CTi-Sensors

TILT – 57A Dynamic Dual-Axis Inclinometer

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5/3/2019

CTi Sensors Technical Document

This is our product specific technical data sheet. The following information is available to assist CTi Sensors customers in product development.

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Contents

1 Introduction

A **Dynamic Inclinometer** is an instrument for measuring angles of slope (or tilt), elevation or depression of an object with respect to gravity while it is not in stationary condition. As motion, vibration and shocks (external acceleration) will introduce errors in the tilt measurements, dynamic inclinometers (or tilt meters) often benefit from an on-board gyroscope and fusion algorithm which combines gyroscope and accelerometer data to rectify errors introduced by external accelerations.

The **TILT-57A** Dynamic Inclinometer series are high performance, high resolution dual axis dynamic inclinometers that use the latest miniature MEMS sensor technology.

1.1 Features

- High-accuracy, dual-axis dynamic tilt sensor
- Measuring range: Pitch: ±180°, Roll: ±90°
- Static accuracy: ≤ 0.03° (Typical)
- High resolution: ≤ 0.003°
- Ultra-low noise: 0.001°/√Hz
- Very low temperature offset drift: ±0.002°/°C (Typical)
- Highest output data rate: up to 2 kHz
- Three-axis accelerometer and three-axis gyroscope data
- Simple ASCII interface language
- IP 67 compliant connector, cable and housing
- Robust aluminum housing
- Low power consumption: 400 mW (80 mA @ 5 V)

1.2 Applications

- Motion and dynamics measurements
- Dynamic platform alignment and stabilization
- Vehicle control: marine, robotics, automotive
- Inertial navigation and GPS compensation
- Agricultural and industrial vehicle tilt monitoring

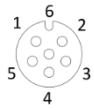
2 Specifications

2.1 Angles	
Range	Pitch: ±180°, Roll: ±90°
Static Accuracy	≤ 0.03° RMS (Typical)
Dynamic Accuracy	< 0.5° RMS (Typical)
Angular resolution	≤ 0.003°
Noise density	0.001°/√Hz
Zero offset error (pitch and roll)	< ±0.02° (@20°C)
Offset change versus temperature	±0.002°/°C (Typical)
2.2 Accelerometer	
Range	±2 g/±4 g/±8 g selectable
Nonlinearity	±0.05% FS
Zero offset error	<±0.5 mg (@20°C)
Bias change versus temperature	±0.03mg/°C (Typical)
Noise density	0.025 mg/√Hz (@200Hz)
Resonant frequency	2.4 kHz
2.3 Gyroscope	
Range	±125/250/500/1000/2000°/s selectable
Nonlinearity	<0.1% FS
Initial bias error (@±500°/s range)	X and Y: <±0.05 °/s/°C Z: <±0.2 °/s/°C
Bias change versus temperature (Typical)	X and Y: <±0.01 °/s/°C (In-run compensated) Z: <±0.025 °/s/°C
Noise density	0.007 dps/√Hz (@10Hz)
2.4 System	
Power source	4.1-38 VDC
Power consumption	400 mW (80 mA @ 5 V)
Data format	ASCII
Output data rate	1 Hz to 2 kHz selectable
GUI software	WinCTi-Tilt-57®
Serial interface options	RS232, RS422, RS485, USB, UART, RS485 w/ multi-drop networking
Temperature sensor resolution	0.2°C
2.5 Mechanics	
Protection	IP 67 (housing, connector and cable)
Dimension	1.64” x 2.14” x 0.85”
Material (cable is optional as a third party product)	Enclosure: anodized aluminum Connector: brass / nickel Cable molded head: TPU Cable carrier: TPU or nylon Conductor insulation: PVC
Temperature range	-40°C to +85°C (-40°F to +185°F)
Connection†	Cable gland connector M8, 6-contact (female)
2.6 Connector and Cable	
MSKS 6F/CS12187	Male cable M8, 6-pin (straight or right angle)

† Cable is a third-party product with temperature tolerance from -40°C to +105°C (-40°F to +221°F).

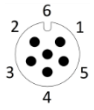
3 Terminal Assignment

Connector	RS232/UART/USB‡	RS422	RS485	Wire Color
Pin 1	+Vin	+Vin	+Vin	Brown
Pin 2	GND	GND	GND	White
Pin 3	TX	TX+	D+	Blue
Pin 4	–	TX-	D-	Black
Pin 5	RX	RX+	D+	Gray
Pin 6	–	RX-	D-	Pink



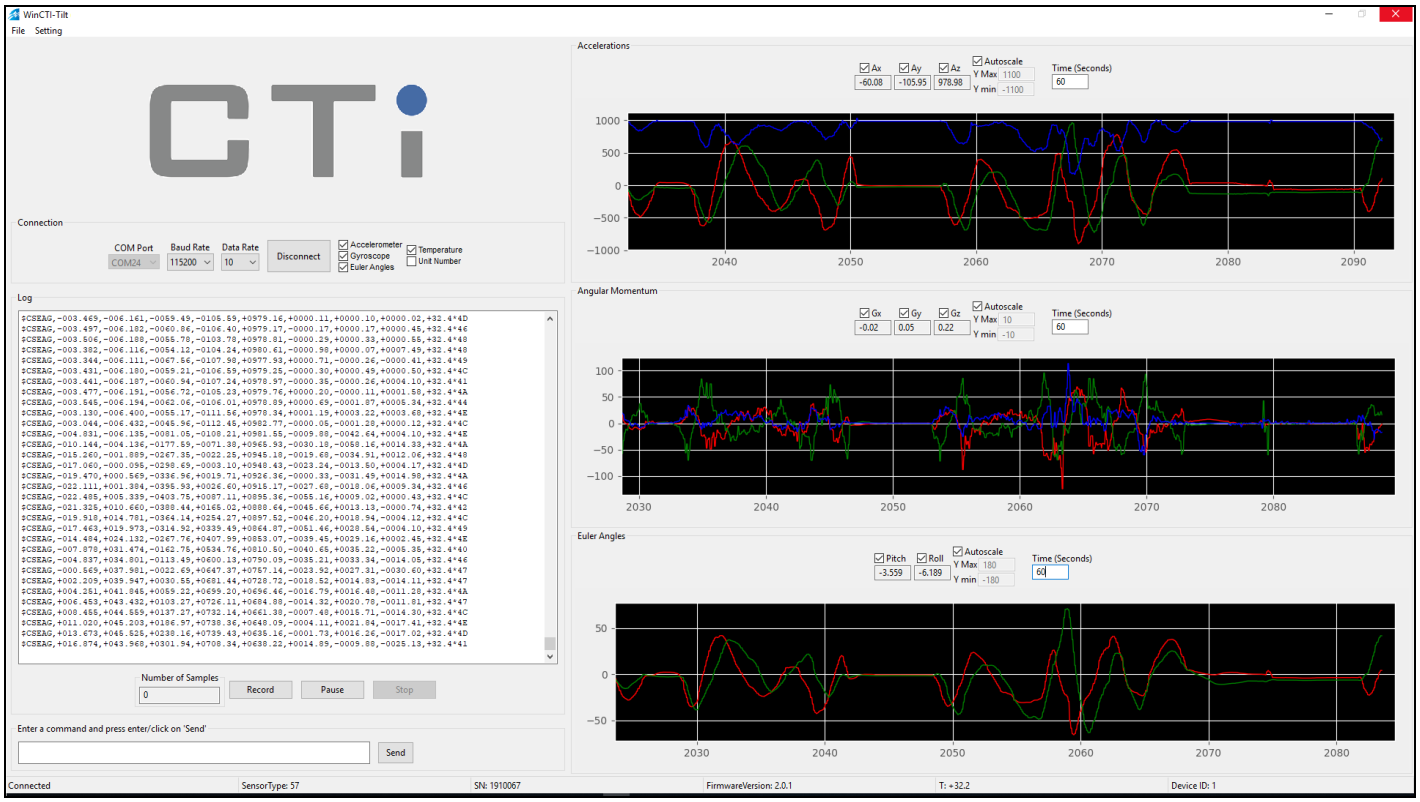
Device:
M 8 – 6-contact (female)

Cable:
M 8 – 6-pin (male)



4 WinCTi-Tilt Software

WinCTi-Tilt is a graphical user interface (GUI) software provided by CTi Sensor Inc. for visualization aid, device configuration, and data logging. WinCTi-Tilt is designed to be intuitive to users. The package can be downloaded from the CTi Sensors website.



‡ USB is a third-party produce with temperature tolerance from -40°C to +105°C (-40°F to +221°F).
‡ USB uses UART interface and a UART to USB cable.

5 Serial Interface and Data Format

The TILT-57A uses the following ASCII format, very similar to the widely used NMEA 0183 protocol, for data output:

- Inclinometer message: $CSEAG,U,$\alpha_X$,$\alpha_Y$,$A_X$,$A_Y$,$A_Z$,$G_X$,$G_Y$,$G_Z$,T*CC<CR><LF>

Which:

A_X,A_Y,A_Z: X, Y and Z accelerations in milli g (three-axis accelerometer data)
G_X, G_Y, G_Z: X, Y and Z angular velocities in deg/s (three-axis gyroscope data)
α_X, α_Y: Roll & Pitch angles in degrees
T: Internal temperature in degrees Celsius
U: Device unit number
CC: Checksum (Two ASCII characters)
<CR> <LF>: Carriage return, and line feed characters

Example:
$CSEAG,1,+006.756,-003.813,+0116.53,-0065.42,+0981.42, ,+000.21,-000.16,-000.27,+29.7*68

Within the inclinometer message, the temperature, accelerometer, gyroscope, or angle portion of the message may be turned on or off. See Section 8 for specific commands.

The inclinometer message may run in full at an output data rate of up to 500 Hz. With only 2 of the 3 data message portions turned on (accelerometer, gyroscope or angles), the inclinometer message may be run at an output data rate of up to 1 kHz. With only 1 of the 3 message portions turned on, the inclinometer message may be run at an output data rate of up to 2 kHz. When running at 1kHz and 2kHz, it is recommended that the other message portions (temperature and unit number) be turned off if they are not needed.

Because the updated data rate is always saved into the device's flash memory but the updated baud rate is not, it is possible to create a scenario where the data rate is too high for the baud rate to support. This will not damage the sensor, but it may print gibberish to the screen. To prevent this problem, if selected data rate is greater than 100 Hz, it is recommended to save the baud rate to the flash memory, or change the data rate to lower number before disconnecting the sensor. The baud rate can be saved to the flash memory with the command "[nBFW<cr>" (without the quotes). If one encounters this problem, it can easily be remedied by setting a lower data rate, i.e. "[1D10<cr>" (so long as the baud rate matches that of the sensor, commands will go through).

6 8-bit Checksum

The checksum is calculated by XORing all characters between $ and * (not including the $ and the * characters) based on the NMEA standard. It results in two hexadecimal characters, which are sent in ASCII format.

7 Header

The header of the inclinometer message will change depending on its contents. Portions of the inclinometer message can be turned on and off with commands seen in the Configuration Commands section below.

Header	Angles	Accelerometer	Gyroscope
$CSEAG	On	On	On
$CSNAG	Off	On	On
$CSENG	On	Off	On
$CSEAN	On	On	Off
$CSNNG	Off	Off	On
$CSNAN	Off	On	Off
$CSENN	On	Off	Off
$CSNNN	Off	Off	Off

8 Configuration Commands

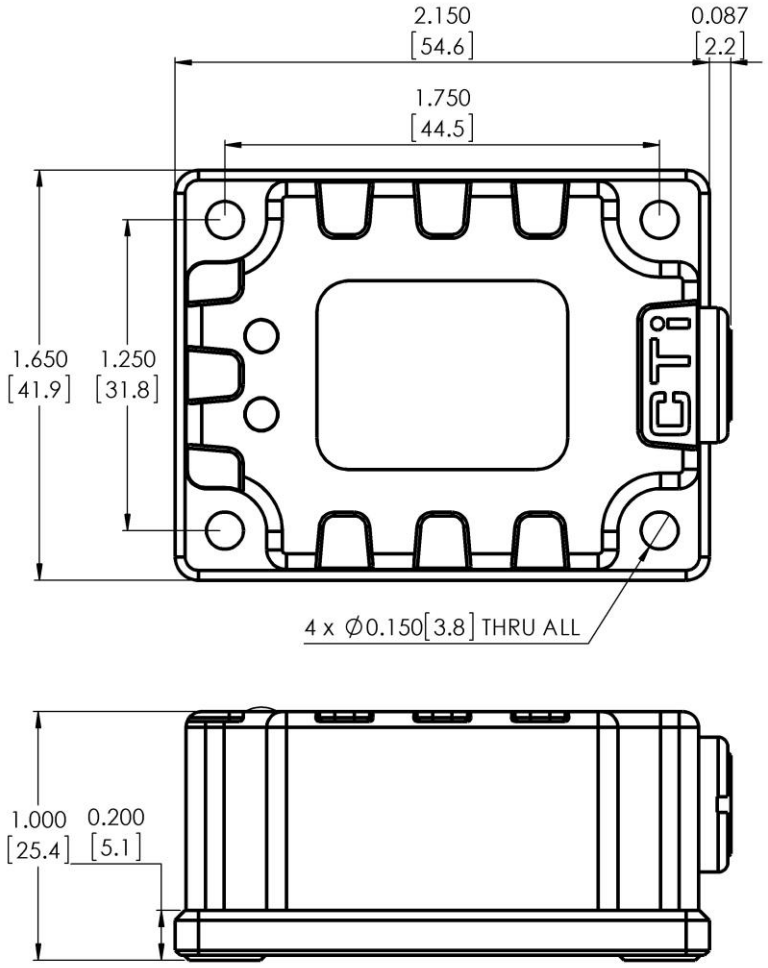
The TILT-57A uses a simple command format which allows the user to change the device configuration and request specific information or data. All commands start with a '[' character, and end with a carriage return character. All responses end with a carriage return and newline character. The table below shows the list of the interface commands for the TILT-57A series.
In the table below, lowercase 'n' represents the unit number, which is set to 1 by default, and can be set by user to any number from 1 to 9. The lowercase letters 'm', 'x', and 'y' represent variable inputs that can be used to set the properties of the device. The lowercase letter 'd' represents variable outputs. In the commands, uppercase letters and other characters do not change.

Command	Comments	Response	Comments
[n<cr>	Ping unit number n	*>!n*	Acknowledge ping
[N?<cr>	Request unit number	*>Unit Number: n*	Returns unit number, default: n=1
[n#m<cr>	Change unit number n to (non-zero) unit number m, 1≤ m ≤ 9	*>New Unit Number: n*	n=old unit number, m=new unit number, default: n=1
[n#FW<cr>	Save unit number into flash memory	*>Current Unit Number, n, was written into flash memory as the default Unit Number for this device!*	Unit number will be changed permanently, and current unit number will be saved into the flash memory as the default unit number.
[nV<cr>	Firmware Version	*>Firmware Version: d.d*	Returns firmware version
[nS<cr>	Serial Number	*>Device n Serial Number: ddddddd*	Returns 7-digit serial number

[nBxxx<cr>	Baud rate setting: xxx= 2:2400, 4:4800, 9:9600, 19:19200, 38:38400, 57:57600, 115:115200, 230:230400, 460:460800, 921:921600 (bps)	*>Change to new Baud Rate: dddddd*	Selected baud rate should support current data rate. Otherwise, baud rate will not be changed.
[nBFW<cr>	Save baud rate into flash memory	*>Current Baud Rate, dddddd, was written into flash memory as the default Baud Rate!*	Baud rate will be changed permanently, and current baud rate will be saved into the flash memory.
[nDxx<cr>	Data rate setting: xx= 1, 2, 5, 10, 20, 25, 40, 50,100, 200, 500, 1000, and 2000 Hz	*>New Output Data Rate: dddd*	Default data rate is 2 Hz. New data rate will be saved into the flash memory.
[nARx<cr>	Selecting accelerometer measurement range: x=2, 4, 8	*> New Accelerometer Range: +/-d g*	New accelerometer range will be saved into the flash memory (Default: ±4 g).
[nGRx<cr>	Selecting gyroscope measurement range: x= 0:2000, 1:1000, 2:500, 3:250 °/s	*>New Gyroscope Range: ±dddd°/s*	New gyroscope range will be saved into the flash memory (Default: ±500°/s)
[nZA<cr>	Zero g offset correction for X and Y axes	*>Accelerometer Zero Offset Adjusted: X Offset: ddd, Y Offset: ddd*	Current values of A_x and A_y will be saved into the flash memory as the zero g offset.
[nMIy<cr>	Output message ON/OFF y = S: single message y = C: Continuous message y = X: Message off	*>Send one Message* *Or* *>Send continuous Message* *Or* *>Message OFF*	Example for inclinometer data: *[1MIS*: Sends out one data message *[1MIC*: Continuously sends out data message *[1MIX*: Stops sending out data message
[nALPFx<cr>	Accelerometer low pass filter setting: x = 0:1, 1:2, 2,:4, 3:8, 4:16, 5:31, 6:62, 7:125, 8:250, 9:500, 10:1000 Hz	*>Accelerometer low pass filter bandwidth: ddd Hz*	Default filter is 31 Hz. New low pass filter will be saved into flash memory.
[nALPF?<cr>	Request accelerometer low pass filter setting.	*>Accelerometer low pass filter bandwidth: ddd Hz*	Default filter is 31 Hz.
[nGLPFx<cr>	Gyroscope low pass filter setting: x = 0:11, 1:21, 2,:40, 3:75, 4:137, 5:255, 6:524, 7:890, Hz	*>Gyroscope low pass filter bandwidth: ddd Hz*	Default filter is 40 Hz. New low pass filter will be saved into flash memory.

[nGLPF?<cr>	Request gyroscope low pass filter setting.	*>Gyroscope low pass filter bandwidth: ddd Hz*	Default filter is 40 Hz.
[nANFx<cr>	Accelerometer message portion ON/OFF x = 0: Off x = 1: On	*>Accelerometer portion of data turned ON/OFF in message.*	Only 1 of 3 data messages can be turned on for sensor to run at 2kHz. Only 2 of 3 messages can be turned on for the sensor to run at 1kHz.
[nGNFx<cr>	Gyroscope message portion ON/OFF x = 0: Off x = 1: On	*>Gyroscope portion of data turned ON/OFF in message.*	Only 1 of 3 data messages can be turned on for sensor to run at 2kHz. Only 2 of 3 messages can be turned on for the sensor to run at 1kHz.
[nENFx<cr>	Roll/Pitch message portion ON/OFF x = 0: Off x = 1: On	*>Euler angles portion of data turned ON/OFF in message.*	Only 1 of 3 data messages can be turned on for sensor to run at 2kHz. Only 2 of 3 messages can be turned on for the sensor to run at 1kHz.
[nTNFx<cr>	Temperature message portion ON/OFF x = 0: Off x = 1: On	*>Temperature portion of data turned ON/OFF in message.*	For optimal performance, should be turned off when the sensor is running at 1kHz or 2kHz.
[nUNFx<cr>	Unit number message portion ON/OFF x = 0: Off x = 1: On	*>Unit number portion of data turned ON/OFF in message.*	For optimal performance, should be turned off when the sensor is running at 1kHz or 2kHz.
[nMICFW<cr>	Save output message ON/OFF status into flash memory	*>Current ON/OFF message status was written into flash memory as the default status!*	Current message ON/OFF status will be saved into flash memory.

9 Dimensional Drawing



Inch
[millimeter]

10 Part Number

TILT – 57A – 3 – A1

Family Series

05 - Small-Sized Board (1”x 1”)

10 - Board with Multiple Interfaces

15 - High Accuracy Analog Inclinometer Board

20 - Low Cost, ABS Plastic Enclosure

3X - High Accuracy, Aluminum Enclosure

5X - Dynamic Inclinometer, Aluminum Enclosure

70 - Harsh Environment, Stainless Steel Enclosure

Housing Material

A - Aluminum

P - ABS Plastic

S - Stainless Steel 316L

O - OEM (No Housing)

Interface

3 - RS232

4 - RS422

8 - RS485

U - USB

S - SSI

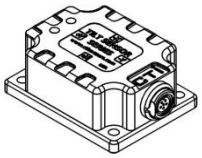
W - Wireless

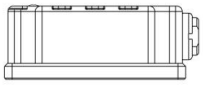
Design Model

A1

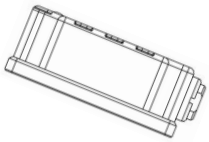
11 Horizontal Installation Position

Measuring range: ±90° (two-dimensional)

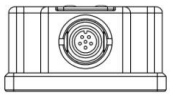




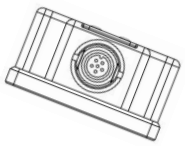
Default
Y=0



Inclination
Y=+30



Default
X=0



Inclination
X=+30

12 Revision History

Revision Number	Revision Date	Description of Changes
1.0	10/2018	• Created document based on initial specifications
1.1	12/2018	• Updated document to reflect new command structure
1.2	2/2019	• Updated document to reflect new message structure
1.3	4/2019	• Updated the GUI picture and some specifications

WARRANTY: This product has 18 months limited warranty. For more information, please visit:
www.CTiSensors.com/warranty

This product is designed and manufactured in the U.S.A.

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