Capacitive 6-Axis Force Sensor

Installation and Operation Manual

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Foreword

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Note:

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

1. Serial number
2. Sensor model (e.g., 9105-CPS-W200RC5)
3. Accurate and complete description of the question or problem
4. Computer and software information. Operating system, PC type, drivers, application software, and other relevant information about your configuration.

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

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## Glossary of Terms

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cross-axis sensitivity</td>
<td>Degree of influence of one component to which the rated load is applied on the outputs of other components, which is expressed in percentage (%FS) to the rated output of each.</td>
</tr>
<tr>
<td>Detection sensitivity</td>
<td>Output change with respect to unit load; which is obtained by (rated output)/(rated load)</td>
</tr>
<tr>
<td>F/T</td>
<td>Force/Torque.</td>
</tr>
<tr>
<td>Hysteresis</td>
<td>Change in the zero point caused by one cycle of push-pull loading as rated: the amount of change is expressed by percentage (%FS/°C) to the rated output.</td>
</tr>
</tbody>
</table>

![Diagram](image-url)
Linearity

Maximum deviation of the calibration curve from the straight line that connects the output at no load and the output at the rated load when the load increases, which is expressed in percentage (%FS) to the rated output.

![Linearity Graph]

\[
\text{Linearity (\%FS)} = \frac{a}{FS} \times 100
\]

Overload

Load exceeding the rated load.

Rated Load

Maximum load that satisfied the specifications of the sensor.

Rated Output

Value obtained by subtracting no-load output from the rated load output.

Zero Point

Output at no load in a predetermined posture, which is also referred to as offset output.

Zero Point Temperature Characteristics

Change in zero point by change in ambient temperature. The amount of change is expressed by a percentage (%FS/°C) to the rated output.
1. Safety

The safety section describes general safety guidelines to be followed with this product, explanation of the notification found in this manual, and safety precaution that apply to the product. More specific notifications are imbedded within the sections of the manual where they apply.

1.1 Explanation of Notifications

The notifications included here are specific to the product(s) covered by this manual. It is expected that the user heed all notifications from the robot manufacturer and/or the manufacturers of other components used in the installation.

| 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, installation, or setup of the product that if not followed could result in damage to equipment. The notification can emphasize but is not limited to specific grease types, good operating practices, or maintenance tips. |
1.2 General Safety Guidelines

The customer should verify that the sensor is rated for maximum loads and torques expected during operation. Refer to Section 7—Specifications or contact ATI Industrial Automation for assistance. Particular attention should be paid to dynamic loads caused by robot acceleration and deceleration. These forces can be many times the value of static forces in high acceleration or deceleration situations.

1.3 Safety Precautions

**CAUTION:** If instructions in this manual for installation and operation of the sensor are not followed, the equipment could be damaged. Read through this manual before using the sensor, and follow installation and operation instructions in accordance with the site’s safety policies and practices. Otherwise, equipment could be damaged during set-up, removal, and use.

**CAUTION:** Do not disassemble or repair sensor. This may cause irreparable damage to the sensor and void the warranty. Leave all fasteners in place and do not disassemble the sensor.

**CAUTION:** Do not store or operate the sensor in environments where there is direct sunlight, high temperatures, and high humidity. These conditions may cause irreparable damage to the sensor. For optimal sensor performance, avoid using and storing the sensor where there is direct sunlight, high temperatures, and high humidity.

**CAUTION:** If the sensor experiences a sudden change in temperature, humidity, or varied temperature distribution, the sensor’s temperature correction feature may no longer function correctly, causing erratic sensor output. When using the sensor, ensure the operating environment is not subject to sudden changes in temperature and humidity. Ensure the sensor’s temperature distribution is not varied.

**CAUTION:** Do not subject the sensor to an external physical impact (e.g. dropping the sensor) or apply an electrical shock to the sensor. This will damage the sensor and cause impaired functionality. While the sensor incorporates precision parts and has passed vibration and impact tests, due caution should be exercised when handling the sensor. When installing, removing, and operating the sensor, be careful that the sensor is supported, and do not exceed the sensor’s electrical capacity.

**CAUTION:** Do not exert excessive forces or torques on the sensor. This can create incorrect detection of forces and cause possible damage to the sensor. When a force is applied to the sensor, torques are exerted on the sensor simultaneously. Be aware that all six axes should fall within the ranges and not exceeding the ratings. If the rating of even one of the six axes is exceeded, correct detection of forces will fail for all axes. Refer to Section 7.2—Basic Specifications for the Capacitive 6-Axis Force Sensor for specific sensor overload values.
2. Product Overview

The F/T Capacitive 6-Axis Force Sensor is a cost-effective solution for a variety of applications such as force control of industrial robots, measuring, assembly, and more. The F/T Capacitive 6-Axis Force sensor detects 3-axis forces (Fx, Fy, and Fz) and 3-axis torques (Tx, Ty, and Tz) simultaneously. The sensor includes integral overload protection and temperature compensation, and it is IP60-rated for protection against dust. Refer to Section 3—System Functionality for more information. The force and torque values are output to the user only in SI units. Refer to Section 7.2—Basic Specifications for the Capacitive 6-Axis Force Sensor.

The sensor consists of aluminum mounting and tool adapter plates, and in the center of both plates, there is waterproof packing. The sensor connects to a robot arm with the (4) captive screws in the mounting adapter plate. Refer to Figure 2.1. In the mounting adapter plate, there is a sensor connector for power and signals, refer to Section 2.1—Customer Interface with Sensor Connection. The customer can attach tooling to the sensor using the (4) M6 threaded holes provided in the tool adapter plate.

![F/T Capacitive 6-axis Force Sensor](image)

2.1 Customer Interface with Sensor Connection

2.1.1 Capacitive Sensor RS-422 Interface Cable to USB (P/N 9105-C-CPS-USB-3)

The USB conversion cable provides power and retrieves RS-422 output from ATI’s Capacitive 6-Axis Force Sensor (limited to 5 V type). The USB conversion connects to a personal computer (PC) or other devices. The cable is 3 m in length. Refer to Figure 2.2.

![RS-422 Interface Cable to USB](image)
2.1.2 Capacitive Sensor RS-422 Interface Cable, Unterminated (P/N 9105-C-CPS-U-5)

The user can communicate and supply power to the sensor and over the unterminated RS-422 cable. The user must mount a connector to the cable or supply a screw terminal. The cable is 5 m in length. Refer to Section 7—Specifications for more information, and refer to Section 4.10—Pin Assignment For the Capacitive Sensor RS-422 Interface Cable (P/N 9105-C-CPS-U-5) for pin assignment.

Figure 2.3—Sensor with Unterminated RS-422 Cable

Power supply voltage specifications value is the value of the sensor inside. When applying power supply voltage, take into account the voltage drop due to the cable. Refer to Table 2.1.

<table>
<thead>
<tr>
<th>Power Supply Voltage Specifications/Actuating Current Specifications</th>
<th>Voltage Drop per 1 m [V/m]</th>
</tr>
</thead>
<tbody>
<tr>
<td>AWG26</td>
<td>AWG28</td>
</tr>
<tr>
<td>5 V (200 mA)</td>
<td>0.030</td>
</tr>
<tr>
<td>24 V (100 mA)</td>
<td>0.015</td>
</tr>
</tbody>
</table>

2.2 F/T Software CD

The F/T software CD contains the software that the user’s computer uses to convert the sensor readings into a usable force and torque output. It has Microsoft Windows drivers and sample programs. Download the most recent release of the capacitive 6-axis force sensor software at: http://www.ati-ia.com/download

The program is compatible with Windows 7/8/8.1/10 environments.
3. System Functionality

This section provides information on the sensor’s mechanical, electrical, and software functionality.

3.1 Mechanical Description

The sensor responds to applied forces and torques in accordance with Newton’s third law which states: for every action there is always an opposed or equal reaction; or, the mutual action of two bodies upon each other always equal and directed to contrary parts.

When forces are applied, the tool adapter plate of the sensor will displace. This displacement between the mounting adapter plate and tool adapter plate is detected by the sensor as a change in capacitance. These detected forces (Fx, Fy, Fz) in the X-, Y-, Z-axis directions and torques (Tx, Ty, Tz) are output values corresponding to their respective axes. Refer to Figure 3.1 and Figure 3.2. When a rated torque is applied to the customer tooling, the maximum displacement between the tool adapter plate and mounting adapter plate is approximately 0.1 mm.

**CAUTION:** Do not apply a force directly to the upper part of the sensor. The upper cover will be misaligned, and the force will not be transmitted correctly to the sensor. Ensure that a force is being applied to the customer tooling.

**CAUTION:** Do not exert excessive forces or torques on the sensor. This can create incorrect detection of forces and possible damage to the sensor. When a force is applied to the sensor, torques are exerted on the sensor at the same time as the forces. Be aware that all of them should fall within the ranges not exceeding the ratings. If the rating of even one of the six axes is exceeded, correct detection of forces will fail for all axes. Refer to Section 7.2—Basic Specifications for the Capacitive 6-Axis Force Sensor for specific sensor overload values.

![Figure 3.1—0.1 mm Displacement of the Sensor](image-url)
3.2 Mechanical Stop
A mechanical stop is integrated in the sensor for protection against overload exceeding the rated load. If the load on the sensor reaches a certain level, the mechanical stop prevents higher displacements as shown in Figure 3.3 to prevent serious failures, such as fracture. Refer to Section 7.2—Basic Specifications for the Capacitive 6-Axis Force Sensor for the rated load ranges.

3.3 Electrical Features
The sensor automatically outputs 6-axis values of temperature-corrected and cross-axis corrected Fx, Fy, Fz, Tx, Ty, and Tz. Refer to Figure 3.4.
3.4 Sensor Output Value

Since the sensor’s output values are scaled, simple calculations must be performed to obtain the loads being sensed. ATI Industrial Automation supplies software to perform these calculations, which is located on the media that came with the sensor.

The value of each axis is output in the range of 0-16383. The initial value at no load is in the zero point output range, and when a load is applied, the numerical value increases or decreases by the following equation:

\[
\text{Output Value} = \text{Applied Load} \times \text{Detection Sensitivity}
\]

The detection sensitivity values are factory set calibration values stored in the sensor. The user does not need to calibrate the sensor during set-up or operation. Refer to Section 7.2—Basic Specifications for the Capacitive 6-Axis Force Sensor and Section 7.3—Digital Output I/F Communication Specifications for more information about detection sensitivity and units.

3.5 ATI CPS Software

The F/T software CD contains the software that the user’s computer uses to convert the sensor readings into usable force and torque output. It also has a sample program, C# source code, and help files. Download the most recent release of the CPS software at: [http://www.ati-ia.com/download](http://www.ati-ia.com/download)

Refer to Section 7—Specifications for more information.

3.5.1 Sample Applications

3.5.1.1 Windows Demo

The Windows demo program can be used in Windows 7/8/8.1/10 operating systems.

3.5.2 Formats Supported for Saving Data Values

To log data values from streaming, the ATI software supports data to be saved in one of the following (2) formats: Comma Seperated Value (CSV) or Text (TXT).
4. Installation

The sensor mounts to the robot wrist (refer to Figure 4.3) using the captive mounting screws supplied. The customer application attaches to the sensor’s tool adapter plate or a tool interface plate with customer fasteners that are installed in the sensor’s tapped holes.

All fasteners used to mount the sensor to the robot and customer’s application should have thread locker applied, and be tightened to a torque value as indicated in Table 4.1. The recommended values in this table are based on engineering standards.

<table>
<thead>
<tr>
<th>Mounting Conditions</th>
<th>Threaded Portion Engagement Length</th>
<th>Fastener Size and Property Class</th>
<th>Recommended Torque</th>
<th>Thread Locker</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensor to robot or robot interface plate (RIP), Supplied (4) captive M6 socket head cap screws</td>
<td>7 mm from the lower surface</td>
<td>M6 x 1.0 Class 8.8</td>
<td>53.1 in-lbs (6 Nm)</td>
<td>Pre-applied Adhesive or Loctite 242</td>
</tr>
<tr>
<td>Sensor to customer application, (4) Customer supplied M6 fasteners</td>
<td>10-12 mm from the upper surface</td>
<td>M6 x 1.0 Class 12.9</td>
<td>53.1 in-lbs (6 Nm)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Socket head cap</td>
<td>53.1 in-lbs (6 Nm)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Socket flat head cap</td>
<td>53.1 in-lbs (6 Nm)</td>
<td></td>
</tr>
</tbody>
</table>
4.1 Interface Plates

The sensor’s mounting adapter plate is typically attached to the robot arm, and the tool adapter plate is typically attached to the customer tooling. However, it may be necessary for interface plate(s) to be utilized to adapt the sensor to the robot arm and customer tooling. Custom robot and tool interface plates can be supplied by ATI to meet the customer’s requirements (refer to Section 8—Drawings of this manual for technical information on mounting features).

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

If the customer chooses to design and build interface plate(s), the following should be considered:

- The interface plate(s) should be designed to include bolt holes for mounting, dowel pins, and a boss for accurate positioning of the robot or other devices and to the adapter plate.
- The thickness of the interface plate(s) must be great enough to provide the necessary thread engagement for the mounting fasteners.
- The mounting fasteners should not extend through the adapter plate to avoid interference with the electronics inside the sensor. Refer to Table 4.1 and Section 8—Drawings for thread depth, mounting patterns, and other details.
- Do not use dowel pin(s) that are too long and will not allow the interface plate to mate flush with the robot and customer tooling. Using a dowel pin that is too long will cause a gap between the interface plate(s) and robot and customer tooling. This will cause damage to the equipment.
- The interface plate(s) must be properly designed to provide rigid mounting for the sensor. The interface plate should not distort under maximum sensor range. Refer to Section 7—Specifications for specifications.
- The interface plate(s) design must provide a flat and parallel mounting surface for the sensor. Refer to Figure 4.1.
- The side of the interface plate(s) mounting to the sensor should have a surface finish of Ra6.3

**Figure 4.1—Interface Plate(s)**
4.2 Routing the Cable

The sensor can be used in a variety of applications. The customer application will affect how best to route the cable and determine the proper bending radius to use. Some applications will allow the sensor and the cable to remain in static condition. Some applications require the sensor to be in a dynamic condition that subjects the cable to repetitive motion. It is important not to expose the sensor cable connector to this repetitive motion and properly restrain the cable close to the sensor connection.

**Figure 4.2—Routing of the Sensor Cable**

![Routing Diagram]

**CAUTION:** Do not subject the sensor cable connector to the repetitive motion of the robot or other device. Subjecting the connector to the repetitive motion will cause damage to the connector. Restrain the cable close to the connector to keep the repetitive motion of the robot from affecting the cable connector.

**CAUTION:** The cable must be capable of withstanding the repetitive motions of the application without failing. The routing of an electrical line must minimize the possibility of over stressing, over bend, pullout, or kinking the lines, especially where it is attached to the sensor. Failure to do so can cause some critical electrical and/or pneumatic lines not to function properly and may result in injury to personnel or damage to equipment. Sharp bends must be avoided as they can damage the cable and sensor; this will void the warranty.

**CAUTION:** When routing cables do not bend less than the minimum bending radius required, refer to Table 4.2 for minimum bending radius. The cable will fail due to fatigue from the repetitive motion. Make sure when routing the cable that the minimum dynamic bending radius is exceeded.
Table 4.2—Sensor Cable Bending Radius

<table>
<thead>
<tr>
<th>Cable Type</th>
<th>Cable Diameter</th>
<th>Static Bending Radius (at room temperature)</th>
<th>Dynamic Bending Radius (at room temperature)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mm (in)</td>
<td>mm</td>
<td>in</td>
</tr>
<tr>
<td>9105-CPSNET</td>
<td>6.2 (.24)</td>
<td>31</td>
<td>1.2</td>
</tr>
<tr>
<td>9105-C-CPS-USB-3</td>
<td>6.2 (.24)</td>
<td>31</td>
<td>1.2</td>
</tr>
<tr>
<td>9105-C-CPS-U-5</td>
<td>6.7 (.26)</td>
<td>33.5</td>
<td>1.3</td>
</tr>
</tbody>
</table>

Notes:
1. Temperature will affect cable flexibility. ATI recommends increasing the minimum dynamic bending radius for lower temperatures.

The sensor cable must be routed so that it is not stressed, pulled, kinked, cut, or otherwise damaged throughout the full range of motion. See the accompanying system manual for the sensor cable interfacing. If the desired application results in cable rubbing, then use a loose plastic spiral wrap for protection.

**CAUTION:** Be careful not to crush the cable by over tightening tie wraps on the cable, since this may damage the cable.

4.3 Installing the Sensor to the Robot

**Tools required:** 5 mm hex wrench

**Supplies required:** Clean rag, Loctite® 242

1. Make sure the mounting surface of the sensor, robot arm, and Robot Interface Plate (RIP) are clean and free of debris.
2. If required, attach the RIP to the robot. Secure with customer supplied fasteners.
3. Apply Loctite 242 to the (4) M6 captive mounting screws. Refer to Table 4.1.
4. Using a 4 mm hex wrench, secure the sensor to the robot or RIP with the (4) M6 captive mounting screws. Tighten to 53.1 in-lbs (6 Nm). The hex wrench will need to be inserted through the tapped M6 holes of the Tool plate.

**Figure 4.3—Installing the Sensor to the Robot**
5. Once the sensor is attached to the robot, the customer application or tool interface plate can be attached. Refer to Figure 4.4.

![Figure 4.4—Installing Customer Tooling to the Sensor](image)

6. Secure the customer tooling or tool interface plate to the tool adapter plate of the sensor using the customer supplied (4) M6 fasteners. Refer to Table 4.1 for proper torque and Loctite specifications. Refer to Section 8—Drawings for mounting details.

7. Attach a power and signal cable to the connection.
   a. Align the white arrow on the cable side with the white portion of the sensor side connector. Refer to Figure 4.5.
   b. Push in the cable side connector until it clicks.

![Figure 4.5—Installing the Cable Connector on the Sensor](image)

8. After the cable is connected to the sensor, the cable is capable of withstanding up to a 30 N pull force. **CAUTION:** The cable must be capable of withstanding the repetitive motions of the application without failing. The routing of an electrical line must minimize the possibility of over stressing, pullout, or kinking the lines. Failure to do so can cause some critical electrical and/or pneumatic lines not to function properly and may result in injury to personnel or damage to equipment.

9. Attach the other end of the sensor cable, to the customer application. For information on routing the cable, refer to Section 4.2—Routing the Cable. To install the sensor interface cable to the USB port of a customer device, refer to Section 4.5—Installing the Interface Cable to USB (P/N 9105-C-CPS-USB-3).

10. After installation is complete, the sensor may be placed into normal operation.
4.4 Removing the Sensor from the Robot

**Tools required:** 5 mm hex wrench

**WARNING:** Do not perform maintenance or repair on the sensor unless the sensor is safely supported or removed from the robot, all energized circuits (e.g. electrical, air, water, etc.) are turned off, pressurized connections are purged, and power discharged from the circuits in accordance with the customer’s safety practices and policies. Injury or equipment damage can occur with the sensor not supported or removed and energized circuits on. Safely remove the sensor, turn off and discharge all energized circuits, purge all pressurized connections, verify all energized circuits are de-energized before performing maintenance or repair on the sensor.

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

1. Turn off all energized circuits (e.g. electrical, air, water, etc.).
2. Supporting the customer tooling and/or tool interface plate, remove the customer supplied screws attaching the customer tooling to the sensor. Refer to Figure 4.3.
3. Remove power and signal cable from the connection as required for service.
   a. For disconnection, hold the base of the connector. Refer to Figure 4.6.
   b. Slide it in the direction of the yellow arrow.
   c. Remove the cable.

**Figure 4.6—Removing the Cable Connector from the Sensor**

4. Supporting the sensor, use a hex wrench to loosen the (4) M6 captive fasteners securing the sensor to the robot or RIP.
5. Remove the sensor.
4.5 Installing the Interface Cable to USB (P/N 9105-C-CPS-USB-3)

1. To install the sensor to the robot arm and cable to the sensor connection, refer to Section 4.3—Installing the Sensor to the Robot.

2. Connect the USB side connector to the USB port on the customer device. Refer to Figure 4.7 and Figure 4.8.

3. The PC should recognize the new sensor, and the message in Figure 4.9 will appear. Note the description of the message will be different for another development environment. The device driver software installation will start automatically.

Figure 4.7—Installation of Interface Cable to USB

Figure 4.8—USB Connection

Figure 4.9—Device Driver Software Installation
4. If this message is clicked for status, a new window will open, as shown in Figure 4.10, and let the user know that the installation has begun and is completing any software updates.

**Figure 4.10—Searching for Updates**

5. The status in the window will change to the status in Figure 4.11.

**Figure 4.11—Installing Driver Software**

6. When the device driver software is installed and ready for use, the message in the window will notify the user as shown in Figure 4.12. The user may be instructed to restart the PC. Follow instructions provided by the user’s device for restart.

**Figure 4.12—Driver Software Installation Complete**
7. Verify that installation was complete by selecting “System Security” from the PC’s control panel as shown in Figure 4.13 and then select “Device Manager” as shown in Figure 4.14.
8. In the Device Manager under “Ports (COM & LPT)”, the USB serial port will be shown with the COM port assigned. In Figure 4.15, (COM7) is assigned. If the user wishes to assign another COM port, refer to Section 4.7—Changing the COM Port Selection.

9. After installation is complete, the user may install the Capacitive 6-Axis Force Sensor demo software. Refer to Section Figure 4.4——Installing Customer Tooling to the Sensor.

4.6 Removing the RS-422 Interface Cable from USB (P/N 9105-C-CPS-USB-3)

**CAUTION:** Do not disconnect the sensor from the user’s PC while the software program is running. This will cause the program to stop working. Stop the program before removing the sensor. Disconnecting the sensor before the software program has stopped running will cause program failures.

1. Turn off all energized circuits (e.g. electrical, air, water, etc) as applicable with the customer’s safety standards and practices.
2. Safely remove the USB side of the cable from the customer device by selecting “Device Manager” from the control panel. Refer to Figure 4.15.
3. Right click on the USB Serial Port, and select disable the device.
4. Remove the USB side of the cable from the customer device. Refer to Figure 4.7 and Figure 4.8.
5. To remove the sensor cable from the sensor connection and/or the sensor from the robot arm, refer to Section 4.4—Removing the Sensor from the Robot.
4.7 Changing the COM Port Selection

1. With the Device Manager screen open, Figure 4.15, right click on the USB Serial Port “(COMx)”. Select “Properties” from the menu shown in Figure 4.16.

![Figure 4.16—Device Menu](image)

2. In the window that appears, select “Port Settings” tab, and then select “Advanced” as shown in Figure 4.17.

![Figure 4.17—Communication Port Properties](image)

3. In the window that appears, as shown in Figure 4.18, the user can select the COM port number.

![Figure 4.18—Advanced Settings (Selecting COM Port Number)](image)

4. After the COM port number is selected, select “OK”.

![Figure 4.18—Advanced Settings (Selecting COM Port Number)](image)
4.8 Adjusting COM Port Latency for the USB Cable Interface

The USB-Serial converter buffers data from the sensor before it is sent to the PC. When the sensor transmits data at the high-speed rate, the PC will not receive data as it is being transmitted by the sensor. This can affect the accuracy of data timing. To mitigate this issue, it is necessary to adjust the latency of the USB-serial converter in the Windows COM port settings. Follow the instructions below.

1. Open Device Manager. Refer to 7, Figure 4.14 and Figure 4.15, from Section 4.5—Installing the Interface Cable to USB (P/N 9105-C-CPS-USB-3).

2. Right click the device and select “Properties”.

3. Select the “Port Settings” tab. Then select “Advanced”.

![Figure 4.19—Properties for COM Port Number](image)

![Figure 4.20—Port Settings (COM Port Numer)](image)
4. Adjust the “Latency Timer” to 1 ms for the most accurate timing. Select “OK”.

**Figure 4.21—Advanced Settings (COM Port Numer)**

4.9 **Install the F/T Demo Software**

1. Insert the CD in the user PC. Navigate to the CD directory and run the “setup.exe” in the main folder. The message in **Figure 4.22** will appear. Select “Next”.

**Figure 4.22—Installation Welcome Screen**
2. The user will be prompted to select the installation folder. Refer to Figure 4.23. Select “Next”.

![Figure 4.23—Select Installation Folder](image)

3. A new message will appear notifying the user that the program is ready to install. Refer to Figure 4.24. Select “Next”, and follow the instructions given by the program to complete installation.

![Figure 4.24—Program Installation](image)

4. Refer to Section 5—Operation to start the program.
4.10 Pin Assignment For the Capacitive Sensor RS-422 Interface Cable (P/N 9105-C-CPS-U-5)

For the pin assignment of the capacitive sensor RS-422 interface cable, refer to Table 4.3.

<table>
<thead>
<tr>
<th>Cable (Model: 9105-C-CPS-U-5)</th>
<th>Connector Pin Number</th>
<th>Wire Color</th>
<th>Signal</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>White</td>
<td>Vcc</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Orange</td>
<td>TxD+</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Red</td>
<td>RxD+</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Yellow</td>
<td>GND</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>Green</td>
<td>TxD-</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>Blue</td>
<td>RxD-</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>Black</td>
<td>GND</td>
</tr>
</tbody>
</table>
5. Operation

**CAUTION:** Do not exert excessive forces or torques on the sensor. This can create incorrect detection of forces and possible damage to the sensor. When a force is applied to the sensor, torques are exerted on the sensor at the same time as the forces. Be aware that all of forces and torques should fall within the ranges not exceeding the ratings. If the rating of even one of the six axes is exceeded, correct detection of forces will fail for all axes. Refer to *Section 7.2—Basic Specifications for the Capacitive 6-Axis Force Sensor* for specific sensor overload values.

5.1 Writing a Capacitive 6-Axis Force Sensor Application

See the ATI Capacitive 6-Axis Force Sensor source code for information on developing a customer application.

5.1.1 Serial Commands

These serial commands can be used in a custom application to control the sensor’s operation.

5.1.1.1 R Command

The “R” command can be used to request a single data reading from the sensor. This returns a single line of data in the format specified in *Table 7.3*.

R command format:

user:  

response: 11FFC1FFC2011200220022000<CR><LF>

5.1.1.2 O Command

The “O” command sets a new zero point for the sensor. The user must send three consecutive “O” characters (ASCII 79 or 4Fh). The sensor will retain the new zero point until it’s powered-cycled.

O command format:

user:  

No return data.
5.1.1.3 S and E Commands

The “S” command starts the high-speed data transmission. The sensor continues to return data in the specified format until the “E” command is sent. The “E” command stops the high-speed data transmission. There is no return data after the “E” command is sent.

S and E command format:

user: S
response: 02001FFE20001FFE20002000<CR><LF>
11FFC1FFC2011200220022000<CR><LF>
21FFE2009200A20041FFF2004<CR><LF>
...
...
...
user: E
No return data.

5.1.1.4 p Command

The “p” reads the detection sensitivity values from the sensor. The sensor responds with a comma-delineated ASCII string of the decimal values for each sensitivity ordered.

p command format:

user: p
response: 32.619,32.750,32.670,1645.800,1636.800,1637.500<CR><LF>

5.2 Environment

The sensor is designed to be used in an operating environment where the temperature is between 0 to 50 °C (32-122 °F) and no more than 95% humidity. When the sensor is being stored, the acceptable storage temperature range is -10 to 60 °C (14 to 140 °F). For complete operation specifications, refer to Section 7.1—Operating Conditions for the Capacitive 6-Axis Force Sensor. To maximize the service life of the sensor, the following points should be observed:

**CAUTION:** Do not store or operate the sensor in environments where there is direct sunlight, high temperatures, and high humidity. These conditions may cause irreparable damage to the sensor. For optimal sensor performance, avoid using and storing the sensor where there is direct sunlight, high temperatures, and high humidity.

**CAUTION:** If the sensor experiences a sudden change in temperature, humidity, or varied temperature distribution, the sensor’s temperature correction feature may no longer function correctly, causing erratic sensor output. When using the sensor, ensure the operating environment is not subject to sudden changes in temperature and humidity. Ensure the sensor’s temperature distribution is not varied.
5.3 Sensor Power Up

CAUTION: At power-on, be careful that the pin assignment on the RS-422 interface cable (9105-C-CPS-U-5) is correct; otherwise, the incorrect pin assignment of the connection terminal may damage the circuit’s electronics. Since the sensor side comes with no protection circuit, it is recommended to use a power supply including an overcurrent protection circuit. For pin assignment, refer to Section 4.10—Pin Assignment For the Capacitive Sensor RS-422 Interface Cable (P/N 9105-C-CPS-U-5). Verify pin assignment; otherwise, incorrect pin assignment of the connection terminal may damage the circuit’s electronics.

After applying power, it takes five to ten seconds for the sensor to start outputting data. It will take an additional ten to thirty minutes for the sensor to fully warm up and reach thermal equilibrium. The sensor output may drift some while it is warming up.

5.4 Calibration

The sensor does not need to be calibrated prior to operation. The sensor is calibrated prior to shipment. When the sensor is shipped to the customer, it contains sensitivity values, which the sensor sends to the computer’s system during installation.

5.5 Operation of the Program

CAUTION: Do not disconnect the sensor from the user’s PC while the software program is running. This will cause the program to stop working. Stop the program before removing the sensor. Disconnecting the sensor before the software program has stopped running will cause program failures.

1. When the sensor program is opened on the user’s device, the following screen will appear. Notice that the program status is “Not Connected” because a port has not been selected. Refer to Figure 5.1. Refer to Section 5.8—Status Messages for more information on the status.

![Figure 5.1—Program StartScreen](image-url)
2. Select a port from the drop down screen. Refer to Figure 5.2.

![Figure 5.2—Port Selection](image)

3. The status will change to “connected”, indicating the program opened a COM port and established a connection with the sensor. Refer to Figure 5.3.

![Figure 5.3—Connected](image)

**NOTICE:** An Axis Saturation status message will appear if the sensor has a load or signal outside of the maximum data value. For more information, refer to Section 5.8—Status Messages and Section 7.2—Basic Specifications for the Capacitive 6-Axis Force Sensor.
4. The user then selects “start” to start streaming data. The status will change to “OK”. Refer to Figure 5.4.

**Figure 5.4—Program Running**

![Figure 5.4](image)

**NOTICE:** Data can only be logged while data is in the process of being streamed.

5. When the program is streaming data, the user can start to log data by user selecting “Choose Output File” under data logging. Refer to Figure 5.5.

**CAUTION:** Logging data at a high-speed data collection rate for extended periods of time could cause the program to stop running. The user is advised to collect high-speed data over short time periods; otherwise collecting at a high-speed rate could cause the program to fail.

6. If desired, the user can choose to log data at a high-speed data collection rate. Refer to Figure 5.5. Refer to Section 5.6.1—Data Collection Rates for further information.

**Figure 5.5—Data Logging**

![Figure 5.5](image)

7. To start collecting data, select the “Start Data Log”. Refer to Figure 5.5.
8. To stop logging data, select “Stop Data Log.” Refer to Figure 5.6. For more information on the format of the output file, refer to Section 5.10—Output File.

Figure 5.6—Stop Data Log

9. To stop streaming data, select “Stop” on the program screen. Refer to Figure 5.7.

Figure 5.7—Stop Streaming

5.6 Data Logging

5.6.1 Data Collection Rates

CAUTION: Logging data at a high-speed data collection rate for extended periods of time could cause the program to stop running. The user is advised to collect high-speed data over short time periods; otherwise collecting at a high-speed rate could cause the program to fail.

The default data streaming rate is 60 samples/second. A high-speed data streaming rate is available and allows the user to observe more finite changes in data. The high-speed data rate collects 1900 samples/second.

To ensure the timing accuracy for data collection is correct for the high-speed rate, it’s important that the COM Port Latency is correctly set. Refer to Section 4.10—Pin Assignment For the Capacitive Sensor RS-422 Interface Cable (P/N 9105-C-CPS-U-5).
5.7 Bias

Biasing is useful for eliminating the effects of gravity (tool weight) or other acting forces. When the bias function is used, the software will collect 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.

In Figure 5.8, the bias feature has been selected. Force and torque values converge zero.

**NOTICE:** When biasing, ensure the force and torque readings are steady-state. Biasing while the sensor is vibrating, accelerating, or decelerating can provide a poor reference for the user’s application.

![Figure 5.8—Bias](image)
5.8 Status Messages
The program will always display a status when idle or running. There are (4) total, and the program will display (1) status at a time.

5.8.1 Not Connected
The program is not connected to a COM port.

5.8.2 Sensor Disconnected
The status appears if the cable is disconnected from the sensor or if the sensor did not respond to the request for F/T data.

5.8.3 Connected
The program opened a COM port and established a connection with the sensor.

5.8.4 OK
Program has started streaming.

5.8.5 Axis Saturation
At least one of the six Fx, Fy, Fz, Tx, Ty, and Tz values has exceeded its maximum data value. Refer to Section 7.2—Basic Specifications for the Capacitive 6-Axis Force Sensor for data value ranges.

5.9 Event Log
At the bottom of the program’s window, there is an event log. Refer to Figure 5.4. This event log will provide the date and time the program connected, disconnected, or failed to connect to the sensor. The event log will also provide an error for invalid data, which is a data packet that the program couldn’t recognize. Contact ATI if this error for invalid data keeps reappearing, and the program will not return to normal.

5.10 Output File
When the output file is opened, the format is the same for a .csv and a .txt file. Refer to Figure 5.10 and Figure 5.9. At the top of the file, the start time for the data logged and units for force (N), torque (Nm), and time (ms) are listed. Below the data is listed under the header for Fx, Fy, Fz, Tx, Ty, Tz, and Time.

**Figure 5.9—.txt Output File**

```
Start Time: 10/7/2015 2:10:09 PM
ATI Industrial Automation Capacitive Force/Torque Sensor
Force Units: N
Torque Units: Nm
Time Units: ms
Fx, Fy, Fz, Tx, Ty, Tz, Time
"-0.1226", "-0.3069", "13.7435", "0.0073", "0.0220", "0.0708", 2
"-0.2759", "-0.3053", "13.6211", "0.0055", "0.0228", "0.0708", 22
"-0.1226", "-0.5191", "13.8639", "0.0073", "0.0208", "0.0727", 22
```

**Figure 5.10—.csv Output File Opened by a Spreadsheet Program**

```
Start Time: 10/7/2015 11:20:29 AM
ATI Industrial Automation Capacitive Force/Torque Sensor
Force Units: N
Torque Units: Nm
Fx, Fy, Fz, Tx, Ty, Tz, Time
-0.1533, -0.5191, 13.5211, 0.0061, 0.0208, 0.08, 2
-0.2759, -0.7023, 13.8639, 0.0049, 0.0226, 0.0727, 12
-0.3066, -0.5191, 13.6517, 0.0073, 0.0208, 0.0727, 27
```
6. Troubleshooting

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

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

**NOTICE:** Please read the F/T manuals before calling customer service. When calling, have the following information available:

1. Serial number
2. Sensor model (e.g., 9105-CPS-W200RC5)
3. Accurate and complete description of the question or problem
4. Computer and software information. Operating system, PC type, drivers, application software, and other relevant information about your configuration.
5. If possible, all information that is displayed on the Capacitive 6-Axis Force Sensor F/T page System Info (manuf.htm).

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

### 6.1 Questions and Answers

#### 6.1.1 Errors with Force and Torque Readings

Bad data from the sensor can cause errors in force/torque readings. These errors can result in problems with transducer biasing and accuracy. Listed below are the basic conditions of bad data. Use this to troubleshoot your problem.

<table>
<thead>
<tr>
<th>Question/Problem</th>
<th>Answer/Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Noise</td>
<td>Noise can be caused by mechanical vibrations and electrical disturbances, possibly from a poor ground. It can also indicate component failure within the system. If using an external power supply and an unterminated RS-422 cable, make sure that the DC supply voltage has little to no noise superimposed.</td>
</tr>
<tr>
<td>Drift</td>
<td>Drift is when the outputs for a constant load do not stabilize, but continues to increase or decrease. This may be observed more easily in resolved data mode using the bias command. Drift is caused by temperature change, mechanical coupling, or internal failure. Mechanical coupling is caused when a physical connection is made between the tool plate and the transducer body (i.e., filings between the tool adapter plate and the transducer body). Some mechanical coupling is common, such as hoses and wires attached to a tool.</td>
</tr>
<tr>
<td>Hysteresis</td>
<td>When the transducer is loaded and then unloaded, output values do not return quickly and completely to their original readings. Hysteresis is caused by mechanical coupling (explained in Drift section) or internal failure.</td>
</tr>
</tbody>
</table>
7. Specifications

7.1 Operating Conditions for the Capacitive 6-Axis Force Sensor

<table>
<thead>
<tr>
<th>Operating Condition</th>
<th>Min</th>
<th>Nominal</th>
<th>Max</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power Supply Voltage</td>
<td>4.8</td>
<td>5.0</td>
<td>5.2</td>
<td>V DC</td>
</tr>
<tr>
<td>Power-up Time</td>
<td></td>
<td>20 ms</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operating Environment¹</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Temperature</td>
<td>0</td>
<td>50 °C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Humidity</td>
<td></td>
<td>95 %</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Storage Temperature Range¹</td>
<td>-10</td>
<td>60 °C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Consumption Current</td>
<td></td>
<td>200 mA</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes:
1. No condensation.

7.2 Basic Specifications for the Capacitive 6-Axis Force Sensor

<table>
<thead>
<tr>
<th>Specification</th>
<th>Min</th>
<th>Nominal</th>
<th>Max</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated Load</td>
<td>200</td>
<td></td>
<td>500</td>
<td>N</td>
</tr>
<tr>
<td>Maximum Rated Load</td>
<td>400</td>
<td></td>
<td>600</td>
<td>Nm</td>
</tr>
<tr>
<td>Single-Axis Overload</td>
<td>10000</td>
<td></td>
<td>3000</td>
<td>N</td>
</tr>
<tr>
<td>Zero Point Output</td>
<td>7536</td>
<td>8192</td>
<td>8847</td>
<td>LSB</td>
</tr>
<tr>
<td>Detection Sensitivity</td>
<td>28</td>
<td>32</td>
<td>36</td>
<td>LSB/N</td>
</tr>
<tr>
<td>Linearity</td>
<td>3</td>
<td>%FS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hysteresis</td>
<td>3</td>
<td>%FS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cross-axis Sensitivity</td>
<td>-5</td>
<td>+5</td>
<td></td>
<td>%FS</td>
</tr>
<tr>
<td>Zero Point Temperature Characteristics</td>
<td>-0.2</td>
<td>+0.2</td>
<td></td>
<td>%FS/°C</td>
</tr>
<tr>
<td>Output</td>
<td>Digital</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Outside Dimensions</td>
<td>Diameter: 80, Height: 32.5 mm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Material</td>
<td>Aluminum Alloy</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Surface Treatment</td>
<td>Alumite Treatment</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weight</td>
<td>Approximately 360 g</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dustproofing Function</td>
<td>IP60</td>
<td>Ingress Protection Code</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## 7.3 Digital Output I/F Communication Specifications

<table>
<thead>
<tr>
<th>Item</th>
<th>Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transmission Method</td>
<td>RS-422</td>
</tr>
<tr>
<td>Resolution</td>
<td>14 bits¹</td>
</tr>
<tr>
<td>Sampling Frequency</td>
<td>60 Hz (Default), 1900 Hz (High-Speed)</td>
</tr>
<tr>
<td>Data Format</td>
<td>Hexadecimal Text</td>
</tr>
<tr>
<td>Baud Rate</td>
<td>921.6 kbps</td>
</tr>
<tr>
<td>Data Bit</td>
<td>8 bits</td>
</tr>
<tr>
<td>Stop Bit</td>
<td>1 bit</td>
</tr>
<tr>
<td>Parity</td>
<td>None</td>
</tr>
<tr>
<td>Flow Control</td>
<td>None</td>
</tr>
</tbody>
</table>

**Table 7.3**—Digital Output I/F Communication Specifications

<table>
<thead>
<tr>
<th>Transmission Protocol²,³,⁴</th>
<th>N</th>
<th>Fx</th>
<th>Fy</th>
<th>Fz</th>
<th>Tx</th>
<th>Ty</th>
<th>Tz</th>
</tr>
</thead>
<tbody>
<tr>
<td>(TEXT Part)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N: Record number (0-9, incremented one by one) 1 byte</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fx - Tz: Digital output values</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(4-digit hexadecimal x 6ch, 0000 - 3FFF), 4 bytes each</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Send (Commands)⁵**

<table>
<thead>
<tr>
<th>Command</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;R&quot; (1 byte): Request simple data</td>
<td></td>
</tr>
<tr>
<td>&quot;O&quot; (1 byte): Reset offset</td>
<td></td>
</tr>
<tr>
<td>&quot;S&quot; (1 byte): Start outgoing data</td>
<td></td>
</tr>
<tr>
<td>&quot;E&quot; (1 byte): Stop outgoing data</td>
<td></td>
</tr>
<tr>
<td>&quot;p&quot; (1 byte): Request detection sensitivity values</td>
<td></td>
</tr>
</tbody>
</table>

**Notes:**

1. Data is transmitted by integer between the minimum value of 0 and the maximum value of 16383.
2. No delimiter between numerical values; end of line CR+LF
3. Resolution in data transmission, not detection resolution of the sensor.
4. About transmission format: this sensor outputs sensor data in hexadecimal text format as described above. Data is digitally output in the order of:
   - N: Record number (0-9, incremented one by one) Fx, Fy, Fz, Tx, Ty, Tz
   - (4-digit hexadecimal x 6ch, 0000 - 3FFF)
5. Refer to **Section 5.1.1—Serial Commands**.
8. Drawings

NOTES: UNLESS OTHERWISE SPECIFIED.
DO NOT SCALE DRAWING.
ALL DIMENSIONS ARE IN MILLIMETERS.

Material: Aluminum.

1. **DO NOT EXCEED INTERFACE DEPTH, MAY CAUSE DAMAGE.**
2. Do not disassemble transducer. Doing so could damage transducer and will void warranty.

See Note 3

---

8. Drawings

Capacitive 6-Axis Force Sensor Installation and Operation Manual

Document #9610-05-Capacitive 6-Axis Force Sensor-04
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.