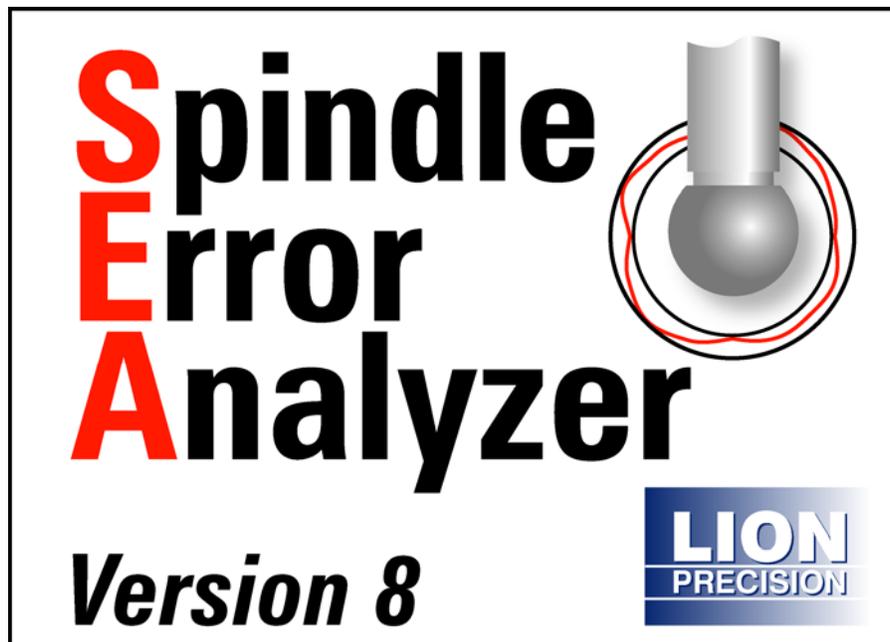


**INSTRUCTION  
MANUAL**

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***Advanced  
Spindle Error Analyzer  
Version 8.4***



**This instruction manual details the operation of the Lion Precision Spindle Error Analyzer Version 8. Please contact us if you have any questions or suggestions on how we can be of greater service to you.**

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Software Version: 8.4  
Manual Version: 005

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# Introduction

The Spindle Error Analyzer System is a hardware and software package for measuring and analyzing the accuracy of spindles on machine tools, hard-disk drives etc.

## ***Fundamental Concepts***

SEA uses noncontact, capacitive sensing to measure error motions as changes in position of precision master targets installed and rotating in the machine spindle. The sensors have a typical range of 250µm with a resolution of 15nm RMS. Actual values may vary depending on the specifics of the system ordered.

The measurements are collected and analyzed by the SEA software. The results of the active measurement or archived measurement file are presented on polar or linear plots with calculated values of error motion measurements.

## ***Tests Performed by SEA***

SEA performs the following tests as described in ISO and ANSI/ASME standards:

- Radial rotating sensitive direction
- Radial fixed sensitive direction
- Tilt fixed sensitive direction
- Axial error motion
- Thermal stability
- Temperature variation error
- Shift vs. RPM

## ***Additional Capabilities of SEA***

- FFT Analysis
- Oscilloscope display
- Analog meter display
- Donaldson reversal test
- Automated Test Sequencing

## **Standards and References**

- ANSI/ASME Standard B5.54-2005, *Methods for Performance Evaluation of CNC Machining Centers*
- ISO230 Part 3 (2001), *Test Conditions for Metal Cutting Machine Tools, Evaluation of Thermal Effects*
- ISO230 Part 7 (2005), *Geometric Accuracy of Axes of Rotation*
- ANSI/ASME B5.57-1998, *Methods for Performance Evaluation of CNC Turning Centers*
- ANSI/ASME B89.3.4, *Axes of Rotation, Methods for specifying and testing*

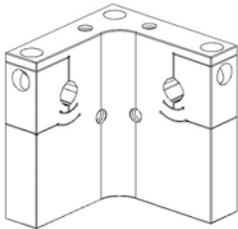
## **Assistance**

For assistance with the installation and operation of the SEA 8 system, please visit our web site at: [www.spindleanalysis.com](http://www.spindleanalysis.com) or contact us at:

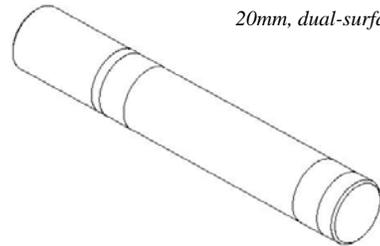
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[www.spindleanalysis.com](http://www.spindleanalysis.com)

## Parts ID

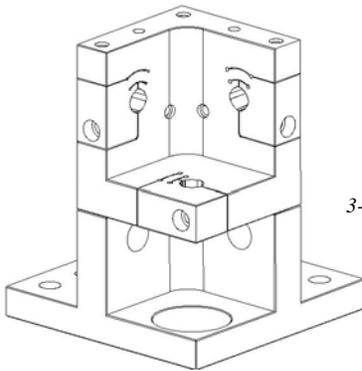
Drawings below identify some of the mechanical components included in the SEA system.



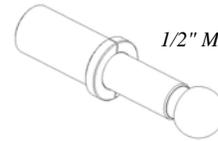
5-Probe Nest Adaptor



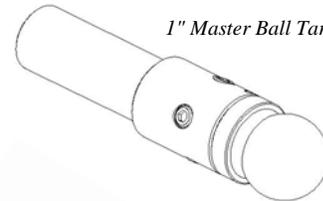
20mm, dual-surface gage pin



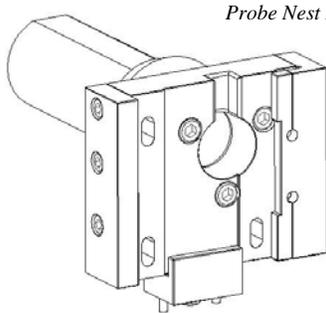
3-Probe Nest



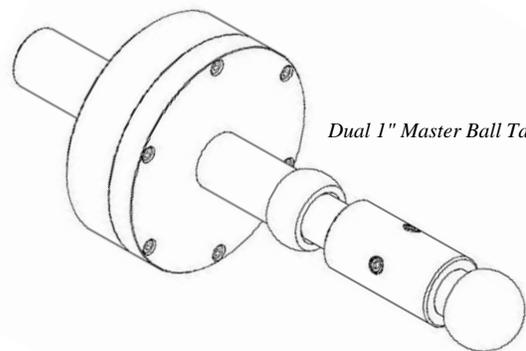
1/2" Master Ball Target



1" Master Ball Target



Probe Nest Lathe Adaptor



Dual 1" Master Ball Target

# Installation

## ***SEA Software***

Install all software before installing the data acquisition device. The SEA software installation includes installation of all required National Instruments driver software.

**Do not** install any software from National Instruments disks included with the National Instruments data acquisition hardware.

### *Minimum Requirements*

Windows XP

1GB (desktop) 1.5GB (laptop)

1GB Free Disk Space (minimum)

1 GHz Processor

1 Available USB port (or PCMCIA Slot if using PCMCIA card)

1024 x 768 Minimum Screen Resolution

### *Procedure*

The SEA installation program installs all necessary hardware drivers. Do not install National Instruments software separately. The SEA program is installed in the PROGRAM FILES\SEA8 directory on your hard disk. If you install the SEA software a second time using the same subdirectory, you will be prompted to confirm the overwrite of the previous installation..

To use the SEA CD-ROM:

1. Insert the CD and wait for the autorun program to load the welcome screen, then select install.
2. If Autorun is disabled on your computer or if the CD fails to autorun for any reason, click on the "My Computer" icon. Then choose the CD-ROM drive. Double click on the program Install.bat.
3. Follow the directions of the installation programs:
4. Once the installation has copied all files from the installation disk, restart the computer.
5. After restarting, run the program by selecting the icon on the desktop, or by selecting **Start > Programs > SEA8**.

The installation CD also contains demo data files and other valuable documents related to spindle measurement and improving machine part quality.

## ***Data Acquisition Hardware***

SEA requires a USB6251 (preferred) or PCMCIA E-series data acquisition card from National Instruments. PCMCIA cards are not recommended.

After the SEA software is installed (which includes National Instruments drivers), install the DAQ device according to National Instruments instructions, and restart the computer.

All National Instruments software was installed with the SEA8 installation. Do not install any National Instruments software from National Instruments CDs.

## ***Security Key (Dongle)***

If an Elite Series sensor system is labeled on the rear panel as “SEA System” you will not require a security key. If you are not using an Elite Series (tan colored) or it is not labeled as an SEA system, then the security key must be attached to a USB port on the computer to perform measurements and collect data. The security key is not required to view or print saved data files.

If upgrading from SEA 7 to SEA8, either the USB or parallel port key may be used.

# Software Basics

## ***Select Mode of Operation***

When the program is launched (**Start > SEA8 > SEA8**), a dialog box appears requiring mode of operation selections in four categories. Selections are as follows:

### ***Measurement System Model***

**Elite Series** - sensors provide TEDS (transducer electronic data sheets) information to the SEA system.

**CB-7** - Older style sensors do not provide TEDS and require the installation of VTEDS files (p. 12).

Use the photographs to help you select your measurement system. If the software key is not connected to the computer, these buttons will be grayed out.

### ***Select DAQ Source***

#### **Select DAQ Device (DEV1, DEV2)**

##### **None**

The first time the program is run, you must select the source of DAQ information. Normally, there is only one to choose from. The installed DAQ devices are listed as: DEV1, DEV2.... After selecting a device, a description of the device will be displayed.

If only viewing or printing data (there is no DAQ device), select None.

### ***View Files Only – Simulator Mode***

**View Files Only** – This mode only produces static displays of files loaded for viewing.

**Simulator Mode** – In this mode, all displays draw data from the internal simulator. Displays update as if making measurements.

## ***Setting Notepad and Acrobat Paths***

Windows Notepad is used for Comments in SEA. For Comments to function, SEA must know the path to the Notepad application.

Adobe Acrobat is used for viewing the pdf manual from the Help menu. SEA must know the path to the Acrobat application.

These paths are entered in the **Main Menu > Configuration > General** screen.

These are typical paths to the files, but it may be different on your computer:

Notepad: C:\Windows\notepad.exe

Acrobat: C:\Program Files\Adobe\Acrobat 8.0\Acrobat\acrobat.exe

Each new version of Acrobat will be placed in a new directory. If you install a new version of Acrobat, this path must be modified.

## Basic Navigation

The SEA software uses several simple conventions that make the software easy to use.

- *Menus display lists of selectable options.*
- *Buttons execute or gain access to features.*
- *Panels display fields of information.*

### Quadrant Displays

SEA starts with four different display panels in four quadrants on your screen. Each quadrant displays a selected view of the current data. The current data may be live data from the sensors, saved data from a previous measurement, or simulated data for training and experimentation.

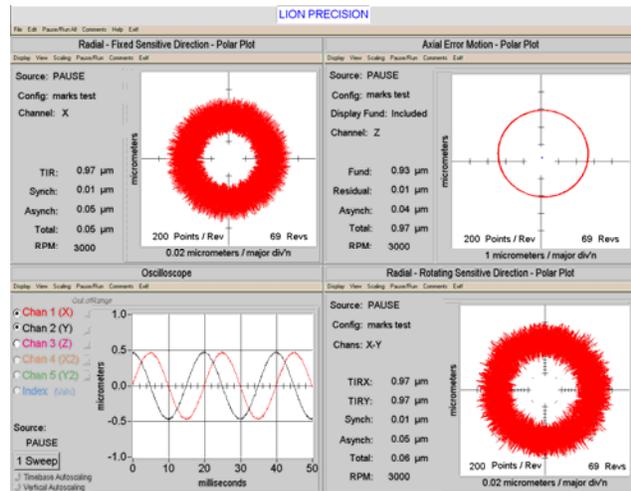
Each quadrant has a menu bar which begins with **Display**. Use the display menu to select which panel to display in that quadrant.

### Logo Screen (Information Quadrant)

Screen prints are often used to document spindle tests. It is helpful to have test information displayed on the screen when the screen is printed.

To display an information quadrant, select **Display > Logo Screen** in a quadrant.

Click in the text box to enter text. To change the displayed image, select **View > Select Graphic** from logo screen's tool bar.



### Maximizing Displays to Full Screen

Initially, each display uses one quarter of the screen (quadrant). Select **View > Maximum Size** to fill the entire screen, or double click the right mouse button over the display to be maximized.

### Minimizing Displays to a Quadrant

Select **View > Normal Size** to return a maximized display to its quadrant, or double click the right mouse button over the display.

## Choosing a Language

To select a language other than English:

1. In any quadrant, select **Display > Configuration Displays > General Configuration**
2. Select the desired language from the **Language** drop down menu
3. Exit and restart the SEA Software

Language choice is remembered between sessions.

## SEA Configuration

SEA software must be properly configured for proper operation. There are different types of configuration information:

**Indicators:** These display information acquired from the system or calculated from other fields.

**Automatic Inputs:** These are required input settings which are automatically acquired from the system.

**Manual Inputs:** These may be required or optional input settings that must be manually entered by the user.

Configuration settings can be saved with **Configuration > Save Configuration** in the main menu bar.

The complete configuration consists of data from several different configuration windows. Access the configuration windows through **Main Menu > Configuration** or individual quadrant **Display > Configuration > [Selected Configuration Window]**.

## ***General Configuration***

<b>Field</b>	<b>Type</b>	<b>Notes</b>
Language	Required Manual Input	
Comment Editor	Optional Manual Input	Path to Windows Notepad. Only required to enter test notes and to view some help files.
PDF Viewer	Optional Manual Input	Path to Adobe Acrobat. Must be entered correctly to view the onscreen manual.
Display Units	Required Manual Input	
Date Format	Required Manual Input	

## ***DAQ Configuration***

DAQ configuration settings determine the operation of the data acquisition board and are critical to the operation of the system. This panel displays the RPM Range possible with the current settings and is updated when the settings are changed. Settings in Analysis Configuration also affect the RPM Range.

<b>Field</b>	<b>Type</b>	<b>Notes</b>
DAQmx Device Name	Required Manual Input	Set during mode selection on program start. Can be modified here.
Active DAQ Channels	Required Manual Input	Setting the DAQ board to access only the channels to be used; increases the maximum sampling rate of the system.
DAQ Gain	Required Manual Input	Default = Minimum ( $\frac{1}{2}$ or 1). Must be adjusted for a $\pm 10V$ input range. For more information click the "DAQ Gain Help" button.

## ***Analysis Configuration***

Relationships between RPM, Points per Revolution, number of sensing channels, and DAQ sample rate have an important impact on the measurement process. Settings in this configuration panel control those relationships.

A sufficient number of samples per revolution is required to obtain a meaningful view of spindle behavior. However, if the DAQ sample rate is too high, the system can become burdened with processing the samples and displaying them on the screen. The Analysis Configuration panel allows adjustment of these parameters and provides feedback regarding system load and processing time.

The slider at the top of the panel selects the mode used to determine the DAQ sample rate: Enter RPM, Enter DAQ Rate, Encoder.

**Enter RPM (recommended):** the user enters the target spindle speed and the Points per Revolution; the DAQ sample rates are calculated and displayed in corresponding indicators

**Enter DAQ Rate:** the user directly enters the DAQ samples per channel per second.

**Encoder:** an encoder connected to the spindle is used to trigger DAQ samples

Field	Type	Notes
Revolutions for Display and Calculations	Required Manual Input	Number of revolutions displayed in test panels and used for calculated values
Points per Revolution	Required Manual Input (RPM and DAQ modes)	Number of individual points displayed during each revolution
	Indicator (Encoder mode)	
Maximum RPM	Indicator	Maximum RPM at which measurements can be made with current settings
Minimum RPM	Indicator	Minimum RPM at which measurements can be made with current settings
Rotation Angle Detector	Required Manual Input	Default = Target Eccentricity Ch. X Target eccentricity is used to determine the angular location of the spindle. Alternatively, an index pulse from a spindle encoder or other “once around” sensor can be used.
Slow/Normal Response	Indicator	Indicates percent of processing load. Slower responses have greater delay between activity at the spindle and display updates
Measured RPM	Indicator	Current measurement of RPM
Target RPM	Required Manual Input	RPM used to calculate the DAQ sample rate based on current setting of Points per Revolution
Set Target RPM to Meas RPM	Button	Transfers the current measured RPM to the Target RPM field.
Samp/ch/sec	Indicator (RPM, Encoder modes)	Indicates the samples per channel per second based on current RPM and Points per Revolution settings
	Required Manual Input (Enter DAQ Rate mode)	Sets the number of samples per channel per second taken by the data acquisition system
Chans	Indicator	Number of channels currently being sampled
Tot Samp/Sec	Indicator	Total number of samples per second taken by the data acquisition system
Encoder Pulses per Rev	Required Manual Input (Encoder mode)	Number of encoder pulses generated per revolution
	Inactive (RPM, DAQ modes)	

DAQ Card Divider	Required Manual Input (Encoder mode)	Divides the encoder pulses per rev to determine DAQ sample rate. For example, a 1024 pulses per rev encoder can be divided by 4 to obtain a 256 DAQ samples per rev rate
	Inactive (RPM, DAQ modes)	

### ***Calibration Configuration***

Calibration information is acquired through TEDS (Elite Systems) or VTEDS (older sensor systems). This is automated and these values should not be changed except in the rarest of circumstances.

The Low/High Sensitivity switch is used to remotely change a sensing channels sensitivity. The Sensitivity switches on the driver front panel are disabled when the sensing system is connected to the SEA data acquisition system. The sensitivity switch is only applicable to CPL290 and DMT22 drivers.

<b>Field</b>	<b>Type</b>	<b>Notes</b>
Sensitivity Switch	Required Manual Input	Only works with CPL290 and DMT22 drivers.
Near Gap	Indicator	The minimum calibrated distance from probe face to target, listed in dimensional units and corresponding output voltage.
Far Gap	Indicator	The maximum calibrated distance from probe face to target, listed in dimensional units and corresponding output voltage.
Sensitivity	Indicator	The amount of output voltage change for a given change in probe/target gap. This is calculated from the Near and Far Gap information.
DAQ Card Range and Resolution	Indicator	Actual near and far gaps after allowing for DAQ Gain setting. For example, a DAQ Gain of 10 will give higher resolution, but input voltage range (and therefore the measurement range) will be limited to less than the calibrated range of the sensors.

## ***Calibration Data***

This panel displays the calibration information for all of the sensor channels in the sensor system. The panels will appear slightly different for Elite Series sensor systems than they do for older model modular systems.

See the TEDS and VTEDS section below for important, detailed information on the functional differences in the two system types.

<b>Field</b>	<b>Type</b>	<b>Notes</b>
Reload	Button	Re-acquires the calibration information from the TEDS or VTEDS source.
Chassis	Indicator	Only visible when connected to an Elite Series system.
Available Slots	Indicator	Number of slots available in the system enclosure
VTEDS Filename	Required Manual Input Non-Elite systems only	Default filenames follow SEA conventions and should not require changing. Should a different filename be necessary, click each filename to specify the desired VTEDS file.
Columnar Data	Indicators	A column for each slot indicates the vital statistics of the sensing channel.
More	Button	The “More” button will open a dialog box with indicators detailing calibration information acquired from TEDS or VTEDS.  It is possible to change these values but this should only be done in the rarest of circumstances and with assistance from Lion Precision. Any manual changes made here will be lost when the SEA 8 program is closed.

## ***TEDS and VTEDS***

TEDS (Transducer Electronic Data Sheet) is technology which enables measurement systems to acquire a wealth of calibration information directly from the sensor. SEA 8 depends heavily on TEDS for configuration information.

The Elite Series is TEDS compliant and provides configuration information to SEA 8 when the software is launched. Older systems (black and gray enclosures) are not TEDS compliant and do not provide the configuration data directly. When SEA 8 is used with older sensing systems, the required TEDS data is provided through VTEDS files (Virtual TEDS). These files are provided on a CD and contain specific calibration information for the system being used.

It is critical that the correct VTEDS files be used with corresponding sensing system.

The VTEDS CD includes an installation program which will install the files in the appropriate folder of the SEA 8 system, provided SEA 8 was installed in default directories. The VTEDS files must be located in the “VTEDS Files” subdirectory of the SEA 8 directory.

## ***Machine Information***

Optional, machine-specific information can be entered here including spindle position information on six axes.

<b>Field</b>	<b>Type</b>	<b>Notes</b>
Operator Name	Optional Manual Input	Value is displayed as part of “time stamp”
Machine ID	Optional Manual Input	Value is displayed as part of “time stamp”
Position/Units	Optional Manual Input	Position settings in six axes and unit of measure. Three of the six axes can be displayed in degrees as well as inches or meters
Graphic File	Optional Manual Input	Click the existing image to load a photo or drawing to represent the machine under test. Possible graphic file types: bmp, pcx, wmf.

## ***Target Configuration***

The size, shape, and accuracy of the targets affect the measurement results. For maximum accuracy, the details of the target must be entered here. Each channel of measurement can have separate values.

<b>Field</b>	<b>Type</b>	<b>Notes</b>
Target Model	Optional Manual Input	Target Model such as “1" Dual Ball”
Target Serial	Optional Manual Input	Target serial number
Last Cal.	Optional Manual Input	Last calibration date of the target
Next Cal.	Optional Manual Input	Target calibration due date
Length X to X2	Required Manual Input	Default = 76.2mm. Distance between the X and X2 probes. Used in tilt measurements. Standard 5-probe nest distance is 76.2mm.
Roundness Error	Required Manual Input	Default = 0.0 $\mu\text{m}$ . Roundness error specification from target calibration information. This can be entered in either micron or micro-inch fields. This value is for reference only and is not used in calculations.
Target Shape	Required Manual Input	Default = Sphere
Target Dimension	Required Manual Input	Default = 25.4mm. Diameter of a round target.

Field	Type	Notes
Target Multiplier	Required Manual/Automatic Input	Sensors are calibrated to flat targets. When the probes are measuring a cylindrical or spherical target, a correction multiplier is required for accurate measurements. When “Auto” is checked, the multiplier is automatically calculated for the selected target shape, size, and calibrated range. Auto values are only available for “C” size probes (C23-C). If an unlisted target or other probe size is used, a manual multiplier can be entered by unchecking the Auto check box.

### ***Diagnostics***

Various status and condition monitors are available in this panel. This information may be used during troubleshooting.

# Making Measurements and Reading Plots

## *Understanding and Interacting with Plots*

### Adjusting Plot Displays

#### *Scaling*

Use the Scaling menu to select Auto or Manual scaling. Auto scaling adjusts to provide the best view of the existing data. Select **Scaling > Manual > Increase** or **Decrease**, or use Page Up and Page Down keys to adjust scaling manually.

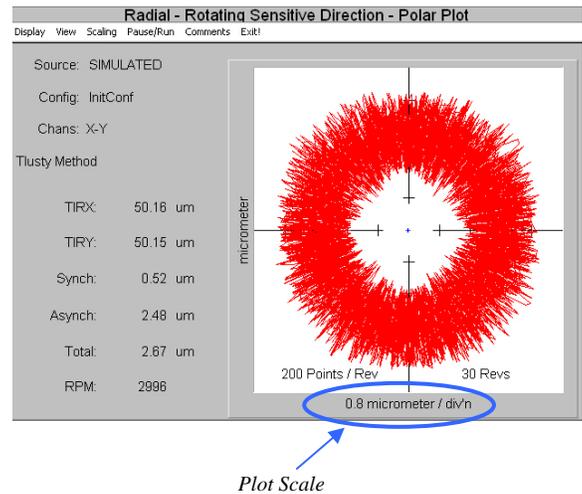
#### **Polar plots**

Polar plots chart measurements at successive angular locations of the spindle. By default, all acquired rotations are displayed simultaneously.

The plot scale is listed at the bottom of the plot.

The center of the plot does not represent zero when the axes do not cross (see example at right). This allows sufficient display resolution of small spindle motions, which would be off-screen if the center were zero.

Calculated values are to the left of the plot. Definitions of the calculated values are in the glossary in this manual and in Help.



#### *Calculated Circles*

Circles can be displayed on the plots to assist in measuring and viewing some important calculated values. To enable circle displays, select **View > Circles**.

**Total** – Displays two blue circles. The origin of the circles is at the center of the plot. The inner circle is the largest diameter possible *inside* of the data points (maximum inscribed circle). The outer circle is the smallest diameter possible *outside* the data points (minimum circumscribed circle). The distance between the circumferences of these circles is the total error motion.

**Average** – The average circle is not actually a circle. This green curve is generated by placing a data point at each angular location. The position of the point is equal to the average of the measurements of all the acquired revolutions at that angular location.

**Least Squares** – Displays a black circle based on a best-fit, least squares calculation of all the displayed data points.

To find the center of polar plot data, SEA uses the MLS (Modified Least Squares) method describe in *A Few Methods for Fitting Circles to Data* by Umback and Jones (IEEE Transactions on Instrumentation and Measurement, V52, I6, December 2003).

## Setup for Making Measurements

### Configuration

The SEA 8 software must be properly configured. Much of the configuration information is accessed directly from the sensing system.

Some configuration information must be entered by the user. This information must be properly entered for accurate measurements.

See the configuration section of this manual for details (p. 8).

### Connection to PC

Connect a 68 pin, high-density cable between the rear panel of the capacitive sensing system and the National Instruments data acquisition system. If the National Instruments USB6251 Data Acquisition Module is used, it is necessary to connect a USB cable between the Module and a USB V2.0 (high speed) port on the PC. The USB V2.0 (high speed) port is necessary due to the high data transfer rates required.

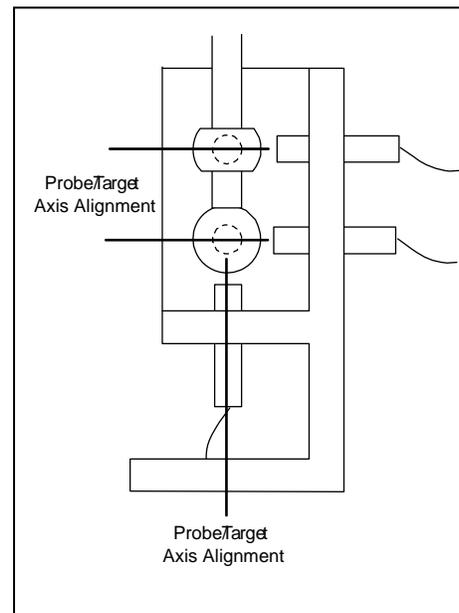
### Mechanical

There are five goals in the mechanical setup:

- Probes never make contact with target during rotation (incidental contact during setup while the spindle is stationary is safe)
- Master ball target axes are aligned with probe axes (balls are centered on the probes)
- Probes are adjusted to the center of their measurement ranges
- Target eccentricity is adjusted to be greater than the expected error motions ( $25\mu\text{m}$  is typical)
- Probes stay in range during the full rotation of the spindle

#### Target Installation

Targets are installed in the tool/part holder of the spindle to be tested.



#### Axis/Channel Relationships

Default settings in the SEA software assume Axis/Channel relationships as listed in the table below. Some individual tests allow the assignment of other Axis/Channel relationships. This flexibility allows a three-channel system to make measurements normally requiring five channels, such as using the Z probe temporarily in the X2-axis to make a Tilt measurement.

<b>Default Axis/Channel Relationships</b>	
<b>Axis</b>	<b>Channel</b>
X	1
Y	2
Z	3
X2 (X-axis probe near spindle nose in 5 probe setups)	4
Y2 (Y-axis probe near spindle nose in 5 probe setups)	5

### *Probe Nest*

Loosen the clamp screws if necessary and install the probes in the nest. Tighten the probe clamps such that the probes are held in place but can still be repositioned by hand.

Mount the probe nest such that the rotating target can be moved into range of the probes in the nest. It is critical to firmly clamp the probe nest to the machine tool table.

### *Positioning Spindle/Targets and Probes*

Each probe must be precisely centered on the spherical surfaces of the targets. Target centers are located and positioned by using the probes and Probe Meter to find the high-spot as the target is repositioned in front of the probe. Center the targets on the probe with a process such as this:

#### *Initial setup*

1. In any quadrant, select **Display > Probe Meter**.
2. Maximize the Probe Meter (double right-click on the panel)
3. Move the spindle/target into the probe nest and approximately center it on the Z-axis probe in the bottom of the probe nest and on the X- and Y-axis probes.

#### *Z-axis centering*

4. Select the Z-axis channel on the Probe Meter (usually channel 3).
5. Physically adjust the Z-axis probe position until the Near/Far indicator on the driver is in the center position.
6. While observing the Probe Meter adjust the spindle X-axis position until the high-spot (maximum positive indication) is indicated on the Probe Meter.
7. While observing the Probe Meter adjust the spindle Y-axis position until the high-spot (maximum positive indication) is indicated on the Probe Meter.
8. The target is now centered over the Z-axis probe.
9. Loosen and move the Z-axis probe away from the spindle so it will not be touched during the following steps.

### *X/Y-axis centering*

10. Select the X channel on the Probe Meter
11. Physically adjust the X-axis probe position until the Near/Far indicator on the respective driver is in the center position.
12. Adjust the spindle Z-axis position until the high-spot (maximum positive indication) is indicated on the Probe Meter.
13. Using the Near/Far indicator on each respective channel, adjust the X- and Y-axis probe positions so they are at the center of range.

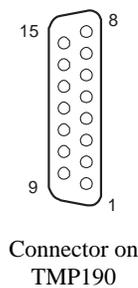
### **Measuring/Adjusting Target Eccentricity**

Target eccentricity is adjusted to provide a once-around signal that is used to determine angular location of the spindle. Eccentricity should be slightly higher than the expected error motion (25µm is typical). Eccentricity is not required when using an index pulse.

1. Select an X- or Y-axis probe on the Probe Meter. (If using a dual-ball target and five-probe nest, first select a probe for the ball nearest the spindle nose).
2. Click Refresh TIR on the Probe Meter.
3. Turn the spindle by hand one rotation.
4. The distance between the TIR markers (sticky needles) is the eccentricity of the target
5. If eccentricity needs adjustment, adjust the target eccentricity according to TechNote LT03-0013 included with the system and available in the Technical Library at [www.lionprecision.com](http://www.lionprecision.com).
6. When the eccentricity is correct, move all probes into center of range as indicated by Near/Far indicators on the drivers.
7. Rotate the spindle again and monitor the Near/Far indicators on all sensor channels. If any channel goes out of range (a red light turns on) during the rotation, slightly reposition that channel's probe and retry until all probes remain in range during the rotation.
8. Tighten all probe clamps.
9. Rotate spindle again to confirm all probes remain in range.

### **Temperature Probes**

Place temperature probes as desired on the machine under test. SEA 8 temperature channels T1 – T7 are related to TMP190 sensors as shown in the table below.



<b>Pin Numbers</b>	<b>Connection</b>	<b>Pin Numbers</b>	<b>Connection</b>
1, 9	Probe 1 (T1)	5, 13	Probe 5 (T5)
2, 10	Probe 2 (T2)	6, 14	Probe 6 (T6)
3, 11	Probe 3 (T3)	7, 15	Probe 7 (T7)
4, 12	Probe 4 (T4)	8	No connection

### *Encoder/Index Connections*

Refer to the TMP190 manual for connection details. Spindles without encoders may still use an Index pulse by using an external sensing source such as a mark and an optical sensor.

## Running Tests

To view live test data while a spindle is being measured, select **Load > Live Display** from the SEA 8 main menu bar.

To view data from saved measurement data, select **Load > Test Data File**.

Reading and interacting with the test plots and panels in general is covered above. The following sections give specific, unique information about the specific tests.

The default channels are listed first as the Possible Channel Combinations.

## Basic Tests

### *Radial: Rotating Sensitive Direction*

<b>Number of Sensors Used</b>	2
<b>Axes Measured</b>	{X, Y}
<b>Possible Channel Combinations</b>	{1, 2} or {4, 5}

X and Y axis measurements are used to create a polar plot using one of two possible methods:

B89.3.4 (r-theta) or

Trusty

The method is selected by **View > Method**.

### *Radial: Fixed Sensitive Direction*

<b>Number of Sensors Used</b>	1
<b>Axes Measured</b>	{X} or {Y}
<b>Possible Channel Combinations</b>	{1} or {2} or {3} or {4} or {5}

X or Y axis measurements are acquired and presented in a polar plot or a linear plot with angular position on the X-axis.

Select the plot type with **View > Polar Plot** or **Linear Plot**.

### *Axial Error Motion*

<b>Number of Sensors Used</b>	1
<b>Axis Measured</b>	{Z}
<b>Possible Channel Combinations</b>	{3} or {1} or {2} or {4} or {5}

Measures spindle motions in the Z-axis using the probe mounted in the bottom of the probe nest.

Polar and linear plots are available (**View > Polar** or **Linear**).

Select **View > Display** to choose one of three different display options are available for the plots:

**Total with Fundamental** – includes error motions at the rotational frequency of the spindle.

**Total without Fundamental** – error motions at the rotational frequency of the spindle are removed from the data before plotting.

**Asynchronous Only** – error motions at the fundamental or harmonics of the rotational frequency are removed before plotting.

The calculated values are not affected by display choice. See the glossary for more information on these display modes.

*Tilt: Fixed Sensitive Direction*

<b>Number of Sensors Used</b>	2
<b>Axes Measured</b>	{X, X2} or {Y, Y2}
<b>Possible Channel Combinations</b>	{1, 4} or {2, 5} or {1, 2} or {1, 3} or {2, 3}

Measurements from both X and X2 (or Y and Y2) channels provide measurements of the synchronous and asynchronous changes in the tilt of the spindle at different angular locations. A standard polar plot (tilt angle in  $\mu$ radians) or a 3D plot are available.

Three channel systems can make Tilt measurements by moving the Z axis probe into the X2 or Y2 position and using **View > Channels** to select the Z axis probe.

Plot type is selected with **View > Polar** or **3D**.

*Thermal*

<b>Number of Sensors Used</b>	1-5, plus up to 7 temperature sensors
<b>Possible Channel Combinations</b>	Any single channel or tilt combinations (up to seven temperature sensors)

The two thermal tests listed in international standards are ETVE (Environmental Temperature Variation Error) and Thermal Drift. The display and basic operation of the panel remains the same for both tests. Only the time of the test, the channels used, and the rotation of the spindle are changed.

The thermal test setup parameters are accessed by clicking **Setup!** on the Thermal menu bar.

Measurements are acquired from all channels enabled in the DAQ configuration.

Clicking sensor buttons enables/disables the display of the channel on the chart. When clicked, the X2 and Y2 buttons rotate through Drift/Tilt/Disabled options. Redraw button must be clicked to display new enable/disable selections.

The value displayed on the buttons is the Range (max-min) for that channel.

A valid filename must be specified for the thermal data.

### *Custom Temperature Channel Names*

Right-click on a temperature channel display button to enter a custom name such as “ambient” or “spindle.”

### *ETVE (Environmental Temperature Variation Error)*

Tests the growth and movement a nonrotating spindle due to changes in ambient temperature.

<b>Standard TVE values:</b>	
Interval 1 Duration	2 minutes
Interval 1 Sample Frequency	5 seconds
Interval 2 Duration	24 hours
Interval 2 Sample Frequency	5 minutes

### *Thermal Drift*

Tests the growth and movement of a rotating spindle due to changes in the temperature distribution caused by heat generated by the spindle motor and/or bearings.

<b>Standard Thermal Drift values:</b>	
Interval 1 Duration	2 minutes
Interval 1 Sample Frequency	3 seconds
Interval 2 Duration	58 minutes
Interval 2 Sample Frequency	10 seconds

### *Shift vs. RPM*

<b>Number of Sensors Used</b>	1-5
<b>Axes Measured</b>	Any
<b>Possible Channel Combinations</b>	All single channels or tilt combinations

The axis of rotation of the spindle may change location with changes in RPM. The test charts changes in the position of the axis of rotation of the spindle against RPM. The operator adjusts RPM and clicks the Save Point button to plot a point.

The first time Save Point is clicked, measurements of the spindle in all axes are set as the reference for future measurements. Successive clicks of Save Point will plot the position change of the spindle at the measured RPM.

Clicking the channel buttons will enable/disable the display of that channel.

Measurements can be taken as the RPM is increased and retaken as the RPM is decreased to display any hysteresis in the RPM/Spindle Position relationship.

## Donaldson Reversal (Target Reversal)

Donaldson Reversal displays data from two Radial – Fixed Sensitive test runs combined in such a way that form errors in the target (out of roundness) are separated from the synchronous error motion of the spindle. The Radial – Fixed Sensitive display must be active in another quadrant during Donaldson Reversal functions.

### *First measurement:*

1. Display the Donaldson Reversal panel in one quadrant.
2. Display Radial – Fixed Sensitive panel in another quadrant.
3. Perform a Radial – Fixed Sensitive measurement.
4. Click **Store A** to store the current Radial – Fixed Sensitive plot in the Donaldson Reversal display.
5. Stop the spindle.

### *Second measurement*

6. Move the probe to a position 180° around the spindle from its original position.
7. Remove and replace the target 180° from its original position in the spindle.
8. Perform another Radial – Fixed Sensitive measurement (do not change any settings).
9. Click **Store B** to store the new Radial – Fixed Sensitive plot in the Donaldson Reversal display.
10. Click **Calculate**.

The synchronous error motion of the target and the spindle are plotted independently. Use the display buttons to turn individual plots on and off.

## Automated Measurement

Automated Measurements is useful for testing time- or speed-related changes in spindle performance.

Automated Measurement repeatedly runs axial or radial tests at a specified time interval or at selected speeds. When testing at predetermined time intervals, each run of the test is called a **Trial** and fills one row in the data file. Multiple trials can be grouped. A **Group** consists of 1 to 1000 trials. Time intervals between Trials and Groups can be set independently. Test runs can include 1 to 1000 Groups. Use caution with large Trial and Group sizes as the data file can become very large.

Click **Setup!** on the menu bar to configure the test.

### *Setup*

Click the Setup button to display the Automated Measurement setup panel.

**Test Type** selects the type of measurement to be performed. The selected test type must be active and configured in another quadrant. The options are:

- Rotating Radial
- Fixed Radial
- Axial

### **Trail and Trial Group Setup**

**Trials/Group:** number of trials per group. 1-1000

**Groups:** number of groups in the test. 1-1000.

**Trial Delay:** delay between individual trials within a group.

0-59 seconds (Summary file save option)

30-59 seconds (SEA and Summary file save option)

**Group Delay:** delay between groups. Must be greater than Trial Delay X Trials/Group

## File Setup

### Save

**Summary:** contains only the resultant data as recorded in the table.

**SEA and Summary:** includes resultant data and the individual samples for later viewing in the SEA quadrants. The **SEA and Summary** selection will generate very large files.

## Auto RPM

Auto RPM automates testing at different spindle speeds. Operators can increase spindle speed, manually or programmatically, and SEA will automatically initiate a measurement at specified speeds. Auto RPM assumes that RPM will *increase* during the automated test. After taking a measurement at the Stop RPM, testing will cease.

**Auto RPM:** enables Auto RPM function

**Start RPM:** lowest RPM at which to measure

**Stop RPM:** highest RPM at which to measure

**Step RPM:** intervals at which to measure

**RPM Window:** error margin for RPM measurement. RPM must fall within the window to trigger a measurement

**Dwell Time:** delay after achieving an RPM before measurements are made

## Limits

Under some circumstances, values reported by SEA, especially RPM, may momentarily report aberrant values such as 0 or 1 RPM. This is due to system processor limitations. In normal operation, the operator rarely notices these quick, momentary values, but should it occur while the Automated Measurements is collecting data, the resulting data would be skewed.

Check the parameters to be monitored and set minimum and maximum values.

Automated Measurements will verify that all checked values are within limits before capturing the data. If any checked values are outside the limits, the system will wait until all return to acceptable values. While waiting, the system will display a red **Beyond Limits** message in the table.

When all selections have been made, click **START Test**. The test will run until the selected number of trials and groups have been completed. The test can be paused or ended before completion by clicking the appropriate button.

**View > Automated Test File** loads a previously saved test file for viewing.

## Utilities

### FFT Frequency Analysis

<b>Number of Sensors Used</b>	1
<b>Axes Measured</b>	Any
<b>Possible Channel Combinations</b>	Any single channel

Used to analyze frequency distributions in error motions. The FFT analysis test acquires sampled amplitude data from a single probe in the *time domain* and converts the data into the *frequency domain*. A graph of amplitude vs. frequency is produced. The graph is updated once per second, showing the FFT results on the most recent data set.

*FFT Views (from **View** menu):*

**Bar Graph** – Bar (column) graph display

**Line Graph** – Continuous line connecting measurements

**Ping** – Plots the results of a triggering event such as a hammer ping.

*Window(from **View** menu):*

Selects the type of mathematical windowing technique for displaying the FFT. Hanning or Rectangular are typical choices.

### *Scaling*

Scaling and axis unit options are available in the **Scaling** menu.

### *Cursor*

A cursor (**View > Show Cursor Values**) can be used display values at any point on the charts X-axis (frequency). Click and drag the mouse pointer to reposition the cursor or use keyboard arrow keys. For fine adjustment, hold the shift key while using arrow keys.

### Oscilloscope

The Oscilloscope is a utility display that emulates a basic oscilloscope, allowing a time based view of the data acquired on any of the five probe channels.

Use the View menu to select DC/AC Coupling and multi-trace or multi-scope mode. Multi-scope mode is only available when the panel is maximized to full screen.

### Probe Meter

The Probe Meter is a utility display that emulates an analog meter indicating the current probe/target gap of the selected probe.

The Probe Meter is best used maximized to full screen.

Any one of the five probe channels can be displayed. Use the mouse or the up or down keyboard arrows to select a different channel.

If the measurement is out of range, red “overrange” text will appear on the meter.

Maximum and minimum indicators retain the maximum and minimum positions of the meter needle. These values are shown digitally below the meter. Click the **Reset TIR** button to reset the maximum and minimum indicators to the current meter indication.

## Saving and Printing Results

Positioning the mouse cursor over **Save** on the main menu will pause the acquisition process. This provides a stable display for screen printing, saving, or on-screen visual analysis. Saving files from the main menu bar saves rotating test data into a .lda file. File size can be from 1-20MB depending on sample rates and other factors.

Thermal, Shift vs. RPM, Automated Test, and Donaldson Reversal test files are saved from their corresponding quadrant windows.

Clicking **Save** will launch the Save dialog box and copy a screenshot to the clipboard. The user enters a file name into which the data will be saved. SEA can append a counter to the end of the file name allowing for automatic increments to the file name during subsequent saves.

**Core File Name:** the base file name and path into which data is saved (c:\machinedata.lda)

**File Name to be saved:** the core file name plus an underscore with automatically incrementing file number (c:\machinedata\_1.lda). This field is automatically filled by SEA, but can be overwritten by the user to specify the final file name.

### Selectable Options:

**Save data file:** saves current data represented on screen to the file name indicated

**Save screen image:** saves a screenshot to the same file name but with .bmp extension

**Print screen image:** launches a print dialog after save operations allowing for direct printing of current screen

**Automatically increment...:** enables the automatic incrementing of file name

## File Structure

Critical files for SEA must be located in appropriate subdirectories. These files are placed in the correct locations during the installation process. This structure is provided in case new files need to be added or to assist in troubleshooting.

### **base = C:\Program Files\SEA8**

Contains all program files

### **base \DOCS**

All Help files

SEA 8.0 Manual

Related documents and text files

### **base \VTEDS Files**

VTEDS files must be in this subdirectory to be used by SEA 8

### **C:\ProgramData\LionPrecision\SEA8\Data**

Default directory for data files. User can save data files to any location.

All sample data files

SEA 8 measurement data files can be stored anywhere

**C:\ProgramData\LionPrecision\SEA8\Setup**

All configuration files

**C:\ProgramData\LionPrecision\SEA8\Language**

Text files with labels and phrases used in SEA 8, translated to the language of the name of the file, e.g. english.txt contains the English labels and phrases.

# Appendices

## *Menu item descriptions*

### Main Menu Bar

#### Save

Placing the cursor over **Save** on the main menu bar will pause the acquisition process.

Clicking **Save** copies a screenshot to the clipboard and launches a dialog box with file save and print options. If a screenshot is all that is necessary, the dialog box can be cancelled. See p. 26 for details.

#### Load

**Live Display:** purges all data buffers then starts or restarts the Data Acquisition device and begins to display data in each of the four quadrants. The source indicator in each quadrant changes to indicate **Live Data**.

**Test Data File:** (\*.lda) – Data is displayed in all radial and axial panels

**Thermal Data File:** (\*.lts) – Data is displayed in the Thermal panel only

**Donaldson Reversal File:** (\*.trv) – Data is displayed in the Donaldson reversal panel only

**Automated Test File:** (\*.lsq) – Data is displayed in the Automated Test panel only

Viewing stored data loads the original configuration file. The configuration settings cannot be changed.

**Simulated Display:** uses internally generated signals to be read by the system for the purpose of testing, demonstrating, and experimenting with the software. A complete waveform simulator is displayed in the first quadrant.

A typical setup simulating common input conditions:

- All Switch Positions: Simulate
- Waveform X: Sine
- Waveform Y: Cosine
- Amplitude (All): 1

#### Configuration

**Show:** loads all quadrants with configuration panels; General, DAQ, Diagnostics, Calibration

**Save Configuration:** saves the current configuration.

**Configure As (new file):** “save as” function for creating new configuration file

**Load Configuration:** loads existing configuration file

**Return to Test Displays:** removes configuration screens from quadrants and reloads test panels

#### Help

**Manual** starts Windows Help with an electronic copy of this manual.

**Typical Setups** displays a photo of a typical setup for the selected machine type.

**Lion Precision Support** lists contact information for Lion Precision technical support

**New Features** displays pdf file describing changes in latest versions of SEA 8

**About** gives version information for SEA 8

### *Exit!*

Closes the program.

## Quadrant Menus

### *Display*

Lists all possible quadrant displays. All Test and Configuration displays can be accessed through this menu. Whether the quadrant is currently a Test or Configuration display changes the groupings in this menu.

### *View*

**View > Maximum Size** enlarges a quadrant panel to full screen.

**View > Normal Size** reduces a full-screen panel to a quadrant.

**View > Polar Plot** provides a polar plot of the error motion.

**View > Linear Plot** provides a linear plot of the error motion with degrees of rotation as the chart's X-axis and error as the chart's Y-axis.

**View > Display > Total** displays the synchronous plus asynchronous error.

**View > Display > Total with Fundamental** displays all spindle motions including motions occurring at the rotational speed of the spindle (includes eccentricity).

**View > Display > Total without Fundamental** removes motions occurring at the rotational speed of the spindle.

**View > Display > Asynchronous Only** displays the asynchronous error only.

**View > Circles > Total [F3]** draws the maximum and minimum value circles on the graph at the next update.

**View > Circles > Average [F4]** draws the average value plot on the graph at the next update.

**View > Circles > Least Squares [F5]** draws the least squares circle on the graph at the next update.

**View > Revolutions > Individual [F6]** causes the display to pause the current data and display the first revolution. While the display is paused, changes in the live data will not be seen on the display. Subsequent selections of this menu item will display subsequent revolutions. The displayed revolution number is indicated in the lower right of the graph.

**View > Revolutions > Choice [F10]** selects up to three revolutions for display. This allows non-consecutive revolutions to be displayed simultaneously in three different colors.

**View > Revolutions > All [ESC]** displays all the revolutions. The display is still paused and the revolutions displayed are the same as those shown in the individual selections.

**View > Channel** allows the selection of X, Y, Z, X2, or Y2. X is the default. Selecting other channels is only meaningful if probes are connected to those channels and channels are enabled in DAQ Configuration.

### ***Setup!***

Some tests require specific setup information not included in the configuration screens. Clicking the Setup! menu item immediately displays a dialog box for setting test parameters.

### ***Scaling***

**Scaling > Rescale [Enter]** when in manual scaling mode scales the current data to fit the plot area.

**Scaling > Auto [End]** monitors the data and changes the scale so that the data is always within 40% to 90% of the scale. Auto-scaling can also be activated by clicking the END key while the quadrant is active.

**Scaling > Manual > Increase [PgUp] or Decrease [PgDn]** deactivates auto-scaling and increases or decreases the graph scale.

## Supported DAQ Hardware

The following National Instrument Data Acquisition hardware has been tested with SEA v8.0 and higher

Model	Resolution (bits)	Advertised Max Scan Rate (kS/s)	Useable Max Scan Rate (kS/s)
USB-6251*	16	1250	1000
DAQCard-6036E (not supported in Windows Vista)	16	200	100
DAQCard-6062E (not supported in Windows Vista)	12	500	250

\*Recommended hardware for ease of use and performance.

SEA 8 uses DAQmx and can query the DAQ module for gain and sample rate information. Many other DAQ modules do not support these functions. As a result, many other DAQ modules may work but are not guaranteed by Lion Precision.

CAUTION: The user must confirm the accuracy of data acquired with any other card.

If requested sample rates exceed hardware maximums, the sample rate will be adjusted to the maximum the hardware can support, and a message will be displayed stating the change in rate.

### When a board fails to start

Confirm that the correct Device Name is entered in the "DAQ Board" entry in the DAQ Setup screen. Only available module names will appear on the pull-down menu for the "DAQ Board" control. When a device is selected, its model name will appear below the control. Confirm that the model name matches the expected name.

If problems persist;

1. Exit SEA
2. Start National Instruments "Measurement and Automation Explorer"
3. Select "NI-DAQmx Devices"
4. An entry similar to "NI USB-6251: "Dev1" will appear
5. The value in quote marks in this example "Dev1" is the device name for your board. If you have multiple boards installed each board will appear with its own device name. Select the device name for the board you wish to use.

If problems still persist, start by entering a very low sample rate such as 1000 to verify basic functionality.

# Glossary

**Asynchronous error motion** - the portion of the total error motion that occurs at frequencies other than integer multiples of the rotation frequency. Asynchronous error motion comprises those components of error motion that are: (a) not periodic (b) periodic but occur at frequencies other than the spindle rotational frequency and its integer multiples, (c) periodic at frequencies that are subharmonics of the spindle rotational frequency.

**Asynchronous error motion value** - the maximum scaled width of the asynchronous error motion polar plot, measured along a radial line through polar profile center.

**Axial error motion** - error motion coaxial with the Z reference axis. Axial slip, end-camming, pistoning and drunkenness are common but inexact terms for axial error motion.

**Axial thermal drift** - applicable when the displacement is parallel to the Z reference axis.

**Axis average line** - a line segment passing through two axially separated radial motion polar profile centers. The axis average line is used to describe the location of an axis of rotation with respect to the reference coordinate axes, or changes in the location, for example, in response to changes in load, temperature or speed.

**Axis of rotation** - a line segment about which rotation occurs

**Axis shift** - a change in position of the axis average line. Causes of axis shift include thermal drift, load changes, and speed changes.

**Bearing** - an element of a spindle that supports the rotor and allows rotation between the rotor and the stator.

**Displacement indicator** - a device that measures displacement between two specified objects.

**Error motion** - changes in position, relative to a calculated axis of rotation. This motion may be measured as motions of the surface of a perfect work piece (a master ball or an optical flat) with its centerline coincident with the axis of rotation.

**Face error motion** - error motion parallel to the Z reference axis at a specified radial location. Face error motion is a combination of axial and tilt error motions. The term "face runout" has an accepted meaning analogous to "radial runout" and hence is not equivalent to face error motion.

**Face thermal drift** - applicable to a combination of axial and tilt displacement measured at a specified radial location.

**Fixed sensitive direction** - the workpiece is rotated by the spindle and the point of machining or measurement is fixed. A lathe has a fixed sensitive direction

**Fundamental axial and face error motion** - that portion of the total error motion that occurs at the rotational frequency of the spindle. Fundamental axial and fundamental face motions are error motions and cause flatness errors on parts. However, fundamental error motion will create a part with the property of circular flatness: The surface is flat and will provide a "sealing surface" at any given radius. This unique property is important to the plumbing industry.

**Fundamental axial error motion value** - twice the scaled distance between the PC center and a specified polar profile center of the synchronous error motion polar plot. Alternatively defined as the amplitude of the rotational frequency component. There is no fundamental radial error motion value - in the radial direction, motion that occurs at the rotational frequency is caused by an off-center reference target and is not a property of the axis of rotation.

**Least squares circle (LSC) center** - the center of a circle which minimizes the sum of the squares of a sufficient number of equally spaced radial deviations measured from it to the error motion polar plot.

**Nonsensitive direction** - is any direction perpendicular to the sensitive direction.

**Perfect spindle** - a spindle having no motion of its axis of rotation relative to the reference coordinate axes or the calculated center.

**Perfect workpiece** - a rigid body having a perfect surface of revolution about a center line

**Radial error motion** - error motion in a direction perpendicular to the Z reference axis and at a specified axial location.

The term "radial runout" has an accepted meaning which includes errors due to centering and workpiece out-of-roundness and hence is not equivalent to radial error motion.

**Radial thermal drift** - applicable when the displacement is perpendicular to the Z reference axis.

**Residual synchronous error motion** - the portion of the axial and face synchronous error motion that occurs at integer multiples of the rotation frequency other than the fundamental. Residual synchronous and synchronous error motions are mathematically identical. These type of errors cause flatness errors on the face of turned parts.

**Residual synchronous error motion value**-the scaled difference in radii of two concentric circles from a specified error motion center just sufficient to contain the residual synchronous error motion polar plot.

**Rotating sensitive direction** - the workpiece is fixed and the point of machining or measurement rotates with the rotor. A boring machine has a rotating sensitive direction.

**Rotor** - the rotating element of a spindle.

**Runout** - the total displacement measured by a displacement indicator sensing against a moving surface or moved with respect to a fixed surface. The terms "T.I.R." (total indicator reading) and "F.I.M." (full indicator movement) are equivalent to runout.

**Sensitive direction** - the sensitive direction is perpendicular to the perfect workpiece surface through the instantaneous point of machining or measurement

**Spindle** - a device which provides an axis of rotation.

**Stator** - the stationary element of a spindle.

**Stator to rotor error motion** - error motion measured between the stator and rotor.

**Structural error motion** - error motion due to internal or external excitation and affected by elasticity, mass, and damping of the structural loop as a function of angle of rotation.

**Structural loop** - the assembly of components which maintain the relative position between two specified objects.

**Synchronous error motion** - the portion of the total error motion that occurs at integer multiples of the rotation frequency. The term average error motion is equivalent but no longer preferred. The method of averaging described in B89.3.4 Fig A11 remains acceptable for the determination of synchronous error motion.

**Synchronous error motion value** - the scaled difference in radii of two concentric circles from a specified error motion center just sufficient to contain the synchronous error motion polar plot.

**Thermal drift** - a changing distance between two objects, associated with a changing temperature distribution within the structural loop due to internal or external sources.

**Thermal drift plot** - a time-based record of thermal drift.

**Thermal drift value** - the difference between the maximum and minimum values over a specified period of time, at a specified speed (or speeds) and with a measured temperature change.

**Tilt error motion** - error motion in an angular direction relative to the Z reference axis. Coning, wobble, swash, tumbling and towering errors are common but inexact terms for tilt error motion.

**Tilt thermal drift** - applicable to a tilt displacement relative to the Z reference axis.

**Total error motion** - the complete error motion as recorded.

**Total error motion value** - the scaled difference in radii of two concentric circles from a specified error motion center just sufficient to contain the total error motion polar plot.

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