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USERS' MANUAL

TILTMETER

Model EAN-92M MEMS type with SDI-12 interface

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1 INTRODUCTION

Encardio-rite model EAN-92M tilt meter is suitable for monitoring inclination and vertical rotation of structures. It is a high resolution tilt meter, is rugged in construction and has excellent temperature stability.

Tilt change in a structure may be caused by construction activity like excavation, tunneling or de-watering that may affect the ground supporting the structure. Change in tilt could also result from loading of the structure, such as loading of a dam during impoundment, loading of a diaphragm wall during excavation or loading of a bridge deck due to wind and traffic. Data from the tilt meter provides early warning of threatening deformations, allowing time for corrective action to be taken or if necessary for safe evacuation of the area.

SDI-12 is the acronym for "Serial Data Interface at 1200 Baud". SDI-12 is an asynchronous, ASCII, serial communications protocol. These instruments are typically low-power (12 volt), are often used in remote locations, and usually communicate with a data logger or other data acquisition device. In this master-slave configuration, the data logger or data acquisition device typically acts as the master (SDI-12 Recorder and Interrogator) to the data monitoring instruments, which are the slaves (SDI-12 sensors). One master can communicate with multiple slaves, so the SDI-12 protocol requires that each device in the serial network be identified with a unique address, which is represented by a single ASCII character.

This communication is achieved by digital communications along a single serial line. The digital addressing system allows an SDI-Recorder to send out an address over a single line that is occupied by sensors with only the pre-configured sensor matching that address will respond (handshake), while the other sensors on the same line will not respond until called and typically stay in "sleep mode"(low power mode), until called (often in a sequence) at a later time by the SD-I Recorder (Master).

1.1 Applications

EAN-92M tiltmeter is widely used in following applications:

- Monitoring vertical rotation of retaining walls.
- Monitoring inclination and rotation of dams, piers, piles and other structures.
- Monitoring stability of structures in landslide areas.
- Monitoring tunnels for convergence and other movement.
- Monitoring safety of structures around zones of excavation or tunneling.
- Monitoring deflection in bridges and struts under different loading conditions.

1.2 Specifications

No. of axes	Uniaxial or Biaxial
Sensor type	Accelerometer
Standard range	± 15°, ± 30°
Sensitivity	± 10 arc second
Accuracy[1]	± 0.1% fs
Supply voltage	12V dc (nominal)
Supply current	Less than 35 mA
Temperature range	-20°C to 80°C
Dimension	32 mm x 160 mm

Weight	0.4 kg (sensor)
Output connection	Integral: 1-3 core cable for Tilt sensor, 2- 3 core cable for IPI sensor

[1] *As tested under laboratory conditions*

1.3 Conventions used in this manual

WARNING: Warning messages calls attention to a procedure or practice, that if not properly followed could possibly cause personal injury.

CAUTION: Caution messages calls attention to a procedure or practice, that if not properly followed may result in loss of data or damage to equipment.

NOTE: Note contains important information and is set off from regular text to draw the users' attention.

This users' manual is intended to provide you with sufficient information for making optimum use of tiltmeters and beam sensors in your applications.

To make this manual more useful we invite valuable comments and suggestions regarding any additions or enhancements. We also request you to please let us know of any errors that may be found while going through the manual.

1.4 How to use this manual

The manual is divided into a number of sections. Each section contains a specific type of information. The list given below tells you where to look for in this manual if you need some specific information.

For understanding principle of tiltmeters: See § 2.1 `Principle of Operation'.

For installation of tiltmeters: See §2.3 `Installation of Tiltmeters'.

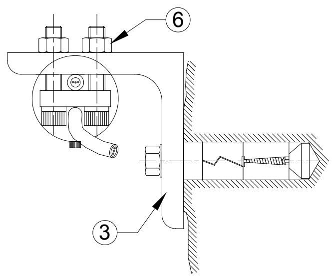
For measurement with readout: See § 3 `Measurements.

2 TILTMETER

2.1 Operation

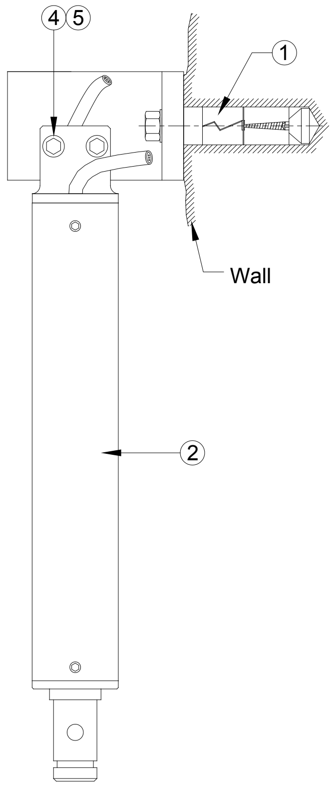
Model EAN-92M tilt meter is built around a precision accelerometer and suitable signal conditioning circuit mounted inside a stainless steel housing. The accelerometer senses force of acceleration due to gravity which is maximum when accelerometer is rotated to full 90 degree tilt position and is zero (minimum) when tilt angle of accelerometer is zero. For in-between tilts, force experienced by accelerometer is equal to product of sine of tilt angle and acceleration due to gravity. The tilt sensor thus provides a bipolar DC voltage output proportional to the sine of tilt angle measured by the tilt meter. The output is zero volts for a truly vertical position.

The sensor provides a relatively low cost tilt measurement solution but still offers excellent resolution, long term stability and a low thermal sensitivity.



The tilt meter can be fixed to any vertical surface, horizontal floor or ceiling by means of suitable mounting accessories consisting of brackets and anchors. These are available separately when ordered.

The EAN-92M is not intended for absolute determination of tilt of structures. Its measures change in tilt of a structure to which the sensor is attached. The initial tilt reading for each tilt sensor is recorded after it has been mounted on the structure to be monitored. Subtracting initial tilt reading from subsequent tilt reading gives change in tilt of structure over a period of time.



2.2 Installation of Tiltmeter

Model EAN-92M tilt meter can be fixed to a vertical surface, suspended from ceiling or mounted on the floor with help of suitable mounting arrangement/bracket available from Encardio-rite as optional accessories.

Item	Description	Qty.
1	Anchor (HSA M8 x 75 Hilti)	1
2	Tilt meter	1
3	Wall mounting bracket	1
4	Allen bolt, SS, M6 x 20	2
5	Plain washer, SS	2
6	Hex. nut, SS, M6	2

2.2.1 Installation on vertical surface

1 Drill a 8 mm Φ x 50 mm deep hole for Hilti anchor HAS M8 x 75 or equivalent on wall of which change in tilt has to be measured.

2 Insert anchor in hole, mount tiltmeter bracket on anchor and tighten slightly.

3 Fix tiltmeter on mounting bracket with two M6 x 20mm Allen bolts. Tighten anchor and Allen bolts/nuts so that the tiltmeter reads almost vertical on the read-out unit.

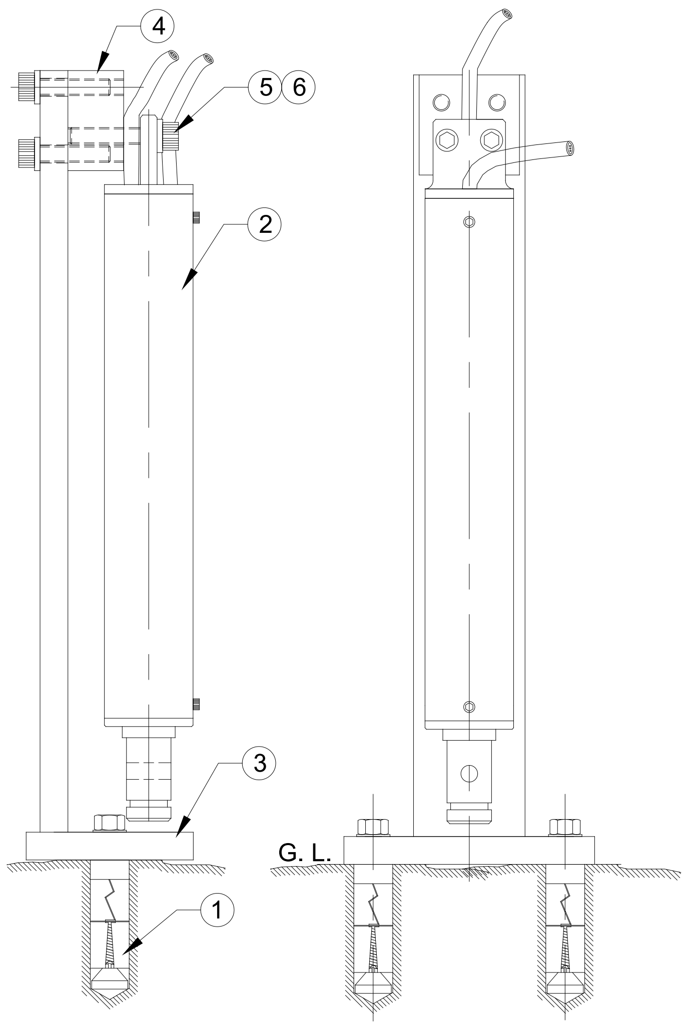
2.2.2 Installation on horizontal surface

1 Using mounting bracket as a template, mark position of two mounting holes. Visually ensure that the two hole positions are almost aligned along axis at which tilt has to be measured.

2 Drill two 8 mm Φ x 50 mm deep holes for Hilti anchor HAS M8 x 75 or equivalent.

3 Insert anchors in holes and mount tiltmeter bracket on anchors and tighten slightly.

4 Fix tiltmeter on mounting bracket with two M6 x 20 mm Allen bolts. Tighten anchors and Allen bolts/nuts so that the tiltmeter reads almost vertical on the read-out unit.



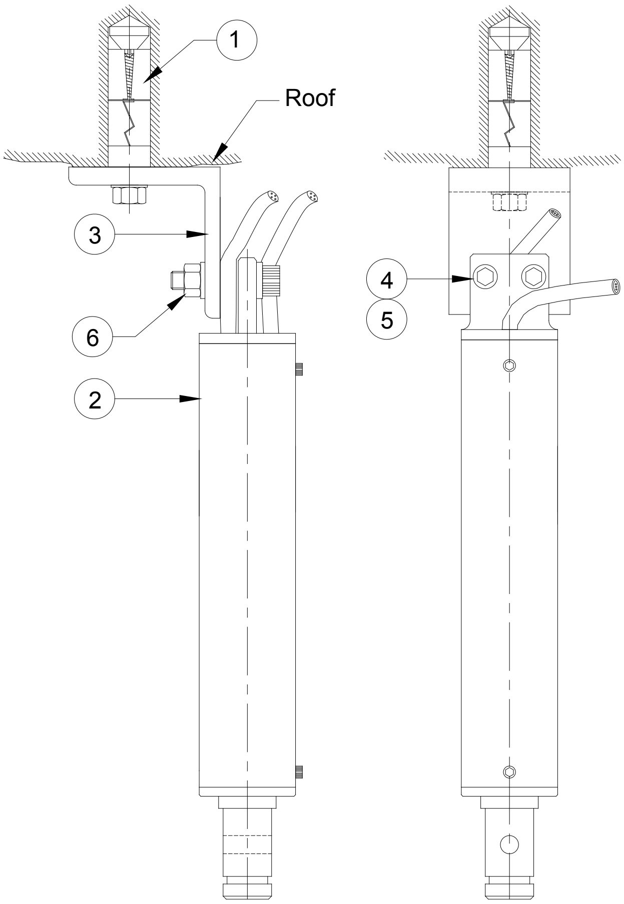
Item	Description	Qty.
1	Anchor (HSA M8 x 75 Hilti)	2
2	Tilt meter	1
3	Surface mounting bracket	1
4	Sensor mount plate	1
5	Allen bolt, SS, M6 x 25	4
6	Plain washer, SS	4

2.2.3 Installation on roof

1 Drill 8 mm Φ x 50 mm deep hole for Hilti anchor HAS M8 x 75 or equivalent on roof at which change in tilt has to be measured.

2 Insert anchor in hole, mount tiltmeter bracket on anchor and tight slightly.

3 Fix tiltmeter on mounting bracket with two M6 x 20mm Allen bolts. Tighten anchor and Allen bolts/nuts so that the tiltmeter reads almost vertical on the read-out unit.



Item	Description	Qty.
1	Anchor (HSA M8 x 75 Hilti)	1
2	Tilt meter	1
3	Roof mounting bracket	1
4	Allen bolt, SS, M6 x 20	2
5	Plain washer, SS	2
6	Hex. nut, SS, M6	2

2.2.4 Tool and accessories

1 Power drill

2 Concrete / Masonry drill bit 8 mm

3 Spanner 8/9, 12/13 mm

4 Allen key 5 mm

3 MEASUREMENT OF TILT

The output of model EAN-92M tilt meter can be read by read or logged from a remote location by an automatic datalogger like Encardio-rite model ESDL-30.

The tiltmeter is supplied with built-in 3 core cable. The cable can be terminated or extended to the nearest measurement station through a suitable junction box. There will be 2 sets of 3 cable when used as IPI sensors.

3.1 Wiring details

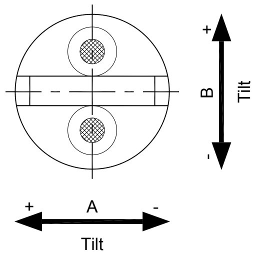
Cable colour	Description
Red	12V DC
Black/Shield	Ground
Green	Output

3.2 Sign convention

Careful orient tilt sensor during installation. Make a note of the orientation. A (+) sign is marked to show the orientation along the A axis.

Uni-axial sensor measures tilt only along axis 'A".

The adjacent figure shows a view from top and also convention used for direction/output signal polarity.



3.3 Measurement using ESDL-30 datalogger

ESDL-30, SDI-12 Datalogger is designed to record data produced by the sensors connected to SDI-12 bus. Datalogger is having 3 SDI-12 ports (channels). Sensors having SDI-12 interface can be connected on a common SDI-12 bus. This bus can be connected to any SDI-12 port of the datalogger. Each reading is stamped with date and time at which the measurement was taken. It has non-volatile flash memory to store up to 2 million data points.

These data files can be downloaded to PC using Configuration Manager software by connecting logger with data cable or Bluetooth. The downloaded readings get stored in the PC's home directory in CSV format. The downloaded files can be transferred to FTP server using internet connection. It can be processed on any common available spreadsheet like Microsoft-Excel.

ESDL-30UNI with built in GSM/GPRS has capability to upload data records directly to remote FTP server. Upload schedule can be set in Data logger using this software for automatic data upload to the FTP server. Schedule can be set as fast as 5 minutes.

SDI-12 inputs should have a unique ID (0-9, a-z or A-Z). Each of the 3 channels of the datalogger can have 61 sensors with ID 1-9 (ID 0 is used for factory purposes, hence not available for use), a-z or A-Z. For a given channel each sensor should have a different ID.

For operational details please refer to the users' manuals of ESDL-30 SDI-12 datalogger and ESDL-30 Configuration Manager.

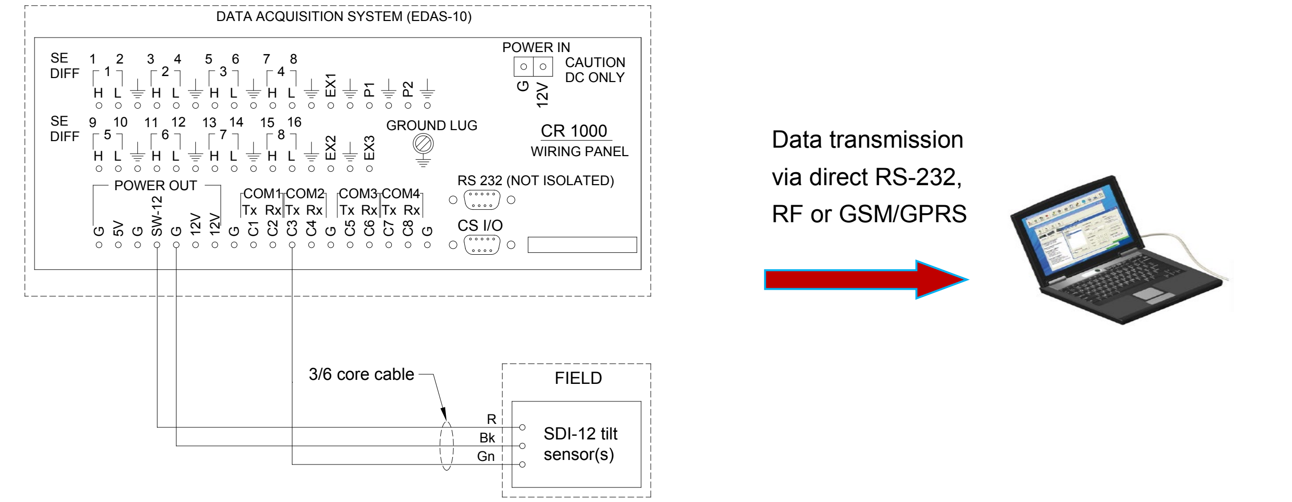
3.4 Measurement using EDAS-10 data acquisition system

Model EAN-92M tiltmeter having SDI-12 interface requires power source of 12V DC which is provided by EDAS-10 data acquisition system through Encardio-rite power supply model EBP-127AH. Since SDI-12 network is connected in bus mode, only 3 core cable is connected to the data acquisition system. A six core cable can also be used for the connection. Depending upon the application, the data acquisition system can be based on Campbell measurement and control modules CR1000, CR800 or CR200.

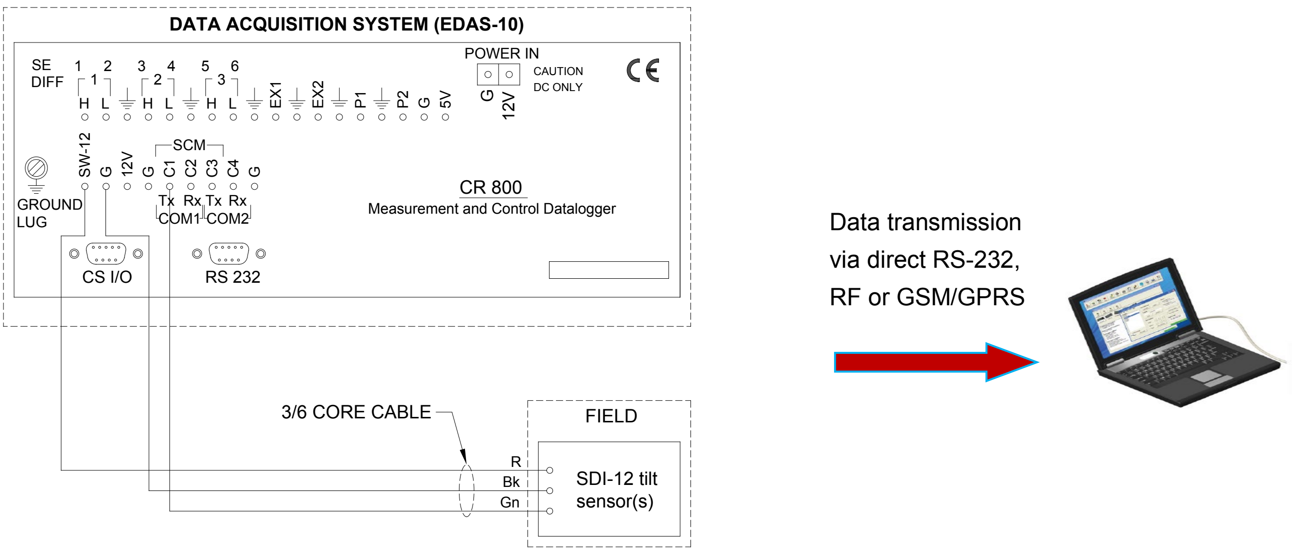
NOTE: For detailed instructions on configuration of Encardio-rite model EDAS-10 data acquisition systems based on measurement and control modules CR 1000/CR 800/CR 200, refer to Campbell Scientific's relevant Users' Manual.

Typical wiring/connection of in-place inclinometer system to CR1000, CR800 or CR200 based data acquisition systems are shown in the figures on the next page. In case data is to be transmitted via GSM/GPRS or RF modem only the CR 1000 or CR 800 based data acquisition system can be used. The CR 200 does not support transmission of data by GSM/GPRS or RF modem.

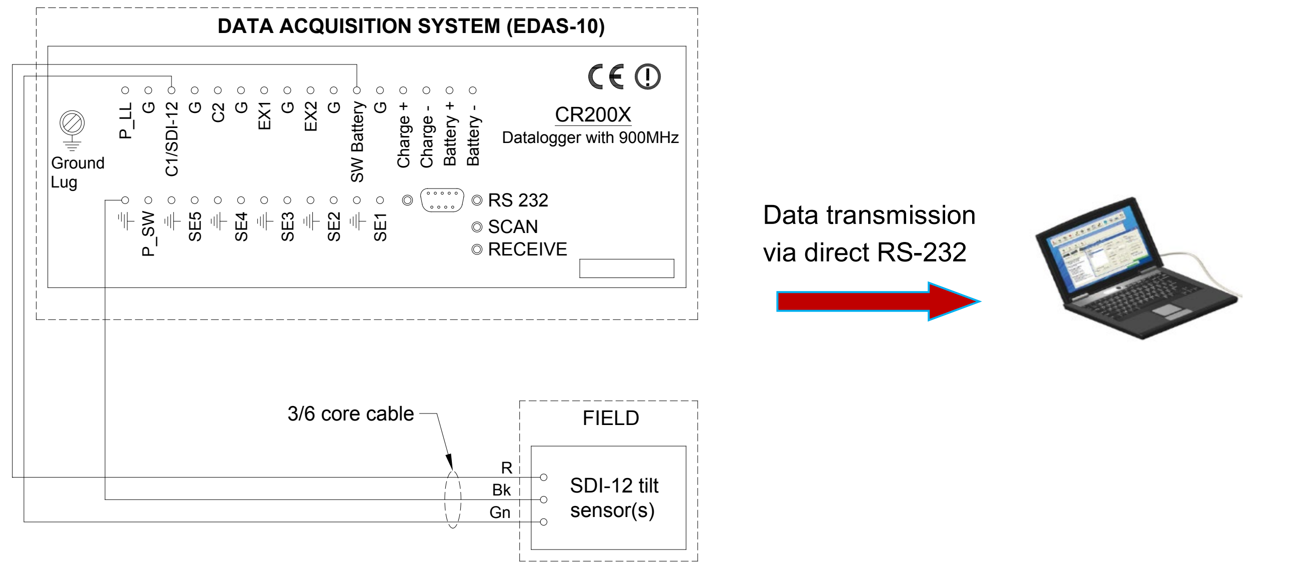
1) Tilt meter with CR1000 System



2) Tilt meter with CR800 System

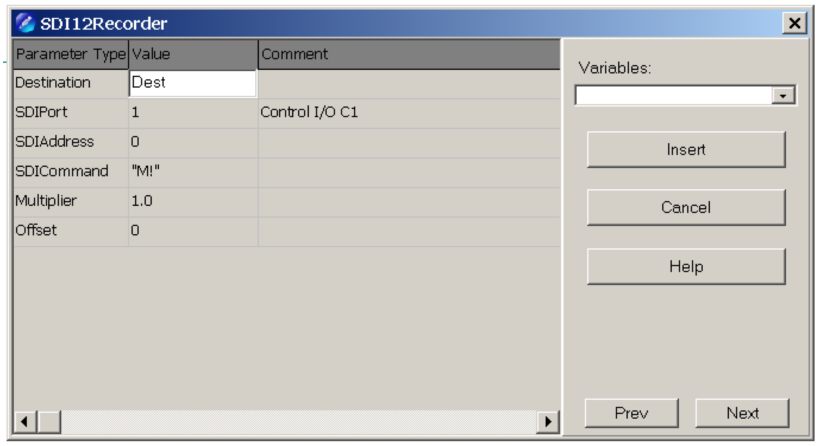


3) Tilt meter with CR200 System



3.4.1.1 <u>***Program for SDI-12 sensor***</u>

Encardio-rite can supply a program for monitoring SDI12 tilt meter based on information provided by the customer. For details, contact Encardio-rite's head office in India.



SDI12 Recorder-The SDI12 Recorder instruction is used to retrieve the results from an SDI12 sensor.

Syntax-SDI12 Recorder (Dest, SDIPORT, SDI Address, SDI Command, Multiplier, Offset)

Where, Destination is the defined address for storage, SDIPORT is the control port connected to sensor, SDI Address is the defined address of the connected sensor, SDI Command is taken as "M!" The Multiplier and Offset have purpose as the name suggests.

aM1!. - An active sensor responds to each command

The SDI-12 command basically has following three components:

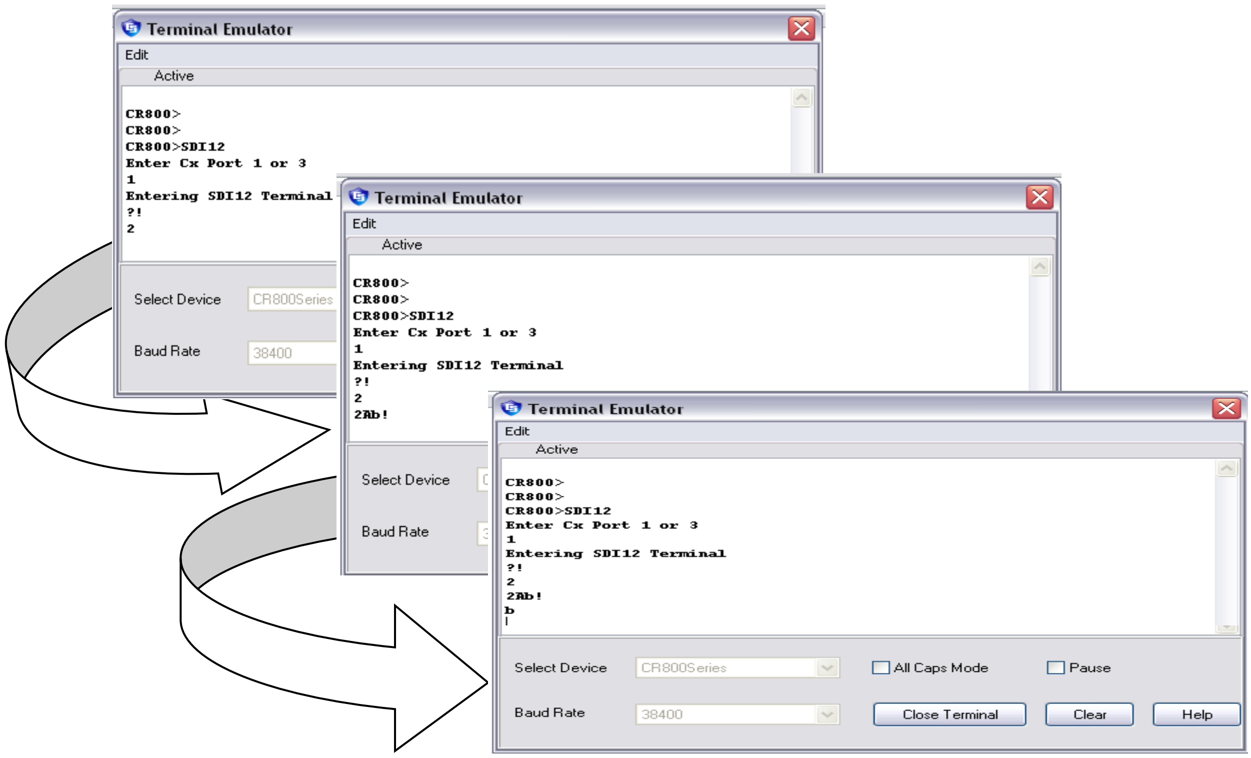
Sensor address (a) - a single character, and is the first character of the command

Command body (e.g., M1) - an upper case letter (the "command") followed by alphanumeric qualifiers.

Command termination (!) – Command terminates with an exclamation mark.

SDI12 Sensor address change:

To change a sensor's address we need to send a command as given below. Command: **0A2!**



(**Previous_AddressANew_Address!)**

Note: Here, 2 = Previous_Address and b = New_Address

3.4.1.2 Typical programming for reading one SDI-12 sensor using CRBasic

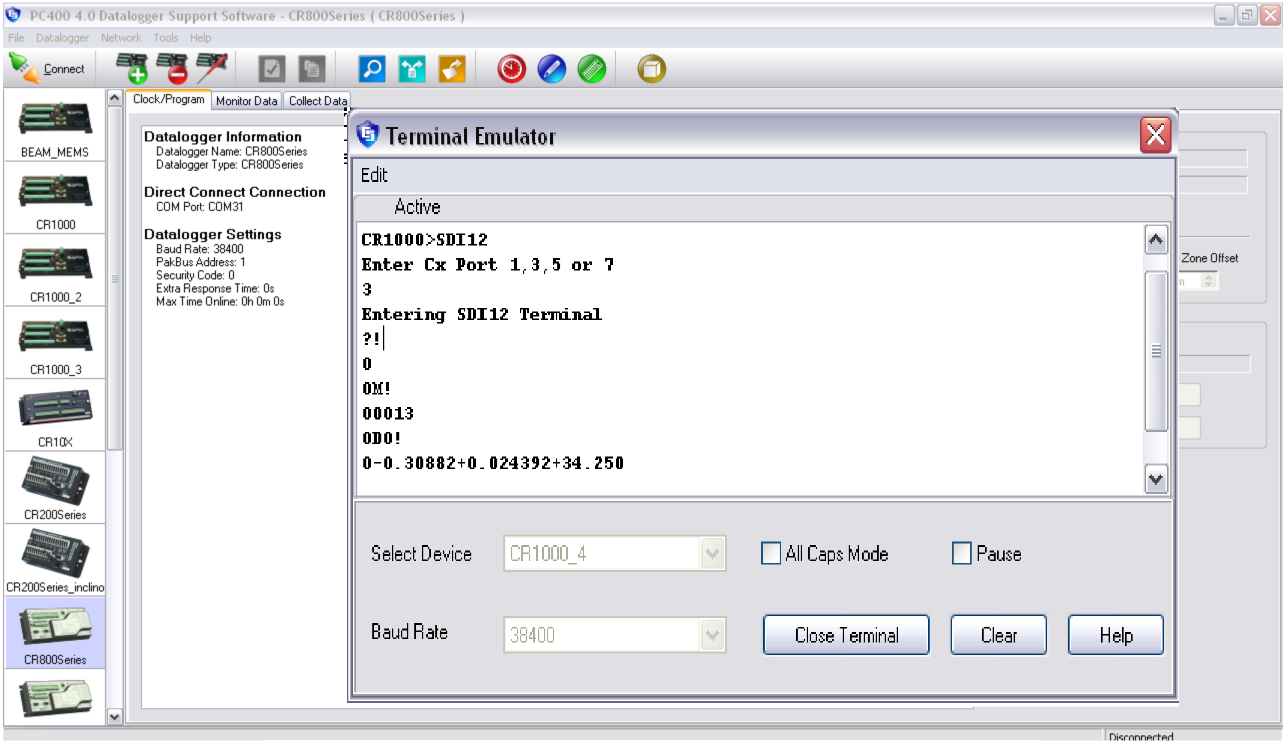
The tilt meter response can be checked before installation at site with the help of simple program module:

```
'' SDI-12 Sensor measurements with CR1000 Series Datalogger
'Declare Public Variables
Public batt_volt
Public PTemp
Public Results(6)
Public Sensor_ID(2)
Public watchdog

'Declare Other Variables --Sensor name can be changed as required
Alias Results(1)=Sensor_1
Alias Results(4)=sensor_2

'Define Data Tables
DataTable (SDI_DATA,True,-1)
        DataInterval (0,5,min,0)
        Sample (1,batt_volt,FP2)
        Sample (1,PTem
        Sample (1,Sensor_1,IEEE4)
        Sample (1,Sensor_2, IEEE4)
        Sample (1,watchdog,FP2)
EndTable

'Main Program
BeginProg
    watchdog=0
        Scan (10,sec,1,0) ' Scanning Interval Can be changed
        PanelTemp (PTemp,250)
        Battery (batt_volt)
        'Sensor_ID()=value
        Sensor_ID(1)=0    'for connected sensor
        Sensor_ID(2)=1
'SW12(1)
Delay(0,3,sec)

' SDI-12 Sensor measurements
SDI12Recorder (Results(1),3,Sensor_ID(1),"M!",1.0,0)
SDI12Recorder (Results(4),3,Sensor_ID(2),"M!",1.0,0)
Delay(0,5,sec)
If watchdog = 0 Then
    watchdog = 10
    EndIf
        CallTable(SDI_Data)
    NextScan
EndProg
```

Figure : Sensor address change

3.4.1.3 Typical programming for reading one SDI-12 sensor using Terminal Emulator

Terminal Emulator emulates a terminal connected to a datalogger or communications device. On selecting a device and baud rate and clicking Open Terminal causes PC400 to attempt to connect with that device. If the device is a datalogger, PC400 will call the datalogger over whatever communications link has been established and will attempt to get a prompt from that datalogger. The data response through emulator is as per figure below.



Terminal Emulator

3.5 Sample Test Certificate

TEST CERTIFICATE

(for 'A' axis calibration)

Item	:	Tiltmeter with SDI -12 interface	Date	:	23.06.2018
Model	:	EAN-92M-B	Temperature	:	32 ºC
Range	:	±15º			
Serial No.	:	Gxxxxxx			
Next calibration due on	:	22.06.2019			

Test data

Test position Arc degrees (A)	Corrosponding SinA	Observed SinA A' axis	Offset corrected SinA A' axis	Non-conformance (% fs) 'A' axis
15	0.2588	0.2590	0.2589	0.0344
12	0.2079	0.2080	0.2079	0.0014
9	0.1564	0.1566	0.1565	0.0091
6	0.1045	0.1048	0.1047	0.0485
3	0.0523	0.0525	0.0524	0.0189
0	0.0000	0.0001	0.0000	0.0000
-3	-0.0523	-0.0522	-0.0523	0.0178
-6	-0.1045	-0.1043	-0.1044	0.0342
-9	-0.1564	-0.1562	-0.1564	0.0307
-12	-0.2079	-0.2078	-0.2079	0.0103
-15	-0.2588	-0.2588	-0.2589	0.0278

Max non-conformance (% fs) : 0.05

Calculation of tilt value (arc degree) :

A = $\sin^{-1}$(observed output)

Wiring colour code :

Wire colour	Signal
Red	+ 12 V (supply)
Black	0 V (supply)
Green	Output signal

Tested by :

TEST CERTIFICATE

(for 'B' axis calibration)

Item	:	Tiltmeter with SDI -12 interface	Date	:	23.06.2018
Model	:	EAN-92M-B	Temperature	:	32 ºC
Range	:	±15º			
Serial No.	:	Gxxxxxx			
Next calibration due on	:	22.06.2019			

Test data

Test position Arc degrees (B)	Corresponding SinA	Observed SinA B' axis	Offset corrected SinA B' axis	Non-conformance (% fs) 'B' axis
15	0.2588	0.2582	0.2587	0.0510
12	0.2079	0.2073	0.2078	0.0617
9	0.1564	0.1557	0.1562	0.0717
6	0.1045	0.1038	0.1043	0.0693
3	0.0523	0.0518	0.0523	0.0251
0	0.0000	-0.0005	0.0000	0.0000
-3	-0.0523	-0.0529	-0.0524	0.0294
-6	-0.1045	-0.1051	-0.1046	0.0338
-9	-0.1564	-0.1569	-0.1564	0.0164
-12	-0.2079	-0.2085	-0.2080	0.0330
-15	-0.2588	-0.2595	-0.2590	0.0780

Max non-conformance (% fs) : 0.08

Calculation of tilt value (arc degree) :

$B = \sin^{-1}$(observed output)

Wiring colour code :

Wire colour	Signal
Red	+ 12 V (supply)
Black	0 V (supply)
Green	Output signal

Tested by :