Operating Manual

PIEZO-RM ™ Digital Level Sensor

http://www.keynes-controls.com/downloads/piezo-rm-manualv105.pdf

Manufactured by Keynes Controls Ltd

Introduction

The PIEZO-RM range of sensors are used for precise measurements of ground and surface water levels. This sensor measures pressure and temperature and performs compensation within the sensor for temperature effects, the specific gravity and relative density of the water and also can be configured to allow for local variation in gravity at the sensor location. The sensor provides a true and highly accurate level measurement.

The PIEZO-RM sensors are fully encapsulated devices and use a separate barometer module to obtain local barometric correction.

Keynes Controls Reserves the right to make changes to the sensors and documentation at any time.

Safety Instructions

EMC

The PIEZO-RM sensor conforms with the essential protection requirements of the EMC Directive 89/336/EEC

Conformity to the CE mark requirements only applies when the installation conditions described in this manual have been met.

Hazardous Products

The PIEZO-RM range of sensors may be classified as Electrical, Electrical-Mechanical and Electronic equipment.

These products are tested and supplied in accordance of the Keynes Controls published specifications or individual requirements as in writing at the time of ordering. The sensors are manufactured so as not to affect adversely the safety of persons and property when correctly deployed, maintained and used by suitably qualified personnel, for the application in which they have been designed.

Calibration Adjustment

The PIEZO-RM range of sensors are designed to provide excellent long term results, however occasionally it becomes necessary to verify or re-calibrate the sensors. Keynes Controls offers an annual re-calibration service via a return to base operation.

Attention: Danger of instrument damage

The sensitive membrane covering the pressure sensor element can be damaged by rough handling.

Do not use sharp items for cleaning the sensitive membrane. Use damp cloth and clean ionised water to clean out the pressure port.

View into pressure port

Table of contents

Page No.	Section	Description
2		Introduction Safety Instruction
4	1.0 2.0	Part Numbers Scope of delivery
5	3.0 3.1 3.2	Network Connections SDI-12 Digital Network Connection RS-485 Digital Network Connection
6	4.0	Quick Reference Guide Programming RS-485 version sensors Standard Commands
7	5.0 6.0	Factory Default Settings Sensor Cable Installation
8	7.0	Sample Commands Start measurements Change sensor ID Number Changing temperature units Changing the pressure units Resetting statistical values Max Pressure, Min Pressure, Max Temperature, Min Temperature.
9	8.0	Water Column True Height Measurement Barometric Effects
10	9.0	Vented Cabling - why we do not use it
11	10.0	Intelligent Sensor Lowering the pressure sensor Cleaning the PIEZO-RM sensor Repairing the PIEZO-RM sensor
12	11.0	Setting up a custom unit
13	12.0 12.1 12.2 12.3 12.4 12.5	Making a measurement Entering the local gravity Setting the filter Saving Parameters Automatic calculation of the maximum and minimum measurements Resetting maximum and minimum values
14	13.0	Physical Dimensions
15	14.0	Selecting a commonly used unit of measurement Selecting temperature units Selecting pressure units
16	15.0	Barometer modules
17	16.0 16.1 16.2	Technical Specifications PIEZO-RM Barom-SDI-12/RS-485 barometers
18	17.0	Installation River profiling - multi-sensor operations.

1.0 Part Numbers

SDI-12 Version Sensor

PIEZO-1-SDI12	**10 m range**
PIEZO-2-SDI12	**20 m range**
PIEZO-5-SDI12	**50 m range**
PIEZO-10-SDI12	**100 m range**

RS-485 Version Sensor

PIEZO-1-485	**10 m range**
PIEZO-2-485	**20 m range**
PIEZO-5-485	**50 m range**
PIEZO-10-485	**100 m range**
PIEZO-20-485	**200 m range**

2.0 Scope of Delivery

Type PIEZO-TM-SDI12 - SDI-12 Digital Communications

Sensor communications cable 1 to 100 m terminated to plug into Keynes expansion boxes or data logger.

Type PIEZO-TM-RS485 -RS-485 Digital Communications

Sensor communications cable 1 to 1000 m terminated to plug into Keynes expansion boxes or data logger.

Accessories

Additional signal cabling. Part No.

Barometer Module Part No. Barom-SDI12 with SDI-12 digital communications
Barom-RS485 RS-485 digital communications

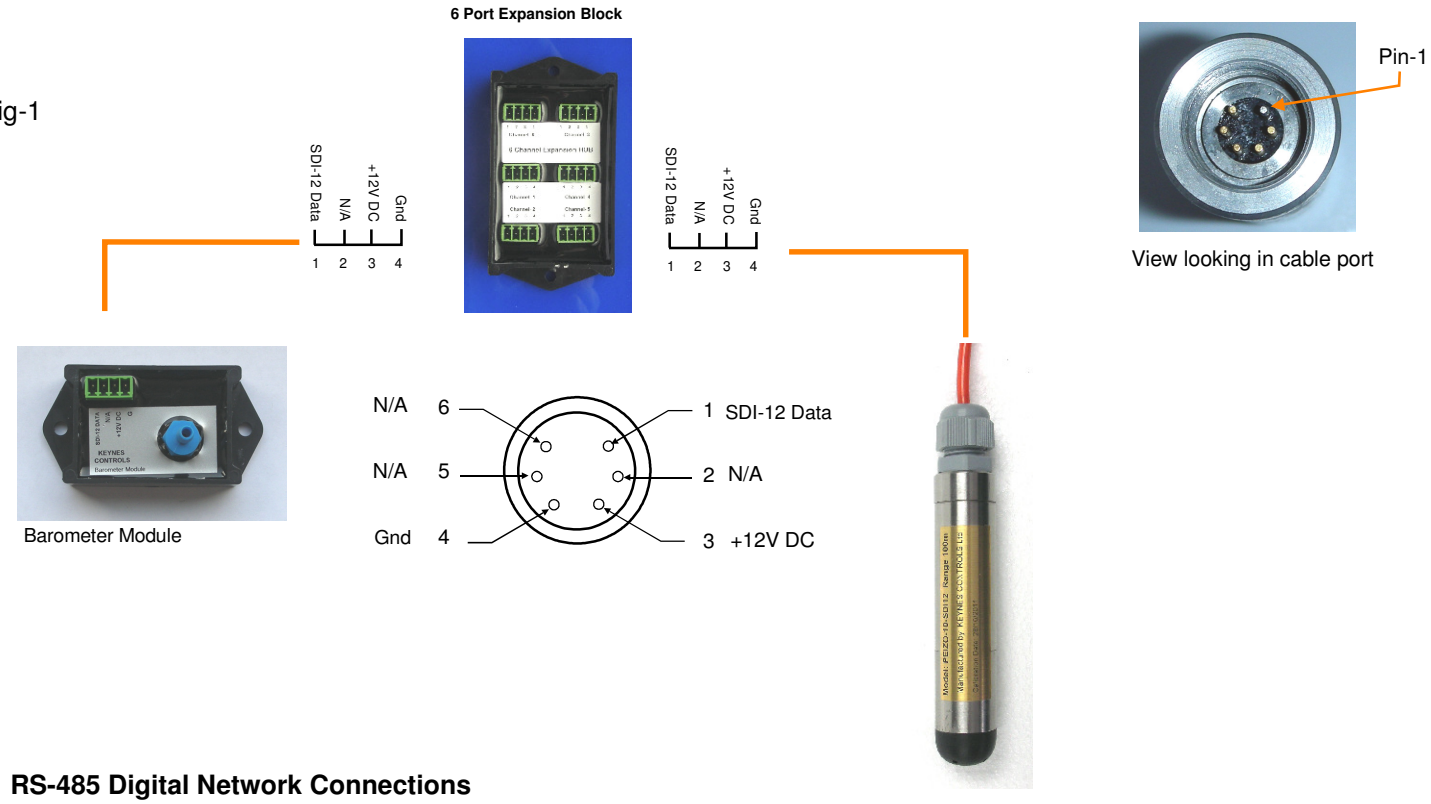
3.0 Network Connections

3.1 SDI-12 Digital Network Connections

Fig 1 shows the signal connections required for connecting the PIEZOI-RM sensor to the SDI-12 digital network.

The sensor is shown connector to the 6 port expansion hub. This part is not required when connecting to third party data loggers and is shown fitted to simply the wiring installation.

Fig-1



3.2 RS-485 Digital Network Connections

Fig 2 shows the signal connections required for connecting the PIEZOI-RM sensor to the SDI-12 digital network.

The sensor is shown connector to the 6 port expansion hub. This part is not required when connecting to third party data loggers and is shown fitted to simply the wiring installation.

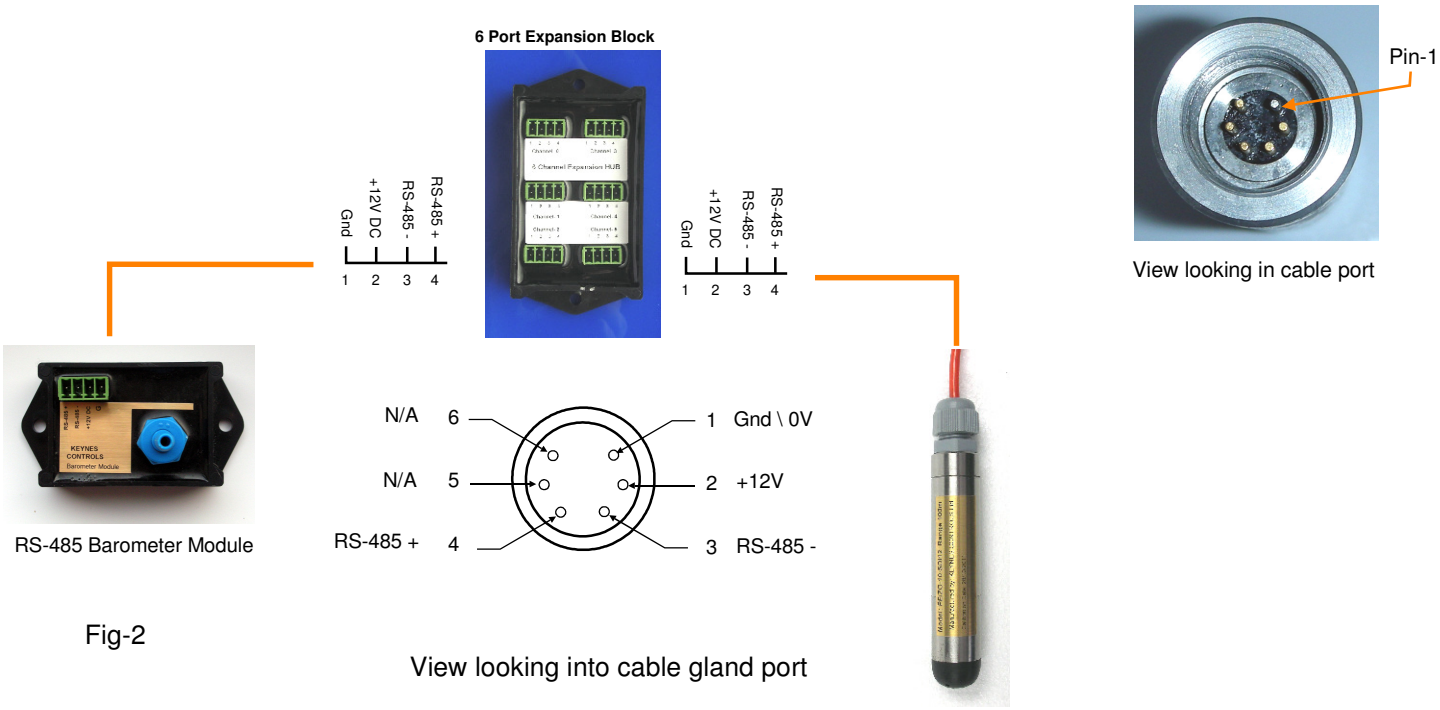


Fig-2

View looking into cable gland port

4.0 Sensor Quick Reference Guide

Programming Support - RS-485 version sensors

The PIEZO-RM sensors has models that support options for RS-485 and SDI-12 digital communication networks. The only difference in the programming support between the different networks is the '%' prefix is inserted at the start of each command for the RS-485 model options.

Example: 0M! – starts a measurement on a SDI-12 sensor - ID = 0.
%0M! – starts a measurement on a RS-485 network sensor - ID = 0.

All of then PIEZO-RM commnds have a read-back feature to enable the status of a command to be determined.

Standard commands

Command		Response	Description
aM!	%aM!	a0tt2	2 values in time tt given by stats
aD0!	%aD0!	a+0.123+25.5	Pressure and temperature values
aD1!	%aD1!	a+0.1299+0.1201+25.9+25.0	Statistical values max P, min P, max T, Min T
aI!	%aI!	a13KEYNESCOPRESR001	Identification string
aV!	%aV!	a	Verification (no action taken at present)

Extended commands

Command	Response	Description
aXP0! aXP1!	a0 or a1	Tests true (0) or uncompensated (1) measurement
aXE9.80665!	a9.80665	Sets local gravity

Temperature

aXUTu! return a+u (units) where u = new unit identifier Temperature units

u=0 → Celcuis,
u=1 → Fahrenheit

aXUT! returns a+u where u = 0 for Deg C and 1 for Deg F

Pressure Units

aXUPu! Returns a+u! Pressure units:
u=0 → mH20
u=1 → ftH20
u=2 → inH20
u=3 → bar
u=4 → psi
with readback

Reset Statistics

This command resets the statstics calculated by the sensor depending on the value of n; as shown below.

aMMn! an Reset statistics

n=1 → Max level n=2 → Min level
n=3 → Max temperature n=4 → Min temperature

Measurement Interval & filter

aXFt,nn,xxxx! at,nn,xxxx t → filter type (should be 0 - mean only)
nn → number of filtered values 1 to 12
xxxx → interval between beasurment * 200ms

6.0 Factory Default Settings

The PIEZO-RM range of sensors default settings are:

ID = 0, Default units - Pressure mH^20 Temperature : ^oC

Standard gravity = 9.80665 m/s^2

Barometric value correction is reference to the standard atmosphere of 1031.25 mbar

Installing the sensor signal cabling

For RS-485 applications use 4 core cable with 0.22 mm2 diameter cores.

For SDI-12 applications on 3 core cable is required.

PIEZO-RS-485 Cable installation

Using the signal details shown in Fig 2 on page 5, solder the signal cable onto the appropriate pins of the sensor.

Screw the cable gland into the top of the sensor with the cable passing through the centre of the gland.

Secure the cable by tightening the gland to grip the cable.

Once the cable gland is secure a watertight seal is made to the cable entry port of the sensor.

The PIEZO-RM can now be deployed.

PIEZO-SDI12 Cable installation

Using the signal details shown in Fig 1 on page 5, solder the signal cable onto the appropriate pins of the sensor. Make sure the pins a covered with a heat shrink covering and that this covering is secured.

Screw the cable gland into the top of the sensor with the cable passing through the centre of the gland.

Secure the cable by tightening the gland to grip the cable.

Once the cable gland is secure a watertight seal is made to the cable entry port of the sensor.

Use the cable gland supplied with the sensor for all cable installations.

This gland is IP68 rated and uses a o-ring seal to prevent water ingress to the glass seal and solder joints.

For additional waterproof protection Keynes advise filling the cable entry port with silicon grease.

7.0 Sample Commands

The following commands are based on those used with SDI-12 based applications and data loggers.

The default factor ID number for the PIEZO-RM range of sensor is ID = 0

Start a measurement

0M! – start measurement
%0M! __ RS485 command

0D0! – Get data across the network.
%0D0! __ RS485 command
water depth - mH^20 default, temp in Deg C

Example reply

for a PIEZO-RM sensor of address ID = 0, water depth of 9.52 m at water temperature 21.09 °C

0+9.5+21.09 —- *typical string*

Changing the sensor address

xAy! or %xy! (*RS485*)

example *0A6!* changes the instrument ID from 0 to 6

Example Setting local gravity.

A PIEZO-RM sensor with ID=4 has the local gravity set to 9.80667

command: *4XE9.80667!* 4+9.80667
%4XE9.80667! (RS485)

Changing the temperature units

A PIEZO-RM sensor with ID = 6 has the temperature units changed from Deg C to Deg F.

command: *6XUT1!*

to check which temperature units are currently units being used by the sensor use

command: 6XUT! returns 0+u where u = units 0 = Deg C 1 = Deg F

Setting the pressure units

Change the pressure unit from a sensor with ID = 3 with initial units of bar to mH^20

command: *3XUP0!* *returns 3+0* where u = 0 is the identifier for the mH^20 unit
%3XUP0! (RS485)

Read the Statistical values max P, min P, max T, Min T

Read the sensor maximum and minimum statistics for a sensor with ID = 2

command: 2D1! returns 2+max_Pressure+min_Pressure+max_Temp+min_Temp
%2D1 (RS485)

units returned will be those set into the sensor for immediate reading.

8.0 Water Column True Height Measurement.

The PIEZO-RM and the barometer sensors can all report data values in engineering units. The simplest and most accurate method of determining the true water height above the sensor is to set both the PIEZO-RM and barometer to return data in units of mH^20

Therefore the true height is calculated to be

Water Column Height = Measured water height (mH^20) - Barometric level (mH^20) corrected to standard atmosphere

The figures on page 5 show the basic sensor layout that is used to record local water levels .

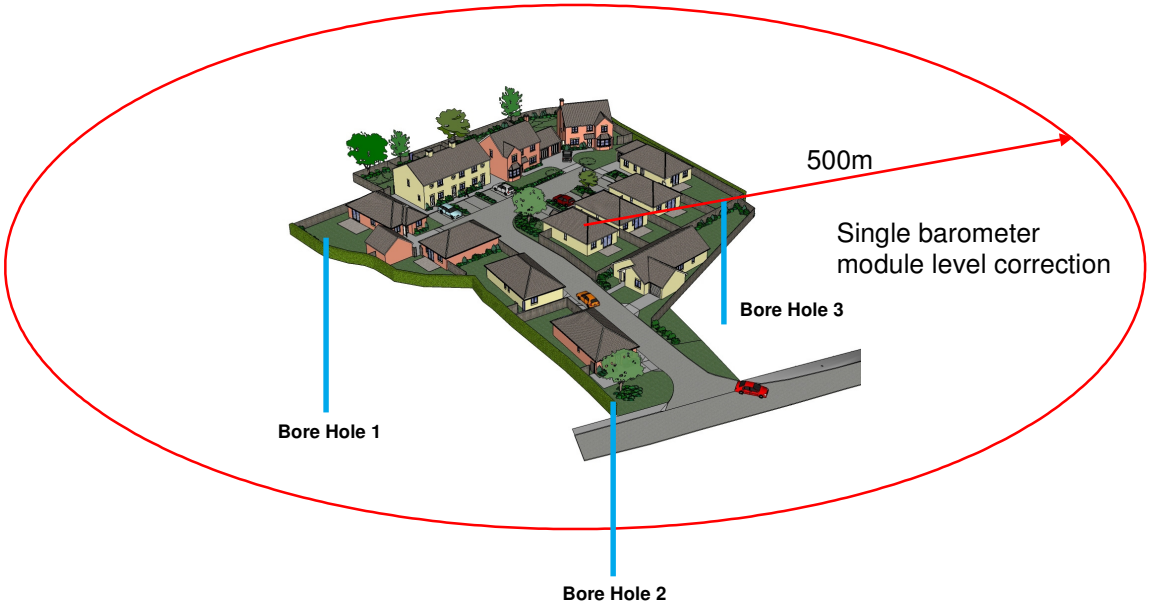


Fig 3

Barometric Effects

For sites requiring multiple PIEZO-RM sensors to be deployed, as shown above, will only require a single barometer module to make the level corrections.

Fig 4

Vented Cabling Errors

Vented cable is cumbersome and heavy to handle, Any humidity build up inside the vent tube of the signal cable will cause moisture to form; that can make its way into a sensor causing measurement errors that cannot be distinguished from true signals. Water in the sensor electronics can can cause erratic behaviour leading to the wrong data values and will eventually fail.

The reliability of the sensor depends on how well the seals securing the cable to the electronics casing are made. Due to a fully encapsulated design of the PIEZO-RM sensors with no wires connecting to the electronics from the outside world, they will be reliable to operate in any environmental conditions for many years.

There is no requirements to fit humidity absorbers or water traps to the PIEZO-RM sensor cabling.

User Defined Signal Cabling

The PIEZO_RM range sensors can be supplied without any signal cabling which can be fitted by any competent technician familiar with a basic soldering iron.

It is possible to swap the data cable for another one better suited to the next project application.

Intelligent Sensor

All of the PIEZO-RM range of sensors are intelligent devices and undertake some data processing operations internally, a series of statistics such maximum, minimum water levels can be obtained directly from the sensor.

All data values are transmitted digitally to a data recorder in order to minimise errors in the digital conversion and to prevent data loss.

The PIEZO-RM can be adjusted electronically to allow for local gravity, water density and temperature in order to obtain the best possible and accurate results.

Lowering the Pressure Sensor

1. Determine the maximum and minimum water levels at the specified measuring point. Calculate the sensor position from these two values. The following pre-requisites must be met:
I) position the sensor just below the minimum water level.
Ii) Difference between the maximum water level and the sensor location < measuring range of the sensor.

Lower the pressure sensor with the cable to the determined depth. The water level is calculated from the sensor element position as shown in Fig 5 on page 14.

The sensor cable should be suitably terminated and secured to a fastening bracket so the sensor position does not move. See Fig 7 on page 14.

The fine adjustment of the sensor position can be performed using the setup parameters available for use with the product. If the water level value is to be referenced to a zero level , then this can be achieved by adding a user offset in the setup parameters. In most cases a course positioning of the sensor will be fine for non permanent positioned locations such as water beds. The sensor can be set to give a 0 level output when the water flow has stopped and the sensor is dry.

Cleaning the PIEZO-RM sensors.

In order to ensure long and reliable service and exact measurement results Keynes Controls ltd recommend to inspect the sensor regularly and to clean the pressure port and cable entry gland and to clean when necessary.

I) For inspection remove the plastic pressure port cap, see Fig 6 page 14, and check that the membrane over the pressure sensor element is not damaged and free of debris.
ii) Clean the soiled membrane using a clean damp cloth.

Repairing the PIEZO-RM

The PIEZO-RM range of sensors cannot be repaired locally, and should any damage have occurred then the unit should be returned to Keynes Controls or accredited dealers when replacement / repair is required.

Making level measurement

The corrected level measurement is calculated in the following manner.

$$\text{Level} = mH_20 \text{ Pressure at 4 } ^oC * \frac{1}{\text{density of water}} * \frac{9.80665}{\text{local gravity}}$$

where
Density of water = -6.017777e-6t2 + 0.0000408t + 0.999841
where t = temperature in ^oC.

The temperature level is derived from sensor built into the PIEZO-RM sensor and fitted onto the sensing element PCB. The water density at any instant in time is calculated internally by the sensor using this temperature reading. The User may manually enter a local gravity value via the XE configuration command.

Entering the local gravity

Commnd	Response	Comment
aXE9.81!	a9.81<CR><LF>	Sets the local gravity to 9.81 m/s^2

Typical rule of thumb gravity value correction: Gravity level diminishes by 0.0003086 m/s2 for each kilometre above sea level. Further details can be found at Jursa, A.S Ed, Handbook of Geophysics and the space environment, 4th ed.

Setting a filter

It is possible to set the PIEZO-RM sensors to provide an average filter value or raw engineering value. The average filter value is setup by the command:

0 = Average value
nn = number of filtered values, maximum value is 12.
xxx = 200 ms intervals between measurements, maximum value is 9999.

Automatic Calculation of the maximum and minimum measurements

The PIEZO-RM sensors support the following data analysis functions.

aM1! = Maximum level / Pressure
aM2! = Minimum level / Pressure
aM3! = Maximum temperature
aM4! = Minimum temperature

The maximum and minimum values can be reset using the XMM command as described in table 2.

Resetting maximum and minimum values

Command	Response	Comment
aXMM1!	a1<CR><LF>	Resets the maximum pressure level to the current value.
aXMM2!	a2<CR><LF>	Resets the minimum pressure level to the current value.
aXMM3!	a3<CR><LF>	Resets the maximum temperature level to the current value
aXMM4!	a4<CR><LF>	Resets the minimum temperature level to the current value

Use the % symbol before any command when using the RS-485 version sensor.

Setting up a custom unit

Unit conversion can be carried out differently from the pre-defined values and is in the form y = bx + c.

Value of n	Variable stored
0	Pressure units Slope =, b
1	Pressure units Offset = c
2	Temperature units Slope = b
3	Temperature units Offset = c

The value of b should be calculated as follows:

For Pressure

$$b = \frac{\text{(Full Scale in User Units - Zero scale in User Units)}}{\text{(Full scale in } mH_20 \text{ at 4 } ^oC \text{ - Zero Scale at } mH_20 \text{ at 4 } ^oC)}$$

For Temperature

$$b = \frac{\text{(Full Scale in User Units - Zero scale in User Units)}}{\text{(Full scale in } ^oC \text{ - Zero Scale in } ^oC)}$$

Setting pressure units to mbar

Command	Response	Comment
AXU0,98,0665!	**A98.0665<CR><LF>**	Sets the slope to 98.0665, equivalent to mbar
AXU1,0!	**A0<CR><LF>**	Sets the offset to 0 as 0 mbar = 0 mH^20 at 4 ^oC

Use the % symbol before any command when using the RS-485 version sensor.

Command	Response	Comment
AXU2,1!	**A1<CR><LF>**	Sets the slope b as same as ^oC
AXU3,-273!	**A-273<CR><LF>**	Sets the offset to -273 to read in Kelvin

Use the % symbol before any command when using the RS-485 version sensor.

Physical Dimensions

The dimensions shown below are correct for all models of the PIEZO-RM sensors.

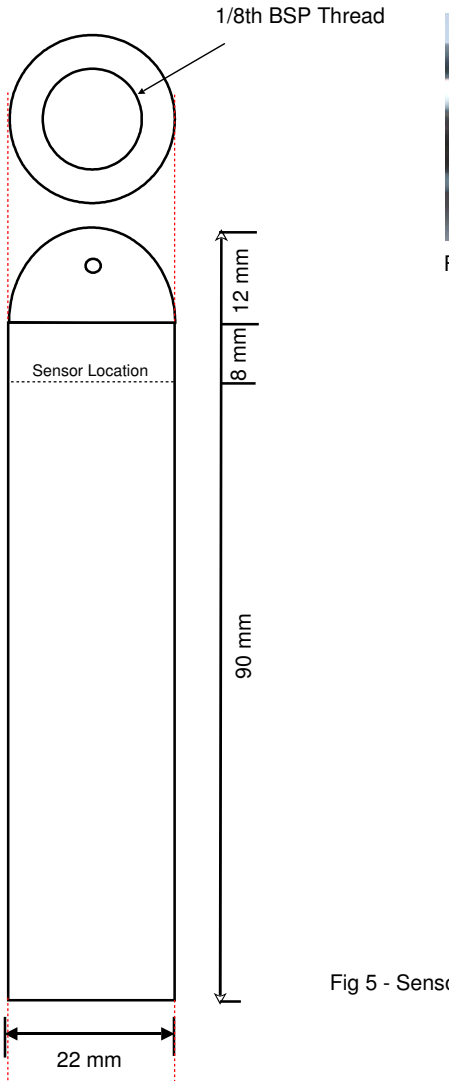
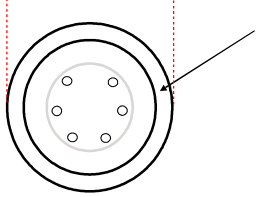


Fig 5 - Sensor Location

Fig - 6 Nose Cone

Note. The water height is measured from the sensor location.



PG9 Thread

2 - 6 mm cable entry gland required.

Cable Gland

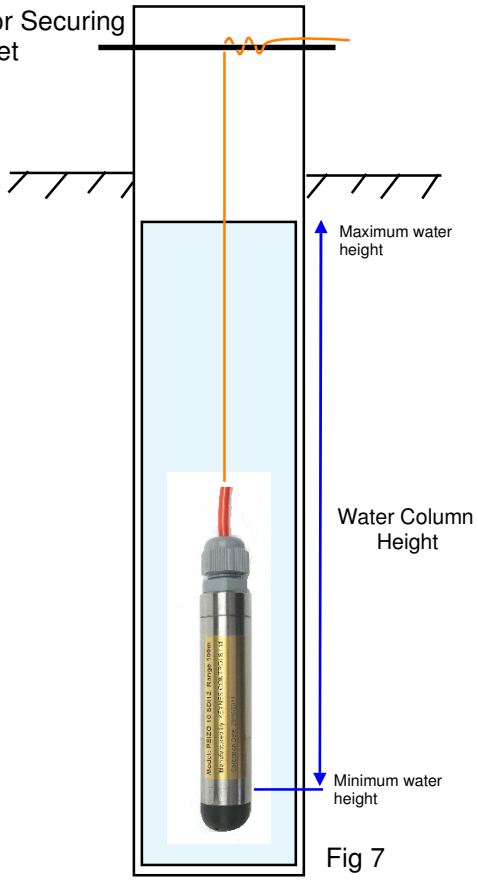


Fig 7

Selecting a commonly used unit of measurement

The PIEZO-RM series of sensors outputs results in engineering units for pressure and temperature. The extended commands aXUTn! and aXUPn! are used to change the output type engineering units respectively. Note the value n specifies the required units.

Selecting temperature units

Command	Response	Comment
aXUT0!	**a0<CR><LF>**	Sets the temperature units to ^{o}C
aXUT1!	**a1<CR><LF>**	Sets the temperature units to ^{o}F
aXUT!	**a1,a0<CR><LF>**	Queries the temperature units

Use the % symbol before any command when using the RS-485 version sensor.

Selecting pressure units

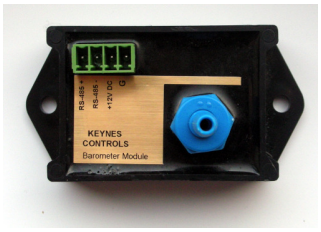
Command	Response	Comment
aXUP0!	**a0<CR><LF>**	Sets the pressure units to mH^20
aXUP1!	**a1<CR><LF>**	Sets the pressure units to ftH^20
aXUP2!	**a2<CR><LF>**	Sets the pressure units to inH^20
aXUP3!	**a3<CR><LF>**	Sets the pressure units to bar
aXUP4!	**a4<CR><LF>**	Sets the pressure units to psi
aXUP!	**a(1..4)<CR><LF>**	Queries the pressure unit with setting a value.

Use the % symbol before any command when using the RS-485 version sensor.

Barometer Modules

The images below show the standard barometer modules available from Keynes Controls.

Both the Barom-SDI12 and Barom-RS485 models are suitable for mounting onto a panel or into a box with a data logger. These models are fully encapsulated and safe from short term immersion. A 4 mm vent port enables an external tube to connect the atmospheric feed from a more suitable location than where the sensor is mounted.



Barom-RS485 model

Barom-SDI12 model

PIEZO-BARO

The Barom-SDI12 and Barom-RS485 models are very easy to install and operate.

The commands to operate the barometer are:

Command: aM! – start measurements
Command: aD0! Returns a+Barometric_Pressure(mbar)+H²0m +temp(Deg C)

Example at barometer with ID=5 is operated by:

Command: 5M!
Command: 5D0! Typical reply 5+1007.4+1.0565+17.9

Command: %5D0!

The **PIEZO-RM** sensor can be supplied calibrated; and range limited to act as a barometer.

This sensor is more accurate than the Barom-SDI12/RS485 models.

Measurement Data:	
Measuring range	0 .. 10m, 0 .. 20m, 0 .. 50m, 0 .. 100m RS-485 0 .. 200 m 0 .. 500m only 0 .. 33ft 0 .. 66ft 0 .. 164ft 0 .. 328ft
Pressure resolution	0.005% FS - deviations of 1 mm can be measured at 10 m range
Long term stability	± 0.05 % FS max. Per year
Linearity, Hysteresis	<0.05% FS
Overload 24 hours with 1.2 times over rating	Max 0.01% FS deviation (Typical)
Temperature compensation range	2 - 30 Deg C under software control -5 to 45 Deg C internal electronic self correction
Temperature resolution	0.1 ºC / 0.1 ºF
Temperature accuracy	± 0.2 ºC / 0.2 ºF SDI-12 & RS-485
Units	M, ft, inch, bar, psi, ºC, ºF
Calibration	6 point calibration
Electrical Data	
Voltage supply	**SDI-12** 10.5 to 16V DC **RS-485** 10.5 to 16V DC
Current compensation	Typical values are
Idle mode Active / measurement	**SDI-12** 0.65 mA **RS-485** 1.15 mA **SDI-12** 2.1 mA **RS-485** 2.6 mA These values may change slightly between sensors. Use figures as a guide only.
Measuring time warm up response	As per section V.V200 ms 500 ms
Length of data lines SDI-12 RS-485	 100 m 1000 m
SDI-12/RS-485 Address mode	Supports enhanced addressing 0 .. 9 A .. Z
General Data:	
Pressure sensor	Ceramic pressure sensor Temperature compensated
Dimensions	102 x 22 mm diameter - length includes noise cone
Material	316 stainless steel - standard Marine Bronze on request Polyurethane - nose cone
Temperature range	-25 ºC .. +70 ºC (non freezing)
CE Conformity	CE conformity according to EN 61000-6
Lifetime	> 1x 10^7 cycles
Protection	IP 68
Weight	102 g

The specifications are correct at the time of printing. Keynes Controls retain the right to change the specification without notice.

Barom-RS485 Technical Specifications

Maximum error of pressure reading over the pressure range.

		Min	Typical	Max	Units
Barometric Pressure					
Resolution			0.1		mbar
Range	750 - 1100				mbar
Absolute Pressure Accuracy	p =750 .. 1100 mbar at 25 ºC	-1.5		1.5	mbar
Pressure Long term stability	12 months		1		mbar
Temperature					
Resolution			0.1 Deg software limited		
Accuracy	20 ºC	-0.8 -2		0.8 2	Deg C Deg C
Operating Range	-40 to 85				Deg C
Power Supply Idle mode Active / measuremen		10	12 1 2.6	18	Volts mA mA

Supported Commnds:

The Barom-SDI-12/RS485 modules support the following commands:

SDI-12 Commands

aM! – start measurement
aD0! – obtain data.

RS-485 Commands

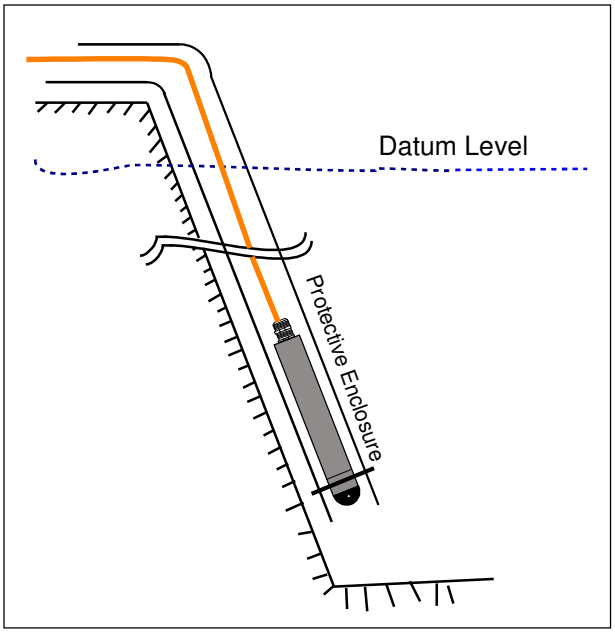
%aM! – start measurements
%aD0! – obtain data

Data string

a + Press-mbar, mH20 @ 4ºC + Temp (Deg C)

The Barom-SDI12 and Barom-RS485 models return barometric pressure in units of mH20 corrected for the standard atmospheric pressure of 1013.25 millibars.

Returns a+Barometric_Pressure(mbar)+$H^2$0m +temp(Deg C)



Installation

The PIEZO-RM sensors can be used in many different applications, for example in tubes and boreholes wider than 1 inch in diameter, in open water and in river profiles.

When deploying the sensors into an application, take care not to allow the PIEZO-RM to become over pressured as this can lead to permanent damage to the ceramic sensing element. When specifying a measurement location, observe the hydrostatic influence in strong currents (>0.5 - 1.5ms^{-1}). Depending on the type of mounting being used, under pressure and over pressure may occur and this will distort the measurements.

In water systems with strong current flows or powerful wave motion then Keynes Controls recommends securing the sensors to a structure with a locking pin. It is advised to secure the sensor into a pipe to add additional protection and to act as a sacrificial anode.

River Profiling - Multi-sensor operations.

Multi-sensor applications such as river profiling are ideally suited for the PIEZO-RM sensors.

The sensors are fully encapsulated and so can be deployed onto a single wired network with up-to 36 sensors on a single network string. The sensors are only powered on during the measurement operation and are switched off at all other times.

As the PIEZO-RM range of sensors are fully sealed units they connect to a standard 3 or 4 wired network. The wiring can be lowered and secured into place without having to consider bulky and heavy vented cables attached to each sensor. Once the sensors are in place they can be operated from a single network port on a suitable data logger or computer system. A single barometer module provides the atmospheric correction to enable the true water height to be determined.

The low power features of the sensors means they are suitable for long term unattended deployment on logger units.

Using the RS-485 type sensor rivers and water ways up to 500 meters in depth can be profiled.

The diagram below demonstrates the options available to communicate with a multi-sensor network.

The expansion Hub can be used to add further environmental sensors or external power to the sensor system.