TuffTilt Digital
Uniaxial & Biaxial Tiltmeters

850 Perimeter Road
Manchester, NH 03103
Phone: 603–669-6400
Fax: 603–622-2690
www.jewellinstruments.com
sales@jewellinstruments.com

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TUFF TILT DIGITAL TILTMETER

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1 Introduction

The ***Tuff Tilt Digital*** is an exciting new digital instrument for indoor and outdoor work requiring precision and rugged durability. It is excellent for continuous monitoring of structural behavior, or short-term testing of machine and structural performance. It fills a gap between our economical MD900-T Digital Clinometer and our Model D711 Scientific Tiltmeter.

The ***Tuff Tilt Digital*** is offered with many powerful features, including: RS232 output, RS422 output, analog output or optional tilt switch output in the RS232 versions, biaxial or uniaxial measurement, and 16-bit A/D resolution. The serial data output is easily interfaced to many GPS receivers, spread spectrum radios, and wireless Ethernet converters. A powerful set of firmware commands enables the user to collect, process and store data, or to send data directly to external devices.

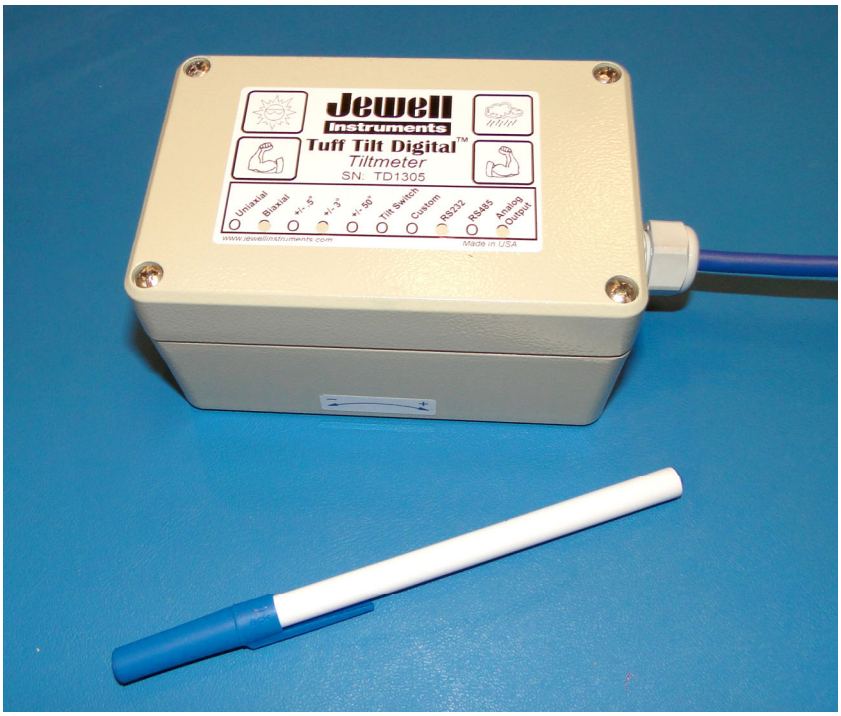


Figure 1. ***Tuff Tilt Digital***

	Tuff Tilt Digital (Standard)	*Tuff Tilt Digital* (Wide Angle)
ANGULAR RANGE	±3 degrees	±50 degrees (greater range available)
RESOLUTION	0.0001 degree	0.002 degree
REPEATABILITY	0.0003 degree (1 arc second), static	0.004 degree, static
TEMPERATURE COEF.	Zero: ±0.0002 degree/°C typical	Zero: ±0.004 degree/°C typical
CHANNELS	Single-axis or dual-axis with 2 orthogonal tilt channels, 1 temperature channel	
LINEARITY	< 0.1% of full span	
TIME CONSTANT	0.15 second	
DIGITAL OUTPUT	RS232 or RS422, transmit and receive Baud rate: 9600 (default), 19200, 28800, 57600, 115200, 230400 NMEA 0183 compatible (x, y, temperature, serial no.), plus other output strings	
OUTPUT DATA RATE	User-selectable from 10 samples/second to 1 sample/24 hours	
POWER REQ'TS	7-28 VDC @ 30 mA, 250 mV peak-to-peak ripple maximum, reverse polarity protected	
ENVIRONMENTAL	–25° to +70°C operational, –30° to +100°C storage. NEMA 4X (IP65)	
MOUNTING	Four no. 8 stainless steel mounting screws included	
MATERIALS	Die cast and painted aluminum	
CABLE & CONNECTOR	3m (10 ft), 6 conductors + one overall shield, PVC jacket. DB9 connector for digital I/O.	
SIZE & WEIGHT	120 x 80 x 60 mm (4.7x 3.2 x 2.4 inches), 0.6 kg (1.5 lb)	

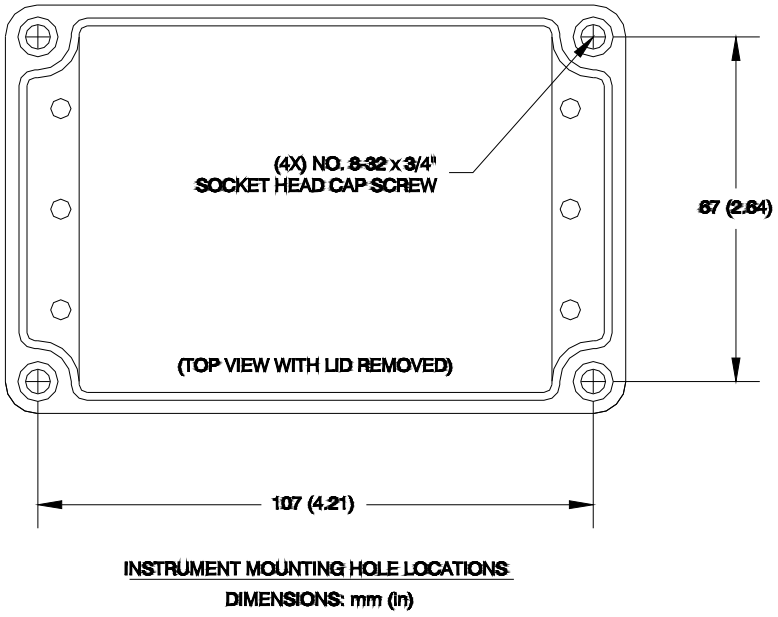


Figure 2. Mounting holes are accessed by removing lid of tiltmeter.
Use 8-32 or 4 mm screws.

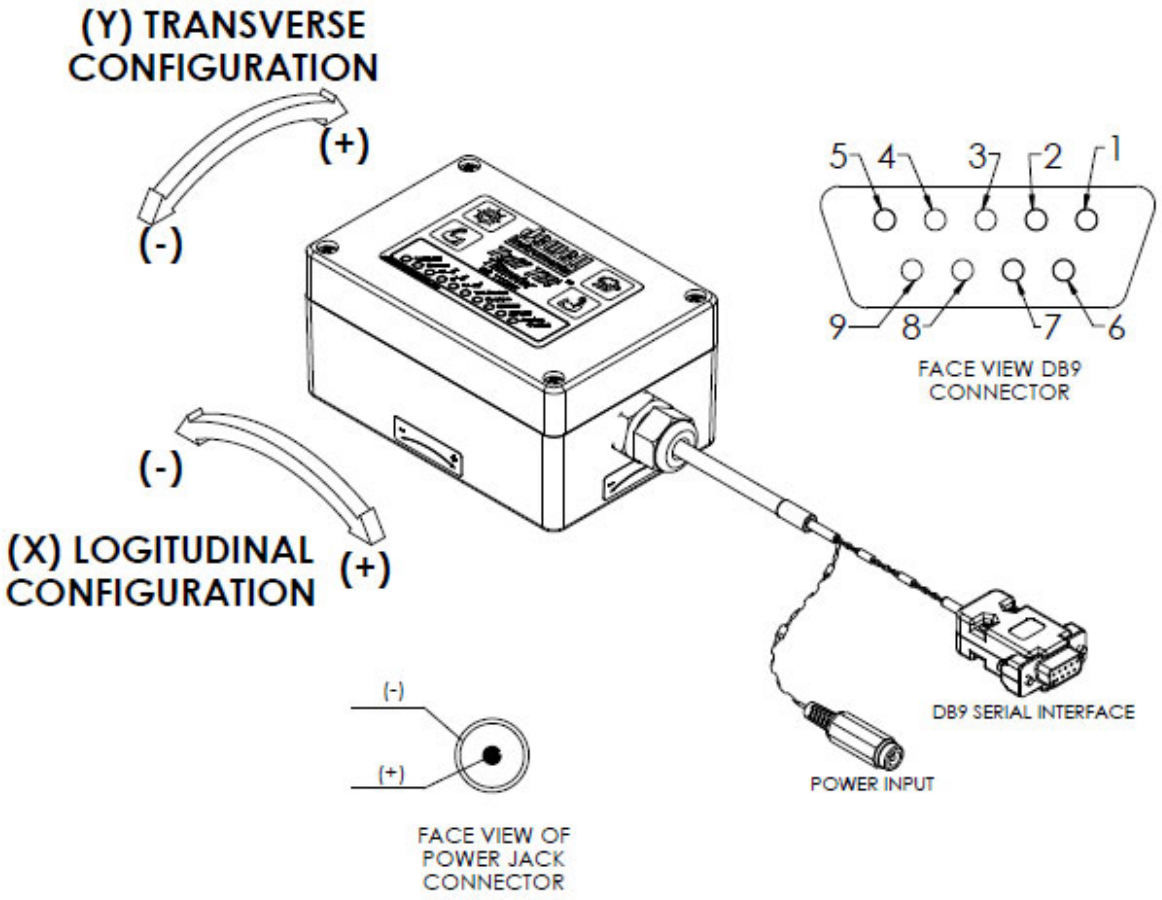
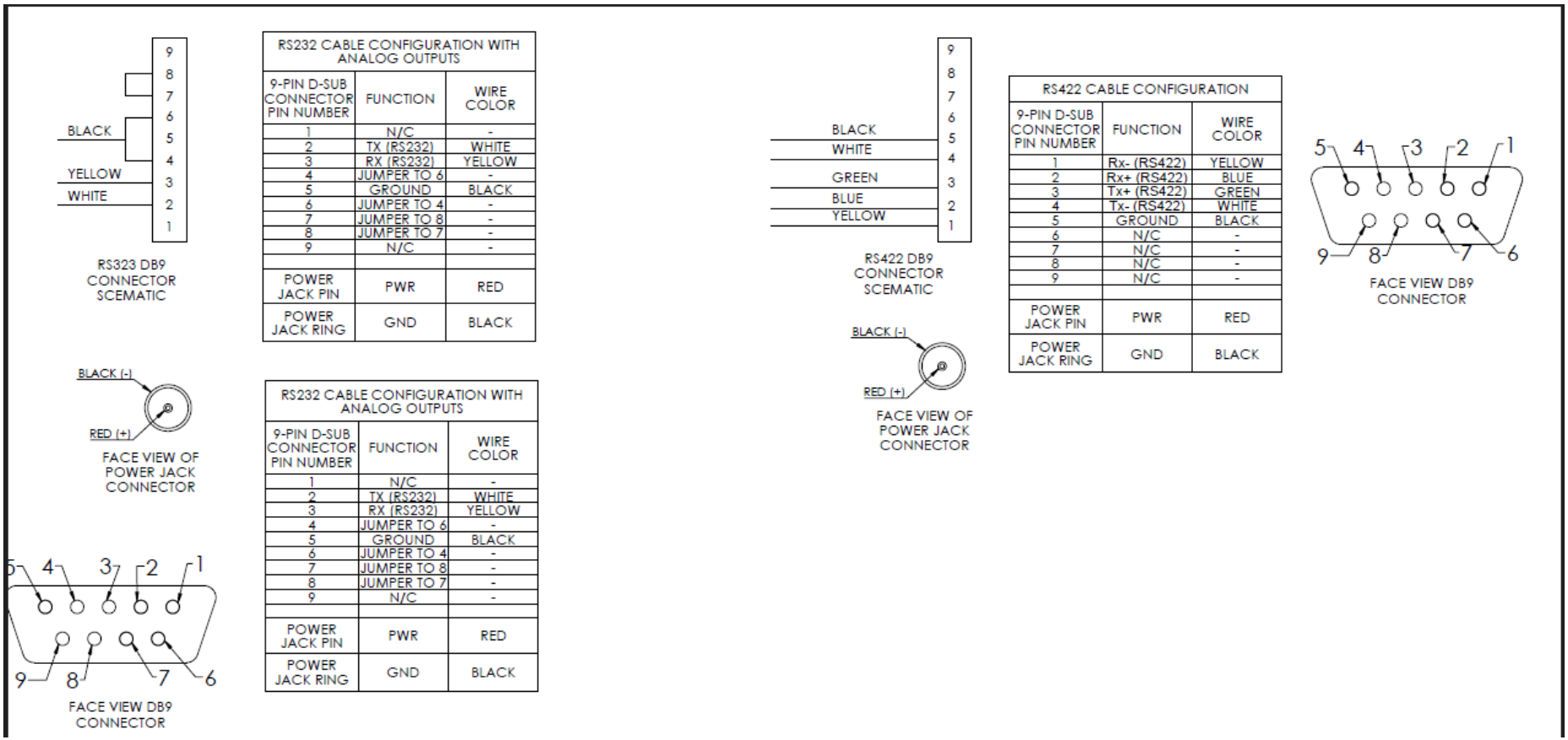


Figure 3. Cable termination details: Tinned ends (left) for power DB9 connector for serial communications, and barrel connector for power input using optional power supply part no. 00254-02.



RS232 CABLE CONFIGURATION WITH ANALOG OUTPUTS		
9-PIN D-SUB CONNECTOR PIN NUMBER	FUNCTION	WIRE COLOR
1	N/C	-
2	TX (RS232)	WHITE
3	RX (RS232)	YELLOW
4	JUMPER TO 6	-
5	GROUND	BLACK
6	JUMPER TO 4	-
7	JUMPER TO 8	-
8	JUMPER TO 7	-
9	N/C	-
POWER JACK PIN	PWR	RED
POWER JACK RING	GND	BLACK

RS232 CABLE CONFIGURATION WITH ANALOG OUTPUTS		
9-PIN D-SUB CONNECTOR PIN NUMBER	FUNCTION	WIRE COLOR
1	N/C	-
2	TX (RS232)	WHITE
3	RX (RS232)	YELLOW
4	JUMPER TO 6	-
5	GROUND	BLACK
6	JUMPER TO 4	-
7	JUMPER TO 8	-
8	JUMPER TO 7	-
9	N/C	-
POWER JACK PIN	PWR	RED
POWER JACK RING	GND	BLACK

RS422 CABLE CONFIGURATION		
9-PIN D-SUB CONNECTOR PIN NUMBER	FUNCTION	WIRE COLOR
1	Rx- (RS422)	YELLOW
2	Rx+ (RS422)	BLUE
3	Tx+ (RS422)	GREEN
4	Tx- (RS422)	WHITE
5	GROUND	BLACK
6	N/C	-
7	N/C	-
8	N/C	-
9	N/C	-
POWER JACK PIN	PWR	RED
POWER JACK RING	GND	BLACK

Figure 4. Wiring connections, Tuff Tilt Digital

Description & Order Numbers	Communications Protocol	
	RS232*	RS422
±3 degrees, Uniaxial, Transverse	98943-09	98943-10
±3 degrees, Uniaxial, Longitudinal	98943-07	98943-08
±50 degrees, Uniaxial, Transverse	98943-15	98943-16
±50 degrees, Uniaxial, Longitudinal	98943-13	98943-14
±3 degrees, Biaxial	98943-11	98943-12
±50 degrees, Biaxial	98943-17	98943-18

* RS232 version is available with optional analog X, Y output or tilt switch output. Please specify when ordering.

Accessories	Order No.
Extra cable	70369
Horizontal mounting plate	84051
Vertical mounting bracket	81439
Power supply (110-240 VAC)	00254-02

2. Installing the Tiltmeter, Making Connections, Tilt Directions

For best results, the tiltmeter should be fastened to a rigid metal or concrete base using four machine screws (no. 8 or M4 size). To access the four mounting holes, first remove the lid of the clinometer (Figure 2). The base to which you will attach the clinometer should be drilled in advance with four threaded or through holes. Use a bolt anchoring system if the base is concrete. The hole pattern must match the 107 x 67 mm hole mounting hole pattern of the clinometer. For stable readings, the mounting screws should hold the clinometer tightly against the base so that it cannot shift or wobble. Replace the lid when installation is complete. *Note: Our horizontal mounting plates and vertical mounting brackets simplify the installation. See the accessory table above and also Figure 5.*

To operate your clinometer, connect the cable assembly as shown in Figure 4. Provide power by connecting the transformer to the power input connector, or use the auxiliary power leads and a separate power supply. Connect the DB9 serial interface connector to a PC or terminal and then follow the instructions in Section 4. Tilt directions are shown in Figure 3.

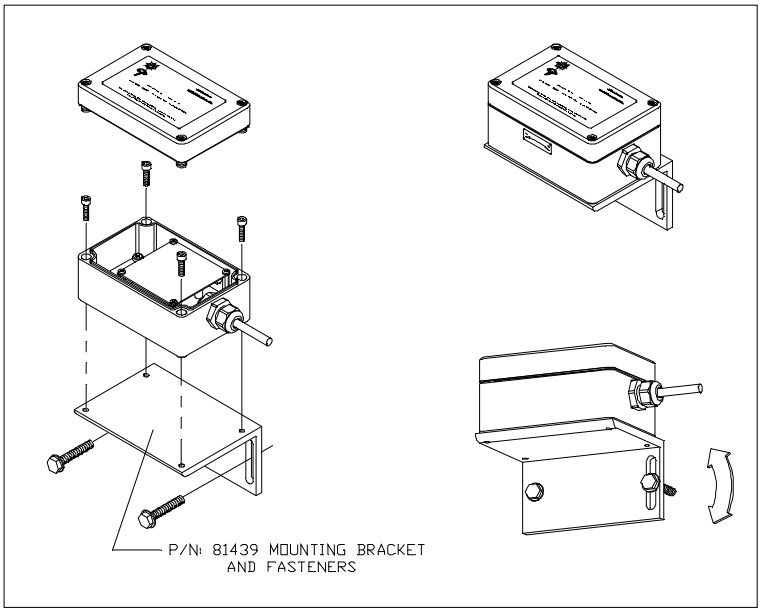
3. Power Requirements and Grounding

Your Tuff Tilt Digital operates on 7-28 volts DC and draws approximately 30 mA of power. Power and ground are connected at pins 2 and 1 respectively of the 6-pin connector. See Figure 4 for wiring details. The enclosure (case) is not grounded except through tranzorbs used for surge protection.

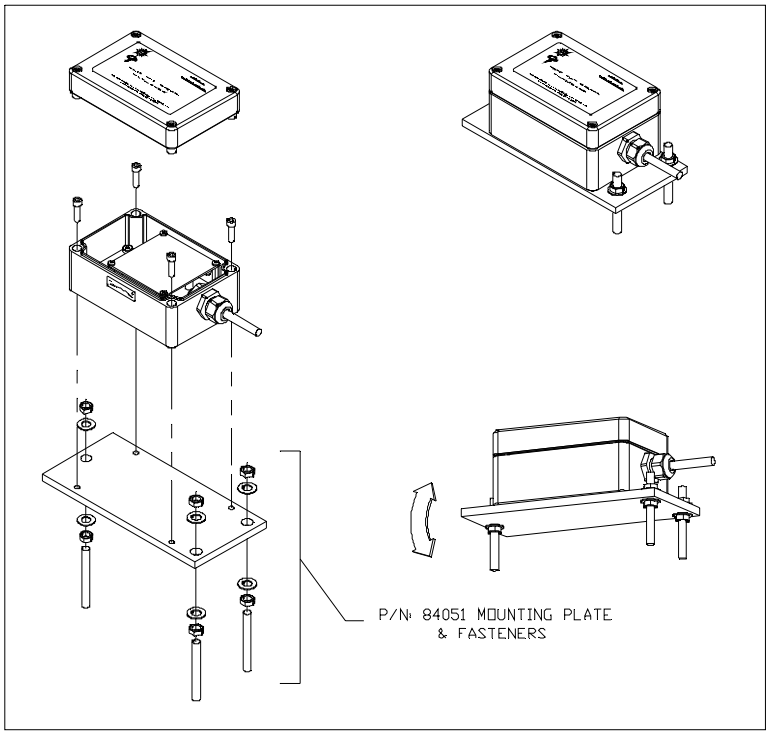
Transient surge absorbers (tranzorbs) connect the power, ground, RS232 and RS422 pins to the case. Screwing the case to a metal substrate at the four mounting holes will ground the case (Figures 2). If the substrate is grounded to the earth, high-voltage transients traveling down the clinometer cable will have a path to

earth ground, reducing the likelihood of damage to the circuitry.

Installing the Tuff Tilt Digital on Vertical Surfaces



Installing the Tuff Tilt Digital on Horizontal Surfaces



Note: The tiltmeter enclosure may also be screwed directly to the mounting surface without use of the P/N 84051 Mounting Plate

Figure 5. Installation Methods

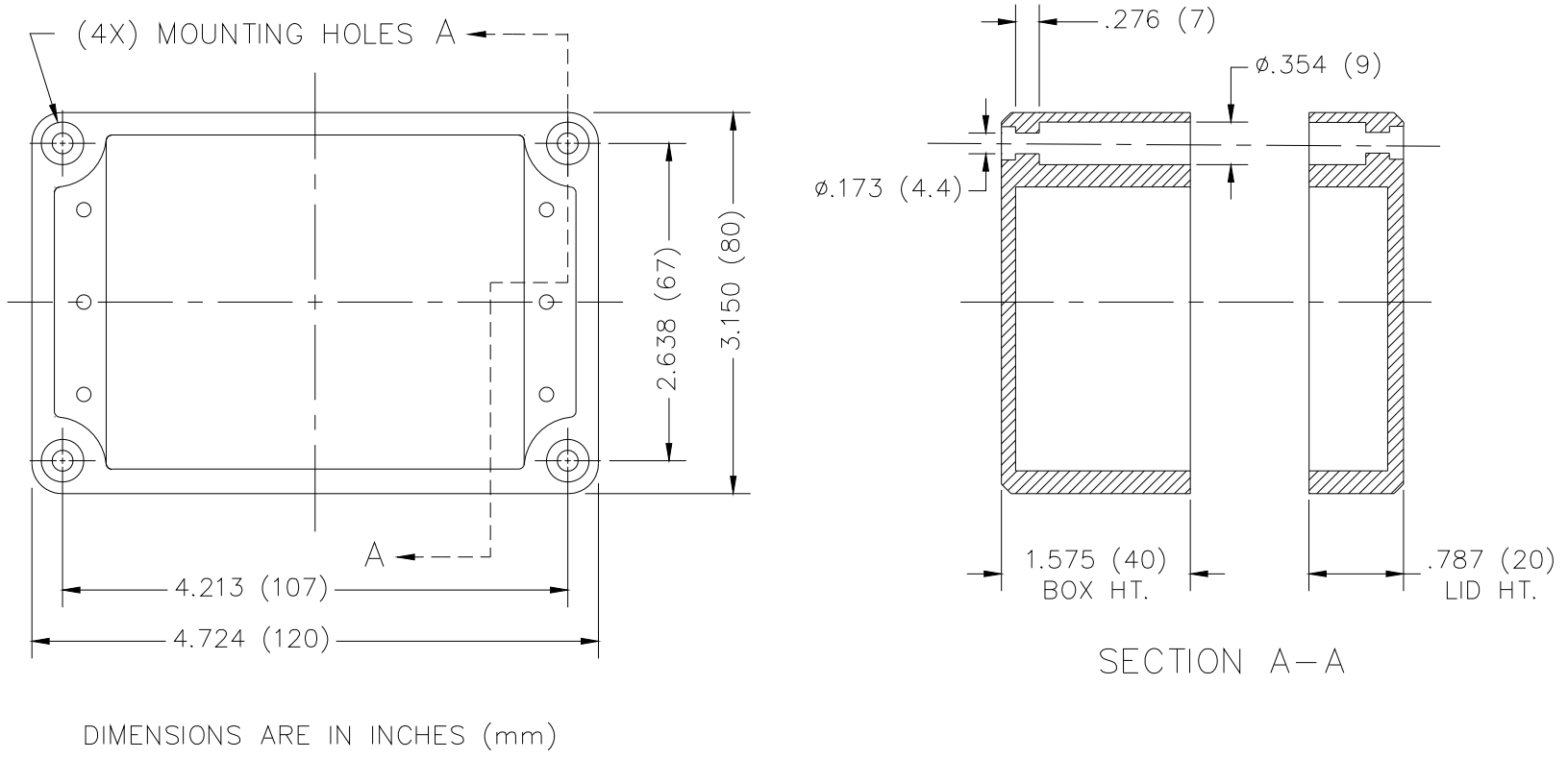


Figure 6. Box Mounting Details

4. Communicating with the *Tuff Tilt Digital*

4.1 Basic Requirements and Settings

You may communicate with your tiltmeter using:

1. ZAGI Software (supplied with the tiltmeter) and a personal computer running Microsoft Windows;
2. A terminal emulator program (e.g. Terminal in Windows 3.1 or HyperTerminal in Windows 95 and later); or
3. A GPS receiver that is capable of sending and receiving terminal commands.

All communication to the tiltmeter is performed through the send (transmit) and receive wires of the serial port. The default parameters for the serial port are set to no parity, 8 bits and 1 stop bit with no hardware or software flow control. The baud rate is the only parameter that is user-selectable. The default baud rate is 9600. Baud rates up to 230400 are supported.

4.2 Firmware Command Format

The format of commands issued by the host is:

*9900<command><CR><LF>

Valid commands are listed in Appendix A.

The input/output processing on the serial port of the ***Tuff Tilt Digital*** is as follows:

(1) Input is read until a <CR> or <LF> (carriage return or line feed) is received. (On a PC, this usually means pressing the 'Enter' or 'Return' key.)

(2) When a line is received, it is parsed to see if it is a command of the device. If it is not, then it is echoed back out, terminated with a <CR> <LF> and we go back to step (1). All strings that are not commands for the unit are echoed. If the command is for the device, we then go to step (3).

(3) The command is processed and we return to step (1). All incoming characters are buffered (up to 1000) while the command is being processed. If the command is for ID 99 and echoing of 99 commands is enabled, the command is echoed after the command result is transmitted.

Default output running firmware version 5 and above is a simple ("SIM") comma-delimited string consisting of X tilt in degrees, Y tilt in degrees, temperature in ºC, and the serial number of the device. Optional outputs consist of a Trimble Navigation proprietary ASCII string with X (Roll) and Y (Pitch) tilts in degrees, and two output formats that follow NMEA Standard 0183, version 2.1, October 15, 1995. This standard may be obtained from:

National Marine Electronics Association (NMEA)
National Office
P.O. Box 3435
New Bern, NC 28564-3435 USA
Tel: 919/638-2626
Fax: 919/638-4885

4.3 Firmware Command Summary

The list below summarizes the most important user-accessible firmware commands. Precede these commands with the string *9900. See Appendix A for additional details.

XY	Outputs a single tilt and temperature measurement. The format of the output depends on the setting of the SO command.
SO-*xxx*	Selects the output format for the XY command. "*xxx*" selects format as follows: ASH: Ashtech compatible NMEA format SIM: Simple x,y,t,sn output string (default) XDR: NMEA XDR format TCM: Trimble Navigation proprietary pitch (Y) and roll (X) string BAE: BAE Systems encoded 11-byte string containing a sync packet, x, y, t, SN, and checksum information. Advanced users only—typically for embedded system integration.
XY-MEMS	Stores tiltmeter readings at selected output rate in nonvolatile memory. (Versions 5.1 and higher)
XY-MEMD	Downloads data from nonvolatile memory. (Versions 5.1 and higher)
XY-M1	Sets the tiltmeter to Mode-1 operation.
XYVR	Displays the sign-on string.
ID	Sets the ID of units in the daisy chain (not currently implemented).
XY-TR-PASH-ON	Translates the Paros provided $PASHS,XDR,P sentences to standard NMEA XDR format.
XY-TR-PASH-OFF	Turns off translation of $PASHS,XDR,P sentences.
XY-EP	Enables power on message.

XY-SP	Disables power on message.
XY-EE	Enables echoing of global 99 commands.
XY-SE	Disables echoing of global 99 commands.
XY-SET-BAUDRATE,*x*	Sets baud rate to value of *x* in bits per second. Selectable values include 9600, 19200, 28800, 57600, 115200 and 230400 baud.
XY-SET-N-SAMP,x	Sets number of samples that are averaged before a reading is transmitted; *x* may have any value from 1 to 1000. Changing this value may also change the output rate.
XY-SET-RSMODE,*x*	Selects serial output mode: *x* = 0 RS232 *x* = 1 RS485 (RS422)
XY-AUTOZ	Turns on auto zero function.
XY-AUTOZOFF	Turns off auto zero function.
XYC*x*	Continuously sends XY data where *x* determines output rate as follows:

x = 0:	8-10 outputs per second
x = 1:	4 outputs per second
x = 2:	1 output per second (default)
x = 3:	1 output every 10 seconds
x = 4:	1 output every 60 seconds
x = 5:	1 output every hour
x = 6:	1 output every 12 hours
x = 7:	1 output every 24 hours
x = 0A:	Averaging of the 8-10 outputs per second data
x = 1A:	Averaging of the 4 outputs per second data
x = 2A or *x* = A:	Averaging of the 1 output per second data

Once initiated, continuous output remains in effect until turned off with the XYC-OFF command (see below).

XYC-OFF	Turns off XYC mode.
XY-SET-CTRL-ON	Enables control feature.
XY-SET-CTRL-OFF	Disables control feature.
XY-SET-CTRLTEST-ON	Sets the control pin high (+5 VDC).
XY-SET-CTRLTEST-OFF	Sets the control pin low (0 VDC).
XY-SET-THRESHOLD,x+,x-,y+,y-	Sets the control thresholds.

XY-SET-HYST,k	Sets the control hysteresis.
XY-DUMP-SETTINGS	Dumps settings of device.
XY-DUMP2	Dumps extended settings of device.

4.4 Sample Data Using the XY Command

The most commonly used command is the XY command, which returns the X and Y tilt angles in degrees and the internal temperature of the ***Tuff Tilt Digital*** in ºC. The format of the returned data depends on the setting of the SO command. The returned data are averages of a series of readings. The number of samples used in the average is set by the XY-SET-N-SAMP command. The following lines illustrate the format of the data returned by the XY command for the range of possible SO settings:

SO = "ASH." Ashtech compatible NMEA output string which returns the North-South (Y) and East-West (X) tilt angle in degrees and the internal temperature of the MD-900-T in ºC:

$PASHS,XDR,A,004.261,D,N,A,004.280,D,E,C,021.288,C,T-N1346
$PASHS,XDR,A,004.261,D,N,A,004.280,D,E,C,021.306,C,T-N1346
$PASHS,XDR,A,004.261,D,N,A,004.280,D,E,C,021.298,C,T-N1346
$PASHS,XDR,A,004.261,D,N,A,004.280,D,E,C,021.332,C,T-N1346

SO = "SIM" (default). Simple X,Y,T,SN output which returns the X and Y tilt angle in degrees and the internal temperature of the MD-900-T in ºC:

$-00.619,000.023,018.910,N0000
$-00.619,000.023,018.923,N0000
$-00.620,000.024,018.932,N0000
$-00.620,000.023,018.951,N0000

SO = "XDR." Standard NMEA XDR output string which returns the North-South (Y) and East-West (X) tilt angle in degrees and the internal temperature of the MD-900-T in ºC:

$YXXDR,A,000.034,D,N,A,-00.625,D,E,C,021.651,C,T-N0000*47
$YXXDR,A,000.034,D,N,A,-00.624,D,E,C,021.675,C,T-N0000*40
$YXXDR,A,000.034,D,N,A,-00.624,D,E,C,021.686,C,T-N0000*4C
$YXXDR,A,000.034,D,N,A,-00.625,D,E,C,021.707,C,T-N0000*45

SO = “TCM.” Proprietary Trimble Navigation pitch (Y-tilt) and roll (X-tilt) output string which returns the tilt angle in degrees and a checksum:

$P-00.907R002.186*1C
$P-00.906R002.183*18
$P-00.908R002.191*15
$P-00.908R002.191*15
$P-00.905R002.190*19

SO = “BAE.” Advanced users only, using the D711-2A(4X). BAE Systems encoded 11-byte output which returns two synchronization bytes, the X (2 bytes) and Y (2 bytes) tilt angle, the internal temperature of the tiltmeter (2 bytes), the serial number (2 bytes), and a checksum byte:

Uª Ä$é TæUª Ä$ä TáUª Ä$ß TÜUª Ä$é Tæ

The BAE output string is not clearly decipherable by HyperTerminal, which sometimes hides characters that it has received and cannot understand. Because of this, it is difficult, if not impossible, to interpret data in this format. The above output string shows four outputs taken from HyperTerminal. The BAE output string is not selectable using ZAGI.

This encoded output command is typically used to communicate with embedded systems, as they can view raw data and perform fast translations.

The first synchronization byte is 0x55, the second is 0xAA. The X and Y bytes use 0.0000277 angular degrees per LSB, hence the total output range of this output mode is limited to the model D711-2A(4X). The temperature uses 0.004 degrees Celsius per LSB. The serial number is a two byte integer. The checksum byte is the result of ANDing bytes 2-7 with 255.

BAE output mode reduces the total number of characters per output to 11 bytes, while transferring the same data as the SIM output mode, which requires 33 bytes. BAE mode also includes checksum and frame synchronization bytes. Refer to Appendix A, Firmware Commands, to decode the output.

5. Maintenance and Troubleshooting

The ***Tuff Tilt Digital*** is packaged in a rugged aluminum box and should provide many years of trouble-free operation. Best results are achieved by keeping the unit clean, dry and within the stated operating and storage temperature ranges.

Problems most commonly result from lack of power, or a broken wire or connection. If the unit does not respond when queried by the host, first verify that it is receiving power. If it still does not respond, remove the lid and check for loose broken wires or a loose or detached internal connector. If these checks still do not reveal the problem, contact Jewell Instruments in Manchester, NH for assistance at telephone: 603/669-6400, fax: 603/622-2690 or e-mail: sales@jewellinstruments.com.

Appendix A. Firmware Commands

Firmware Commands

Valid commands are listed below. Some commands have more than one string to trigger the command. "tt" stands for the target ID (99) and "ss" stands for the source ID (00). Settings stored in nonvolatile memory remain in effect until disabled, even after a power cycle.

```
--------------------------------------
XY      Outputs a single tilt measurement.  The format of the output
        depends on the setting of the SO command.

        Syntax: *ttssXY<CR><LF>

        Error Strings: None.

        Default: N/A

        Persistence: N/A

        Example:
        command: *9900XY<CR><LF>
        response: $YXXDR,A,-00.920,D,N,A,-00.210,D,E,C,030.045,C,T-N1212*57

--------------------------------------
SO      Selects the output format for the XY command.  The possible formats
        are:

        -SIM
                $x.x,y.y,t.t,sn<CR><LF>
                  |   |   |   |
                  |   |   |   Serial number
                  |   |   Temperature of tiltmeter
                  |   Y-tilt value in degrees
                  X-tilt value in degrees
                Example:
                $-00.920,-00.210,030.045,N1212

        -XDR
                $YXXDR,A,x.x,D,N,A,x.x,D,E,C,x.x,C,T-sn*hh<CR><LF>
                       |  |  | | |  |  | | |  |  | |  |  |
                       |  |  | | |  |  | | |  |  | |  |  Checksum
                       |  |  | | |  |  | | |  |  | |  Serial number
                       |  |  | | |  |  | | |  |  | Comment, T for temperature
                       |  |  | | |  |  | | |  |  Units, C=degrees C
                       |  |  | | |  |  | | |  Temperature of tiltmeter
                       |  |  | | |  |  | | Data Type, C=Temperature
                       |  |  | | |  |  | Comment, E for East/West (X) direction
                       |  |  | | |  |  Units, M=microradians, D=degrees
                       |  |  | | |  X (E)-tilt value
                       |  |  | | Data Type, A=Angular
                       |  |  | Comment, N for North/South (Y) direction
                       |  |  Units, M=microradians, D=degrees,
                       |  Y (N)-tilt value
                       Data Type, A=Angular
                Example:
                $YXXDR,A,-00.920,D,N,A,-00.210,D,E,C,030.045,C,T-N1212*57
```

```
-ASH
        $PASHS,XDR,A,x.x,D,N,A,x.x,D,E,C,x.x,C,T-sn<CR><LF>
                   |  |  | | |  |  | | |  |  | |  |
                   |  |  | | |  |  | | |  |  | |  Serial number
                   |  |  | | |  |  | | |  |  | Comment, T for temperature
                   |  |  | | |  |  | | |  |  Units, C=degrees C
                   |  |  | | |  |  | | |  Temperature of tiltmeter
                   |  |  | | |  |  | | Data Type, C=Temperature
                   |  |  | | |  |  | Comment, E for East/West direction
                   |  |  | | |  |  Units, M=microradians, D=degrees
                   |  |  | | |  X (E)-tilt value
                   |  |  | | Data Type, A=Angular
                   |  |  | Comment, N for North/South direction
                   |  |  Units, M=microradians, D=degrees
                   |  Y (N)-tilt value
                   Data Type, A=Angular
        Example:
        $PASH,XDR,A,-00.920,D,N,A,-00.210,D,E,C,030.045,C,T-N1212

-TCM
        $Py.y,Rx.x*hh<CR><LF>
          |   |    |
          |   |    |
          |   |    CheckSum
          |   Roll= X-tilt value in degrees
          Pitch= Y-tilt value in degrees
        Example:
        $P-00.905R002.190*19

-BAE
   abcdefghijk
   ||||||||||
   |||||||||Byte 10(k): Checksum of bytes 2-7 ANDed with decimal 255
   |||||||||
   ||||||||Byte 8-9(i,j): Serial number in hexadecimal format
   ||||||||
   ||||||Byte 6-7(g,h): Temperature in Deg. C.  Bits 14 - 0 = magnitude
   ||||||        (LSB bit = 0.004 Deg. C.), Bit 15 = sign
   ||||||
   ||||Byte 4-5(e,f): Y Axis Level Data.  Bits 14 - 0 = magnitude
   ||||          (LSB bit = 0.0000277 degrees), Bit 15 = sign
   ||||
   ||Byte 2-3(c,d):    X Axis Level Data.  Bits 14 - 0 = magnitude
   ||            (LSB bit = 0.0000277 degrees), Bit 15 = sign
   ||
   |Byte 1(b): 0xAA, 2nd Synchronization Byte
   |
   Byte 0(a): 0x55, 1st Synchronization Byte
```

Syntax: *ttssSO-<output format><CR><LF>

Error Strings:
ERR XY-SO BAD PARAMETER
<output format> was invalid.
ERR XY-SO PARSE ERROR
Could not parse <output format>.

Default: SIM

Persistence: Setting is stored in nonvolatile memory.

Example:
command: *9900SO-XDR<CR><LF>
response: <none>

XY-MEMS Stores the tiltmeter readings in simple format (SO-SIM) at selected output rate in nonvolatile memory.

Syntax: *ttssXY-MEMS<CR><LF>

Error Strings: None.

Default: N/A

Persistence: Subsequent tiltmeter readings stored in nonvolatile memory until memory is full. Maximum of approximately 150 lines of data.

Example:
command: *9900XY-MEMS<CR><LF>
response: <none>

XY-MEMD Downloads the tiltmeter readings in nonvolatile memory to PC.

Syntax: *ttssXY-MEMD<CR><LF>

Error Strings: None.

Default: N/A

Persistence: Stored tiltmeter readings downloaded at rate of 1 per second to PC in ASCII comma-delimited string.

Example:
command: *9900XY-MEMD<CR><LF>
response: $start:11-11-1997 18:43:09 4/sec
$000.699,-01.022,025.116,N1028
$000.699,-01.022,025.116,N1028
$000.698,-01.021,025.110,N1028
$000.698,-01.022,025.122,N1028

XY-M1 Sets the operation to Mode 1. This command groups several other commands together for convenience. The commands that are issued are:

- XY-TR-PASH-ON
- XY-SO-XDR
- XY-SE
- XY-SP

Syntax: *ttssXY-M1<CR><LF>

Error Strings: None.

Default: N/A

Persistence: Setting is stored in nonvolatile memory.

Example:
command: *9900XY-M1<CR><LF>
response: AGI Model D711-2A(4X) Firmware V2.2 SN-N1212 ID01

XYVR Displays the sign-on string.

Syntax: *ttssXYVR<CR><LF>

Error Strings: None.

Default: N/A

Persistence: N/A

Example:
command: *9900XYVR<CR><LF>
response: AGI Model D711-2A(4X) Firmware V5.2 SN-N1212 ID01

ID *This command is not currently supported.* Sets the ID of units in the daisy chain. The first device in the serial chain sets its ID to the source ID plus one (ss+1), and then outputs a the ID command to the next device with the source ID set to its new ID. The target ID of this command must be 99.

Syntax: *99ssID<CR><LF>

Error Strings: None.

Default: 01

Persistence: Setting is stored in nonvolatile memory.

Example:
command: *9900ID<CR><LF>
response: *9901ID<CR><LF>

XY-TR-PASH-ON Translates the Paros provided $PASHS,XDR,P sentences to standard NMEA XDR format. An example input PASH string would be:

$PASHS,XDR,P,1.000123,B,SN123,C,22.12,C,SN123,H,32.11,P,SN123<CR><LF>

The translated string would then be:

$WIXDR,P,1.000123,B,SN123,C,22.12,C,SN123,H,32.11,P,SN123*hh<CR><LF>

Syntax: *ttssXY-TR-PASH-ON<CR><LF>

Error Strings: None.

Default: Off.

Persistence: Setting is stored in nonvolatile memory.

Example:
command: *9900XY-TR-PASH-ON<CR><LF>
response: <none>

XY-TR-PASH-OFF Turns off translation of $PASHS,XDR,P sentences.

Syntax: *ttssXY-TR-PASH-OFF<CR><LF>

Error Strings: None.

Default: N/A

Persistence: Setting is stored in nonvolatile memory.

Example:
command: *9900XY-TR-PASH-OFF<CR><LF>
response: <none>

XY-EP Enables power on message. Power on message is:
AGI Tiltmeter Firmware V5.2 SN-N1212 ID01
Where V5.2 is the firmware version, SN-N1212 is the serial number of the device and ID01 is the target's ID.

Syntax: *ttssXY-EP<CR><LF>

Error Strings: None.

Default: On.

Persistence: Setting is stored in nonvolatile memory.

Example:
command: *0100XY-EP<CR><LF>
response: <none>

XY-SP Disables power on message.

Syntax: *ttssXY-SP<CR><LF>

Error Strings: None.

Default: N/A

Persistence: Setting is stored in nonvolatile memory.

Example:
command: *9900TR-SP<CR><LF>
response: <none>

XY-EE Enables echoing of global 99 commands. If the unit receives a command for ID 99, then the unit will respond to the command and echo the command when it is done.

Syntax: *ttssXY-EE<CR><LF>

Error Strings: None.

Default: On.

Persistence: Setting is stored in nonvolatile memory.

Example:
command: *0100XY-EE<CR><LF>
response: <none>

XY-SE Disables echoing of global 99 commands. If the unit receives a command for ID 99, then the unit will respond, but the unit will NOT echo the command when it is done.

Syntax: *ttssXY-SE<CR><LF>

Error Strings: None.

Default: N/A

Persistence: Setting is stored in nonvolatile memory.

Example:
command: *0100XY-SE<CR><LF>
response: <none>

XY-SET-BAUDRATE,*x* Changes communications baud rate. Maximum supported baud rate is 57,600 baud. The parameter *x* is an integer with up to six places, defining the baud rate as follows:

```
  9600 = 9600 baud
 19200 = 19200 baud
 28800 = 28800 baud
 57600 = 57600 baud
115200 = 115200 baud
230400 = 230400 baud
```

Syntax: *ttssXY-SET-BAUDRATE,*x*<CR><LF>

Error Strings: ERR XY-SET-BAUDRATE,*x* PARSE ERROR.

Default: 9600

Persistence: Setting is stored in nonvolatile memory.

Example:
command: *9900XY-SET-BAUDRATE,57600<CR><LF>
response: <none>

XY-SET-N-SAMP,*x* Sets the number of samples that are averaged before a reading is transmitted. The parameter *x* is an integer between 1 and 1000 equal to the number of samples that are averaged.

Syntax: *ttssXY-SET-N-SAMP,*x*<CR><LF>

Error Strings: None.

Default: Depends on data output rate, as specified by the XYC*x* command.

The default numbers of samples averaged for each data rate are:

```
XYC0:  28
XYC1: 100
XYC2: 460
XYC3: 500
XYC4: 500
XYC5: 500
XYC6: 500
XYC7: 500
```

If the number of samples specified exceeds the number listed above for XYC0, XYC1 or XYC2, the microprocessor reduces the data output rate until it has enough time to collect and average all of the samples.

Persistence: Once initiated, the same averaging remains in effect even with power cycle. (Setting is stored in nonvolatile memory.) Can be changed by reissuing the command with a different value for x, or by changing the output rate with the XYCx command.

Example:
command: *9900XY-SET-N-SAMP,250<CR><LF>
response: <none>

XY-SET-RSMODE,*x* Sets output protocol to RS232 or RS485(RS422), as follows:

x = 0: RS232
x = 1: RS485(RS422)

Syntax: *ttss XY-SET-RSMODE,*x*<CR><LF>

Error Strings: None.

Default: Set in factory to customer specification.

Persistence: Once initiated, remains in effect even with power cycle. (Setting is stored in nonvolatile memory.)

Example:
command: *9900XY-SET-RSMODE,*0*<CR><LF>
response: <none>

CAUTION: If you change the output protocol, you will no longer be able to communicate with the tiltmeter unless you have the correct interconnect cable.

XY-AUTOZ Turns autozero function on, causing tiltmeter to subtract current X and Y readings from all subsequent X and Y readings.

Syntax: *ttssXY-AUTOZ <CR><LF>

Error Strings: None.

Default: Off.

Persistence: Setting is stored in nonvolatile memory.

Example:
command: *9900XY-AUTOZ<CR><LF>
response: <none>

XY-AUTOZOFF Turns autozero function off, causing tiltmeter to display non-biased (unshifted) position readings.

Syntax: *ttssXY-AUTOZ-OFF<CR><LF>

Error Strings: None.

Default: Off.

Persistence: Setting is stored in nonvolatile memory.

Example:
command: *9900XY-AUTOZ-OFF<CR><LF>
response: <none>

XYC*x* Continuously sends XY data - even after power has been turned off and then on again. Timing is determined by the microprocessor's crystal and is approximate. The parameter *x* is an integer between 1 and 7, the letter A, or 0A, 1A, or 2A.

An A indicates the use of the moving average function, in which the moving average of the data is output. When the moving average function is used, the first output is delayed until the first *n* readings have been taken, where *n* is the number of readings to be averaged. After that, the outputs occur at the same rate as the readings. For example, the command XYC2A outputs the moving average of the same data that would be output if the user issued the command XYC2. Since XYC2 outputs data once per second, XYC2A also outputs once per second. However, the first output occurs after a four-second delay, in which the first four readings (at a rate of 1 per second) are averaged. The second output is the average of readings 2-5, the third output is the average of readings 3-6, and so on, creating an output rate equal to that of XYC2.

The parameter *x* determines rate of continuous output as follows:

x = 0:	8-10 per second
1:	4 per second
2:	1 per second
3:	1 every 10 seconds
4:	1 every 60 seconds
5:	1 every 60 minutes
6:	1 every 12 hours
7:	1 every 24 hours
0A:	Average of 8-10 outputs/sec data. 10 readings are averaged.
1A:	Average of 4 outputs/second data. 4 readings are averaged.
2A or A:	Average of 1 output/second data. 4 readings are averaged.

Syntax: *ttssXYC*x*<CR><LF>

Error Strings: None.

Default: Off.

Persistence: Once initiated, continuous output remains in effect even with power cycle. (Setting is stored in nonvolatile memory.) Must be turned off using the XYC-OFF command (see below).

Example (with SO="SIM"):
command: *9900XYC1<CR><LF>
response: $-00.699,000.070,020.290,N0000
$-00.699,000.071,020.309,N0000
$-00.699,000.071,020.313,N0000
$-00.699,000.071,020.330,N0000
$-00.699,000.071,020.348,N0000
$-00.700,000.070,020.360,N0000

XYC-OFF Turns off XYC mode.

Syntax: *ttssXYC-OFF<CR><LF>

Error Strings: None.

Default: N/A.

Persistence: Setting is stored in nonvolatile memory.

Example:
command: *0100XYC-OFF<CR><LF>
response: *0100XYC-OFF<CR><LF>

XY-SET-CTRL-ON Enables control feature. If the tilt exceeds either threshold in any direction, the control pin will go high (+5 VDC) until the tilt falls below the positive threshold value minus the hysteresis value, or falls above the negative threshold value plus the hysteresis value.

Syntax: *ttssXY-SET-CTRL-ON<CR><LF>

Error Strings: None.

Default: On.

Persistence: Setting is stored in nonvolatile memory.

Example:
command: *9900XY-SET-CTRL-ON<CR><LF>
response: <none>

XY-SET-CTRL-OFF Disables control feature. The control pin will remain at ground potential (0 VDC) unless the user issues the command XY-SET-CTRLTEST-ON or turns the control feature on again by issuing the command XY-SET-CTRL-ON.

Syntax: *ttssXY-SET-CTRL-OFF<CR><LF>

Error Strings: None.

Default: On.

Persistence: Setting is stored in nonvolatile memory.

Example:
command: *9900XY-SET-CTRL-OFF<CR><LF>
response: <none>

XY-SET-CTRLTEST-ON Sets the control pin high (+5 VDC), regardless of whether control feature is on or off. Convenient for testing control functionality regardless of tilt.

Syntax: *ttssXY-SET-CTRLTEST-ON<CR><LF>

Error Strings: None.

Default: Off.

Persistence: Control pin stays high until the user issues the command XY-SET-CTRLTEST-OFF or disconnects power.

Example:
command: *9900XY-SET-CTRLTEST-ON<CR><LF>
response: <none>

XY-SET-CTRLTEST-OFF Sets the control pin low (0 VDC). If the control feature is on and the tilt falls above the positive threshold value minus the hysteresis value, or falls below the negative threshold value plus the hysteresis value, the control pin may go high again immediately. XY-SET-CTRL-OFF turns off the control feature altogether.

Syntax: *ttssXY-SET-CTRLTEST-OFF<CR><LF>

Error Strings: None.

Default: Off.

Persistence: None. If the control feature is on and the tilt exceeds the hysteresis value, the control pin may go high again immediately.

Example:
command: *9900XY-SET-CTRLTEST-OFF<CR><LF>
response: <none>

XY-SET-THRESHOLD,x+,x-,y+,y- Sets the control thresholds. The parameter x+ is the positive threshold for the x axis in the current output units (default is degrees), and so on for parameters x-, y+, and y-. If the tilt exceeds either threshold on either axis, and the control feature is on, the control pin goes high (+5 VDC) until the tilt falls below the positive threshold value minus the hysteresis value, or falls above the negative threshold value plus the hysteresis value.

Syntax: *ttssXY-SET-THRESHOLD,x+,x-,y+,y-<CR><LF>

Error Strings: ERR XY-SET-THRESHOLD PARSE ERROR.

Default:
x+ = 1
x- = -1
y+ = 1
y- = -1

Persistence: Setting is stored in nonvolatile memory.

Example:
command: *9900XY-SET-THRESHOLD,5,-3.244,4.0,0<CR><LF>
response: <none>

XY-SET-HYST,x Sets the control hysteresis, where the parameter x is the hysteresis value in the current output units (default is degrees). If the tilt exceeds either threshold on either axis, and the control feature is on, the control pin remains high (+5 VDC) until the tilt falls below the positive threshold value minus the hysteresis value, or falls above the negative threshold value plus the hysteresis value.

Syntax: *ttssXY-SET-HYST,x<CR><LF>

Error Strings: ERR XY-SET-HYST PARSE ERROR.

Default: 0

Persistence: Setting is stored in nonvolatile memory.

Example:
command: *9900XY-SET-HYST,0.5<CR><LF>
response: <none>

XY-DUMP-SETTINGS Dumps settings of device.

Syntax: *ttssXY-DUMP-SETTINGS<CR><LF>

Error Strings: None.

Default: N/A

Persistence: N/A

Example:
command: *9900XY-DUMP-SETTINGS
response:

```
APPLIED GEOMECHANICS Tiltmeter     Firmware V5.0 SN-N2144 ID01
01: Vbias= 2047.000000000 2047.000000000 NaN            NaN
01: Vgain=    0.005000000    0.005000000    0.000610350    0.000610350
01: Vmin:  -2.50  -2.50   2.50   2.50
01: Vmax:   2.50   2.50   2.50   2.50
01: a0=    0.00000    0.00000    0.00000    0.00000    0.00000    0.00000
01: a1=    0.00000    0.00000    0.00000    0.00000    0.00000    0.00000
01: a2=    0.00000    0.00000    0.00000    0.00000    0.00000    0.00000
01: a3=    0.00000    0.00000    0.00000    0.00000    0.00000    0.00000
01: Tcoef 0: Ks=      0.0003 Kz=           0 Tcal=          25
01: Tcoef 1: Ks=      0.0003 Kz=           0 Tcal=          25
01: N_SAMP=1000 Xzero=  0.00 Yzero=  0.00
01: TR-PASH-OFF E99-ON  SO-NMEA-SIM XY-EP  9600 baud FV-
```

```
---------------------------------------
XY-DUMP2    Dumps extended settings of device.

        Syntax: *ttssXY-DUMP2<CR><LF>

        Error Strings: None.

        Default: N/A

        Persistence: N/A

        Example:
        command: *9900XY-DUMP2
        response:

01: TBias: 8.95
Above 0.00(KZMinTemp): kz[0]=           0, kz[1]=      0.0011
Below 0.00(KZMinTemp): kz[2]=           0, kz[3]=      0.0011
01: ADCDelay:  310
01: PCA Model: 84833-13
01: Firmware Version: 5.10 Rev D
01: X Ch Gain= 1.0000, Y Ch Gain= 1.0000, Temperature Gain= 1.0000
01: Output Mode: Degrees
01: Using RS232
01: Real Time Clock: Not Installed
01: External Flash Capacity: 0 Bytes(Not Installed)
01: Relay Thresholds:
01:   Xpositive=1.0000   Xnegative=-1.0000
01:   Ypositive=1.0000   Ynegative=-1.0000
01: Calibration method: Dynamic
01: Positive Limit=1.5000   Negative Limit=-1.5000
01: Calibration Points:041  X: Disabled  Y: Enabled
01: Uniaxial (x2) Sensor Type (2)
01: ADC Channels: Two
```

Appendix B. Warranty and Limitation of Liability

WARRANTY and LIMITATION of LIABILITY

Standard goods (those listed in Jewell Instruments' published sales literature, excluding software) manufactured by Jewell Instruments LLC are warranted against defects in materials and workmanship for twelve (12) months from the date of shipment from Jewells' premises with the following exceptions: Series 900 analog or digital clinometers are warranted against defects in materials and workmanship for 90 days from the delivery date. Jewell will repair or replace (at its option) goods that prove to be defective during the warranty period provided that they are returned prepaid to Jewell and:

(a) that the goods were used at all times for the purpose for which they were designed and in accordance with any instructions given by Jewell in respect of them,
(b) that notice is received by Jewell within 30 days of the defects becoming apparent, and
(c) that return authorization is received from Jewell prior to the goods being sent back.

Should goods be damaged in transit to the Purchaser, Jewell will accept no liability unless the Purchaser can show that such damage arose solely from Jewell's failure to pack the goods properly for shipment.

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January 2013

Appendix C. Revision Record

Appendix D. Revision Record

REV.	PAGE NOS.	ECN NO.	DESCRIPTION OF CHANGE	DATE
C	ALL	25069	"Jewell" was "Applied Geomechanics" Added Revision Record, & Table of Content	1/30/13
D	Page 30	25580	Revised "ZAGI" screenshot to version 3.3.3	7/17/13
E	Pages 2, 3, 5, 6	25746	Revised part numbers, RS422 was RS485	9/30/13
F	All		Removed ZAGI software instructions. Changed photo showing wiring to match OD.	1/3/25