. No two sensors share a F/T calibration serial number.
2. This field identifies the calibration. For sensing ranges, refer to the *9620-05-B-Sano74* manual.
3. When powered on, the sensor records the peak values detected on any single axis. If the sensor detects all-time peak values higher than the ATI factory defaults, the sensor has been loaded past the intended calibrated sensing range.

5.2.3 Object 0x2023: Console Over EtherCAT

This object allows the system to communicate with a serial interface console. For serial console commands, refer to *Section 6—Console Commands via Serial*.

Table 5.3—Object Index (hex) 0x2080: Diagnostic Readings

Subindex	Name	Type	Description
0x01	Command	STRING(100)	A command is sent to the console.
0x02	Response	STRING(100)	A response prints to the console.
0x03	Commit	UNIT16	Type "1" to activate the command.

5.2.4 Object 0x2060: Monitor Conditions

This read and write object configures an axis, a threshold value, and a direction to continuously evaluate against the current F/T data. Enable and reset the Monitor Condition in *Object 0x7010: Control Codes*. If a Monitor Condition occurs, Status bit 16 is set (*Section 5.2.8—Object 0x6010: Status Code*). In this object, the following fields are available:

<table>
<tr><th colspan="5">Table 5.4—Object Index (hex) 0x2080: Diagnostic Readings</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 F/T 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, 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.</td></tr>
<tr><td>0x04</td><td>Commit</td><td>UNIT16</td><td colspan="2">Type "123" here to set the changes</td></tr>
</table>

5.2.5 Object 0x2080: Diagnostic Readings

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

Table 5.5—Object Index (hex) 0x2080: Diagnostic Readings			
Subindex	**Name**	**Type**	**Description**
0x01	Supply Voltage	UINT16	The voltage of the external power supply x 10.
0x02	PCB Temperature	INT16	The sensor board temperature in °C x10.
0x03	Status Message	STRING(40)	A priority status code error message (refer to *Table 5.6*)
0x04	TAP Temperature	INT16	The TAP temperature in °C x 10.
0x05	Mounting Side Temperature	INT16	The mounting side temperature in °C x 10.

If an error occurs, a text message displays in the SDO-0x2080 subindex 0x03. If more than one error occurs, the highest priority error in the following table displays its text message.

Table 5.6—Errors in the Diagnostic Readings Status Message	
Priority	**Text Error Messages**
1	Supply voltage out of range
2	Gage temperature out of range
3	Calibration checksum error
4	Gage(s) disconnected: <list>
5	Gage(s) out-of-range: <list>
6	F/T out of range
7	Hardware or stack error
8	Simulated error
9	Monitor condition 0
10	Error (unspecified)
11	No status code errors

5.2.6 Object 0x2090: Version

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

Table 5.7—Object Index (hex) 0x2090: 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	sensorHwVer	UINT16	Sensor Hardware Version
0x06	sensorInstrument	UINT16	Internal manufacturing data

5.2.7 Object 0x6000: Reading Data

This read-only object represents the current Force and Torque data and is mapped into the TxPDO input data. In this object, the following fields are present:

Table 5.8—Object Index (hex) 0x6000: Reading Data			
Subindex	**Name**	**Type**	**Description**
0x01	Fx	DINT	These fields contain the 32-bit F/T resolved data, in counts. For the force data to be in units, divide the force counts values by the counts per force field from the calibration object. For the torque data to be in units, divide the torque counts values by the counts per torque field from the calibration object.
0x02	Fy		
0x03	Fz		
0x04	Tx		
0x05	Ty		
0x06	Tz		

5.2.8 Object 0x6010: Status Code

This object contains a single DINT value (at subindex 0). Refer to *Section 7.2—Status Code.*

5.2.9 Object 0x6020: Sample Counter

This object contains a single 32-bit unsigned integer (UDINT) at subindex 0 that increases by one each time one complete set of gage data is read. This number rolls over from 4 294 967 295 (2^{32}-1) to 0 without signalling an error. The sample counter is reset to zero during power up.

5.2.10 Object 0x6030: Gage Data

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

Table 5.9—Object Index (hex) 0x6030: Raw Unbiased Gage Data			
Subindex	**Name**	**Type**	**Description**
0x01	Gage 0	DINT	These fields contain the 32-bit gage data.
0x02	Gage 1		
0x03	Gage 2		
0x04	Gage 3		
0x05	Gage 4		
0x06	Gage 5		
0x07	Gage 6		
0x08	Gage7		

5.2.11 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 5.10—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/s².
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		

5.2.12 IMU Accuracy Checking Procedure

The IMU contains a self-accuracy check, which monitors the output of the accelerometer and gyroscope. The corresponding outputs are described in *Table 5.11.*

Table 5.11—IMU Accuracy Bit Assignments	
Description	**Bits**
Linear Acceleration Accuracy Level	76
Accelerometer Accuracy Level	54
Gyro Accuracy Level	32

The accuracy of the IMU data is reported to the end user with the following definitions:

Table 5.12—IMU Accuracy Level Mask		
Description	**Binary Value**	**Decimal Value**
Unreliable	00	0
Accuracy Low	01	1
Accuracy Medium	10	2
Accuracy High	11	3

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 *9620-05-B-Sano74* manual.

By referencing *Table 5.11* and *Table 5.12,* the user can match the binary output with an accuracy level. For example, if the binary output was 0010 0100, it would indicate the linear accelerometer (00) is unreliable, the accelerometer (10) is medium accuracy, and the gyroscope (01) is low accuracy.

5.2.13 Object 0x7010: Control Codes

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

<table>
<tr><th colspan="6">Table 5.13—Object Index (hex) 0x7010: Control Codes</th></tr>
<tr><th>Subindex</th><th>Name</th><th>Type</th><th colspan="3">Description</th></tr>
<tr><th colspan="3"></th><th>Bit</th><th colspan="2">Function</th></tr>
<tr><td rowspan="15">0x01</td><td rowspan="15">Control1</td><td rowspan="15">DINT</td><td>0</td><td colspan="2">1 = Set bias (tare) against current load
0 = Leave bias unchanged[1]</td></tr>
<tr><td>1</td><td colspan="2">Clear Monitor Condition 0:
1= Clear
0 = Leave alone</td></tr>
<tr><td>2</td><td colspan="2">1 = Clear bias
0 = Leave bias unchanged</td></tr>
<tr><td>3</td><td colspan="2">1 = Output gages 0-5 on PDO
0 = Output F/T in PDO</td></tr>
<tr><td>4-7</td><td colspan="2">Filter Selection. Refer to *Section 4.4—Low-Pass Filter*.</td></tr>
<tr><td>8-11</td><td colspan="2">Active Calibration:
0 = Use the calibration in slot 0
1 = Use the calibration in slot 1
2 = Use the calibration in slot 2
All other values are reserved.</td></tr>
<tr><td>12-15</td><td colspan="2">Sample Rate:
0 = 500 Hz
1 = 1000 Hz
2 = 2000 Hz
3 = 4000 Hz
4 = 8000 Hz
All other values are reserved.</td></tr>
<tr><td>16</td><td colspan="2">IMU Calibrate Save Function:
After the user completes the calibration procedure as described in *Section 3.5—IMU Dynamic Calibration Procedure* of the *9620-05-B-Sano74* manual, the dynamic calibrations must be saved to memory to be retained through power cycles.
The command is issued to the IMU on each rising edge of this bit.</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 5.2.13.1—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>
</table>

<table>
<tr><th colspan="6">Table 5.13—Object Index (hex) 0x7010: Control Codes</th></tr>
<tr><th>Subindex</th><th>Name</th><th>Type</th><th colspan="3">Description</th></tr>
<tr><td rowspan="4">0x01</td><td rowspan="4">Control1</td><td rowspan="4">DINT</td><td rowspan="3">24-27</td><td colspan="2">IMU gyroscope gain selection. This value will remain as 5, as 2000 degrees per second (DPS) is the only allowable gain selection for the gyroscope. Refer to Section 5.2.13.1—IMU Accelerometer and Gyroscope</td></tr>
<tr><th>Value</th><th>Gain</th></tr>
<tr><td>5</td><td>2000 DPS</td></tr>
<tr><td>28-31</td><td colspan="2">Reserved</td></tr>
<tr><th></th><th></th><th></th><th>Bit</th><th colspan="2">Function</th></tr>
<tr><td rowspan="3">0x02</td><td rowspan="3">Control2</td><td rowspan="3">DINT</td><td>0</td><td colspan="2">Enable checking of Monitor Condition 0</td></tr>
<tr><td>1-30</td><td colspan="2">Reserved</td></tr>
<tr><td>31</td><td colspan="2">Simulated Error Control</td></tr>
<tr><td colspan="6">Notes:
1. The 0 represents a default value, which resets every time a new gain is established. For insance, if the user sets the accelerometer gain to 2g, 0 will then represent 2g until the gain is changed again.</td></tr>
</table>

5.2.13.1 IMU Accelerometer and Gyroscope

NOTICE: Prior to streaming or setting up IMU data, the user needs to complete an IMU calibration as outlined in *Section 3.5—IMU Dynamic Calibration Procedure* of the *9620-05-B-Sano74* manual.

The Sano74 IMU accelerometer and gyroscope can be configured via bits 20-27. The following four combinations outlined in *Table 5.14* are available for the user. Any other combination of accelerometer and gyroscope gain selections will result in an error.

Table 5.14—Allowed IMU Configurations	
Accelerometer Gain	**Gyroscope Gain**
2g	2000 DPS
4g	2000 DPS
8g	2000 DPS
16g	2000 DPS

To stream IMU data, reference *Section 5.2.11—Object 0x6050: IMU Data.*

5.2.14 EtherCAT Communication Objects

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

5.2.14.1 Object 0x1000: Device Type

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

Table 5.15—Object Index (hex) 0x1000: Device Type			
Type	**Description**	**Default Value (hex)**	**Default Value (decimal)**
UDINT	The EtherCAT device category under which the ATI EtherCAT Sano is categorized.	0x00000192	402

5.2.14.2 Object 0x1008: Device Name

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

Table 5.16—Object Index (hex) 0x1008: Device Name		
Type	**Description**	**Default Value (string)**
STRING	The name of the device as a non-zero terminated string. Do not use for product identification.[1]	"ATI Sano74 F/T Sensor"
Note: 1. Because this field can change, do not use this field for product identification. For fields that can be used for product identification, refer to *Section 5.2.14.3—Object 0x1018: Identity*.		

5.2.14.3 Object 0x1018: Identity

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

Table 5.17—Object Index (hex) 0x1018: Identity Object

Subindex (Hex)	Name	Functionality	Type	Default Value (hex)	Default Value (decimal)
0x01	Vendor ID	This Vendor ID number is assigned by EtherCAT® Technology Group uniquely to ATI.[1]	UDINT	0x00000732	1842
0x02	Product Code	This Product Code is assigned by ATI uniquely to the EtherCAT Sano sensors.[2]	UDINT	0x26483053	642265171
0x03	Revision Number	This field is subject to change and should not be used for identification purposes.[3]	UDINT	N/A	
0x04	Serial Number	This field is subject to change and should not be used for identification purposes.[4]			

Note:

1. Because this field does not change among ATI products, use Vendor ID for product identification.
2. For EtherCAT Sano sensors, this field does not change and can be used for product identification.
3. To identify a sensor model and calibration size, refer to *Section 5.2.2—Object 0x2021: Calibration*, subindex 0x02 (calibration part number).
4. To identify an individual sensor, refer to *Section 5.2.2—Object 0x2021: Calibration*, subindex 0x01 (F/T Serial).

5.2.14.4 Unused EtherCAT Objects

The EtherCAT® Technology Group defines the structure of these object but leaves them as optional. Currently, ATI does not use these fields. Instead, the information is included in *Section 5.2—EtherCAT Dictionary Objects (SDO Data), ATI Specific*. To know what ATI objects should be reference, refer to the following table:

Table 5.18—Unused EtherCAT Objects					
Object Index (Hex)	**Object Name**	**Type**	**Cross-Reference to the ATI Specific Area Objects**	**Default Value (hex)**	**Default Value (decimal)**
0x1001	Error Register	USINT	To monitor the F/T sensor status code, refer to *Section 5.2.8—Object 0x6010: Status Code*.	0x00	0
0x1009	Hardware Version	STRING	To view the F/T sensor hardware version, refer to *Section 5.2.6—Object 0x2090: Version*.	N/A	
0x100A	Software Version	STRING	To view the sensor software version, refer to *Section 5.2.6—Object 0x2090: Version*.		

5.3 Converting F/T Data from Counts to Units

Upon receipt of each real-time PDO sample, divide the force and torque counts values by the counts per force and counts per torque values from *Section 5.2.2—Object 0x2021: Calibration* to calculate the F/T units values.

Important notes about units:

- End users may select and set F/T units are in the calibration object.
- For different units, the software for the EtherCAT master device can adjust the counts per force and counts per torque values so that the resulting units are in the end user's desired units.

For example, the calibration outputs 1,000,000 counts per Newton (N). To convert the output in counts per pound force (lbf), follow this calculation:

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

6. Console Commands via Serial

These console commands can be used to view the status, parameters, and adjust settings of the sensor. To set up a serial console, refer to *Section 3.2—Set-up of the RS485 Communication Interface*.

6.1 Summary of Commands

Table 6.1—Console Commands

Command	Operands	Description	User Read/ Write
HELP H MAN ?	(none)	This command prints a list of the main commands and software version.	Read
BIAS	(none)	Prints the current bias status of the sensor.	Read
	on	Turns the bias feature on and sets the F/T output to 0.	Write
	off	Turns the bias feature off and clears the bias bit.	
	values	Turns the bias feature on with values defined by user.	
PEAK	(none)	Prints the highest and lowest F/T values in units that occurred for a runtime and for all-time since the last peak reset command was sent.	Read
	C	Prints the highest and lowest F/T values in counts that occurred for a runtime and for all-time since the last peak reset command was sent.	Read
	RESET	Sets the current F/T values back to default values.	Write
C	(none)	A query command starts the high-speed transmission of F/T data. This command prints continuous lines of F/T data in units until the end user holds another key, such as Enter. Data reports at the rate specified in the rdtRate.	Read
	Section 6.2—Operands for the Query (C or S) Command	Prints user-specified gage, F/T, or IMU data in continuous mode.	Read
S	(none)	A query command starts the high-speed transmission of F/T data. This command prints a single line of F/T data in units.	Read
	Section 6.2—Operands for the Query (C or S) Command	Prints user-specified gage, F/T, or IMU data in a single line.	Read
SET	(none)	Prints all settings or values. Reference *Section 6.3—Set Command*	Read
	[field name]	Prints setting value for specific field typed by the user.	Read
	[field name] [value]	Sets specific setting field with value entered.	Write

Table 6.1—Console Commands			
Command	**Operands**	**Description**	**User Read/ Write**
SIMERR	(none)	Reports if the simmulated error functionality is enabled or disabled. This command refers to bit 28 from *Table 7.2*. The simulated error command is useful for customers, who need to test their error handling routines. When a simmulated error occurs, the “red” status LED turns on; refer to *Section 4.2.1—Status LED*.	Read
	ON	Turns on the simulated error functionality.	Write
	OFF	Turns off the simulated error functionality.	Write
RESET	(none)	Sets the sensor's processor or MCU. Prints a status report of the processor.	Read/ Write
SAVEALL	(none)	This command saves all parameters and values to the sensor's memory (NVM).	Write
STATUS	(none)	This command prints a report on the current condition of the sensor's hardware. If an underlying problem is within the sensor, the end user can forward this information to ATI for troubleshooting.	Read
VIEW	(none)	The view calibration command prints all the sensor's properties: calibration range, units, date, and family.	Read
	0	Prints properties for Calibration 0.	
	1	Prints properties for Calibration 1.	
	2	Prints properties for Calibration 2	
	A	Prints properties for the active calibration.	
DIAG	(none)	Prints a diagnostic report that includes F/T readings in units, gage readings, status code, temperature, active calibration information, the current baud rate, the current filter, the current sampling rate, and persistent peak data.	Read
SYSVER	(none)	Prints the firmware version.	Read
WHOAMI	(none)	Prints the console input source.	Read
IMUSave	(none)	Saves IMU calibration data following procedure outlined in *9620-05-B-Sano74* manual	Write
ACCLCAL	2g	Sets the IMU accelerometer sensing range between +/- 2g and the gyroscope to 2000 DPS. Refer to *Section 6.4—IMU Data*	Write
	4g	Sets the IMU accelerometer sensing range between +/- 4g and the gyroscope to 2000 DPS	
	8g	Sets the IMU accelerometer sensing range between +/- 8g and the gyroscope to 2000 DPS	
	16g	Sets the IMU accelerometer sensing range between +/- 16g and the gyroscope to 2000 DPS	
MC	(none)	Prints all monitor conditions.	Read

6.2 Operands for the Query (*C* or *S*) Command

The type of data reported from the query command can be adjusted using operands. This feature is useful for users who want to develop their own program for storing the data to an external file or view the data in figures such as charts. A list of operands is in the following table.

If a query command is issued without an operand(s), the operand(s) from the previous query command is used in the data print out. The power-on default specifier is the following: `FXYZTXYZ`.

Table 6.2—Operands for the Query Commands

Category	Operand	Notes
Gage number(s)	0	Gage values are printed in counts only. As many as all gage numbers can be reported or as few as a single gage number.
	1	
	2	
	3	
	4	
	5	
	6	
	7	
Axis	x	The user can choose to view force and torque data in the x, y, z axis. The output value can be displayed in F/T counts or engineering units. Counts are converted to units by scaling or dividing the count value by the *cpf* or *cpt* fields in *Table 5.3—Set Commands*.
	y	
	z	
Force and/or Torque	f	The XYZM force data is displayed.
	t	The XYZM torque data is displayed.
Temperature	i	Specifies sensor mounting side temperature. Prints in degrees C.
	j	Specifies sensor tooling side temperature. Prints in degrees C.
Magnitude	m	Force or torque data is displayed as the magnitude of the vector components in the x, y, and z axis. The output value can be displayed in F/T counts or engineering units. Counts are converted to units by scaling or dividing the count value by the *cpf* or *cpt* fields in *Table 5.3—Set Commands*.
Counts or Units	c	The XYZM data is displayed in counts.
	u	The XYZM data is displayed with the selected user units, for example: N or Nm. Units are the default setting.
Numeric System	h	The data is displayed as a hexadecimal number. Any data that prints in units printed is always displayed as a decimal number by default.
	d	The data is displayed as a decimal number.
Format	>	The data is displayed in a formatted, human readable output, for example: lined-up columns. > is the default setting.
	<	The data is displayed in a compressed output that has no leading zeros, trailing zeros, or unnecessary blanks. This output is intended for high-speed applications that are used in an automated setting.
Additional inputs to aid in the development of a software program	s	This input specifies a CRC.
	#	This input specifies a sample counter that is incremented each time that a *C* or *S* line is printed.
	@	This input specifies an ADC read counter that is incremented each time that the ADC is read.
	$	$ is a long specifier tag that indicates the IMU specifier. Refer to *Section 6.4—IMU Data*
Troubleshooting	!	This command specifies the 32-bit status code. Refer to *Table 7.2*

The following are examples of a *C* or *S* command with specifiers:

1. C XTY is interpreted as:

   user: `c xty`

   response: `0.001 N      0.0009 Nm`

   a. The C is a command for reporting continuous lines of data.
   b. The X specifies printing F_x, because force is the default.
   c. The T specifies printing torques whenever an x, y, z, or m is seen from now on (on this line).
   d. The Y specifies printing T_y.

2. C TXY is interpreted as:

   user: `c txy`

   response: `0.0009 Nm    0.0009 Nm`

   a. The C is a command for reporting continuous lines of data.
   b. The T specifies printing torques whenever an x, y, z, or m is seen from now on (on this line).
   c. The X specifies printing T_x.
   d. The Y specifies printing T_y.

3. S D0123 is interpreted as:

   user: `s d01234567`

   response: `246123      245592      246707      246029`

   a. The S is a command for reporting a single line of data.
   b. The D specifies printing raw ADC values in counts decimal.
   c. A number 0 through 7 specifies to print the data for the corresponding gage number. For example, the 0 specifies to print data for gage 0, and the 3 specifies to print data for gage 3.

4. S CDFXYZTXYZ is interpreted as:

   user: `s cdfxyztxyz`

   response: `961    959    963    960    966    965`

   a. The S is a command for reporting a single line of data.
   b. The C and D specifies printing x, y, z, or m FT data in counts decimal.
   c. The F specifies printing torques whenever an X, Y, Z, or M is seen from now on (on this line).
   d. The T specifies printing the torques whenever an X, Y, Z, or M is seen from now on (on this line).

6.2.1 Converting Counts Per Force/Torque to F/T Values with Units

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 command (*"Table 6.3—Set Commands"*).

For example: if a calibration reports 1,000,000 counts per N and the F_z reports 4,500,000 counts, then the force applied in the Z axis is 4.5 N.

6.3 Set Command

The set command allows users to either view or set specific settings, which are outlined in *Table 6.3—Set Commands.* The following are examples of a set command with specifiers:

1. Example: set baud

user: `set baud`

response:`baud 115200`

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

```
user:       set baud 1000000
response:   baud 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-volatile 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 6.3.*
- Remember to send a saveall command to ensure all changes are saved to non-volatile memory.

<table>
<tr><th colspan="5">Table 6.3—Set Commands</th></tr>
<tr><th>Field</th><th>Read/Edit</th><th>Example</th><th>Data Type</th><th>Description</th></tr>
<tr><td>SerialNum</td><td>Read</td><td>FT00123</td><td>STRING(8)</td><td>Calibrated F/T serial number</td></tr>
<tr><td>partNum</td><td>Read</td><td>Num-4</td><td>STRING(30)</td><td>Calibration part number</td></tr>
<tr><td>calFamily</td><td>Read</td><td>ENET</td><td>STRING(8)</td><td>Always reads “ENET”</td></tr>
<tr><td>CalTime</td><td>Read</td><td>1970-01-01 00:00</td><td>STRING(30)</td><td>Date and time sensor was calibrated</td></tr>
<tr><td>max0</td><td rowspan="6">Read</td><td rowspan="6">2147483647</td><td rowspan="6">32-bit unsigned integer</td><td rowspan="3">Maximum rated force value in counts for the that axis.</td></tr>
<tr><td>max1</td></tr>
<tr><td>max2</td></tr>
<tr><td>max3</td><td rowspan="3">Maximum rated torque value in counts for that axis.</td></tr>
<tr><td>max4</td></tr>
<tr><td>max5</td></tr>
</table>

Table 6.3—Set Commands				
Field	**Read/Edit**	**Example**	**Data Type**	**Description**
maxer0	Read	2147483647	32-bit unsigned integer	Extended Rated maximum rated force value in counts for that axis. This value is restricted to a limited amount of cycles. Refer to *Section 6.5—Extended Load Range*
maxer1				
maxer2				
maxer3				Extended Rated maximum rated torque value in counts for that axis. This value is restricted to a limited amount of cycles. Refer to *Section 6.5—Extended Load Range*
maxer4				
maxer5				
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		
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

<table>
<tr><th colspan="6">Table 6.3—Set Commands</th></tr>
<tr><th>Field</th><th>Read/Edit</th><th>Example</th><th>Data Type</th><th colspan="2">Description</th></tr>
<tr><td>adcRate</td><td rowspan="5">Read and Edit</td><td>1000 (default)</td><td rowspan="3">16-bit unsigned integer</td><td colspan="2">ADC rate in Hz: 1000, 2000, 4000, 8000, 16000.</td></tr>
<tr><td>rdtRate</td><td>40</td><td colspan="2">RDT transmission rate in Hz. This number can range from 1 to the ADC Rate.</td></tr>
<tr><td>filTc</td><td>0 (default)</td><td colspan="2">(IIR) filter code
This setting changes the parameter that determines data filtering.</td></tr>
<tr><td>calib</td><td>1</td><td>8-bit unsigned integer</td><td colspan="2">Three calibrations to use. Either 0, 1, or 2.</td></tr>
<tr><td>location</td><td>Bench</td><td>STRING(40)</td><td colspan="2">Shows physical location.</td></tr>
<tr><td>hwRev</td><td>Read</td><td>04</td><td>16-bit unsigned integer</td><td colspan="2">Hardware revision number</td></tr>
<tr><td rowspan="7">ttdu</td><td rowspan="11">Read and Edit</td><td rowspan="7">2</td><td rowspan="7">8-bit unsigned integer</td><td colspan="2">Tool Transform Distance Units:</td></tr>
<tr><th>Value</th><th>Unit</th></tr>
<tr><td>0</td><td>in</td></tr>
<tr><td>1</td><td>ft</td></tr>
<tr><td>2</td><td>mm</td></tr>
<tr><td>3</td><td>cm</td></tr>
<tr><td>4</td><td>m</td></tr>
<tr><td rowspan="4">ttau</td><td rowspan="4">1</td><td rowspan="4">8-bit unsigned integer</td><td colspan="2">Tool Transform Angle Units:</td></tr>
<tr><th>Value</th><th>Unit</th></tr>
<tr><td>0</td><td>degrees</td></tr>
<tr><td>1</td><td>radians</td></tr>
<tr><td>ttdx</td><td rowspan="6">Read and edit</td><td>0 (default)</td><td rowspan="6">float</td><td colspan="2" rowspan="3">Tool Transform distances</td></tr>
<tr><td>ttdy</td><td>0 (default)</td></tr>
<tr><td>ttdz</td><td>0 (default)</td></tr>
<tr><td>ttrx</td><td>0 (default)</td><td colspan="2" rowspan="3">Tool Transform rotation angles</td></tr>
<tr><td>ttry</td><td>0 (default)</td></tr>
<tr><td>ttrz</td><td>0 (default)</td></tr>
<tr><td>baud</td><td rowspan="2">Read and edit</td><td>115200 (default)</td><td>32-bit unsigned integer</td><td colspan="2">UART baud rate. Must be between 300 and 3M. All baud rates are temporary until saveall command is sent.</td></tr>
<tr><td>msg</td><td>1</td><td rowspan="2">8-bit unsigned integer</td><td colspan="2">0=print only prompted messages
1=print all messages</td></tr>
<tr><td>serial</td><td>Read</td><td>0</td><td colspan="2">0= Ethernet and serial
1=Serial-only mode.</td></tr>
</table>

Table 6.3—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.

6.4 IMU Data

NOTICE: Prior to streaming or setting up IMU data, the user needs to complete an IMU calibration as outlined in the *9620-05-B-Sano74* manual

6.4.1 Configuring Accelerometer and Gyroscope

The Sano74 IMU accelerometer and gyroscope can be configured by using the `acclcal` command (reference *Table 6.1).* The following four 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

6.4.2 Streaming IMU Data

Accelerometer and gyroscope IMU data is streamed via C/S commands using long specifiers. After a specifier tag **$** from *Table 6.2*, long specifiers outline IMU steaming data. Additional modifiers may be used to control the type of data. Reference *Table 6.5——IMU Specifiers* for IMU data streaming options.

Table 6.4—IMU Specifiers

Specifier	Name	Modifiers[1]	Units	Type	Axes
$A	Accelerometer	C	counts	16-bit	XYZ
		U	m/s^2		
$G	Gyroscope	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
$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 6.4.3—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.

6.4.3 IMU Accuracy Checking Procedure

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

Table 6.5—IMU Accuracy Level Mask		
Description	**Binary Value**	**Decimal Value**
Unreliable	00	0
Accuracy Low	01	1
Accuracy Medium	10	2
Accuracy High	11	3

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 IMU Dynamic Calibration Procedure outlined in the *9620-05-B-Sano74* manual.

To properly read the accuracy level output, the user will need to convert the hexadecimal output into binary.

1. Example: Accuracy Levels

user: `s $acl`

response: `s $acl`
`24`

- By entering the `s` command with the operand `$acl`, the sensor will print the acceleration and gyromscope accuracy levels.
- Data is printed in hexadecimal. The user will need to convert the hexadecimal output to binary to read the accuracy level. In this example, 24 would convert to 0010 0100 in binary.
- By referencing *Table 6.5,* the user can match the binary output with an accuracy level. In this example, 0010 0100 would indicate the linear accelerometer (00) is unreliable, the accelerometer (10) is medium accuracy, and the gyroscope (01) is low accuracy.

6.5 Extended Load Range

ATI's Sano sensors are equipped with an extended load range functionality, which allows the user to exceed the calibrated load rating of the sensor for up to 250,000 cycles within the specified extended load range. The specific extended range is outlined in the following table.

Table 6.6—Calibration and Extended Sensing Range

Axis	Calibration Range	Extended Range
F_x	130 N	130 N
F_y	130 N	130 N
F_z	400 N	400 N
T_x	12 Nm	20 Nm
T_y	12 Nm	20 Nm
T_z	12 Nm	20 Nm

A counter is available to keep track of how many cycles the sensor has operated within this extended load range. The counter will track every time the unit exceeds the normal calibration range, and every time the unit exceeds the extended sensing range.

This counter is called FtOorCountMr for the normal calibration measurement range and FtOorCountER for the extended range. Executing a `set ft` command will report a total count for each range. For example:

user: `set ft`

response:

```
Field           Value
-----           -----
ftOorCountMr    5910
ftOorCountEr    0
```

The same fields, and corresponding values, can be found within the status command response. For EtherCAT users, these counters are available within Object 0x2021. Refer to *Section 5.2.2—Object 0x2021: Calibration.*

While the extended load range provides the user application flexibility, any data streamed while the sensor operates within the extended load range is not guaranteed to meet accuracy specifications.

7. Troubleshooting

This section includes solutions to some issues that might arise when setting-up and using the sensor. For more troubleshooting guidance, refer to the *9620-05-B-Sano74* manual. Answers to frequently asked questions are available from the ATI website: *https://www.ati-ia.com/library/documents/FT_FAQ.pdf*.

> Note:
>
> Please read the manual before calling customer service. Before calling, have the following information available:
>
> 1. Serial number, for example: FT01234
> 2. Sensor model, for example: Sano74
> 3. Calibration, for example: SI-130-10
> 4. Accurate and complete description of the question or concern.
>   For the status code; refer to *Section 5.2.8—Object 0x6010: Status Code*.
> 5. Computer and software information. for example: operating system, PC type, drivers, and application software.
>
> Be near the F/T system when calling (if possible).

Please contact an ATI representative for assistance, if needed:

ATI Industrial Automation
1031 Goodworth Drive
Apex, NC 27539 USA
Tel: +1 919-772-0115 • Fax: +1 919-772-8259 • *www.ati-ia.com*

Application Engineering
E-mail: *ft.support@novanta.com*

24/7 Support: +1 855 ATI-IA 00 (+1 855-284-4200)

7.1 LED Errors

Table 7.1—LED Errors

Symptom	Resolution
Status LED stays red after the (20) second power up phase.	Check the sensor cable connections. Verify the sensor cable is not damaged. There may be an internal error in the sensor. Check the status code, refer to *Table 7.2*
Status LED is red for the first (20) seconds, after power up, and then turns green.	Normal.
The EtherCAT Link/Activity LEDs are not green or flashing green.	Check the sensor and EtherCAT cables' connections. Verify the EtherCAT Master device has the correct ECAT ESI file.
The EtherCAT Link/Activity LEDs are not illuminated (no activity and power is supplied to the sensor).	Verify the proper port (on the EtherCAT Master or junction) is ON and permits communication.

7.2 Status Code

<table>
<tr><th colspan="8">Table 7.2—Object Index (hex) 0x6010: Status Code</th></tr>
<tr><th>Bit No.</th><th>Bit Pattern</th><th>Status</th><th colspan="4">Description</th><th>Error?</th></tr>
<tr><td>0</td><td>00000001</td><td>Gage Temperature Out of Range</td><td colspan="4">This bit is active (high) if the temperature is outside the range -5 to 70°C.</td><td>Yes</td></tr>
<tr><td>1</td><td>00000002</td><td>Supply Voltage Out of Range</td><td colspan="4">This bit is active (high) if the input voltage is outside the range of 12 V to 30 V.</td><td>Yes</td></tr>
<tr><td>2</td><td>00000004</td><td>Broken Gage</td><td colspan="4">This bit is active (high) when a gage reads positive full scale, which indicates that the electrical connection to a gage is open or disconnected.[1]</td><td>Yes</td></tr>
<tr><td>3</td><td>00000008</td><td>Busy</td><td colspan="4">The sensor is performing (1) or more of the following activities that may temporarily affect the F/T data:
• Committing a change to Object 0x2021: Calibration
• Changing the filter time constant
• Changing the calibration in use
• Changing the ADC sampling rate
• Writing to flash memory
• Any ADC ISR overrun</td><td>Yes</td></tr>
<tr><td>4</td><td>00000010</td><td colspan="5">Reserved</td><td>No</td></tr>
<tr><td>5</td><td>00000020</td><td>Common Error</td><td colspan="4">The sensor's microcontroller has detected a system level error. The error should clear after a power cycle. If the issues persists, contact ATI for assistance.</td><td>Yes</td></tr>
<tr><td>6-14</td><td>00007FC0</td><td colspan="5">Reserved</td><td>No</td></tr>
<tr><td>15</td><td>00008000</td><td>F/T Out of Range Extended Rating</td><td colspan="4">Force/Torque Out Of Range Extended Rating. This bit is set whenever a force/torque sample is out of extended load range, based on SET MAXER0 to MAXER5.</td><td>Yes</td></tr>
<tr><td>16</td><td>00010000</td><td>Monitor Condition 0 Output</td><td colspan="4">The sample data is not true for the condition set in Section 5.2.4—Object 0x2060: Monitor Conditions.</td><td>Yes</td></tr>
<tr><td rowspan="5">17-18</td><td rowspan="5">00060000</td><td rowspan="5">IMU Accelerometer Accuracy</td><th>Status Bit 18</th><th>Status Bit 17</th><th>Decimal Value</th><th>Description</th><td rowspan="5">Yes</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>IMU Not Present</td><td colspan="4">IMU is not present or IMU accelerometer reliability is not at least medium</td><td>Yes</td></tr>
<tr><td>20-25</td><td>07FE0000</td><td colspan="5">Reserved</td><td>No</td></tr>
<tr><td>26</td><td>04000000</td><td>Gage Out of Range Warning</td><td colspan="4">This bit is active if a strain gage warning range (gageMinRangeWarn to gageMaxRangeWarn) has been exceeded during the past hold time, which is normally 32 samples.</td><td>Yes</td></tr>
<tr><td colspan="8">Note:
1. For more information about resolving errors, refer to Section 7—Troubleshooting.
2. After 32 sample periods, this bit resets after the error condition clears and the data has normalized.
3. Force/Torque Out of Range is comparable to what previous F/T sensor manuals identified as saturation.</td></tr>
</table>

Table 7.2—Object Index (hex) 0x6010: Status Code				
Bit No.	**Bit Pattern**	**Status**	**Description**	**Error?**
27	08000000	Gage Out of Range	The bit is active if a strain gage output operating range has been exceeded in any of the past 32 samples.	Yes
28	10000000	Simulated Error	This bit mirrors the "Simulated Error Control" bit in *Section 5.2.13—Object 0x7010: Control Codes*. It can be used to test user error handling.	Yes
29	20000000	Calibration checksum error	This bit is set if the active calibration has an invalid checksum.	Yes
30	40000000	Force/Torque Out of Range[2]	This bit is set whenever a F/T sample exceeds the calibrated range or mathematically saturated. This check occurs before digital filtering.[1]	Yes
31	80000000	Error	This bit is set whenever any status code bit that indicates an error is set.	Yes

Note:

1. For more information about resolving errors, refer to *Section 7—Troubleshooting*.
2. After 32 sample periods, this bit resets after the error condition clears and the data has normalized.
3. Force/Torque Out of Range is comparable to what previous F/T sensor manuals identified as saturation.

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

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

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

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

Binary Number	1	0	0	0	0	0	00 0000 000	0	0000 0000 00	0	0	0	1	0	1
Bit Position	**31**	**30**	**29**	**28**	**27**	**26**	**25 to 17**	**16**	**15 to 6**	**5**	**4**	**3**	**2**	**1**	**0**

So in this example, bit number 0, 2 and 31 are on. According to the preceding table, the sensor has a "temperature", "broken gage error", and "any error" status codes (refer to *Table 7.2*).

7.2.3.1 Status Code: Force/Torque Out of Range

Bit 30 in *Table 7.2* is set when a F/T load is outside the sensor's accurate detection capability (see Table 9.1 - Measurement Uncertainty).

Bit 15 in *Table 7.2* is set when a F/T load is outside of the sensor's Extended Range. A range of elevated forces and torques that allows the user to momentarily exceed the sensing range for specialized and infrequent operations.

Bit 30 is set when the following condition is TRUE:

The total percentage of the calibrated range used by the F/T axes is greater than 105%. Refer to the following equation.

$$\frac{\sqrt{Fx^2+Fy^2}}{FxyCalibrated\ Range}+\frac{\sqrt{Tz^2}}{TzCalibrated\ Range}\geq 105\%\ or\ \frac{\sqrt{Fz^2}}{FzCalibrated\ Range}+\frac{\sqrt{Tx^2+Ty^2}}{TxyCalibrated\ Range}\geq 105\%$$

Bit 15 is set when the following condition is TRUE:

The total percentage of the extended range used by the F/T axes is greater than 105%. Refer to the following equation.

$$\frac{\sqrt{Fx^2+Fy^2}}{FxyExtended\ Range}+\frac{\sqrt{Tz^2}}{TzExtended\ Range}\geq 105\%\ or\ \frac{\sqrt{Fz^2}}{FzExtended\ Range}+\frac{\sqrt{Tx^2+Ty^2}}{TxyExtended\ Range}\geq 105\%$$

For example, if the following loads are applied to a Sano74 sensor, which has the following calibration range:

Table 7.3—Example of F/T Out of Range

Axis	Applied Load	Calibration Range	Extended Range
F_x	30 N	130 N	130 N
F_y	-25 N	130 N	130 N
F_z	40 N	400 N	400 N
T_x	0.6 Nm	12 Nm	20 Nm
T_y	1.3 Nm	12 Nm	20 Nm
T_z	-6.2 Nm	12 Nm	20 Nm

Example:

$$\frac{\sqrt{(30\ N)^2+(-25\ N)^2}}{100}+\frac{\sqrt{(-6.2\ Nm)^2}}{8}\geq 105\%$$

$$39\% + 78\% \geq 105\%$$

$$117\% \geq 105\%$$

$$TRUE$$

This TRUE means that the F/T load is outside of the sensor's detection range. So bit 30, *Table 7.2*, is set and indicates an error.

7.3 Basic Guidance for Troubleshooting

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

Symptom: Noise — jumps in F/T readings greater than 0.05% of full-scale counts.	**Cause:** Noise can be caused by mechanical vibrations and electrical disturbances that are possibly from a poor ground. Electrical interference can also come from a high noise output device such as a motor. **Solution:** Make sure that the DC supply voltage for the Sano sensor has little to no noise superimposed. Ground the sensor by connecting the cable's shield to ground. In most setups, 0 V is also connected to the ground. Connect the robot or other fixture to the same ground. Verify that the sensor cables do not cross over other cables. Verify the sensor cables are not within close proximity to other equipment that could generate electrical noise. Avoid sources of mechanical noise. If not possible, apply a filter to the data as described in *Section 4.4—Low-Pass Filter*. For more information about Noise, refer to *Section 7.4—Reducing Noise*.
	Cause: Noise can also indicate component failure within the system. **Solution:** Check the status code of the sensor; refer to *Section 5.2.8—Object 0x6010: Status Code*. Perform an accuracy check as described in the *9620-05-B-Sano74* manual or in *Section 4.5: How do I evaluate the accuracy of health of the sensor?* in the Frequently Asked Questions (FAQ) ATI document located at: *https://www.ati-ia.com/library/documents/FT_FAQ.pdf*. If the sensor fails the accuracy check, return the sensor to ATI for inspection. Contact ATI at *ati-rma-admin@novanta.com* for a Returned Materials Authorization (RMA).
Symptom: Drift — when the F/T data continues to increase or decrease after a load is removed.	**Cause:** Some drift from a change in temperature is normal. Drift is observed more easily in the Z axis, compared to the X and Y axes. **Solution:** For approximately thirty minutes, allow the sensor to warm-up until it is at a steady state with the air and other objects touching the sensor. Use the bias command to shift the readings back to zero. Bias regularly. Use an insulator between the sensor and any tooling or fixtures that are at a different temperature. Avoid creating a temperature gradient across the sensor. Shield the sensor from excessive air flow. For more information about how to avoid drift from temperature change, refer to the following ATI document: *https://www.ati-ia.com/Library/Documents/DriftExplanation.pdf*.

Symptom: Hysteresis — when the sensor is loaded from a zeroed or biased state and then the load is removed, the sensor output does not immediately return to zero.	**Cause:** Mechanical coupling or internal failure can cause Hysteresis which is outside of the sensor's specified and acceptable measurement uncertainty (error) range. **Solution:** Verify the sensor is properly installed, fasteners are tightened, and the customer tooling is securely installed; refer to the *Installation Section* in the *9620-05-B-Sano74* manual. Use the bias command to shift the readings back to zero.
Symptom: *Object 0x6010: Status Code*; **Bit 1 - Supply voltage is out of range.**	**Cause:** If the supply voltage is out of range, the bit is active which indicates a potential system fault or failure. **Solution:** Power cycle the system. Verify the power supply is within range per *Section 8—Specifications*.
Symptom: *Object 0x6010: Status Code*; **Bit 3 - Busy Bit**	**Cause:** While the sensor is busy, the Busy Bit will be ON = 1. The sensor is busy applying a change such as an ADC rate change, filter, or an active calibration. **Solution:** After applying changes, wait until the Busy Bit is OFF = 0. Then read data or make any other changes.
Symptom: *Object 0x6010: Status Code*; **Bit 2, 26, 27, or 30 - Out of Range**	**Cause:** The Sano sensor may have been overloaded, and now the gages are in a saturated state. **Solution:** Remove applied loads. If the errors do not go away, continue troubleshooting. Unmount the sensor. Improper mounting methods can induce high loads in the sensor. If errors such as "F/T Out of Range", "Gage Out of Range", or "Gage Broken" persist, the sensor is likely permanently damaged due to overload. Perform an accuracy check (refer to the *9620-05-B-Sano74*) or refer to *Section 4.5: How do I evaluate the accuracy of health of the sensor?* in the Frequently Asked Questions (FAQ) ATI document located at: *https://www.ati-ia.com/library/documents/FT_FAQ.pdf*. If the sensor fails the accuracy check, return the sensor to ATI for inspection. Contact ATI at *ati-rma-admin@novanta.com* for a Returned Materials Authorization (RMA).
Symptom: *Object 0x6010: Status Code*; **Bit 17 or 18—IMU Accuracy is not high.**	**Cause:** The zero offsets of the IMU hardware are out of adjustment. **Solution:** Complete the IMU Dynamic Calibration Procedure in the in the *9620-05-B-Sano74* manual.

Symptom	Cause / Solution
Symptom: The sensor and/or EtherCAT program is not responsive.	**Cause:** The sensor has insufficient power supply. **Solution:** Verify the power supply meets the requirements listed in *Section 8—Specifications*. Verify the cables are not damaged and are properly routed per the *Installation Section* in the *9620-05-B-Sano74* manual.
	Cause: The software ESI file is not properly installed or not current. **Solution:** ATI offers multiple EtherCAT products which use different ESI files. Download the latest EtherCAT Sano ESI file from the ATI website. Load this ESI file into the EtherCAT Master. The way to download the file depends on the Master. ESI files are also referred to as .XML files or Device Description Files. For more information, refer to *Section 5.3—Converting F/T Data from Counts to Units*.
	Cause: Third party hardware is not compatible with EtherCAT. **Solution:** Verify that the Robot/PLC/PC acts as an EtherCAT Master. Use EtherCAT junctions to split signals, because standard Ethernet switches do not work with EtherCAT. If the Master device has multiple ports, verify that the sensor is connected to the correct port. Some PC EtherCAT Masters require specific drivers to be installed on the correct port so that the system may properly work with EtherCAT.
	Cause: The sensor has a hardware or software failure. **Solution:** Observe the Sano sensor LEDs; refer to *Section 4.2—LED Normal Operation*.
Symptom: The sensor is connected but not streaming data	**Cause:** The user's devices are not compatible with real time EtherCAT communication. **Solution:** Confirm the sensor system is compatible with real time EtherCAT communication.
	Cause: The connection from the user's device to the sensor is interrupted. **Solution:** Try a direct connection from the user's EtherCAT device to the Sano sensor. Standard Ethernet network switches can not be used in EtherCAT systems. If needed, use an EtherCAT junction device instead of Ethernet switches.
	Cause: The sensor has had a hardware or software failure. **Solution:** Observe the Sano sensor LEDs; refer to *Section 4.2—LED Normal Operation*.

Symptom: The sensor does not report accurate F/T data.	**Cause:** The sensor may have been overloaded beyond its calibration limits. For calibration limits, refer to the *9620-05-B-Sano74* manual. **Solution:** Check the status code. Error bits related to overload are: 2, 26, 27, and 30. See solution for *Symptom—Object 0x6010: Status Code; Bit 2, 26, 27, or 30 - Out of Range*. **Cause:** The sensor system configuration is not set-up correctly. **Solution:** Verify the installation is correct; refer to *Section 3—Installation* or contact ATI for assistance. **Cause:** The sensor is not properly installed, for example: improper fasteners are used, or the sensor is not mounted to a flat, stiff surface. **Solution:** Verify the sensor is correctly installed; refer to the *Installation* and *Troubleshooting Sections* in the *9620-05-B-Sano74* manual. **Cause:** Mechanical coupling—an external object such as customer tooling or utilities is contacting a sensor's surface between the mounting side and tool side. **Solution:** Remove any debris between the tool side and interface plate. Use proper cable management for cables and hoses; do not connect them tightly between the mounting and tool side of the sensor. Anything that contacts surfaces such as the through hole in the sensor or cover plates on either side of the sensor induces loading or movement that could result in inaccurate F/T data.
Symptom: The values do not match expected values, for example: the F/T values are fluctuating but are higher than a known applied load.	**Cause:** The user may be viewing gage data instead of F/T data. **Solution:** *Object 0x6030: Gage Data* reports strain gage data. Gage data is not a 1:1 correlation to F/T axis data. To view F/T data, refer to *Object 0x6000: Reading Data*. **Cause:** The sensor outputs data in counts. Counts must be divided by the Counts per Force (CpF) or Counts per Torque (CpT) in order to convert them to Calibration units (such as N and Nm). **Solution:** Verify if the user or user's software is scaling the F/T values to convert into units. Use the CpF and CpT to convert the raw F/T values into units. For the CpF and CpT values, refer to *Section 5.2.2—Object 0x2021: Calibration*. **Cause:** If the raw F/T values are already converted into units and the values are high or nonsensical, verify that the sensor is not in one of these conditions: saturation, gage out of range, or F/T out of range. Check the status code of the sensor; refer to *Section 5.2.8—Object 0x6010: Status Code*. **Solution:** If the values exceed the ATI sensor's calibration range per the *9620-05-B-Sano74* manual, the reported values are incorrect. For more information, refer to *Section 2.1: Measurement Range & Overload Limits* in the Frequently Asked Questions (FAQ) ATI document located at: *https://www.ati-ia.com/library/documents/FT_FAQ.pdf*.

Symptom: The initial F/T values are non-zero and no load is applied.	Normal. Bias the sensor to bring all the F/T values back to zero.

7.4 Reducing Noise

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

7.4.2 Electrical Interference

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

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

8. Specifications

The requirements for the EtherCAT sensor interface are covered in the following sections. For ATI F/T sensor model specifications, refer to the *9620-05-B-Sano74* manual.

8.1 Electrical Specifications

Table 8.1—Power Supply[1]			
Power Source	Voltage		
	Minimum	Nominal	Maximum
DC Power	12 V	24 V	30 V

Notes:

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

9. Terms and Conditions of Sale

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

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

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D. Custom Application

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

Please contact an ATI representative for assistance, if needed:

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