RST INSTRUMENTS LTD.

MEMS Track Monitoring System
Instruction Manual

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MEMS Track Monitoring System

Product: MEMS Track Monitoring System
Installation Manual

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1 GENERAL DESCRIPTION

RST Micro-Electro-Mechanical Systems (MEMS) Track Monitoring System is intended for monitoring settlement and twist of railroad tracks which may be affected by nearby construction activity, such as tunnelling or adjacent excavation, or which are located near hazardous zones such as potential washout or landslide areas.

The Track Monitoring System consists of bussed settlement sensors mounted longitudinally along the track alignment, typically with a mount spacing of 2 or 3 meters and one, or several, bussed twist sensors mounted perpendicularly to the settlement sensors. The settlement and twist sensors are based on the same MEMS devices used in the MEMS Tilt & Inclination Series of products from RST Instruments. These sensors are fully compatible with flexDAQ dataloggers and the GeoViewer data display and management software.

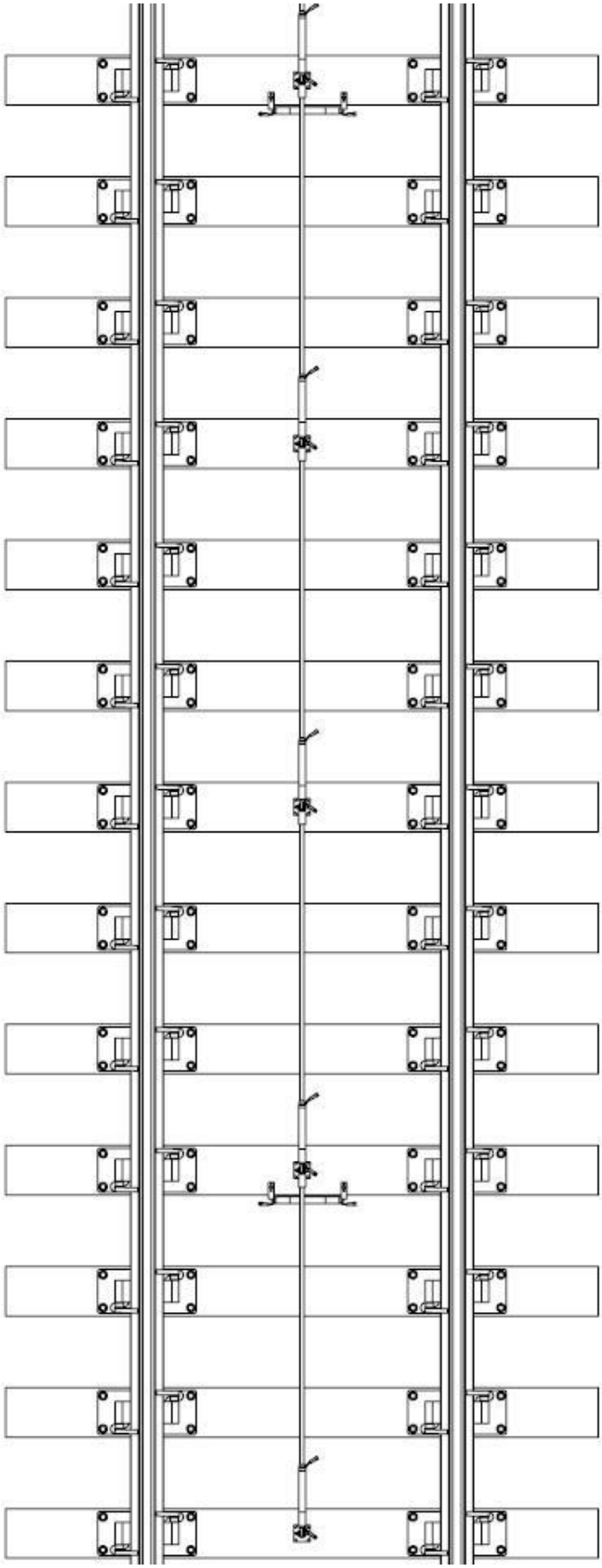

Figure 1: MEMS Track Monitoring System Overview

2 INSTALLATION

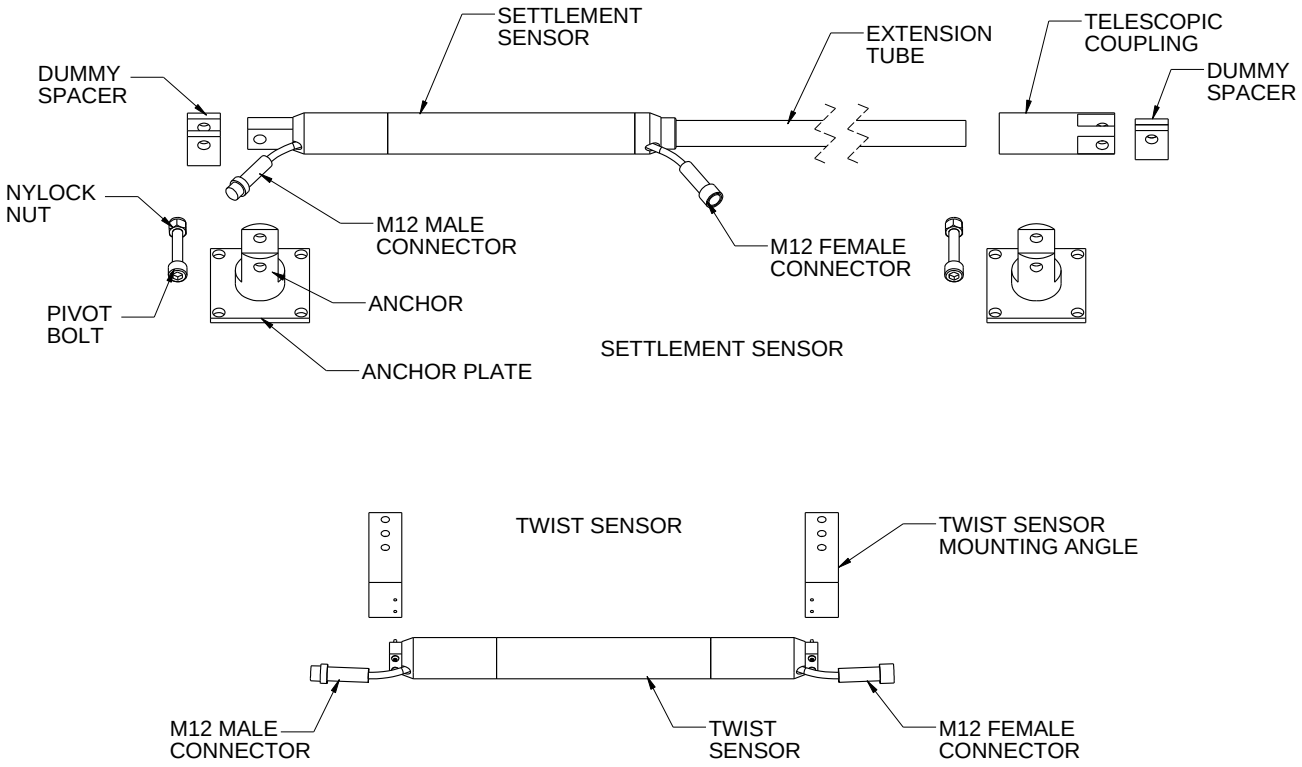

Figure 2: MEMS Track Monitoring System Components

2.1 INSTALLING SETTLEMENT SENSORS

1. Lay Anchor Plates and Extension Tubes along the tracks. This helps to locate where to place the Anchor Plates.

   Note: Spacing between Anchor Plates is specified by user when ordering. Extension Tubes and Cables are cut to the approximate length accordingly.

2. Place the first Anchor Plate at the desired location.
3. Fix the Anchor Plate to tie.

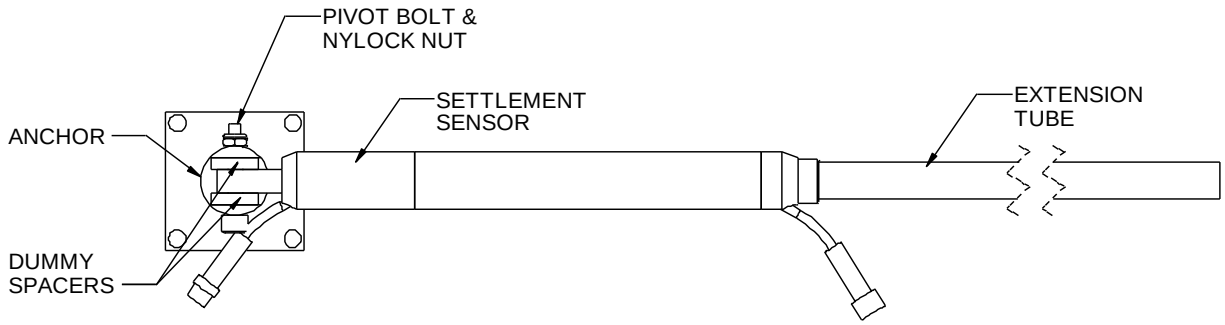

Figure 3: Connecting first set of Anchor Plate and Settlement Sensor

4. Attach the first Settlement Sensor onto the Anchor Plate. (See figure 3)
5. Place two Dummy Spacers on the first Anchor Plate as show in figure 3.

   Note: Dummy spacers are only used on the first anchor and on the last anchor of the MEMS Track Monitoring System.
6. Slide the Pivot Bolt through the Anchor, the Settlement Sensor, and the Dummy Spacers. Lock the Pivot Bolt with the provided Nylock Nut. (See figure 3)

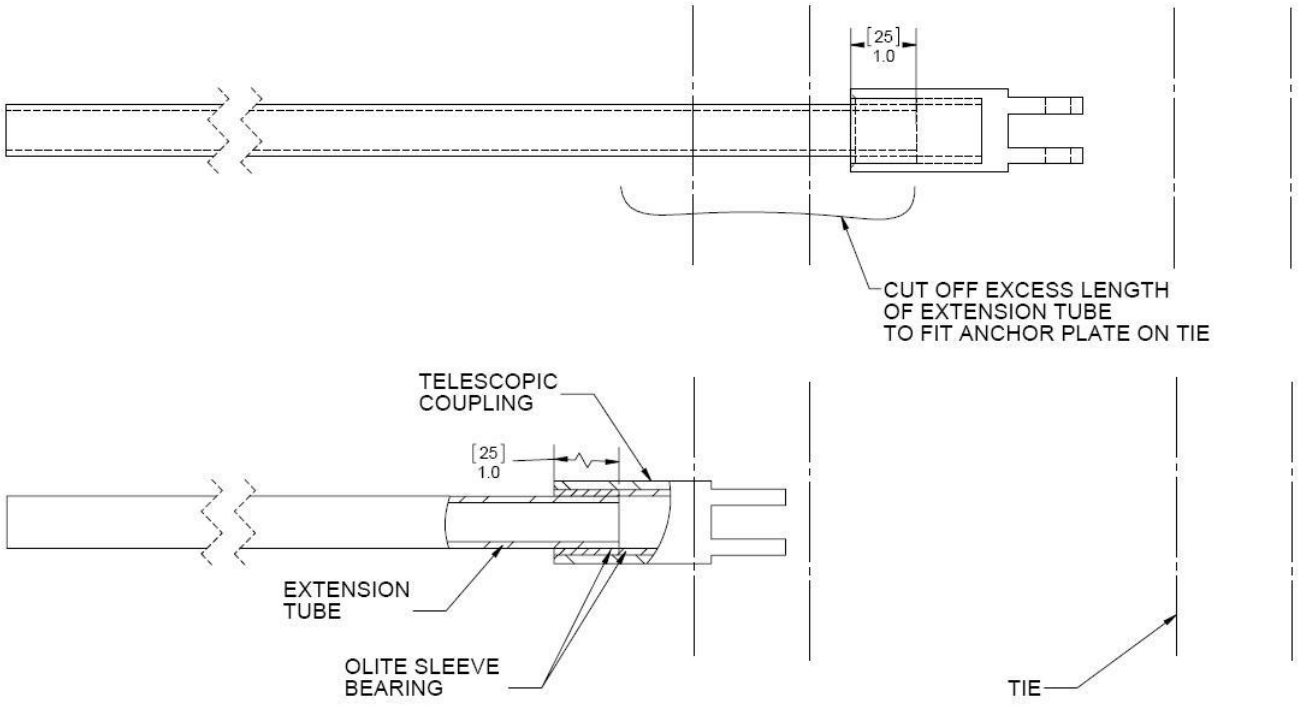

Figure 4: Telescopic Coupling Connection Detail

7. Determine where to place the next Anchor Plate on tie.

8. Calculate the length needed to cut on the Extension Tube in order for the next Anchor Plate sit on a tie. (See figure 4)

   Note: Consider the ambient temperature when you cut the Extension Tube. The Telescopic Coupling must accommodate both expansion and contraction of the tube due to temperature change. Extension Tube should be pushed into the Telescopic Coupling by 25mm or 1".

9. Cut excess length of Extension Tube.

   Debur all edges after Extension Tube is cut and make sure Extension Tube is **round.**

10. Slide the Telescopic Coupling over the Extension Tube by 25mm or 1".

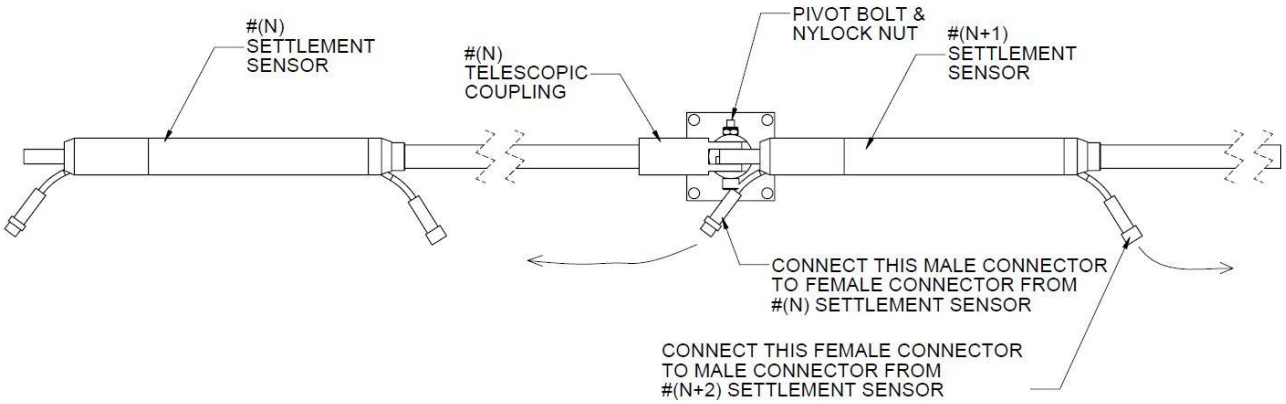

Figure 5: Connecting next set of Settlement Sensor

11. Attach the Telescopic Coupling onto the next Anchor Plate.
12. Attach the next set of Settlement Sensor onto the Anchor Plate. (See figure 5)
13. Slide the Pivot Bolt through the Anchor, the Settlement Sensor, and the Telescopic Coupling. Lock the Pivot Bolt with the provided Nylock Nut.
14. Fix the Anchor Plate to tie.
15. Connect male connector from #(N+1) Settlement Sensor to female connector from #(N) Settlement Sensor.
16. Repeat step 7 to 15 until all Settlement Sensors are installed.

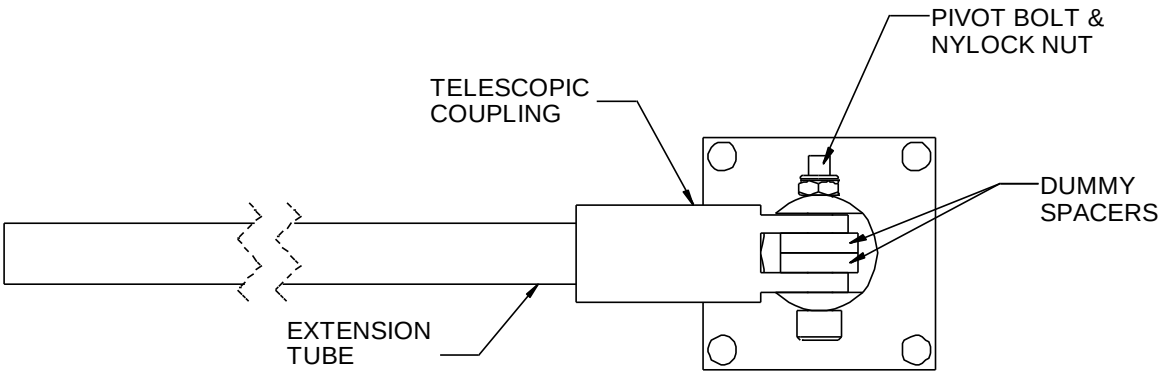

Figure 6: Connecting last set of Anchor Plate and Telescopic Coupling

17. Place two Dummy Spacers on the last set of Anchor Plate. (See figure 6)

    Note: Dummy spacers are only used on the first Anchor Plate and on the last Anchor Plate of the system.

18. Slide the Pivot Bolt through the Anchor, the Telescopic Coupling, and the Dummy Spacers. Lock the Pivot Bolt with the provided Nylock Nut.
19. Tie off excess cable along the Extension Tube loosely with cable ties.
20. Measure and record the gauge length for each set of Settlement Sensor and the corresponding serial number. Gauge length for Settlement Sensor is measure from pivot Anchor to pivot Anchor. (See figure 7)
21. Add half of a pipe as protective cover for the MEMS Track Monitoring System is optional.

2.2 INSTALLING TWIST SENSORS

1. Place Twist Sensor perpendicular to Settlement Sensor on the same tie where the Anchor Plate is installed at desired location. (See figure 7)
2. Fix the Mounting Angle to tie.
3. Connect the male connector from the Twist Sensor to the female connector from #(N) Settlement Sensor
4. Connect the female connector from the Twist Sensor to the male connector from #(N+1) Settlement Sensor.
5. Tie off excess cable to Anchor.
6. Repeat step 1 – 5 until all Twist Sensors are installed.
7. Measure and record the gauge length for each Twist Sensor and the corresponding serial number. Gauge length for Twist Sensor is measure from mounting bolt to mounting bolt on the Mounting Angles. (See figure 7)

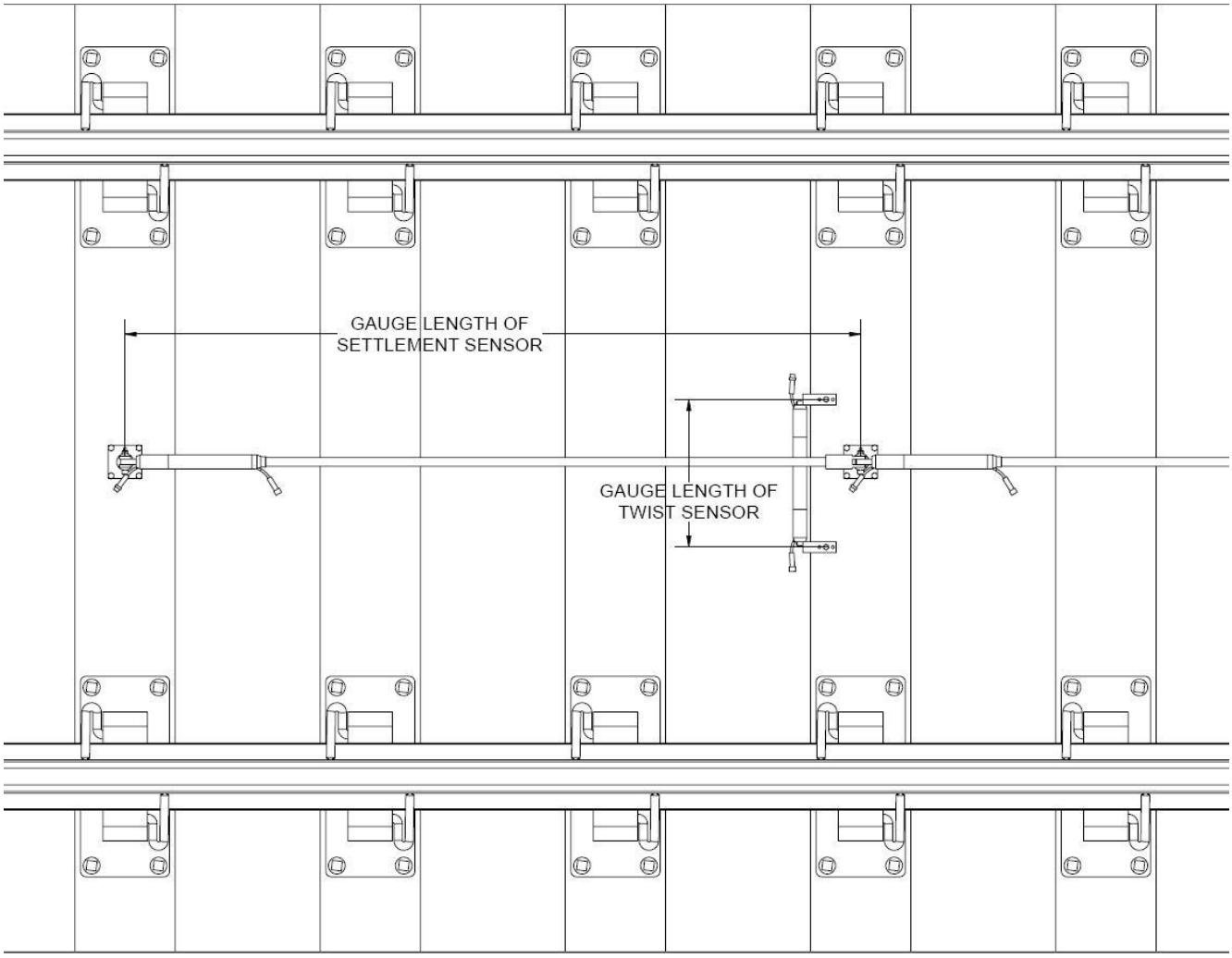

Figure 7: Installing Twist Sensor

3 OPERATION

Each MEMS Settlement Sensor or Twist Sensor consist of a ±15° sensor mounted inside an Ø1.25" Stainless Steel housing. Each sensor output sinθ, which is read by a Datalogger or a Handheld (See Section 5 for electrical connection details). Any settlement or twist along the tracks or ties will change the angle output of the Settlement Sensor or Twist Sensor. This angle along with the measured gauge length can be used to calculate the displacement the tracks or ties have moved or twisted. The displacement can be calculated using the following equation:

$$\Delta d = L \times (\sin\theta_c - \sin\theta_I)$$

Equation 1: Tilt Displacement

Δd = Change of displacement
L = Gauge Length of each Settlement Sensor or Twist Sensor
$\sin\theta_I$ = Initial tilt
$\sin\theta_C$ = Current tilt

MEMS Track Monitoring System's data should be read during quiet times, not when heavy pile driving or construction activity is present.

3.1 RECORDING INITIAL READINGS

It is important to immediately take an initial reading ($\sin\theta_I$) after an installation, as this will be the reference point from which relative displacements will be taken.

1. Record the serial number of the MEMS Settlement Sensor or Twist Sensor.
2. Record the reading.
3. Repeat steps 1-2 for all MEMS Settlement Sensors and Twist Sensors.

3.2 RECORDING CURRENT READINGS

To find out the amount of tilt ($\sin\theta_C$):

1. Record the serial number of the MEMS Settlement Sensor or Twist Sensor.
2. Record the reading.
3. Repeat steps 1-2 for all MEMS Settlement Sensors and Twist Sensors.

3.3 SIGN CONVENTION

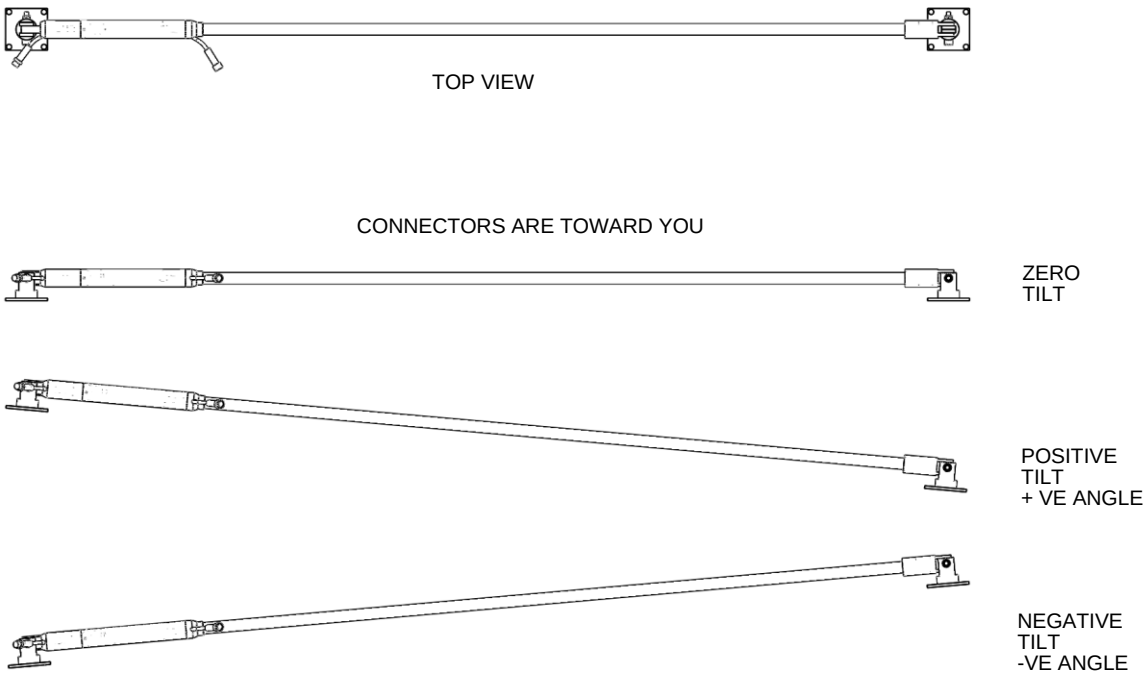

Figure 8: Settlement Sensor Sign Convention

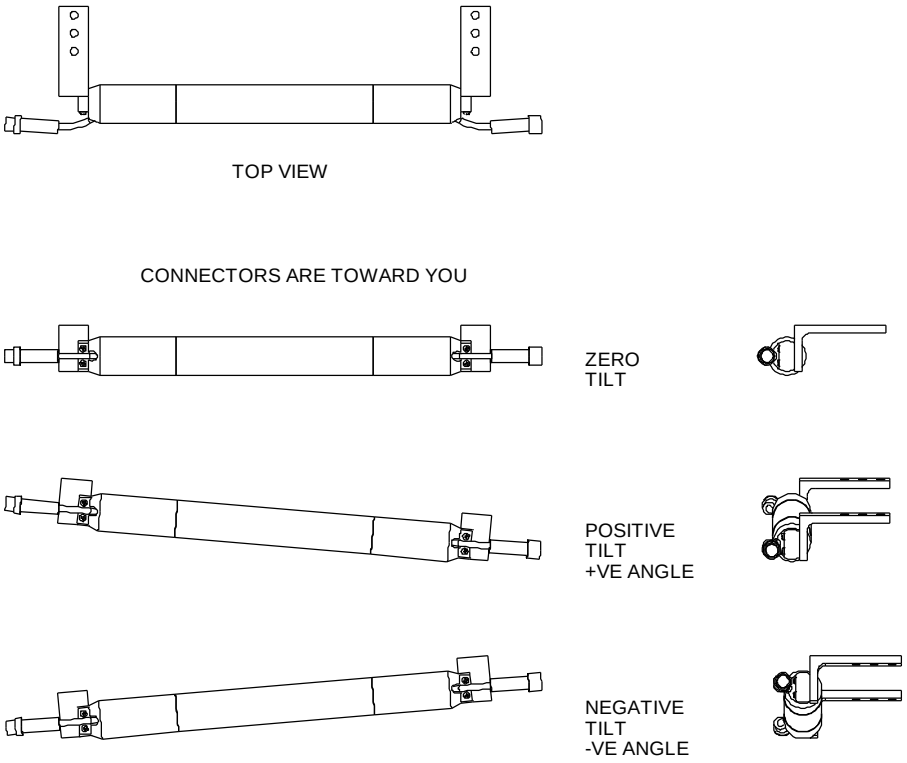

Figure 9: Twist Sensor Sign Convention

4 SPECIFICATIONS

4.1 ENVIRONMENTAL

Operating temperature	-40°C to +80°C

4.2 ELECTRICAL

Sensor	MEMS Tilt Sensor
Range	± 15 Degree Standard
Resolution	0.0013 Degree
Null Repeatability	<0.004 Degree

4.3 MECHANICAL

Gauge Length	2 or 3 meters
Housing Diameter	32mm (1 ¼") (sensor)
Extension Tube Diameter	20mm

5 ELECTRICAL CONNECTIONS

1. Under the Color 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, according to the type of system being used.

5.1 (DIGITAL OUTPUT) MEMS TRACK MONITORING SYSTEM

Wire Color	MEMS Track Monitoring System
Red	V+
Black	Gnd
Green	A+
White	B-

5.2 (DIGITAL OUTPUT - M12 CONNECTOR) MEMS TRACK MONITORING SYSTEM

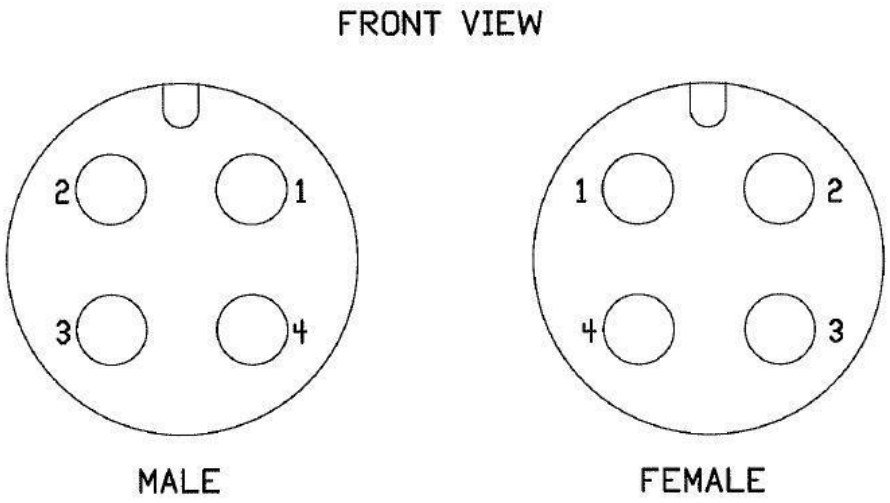

Figure 10: M12 Connectors

PIN	Wire Color	MEMS Track Monitoring System
1	Brown	12V
2	White	Ground
3	Blue	A+
4	Black	B-

6 APPENDIX A: SAMPLE CALIBRATION CERTIFICATE

Calibration Record

200 - 2050 Hartley Ave., Coquitlam, British Columbia, Canada V3K 6W5
Tel: 604.540.1100 • Fax: 604.540.1005 • Toll Free: 1.800.665.5599 (North America only)
e-mail: info@rstinstruments.com • Website: www.rstinstruments.com

MEMS Uniaxial Track Settlement Sensor - Digital Bus Output

Customer: RST
Order Number: Q0000x
Model Number: IC9000
Serial Number: UI0001
Calibration Date: 9-Feb-11

Wiring:

Colour	Function	Pin
Brown	V+	1
White	Gnd	2
Blue	A+	3
Black	B-	4

References: Inclinometer Frame RST-06
Referenced to National Standards Annually

Face Frame Angle Degrees	Sin ⊖	Swing Right Sin ⊖	Swing Left Sin ⊖	Mean Sin ⊖	Error Sin ⊖
15	0.25882	0.25881	0.25884	0.25883	-0.00001
10	0.17365	0.17366	0.17366	0.17366	-0.00001
5	0.08716	0.08715	0.08717	0.08716	0.00000
0	0.00000	0.00000	0.00002	0.00001	-0.00001
-5	-0.08716	-0.08722	-0.08717	-0.08719	0.00004
-10	-0.17365	-0.17366	-0.17369	-0.17368	0.00003
-15	-0.25882	-0.25887	-0.25884	-0.25885	0.00004

Calibrated By: W. Mok

Figure 11: Calibration Certification for MEMS Track Settlement Sensor

Calibration Record

200 - 2050 Hartley Ave., Coquitlam, British Columbia, Canada V3K 6W5
Tel: 604.540.1100 • Fax: 604.540.1005 • Toll Free: 1.800.665.5599 (North America only)
e-mail: info@rstinstruments.com • Website: www.rstinstruments.com

MEMS Uniaxial Track Twist Sensor - Digital Bus Output

Customer:	RST
Order Number:	Q00000x
Model Number:	IC9100
Serial Number:	UI0002
Calibration Date:	10-Feb-11

Wiring:

Colour	Function	Pin
Brown	V+	1
White	Gnd	2
Blue	A+	3
Black	B-	4

References: Inclinometer Frame RST-06
Referenced to National Standards Annually

Face Frame Angle Degrees	Sin ⊖	Swing Right Sin ⊖	Swing Left Sin ⊖	Mean Sin ⊖	Error Sin ⊖
15	0.25882	0.25881	0.25880	0.25881	0.00001
10	0.17365	0.17362	0.17364	0.17363	0.00001
5	0.08716	0.08713	0.08713	0.08713	0.00002
0	0.00000	-0.00003	0.00000	-0.00001	0.00001
-5	-0.08716	-0.08720	-0.08719	-0.08720	0.00004
-10	-0.17365	-0.17367	-0.17367	-0.17367	0.00002
-15	-0.25882	-0.25881	-0.25880	-0.25881	-0.00001

Calibrated By: W. Mok

Figure 12: Calibration Certification for MEMS Track Twist Sensor