X3Q — Dual-Axis Solid State Inclinometer

Description:

The **X3Q** is a dual-axis absolute inclinometer utilizing solid state MEMS technology to sense tilt angles over the entire 360° range. Each axis appears as a virtual incremental encoder and reports the incremental and absolute tilt angle via 3-channel quadrature outputs. Any resolution may be specified between 4 and 36000 positions per 360 degrees (1 to 9000 CPR). Positions are reported 560 times per second. Each sensor is factory calibrated to provide absolute angular accuracy of ±0.20 degrees at 25°C. The **X3Q** can be ordered with three different mounting orientations so that the absolute zero positions and axes are assigned as desired. A wide range of electronic damping values may be specified which average multiple samples over time to provide the most stable output and the desired amount of smoothing. The **X3Q** incorporates a number of patent pending breakthroughs to create a new type of inclinometer that is rugged, compact, solid state, fast, flexible and easy to use.

Features:

- Patent pending
- RoHS compliant
- Dual Absolute Quadrature™
- Full 360° range
- Dual axis
- 1 to 9000 CPR (full quadrature cycles per revolution)
- 4 to 36000 positions per revolution
- Selectable damping
- MOSFET outputs
- Rugged and miniature
- US Digital warrants its products against defects in materials and workmanship for two years. See complete warranty for details.

RoHS 2002/95/EC

Recommended Operating Conditions:

Parameter	Min.	Typ.	Max.	Units
Supply Voltage	3.85	5.0	5.5	Volts
Supply Current	-	30	50	mA
Voltage of J1 Open Drain Outputs	-0.3	5.0	20	Volts
Current of J1 Open Drain Outputs (continuous)	-	-	500	mA
Resistance of J1 Open Drain Outputs	-	-	0.35	Ohms
Source Current of J1 Open Drain Outputs	-	-	1.5	mA
Operating Temperature	-20	25	70	℃

- J1 open drain outputs have onboard 3.3K pull-up resistors to the supply voltage.

Absolute Maximum Ratings:

Parameter	Min.	Max.	Units
Supply Voltage	-0.3	7.0	Volts
Storage Temperature	-40	125	℃
Acceleration (any axis)	-	3000	*g* for 0.5 ms
	-	10000	*g* for 0.1 ms

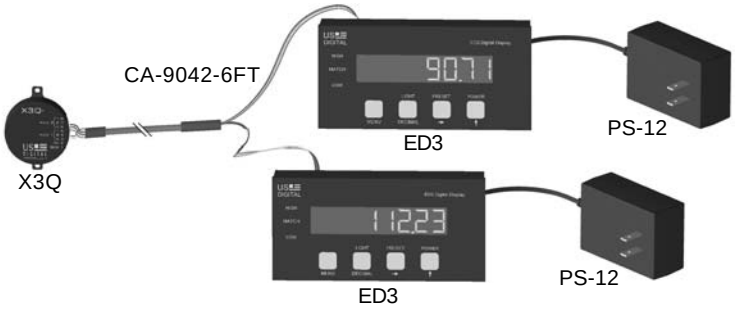
Mechanical Specifications:

Case Material	Black anodized 6061-T6 aluminum
Weight	0.72 oz.

Setup Example:

Single-axis:

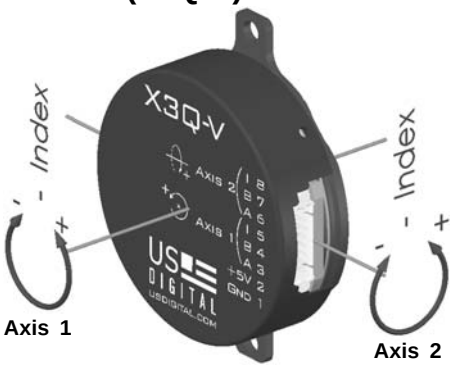
Dual-axis:



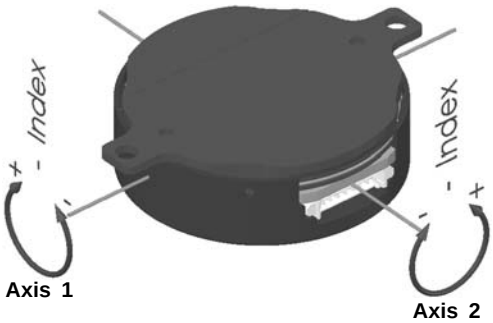
Mounting Orientation:

Top (X3Q-T):

Vertical (X3Q-V):



Bottom (X3Q-B):



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Accuracy / Function Specifications:

➢ Damping @ 500ms unless otherwise specified.

Parameter	Min.	Typ.	Max.	Units	Note
Angular Error @ 25°C (any axis)	-	±0.03	±0.20	Degrees	On-axis within ±10 degrees
Angular Error @ -20 to 70°C (any axis)	-	-	±TBD	Degrees	On-axis within ±10 degrees
Position Update Rate	554	560	566	Hz	
Quadrature Update Rate	-	-	5660	Full cycles per sec.	Emulated quadrature output bursts up to 10 full cycles 560 times per second
Quadrature Cycle Width	40	45	-	Microseconds	
Quadrature State Width	10	11.3	-	Microseconds	
Cycles Per Revolution	1	-	9000	CPR	
Positions Per Revolution	4	-	36000	PPR	
Electronic Damping Period*	2	125	5000	Milliseconds	Specified when ordering
Power-up Index Assertion Duration**	-	500	-	Milliseconds	Indexes are true for first 0.5 sec. of start-up

* All internal readings are averaged over the specified period, updated every 1.786mSec. The oldest samples are flushed first to provide the desired degree of smoothing.

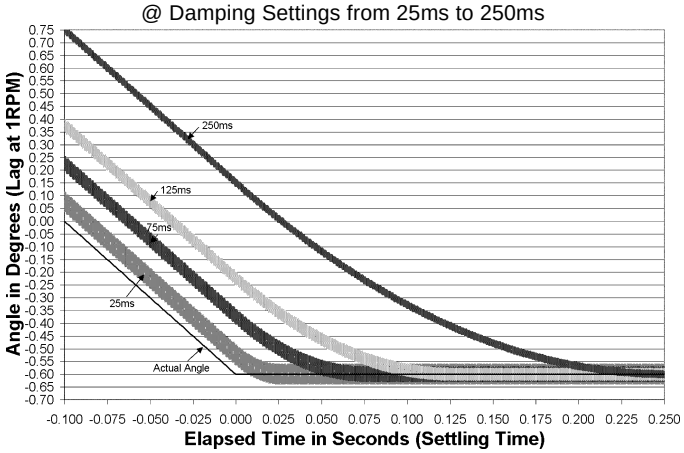
** Intentional delay intended to reset the user's position counter after power up. The **X3Q** will then send a quadrature stream to update the user counter to the absolute position.

Noise and Damping:

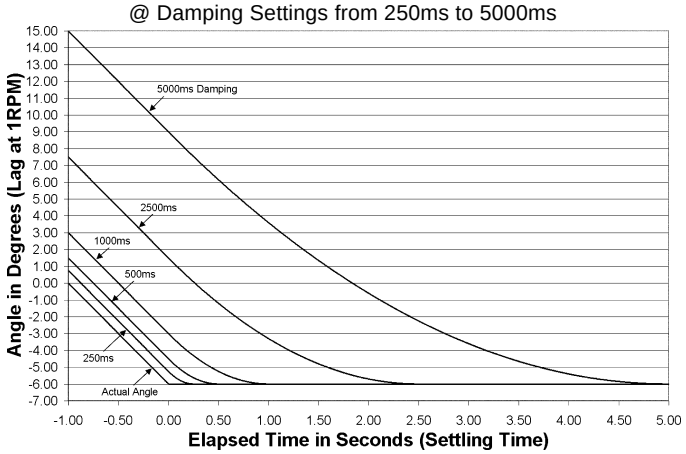
Graphs A, B, and C show the typical positional noise as a function of damping. The thickness of each line in graph A indicates the amount of positional noise for each damping value. Electronic damping is achieved by averaging multiple samples together to improve accuracy and reduce noise. The longer the damping, the more positions are averaged together (more smoothing), the slower the response time, and the more stable the reported position. The number of samples per reported position can be calculated by the damping time divided by 1.786mSec.

Example: When the damping is set to 125mSec, each reported position will be the average of the previous 70 samples, 250mSec will be the average of the previous 140 samples, etcetera. Each average position is updated and reported every 1.786mSec regardless of the damping value. To most closely match the damping of the **X3Q** to US Digital's optical encoder type inclinometers such as the **T5**, **T6**, and **A2T**, specify 125mSec for standard damping, and 250mSec for double damping.

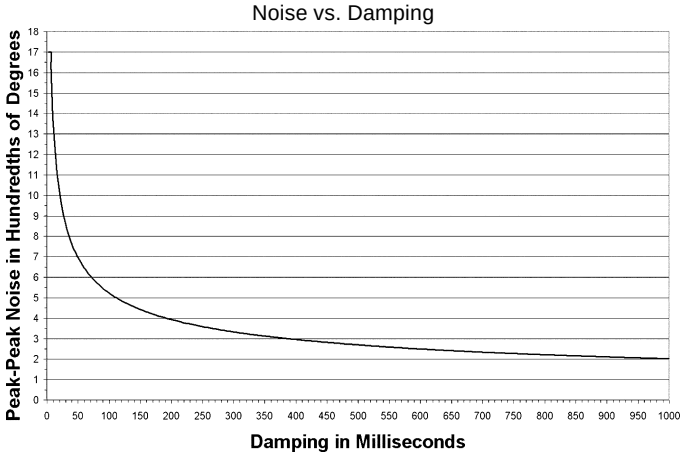
Graph A
Actual Position vs. Reported Position
@ Damping Settings from 25ms to 250ms



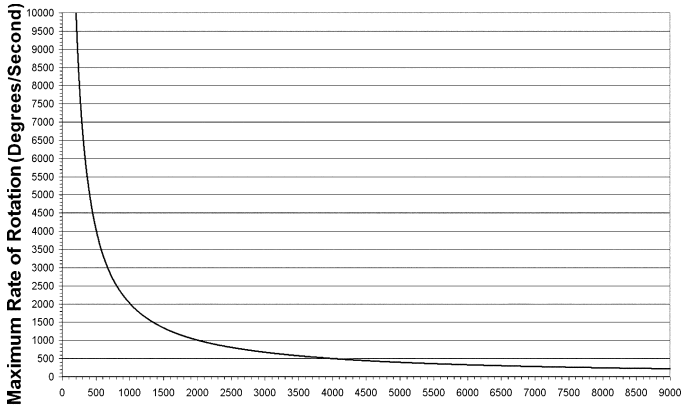
Graph B
Actual Position vs. Reported Position
@ Damping Settings from 250ms to 5000ms



Graph C
Noise vs. Damping



Graph D
Maximum Rate of Rotation vs. Resolution



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Quadrature Outputs:

Connecting to the **X3Q** is as easy as connecting to an incremental encoder with quadrature outputs. As with any incremental encoder, the user can employ standard quadrature decoding methods to obtain the position. One quadrature state change will be sent for each position change.

Example: If the resolution is set to 9000 cycles per revolution (CPR), then 36000 quadrature state changes will be sent per revolution.

The internal microcontroller calculates the absolute position for both axes each 1.786mSec and sends a quadrature burst to update the user position counter. If the position has changed, then the appropriate number of quadrature state changes will be sent up to a maximum of 40 (10 full cycles) per burst. Each transition is separated by 11.25 microseconds. The maximum rate of position change is limited by the time to send the quadrature bursts. A maximum of 5600 full quadrature cycles can be sent per second (10 cycles per 1.786 mSec). Graph D on page 2 of this data sheet shows the maximum reportable rate of rotation in degrees per second for each resolution. The **X3Q** will continue to report accurate position and no problems will occur when the rate of rotation exceeds the maximum reporting limits. The internal position register will continue to track the real-time position; but, the quadrature stream will simply send the current position at a rate within the designed limits.

The maximum reportable rate of rotation in degrees per second is calculated as follows:
MaxDegreesPerSec = 2,016,000 / CPR (where CPR is the resolution in full cycles per rev.)
Examples: 9000 CPR = 224 Deg/Sec, 900 CPR = 2240 Deg/Sec

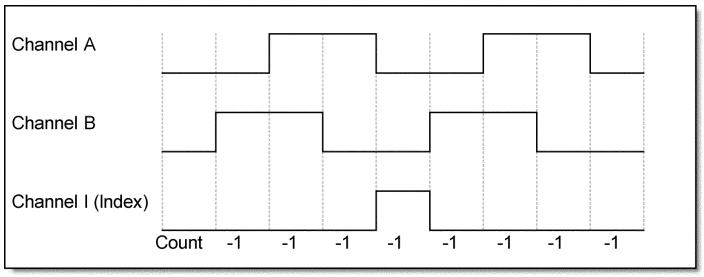
The index will be asserted high and stay asserted for as long as the axis is at the zero position. The index is internally ANDed with the low state of the A and B channels. If the position sweeps past zero, then the index will be asserted at zero position and then deasserted as that axis leaves the zero position. This index signal can be used to reset the user counter that stores the position. The user position counter can be reset by the index output every time the axis is at zero position and after power up as described below.

Conveying Absolute Position:

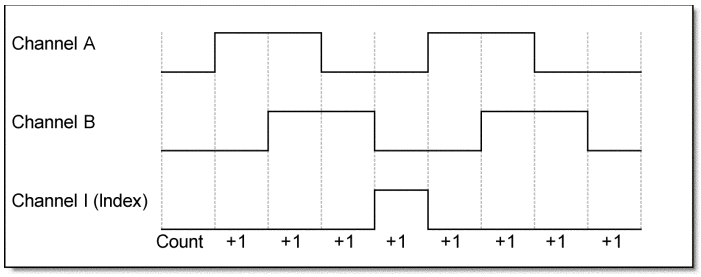
In addition to providing incremental information, the **X3Q** sends absolute position as follows: immediately after powering up, the internal microcontroller sets the outputs to zero position by setting the A and B quadrature outputs low and the index output high for 500mSec. It will then read the absolute position and send bursts of quadrature sequences to increment or decrement the user counter to the absolute position. The most efficient direction will be chosen, whichever direction is faster. Further real-time position changes will continue to be reported as quadrature outputs. Worst case time to send the maximum sequence is determined by the resolution. If the resolution is set to the maximum of 9000 CPR (36000 positions per revolution), then up to 4500 quadrature cycles will be sent. Since up to 10 cycles can be sent per 1.786mSec, this will take 804mSec.

Phase Relationship:

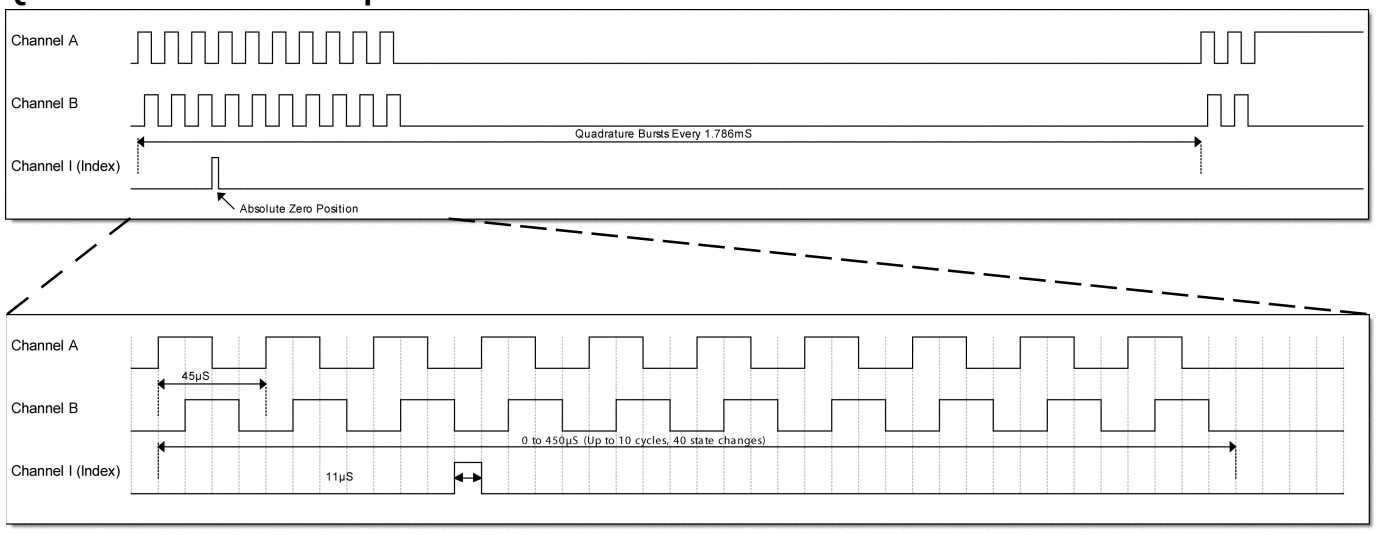
Negative Rotation (B leads A):



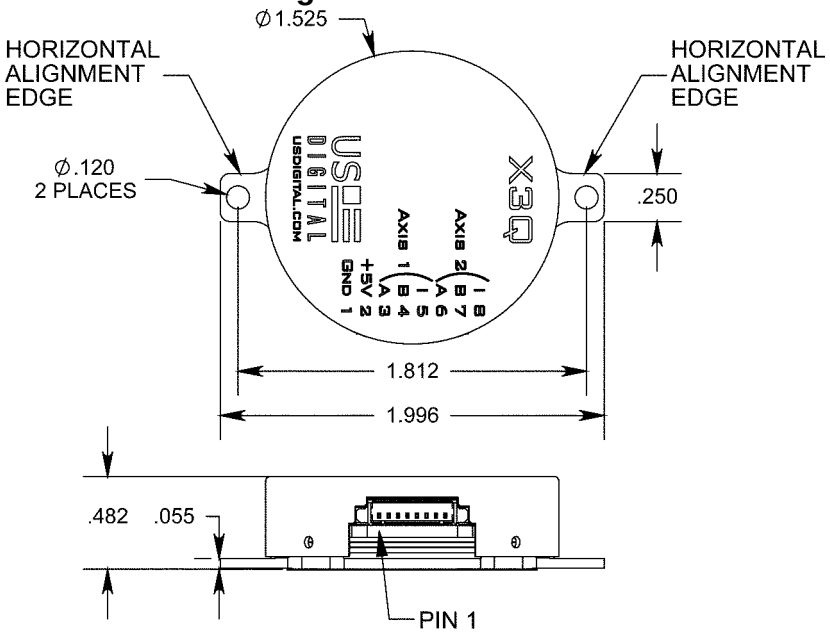
Positive Rotation (A Leads B):



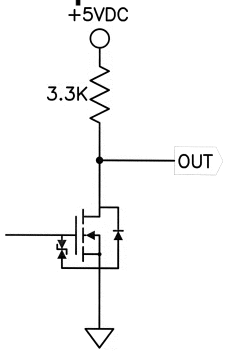
Quadrature Burst Examples:



Mechanical Drawing:



J1 Open Drain Output Schematic:



J1 Pin-out (8-pin):

Pin	Description
1	Ground
2	+5VDC Power Supply Input
3	Axis 1 - A Channel Quadrature Output
4	Axis 1 - B Channel Quadrature Output
5	Axis 1 - Index Output
6	Axis 2 - A Channel Quadrature Output
7	Axis 2 - B Channel Quadrature Output
8	Axis 2 - Index Output

Compatible Cables / Connectors:

Both Axes	Description
CON-MIC8	8-pin micro connector
CA-9040-1FT	8-pin micro connector with 8 discrete wires
CA-9041-6FT	8-pin micro connector on one end of a round 8 conductor cable
CA-9042-6FT	8-pin micro connector connected to two 5-pin finger-latching connectors via a round 8 conductor cable
Axis 1 Only	**Description**
CA-9038-1FT	8-pin micro connector with 5 discrete wires
CA-8882-6FT	8-pin micro connector connected to a 5-pin finger-latching connector via a round 6 conductor cable
Axis 2 Only	**Description**
CA-9039-1FT	8-pin micro connector with 5 discrete wires
CA-8941-6FT	8-pin micro connector connected to a 5-pin finger-latching connector via a round 6 conductor cable

Attention:
- Specify cable length when ordering.
- Custom cable lengths are available. See the **Micro Cables / Connectors** data sheet for more information.

Ordering Information:

X3Q Pricing:
$120.00 / 1
$102.00 / 10
$87.60 / 50
$81.60 / 100

Cost Modifier:
- Add $6.00 for **T**-option.

Accessories:

Mounting Screw:	
Part #:	**SCREW-290**
Description:	Pan-head 4-40 x 1/4"
Price:	$0.26 ea.

- Qty. 2 are required for mounting.

Part #:

X3Q - [ ] — [ ] — [ ] — [ ]

Mounting Orientation:	Resolution:	Damping:	Option:
B = Bottom **T** = Top **V** = Vertical	Specify any number from **1** to **9000** CPR (cycles per rev.).	Specify any number from **2** to **5000** milliseconds.	**T** = Adds 5mm thick transfer adhesive to mounting surface of inclinometer.

Example Part #s:
- X3Q-T-9000-500 (Top mounted, Highest resolution, 1/2 second settling time provides great stability.)
- X3Q-B-360-25 (Bottom mounted, low resolution, very fast response time at the expense of positional noise.)
- X3Q-V-2500-125 (Most similar to T6S-2500-I.)

Each **X3Q** is configured at the factory to the specified parameters before shipping from stock with little to no lead-time.

Technical Data, Rev. 07.09.07 July 2007

Dimensions shown are in inches.

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