User Guide

TCM2.5 & TCM2.6

PNI
SENSOR CORPORATION

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About the TCM2.5/2.6

Thank you for purchasing the TCM2.5/2.6. The TCM2.5 has been designed as a drop-in replacement for PNI Corporation's TCM2 family of products. The TCM2.5 uses the same board size, interface connector, and RS-232 protocol as the TCM2 modules to allow for ease of integration with existing systems. The TCM2.6 has all the features of the TCM2.5, but is about half the size and weight and has an extended temperature range.

The TCM2.5/2.6 are the choice for existing applications that require compatibility with PNI Corporation's TCM2 family of products.

The TCM2.5/2.6 integrates 3-axis magnetic field sensing, 2-axis tilt sensing, and compass heading into a single module. Advantages include compatibility with existing systems, low power consumption, large signal noise immunity under all conditions, and a large magnetic field measurement range.

The TCM2.5/2.6 combines PNI Corporation's patented Magneto-Inductive (MI) sensors and measurement circuit technology with a MEMS accelerometer for unparalleled cost effectiveness and performance. The MI sensor changes inductance by 100% over its field measurement range. This variable inductance property is used in a cost and space efficient ASIC (PNI 11096) which incorporates a temperature and noise stabilized oscillator/counter circuit which is inherently free from offset drift.

The TCM2.5/2.6's advantages make it suitable for many applications, including:

- Remote terrestrial antenna direction indicators
- Side-scan sonar
- ROV, AUV control
- Survey equipment
- Robotics systems
- Vehicle detection

With its many potential applications, the TCM2.5/2.6 provides a command set designed with flexibility and adaptability in mind. Many parameters are user-programmable, including reporting units, a wide range of sampling configurations, output damping, and more. We hope the TCM2.5/2.6 will help you to achieve the greatest performance from your target system. Thank you for selecting the TCM2.5/2.6.

Installation

This section describes how to configure, program, and control the TCM2.5/2.6 in your host system. To install the TCM2.5/2.6 into your system, follow these steps:

- **Make electrical connections to the TCM2.5/2.6**
- **Evaluate the TCM2.5/2.6 using the included TCM Studio Program**
- **Choose a mounting location**
- **Mechanically mount the TCM2.5/2.6**
- **Perform user calibration**

Electrical Connections

Included with the TCM2.5/2.6 Interface Kit is a cable to allow for the unit to be connected to your host system. On one end of the cable is the connector needed to mate with the TCM2.5/2.6. The cable's wires are color coded as indicated below.

PNI also has a 6-foot cable with a DB9 connector attached. Contact PNI Corporation for purchasing information.

Table 1: TCM2.5/2.6 PIN Descriptions

PIN	Wire Color	TCM2.5 PIN Description	PIN	Wire Color	TCM2.6 PIN Description
1	Orange	Vsupply (5 V regulated)	1	Black	Power Ground
2	Red	Vsupply (6 to 18 V unregulated)	2	Gray	NC
3	Black	Power Ground	3	Green	RS232 Ground
4	Blue	RxD (RS-232) -5 to 5V	4	Orange	NC
5	Yellow	TxD (RS-232) -5 to 5V or -12 to 12V	5	Violet	NC
6	White	RTS, Wake from Sleep	6	Brown	NC
7	Green	Data Ground	7	Yellow	TxD
8	Brown	NC	8	Blue	RxD
9	Purple	NC	9	Red	5 VDC
10	Gray	Data Ground			

RS-232 Serial Communication Interface

Parameters   8 data bits, 1 start bit, 1 stop bit, no parity, flow control none

Baud Rate   300 to 115200

Communicating with the TCM2.5/2.6

Once the TCM2.5/2.6 is powered up and the RS232 connection is made with one of the PC's COM ports, you may begin exchanging ASCII serial data with the TCM2.5/2.6. The most direct means is to run any modem or terminal emulation software. Specify the COM port that you have the TCM2.5/2.6 connected to and set the baud rate to the same baud rate of the TCM2.5/2.6. The default baud rate for the TCM2.5/2.6 is 9600. Remember that the TCM2.5/2.6 does not echo characters by default, so you may wish to select the echo output option in your terminal emulation program or press <Ctrl> e on the keyboard.

TCM Studio – Evaluation Program

The TCM2.5/2.6 evaluation software communicates with the TCM2.5/2.6 through the COM port of your PC. It provides an easy to use interface, so that instead of issuing command codes manually, you can use buttons, check boxes, and dialog boxes. It reads the Binary responses of the TCM2.5/2.6 output strings and formats its sensor data into labeled and easy-to-read data fields. The program also includes the ability to log and save the outputs of the TCM2.5/2.6 to a file. All of this is so that you may begin to learn the capabilities of the TCM2.5/2.6 while using the TCM Studio program's more friendly interface.

To install the TCM Studio program onto a **Windows** system:

1. Drag the "TCM Studio.exe" to the working directory of your computer.
2. Move the Quesa plug-in (Quesa.dll) into either the Windows System or System32 folder.   Quesa is the OpenGL rendering engine and the 3D Model of the TCMStudio will not run without it.
   - For Windows 2000/NT copy to: /WinNT/System32 folder
   - For Windows XP copy to: /Windows/System32 folder

To Install the TCM Studio program onto a **Mac OSX** system:

1. Drag the "TCM Studio" to the working directory of your computer.
2. Move the Quesa plug-in (Quesa) to: /Library/CFMSupport

Hardware Setup:

1. Connect the unit to a serial port of the PC via the included cable. (A USB to Serial Adapter can be used; Keyspan USA-19QW was tested.)
2. Supply power

[Connection Tab]

Initial Connection:

1. Select the serial port the unit is plugged into.
2. Select 9600 as the baud rate (default).
3. Click on the **<Connect>** button.
4. Once a connection is made the "Connected" light will turn green.

Change Baud Rate:

1. Select new baud rate for the module.
2. Select same baud rate for the computer.
3. Click on the **<Connect>** button.

Change Modules:

Once connection has been made, the TCM Studio will remember the last settings. Any time a module is switched out, clicking on the **<Connect>** button once the new module is attached will reestablish a connection as long as the module baud rate is the same as the previous unit.

[Configuration Tab]

North Reference:

Magnetic: When the "Magnetic" radio button is selected, heading will be relative to Magnetic North.

True: When the "True" radio button is selected, heading will be relative to True North. To use North Heading in "True" mode, the declination needs to be set in the "Declination" window.

Options:

Use to select halting continuous output by sending a single "h" command.

Damping:

Enabled: Use to select if the filter (damping) is to be used

Time Const: Use to select 4, 8, 16, or 32 samples and apply the values to a filter prior to calculating the heading. These filters allow for a much more stable reading, but can make the acquisition of the data by the program slower. The default setting is 8.

Reading Units:

- **Compass:** Use to select either Degrees or Mils as the unit of measure.
- **Inclinometer:** Use to select either Degrees or Mils as the unit of measure.
- **Temperature:** Use to select either Celsius or Fahrenheit as the unit of   measure.

Default:

This button will set the TCM2.5/2.6 module back to the factory default settings for the parameters shown on the screen.

Note: This is similar, but with less parameters, to the *factory* command.

[Calibration Tab]

Start (stop)

Toggle button to begin and end calibration

Calibration Procedure:

1. Click on the **<Start>** button to begin.
2. Begin rotating the TCM2.5/2.6 in a circle while applying pitch and roll to the unit. The unit will have the appearance of a "wobbling top" as it is moved through the calibration routine.
3. Turn the TCM2.5/2.6 around at least twice changing the pitch and roll as much as possible.
4. Each turn should take longer than 30 seconds. The turn does not need to be a perfect circle. In the calibration mode, the TCM2.5/2.6 is trying to take as many different data points as possible to determine the magnetic anomalies. The more pitch and roll points you give it, the better it is able to determine the vertical magnetic fields. If possible, apply as close to a   ± 90° pitch and ± 90° roll. Doing so will improve the quality of the calibration. Do not worry about exceeding the tilt range of the unit.
5. Once two complete rotations have been completed, click on the **<Stop>** button to finish the calibration.

Score

The TCM2.5/2.6 provides feedback on calibration through the calibration score, which has the following format: "...HnVnMn.n...."

The first two numbers in the calibration score, HnVn, respectively describe the quality of the calibration for the horizontal component and vertical component of the host system's local magnetic field. Higher numbers reflect higher quality. The highest possible score is a "9". The factors that contribute to a good score for Hn and Vn are as follows:

- a good, magnetically quiet location was chosen for the user calibration procedure.
- the magnetic environment is stable; there are no large sources of changing fields.
- the calibration data points included changes in system heading and inclination to allow for proper measurement of the horizontal and vertical field vectors.
- there are no significant soft-iron distortion effects.

The last number in the score, Mn.n, describes the magnitude of local field. Larger numbers denote strong local fields. Small local fields are preferable, since less correction will be necessary, and they utilize less of the magnetometers' dynamic range. A magnitude score greater than 30 indicates strong magnetic fields at the TCM2.5/2.6 location; you should consider alternative mounting locations. Any score less than 10 is very good.

> **Note:** The calibration score values mostly provide a qualitative estimation. For example, a good score would be H9V9Mn.n. A poor score as anything less than H9V9Mn.n. A poor V score generally indicates that you need to tilt more during the calibration. A poor H score indicates you did not turn two full circles or that you turned too quickly.

6. If the calibration is not sufficient then click on the **<Start>** button and begin the calibration again.

Clear:

This button will clear the user calibration in the unit. Once selected, the unit will revert back to its factory calibration.

[Test Tab]

Current Reading:

Once the **<GO>** button is selected the unit will begin outputting Heading, Pitch and Roll information. Selecting the **<Stop>** button or changing tabs will halt the output of the unit.

3D Model:

The helicopter will follow the movement of the attached module and give a clear representation of the module's orientation.

[Data Logger Tab]

1. Select the data to log in the "Data" window.
2. Use **Shift-Ctrl-Click** and **Ctrl-Click** to select multiple items.
3. Click on the **<GO>** button to start logging; click the **<STOP>** button to stop logging.
4. Click on the **<Export>** button to save the data to a file.
5. Click on the **<Clear>** button to clear the data from the window.

[System Log Tab]

Export:

Select the **<Export>** button to save the system log to a file.

Where to install the TCM2.5/2.6

The TCM2.5/2.6's magnetometers' wide dynamic range and its sophisticated calibration algorithms allow it to operate in many environments. For optimal performance however, you should mount the TCM2.5/2.6 with the following considerations in mind:

The TCM2.5/2.6's magnetometers should not saturate

The TCM2.5/2.6 can be calibrated for large static magnetic fields. However, each axis of the TCM2.5/2.6's magnetometers has a maximum dynamic range of ±80 µT (this can be read using the TCM Studio with by going to the datalogger and selecting "Magnetometer Output); if the total field exceeds this value for any axis, the TCM2.5/2.6 will not give accurate heading information. When mounting the TCM2.5/2.6, consider the effect of any sources of magnetic fields in the local environment that when added to the earth's field may saturate the TCM2.5/2.6's sensors. For example, large masses of ferrous metals such as transformers and vehicle chassis, large electric currents, permanent magnets such as electric motors, and so on.

Locate the TCM2.5/2.6 away from local sources of changing magnetic fields

It is not possible to calibrate for changing magnetic anomalies. Thus, for greatest accuracy, keep the TCM2.5/2.6 away from sources of local magnetic anomalies that will change with time; for instance, electric equipment that will be turned on and off or nearby ferrous bodies that will be changing positions. Make sure the TCM2.5/2.6 is not mounted close to cargo or payload areas that may be loaded with large sources of local magnetic fields.

The TCM2.5/2.6 should be mounted in a physically stable location

Choose a location that is isolated from excessive shock, oscillation, and vibration.

Mechanically mounting the TCM2.5/2.6

Refer to the TCM2.5/2.6 Dimensional Specification later in this manual for the TCM2.5/2.6 board dimensions and the orientation of the reference frame.

The TCM2.5/2.6 is factory calibrated with respect to the mounting holes, as shown below, thus it must be aligned within the host system with respect to these mounting holes, not the board edges.
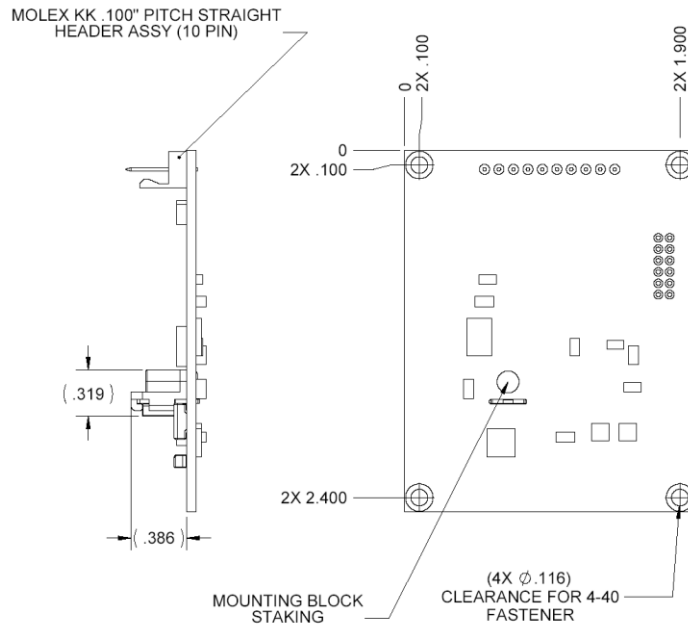
Figure 1: TCM2.5 Mounting Diagram
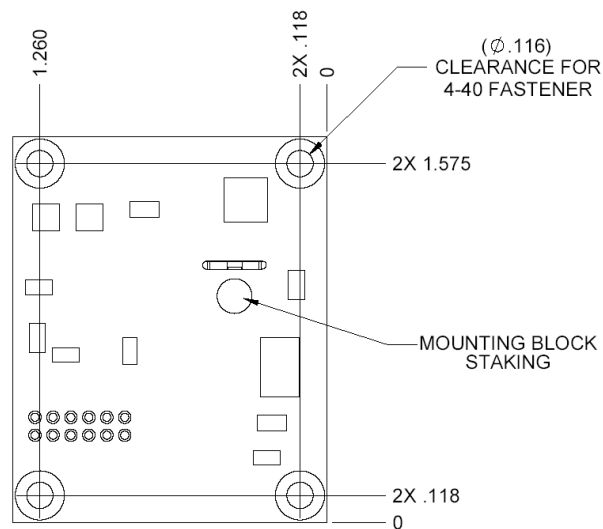
Figure 2: TCM2.6 Mounting Diagram

Using the TCM2.5/2.6

RS232 Data Output Word

The TCM2.5/2.6 sends an "output word" in ASCII across the RS232 serial link when issued the **s?** (Single Output Word) command, or when in **go** (Continuous Sampling) mode. This data output word may be configured by the user for the desired format and configuration. You may select either NMEA 0183, or TCM2 standard output word formats, with the **sdo=** (Set RS-232 Output Word) command.

NMEA 0183 Format

The TCM2.5/2.6 can be configured to conform to the NMEA (National Maritime Electronics Association) 0183 specification, which describes a standard RS232 bus format for exchange of a variety of navigation information (GPS, radar, compass, and so on). In the NMEA output format, only compass heading information is available. Inclinometer, magnetometer, thermometer data and the distortion detection warning are all unavailable.

`$HCHDM,<compass>,M*checksum<cr><lf>`   !for magnetic heading

For example,

`$HCHDM,182.3,M*checksum<cr><lf>`   !for magnetic heading = 182.3 °

The checksum value is the result of XOR'ing the ASCII bytes between the '$' and '*' characters. This one byte value is reported in the output word by two ASCII characters representing two hex digits, with the most significant nibble first. For example, "`...*A3<cr><lf>`" indicates that the output word has a decimal checksum value of 163.

TCM2.5/2.6 Standard Output

The TCM2.5/2.6 standard output format may be configured to provide all of the sensor data parameters available, or only those parameters required.

```
$C<compass>P<pitch>R<roll>X<Bx>Y<By>Z<Bz>T<temp>E<error
code>*checksum<cr><lf>
```

View the sections covering the commands: **c?** (Compass Update), **m?** (Magnetometer Update), **i?** (Inclinometer Update), **t?** (Temperature Update) for detailed information regarding the character formatting and resolution of the values for each of the data parameters in the output word.

Example

The TCM2.5/2.6 will return the following:

```
$C328.3P28.4R-12.4X55.11Y12.33Z-18.43T22.3E001*checksum<cr><lf>
```

under the following conditions:

- compass heading = 328.3 ° (true or magnetic, depending on configuration)
- pitch = 28.4 °
- roll = -12.4 °
- Bx = 55.11µT (x-component of magnetic field)
- By = 12.33 µT (y-component of magnetic field)
- Bz = -18.43 µT (z-component of magnetic field)
- Temperature = 22.3 ° (F/C depending on configuration)
- E001 = Distortion flag is raised–magnetic anomaly nearby

Any parameters not enabled are not included in the output word.

For example:

```
$C328.3T22.3*checksum<cr><lf>
```
!for compass and thermometer information only.

The checksum value is computed and reported identically to that for the NMEA output format.

Command Syntax

There are three types of commands you may issue to the TCM2.5/2.6:

- User Configuration Parameter commands which set user-definable parameters.

- Request for Data commands which query the TCM2.5/2.6 for data or for the stored value of user-definable parameters.

- Action commands which prompt the TCM2.5/2.6 to perform a specific action.

All commands must be followed with a <cr>, or <cr><lf>. The <lf> characters are ignored by the TCM2.5/2.6, but are supported to allow compatibility with a variety of terminals.

Commands are case sensitive.

Programming Conventions

Set TCM2.5/2.6 user parameters: <parameter>=<value><cr>

Query TCM2.5/2.6 data (parameter or sensor values):   <parameter>?<cr>

Action command: <command><cr>

Detailed descriptions of all commands are in the "Command List" and a command summary is shown in "Command List Quick Reference"

Data Transmission

The TCM2.5/2.6 will transmit data across the RS-232 interface in response to input commands, and will also transmit data output words automatically when placed in continuous output mode. The response to the various commands is as follows:

Input Command	TCM2.5/2.6 Response
Valid parameter-setting commands	:<cr><lf>
Valid action command	varies according to command
Valid Parameter query commands	:<parameter>=<value><cr><lf>
Invalid, or unrecognized command	:E<code><cr><lf>
Valid sensor query command	varies according to command

The ':' character signifies a successfully identified and executed command.

Table 2: Input Command Responses

Error Codes

Error codes are given in the output word immediately before the checksum output indicated by the letter "E" followed by three ASCII characters representing hexadecimal digits (for example, ASCII F equals hexadecimal value F, or decimal value 15). Each error condition corresponds to one bit within one of the hexadecimal digits. When the error condition exists, that bit will be set equal to 1 in the error code transmitted by the TCM2.5/2.6. The error conditions and their corresponding bit locations are listed below. Refer to **Table 4: Common Error Codes** for a list of the most common error codes.

Table 3: Bit Locations of Error Conditions

1st ASCII Character	
Bit 3 (MSB)	EEPROM1 error
Bit 2	EEPROM2 error
Bit 1	Reserved for future use (always 0)
Bit 0 (LSB)	Reserved for future use (always 0)
2nd ASCII Character	
Bit 3 (MSB)	Reserved for future use (always 0)
Bit 2	Command parameter invalid
Bit 1	Reserved for future use (always 0)
Bit 0 (LSB)	Command invalid or not supported on current TCM
3rd ASCII Character	
Bit 3 (MSB)	Reserved for future use (always 0)
Bit 2	Magnetometer out of range
Bit 1	Inclinometer out of range
Bit 0 (LSB)	Reserved for future use (always 0)

Table 4: Common Error Codes

Error Code	Description
E002	Inclinometer out of range
E004	Magnetometer out of range
E006	Magnetometer out of range + Inclinometer out of range
E010	Command invalid or not available
E040	Command parameter invalid
E050	Command invalid or not available + Command parameter invalid
E400	EEPROM2 error [a]
E800	EEPROM1 error [a]
EC00	EEPROM2 error + EEPROM1 error [a]

a. Indicates that the TCM2.5/2.6 EEPROM has been corrupted. Contact PNI for assistance.

Description of Error Conditions

Command Parameter Invalid – contains an invalid or out of range value.

Command invalid or not available on current model of TCM2 – is not recognized by the TCM2.5/2.6. The syntax is incorrect, or you have entered a command which is not supported by the TCM model you are using.

Inclinometer out of range – the inclinometer sensor is detecting an attitude that is outside of its operational range of maximum pitch and roll. When this error flag is raised, compass and inclinometer output data should be disregarded.

Magnetometer out of range – the magnetometer sensors are detecting an ambient magnetic field that exceeds the maximum field measurement range of the magnetometer in any of the three axes.

Compass Operating Modes

Standby Mode

The TCM2.5/2.6 is in Standby mode when you issue an h (**Halt**) command or ax (**Warm Reboot**). You may configure and verify the TCM2.5/2.6's user parameters in the Standby mode (set sampling rate, filter parameters, and so on.) You may also query the TCM2.5/2.6 for single updates of compass heading, pitch and roll, magnetic field strength, and temperature.

Sampling in Standby Mode

You can receive data from the TCM2.5/2.6 sensors from the **h** (Halt Continuous Sampling, Enter Standby) mode. You may wish to do this if you are manually operating the TCM2.5/2.6 for evaluation purposes, or if the TCM2.5/2.6 only needs to be polled periodically. With the TCM2.5/2.6 in the Standby mode, you can query sensor data by either issuing single parameter updates with commands like **c?** (Compass Update), **m?** (Magnetometer Update) or you can receive output word updates by issuing the **s?** (Single Update of Output Word) command. The output word may be configured as previously described in "TCM2.5/2.6 Standard Output" to provide either NMEA formatted compass data, or the TCM2.5/2.6 Standard output word, which presents any combination of TCM2.5/2.6 sensor data that you wish to receive. The single parameter updates allow you to immediately query any sensor data.

Continuous Sampling Mode

After configuring the TCM2.5/2.6 in the Standby mode, issue the **go** command to place the TCM2.5/2.6 into Continuous Sampling mode. In this mode, the TCM2.5/2.6 samples its sensors, processes, and outputs this sensor data at a rate determined by the SP parameter, default is 8 Hz.

User Calibration

All compasses can perform well in a controlled environment, where the ambient magnetic field consists solely of the earth's field. In most practical applications, however, an electronic compass module will be mounted in a host system such as a vehicle that can contain large sources of local magnetic fields: ferrous metal chassis, transformer cores, electrical currents, and permanent magnets in electric motors.

By performing the user calibration procedure, you allow the TCM2.5/2.6 to identify the major sources of these local magnetic anomalies and subsequently cancel out their effects when measuring the earth's magnetic field for computing compass headings. When you perform the user calibration procedure, the TCM2.5/2.6 takes a series of magnetic field measurements. It analyzes these total field measurements in order to identify the components that are created by the earth's field, which is the desired signal, from those components that are generated by the local environment, which we wish to subtract out.

The end goal of the procedure for the TCM2.5/2.6 is to have an accurate measurement of the static three-dimensional magnetic field vector generated by its host system at its mounting location. This vector is subsequently subtracted out of run-time field measurement to yield the resultant earth's field vector.

One major benefit from the TCM2.5/2.6's triaxial magnetometer/triaxial inclinometer system configuration is its ability to compensate for distortion effects in all orientations throughout its usable tilt range. As we have mentioned, a compass must measure the local field vector generated by the host system at its current position within the system in order to accurately calibrate. Because the TCM2.5/2.6's magnetometer is strapped-down, or fixed with respect to its host system, this local field vector does not change as the host system's attitude changes, allowing the TCM2.5/2.6 to accurately compensate in all pitch and roll orientations. Gimbaled fluxgates, for instance, are unable to provide accurate calibration in non-level orientations because its magnetometers, being gimbaled, change position with respect to the host system as attitude changes. This presents a different local distortion field than that measured during calibration.

Multipoint Calibration (mpcal)

Key Points

- Tilt as much as possible during the calibration. This allows the compass to take full advantage of the 3-axis magnetometer.
- Move slowly, take as much as 30 seconds to complete a circle. You are trying to get an even sampling of the magnetic field over as many headings and tilts as possible.
- Pay attention to the calibration score. Performance will be compromised if you accept a low score.
- If you get a poor calibration, clear it before making a new calibration.

Procedure

1. Clear any previous calibration by sending `cc`.

2. Enable multipoint calibration by sending `mpcal=e`.

3. Put the TCM2.5/2.6 into continuous mode by sending `go`.

4. Begin rotating the TCM2.5/2.6 in a circle while applying pitch and roll to the unit. The unit will have the appearance of a "wobbling top" as it is moved through the calibration routine.
    - Turn the TCM2.5/2.6 around at least twice changing the pitch and roll as much as possible. Each turn should take longer than 30 seconds. The turn does not need to be a perfect circle.
    - In the calibration mode, the TCM2.5/2.6 is trying to take as many different data points as possible to determine the magnetic anomalies.
    - The more pitch and roll points you give it, the better it is able to determine the vertical magnetic fields.
    - Apply as close to a ± 90° pitch and ± 90° roll as possible. Doing so will improve the quality of the calibration. Do not worry about exceeding the tilt range of the unit.

5. Halt the TCM2.5/2.6 by sending `h` if **halt=e**; or `h` `<return>` if **halt=d**.

6. Finish the calibration by sending `mpcal=d`.

7. Check the calibration score by sending `lc?`.
    - If the calibration score is not satisfactory, repeat the calibration process

<u>*Interpreting the Calibration Score*</u>

The TCM2.5/2.6 provides feedback on calibration through the calibration score, which has the following format: "...HnVnMn.n...."

The first two numbers in the calibration score, HnVn, respectively describe the quality of the calibration for the horizontal component and vertical component of the host system's local magnetic field. Higher numbers reflect higher quality. The highest possible score is a "9". The factors that contribute to a good score for Hn and Vn are as follows:

- a good, magnetically quiet location was chosen for the user calibration procedure.

- the magnetic environment is stable; there are no large sources of changing fields.

- the calibration data points included changes in system heading and inclination to allow for proper measurement of the horizontal and vertical field vectors.

- there are no significant soft-iron distortion effects.

The last number in the score, Mn.n, describes the magnitude of local field. Larger numbers denote strong local fields. Small local fields are preferable, since less correction will be necessary, and they utilize less of the magnetometers' dynamic range. A magnitude score greater than 30 indicates strong magnetic fields at the TCM2.5/2.6 location; you should consider alternative mounting locations. Any score less than 10 is very good.

Note: The calibration score values mostly provide a qualitative estimation. For example, a good score would be H9V9Mn.n. A poor score as anything less than H9V9Mn.n. A poor V score generally indicates that you need to tilt more during the calibration. A poor H score indicates you did not turn two full circles or that you turned too quickly.

Soft Iron Effects

The TCM2.5/2.6 can calibrate for hard iron effects, or local fields that can be modeled as static fields such as those created by permanent magnets. Hard iron distortions are significant in most systems. There is another class of iron effects, soft iron, that are an amplification of magnetic fields created by highly permeable materials, such as ferrous metals. The TCM2.5/2.6 does not compensate for soft iron effects. Soft iron effects, however, are generally far weaker than hard iron effects in most systems, and can be more readily defeated by choosing a suitable location to mount your compass module.

In some systems, however, it may be difficult to avoid large masses of ferrous metal that may create non-trivial soft iron effects, such as an armor plate in a tracked vehicle. In these instances, try to locate the module as far away from the ferrous metals as possible. Soft iron effects decrease with distance by an inverse square relation so even modest separation can be effective.

Other Limitations

As discussed, the TCM2.5/2.6 models local disturbances as a static magnetic vector contribution to the earth's field. Any local fields, which are not static, will create errors. You cannot calibrate for anomalies that are not fixed with respect to the compass. For example, you may know that the TCM2.5/2.6 will be used in close proximity to other vehicles. You cannot calibrate for the effects of these other vehicles, as they will be moving with respect to the TCM2.5/2.6. This is a limitation universal to all compasses. Consider, therefore, the TCM2.5/2.6's position relative to any potential sources of field that will not be static: magnetic cargo or payloads that may be placed in close proximity, fans or other electrical equipment that may be turned on and off, and so on.

The TCM2.5/2.6 can calibrate for any environment that creates a magnetic field that does not exceed the dynamic range of its magnetometers.

Declination Value

Declination, also called magnetic variation, is the difference between true and magnetic north, relative to a point on the earth. It is measured in degrees east or west of true north. Correcting for declination is accomplished by storing the correct declination angle, and then changing the heading reference from magnetic north to true north. Declination angles vary throughout the world, and change very slowly over time. For the greatest possible accuracy, go to the National Geophysical Data Center web page below to get the declination angle based on your latitude and longitude: `http://www.ngdc.noaa.gov/cgi-bin/seg/gmag/fldsnth1.pl`

Pitch and Roll

The TCM2.5/2.6 uses accelerometers to measure the orientation of the compass with respect to gravity. Since the compass also measures the complete magnetic field, the TCM2.5/2.6 can correct for the tilt of the compass to provide an accurate heading.

The TCM2.5/2.6 utilizes Euler angles as the method for determining accurate orientation. This method is the same used in aircraft orientation where the outputs are Heading (Yaw), Pitch and Roll. When using Euler angles pitch and roll are defined as the angle rotated around an axis through the center of the fuselage; pitch is rotation around an axis through the center of the wings. These two rotations are independent of each other since the rotation axes rotate with the plane body.

For the TCM2.5/2.6 a *positive pitch* is when the *front edge of the board is rotated upward* and a *positive roll* is when the *right edge of the board is rotated downward.*
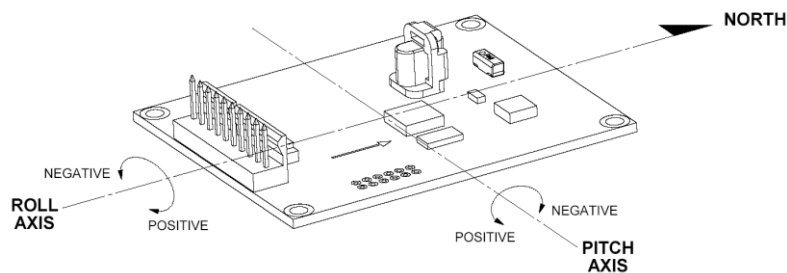

Figure 3: TCM2.5 Pitch & Roll Axes
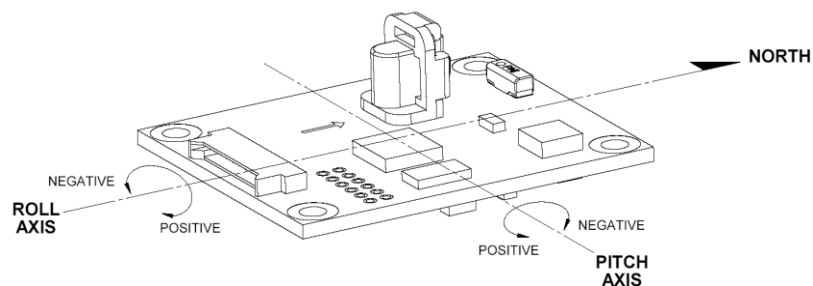
Figure 4: TCM2.6 Pitch & Roll Axes

Programming Commands

Table 5: Command List Quick Reference

Command	Description
Request for Data Commands	
c?	Compass Update
i?	Inclinometer Update
lc?	Query Last Calibration Score
m?	Magnetometer Update
s?	Single Update Output Word
t?	Temperature Update
Action Commands	
cc	Clear Calibration Data
factory	Factory Settings
go	Enter Continuous Mode
h	Halt Continuous Sampling, Enter Standby
halt=	Enable Single Character Halt
mpcal=	Multipoint Calibration
sleep	Sleep Mode (improved sleep mode over TCM2)
wake	Wake Mode (requires separate program and connection of RTS pin)
ax	Warm Reboot
User Configuration Parameter Commands	
b=	Set Baud Rate
damping=	Enable Filter for damping of output
ec=	Enable Compass Data for Output Word
em=	Enable Magnetometer Data for Output Word
ep=	Enable Pitch Data for Output Word
er=	Enable Roll Data for Output Word
et=	Enable Temperature Data for Output Word
ma=	Select Magnetometer Output Option
mag_dec=	Set Declination Angle
sdo=	Set RS232 Output Word Format
sn=	Select Magnetic or True North
timeconst=	Set the value for filtering (damping) of outputs.
uc=	Set Compass Units
ui=	Set Inclinometer Units
ut=	Set Temperature Units

Command differences between the TCM2.5/2.6 and previous TCM2 units

To keep the software compatible with existing systems, when any of the commands below are sent the unit will respond with the ":" as if it had accepted the command. Querying the command will result in an error code, since the command is obsolete and not being used.

Command	Description
Commands not used for the TCM2.5/2.6	
autocal	Autocalibration
%skip=	Skip measurements
cclip=	Set Clip Value
clock=	Set Clock rate
ed=	Enable Magnetic Distortion Alarm
fast=	Enable Fast Sampling
sao=	Select Analog Output Option
save	Unit automatically saves any changed settings
seriallp=	Lower Power Serial Consumption (specific to older chip)

Table 6: TCM2 vs TCM2.5/2.6 Commands

Request for Data Commands

Query Commands

c?   (Compass Update)

Description   Samples the magnetometer and inclinometer sensors, then calculates and returns the compass heading. When in Standby mode (**h)** use this command to query the compass reading regardless of whether compass data has been selected for inclusion in the output word.

Syntax   c?<cr>

Output   when compass units are set to degrees:

            $Cnnn.n[Ennn]*checksum<cr><lf>:<cr><lf>

               when compass units are set to mils:

            $Cnnn.n[Ennn]<cr><lf>:<cr><lf>

Resolution   0.1˚ **or** 2 mils

Valid Values   0 to 359.9˚ **or,** 0 to 6399 mils

Example   If TCM2 is configured for degrees:

            c?<cr>

            $C255.5[Ennn]*checksum<cr><lf>:<cr><lf>

               If TCM2 is configured for mils:

            c?<cr>

            $C4480[Ennn]*checksum<cr><lf>:<cr><lf>

Related Commands   uc= (Set Compass Units)

                    ec= (Compass Data Enable)

i?   (Inclinometer Update)

Description   Samples and returns the pitch and roll inclinometer data. When in Standby mode (**h**) use this command to query the inclinometer readings regardless of whether inclinometer data has been selected for inclusion in the output word.

Syntax   `i?<cr>`

Output   When the inclinometer units are set to degrees:

`$P(-)nn.nR(-)nn.n[Ennn]*checksum<cr><lf>:<cr><lf>`

When inclinometer units set to mils:

`$P(-)nnnR(-)nnn[Ennn]*checksum<cr><lf>:<cr><lf>`

Resolution   0.1° or 2 mils

Valid Values   0 to $\pm$80 ° **or,** 0 to $\pm$1421.6 mils

Example   `i?<cr>`

`$P-30.0R-20.1[Ennn]*checksum<cr><lf>:<cr><lf>`

Related Commands   ep= (Enable Pitch)

er= (Enable Roll)

lc?   (Query Last Calibration Score)

Description   Reports the score generated by the last calibration procedure executed, as stored in EEPROM. Use this command to recall the quality of the last calibration procedure.

Syntax   `lc?<cr>`

Output   `HnVnMn.nn<cr><lf>`

Valid Values   0-9 for H and V

Example   `lc?<cr>`

          `H7V8M8.00<cr><lf>`   !An example of a poor score

Related Commands   mpcal (Multipoint Calibration)

m?   (Magnetometer Update)

Description   Samples and returns the X, Y, and Z axes of magnetometer data. When in Standby mode (**h**) use this command to query the magnetometer readings regardless of whether magnetometer data has been selected for inclusion in the output word.

Syntax   `m?<cr>`

Output   `$X(-)nn.nnY(-)nn.nnZ(-)nn.nn[Ennn]<cr><lf>:<cr><lf>`

Resolution   0.01 µT

Valid Values   0 to ±79.9 µT

Example   `m?<cr>`

          `$X25.00Y10.50Z-03.00[Ennn]*checksum<cr><lf>:<cr><lf>`

Related Commands   em= (Enable Magnetometer)

s?   (Single Update of Output Word)

Description   Transmits the output word you specified. This command can only be used in the Standby (**h**) mode. The Select RS232 Output Word Format (**sdo=**) command allows you to select between NMEA or TCM2.5/2.6 Standard formats for the output word. If TCM2.5/2.6 Standard output is selected, only those data parameters that are enabled (with **ec**, **ep**, **er**, **em**, **et**) will be output.

Syntax   `s?<cr>`

Output   Refer to "RS232 Data Output Word" for a full description of the output word formats.

Example   `s?<cr>`
`$C328.3P28.4R-12.4X55.1Y12.3Z-18.4T22.3[Ennn]*check-`
`sum<cr><lf>:<cr><lf>`

Related Commands   sdo= (Select RS232 Output Word Format)

                         ec= (Enable Compass Data for Output Word)

                         ep= (Enable Pitch Data for Output Word)

                         er= (Enable Roll Data for Output Word)

                         em= (Enable Magnetometer for Output Word)

                         et= (Enable Temperature Data for Output Word)

t?   (Temperature Update)

Description   Sample and return the ambient temperature. When in the Standby mode (**h**) use this command to query the temperature readings regardless of whether temperature data has been selected for inclusion in the output word.

Syntax   `t?<cr>`

Output   When the units are set to Celsius:
                `$T(-)nnn.n[Ennn]*checksum<cr><lf>:<cr><lf>`

                When units set to Fahrenheit:
                `$T(-)nnn[Ennn]*checksum<cr><lf>:<cr><lf>`

Resolution   0.5 °C or 1 °F

Valid Values   -40.0 to 85.0 °C **or** -40 to 185 °F

Example   `t?<cr>`

                `$T25.5[Ennn]*checksum<cr><lf>:<cr><lf>`

Related Commands   et= (Enable Temperature)

ut= (Set Temperature Units)

Action Commands

?   (Help Command)

Description All TCM2.5/2.6 commands are displayed using the "?" command.

cc   (Clear Calibration Data)

Description   Erases all calibration data. Any further magnetometer or compass output is not corrected for any local fields. This command is only valid during Standby Mode (**h**). Use this command before recalibrating the TCM2.5/2.6 for a new or changed local magnetic environment.

Syntax   cc<cr>

Output   HnVnMn.nn<cr><lf>

Example   cc<cr>

H0V0M0.00<cr><lf>

Query Response   lc? (Last Calibration Score)

Related Commands   mpcal= (Multipoint Calibration)

c? (Compass Update)

factory   (Factory Settings)

Description   Resets the TCM2.5/2.6 to the factory settings. The internal modes are set to the following factory defaults

b=5	er=e	mpcal=d	ut=c
cc	et=d	sdo=t	
damping=d	timeconst=8	sn=m	
ec=e	halt=d	sp=8	
em=d	ma=u	uc=d	
ep=e	mag_dec=0.0	ui=d	

Syntax   `factory<cr>`

Output   `H0V0m0.00<cr><lf>`

Example   `factory<cr>`

go   (Enter Continuous Sampling Mode)

Description   Enters the Continuous Sampling Mode (**go**). The TCM2.5/2.6 immediately begins outputting sensors data at rate specified by the SP parameter, default is 8 Hz. Data is automatically transmitted according to the Output Word Format (**sdo=**) currently specified. To exit the TCM2.5/2.6 and return to Standby mode, issue the Halt Continuous Sampling (**h**) command.

Syntax   `go<cr>`

Output   Selected data output word.

Example   `go<cr>`

Related Commands   s? (Single Update of Output Word)
h (Halt Continuous Sampling)

h   (Halt Continuous Sampling, Enter Standby)

Description   Exits Continuous Sampling Mode (**go**) and enters Standby mode (**h**). If this command is received while the TCM2.5/2.6 is transmitting an output word, the remainder of the output word will be sent before the TCM2.5/2.6 changes modes.

Syntax   `h<cr>`

Output   `:[Ennn]<cr><lf>`

Related Commands   go (Enter Continuous Sampling Mode)
                        halt= (Enable Single Character Halt)

halt=   (Enable Single Character Halt)

Description   The **halt** command during **go** mode has optionally been made a single character command using the **halt=e** command.

Syntax   `halt=d<cr>`

Output   `:[Ennn]<cr><lf>`

Valid Values

Input	Description
e	Enable, h command for halting the ouput
d	h <cr> command for halting the output (default setting)

Table 7: Valid `halt=` Values

Query Response   halt?   `:halt=`

Related Commands   go (Enter Continuous Sampling Mode)

mpcal=   (Multipoint Calibration)

Description Initiates a multipoint calibration. This command is only valid when used in conjunction with Enter Continuous Sampling Mode (**go**). The TCM2.5/2.6 samples its sensors and adds the data point to the current set of calibration data.

Syntax   `mpcal=e<cr>`

`:<cr><lf>`

`go<cr>`

`.......`

`......` take data in continuous mode

`h<cr>` (or `h`)

`:<cr><lf>`

`mpcal=d<cr>`

Valid Values

Input	Description
e	e, enable multipoint calibration
d	d, disable multipoint calibration (default setting)

Table 8: Valid `mpcal=` Values

Output   `HnVnMn.nn<cr><lf>`

The TCM2.5/2.6 only reports a calibration score after it has been put in Standby mode (**h**), and multipoint calibration has been disabled (mpcal=d)

Example   `mpcal=e<cr>`

`:<cr><lf>`

`go<cr>`

`........`

`.......` take data in continuos mode

`h<cr>`

`:<cr><lf>`

`mpcal=d<cr>`

`H4V3M5.00:<cr><lf>`   (This is an example of a poor score)

Query Response   mpcal?   `:mpcal=`

Related Commands   lc? (Query Last Calibration Score)

sleep (Sleep Mode)

Description Enters the sleep mode of operation. This command turns off the internal clocks and the RS-232 chip.

Syntax `sleep<cr>`

Output

Example

Related Commands wake (Wake Mode)

wake (Wake Mode)

Note: *Only used with the TCM2.5*

Description Enters the wake mode of operation. To wake the TCM2.5, a falling edge on the int2 (interrupt 2) pin of the processor is required. This is achieved by connecting pin 6 of the TCM2.5 connector to the RTS pin (pin 4 on a DB25 and pin 7 on a DB9) of the COM port.

A sample wake.c program example is provided at the end of this document. To wake the TCM2.6, toggle RxD line

Syntax `wake<cr>`

Output

Example

Related Commands sleep (Sleep Mode)

User Configuration Parameter Commands

The following commands allow you to set and query the values of the TCM2.5/2.6's user configuration parameters. These parameters specify how the TCM2.5/2.6 will operate, such as damping, baud rate, and so on. The TCM2.5/2.6 stores all parameter values in EEPROM when specified, so that after a reboot or power cycling, it will return to the last configuration set. Note that any parameter that specifies a numeric value must be specified with the appropriate units of the current setting.

b=   (Set Baud Rate)

Description   Sets the baud rate for the RS232 interface. *Note: This is now an immediate command and a reset is no longer required.*

Syntax   `b=n<cr>`

Output   `:<cr><lf>`

Valid Values

Input	Baud Rate
1	300
2	1200
3	2400
4	4800
5	9600 (default setting)
6	19200
7	38400
8	115200

Table 9: Valid b= Values

Example   `b=5<cr>`   !set baud rate to 9600 baud

`:<cr><lf>`

Query Response   `b?`   `:b=`

damping=   (Set Digital Damping)

Description Enables or disables filtering of the output.

Syntax   `damping=n<cr>`

Output   `:[Ennn]<cr><lf>`

Valid Values

Input	Description
e	enable damping
d	disable damping (default setting)

Table 10: Valid `damping=` values

Example   `damping=e<cr>`   !enable damping

          `:<cr><lf>`

Query Response   `damping?`   `:damping=`

Related Commands   `timeconst=`   (set time constant for digital damping)

ec=   (Enable Compass Data for Output Word)

Description Enables or disables compass data for inclusion in the TCM2.5/2.6 Standard Output Word.

Syntax   `ec=n<cr>`

Output   `:[Ennn]<cr><lf>`

Valid Values

Input	Description
e	Compass data enabled. It will be included in the output word. (Default setting)
d	Compass data disabled. It will be excluded in the output word

<div align="center">

Table 11: Valid ec= Values
</div>

Example `ec=e<cr>`   !include compass data in output word

  `:<cr><lf>`

Query Response   `ec?`   `:ec=`

em=   (Enable Magnetometer Data for Output Word)

Description Enables or disables magnetometer data for inclusion in the TCM2.5/2.6 Standard Output Word

Syntax   `em=n<cr>`

Output   `:[Ennn]<cr><lf>`

Valid Values

Input	Description
e	Magnetometer data enabled. It will be included from the output word.
d	Magnetometer data disabled. It will be excluded in the output word. (Default setting)

<div align="center">

Table 12: Valid em= Values
</div>

Example   `em=e<cr>`   !enable magnetometer data

  `:<cr><lf>`

Query Response   `em?`   `:em=`

ep=   (Enable Pitch Data for Output Word)

Description   Enables or disables pitch data for inclusion in the TCM2.5/2.6 Standard Output Word.

Syntax   `ep=n<cr>`

Output   `:[Ennn]<cr><lf>`

Valid Values

Input	Description
e	Pitch data enabled. It will be included from the output word. (Default setting)
d	Pitch data disabled. It will be excluded in the output word

<div align="center">

Table 13: Valid ep= Values

</div>

Example   `ep=e<cr>`   !include pitch data in output word
   `:<cr><lf>`

Query Response   `ep?`   `:ep=`

er=   (Enable Roll Data for Output Word)

Description   Enables or disables roll data for inclusion in the TCM2.5/2.6 Standard Output Word.

Syntax   `er=n<cr>`

Output   `:[Ennn]<cr><lf>`

Valid Values

Input	Description
e	Roll data enabled. It will be included from the output word. (Default setting)
d	Roll data disabled. It will be excluded in the output word

<div align="center">

Table 14: Valid `er=` Values

</div>

Example   `er=e<cr>`   !include roll data in output word

          `:<cr><lf>`

Query Response   `er?`   `:er=`

et=   (Enable Temperature Data for Output Word)

Description Enables or disables temperature data for inclusion in the TCM2.5/2.6 Standard Output
Word.

Syntax   `et=n<cr>`

Output   `:[Ennn]<cr><lf>`

Valid Values

Input	Description
e	Temperature data enabled. It will be included from the output word.
d	Temperature data disabled. It will be excluded in the output word. (Default setting)

<div align="center">

Table 15: Valid `et=` Values

</div>

Example   `et=e<cr>`   !include temperature data in output word

          `:<cr><lf>`

Query Response   `et?`   `:et=`

ma= (Select Magnetometer Output Option)

Description Outputs either corrected or non corrected magnetometer readings. If corrected readings are selected, the magnetometer readings output by the TCM2.5/2.6 reflect corrections to ambient field as a result of user calibration. If not corrected, the magnetometer readings output reflect total ambient field, including local fields. Note that compass readings always are based upon corrected magnetometer readings.

Syntax `ma=n<cr>`

Output `:[Ennn]<cr><lf>`

Valid Values

Input	Description
c	Choose corrected magnetometer readings.
u	Choose non corrected magnetometer readings. (Default setting)

Table 16: Valid ma= Values

Example `ma=c<cr>` !corrected magnetometer readings

`:<cr><lf>`

Query Response ma? `:ma=`

mag_dec= (Set Declination Angle)

Description Sets the magnetic declination angle in degrees. Sets the declination offset for a reading of True North. Based on the setting of the Compass Units (**uc)** command. Positive declination is easterly declination and negative is westerly declination. This is not applied until True North is set to true.

Syntax `mag_dec=nn.n<cr>`

Output `:[Ennn]<cr><lf>`

Valid Values

Input	Description
nn.n	Declination angle in degrees (default is set to 0.0)

<div align="center">

Table 17: Valid `mag_dec=` Values

</div>

Example   `mag_dec=17.2`   !sets the declination angle to 17.2 degrees

            `:<cr><lf>`

Query Response   mag_dec?   `:mag_dec=`

sdo=   (Set RS232 Output Word Format)

Description Sets the output word format to be used in response to the Single Update Output Word
(**sdo?**) command and in Continuous Output Mode (**go**).

Syntax   `sdo=n<cr>`

Output   `:[Ennn]<cr><lf>`

Valid Values

Input	Description
t	Standard TCM output string (default)
n	NMEA 0183 output string

<div align="center">

Table 18: Valid `sdo=` Values

</div>

Example   `sdo=t<cr>`   !output word format to TCM standard
            `:<cr><lf>`

Query Response   sdo?   `:sdo=`

sn= (Select Magnetic or True North)

Description Selects either magnetic or true north. True North sets the heading reference to True North or Magnetic North. If the value is set to true, then declination is applied to get the True North heading.

Syntax `sn=n<cr>`

Output `:[Ennn]<cr><lf>`

Valid Values

Input	Description
t	True North
m	Magnetic North (default setting)

Table 19: Valid `sn=` Values

Example `sn=t<cr>` !the declination angle set with mag_dec is added to the

!computed heading

`:<cr><lf>`

Query Response sn? `:sn=`

Related Commands mag_dec= (Set Declination Angle)

sp=   (Set Sampling Period)

Description   This command is used to set the sampling rate at which the data will be output in Hz.
NOTE: The function of this command has changed from the TCM2 in which the sp was the clock divisor to derive the output rate.

Syntax   sp=n<cr>

Output   : [Ennn] <cr><1f>

Valid Values

Input	Description
1	1 Hz output rate
2	2 Hz output rate
3	3 Hz output rate
4	4 Hz output rate
5	5 Hz output rate
6	6 Hz output rate
7	7 Hz output rate
8	8 Hz output rate (default)

Table 20: Valid sp= Values

Example   sp=4<cr>   !output rate 4 Hz

:<cr><lf>

Query Response   sp?   :sp=

timeconst= (Set Time Constant for Digital Damping)

Description This command is used with the digital damping command. It sets the time constant to **nn** samples for the digital damping.

Syntax `timeconst=n<cr>`

Output `:[Ennn]<cr><lf>`

Valid Values

Input	Description
Integer value between 1 – 4	Set the measured time constant = 4
Integer value between 5 – 8	Set the measured time constant = 8 (default setting)
Integer value between 9 – 16	Set the measured time constant = 16
Integer value between 16 – 32	Set the measured time constant = 32

Table 21: Valid `timeconst=` Values

Example `timeconst=16<cr>` !Filter over 16 measurements

`:<cr><lf>`

Query Response timeconst? `:timeconst=`

Related Commands damping= (Set Digital Damping)

uc=   (Set Compass Units)

Description   Sets the units to be used for the input and output of the heading data.

Syntax   `uc=n<cr>`

Output   `:[Ennn]<cr><lf>`

Valid Values

Input	Description
d	degrees, 360 x in a full circle (Default setting)
m	mils, 6400 mils in a full circle

Table 22: Valid `uc=` Values

Example   `uc=d<cr>`   !set units to degrees
             `:<cr><lf>`

Query Response   `uc?`   `:uc=`

ui=   (Set Inclinometer Units)

Description   Sets the units to be used for the input and output of the tilt (pitch & roll) data.

Syntax   `ui=n<cr>`

Output   `:[Ennn]<cr><lf>`

Valid Values

Input	Description
d	degrees, 360 x in a full circle (Default setting)
m	mils, 6400 mils in a full circle

Table 23: Valid `ui=` Values

Example   `ui=d<cr>`   !set units to degrees
             `:<cr><lf>`

Query Response   `ui?`   `:ui=`

ut= (Set Temperature Units)

Description Sets the units to be used for the input and output of the temperature data.

Syntax `ut=n<cr>`

Output `:[Ennn]<cr><lf>`

Valid Values

Input	Description
f	Fahrenheit
c	Celsius (Default setting)

<div align="center">

Table 24: Valid `ut=` Values

</div>

Example `ut=f<cr>`   !set units to Fahrenheit

`:<cr><lf>`

Query Response   ut?   `:ut=`

TCM2.5/2.6 Code Example

Wake C program

```c
/* wake.c - Sample program to wake the TCM2.5/2.6 after is has been put in
sleep mode */
/* Wake toggles the RTS line to give the TCM2.5/2.6 a (falling) edge */
/* P Milford 1/10/96 */

/* Usage:  wake 1  - wakes a tcm2.5/2.6 on com port 1 (default) */
/* wake 2 - wakes a tcm2.5/2.6 on com port 2, etc. */

#include <stdio.h>
#include <stdlib.h> /* for atoi */
#include <conio.h>  /* For inp/out */

/* Addresses in IO space of the serial port base addresses */

#define PORT1 0x3F8
#define PORT2 0x2F8
#define PORT3 0x3E8
#define PORT4 0x2E8

#define MCR 4            /* Offset to the Modem control register */
#define RTS 2            /* RTS is bit 2 of the MCR*/

int main(int argc, char *argv[])
{
int tmp, port=PORT1;     /* Defaul to serial port 1 */

/* If there are args, look at the first one only */

    if(argc == 2) {       /* Figure out which serial port to use */
      switch(atoi(argv[1])) {
        case 1: port = PORT1; break;
        case 2: port = PORT2; break;
        case 3: port = PORT3; break;
        case 4: port = PORT4; break;
      others: port = PORT1;
      };
    };
    tmp = inp(port+MCR);     /* Read current line status */
    outp(port+MCR, tmp ^ RTS);  /* Toggle the RTS line */
    outp(port+MCR, tmp);     /* Restore the RTS line */
return 0;
};
```

Performance Specifications

Parameter	Typical		Units
Heading Specifications			
Accuracy over tilt range	0.8°		Deg RMS
Resolution	0.1°		
Repeatability [1]	0.1°		
Max Dip Angle	85°		Deg
Magnetometer Specifications			
Calibrated Field Measurement Range	± 80		µT
Magnetic Resolution	± 0.05		
Magnetic Repeatability	± .1		
Tilt Specifications			
Pitch Accuracy	0.2°		Deg RMS
Roll Accuracy	0.2°		
Tilt Range	± 50°		Deg
Tilt Resolution	0.1°		
Tilt Repeatability [1]	0.1°		Deg RMS
Calibration			
Hard Iron Calibration	Yes		
Soft Iron Calibration	No		
Mechanical Specifications	**TCM2.5**	**TCM2.6**	
Dimensions (L x W x H)	6.4 x 5.1 x 1.4	3.4 x 4.3 x 1.3	cm
Weight	14	7	grams
Mounting Options	Screw Mounts/Standoffs horizontal		
Connector for RS-232	10-pin	9-pin	
I/O Specifications			
Time to Good Initial Data from Power-On	210		msec
Time to Good Initial Data from Sleep Mode	80		msec
Maximum Sample Rate	8		samples/sec
RS-232 Communication Rate	300 to 115200		baud
Output Formats	TCM2 ASCII Protocol		
Power Specifications	**TCM2.5**	**TCM2.6**	
Supply Voltage	5 V (regulated) 6 to 18 (unregulated)	3.8 to 5.0 V (unregulated)	VDC
Current Draw at maximum sample rate	20 typical	20 typical	mA
Sleep Mode	0.6 typical	0.6 typical	
Environmental Specifications			
Operating Temperature	– 20 to 70		°C
Storage Temperature	– 40 to 85		

[1] Repeatability is based on statistical data at ±3 sigma limt about the mean
Table 25: TCM2.5/2.6 Specifications

Mechanicals

TCM2.5 Board and Cable

The default orientation for the TCM2.5/2.6 is for the silk-screened arrow to point in the "forward" direction. That puts the edge opposite of the Molex connector as the front edge of the board.
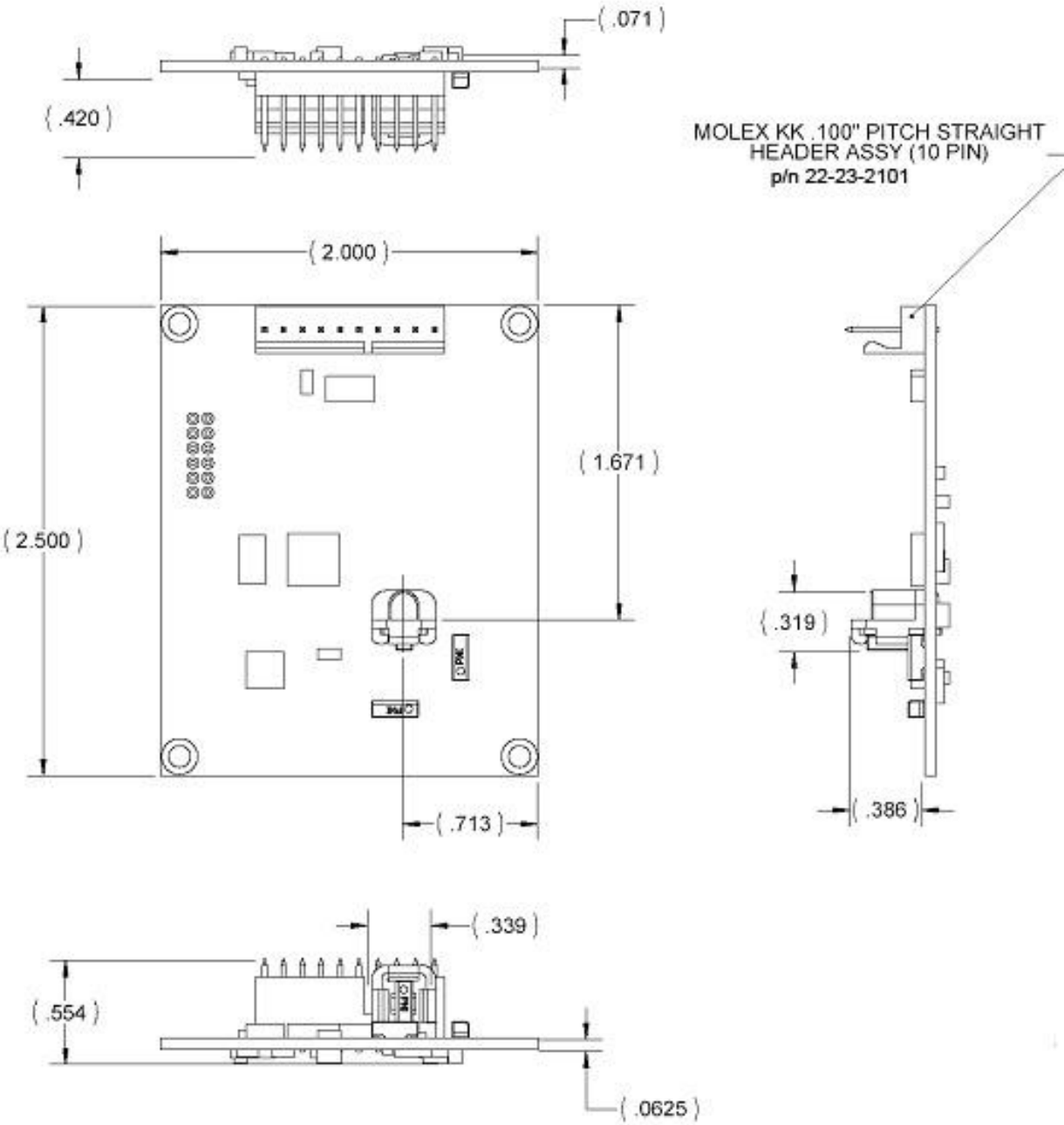

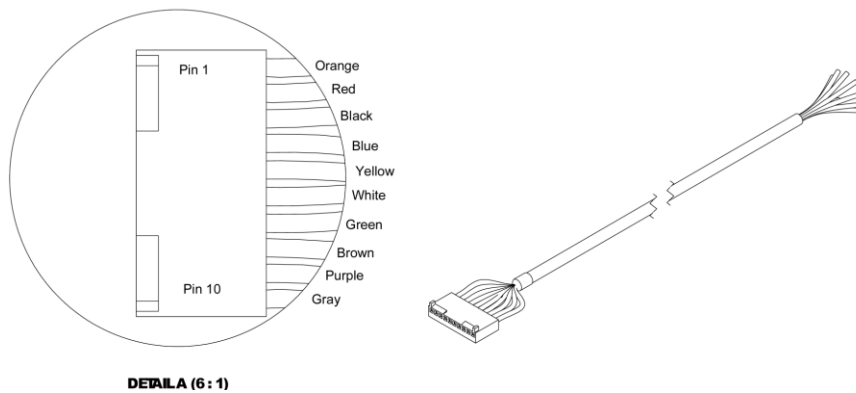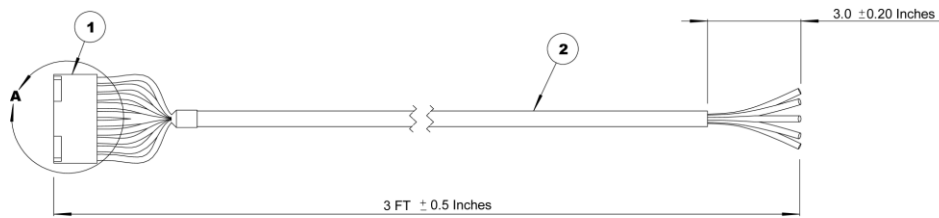**Figure 5: TCM2.5 Board Drawing**

3 ft. Cable Assembly

Figure 6: 3' Cable Drawing

PIN	Wire Color	Description
1	Orange	Vsupply (5 V regulated)
2	Red	Vsupply (6 to 18 V unregulated)
3	Black	Power Ground
4	Blue	RxD (RS-232) -5 to 5V
5	Yellow	TxD (RS-232) -5 to 5V or -12 to 12V
6	White	RTS, Wake from Sleep
7	Green	Data Ground
8	Brown	NC
9	Purple	NC
10	Gray	Data Ground

Table 26: Molex Connector TCM2.5 Pin Descriptions

TCM2.6 Board and Cable

The default orientation for the TCM2.6 is for the silk-screened arrow to point in the "forward" direction. That puts the edge opposite of the Molex connector as the front edge of the board.
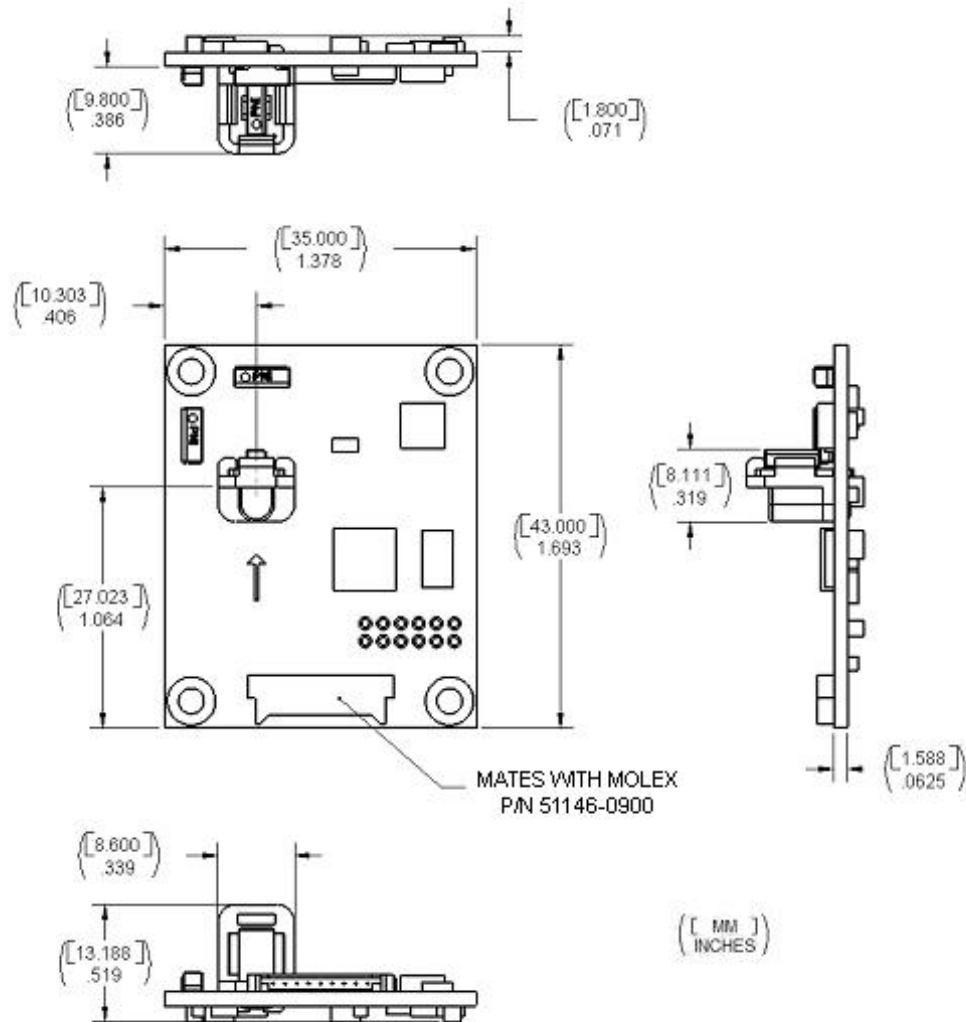

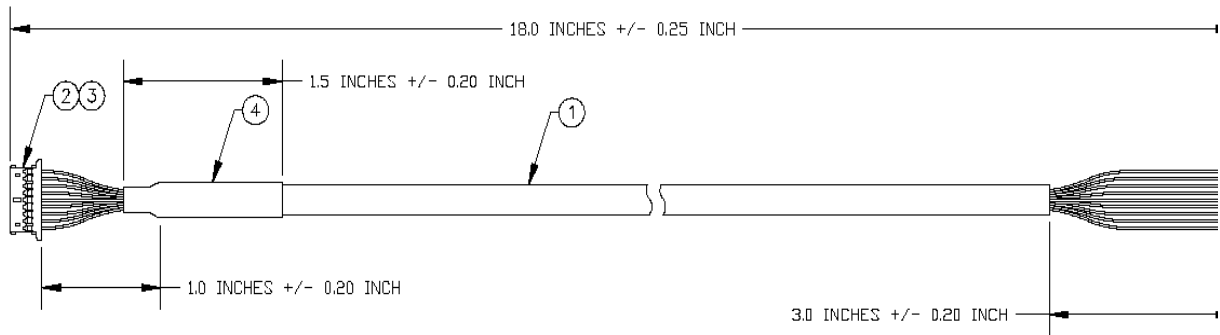**Figure 7: TCM2.6 Board Drawing**

18 in. Cable Assembly

Figure 8: 18" Cable Drawing

PIN	Wire Color	Description
1	Black	Power Ground
2	Gray	NC
3	Green	RS232 Ground
4	Orange	NC
5	Violet	NC
6	Brown	NC
7	Yellow	TxD
8	Blue	RxD
9	Red	5 VDC

Table 27: Molex Connector TCM2.6 Pin Description