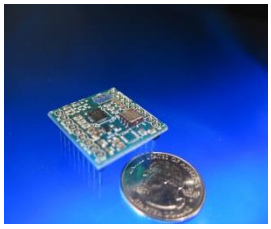
DATASHEET

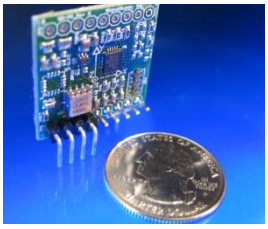
SQ-SI-360DA

SOLID-STATE MEMS INCLINOMETER

±70 ° DUAL AXIS, 360 ° SINGLE AXIS, SERIAL AND ANALOG OUTPUT

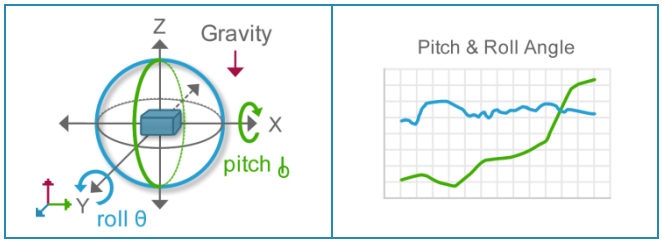


SQ-SI-360DA-HMP



SQ-SI-360DA-VMP

FUNCTIONAL DIAGRAMS



FUNCTION

- ± 70 ° dual axis angle measurement
- 360 ° single axis angle measurement
- UART serial output and analog output

APPLICATIONS

- Platform and vehicle leveling
- Satellite dish and antenna alignment
- Machine control and monitoring
- Angle measurement and recording
- Computer input, head tracking, and mouse pointing

DESCRIPTION

The inclinometer module performs calibrated angle measurement with analog voltage and digital serial outputs.

FEATURES

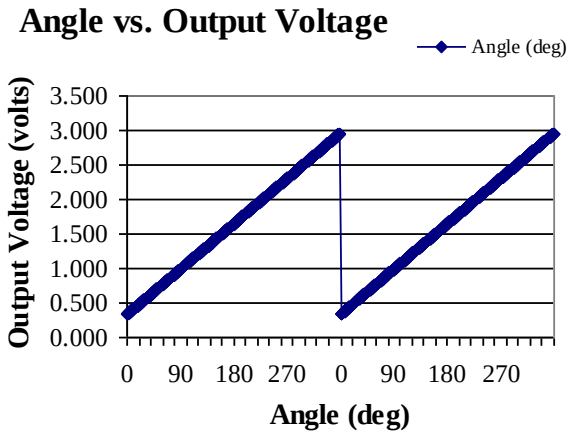
- 0.1 ° resolution - digital serial output
- Low temperature drift
- Factory calibrated angle output
- High reliability solid-state MEMS
- Digital filtering for stable measurement
- Direct PC interface cable
- Made in the USA

THEORY OF OPERATION

The inclinometer uses two factory calibrated accelerometers to measure and compute angles made between its axes and the gravity vector. The trigonometric conversions between acceleration and angle are made by an onboard processor. Digital filtering reduces the impact of spurious acceleration and vibration on the reported angle.

EXAMPLE ANALOG OUTPUT

The graph below shows an example of the analog output from a device in single axis mode. The device is rotated 720º clockwise from a 0º starting position at a rate of 180º/sec. The output is linear with a piecewise overflow at 360º. The second axis output is similar, but each axis reaches a maximum at 180º and descends back to 0º rather than overflowing.



RANGE AND SCALE

PARAMETER	UNITS	VALUE
Scale Factor	V/deg	$0.0022 \times V_{cc}$
Offset (0º value)	V	$0.100 \times V_{cc}$
Max (359º value)	V	$0.895 \times V_{cc}$

$$Output(\mathrm{V}) = Offset(\mathrm{V}) + ScaleFactor(\mathrm{V/deg}) \times Angle(\mathrm{deg})$$

$$Angle(\mathrm{deg}) = \frac{Output(\mathrm{V}) - Offset(\mathrm{V})}{ScaleFactor(\mathrm{V/deg})}$$

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ABSOLUTE MAXIMUM RATINGS

PARAMETER	MIN	TYPICAL	MAX	NOTES
Voltage on $+V_{cc}$ - without regulator - NR option	-		4.2 V	With respect to GND
Voltage on $+V_{cc}$ - with regulator - R option	-		5.8 V	
Voltage on any input pin			5.8 V	With respect to GND
Peak-to-peak supply noise - without regulator -NR option			50 mV	
Peak-to-peak supply noise - with regulator - R option			200 mV	
Operating temperature	-40 ºC		85 ºC	
Shock survivability			500 g_n	Where 1 g_n is assumed to be = 9.81 m/s^2
Operating vibration			0.25 g_n	

Note: Exposure to conditions outside of the Absolute Maximum Ratings may damage the device. Prolonged exposure to conditions at the Absolute Maximum Ratings may result in degraded performance of the device over time.

ELECTRICAL CHARACTERISTICS

[Test conditions: 3.3v regulator, 25 ºC unless otherwise specified]

PARAMETER	MIN	TYPICAL	MAX	NOTES
Supply voltage - without regulator - NR option	2.9 V		3.5 V	With respect to GND 12 V versions also available. Consult the factory.
Supply voltage - with 3.0 volt regulator - 3.0R option	3.2 V		5.8 V	
Supply voltage - with 3.3 volt regulator - 3.3R option	3.5 V		5.8 V	
Supply current - HP option		4.6 mA		
Supply current - LP option		1.6 mA		
Supply current - ULP option	0.5 µA	40 µA	1.9 mA	Operating at 1 sample per second, no filtering, no oversampling
Output voltage*	0.3 V		0.9 × V_{cc}	See note below regarding V_{cc}
Sensitivity*		0.0022 × V_{cc} /deg		
Full-scale output range*	0.100 × V_{cc}		0.895 × V_{cc}	
Analog output current			20 µA	
Input voltage High	2.0 V			
Input voltage Low			0.8 V	
Output voltage High	0.895 × V_{cc}		V_{cc}	
Output voltage Low	0 V		0.100 × V_{cc}	

***Note:** For the NR model (without onboard regulator), *Vcc* is the voltage supplied to the device. For the 3.0R and 3.3R models (3.0 V or 3.3 V onboard regulators), *Vcc* is 3.0 V or 3.3 V respectively. If your application requires using a 12 V supply, consult the factory for 12 V models.

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PERFORMANCE PARAMETERS

[Test conditions: 3.3v regulator, 25 ° C unless otherwise specified]

PARAMETER	SPECIFICATION		NOTES			
Angle accuracy (differential) - HP option	± 1 °		From any angle to any other angle within range			
Angle accuracy (differential) - LP option	± 2 °					
Angle accuracy (differential) - ULP option	± 2 °					
Angle resolution	2 ° (analog), 0.1 ° (digital)					
Alignment accuracy	± 2 °					
Angle range - Dual Axis Tilt Mode	± 70 ° (X and Y tilt)		Dual axis X and Y tilt angle ranges with respect to horizontal.			
Angle range - Single Axis Gimbaled Mode	360 ° (Z rotation)		Single axis rotation angle measurement valid while Z axis (vector normal to circuit board) is within ± 45 ° of horizontal.*			
Typical angular drift due to temperature. Values represent 1 sigma confidence in tilt mode. - IND option			**Angle range**			
			± 10 °	± 45 °	± 70 ° **	360 ° (single axis)
	Temperature range	15 C to +35 C	± 0.06 °	± 0.06 °	± 0.3 °	± 0.1 °
		0 C to +70 C	± 0.3 °	± 0.3 °	± 1.6 °	± 0.6 °
		-40 C to +85 C	± 0.4 °	± 0.4 °	± 1.7 °	± 0.8 °
Typical angular drift due to temperature. Values represent 1 sigma confidence in tilt mode. - LC option			**Angle range**			
			± 10 °	± 45 °	± 70 ° **	360 ° (single axis)
	Temperature range	15 C to +35 C	± 0.3 °	± 0.3 °	± 1.7 °	± 0.6 °
		0 C to +70 C	± 1.3 °	± 1.4 °	± 7.8 °	± 2.8 °
		-40 C to +85 C	± 1.9 °	± 2.1 °	± 8.5 °	± 4.2 °

*** Note:** Angle ranges measured with respect to deviations from horizontal.
**** Note:** Useable up to +/- 80 ° with degraded accuracy.

OUTPUT CHARACTERISTICS

PARAMETER – HP AND LP VERSIONS	TYPICAL	NOTES
Update rate - HP option	40 Hz	Analog update rate and digital serial packet rate
Update rate - LP option	5 Hz	
Update rate - ULP option	2 Hz	
Warm up time from power on - S option	1.0 s	Angle jitter and vibration are digitally filtered
Measurement settling time - S option	0.5 s	
Warm up time from power on - F option	0.2 s	
Measurement settling time - F option	0.1 s	
Analog output resolution	8 bit	9 bit actual resolution after PWM reconstruction

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		filter
PWM modulation frequency	5 kHz to 20 kHz	
PWM reconstruction filter bandwidth	10 Hz	Single pole RC
Output impedance	10 kΩ	

PARAMETER – ULP VERSION	TYPICAL	NOTES
Update rate - ULP option	On demand up to 20 Hz	Serial output only. Analog output disabled.

PIN CONFIGURATION

PIN	SIGNAL NAME	USAGE
1	Ground	
2	UART Transmit	Digital Output – UART transmit line. Push-pull (not open collector). If not used, solder to open circuit for mechanical stability. **Do not** connect to GND or current drain will increase.
3	UART Receive	Digital Input – UART receive line. If not used, **solder to V+.**
4	Baud Select	Digital Input – HP and LP version only. High (or open) selects high baud rate. Low selects low baud rate. If not used, **solder to V+.**
5	$+V_{cc}$ Supply	
6	Y Tilt / Z Rotation Output	Analog Output – If not used, solder to open circuit for mechanical stability. **Do not** connect to GND or current drain will increase.
7	X Tilt / Z Tilt Output	Analog Output – If not used, solder to open circuit for mechanical stability. **Do not** connect to GND or current drain will increase.
8	Dual Axis Tilt Mode / Single Axis Gimbaled Mode Select	Digital Input – High (or open) selects Dual Axis Tilt Mode, Low selects Single Axis Gimbaled Mode. If not used, solder to open circuit for mechanical stability.
9	Noise Estimator	Solder to open circuit for mechanical stability. **Do not** connect to GND
10	NC	Solder to open circuit for mechanical stability. **Do not** connect to GND.
11	Self Test	Solder to open circuit for mechanical stability. **Do not** connect to GND
12	Resolution Select	Solder to open circuit for mechanical stability. **Do not** connect to GND
13	Flip X-Y	Solder to open circuit for mechanical stability. **Do not** connect to GND
14	NC	Solder to open circuit for mechanical stability. **Do not** connect to GND
15	/Reset & Prog 1	Digital Input – Active low reset. Bring low for >10 mS to reset device. If not used, solder to open circuit for mechanical stability. **Do not** connect to GND. Also used for FLASH programming.
16	Prog 2	Digital Input – If not used, solder to open circuit for mechanical stability. **Do not** connect to GND. Also used for FLASH programming.
17	NC	Solder to open circuit for mechanical stability. **Do not** connect to GND
18	NC	Solder to open circuit for mechanical stability. **Do not** connect to GND

***Note:** Grey boxes indicate that a signal is available only on a custom application basis. NC means "no connection".

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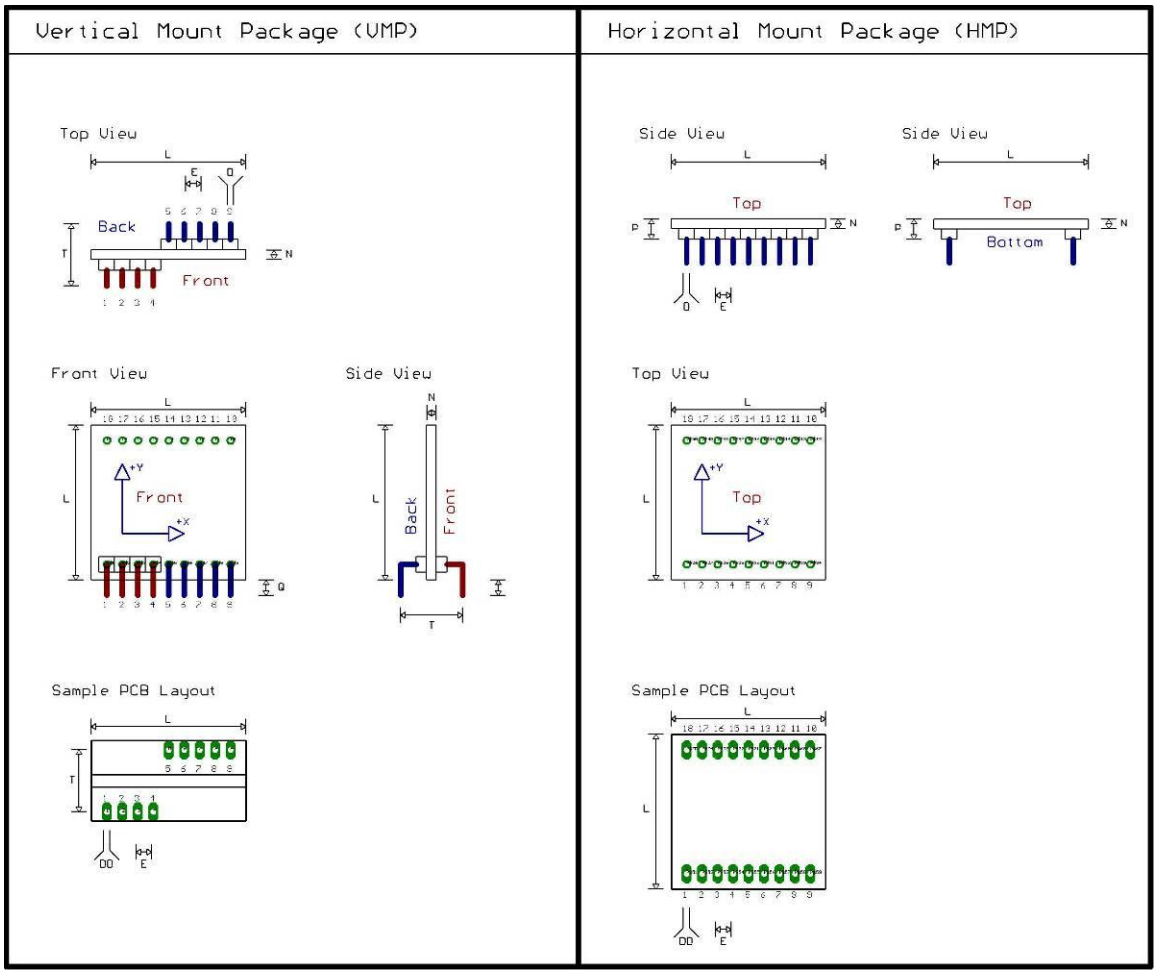
SQ-SI-360DA SERIES PACKAGE



DIMENSIONS

DIMENSION	MILLIMETERS	INCHES	DESCRIPTION	NOTES
T	10.16	0.40	N/A	Pin center to center
L	25.40	1.00	Side length	
E	2.54	0.10	Pitch	Pin center to center
D	0.80	0.032	Pin diameter	
DD	1.00	0.040	Hole diameter	
N	1.63	0.064	PCB thickness	
S	20.32	0.80	Pin row spacing	

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DESIGN, LAYOUT, AND ASSEMBLY CONSIDERATIONS

1. Since the device is a subassembly of surface mount components, it is not suitable for automatic assembly or wave soldering.
2. Hand soldering of pins or SMT pads is specified for 3 seconds at 218 ºC.
3. Pins labeled NC (no connect) should be soldered to open connection pads / pins for mechanical stability.
4. The designer should test the device's output voltage through its entire desired angle range during prototyping to ensure that it is working properly in the application.
5. The device can be mounted vertically or horizontally, but the direction must be oriented correctly to measure the desired angles.

SERIAL INTERFACE: HP AND LP VERSIONS*

UART FORMAT: 8-N-1

8 data bits, 1 stop bit, no parity, no flow control: 115,200 baud or 57,600 baud, pin-selectable. (**Available in 19,200 baud by special order.)**

One byte commands can be sent from the host to control various functions of the device. The following commands can be sent to the devices via the UART. The data encoding is HEX, not ASCII.

INTERROGATE

0x01 (Interrogate Mode command)
The inclinometer responds with one data packet [10 bytes] after receiving the Interrogate Mode command. The maximum delay between a request and the data packet response is 1 Update Period. The host should not issue a new Interrogate Mode command before it has received a response to a previous Interrogate Mode command.

STREAM

0x02 (Stream Mode command)
The inclinometer begins sending data packets [10 bytes] continuously at the given Update Rate. The maximum delay between a request and the first data packet response is one Update Period.

RESET

0x83 (Reset command)
The inclinometer initiates its Power-on Reset sequence (see Power-on Reset below).

RESET SOURCES

Power-on Reset and RST pin

When the inclinometer is disconnected from power it reverts to its default settings in Interrogate Mode. It transmits 1 data packet [10 bytes] after its Warm Up time to indicate that measurements are stabilized.

* For the ULP version see the document "SQ-SI ULP Addendum" available at http://www.signalquest.com

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SERIAL PACKET FORMAT: HP AND LP VERSIONS

	BYTE	DUAL AXIS TILT MODE	SINGLE AXIS GIMBALED MODE	NOTES
Header	0	Sync byte 1	Sync byte 1	0xFE
	1	Sync byte 2	Sync byte 2	0xFE
Payload	2	X Tilt (high byte)	Z Rotation (high byte)	Format: 16-bit, unsigned integer *Output_Value* = *Measured_Angle* × 10. For example, a measured angle of 127.5 ° results in an output value of 1275.
	3	X Tilt (low byte)	Z Rotation (low byte)	
	4	Y Tilt (high byte)	Z Tilt* (high byte)	
	5	Y Tilt (low byte)	Z Tilt* (low byte)	
	6	Factory1	Factory1 (high byte)	Undefined
	7	Factory2	Factory2 (low byte)	
Checksum	8	Checksum (high)	Checksum (high)	Format: 16-bit, unsigned integer sum of the 16 bit unsigned integer payload values. The checksum **does not** include the two sync bytes (0xFE 0xFE).
	9	Checksum (low)	Checksum (low)	

***Note:** Z Tilt is not supported at this time. This measurement should be considered invalid. It may be used in several special cases. Its range is 0 ° to 80 °, but the output validity is not supported by this datasheet. Please consult the factory if you would like to learn more about Z Tilt.

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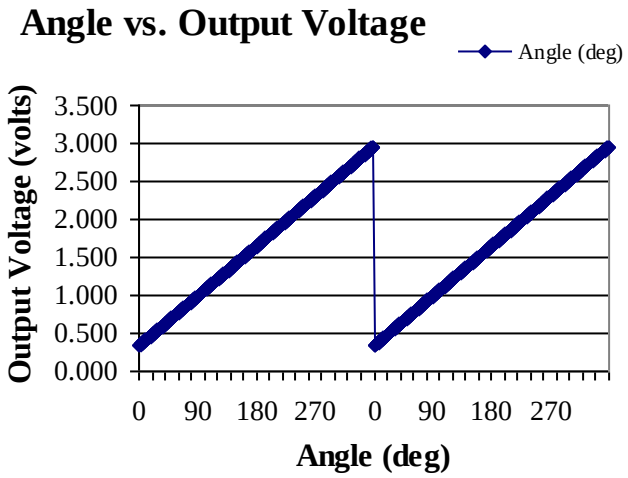
EXAMPLE OUTPUT: HP AND LP VERSIONS*

EXAMPLE SUPPLY VOLTAGE		
$+V_{cc}$	3.300	V
Sensitivity	0.01289	V/bit
Scale factor	0.00731	V/deg
Offset value	0.3300	V
Max value	2.9552	V



EXAMPLE ANGLE	OUTPUT (BITS)	OUTPUT (V)
0	26	0.335
10	31	0.399
20	37	0.477
30	43	0.554
40	48	0.618
50	54	0.696
60	60	0.773
70	65	0.837
80	71	0.915
90	77	0.992
100	82	1.057
110	88	1.134
120	94	1.211
130	99	1.276
140	105	1.353
150	111	1.430
160	116	1.495
170	122	1.572
180	128	1.650
190	133	1.714
200	139	1.791
210	145	1.869
220	150	1.933
230	156	2.010
240	162	2.088
250	167	2.152
260	173	2.230
270	179	2.307
280	184	2.371
290	190	2.449
300	196	2.526
310	201	2.591
320	207	2.668
330	213	2.745
340	218	2.810
350	224	2.887

* For supply voltages other than 3.3V see the document “Inclinometer Worksheet” available at http://www.signalquest.com

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ORIENTATION

TERMINOLOGY

Gravity means a vector pointing from the device toward the center of the earth.
X means a vector parallel to the white silkscreen arrow "X" printed on the main circuit board.
Y means a vector parallel to the white silkscreen arrow "Y" printed on the main circuit board.
Z means a vector passing through the white silkscreen dot "Z" printed on the main circuit board, at 90º to the board.
Horizontal means the silkscreen arrow is pointing at a right angle to gravity.
Straight Down means the silkscreen arrow is parallel to gravity.
Straight Up means that the silkscreen arrow is anti-parallel to gravity (i.e. pointing toward the sky).
Plumb Line is a line with a weight on the end hanging straight down.

DUAL AXIS TILT MODE

In Dual Axis Tilt Mode the X Tilt and Y Tilt angles are measured between gravity and the white silkscreen arrows printed on the main circuit board. If you passed a Plumb Line through the inclinometer's X, Y, Z origin, the X and Y Tilt angles could be measured by placing a protractor's straight edge on the plum line and then reading the angles made with each arrow.

Y Tilt = Pitch (first angle)
X Tilt = Roll (second angle)

Holding Y Horizontal

When X is Horizontal, X Tilt = 90 º.
When X is Straight Up, X Tilt = ~180 º.
When X is Straight Down, X Tilt = ~0 º.

Holding X Horizontal

When Y is Horizontal, Y Tilt = 90 º.
When Y is Straight Up, Y Tilt = ~180 º.
When Y is Straight Down, Y Tilt = ~0 º.

SINGLE AXIS GIMBALED MODE

In Single Axis Gimbaled Mode, the Z Rotation angle is defined as a rotation about the Z axis of the device. Typically, the inclinometer will be mounted using the VMP package for Single Axis Gimbaled Mode operation. For the Z Axis Rotation angle to remain in range, the Z Axis must be near horizontal. The Z axis should be kept to less than ± 45 º of deviation from horizontal.

.
When X is Horizontal, Y is Straight Up, Z Rotation = 0 / 360 º.
When Y is Horizontal, X is Straight Down, Z Rotation = 90 º.
When X is Horizontal, Y is Straight Down, Z Rotation = 180 º.
When Y is Horizontal, X is Straight Up, Z Rotation = 270 º.

IMPORTANT NOTES

- Regardless of the mode, the inclinometer measures angles with respect to gravity. It cannot measure rotation about the gravity vector. All rotations about gravity are *invisible* to the sensor and are considered equivalent.

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ORDERING GUIDE

OPTIONS	CODE	OPTION	NOTES
Power regulator option	-NR	No onboard regulator	Special order only
	-3.0R	3.0 V onboard regulator	Special order only
	-3.3R	3.3 V onboard regulator	Standard version (stock)
Pin package option	-HMP	Horizontal mount package	Fits into standard 0.100” grid circuit board
	-VMP	Vertical mount package	Available for SQ-SI family only
	-NP	No pins installed	Fits inside potting box enclosures (SQ-ENCL-1)
Performance option	-HP	High performance	Better if power consumption is not a primary concern
	-LP	Low power	Better if low power consumption is critical
	-ULP	Ultra low power	Pre-release version available now
Accuracy	-IND	High accuracy	Suitable for industrial applications needing precise measurement
	-LC	Low cost	Suitable for high volume, lower accuracy, cost sensitive applications
Damping option (used for HP and LP version only)	-S	500 mS settling time	Better noise rejection, slower response time – This model uses a 0.5 second moving average filter to provide digital damping. This reduces the impact that spurious accelerations and vibrations have on the angle reading. This model will reject noise better than the “F” model, but with the tradeoff of a slower response time.
	-F	100 mS settling time	Faster response time, poorer noise rejection – This model uses a 0.1 second moving average filter to provide digital damping. This model will respond more quickly to changes in angle than the “S” model, but with the tradeoff of poorer noise rejection.
Other option	-Custom	Customer-specific requirements	Please contact SignalQuest if you require an option not listed in this table. For example, various baud rates, setting times, update rates and voltage regulator options may be available on request.

EXAMPLE PART NUMBER

SQ-SI-360DA-3.3R-HMP-IND-HP-S

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ACCESSORIES

PART NUMBER	DESCRIPTION
SQ-USB2-TTL	▪ Self-powering USB cable used to directly connect device to a PC. ▪ Installs a "virtual COM port" on host PC (i.e. COM 3). ▪ Converts PC voltage levels to device voltage levels and supplies power. ▪ Allows multiple devices to be easily connected to a single computer. ▪ Compatible with SignalVIEW real time display and data logging software. ▪ DLL provided for custom application development in VC++, C#, VB, etc…
SQ-RS232-TTL	▪ Same as above cable, but external power is required for devices without –LP option.
SQ-ENCL-1	▪ Potting box enclosure. Fits models without pins installed (-NP option). Order one if using SQ-SI family or two if ordering SQ-SI2X family.

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LIMITATIONS AND WARNINGS

LIFE SAFETY

This product is not designed for use in life support and/or safety equipment where malfunction of the product can reasonably be expected to result in personal injury or death. Buyer uses this product in such applications at Buyer's own risk and agrees to defend, indemnify, and hold harmless SignalQuest, LLC from any and all damages, claims, suits, or expenses resulting from such misuse.

DYNAMIC ENVIRONMENTS

The device is designed to be used to measure angles in a quasi-static environment where external vibrations and accelerations are kept to a minimum. Digital and analog signal processing methods are employed to reduce the effects of transient acceleration and small vibrations on the angle reading; however, under dynamic conditions where external accelerations or vibrations are present, the sensor's performance may be degraded.

VARIATIONS IN EARTH'S GRAVITY

This device is designed to be used near the earth's surface only. Substantial changes in gravity will degrade the performance of the sensor. This device is not intended or qualified to be used in aviation.

TESTING

The performance of each system is verified through build-time testing. Each system is tested before and after factory calibration to ensure reliable performance.

SYSTEM INTEGRATION TESTING

Thorough testing should be carried out prior to product release to ensure system integration has not introduced unforeseen problems. The system integrator assumes the ultimate responsibility for the safety of the target application.

NOTICE

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FURTHER INFORMATION

For pricing, delivery, and ordering information, please contact SignalQuest at (603) 448-6266
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