In-Place MEMS Tiltmeter Instruction Manual

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REVISION HISTORY

Rev.	Revision History	Date	Prepared By	Approved By
A	Initial Release	5 March 2024	TW, SM	PL
B	Specifications table updated	4 December 2024	SM	SP

1 OVERVIEW

RST's In-Place MEMS Tiltmeters measure tilt in two axial planes perpendicular to the surface of the base plate. The unit is intended to be permanently installed, providing long-term observation with maximum resolution and sensitivity. It is conveniently designed for manual monitoring or remote data acquisition.

The system consists of a Tiltmeter mounting plate, interconnecting cable, and Datalogger or readout instrument. The electronics are housed in a NEMA 4X (IP-65) enclosure for environmental protection and typically mounted to a bracket or plate which is then bolted or bonded to the structure. For maximum resistance against water ingress, the cable is hard wired to the enclosure. The interconnecting cable is suitable for direct burial. The signal is output via the digital bus option, allowing several Tiltmeters to be daisy-chained on a single cable.

RST's In-Place Tiltmeters are mounted on vertical or horizontal surfaces and can measure differential angles in the X or Y directions. The Biaxial MEMS Tiltmeter is housed in a cast aluminum water-resistant NEMA 4X box and can be mounted vertically with an angle bracket or horizontally with a mounting plate.

Due to the excellent zero and range stability, no sensor leveling is required- i.e. the enclosure should be mounted as close to level as possible, but no secondary level adjustment is required. This is in contrast to electrolytic sensors which have high coefficients of thermal sensitivity, necessitating precise leveling on the structure.

Figure 1: In-Place Tiltmeter Unit

1.1 APPLICATIONS

The In-Place Tiltmeters can be used in a variety of applications, such as for:

- Monitoring tilt of retaining and building walls.
- Monitoring tilt of concrete dams.
- Structural load testing.
- Building safety around adjacent excavations.
- Various horizontal or vertical applications.
- Observation of benches and berms in open-pit mines.
- Landslide monitoring.
- Ground subsidence monitoring.
- Bridge pier monitoring.
- Applications where the failure mode is expected to have a rotational component.

1.2 FEATURES

Features of In-Place Tiltmeters include:

- Ease of installation.
- Datalogger and/or manual readout compatible.
- NEMA 4X (IP-65) weatherproof enclosure.
- High accuracy and repeatability.
- Cost-effective.
- Digital bus output.

1.3 Intended Audience

This guide is for the personnel responsible for installing or using RST's In-Place Tiltmeter System. This manual provides steps for installing the Tiltmeter System, how to take readings and interpret them.

1.4 Icons and Conventions Used In This Guide

This guide uses the following icons to call attention to important information.

	**WARNING:** This icon appears when an operating procedure or practice, if not correctly followed, could result in personal injury or loss of life.
	**CAUTION**: This icon appears when an operating procedure or practice, if not strictly observed, could result in damage to or destruction of equipment.
	**NOTE**: This icon appears to highlight specific non-safety related information.

2 Safety

	**WARNING:** Always follow safety precautions and use proper personal protective equipment (PPE) including safety glasses and high-visibility clothing when working in the field with this equipment.

3 INSTALLATION

3.1 REQUIRED TOOLS AND COMPONENTS

Before installing the In-Place Tiltmeter System, ensure the following components and tools are present:

- In-Place Tiltmeter
- Horizontal/Vertical Mounting Brackets
- Readout unit such as CR6 Datalogger or Rugged Handheld Device
- RSTAR Affinity Datalogger
- Level
- PH2 Phillips screwdriver, or similar
- 16 mm wrench
- Anchor kit (consisting of (2) anchors, (4) washers, (4) 10 mm SS nuts (SOLD SEPARATELY))

3.2 INSTALLATION GUIDELINES

1. Determine the MEMS Tiltmeter installation location and orientation (horizontal or vertical). Ensure that the location surface is clean and free of obstructions.
2. Hold the mounting bracket at the intended location and mark the anchor locations at a distance equal to the Tiltmeter bolt pattern. Ensure the anchor markings are level and inline (use a level to confirm).
3. Remove the bracket and using an appropriately sized drill bit, drill holes in the markings to the appropriate depth that will accommodate the selected anchor fixings.
4. Remove dust from the drilled holes, using compressed air if needed. Install the anchors with fixings securely.
5. Position the mounting bracket with the fixings tightened loosely. Adjust and orientate the bracket using the level. When the bracket placement is finalized, tighten the fixings.
6. Securely attach the Tiltmeter to the mounting bracket. Refer to Section 3.4 for wiring connections.

NOTE: When selecting the installation location, ensure the following:

1. The enclosure's interior is accessible for connecting the sensors after the unit has been mounted.
2. The mounting location is a rigid structure, free from vibration.
3. Avoid areas of rapid/extreme temperature changes (such as direct sunlight or near heating/cooling equipment).

   For exposed units, a sunshade and/or external insulation is recommended.

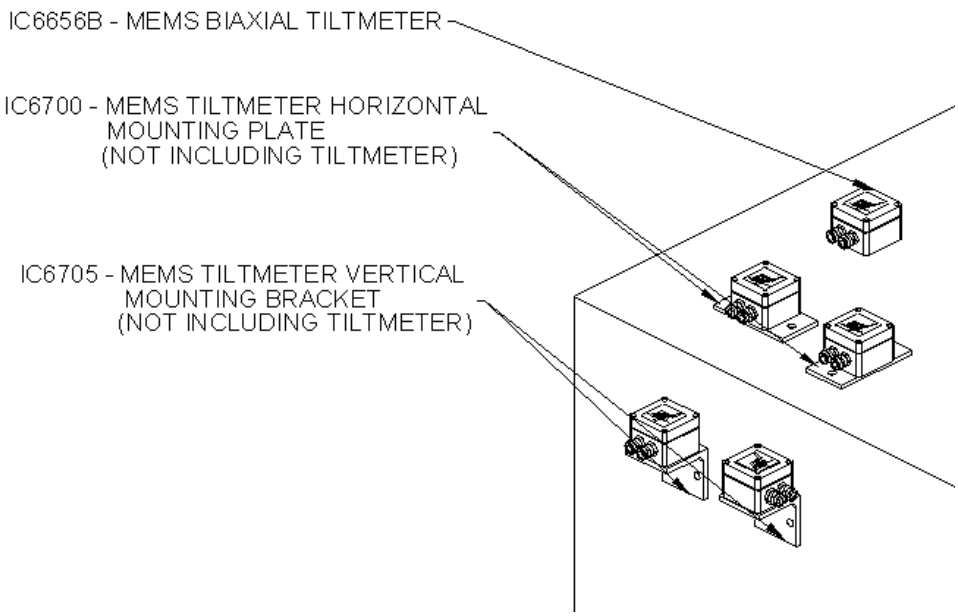

Figure 2: Tiltmeter General Arrangement

3.3 READING TILTMETER OUTPUT

The output of the sensors is in sin θ, which can be read with Rugged Handheld Device with Interface, a CR6 Datalogger or the RSTAR Affinity Data Logger.

NOTE: Refer to the specific data logger or readout unit's instruction manual for complete instructions on operation.

3.4 DIGITAL BUS TILTMETER ELECTRICAL CONNECTIONS

1. Under the Colour Code Table, look up the lead designations for the type of cable being used.

2. Under the Electrical Connections Table, make the appropriate lead connections.

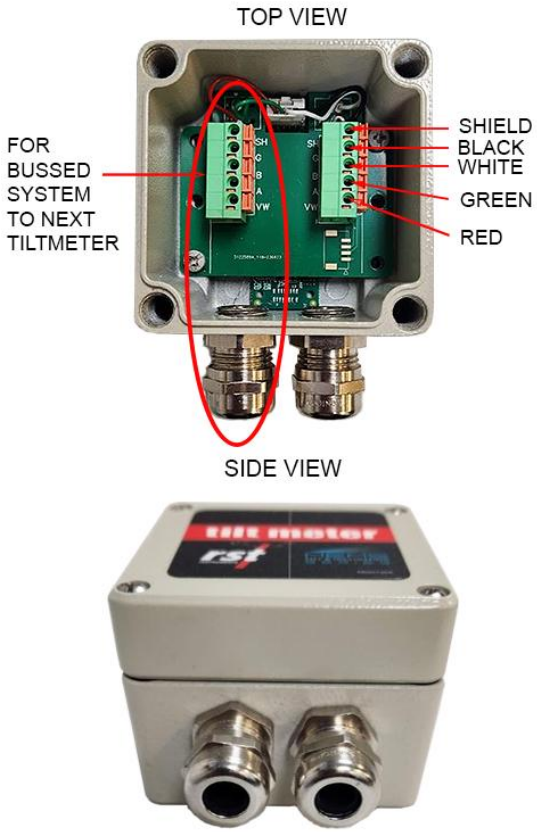

Figure 3: Digital Bus Tiltmeter Electrical Connections

Tiltmeter	Wire Colour
V+	Red
G	Black
A	Green
B	White
SH	Shield

Table 1: Wiring Table

4 PRODUCT SPECIFICATIONS

Item	Specification
Range	±30°
Resolution	0.0002° (0.004° mm/m)
Sensor Precision	± 0.0013° (0.02 mm/m)[1] ± 0.0005° (0.01 mm/m)[2]
Sensor 24 h Stability	± 0.03 mm/m[1] ± 0.01 mm/m[2]
Sensor	MEMS (Micro-Electro-Mechanical Systems) Accelerometer
Temperature Dependent Uncertainty	± 0.016 mm/m/°C (± 0.001°/°C) for ±5° from vertical ± 0.033 mm/m/°C (± 0.002°/°C) for ±15° from vertical
Temperature Accuracy	±0.5°C (0°C to 60°C) ±1.0°C (-40°C to 60°C)
Temperature Resolution	0.06°C
Operating Temperature	-40 to +60°C (-40 to 140°F)
Dimensions	80 x 80 x 61mm (3.15 x 3.15 x 2.4 in.)
Electrical	
Signal Output	RS485 Digital Bus (ASCII commands or MODBUS RTU Protocol)
Supply Voltage	5 to 15V DC
Operating Current	490 µA (Reading Average, per sensor)
Standby Current	<20 µA (per sensor)

[1]: 99% Confidence Interval

[2]: 68% Confidence Interval

5 ORDERING INFORMATION

Item	Specification
Biaxial	Part #
MEMS Biaxial Tiltmeter – digital bus output	IC6656B
Mounting	Part #
MEMS Tiltmeter Horizontal Mounting Plate	IC6700
MEMS Tiltmeter Vertical Mounting Bracket	IC6705
2 twisted pairs cable with polyurethane jacket	EL380004
Readouts & Data loggers	Part #
Rugged Handheld PC	IC32000-NAUTIZ
Digital Interface for Rugged Handheld PC	ELGL4010
DT2485 DT-BUS Data logger	DT2485
FlexDAQ Data loggers	
RSTAR Affinity Data logger	

6 SERVICE, REPAIR AND CONTACT INFORMATION

This product does not contain any user-serviceable parts. Contact RST for product services or repairs.

- For sales information: sales@rstinstruments.com
- For technical support: support@rstinstruments.com
- Website: www.rstinstruments.com
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APPENDIX A: ANALYZING THE DATA

Each Tiltmeter is identified by a Serial Number and has a corresponding calibration certificate. See Appendix B: Sample Calibration Sheet for a sample calibration certificate.

The sensing principle of the MEMS Tiltmeter is the same as an accelerometer with the sensitive axis oriented horizontally.

The measured phenomenon is then the component of gravity transverse to the sensitive axis, i.e.

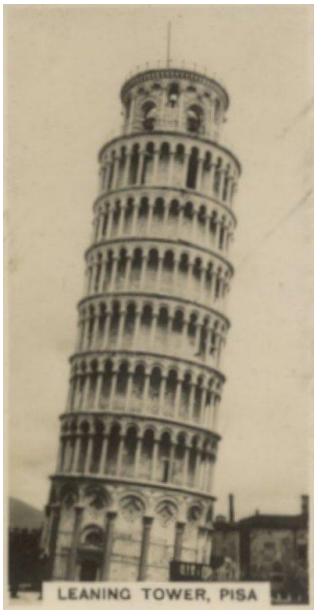
$$a = g \,.\, \sin(\alpha)$$

Commonly, Tiltmeter data is interpreted as linear motion – i.e. rotation about a presumed radius gives an equivalent motion. In many cases, where the ultimate variable of interest is lateral displacement at some presumed radius due to rotation, the accelerometer result can be simply rescaled, i.e.

$$X = r \,.\, \sin(\alpha)$$

$$= \frac{r \,.\, a}{g}$$

CAUTION: For Tiltmeters mounted on rigid bodies, the radius must be chosen carefully.



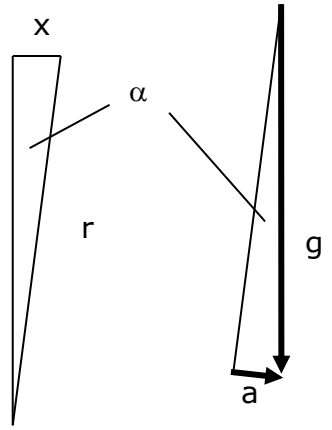


Figure 4: Tilt Data Interpretation

In cases where the actual angle is sought, the arcsine function or a polynomial equivalent may be used:

$$\alpha = arcsine\ (a/g)$$

NOTE: Digital tiltmeters cannot be used to measure “dynamic tilt”.

APPENDIX B: SAMPLE CALIBRATION SHEET

Calibration Record

RST Instruments Ltd., 11545 Kingston Street, Maple Ridge, BC, Canada V2X 0Z5
Tel: 604-540-1100 • Fax: 604-540-1005 • Toll free: 1-800-665-5599 (North America only)
www.rstinstruments.com

MEMS Biaxial Tiltmeter - Digital Output

Serial Number: EM3501
Calibration Date: Feb. 27, 2018
Cable Length: 6 m
Serial Number: EM3501
Calibration Date: Feb. 27, 2018
Inclinometer Frame: RST-07

Referenced to National Standards Annually

Wiring

Colour	Function
Red	Voltage +
Black	Ground
Green	RS485 A +
White	RS485 B -

A – Axis

Applied Degrees	Applied Sin	Displayed Sin	Error Sin
-15	-0.25882	-0.25882	0.00000
-10	-0.17365	-0.17364	0.00001
-5	-0.08716	-0.08716	0.00000
0	0.00000	0.00000	0.00000
5	0.08716	0.08715	0.00001
10	0.17365	0.17364	0.00001
15	0.25882	0.25881	0.00001

B - Axis

Applied Degrees	Applied Sin	Displayed Sin	Error Sin
-15	-0.25882	-0.25883	0.00001
-10	-0.17365	-0.17365	0.00000
-5	-0.08716	-0.08716	0.00000
0	0.00000	0.00000	0.00000
5	0.08716	0.08715	0.00001
10	0.17365	0.17364	0.00001
15	0.25882	0.25880	0.00002

This instrument has been calibrated using standards traceable to the NIST in compliance with ANSI Z540-1

Calibrated by: H. Hunag Date: 27-Feb-18

APPENDIX C: DIGITAL TILT BUS COMMAND REFERENCE

ASCII COMMANDS

COMMUNICATION INTERFACE

Electrical Specifications	= RS-485
Data Transmission	= 9600 baud/8 data/no party/1 stop

COMMAND FORMAT

All commands have the following format: @@#####_ComandString<CR>

@@	= Address detect mode character string
#####	= Address in decimal format, 0-9
_	= Character to terminate address, char not in 0-9
ComandString	= Command to be processed
<CR>	= Carriage return, hex 0x0D. Command termination character.

NOTE: In case only one device is connected, the special address **65535** can be used to access the device.

COMMANDS

There are two commands required to retrieve a set of readings from the Digital Tilt Bus.
TR = Take a set of readings
SR = Send the last set of readings
Reading set = reading from tilt sensor A, tilt sensor B and temperature.

TR

The TR command causes the Digital Tilt Bus to take a set of sensors reading and store the set in memory. Only the most current reading set is stored. The stored reading set is maintained until power is removed from the Digital Tilt Bus or a new reading set is taken.

TR	= Take a single reading set then enter low power mode.
TR 1	= Put sensors in continuous reading mode. Sensors do not power down.
TR 0	= Take a single reading then enter low power mode. Terminate continuous mode.

Sample Command:	@@100023 TR 1<**CR**>
Return String:	TR 1<**CR**>

SR

The SR command causes the Digital Tilt Bus to send the latest reading set. The reading set will not be updated unless continuous reading mode has been entered. If the TR has not been processed, the entries in the returned reading set defaults to 0. The entries are comma separated.

Sample Command:	@@12345 SR<**CR**>
Return String:	SR,ReadingA,ReadingB,Temperature <CR>
ReadingA Format:	#.######

ReadingA Format:	#.######
Temp Format:	#.##
Default Reading	SR,0.00000,0.00000,0.00

Error Response:
If an invalid address is entered, there will be no response. If an invalid command is entered, the echoed command followed by a '?' will be sent.

TYPICAL READING SEQUENCE

- Power on
- Wait 600ms
- Send TR command: Wait for CR after echo.
- Bi-Axial: Wait 2100 ms.
- Send SR command: Wait for CR after echo and data.
- Update rate in continuous mode
- Bi-Axial = 1650 ms