Model 6191

Tilt Box (Biaxial MEMS)

Instruction Manual

GEOKON

Document Revision: Initial | Release date: 12/18/25

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1. INTRODUCTION

The GEOKON Model 6191 MEMS Tilt Box is designed for permanent long-term monitoring of changes in tilt of structures such as dams, embankments, foundation walls, retaining walls, buildings, and the like. The unit is mounted to a structure and measures tilt in biaxial directions, in vertical (Model 6191) or horizontal (Model 6191-H) orientations. Angular changes of as little as two arc seconds can be detected.

The unit consists of a MEMS (Micro-Electro-Mechanical Systems) tilt sensor, installed inside an IP66-rated aluminum housing. An internal thermistor is installed to measure temperature.

This unit uses industry standard Modbus® Remote Terminal Unit (RTU) protocol to communicate. It employs an RS-485 (half duplex) electrical interface, recognized for its prevalence, simplicity, and success as a robust, industrial physical layer.

Tilt boxes can mounted interdependently. They can also be combined in a string via a four-wire bus digital cable during field installation. A cable from the independent tilt box, or the endmost tilt box when utilized as a string, connects the unit (s) to the chosen readout (PC, data logger, SCADA system, etc.). The tilt box is designed to be used with GEOKON Model 02-313P9LTD cable, meant for digital applications. This cable can be ordered at a pre-determined length and prepped at the factory. Alternatively, cable can be bought in bulk spools and prepped in the field (see Appendix C).

The output consists of calibrated tilt readings and temperatures for each tilt box. For strings, this information can be easily imported into MS Excel, or any data visualization software, without the need to convert raw data into engineering units.

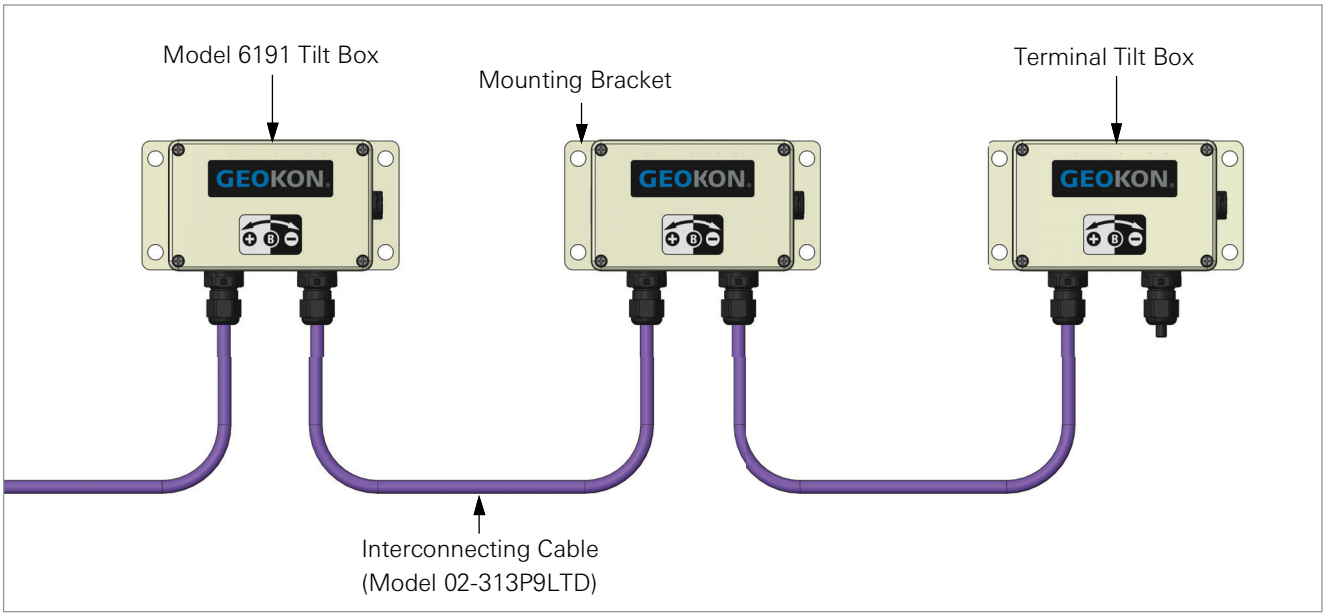

FIGURE 1: *String of Interconnected Model 6191 MEMS Tilt Boxes*

2. INSTALLATION

2.1 PRELIMINARY TESTS

The tilt box can be tested prior to installation. To do this, a Model 02-313P9LTD cable must be connected to the tilt box as outlined in Section 2.3. Follow the steps below to perform the test.

1. Connect the readout to a compatible data logger (refer to Section 3) or PC with the Model 8020-38 Addressable Bus Converter (refer to Section 3.2.2).
2. Hold the unit in a vertical position and observe the reading. The unit must be held in a steady position. The observed reading should be stable. The temperature indicated on the readout should be close to ambient.
3. Check electrical continuity using an ohmmeter. Resistance between any conductor and the shield or the case should exceed two megaohms.

If any of these preliminary tests fail, refer to Section 4 for troubleshooting.

2.2 TILT BOX INSTALLATION

GEOKON will pre-address each unit when a set of tilt boxes are purchased as a string. During installation, confirm that the tilt boxes are placed in numerical order from lowest to highest. The terminal tilt box will be set as the highest number.

Note: Sudden changes in temperature will cause both the structure and the tilt box to undergo transitory physical changes, which will show up in the readings. For best results, the unit should be shielded from direct sunlight.

1. Place the tilt box on the mounting surface.
2. Align the unit so that the A and B axis are aligned with the direction of the expected tilt.
3. Use the holes in the mounting plate to mark where the drop-in anchors will be installed and perform the following:
    a. Using a hammer drill, drill four 9.5 mm x 32 mm (3/8 x 1 1/4 inch) holes. Clean the holes thoroughly, blowing out with compressed air if possible.
    b. Insert the drop-in anchors, threaded side up, into the holes. Insert the Model TLS-208 Setting Tool into the anchors and strike with a hammer until the lip of the anchor touches the lip of the setting tool.
    c. Thread the supplied 1/4-20 threaded anchor rods into the anchors.
    d. Slide the tilt box over the anchor rods until it is flush with the mounting surface.
    e. Secure the 1/4-20 nuts onto the anchor rods.

2.3 CONNECTING THE READOUT/INTERCONNECTING CABLE

1. Remove the four screws in the cover.

Caution! Screws are not retained in the cover, take care to not lose them.

2. Loosen the nut on the cable fitting and remove the black plastic dowel.
3. Slide the connecting cable through the cable gland nut and fitting.
4. Connect the cable leads to the IN terminal block by pulling up on an orange tab, inserting the lead, and then pressing down on the tab. Refer to Table 1 for wiring. Repeat for the OUT terminal block if connecting to another tilt box unit.

Important! To prevent a short circuit, do not allow the cable leads to touch each other during or after wiring.

RS-485 Port Wiring		
Position	**Conductor Color**	**Description**
485+	WHITE	RS-485 Data+
485-	GREEN	RS-485 Data-
12V	RED	12 V Bus
GND	BLACK	Bus Ground
SHD	BARE	Analog Ground (Shield)

TABLE 1: *RS-485 Port Wiring*

5. Pull gently on each conductor to ensure it is secure.
6. Tighten the cable gland nut until it firmly grips the outer jacket of the cable. The cable gland nut must be properly tightened to prevent water entry. Do not overtighten, as this might strip the plastic threads.
7. Pull gently on the cable to ensure it is held in place by the cable gland.
8. If installing a string, repeat these steps until all units are connected.
9. The **last** device in the string should have a jumper applied on location J3. For tilt box units using the RS-485 OUT port to connect to another unit, remove the termination jumper as shown below.

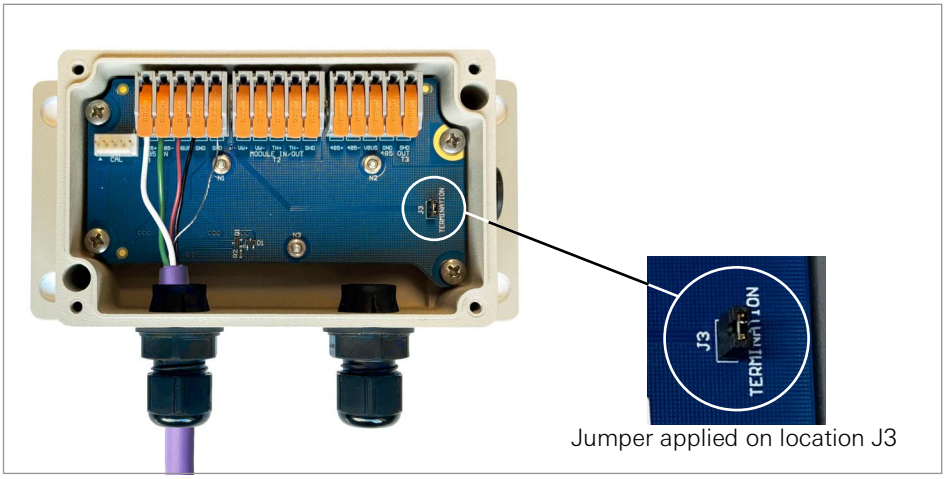

FIGURE 2: *Terminator Jumper Location*

10. Seal the Enclosures
    a. Make sure the cover gasket and the mating ridge on the enclosure are clean and that the gasket is properly seated inside the groove on the cover. Place the cover on the unit.
    b. Tighten the cover screws slowly. If using an electric screwdriver, **do not fully tighten screws**. Preform the final tightening by hand. Work in a diagonal pattern.

Note: Make sure any unused cable glands are sealed with the provided dowel and the cable gland nut is tightened.

3. TAKING READINGS

3.1 COMPATIBLE DATA LOGGERS

GEOKON can provide several data logger options. Devices compatible with this product are listed below. For further details and instruction consult the corresponding Manual(s) at geokon.com/Dataloggers.

DATA LOGGERS:

- **GeoNet Series**

  The GeoNet Data Logger series is designed to collect and transfer data from vibrating wire, RS-485, and analog instruments. GeoNet offers a wide range of telemetry options, including LoRa, cellular, Wi-fi, satellite, and local. Data loggers can work together to operate in a network configuration, or be used separately as standalone units. GeoNet devices arrive from the factory ready for deployment and may commence with data acquisition in minutes.

  Data is transferred to a secure cloud-based storage platform where it can be accessed through the GEOKON OpenAPI. Industry leading data visualization software, such as the free GEOKON Agent Software, can be used with the OpenAPI for data viewing and reporting. Data loggers without network capabilities are also available.

- **8600 Series**

  The Model 8600 Series Data Logger is designed to support the reading of a large number of GEOKON instruments for various unattended data collection applications using GEOKON Model 8032 Multiplexers. Weatherproof packaging allows the unit to be installed in field environments where inhospitable conditions prevail. The Nema 4X enclosure also has a provision for locking to limit access to responsible field personnel.

3.2 READING WITH RS-485 COMMUNICATIONS

3.2.1 DATA LOGGER CONNECTION

If your data logger has built-in RS-485 communications, connect the Model 6191 Tilt Box using a cable and the wiring diagram below. (The data logger must have the appropriate port available.)

Data Logger Connection	Conductor Color	6191 Connection (RS-485 IN)
12 V (OUT)	RED	12 V
485+	WHITE	485+
485-	GREEN	485-
GND	BLACK	GND
SHIELD	BARE	SHD

TABLE 2: *Data Logger with built-in RS-485 Conversion to Model 6191 Tilt Box Wiring Table*

If your data logger does not have built-in RS-485 communications, the converter below can be utilized.

3.2.2 MODEL 8020-38 ADDRESSABLE BUS CONVERTER

The Model 8020-38 allows a Model 6191 Tilt Box to be connected to personal computers, readouts, data loggers without built-in RS-485 communications, and programmable logic controllers. The converter acts as a bridge using the TTL or USB protocols between readers and the GEOKON RS-485-enabled tilt box units.

FIGURE 3: *Model 8020-38 RS-485 to TTL/USB Converter*

If utilizing a Model 8020-38 to connect the Model 6191 Tilt Box to a data logger, wire the connections as shown in both tables below. (The data loggers must have the appropriate port available.)

Data Logger Connection	Conductor Color	8020-38 Connection
V+	RED	12 V (IN)
TX	WHITE	TX (IN)
RX	GREEN	RX (OUT)
GND	BLACK	GND
SHD	BARE	SHIELD

TABLE 3: *Data Logger to Model 8020-38 Wiring*

8020-38 Connection	Conductor Color	6191 Connection (RS-485 IN)
12 V (OUT)	RED	12 V
485+	WHITE	485+
485-	GREEN	485-
GND	BLACK	GND
SHIELD	BARE	SHD

TABLE 4: *Model 8020-38 to 6191 Tilt Box Wiring*

For more information, please refer to the Model 8020-38 Instruction Manual (geokon.com/8020-38).

3.3 MEASURING TEMPERATURES

Although the temperature dependence of the MEMS sensor is very small, the structure being monitored is usually affected by temperature to some degree; therefore, the sensor temperature should always be recorded, and efforts should be made to obtain readings when the tilt box and structure are at thermal equilibrium. The best time for this tends to be in the late evening or early morning hours.

Each tilt box is equipped with a thermistor for reading temperature. This enables temperature-induced changes in tilt to be distinguished from tilts due to other sources. The thermistor gives a varying resistance output as the temperature changes.

3.4 ENVIRONMENTAL FACTORS

Since the purpose of the tilt sensor is to monitor site conditions, factors that may affect these conditions should be observed and recorded. Seemingly minor effects may have real influence on the behavior of the structure being monitored and may give an early indication of potential problems. Some of these factors include, but are not limited to, blasting, rainfall, tidal or reservoir levels, excavation and fill levels and sequences, traffic, temperature and barometric changes, changes in personnel, nearby construction activities, seasonal changes, etc.

4. TROUBLESHOOTING

Maintenance and troubleshooting is confined to periodic checks of the cable connections. The sensors are sealed and there are no user serviceable parts.

Should difficulties arise, consult the list of possible solutions shown below. Visit geokon.com/Technical-Support for additional troubleshooting help.

SYMPTOM: TILT BOX READINGS ARE UNSTABLE OR FAIL TO READ

- ☐ Is there a source of electrical noise nearby? Most probable sources of electrical noise are motors, generators, and antennas.
- ☐ Check all cable connections, terminals, and plugs.
- ☐ Make sure the shield drain wire is connected to ground whether using a portable readout or data logger.
- ☐ Does the readout work with another tilt box? If not, the readout may have a low battery or be malfunctioning.
- ☐ Water may have penetrated the interior of the tilt box or connectors. Contact GEOKON.

APPENDIX A. SPECIFICATIONS

A.1 MODEL 6191 MEMS TILT BOX SPECIFICATIONS

Range[1]	±90°
Resolution[2]	±0.00025° (±0.004 mm/m)
Precision[3]	±0.0075° (±0.13 mm/m)
Nonlinearity	±0.005° across ±30° range (±0.09 mm/m)
Temperature Dependent Uncertainty	±0.001° across ±5° angular range (±0.016 mm/m) ±0.0016° across ±15° angular range (±0.026 mm/m) ±0.0026° across ±30° angular range (±0.042 mm/m)
Operating Temperature	-40 to +80 °C
Temperature Accuracy	±0.5 °C
Power Supply Voltage	12 VDC ±20%
Operating Current[4]	12 mA ±1 mA
Standby Current[4]	2 mA ±0.1 mA
Maximum Supply Current[5]	500 mA
Interface	RS-485
Protocol	MODBUS
Baud Rate	115,200 bps
Ingress Protection	IP66
Tilt Box Material	Aluminum with Powder Coat finish
Mounting Bracket Material	Aluminum
Weight	0.9 kg (1.98 lb)

TABLE 5: *Model 6191 MEMS Tilt Box Specifications*

Note:

[1] Calibrated Range: ±30°.

[2] 99% confidence interval (i.e. 99 out of 100 individual readings fall within this tolerance).

[3] Includes random walk (changes between consecutive readings that have no discernible cause) and seismic noise during testing.

[4] Operating and standby current are for each individual unit in a string.

[5] Per entire String.

A.2 PARTS LIST

6191	Addressable MEMS Tilt Box, for Vertical Installation
6191-H	Addressable MEMS Tilt Box, for Horizontal Installation
TLS-208	Rawl Setting tool, 1/4"
02-313P9LTD	Interconnecting Cable

TABLE 6: *Model 6191 Parts List*

APPENDIX B. UNIT DIMENSIONS

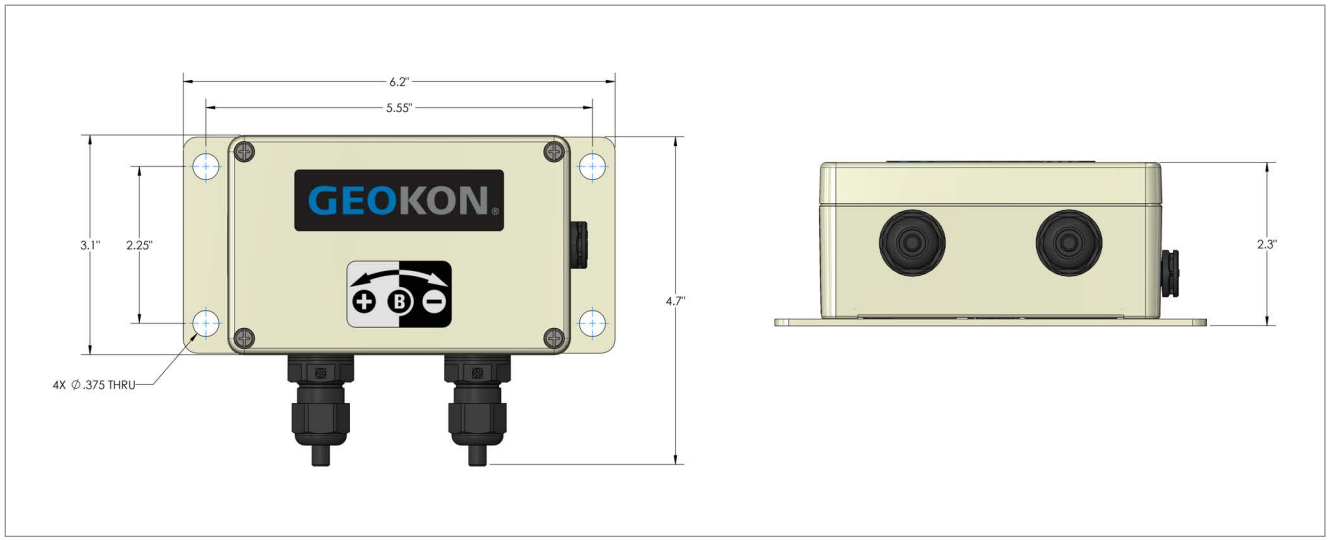

FIGURE 4: *Tilt Box Dimensions*

APPENDIX C. CABLE PREPARATION

When purchasing a bulk spool of GEOKON Model 02-313P9LTD digital cable, the cable end preparation must be performed in the field.

1. On both ends of the cable, trim off 4" of the jacket, exposing the five individual wires.
2. Remove excess insulation.
3. Strip all wires 9.5 mm (3/8”).
4. The ends of the wires should be as neat as possible (e.g., twisted or tinned), to ease insertion into the tabs of the tilt box or data logger.

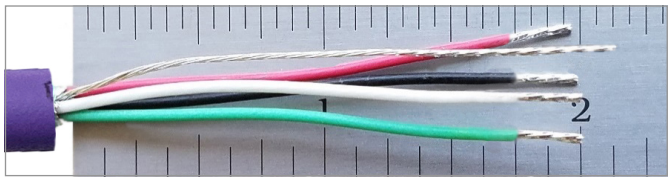

FIGURE 5: *Cable Prepped*

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