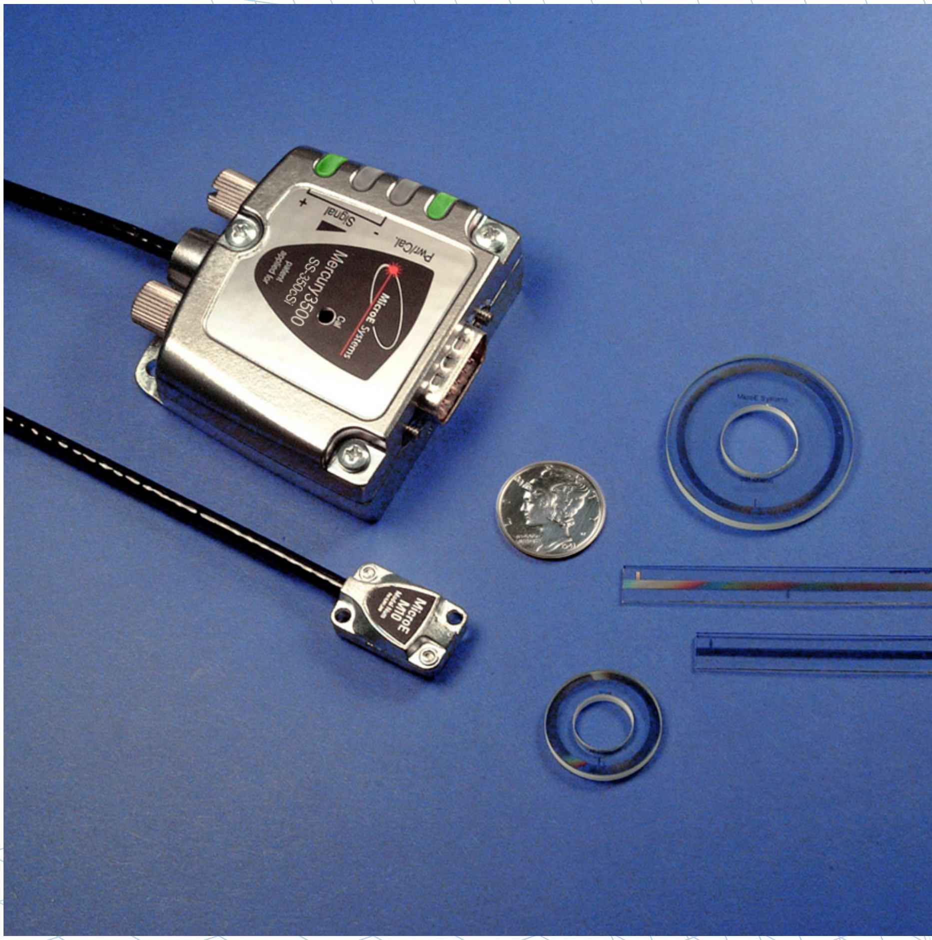
Mercury™ 3500Si

Smart Programmable Encoder Systems with High Speed Serial Word Output

Installation Manual and Reference Guide



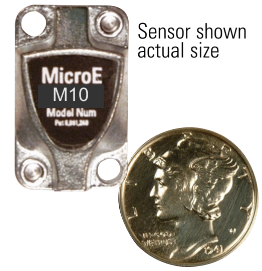
GSI MicroE Systems®

Enabling Technology™

Manual No. IM-M3500Si Rev D

Introduction

MicroE Systems was founded to advance encoder technology to a level never before achieved. Our objective was to design encoder systems that would be small enough to fit into densely packed OEM equipment designs, affordable enough for cost-sensitive applications and easy enough to enable installation, setup and alignment by assemblers with little training. We are pleased to say that all of these goals have been realized with the introduction of the Mercury family of encoders.



Sensor shown actual size

Precautions

1 Follow standard ESD precautions. Turn power off before connecting the sensor. Do not touch the electrical pins without static protection such as a grounded wrist strap.

2 Do not touch the glass scale unless you are wearing talc-free gloves or finger cots. Please read this installation manual for full instructions.

LASER SAFETY INFORMATION: Mercury & ChipEncoder

This product is sold solely for use as a component (or replacement) in an electronic product; therefore it is not required to, and does not comply with, 21 CFR 1040.10 and 1040.11 which pertain to complete laser products. The manufacturer of the complete system-level electronic product is responsible for complying with 21 CFR 1040.10 and 1040.11 and for providing the user with all necessary safety warnings and information.

MicroE encoders contain an infrared laser diode or diodes. Emitted invisible laser radiation levels have been measured to be within the CDRH Class 1 range, which is not considered hazardous; however, to minimize exposure to the diverging beam, the encoder sensor should be installed in its operational configuration in close proximity to the encoder scale before power is applied.

INVISIBLE LASER RADIATION
DO NOT VIEW DIRECTLY WITH OPTICAL INSTRUMENTS
(MICROSCOPES, EYE LOUPES OR MAGNIFIERS)

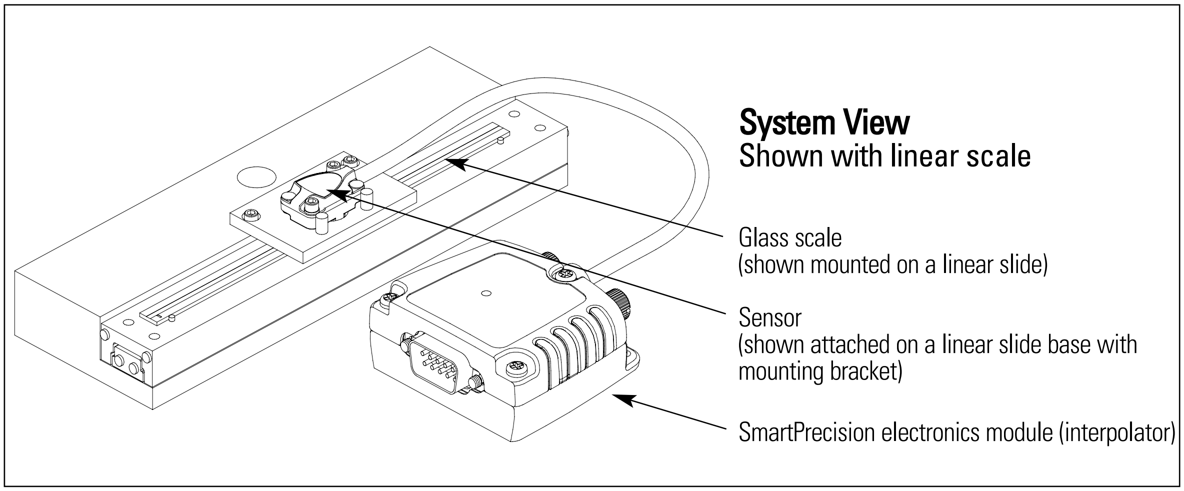
- Invisible laser radiation; wavelength: 850 nm
- Max power 2.4 mW CW (4.8 mW CW for Mercury II™)
- CAUTION – The use of optical instruments with this product will increase eye hazard. DO NOT VIEW DIRECTLY WITH OPTICAL INSTRUMENTS (MICROSCOPES, EYE LOUPES OR MAGNIFIERS).
- All maintenance procedures such as cleaning must be performed with the MicroE encoder turned off.
- Do not insert any reflective surface into the beam path when the encoder is powered.
- Do not attempt to service the MicroE encoder.

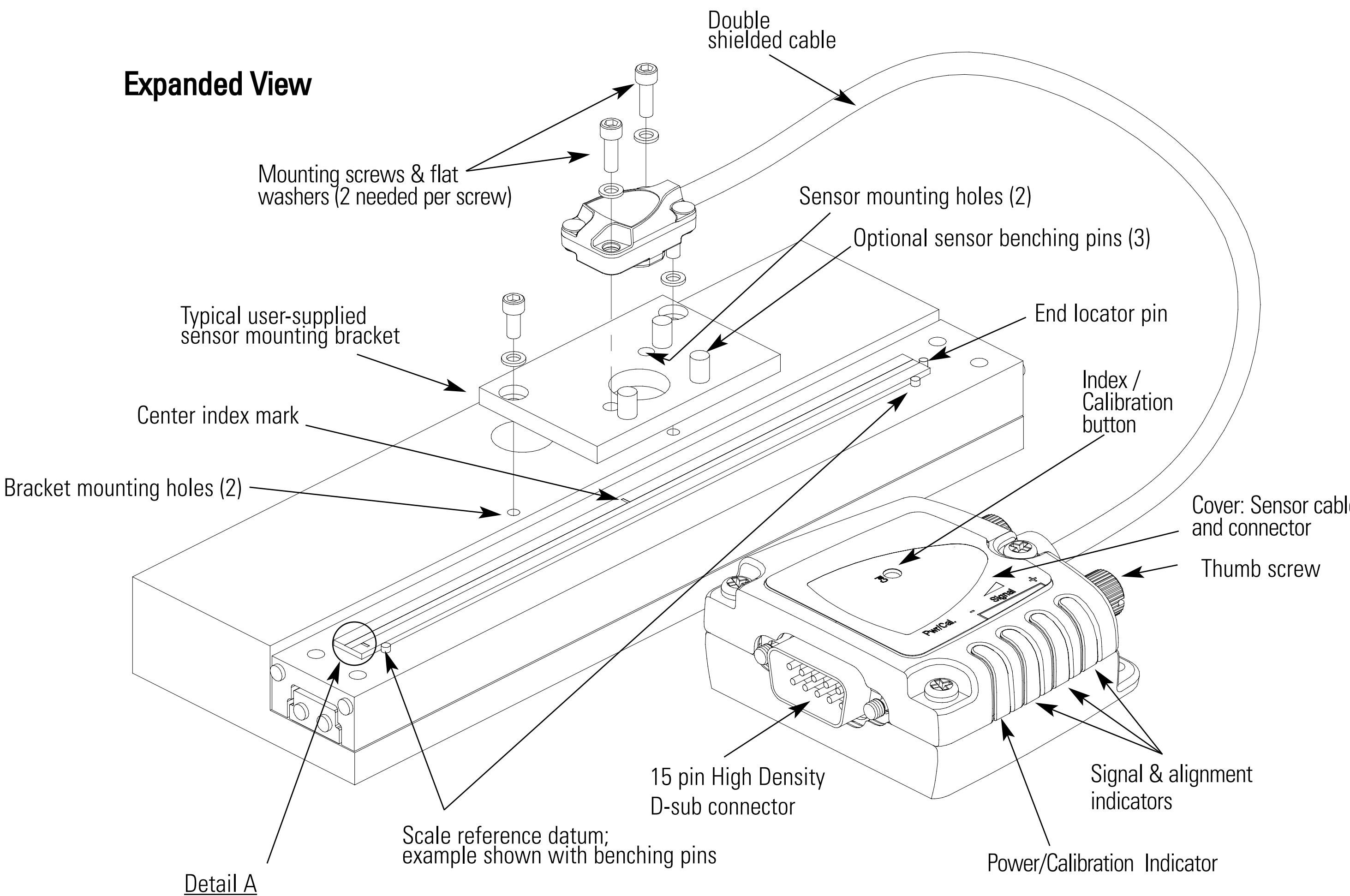
Patents

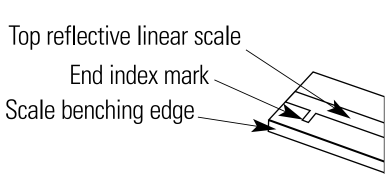
Covered by the following patents: US 5,991,249; EP 895,239; JP 3,025,237; US 6,897,435; and EP 1,451,933. Additional patents and patents pending may apply.

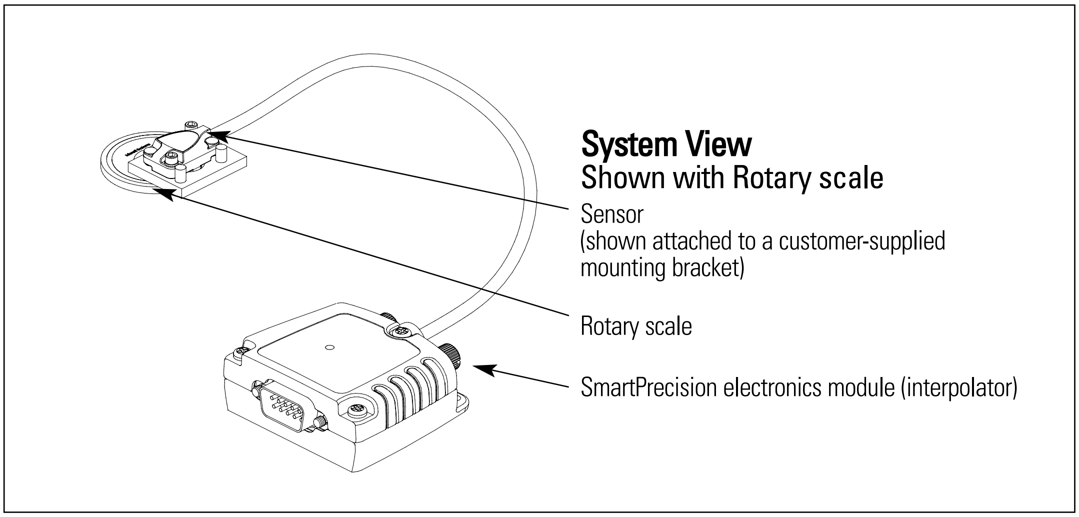
Table Of Contents

Mercury 3500Si Encoder System
with Linear scale

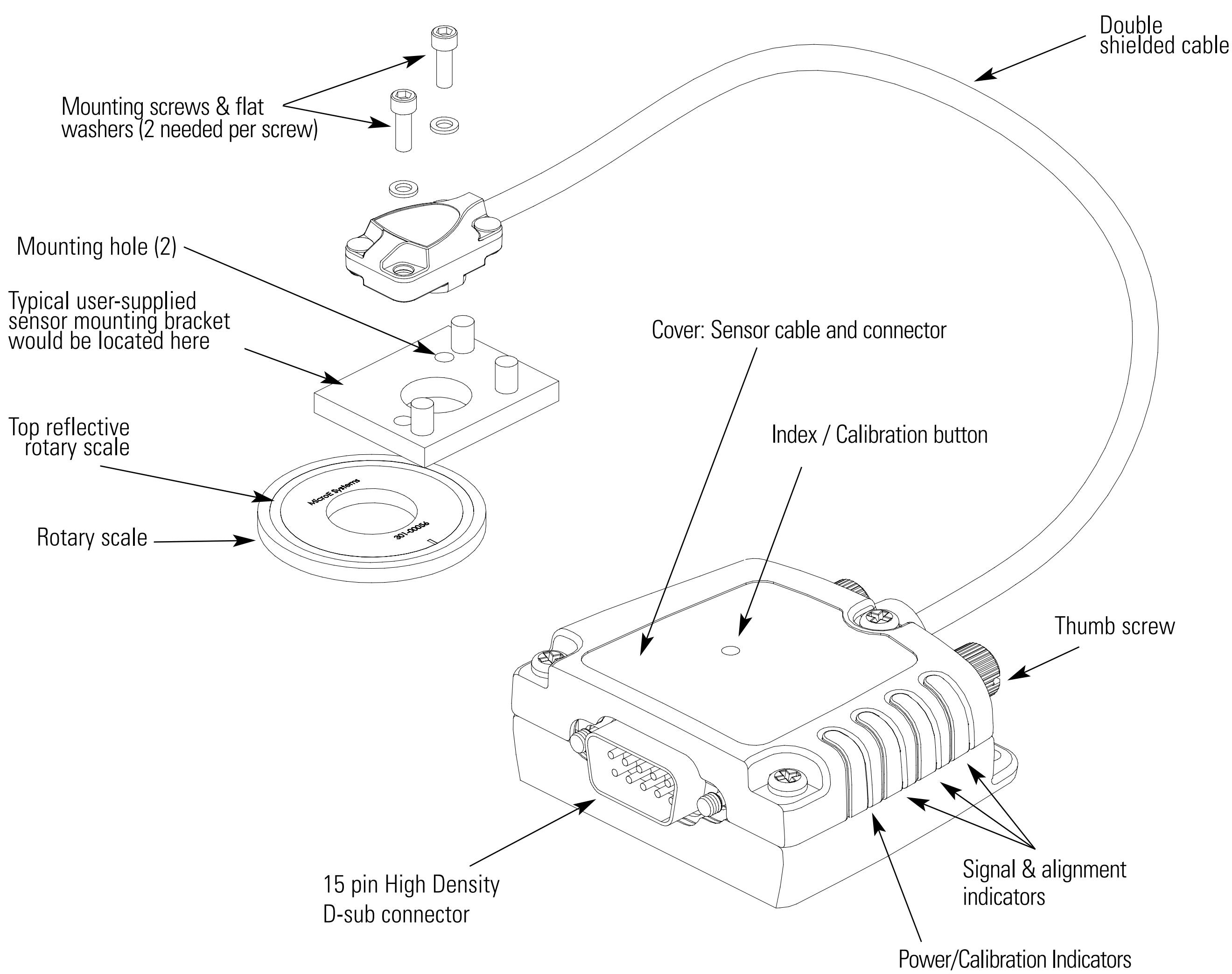








Expanded View



Installation Instructions
Linear Encoders - Using Alignment Tool - *Mounting*

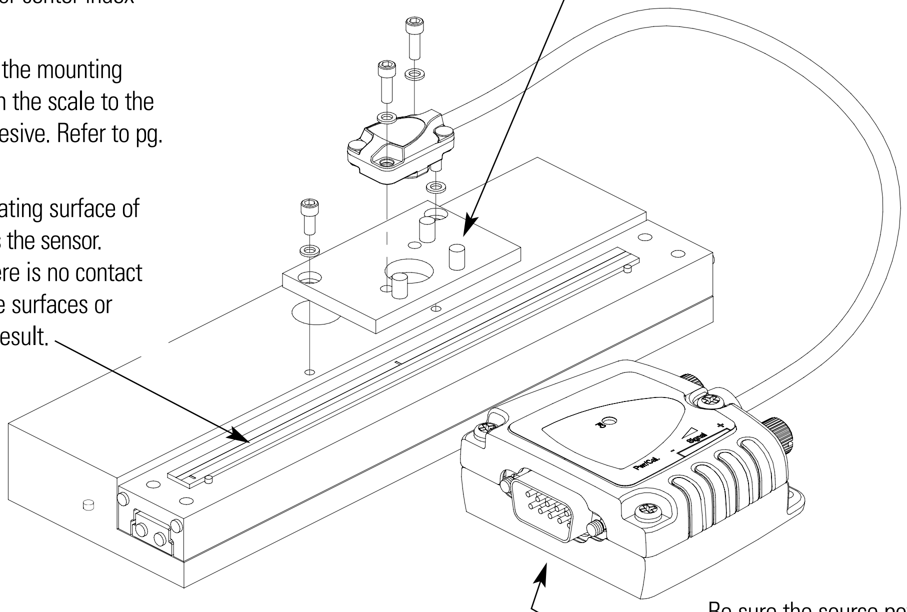
1 Attach the scale to the base slide. Reference the preferred datum on the interface drawing for either end or center index orientation.

Depending on the mounting method, attach the scale to the slide with adhesive. Refer to pg. 8 for details.

Be sure the grating surface of the scale faces the sensor. Insure that there is no contact between these surfaces or damage may result.

2 Install the sensor on your mounting surface referencing the appropriate datum surface as shown on the interface drawing. Use 2 washers per mounting screw.

Benching pins may be used to locate the sensor if the system mechanical tolerances are adequate. See data sheet for alignment tolerances, or keep mounting screws loose for sensor alignment if benching pins are not used.



4 Be sure the source power is off before connecting the SmartPrecision plug.

Connect the SmartPrecision electronics to the controller using the pinout diagram described on the interface drawing.

Insure proper system grounding. Refer to the procedure on pg 9.

Tighten the thumb screws.

Power up the system. The Power/Calibration indicator will illuminate.

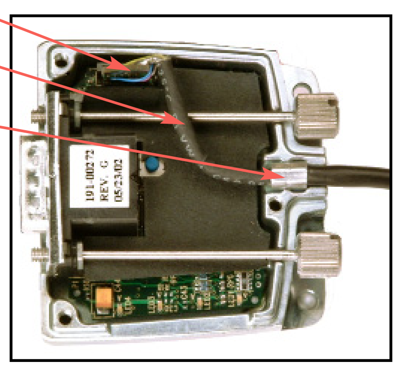
3 CAUTION: observe precautions for handling electrostatic sensitive devices.

Route the sensor cable through your equipment to the SmartPrecision electronics.

A) Remove the three cover screws and the top half of the connector housing. Do not pull on the 15-pin D-sub connector or the circuit board under the insulation layer.

B) Attach the sensor's 5 X 2 connector to the mating 5 X 2 connector on the circuit board.

C) Route the sensor cable through its channel in the center of the connector body and place the cable's hex sleeve in the matching recess. Attach the top half of the connector housing to the bottom half using the three cover screws.



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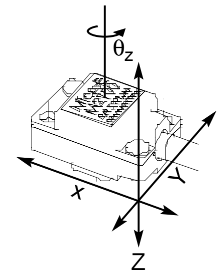
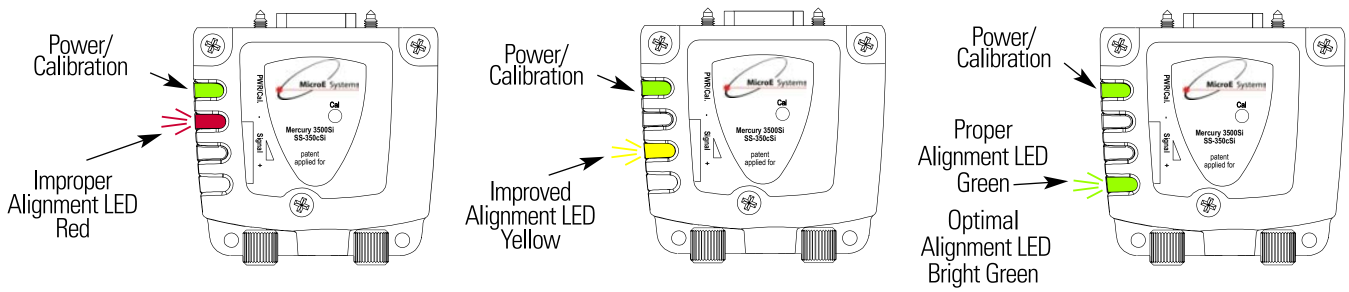
If benching dimensions cannot be provided, proper sensor alignment may require minor adjustments to the sensor position with respect to the scale. This can be performed easily using the LED alignment indicators, as illustrated below.

The red, yellow, or green LED will light depending on sensor alignment. Slowly move the sensor by allowing it to slide on the mounting surface until the green or Proper Alignment LED, is illuminated. Optimal alignment will be displayed as a "Bright Green" LED.

IMPORTANT: Confirm that the Proper Alignment LED blinks when passing over the index. If not, readjust the sensor in the Y direction and repeat the above procedure. When alignment is completed, tighten the sensor mounting screws (0.37Nm [3.3 inch-lbs.] maximum torque).



To align the sensor, move it in the Y or θ_Z directions.



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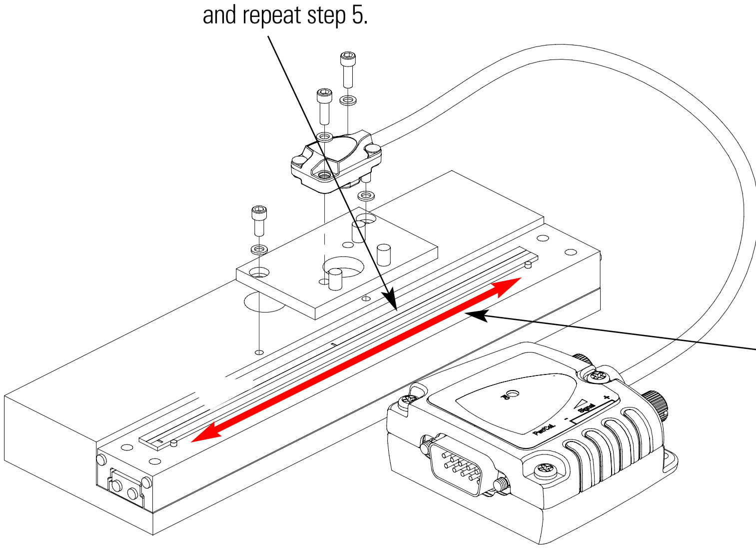
Confirm proper alignment over the full range of motion. The "Proper Alignment" LED must remain on over the entire range. If not aligned over the entire range of motion, loosen the sensor mounting screws and repeat step 5.



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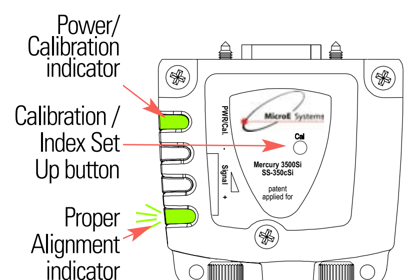
IMPORTANT

OUTPUT CALIBRATION PROCEDURE

This procedure must be completed for proper system operation each time the sensor is aligned or if the SmartPrecision electronics module is replaced



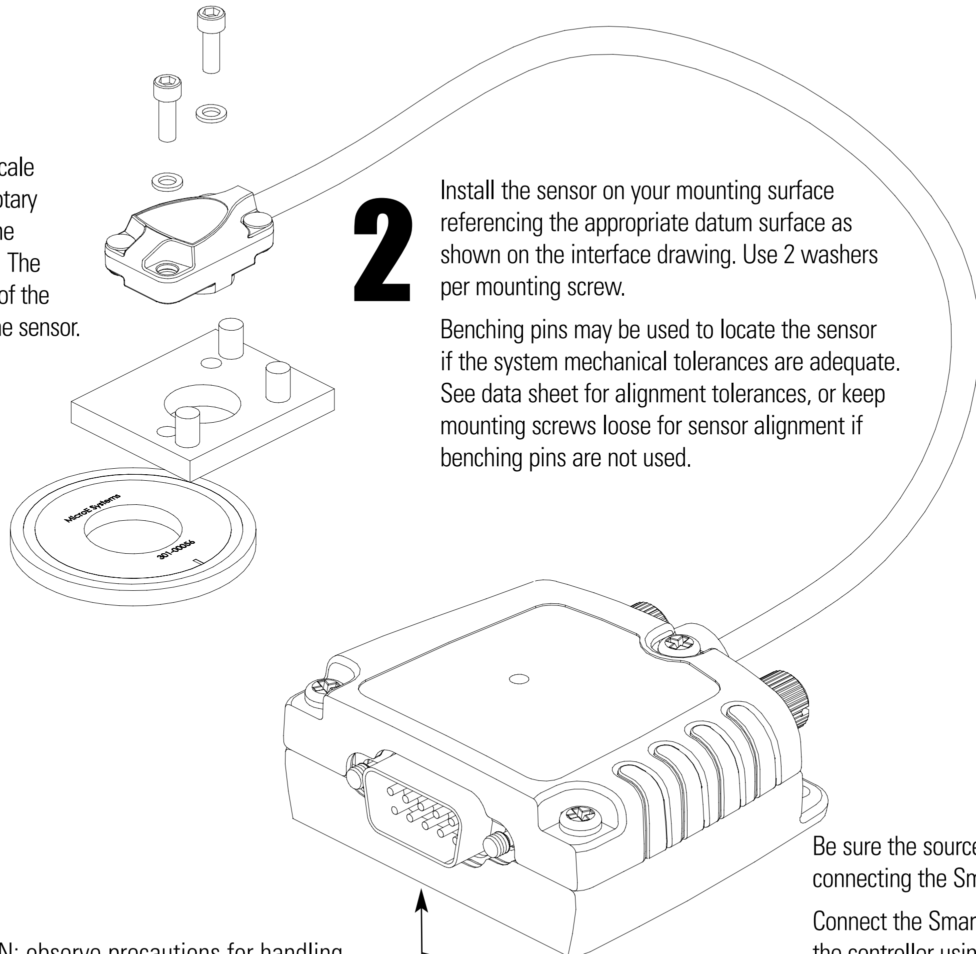
Position the sensor at least 7mm (1/4") away from the index mark on the scale. Next, push the Index/Calibration button inside the module with a small diameter shaft, such as a bare cotton swab.

The Power/ Calibration indicator will flash continuously. Move the scale past the sensor in both directions so that the index mark passes under the sensor. When the calibration procedure is complete, the Power/Calibration indicator stops flashing.

Installation Instructions

Rotary Encoders - Using Alignment Tool - *Mounting*

1 Attach your hub/scale assembly to the rotary device. Refer to the interface drawing. The reflective surface of the scale must face the sensor.



2 Install the sensor on your mounting surface referencing the appropriate datum surface as shown on the interface drawing. Use 2 washers per mounting screw.

Benching pins may be used to locate the sensor if the system mechanical tolerances are adequate. See data sheet for alignment tolerances, or keep mounting screws loose for sensor alignment if benching pins are not used.

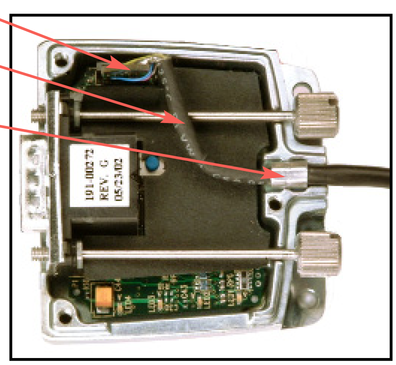
3 CAUTION: observe precautions for handling electrostatic sensitive devices.

Route the sensor cable through your equipment to the SmartPrecision electronics.

A) Remove the three cover screws and the top half of the connector housing. Do not pull on the 15-pin D-sub connector or the circuit board under the insulation layer.

B) Attach the sensor's 5 X 2 connector to the mating 5 X 2 connector on the circuit board.

C) Route the sensor cable through its channel in the center of the connector body and place the cable's hex sleeve in the matching recess. Attach the top half of the connector housing to the bottom half using the three cover screws.



4 Be sure the source power is off before connecting the SmartPrecision plug.

Connect the SmartPrecision electronics to the controller using pinout diagram described on the interface drawing.

Insure proper system grounding. Refer to the procedure on pg 9.

Tighten the thumb screws.

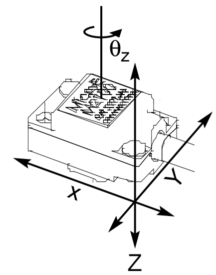
Power up the system. The Power/Calibration indicator will illuminate.

5

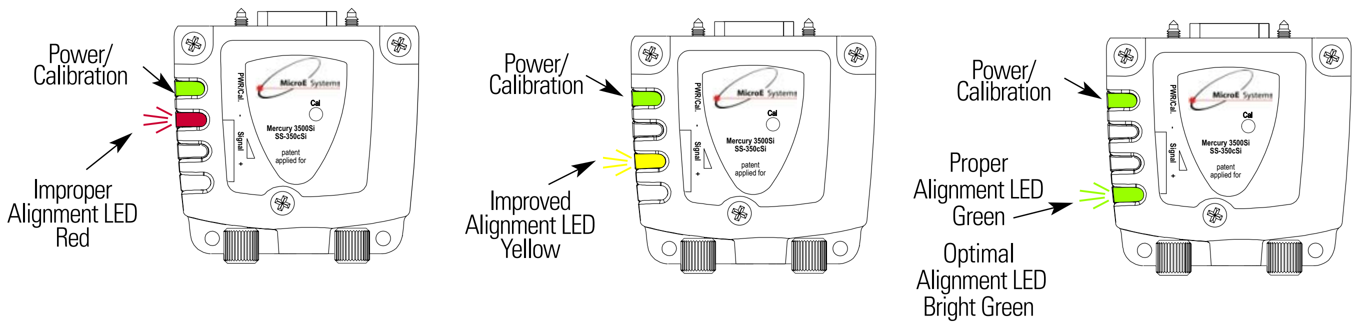
If benching dimensions cannot be provided, proper sensor alignment may require minor adjustments to the sensor position with respect to the scale. This can be performed easily using the LED alignment indicators, as illustrated below.

The red, yellow, or green LED will light depending on sensor alignment. Slowly move the sensor by allowing it to slide on the mounting surface until the green or Proper Alignment LED, is illuminated. Optimal alignment will be displayed as a "Bright Green" LED.

IMPORTANT: Confirm that the Proper Alignment LED blinks when passing over the index. If not, readjust the sensor in the Y direction and repeat the above procedure. When alignment is completed, tighten the sensor mounting screws (0.37Nm [3.3 inch-lbs.] maximum torque).



To align the sensor, move it in the Y or θ_z directions.



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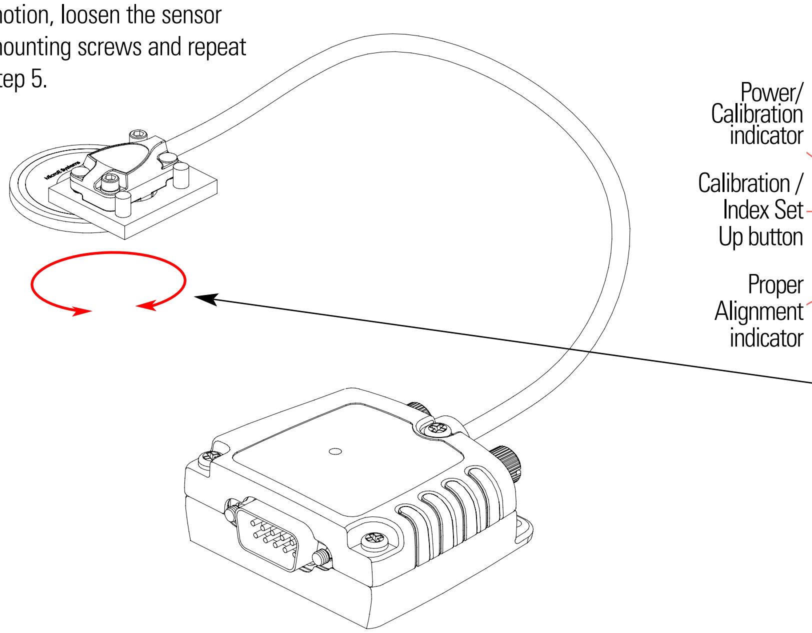
Confirm proper alignment over the full range of motion. The "Proper Alignment" LED must remain on over the entire range. If not aligned over the entire range of motion, loosen the sensor mounting screws and repeat step 5.



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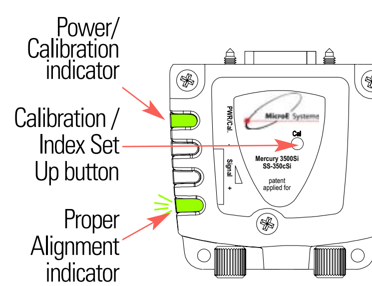
IMPORTANT

OUTPUT CALIBRATION PROCEDURE

This procedure must be completed for proper system operation each time the sensor is aligned or if the SmartPrecision electronics module is replaced.



Position the sensor at least 7mm (1/4") away from the index mark on the scale. Next, push the Index/Calibration button inside the module with a small diameter shaft, such as a bare cotton swab.

The Power/Calibration indicator will flash continuously. Move the scale past the sensor in both directions so that the index mark passes under the sensor. Do not run off the end of the scale when using a segment scale. When the calibration procedure is complete, the Power/Calibration indicator stops flashing.

Reference Section

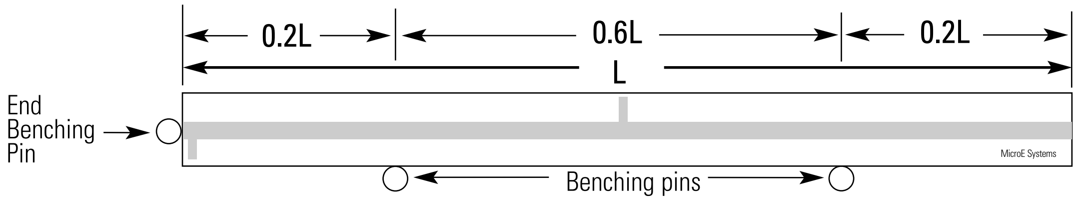
Installation of Linear Scales

Positioning the Scale

Note: Before beginning mounting procedure, use talc-free gloves or finger cots to handle the scales.
"Benching" the scale to the system means aligning the scale by means of benching pins. Pin locations are described on the appropriate interface drawing.
Two benching pins are recommended on the long side of the scale and one at the end as shown . This is marked datum A on the interface drawing.

1 Position the benching pins in from either end. 20% of the overall scale length is the recommended location from the edge.

2 Be sure the benching pins do not extend too high in the Z direction to prevent mechanical interference with the sensor or sensor mount.



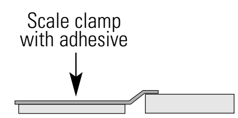
Mounting the Scale

MicroE Systems' linear scales should be affixed to the mounting surface. Two different approaches are described below:

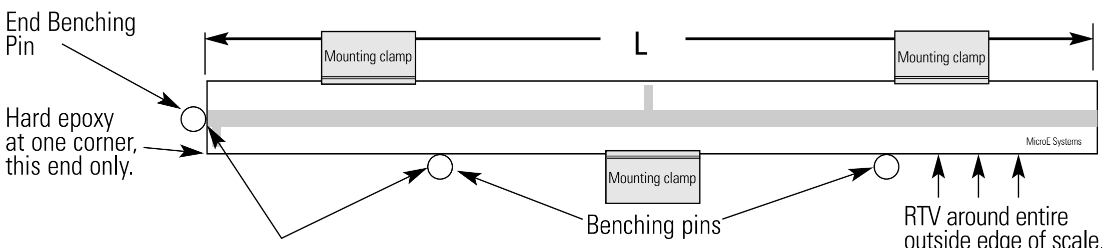
Epoxy and RTV Mounting (Recommended for best accuracy)

1 Make sure the mounting surface is clean and dry.

3 Optionally, scale clamps may be used to secure the scale while the adhesive cures. Avoid damage to the top surface.



Side view showing optional scale clamps and scale. Space clamps every 75mm on scales over 150 mm in length.



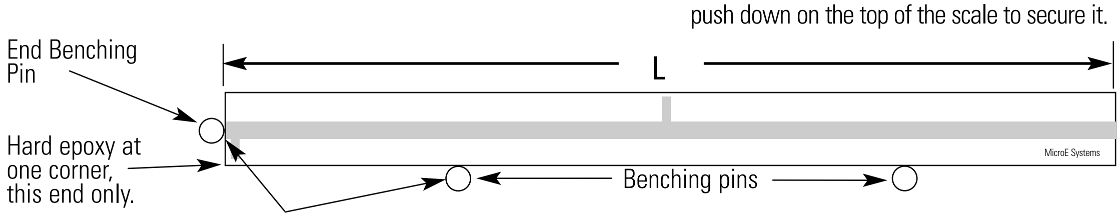
2 Align the scale by placing the edges against the benching pins.

4 Apply a hard epoxy, such as Tra-Con's Tra-Bond 2116, to the end of the scale at the end benching pin. Apply 100% Silicone RTV adhesive around the edges of the scale. This method allows thermal expansion from the benched end of the scale. After adhesive curing, remove the scale mounting clamps or, if permanently installing clamps, make sure they do not interfere with the sensor or sensor mount.

Two Sided Adhesive Tape Mounting

1 Make sure the mounting surface is clean and dry. Peel the cover paper off and place the scale above the final location.

3 Gently place the scale on the mounting surface. Positioning adjustments can be made until the scale is firmly pressed down. After final positioning, push down on the top of the scale to secure it.



2 Align the scale by placing the edges against the benching pins.

Grounding Instructions for Mercury 3500Si Encoder Systems

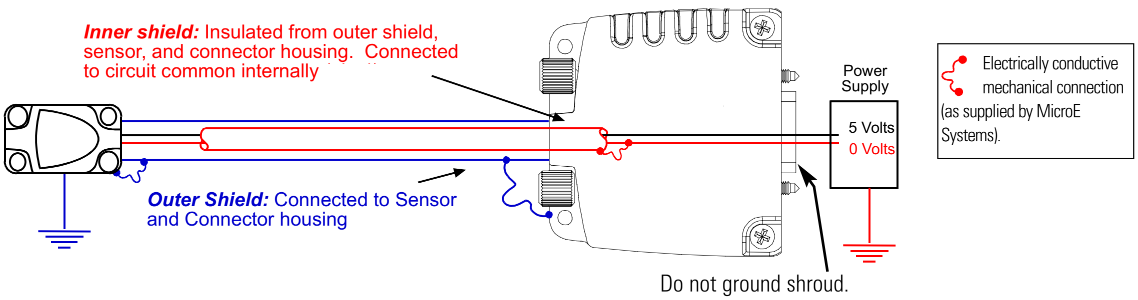
For Mercury 2000 and 3000 encoder systems to operate reliably, it is essential that the sensor and cable shield are grounded properly according to the following instructions. The diagrams below show how to make the connections when the encoder's connector is plugged into the customer's controller chassis. If a customer-supplied extension cable is used, it should be a double shielded cable with conductive connector shells and must provide complete shielding over the conductors contained within it over its entire length. Furthermore, the shields should be grounded at the connection to the controller chassis the same way as the encoder connectors in the diagrams below.

Note: For best performance, isolate encoder shield from motor cable shields and separate encoder cable as far possible from motor cables.

Sensor mounted with good electrical contact to a well-grounded surface (preferred)

1. 15-pin D-sub connector grounding: The encoder's connector shell must be in intimate, electrically conductive contact with the customer-supplied mating connector, which must be isolated from the controller's ground. If a customer-supplied shielded cable connects the encoder to the controller, then the shielding on the customer-supplied cable must be isolated from the controller's ground.

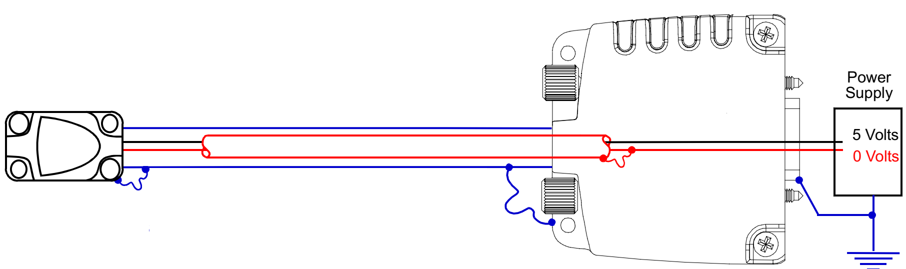
2. The sensor mounting surface must have a low impedance (DC/AC) connection to ground. The encoder sensor mounting surface may have to be masked during painting or anodizing to insure good electrical contact with the sensor.



Sensor mounted to a surface that is grounded through bearings or a poorly-grounded surface, or a non-conducting surface

1. 15-pin D-sub connector grounding: The encoder's connector shell must be in intimate, electrically conductive contact with the customer-supplied mating connector, which must be connected to the controller's ground. If a customer-supplied shielded cable connects the encoder to the controller, then the shielding on the customer-supplied cable must be connected to the controller's ground. The controller must be grounded to earth at the point of installation.

2. The encoder sensor must be mounted so that it is electrically isolated from ground.



Recommendations for Power

Mercury encoders require a minimum of 4.75V DC continuously. When designing circuits and extension cables to use Mercury encoders, be sure to account for voltage loss over distance and tolerances from the nominal supply voltage so that at least 4.75V DC is available to the Mercury encoder under all operating conditions. The input voltage should not exceed 5.25V DC.

Customer Interface Cable Requirements

Customer cables that interface to Mercury series encoders must have the following characteristics:

- Twisted pair signal wiring.
- Characteristic impedance of 100-120 ohms.
- Sufficient wire gauge to meet the minimum voltage requirement at the encoder, for example 24AWG gauge wire for a 2m length cable. Examples of acceptable cables with 24 AWG gauge wire and 5 twisted pairs are Belden 9832, 8105 or other manufacturer's equivalents.
- Single shield cable with a minimum of 90% coverage. Note that a double shielded cable may be required in high-noise applications.

Signal Wiring:

Each differential signal should be connected to a corresponding twisted pair as follows:

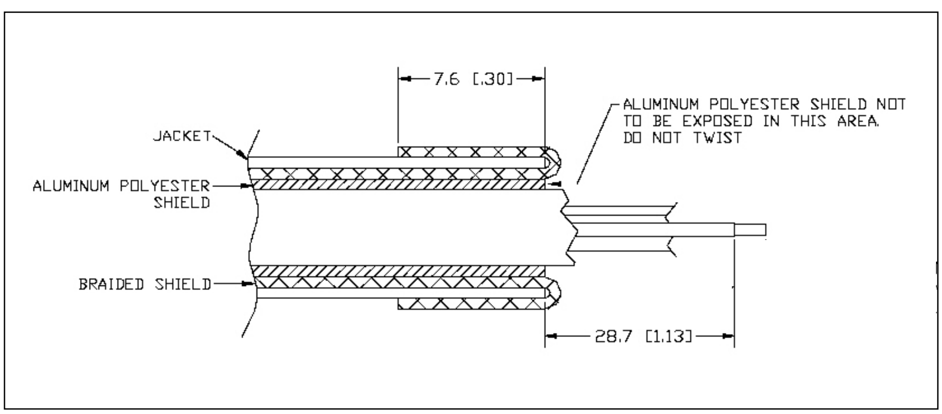
Mercury 3500Si

Signal	Twisted Pair
SD0+ SD0-	Pair 1
SCF+ SCF-	Pair 2*
SCK+ SCK-	Pair 3
N_CS+ N_CS-	Pair 4
+5V GND	Pair 5

* Optional

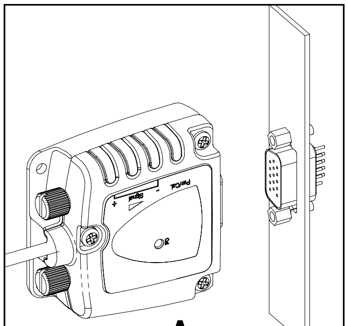
Shield Termination:

The customer's cable shield should be in 360° contact with the connector shroud and the connector shell to provide complete shielding. The connector shell should be metal with conductive surfaces. Suggested metal connector shells for use with Mercury 3500, 3000, 3500Si, and 2000 encoders: AMP 748676-1 or equivalent; for Mercury 1000 and 1500S encoders: AMP 745172-3, -2, or -1 where the dash number is dependent on the customer's outside cable diameter. The shield should be terminated as illustrated in the following diagram.



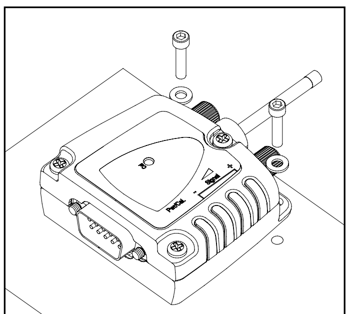
Fold braided shield back over jacket. Example shows double-shielded cable. Dimensions shown are for illustration only.

SmartPrecision Module Mounting Options



A

The SmartPrecision electronics module may be mounted directly to a bulkhead connector using the integral thumb screws shown in figure A.



B

Alternatively, the module may be used with an extension cable and mounted to a base plate using the mounting tabs as shown in figure B.

Serial Output Specification

Introduction

Historically, the method of choice for many optical position feedback systems has been A quad B (Quadrature) output. The limitation of this method is output speed, especially when the interpolation level is large. When the optical sensor speed is fast and/or the interpolation multiplier is large, the Quadrature output frequencies will be extremely high and out of the range of the Quadrature counters of most standard motion controllers. This limitation can be avoided by sending the position information in parallel format or in a serial word format.

The parallel formats are cumbersome to cable (especially wide word lengths) and are more susceptible to noise interference.
Therefore, a serial data word format is the data communication method of choice.

The SS350SI Interpolator has the ability to output a position word in a serialized format. This allows very fast communication between an interpolator and customer application. The speed limitation of the Quadrature format is thus eliminated.

Signal Description

The interface to the SS350SI Interpolator uses the following signals to implement serial communication, n_spiEnable (n_CS), spiDataOut (SDO), spiClockIn (SCK), and optionally spiClockOut (SCF).

Each signal is differential and RS-422 compatible. See table for interpolator signal names, pin names, and pin locations:

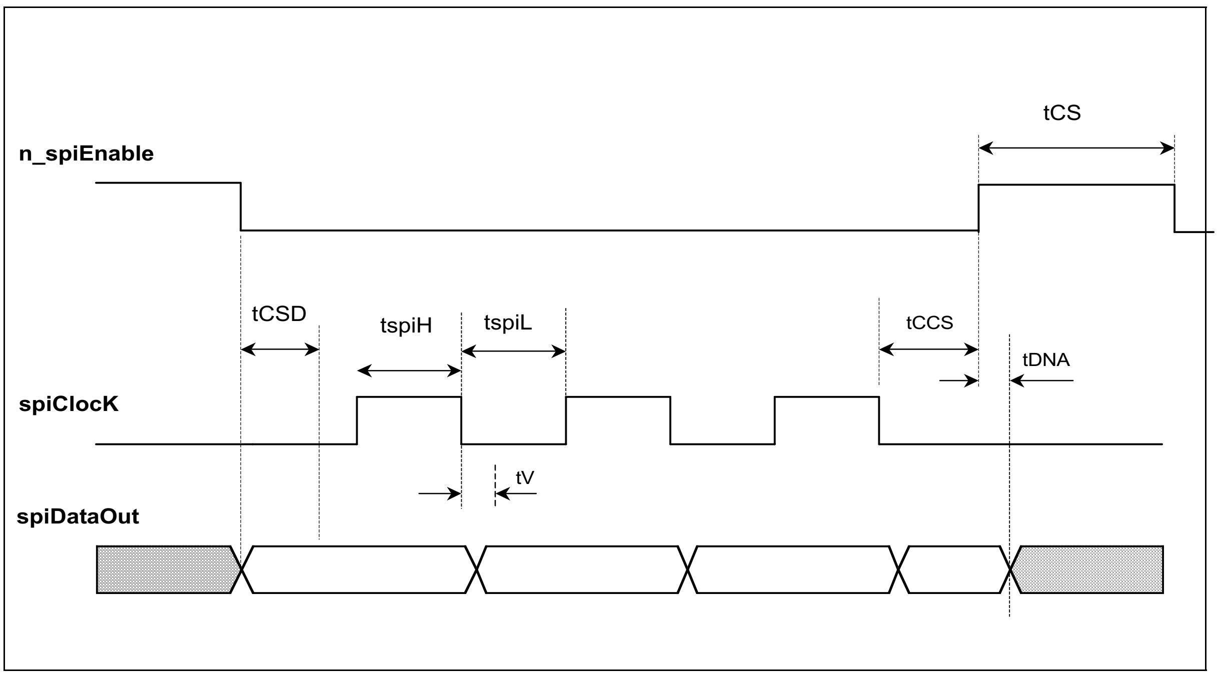
Signal Name	Pin Name	Function	I/O Interpolator referenced	15 Pin HD Connector Pin Number
n_spiEnable	n_CS+	Chip Select+	Input	7
	n_CS-	Chip Select-	Input	8
spiClockIn	SCK+	Serial Clock+	Input	14
	SCK-	Serial Clock-	Input	15
spiDataOut	SDO+	Serial Data Output+	Output	5
	SDO-	Serial Data Output-	Output	4
spiClockOut	SCF+	Serial Clock Feedback+	Output	10
	SCF-	Serial Clock Feedback-	Output	9

SmartPrecision 3500Si Interpolator Operation

Standard Communication Mode

Asserting the n_spiEnable signal freezes the current position word buffer and status information within the interpolator. The serial data is valid 50ns after the assertion of n_spiEnable signal. The n_spiEnable signal is kept asserted while spiClock signal toggles out the data.

Each serial data bit is valid on the falling edge of the clock signal. A high to low transition of the n_spiEnable signal must be accomplished between acquisitions to allow the internal serial data buffer to update with new information.



Communication Mode Timing

Symbol	Parameter	Minimum	Maximum	Units
tspiH	spiClockIn High Time	25 *		ns
tspiL	spiClockIn Low Time	25 *		ns
tCSD	n_spiEnable to DataValid		50	ns
tV	↓spiClockIn to Data Valid		25	ns
tCCS	spiClockIn to n_spiEnable	0		ns
tCS	n_spiEnable High	50		ns
tDNA	n_spiEnable to HiZ		50	ns

*Assuming no propagation delay from user's electronics and cabling. Please refer to page 16 for details.

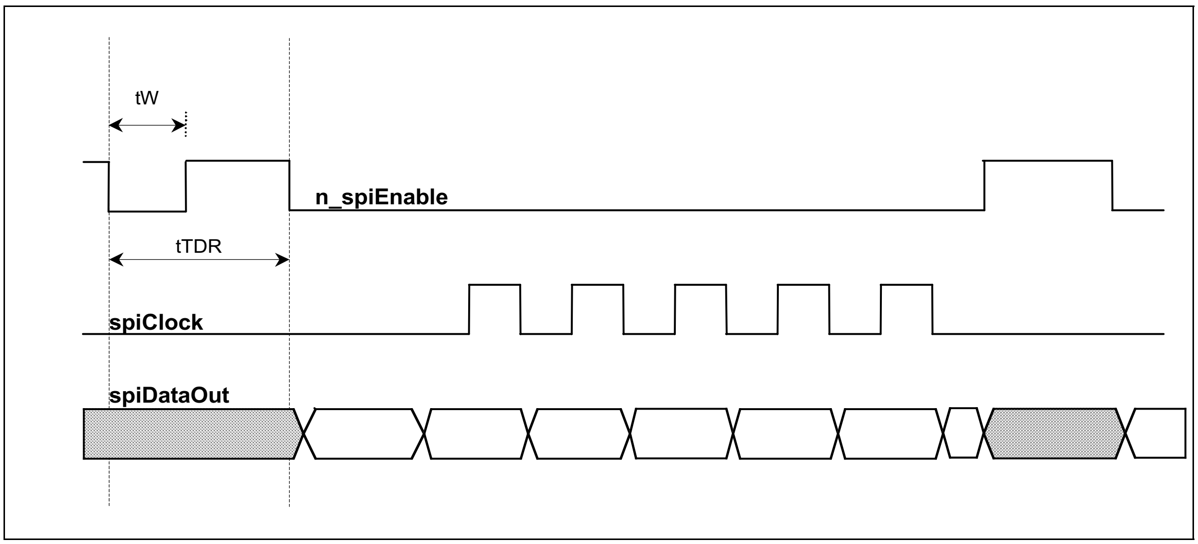
Trigger Communication Approach:

The Trigger Approach can be used in applications where synchronization of the position data to an event is required. Often, this mode is used when a fixed latency between a clock signal and the sampled position data is required. The customer can choose this mode of operation by using the optional SmartPrecision Software. In this mode, triggering is controlled by the n_spiEnable signal.

The n_spiEnable signal starts the process by immediately resetting the internal calculators and acquiring the latest AD converter information. Old data in the calculation chain is discarded and the initiation of a new position calculation is started.

The new data is ready in 1180ns. The n_spiEnable signal for retrieving the data must be asserted within 340ns after the new data is ready or the triggered acquisition will be over written by new data.

Shifting the data out of the interpolator's serial port is accomplished exactly as in the Standard Communication mode of operation. In order to sample the next position, n_spiEnable must be brought high and then reasserted. See the Trigger Approach timing diagram below.



Trigger Approch Timming Diagram

Symbol	Parameter	Minimum	Maximum	Units
tspiH	SCK High Time	25		ns
tspiL	SCK Low Time	25		ns
tTDR	n_spiEndable to DataReady	1180	1520	ns
tW	n_spiEnable width	50		ns
tCSD	n_spiEnable to DataValid		50	ns
tV	↓SCK to Data Valid		25	ns
tCCS	SCK to n_CS	0		ns
tCS	n_CS High	50		ns
tDNA	n_CS to HiZ (no HiZ)		50	ns

Serial Output Specification

Important Notes:

The user must wait 1180ns after a trigger for the data acquisition to make its way through the position calculator. After the 1180ns calculation latency the position number is available at the serial output buffer.

This position number is valid for 340ns before the calculator pipeline overwrites the value in the serial output buffer. Asserting the n_spiEnable within 340ns of data being valid will freeze the serial output buffer for data transfer.

n_spiEnable is sampled by an internal clock when in the Trigger Approach mode. The uncertainty of this measurement is 80ns.

When not in the trigger mode, n_spiEnable is not sampled by an internal clock and there is no synchronization of the interpolator calculation to an external event. The uncertainty of this measurement is 340ns.

Data Format:
The data word, which is made up from the position and status words, are transferred with the most significant bit (MSB) first. The data word length is 38 bits wide .

Status Word:
The status word is 8 bits wide. The status word may be placed either before or after the position word within the data word. The Status word placement can be set using the optional SmartPrecision Software.

Status Byte Definition:

Bit	Name	Description
0	redAlarm	asserted low if signal level is out of range
1	yellowAlarm	asserted low if signal level is near out of range
2	indexMode	asserted high indicates index angle in acquire mode
3	indexWindow	asserted high when encoder is within physical window
4 to 7	reserved	

Example: 0000_0011 (Normal Operation)

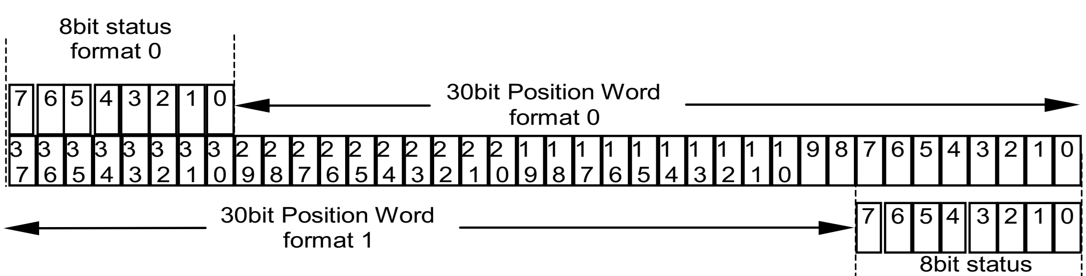
Position Word:
The position word is 30 bits in length. The position word is made up of an 18 bits of fringe data and 12 bits of interpolation data.

Fringe Data: (Programmable up to 18bits)
The fringe counter keeps track of the number of electrical cycles encountered caused by a grating moving past a sensor. The size of the fringe counter is programmable from 3 bits wide to 18 bits wide (factory default). The width is selectable through the optional SmartPrecision Software. Reducing the size of the fringe counter will increase the overall sample rate of the system. At 18 bits, the counter is large enough to keep track of a grating length of 5.24 meters.

Note: The fringe counter size should be larger than the anticipated range of motion to guarantee that the counter will not "roll over".

In normal operation, the fringe counter can "roll over" to a negative number with a small amount of movement upon power up.

Interpolation Data: (Lower 12bits)
The interpolation depth of the SS350SI is always 4096. If the user prefers smaller interpolation depths then fewer spiClock signal clocks can be sent to the interpolator and fewer bits will be shifted out. This will also increase the maximum sample rate for the system.



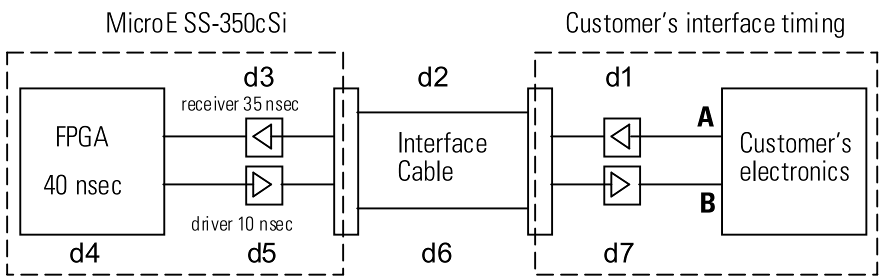
38 bit word

Serial Clock Feedback

The Serial Clock Feedback (SCF) signal may be used to compensate for propagation delays caused by line receivers/drivers and the interface cabling between the SS350cSi and the customer electronics. The spiClockIn (SCK) signal is "looped" back as an output to create the Serial Clock Feedback signal. Please see Delay Diagram below:

Note: The timing diagram information lists the timing delays between a request for data at point A and the receipt of data at point B. It does not include the interface cable, line drivers/receivers or any other electronics needed at the customer interface for signal acquisition.

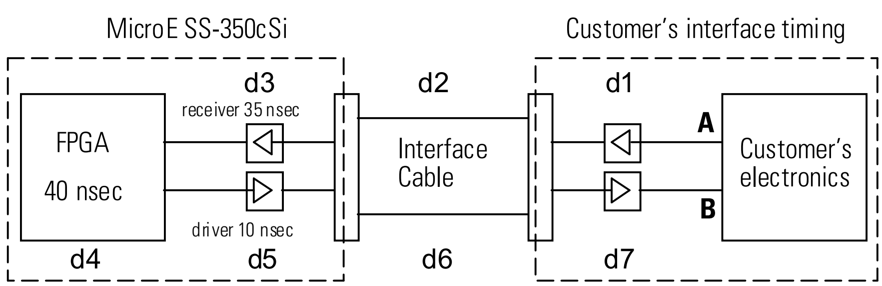
Maximum Propagation Delay. (Serial Clock Feedback - not used)



There is a propagation delay due to the clock being sampled at position A and the Data being sampled at position B.

Propagation Delay = d1+d2+d3+d4+d5+d6+d7

Maximum Propagation Delay. (Serial Clock Feedback signal implemented)



Propagation delay is eliminated because both data and clock are sampled at position B

System Latency=d1+d2+d3+d4+d5+d6+d7

Index Processing

A unique physical position is referenced on all gratings and is called an index position. The value of this position is determined during an index capture routine initiated by a button press or the SmartPrecision Software and is permanently stored for use after power cycling. The index value has the same resolution as the interpolated position.

The SS-350cSi has four modes of operation that use the index position to generate a physical reference position. The position word calculated by the SS-350cSi electronics is a 30-bit number, which includes 18 fringe counter bits and 12 sub-fringe interpolation bits. The fringe counter keeps track of the number of electrical cycles encountered caused by a grating moving past a sensor and can be reset. The sub-fringe position is absolute because the voltage relationship between sine and cosine are fixed electrically and therefore cannot be reset or cleared.

A physical mark on the grating called an index window is used to generate an accurate index position. The index window is approximately one fringe wide. By monitoring the edges of the window with respect to the absolute sub-fringe position during the index capture mode, an accurate index position is calculated and stored.

At power up the encoder is in an undefined position relative to the outside world. By traveling past the index mark on the scale and knowing where the index is relative to the outside world the encoder position becomes defined. The M3500Si supports the following index processing modes:

No Index: No changes are made to the position word at the index mark.

Mode 1: Zeros the fringe counter at the first encounter with index mark after power up.

Mode 2: Zeros the fringe counter at every encounter with index mark.

Mode 3: Zeros the fringe counter at the first encounter with index mark after power up and subtracts the index position from the calculated position making the index mark the zero position of the encoder.

Mode 4: Zeros the fringe counter at every encounter with index mark after power up and subtracts the index position from the calculated position making the index mark the zero position of the encoder.

The Index mode can be factory set or selected by the customer using the optional SmartPrecision software.

Troubleshooting

Problem
The Power/Calibration indicator will not come on.

Solution
- Make sure that the SmartPrecision electronics' 15-pin HD connector is fully seated and connected.
- Confirm that +5 Volts DC is being applied to pin 12 on the SmartPrecision electronics' 15-pin HD connector and that pin 13 is connected to ground.

Problem
None of the SmartPrecision electronics' LEDs turn on.

Solution
- Refer to the Grounding Reference Guide on pg. 9.

Problem
Can't get the SmartPrecision electronics' "Signal" LEDs better than red or yellow; or the green, " Proper Alignment" indicator doesn't stay illuminated over the full length of the scale.

Solution
- Verify that the sensor head has been aligned to the scale and that the mounting screws are tight. Check the dimensions for the mechanical mounting holes (and clamps if any) to make sure that the sensor is correctly located over the scale. Refer to appropriate the interface drawing.
- Check that the scale is firmly mounted and can't jiggle or move in other than the intended direction.
- Make sure that the scale is clean over its entire length or circumference.

Problem
The green Power/Calibration indicator is flashing unexpectedly.

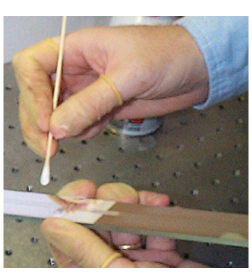
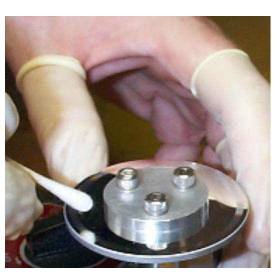
Solution
- Part of the normal setup procedure is to activate the SmartPrecision electronics' index capture process by pressing the recessed button on the SmartPrecision electronics' connector body. The On/Index LED will begin to flash until the index mark on the scale passes under the sensor at least one time in each direction.

Problem
Can't complete the Capture Index process - the green Power/Calibration indicator doesn't stop flashing.

Solution
- Verify that the sensor is mounted in the correct orientation to the scale for the desired index mark. Refer to the interface drawing.
- Refer to step 5 of the installation procedure to insure proper operation.

Cleaning scales


General Particle Removal
Blow off the contamination with nitrogen, clean air, or a similar gas.

Contamination Removal
Use a lint-free cleanroom wipe or cotton swab dampened with isopropyl alcohol or acetone only. Handle the scale by the edges. Do not scrub the scale.

Contact MicroE Systems

Thank you for purchasing a MicroE Systems product. You should expect the highest level of quality and support from MicroE. If you want to download the Mercury Encoder Installation Manual, Data Sheet or Interface Drawing, browse www.microesys.com and click on the Mercury Encoders button.

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