TRAIN MEASUREMENT SYSTEM

OWNER'S MANUAL

PART NUMBER: TMS-E232-1AD

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Watson Industries prides itself on solving customer problems and serving their needs in a timely fashion. This manual is intended to facilitate this goal and to provide written information about your product. We ask that you carefully read this manual. Becoming familiar with the manual will help you understand the product's capabilities and limitations, as well as provide you with a basic understanding of its operation. If, after reading the manual, you require further assistance, do not hesitate to call Watson Industries with your questions and comments.

CAUTION!

Watson Sensors are rugged devices that have been used successfully in a number of harsh environments. The components have been qualified to withstand a mechanical shock of 500g's or greater, and most enclosures provide an added level of protection. However, dropping a sensor from waist height onto a hard floor can cause a shock level of 600g's. At this level, damage is likely to occur.

Introduction

The TMS-E232 is a solid-state, instrument package consisting of two single axis, solid-state angular rate gyros and one accelerometer, interfaced to a microprocessor that provides angular rate integration, bias removal, scale-factor compensation and a data management functions. This product is manufactured for heavy industrial applications through extended testing, EMI/RFI filter enhancements, internal shock mounts and a rugged enclosure.

Product Description

The sensor provides a serial RS-232 signal as the primary output. The output is refreshed up to 90 times per second.

The microprocessor system, which also supports RS-232 serial input, allows the sensor to be adjusted using data terminal equipment. A PC running data communications software is all that is needed. See Appendix A more information on the Serial Output.

The gyros are installed nominally orthogonal and final adjustment of cross-axis alignment is carried out using the microprocessor with sensor adjustment-data held in non-volatile memory. This avoids the need for physical adjustment.

Integrating the rate signal over time and subtracting the resulting value from the rate signal provides a bias-free rate signal. The integrator time-constant is held in non-volatile memory and is settable using the RS-232 interface.

Installation

Orientation/Mounting

The connector face of the unit must face either forward or aft and the mounting plane must be level and either on top or under the unit. The various orientations allowed are to be accommodated when the orientation setting in the TMS is applied. The unit has four mounting holes with clearance for one-quarter inch bolts for a flat surface mount. If high shock loads are expected (greater than 20G or repeated shocks greater than 10G), appropriate shock mounting should be used to prevent damage. Vibration isolation should also be used if operation in 5G rms or greater vibration environments is expected.

Environment

Avoid mounting sites that are subject to significant temperature variation over the duration of the test. Rapid temperature variation can induce noticeable rate sensor bias drift. The operational temperature range is –40 to +60 degrees Celsius.

Power

This unit has an internal regulator to allow operation over a wide voltage input range. Best operation is obtained at either 12 or 24 VDC level, although operation is fully satisfactory down to 10 VDC and up to 35 VDC (reverse voltage protected). Power draw of the unit is less than 6 Watts. Internal capacitors are provided to remove a reasonable level of power line noise, however, capacitors should be added for long power line wiring or if noise is induced from other loads on the circuit. The TMS power system is isolated from the TMS signal system.

Calibration

The TMS is calibrated at the factory before it is shipped to the user. It is recommended that the unit be examined annually for evaluation and recalibration.

Operation

Theory

This product has two parts to its function, the roll system and the turn rate system. They are very different systems, but they are connected in that the roll system requires an accurate turn rate system.

Turn Rate System
The turn rate system is a simple washout loop with controls on amount of error to be corrected and of the time constant of the loop. The general configuration is as shown below:

Turn Rate Gyro   Time Constant   Limiter
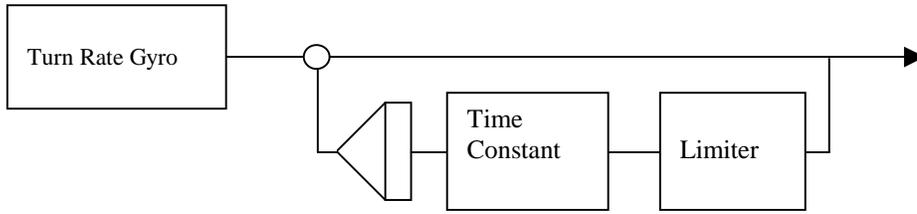
The benefits of this design are that the errors are continually corrected, but there are some limitations. Heading changes will accumulate as if they are bias errors, so the system tries to detect heading changes and reduces the error correction gain for those conditions.

Initialization	Stopped	Level		Time Constant
Y	Y	Y		5
Y	Y	N		10
Y	N	Y		30
Y	N	N		90
N	Y	Y		10
N	Y	N		20
N	N	Y		60
N	N	N		120

The stopped condition is controlled by speed (must be under 5 KPH, set by menu) and by accelerometer noise (must be under 0.03 Grms, set by menu). The level condition is set by a roll angle of less than 3 degrees, set by menu. Rate max is a turn rate threshold of 3 degrees per second, set by menu. The limit imposed on the rate error is 3 degrees per second and also is settable by the user menu.

The effect is to close the loop quickly when the turn rate is expected to be zero and to open the loop when turns are expected. The loop cannot be fully opened because of the possibility that the condition was misread and the loop closure is needed to bring the system back in line.

Roll System
The roll system is a second order washout loop with controls on amount of error to be corrected and of the time constant of the loop. The general configuration is as shown below:
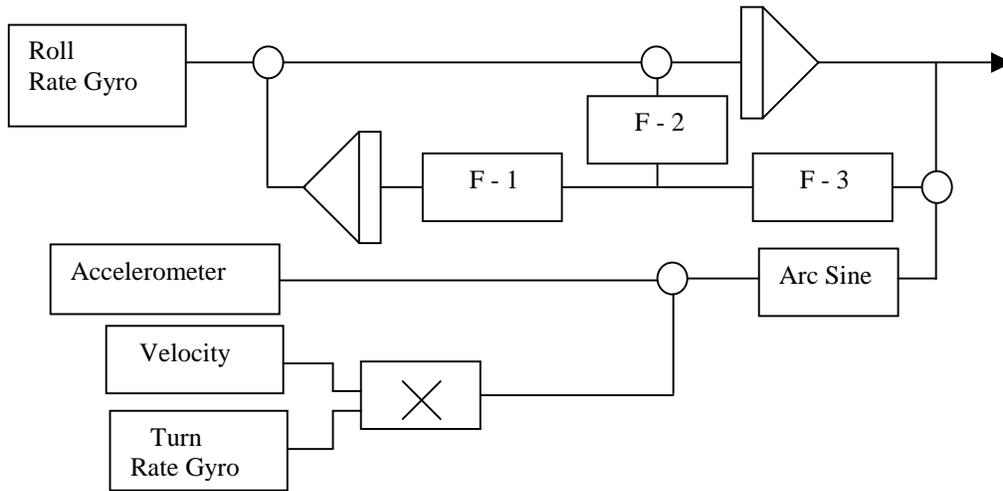
The benefits of this design are that the errors are continually corrected, but there are some limitations. Velocity errors and turn rate errors will offset the roll reference so great care must be taken to accurately set up the system parameters.

The F-1 and F-2 parameters are time constant related. The time constant is the main roll time constant as shown in the user menu. The nominal value is 20 seconds.

The F-3 parameter is limiter related. The limit is the roll error limit as shown in the user menu. The nominal value is 3 degrees.

Initialization	Stopped	Level		Time Constant
Y	Y	Y		5
Y	Y	N		5
Y	N	Y		10
Y	N	N		10
N	Y	Y		5
N	Y	N		10
N	N	Y		20
N	N	N		20

The long-term reference for the roll angle is the lateral accelerometer. To get the best performance from this reference, it is has dynamic compensation added to its signal. The dynamic compensation is basically just a calculated value for the centrifugal force. When the accelerometer data has the centrifugal force removed, all that is left is the sine of the angle from level times one G. There is noise from the accelerometer data being sensitive to vibration, but the long-term average is zero from that factor.

Initialization

At switch-on, the integrator time constant is set to a short time constant and is adjusted as conditions allow so the gyro can be stabilized as quickly as possible. Temperature–mapped adjustments to bias and gain are applied to each gyro and the accelerometer and the error correction will begin to accumulate the signals from the sensors unless a 'hold' command freezes the action. The data during this interval may be used, but the accuracy will be poor in the beginning. The time between switch-on and end of initialization is user settable and is at 20 seconds nominal.

Normal Operation

During normal operations, the TMS will output highly accurate angular rate data, roll angle data and lateral accelerometer data for the user to interpret. These data items are selectable for output by an interactive menu system built into the unit.

Normal operation requires a velocity input of analog input, binary RS-232 input, GPS/NMEA/VTG RS-232 input or wheel encoder pulse input. This is used to calculate the dynamics of the train motion to compensate the sensor outputs.

User Control Operation

In this function, the TMS will output highly accurate inertial data for the user to interpret, but the data flow will be interrupted when user commands are being processed by the TMS.

Interface

The TMS has analog, logic, and serial digital interface capabilities. The most common way to acquire data from the TMS is to use the RS-232 serial output. There are two RS-232 output formats: decimal ASCII and binary. The exact formatting structure is discussed in next section. Additionally, an analog output of the roll angle is provided at two degrees per volt.

RS-232 Output Formats

The nominal interface settings are:

> 9600 Baud
> 8 Bit Data
> 1 Start Bit
> 1 Stop Bit
> No Parity

The baud rate may be changed from the nominal value of 9600 baud by modifying the default value in the EEPROM of the unit to 38400, 19200, or 4800 baud.

The TMS sends a text header during initialization that identifies the unit by part number and by serial number and gives the date of last calibration. This whole message can be temporarily or permanently suppressed or restored by a "*" command (see below) from the interfacing computer.

Data transmission is controlled by either a ":" or a "+" command. If data is not flowing, send a carriage return. If the unit responds with data, the unit is controlled by the ":" command. Sending a ":" should cause the data to free flow.

If the above does not produce a data transmission, send a "+" command. If the data does not flow, then send a carriage return. If a line of data is returned, then sending a ":" should set the data to freely flow. If data still does not flow, check the connections, the terminal settings and unit power connections.

There are two serial data output formats: Decimal ASCII & Binary.
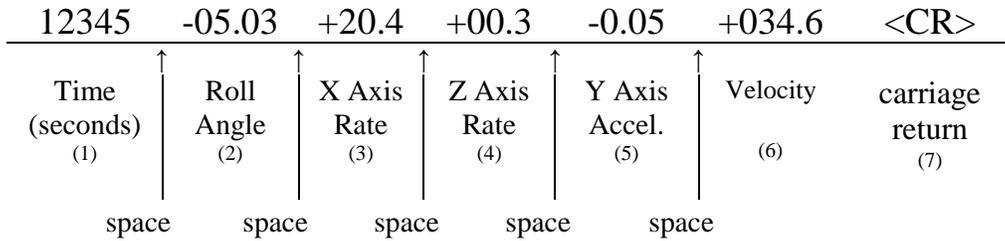
Decimal ASCII
Nominal Output String:
The nominal RS-232 output consists of a string of decimal ASCII characters sent asynchronously at regular interval. All of the channels of data can be selected or deselected for output by the user. The number of strings sent per second depends on the baud rate and the channels selected. The fastest possible data rate is 90 frames per second. The contents of the "as shipped" string are formed as follows:

1. A six character string representing the time since the last reset in seconds, ending in a space for up to 65,535 seconds.

2. A seven character string representing the roll angle starting with a "+" or a "-", followed by two digits, a decimal point, two digits and a space for up to ±19.99 degrees.

3. A six character string representing the X Axis Rate starting with a "+" or a "-", followed by two digits, a decimal point, two digits and a space for up to ±49.9 degrees/second.

4. A six character string representing the Z Axis Rate starting with a "+" or a "-", followed by two digits, a decimal point, one digit and a space for up to ±49.9 degrees/second.

5. A six character string representing the Y Axis Acceleration starting with a "+" or a "-", followed by two digits, a decimal point, one digit and a space for up to ±9.99 "G's"

6. A seven character string representing the Velocity starting with a "+" or a "-", followed by two digits, a decimal point, one digit and a space for up to ±399.9 Kilometers/hour.

7. The string is terminated by a carriage return. There will then be a short interval with no data transmission before the next string begins.

Example:

12345	-05.03	+20.4	+00.3	-0.05	+034.6	<CR>
Time (seconds) (1)	Roll Angle (2)	X Axis Rate (3)	Z Axis Rate (4)	Y Axis Accel. (5)	Velocity (6)	carriage return (7)

space   space   space   space   space

In the user command mode (double space bar enabled) the string automatically inserts data items ahead of the carriage return that includes:

7. A six character string representing the roll angle without dynamic corrections starting with a "+" or a "-", followed by two digits, a decimal point, one digit and a space for up to ±89.99 degrees.

8. A six character string representing the roll angle with dynamic corrections starting with a "+" or a "-", followed by two digits, a decimal point, one digit and a space for up to ±89.99 degrees.

9. A six character string representing the X Axis Rate Bias Adjustment starting with a "+" or a "-", followed by two digits, a decimal point, two digits and a space for up to ±49.9 degrees/second.

10. A six character string representing the Z Axis Rate Bias Adjustment starting with a "+" or a "-", followed by two digits, a decimal point, one digit and a space for up to ±49.9 degrees/second.

11. A four character string representing the temperature inside the TMS starting with a "+" or a "-", followed by two digits and a space for –40 to +87 degrees C.

12. A four-character string representing the Status Flags in octal:

The first digit represents the Non-Volatile Memory Checksum:

"0" = no fault; "1" = Checksum failure.

The second digit indicates the condition codes:
"4" = Stopped (low velocity and low vibration).
"2" = Level (set for small Reference Pendulum angles)
"1" = ACRMS (low vibration)

Second Digit	Noise or Speed Threshold Exceeded	Level Threshold Exceeded	Vibration Threshold Exceeded	
7	Yes	Yes	Yes	4 + 2 + 1
6	Yes	Yes	No	4 + 2
5	Yes	No	Yes	4 + 1
4	Yes	No	No	4
3	No	Yes	Yes	2 + 1

2	No	Yes	No	2
1	No	No	Yes	1
0	No	No	No	

The Third digit indicates additional condition code:
        "4" = velocity above threshold
        "2" is not in use
        "1" = Excessive Roll Error

Third Digit	X Axis Rate Bias Limit Exceeded	Not in Use	Z Axis Rate Bias Limit Exceeded	
5	Yes	0	Yes	4 + 1
4	Yes	0	No	4
1	No	0	Yes	1
0	No	0	No	

13.   A four character string representing the Velocity starting with a "+" or a "-", followed by two digits, a decimal point, one digit and a space for up to ±399.9 Kilometers/hour.

The first digit represents the logic input commands:

First Digit	Time Reset	Negative Velocity	
3	On	Yes	2 + 1
2	On	No	2
1	Off	Yes	1
0	Off	No	

"2" Timer Reset
"1" Negative Velocity

The second digit indicates the command condition:
        "4" = Free mode (infinite time constant).
        "2" = Double space bar enabled.
        "1" = Initialization in progress.

Second Digit	Free Mode	Double Space Bar	Initialization In Progress	
7	Yes	Yes	Yes	4 + 2 + 1
6	Yes	Yes	No	4 + 2
5	Yes	No	Yes	4 + 1
4	Yes	No	No	4
3	No	Yes	Yes	2 + 1
2	No	Yes	No	2
1	No	No	Yes	1
0	No	No	No	

The Third digit indicates the orientation of the TMS:
        "0" is mount on top, connector aft.
        "1" is mount on top, connector forward.

"2" is mount down, connector aft.
"3" is mount down, connector forward.

(NOTE that the user menu input for orientation is a different number set: "4" is mount on top, connector aft, "3" is mount on top, connector forward, "2" is mount down, connector aft, and "1" is mount down, connector forward.)

14.   The string is terminated by a carriage return. There will then be a short interval with no data transmission before the next string begins.

Procedure to Change to Decimal ASCII Format
Hook the unit up to your computers serial port.
Use a Terminal software program to interface with the unit.

Turn on the unit. Wait for 2 seconds.
Hit the space bar twice.
Wait for the start up input interval to end (5 seconds).

Now the unit will take in the keyboard commands.
To toggle the serial output enable send a colon (:) or plus (+) as required. (See RS-232 INPUT COMMANDS Section)
To change to the decimal ASCII format, first type in the underline character (_).
This will temporarily change the unit to the decimal ASCII format.
To save this change in non-volatile memory, type in the double quote character (").
This means the unit will automatically start up in the decimal ASCII mode.

 Binary Format

The other output format available is a binary format. The binary format provides generally the same angular rate information as the decimal ASCII format, but in a compact binary file format. In this format, there are 3 words sent that represent 3 fourteen bit output channels. This format is for highly experienced users only.

1st Data Word (Time since reset)

Upper Byte

Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
"1"	X	X	X	X	X	X	X

Lower Byte

Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
"1"	X	X	X	X	X	X	X

2nd Data Word (X Axis Rate)

Upper Byte

Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
"1"	X	X	X	X	X	X	X

Lower Byte

Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
"1"	X	X	X	X	X	X	X

3rd Data Word (Z Axis Rate)

Upper Byte

Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
"1"	X	X	X	X	X	X	X

Lower Byte

Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
"1"	X	X	X	X	X	X	X

And so on and the frame ending in a carriage return.

The most significant bit (MSB) of the data bytes are set to "1", but the last byte, a carriage return, has a lower ASCII and has "0" at the MSB. This allows the user to synchronize to the binary data frame.

To reconstitute the data, as the data words are received, the lower byte is shifted left to shift out the MSB. The upper byte is then connected to the lower as a 16 bit word. This word is then shifted left to shift out the MSB of what was the upper byte. What remains is a signed fractional word with a resolution of 13 bits plus a sign bit.

Procedure to Change to Binary Format
Hook the unit up to your computers serial port.
Use a HyperTerminal program to interface with the unit.

Turn on the unit. Wait for 2 seconds.
Hit the space bar twice.
Wait for the initialization to end.

Now the unit will take in the keyboard commands.
To toggle the serial output enable send a colon (:) or plus (+) as required. (see RS-232 INPUT COMMANDS Section) To change to the binary format, first type in the caret character (^).
This will temporarily change the unit to the binary format.
To save this change, type in the double quote character (").
This means the unit will automatically start up in the binary mode.

RS-232 Input Formats

The RS-232 input commands are provided for the purpose of unit test and installation set-up. The same parameters are used as for the output (9600 baud ASCII nominal, or as reset in the units EEPROM). There are seven commands intended for use by the user (others are used at the factory for alignment and calibration).

1.   An "!" command will reinitialize the unit. Further, the access to initialization is inhibited such that a spacebar command must be sent within 2.5 seconds of the "!" command for initialization to be engaged. This command is inactive when GPS or Binary velocity inputs are active. Power cycling will provide the same function in all configurations.

2.   A "_" command will change the output format to decimal ASCII. This change is made non-volatile in the unit on EEPROM by keying in the quote (") character. Double spacebar at initialization is required for access to this command.

3. A "^" command will change the output format to binary. This change is made non-volatile in the unit on EEPROM by keying in the quote (") character. Double spacebar at initialization is required for access to this command.

4. A ":" command will toggle the output to send a frame of data upon receiving any non-command character (On to Off; Off to On). This change is made non-volatile in the unit on EEPROM by keying in the quote (") character. Double spacebar at initialization is required for access to this command.

5. A "+" command will suppress or restore the transmission of data. This command will toggle the data transmission (On to Off; Off to On). Double spacebar at initialization is required for access to this command.

6. An "*" command will suppress or restore the initialization message in the Decimal ASCII mode. This command will toggle the transmitting of the text header during initialization (On to Off; Off to On). This change is made non-volatile in the unit on EEPROM by keying in the quote (") character. Double spacebar at initialization is required for access to this command.

7. An "&" command brings up a menu to configure the TMS. The selection of baud rates under this mode is made non-volatile in the unit on EEPROM by keying in the quote (") character. Double spacebar at initialization is required for access to this command.

The commands "~", "@", "#", "$", "(", ")", "{", "}", "|", "<", ">", and "?" are used by the Watson factory to calibrate the unit and should be used only with the assistance of the factory. If an undesired function is called, a "Q", and sometimes Escape or a Delete will interrupt the command and return to operation with the least disturbance to the system. All other unspecified characters such as carriage return, line feed and space are ignored by the system.

If there are problems with the system "hanging up" during the binary output mode, check for cross talk between the serial transmit and receive line in your installation. In addition, check to see that the communications program used is not sending an echo.

Velocity Inputs
A) Analog: 40 KPH per Volt scale, +/-400 KPH Range. This is a differential input signal with a common mode range of 100 Volts.

B) Serial Binary: 14 bit fractional, two byte number, +/-400 KPH Range. The format is similar to the binary output format. The frame delimiter is also a carriage return. Updates should be made at least once every five seconds.

Velocity Word

Upper Byte								Lower Byte							
Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
"1"	X	X	X	X	X	X	X	"1"	X	X	X	X	X	X	X

C) GPS Format: The GPS NMEA VTG message format can be sent to the TMS directly. The TMS will extract the unsigned velocity data and apply it with a polarity correction provided by the Direction Command. The range is 400 KPH. Updates are required at least once every five seconds.

D) Pulse Input: The TMS will read and scale pulse rates as unsigned velocity. Settings of wheel diameter (0.5 to 1.999 Meters) and encoder resolution (1000 to 6000 Pulses Per Revolution) are allowed to get a range of 400 KPH.

Logic Input Commands

The Direction command switches the polarity of the velocity input for the pulse velocity or the GPS velocity since these formats have no polarity of their own.   There is no effect on the other velocity input formats. This command is set by closing the connection between the Direction command (pin N) and its signal ground (pin V). The TMS has a pull up resistor within it to control this command. When set, the velocity will be presented as negative, otherwise it is positive.

The Time Reset Command (pin D) sets the time counter to zero when it is grounded (to pin V). The TMS has a pull up resistor within it to control this command. When grounded, the time counter will be held at zero, when it is released, the timer continues to count from zero.

Analog Output

Analog signals are output from a 12 bit digital to analog converter through an operational amplifier. Each analog output has a 300 ohm resistor in series to eliminate oscillations from high capacitance loads. The output range for all of the analog output channels is ±10 Volts with respect to the common signal ground. The outputs include:

Signal	Pin	Range	Output Range	0 VDC	Scale Factor
Bank	A	±20°	±10V	0°	2°/V

Note that the analog switches are disabled after certain serial commands are sent to the unit. This prevents software/hardware switch conflicts.

The best signal may depend on shielding and grounding for the environment of the installation. Connections of various combinations for the serial signal ground (Pin U), the analog signal ground (Pin U), the power ground (Pin K), and the case ground (Pin G) should be tried to find the best conditions.

Specifications

Attitude

Range: Bank (Superelevation)	±20°	
Resolution:	0.02°	Binary mode (14 bit)
Analog Scale Factor:	2°/V	±10V Output
Accuracy: Static	±0.3°	
* Accuracy: Dynamic	±0.5%	

Angular Rate

Range: Roll, Yaw	±45°/sec	
Resolution:	0.025°/sec	Binary mode (14 bit)
Scale Factor Accuracy:	±0.5%	
Bias: Roll, Yaw	< 0.2°/sec (Analog)	±0.02°/sec Binary mode (14 bit)
Non-Linearity:	< 0.1%	Full scale range
Bandwidth:	11 Hz	
Noise:	< 0.03°/sec rms	

Acceleration

Range: Lateral	±10g	
Resolution:	4mg	
Scale Factor Accuracy:	2%	
Bias: Lateral	< 10mg	
Non-Linearity:	0.1%	Full scale range
Bandwidth:	3 Hz	

Environmental

Temperature: Operating	-40°C to +85°C	
Temperature: Storage	-50°C to +85°C	
Vibration: Operating	5g rms	20 Hz to 2 KHz
Vibration: Survival	10g rms	20 Hz to 2 KHz
Shock: Survival	1000g	10mS ½ sine wave

Electrical

Frame Rate:	71.1 Hz	Maximum
Startup Time: Data	5 sec	
Startup Time: Fully operational	10 sec	
Input Power:	10 to 30VDC	6W
Input Current:	500mA @ 12VDC	250mA @ 24VDC
Input Velocity:	±10VDC	Full scale (±400kph)
Digital Output:	RS-232	
Analog Output:	±10VDC	
Analog Output Impedance:	300 Ohm	Per line

Physical

Size: Including Mounting Flanges	7.50"W x 8.25"L x 3.20"H	19 x 21 x 8.1 (cm)
Weight:	240oz (15lb)	6800 grams (6.8Kg)
Connection:	MS-27656T-15B-19P	MIL-C-38999 Series 1

* Assumes accurate velocity data.
Actual accuracy can be calculated as the listed percentage multiplied by the change in value over the entire dynamic maneuver.
† Velocity input is required, see table below.
• Specifications are subject to change without notice.
• This product may be subject to export restrictions. Please consult the factory.

TMS-E232 Input Velocity Formats

Format	Specifications
Analog:	±400 kph; 40 kph / volt
Binary RS-232:	±400 kph; 14 bit
GPS RS-232:	NMEA 183, VTG format
Pulse Counter:	1000 to 6000 pulses per revolution; 0.5 to 2 meter diameter wheel

Connections / Dimensions

The connector is MIL-C-38999 Series 1, type MS-27656T-15B-19P. The pin assignments are as follows:

Pin A -   Analog Bank Output

Pin B -   NC

Pin C -   NC

Pin D -   Time Reset Logic Input

Pin E -   NC

Pin F -   NC

Pin G -   Case Ground

Pin H -   NC

Pin J -   +12 to +24 Volt Power

Pin K -   Power Ground

Pin L -   RS-232 Serial Data Input

Pin M -   RS-232 Serial Data Output

Pin N -   Direction Command

Pin P -   Analog velocity in (+), differential

Pin R -   Analog velocity in (-), differential

Pin S -   Pulse velocity in (+), opto-isolated

Pin T -   Pulse velocity in (-), opto-isolated

Pin U -   RS-232 Serial Data Ground

Pin V -   Direction Command Ground and Analog Signal Ground
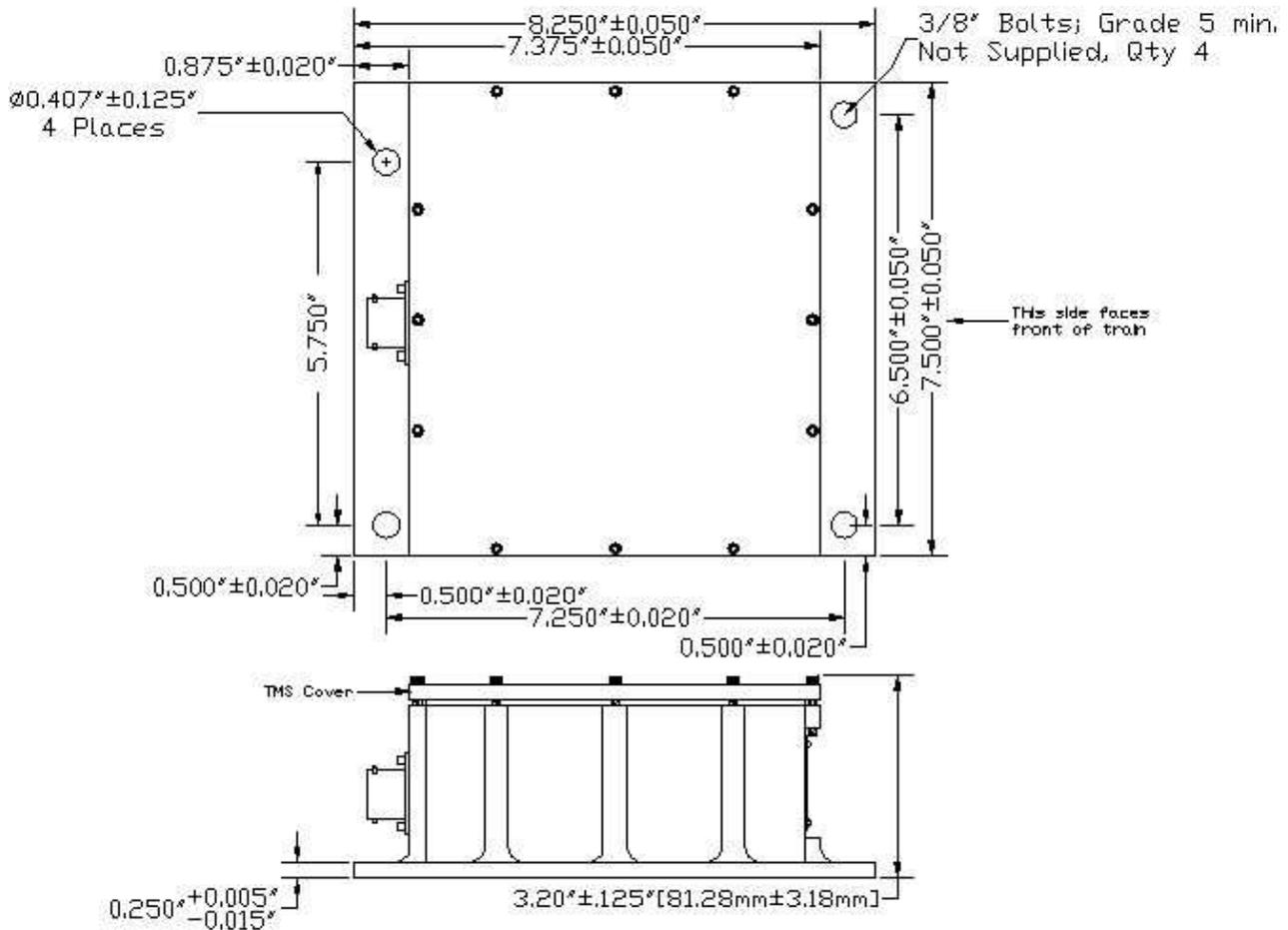
TMS-E232-1AD
Figure 1

Warning

Rough handling, dropping, or miswiring this unit is likely to cause damage.

DISCLAIMER

The information contained in this manual is believed to be accurate and reliable; however, it is the user's responsibility to test and to determine whether a Watson Industries' product is suitable for a particular use.

Suggestion of uses should not be taken as inducements to infringe upon any patents.

WARRANTY

Watson Industries, Inc. warrants, to the original purchaser, this product to be free from defective material or workmanship for a period of two full years from the date of purchase. Watson Industries' liability under this warranty is limited to repairing or replacing, at Watson Industries' sole discretion, the defective product when returned to the factory, shipping charges prepaid, within two full years from the date of purchase. The warranty described in this paragraph shall be in lieu of any other warranty, express or implied, including but not limited to any implied warranty of merchantability or fitness for a particular purpose.

Excluded from any warranty given by Watson Industries are products that have been subject to abuse, misuse, damage or accident; that have been connected, installed or adjusted contrary to the instructions furnished by seller; or that have been repaired by persons not authorized by Watson Industries.

Watson Industries reserves the right to discontinue models, to change specifications, price or design of this product at any time without notice and without incurring any obligation whatsoever.

The purchaser agrees to assume all liabilities for any damages and/or bodily injury that may result from the use, or misuse, of this product by the purchaser, his employees or agents. The purchaser further agrees that seller shall not be liable in any way for consequential damages resulting from the use of this product.

No agent or representative of Watson Industries is authorized to assume, and Watson Industries will not be bound by any other obligation or representation made in connection with the sale and/or purchase of this product.

PRODUCT LIFE

The maximum expected life of this product is 20 years from the date of purchase. Watson Industries, Inc. recommends the replacement of any product that has exceeded the product life expectation.

Customer Service

All repairs, calibrations and upgrades are performed at the factory. Before returning any product, please contact Watson Industries to obtain a Returned Material Authorization number (RMA).

Return Address & Contact Information

Watson Industries, Inc.
3035 Melby Street
Eau Claire, WI 54703
ATTN: Service Department
Telephone: (715) 839-0628   Fax: (715) 839-8248   email: support@watson-gyro.com

Returning the Product

Product shall be packaged making sure there is adequate packing around all sides. Correspondence shall include:
- Customer's Name and Address
- Contact Information
- Equipment Model Number
- Equipment Serial Number
- Description of Fault

It is the customer's responsibility to pay all shipping charges from customer to Watson Industries, including import and transportation charges.

Appendix A

Activating Command mode or Double Spacebar Access to commands

Hook the unit up to your computers serial port.
Use HyperTerminal program to interface with unit.

Turn on unit. Wait for the startup message to appear on display.
Hit the space bar twice within the first 5 seconds of turn on.
Sometimes it takes a few tries to get the hang of this.
Wait for the data string to start transmitting.

Now the unit will take in the keyboard commands.

Command Mode Menus

Activate Command Mode (See above).

Now the unit will take in the keyboard commands.
Typing '&' will bring up this main menu:

```
TYPE IN THE NUMBER OF YOUR SELECTION (OR 'Q' TO QUIT):
    1 = SET OUTPUT CHANNELS
    2 = SELECT MOUNTING ORIENTATION
    3 = SELECT VELOCITY INPUT MODE
    4 = SET LIMITS AND TIME CONSTANTS
    5 = SET NEW BAUD RATE
```

Typing in a '1' brings up this menu:

```
  TO SET FOR OUTPUT FOR ANY OF THE FOLLOWING DATA ITEMS,
PRESS Y"
  TO AVOID ANY OF THE FOLLOWING DATA ITEMS, PRESS N"
  TO QUIT AND DISREGARD ANY OTHER DATA, PRESS Q"

  *** DO YOU WANT TO PROCEED?  (Y/N/Q)  Y
```

For more information on this menu see Appendix A1

Typing in a '2' brings up this menu:

```
TYPE IN THE NUMBER OF YOUR SELECTION (OR 'Q' TO QUIT):
    1 = MOUNTING FLANGE ON BOTTOM, CONNECTOR AT FRONT
    2 = MOUNTING FLANGE ON BOTTOM, CONNECTOR AT BACK
    3 = MOUNTING FLANGE ON TOP, CONNECTOR AT FRONT
    4 = MOUNTING FLANGE ON TOP, CONNECTOR AT BACK
```

For more information on this menu see Appendix A2

Typing in a '3' brings up this menu:

```
TYPE IN THE NUMBER OF YOUR SELECTION (OR 'Q' TO QUIT):
   1 = ANALOG INPUT (40 KPH/VOLT)
   2 = SERIAL BINARY INPUT
   3 = SERIAL GPS NMEA 183 INPUT
   4 = DIGITAL FREQUENCY INPUT
```

For more information on this menu see Appendix A3

Typing in a '4' brings up this menu:

```
TYPE IN THE NUMBER OF YOUR SELECTION (OR 'Q' TO QUIT):
   1 = SET SPEED LIMIT FOR STOPPED CONDITION

   2 = SET YAW RATE LIMIT FOR CORRECTION CONDITION
   3 = SET ROLL ANGLE LIMIT FOR LEVEL CONDITION
   4 = SET ROLL RATE ERROR LIMIT
   5 = SET YAW RATE ERROR LIMIT
   6 = SET MAIN ROLL TIME CONSTANT
   7 = SET MAIN YAW RATE TIME CONSTANT
   8 = SET INITIALIZATION TIME
```

For more information on this menu see Appendix A4

Typing in a '5' brings up this menu:

```
TYPE IN THE NUMBER OF YOUR SELECTION (OR 'Q' TO QUIT):
(EFFECTIVE NEXT POWER-UP)
   1 = 38.4 K BAUD
   2 = 19.2 K BAUD
   3 = 9.6 K BAUD
   4 = 4.8 K BAUD
```

For more information on this menu see Appendix A5

Appendix A.1

To change output channel selections, type '1' at the main menu.
This will bring up the menu:

```
TO SET FOR OUTPUT FOR ANY OF THE FOLLOWING DATA ITEMS,
PRESS Y"
 TO AVOID ANY OF THE FOLLOWING DATA ITEMS, PRESS N
 TO QUIT AND DISREGARD ANY OTHER DATA, PRESS Q

 *** DO YOU WANT TO PROCEED?  (Y/N/Q)
```

Type in a "Y"
        This will bring up the next lines:

```
 TO SET FOR OUTPUT FOR ANY OF THE FOLLOWING DATA ITEMS, PRESS Y"
  TO AVOID ANY OF THE FOLLOWING DATA ITEMS, PRESS N
  TO QUIT AND DISREGARD ANY OTHER DATA, PRESS Q

  *** DO YOU WANT TO PROCEED?  (Y/N/Q)  Y


   DO YOU WANT OUTPUT OF

 TIME SINCE RESET?
```

        Type 'Y' to enable the output of the time counter.
        Typing an 'N' disables this output.

    This will bring up the next line:

```
 TO SELECT ACCESS FOR ANY OF THE FOLLOWING COMMAND ITEMS, PRESS Y
  TO AVOID ANY OF THE FOLLOWING C TO SET FOR OUTPUT FOR ANY OF THE
 FOLLOWING DATA ITEMS, PRESS Y"
  TO AVOID ANY OF THE FOLLOWING DATA ITEMS, PRESS N
  TO QUIT AND DISREGARD ANY OTHER DATA, PRESS Q

  *** DO YOU WANT TO PROCEED?  (Y/N/Q)  Y


   DO YOU WANT OUTPUT OF

 TIME SINCE RESET?  N
 ROLL ANGLE?
```

        Type 'Y' to enable the output of the Roll Angle.
        Typing an 'N' disables this output.

This will bring up the next line:

```
TO SELECT ACCESS FOR ANY OF THE FOLLOWING COMMAND ITEMS, PRESS Y
 TO AVOID ANY OF THE FOLLOWING C TO SET FOR OUTPUT FOR ANY OF THE
FOLLOWING DATA ITEMS, PRESS Y"
 TO AVOID ANY OF THE FOLLOWING DATA ITEMS, PRESS N
 TO QUIT AND DISREGARD ANY OTHER DATA, PRESS Q

 *** DO YOU WANT TO PROCEED?  (Y/N/Q)  Y


  DO YOU WANT OUTPUT OF

TIME SINCE RESET?  N
ROLL ANGLE?  Y
ROLL RATE?
```

Type 'Y' to enable the output of the Roll Rate.
Typing an 'N' disables this output

This will bring up the next line:

```
TO SELECT ACCESS FOR ANY OF THE FOLLOWING COMMAND ITEMS, PRESS Y
 TO AVOID ANY OF THE FOLLOWING C TO SET FOR OUTPUT FOR ANY OF THE
FOLLOWING DATA ITEMS, PRESS Y"
 TO AVOID ANY OF THE FOLLOWING DATA ITEMS, PRESS N
 TO QUIT AND DISREGARD ANY OTHER DATA, PRESS Q

 *** DO YOU WANT TO PROCEED?  (Y/N/Q)  Y


  DO YOU WANT OUTPUT OF

TIME SINCE RESET?  N
ROLL ANGLE?  Y
ROLL RATE?  Y
TURN RATE?  Y
```

Type 'N' to update the enable status of these commands. Typing 'Q' will
quit without update the command status. Typing an 'Y' starts the command
menu sequence over.

This will bring up the next line:

TO SELECT ACCESS FOR ANY OF THE FOLLOWING COMMAND ITEMS, PRESS Y
 TO AVOID ANY OF THE FOLLOWING C TO SET FOR OUTPUT FOR ANY OF THE
FOLLOWING DATA ITEMS, PRESS Y"
 TO AVOID ANY OF THE FOLLOWING DATA ITEMS, PRESS N
 TO QUIT AND DISREGARD ANY OTHER DATA, PRESS Q

 *** DO YOU WANT TO PROCEED? (Y/N/Q) Y

  DO YOU WANT OUTPUT OF

TIME SINCE RESET? N
ROLL ANGLE? Y
ROLL RATE? Y
TURN RATE? Y
LATERAL ACCELERATION?

Type 'Y' to enable the output of the Lateral Acceleration.
Typing an 'N' disables this output.

This will bring up the next line:

TO SELECT ACCESS FOR ANY OF THE FOLLOWING COMMAND ITEMS, PRESS Y
 TO AVOID ANY OF THE FOLLOWING C TO SET FOR OUTPUT FOR ANY OF THE
FOLLOWING DATA ITEMS, PRESS Y"
 TO AVOID ANY OF THE FOLLOWING DATA ITEMS, PRESS N
 TO QUIT AND DISREGARD ANY OTHER DATA, PRESS Q

 *** DO YOU WANT TO PROCEED? (Y/N/Q) Y

  DO YOU WANT OUTPUT OF

TIME SINCE RESET? N
ROLL ANGLE? Y
ROLL RATE? Y
TURN RATE? Y
LATERAL ACCELERATION? Y
VELOCITY?

Type 'Y' to enable the output of the Velocity.
Typing an 'N' disables this output

This will bring up the last lines:

```
TO SELECT ACCESS FOR ANY OF THE FOLLOWING COMMAND ITEMS, PRESS Y
 TO AVOID ANY OF THE FOLLOWING C TO SET FOR OUTPUT FOR ANY OF THE
FOLLOWING DATA ITEMS, PRESS Y"
 TO AVOID ANY OF THE FOLLOWING DATA ITEMS, PRESS N
 TO QUIT AND DISREGARD ANY OTHER DATA, PRESS Q

 *** DO YOU WANT TO PROCEED?  (Y/N/Q)  Y


  DO YOU WANT OUTPUT OF

TIME SINCE RESET?  N
ROLL ANGLE?  Y
ROLL RATE?  Y
TURN RATE?  Y
LATERAL ACCELERATION?  Y
VELOCITY?  Y


    Y = GOBACK, N = INSTALL DATA & QUIT, Q = QUIT
    DO YOU WANT TO TRY TO SET DATA AGAIN?
```

Type 'N' to update the enable status of these commands. Typing 'Q' will quit without update the command status. Typing an 'Y' starts the command menu sequence over. Changes made will not change the non-volatile settings. To make these new setting the default value, send a Quotation Mark (").

Appendix A.2

To set mounting orientation, type '2' at the main menu.
This will bring up the menu:

```
TYPE IN THE NUMBER OF YOUR SELECTION (OR 'Q' TO QUIT):
  1 = MOUNTING FLANGE ON BOTTOM, CONNECTOR AT FRONT
  2 = MOUNTING FLANGE ON BOTTOM, CONNECTOR AT BACK
  3 = MOUNTING FLANGE ON TOP, CONNECTOR AT FRONT
  4 = MOUNTING FLANGE ON TOP, CONNECTOR AT BACK
```

Type in the desired orientation number and the orientation will be set immediately and as the default.

Appendix A.3

To set the analog output polarity, type '3' at the main menu.
This will bring up the menu:

```
TYPE IN THE NUMBER OF YOUR SELECTION (OR 'Q' TO QUIT):
   1 = ANALOG INPUT (40 KPH/VOLT)
   2 = SERIAL BINARY INPUT
   3 = SERIAL GPS NMEA 183 INPUT
   4 = DIGITAL FREQUENCY INPUT
```

To change the velocity source to the analog input, type '1'. This input does not inhibit serial communications in any way.

To change the velocity source to the serial binary input, type '2'. This input does not work when double space bar is invoked.

To change the velocity source to the GPS NMEA 183 "VTG" input, type '3'. This input does not work when double space bar is invoked. When using this format, the baud rate of the serial input or output must match that of the GPS system.

To change the velocity source to the pulse encoder input, type '4'. This input does not inhibit serial communications in any way. This will bring up the next line:

```
TYPE IN THE NUMBER OF YOUR SELECTION (OR 'Q' TO QUIT):
   1 = SET PULSE RATE PER REVOLUTION
   2 = SET WHEEL DIAMETER
```

To set the number of encoder pulses per revolution, type '1'.

```
ENTER 'Q' TO MOVE ON UNCHANGED
ENTER PULSES PER REVOLUTION OF THE WHEEL (1000 TO 6000):
```

To set the diameter of the encoder's wheel, type '2'.

```
ENTER 'Q' TO MOVE ON UNCHANGED
ENTER WHEEL DIAMETER IN METERS (0.5 TO 1.999):
```

Appendix A.4

To change command mode, type '4' at the main menu.
This will bring up the menu:

```
TYPE IN THE NUMBER OF YOUR SELECTION (OR 'Q' TO QUIT):
  1 = SET SPEED LIMIT FOR STOPPED CONDITION

  2 = SET YAW RATE LIMIT FOR CORRECTION CONDITION
  3 = SET ROLL ANGLE LIMIT FOR LEVEL CONDITION
  4 = SET ROLL RATE ERROR LIMIT
  5 = SET YAW RATE ERROR LIMIT
  6 = SET MAIN ROLL TIME CONSTANT
  7 = SET MAIN YAW RATE TIME CONSTANT
  8 = SET INITIALIZATION TIME
```

To update command mode, type '1'.
    The following message will appear:

```
ENTER 'Q' TO MOVE ON UNCHANGED
ENTER SPEED IN KPH (0.5 TO 10, 5 NOMINAL):
```

Enter the velocity with up to one decimal place.

Note: Input values outside the limit range are rejected (with 'ENTRY EXCEEDS LIMITS - TRY AGAIN' message) and the unit returns to the previous menu

To update command mode, type '2'.

    The following message will appear:

```
ENTER 'Q' TO MOVE ON UNCHANGED
ENTER YAW RATE ERROR LIMIT IN DEGREES/SECOND (0.5 TO 10, 3 NOMINAL):
```

Enter the yaw rate error limit with up to one decimal place.

Note: Input values outside the limit range are rejected (with 'ENTRY EXCEEDS LIMITS - TRY AGAIN' message) and the unit returns to the previous menu

To update command mode, type '3'.
    The following message will appear:

```
ENTER 'Q' TO MOVE ON UNCHANGED
ENTER ROLL ANGLE LEVEL LIMIT IN DEGREES (0.1 TO 3, 0.5 NOMINAL):
```

Enter the roll angle level limit with up to one decimal place.

Note: Input values outside the limit range are rejected (with 'ENTRY EXCEEDS LIMITS - TRY AGAIN' message) and the unit returns to the previous menu

To update command mode, type '4'.
        The following message will appear:

```
ENTER 'Q' TO MOVE ON UNCHANGED
ENTER ROLL ERROR LIMIT IN DEGREES (0.1 TO 10, 3 NOMINAL):
```

Enter the roll error limit with up to one decimal place.

Note: Input values outside the limit range are rejected (with 'ENTRY EXCEEDS LIMITS - TRY AGAIN' message) and the unit returns to the previous menu

To update command mode, type '5'.
        The following message will appear:

```
ENTER 'Q' TO MOVE ON UNCHANGED
ENTER YAW RATE ERROR LIMIT IN DEGREES/SECOND (0.1 TO 5, 3 NOMINAL):
```

Enter the yaw rate error limit with up to one decimal place.

Note: Input values outside the limit range are rejected (with 'ENTRY EXCEEDS LIMITS - TRY AGAIN' message) and the unit returns to the previous menu

To update command mode, type '6'.
        The following message will appear:

```
ENTER 'Q' TO MOVE ON UNCHANGED
ENTER MAIN ROLL TIME CONSTANT IN SECONDS (5 TO 100, 20 NOMINAL):
```

Enter the main roll time constant as an integer.

Note: Input values outside the limit range are rejected (with 'ENTRY EXCEEDS LIMITS - TRY AGAIN' message) and the unit returns to the previous menu

To update command mode, type '7'.
        The following message will appear:

```
ENTER 'Q' TO MOVE ON UNCHANGED
ENTER MAIN YAW RATE TIME CONSTANT IN SECONDS (10 TO 200, 120 NOMINAL):
```

Enter the main yaw rate time constant as an integer.

Note: Input values outside the limit range are rejected (with 'ENTRY EXCEEDS LIMITS - TRY AGAIN' message) and the unit returns to the previous menu

To update command mode, type '8'.
        The following message will appear:

```
ENTER 'Q' TO MOVE ON UNCHANGED
ENTER INITIALIZATION TIME IN SECONDS (5 TO 100, 20 NOMINAL):
```

Enter initialization time as an integer.

Note: Input values outside the limit range are rejected (with 'ENTRY EXCEEDS LIMITS - TRY AGAIN' message) and the unit returns to the previous menu

Appendix A.5

To set new baud rate, type '6' at the main menu.
        This will bring up the menu:

```
TYPE IN THE NUMBER OF YOUR SELECTION (OR 'Q' TO QUIT):
(EFFECTIVE NEXT POWER-UP)
   1 = 38.4 K BAUD
   2 = 19.2 K BAUD
   3 = 9.6 K BAUD
   4 = 4.8 K BAUD
```

To change to 38,400 Baud, type '1'.
To change to 19,200 Baud, type '2'.
To change to   9,600 Baud, type '3'.
To change to   4,800 Baud, type '4'.

The baud rate change will take effect immediately. To make the new baud rate the default setting, send a Quote symbol (") using the new baud rate. Otherwise the old baud rate will return the next time the unit is powered up.