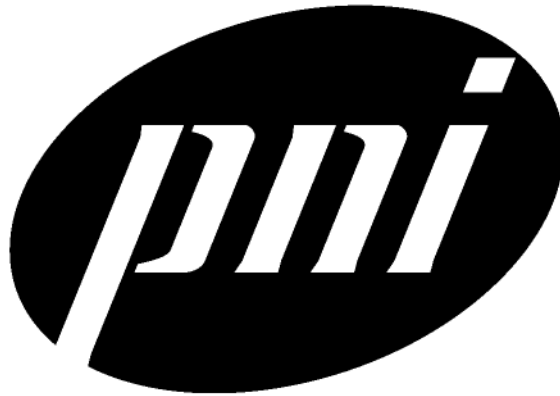


---

# PNI Corporation

## TCM2 Electronic Sensor Module User's Guide



---

© Copyright

PNI Corporation 2004

All Rights Reserved. Reproduction, adaptation, or translation without prior written permission is prohibited, except as allowed under copyright laws.

Part No. 10824

Document No. 1000281

Revision 3.0

February 2004

Printed in USA

PNI Corporation

5464 Skylane Blvd., Suite A

Santa Rosa, CA 95403, USA

Tel: (707) 566-2260

Fax: (707) 566-2261

#### Notice.

The information contained in this document is subject to change without notice. Companies, names, and data used in examples herein are fictitious unless otherwise noted. PNI Corporation makes no warranty of any kind with regard to this material, including but not limited to, the implied warranties of merchantability and fitness for a particular purpose. PNI Corporation shall not be liable for errors contained herein or for incidental or consequential damages in connection with the furnishing, performance, or use of this material.

#### Restricted Rights Legend.

Use, duplication, or disclosure by the U.S. Government is subject to restrictions as set forth in subparagraph (c) (1) (ii) of the Rights in Technical Data and Computer Software clause at DFARS 252.227-7013 for DOD agencies, and subparagraphs (c) (1) and (c) (2) of the Commercial Computer Software Restricted Rights clause at FAR 52.227-19 for other agencies.

#### Conventions Used in this Manual.

Any data that is sent to or received from the TCM2 is presented in monospace font, for example: `$C326.3*check-sum<cr><lf>`. Place markers for ASCII characters are indicated by the character "n." Any monospace characters in straight brackets denote transmitted data that may or may not be in the character string, depending on the circumstances. For instance `[Ennn]` is the error code string that is output by the TCM2 only when an error condition exists. Also, (-) denotes the presence of a negative sign in a character string when the corresponding value is negative. The parentheses are not included in the output string, and only serve to demark the hyphen.

TCM2 commands can be identified either by their mnemonic, for example, `h`, or by their full name, for example, Halt continuous sampling.

Items in angle brackets either denote special characters or summary data, for example, `<cr>` denotes the carriage return character, `<lf>` denotes a line feed, and `<error code>` denotes all the characters for an error code string.

#### Warranty.

PNI warrants that each PNI Product to be delivered hereunder, if properly used, will be free from defects in material and workmanship and will operate in accordance with PNI's published specifications and documentation for the Product in effect at time of order acceptance if operated as directed by them for one year following the date of shipment unless a different warranty time period for such Product is specified: (i) in PNI's Price List in effect at time of order acceptance; or (ii) on PNI's web site ([www.pnicorp.com](http://www.pnicorp.com)) at time of order acceptance. PNI will make no changes to the specifications or manufacturing processes that affect form, fit, or function of the product without written notice to the OEM. PNI may at any time make minor changes to specifications or manufacturing processes that do not affect the form, fit, or function of the product. This warranty will be void if the products, serial number, or other identification marks have been defaced, damaged, or removed. This warranty does not cover wear and tear due to normal use, or damage to the product as the result of improper usage, neglect of care, alteration, accident, or damage to the product as the result of improper usage, neglect of care, alteration, accident, or unauthorized repair.

THE ABOVE WARRANTY IS IN LIEU OF ANY OTHER WARRANTY, WHETHER EXPRESS, IMPLIED, OR STATUTORY, INCLUDING, BUT NOT LIMITED TO, ANY WARRANTY OF MERCHANTABILITY, FITNESS FOR ANY PARTICULAR PURPOSE, OR ANY WARRANTY OTHERWISE ARISING OUT OF ANY PROPOSAL, SPECIFICATION, OR SAMPLE. PNI NEITHER ASSUMES NOR AUTHORIZES ANY PERSON TO ASSUME FOR IT ANY OTHER LIABILITY.

If any PNI Product furnished hereunder fails to conform to the above warranty, OEM's sole and exclusive remedy and PNI's sole and exclusive liability will be, at PNI's option, to repair, replace, or credit OEM's account with an amount equal to the price paid for any such Product which fails during the applicable warranty period provided that (i) OEM promptly notifies PNI in writing that such Product is defective and furnishes an explanation of the deficiency; (ii) such Product is returned to PNI's service facility at OEM's risk and expense; and (iii) PNI is satisfied that claimed deficiencies exist and were not caused by accident, misuse, neglect, alteration, repair, improper installation, or improper testing. If Product is defective, transportation charges for the return of Product to OEM within the United States and Canada will be paid by PNI. For all other locations, the warranty excludes all costs of shipping, customs clearance, and other related charges. PNI will have a reasonable time to make repairs or to replace Product or to credit OEM's account. PNI warrants any such repaired or replacement product to be free from defects in material and workmanship on the same terms as the product originally purchased.

# Contents

## 1 Getting Started

- About the TCM2 1-2
  - Packing List 1-3
  - Products and Accessories 1-3
- Installation 1-4
  - Electrical Connections 1-4
  - Communicating with the TCM2 1-6
  - Evaluation Software 1-6
  - Where to Install the TCM2 1-7
  - Mechanically Mounting the TCM2 1-8

## 2 Using the TCM2

- RS232 Data Output Word 2-2
  - NMEA 0183 Format 2-2
  - TCM2 Standard Output 2-3
- Command Syntax 2-4
  - Programming Conventions 2-4
- Data Transmission 2-5
- Error Codes 2-6
  - Description of Error Conditions 2-7
- Compass Operating Modes 2-8
  - Standby Mode 2-8
  - Sampling in the Standby Mode 2-8
  - Continuous Sampling Mode 2-8
- Analog Outputs 2-9
- Digital Damping 2-10
- Output Response Time 2-11
- Latency 2-12
- Magnetic Distortion Alarm 2-13
  - How to Use the Magnetic Distortion Alarm 2-13
  - How to Interpret the Magnetic Distortion Alarm 2-13
- Pitch and Roll Output 2-14
- User Calibration 2-15
  - Automatic Calibration 2-16
  - Soft Iron Effects 2-17
  - Other Limitations 2-17
- Calibration Procedures 2-18
  - Multipoint Calibration (mpcal) 2-19
  - CAL3 Procedure 2-20
  - Temperature Sensor Calibration 2-22

## 3 Programming Commands

- Command List Quick Reference 3-2
- Differences Between TCM2 Firmware Version 2.82 and 2.34A 3-4
  - Changes to the EEPROM 3-4
- Command List 3-5
- Request for Data Commands 3-6
- Action Commands 3-11
- User Configuration Parameter Commands 3-17

## 4 Troubleshooting

- Trouble-Shooting the TCM2 4-2
- Limitations of the Inclinometer 4-6

## **5 Performance Specification**

Specifications 5-2

Assembly Views 5-3

3-Foot Cable 5-6

Optional 6-Foot Cable 5-8

About the TCM2	1-2
Installation	1-4
Packing List	1-3
Electrical Connections	1-4
Communicating with the TCM2	1-6
Evaluation Software	1-6
Where to Install the TCM2	1-7
Mechanically Mounting the TCM2	1-8

---

## Getting Started

## About the TCM2

Thank you for purchasing the TCM2. You have chosen a product that represents the largest step forward in compass technology for many years. The TCM2 is a state-of-the-art, low power, high performance electronic compass sensor module that combines a revolutionary three-axis magnetometer with a high-performance two-axis tilt sensor.

All compasses must be referenced to level to be accurate, but instead of using a clumsy universal joint or fluid bath to hold its sensors level, the TCM2 uses a highly accurate inclinometer (tilt sensor) to allow the microprocessor to mathematically correct for tilt. This *electronic gimbaling* eliminates moving parts and provides more information about the environment: pitch and roll angles and three-dimensional magnetic field measurement in addition to compass output. This extra data allows the TCM2 to provide greater accuracy in the field by calibrating for distortion fields in all tilt orientations, providing an alarm when local magnetic anomalies are present, and giving out-of-range warnings when the unit is being tilted too far.

At the heart the TCM2, its patented magneto-inductive magnetometers are the first major advance in compass magnetometers since the fluxgate was invented in the 1930's. Their solenoidal, single-winding construction provides a more compact, reliable, and cost-effective solution than toroidal fluxgates. They also consume roughly an order of magnitude less power. Their dynamic range and sensitivity can be easily tailored to the exact needs of any application. The TCM2's magnetometers provide a very large dynamic range and hence can be calibrated for systems that have extremely strong fields, such as military vehicles.

The TCM2's advantages make it suitable for many applications, including:

- GPS systems requiring backup azimuth data
- Automobile and marine navigation systems
- Virtual reality input devices
- Robotics
- Original equipment instrumentation for automobiles
- Oceanographic buoys and data stations

With its many potential applications, the TCM2 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 will help you to achieve the greatest performance from your target system. Thank you for selecting the TCM2.

---

## Packing List

Your TCM2 Evaluation Kit should contain the following items:

- TCM2 Electronic Sensor Module
- Interface Cable, 3 foot (optional 6-foot cable available for purchase)  
 Connects between the TCM2 and the host system and power supply. Refer to “TCM2 Pin Descriptions” on page 1-4 for a complete description.
- User's Guide
- 3.5" floppy disk containing TCM2 evaluation software

The 3.5" floppy is a high-density disk formatted for DOS systems. It contains the TCM2.EXE program that executes on any IBM-AT compatible computer running DOS. For instructions on installing and using the TCM2.EXE program, refer to “Evaluation Software” on page 1-6.

If any of the 4 items are missing please contact PNI Corp.

---

### **CAUTION**

*The TCM2 board is an ESD-sensitive device and must be handled accordingly.*

---

## Products and Accessories

**Table 1-1. Products and Accessories**

<b>Product</b>	<b>Part Number</b>
TCM2-20	10639
TCM2-20 (with user's guide, 3-ft. cable, and software)	90001
TCM2-50	10651
TCM2-50 Includes user's guide, 3-ft. cable, and software)	90002
TCM2 Inclinometer only	10657
TCM2 Inclinometer only (with user's guide, 3-ft. cable, and software)	90003
TCM2 Magnetometer only	10660
TCM2 Magnetometer only (with user's guide, 3-ft. cable, and software)	90004
<b>Accessories</b>	
6-ft. cable	10826
User's Guide	10824

---

## Installation

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

- ❑ Make electrical connections to the TCM2
- ❑ Evaluate the software
- ❑ Choose a mounting location
- ❑ Mechanically mount the TCM2
- ❑ Calibrate for hard-iron distortion effects using either the MPCAL or CAL3 calibration procedures.

---

## Electrical Connections

The TCM2 evaluation kit contains a cable to connect to the TCM2. On one end of the cable is the connector needed to mate to the TCM2. The header is MOLX 22-03-2101 style, with 0.100" centers. The mating receptacle is MOLX 22-01-3107, or equivalent. The crimps are MOLX 08-50-0114). 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 1-2. TCM2 Pin Descriptions**

Pin	Wire Color	Description
1	Orange	Vsupply (5 V regulated ( $\pm 5\%$ )) <sup>a</sup>
2	Red	Vsupply (6-18 V unregulated) <sup>a</sup>
3	Black	Power Ground
4	Blue	RxD (RS-232) -5 to 5 V
5	Yellow	TxD (RS-232) -5 to 5 V or -12 to 12 V. These ranges are compatible with most RS-232 chips.
6	White	RTS, Wake from Sleep
7	Green	Data ground, connected to the RS-232 ground
8	Brown	Analog Output 2
9	Purple	Analog Output
10	Gray	Data Ground

a. Do not apply power to both pin 1 and pin 2 simultaneously.



***Procedure***

- 1 Attach a single 9V battery to the unregulated supply and power ground pins of the TCM2's connector (pins 2 and 3 respectively) to apply power to the TCM2.
- 2 On the TCM2 connector, connect the three signals used (RxD, TxD, and Data ground) for the RS-232 (pin 4 (blue), pin 5 (yellow), and pin 7 (green)) to the corresponding pins on one of the COM ports on the PC. Refer to [Table 1-4](#) and [Table 1-5](#) for connector information.

**Table 1-3. RS-232 Serial Communication Interface**

<b>Parameters</b>	8 data bits, 1 start bit, 1 stop bit, no parity
<b>Transmit Voltages</b>	±5V to ±15V
<b>Baud Rate</b>	300 to 38400

**Table 1-4. DB25 COM Port Connector**

COM Port		TCM2 Connector	
Pin number	Signal	Pin number	Signal
2	TxD	4	RxD
3	RxD	5	TxD
7	Ground	7	Data ground
4	RTS	6	Wake from sleep

**Table 1-5. DP9 COM Port Connector**

COM Port		TCM2 Connector	
Pin number	Signal	Pin number	Signal
2	RxD	4	TxD
3	TxD	5	TxD
5	Ground	7	Data ground
7	RTS	6	Wake from sleep

**NOTE**

Some COM ports have pins 2 as TxD and 3 as RxD.

---

## Communicating with the TCM2

Once the TCM2 is powered up and the RS232 connection is made with one of the PC's COM ports, you may begin swapping ASCII serial data with the TCM2. The most direct means is to run any modem or terminal emulation software. Specify the COM port that you have the TCM2 connected to and set the baud rate to the same baud rate of the TCM2. The default baud rate for the TCM2 is 9600. Remember that the TCM2 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.

---

## Evaluation Software

The TCM2.exe DOS evaluation program communicates with the TCM2 through the COM port of your PC. It puts an easy-to-use interface onto the ASCII command language used by the TCM2, so that instead of issuing command codes manually, you can use buttons, check boxes, and dialog boxes. It reads the ASCII responses of the TCM2 instead of reading the ASCII output strings of the TCM2 and formats its sensor data into labeled and easy-to-read data fields. It simultaneously presents a terminal window that shows you the actual ASCII strings being exchanged with the TCM2, so that you may observe and begin to learn the TCM2's command syntax as you use the evaluation program's more friendly interface.

To install the program on your computer, copy the TCM2.EXE file from the floppy disk to your hard drive. Usage of the program is menu-driven. There are three ways to navigate the menu buttons.

- Use the keyboard's Tab key to move sequentially through the menu items.
- Use the keyboard's arrow keys to move through the menu items.
- On the keyboard, enter the shortcut key (the key in the menu item that is white) to go directly to that menu item. For example, the *Set Program i/o Parameters* button the "P" in Program is white in color.

---

### NOTE

The TCM2.EXE program cannot use the 38400 baud rate. Do not use TCM2.exe to change the baud rate to 38400. If the TCM2 is set to 38400 (b=7), the TCM2.exe program will not be able to communicate with the PC.

The 38400 baud rate can be used with other terminal programs that support this rate. Examples of these programs are TELIX, PROCOMM, and HyperTerminal in the Accessories list of Windows. When using a terminal program you will need to set the correct baud rate, no parity, 1 stop bit, 8 data bits and the COM port.

The TCM2.exe program will default to COM2 and baud rate of 9600. To start the TCM2.exe program on COM1, invoke the TCM2.EXE program with the following command:

```
TCM2 1 (TCM2 "space" 1)
```

Alternately, the COM Port and baud rate can be set in the TCM2.EXE program.

---

### NOTE

The Compass Baud Rate and the Program Baud Rate *must* be the same. In general, you should set the Compass Baud Rate before changing the Program Baud Rate.

To set the Compass baud rate, and the TCM2.EXE program baud rate and COM port:

- 1 From the TCM2.EXE program, select **Set Compass I/O Parameters**, set the *Baud Rate* to the desired value, and then select **OK**.

- 2 Select **Set Program I/O Parameters**, choose the correct *COM Port* and *Baud Rate*, and then press **OK**.

The bottom screen echos the commands when the different buttons are selected. It can also serve as a terminal program by pressing the F1 key. In the terminal mode, you can type commands directly to the TCM2. To return to user interface control, press the F2 key.

The program also includes a data logging feature. In the Program I/O Parameters menu, you can open a data file (Logging on enabled). After you open the data file, all of the data going to or coming from the TCM2 compass will be saved to the file. When you are done collecting data, close the data file. The file is saved in ASCII text.

---

## Where to Install the TCM2

The TCM2'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 with the following considerations in mind:

### *The TCM2's magnetometers should not saturate*

The TCM2 can be calibrated for large static magnetic fields. However, each axis of the TCM2's magnetometers has a maximum dynamic range of  $\pm 80 \mu\text{T}$ ; if the total field exceeds this value for any axis, the TCM2 will report a magnetometer out of range error condition. When mounting the TCM2, 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'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 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 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 is not mounted close to cargo or payload areas that may be loaded with large sources of local magnetic fields.

To test the magnetic environment of a location:

- 1 Clear any previous calibration data:
  - On the terminal program, send the command `cc <Enter>`.
  - On the TCM2.exe program, select **User Calibration, Clear Previous Calibration**. After a few seconds, the Start Multipoint Calibration button will be displayed. Select **Quit**.
- 2 Set the TCM2 to output the X, Y, and Z sensor data.
  - On the terminal program, send the command `em=e`.
  - On the TCM2.exe program, select **Set Compass I/O Parameters** and then set the *Magnetometer Output* to **Enabled**.
- 3 Put the TCM2 into Continuous Output mode:
  - On the terminal program, send the command `go`.
  - On the TCM2.exe program, select **Start Continuous Sampling**.
- 4 Place the unit in the desired mounting location and note the magnetometer output X, Y, and Z

## Installation

values. If you see a `Magnetometer Out of Range` error, ignore it for now.

- 5 Pick a direction to begin moving the TCM2, either forward or backward (X sensor), side-to-side (Y sensor), or up or down (Z sensor). The process will eventually go through all combinations with the intent of moving away from any distortions until a location can be found where the TCM2 will be able to operate.
- 6 Slowly move the TCM2 in the first direction *only*, until the values of the corresponding sensor stop changing with the movement, or at least the change can be attributed to background noise. It may be that the sensor will still be changing, but it is the least amount of change seen.
- 7 Select the next direction to move, starting at the finishing point of the previous move. Continue until this sensor's values stop changing as in the step above.
- 8 Finally, move the TCM2 along the final sensor direction as done previously. At the end of this movement, the location achieved is the best location to mount the TCM2 relative to the initial desired location.
- 9 Experiment with different configurations of cargo, as well as turning various equipment on and off to determine if the TCM2's sensors saturate or detect significant changes in local magnetic anomalies.

### *Example Test Scenario*

The TCM2 starts at point A, which is directly behind an antenna mounted on the top of a van. Begin by moving the TCM2 rearward, away from the antenna along the X axis. At some distance the X values stop changing significantly with movement. From that point begin moving the TCM2 to the right along the Y axis, maintaining the relative rearward location already determined, until the Y sensor stops changing. From this end point move the TCM2 upward along the Z axis. At some point the Z value will have little change. Thus, the best mounting position is achieved.

### *The TCM2 should be mounted in a physically stable location*

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

### *The TCM2 should be mounted as close to level as possible*

To maximize the tilt range over which the compass operates, the TCM2 should be mounted as close to level as possible, as indicated by the Pitch and Roll output of the TCM2.

---

## Mechanically Mounting the TCM2

Refer to the TCM2 Dimensional Specification in [Chapter 5, "Performance Specification"](#) for the TCM2 board dimensions, location of the mounting holes, and the orientation of the reference frame. The TCM2 is factory calibrated with respect to the mounting holes, thus it must be aligned within the host system with respect to these mounting holes, not the board edges.

- RS232 Data Output Word 2-2
  - NMEA 0183 Format 2-2
  - TCM2 Standard Output 2-3
- Command Syntax 2-4
  - Programming Conventions 2-4
- Data Transmission 2-5
- Error Codes 2-6
- Compass Operating Modes 2-8
  - Standby Mode 2-8
  - Sampling in the Standby Mode 2-8
  - Continuous Sampling Mode 2-8
  - Analog Outputs 2-9
- Digital Damping 2-10
- Output Response Time 2-11
- Latency 2-12
- Magnetic Distortion Alarm 2-13
- Pitch and Roll Output 2-14
- User Calibration 2-15
  - Automatic Calibration 2-16
  - Soft Iron Effects 2-17
  - Other Limitations 2-17
- Calibration Procedures 2-18
  - Multipoint Calibration (mpcal) 2-19
  - CAL3 Procedure 2-20
  - Temperature Sensor Calibration 2-22

---

## Using the TCM2

## RS232 Data Output Word

The TCM2 sends an “output word” in ASCII form 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 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. Inclinator, 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 Standard Output

The TCM2 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>
```

For detailed information regarding the character formatting and resolution of the values for each of the data parameters in the output word, refer to “Programming Commands” on page 3-1 for the following commands: **c?** (Compass Update), **m?** (Magnetometer Update), **i?** (Inclinometer Update), **t?** (Temperature Update).

### *Example*

The TCM2 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 = 55.11 μT (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.
```

If all data parameters are disabled, no message will be output in response to **s?** or in continuous output mode, unless an error condition exists. 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:

- User Configuration Parameter commands which set user-definable parameters.
- Request for Data commands which query the TCM2 for data or for the stored value of user-definable parameters.
- Action commands which prompt the TCM2 to perform a specific action.

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

---

## Programming Conventions

Set TCM2 user parameters:                                       <parameter>=<value><cr>

Query TCM2 data (parameter or sensor values):             <parameter>?<cr>

Action command:   <command><cr>

Detailed descriptions of all commands are in the “[Command List](#)” on page 3-5 and a command summary is shown in “[Command List Quick Reference](#)” on page 3-2.



---

## Data Transmission

The TCM2 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:

**Table 2-1. Command Responses**

<b>Input Command</b>	<b>TCM2 Response</b>
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.

## 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. The error conditions and their corresponding bit locations are listed in [Table 2-2](#). Refer to [Table 2-3](#) for a list of the most common error codes.

**Table 2-2. Error Codes**

<b>1st ASCII Character</b>	
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)
<b>2nd ASCII Character</b>	
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 available on current model of TCM2
<b>3rd ASCII Character</b>	
Bit 3 (MSB)	Reserved for future use (always 0)
Bit 2	Magnetometer out of range
Bit 1	Inclinometer out of range
Bit 0 (LSB)	Magnetic distortion alarm

Thus, if the following error conditions existed: command parameter invalid and magnetic distortion alarm, then the corresponding error message would be: E041 .

**Table 2-3. Common Error Codes**

Error Code	Description
E001	Magnetic distortion alarm <sup>a</sup>
E002	Inclinometer out of range
E003	Magnetic distortion alarm and inclinometer out of range
E004	Magnetometer out of range
E005	Magnetometer out of range and magnetic distortion alarm
E006	Magnetometer out of range and Inclinometer out of range
E007	Magnetometer out of range, Inclinometer out of range, and magnetic distortion alarm
E010	Command invalid or not available
E040	Command parameter invalid
E050	Command invalid or not available, and command parameter invalid
E400	EEPROM2 error <sup>b</sup>
E800	EEPROM1 error <sup>b</sup>
EC00	EEPROM2 error and EEPROM1 error <sup>b</sup>

a. Indicates that the unit has detected magnetic field anomalies that can compromise compass and magnetometer accuracy based upon the stored values of the last calibration. Refer to “Magnetic Distortion Alarm ” on page 2-13 for more information.

b. Indicates that the TCM2 EEPROM has been corrupted. Contact PNI Corporation 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. The syntax is incorrect, or you have entered a command which is not supported by the TCM2 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. Note that extreme out of range conditions may not be detected. For example, when the inclinometer is upside down due to the physical dimensions of the inclinometer, it could output angles within the range of the inclinometer even though they are not valid angles.

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

**Magnetic distortion alarm** – the TCM2 is detecting a local magnetic anomaly that may be compromising the accuracy of compass and magnetometer readings. Refer to “Magnetic Distortion Alarm ” on page 2-13 for more details on this feature.

## Compass Operating Modes

---

### Standby Mode

The TCM2 is in Standby mode when you issue an **h** (**Halt**) command or **ax** (**Warm Reboot**). During Standby mode the TCM2 is idle and not sampling any sensors. You may configure and verify the TCM2's user parameters in the Standby mode (set sampling rate, filter parameters, and so on.) You may also query the TCM2 for single updates of compass heading, pitch and roll, magnetic field strength, and temperature. Because the TCM2's sensors are not sampling continuously during Standby, filtering is automatically disabled, and power consumption is reduced.

### Sampling in the Standby Mode

You can activate and receive data from the TCM2 sensors from the **h** (Halt Continuous Sampling, Enter Standby) mode. You may wish to do this if you are manually operating the TCM2 for evaluation purposes, or if the TCM2 only needs to be polled sporadically. With the TCM2 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 Standard Output” on page 2-3 to provide either NMEA formatted compass data, or the TCM2 Standard output word, which presents any combination of TCM2 sensor data that you wish to receive. The single parameter updates allow you to immediately query any sensor data.

---

**NOTE**

---

Because the sensors are not continuously sampling in the Standby mode, data damping is automatically disabled. Thus, any updates you request will *not* be damped.

### Continuous Sampling Mode

After configuring the TCM2 in the Standby mode, issue the **go** command to place the TCM2 into Continuous Sampling mode. In this mode, the TCM2 samples its sensors, processes, and stores this sensor data at the periodic rate you specify with the **sp=** (Set Sampling Period Divisor), **clock=** (Set Clock Rate), and **fast=** (Enable Fast Sampling) commands. The principle means of output from the TCM2 is via RS-232 serial communications. You may configure the TCM2 either to output the latest sensor data on a continuous, unprompted basis, or to provide an update only upon demand.

- continuous output (serial)
- analog output
- quadrature output

The TCM2 will output the specified output word at the chosen period rate. As soon as a new set of sensor data is processed by the TCM2, it is immediately transmitted. As discussed in “RS232 Data Output Word” on page 2-2, the output word can either be NMEA or TCM2 Standard formats.

The continuous output mode should be utilized if you wish to have the TCM2 automatically provide a periodic output without being prompted by the host system.

---

## Analog Outputs

The TCM2 supports analog output of compass heading data to provide compatibility with a wide range of existing systems. The analog output is enabled by **sao=e** (Select Analog Output) command. However, analog output modes do not provide full resolution, error flags, tilt data, or magnetic field information, so if you are implementing the TCM2 into a new design, utilizing the RS-232 interface is strongly recommended.

There are two analog output formats available: linear and quadrature. Use the Select Analog Output mode command, **sao=l** (linear) **sao=q** (quadrature) or **sao=d** (disabled) to configure the TCM2 to provide the analog output mode that you desire. Refer to “sao=” on page 3-25.

### *Linear Mode*

The TCM2’s digital compass heading is converted to a DC voltage ranging from 0 to 4.98 V by an 8-bit digital-to-analog converter (DAC). Thus, heading resolution is 8 bits (256 increments), around a full circle. Specifically, the 5V range is divided into 19.6 mV increments, where each increment corresponds to a 1.4 ° change in compass heading.

Thus, an output voltage of 19.6 mV corresponds to a 1.4 ° compass heading. An output voltage of 2.5 V corresponds to a compass heading of 179.5 °. Note that there is an abrupt switch in output voltage at 360 °, from 4.98 V to 0 V.

### *Quadrature Mode*

Two DC voltages provide the sine and cosine of the heading angle, thus eliminating voltage discontinuities. Analog output 1 (pin 9) is cosine of the heading; analog output 2 (pin 8) is sine of the heading. 4.98 V corresponds to  $\sin(\text{heading})$  or  $\cos(\text{heading})$  equal to 1.0 V corresponds to  $\sin(\text{heading})$  or  $\cos(\text{heading})$  equal to  $-1$ . If the compass is facing north, 0 °, you will see 4.98 V at pin 9 ( $\cos(0^\circ) = 1$ ) and 2.5 V at pin 8 ( $\sin(0^\circ) = 0$ ).

---

#### **NOTE**

You should always place a buffer between the TCM2 analog output and the input of an ADC. The analog output should swing from 0 V to 4.98 V. If you do not see the maximum output reach 4.98 V, you are probably loading the TCM2 analog output.

---

## Digital Damping

Digital damping is used to filter the output (**damping=**). The damping uses an IIR filter on the measured data. It is only enabled during continuous mode. The digital damping feature computes the following:

$$\text{output}=(1-f(\text{timeconst})) \times \text{current measurement} + f(\text{timeconst}) \times \text{oldmeasurements}$$

It outputs this as the current measurement and stores it in place of the old measurements. The function  $f$  is as follows:

$$f=10^{(\log(1/2)/\text{timeconst})}$$

The time constant is set using the **timeconstant=n** (Set Time Constant for Digital Damping) command, the filter time constant over about  $n$  measurements. If the sample rate is 16 Hz and  $n=32$ , filtering is done over about 32 measurements or for a damping period of 2 seconds.

The **%skip=n** (Skip Measurements) command can be used with digital damping. It allows the TCM2 to take fast continuous measurements but output every  $n$ th one. This is useful if you want to filter the output over a large sample. In this mode if every sample was output, due to the low pass filter, every output will not be significantly different from one another, and hence, it would be more useful to output every  $n$ th one. For example, if the sample rate is 16 Hz and the time constant is set to 30 samples, a reasonable value for **%skip** is 15.

## Output Response Time

The TCM2 samples the sensors at the rate selected by the **clock=** (Set Clock Rate) command (between 5 - 40 Hz). Measurement of the sensors requires about 50 mS in normal mode, **fast = d** (Enable Fast Sampling) and about 30 mS in fast mode, **fast = e** (Disable Fast Sampling). Refer to “Command List” on page 3-5 for details on the different modes and clock rates. Computation is overlapped with measurement of the sensors and requires about 20 mS. If the data output time (set by **b=**) command and output word length) exceeds the clock rate (set by **clock=**), the TCM2 will skip a sensor measurement. You must increase the baud rate, or decrease the clock rate on message length.

## Latency

In the **go** (Enter Continuous Sampling) mode, the *maximum latency* from the time a measurement starts, to the end of the data transmission is as follows:

**Table 2-4. Maximum Latency**

	<b>Normal</b>	<b>Fast</b>
Measurement time	50 mS	30 mS
Computation time	20 mS	20 mS
Output word length 30 at 9600 baud rate	30 mS	30 mS
Output word length 39 at 38400 baud rate	8.5 mS	8.5 mS
Total time at 9600 baud rate	100 mS	80 mS
Total time at 38400 baud rate	78.5 mS	58.5 mS



## Magnetic Distortion Alarm

The TCM2's magnetic distortion alarm indicates magnetic anomalies that can compromise compass and magnetometer accuracy. The process of user calibration (See [“User Calibration” on page 2-15](#)) allows the TCM2 to measure the nominal local magnetic field. This field value is then stored as a reference. During continuous sampling, the TCM2 evaluates the quality of magnetic environment by utilizing an algorithm that compares the instantaneous magnetic field information against the stored reference. If significant deviations are detected, the magnetic distortion alarm error flag is raised (if enabled).

---

### How to Use the Magnetic Distortion Alarm

To utilize the alarm, you must first perform a user calibration. Refer to [“User Calibration” on page 2-15](#). Next, the magnetic distortion alarm must be enabled by using the **ed=** (Enable Magnetic Distortion Alarm) command. From this point on, TCM2 output of compass or magnetometer data will be flagged with the magnetic distortion alarm code if the distortion condition exists. See the discussion of TCM2 error codes in [“Error Codes ” on page 2-6](#).

---

### How to Interpret the Magnetic Distortion Alarm

The TCM2 raises the magnetic distortion alarm when it detects a local magnetic anomaly. Your system should consider compass and magnetometer outputs to be suspect when the alarm is raised. The alarm can indicate short-term disturbances; for example, if the TCM2 is placed next to a large source of ferrous metal, or if a nearby piece of electrical equipment is activated. The alarm can also indicate long term disturbances; if, for instance, the TCM2 has been reinstalled in a different system without recalibration in which case the TCM should be recalibrated.

## Pitch and Roll Output

The TCM2 uses a fluid-filled tilt sensor to measure the orientation of the compass with respect to gravity. Since the compass also measures the complete magnetic field, the TCM2 can correct for the tilt of the compass to provide an accurate heading.

The tilt sensor measures the angles between the compass Z axis and the gravity vector. This is a different set of angles than the pitch and roll angles as commonly used in an airplane. The pitch and roll of an airplane is usually 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.

Because the tilt sensor uses gravity, it is really measuring rotations around the level Earth coordinate axes. Because these are fixed, and do not rotate with the body, the pitch and roll output by the TCM2 will act differently than the pitch and roll defined in an airplane.

You can use the tilt data output by the TCM2 to calculate the orientation of the TCM2 with respect to the level Earth coordinate frame. Define a vector G that is perpendicular to the compass board (and therefore is parallel to the Z-axis of the compass.) The coordinates of G = (X, Y, Z) in the level Earth frame will be:

$$Z = (SQRT(1 + \tan(P)^2 + \tan(R)^2))^{-1}$$

$$X = Z \tan(P)$$

$$Y = Z \tan(R)$$

where P and R are the pitch and roll reported by the TCM2.

The tilt range we specify for the TCM2 is the angle this G vector makes relative to gravity. This tilt sensor is accurate within this tilt range. The inclination of the compass relative to gravity,  $\theta$ , can be easily calculated as:

$$\theta = \arctangent((X^2 + Y^2)/Z^2),$$

where X, Y, and Z are the components of the G vector given above.

The compass will only compensate for the tilt within specifications when the inclination is less than the TCM2 tilt range.

## 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 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 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 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's triaxial magnetometer/biaxial inclinometer system configuration is its ability to compensate for hard-iron 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'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 to accurately compensate in all pitch and roll orientations. Gimbale fluxgates, for instance, are unable to provide accurate calibration in non-level orientations because its magnetometers, being gimbale, change position with respect to the host system as attitude changes. This presents a different local distortion field than that measured during calibration.

## Automatic Calibration

The principal of automatic calibration is to correct for any deviations from the initial calibration corrections. The magnetic anomalies of a system can change over time. Hence, after initial calibration, you might need to recalibrate the system to get accurate compass data. The automatic calibration feature allows you to enable the TCM2 to automatically correct for magnetic anomalies in the system.

Automatic calibration is not required for most purpose and better results will be obtained from rerunning the multipoint calibration. It continuously updates the estimated hard iron distortion vector. At 10 Hz, the response time of the TCM2 will not be affected even with automatic calibration enabled. However, if the TCM2 is sampling faster than 10 Hz and auto calibration is set, the real time response of the TCM2 is not fully maintained.

---

### CAUTION

*This mode should be used with care, there are a number of environmental characteristics that lead to incorrect results. This mode should not be used in environments where there are many transient magnetic anomalies or the system has a continuous repetitive movement that does not cover much of a circle while pitching and/or rolling.*

---

Automatic calibration should be enabled after multipoint calibration. The following commands are used to enable automatic calibration:

```
autocal=e           !Enable automatic calibration
go                 !Run in this mode, take data points
h                 !Update the EEPROM with the newly computed
                  ! hard iron distortion.
autocal=d           ! Disable the autocal mode.
```

To check how well the automatic calibration improved the score, use the **lc?** (Last Calibration) command.

---

### NOTE

The EEPROM does not save the new autocal computed coefficients until the data acquisition is halted (**h**), if power is lost during autocal, before it is halted, the TCM2 will restart with the prior **mpcal** (Multipoint Calibration) values.

---

## Soft Iron Effects

The TCM2 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 soft iron effects that are created by the amplification of magnetic fields by highly permeable materials, such as ferrous metals. The TCM2 does not currently 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.

The TCM2, does collect sufficient data to be mathematically capable of calibration for soft iron effects. Algorithms are currently being developed to implement a soft iron calibration in later models. If you do have soft iron effects from your system, contact PNI Corp. for the soft iron correction software that runs on your PC. The algorithm is too large to fit on to the current 8-bit microprocessor used on the TCM2, hence, the program allows for the algorithm to run on a PC and loads the coefficients into the EEPROM of the TCM2.

---

## Other Limitations

As discussed, the TCM2 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 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. This is a limitation universal to all compasses. However, the TCM2 does present a warning when such local disturbances occur. See [“Magnetic Distortion Alarm” on page 2-13](#).

Consider, therefore, the TCM2'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 can calibrate for any environment that creates a magnetic field that does not exceed the dynamic range of its magnetometers.

## Calibration Procedures

There are two basic operations related to user calibrations:

- Calibrating the TCM2 for the first time, or for a new installation.
- Updating the TCM2's calibration.

There are two internal calibration routines available for calculating the effects of hard iron magnetism on the compass.

- Multipoint Calibration
- CAL3

Multipoint is convenient for most users as it does not require any precision positioning. Depending on your equipment configuration, you may find the alternative routine, CAL3, to provide an easier, accurate, and quicker method of measuring hard iron correction. Both calibration procedures are described below.

You must be in Standby mode in order to issue calibration commands. The TCM2 cannot accept other commands during the calibration procedure.

---

## Multipoint Calibration (mpcal)

### *Key Points for the MPCAL Routine*

- Tilt as much as possible during the calibration. This allows the compass to take full advantage of the 3-axis magnetometer.
- Move slowly, take at least a minute to make a full circle. You are trying to get an even sampling of the magnetic field over as many headings and tilts as possible.
- If you get a poor calibration, clear it before making a new calibration.
- Pay attention to the score. A poor score is not good enough.

### Procedure

- 1 Clear any previous calibration by sending `cc`.
- 2 Enable multipoint calibration by sending `mpcal=e`.
- 3 Put the TCM2 in continuous mode by sending `go`.
- 4 Turn the host system with the TCM2 installed around at least twice changing the pitch and roll as much as possible.  
  
Each turn should take longer than 1 minute. The turn does not need to be a perfect circle. In the calibration mode, the TCM2 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  $\pm 90^\circ$  pitch and  $\pm 90^\circ$  roll. Doing so will improve the quality of the calibration. Do not worry about exceeding the range of the inclinometer.
- 5 Halt the TCM by sending `h` if **halt=e**; or `h <return>` if **halt=d**.
- 6 Check the calibration score by sending `lc?`.
  - If the calibration score is not satisfactory, set the TCM in the `go` (Enter Continuous Sampling) mode and take more data points for 1 or 2 turns.
  - If the score still does not improve much, disable multipoint calibration by sending `mpcal=d`, clear the last calibration by sending `cc` and rerunning the multipoint calibration `mpcal=e`.

The hard iron calibration algorithm uses a Kalman filtering algorithm. Hence it is best to slowly move the TCM2 during hard iron calibration.

### Interpreting the Calibration Score

The TCM2 provides feedback on calibration through the calibration score, which has the following format: `...HnVnMn...`

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 of the TCM2's host is stable, there are no large sources of changing fields.
- the calibration data points included a change in system inclination to allow for proper mea-

### Calibration Procedures

surement of the horizontal and vertical field vectors.

- there are no significant soft-iron distortion effects.

The last number in the score, Mn.nn, describes the magnitude of local field generated by the host system. 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 location; you should consider alternative mounting locations. Any score less than 10 is very good. You can use the **em=e** (Enable Magnetometer Data for Output Word) command to find positions on your equipment with the least magnetic field. Refer to “Where to Install the TCM2” on page 1-7 for locating the TCM2 away from local sources of changing magnetic fields.

The calibration score values mostly provide a qualitative estimation. For example, a good score would be H9V9Mn . nn. A poor score as anything less than H9V9Mn . nn. 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.

---

## CAL3 Procedure

The CAL3 calibration requires you to take three measurements in three orientations. It is very important for the accuracy of the routine that the orientations be as exact as possible. Error in positioning will translate directly into errors in the hard iron calibration.

The CAL3 calibration requires you to take one measurement, turn the system 180 ° exactly, take another measurement, turn the system upside-down exactly, and take a third measurement. The compass is taking two measurements on each axis with the directions reversed between them. The average of the two measurements is the hard iron vector that the TCM2 needs to correct.

---

### NOTE

Do not use the TCM2.exe program to run this calibration. Use a terminal program such as HyperTerminal instead.

---

### Procedure

- 1 Position the system to start. See [Figure 2-1](#).
- 2 Type CAL3 and press the keyboard's Enter key.

The TCM2 will take a measurement and prompt you to turn the system 180 °. It is very important that this be as exact as possible. In general, this will require some sort of fixture to hold and position your sensor.

- 3 Turn the system exactly 180 ° and press the keyboard's Space bar to continue. See [Figure 2-2](#).

The TCM2 will take a measurement, you will be prompted to turn the system upside-down. It is very important that the Z-axis in the new position be exactly 180 ° from the original position.

- 4 Turn the system upside-down and press the keyboard's Space bar to continue. See [Figure 2-3](#).

The TCM2 will take the third measurement and calculate the hard iron correction.



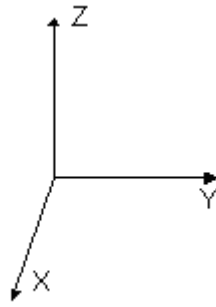


Figure 2-1. Measurement 1

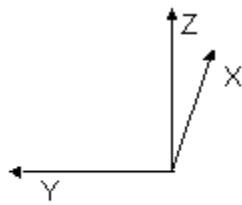


Figure 2-2. Measurement 2

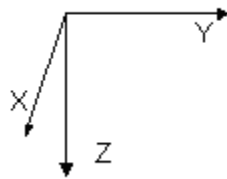


Figure 2-3. Measurement 3

---

## Temperature Sensor Calibration

The temperature sensor of the TCM2 can be easily calibrated if you can put the TCM2 in two environments with known temperatures. The TCM2 does not require temperature compensation for the inclinometer.

To calibrate the temperature sensor of the TCM2 electronic compass module, perform the following steps:

- 1 Send the following command to change the output word to the raw outputs (as opposed to the TCM2 standard output word or NMEA 0183 output word):

```
sdo=r
```

"r" stands for raw output.

---

### NOTE

All commands are followed by hitting the <Enter> key (which is the carriage return of the keyboard). When you ask for an update of the output word with the `s?` (Single Update of Output Word) or `g0` Enter Continuous Sampling Mode, the TCM2 will output the raw pitch, roll, 3 axis magnetometers (X, Y, and Z) and temperature readings. For example:

```
$P0388,0077 R00B8,0320 X57D8,6D46 Y6680,5FB6 Z6328,631C T0269
```

- 2 Place the TCM2 in an environment with a known temperature in Celsius (T1). For example: T1 = 10 °C.
- 3 Query the TCM2 for an update of the output word with the `s?` (Single Update of Output Word) command. Write down the raw temperature reading (which is the number at the end following the letter "T" in the output word). This temperature is TR1.
- 4 Change temperature of the environment of the TCM2 to a new known temperature in Celsius (T2). For example, T2 = 20 °C.
- 5 Query the TCM2 for an update of the output word with the `s?` command. Write down the raw temperature reading. This is TR2.
- 6 Solve the following two equations for the temperature constants KT0 and KT1:

$$T1 = KT1 \cdot TR1 + KT0$$

$$T2 = KT1 \cdot TR2 + KT0$$

Then:

$$T1 - T2 = KT1 \cdot TR1 - KT1 \cdot TR2 + KT0 - KT0$$

$$T1 - T2 = KT1 \cdot (TR1 - TR2)$$

$$KT1 = \frac{(T1 - T2)}{(TR1 - TR2)}$$

$$KT0 = T1 - KT1 \cdot TR1 \text{ or } KT0 = T2 - KT1 \cdot TR2$$

- 7 The coefficients must be scaled for use in the TCM2.

$$\%KT0 = 10 \cdot KT0$$

$$\%KT1 = 40960 \cdot KT1$$

- 8 Send the TCM2 the commands to set the temperature coefficients as follows (assume %KT0=26.23749 and %KT1=0.02389):

*%KT0 = 26.23749*

*%KT1 = 0.02389*

---

**CAUTION**

---

*Failure to properly input the following command sequence could corrupt the TCM2 EEPROM. Never leave the \*facal= command enabled (that is, facal=e).*

- 9 Send the TCM2 the ax (Warm Reboot) command. On versions 2.77 and higher, give the TCM2 \*facal=e, then ax, and then \*facal=d.

The TCM2 should now use the coefficients KT0 and KT1 which you just stored. Calibration of the temperature sensor should be complete, and outputs of temperature in the TCM2 standard output word should be the correct temperature sensed by the sensor. To check that the TCM2 actually stored these coefficients, you can query the TCM2 what these coefficients are with the following commands:

*%KT0?*

*%KT1?*

- 10 Send the TCM2 the sdo=t command (the command to change the output word back to the standard TCM2 output word).

Using the TCM2  
**Calibration Procedures**

Command List Quick Reference 3-2  
Differences Between TCM2 Firmware Version 2.82 and 2.34A 3-4  
    Changes to the EEPROM 3-4  
Command List 3-5  
Request for Data Commands 3-6  
Action Commands 3-11  
User Configuration Parameter Commands 3-17

---

## Programming Commands

## Command List Quick Reference

**Table 3-1. Command List**

<b>Command</b>	<b>Description</b>	<b>Page</b>
<b>Request for Data Commands</b>		
c?	Compass Update	<a href="#">page 3-6</a>
i?	Inclinometer Update	<a href="#">page 3-7</a>
lc?	Query Last Calibration Score	<a href="#">page 3-8</a>
m?	Magnetometer Update	<a href="#">page 3-8</a>
s?	Single Update Output Word	<a href="#">page 3-9</a>
t?	Temperature Update	<a href="#">page 3-9</a>
<b>Action Commands</b>		
autocal	Automatic Calibration	<a href="#">page 3-11</a>
ax	Warm Reboot	<a href="#">page 3-12</a>
cc	Clear Calibration Data	<a href="#">page 3-12</a>
factory	Factory Settings	<a href="#">page 3-13</a>
go	Enter Continuous Mode	<a href="#">page 3-13</a>
h	Halt Continuous Sampling, Enter Standby	<a href="#">page 3-14</a>
halt=	Enable single character halt	<a href="#">page 3-14</a>
mpcal	Multipoint Calibration	<a href="#">page 3-15</a>
sleep	Sleep Mode	<a href="#">page 3-16</a>
wake	Wake Mode	<a href="#">page 3-16</a>
<b>User Configuration Parameter Commands</b>		
%skip=	Skip Measurements	<a href="#">page 3-17</a>
b=	Set Baud Rate	<a href="#">page 3-17</a>
cclip=	Set Clip Value	<a href="#">page 3-18</a>
clock=	Set Clock Rate	<a href="#">page 3-19</a>
damping=	Set Digital Damping	<a href="#">page 3-19</a>
ec=	Enable Compass Data for Output Word	<a href="#">page 3-20</a>

**Table 3-1. Command List**

Command	Description	Page
ed=	Enable Magnetic Distortion Alarm	<a href="#">page 3-20</a>
em=	Enable Magnetometer Data for Output Word	<a href="#">page 3-21</a>
ep=	Enable Pitch Data for Output Word	<a href="#">page 3-21</a>
er=	Enable Roll Data for Output Word	<a href="#">page 3-22</a>
et=	Enable Temperature Data for Output Word	<a href="#">page 3-22</a>
fast=	Enable Fast Sampling	<a href="#">page 3-23</a>
ma=	Select Magnetometer Output Option	<a href="#">page 3-23</a>
mag_dec=	Set Declination Angle	<a href="#">page 3-24</a>
sao=	Select Analog Output Mode	<a href="#">page 3-25</a>
sdo=	Set RS232 Output Word Format	<a href="#">page 3-25</a>
serialp=	Low Power Serial Consumption	<a href="#">page 3-26</a>
sn=	Select Magnetic or True North	<a href="#">page 3-27</a>
sp=	Set Sampling Period Divisor	<a href="#">page 3-28</a>
timeconst=	Set Time Constant for Digital Damping	<a href="#">page 3-28</a>
uc=	Set Compass Units	<a href="#">page 3-29</a>
ui=	Set Inclinometer Units	<a href="#">page 3-29</a>
ut=	Set Temperature Units	<a href="#">page 3-30</a>

---

## Differences Between TCM2 Firmware Version 2.82 and 2.34A

Firmware version 2.82 is backward compatible with the 2.34A version of the TCM2 firmware except for the following changes:

- The TCM2 takes about 430 mS to start up when power is first applied to the unit. Previously it took about 250 mS to start up.
- All parameters set by the user via the command set were immediately written to EEPROM. In version 2.82, most commands do not update the EEPROM. The new parameters are not updated until one of the following updating commands are issued. If the power was disconnected before the new parameters were updated by one of the updating commands, those new parameters would be lost.

**Table 6-2. Updating Commands**

go	cc
h	save
ax	mpcal=d
factory	cal3

---

## Changes to the EEPROM

The changes to the EEPROM are not visible to the user. Version 2.82 duplicates the factory calibration coefficients, user hardiron coefficients, and user configurations in two different memory locations of the EEPROM. Also, the factory calibration coefficients, user coefficients, and the user configuration parameters are all stored in separate banks of memory in the EEPROM. Changes were made to make the data in the EEPROM less susceptible to corruption.

The EEPROM changes are as follows:

- 1 Changed from an 8 bit checksum to a 16 bit checksum.
- 2 The coefficients are stored in three different sections of the EEPROM. Each section can only be accessed if that section is enabled. The three sections are:
  - **Factory Calibration:** If this section of the EEPROM is corrupt, error E400 will appear.
  - **User Coefficient:** The hardiron and softiron calibration coefficients will be stored here. If this section of the EEPROM is corrupt, error E800 will appear.
  - **User Configurations:** All user set configurations will be saved in this section of the EEPROM. If this section is corrupt, error E800 will appear.
- 3 The three sections of the EEPROM are each backed up in a separate bank of EEPROM. The user correction and user configuration banks are updated each time a Write to EEPROM is done.



## Command List

All of the TCM2 commands are summarized in a list in Appendix B, along with the default values for all of the user parameters that are set when you receive the TCM2.

---

### ctrl-e, ctrl-n (Special Commands)

The TCM2 ordinarily does not echo characters received over the RS232 interface. You may enable echo by typing `<Ctrl> e` or disable it by typing `<Ctrl> n`.

## Request for Data Commands

These commands are used to request data from the TCM2.

---

### **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**

Degree	Mils
0 to ±20.0 °	0 to ±355.5 mils
0 to ±55 °	0 to ±973.5 mils
0 to ±80 °	0 to ±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. For a complete description of user calibration, [Refer to “User Calibration” on page 2-15.](#)

**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)  
autocal (Auto 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  $\mu$ T

**Valid Values** 0 to  $\pm 79.9 \mu$ T

**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. Refer to “Data Transmission” on page 2-5 for a full discussion of output word formatting. 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 Standard formats for the output word. If TCM2 Standard output is selected, only those data parameters that are enabled (with **ec**, **ep**, **er**, **em**, **et**) will be output.

---

**NOTE** In Standby mode (**h**), the TCM2 sensors are idle. When this command is issued in Standby mode, the TCM2 will first sample its sensors before transmitting the output word.

---

**Syntax** s?<cr>

**Output** Refer to “RS232 Data Output Word” on page 2-2 for a full description of the output word formats.

**Example** s?<cr>  
 \$C328.3P28.4R-12.4X55.1Y12.3Z-18.4T22.3 [Ennn] \*checksum<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

Programming Commands  
**Request for Data Commands**

**Valid Values**

Celsius	Fahrenheit
25.0 to 100.0 °C	-13 to 212 °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)

All TCM2 commands are displayed using the "?" command.

### autocal (Automatic Calibration)

**Description** This is an advanced calibration technique that is used after Multipoint Calibration (**mpcal**). Refer to “User Calibration” on page 2-15 for details.

**Syntax** autocal=e<cr>  
 :<cr><lf>  
 go<cr>  
 .....  
 ..... take data in continuous mode  
 h<cr> (or h)  
 autocal=d  
 :<cr><lf>

**Valid Values**

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

**Example** autocal<cr>  
 go<cr>  
 .....  
 ..... data in continuous mode  
 h<cr>  
 :<cr><lf>  
 autocal=d<cr>  
 :<cr><lf>

**Query Response** autocal? :autocal=

**Related Commands** lc? (Query Last Calibration Score)  
mpcal= (Multipoint Calibration)

---

## **ax** (Warm Reboot)

**Description** Resets the TCM2. The TCM2 halts its current activity, and resets to the operational mode last specified. Thus, the output mode selected before the Warm Reboot (**ax**) command remains the same after the warm reboot.

**Syntax** ax<cr>

**Output** <cr>

**Example** ax<cr>

**Related Commands** h (Halt Continuous Sampling)

---

## **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 for a new or changed local magnetic environment. [Refer to “User Calibration” on page 2-15.](#)

**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)  
autocal= (Automatic Calibration)  
c? (Compass Update)



---

## factory (Factory Settings)

*For version 2.34 and higher*

**Description** Resets the TCM2 to the factory settings. The internal modes are set to the following factory defaults:

autocal=d	er=e	serialp=d
b=9600	et=d	%skip=1
cc	fast=d	sn=m
clock=16	halt=d	sp=1
damping=d	ma=u	timeconst=8
ec=e	mag_dec=10	uc=d
ed=e	mpcal=d	ui=d
em=d	sao=d	ut=c
ep=e	sdo=t	

**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 immediately begins sampling sensors at the specified rate of the Set Clock Rate (**clock=**) command. Data is automatically transmitted at the sampling rate, and according to the Output Word Format (**sdo=**) currently specified. To exit the TCM2 and return to Standby mode, issue the Halt Continuous Sampling (**h**) command. Refer to “Continuous Sampling Mode” on page 2-8 and to “Latency” on page 2-12 for more information.

**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 is transmitting an output word, the remainder of the output word will be sent before the TCM2 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)

*For versions 2.82 and higher*

**Description** In the previous versions of the TCM2, during Enter Continuous Sampling Mode (**go**), sometimes the **halt** command was not accepted. This is because interrupts are disabled during inclinometer readings to synchronize the sensor readings. Interrupts are off for several milliseconds, potentially permitting a receive buffer overflow. To correct this, the **halt** command during **go** mode has optionally been made a single character command using the **halt=e** command. Refer to “Standby Mode” on page 2-8 for more information.

**Syntax** halt=d<cr>

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

### Valid Values

Input	Description
e	halt=e
d	h, cr command for halting the output (default setting)

**Query Response** halt? :halt=

**Related Commands** go (Enter Continuous Sampling Mode)

---

## mpcal (Multipoint Calibration)

**Description** Initiates a multipoint calibration. This command is only valid during Enter Continuous Sampling Mode (**go**). The TCM2 samples its sensors and adds the data point to the current set of calibration data. For a full description of the user calibration procedure, Refer to “[User Calibration](#)” on page 2-15.

**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)

**Output** HnVnMn.nn<cr><lf>  
 The TCM2 only reports a calibration score after it has been put in Standby mode (**h**).

**Example** mpcal=e<cr>  
 :<cr><lf>  
 go<cr>  
 .....  
 ..... take data in continuous 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)  
 autocal= (Automatic Calibration)

## 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)

**Description** Enters the wake mode of operation. To wake the TCM2, a falling edge on the int2 (interrupt 2) pin of the processor is required. This is achieved by connecting pin 6 of the TCM2 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 is provided on the TCM2.exe diskette.

**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's user configuration parameters. These parameters specify how the TCM2 will operate, such as sampling rate, baud rate, and so on. The TCM2 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 current setting of the appropriate units.

---

### **%skip=** (Skip Measurements)

**Description** Takes continuous measurements but outputs at a slower rate. For instance you could set the time constant to 100 in the digital damping mode and set `%skip=50` and output every fiftieth measurement. This command is used with the Set Digital Damping (**damping=**) command.

**Syntax** `%skip=n<cr>`

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

#### Valid Values

Input	Description
Integer value between 1 - 255	Skip n number of measurements. (Default is set to 1)

**Example** `%skip=integer<cr>` !set number of measurements to skip  
`:<cr><lf>`

**Query Response** `%skip?` `:%skip=`

**Related Commands** `damping=` (Set Digital Damping Mode)  
`timeconst=` (Set Time Constant for Digital Damping)

---

### **b=** (Set Baud Rate)

**Description** Sets the baud rate for the RS232 interface. The new baud rate specified is not used immediately, but only after the TCM2 has been reset with a Warm Reboot (**ax**) command or by cycling power on and off.

**User Configuration Parameter Commands****NOTE**

The TCM2.EXE program cannot use the 38400 baud rate. Do not use TCM2.exe to change the baud rate to 38400. If the TCM2 is set to 38400 (b=7), the TCM2.exe program will not be able to communicate with the PC.

The 38400 baud rate can be used with other terminal programs that support this rate. Examples of these programs are TELIX, PROCOMM and the telephone icon in the Accessories window of Windows. When using a terminal program you will need to set the correct baud rate, no parity, 1 stop bit, 8 bits and the COM port.

**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

**Example** b=5<cr> !set baud rate to 9600 baud  
:<cr><lf>

**Query Response** b? :b=

---

**cclip=** (Set Clip Value)

**Description** Sets a clipping value for the maximum positive and negative angle of the inclinometer. When the inclinometer angle exceeds this value, it is clipped to output that value along with an out-of-range flag.

**Syntax** cclip=nn.n<cr>

**Output** :<cr><lf>

**Valid Values**

Input	Description
Positive floating point minus the range of the inclinometer.	Clip the reading of the inclinometer at this value. (Default is 1 degree)
<b>Example</b> <code>cclip=nn.n&lt;cr&gt;</code> <code>:&lt;cr&gt;&lt;lf&gt;</code>	!set the value for the clip angle
<b>Query Response</b> <code>cclip?</code>	<code>:cclip=</code>

## clock= (Set Clock Rate)

**Description** Allows you to have precise control of the clock rate. The ability to sample at the higher speeds must be matched with the amount of data being output at each sample. At 9600 baud, each character requires about 1 mS to output, so at 30 Hz, the most that can be output is 30 characters, which is not enough for all data outputs to be enabled in the output word.

**Syntax** `clock=nn.nn<cr>`

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

**Valid Values** From 5 Hz to 40 Hz. 5 is equal to 5 Hz, 10 is equal to 10 Hz, and so on. (Default is set to 16 Hz)

**Example** `clock=30<cr>` !set clock rate to 30 Hz  
`:<cr><lf>`

**Query Response** `clock?` `:clock=`

**Related Commands** `fast=` (Enable Fast Sampling)  
`sp=` (Set Sampling Period Divisor)

## damping= (Set Digital Damping)

**Description** Enables or disables filtering of the output. The damping uses an IIR filter on the measured data. It is only enabled during Enter Continuous Sampling Mode (**go**). Refer to “Digital Damping” on page 2-10 for more information.

**Syntax** `damping=n<cr>`

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

**Valid Values**

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

**Example** damping=e<cr>                   !enable damping  
          :<cr><lf>

**Query Response** damping?                   :damping=

**Related Commands** %skip= (Skip Measurements)

---

**ec=** (Enable Compass Data for Output Word)

**Description** Enables or disables compass data for inclusion in the TCM2 Standard Output Word. For a description of the TCM2 Standard Output Word format, [refer to “TCM2 Standard Output” on page 2-3.](#)

**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.

**Example** ec=e<cr>                   !include compass data in output word  
          :<cr><lf>

**Query Response** ec?                   :ec=

---

**ed=** (Enable Magnetic Distortion Alarm)

**Description** Enables or disables the magnetic distortion alarm output feature. If enabled, the TCM2 reports the magnetic distortion condition when detected. The magnetic distortion alarm is reported as an error flag in the error code response in TCM2 output messages. For a full description of the magnetic distortion alarm, [refer to “Magnetic Distortion Alarm ” on page 2-13.](#)

**Syntax** ed=n<cr>



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

**Valid Values**

Input	Description
e	Magnetic distortion alarm enabled. (Default setting)
d	Magnetic distortion alarm disabled.

**Example** ed=e<cr> !enable magnetic distortion alarm  
 :<cr><lf>

**Query Response** ed? :ed=

## em= (Enable Magnetometer Data for Output Word)

**Description** Enables or disables magnetometer data for inclusion in the TCM2 Standard Output Word. For a description of the TCM2 Standard Output Word format, refer to “TCM2 Standard Output” on page 2-3.

**Syntax** em=n<cr>

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

**Valid Values**

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

**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 Standard Output Word. For a description of the TCM2 Standard Output Word format, refer to “TCM2 Standard Output” on page 2-3. For a description of Pitch and roll, refer to “Pitch and Roll Output” on page 2-14.

**Syntax** ep=n<cr>

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

**Valid Value** s

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

**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 Standard Output Word. For a description of the TCM2 Standard Output Word format, [refer to “TCM2 Standard Output” on page 2-3](#). For a description of Pitch and roll, [refer to “Pitch and Roll Output” on page 2-14](#).

**Syntax** er=n<cr>

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

**Valid Values** s

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

**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 Standard Output Word. For a description of the TCM2 Standard Output Word format, [refer to “TCM2 Standard Output” on page 2-3](#).

**Syntax** et=n<cr>

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

**Valid Values**

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

**Example** et=e<cr> !include temperature data in output word  
 :<cr><lf>

**Query Response** et? :et=

## fast= (Enable Fast Sampling)

**Description** Enables or disables fast sampling. This command in conjunction with the Set Clock Rate (**clock=**) command allows the unit to sample up to 30 Hz with less accurate magnetometer and compass measurements. The random noise in the compass heading measurements increases to about  $\pm 0.3^\circ$  in this mode. Use this command at sample rates greater than 16 Hz.

**Syntax** fast=n<cr>

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

**Valid Values**

Input	Description
e	enable fast sampling
d	disable fast sampling (Default setting)

**Example** fast=e<cr> !enable fast sampling mode  
 :<cr><lf>

**Query Response** fast? :fast=

## 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 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.

Programming Commands  
User Configuration Parameter Commands

**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)

**Example** ma=c<cr> !corrected magnetometer readings  
:<cr><lf>

**Query Response** ma? :ma=

---

## mag\_dec= (Set Declination Angle)

*For version 2.34 and higher*

**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.

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>

**Syntax** mag\_dec=nn.n<cr>

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

**Valid Values**

Input	Description
nn.n	declination angle in degrees (The default value is set to 10)

**Example** mag\_dec=17.2 !sets the declination angle to 17.2 degrees  
:<cr><lf>

**Query Response** mag\_dec? :mag\_dec=

**Related Commands** sn= (Select Magnetic or True North)

## sao= (Select Analog Output Mode)

**Description** Sets the mode for analog output. For a full description of analog output modes, refer to “Analog Outputs” on page 2-9.

**Syntax** sao=n<cr>

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

### Valid Values

Input	Description
d	Analog output disabled. (Default setting)
l	Linear analog output enabled.
Q	Quadrature analog output enabled.

**Example** sao=l<cr> !set analog output mode to linear  
 :<cr><lf>

**Query Response** sao? :sao=

## 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**). For a full description of TCM2 output words, refer to “RS232 Data Output Word” on page 2-2.

**Syntax** sdo=n<cr>

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

### Valid Values

Input	Description
t	standard TCM2 output word (Default setting)
r	raw data

**Example** sdo=t<cr> !output word format to TCM2 standard  
 :<cr><lf>

Query Response sdo? :sdo=

---

## serialp= (Low Power Serial Communication)

**Description** Places the TCM2 into low power mode. The following tables shows the power consumption in the different modes. Note that the power consumption will vary  $\pm 0.5$  mA between units. The following measurements were made on serial number 7536.

**Table 3-3. Power Supply via the Unregulated Input: serialp=d**

Modes	Power Consumption
Standby Mode	11.7 mA
Continuous sample at 16 Hz	16.74 mA
Continuous sample at 8 Hz	15.65 mA
Continuous sample at 1 Hz	14.6 mA
Sleep mode	2.87 mA

**Table 3-4. Power Supply via the Unregulated Input: serialp=e**

Modes	Power Consumption
Standby Mode	4.0 mA
Continuous sample at 16 Hz	13.6 mA
Continuous sample at 8 Hz	10.23 mA
Continuous sample at 1 Hz	7.5 mA
Sleep mode	2.87 mA

**Table 3-5. Power Supply via the 5 V Regulated Input: serialp=d**

Modes	Power Consumption
Standby Mode	11.3 mA
Continuous sample at 16 Hz	16.0 mA
Continuous sample at 8 Hz	15.0 mA
Continuous sample at 1 Hz	14.0 mA
Sleep mode	2.7 mA

**Table 3-6. Power Supply via the 5 V Regulated Input: seriallp=e**

Modes	Power Consumption
Standby Mode	3.88 mA
Continuous sample at 16 Hz	12.45 mA
Continuous sample at 8 Hz	9.55 mA
Continuous sample at 1 Hz	7.0 mA
Sleep mode	2.87 mA

**Syntax** seriallp=n<cr>

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

**Valid Values**

Input	Description
e	enable
d	disable (Default setting)

**Example** seriallp=e<cr>  
 :<cr><lf>

**Query Response** seriallp? :seriallp=

**sn=** (Select Magnetic or True North)

*For version 2.34 and higher*

**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>

Programming Commands  
User Configuration Parameter Commands

Valid Values

Input	Description
t	true north (Default setting)
m	magnetic north

**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 Divisor)

**Description** Divides the clock rate set by Set Clock Rate (`clock=`). For the TCM2, this command is meant to be used in conjunction with the `clock=` command to set the sampling period below 5 Hz. In the TCM1, this command was used to divide down the 8 Hz sampling rate. It can be used the same way in the TCM2 if the clock rate is set to 8 Hz.

**Syntax** `sp=nnn<cr>`

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

Valid Values

Input	Description
1 to 5	Sample every second sample of the clock rate. (Default setting is 1)

**Example** `sp=5<cr>`  
`:<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. Refer to “[damping=](#)” on page 3-19.

**Syntax** `timeconst=n<cr>`



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

**Valid Values**

Input	Description
Integer value between 1-255	Set the measured time constant. (Default setting is 8)

**Example** timeconst=16<cr> !Filter over 16 measurements  
 :<cr><lf>

**Query Response** timeconst? :timeconst=

**Related Commands** damping= (Set Digital Damping)  
 %skip= (Skip Measurements)

**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 °in a full circle (Default setting)
m	mils, 6400 mils in a full circle

**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>

Programming Commands  
User Configuration Parameter Commands

Valid Values

---

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

**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 input and output of temperature data.

**Syntax** `ut=n<cr>`

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

Valid Values

---

Input	Description
f	Fahrenheit
c	Celsius (Default setting)

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

**Query Response** `ut?` :ut=

Trouble-Shooting the TCM2 4-2  
Limitations of the Inclinometer 4-6

---

## Troubleshooting

## Trouble-Shooting the TCM2

- ❑ When I connect the TCM2 to my PC, there is no response from the TCM2
  - Make sure that you are giving the TCM2 the correct power, refer to “Electrical Connections” on page 1-4 for proper connection of power, ground, TXD, RXD, and data ground.
  - The TCM2 is defaulted to **h** (standby) mode. To enable the TCM2 either type the **go** (Enter Continuous Sampling) command or select the *start continuous sampling* button in the TCM2.exe program. This button is located at the top middle position on the TCM2.exe display.
  - With the TCM2.EXE program (or any terminal program you use), the program must be set to the correct COM port and baud rate that the TCM2 is currently using. The TCM2.EXE program default is COM2. For COM1, type `TCM2 1` when you launch the program to select the COM1 port or use the *set Program i/o parameters...* button to select the COM port and reset the TCM2.
  - When you change the baud rate, the TCM2 does not start using the new baud rate until after an **ax** (Warm Reboot) command or **save** (Save Settings) command has been sent, followed by cycling the power off and on again. When cycling the power after the **save** command, make sure a **..:** is returned from the TCM2 before cycling power off. If power is removed during a write to the EEPROM, it can get corrupted.
  - If you change the baud rate to 38400 using the TCM2.EXE program and then cannot communicate with the TCM2, you will have to find a computer and terminal program (such as TELIX or PROCOMM) that can communicate at 38400. Then you can set the TCM2 to the desired baud rate. There is no other way to change the baud rate of the TCM2 from 38400 after it has been changed; that is, there is no hard reset which will change the baud rate.

---

### NOTE

---

The TCM2.EXE program CAN ONLY use baud rates up to 19200. Although it can give the command to change the baud rate to a faster baud rate, the TCM2.EXE will not be able to communicate at a baud rate greater than 19200.

- The TCM2 needs to be set to the same baud rate as the communication program. If you do not know the baud rate of the TCM2, try using COM1 and each baud rate. If none of those combinations work, try using COM2 and each baud rate.
- ❑ The calibration score looks good, but when I move the TCM2, the output of heading only changes a few degrees when I turn the TCM2 through 360 °
  - A good score is H9V9Mnn.n where nn.n < 30.0  $\mu$ T. Any value of the H and V that is less than 9 is not a good score.
  - Your previous calibration may have been "bad" and you may not have cleared the previous calibration data (the **cc** command) before starting the new calibration.
  - You may have softiron. The Multipoint and CAL3 calibration procedures remove the effects of hardiron, but will not account for softiron. Softiron effect is a magnetic anomaly vector that changes as you rotate it around the earth's field. This is a much more complicated anomaly to fix. Refer to “Soft Iron Effects” on page 2-17 for more information.

❑ The heading from the TCM2 jumps around or just seems wrong

- First look for any error code. *Refer to “Error Codes ” on page 2-6* for detailed error code descriptions.
- The heading of the TCM2 is calculated using the 3 magnetometer outputs and 2 axis inclinometer. It is important to identify the sensor that is noisy. Send the following commands to enable all the sensor outputs:

```
em=e          !magnetometer data enabled
ep=e          !enable pitch data for output word
er=e          !enable roll data for output word
ec=e          !enable compass data for output word
go           !enter continuous sampling mode
```

Check the values of pitch, roll, and the X, Y and Z magnetometers. Check if any of the sensors are noisy. If the magnetometers are noisy, look for external sources of magnetic fields that could be changing. If the inclinometer is noisy, check for vibration.

- Check for any distortion sensed by the TCM2 by checking if there is an error flag (“Ennn”) in the output word. If there is an error flag including “E001” or “E004”, then you may not have cleared the calibration data (**cc**) before a new calibration. If the error flag is then “E400”, then there is a serious EEPROM error, and you must contact PNI Corp. to determine how to restore the EEPROM coefficients.
- Check whether the three magnetometer sensors are working by giving the following commands:

```
sdo=r          !set data output to raw
s?            !get a single update of the output word
```

The first line of the output will look like this:

```
$Pnnnn,nnnn Rnnnn,nnnn Xnnnn, nnnn Ynnnn,nnnn Znnnn,nnnn
Tnnnn<cr><lf>:<cr><lf>
```

If both numbers (nnnn,nnnn) after X, Y or Z are 0000 (for example, X 0000,0000), then that sensor or the drive circuitry is malfunctioning. Please contact PNI Corp.

- To put the TCM2 back in normal operating mode, give the **sdo=t** (Set RS232 Output Word Format) command for the Standard TCM2 output word or **sdo=n** command for the NMEA 0183 output word.

❑ The pitch or roll output does not change

- First make sure that the inclinometer is not set to clip at any particular angle with the “cclip?” command. Either set the clip to 0 (**cclip=0**) or set the clip to a value that is greater than the tilt range of your system (for example, **cclip=19** °).
- Make sure that you are giving the TCM2 power correctly, [refer to “Electrical Connections” on page 1-4](#).
- Check the voltage level applied to the TCM2. The sensor accuracy depends on the present voltage level and current level.

**Trouble-Shooting the TCM2**

❑ The output rate is slower than it should be

- The output rate is a function of a number of commands: **clock=** (Set Clock Rate), **sp=** (Set Sampling Period Divisor) and **%skip=** (Skip Measurements) commands. The sampling rate is equal to the clock divided by the sampling period (clock/sp). The TCM2 uses the **%skip** value even when damping is not enabled. The actual output rate is equal to the sampling rate (clock/sp) divided by the number of samples that the TCM2 is to skip (**%skip**). Therefore, the output rate is clock/sp/%skip. If you are not using the digital damping feature, then use the **%skip=0** command so that the TCM2 does not skip any outputs.

1 There is an error message (“Ennn”) in the output word.

- Refer to “Error Codes ” on page 2-6 for descriptions of each error code and the most likely cause for the error.

2 When the host system moves, the fluid in the inclinometer sloshes around and gives inaccurate tilt, which results in inaccurate heading calculations.

- If the TCM2 will experience significant vibration or sloshing, there are two ways to dampen the effect. First, try the “digital damping” function, refer to “Digital Damping” on page 2-10. Second, a more viscous fluid can be used in the inclinometer. You must contact PNI Corp. for pricing and ordering a TCM2 with a different inclinometer.

3 I want to see if the compass is accurate.

- Try this simple functional test.

1 Set the TCM2 on a flat surface and mark its location.

2 Take a reading of the heading.

3 Turn the compass 180 ° and take another reading.

Try this at about 4 different orientations (for example, starting at 0 °, 45 °, 90 °, and 135 °) The compass should read a difference of 180 ° between pairs of readings. Watch out for nearby metal; most tables, for example, have metal parts that distort the magnetic field and will make the compass give inaccurate readings.

❑ What else should I not do?

- Do not remove power before a command is complete. Power *must not* be removed from the TCM2 while the TCM2 is executing a command. Doing this can erase the EEPROM because the EEPROM is not write-protected at that time. You *must* wait for the TCM2 complete the command. For example, when you send a command **em=d** (disable magnetometers), it will return a “:” to indicate it is finished.
- Do not set the baud rate too fast. With the TCM2.EXE program (or any terminal program you use), the program must be set to the correct COM port and baud rate that the TCM2 is currently using. The TCM2.EXE program default is COM2. For COM1, type `TCM2 1` when you launch the program to select the COM1 port or use the *set Program i/o parameters...* button to select the COM port and reset the TCM2.

Also, you can overflow the serial input buffer of your computer if the **b=** (Set Baud Rate) and **sp=** (Set Sampling Period Divisor) are set too fast. For example, many 486 computers cannot process the serial input if the sample rate is 30 Hz and the baud rate is 38400.

- Do not use steel parts (or other parts which can be magnetized) near the TCM2. Steel and other parts can be magnetized, meaning that the material will take on a different magnetic charge than the charge it had during calibration. These parts can be magnetized by moving a magnet (or any source of a magnetic field) near them. If you must use a certain part with these properties, then your customers should be warned to keep the product away from sources of magnetic fields which could magnetize that part. They should also look for the E001 error. Auto calibration function of the TCM2 can be used for these situations. Auto calibration will try to adjust the hardiron calibration coefficients to reflect the change but if the magnetization is too large, a full multipoint calibration will be necessary.
- Do not put a magnet on the TCM2 compass. Some components on the board can become magnetized if exposed to a strong magnetic field.
- We recommend conformal coat if the board will be exposed to moisture or sources of contamination.

## Limitations of the Inclinometer

While the TCM2 electronic compass can handle many rugged environments and dynamic situations, there are limits. The majority of the limits result from the inclinometer (the tilt sensor), which is filled with an electrolytic fluid.

### *Acceleration*

When the TCM2 is in acceleration, the fluid in the tilt sensor will be thrown up against the side of its bubble. Examples of situations with acceleration include banking turns of an airplane and take off of an airplane. The tilt sensor will measure the angle of the fluid as the tilt of the system because it cannot distinguish between acceleration and tilt. The error from this measurement will result in an error in the calculated heading. Therefore, the host system has to be able to tolerate inaccurate heading when acceleration is present. A formula which relates acceleration to the error in tilt is as follows:

$$\text{Acceleration} = 5 * \text{gravity} * \text{tangent}(A)$$

where A is the error measured in degrees (solve for A to get the error). This equation only applies to the standard 20% dampened tilt sensor fluid used on the TCM2. The scale factor 5 will be different for different types of tilt sensor fluids. For example, with acceleration of about 0.84 m/sec\*sec and gravitational force of 9.8 m/sec\*sec, then the error *in tilt* will be about 1°. The related error in heading will be from 1° to about 8°, depending on where the compass is on earth. Here in Mountain View, CA, the error in heading for 1° of tilt will be about +/-2.1°.

### *Settling Time*

After a sudden change in heading, the settling time for the inclinometer (which is the limiting factor) is approximately 300 mS.

### *Shock*

The limiting factor for surviving shock is the inclinometer. The vendor of the inclinometer provided the only test results we have for the inclinometer: it was shown to withstand 20 g for 11 mS and to withstand 11 g for 18 mS. We do not have any test results for any other situations.

### *Vibration*

The natural frequency of the standard fluid in the inclinometer is approximately 20 Hz. If the system has frequencies that are within a few hertz of this, the tilt sensor will give inaccurate readings, which means that the heading will also be inaccurate. If your application has frequencies in this range, contact PNI Corp. to discuss using a different fluid in the inclinometer.



Specifications 5-2

- Heading and Tilt Specifications 5-2
- Magnetic Field Specifications for the TCM2-20, TCM2-50, and the Magnetometer Only 5-2
- General Specifications 5-3
- Assembly Views 5-3
- 3-Foot Cable 5-6
- Optional 6-Foot Cable 5-8

---

## Performance Specification

## Specifications

The TCM2-20 electronic compass sensor module has  $\pm 20^\circ$  of tilt compensation, while the TCM2-50 has  $\pm 50^\circ$  of tilt compensation.

**Table 5-1. Heading and Tilt Specifications**

	TCM2-20	TCM2-50	Inclinometer Only
<b>Heading Specifications</b>			
Accuracy when Level	$0.5^\circ$	$1.0^\circ$	N/A
Accuracy when tilted	$1.0^\circ$	$1.5^\circ$	N/A
Resolution	$0.1^\circ$	$0.1^\circ$	N/A
Repeatability	$\pm 0.1^\circ$	$\pm 0.3^\circ$	N/A
<b>Tilt Specifications</b>			
Accuracy	$\pm 0.5^\circ$	$\pm 1.0^\circ$	$\pm 1.0^\circ$
Resolution	$0.1^\circ$	$0.3^\circ$	$0.3^\circ$
Repeatability	$\pm 0.2^\circ$	$\pm 0.3^\circ$	$\pm 0.3^\circ$
Range	$\pm 20^\circ$	$\pm 50^\circ$	$\pm 50^\circ$

**Table 5-2. Magnetic Field Specifications for the TCM2-20, TCM2-50, and the Magnetometer Only**

Absolute Accuracy	$\pm 1 \mu\text{T}$ up to $70 \mu\text{T}$ (typical) $\pm 5 \mu\text{T}$ from $70 \mu\text{T}$ to $80 \mu\text{T}$
Resolution	$0.01 \mu\text{T}$
Repeatability	$\pm 0.2 \mu\text{T}$
Range	$\pm 80 \mu\text{T}$

**Table 5-3. General Specifications**

<b>Power Requirements</b>	
Supply Voltage	+5 VDC regulated or 6 to 18 VDC unregulated
Current <sup>a</sup>	
Operating Standard Mode	15 to 20 mA, depending on user configuration
Operating Low Power Mode	7 to 13 mA, depending on user configuration
Sleep Mode	2.5 mA
<b>Physical Measurements</b>	
Dimensions	2.5 in. x 2.0 in. x 1.25 in.
Weight	1.6 ounces
<b>Interfaces</b>	
Digital	RS232C or NMEA0183
Analog	0.5 V linear, 19.53 mV resolution (256 discrete levels) 0.5 V quadrature (sine and cosine)
<b>Temperature Information<sup>b</sup></b>	
Accuracy after Calibration	$\pm 1$ °C, $\pm 2$ °F
Resolution	$\pm 1$ °C, $\pm 2$ °F
Range	-20 °C to 70 °C
<b>Environmental Characteristics</b>	
Operating Temperature	-20 °C to 70 °C
Storage Temperature	-30 °C to 90 °C
a. For version 2.82K only.	
b. Sensor is uncalibrated.	

## Assembly Views

Unless otherwise noted:

- Units are in U.S. inches
- Tolerances are:
  - x.x =  $\pm 0.1$
  - x.xx =  $\pm 0.01$
  - x.xxx =  $\pm 0.005$
- The compass module should be aligned within the host system with respect to the centers of the mounting holes.

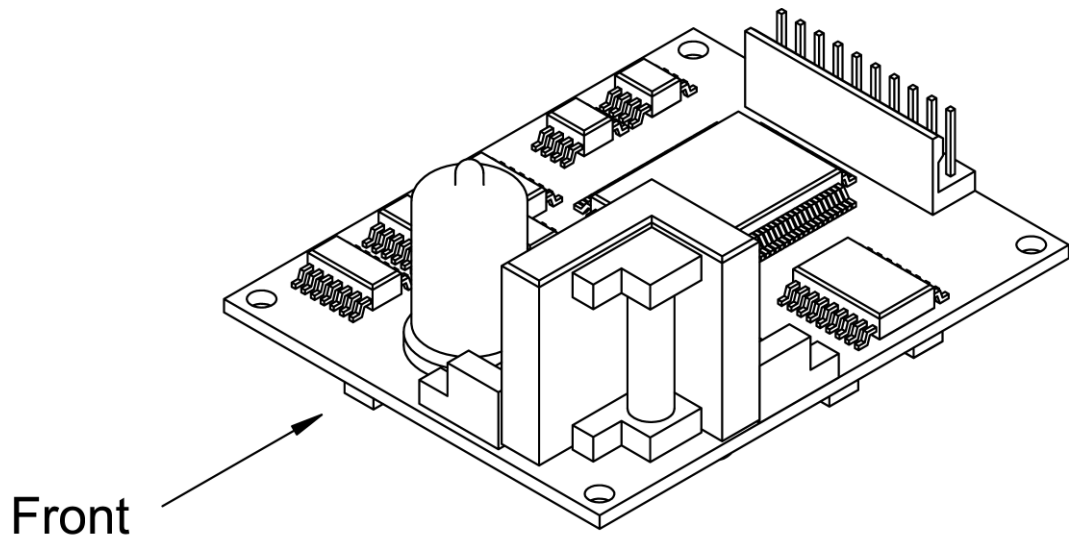


Figure 5-1. Front View

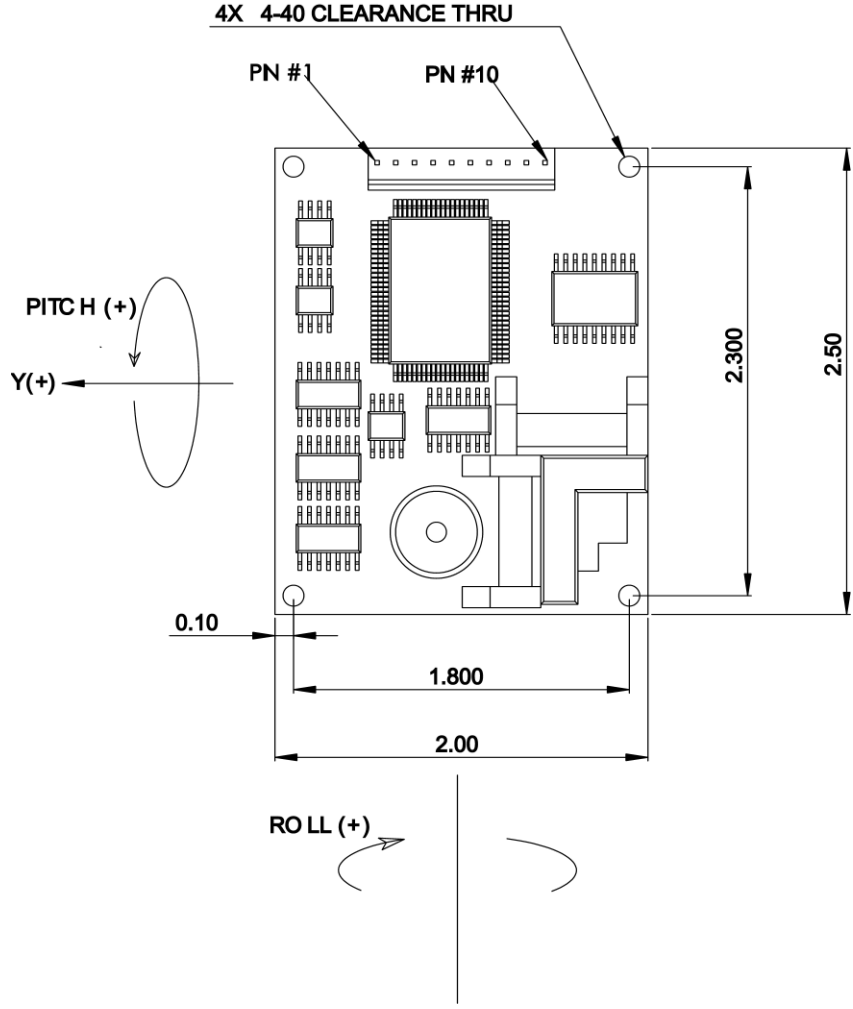


Figure 5-2. Top View

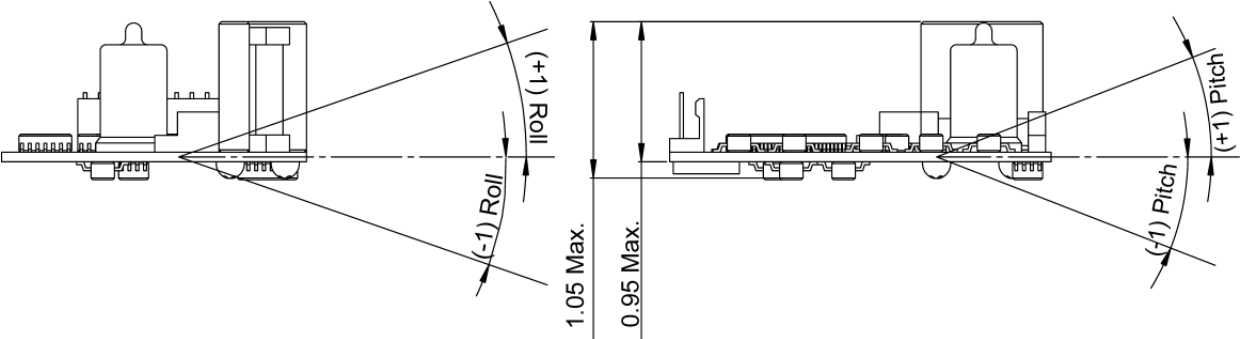
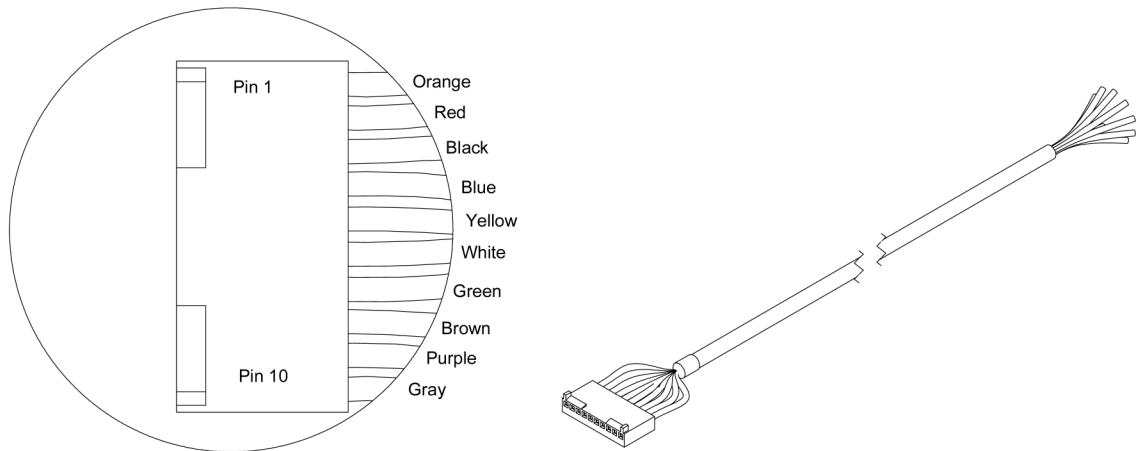
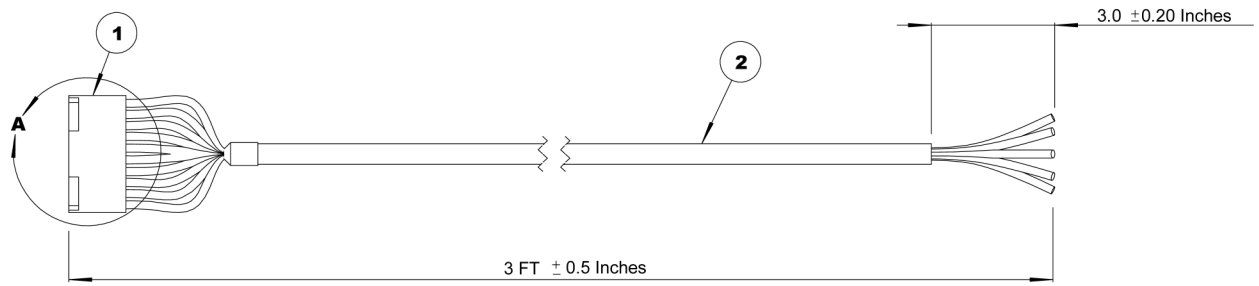


Figure 5-3. Side Views

### 3-Foot Cable



**DETAIL A (6 : 1)**

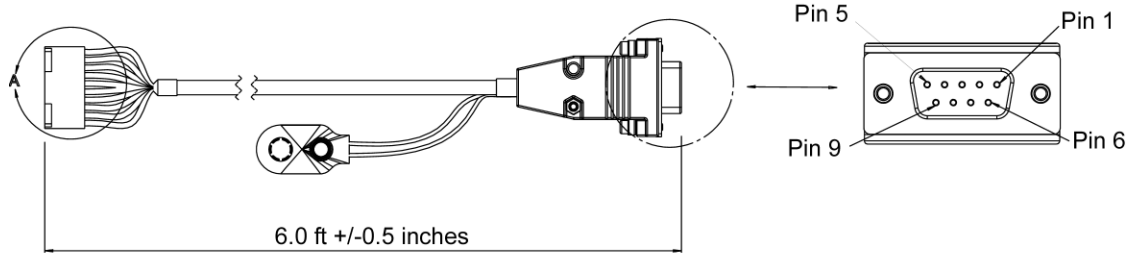
**Figure 5-4. 3-Foot Cable with Molex Connector**

**Table 5-4. Molex Connector Pin Description**

<b>Pin</b>	<b>Wire</b>	<b>Description</b>
1	Orange	Vsupply (5VDC $\pm$ 5%)
2	Red	Vsupply (6 - 18 VDC)
3	Black	GND (power)
4	Blue	RXD (RS-232)
5	Yellow	TXD (RS-232)
6	White	Mouse Input (not used)
7	Green	GND (data)
8	Brown	Analog Output 2
9	Purple	Analog Output
10	Gray	GND (data)

## Optional 6-Foot Cable

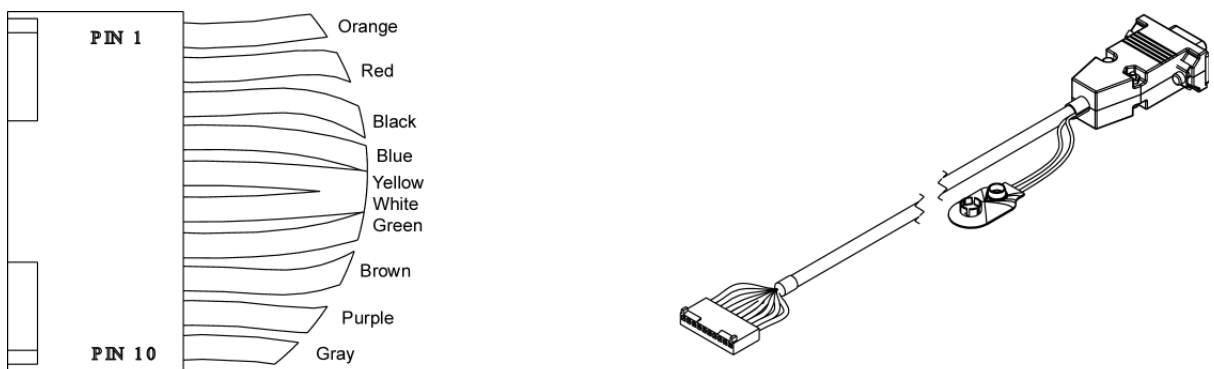
Unless otherwise specified all units are in standard U.S. inches.



**Figure 5-5. 6-Foot Cable with Detail View of DB9 Connector**

**Table 5-5. DB9 Connector Pin Description**

Pin	Wire	Description
1	not connected	
2	Yellow	TXD (RS-232)
3	Blue	RXD (RS-232)
4	not connected	
5	Green	GND (data)
6	not connected	
7	White	Mouse Input (unused)
8	not connected	
9	not connected	



**DETAIL A (6 : 1)**

**Figure 5-6. 6-Foot Cable with Detail View of Molex Connector**



**Table 5-6. Molex Connector Pin Description**

<b>Pin</b>	<b>Wire</b>	<b>Description</b>
1	Orange	Vsupply (5VDC $\pm$ 5%)
2	Red	Vsupply (6 - 18 VDC)
3	Black	GND (power)
4	Blue	RXD (RS-232)
5	Yellow	TXD (RS-232)
6	White	Mouse Input (not used)
7	Green	GND (data)
8	Brown	Analog Output 2
9	Purple	Analog Output
10	Gray	GND (data)

Performance Specification  
**Specifications**