Application Notes (2):

Serial Communication for DWL5000XY / DWL5500XY Tilt Sensor Module

(Version 2.0)

Table of Content

Chapter 1: RS485 Serial Communication Protocol for Single DWL5000XY / DWL5500XY Tilt Sensor

1.1 Serial Port Settings

Following are the serial port settings to enable the serial communication:

Baud Rate	115200
Parity	None
Data Bits	8
Stop Bits	1 Stop Bit
Handshake	None

1.2 Data Frame Format

Received data or the data to be transmitted out from/to tilt sensor module is followed by below format:

Source	Destination	Mode	Data
1 Byte	1 Byte	1 Byte	5 Bytes

Data Format : Hexadecimal

Source (1 Byte) : Sender command

Destination (1 Byte) : Receiver command

Mode (1 Byte) : Mode selection command

Data(5 Byte) : Received data / data to be sent out

1.3 Commands for Source and Destination

Both the source and destination have the same command as listed below:

Command	Descriptions
0x01	Sensor 1
0x02	Sensor 2
0x03	Sensor 3
0x04	Sensor 4
0x05	All sensor
0x06	Computer
0x07	Control Box

I.e Command for selection of Single Axis Mode from Computer to sensor 1:

(0x06, 0x01, 0x01, 0x00, 0x00, 0x00, 0x00, 0x00)

Source (0x06): Computer

Destination (0x01): Sensor

Mode (0x01): Single Axis Mode

1.4 Commands for Mode Selection

Following shows the command of mode selection:

Command	Descriptions
0x01	Single Axis Mode
0x02	Dual Axis Mode
0x03	Vibro Mode
0x0B	Calibration Mode
0x10	Alternate Zero in Single Axis Mode
0x13	Alternate Zero in Dual Axis Mode

The detailed information of each command is explained in the section 1.4.1 to 1.4.6.

1.4.1 Single Axis Mode

To set the tilt sensor module into Single Axis Mode:

<< (To sensor) : 0x06, 0x01, 0x01, 0x00, 0x00, 0x00, 0x00, 0x00

	Command	Descriptions
Byte 1	0x06	From computer
Byte 2	0x01	To Sensor 1
Byte 3	0x01	Single Axis Mode
Byte 4	0x00	No Applicable
Byte 5	0x00	
Byte 6	0x00	
Byte 7	0x00	
Byte 8	0x00	

Data return from tilt sensor module:

>> (From sensor) : 0x01, 0x06, 0x01, 0x4E, 0xBE, 0x02, 0x01, 0x00

	Command	Descriptions
Byte 1	0x01	From Sensor 1
Byte 2	0x06	To computer
Byte 3	0x01	Single Axis Mode
Byte 4	0x4E	Angle value
Byte 5	0xBE	
Byte 6	0x02	
Byte 7	0x01	0x01: Single Axis Position 0x02: Dual Axis Position
Byte 8	0x00	No Applicable

Following equation shows the conversion of angle from the received data:

Angle value = (((Byte 6 << 16) + (Byte 5 << 8) + Byte 4) - 180000) / 1000

Byte 7 represents the sensor position. 0x01 represents the tilt sensor is in single axis position, 0x02 represents the dual axis position.

** Please make sure Byte 7 is in Single Axis Position (0x01) when using Single Axis Mode.

1.4.2 Dual Axis Mode

To set the tilt sensor module into Dual Axis Mode:

<< (To sensor) : 0x06, 0x01, 0x02, 0x00, 0x00, 0x00, 0x00, 0x00

	Command	Descriptions
Byte 1	0x06	From computer
Byte 2	0x01	To Sensor 1
Byte 3	0x02	Dual Axis Mode
Byte 4	0x00	No Applicable
Byte 5	0x00	
Byte 6	0x00	
Byte 7	0x00	
Byte 8	0x00	

Data return from tilt sensor module:

>> (From sensor) : 0x01, 0x06, 0x02, 0x4E, 0xBE, 0x02, 0x02, 0x10

	Command	Descriptions
Byte 1	0x01	From Sensor 1
Byte 2	0x06	To computer
Byte 3	0x02	Dual Axis Mode
Byte 4	0x4E	Angle value
Byte 5	0xBE	
Byte 6	0x02	
Byte 7	0x01	0x01: Single Axis Position 0x02: Dual Axis Position
Byte 8	0x0A	0x0A: X-Axis Angle value 0x0B: Y-Axis Angle value

Following equation shows the conversion of angle from the received data:

Angle value = (((Byte 6 << 16) + (Byte 5 << 8) + Byte 4) - 1800000) / 10000

When Byte 8 equals to 0x0A, Byte 7 represents the sensor position. 0x01 represents the tilt sensor is in single axis position, 0x02 represents the dual axis position.

** When using Dual Axis Mode, please make sure Byte 7 is in Dual Axis Position (0x02) when Byte 8 equals to 0x0A.

Byte 8 represents the received Angle value is in X-Axis or Y-Axis. 0x0A represents the received angle value is X-Axis Angle value, 0x0B represents the received angle value is Y-Axis Angle value.

1.4.3 Vibro Mode

To set the tilt sensor module into Vibro Mode:

<< (To sensor) : 0x06, 0x01, 0x03, 0x00, 0x00, 0x00, 0x00, 0x00

	Command	Descriptions
Byte 1	0x06	From computer
Byte 2	0x01	To Sensor 1
Byte 3	0x03	Vibro Mode
Byte 4	0x00	No Applicable
Byte 5	0x00	
Byte 6	0x00	
Byte 7	0x00	
Byte 8	0x00	

Data return from tilt sensor module:

>> (From sensor) : 0x01, 0x06, 0x03, 0x4E, 0xBE, 0x00, 0x020, 0x00

	Command	Descriptions
Byte 1	0x01	From Sensor 1
Byte 2	0x06	To computer
Byte 3	0x02	Vibro Mode
Byte 4	0x70	Vibro value
Byte 5	0x89	
Byte 6	0x00	No Applicable
Byte 7	0x00	
Byte 8	0x10	

Following equation shows the conversion of angle from the received data:

Angle value = ((Byte 5 << 8) + Byte 4) / 10000

1.4.4 Calibration Mode

To set the tilt sensor module into Calibration Mode:

<< (To sensor) : 0x06, 0x01, 0x0B, 0xA0, 0x00, 0x00, 0x00, 0x00

<< (To sensor) : 0x06, 0x01, 0x0B, 0xB0, 0x00, 0x00, 0x00, 0x00

	Command	Descriptions
Byte 1	0x06	From computer
Byte 2	0x01	To Sensor 1
Byte 3	0x0B	0x0B: Calibration Mode
Byte 4	0x00	0xA0: Acknowledgement to sensor module to start calibration mode 0xB0: Start current calibration step
Byte 5	0x00	No Applicable
Byte 6	0x00	
Byte 7	0x00	
Byte 8	0x00	

Data return from tilt sensor module:

>> (From sensor) : 0x01, 0x06, 0x0B, 0x17, 0x1E, 0x00, 0x01, 0x5F

	Command	Descriptions
Byte 1	0x01	From Sensor 1
Byte 2	0x06	To computer
Byte 3	0x0B	0x0B: Calibration Mode
Byte 4	0x17	0x17: Current calibration step is completed
Byte 5	0x1E	Counter for calibration
Byte 6	0x00	No Applicable
Byte 7	0x01	0x01: Calibration Step 1 ready 0x02: Calibration Step 2 ready 0x03: Calibration Step 3 ready 0x04: Calibration Step 4 ready 0x05: Calibration Step 5 ready 0x06: Calibration Step 6 ready 0x07: Calibration Step 7 ready 0x08: Calibration Step 8 ready
Byte 8	0x5F	No Applicable

Please refer to 1.4.4.1 for detailed calibration steps.

1.4.4.1 Detailed Calibration Steps:

1. Please refer to Appendix 1 for proper instrument setup for calibration. Send the following command from computer to respective sensor to make sure the sensor is ready for calibration mode:

<< (To sensor): 0x06, 0x01, 0x0B, 0xA0, 0x00, 0x00, 0x00, 0x00

	Command	Descriptions
Byte 1	0x06	From computer
Byte 2	0x01	To Sensor 1
Byte 3	0x0B	Calibration Mode
Byte 4	0xA0	0xA0: Acknowledgement to sensor module
Byte 5	0x00	No Applicable
Byte 6	0x00	
Byte 7	0x00	
Byte 8	0x00	

2. Wait for response from the sensor. Once the calibration mode is activated, Byte 4 and Byte 7 show 0x0A and 0x01 respectively.

>> (From sensor): 0x01, 0x06, 0x0B, 0x0A, 0x00, 0x00, 0x01, 0x5F

	Command	Descriptions
Byte 1	0x01	From Sensor 1
Byte 2	0x06	To computer
Byte 3	0x0B	Calibration Mode
Byte 4	0x0A	Calibration mode has been activated
Byte 5	0x00	No Applicable
Byte 6	0x00	
Byte 7	0x01	0x01: Calibration Step 1 is ready
Byte 8	0x5F	No Applicable

3. Locate the sensor module as following Figure 1. The sensor is ready for user to perform calibration step 1.

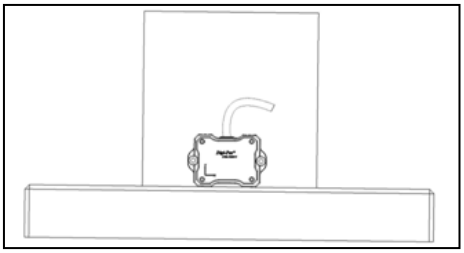


Figure 1. Tilt Sensor Module Position of Calibration Step 1

4. Send the following command from computer to respective sensor to trigger on the calibration step 1:

<< (To sensor): 0x06, 0x01, 0x0B, 0xB0, 0x00, 0x00, 0x00, 0x00

	Command	Descriptions
Byte 1	0x06	From computer
Byte 2	0x01	To Sensor 1
Byte 3	0x0B	Calibration Mode
Byte 4	0xB0	0xB0: Start Current Calibration Step
Byte 5	0x00	No Applicable
Byte 6	0x00	
Byte 7	0x00	
Byte 8	0x00	

5. Wait for response from the sensor. The sensor will broadcast the following response with Byte 5 counting from 0x00 to 0x1E. Once the value of Byte 5 is counted to 0x1E, Byte 4 value shows 0x17 from 0x0A and Byte 7 shows 0x02, calibration step 1 is completed. If byte 4 from sensor response **is not equal** to 0x17 and byte 7 response **is not equal** to 0x02 after byte 5 is counted to 0x1E, reboot (power off and power on again) the sensor module and redo the calibration process from the beginning (Step 1).

>> (From sensor): 0x01, 0x06, 0x0B, 0x17, 0x1E, 0x00, 0x02, 0x5F

	Command	Descriptions
Byte 1	0x01	From Sensor 1
Byte 2	0x06	To computer
Byte 3	0x0B	Calibration Mode
Byte 4	0x17	0x0A: Calibration is undergoing 0x17: Current calibration step is completed
Byte 5	0x1E	Counter for calibration
Byte 6	0x00	No Applicable
Byte 7	0x02	0x02: Calibration Step 2 is ready
Byte 8	0x5F	No Applicable

6. Locate the sensor module as following Figure 2. The sensor is ready for user to perform calibration step 2.

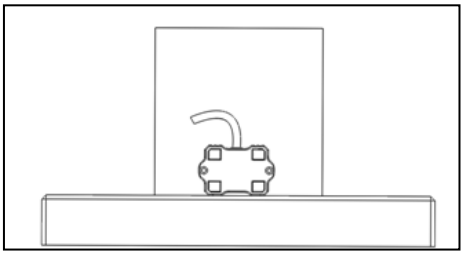


Figure 2. Tilt Sensor Module Position of Calibration Step 2

7. Send the following command from computer to respective sensor to trigger the calibration step 2:

<< (To sensor): 0x06, 0x01, 0x0B, 0xB0, 0x00, 0x00, 0x00, 0x00

	Command	Descriptions
Byte 1	0x06	From computer
Byte 2	0x01	To Sensor 1
Byte 3	0x0B	Calibration Mode
Byte 4	0xB0	Start current calibration step
Byte 5	0x00	No Applicable
Byte 6	0x00	
Byte 7	0x00	
Byte 8	0x00	

8. Wait for response from the sensor. The sensor will broadcast the following response with Byte 5 counting from 0x00 to 0x1E. Once the value of Byte 5 is counted to 0x1E, Byte 4 value should show 0x17 from 0x0A and Byte 7 shows 0x03, calibration step 2 is completed. If byte 4 from sensor response **is not equal** to 0x17 and byte 7 response **is not equal** to 0x02 after byte 5 is counted to 0x1E, reboot (power off and power on again) the sensor module and redo the calibration process from the beginning (Step 1).

>> (From sensor): 0x01, 0x06, 0x0B, 0x17, 0x1E, 0x00, 0x03, 0x5F

	Command	Descriptions
Byte 1	0x01	From Sensor 1
Byte 2	0x06	To computer
Byte 3	0x0B	Calibration Mode
Byte 4	0x17	0x0A: Calibration is undergoing 0x17: Current calibration step is completed
Byte 5	0x1E	Counter for calibration
Byte 6	0x00	No Applicable
Byte 7	0x03	0x03: Calibration Step 3 is ready
Byte 8	0x5F	No Applicable

9. For DWL5000XY model, repeat step 6 to step 8 above for Calibration Step 3 until Calibration Step 8. Please locate the sensor module in following position respectively. Once the following response is received, the calibration process is completed.

>> (From sensor): 0x01, 0x06, 0x0B, 0x0A, 0x1E, 0x00, 0x08, 0x5F

The sensor module will automatically change to dual axis mode and broadcast dual axis angle measurement (Please refer to 1.4.2 Dual Axis Mode) after the calibration process is completed.

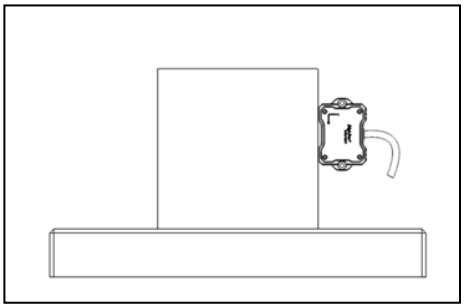


Figure 3. Tilt Sensor Module Position of Calibration Step 3

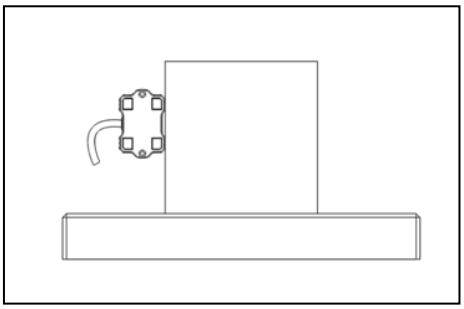


Figure 4. Tilt Sensor Module Position of Calibration Step 4

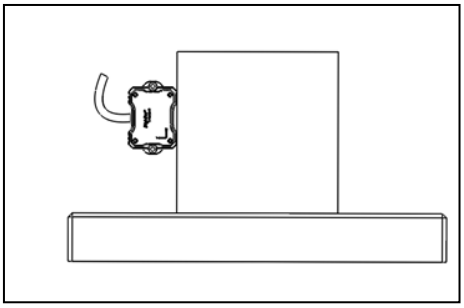


Figure 5. Tilt Sensor Module Position of Calibration Step 5

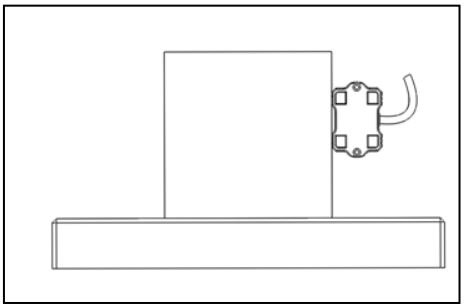


Figure 6. Tilt Sensor Module Position of Calibration Step 6

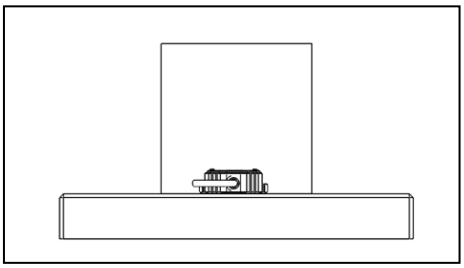


Figure 7. Tilt Sensor Module Position of Calibration Step 7

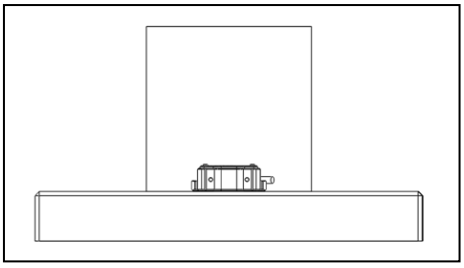


Figure 8. Tilt Sensor Module Position of Calibration Step 8

10. For DWL5500XY model, please perform only 4 steps calibration as shown in Figure 1, 2, 7, 8. The sensor module will automatically change to dual axis mode and broadcast dual axis angle measurement (Please refer to 1.4.2 Dual Axis Mode) after the calibration process is completed.

1.4.5 Alternate Zero in Single Axis Mode

To set Alternate Zero in Single Axis Mode:

<< (To sensor) : 0x06, 0x01, 0x10, 0x3C, 0x00, 0x00, 0x00, 0x00

	Command	Descriptions
Byte 1	0x06	From computer
Byte 2	0x01	To Sensor 1
Byte 3	0x10	Alternate Zero in Single Axis Mode
Byte 4	0x3C	0x3C: Set Alternate Zero 0x46: Reset Alternate Zero
Byte 5	0x00	No Applicable
Byte 6	0x00	
Byte 7	0x00	
Byte 8	0x00	

Data return from tilt sensor module:

>> (From sensor) : 0x01, 0x06, 0x10, 0x4E, 0xBE, 0x02, 0x00, 0x00

	Command	Descriptions
Byte 1	0x01	From Sensor 1
Byte 2	0x06	To computer
Byte 3	0x10	Alternate Zero in Single Axis Mode
Byte 4	0x4E	Reference angle value
Byte 5	0xBE	
Byte 6	0x02	
Byte 7	0x00	No Applicable
Byte 8	0x00	

Following equation shows the conversion of angle from the received data:

Reference angle value = (((Byte 6 << 16) + (Byte 5 << 8) + Byte 4) - 180000) / 1000

1.4.6 Alternate Zero in Dual Axis Mode

To set Alternate Zero in Dual Axis Mode:

<< (To sensor) : 0x06, 0x01, 0x13, 0x3C, 0x00, 0x00, 0x00, 0x00

	Command	Descriptions
Byte 1	0x06	From computer
Byte 2	0x01	To Sensor 1
Byte 3	0x13	Alternate Zero in Dual Axis Mode
Byte 4	0x3C	0x3C: Set Alternate Zero 0x46: Reset Alternate Zero
Byte 5	0x00	No Applicable
Byte 6	0x00	
Byte 7	0x00	
Byte 8	0x00	

Data return from tilt sensor module:

>> (From sensor) : 0x01, 0x06, 0x13, 0x4E, 0xBE, 0x02, 0x00, 0x14

	Command	Descriptions
Byte 1	0x01	From Sensor 1
Byte 2	0x06	To computer
Byte 3	0x13	Alternate Zero in Dual Axis Mode
Byte 4	0x4E	Reference angle value
Byte 5	0xBE	
Byte 6	0x02	
Byte 7	0x00	
Byte 8	0x14	0x14: X-Axis Reference Angle value 0x15: Y-Axis Reference Angle value

Following equation shows the conversion of angle from the received data:

Reference angle value = (((Byte 6 << 16) + (Byte 5 << 8) + Byte 4) - 180000) / 1000

1.4.7 Location Setting

To set location:

<< (To sensor) : 0x06, 0x05, 0x08, 0x01, 0x01, 0x00, 0x00, 0x5A

	Command	Descriptions
Byte 1	0x06	From computer
Byte 2	0x01	To Sensor 1
Byte 3	0x08	Location Setting
Byte 4	0x01	Country Index** (Please refer to Appendix 2 Country and City index)
Byte 5	0x01	City Index** (Please refer to Appendix 2 Country and City index)
Byte 6	0x00	No Applicable
Byte 7	0x00	
Byte 8	0x5A	

**User is required to select the country and city (or its nearest city/location) where device is operating.

Data return from tilt sensor module:

>> (From sensor) : 0x01, 0x06, 0x08, 0x01, 0x01, 0x00, 0x00, 0x00

	Command	Descriptions
Byte 1	0x01	From Sensor 1
Byte 2	0x06	To computer
Byte 3	0x08	Location Setting
Byte 4	0x01	Country Index
Byte 5	0x01	City Index
Byte 6	0x00	No Applicable
Byte 7	0x00	
Byte 8	0x00	

Chapter 2: Serial Communication Protocol for Control Box

2.1 Serial Port Settings

Following are the serial port settings to enable the serial communication:

Baud Rate	115200
Parity	None
Data Bits	8
Stop Bits	1 Stop Bit
Handshake	None

2.2 Data Frame Format

Received data or the data to be transmitted out from/to tilt sensor module is followed by below format:

Source	Destination	Mode	Data
1 Byte	1 Byte	1 Byte	5 Bytes

Data Format : Hexadecimal

Source (1 Byte) : Sender command

Destination (1 Byte) : Receiver command

Mode (1 Byte) : Mode selection command

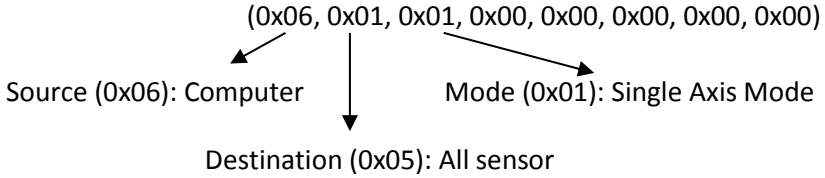
Data(5 Byte) : Received data / data to be sent out

2.3 Commands for Source and Destination

Both the source and destination have the same command as listed below:

Command	Descriptions
0x01	Sensor 1
0x02	Sensor 2
0x03	Sensor 3
0x04	Sensor 4
0x05	All sensor
0x06	Computer
0x07	Control Box

I.e Command for selection of Single Axis Mode from Computer to sensor 1:



2.4 Commands for Mode Selection

Following shows the command of mode selection:

Command	Descriptions
0x01	Single Axis Mode
0x02	Dual Axis Mode
0x03	Vibro Mode
0x0B	Calibration Mode
0x10	Alternate Zero in Single Axis Mode
0x13	Alternate Zero in Dual Axis Mode
0x20	Relay Mode

The detailed information of each command is explained in section 2.4.1 to 2.4.7.

2.4.1 Single Axis Mode

To set the tilt sensor module into Single Axis Mode:

<< (To control box): 0x06, 0x05, 0x01, 0x00, 0x00, 0x00, 0x00, 0x00

	Command	Descriptions
Byte 1	0x06	From computer
Byte 2	0x05	To All Sensors
Byte 3	0x01	Single Axis Mode
Byte 4	0x00	No Applicable
Byte 5	0x00	
Byte 6	0x00	
Byte 7	0x00	
Byte 8	0x00	

Data return from control box:

>> (From control box): 0x01, 0x06, 0x01, 0x4E, 0xBE, 0x02, 0x01, 0x00

	Command	Descriptions
Byte 1	0x01	0x01: From Sensor 1 0x02: From Sensor 2 0x03: From Sensor 3 0x04: From Sensor 4
Byte 2	0x06	To computer
Byte 3	0x01	Single Axis Mode
Byte 4	0x4E	Angle value
Byte 5	0xBE	
Byte 6	0x02	
Byte 7	0x01	0x01: Single Axis Position 0x02: Dual Axis Position
Byte 8	0x00	No Applicable

Following equation shows the conversion of angle from the received data:

Angle value = (((Byte 6 << 16) + (Byte 5 << 8) + Byte 4) - 180000) / 1000

Byte 7 represents the sensor position. 0x01 represents the tilt sensor is in single axis position, 0x02 represents the dual axis position.

** Please make sure Byte 7 is in Single Axis Position (0x01) when using Single Axis Mode.

2.4.2 Dual Axis Mode

To set the tilt sensor module into Dual Axis Mode:

<< (To control box): 0x06, 0x05, 0x02, 0x00, 0x00, 0x00, 0x00, 0x00

	Command	Descriptions
Byte 1	0x06	From computer
Byte 2	0x05	To All Sensors
Byte 3	0x02	Dual Axis Mode
Byte 4	0x00	No Applicable
Byte 5	0x00	
Byte 6	0x00	
Byte 7	0x00	
Byte 8	0x00	

Data return from control box:

>> (From control box): 0x01, 0x06, 0x02, 0x4E, 0xBE, 0x02, 0x02, 0x0A

	Command	Descriptions
Byte 1	0x01	0x01: From Sensor 1 0x02: From Sensor 2 0x03: From Sensor 3 0x04: From Sensor 4
Byte 2	0x06	To computer
Byte 3	0x02	Dual Axis Mode
Byte 4	0x4E	Angle value
Byte 5	0xBE	
Byte 6	0x02	
Byte 7	0x02	0x01: Single Axis Position 0x02: Dual Axis Position
Byte 8	0x0A	0x0A: X-Axis Angle value 0x0B: Y-Axis Angle value

Following equation shows the conversion of angle from the received data:

Angle value = (((Byte 6 << 16) + (Byte 5 << 8) + Byte 4) - 1800000) / 10000

When Byte 8 equals to 0x0A, Byte 7 represents the sensor position. 0x01 represents the tilt sensor is in single axis position, 0x02 represents the dual axis position.

** When using Dual Axis Mode, please make sure Byte 7 is in Dual Axis Position (0x02) when Byte 8 equals to 0x0A.

Byte 8 represents the received Angle value is in X-Axis or Y-Axis. 0x0A represents the received angle value is X-Axis Angle value, 0x0B represents the received angle value is Y-Axis Angle value.

2.4.3 Vibro Mode

To set the tilt sensor module into Vibro Mode:

<< (To control box): 0x06, 0x05, 0x03, 0x00, 0x00, 0x00, 0x00, 0x00

	Command	Descriptions
Byte 1	0x06	From computer
Byte 2	0x05	To All Sensors
Byte 3	0x03	Vibro Mode
Byte 4	0x00	No Applicable
Byte 5	0x00	
Byte 6	0x00	
Byte 7	0x00	
Byte 8	0x00	

Data return from control box:

>> (From control box) : 0x01, 0x06, 0x03, 0x4E, 0xBE, 0x00, 0x00, 0x00

	Command	Descriptions
Byte 1	0x01	0x01: From Sensor 1 0x02: From Sensor 2 0x03: From Sensor 3 0x04: From Sensor 4
Byte 2	0x06	To computer
Byte 3	0x03	Vibro Mode
Byte 4	0x4E	Vibro value
Byte 5	0xBE	
Byte 6	0x00	No Applicable
Byte 7	0x00	
Byte 8	0x00	

Following equation shows the conversion of angle from the received data:

Angle value = ((Byte 5 << 8) + Byte 4) / 10000

2.4.4 Calibration Mode

To set the tilt sensor module into Calibration Mode:

<< (To control box) : 0x06, 0x01, 0x0B, 0xA0, 0x00, 0x00, 0x00, 0x00

<< (To control box) : 0x06, 0x01, 0x0B, 0xB0, 0x00, 0x00, 0x00, 0x00

	Command	Descriptions
Byte 1	0x06	From computer
Byte 2	0x01	0x01: To Sensor 1 0x02: To Sensor 2 0x03: To Sensor 3 0x04: To Sensor 4
Byte 3	0x0B	0x0B: Calibration Mode
Byte 4	0x00	0xA0: Acknowledgement to sensor module to start calibration mode 0xB0: Start current calibration step
Byte 5	0x00	No Applicable
Byte 6	0x00	
Byte 7	0x00	
Byte 8	0x00	

Data return from control box:

>> (From control box) : 0x01, 0x06, 0x0B, 0x17, 0x1E, 0x00, 0x01, 0x5F

	Command	Descriptions
Byte 1	0x01	0x01: From Sensor 1 0x02: From Sensor 2 0x03: From Sensor 3 0x04: From Sensor 4
Byte 2	0x06	To computer
Byte 3	0x0B	0x0B: Calibration Mode
Byte 4	0x17	0x17: Current calibration step is completed
Byte 5	0x1E	Counter for calibration
Byte 6	0x00	No Applicable
Byte 7	0x01	0x01: Calibration Step 1 ready 0x02: Calibration Step 2 ready 0x03: Calibration Step 3 ready 0x04: Calibration Step 4 ready 0x05: Calibration Step 5 ready 0x06: Calibration Step 6 ready 0x07: Calibration Step 7 ready 0x08: Calibration Step 8 ready
Byte 8	0x5F	No Applicable

Please refer to 2.4.4.1 for detailed calibration steps.

2.4.4.1 Detailed Calibration Steps:

11. Please refer to Appendix 1 for the proper instrument setup for calibration. Send the following command from computer to control box to make sure the sensor is ready for calibration mode:

<< (To control box): 0x06, 0x01, 0x0B, 0xA0, 0x00, 0x00, 0x00, 0x00

	Command	Descriptions
Byte 1	0x06	From computer
Byte 2	0x01	0x01: To Sensor 1 0x02: To Sensor 2 0x03: To Sensor 3 0x04: To Sensor 4
Byte 3	0x0B	Calibration Mode
Byte 4	0xA0	0xA0: Acknowledgement to sensor module
Byte 5	0x00	No Applicable
Byte 6	0x00	
Byte 7	0x00	
Byte 8	0x00	

12. Wait for response from the control box. Once the calibration mode is activated, Byte 4 and Byte 7 show 0x0A and 0x01 respectively.

>> (From control box): 0x01, 0x06, 0x0B, 0x0A, 0x00, 0x00, 0x01, 0x5F

	Command	Descriptions
Byte 1	0x01	0x01: From Sensor 1 0x02: From Sensor 2 0x03: From Sensor 3 0x04: From Sensor 4
Byte 2	0x06	To computer
Byte 3	0x0B	Calibration Mode
Byte 4	0x0A	Calibration mode has been activated
Byte 5	0x00	No Applicable
Byte 6	0x00	
Byte 7	0x01	0x01: Calibration Step 1 is ready
Byte 8	0x5F	No Applicable

13. Locate the sensor module as following Figure 1. The sensor is ready for user to perform calibration step 1.

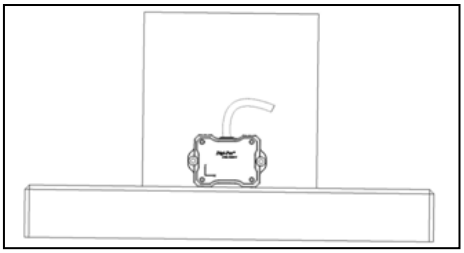


Figure 1. Position of Calibration Step 1

14. Send the following command from computer to control box to trigger on the calibration step 1:

<< (To control box): 0x06, 0x01, 0x0B, 0xB0, 0x00, 0x00, 0x00, 0x00

	Command	Descriptions
Byte 1	0x06	From computer
Byte 2	0x01	0x01: To Sensor 1 0x02: To Sensor 2 0x03: To Sensor 3 0x04: To Sensor 4
Byte 3	0x0B	Calibration Mode
Byte 4	0xB0	0xB0: Start Current Calibration Step
Byte 5	0x00	No Applicable
Byte 6	0x00	
Byte 7	0x00	
Byte 8	0x00	

15. Wait for response from the control box. The control box will broadcast the following response with Byte 5 counting from 0x00 to 0x1E. Once the value of Byte 5 is counted to 0x1E, Byte 4 value shows 0x17 from 0x0A and Byte 7 shows 0x02, calibration step 1 is completed. If byte 4 from control box response **is not equal** to 0x17 and byte 7 response **is not equal** to 0x02 after byte 5 is counted to 0x1E, reboot (power off and power on again) the control box and redo the calibration process from the beginning (Step 1).

>> (From control box): 0x01, 0x06, 0x0B, 0x17, 0x1E, 0x00, 0x02, 0x5F

	Command	Descriptions
Byte 1	0x01	0x01: From Sensor 1 0x02: From Sensor 2 0x03: From Sensor 3 0x04: From Sensor 4
Byte 2	0x06	To computer
Byte 3	0x0B	Calibration Mode
Byte 4	0x17	0x0A: Calibration is undergoing 0x17: Current calibration step is completed
Byte 5	0x1E	Counter for calibration
Byte 6	0x00	No Applicable
Byte 7	0x02	0x02: Calibration Step 2 is ready
Byte 8	0x5F	No Applicable

16. Locate the sensor module as following Figure 2. The sensor is ready for user to perform calibration step 2.

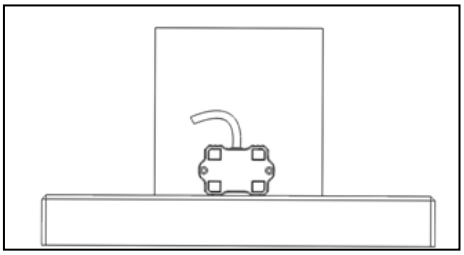


Figure 2. Position of Calibration Step 2

17. Send the following command from computer to control box to trigger the calibration step 2:

<< (To control box): 0x06, 0x01, 0x0B, 0xB0, 0x00, 0x00, 0x00, 0x00

	Command	Descriptions
Byte 1	0x06	From computer
Byte 2	0x01	0x01: To Sensor 1 0x02: To Sensor 2 0x03: To Sensor 3 0x04: To Sensor 4
Byte 3	0x0B	Calibration Mode
Byte 4	0xB0	Start current calibration step
Byte 5	0x00	No Applicable
Byte 6	0x00	
Byte 7	0x00	
Byte 8	0x00	

18. Wait for response from the control box. The control box will broadcast the following response with Byte 5 counting from 0x00 to 0x1E. Once the value of Byte 5 is counted to 0x1E, Byte 4 value should show 0x17 from 0x0A and Byte 7 shows 0x03, calibration step 2 is completed. If byte 4 from control box response **is not equal** to 0x17 and byte 7 response **is not equal** to 0x02 after byte 5 is counted to 0x1E, reboot (power off and power on again) the control box and redo the calibration process from the beginning (Step 1).

>> (From control box): 0x01, 0x06, 0x0B, 0x17, 0x1E, 0x00, 0x03, 0x5F

	Command	Descriptions
Byte 1	0x01	0x01: From Sensor 1 0x02: From Sensor 2 0x03: From Sensor 3 0x04: From Sensor 4
Byte 2	0x06	To computer
Byte 3	0x0B	Calibration Mode
Byte 4	0x17	0x0A: Calibration is undergoing 0x17: Current calibration step is completed
Byte 5	0x1E	Counter for calibration
Byte 6	0x00	No Applicable
Byte 7	0x03	0x03: Calibration Step 3 is ready
Byte 8	0x5F	No Applicable

19. For DWL5000XY model, repeat step 6 to step 8 above for Calibration Step 3 until Calibration Step 8. Please locate the sensor module in following position respectively. Once the following response is received, the calibration process is completed.

>> (From control box): 0x01, 0x06, 0x0B, 0x0A, 0x1E, 0x00, 0x08, 0x5F

The sensor module will automatically change to dual axis mode and broadcast dual axis angle measurement (Please refer to 1.4.2 Dual Axis Mode) after the calibration process is completed.

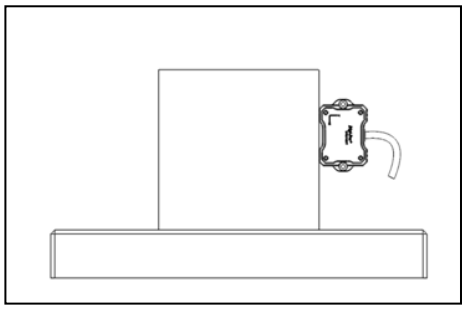


Figure 3. Position of Calibration Step 3

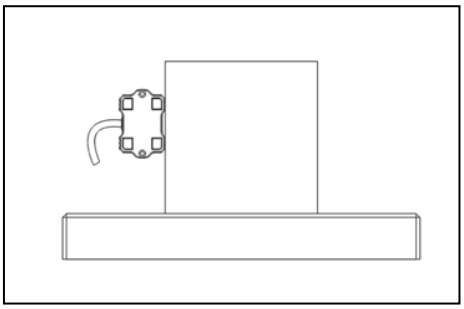


Figure 4. Position of Calibration Step 4

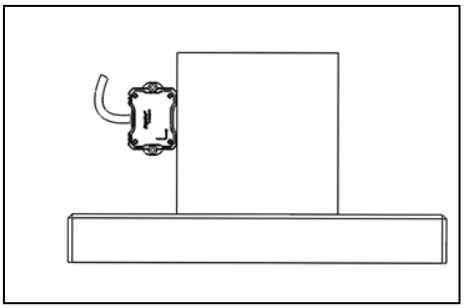


Figure 5. Position of Calibration Step 5

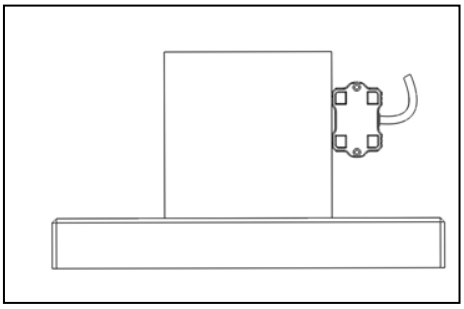


Figure 6. Position of Calibration Step 6

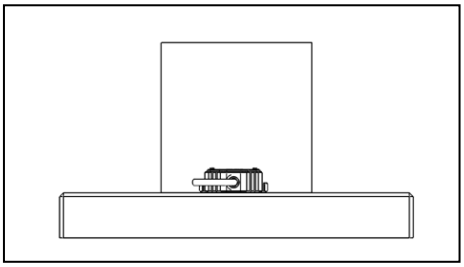


Figure 7. Position of Calibration Step 7

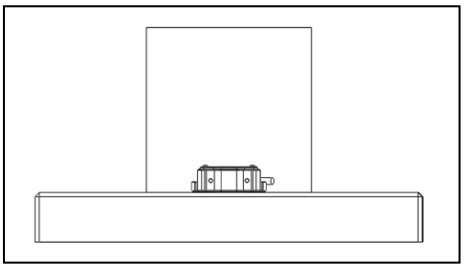


Figure 8. Position of Calibration Step 8

20. For DWL5500XY model, please perform only 4 steps calibration as shown in Figure 1, 2, 7, 8. The sensor module will automatically change to dual axis mode and broadcast dual axis angle measurement (Please refer to 2.4.2 Dual Axis Mode) after the calibration process is completed.

2.4.5 Alternate Zero in Single Axis Mode

To set Alternate Zero in Single Axis Mode:

<< (To control box): 0x06, 0x05, 0x10, 0x3C, 0x00, 0x00, 0x00, 0x00

	Command	Descriptions
Byte 1	0x06	From computer
Byte 2	0x05	To All Sensors
Byte 3	0x10	Alternate Zero in Single Axis Mode
Byte 4	0x3C	0x3C: Set Alternate Zero 0x46: Reset Alternate Zero
Byte 5	0x00	No Applicable
Byte 6	0x00	
Byte 7	0x00	
Byte 8	0x00	

Data return from control box:

>> (From control box): 0x01, 0x06, 0x10, 0x4E, 0xBE, 0x02, 0x00, 0x00

	Command	Descriptions
Byte 1	0x01	0x01: From Sensor 1 0x02: From Sensor 2 0x03: From Sensor 3 0x04: From Sensor 4
Byte 2	0x06	To computer
Byte 3	0x10	Alternate Zero in Single Axis Mode
Byte 4	0x4E	Reference angle value
Byte 5	0xBE	
Byte 6	0x02	
Byte 7	0x00	No Applicable
Byte 8	0x00	

Following equation shows the conversion of angle from the received data:

Reference angle value = (((Byte 6 << 16) + (Byte 5 << 8) + Byte 4) - 180000) / 1000

2.4.6 Alternate Zero in Dual Axis Mode

To set Alternate Zero in Dual Axis Mode:

<< (To control box): 0x06, 0x05, 0x13, 0x3C, 0x00, 0x00, 0x00, 0x00

	Command	Descriptions
Byte 1	0x06	From computer
Byte 2	0x05	To All Sensors
Byte 3	0x13	Alternate Zero in Dual Axis Mode
Byte 4	0x3C	0x3C: Set Alternate Zero 0x46: Reset Alternate Zero
Byte 5	0x00	No Applicable
Byte 6	0x00	
Byte 7	0x00	
Byte 8	0x00	

Data return from control box:

>> (From control box): 0x01, 0x06, 0x13, 0x4E, 0xBE, 0x02, 0x00, 0x14

	Command	Descriptions
Byte 1	0x01	0x01: From Sensor 1 0x02: From Sensor 2 0x03: From Sensor 3 0x04: From Sensor 4
Byte 2	0x06	To computer
Byte 3	0x13	Alternate Zero in Dual Axis Mode
Byte 4	0x4E	Reference angle value
Byte 5	0xBE	
Byte 6	0x02	
Byte 7	0x00	
Byte 8	0x14	0x14: X-Axis Reference Angle value 0x15: Y-Axis Reference Angle value

Following equation shows the conversion of angle from the received data:

Reference angle value = (((Byte 6 << 16) + (Byte 5 << 8) + Byte 4) - 1800000) / 10000

2.4.7 Relay Mode

To trigger the relay output:

<< (To control box): 0x06, 0x05, 0x20, 0xCC, 0xBB, 0xBB, 0xBB, 0x00

	Command	Descriptions
Byte 1	0x06	From computer
Byte 2	0x05	To All Sensors
Byte 3	0x20	Relay Mode
Byte 4	0xCC	0xCC: Set Relay1 Output to Normally Open (NO) 0xBB: Set Relay1 Output to Normally Closed (NC)
Byte 5	0xBB	0xCC: Set Relay2 Output to Normally Open (NO) 0xBB: Set Relay2 Output to Normally Closed (NC)
Byte 6	0xBB	0xCC: Set Relay3 Output to Normally Open (NO) 0xBB: Set Relay3 Output to Normally Closed (NC)
Byte 7	0xBB	0xCC: Set Relay4 Output to Normally Open (NO) 0xBB: Set Relay4 Output to Normally Closed (NC)
Byte 8	0x00	No Applicable

Data return from control box:

>> (From control box): 0x07, 0x06, 0x20, 0xAA, 0xBB, 0xBB, 0xBB, 0x00

	Command	Descriptions
Byte 1	0x07	From Control Box
Byte 2	0x06	To computer
Byte 3	0x20	Relay Mode
Byte 4	0xAA	0xAA: Relay1 Output is set to Normally Open (NO) 0xBB: Relay1 Output is set to Normally Closed (NC)
Byte 5	0xBB	0xAA: Relay2 Output is set to Normally Open (NO) 0xBB: Relay2 Output is set to Normally Closed (NC)
Byte 6	0xBB	0xAA: Relay3 Output is set to Normally Open (NO) 0xBB: Relay3 Output is set to Normally Closed (NC)
Byte 7	0xBB	0xAA: Relay4 Output is set to Normally Open (NO) 0xBB: Relay4 Output is set to Normally Closed (NC)
Byte 8	0x00	No Applicable

2.4.8 Location Setting

To set location:

<< (To sensor) : 0x06, 0x05, 0x08, 0x01, 0x01, 0x00, 0x00, 0x5A

	Command	Descriptions
Byte 1	0x06	From computer
Byte 2	0x05	To All Sensors
Byte 3	0x08	Location Setting
Byte 4	0x01	Country Index** (Please refer to Appendix 2 Country and City index)
Byte 5	0x01	City Index** (Please refer to Appendix 2 Country and City index)
Byte 6	0x00	No Applicable
Byte 7	0x00	
Byte 8	0x5A	

**User is required to select the country and city (or its nearest city/location) where device is operating.

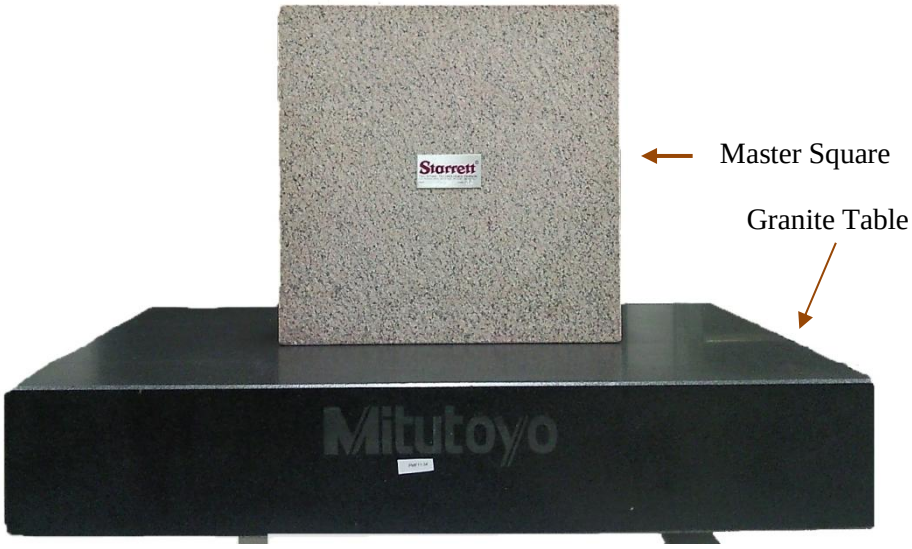
Data return from tilt sensor module:

>> (From sensor) : 0x01, 0x06, 0x08, 0x01, 0x01, 0x00, 0x00, 0x00

	Command	Descriptions
Byte 1	0x01	0x01: From Sensor 1 0x02: From Sensor 2 0x03: From Sensor 3 0x04: From Sensor 4
Byte 2	0x06	To computer
Byte 3	0x08	Location Setting
Byte 4	0x01	Country Index
Byte 5	0x01	City Index
Byte 6	0x00	No Applicable
Byte 7	0x00	
Byte 8	0x00	

APPENDIX 1: USER CALIBRATION

Calibration Instruments:



	DWL5000XY	DWL5500XY
Granite Table	Grade AA (Levelled to ≤10 arcsec)	Grade AA (Levelled to ≤1.0 arcsec)
Master Square	Flatness : ≤ 2.0µm Perpendicularity: ≤ 2.0µm Parallelism: ≤ 2.0µm	Not Required
Number of Calibration Steps	8	4

** Allow sufficient time for device to warm up and stabilise after turning on the device.

** Hold the device firmly and do not move the device during calibration process.

APPENDIX 2: Country and City Index

Country	Country Index	City	City Index
Argentina	0x01	Tucuman	0x01
Argentina	0x01	Cordoba	0x02
Argentina	0x01	Rosario	0x03
Argentina	0x01	Buenos Aires	0x04
Argentina	0x01	Bahia Blanca	0x05
Argentina	0x01	Trelew	0x06
Argentina	0x01	Sarmiento	0x07
Australia	0x02	Darwin	0x01
Australia	0x02	Cairns	0x02
Australia	0x02	Salta	0x03
Australia	0x02	Alice Springs	0x04
Australia	0x02	Maryborough	0x05
Australia	0x02	Brisbane	0x06
Australia	0x02	Perth	0x07
Australia	0x02	Kempsey	0x08
Australia	0x02	Canverra	0x09
Australia	0x02	Sydney	0x0A
Australia	0x02	Albury	0x0B
Australia	0x02	Melbourne	0x0C
Australia	0x02	Hobart	0x0D
Austria	0x03	--	0x01
Bangladesh	0x04	--	0x01
Belgium	0x05	--	0x01
Bolivia	0x06	--	0x01
Brazil	0x07	Nova Lisboa	0x01
Brazil	0x07	Belem	0x02
Brazil	0x07	Brazilia	0x03
Brazil	0x07	Colombo	0x04
Brazil	0x07	Luanda	0x05
Brazil	0x07	Goiania	0x06
Brazil	0x07	Salvador	0x07
Brazil	0x07	Caravelas	0x08
Brazil	0x07	Sao Paulo	0x09
Brazil	0x07	Victoria	0x0A
Brazil	0x07	Rio de Janeiro	0x0B
Brazil	0x07	Porto Alegre	0x0C
Brazil	0x07	Pelotas	0x0D
Canada	0x08	Whitehorse	0x01
Canada	0x08	Fort McMurray	0x02
Canada	0x08	Prince George	0x03
Canada	0x08	Edmonton	0x04
Canada	0x08	Winnipeg	0x05
Canada	0x08	Saskatoon	0x06
Canada	0x08	Vancouver	0x07

Canada	0x08	Victoria	0x08
Canada	0x08	Calgary	0x09
Canada	0x08	Ottawa	0x0A
Canada	0x08	Quebec	0x0B
Canada	0x08	Montreal	0x0C
Canada	0x08	Toronto	0x0D
Chile	0x09	Puerto Montt	0x01
Chile	0x09	Santiago	0x02
Chile	0x09	Valparaiso	0x03
Chile	0x09	Arica	0x04
China	0x0A	Beijing	0x01
China	0x0A	Tianjin	0x02
China	0x0A	Shanghai	0x03
China	0x0A	Wuhan	0x04
China	0x0A	Dongguan	0x05
China	0x0A	Shantou	0x06
China	0x0A	Guangzhou	0x07
China	0x0A	Shenzhen	0x08
Colombia	0x0B	Bogota	0x01
Colombia	0x0B	Popayan	0x02
Colombia	0x0B	Medellin	0x03
Colombia	0x0B	Cali	0x04
Costa Rica	0x0C	--	0x01
Croatia	0x0D	--	0x01
Czech Republic	0x0E	--	0x01
Denmark	0x0F	Korsor	0x01
Denmark	0x0F	Copenhagen	0x02
Denmark	0x0F	Middelfart	0x03
Denmark	0x0F	Torshavn	0x04
Dominica	0x10	--	0x01
Ecuador	0x11	--	0x01
Egypt	0x12	--	0x01
El Salvador	0x13	--	0x01
Estonia	0x14	--	0x01
Finland	0x15	--	0x01
France	0x16	Lille	0x01
France	0x16	Paris	0x02
France	0x16	Strasbourg	0x03
France	0x16	Nantes	0x04
France	0x16	Lyon	0x05
France	0x16	Bordeaux	0x06
France	0x16	Marseille	0x07
France	0x16	Toulouse	0x08
Germany	0x17	Flensburg	0x01
Germany	0x17	Rostock	0x02
Germany	0x17	Hamburg	0x03
Germany	0x17	Bremen	0x04
Germany	0x17	Berlin	0x05
Germany	0x17	Hanover	0x06

Germany	0x17	Bielefeld	0x07
Germany	0x17	Essen	0x08
Germany	0x17	Leipzig	0x09
Germany	0x17	Dresden	0x0A
Germany	0x17	Cologne	0x0B
Germany	0x17	Frankfurt	0x0C
Germany	0x17	Nuremberg	0x0D
Germany	0x17	Munich	0x0E
Germany	0x17	Stuttgart	0x0F
Germany	0x17	Freiburg	0x10
Greece	0x18	--	0x01
Guatemala	0x19	--	0x01
Hong Kong	0x1A	--	0x01
Hungary	0x1B	--	0x01
India	0x1C	New Delhi	0x01
India	0x1C	Lucknow	0x02
India	0x1C	Ahmadabad	0x03
India	0x1C	Kolkata	0x04
India	0x1C	Mumbai	0x05
India	0x1C	Hyderabad	0x06
India	0x1C	Bangalore	0x07
India	0x1C	Chennai	0x08
Indonesia	0x1D	--	0x01
Ireland	0x1E	--	0x01
Israel	0x1F	--	0x01
Italy	0x20	Rome	0x01
Italy	0x20	Milan	0x02
Italy	0x20	Trieste	0x03
Japan	0x21	Wakkanai	0x01
Japan	0x21	Asahikawa	0x02
Japan	0x21	Sapporo	0x03
Japan	0x21	Aomori	0x04
Japan	0x21	Tohoku	0x05
Japan	0x21	Akita	0x06
Japan	0x21	Morioka	0x07
Japan	0x21	Sendai	0x08
Japan	0x21	Niigata	0x09
Japan	0x21	Mito	0x0A
Japan	0x21	Kanazawa	0x0B
Japan	0x21	Tokyo	0x0C
Japan	0x21	Yokohama	0x0D
Japan	0x21	Shizuoka	0x0E
Japan	0x21	Nagoya	0x0F
Japan	0x21	Kyoto	0x10
Japan	0x21	Osaka	0x11
Japan	0x21	Kobe	0x12
Japan	0x21	Okayama	0x13
Japan	0x21	Hiroshima	0x14
Japan	0x21	Matsuyama	0x15

Japan	0x21	Fukuoka	0x16
Japan	0x21	Kochi	0x17
Japan	0x21	Oita	0x18
Japan	0x21	Kumamoto	0x19
Japan	0x21	Kagoshima	0x1A
Japan	0x21	Naha	0x1B
Kenya	0x22	--	0x01
Korea	0x23	--	0x01
Latvia	0x24	--	0x01
Lithuania	0x25	--	0x01
Luxembourg	0x26	--	0x01
Macedonia	0x27	--	0x01
Malaysia	0x28	--	0x01
Mexico	0x29	Mexico City	0x01
Mexico	0x29	Puebla	0x02
Mexico	0x29	Guadalajara	0x03
Mexico	0x29	Leon	0x04
Mexico	0x29	San Luis Potosi	0x05
Mexico	0x29	Acapulco	0x06
Mexico	0x29	Torreon	0x07
Mexico	0x29	Monterrey	0x08
Mexico	0x29	Merida	0x09
Mexico	0x29	Cancun	0x0A
Mexico	0x29	Chihuahua	0x0B
Mexico	0x29	Ciudad Juarez	0x0C
Mexico	0x29	Mexicali	0x0D
Morrocco	0x2A	Marrakech	0x01
Morrocco	0x2A	Casablanca	0x02
Morrocco	0x2A	Tangier	0x03
Netherland	0x2B	--	0x01
New Zealand	0x2C	Auckland	0x01
New Zealand	0x2C	Wellington	0x02
New Zealand	0x2C	Christchurch	0x03
New Zealand	0x2C	Dunedin	0x04
Norway	0x2D	Oslo	0x01
Norway	0x2D	Soknedal	0x02
Norway	0x2D	Skogn	0x03
Norway	0x2D	Bodo	0x04
Norway	0x2D	Trondheim	0x05
Norway	0x2D	Sorkjosen	0x06
Norway	0x2D	Tromso	0x07
Norway	0x2D	Hammerfest	0x08
Panama	0x2E	--	0x01
Paraguay	0x2F	--	0x01
Peru	0x30	Arequipa	0x01
Peru	0x30	Talara	0x02
Peru	0x30	Lima	0x03
Philippines	0x31	--	0x01
Poland	0x32	--	0x01

Portugal	0x33	--	0x01
Puerto Rico	0x34	--	0x01
Romania	0x35	--	0x01
Russia	0x36	--	0x01
Saudi Arabia	0x37	--	0x01
Singapore	0x38	--	0x01
Spain	0x39	Rota	0x01
Spain	0x39	Mallorca	0x02
Spain	0x39	Barcelona	0x03
Sri Lanka	0x3A	--	0x01
Sweden	0x3B	Adak	0x01
Sweden	0x3B	Helsingborg	0x02
Sweden	0x3B	Venige	0x03
Sweden	0x3B	Apelviksaas	0x04
Sweden	0x3B	Hogstorp	0x05
Sweden	0x3B	Stockholm	0x06
Sweden	0x3B	Svinesund	0x07
Switzerland	0x3C	Basel	0x01
Switzerland	0x3C	Zurich	0x02
Switzerland	0x3C	Berne	0x03
Switzerland	0x3C	Lucerne	0x04
Switzerland	0x3C	Chur	0x05
Switzerland	0x3C	Lausanne	0x06
Switzerland	0x3C	Geneva	0x07
Taiwan	0x3D	--	0x01
Thailand	0x3E	Bangkok	0x01
Thailand	0x3E	Songkhla	0x02
Turkey	0x3F	--	0x01
United Kingdom	0x40	Perth	0x01
United Kingdom	0x40	Glasgow	0x02
United Kingdom	0x40	Manchester	0x03
United Kingdom	0x40	Nottingham	0x04
United Kingdom	0x40	Birmingham	0x05
United Kingdom	0x40	London	0x06
United Kingdom	0x40	Bristol	0x07
United Kingdom	0x40	Sunderland	0x08
United States	0x41	Seattle	0x01
United States	0x41	Portland	0x02
United States	0x41	Boston	0x03
United States	0x41	Detroit	0x04
United States	0x41	Chicago	0x05
United States	0x41	New York	0x06
United States	0x41	Indianapolis	0x07
United States	0x41	Washington DC	0x08
United States	0x41	Columbus	0x09
United States	0x41	Saint Louis	0x0A
United States	0x41	Kansas City	0x0B
United States	0x41	San Francisco	0x0C
United States	0x41	Nashville	0x0D

United States	0x41	Charlotte	0x0E
United States	0x41	Memphis	0x0F
United States	0x41	Oklahoma City	0x10
United States	0x41	Denver	0x11
United States	0x41	Las Vegas	0x12
United States	0x41	San Diego	0x13
United States	0x41	Atlanta	0x14
United States	0x41	Dallas	0x15
United States	0x41	Los Angeles	0x16
United States	0x41	Phoenix	0x17
United States	0x41	Jacksonville	0x18
United States	0x41	Houston	0x19
United States	0x41	Fort Worth	0x1A
United States	0x41	Austin	0x1B
United States	0x41	Orlando	0x1C
United States	0x41	San Antonio	0x1D
United States	0x41	El Paso	0x1E
United States	0x41	Miami	0x1F
Uruguay	0x42	--	0x01
Venezuela	0x43	--	0x01
Vietnam	0x44	--	0x01