BluTilt User Manual

YieldPoint Inc
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**Specification**

**BluTilt** is a full 360 arcdeg triaxial tiltmeter for very precise measurement (0.001 arcdeg resolution) of changes in inclination. These instruments use a very low noise MEMS accelerometer that enables a resolution of 0.001 arcdeg with a 24hr stability of +/-0.001 arcdeg.

The **d-Tilt/BluTilt** features full (360 arcdeg) tri-axial measurement so that placement on structures does not require precise leveling. The **d-Tilt/BluTilt** can be attached to a beam or mounted directly to any structure. The **d-Tilt/BluTilt** is also available in borehole model (shown) with a 38mm OD.

The **BluTilt** has an internal logging capability that can store 30,000 readings. The results are downloaded over Bluetooth 5 to an android device. The reading interval and clock synchronization are also handled via Bluetooth 5.

The **d-Tilt** is available in several different types of package including being incorporated in a tilt beam.
**Reporting Modes for BluTilt**

<table>
<thead>
<tr>
<th>Mode</th>
<th>Mode</th>
<th>Temp</th>
<th>Channel 1</th>
<th>Channel 2</th>
<th>Channel 3</th>
<th>Channel 4</th>
<th>Channel 5</th>
<th>Mode</th>
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<tr>
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<td>T°</td>
<td>Ax</td>
<td>Ay</td>
<td>Az</td>
<td>-</td>
<td>-</td>
<td>0</td>
</tr>
<tr>
<td>Vector</td>
<td>1</td>
<td>T°</td>
<td>α</td>
<td>nₓ</td>
<td>nᵧ</td>
<td>nₗ</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>Pitch/Roll</td>
<td>2</td>
<td>T°</td>
<td>θ</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Pitch/Roll/Yaw</td>
<td>3</td>
<td>T°</td>
<td>θ</td>
<td>ψ</td>
<td>-</td>
<td>2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Tilt_mode 0 - Raw Data:**

The raw data from the accelerometer is a 20-bit result varying from 256,000 (+1g) to -256,000 (-1g). The values for the three axes, x, y and z are reported.

**Tilt_mode 1 - Vector:**

Simple vector algebra provides the means to determine the difference between two accelerometers, for example an initial reference reading (\(\mathbf{a}\)) and a current reading (\(\mathbf{b}\)). The scalar product \(\mathbf{a} \cdot \mathbf{b}\) gives the angle (\(\alpha\)) between the two vectors

\[
\mathbf{a} \cdot \mathbf{b} = (aₓ, aᵧ, aₗ) \cdot (bₓ, bᵧ, bₗ) = aₓbₓ + aᵧbᵧ + aₗbₗ = |\mathbf{a}| |\mathbf{b}| \cos \alpha \quad (1)
\]

or rearranging:

\[
\cos \alpha = \frac{aₓbₓ + aᵧbᵧ + aₗbₗ}{\sqrt{aₓ² + aᵧ² + aₗ²} \sqrt{bₓ² + bᵧ² + bₗ²}} \quad (2)
\]

The unit vector \(\mathbf{n}\) (the axis of rotation) which is normal to both \(\mathbf{a}\) and \(\mathbf{b}\), such that \(\mathbf{a}\), \(\mathbf{b}\) and \(\mathbf{n}\) form a right handed triplet.

\[
\mathbf{a} \times \mathbf{b} = (aₓ, aᵧ, aₗ) \times (bₓ, bᵧ, bₗ) = |\mathbf{a}| |\mathbf{b}| \mathbf{n} \sin \alpha \quad (3)
\]

or
\[ \mathbf{n} \sin \alpha = \left( \frac{1}{\sqrt{a_x^2 + a_y^2 + a_z^2}} \right) \left( \frac{1}{\sqrt{b_x^2 + b_y^2 + b_z^2}} \right) \begin{pmatrix} a_y b_z - a_z b_y \\ a_z b_x - a_x b_z \\ a_x b_y - a_y b_x \end{pmatrix} \] (4)

**Note:** The default reference vector (\( \mathbf{a} \)) is (0,0,1) or z-axis up. From equation 4, with this setting the z-component of \( \mathbf{n} \) is always zero (\( a_n b_y - a_y b_n = 0 \)). Physically this means that the axis of rotation lies in the horizontal plane.

**tilt_mode 2 Pitch and Roll**

As explained in AN3461 the change in orientation of the BluTilt can be described by three angles, usually referred to as pitch(\( \phi \)), roll(\( \theta \)) and yaw(\( \psi \)). The rotational matrices for each are:

\[ R_x(\phi) = \begin{pmatrix} 1 & 0 & 0 \\ 0 & \cos \phi & \sin \phi \\ 0 & -\sin \phi & \cos \phi \end{pmatrix} \] ....(5)

\[ R_y(\theta) = \begin{pmatrix} \cos \theta & 0 & -\sin \theta \\ 0 & 1 & 0 \\ \sin \theta & 0 & \cos \theta \end{pmatrix} \] ....(6)

\[ R(\psi) = \begin{pmatrix} \cos \psi & \sin \psi & 0 \\ -\sin \psi & \cos \psi & 0 \\ 0 & 0 & 1 \end{pmatrix} \] ....(7)

There are six possible orders in which the rotation matrices can be applied and the composite rotations do not commute. Typically the convention used is \( R_{xyz} \) (pitch is applied first, then roll and finally yaw).

For BluTilt, all readings are based on the earth’s gravitational field which is vertical. Rotations in the horizontal plane (yaw) cannot be measured (Note:this would require a compass). Hence even a triaxial accelerometer can only really measure tilt in two directions (typically pitch and roll).

However a triaxial accelerometer does allow for the device to be mounted in any orientation (z-up, y-up, z down etc). In total there are six orientations as shown below. The user should use the BluPoint App to send the **tilt_z_up** command to register the orientation in which the BluTilt has been attached on the structure.
Figure 6. The 6 tilt_z_up settings.

**Tilt_mode 3: Three angles.**

The ‘three angle” mode uses the scheme presented in AN 1057 from analog devices. The values vary from -180° to +180° according to the figure shown below. The formulae are:
\[
\phi = \tan^{-1}\left(\frac{a_x}{\sqrt{a_y^2 + a_z^2}}\right)
\]

\[
\theta = \tan^{-1}\left(\frac{a_y}{\sqrt{a_x^2 + a_z^2}}\right)
\]

\[
\psi = \tan^{-1}\left(\frac{\sqrt{a_x^2 + a_y^2}}{a_z}\right)
\]

When the BluTilt is aligned with z-up the three angles are zero.

**How to Setup the BluTilt using the BluPoint App.**

The setting for the BluTilt are applied using the LogPoint component. The results can be observed using the ViewPoint Component.

**Configuration Commands for BluTilt.** Each command must be preceeded by *ucom*

- `tilt` -> print raw tilt values for calibration
- `temp` -> print temperature offset
- `temp 50` -> set temperature offset
- `tilt_ref` -> print reference reading for vector product
- `tilt_ref_set` -> set current position as reference reading for vector product
- `tilt_z_up` -> print set tilt orientation
- `tilt_z_up 2` -> set tilt orientation 0 to 6
- `tilt_mode` -> print tilt mode, 0=raw, 1=vector, 2=two angle, 3=three angle
- `tilt_mode 2` -> set tilt mode

- `tilt_gain` -> print gain calibration constant for each axis
- `tilt_gain 1` 1.0025 -> set gain calibration constant on axis 1 (0=x,1=y,2=z)

- `tilt_offset` -> print offset calibration constant for each axis
- `tilt_offset 1` 2500 -> set offset calibration constant on axis 1
Step 1: Connect to the BluTilt in LogPoint

Open the LogPoint component and connect to the BluTilt of interest. In the case 200166807(YYMM66###).
Step 2: Use CUSTOM CMD to determine the tilt_mode.

Enter the **uc**om tilt_mode command (with no value) through custom command.
The response to `ucom tilt_mode`

The `tilt_mode=1` response indicates that the device is in vector mode.

**Step 3: Change the tilt_mode**

Using the CUSTOM CMD `ucom tilt_mode 2`
The message returned, *tilt_mode set to 2* indicates the change has been made.

Return to ViewPoint and connect to the BluTilt to see readings.
The two angles (Mode 2) are returned. The final csv for each reading is the tilt_mode.

**Installing a YieldPoint BluTilt – Smooth Concrete Surface**

The BluTilt will be installed using 4 Tapcon® screws

**Step 1:** Select the appropriate Tapcon screw: Standard or Stainless Steel.

*Note: Standard vs. Stainless Steel Concrete Screws*
The standard blue Tapcon® is suitable for use in indoor applications where moisture is not present. Standard blue Tapcons are coated with a blue Climaseal® coating that provides good rust resistant. The stainless steel screw is made from a 410 stainless steel and is coated with a silver Climaseal® designed for applications where added rust resistant is required.

Step 2: Using a hammer drill and a carbide tipped masonry bit meeting ANSI standards, drill four (4) holes of the correct diameter required for the diameter of the screw that is being installed.

**Note: Diameter of Hole**

Hole diameter is critical when installing Tapcons. The tolerance between the hole diameter and the diameter of the Tapcon screw being used is very tight and any variations will affect the holding values. Each diameter of concrete screw has a specific diameter carbide drill bit that must be used for installation. The 3/16” diameter screw requires a 5/32” hole and the 1/4” requires a 3/16” hole. The hole must be drilled using a hammer drill with a carbide tipped bit meeting ANSI standards. A bit that meets ANSI standards will ensure that the hole diameter will meet the requirements of the Tapcon®.

Make sure that the depth of the hole will be a minimum of 1/2” deeper than the Tapcon® concrete screw will penetrate. If possible make sure that the screw embedement length into the concrete. Best practice may vary if the concrete has rebar reinforcement that could be damaged by drilling longer holes.

**Note: Depth of Hole**

The depth of the hole that a Tapcon® concrete screw will be installed into is critical. The hole must be drilled 1/4” deeper than the screw will penetrate. This extra space at the bottom of the hole allows for an area for the dust created during the tapping process to fall without impacting installation. If enough space is not created during the drilling process, space may fill up with dust. The concrete screw taps threads into the base material and the screw could bottom out and prevent full installation. This situation may also lead the concrete screw to become bound in the hole and unable to be removed or inserted deeper.

Step 3: With a wire brush, compressed air or vacuum clean out the hole of all dust created during the drilling process.

Step 4: Coat the base of the BluTilt enclosure with either a structural adhesive or silicone.
Step 5: Use 4 Tapcon screws either 1.5” or 2” long, to tightly secure the BluTilt. Align the hole in the fixture over the hole in the base material. Insert the concrete screw through a hole in the fixture and into the hole in the base material.

Step 6: Using a wrench or drill, rotate the screw until the head of the concrete screw is tight against the surface of the fixture. Make sure that the screw is not over-torqued as this may strip the threads in the base material and cause it to spin in the hole.

Step 7: Wipe away any excess silicone or structural adhesive.

Note: Tapcon Layout

2 layouts are acceptable for the 4 tapcon screws:

OPTION 1

[Image of Tapcon Layout]

OPTION 2