NCS32100

Industrial Dual Inductive Rotary Position Sensor

September 30, 2022

Inductive Position Sensing

Industrial Dual Inductive (NEW!)

- onsemi has been doing inductive sensors for automotive for 20 years
- We have a *new approach** that is designed for high accuracy and high-speed industrial applications

Traditional Single Inductive (OLD)

- Primarily used for automotive
- Designed for cost and automotive reliability
- Low accuracy and low speed

* Patents: 3 issued, 4 pending

NCS32xxx: Dual Inductive Sensor Products

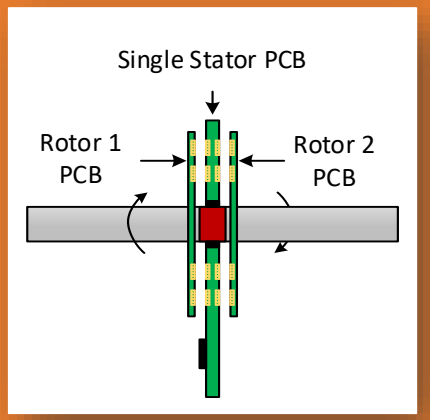
Rotary Position Sensor

- Compatible with any sensor size
- 20 bits resolution and +/-50 arcsec or better accuracy for a 38 mm sensor

Linear Position Sensor

- Measures linear displacement and velocity
- <10um accuracy

Torque Sensor



- Measures torque on a shaft using 2 rotors and 1 stator with a single interface chip

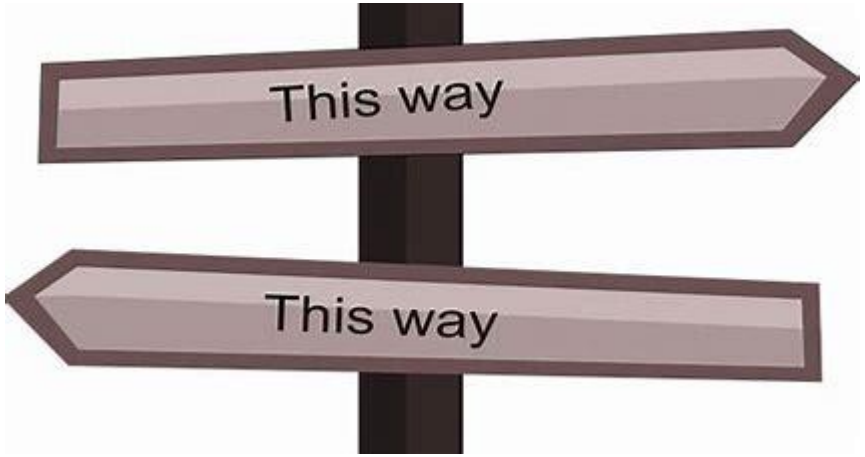
Predictive Maintenance

- Measures the vibration exhibited by worn bearings for predictive maintenance

Position Sensor “Trade Space”

NCS32100 is a disruptive solution that helps encoder systems get more speed and accuracy without high cost

Position sensor solutions today typically pick an area of the “trade space” in which to excel at the expense of one or more other areas (Speed, Accuracy, Cost)



NCS32100 has good performance in all areas of the trade space:

High accuracy (typical spec +/- 50 arcsec, precision alignment accuracy +/- 15-20 arcsec)

High reliability (not sensitive to temperature, vibration, magnetic fields or contaminants such as liquids, dirt and dust)

Low cost (taking the supporting circuitry and PCBs into account

Flexible sensor diameter options (current reference design uses 38mm diameter sensor, but there are other sensor options).

High speed (up to 100,000 RPM)

NCS32100 Position Sensor Anatomy

NCS32100 Chip

Sensor front end
- Automatic gain (PGA)
- ADC

DSP
MCU (M0+)
- Firmware
- Configuration / calibration
- NVM (flash)
- Configurable communication interface

Position Sensor

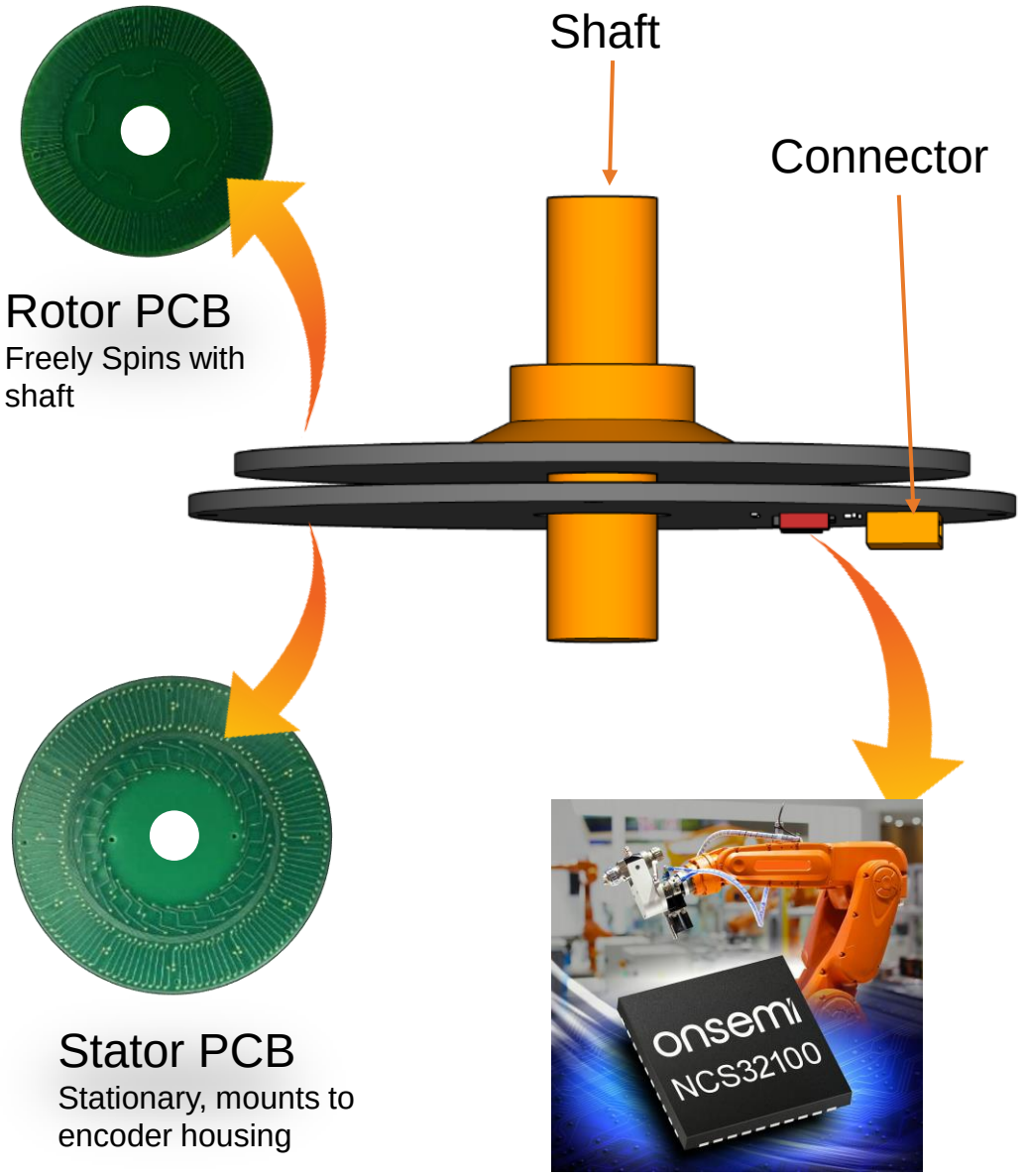
Stator PCB
- Dual inductive coil design
- Excitation coils
- Interface to NCS32100

Rotor PCB

Bearing
Shaft
Housing
Connector

Reference Design and Evaluation boards

Complete Sensor Position Solution



Key Benefits of NCS32100

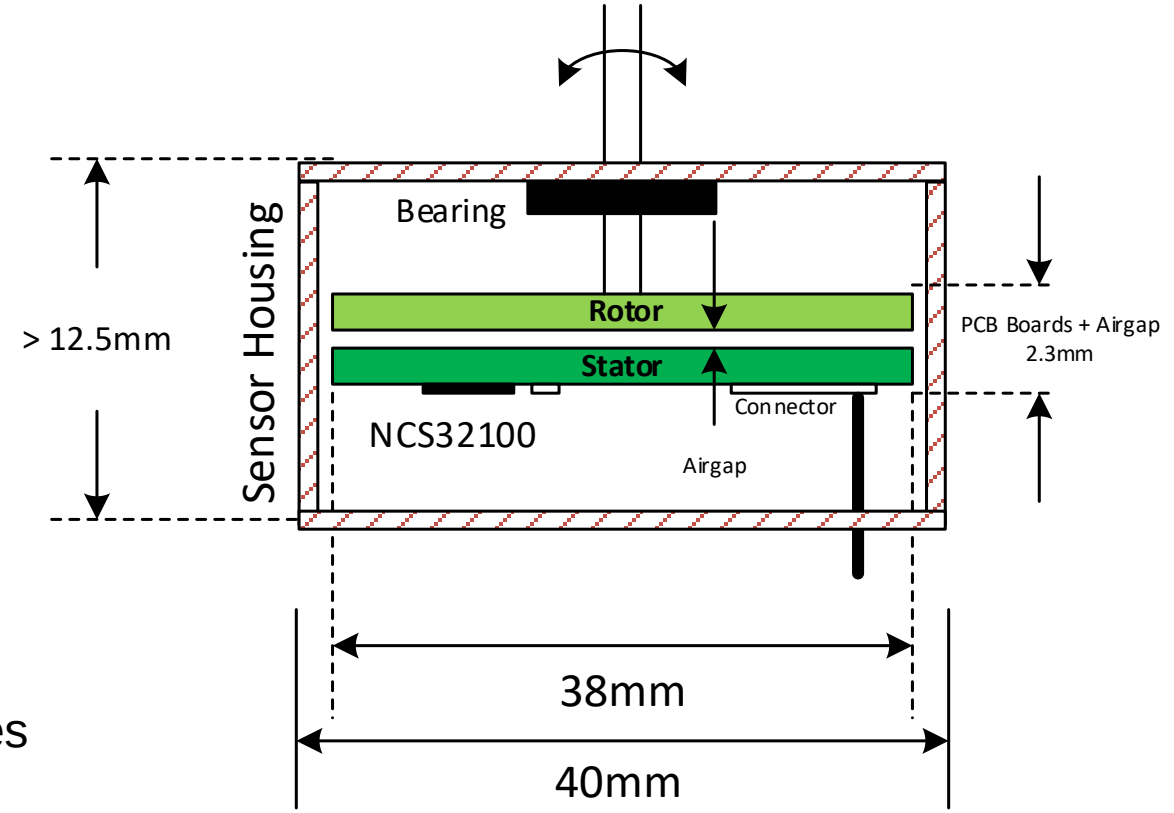
- Highly differentiated performance
  - +/- 50 arcsec accuracy or better
  - High Accuracy (+/- 50 arcsec) **At** High Speed (6,000 RPM*)
- Simple and easy to use: the heavy lifting is already done
  - Integrated MCU, firmware included, outputs position and velocity instead of raw analog signal from which position must be derived
- Flexible Mechanical specifications (+/- 0.25mm alignment)
  - Integrated calibration that accounts for mechanical errors
  - Get +/-50 arcsec accuracy with up to 0.25mm misalignments (e.g. airgap, tilt)
- Highly configurable product
  - Allows part to work with different sized PCB sensor designs
  - Customers can differentiate through PCB sensor designs

* +/-50 arcsec accuracy at 6,000 RPM is true at 2 sigma of the 500ns timing jitter

NCS32100: Dual Inductive-Based Rotary Position Sensor

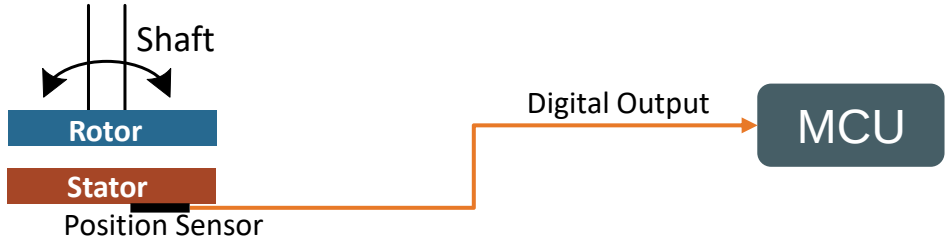
Enables a high-accuracy, high-speed Rotary Position Sensor designed to be robust for industrial environments.

- Sensor consists of two PCBs
  - A rotor with two printed inductors (No soldered components on rotor)
  - A stator with printed inductors as well as an encoder IC
- +/-50 arcsec accuracy for a 38mm sensor
- Absolute encoder: position and velocity
- 6,000 RPM full accuracy* (100,000 RPM maximum)
- 20-bit single-turn resolution output
- 24-bit multi-turn count resolution output
- Contactless
- Optional Battery Backup
- Integrated self-calibration that accounts for PCB asymmetries
- Secondary calibration that helps with mechanical errors



* +/-50 arcsec accuracy at 6,000 RPM is true at 2 sigma of the 500ns timing jitter, reduced position accuracy above 6000 rpm

Digital Output Speed Comparison

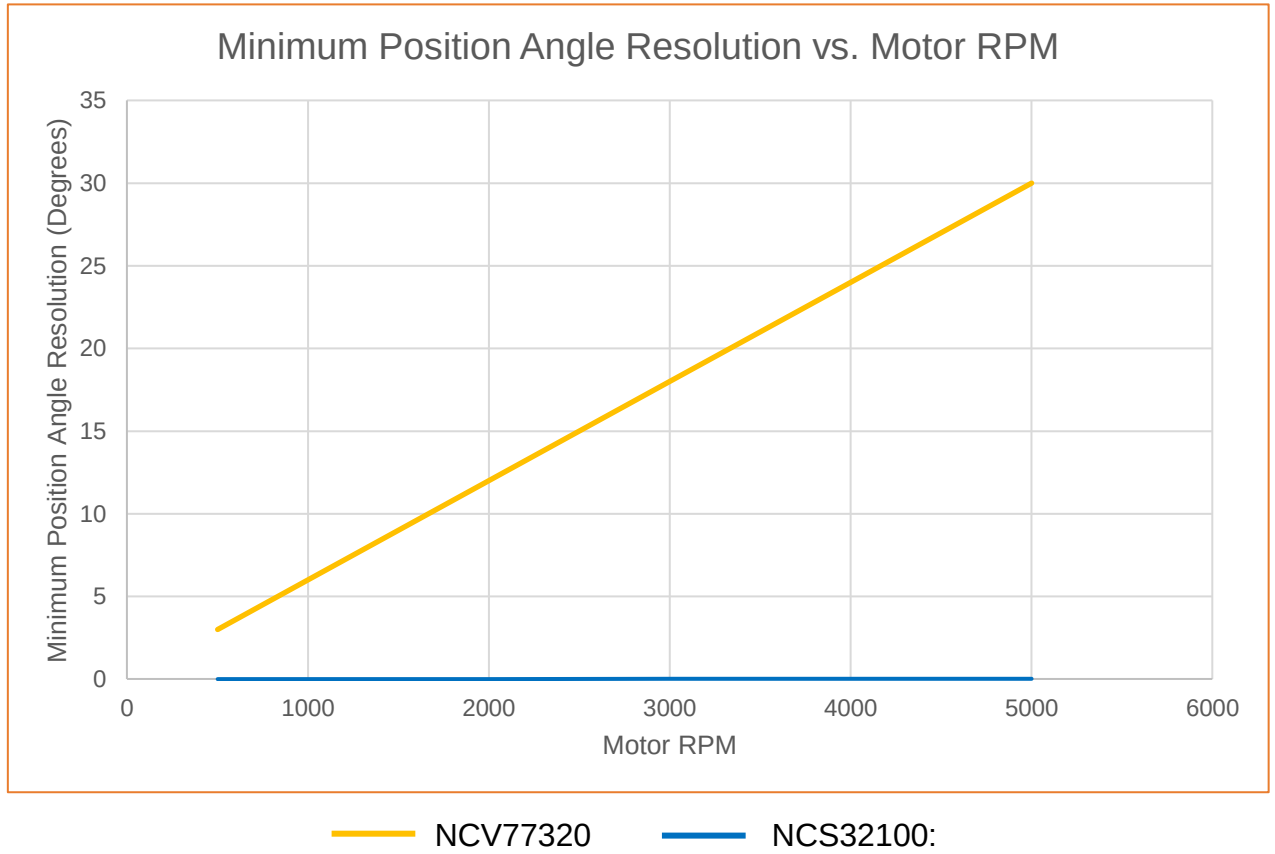


The minimum (fastest) digital output rates:

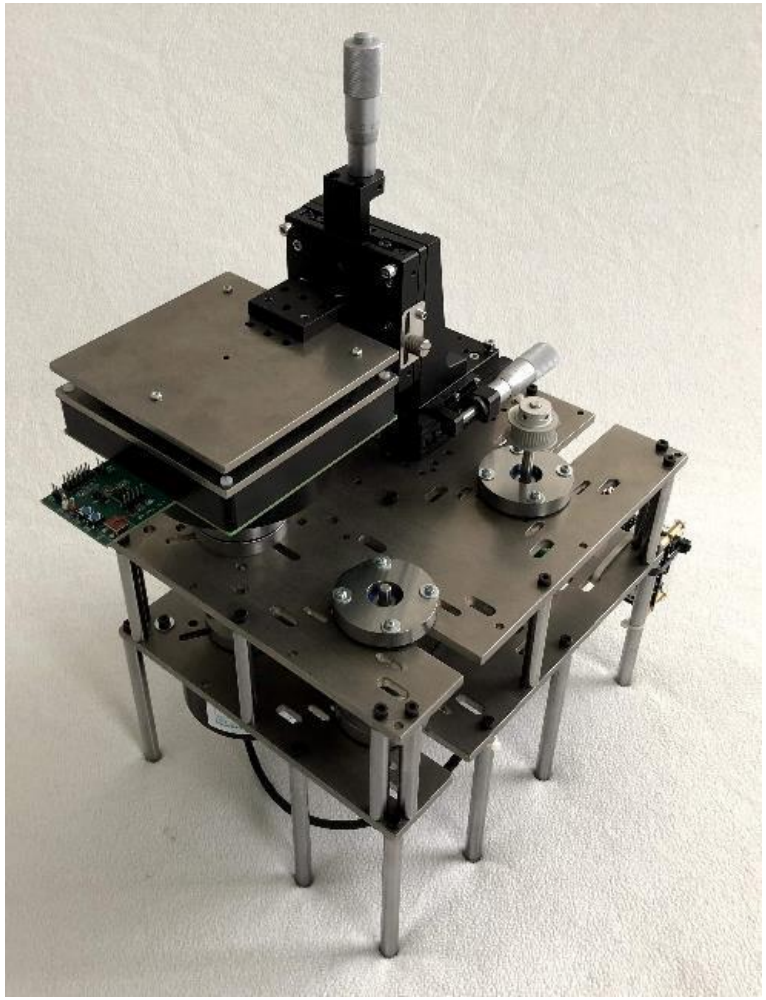
- NCV77320 is 1msec (SENT)
- NCS32100 is 65.5usec (UART)

As the Rotor RPM increases, the minimum position angle accuracy decreases due to timing jitter.

Rotor RPM:	Rotor RPS:	1 mechanical revolution (seconds):	NCV77320: degrees (arcsec)	NCS32100: degrees (arcsec)
5000	83.3	0.012	30 (108,000)	0.0138900 (50)
4000	66.7	0.015	24 (86,400)	0.0110000 (40)
3000	50	0.02	18 (64,800)	0.0083334 (30)
2000	33.3	0.03	12 (43,200)	0.0055556 (20)
1000	16.7	0.06	6 (21,600)	0.0055556 (20)
500	8.33	0.12	3 (10,800)	0.0055556 (20)



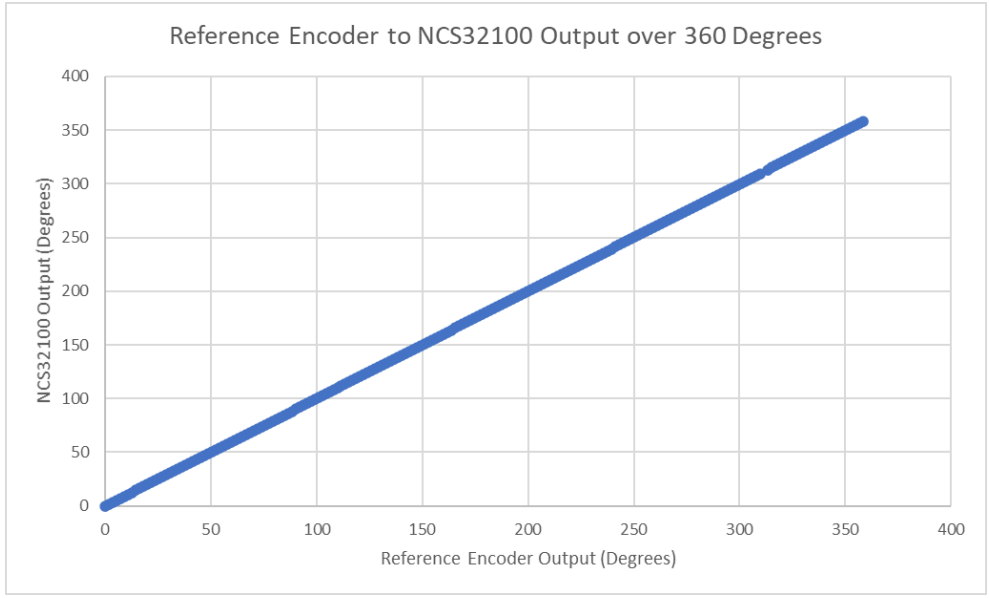
NCS32100: Sensor Characterization

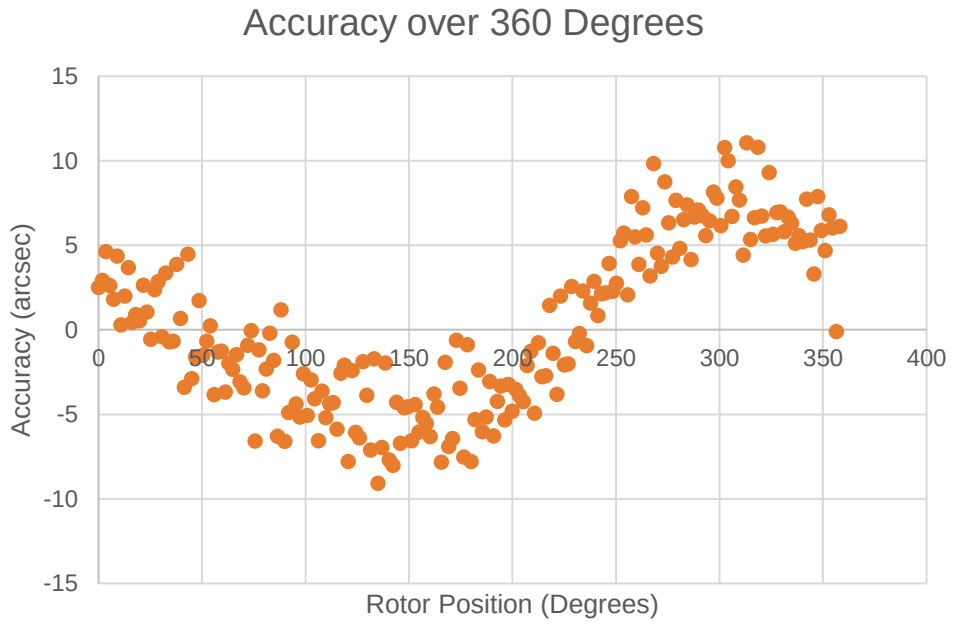


NCS32100 and Reference Encoder are connected to the same shaft and compared against each other.

Demonstrated +/- 15 arcsec typical accuracy.

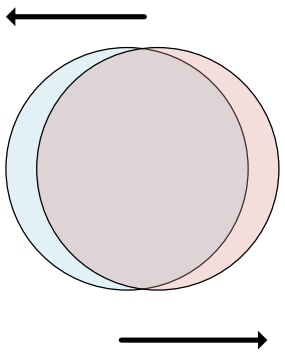
Difference between NCS32100 output and Reference encoder output is within the accuracy of the reference.





Gurley Reference Encoder Accuracy = 10 arcsec

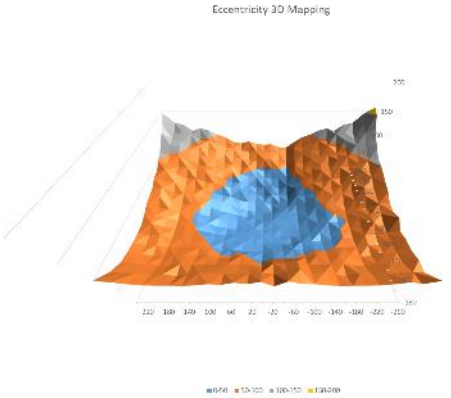
NCS32100 Accuracy over Eccentricity – One Time Calibration



X Axis Eccentricity (um)

Y Axis Eccentricity (um)

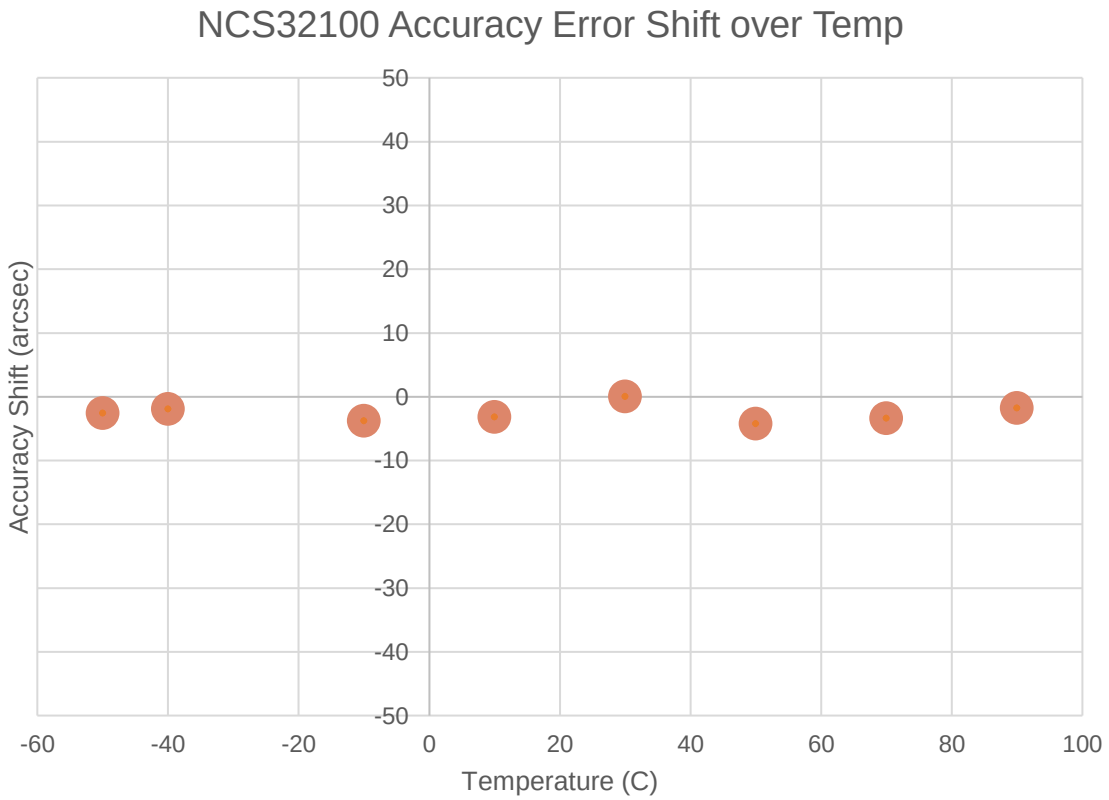
	-260	-240	-220	-200	-180	-160	-140	-120	-100	-80	-60	-40	-20	0	20	40	60	80	100	120	140	160	180	200	220	240
180	157	146	127	123	109	115	110	101	94	82	68	70	77	76	78	85	80	82	94	101	110	115	109	123	127	146
160	151	133	115	115	112	97	97	89	82	78	62	65	67	68	70	68	73	78	82	89	97	98	112	115	115	133
140	133	124	112	108	94	97	87	83	76	68	54	55	61	62	59	60	66	68	76	83	87	97	99	108	112	124
120	122	114	109	95	90	86	81	76	65	63	46	51	50	44	50	56	54	63	65	76	81	86	98	106	109	114
100	113	104	99	96	87	75	75	67	62	57	43	40	37	39	41	45	50	57	62	67	75	75	87	96	99	104
80	104	99	92	85	83	76	75	63	54	43	33	23	33	31	26	35	44	43	54	63	75	76	83	85	92	99
60	102	90	92	82	70	69	61	59	54	44	22	21	23	15	24	26	41	44	54	59	61	69	70	82	92	90
40	97	88	81	75	66	59	59	49	40	38	22	17	12	17	17	20	25	38	40	49	59	59	66	75	81	88
20	92	81	81	66	64	60	54	49	38	30	25	19	10	10	9	14	21	30	38	49	54	60	64	66	81	81
0	88	78	76	66	55	55	53	45	34	27	26	25	20	15	14	13	21	27	34	45	53	55	55	66	76	78
-20	80	77	64	61	54	51	48	39	36	28	27	26	27	22	19	22	23	28	36	39	48	51	54	61	64	77
-40	78	71	68	60	51	47	49	41	33	28	26	25	23	22	25	24	23	28	33	41	49	51	51	60	68	71
-60	85	66	69	57	51	50	43	41	35	29	27	26	27	28	28	29	30	29	35	41	51	52	51	57	69	66
-80	73	66	61	61	51	51	43	39	41	39	31	32	31	30	32	35	36	39	41	52	51	52	51	61	61	66
-100	77	67	59	59	53	52	51	47	47	42	48	42	40	34	36	38	44	42	51	52	52	52	53	59	59	67
-120	77	68	64	57	57	60	62	57	59	52	49	48	48	40	49	57	51	52	59	57	62	60	57	57	64	68
-140	81	72	71	66	62	63	68	66	65	66	79	73	71	55	65	65	67	66	65	66	68	63	62	66	71	72
-160	81	83	80	79	74	75	68	74	80	80	91	84	75	81	78	78	79	80	80	74	68	75	74	79	80	83
-180	101	89	96	89	84	83	83	81	84	89	90	99	80	98	89	94	86	89	84	81	83	83	84	89	96	101



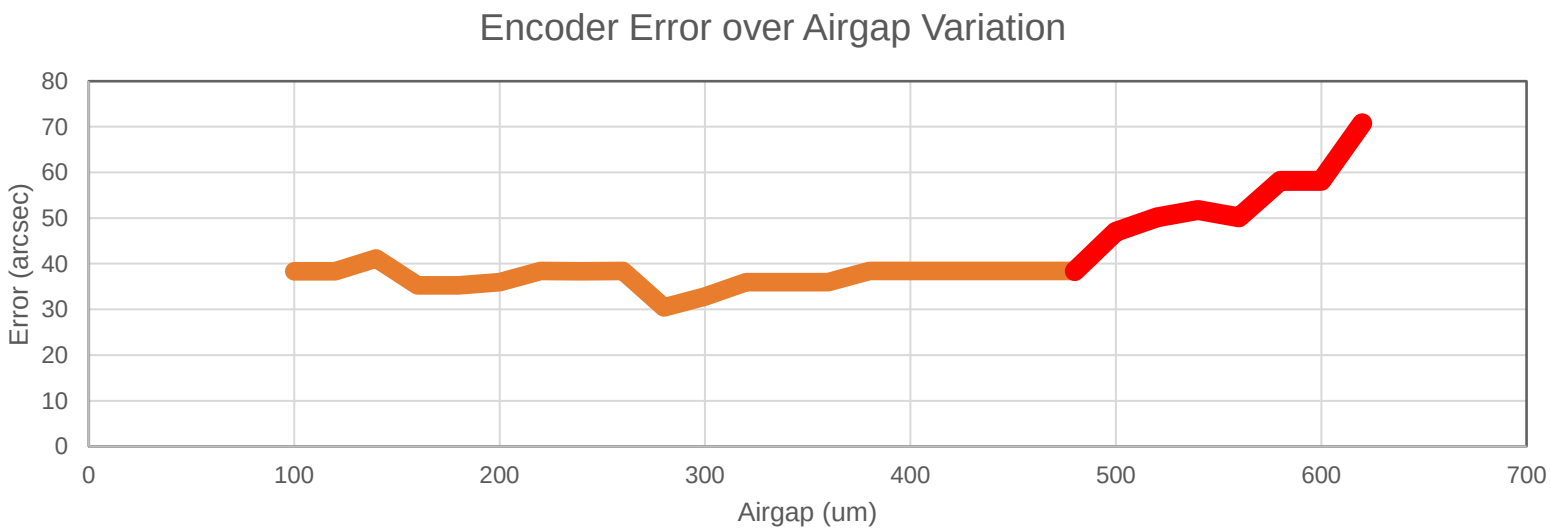
- No recalibration performed
- < 50 arcsec (green) maintained up to +/-140um in any direction from center
- Recalibration will expand the mechanical tolerance to +/- 240um in any direction from the center
- Measurement in each location represents max accuracy error in arcsec over a full 360-degree sweep

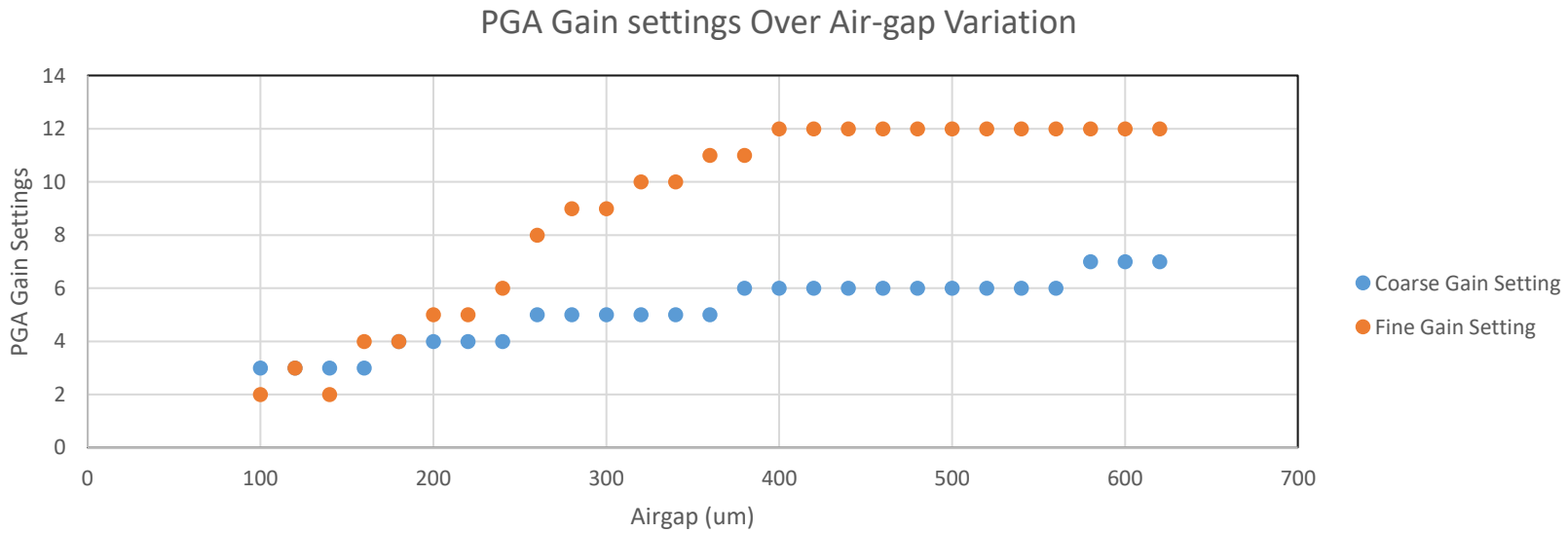
Performance Over Temperature

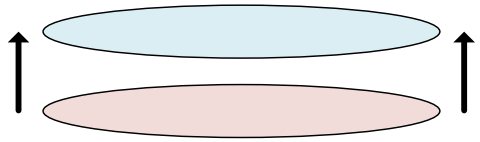
- NCS32100 is insensitive to temperature to a first order.
- Small accuracy shifts shown are due to noise. Low pass filter was bypassed for this test (see slide “NCS32100 Noise Performance”).
- Sensor accuracy can shift if thermal expansion of the housing and encoder fixture causes the rotor/stator assembly to shift.



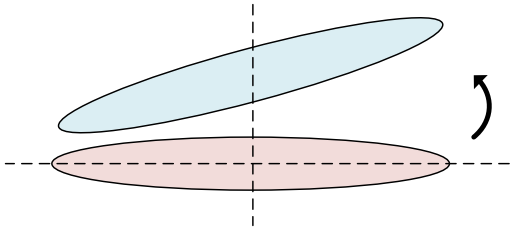
NCS32100: Accuracy over Air-gap Variation





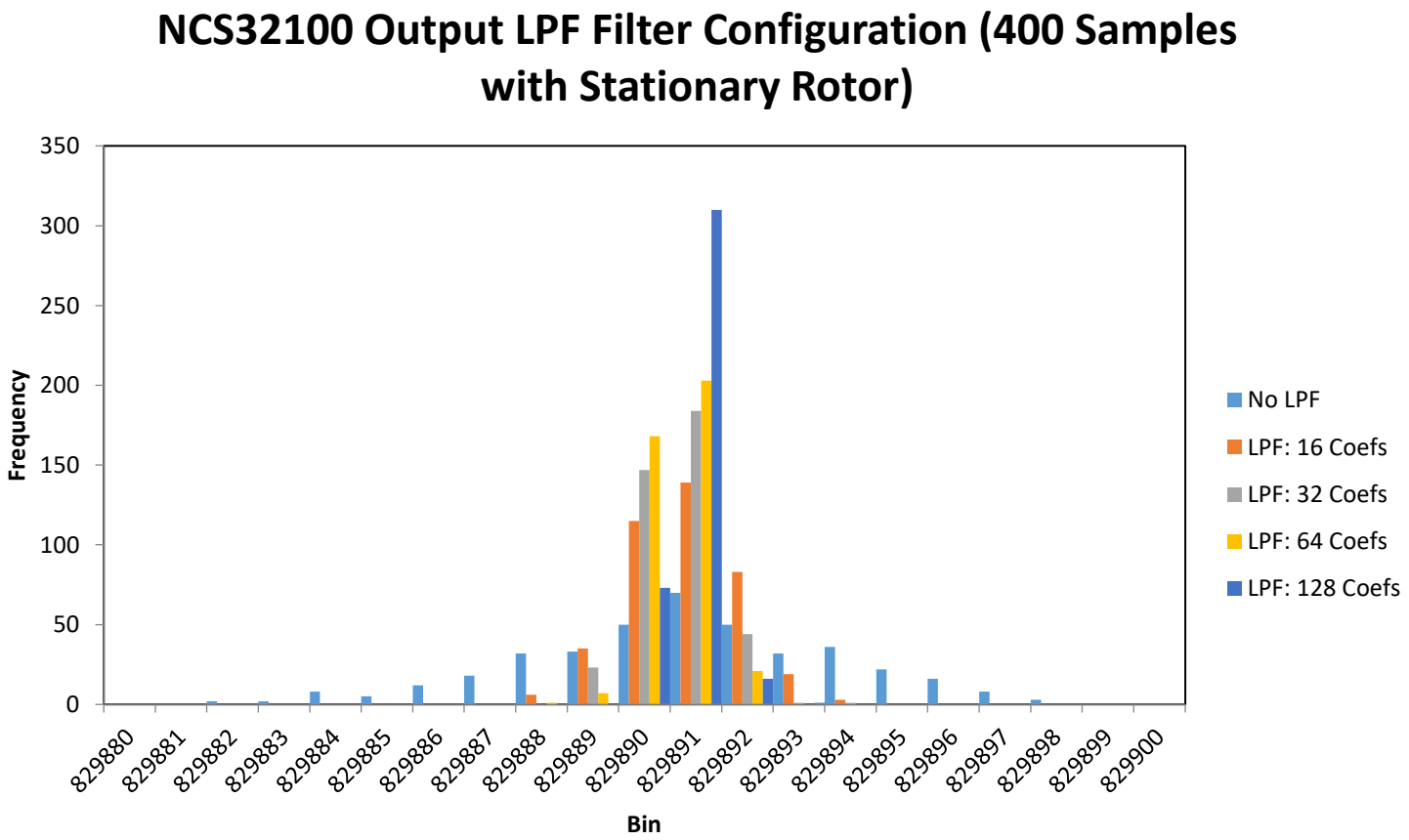


- Acceptable rotor-to-stator air gap: 0.1mm – 0.5mm

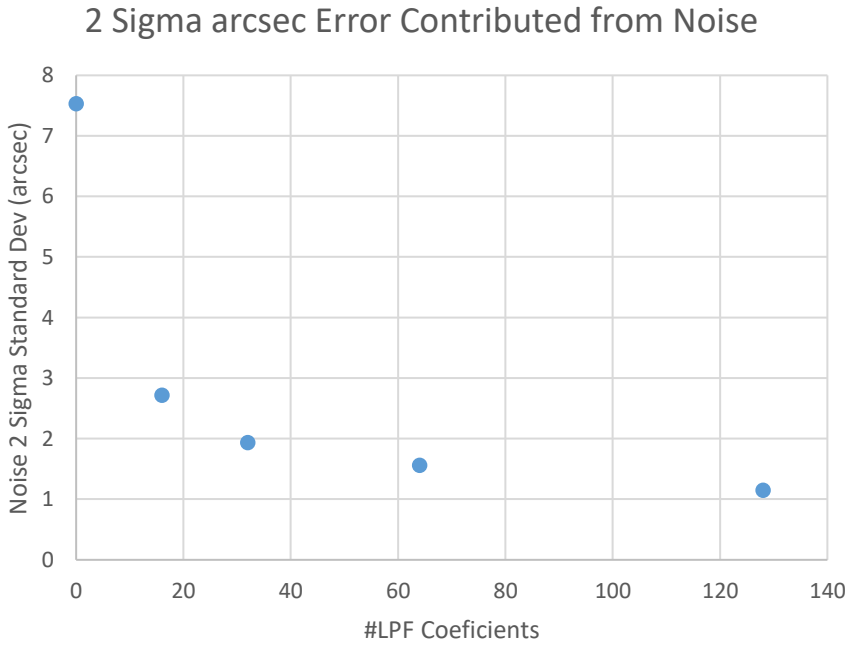


- Acceptable rotor-to-stator tilt: 0.5 degrees

NCS32100 Noise Performance



- The digital IIR Low Pass Filter is configurable
- There are 5 coefficient options (0, 16, 32, 64, and 128)
- IIR filter does not add latency but does introduce settling time.



NCS32100 Optional Features

- Sensor Configuration
  - NCS32100 can be configured to work with many different sensor designs and patterns

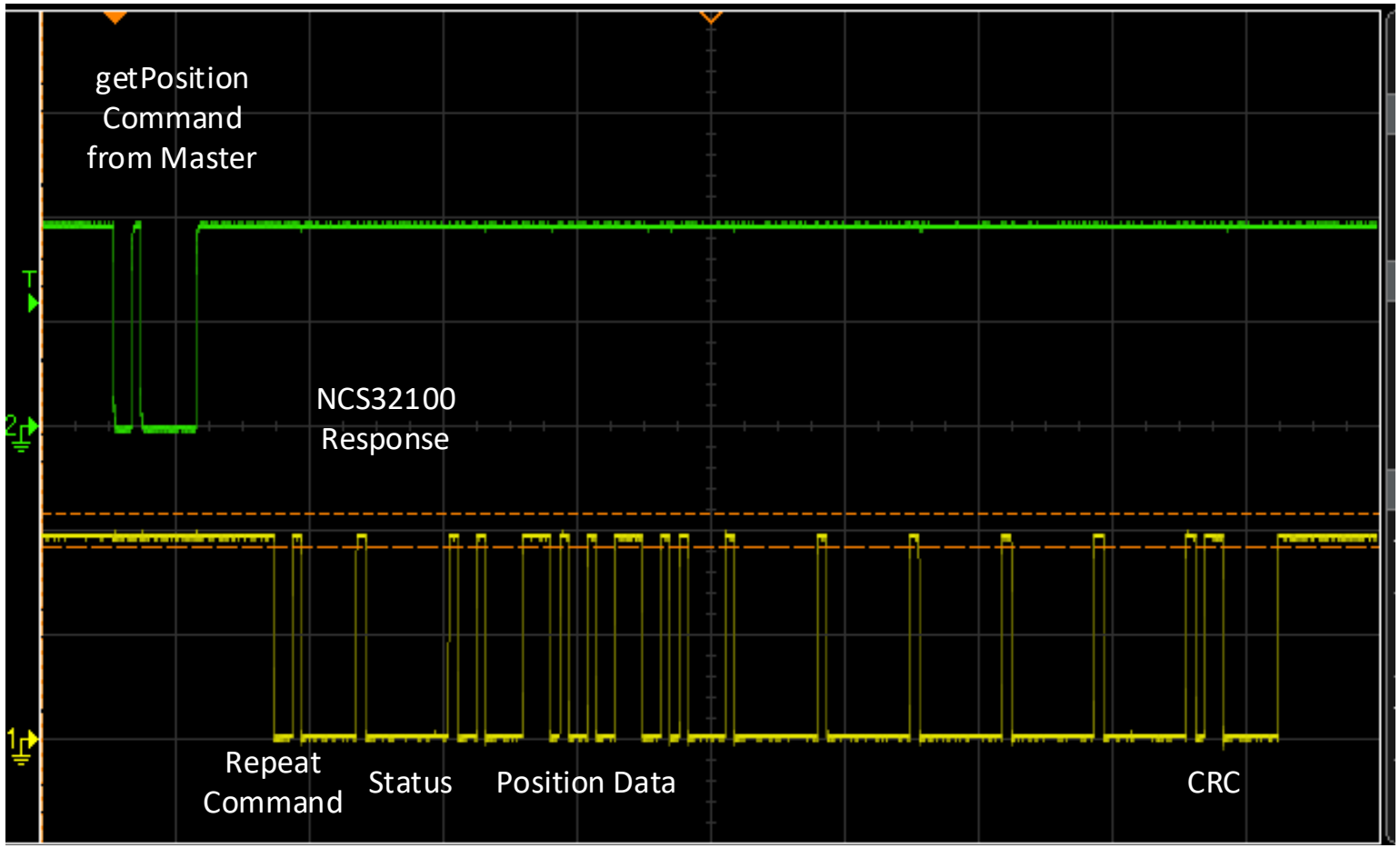
- Latency Extrapolation
  - NCS32100 can be configured to negate system latencies by using extrapolation filters

- Low Pass Filtering
  - Options for filtering position and velocity outputs with 16, 32, 64, or 128 coefficients

- Open Coil Detect
  - NCD32100 can be configured to check for unintended breaks in the sensor coils

- Position auto zero
  - User can reset the absolute position index to any position desired

NCS32100: 2.5MHz UART Interface



- Offers a command set for
  - Position
  - Velocity
  - Turns count
  - Battery Voltage Measurement
  - Temperature
  - Configuration Registers
  - Reading / Writing NVM
  - Resetting Turns count
  - Resetting Position Index
  - Error Status
- Data responses are 11 bytes
- 3us response timing

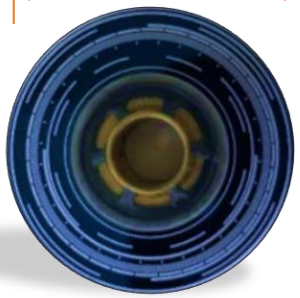
Sensor Calibration

- NCS32100's calibration routine allows sensors to be self-calibrated
  - Self-calibration can be achieved by the NCS32100 itself prompted by a single command from the master. (3 seconds)
  - This reduces the error due to asymmetries in the PCB sensor coils.
  - Self-calibration can also be achieved by the STM32 master on the evaluation board (5 seconds). Firmware for external master will be open to the customer
- To perform Self-Calibration
  - No reference encoder is needed to perform the self-calibration
  - Calibration can be run at any time, even by the end customer in the field
  - Rotor must be moving at 100 to 1000 RPM
- Secondary Calibration
  - Secondary calibration is also available to improve linearity. The NCS32100 firmware currently allows for 16 secondary calibration coefficients to reduce single period 360 degree period error.

System Solution Comparison Example

Optical Encoder Solution

38mm Diameter



Optical Disk

+

Stator PCB
(with 50+ components)

+

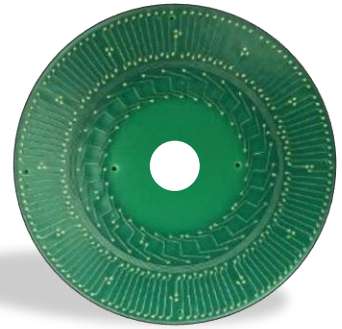
LED Driver PCB
(with additional 50+ components)

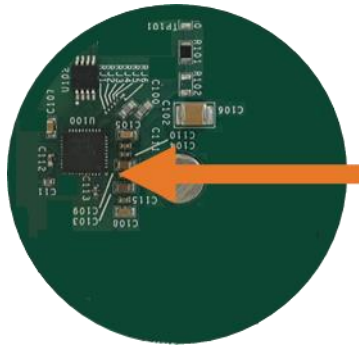
100+ components

Rotor PCB
(single layer, no components)

+

Stator PCB
(12 Components on backside)





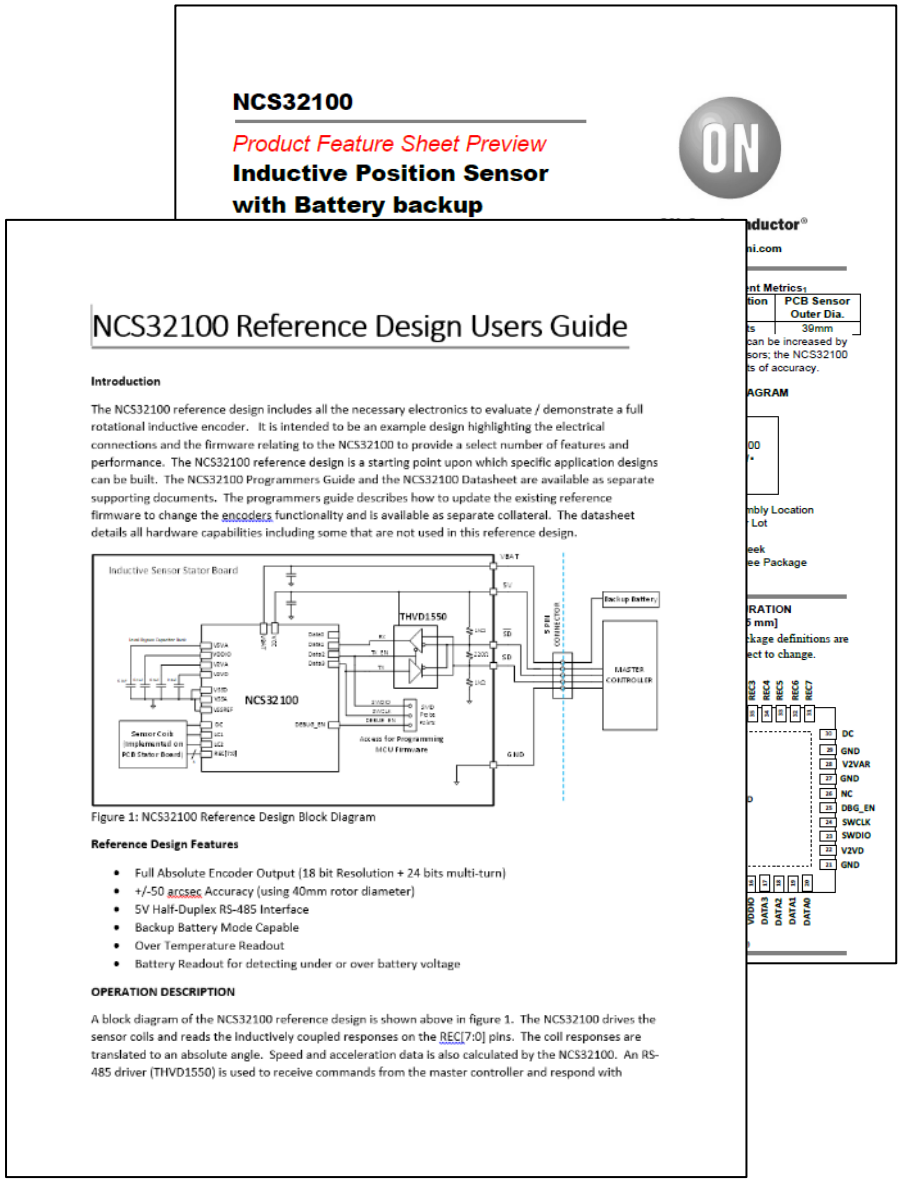
<u>Stator PCB Backside</u>
NCS32100
(5mm x 5mm Package)

12 components

BACKUP

NCS32100 Design Aids

- Reference Design Manual
  - PCB design for a 38 mm rotary sensor
  - RS-485 5-Pin Interface
  - Firmware supports +/- 50 arcsec or better accuracy with position and velocity readout
    - Battery backup
    - Error reporting
- Evaluation Board
  - Simple demonstration of both rotary PCB sensors working with the NCS32100.
  - Strata enabled
- Feature Sheet detailing NCS32100 hardware.



NCS32100

Product Feature Sheet Preview

Inductive Position Sensor with Battery backup

NCS32100 Reference Design Users Guide

Introduction

The NCS32100 reference design includes all the necessary electronics to evaluate / demonstrate a full rotational inductive encoder. It is intended to be an example design highlighting the electrical connections and the firmware relating to the NCS32100 to provide a select number of features and performance. The NCS32100 reference design is a starting point upon which specific application designs can be built. The NCS32100 Programmers Guide and the NCS32100 Datasheet are available as separate supporting documents. The programmers guide describes how to update the existing reference firmware to change the encoders functionality and is available as separate collateral. The datasheet details all hardware capabilities including some that are not used in this reference design.

Figure 1: NCS32100 Reference Design Block Diagram

Reference Design Features

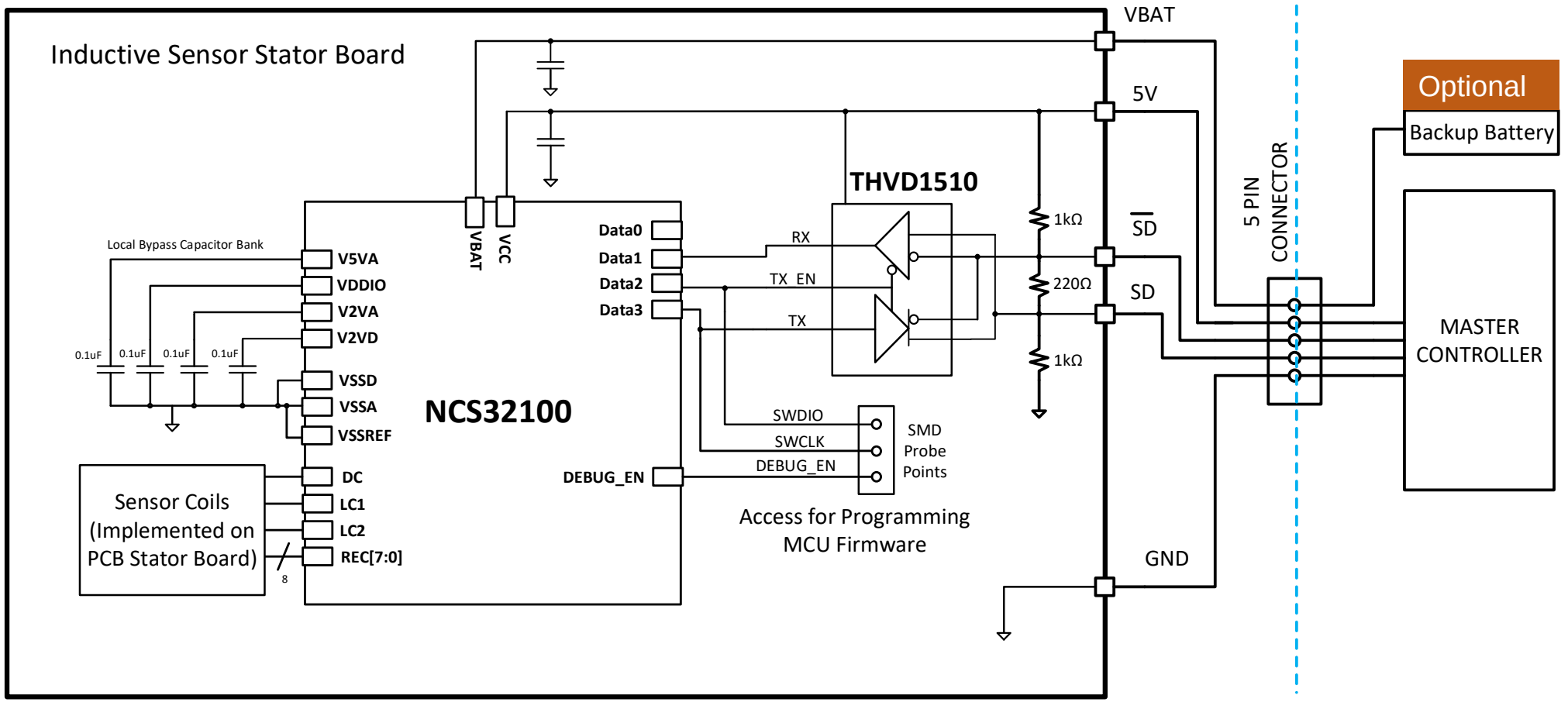
- Full Absolute Encoder Output (18 bit Resolution + 24 bits multi-turn)
- +/-50 arcsec Accuracy (using 40mm rotor diameter)
- 5V Half-Duplex RS-485 Interface
- Backup Battery Mode Capable
- Over Temperature Readout
- Battery Readout for detecting under or over battery voltage

OPERATION DESCRIPTION

A block diagram of the NCS32100 reference design is shown above in figure 1. The NCS32100 drives the sensor coils and reads the inductively coupled responses on the REC[7:0] pins. The coil responses are translated to an absolute angle. Speed and acceleration data is also calculated by the NCS32100. An RS-485 driver (THVD1550) is used to receive commands from the master controller and respond with

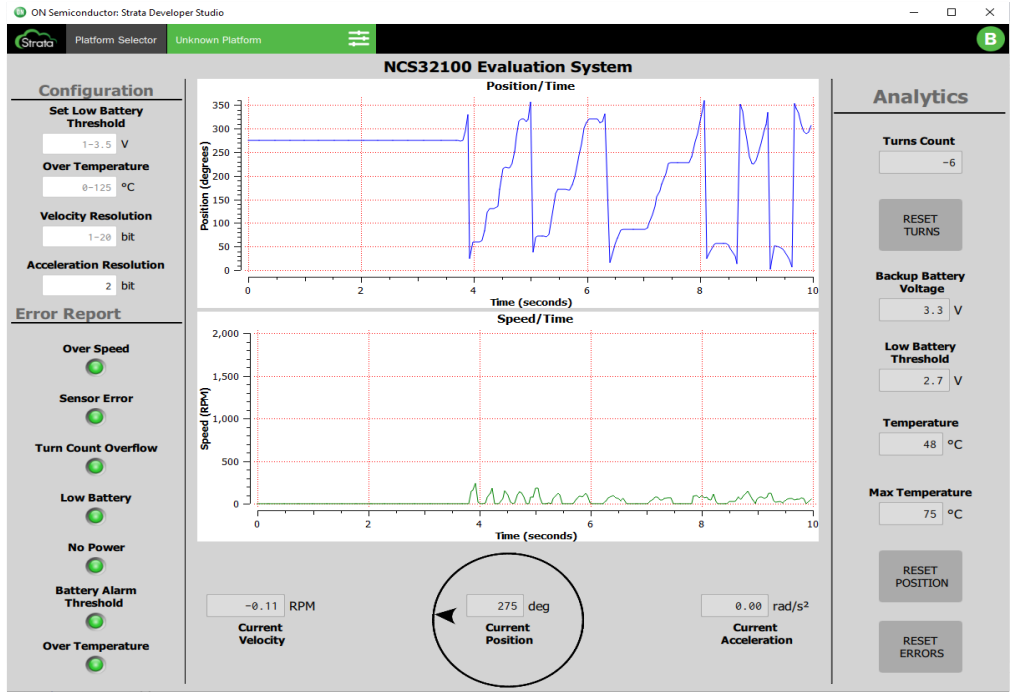
NCS32100: Simple PCB Designs

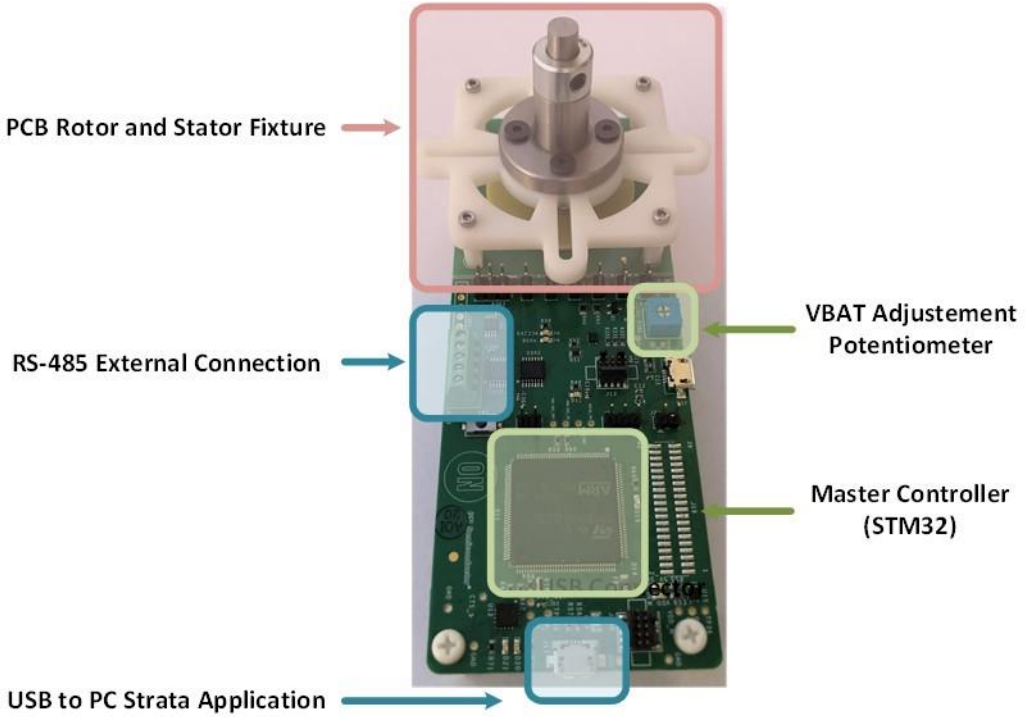
- No soldered components on Rotor board
- On the Stator, the Encoder (NCS32100) drives, reads, and encodes the signals from the PCB sensor
- Sensors can be configured for different sizes and accuracy

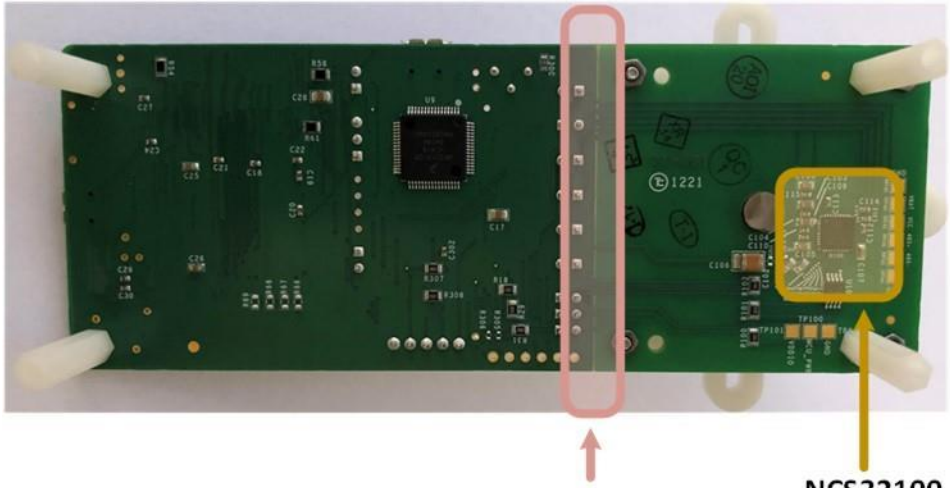


NCS32100 Evaluation Board

- Evaluation board allows users to develop their product with the NCS32100.
- Interfaces with Strata Developer Studio
- Perforation on board allows user to snap off master controller portion. Sensor can be mounted to custom application for evaluation.







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