RST INSTRUMENTS LTD.

# MEMS Tilt Beam
# Instruction Manual



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# MEMS Tilt Beam Instruction Manual



**Product:** MEMS Tilt Beam Instruction Manual

(No Window Version)

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# 1 GENERAL DESCRIPTION

RST Instruments MEMS Sensor Tilt Beam is mounted on vertical or horizontal surfaces and can measure differential angles in the X or Y directions. The Horizontal or Vertical MEMS Tilt Beam system consists of a fiberglass beam with mounting brackets, and a uniaxial MEMS sensor. The Vertical Tilt Beam is capable of uniaxial as well as biaxial MEMS sensors (optional). Because of the excellent zero and range stability, no separate sensor leveling is required- i.e. the enclosure should be mounted as close to level as possible, but no secondary level adjustment is required.

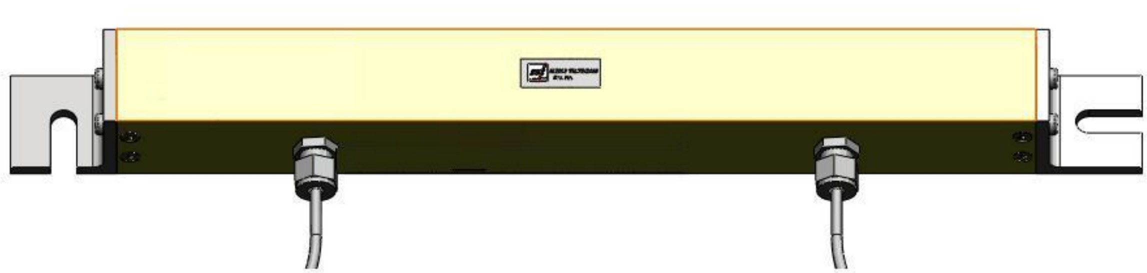


**Figure 1: MEMS Tilt Beam**

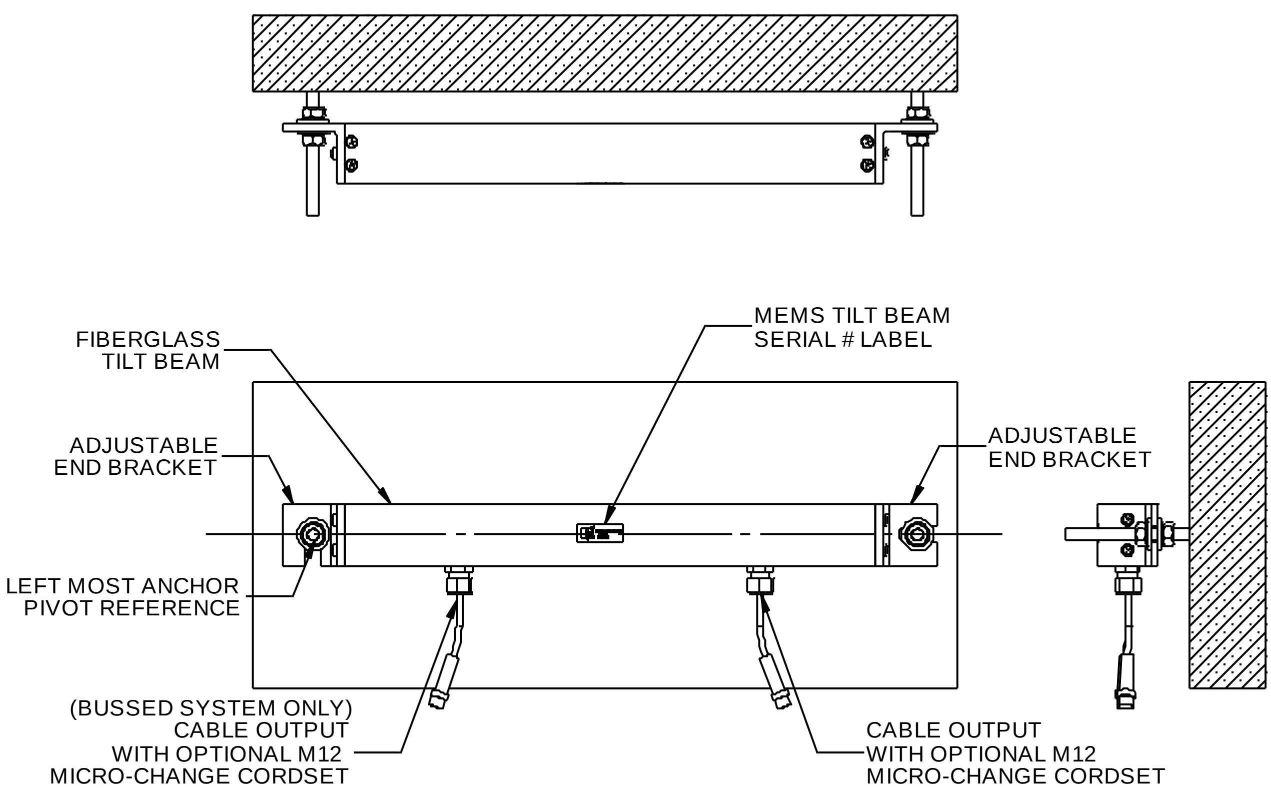



**Figure 2: MEMS Tilt Beam Details**

# 2 MATERIALS

## 2.1 REQUIRED TOOLS/COMPONENTS

Before beginning the installation of the Horizontal or Vertical MEMS Tilt Beam, ensure that all of the components and tools required for installation are present. See the list below for tools and equipment required for a typical installation:

- MEMS Tilt Beam(s)
- (1) Readout (IC6800-V, FlexDaq 1000/800 Datalogger, or Field PC Interface)
- (1) Level
- (1) Phillips screw driver
- (1) Anchor kit consisting of (2) 10mm SS anchors, (4) belleville washers, (4) nylon washers, (2) nylon bushing, (4) 10mm SS nuts
- (2) 16mm wrench

# 3 INSTALLATION

Determine the MEMS Tilt Beam installation location. The location must allow for access to connect the sensors after the unit has been mounted. The mounting angles should be securely attached with the supplied hardware to a rigid structure that is free of vibration. Care should be taken to avoid areas of rapid or extreme changes in temperature such as direct sunlight or near heating or cooling equipment. For exposed units, a sun shade and or external insulation is recommended.

The output of the MEMS sensor(s) is either analog or digital, which can be read with RST IC6800-V Readout, FlexDaq 1000/800 Datalogger, or Field PC.  The MEMS sensors have excellent zero and full scale stability. As a result, precision sensor zeroing is not necessary. This is in contrast to electrolytic sensors which have high coefficients of thermal sensitivity, necessitating precise leveling on the structure.

## 3.1 ANCHOR INSTALLATION

It is important to install the anchors at a distance equal to the MEMS Tilt Beam mounting angles pattern (using a level, ensure the anchors are installed inline horizontally or vertically) (see figure 3).

The anchors should:

1. Protruding horizontally, in all planes, from the structure (not necessarily perpendicular to the structure)
2. In plane (i.e. reading level, if a level were placed across both anchors)
3. Allow anchors to set.

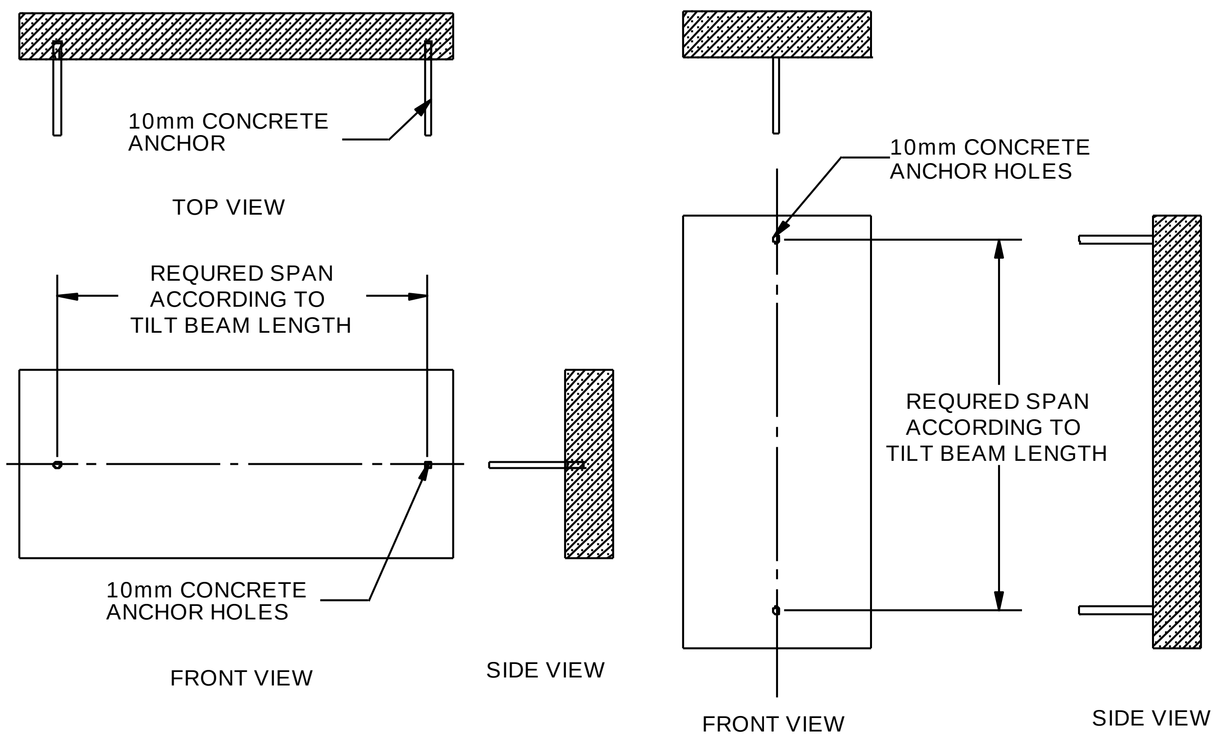



**Figure 3: Horizontal & Vertical Tilt Beam Concrete Anchor Orientation**

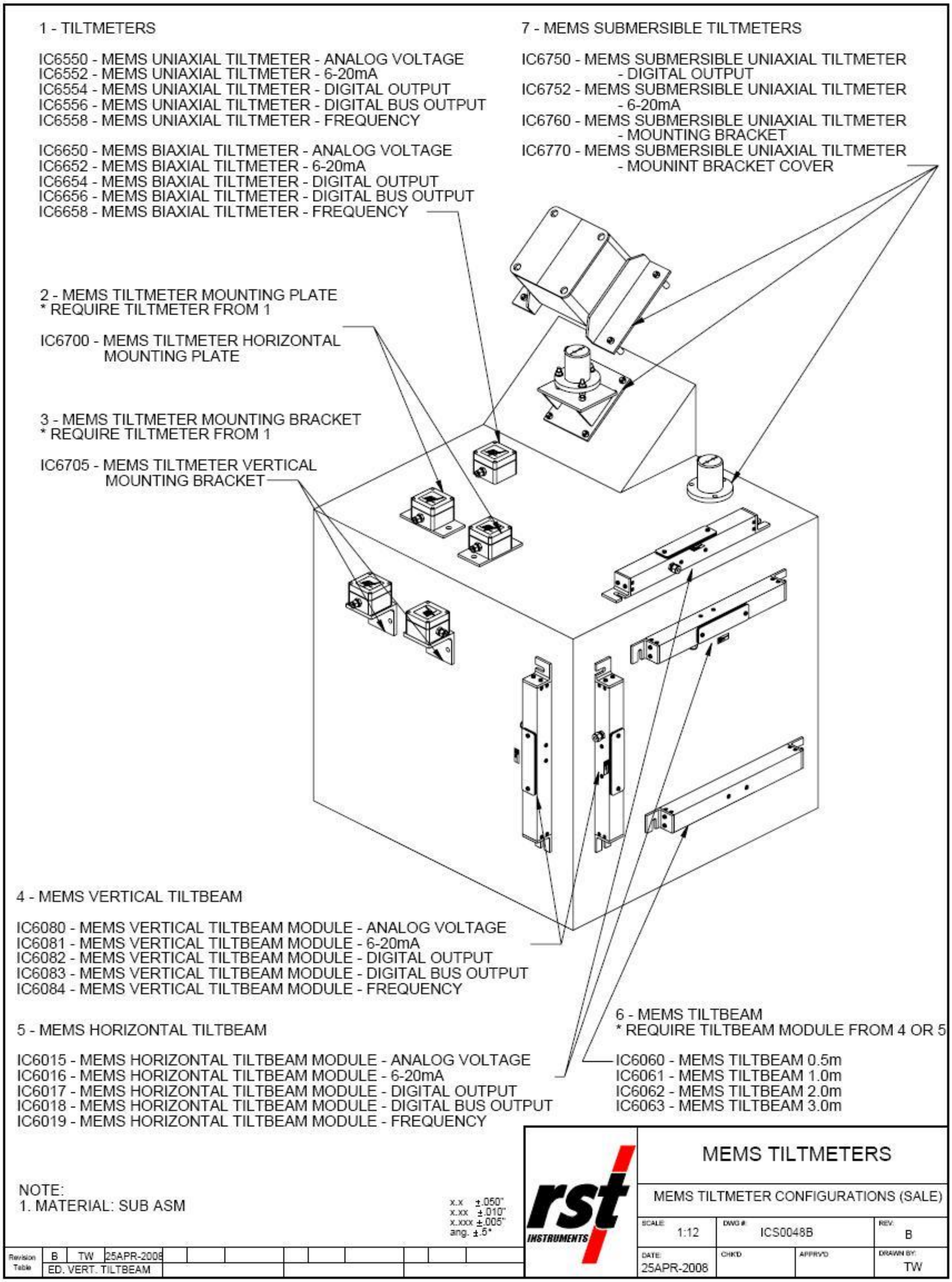



**Figure 4: MEMSTilt Beam/Meter General Arrangement**

## 3.2 SINGLE MEMS TILT BEAM INSTALLATION

Determine the MEMS Tilt Beam installation orientation (i.e. Is the Beam to be installed on the ceiling, wall, or floor). Refer to Figure 4 and adjust mounting brackets accordingly.

1. Thread a 10mm nut onto each anchor until they reach the desired position (ensure the nuts are in plane)
2. Place a Belleville washer over each anchor (see Figure5)
3. Place a Nylon washer over each anchor
4. Place a Nylon bushing over each anchor
5. Slide the MEMS Tilt Beam onto the Nylon Bushings
6. Place a Nylon Washer over each anchor
7. Place a Belleville washer over each anchor (see Figure5)
8. Thread a 10mm nut onto each anchor, finger tight, and ensure that the Beam is horizontal or vertical
9. For a **single** beam installation, where (2) Belleville washers are used per anchor, turn the nut 2-3 wrench flats (120°-180°) (see Figure 5)
10. For a **double** beam installation, where (4) Belleville washers are used per anchor, turn the nut 4-5 wrench flats (240°-300°) (see Figure 5)

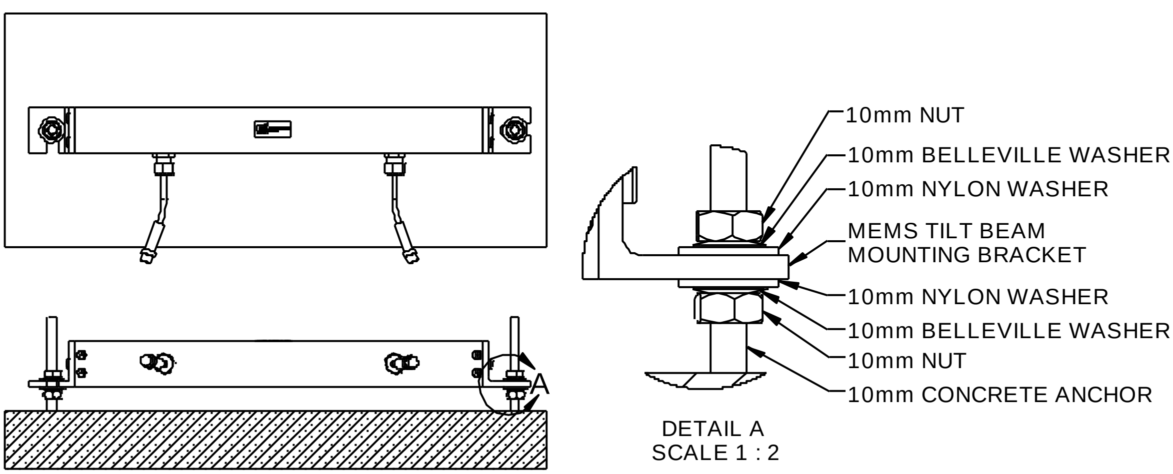



**Figure 5: Single Beam Mounting Details**

## 3.3 MULTIPLE MEMS TILT BEAMS INSTALLATION

Determine the MEMS Tilt Beam installation orientation (i.e. Is the Beam to be installed on the ceiling, wall, or floor). Refer to Figure 4 and adjust mounting brackets accordingly. Ideally, the beams should be staggered (see Figure 6).

There are two ways to complete this installation:

- Installing the odd beams first and then the even beams afterwards
- Or, install one beam at a time in succession, by placing beams on top and then in behind.

In either case, you should end up with a staggered installation as shown in Figure 6.

The following installation procedure is for installing one beam at a time in succession.

1. Thread a 10mm nut onto the first two anchors until they reach the desired position (ensure the nuts are in plane, not necessarily the same distance from the wall as the wall may be bowed)
2. Place a Belleville washer over the 1st and 2nd anchors (see Figure 6)
3. Place a Nylon washer over the 1st and 2nd anchors
4. Place a Nylon bushing over the 1st and 2nd anchors
5. Slide the MEMS Tilt Beam onto the Nylon Bushings
6. Place a Nylon Washer over the 1st and 2nd anchors
7. Place a Belleville washer over the 1st and 2nd anchors (see Figure 5 or 6)
8. Thread a 10mm nut onto the 1st anchor, finger tight, and ensure that the Beam is horizontal or vertical
9. Tighten the nut 2-3 wrench flats (120°-180°)
10. Thread a 10mm nut onto the 3rd anchor (position nut so that the next beam when installed will be parallel to the previously installed beam (see Figure 6)
11. Place a Belleville washer and then a Nylon washer and Nylon Bushing over the nut installed in step 10 (see Figure 6 for orientation of washer)
12. Place a Belleville washer and then a Nylon washer and Nylon Bushing over the Belleville washer on the 2nd anchor (see Figure 6)
13. Slide the MEMS Tilt Beam onto the 2nd and 3rd anchors, adjust the nut on the 3rd anchor until the beam is parallel
14. Place a Nylon Washer, and then a Belleville washer over the 2nd and 3rd anchor
15. Place a Nylon bushing over the 2nd and 3rd anchor
16. Thread a 10mm nut onto the 2nd anchor, finger tight, and ensure that the Beam is horizontal or vertical
17. Tighten the nut 4-5 wrench flats (240°-300°)
18. Repeat steps 10-17 incrementing anchor references by 1 (i.e. in step 10, the 3rd anchor would now become the 4th anchor etc.)

The beams when installed should be staggered and the washers and nuts should be installed as shown in Figure 6.

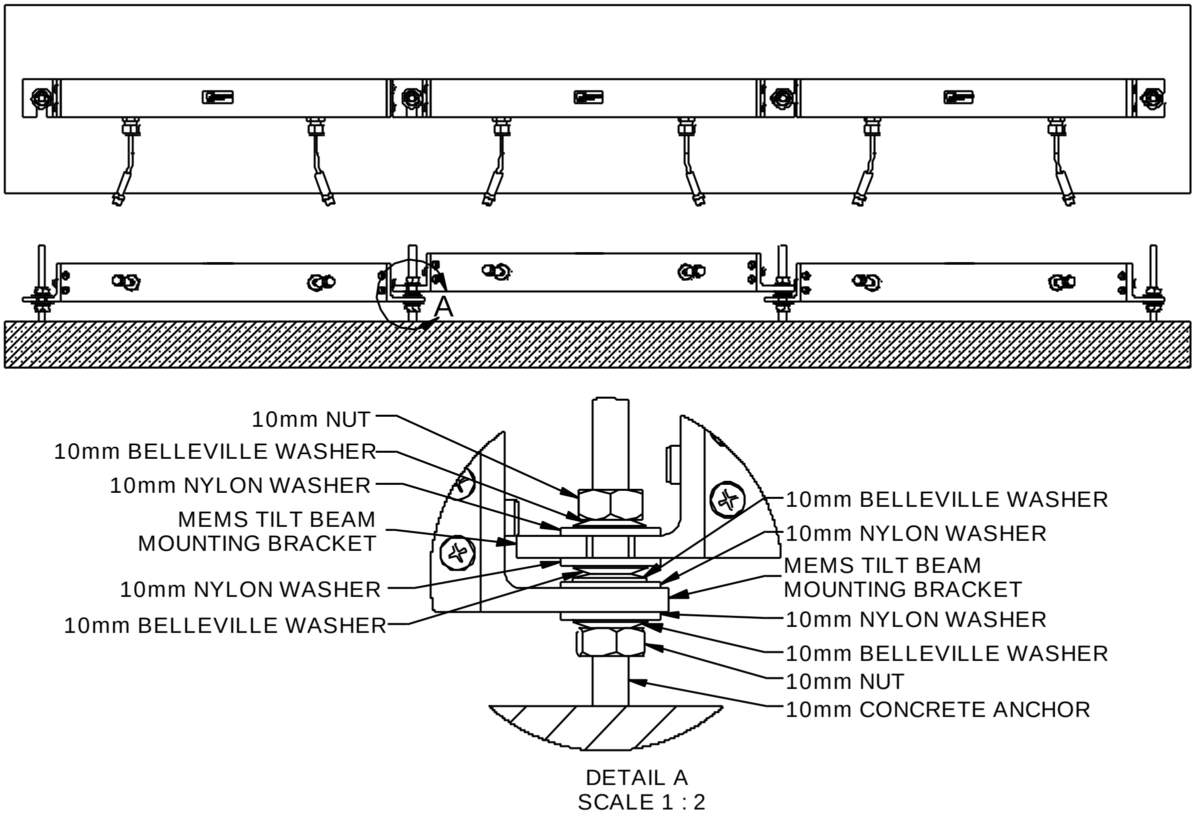



**Figure 6: Multiple Beam Configurations**

## 3.4 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, according to the type of system being used.
3. Horizontal and Vertical Tilt Beam system measure the A-axis (Green & White). Vertical Tilt Beam system is capable of measuring the B-axis (optional) (Orange & Blue).

Information regarding your sensor configuration and cable type is listed below and on your Calibration Certificate.

### 3.4.1 Uniaxial / Biaxial Tilt Beam (Analog Output) Electrical Connection

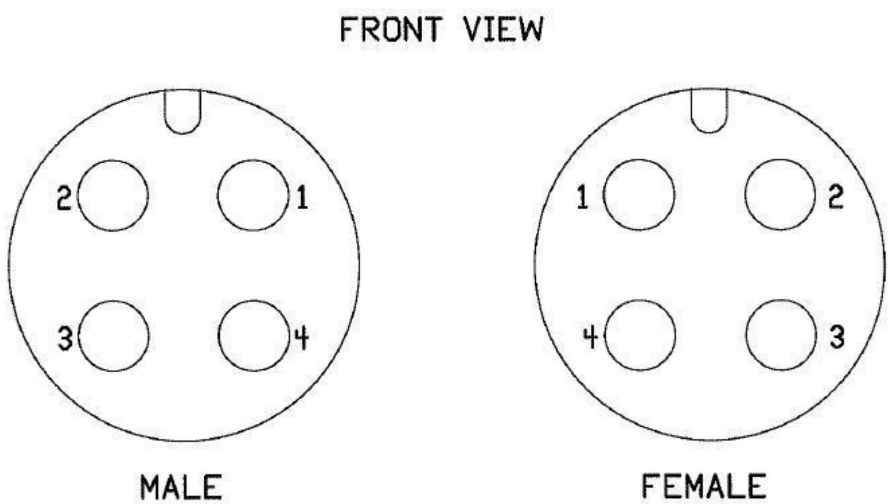
| Wire Color | Tiltmeter | Datalogger |
|---|---|---|
| Red | 12V | 12V |
| Black | Ground | Ground |
| Green | A+ | xH |
| White | A- | xL |
| Orange | B+ | yH |
| Blue | B- | yL |

Note: B+ and B- (Blue and Orange) are only for **Biaxial** Tilt beam.
For **BUSSED** systems only, use the cable with the jacket stripped 25mm back for the Cable Output.

### 3.4.2 Uniaxial / Biaxial Tilt Beam (Digital Output) Electrical Connection

| Wire Color | Tiltmeter |
|---|---|
| Red | V+ |
| Black | Ground |
| Green | RS485 A+ |
| White | RS485 B- |

### 3.4.3 Uniaxial / Biaxial Tilt Beam (Digital Output with M12 Connector) Electrical Connection




| PIN | Wire Color | Tiltmeter |
|---|---|---|
| 1 | Brown | 12V |
| 2 | White | Ground |
| 3 | Blue | RS485 A+ |
| 4 | Black | RS485 B- |

**Figure 7: Pins Configuration for optional M12 Micro-Change Connector**

## Analyzing the Data

Each MEMS Tilt Beam is identified by a Serial Number, and has a corresponding Calibration Certificate (See Sample Calibration Certificate). To convert the sensor signal into meaningful data, simply substitute the values from the readings and the Calibration Constants into the following formula:

$$\textbf{Sin}\ \alpha = \mathbf{m(V\text{-}b)}$$

Where

- **V** is the Tiltmeter Output signal.
- **m** is the predetermined Calibration Constant.
- **b** is the predetermined Calibration Constant.

The sensing principle of the MEMS Tilt Beam is that of an accelerometer with the sensitive axis is oriented horizontally. The measured phenomenon is then the component of gravity transverse to the sensitive axis, i.e.

$$a = g \text{ sine}(\alpha)$$

Commonly, MEMS Tilt Beam data are 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.

$$x = r \text{ sine}(\alpha)$$

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

In the case of a uniaxial MEMS Tilt Beam, radius (r) is the beam length. For MEMS Tilt Beam on rigid bodies, the radius must be chosen with some care.

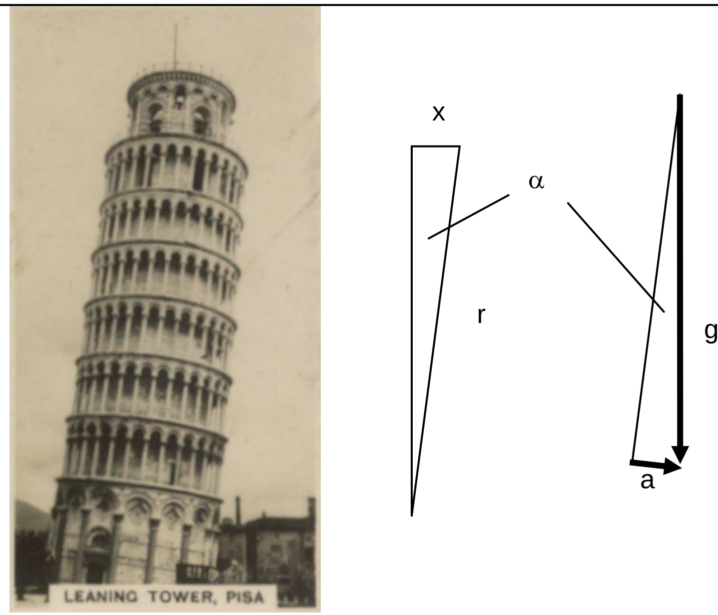



**Figure 8: Tilt Data Interpretation**

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

$$\alpha = \text{arcsine}(a/g)$$

It should be noted that measuring “dynamic tilt” may be a concept error: the lateral dynamic accelerations may exceed the tilt accelerations

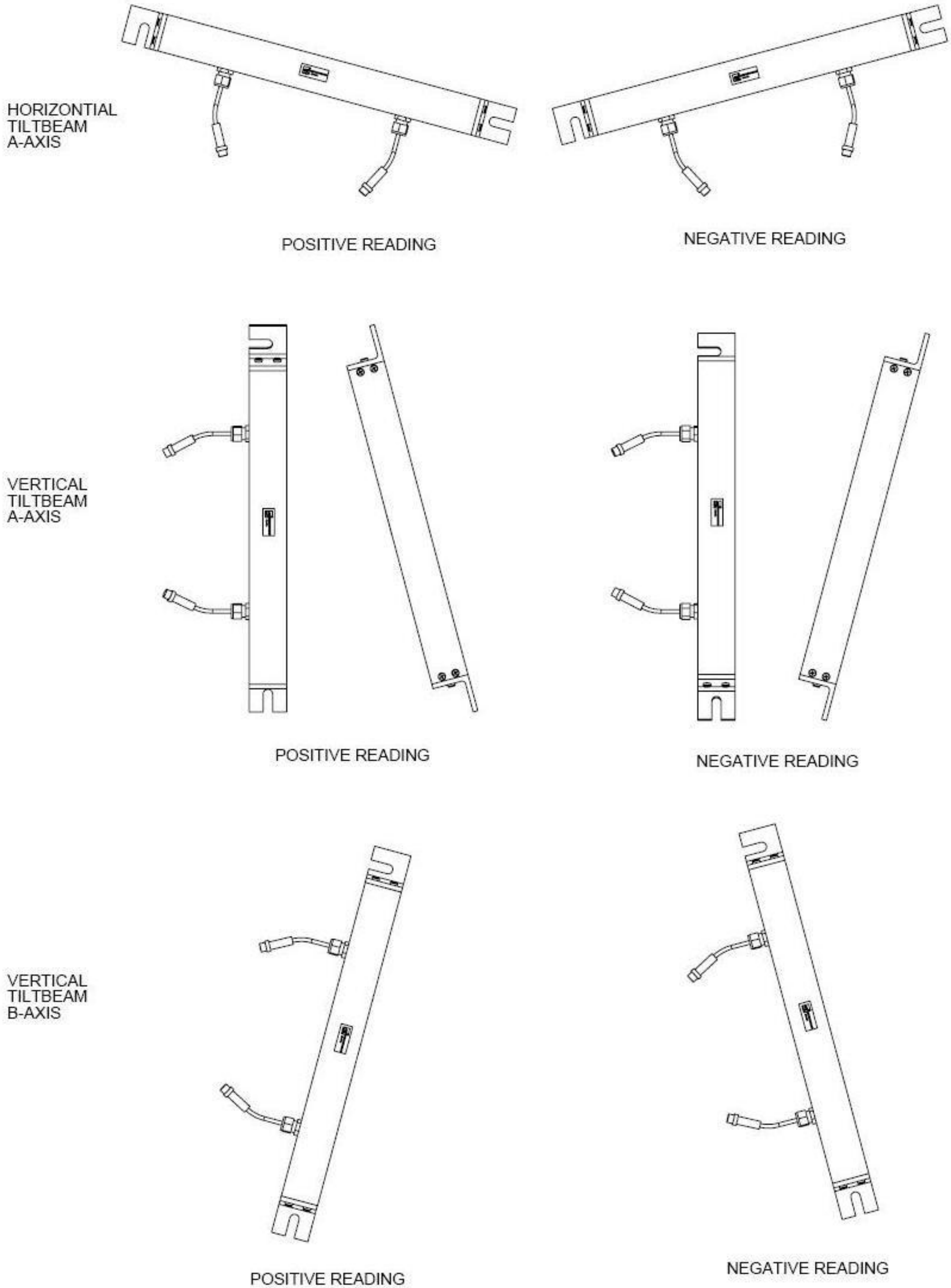



**Figure 9: MEMS Tiltbeam Directional Reading**

# 4 Specifications

| | |
|---|---|
| **4.1 ENVIRONMENTAL** | |
| Operating temperature | -40°C to +80°C |
| **4.2 ELECTRICAL** | |
| Sensor | 0ne/Two MEMS Tilt Sensor(s) |
| Range | ± 15 Degree Standard |
| Resolution | 0.0013 Degree |
| Null Repeatability | <0.004 Degree |
| Signal Cable | 22 Gauge Shielded Twisted |
| Datalogger<br>Analog Readout | FlexDaq 1000/800<br>IC6800-V |

# Appendix A: Sample Calibration Certificate (Digital Output)

## 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 Horizontal Uniaxial Tiltbeam - Digital Bus Output

| | | |
|---|---|---|
| Customer: | RST | |
| Work Order Number: | Qxxxxx | |
| Model: | IC6018-P | |
| Serial Number: | Emxxxx | |
| Date: | 5-Feb-10 | |
| References: | Inclinometer Frame | RST-06 |
| | Referenced to National Standards Annually | |

| Face Frame Angle Degrees | A+/- | Sin ⊖ | Swing Right Sin ⊖ | Swing Left Sin ⊖ | Mean Sin ⊖ | Error Sin ⊖ |
|---|---|---|---|---|---|---|
| 5 | L | 0.08716 | 0.08718 | 0.08719 | 0.08718 | -0.00003 |
| 4 | L | 0.06976 | 0.06967 | 0.06966 | 0.06966 | 0.00009 |
| 3 | L | 0.05234 | 0.05238 | 0.05241 | 0.05240 | -0.00006 |
| 2 | L | 0.03490 | 0.03498 | 0.03495 | 0.03496 | -0.00007 |
| 1 | L | 0.01745 | 0.01744 | 0.01749 | 0.01746 | -0.00001 |
| 0 | | 0.00000 | 0.00002 | 0.00003 | 0.00002 | -0.00002 |
| 1 | R | -0.01745 | -0.01753 | -0.01750 | -0.01752 | 0.00007 |
| 2 | R | -0.03490 | -0.03484 | -0.03484 | -0.03484 | -0.00006 |
| 3 | R | -0.05234 | -0.05227 | -0.05226 | -0.05226 | -0.00007 |
| 4 | R | -0.06976 | -0.06982 | -0.06982 | -0.06982 | 0.00006 |
| 5 | R | -0.08716 | -0.08712 | -0.08712 | -0.08712 | -0.00004 |

Calibrated By: M. Hubbard

# Appendix B: Sample Calibration Certificate (Analog Output)

## 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 Horizontal Tilt

| | | | |
|---|---|---|---|
| Customer: | RST | Date: | 14-Sep-09 |
| Serial Number: | 00000 | Beam Length: | 2 m |
| Model: | IC6015 | Cable Length: | 30 m |
| Work Order Number: | Q000000 | Cable Type: | EL380004 |

References:
Calibration Frame E0105
CR1000 Logger 17291
Referenced Annually To National Standards.

| Wire | Description | Terminal Position |
|---|---|---|
| Red | P+ | 1 |
| Black | P- | 2 |
| Green | A+ | 3 |
| White | A- | 4 |

| Applied Angle (Deg) | Applied Angle (Sin) | Tiltmeter Output (V) | Calculated Angle (Sin) |
|---|---|---|---|
| 5 | 0.0872 | 1.689 | 0.0872 |
| 4 | 0.0698 | 1.408 | 0.0698 |
| 3 | 0.0523 | 1.128 | 0.0523 |
| 2 | 0.0349 | 0.848 | 0.0349 |
| 1 | 0.0175 | 0.568 | 0.0174 |
| 0 | 0.0000 | 0.287 | 0.0000 |
| -1 | -0.0175 | 0.008 | -0.0174 |
| -2 | -0.0349 | -0.272 | -0.0348 |
| -3 | -0.0523 | -0.552 | -0.0523 |
| -4 | -0.0698 | -0.832 | -0.0697 |
| -5 | -0.0872 | -1.113 | -0.0872 |

$\sin \alpha = \mathbf{m(V\text{-}b)}$

$m = \mathbf{0.062256}$
$b = \mathbf{0.28790}$

For A axis : Positive angle = Right side tilts down

Calibrated By: J. Chu