Accubar® SDI-12 Barometric Pressure Sensor

5600-0120-3

Users Manual

OPERATIONS & MAINTENANCE MANUAL

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Manual Version Control

Version	Date	Author	Change Description
1.01	March 2014	Lewis	Initial Release
Rev A	Sept 2014	Robin Ovington	Formatting changes
Rev B	Nov 2017	Jerry	Added additional operational and specification details. Corrected a couple of items inadvertently brought over from the 5600-0120-1, -2 manual.

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1 Introduction

The 5600-0120-3 ACCUBAR® Pressure Sensor is a solid-state pressure transducer suitable for data collection and monitoring applications. The ACCUBAR® sensor has been designed with the following features to operate in a wide range of applications:

low power consumption	standby power is 0.05 mA, average power when taking measurements every 15 minutes via SDI-12 is less than 0.1 mA typical.
high accuracy	0.2 mB (hPa) -3A version at 20°C
full temperature compensation	0.3 mB accuracy (-3A) is maintained over the temperature range of -40° to +60°C.
selectable units	the sensor can be configured to output the data in mB, hPa, kPa, "Hg, mmHg, Atm, and psi.
non-volatile setup	the setup is stored in EEROM and remains even when power is removed from the sensor
wide operating voltage	the sensor operates over the voltage range of 8 to 16 VDC

2 Quick Start

The Barometer comes prepared with a short cable to connect to your SDI-12 Data Recorder.

- Black – Ground
- Red – Power (8-16VDC)
- White – SDI-12 Data

The unit comes configured from the factory at SDI-12 address 0 and ready to make barometric pressure readings in mB (hPa). Just issue the basic SDI-12 start measurement command “M” to address 0 (0M!) and the unit will initiate a reading of the barometric pressure. Get the data back with a “D0” command (0D0!) (done automatically by most data recorders when they are measuring) and the unit will return the barometric pressure plus a units indicator number.

If using with other SDI-12 sensors, then the unit will need to be set to a unique address. This is done with the change address command (aAb!) where “a” is current address and “b” is the new address. The unit needs to be only SDI-12 module on the bus at address “a” when this command is issued, or you will end up changing both units to address “b”. For example, to change the address from the factory default of “0” to “2”, issue the command:

0A2!

All future commands will then need to be sent to address 2.

To query a module as to its address, ensure that it is the only SDI-12 module on the bus and then issue the address query command:

?!

The unit will respond with its address.

To confirm the SDI-12 communication with a module, the SDI-12 send identification command can be issued (to address 0 in the example):

0I!

The unit will respond with its identification string. The string from the SDI-12 barometer will look similar to the following:

013 SUTRON BARO-12.120120002B1.01

which shows a response from address 0, that the unit supports SDI-12 specification 1.3 (and therefore 1.2, 1.1, and 1.0), that the manufacturer is SUTRON, and that the model is a BARO-1.

3 Cabling

3.1 Sutron-Supplied Cable

The ACCUBAR® comes with a cable pre-wired to an internal terminal strip. The wiring of the cable is as follows.

Name	Color	Description
SDI-12 DATA	**White**	**Connect to data recorder SDI-12 Data line**
POWER	**Red**	**8 to 16V**
GND	**Black**	**Connect to Ground**
B-OUT	Brown	RS-232 data out
A-IN	Green	RS-232 data in

Only the first three wires are needed to use the ACCUBAR® SDI-12 interface. The last can be used as part of an RS-232 interface to upgrade the firmware in the unit and are not needed for an SDI-12 connection.

4 Setup & Operation

4.1 Introduction

This section will familiarize you with the steps and commands needed to alter the setup of the ACCUBAR®. If you will use the ACCUBAR® sensor at address 0 (the factory default) and can accept the output in units of mB (hPa), you will not need to use these commands. Typically, you will need to issue some of the commands, so we recommend you learn how to do so. Learning to issue commands also helps if you need to troubleshoot a sensor.

To issue commands to the ACCUBAR® via SDI-12, you will need to connect it to a data recorder, such as a Sutron 7310, 8210, 8310, 9210, or Xpert which is capable of issuing standard and extended SDI-12 commands. Follow the instructions in Sections 2 and 3 in order to make these connections.

4.2 Nomenclature

All commands have three components: the **device address**, the **command body**, and the **command termination**.

The **device address** is a single character and is the first character of a command. In the examples that follow, it is usually the number 0 (the default address as shipped from the factory).

The **command body** and the responses are shown as a combination of upper and lower case letters. The upper case letters are the fixed portions of the command and the lower case letters are the variables or values. In the specific examples, you will see that the lower case letters are replaced with actual numbers.

All commands are shown with an exclamation point (!) as the **command terminator**.

4.3 Setting the Address

If you are using the ACCUBAR® connected with other SDI-12 devices, you will need to change the ACCUBAR® address. Otherwise, skip this section. The address simply lets multiple devices share the same wiring. When the data recorder needs data from a particular sensor, it requests data using an address. Only the device with the matching address will reply. For convenience in setting up the unit when only one sensor is connected, the ACCUBAR® supports wildcard addresses of asterisk (*) and question mark (?).

The default address is 0.

Using a Command to Set the Address

Also, no other SDI-12 devices connected to the system should be set to address 0 or to the desired ACCUBAR® address. Hint: if you do not know the address of a particular ACCUBAR®, use the unknown address command to have the ACCUBAR® identify itself.

NOTE: There can only be one ACCUBAR® connected in order for the unknown address command to work. The syntax for the unknown address command is

*X?!

The ACCUBAR® also supports an alternate version of the unknown address command which is a command acknowledge to a wildcard address. The syntax for this version is:

*!

Beginning with version 1.2 of the SDI-12 specification there is an address query command defined. Therefore another version of the request unknown address or address query command is:

?!

The extended SDI-12 command for setting the ACCUBAR®'s address is the XAD command

0XADnAn!	where a is the current address of the device, n is the new SDI-12 address and n is the same address repeated (0 to 9, :;<=>?,A to Z,a to z).

Note that the command follows the SDI-12 standard beginning with the address and ending with "!".

The ACCUBAR® will issue a reply message in response to the command if the command was recognized. The message will be 00011 which is explained in the Command Reference. If you do not get this message, try the command again to ensure there was not a typo. Note: The ACCUBAR® will not respond if the command is invalid, i.e., there is a typing mistake in the command or the two copies of the new address do not match.

As an example, the following command would set the ACCUBAR® address to 5:

0XAD5A5!

Subsequently, the address can be set to a different address, 9 for example, by the command:

5XAD9A9!

The ACCUBAR® also supports an alternate version of the set Address command as specified in SDI-12 standard version 1.2.

0An!	where 0 is the current address of the device, n is the new SDI-12 address (0 to 9, A to Z, a to z).

As an example, the following command would set the ACCUBAR® address to 5:

0A5!

The ACCUBAR® will respond with the new address which is 5.

Subsequently, the address can be set to a different address, 9 for example, by the command:

5A9!

Verifying the Address and Operation

The ACCUBAR® will respond with an identifying message when it receives the *send identification* command, I. The format of the command is:

aI!	Where a is the address for the ACCUBAR®.

The ACCUBAR® will reply with

a13 SUTRON BARO-12.1ssssssBvvvv	Where:
a	SDI-12 address
13	supports SDI version 1.3 commands
SUTRON	manufacturer SUTRON
BARO-1	Accubar model number
2.1	hardware revision level
sssssss	sensor serial number
Bvvvv	the software revision

If you do not get a reply, check the address setting for the ACCUBAR® and make sure you use the proper address for the sensor.

Commands (Overview)

The commands to set up and operate the ACCUBAR® are those defined by the SDI specifications 1.0 plus some extended commands defined by Sutron. All commands start with a single-character address and end in an exclamation point. The address is a single character with values 0 to 9, :;<=> ?, A to Z, and a to z. Values are entered in the form of a polarity (+ or -) sign followed by up to seven digits, including a decimal point. The commands are in ASCII and all the replies use printable ASCII characters followed by <CR> <LF>.

The ACCUBAR® replies to all SDI commands it supports. If the ACCUBAR® receives a command it does not support, no reply is made. The reply will have one of two forms:

a0000 where a is the address and the 0000 indicates that there is no further message to send

or

atttn	where a is the address, ttt is the amount of time, in seconds, the ACCUBAR® needs to make the measurement or process the command and n is the number of values that can be collected. In this form the sensor will also respond with its address when the data is ready to collect. This response is called a service request.
and	
a	

If you issued the *change address* command or the *identify* command described in the previous sections, you already have some experience with using ACCUBAR® commands. There are other commands available to make measurements, set the type of output units for the measurements, perform special scaling of the measurements, etc. The following sections describe the commands by function.

Making a Measurement

There are four classes of measurement commands which will be referred to as M commands (Measurement Commands), C commands (Concurrent Measurement Commands), MC commands (Measurement commands with CRC-16), and CC commands (Concurrent Measurement Commands with CRC-16). Concurrent measurement commands are new to version 1.2 of the SDI-12 specification. The commands with CRC-16 are new to version 1.3 of the SDI-12 specification. In the original class of "M" measurement commands, the data recorder issued the measurement command and then waited for the sensor to complete the measurement before continuing the data collection cycle. Only one sensor could be accessed at a time and a maximum of nine parameters could be returned. With version 1.2 of the specification, concurrent measurements were defined. With a concurrent measurement, the data recorder can request the sensor to take a measurement, determine how long it will be until the sensor has a reading, and then continue on making requests to other sensors on the SDI-12 bus. This way multiple sensors are taking measurements concurrent with each other. Once the measurement time for a sensor has expired the data recorder polls the sensor for the data. The CRC-16 commands that were added in version 1.3 of the specification add a 16 bit cyclic redundancy check (CRC-16) to the returned data values. This provides an additional means for the data recorder to ensure that the collected data has not been corrupted.

Selecting a Measurement Command Class

Always supported

The first requirement is that the data recorder support the command. All SDI-12 data recorders support the non-concurrent measurement M command. With the M command the data recorder collects data from the sensors one at a time.

Multiple long measurement time sensors

When collecting data from several SDI-12 sensors that have long measurement times, the complete data collection cycle can be shortened by utilizing concurrent commands. The data The data recorder can initiate the measurement on all the sensors and when each finishes, then collect the data from all of them. Since the measurement times overlap, the complete data collection cycle is shorter. There is no advantage to the concurrent measurement C command when there is only one sensor.

Improved data integrity checking

The measurement command classes with CRC-16 (MC and CC) offer additional data integrity checking over the non CRC-16 commands (M and C). The non CRC-16 commands offer data integrity checking in the form of parity and the SDI-12 command structure. The CRC-16 commands offer some additional data integrity through the addition of a CRC-16. Since the CRC-16 commands are brand new in SDI-12 version 1.3, not as many data recorders support them. In most applications, lack of this support on the part of the data recorder will not be missed since non CRC-16 SDI-12 commands still offer significant data integrity checking. If the data recorder supports CRC-16 commands, then it is recommended to use them when collecting data from this sensor in order to benefit from the increased noise immunity.

Making a Non-Concurrent Measurement (M command)

The command to tell the ACCUBAR® to make a measurement with the original measurement command is:

aM!	where a is the address character, and M is the command to make a measurement

Most data recorders will issue this command and automatically handle the reply to collect data. You can also issue the command yourself. In reply, the ACCUBAR® will respond with

attt2	acknowledging it is address a and indicating that after ttt seconds are allowed for the measurement, 2 values can be collected.

When the measurement is complete, the ACCUBAR® responds with a service request

A	where a is the address character

Note that you still don't have any data from the ACCUBAR®. To request the data after a measurement,

aD0!	where a is the address character and D0 is the command to retrieve measured data. (Note: 0 is zero, not the letter O)

In this case the ACCUBAR® will reply with two values in the format:

avu	where a is the address, v is the data value and u indicates the units. Both v and u have the format of a polarity (+ or -) sign followed by up to seven digits, including a decimal point. One example of a response would be 0+1013.25+0

The u indicates the units of the measurement. When u is 0, the value has units of mB(hPa). When u is 1, the units are inches of mercury ("Hg). When u is 9, the units depend on a user entered slope and offset. u can also take on additional values if a station elevation offset has been entered. The following table summarizes all the values of u.

0 units are mB (hPa)
1 units are "Hg
2 units are kPa
3 units are mmHg
4 units are Atm
5 units are psia
9 units depend on user-entered scale and offset.

If the station elevation offset is non-zero, then one of the following values of u will be returned:

10 units are mB + station elevation offset
11 units are "Hg + station elevation offset
12 units are kPa + station elevation offset
13 units are mmHg + station elevation offset
14 units are Atm + station elevation offset
15 units are psia + station elevation offset
19 user units with non-zero station elevation offset
(mB + elevation offset) ∗ user scale + user offset
set by XE or XS Set by XUU

In most cases, you will not set up the recorder to store this units identifier. It is provided in response to the standard measure command to eliminate confusion as to the computation used to come up with the final value.

Making a Concurrent Measurement (C command)

The command to tell an ACCUBAR® to make a concurrent measurement is:

aC!	where a is the address character, and C is the command to make a concurrent measurement

The concurrent measurement command was first defined in version 1.2 of the SDI-12 specification. Therefore the data recorder will have to be SDI-12 version 1.2 or higher compliant before it can be

expected to issue this command and automatically handle the reply to collect data. You can also issue the command yourself. In reply, the sensor will respond with

attt02	Acknowledging it is address a and indicating that after ttt seconds are allowed for the measurement, 2 values can be collected.

When the measurement is complete, the sensor does NOT issue a service request. Note: this is different from the M command.

To request the data after a measurement,

aD0!	where a is the address character and D0 is the command to retrieve measured data. Note: the number zero follows D, not the letter O.

In this case, the ACCUBAR® will reply with two values in the format:

avu	where a is the address, v is the data value and u indicates the units. Both v and u have the format of a polarity sign (+ or –) followed by up to seven digits, including a decimal point.

The u indicates the units of the measurement. When u is 0, the value has units of mB(hPa). When u is 1, the units are inches of mercury ("Hg). When u is 9, the units depend on a user entered slope and offset. u can also take on additional values if a station elevation offset has been entered. The following table summarizes all the values of u.

0 units are mB (hPa)
1 units are "Hg
2 units are kPa
3 units are mmHg
4 units are Atm
5 units are psia
9 units depend on user-entered scale and offset.

If the station elevation offset is non-zero, then one of the following values of u will be returned:

10 units are mB + station elevation offset
11 units are "Hg + station elevation offset
12 units are kPa + station elevation offset
13 units are mmHg + station elevation offset
14 units are Atm + station elevation offset
15 units are psia + station elevation offset
19 user units with non-zero station elevation offset
(mB + elevation offset) ∗ user scale + user offset
set by XE or XS Set by XUU

In most cases, you will not set up the recorder to store this units identifier. It is provided in response to the standard measure command to eliminate confusion as to the computation used to come up with the final value.

Making a Non-Concurrent Measurement with CRC-16 (MC command)

The command to tell the ACCUBAR® to make a non-concurrent measurement with a CRC-16 check on the data is:

aMC!	where a is the address character, and MC is the command to make a non-concurrent measurement with a CRC-16

The non-concurrent measurement with CRC-16 command was first defined in version 1.3 of the SDI-12 specification. Therefore the data recorder will have to be SDI-12 version 1.3 or higher compliant before it can be expected to issue this command and automatically handle the reply to collect data. You can also issue the command yourself. In reply, the ACCUBAR® will respond with

attt2	acknowledging it is address a and indicating that after ttt seconds are allowed for the measurement, 2 values can be collected.

When the measurement is complete, the sensor responds with a service request

a	where a is the address character

Note that you still do not have any data from the ACCUBAR®. To request the data after a measurement,

aD0!	where a is the address character and D0 is the command to retrieve measured data. Note: the number zero follows D, not the letter O.

In this case, the sensor will reply with two values in the format:

avuC	where a is the address, v is the data value, u indicates the units, and C is the CRC-16 encoded into 3 ASCII characters. Both v and u have the format of a polarity sign (+ or –) followed by up to seven digits, including a decimal point. The CRC-16 is always the last three characters which are never a numeric digit.

The u indicates the units of the measurement. When u is 0, the value has units of mB(hPa). When u is 1, the units are inches of mercury ("Hg). When u is 9, the units depend on a user entered slope and offset. u can also take on additional values if a station elevation offset has been entered. The following table summarizes all the values of u.

0 units are mB (hPa)
1 units are "Hg
2 units are kPa
3 units are mmHg
4 units are Atm
5 units are psia
9 units depend on user-entered scale and offset.

If the station elevation offset is non-zero, then one of the following values of u will be returned:

10 units are mB + station elevation offset
11 units are "Hg + station elevation offset
12 units are kPa + station elevation offset
13 units are mmHg + station elevation offset
14 units are Atm + station elevation offset
15 units are psia + station elevation offset
19 user units with non-zero station elevation offset
(mB + elevation offset) ∗ user scale + user offset
set by XE or XS Set by XUU

In most cases, you will not set up the recorder to store this units identifier. It is provided in response to the standard measure command to eliminate confusion as to the computation used to come up with the final value.

Making a Concurrent Measurement with CRC-16 (CC command)

The command to tell the ACCUBAR® to make a concurrent measurement with CRC-16 check on the data is:

aCC!	where a is the address character, and CC is the command to make a concurrent measurement with a CRC-16 check on the returned data

The concurrent measurement with CRC-16 command was first defined in version 1.3 of the SDI-12 specification. Therefore the data recorder will have to be SDI-12 version 1.3 or higher compliant before it can be expected to issue this command and automatically handle the reply to collect data. You can also issue the command yourself. In reply, the ACCUBAR® will respond with

attt02	acknowledging it is address a and indicating that after ttt seconds are allowed for the measurement, 2 values can be collected.

When the measurement is complete, the sensor does NOT issue a service request. Note: this is different from the M and MC commands.

To request the data after a measurement,

aD0!	where a is the address character and D0 is the command to retrieve measured data. Note: the number zero follows D, not the letter O.

In this case, the sensor will reply with two values in the format:

avuC	where a is the address, v is the data value, u indicates the units the value is expressed in, and C is the CRC-16 encoded into 3 ASCII characters. Both v and u have the format of a polarity sign (+ or –) followed by up to seven digits, including a decimal point. The CRC-16 is always the last three characters which are never a numeric digit.

The u indicates the units of the measurement. When u is 0, the value has units of mB(hPa). When u is 1, the units are inches of mercury ("Hg). When u is 9, the units depend on a user entered slope and offset. u can also take on additional values if a station elevation offset has been entered. The following table summarizes all the values of u.

0 units are mB (hPa)
1 units are "Hg
2 units are kPa
3 units are mmHg
4 units are Atm
5 units are psia
9 units depend on user-entered scale and offset.

If the station elevation offset is non-zero, then one of the following values of u will be returned:

10 units are mB + station elevation offset
11 units are "Hg + station elevation offset
12 units are kPa + station elevation offset
13 units are mmHg + station elevation offset
14 units are Atm + station elevation offset
15 units are psia + station elevation offset
19 user units with non-zero station elevation offset
(mB + elevation offset) * user scale + user offset
set by XE or XS Set by XUU

In most cases, you will not set up the recorder to store this units identifier. It is provided in response to the standard measure command to eliminate confusion as to the computation used to come up with the final value.

Other Measurements

The SDI-12 standard allows for other measurement commands such as M1, M2 etc., other current measurement commands such as C1, C2, etc., other non-concurrent measurements with CRC-16 such as MC1, MC2, etc, and other concurrent measurement with CRC-16 such as CC1, CC2, etc. This unit maintains symmetry across all four classes of commands, that is, it returns the same information to a C1 as it does to a M1 or a MC1 or a CC1. The ACCUBAR® supports the following optional measurement commands:

aM1! aC1! aMC1! aCC1!	measure mB (hPa) using factory calibration. Do not apply any user scaling, station elevation or offsets. This returns 1 value and the units are fixed to mB (hPa).
aM2! aC2! aMC2! aCC2!	measure temperature (Celsius or Fahrenheit). This returns two values: the temperature and the units. The units will be 0 for Celsius and 1 for Fahrenheit.
aM3! aC3! aMC3! aCC3!	measure user scale, user offset, elevation offset. Use this if you want to view the user-entered values that can affect the value returned by the M command.
aM4! aC4! aMC4! aCC4!	measure calibration lab scale and offset. Use this if you want to view the calibration lab values that can affect the value returned by the M, C, MC, and CC commands.
aM6! aC6! aMC6! aCC6!	Measure temperature and pressure. The output is the concatenation of the M2 and M commands. Temperature, temperature units, Pressure, Pressure units.
aM7! aC7! aMC7! aCC7!	Measure mB and degrees C using factory calibration. Do not apply any user scaling, field calibration or offsets. This returns two values and the units are fixed to mB and degrees C.

Remember to issue the aD0! command after the measurement is complete in order to retrieve the data.

Changing the Units

As noted above, the aM! command can return the pressure in several different units. The selection of the units is made using the XUP command:

aXUP+n+d!	where n is one of the selections from the following table and d is the number of digits to the right of the decimal point.

N	Type Units	Comments
0	mB (hPa)	
1	inches of mercury	
2	kPa	
3	mmHg	
4	Atm	
5	psia	
9	user units	the value has units that depend on the values entered using the XUU command.

For example, the command

aXUP+0+2!

will specify the output to be in the default units (mB) with a resolution of 2 decimal places. The second parameter (2 in the example) is optional. If omitted, the resolution is not changed.

Setting User Units

If you want the sensor to read out in units other than the factory-programmed units, you will need to use the XUP command to set the units to 9, user units. When user units are selected, the software will use the equation:

output = mB * scale + offset

where scale and offset are values you can enter into the system.

The XUU command is used to enter the user scale and offset. The format of the command is:

aXUUso!	where s is the signed scale and o is the signed offset.

For example, the following command will set the scale to 70.32 and the offset to 0.0:

aXUU+70.32+0

Similarly, the slope and offset can be set to any values that will produce the desired units.

NOTE: Remember that both a XUU and a XUP command are required for the ACCUBAR® to report in user-defined units.

Setting Station Elevation

The ACCUBAR® will usually be installed at an elevation other than sea level. To have the ACCUBAR® report the atmospheric pressure at sea level, the sensor's elevation offset from sea level must be entered. The ACCUBAR® has two commands that can be used to enter this elevation offset. The XE command allows direct setting of an elevation offset which will be added to the measurement to compute atmospheric pressure at sea level:

aXEou!	where o is adjustment value with units u. u can have units 0=mB (hPa), 1="Hg, 2=kPa, 3=mmHg, 4=Atm, 5=psia, or 9=user units.

For example, the command:

aXE+20.2+0!

would set the elevation offset pressure to 20.2 with units of mB (hPa).

The other command used to set the elevation offset is the XS command. This command causes the sensor to make pressure readings and automatically compute a new elevation offset. You can use this command only if you have a stable, known pressure on the sensor. The command has the format:

aXSdu!	use this form when the sensor is at a stable, known pressure. The d represents the desired reading and u the units.

If the sensor was stable at 1005.23 mB, the following command would adjust the elevation offset to insure the 1005.23 mB reading:

0XS+1005.23+0!

If the sensor was under pressure and stable at 29.921 inches of mercury, the following command would adjust the elevation to ensure the 29.921" Hg reading:

0XS+29.921+1!

When the ACCUBAR® is done with the self-calibration, the new elevation offset is stored into memory. A subsequent aD0! command will display this offset in units of mB. The offset can also be displayed using the M3 command. The returned value will be in the current units of pressure.

4.4 Configuring the Averaging Time

Setting the Averaging Time

The ACCUBAR® supports user selectable averaging time for SDI-12 readings. The time period in seconds is specified with the aXT+t extended command.

For example, the command

0XT+10!

will set the averaging time to 10 seconds for an ACCUBAR® at address 0.

Note: The averaging time is not the same as the time till completion of a reading. When the ACCUBAR® is awakened by the SDI-12 data recorder and a measurement is requested, the ACCUBAR® calibrates its internal A/D converter before taking the reading. This removes any drift from the analog readings before the pressure measurement is started.

The ACCUBAR® software supports two speed regions. If the requested time is less than 1 second then the unit enters a higher speed mode. In the high accuracy mode (t >1) there is approximately a 1.7 second overhead involved in the initial calibration before the ACCUBAR® starts the pressure measurement averaging. With the high speed mode the overhead drops to 0.8 seconds.

Note: It is recommended that a measurement be manually initiated (an M, M1, or M2 command) after issuing the XT command to insure that the new coefficients are flushed through the measurement system. This is particularly true with units operating in the background measurement mode. Depending on when the XT command is issued with respect to the background measurement, there is the possibility that the first reading after issuing the XT command will be incorrect.

4.5 Measurement time, Response time, and Power up delay

The ACCUBAR® is a low power SDI-12 sensor. As such, it is typically always powered up and ready to respond to a measurement command. For applications where the ACCUBAR® will only be powered for a measurement, power must be supplied to the unit for at least 3 seconds before issuing the first command to the unit to allow sufficient time for the unit to complete its internal power up self-tests. The response time of the pressure transducer internal to the ACCUBAR® is less than 100 ms. When testing the ACCUBAR® performance, applied pressure must be stable for 100 ms before issuing the measurement command. The actual time to perform the measurement is dependent upon the averaging configured in the unit and is described in further detail in the preceding section on Configuring the Averaging Time.

4.6 Resetting the unit to Factory Default Configuration

The ACCUBAR® supports a reset to factory default command. The reset to factory defaults command provides a means to reset most user configurable parameters in a unit back to the factory defaults. If the previous history of a unit is not known, it is recommended that this command be issued before configuring the unit to ensure a known starting configuration.

aXFD!	where a is the address character, XFD is the extended command to reset the unit to the factory default configuration. Note: The address is not changed.

Note: It is recommended that the unit be powered down and back up after issuing this command.

A reset to factory defaults sets:

- XUP: Pressure Units to mB (hPa)
- XUT: Temperature Units to Degrees C
- XT: Averaging to one sample in slow mode
- XE: Offset to 0 (may have been previously set by the XS command)
- XOM: To factory default (dependent upon model).
- XUU: Resets user scale factor to 1 and offset to 0

Items not reset:

- Address
- Metrology lab calibration coefficients
- Resolution of pressure data returned as had been set by the XUP command.

5. Command Reference

This chapter documents the commands supported by the ACCUBAR. The commands are listed in alphabetical order within a section.

5.1 Accubar Basic SDI-12 Commands

	Command Description	Command Syntax (command underlined)	ACCUBAR® response (underlined) "a" represents the single-character address
	Acknowledge active	a!	a
?	Request Address	?! Also see X? command.	a indicating that the current address is a. **Note**: ACCUBAR® should be the only sensor on the SDI-12 bus when this command is given, otherwise there will be a communications collision when all units respond.
Ab	Set SDI-12 address	aAb! b new SDI-12 address Example: 5A9! (set address 5 to address 9, the address was previously set to 5)	b indicating that the new address is b.
C	Request Default Concurrent Pressure Measurement	aC! aD0!	attt02 ttt is the time in seconds until the measurement is ready, 02 is the number of values that can be collected axu where x is the signed pressure value and u is the signed indicator of the units. The units are set by the XUP command.
C1	Request Concurrent Pressure Measurement in mB (factory calibrated value)	aC1! aD0!	attt01 ttt is the time in seconds until the measurement is ready, 01 is the number of values that can be collected. ap where p is the signed pressure value in mB

	Command Description	Command Syntax (command underlined)	Sensor response (underlined) "a" represents the single-character address
C2	Request Concurrent Temperature Measurement	aC2! aD0!	attt02 ttt is the time in seconds until the measurement is ready and 02 is the number of values that can be collected atu where t is the temperature and u is the units 0= Celsius and 1=Fahrenheit. Use the XUT command to set the units.
C3	Request User Scale, User Offset, and Field Calibration Offset	aC3! aD0!	a00003 000 is the time in seconds until the measurement is ready and 03 is the number of values that can be collected asoc where, s is the user scale and o is the user offset (mB), and c is the field calibration offset (mB).
C4	Request Standards lab Calibration Scale and Offset	aC4! aD0!	a00002 000 is the time in seconds until the measurement is ready and 02 is the number of values that can be collected aso where, s is the scale calibration and o is the offset calibration(mB).

	Command Description	Command Syntax (command underlined)	Sensor response (underlined) "a" represents the single-character address
C6	Request Concurrent Temperature and Pressure Measurement	aC6! aD0!	attt04 ttt is the time in seconds until the measurement is ready and 04 is the number of values that can be collected atupv where t is the temperature, u is the temperature units, p is the pressure, and v is the pressure units. Use the XUT command to set the temperature units and the XUP command to set the pressure units.
C7	Request Concurrent factory calibration Pressure and Temperature Measurement	aC7! aD0!	attt02 ttt is the time in seconds until the measurement is ready and 02 is the number of values that can be collected apt where p is the pressure in mB and t is the temperature in degrees Celsius.
CC	Request Default Concurrent Pressure Measurement with CRC-16	aCC! aD0!	attt02 ttt is the time in seconds until the measurement is ready, 2 is the number of values that can be collected axuC where x is the signed pressure value, u is the signed indicator of the units, and C is the 3 character CRC. The units are set by the XUP command.
CC1	Request Concurrent Pressure Measurement in mB with CRC-16	aCC1! aD0!	attt01 ttt is the time in seconds until the measurement is ready, 1 is the number of values that can be collected. apC where p is the signed pressure value in mB and C is the 3 character CRC
CC2	Request Concurrent Temperature Measurement with CRC-16	aCC2! aD0!	attt02 ttt is the time in seconds until the measurement is ready and 2 is the number of values that can be collected atuC where t is the temperature, u is the units 0= Celsius and 1=Fahrenheit, and C is the 3 character CRC. Use the XUT command to set the units.

	Command Description	Command Syntax (command underlined)	Sensor response (underlined) "a" represents the single-character address
CC3	Request User Scale, User Offset, and Field Calibration Offset with CRC-16	aCC3! aD0!	a00003 000 is the time in seconds until the measurement is ready and 3 is the number of values that can be collected asocC where, s is the user scale and o is the user offset (mB), c is the field calibration offset in the current pressure units, and C is the 3 character CRC.
CC4	Request Standards lab Calibration Scale and Offset with CRC-16	aCC4! aD0!	a00002 000 is the time in seconds until the measurement is ready and 2 is the number of values that can be collected asoC where, s is the scale calibration, o is the offset calibration(mB), and C is the CRC.
CC6	Request Concurrent Temperature and Pressure Measurement with CRC-16	aCC6! aD0!	attt04 ttt is the time in seconds until the measurement is ready and 04 is the number of values that can be collected atupvC where t is the temperature, u is the temperature units, p is the pressure, v is the pressure units, and C is the CRC. Use the XUT command to set the temperature units and the XUP command to set the pressure units.
CC7	Request Concurrent factory calibration Pressure and Temperature Measurement with CRC-16	aCC7! aD0!	attt02 ttt is the time in seconds until the measurement is ready and 02 is the number of values that can be collected aptC where p is the pressure in mB, t is the temperature in degrees Celsius, and C is the CRC.

	Command Description	Command Syntax (command underlined)	Sensor response (underlined) "a" represents the single-character address
D0	Request Data	aD0! **NOTE:** This command is only issued after a measurement command. It should not be issued until the measurement time has expired or a service request has been received.	av v contains the previously-requested measurement values. For example, 0+1013.25+0 If the above value was received and the previous measurement command was an M, that would indicate that the pressure is 1013.25 mB. **Note:** If the ACCUBAR® only returns the address, and no data values, that indicates that there is no data available. A measurement command has not been issued OR the command was aborted by sending a new command before the measurement time expired OR a service request has been received.
I	Send Identification	aI!	a13 SUTRON BARO-12.1ssssssBvvv 13 supports SDI version 1.3 commands SUTRON manufacturer BARO-1 Accubar model number 2.1 hardware revision level ssssss the sensor serial number Bvvv the software revision
M	Request Default Pressure Measurement	aM! aD0!	attt2 ttt is the time in seconds until the measurement is ready, 2 is the number of values that can be collected a service request axu where x is the signed pressure value and u is the signed indicator of the units. The units are set by the XUP command.

	Command Description	Command Syntax (command underlined)	ACCUBAR® response (underlined) "a" represents the single-character address
M1	Request Pressure Measurement in mB (factory calibrated value)	aM1! aD0!	attt1 ttt is the time in seconds until the measurement is ready, 1 is the number of values that can be collected. a service request ap where p is the signed pressure value in mB
M2	Request Temperature Measurement	aM2! aD0!	attt2 ttt is the time in seconds until the measurement is ready and 2 is the number of values that can be collected a service request atu where t is the temperature and u is the units 0= Celsius and 1=Fahrenheit. Use the XUT command to set the units.
M3	Request User Scale, User Offset, and Field Calibration Offset	aM3! aD0!	a0003 000 is the time in seconds until the measurement is ready and 3 is the number of values that can be collected asoc where, s is the user scale and o is the user offset, and c is the field calibration offset. The field calibration is returned in the current units.
M4	Request Standards lab Calibration Scale and Offset	aM4! aD0!	a0002 000 is the time in seconds until the measurement is ready and 2 is the number of values that can be collected aso where, s is the scale calibration and o is the offset calibration(mB).

	Command Description	Command Syntax (command underlined)	ACCUBAR® response (underlined) "a" represents the single-character address
M6	Request Temperature and Pressure Measurement	aM6! aD0!	attt4 ttt is the time in seconds until the measurement is ready and 4 is the number of values that can be collected a service request atupv where t is the temperature, u is the temperature units, p is the pressure, and v is the pressure units. Use the XUT command to set the temperature units and the XUP command to set the pressure units.
M7	Request factory calibration Pressure and Temperature Measurement	aM7! aD0!	attt2 ttt is the time in seconds until the measurement is ready and 2 is the number of values that can be collected a service request apt where p is the pressure in mB and t is the temperature in degrees Celsius.
MC	Request Default Pressure Measurement with CRC-16	aMC! aD0!	attt2 ttt is the time in seconds until the measurement is ready, 2 is the number of values that can be collected a service request axuC where x is the signed pressure value, u is the signed indicator of the units, and C is the 3 character CRC. The units are set by the XUP command.
MC1	Request Pressure Measurement in mB with CRC-16	aMC1! aD0!	attt1 ttt is the time in seconds until the measurement is ready, 1 is the number of values that can be collected. a service request apC where p is the signed pressure value in mB and C is the 3 character CRC

	Command Description	Command Syntax (command underlined)	Sensor response (underlined) "a" represents the single-character address
MC2	Request Temperature Measurement with CRC-16	aMC2! aD0!	attt2 ttt is the time in seconds until the measurement is ready and 2 is the number of values that can be collected a service request atuC where t is the temperature, u is the units 0= Celsius and 1=Fahrenheit, and C is the 3 character CRC. Use the XUT command to set the units.
MC3	Request User Scale, User Offset, and Field Calibration Offset with CRC-16	aMC3! aD0!	a0003 000 is the time in seconds until the measurement is ready and 3 is the number of values that can be collected asocC where, s is the user scale and o is the user offset (mB), c is the field calibration offset (current pressure units), and C is the 3 character CRC.
MC4	Request Standards lab Calibration Scale and Offset with CRC-16	aMC4! aD0!	a0002 000 is the time in seconds until the measurement is ready and 2 is the number of values that can be collected asoC where, s is the scale calibration, o is the offset calibration (mB), and C is the 3 character CRC.

	Command Description	Command Syntax (command underlined)	Sensor response (underlined) "a" represents the single-character address
MC6	Request Temperature and Pressure Measurement with CRC-16	aMC6! aD0!	attt04 ttt is the time in seconds until the measurement is ready and 04 is the number of values that can be collected a service request atupvC where t is the temperature, u is the temperature units, p is the pressure, v is the pressure units, and C is the 3 character CRC. Use the XUT command to set the temperature units and the XUP command to set the pressure units.
MC7	Request factory calibration Pressure and Temperature Measurement with CRC-16	aMC7! aD0!	attt02 ttt is the time in seconds until the measurement is ready and 02 is the number of values that can be collected a service request aptC where p is the pressure in mB, t is the temperature in degrees Celsius, and C is 3 character CRC.
R0 R1 . . . R9	Request Continuous Measurement Readings	aR0! aR1! . . . aR9!	a Unit only returns its address because it **does not provide continuous measurements**.
V	Initiate Verify sequence	aV! aD0!	attt5 indicating that the command will be complete in ttt seconds and 5 values can be collected. a service request arespu where r is the ROM checksum, e is the EEROM checksum, s is the number of resets since power up, p is the number of power ups, and u is the number of unexpected interrupts.

5.2 Accubar Extended Commands

	Command Description	Command Syntax (command underlined)	Sensor response (underlined) "a" represents the single-character address
X?	Request unknown address	*X?! This command causes any Sutron ACCUBAR® to identify itself. If you have more than one ACCUBAR® connected, the result may be garbled. There is no guarantee that non-ACCUBAR® devices will respond to this command.	a Accubar's address.
XAD	Set SDI-12 address (Sutron extended version) see A command for SDI-12 standard version.	aXADnAn! n new SDI-12 address, repeated twice Example: 5XAD9A9! (set address 5 to address 9, the address was previously set to 5)	a0011 no response if addresses do not match **Note:** if the DIP switches are set to a non-zero address then upon power-up the address will be the dip-switch address. **Note:** a D0 command issued to the new address after the XAD command will return the new address.
XE	Set Elevation offset	aXExu! where x is the pressure offset u indicates the units of the offset, 0=mB (hPa), 1="Hg, 2=kPa, 3=mmHg, 4=Atm, 5=psia, or 9=user units. Example: 0XE+20.05+0 (set elevation offset to +20.05 mB) **Note:** Offset can be queried by issuing aXE! Followed by a aD0! **Note:** Prior to version B1.02 only mb(hPa) or "Hg supported for the units.	a0011 indicating that the command will take 1 second and 1 value can be collected. a service request **Note:** a D0 command issued after the XE command will return the offset in the current units of pressure.
XFD	Reset to Factory defaults	aXFD! This command resets most user configurable configuration items back to the factory defaults. It does not reset the address nor does it affect metrology lab calibrations. **Note:** It is recommended that the unit be powered down and back up after use of this command.	a0101 indicating that the command will take 10 seconds and 1 value can be collected. a service request **Note:** a D0 command issued after the XFD command will return the operating mode

	Command Description	Command Syntax (command underlined)	ACCUBAR® response (underlined) "a" represents the single-character address
XS	Self-Cal the Elevation Offset	aXSdu! where d is the desired reading for the sensor and in the units indicated by u. The ACCUBAR® will make repeated measurements and adjust the elevation offset to insure the reading matches the value entered. Example: 0XS+1007.9+0 (sensor is at 1007.9 mB, adjust offset to insure this reading)	attt1 where ttt indicates the command will be complete in ttt seconds and 1 indicates one value can be collected. **Note:** a D0 command issued after XS is complete will display the new offset in the current units of pressure. The offset can also be displayed using the M3 command.
XT	Set Averaging Time	aXT+t! t = averaging time in seconds (0 to 120 seconds) Example: 0XT+10! (sets the averaging time to 10 seconds)	a0012 indicating the command will be complete in 1 second and 2 values can be collected **Note:** a D0 command issued after the XT will return the average time and the number of samples to be averaged during the average time. Actual time to return the measurement will be longer due to calibration overhead.

	Command Description	**Command Syntax** **(command underlined)**	**ACCUBAR® response (underlined)** **"a" represents the single-character address**
XUP	Set pressure units (Version 1.5 and higher for setting number of decimal places)	aXUP+n+d! n = 0 mB (hPa) n = 1 "Hg n = 2 kPa n = 3 mmHg n = 4 Atm n = 5 psia n = 9 user units d = number of places right of the decimal (optional parameter) Example: 0XUP+9+2! Select user units with 2 right digits-- (make sure you use XUU command to set the scale and offset for the desired user units)	a0012 indicating the command will be complete in 1 second and 2 values can be collected **Note:** a D0 command issued after the XUP will return the value of the units that are selected and the number of digits right of the decimal point. **Note:** Current settings can be queried by issuing the aXUP! Command followed by the aD0! Command.
XUT	Set temperature units	aXUTn! n = 0 for Celsius, n = 1 for Fahrenheit Example: 0XUT1! (set temperature units to F) **Note:** Current settings can be queried by issuing the aXUT! Command followed by the aD0! Command.	a0011 indicating the command will take 1 second to complete and 1 value can be collected. **Note:** a D0 command issued after the XUT will return the value of the units that are selected.
XUU	Set User Units	aXUUso! where s is the pressure scale factor and o is the offset, User output = (mB)*scale + offset Example: 0XUU+27.63+0 (27.63 user units per mB) **Note:** Current settings can be queried by issuing the aXUU! Command followed by the aD0! Command.	a0012 **Note:** a D0 command issued after XUU will return the scale and offset. **Note**: a scale of 0 is invalid. **Note:** Be sure that the units of pressure (XUP) are set to user units (9).

6. Installation

The ACCUBAR® will return accurate and reliable pressure data in any mounting position. We recommend, however, mounting the sensor with the connector and cable gland pointing downward. This will prevent any moisture from following the cable or tubing down to the ACCUBAR® sensor.

The ACCUBAR® mounts to a panel or surface through two holes that are accessible under the sensor cover. The through-holes accommodate #4, #6, M3, or M3.5 hardware. In addition, the unit is supplied with optional external mounting feet. The external mounting feet support #8, #10, #12, M4, or M5 hardware.

The ACCUBAR® barometric pressure fitting is a hose barb for a 3/16" ID tubing.

If the supplied cable is to be replaced with an installation specific one, then it should be noted that the terminal block accommodates wire sizes from 30 AWG to 14 AWG or up to 1.5 mm^2. The recommended length of bare wire is 0.22" or 5.5 mm. The cable gland accepts cables with an O.D. anywhere between 0.12" and 0.26" (3-6.5 mm).

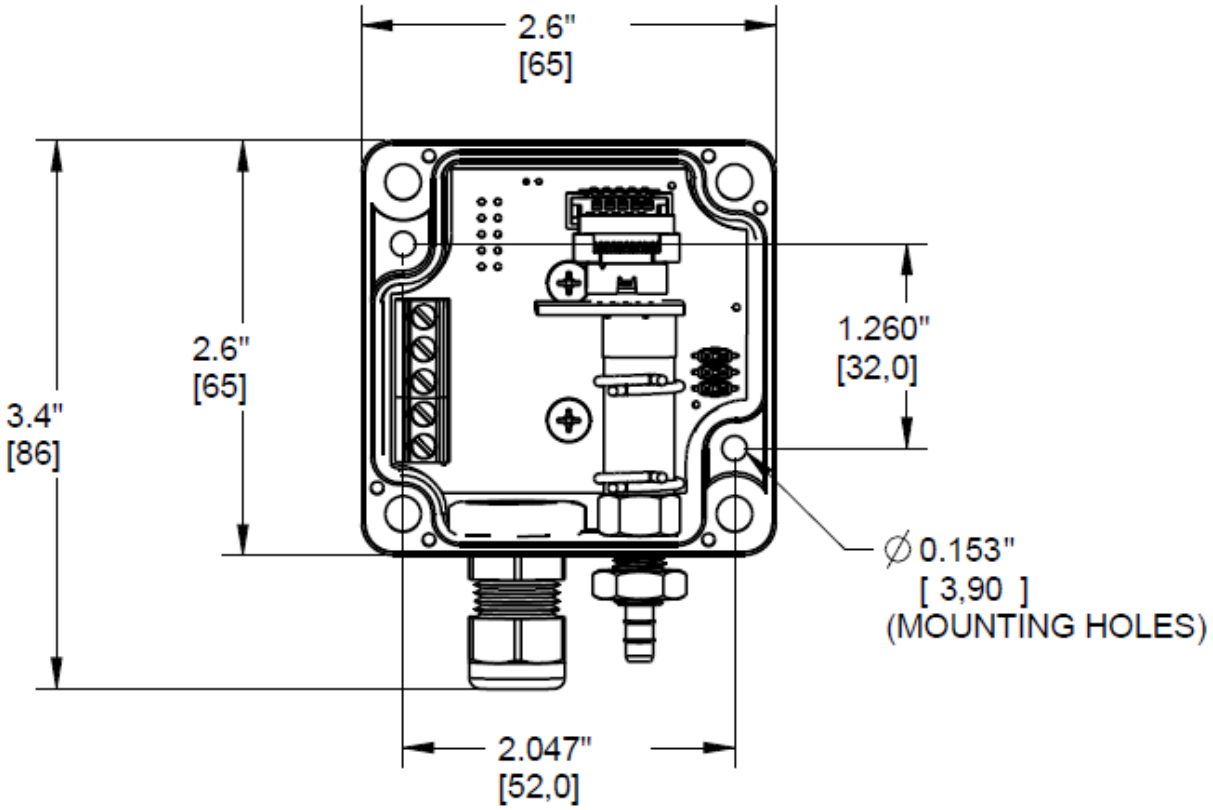


Figure 1 – Using Hidden Mounting Screws

Optional external mounting feet are also supplied with the unit. There are two sets, one marked R and the other marked L. The following two figures show the unit in both configurations.

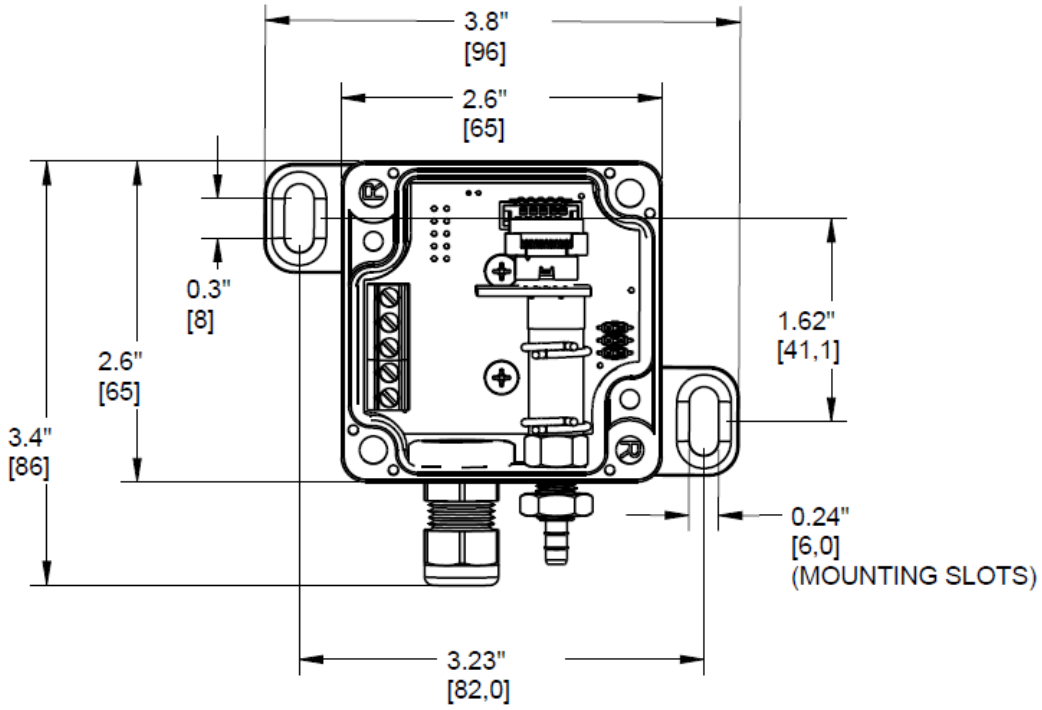


Figure 2 - Using External R feet

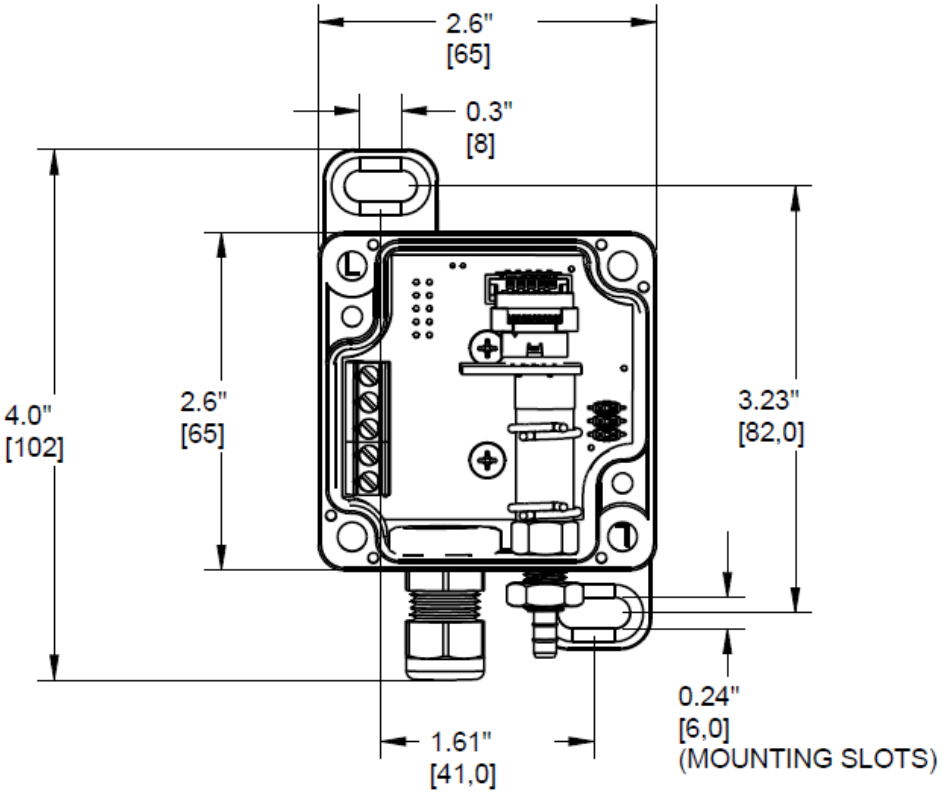


Figure 3 - Using External L Feet

7. Calibration

The Accubar under goes a rigorous screening and testing at the factory before it is shipped to ensure that it meets the accuracy specifications over temperature and that it is stable both in zero and span and will continue to be accurate over time. Even though the ACCUBAR® is highly stable, it is recommended that the Accubar, like all precision measurement instruments, be placed on a periodic calibration schedule.

Factory Calibration

The initial factory calibration covers the complete temperature range from -40 to +60 degrees C and also covers the complete pressure range from 500 to 1100 mB. This ensures that the ACCUBAR® meets the specifications over the complete pressure and temperature range. An Accubar can be sent back to the factory for a complete calibration over temperature. The Sutron Part number for this calibration service is: 8700-0005

Metrology Lab Calibration

The ACCUBAR® does have the provision for a calibration to be performed by a Metrology Lab. The calibration coefficients that can be entered by a metrology lab are a scale and an offset parameter. There is not a provision for any temperature dependent parameters. Most metrology labs would not have the capabilities to provide a calibration over temperature and pressure. To accurately calibrate an ACCUBAR® requires a reference accuracy better than 0.1 mB, ideally 0.02 mB.

To collect data for calibration of the Accubar, the M1 command should be utilize. This will ensure that field offset or old calibration coefficients do not affect the accuracy of the data collected. The command that is utilized to enter the Metrology Lab Coefficients is:

aXCosc!	where a is the address character, XC is the extended command to set the calibration coefficients, o is the offset in mB, s is the scale factor, and c is the checksum. (added in version B1.02)

The Checksum is the 8 bit sum of the 7 bit ASCII characters (parity is striped) from and including the address character through the last character of the scale factor. It does not include the checksum string nor its delimiting polarity sign. The checksum is transmitted as an ASCII string. That means that if the 8-bit sum is 236 then the value of c is +236. The command to set the offset of the unit at address 0 to 0.0000 and the scale factor to 1.0000 would be:

0XC+0+1+130!

The calibration coefficients affect the output of the M command. This command does not affect the output of the M1 command. The data output by the M command is computed from the following equation:

Pressure = units offset + units scale * (field offset + calibration scale *(press. in mB - calibration offset))

where:

press. in mB is the factory calibration pressure as returned by the M1 command.

calibration offset is entered by the XC command

calibration scale is entered by the XC command

field offset is entered by the XE or XS commands

units scale and units offset are set by the combination of the XUP and XUU commands.

Note: Calibration scale and calibration offset can be determined via the M4 command.

Note: The current value of field offset, user units offset, and user units scale can be determined via the M3 command.

8. Troubleshooting and Maintenance

Troubleshooting

The following checklist will help in troubleshooting problems:

Problem	Possible Cause
No data	Faulty wiring -- check all wiring and terminations
	No power -- check fuse in the data recorder and power at sensor. There is no fuse in the sensor itself.
	Wrong address requested -- make sure the data recorder is set up to request data at the proper address
	Wrong address set in sensor -- use the identify command to make sure the sensor is responding to the proper address.
	Command or address is wrong case -- all ACCUBAR® commands are capital letters, make sure address is proper case and commands are upper case.
	With RS-232, make sure that Transmit and Receive Data are not reversed.
Garbled data	Multiple sensors set to the same address -- check address settings of all SDI sensors. Remove all other sensors from the recorder and add them one at a time. Communication is defined to be 1200, E, 7, 1.
	Command issued to a wild card address (* or ?). Remove all other sensors from the recorder and try again.
Erroneous data	Wrong units selected -- use the M command and look at the units field. Verify that the desired units are selected.
	Erroneous offset entered -- display the elevation offset using the M3 command and verify it. Re-calibrate the offset.
	Erroneous user scale and offset entered -- display the user scale and offset using the M3 command and verify.

Maintenance

Typical maintenance for the sensor consists of checking the wiring to make sure it is not corroded or frayed, checking the tubing to make sure it is intact and leak-free, and checking or setting the elevation offset.

Maintenance should be performed at least every year in order to insure that the sensor meets the accuracy specifications.

9. Specifications for 5600-0120-3 Barometric ACCUBAR®

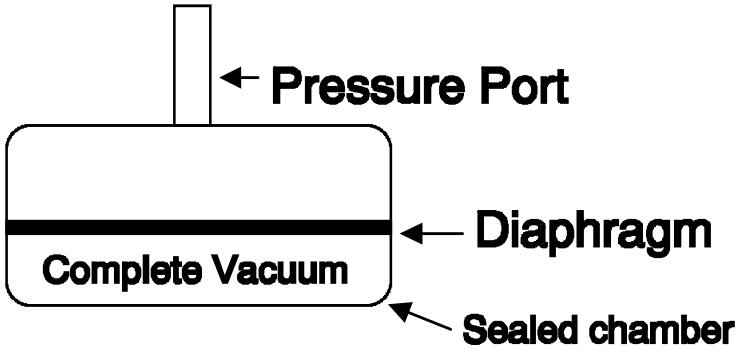
Dimensions	2.6" X 2.6" X 1.6" excluding cable gland, hose barb, and optional supplied mounting feet
Weight	0.3 lb.
Range	500 to 1100mB (hPa) 14.8 to 32.5” Hg
Elevation	-2300 to 18,300 feet (-700 to 5600 meters)
Calibrated Temp Range	-40°C to +60°C
Operational/Storage Range	-50°C to +70°C
Operating Humidity	0-100% Non-condensing
Accuracy	0.4, 0.3, 0.2 mB (hPa) @ 20C depending on version. An additional 0.1 mB over the temperature range
Resolution	Better than 0.01mB
Averaging Time	0 to 120 seconds (user selectable)
Supply Voltage	+8 to +16VDC (reverse polarity protected)
Power Consumption	
SDI-12 (active)	3.5 mA typ., 4 mA max
Quiescent	0.05 mA typ., 0.1mA max
RS-232 connected	Additional 3.2 mA
Communication Rate	1200 baud
Pressure Units Supported	mB, hPa, kPa, ”Hg, mm Hg, ATM, psi
Pressure Fitting	Hose barb for 3/16" ID hose
Cable Fitting	Cable gland for 0.12” to 0.26” diameter cable to terminal block for 14-30 AWG wire
Enclosure Rating	NEMA-4X (IP66)
Enclosure Material	Corrosion Resistant UV Stabilized Polycarbonate

Appendix A -- Introduction to Pressure Measurement

TYPES OF PRESSURE MEASUREMENTS

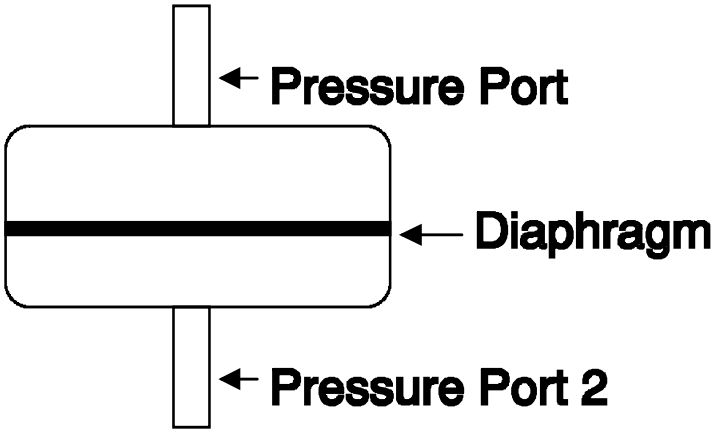
ABSOLUTE (PSIA)

Pressure is measured with respect to an absolute vacuum.



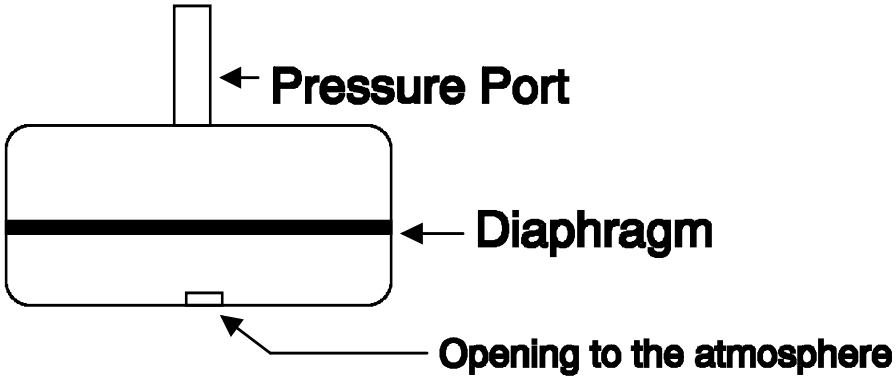
DIFFERENTIAL (PSID)

Pressure is measured with respect to a second pressure port.



GAUGE (PSIG)

Pressure is measured with respect to atmospheric pressure. Same as a differential pressure sensor with the second port open to the atmosphere.



PRESSURE UNITS

BAROMETRIC

PSIA pounds per square inch absolute (industrial units)

mB millibars

hPa hectoPascals (WMO unit of measure)

mmHg millimeters of mercury at 0 degrees C (scientific units)

"Hg inches of mercury at 0 degrees C (common US unit)

ATM Atmospheres

torr same as millimeters of mercury

PRESSURE EQUIVALENTS

millibars	hPa	"Hg	PSI	mmHg	ATM	altitude in ft.
1100	1100	32.483	15.954	825.07	1.0856	-2291
1050	1050	31.006	15.229	787.56	1.0363	-989
1013.3	1013.3	29.921	14.696	760.00	1.0000	0
1000	1000	29.530	14.504	750.06	0.9869	364
950	950	28.053	13.779	712.56	0.9376	1773
900	900	26.577	13.053	675.05	0.8882	3243
850	850	25.100	12.328	637.55	0.8389	4781
800	800	23.624	11.603	600.05	0.7895	6394
750	750	22.147	10.878	562.55	0.7402	8091
700	700	20.671	10.153	525.04	0.6908	9882
650	650	19.194	9.427	487.54	0.6415	11780
600	600	17.718	8.702	450.04	0.5922	13800

GAUGE

PSIG or PSI pounds per square inch

feet of water (USGS conversion factor is 2.3073 * PSI)

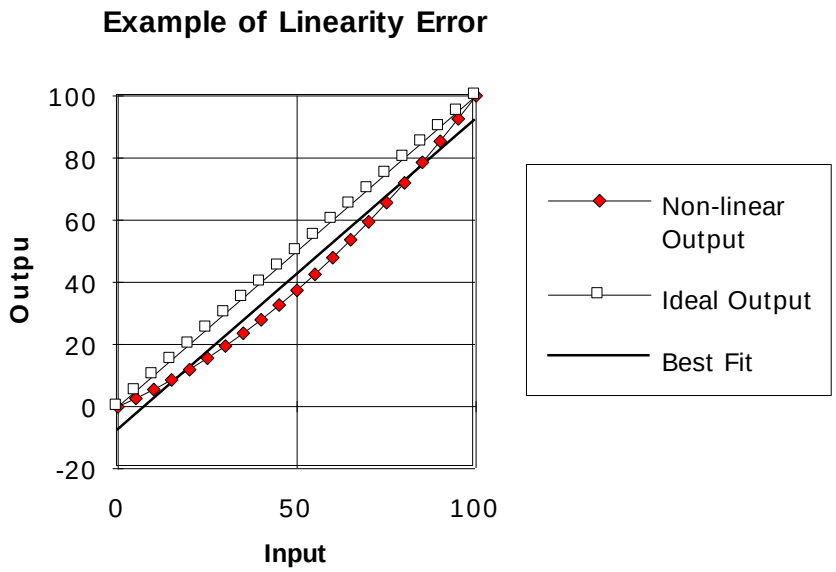
PRESSURE EQUIVALENTS

PSI	feet of Water	kPa
0	0.000	0.000
5	11.537	34.474
10	23.073	68.948
15	34.610	103.421
20	46.146	137.895
22	50.761	151.685
35	80.756	241.317

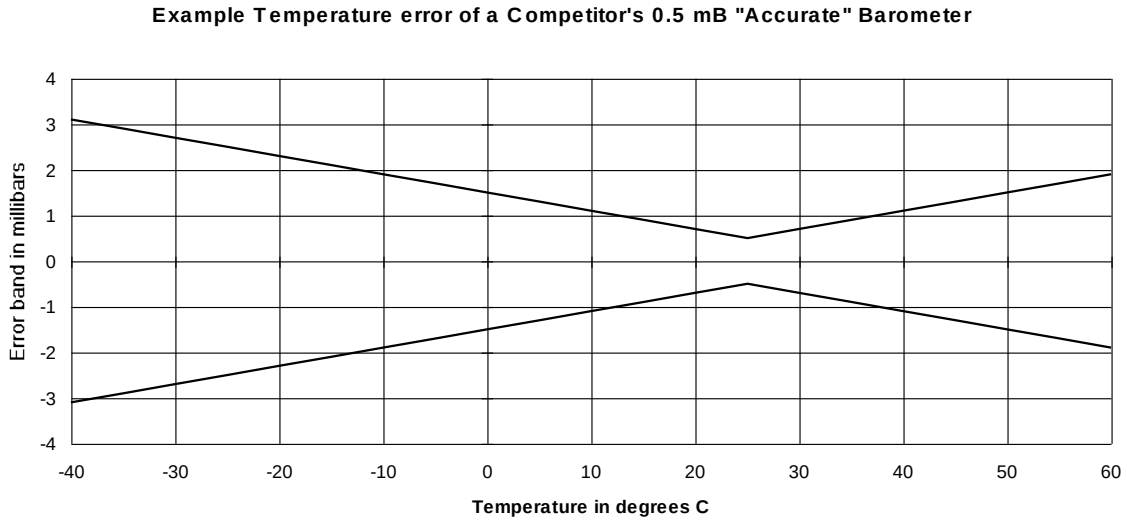
ERROR DEFINITIONS AND EXAMPLES

Linearity:

Linearity error is the deviation of the output from a straight line. Many transducers for measuring physical phenomena have outputs which do not vary linearly with the phenomena being measured. Sometimes the deviation from linear is slight and is accepted as part of the error of the device, in other cases manufacturers attempt to "linearize" the output. Usually when this done through an analog means, there will be a residual non-linearity, i.e., the non-linearity is not completely removed. The following non-linearity graph illustrates why a two point calibration (zero and full scale) is many times insufficient and ensures that the maximum error is achieved. A best fit straight line decreases the maximum error by ensuring that the errors fall evenly on both sides.



Temperature coefficient -- This is made up of two components, the temperature coefficient of the offset and the temperature coefficient of the slope. These can be referred to as thermal shifts, temperature dependence, and other names. The offset is sometimes referred to as zero. The slope is sometimes referred to as span, sensitivity, or scale factor. The following graph illustrates why the temperature coefficient is an important specification for remote equipment. In an indoor environment a competitor's barometer is about a 0.5 mB instrument. Over the operating temperature range of Sutron equipment, it degrades to a ±3 mB instrument.



Hysteresis - This is a measure of deviation in the output when passing through an input point from two different directions. If a pressure transducer has zero pressure applied, then 10 PSI, then 22 PSI, then 10 PSI, the difference between the two 10 PSI readings would be a measure of the pressure hysteresis of the transducer. Pressure transducers can also have temperature hysteresis errors. Sometimes hysteresis is lumped in with other non-repeatability errors.

ACCURACY - Accuracy is a measure of how closely the sensor's output matches the "true" value of the parameter being sensed.

PRECISION - Precision is a measure of the repeatability of the sensor. It will most always be better than the accuracy of the sensor.

RESOLUTION - The resolution of a sensor is the smallest change in the input that is reflected in the output. For digital sensors it also refers to the smallest increment of the output. This may be greater than or less than the sensor's resolution with respect to its input. Greater resolution does not imply greater accuracy. Resolution and Accuracy are two independent variables. The advantage of resolution in excess of accuracy is that changes in the input parameter can be detected and tracked.

Appendix B – Sutron Customer Service Policy

Dear Customer:

Thank you for making the important decision to purchase Sutron equipment. All Sutron equipment is manufactured and tested to the highest quality standards as set by Sutron's Quality Assurance Department. Our Customer Service Representatives have years of experience with equipment, systems and services. We have electronic technicians with field and applications experience, not limited to technical school training.

Sutron Equipment Repairs

Sutron maintains a Repair Department at the Virginia factory (22400 Davis Drive, Sterling, VA 20164). Turn-around time normally ranges from 10-30 days after Sutron receives equipment for repair. Prior to returning any equipment for repair, please call Customer Service at (703) 406-2800 for a Return Material Authorization (RMA) number. Next send the faulty equipment back to the Virginia factory*.

Sutron Customer Service will repair Sutron-manufactured equipment sent to us for repair within 30 days of the time we receive the item or that repair is free of charge. Please provide our Customer Service Representative with your email address when receiving the RMA number so that we can email you when your equipment is received at Sutron and again when it is shipped back to you. Expedited repairs can be completed within one (1) week for an additional expedite fee of $200.00. Repaired equipment is warranted for a period of 180 days after the repair shipment date.**

Note: The 30 day guarantee does not apply to bulk shipments of 10 or more repair items. We appreciate your cooperation in achieving a quick turn-around by promptly providing cost approval decisions, Purchase Order and credit card information once we have supplied you with a repair estimate.

Customer Phone Support - 8:00 am to 8:00 pm EST

Customer Service Representatives routinely handle a wide variety of questions every day. When equipment questions arise, please feel free to contact me or one of Sutron's Customer Service Representatives. We are available from 8:00 am to 8:00 pm EST Monday through Friday and will be happy to take your calls. The main Customer Service number is (703) 406-2800, extension #5. After 5 pm EST Monday through Friday, please use extension #6. We typically answer most sensor and interface questions on the first call. If we cannot quickly answer a question on an interface, we will work with you until we find a solution. Sometimes a problem is application related. Although we pride ourselves on handling 95% of application related questions over the phone, we maintain constant contact with our Integrated Systems Division and Engineering Division for additional assistance.

Training

Training is an important part of the Sutron Customer Service Success policy. With proper training, you will learn how to take advantage of all the benefits and tools that Sutron equipment provides. We are available for, and frequently provide, on-site introductory training at our Customers' facilities. We also hold three (3) day training seminars approximately four times per year at our Sutron headquarters in Sterling (near Washington, DC). Contact me or your Sutron Regional Sales Manager for details.

On-Site Visits

Of course not all problems can be fixed over the phone. Sometimes a customer needs an on-site technician to identify site related problems or troubleshoot a network. Sutron provides these services at a reasonable cost. Please call for details. If you would like to learn more about Sutron products, please email sales@sutron.com. Thank you again for your business.

Paul Delisi
Customer Service Manager
pdelisi@sutron.com

**Transportation charges for equipment returns are the responsibility of the Customer.*
*** See Warranty on next page. Any products repaired or replaced under Warranty will be warranted for the balance of the Warranty period or for a period of 180 days from the repair shipment date, whichever is greater.*

Appendix C – Commercial Warranty

SUTRON CORPORATION WARRANTS that the equipment manufactured by its Manufacturing Division shall conform to applicable specifications and shall remain free from defects in workmanship and material for a period ending two years from the date of shipment from Sutron's plant.

Sutron's obligation under this Warranty shall be limited to repair at the factory (22400 Davis Drive, Sterling, VA 20164) or, at Sutron's option, replacement of the defective product. In no event shall Sutron be responsible for incidental or consequential damages, whether or not foreseeable or whether or not Sutron has knowledge of the possibility of such damages. This Warranty shall not apply to products that have been damaged through negligence, accident, misuse or acts of nature such as floods, fires, earthquakes, lightning strikes, etc.

Sutron's liability, whether in contract or in tort, arising out of warranties or representations, instructions or defects from any cause, shall be limited exclusively to repair or replacement parts under the aforesaid conditions.

SUTRON'S WARRANTY IS THE EXCLUSIVE REMEDY FOR ANY BREACH OF WARRANTY. SUTRON EXPRESSLY DISCLAIMS ANY REMEDIES OF "COVER" AND ANY WARRANTIES IMPLIED BY LAW, INCLUDING BUT NOT LIMITED TO ANY WARRANTY OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE. THE TOTAL LIABILITY OF SUTRON AND ITS SUBSIDIARIES, AFFILIATES, EMPLOYEES, DIRECTORS, OFFICERS AND AGENTS ARISING OUT OF THE AGREEMENT, PERFORMANCE, NONPERFORMANCE, OR OBLIGATIONS IN CONNECTION WITH THE DESIGN, MANUFACTURE, SALE, DELIVERY, AND/OR USE OF GOODS AND/OR SERVICES IN NO CIRCUMSTANCE INCLUDES ANY LIQUIDATED, INCIDENTAL OR CONSEQUENTIAL DAMAGES OF ANY KIND, NOR EXCEED AN AMOUNT THAT IS UNREASONABLY DISPROPORTIONATE TO THE TOTAL PAYMENT RECEIVED FOR THE GOODS/SERVICES GIVING RISE TO ANY CLAIM, EXCEPT ONLY IN THE CASE OF DAMAGES ARISING DUE TO SUTRON'S WILLFUL MISCONDUCT.

Sutron requires the return of the defective electronic products or parts to the factory to establish claim under this Warranty. The customer shall pre-pay transportation charges to the factory. Sutron shall pay transportation charges for the return of the repaired equipment to the customer when the validity of the damage claim has been established. Otherwise, Sutron will pre-pay shipment and bill the amount to the customer. All shipments shall be accomplished by best-way surface freight.

Sutron shall in no event assume any responsibility for repairs or alterations made other than by Sutron. Any products repaired or replaced under this Warranty will be warranted for the balance of the Warranty period or for a period of 180 days from the repair shipment date, whichever is greater. Products repaired at cost will be warranted for 90 days from the date of shipment.

NON-SUTRON MANUFACTURED EQUIPMENT

The above Warranty applies only to products manufactured by Sutron. Equipment provided, but not manufactured by Sutron, is warranted and will be repaired to the extent of and according to the current terms and conditions of the respective equipment manufacturers.

EXTENDED WARRANTY AND ON-SITE MAINTENANCE

Extended warranty and on-site maintenance contracts are available. Price quotations may be obtained from Sutron Customer Service Representatives.