TILT Sensors:
CXTILT02E Digital Inclinometer

- **Roll & Pitch Output**
- **0.03° Resolution**
  0.1° Accuracy with EC version
- **RS-232 Interface**
- **Programmable Resolution and Settling Time**

CXTILT02E

The CXTILT02E inclinometer offers outstanding resolution, response speed, and accuracy. The CXTILT02E measures the tilt angle of an object with respect to the horizontal in a static environment. To measure tilt, also called roll and pitch, the sensor makes use of two micro-machined accelerometers, one oriented along the X-axis and one along the Y-axis.

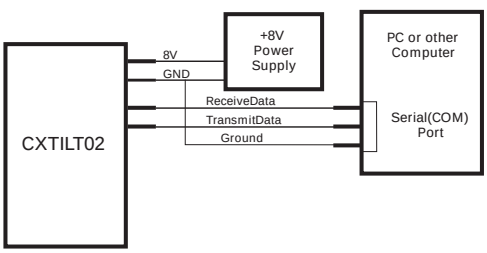

Figure 1. Typical CXTILT02E application

The CXTILT02E is a "smart" sensor with an on-board micro-controller, A/D converter, and temperature sensor. The combination of sensing elements and digital electronics yields a system requiring no user calibration. The sensor's resolution and settling time are programmable, allowing the CXTILT02E to be customized for various applications.

CXTILT02EC

Minimum Temperature Drift

In more demanding measurement applications, where high accuracy must be maintained over a wide temperature range of -40 to 85°C, the CXTILT02EC provides superior performance. The CXTILT02EC employs Crossbow's Softsensor™ Calibration and an on-board temperature sensor to internally compensate for temperature induced drift.

Linearized

The CXTILT02EC is also characterized by extremely high linearity and designed specifically for use in construction environments. This extremely high linearity is achieved through Crossbow's proprietary Softsensor™ linearization calibration.

ORDERING INFORMATION

Part#	Description	Angular Range	Temperature Range	Accuracy (±20°)	Accuracy (±45°)
CXTILT02E	Enhanced	±75°	0 to 70°C	±0.4°	±1.5°
CXTILT02EC	Enhanced & Compensated	±75°	-40 to 85°C	±0.1°	±0.1°

Crossbow
408/965-3300 • FAX 408/324-4840 • www.xbow.com

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Specifications

Parameter	CXTILT02E	CXTILT02EC	Units/Remarks
Angular Range	± 75°	± 75°	From Horizontal
Angular Resolution	See Table 1	See Table 1	
Settling Time	See Table 1	See Table 1	
Null Angular Offset	0.5°	0.5°	Provided w/ sensor
Angular Drift w/Temp	1.5°	0.7°	Over Temp Range
NonLinearity (±45°)	< 3%	0.3%	Measured at 25° C
Transverse Sensitivity	1%	1%	Typical
RS-232 Interface	9600	9600	Baud
Temperature Range	0 to 70°C	-40 to +85°C	
Supply Voltage	8 - 30	8 - 30	Volts DC
Supply Current	60	60	mA
Weight	90	90	grams
Cable Length	2.5	2.5	feet

Notes

All frequency break points are -3 dB, single pole, -6 dB per octave roll-off. Nonlinearity is the deviation from a best fit straight line at full scale. Transverse sensitivity is error measured in the primary axis output created by forces induced in the orthogonal axis. Zero g drift is specified as the typical change in 0 g level from its initial value at +25 °C to its worst case value at T_{min} or T_{max}. Transverse sensitivity error is primarity due to the effects of misalignment (i.e., much of it can be tuned out by adjusting the package orientation).

Specifications subject to change without notice

Resolution-Level	Lowpass Frequency (0 - Hz)	Resolution (±10°) (deg. rms)	Resolution (±45°) (deg. rms)	Time Constant (s)
0	100	0.286	0.343	0.010
1	50	0.202	0.243	0.020
2	25	0.143	0.172	0.040
3	12.5	0.101	0.121	0.080
4	6.7	0.074	0.089	0.149
5	3.1	0.050	0.060	0.323
6	1.5	0.035	0.042	0.667
7	0.7	0.024	0.029	1.429
8	0.35	0.017	0.020	2.857
9	0.17	0.012	0.014	5.882

Table 1. Resolution vs. resolution-level configuration

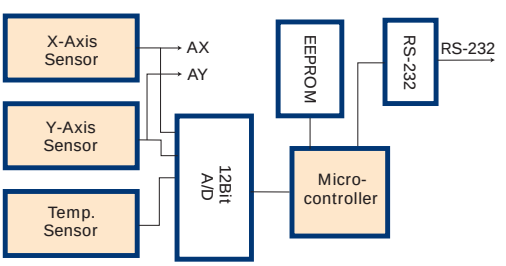

Figure 2. Block Diagram of CXTILT02E

CXTILTO2E PACKAGE

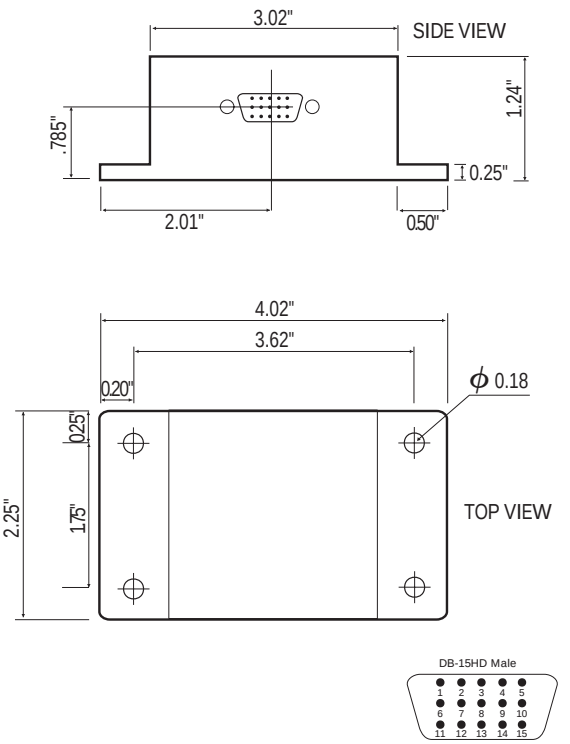

Figure 3. CXTILT02E Aluminum Package

Pin Function Description

Pin No.	Mneumonic	Function
4	TD	Transmit Data
3	RD	Receive Data
1	GND	GND
11	VCC	VCC (8-30 V DC)

Byte	Description
0	Header (always 255)
1	Pitch MSB (0-255)
2	Pitch LSB (0-255)
3	Roll MSB (0-255)
4	Roll LSB (0-255)
5	Checksum (8 bit sum of bytes 1-4)

Note: Angles are represented as two's complement 16 bit numbers. 90° corresponds to 32,767. -90° corresponds to -32,768. The 16 bit signed angle can be obtained by this simple 'C' expression: (int) Roll = (int) 256 * Roll

Table 2. Contents of angle packet

Serial RS-232 Interface

The serial RS-232 interface consists of three lines RD (Receive Data), TD (Transmit Data), and GND (Ground). These three lines are used to asynchronously transmit serial data between the host (PC or other computer) and the CXTILT02E. The signal levels are ± 9V so that the interface is directly compatible with the RS-232 standard. Communications should be configured to 9600 baud, 8 data bits, 1 stop bit, no start bits, no parity, and no flow control.

The CXTILT is configured and polled by sending commands via the serial link. Commands consist of single and multiple byte instructions sent from the host to the CXTILT02E. The CXTILT02E responds by sending single byte and multiple byte packets back to the host. When sending successive commands (e.g., polling the CXTILT02E for angular information), it is recommended that the controlling software wait for a complete response from the CXTILT02E before issuing new commands. Table 2 lists the contents of each packet, and Table 3 shows the commands and responses of the unit.

Angular Resolution

The angular noise limits the resolution or granularity with which small angular changes can be detected. The angular noise is dependent on the measurement bandwidth. The measurement bandwidth is the set of frequencies to which the tilt sensor responds. Decreasing the measurement bandwidth increases the resolution. At the same time, however, decreases in measurement bandwidth also increase the settling time of the sensor. If the measurement bandwidth is set too low, the tilt sensor may take an unacceptably long time to settle to its final value. The CXTILT02E is unique in its ability to provide high-resolution and short settling time. The CXTILT02E is factory configured to the default resolution and settling time listed in the Specifications section, as well as shown in Table 1. The CXTILT02E is also unique in its ability to be user configured for different measurement bandwidths (and hence resolution and settling time). The sensor is configured via the RS-232 interface.

Setting the Resolution Level

The measurement bandwidth of the tilt sensor is configured via the RS-232 interface. The serial command "N" followed by a "resolution level" (0-9,binary) is sent to the CXTILT02E to configure the measurement bandwidth. The "resolution-level" is simply an unsigned number between 0 and 9 that sets the measurement bandwidth internal to the CXTILT02E. The CXTILT02E changes the digital filtering internal to the sensor in response to this command. Table 1 shows the resolution and settling time constant for various values of resolution level. Note that the CXTILT02E returns to the default resolution level (5) upon power-up and must be re-configured.

Calibration

The CXTILT02E is factory calibrated and, in most circumstances, requires no on-site calibration by the user. The sensor's scale factor and offset are calibrated at the factory, and this information is stored in the system EEPROM. The limitations in absolute accuracy are errors in alignment induced during mounting, accuracy limitations in the factory calibration jig, and long term drifts in the electronic components. When better than 0.6° of "absolute" accuracy is required, the sensor should be leveled on-site. Also if the part has been placed in storage for an extended time period or exposed to temperature extremes, calibration for absolute level is recommended. The on-site procedure is to simply place the CXTILT02E on a known level surface and read the angular value it is reporting. The sensor should in theory read 0.00, but the sensor might report a slight offset. Record this offset and subtract it from all of the readings reported by the CXTILT02E. This procedure delivers the best absolute accuracy performance.

Development Software

Crossbow development software X-VIEW is shipped with the CXTILT02E for use with PCs running MS Windows95. The software demonstrates the functionality of the CXTILT02E. It is a convenient way to get started with system development, evaluate the performance of the CXTILT02E sensor, or use the CXTILT02E in straightforward leveling applications. The software is a run-time application based on National Instrument's LabView software and requires a 486 and Windows95. The software is shipped on a 3.5" floppy disk. For software installation, simply copy the INSTALL file on the disk to your hard drive and double click. Figure 5 shows a screen shot of the display.

Customizations

Custom packages and serial output features of the CXTILT02E are available for OEM customers. Please contact the factory for more information.

Command (ASCII)	Command (Integer)	Function Description / Response
R	82	Reset. Resets the CXTILT firmware. An ASCII 'H' (72) is sent in response.
G	71	Get Angle Packet. The CXTILT returns its current angular position. The data is in a 6 byte packet defined in the adjacent table.
N <0-9>	78 <0-9>	Set Resolution Level. A 2 byte command sequence that configures the CXTILT's internal digital filter. The second byte, an integer of value 0-9, sets the level of filtering.
C	67	Continuous Mode: Transfers packet continuously at maximum rate.
S	83	Stop Continuous Mode.

Table 3. CXTILT02E Serial Commands

Figure 5. X-VIEW development software