SDI-12 COMMUNICATION WITH TRUBLUE DATA LOGGERS

APPLICATION NOTE

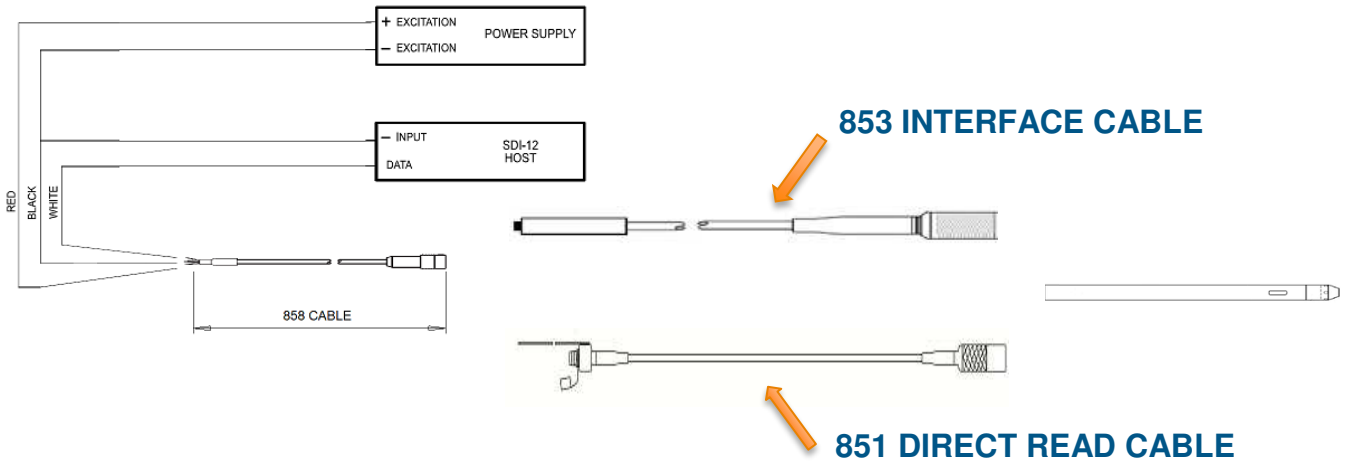
It is often desired to utilize the data logger as a transducer and a data logger simultaneously. Logged data is stored in the on-board memory, polled data is sent to a network capable auxiliary logger or telemetry system that captures the live data and transmits from a remote location. These devices often require a standard SDI-12 connection like that of our KPSI Digital Series transducers.

SDI-12 is a highly valuable option when it comes to remote data logging. By utilizing this output system several advantages occur including a minimal drain on current leading to longer life for the battery operated sensors. Additionally the use of SDI-12 allows for multiple sensors to be used on a common wire.

SDI-12 WIRING

Only three wires are needed to use the SDI-12 interface. A fourth wire (cable shield — bare wire) is added for user convenience.

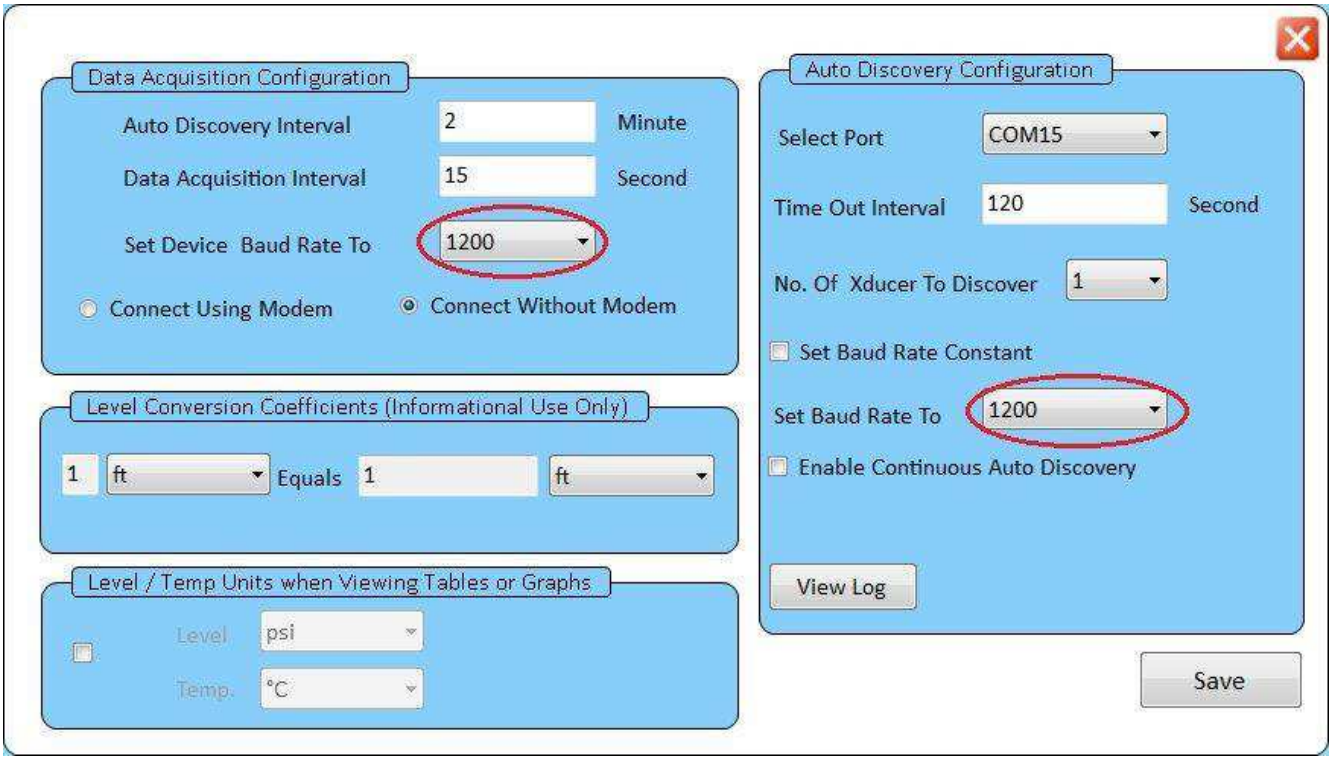
1. **Serial data (white)** — SDI-12 interface between sensors and data recorders.
2. **Ground (black**) — Supply return and earth ground.
3. **Supply (red)** — this line is internally regulated and can accept 8-28 VDC.



850-00858 HIROSE TO FLYING LEADS COMMUNICATION CABLE

This communication cable provides connection from the hirose connector of the 853 or 851 Field cable to terminals requiring flying leads. This allows for the instrument to be utilized as both a transducer and data logger simultaneously. This is achieved by storing logged data with the on-board memory included inside the instrument while sending polled data to a network capable auxiliary data logger or telemetry system.

NOTE: THIS CONNECTION REQUIRES THAT BOTH BAUD RATES IN TRUWARE [UNDER ADVANCED SYSTEM SETTINGS] BE CHANGED TO 1200.



OPERATION

Your transducer was shipped from the factory preset to address 0 (zero), and with the pressure units set to those requested in your order. However, if modifications are required for your application, you should familiarize yourself with the steps and commands needed to alter the setup of the transducer.

To issue commands to the sensor via SDI-12, you will need to connect it to a data recorder that is capable of issuing standard and extended SDI-12 commands

NOMENCLATURE

All commands have three components: the **SENSOR ADDRESS**, the **COMMAND BODY**, and the **COMMAND TERMINATION.**

The **SENSOR 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 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**.

SETTING THE ADDRESS

If you are using the sensor connected to common wiring with other SDI-12 sensors, you may need to change the default sensor address. Otherwise, skip this section. A unique address assigned to each sensor is an absolute requirement for multiple sensors to share the same wiring. When the data recorder needs data from a particular sensor, it requests data using a particular address. Only the sensor with the matching address can reply. Two or more sensors with same address replying will garble this reply. The factory default SDI-12 address (0) is best reserved only for single sensors operating alone on dedicated wiring.

USING THE GET/SET SENSOR ADDRESS COMMANDS

No other SDI-12 sensors connected to the system should be set to address 0 or to the desired sensor address. Hint: If you do not know the address of a particular sensor, first use the ***Get Unknown Address*** command to have the sensor identify itself. Its syntax is as follows:

?!	**NOTE:** There can be only one SDI-12 sensor connected to common wiring in order for the ***Get Unknown Address*** command to work.

The SDI-12 command for changing a sensor's address is **"A" (Set Sensor Address)**.

aAn!	Where **"a"** is the current address of the sensor, **"n"** is the new SDI-12 address Valid addresses are 0 to 9, A to Z, a to z.

The sensor will issue a reply message in response to the command, if the command was recognized. The message will be the new address "n."

Note that both commands above follow the SDI-12 standard of ending with a "!"terminator.

As an example, the following Set Sensor Address command would set the sensor address from 0 to 5:

0A5!

The sensor 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 tables below are sample commands and responses for the KPSI 500. Other models have the same response for their respective model.

The sensor will respond with an identifying message when it receives the ***Identify*** command "**I**."

The format of the command is:

aI!	Where "a" is the address for the sensor

The sensor will reply with:

a13-KPSI---500---hhh-ssssss-vvv	**Where:** "a" is SDI-12 address "13" is SDI protocol version (read 1.3) "KPSI" is Brand Name "500" is KPSI Model Number "hhh" is Hardware revision level "ssssss" is Sensor serial number (up to 8 char.) "vvv" is Software version

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

COMMAND (FUNCTIONAL OVERVIEW)

The commands to set up and operate the sensor are those defined by the SDI-12 specifications Version 1.0, Version 1.1, Version 1.2, and Version 1.3, plus extended commands. **NOTE: ALL SENSOR COMMANDS ARE UPPER CASE.** 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, or a to z. Values are entered in the form of a polarity sign (+ or -) 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 case of the letters is important. An "A" is not the same as an "a."**

The sensor replies to all SDI commands it supports. If the sensor receives a command it does not support, no reply is made. The reply (response) will have one of three forms:

a0000	Where "a" is *sensor address* and 0000 indicates that no further message to be sent.

atttn **:** **a**	Where "a" is *sensor address*, "ttt" is *time (in seconds)* sensor needs to make the measurement or process command, and "n" is the *number of data values* (limited to 9) that may be fetched by the *Get Data* ("D0") command when data is ready. In this older form, the sensor responds a second time with its address "a" when the data is ready (if "ttt" was not 000). This second response is called a *Service Request* response. This format is generated by older *non-concurrent* measurement commands (see "M[v]" commands below) and other older commands.

atttnn	Where "a" is *sensor address*, "ttt" is *time (in seconds)* sensor needs to make the measurement or process the command and "nn" is the *number of data values* that may be fetched by the *Get Data* ("D0") command when data is ready. This newer response format (in SDI Version 1.2 and later) does not generate the second *Service Request* response and can return a larger number of values ("nn") limited to 99. This format is generated by a newer *concurrent* measurement commands (see "C[v]" commands below).

If you issued the *Change Sensor Address* command or the *Identify* command described in the previous sections, you already have some experience with using commands. There are other commands available to make measurements, set the type of output units for the measurements, perform special scaling of the measurements, do field calibration, and the like. The following sections describe the commands by function.

MAKING A MEASUREMENT

There are two classes of measurement commands which will be referred to as **START NON-CONCURRENT MEASUREMENT ("M[V]") COMMANDS)** and **START CONCURRENT MEASUREMENT ("C[V]") COMMANDS).** In the first class the data recorder issues the measurement command and then waits for the sensor to complete the measurement before continuing the data collection cycle. Only one sensor can be accessed at a time and a maximum of nine parameters can be returned.

With Version 1.2 of the specification, *concurrent* measurements are permitted. 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 making requests to other sensors on the SDI-12 bus. This way, multiple sensors are taking measurements concurrently. Once the measurement time for a sensor expires, the data recorder polls that sensor for its data.

STARTING A NON-CONCURRENT MEASUREMENT (M[V] COMMAND)

The original command to tell the sensor to start a measurement non-concurrently is:

aM[v]!	Where "a" is the *address* character, and "M[v]" is *a Start* **NON-CONCURRENT MEASUREMENT** command. An optional digit "v" identifies command *variations*.

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 sensor will respond with:

atttn	Acknowledges it is from sensor with address "a", that "ttt" seconds are required before the measurement is completed, and "n" values will appear in final data stream acquired.

When the measurement is complete, the sensor sends a second response, called a *Service Request:*

a	Where *Service Request* response contains only "a," the *address* of the sensor.

Note that you still have no data from the sensor. To get data, enter the *Get Data* command to sensor:

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".

Depending on the *variation* of the command, the sensor will reply with one of these response formats:

av **avu** **avvv**	Where "a" is the *address*, "v" is a *data value*, and "u" is an optional *units* indicator. Both "v" and "u" have the format of a polarity sign (+ or -) followed by up to seven digits, including a decimal point. Format returned depends on the command variation.

The "u" indicates the *units* of the measurement according to the following tables:

0	units are feet of water
1	units are psi
2	units are kilopascal
3	units are cm of water
4	units are meters of water
5	units are mm of water
9	units depend on user-entered scale factors (slope and offset).

If the field calibration offset is non-zero, then one of the following values of "u" will be returned:

10	units are feet of water with non-zero field calibration offset
11	units are psi with non-zero field calibration offset
12	units are kilopascal with non-zero field calibration offset
13	units are cm of water with non-zero field calibration offset
14	units are meters of water with non-zero field calibration offset
15	units are mm of water with non-zero field calibration offset
19	user units with non-zero field calibration offset (psi + field calibration offset) * user slope + user offset (set by XE or XS) (set by XUU) (set by XUU)

If the unit has had its calibration modified at a standards lab other than at TE Connectivity, then the value returned for "u" will have one hundred (100) added to it. In other words, if the "**XC**" command has been utilized to set the calibration scale factor *(slope)* to other than 1 or the calibration *offset* factor to other than 0, then 100 will be added to the unit's indicator.

STARTING A CONCURRENT MEASUREMENT (C[V] COMMAND)

The command to tell the sensor to start a concurrent measurement is:

aC[v]!	Where "a" is the *address* character, and "C[v]" is a **START CONCURRENT MEASUREMENT** command. An optional digit "v" identifies command *variations*.

In reply, the sensor will respond with:

atttnn	Acknowledges it is from sensor with *address* "a", that "ttt" seconds are required before the measurement is completed, and "nn" values will appear in final data stream acquired. Note the 2-digit "nn" returned allows for a larger number of data items to be returned in the eventual data response (though not utilized by model 500 sensor).

When the measurement is complete, the sensor does NOT issue the second response, known as a Service Request response, as did an "M" command. To request the data you must enter the Get Data command only after the first response's estimated time for completion (ttt) has expired:

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".

As in all of the other (non-CRC) "M" and "C" commands, a **"D0"** command must eventually be issued to get the data from the sensor. In its response, three data measurements and a CRC appendage are returned as follows:

a+3.14+2.718+1.414lpz	Where ("**lpz"**) is the three-character CRC code appendage.

Depending on the variation of the command, the sensor will reply with one of these response formats:

av **avu** **avvv**	Where "a" is the *address*, "v" is a *data value*, and "u" is an optional *units* indicator. Both "v" and "u" have the format of a polarity sign (+ or -) followed by up to seven digits, including a decimal point. Format returned depends on the command variation.

MEASUREMENT COMMAND VARIATIONS

To enhance the error detection capability in SDI-12 data collection systems, variations of the **START NON-CONCURRENT MEASUREMENT** commands (**M**, **M1** ... **M9**) and **START CONCURRENT MEASUREMENT** commands **(C**, **C1**, ...**C9**) are available. One variation requests that the data be returned with a 16-bit **Cyclic Redundancy Check (CRC)** appended. It adds a **"C"** to command, such as **MC**, **MC1**, **CC**, or **CC1.** The number of measurements returned in response is the same as the measurements returned for a **non-CRC** command, but with a CRC appendage following them.

An example of such a command follows:

aMC!	Where "a" is the address character, "M" is a basic command to make a measurement, and "C" is the added command letter requesting a CRC appendage.

The sensor might respond with:

a0053	Acknowledging it is at address "a" and indicating that after 5 seconds, three (3) measurements will be ready to read with "**D0**" command.

When an "M" command measurement is complete, the sensor responds with an extra ***Service Request*** response.

a	Where "a" is the address character.

As in all of the other (non-CRC) "M" and "C" commands, a **"D0"** command must eventually be issued to get the data from the sensor. In its response, three data measurements and a CRC appendage are returned as follows:

a+3.14+2.718+1.414lpz	where ("**lpz"**) is the three-character CRC code appendage.

OTHER NON-CONCURRENT MEASUREMENTS

The SDI standard allows for several other *measurement* command variations, such as "**M1**," "**M2,**" and the like. The sensor supports the following ones:

aM1!	Measure psi using factory calibration. Does not apply user scaling, field calibration, or offsets. Returns 1 value and the units are fixed to psi.
aM2!	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!	Measure scale factors: user *slope*, user *offset*, and field calibration *offset*. Use this if you want to view user-entered values that can affect the value returned.
aM4!	Measure calibration lab slope and offset. Use this if you want to view the calibration lab values that can affect the value returned.
aM5!	This command requests *high accuracy PCB* (printed circuit board) *temperature. For the* **KPSI® 380 Series, this command requests the high accuracy nickel RTD temperature.**
aM6!	Measure internal battery and external voltages
aMC6!	Measure internal battery and external voltages w/CRC
aM7!	This command combines M0 and M2 for both pressure and temperature.
aM8!	Measure conductivity
aMC8!	Measure conductivity w/CRC
aM9!	Measure conductivity probe temperature
aMC9!	Measure conductivity probe temperature w/CRC

Remember to issue the "**D0**" command after the measurement is complete (as signaled by extra ***Service Request*** response), in order to retrieve the data.

OTHER CONCURRENT MEASUREMENTS

The SDI standard allows for other concurrent measurement commands, such as “C1,” “C2,” etc. The sensor supports the following optional concurrent measurements commands:

aC1!	Measure psi using factory calibration. Does not apply user scaling, field calibration, or offsets. Returns 1 value and the units are fixed to psi.
aC2!	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.
aC3!	Measure user scale factors: user *slope*, user *offset*, field calibration *offset*. Use this if you want to view user-entered values that can affect the value returned.
aC4!	Measure calibration lab slope and offset. Use this if you want to view the calibration lab values that can affect the value returned.
aC5!	This command requests a concurrent high accuracy printed circuit board (PCB) temperature. *For the* **KPSI 380 Series, this command requests the high accuracy nickel RTD temperature.**
aC6!	Measure internal battery and external voltages - Concurrent Mode
aCC6!	Measure internal battery and external voltages - Concurrent Mode w/CRC
aC7!	This command combines C0 and C2 for both pressure and temperature.
aC8!	Measure conductivity- Concurrent Mode
aCC8!	Measure conductivity- Concurrent Mode w/CRC
aC9!	Measure conductivity probe temperature Concurrent Mode
aCC9!	Measure conductivity probe temperature Concurrent Mode w/CRC

Remember to issue the “D0” command after the measurement is complete (after estimated time for completion expires), in order to retrieve the data.

CHANGING THE UNITS

PRESSURE

As previously stated, all *Start Measurement* commands can return the pressure in several different units. The selection of the units is made using the "XUP" command:

aXUPnd!	Where "n" is one of the selections from the following table and "d" is the signed (+) data display scaling (number of digits to the right of the decimal point) appropriate to the new units.

n	Units	Description
+0	ft of water	The conversion of feet of water uses the factor 2.3073 ft per psi.
+1	psi	Pounds per square inch (default conversion factor = 1)
+2	kPa	Kilopascal
+3	cm of water	The conversion factor is 70.3265 cm per psi.
+4	m of water	The conversion factor is 0.703265 m per psi.
+5	mm of water	The conversion factor is 703.265 mm per psi
+9	user units	The value has units that depend on the factor entered using the "XUU" command. See ***Setting User Units*** below.

For example, the following command to sensor "0:"

0XUP+0+2!

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

CONDUCTIVITY

As previously stated, all Start Measurement commands can return the conductivity in several different units. The selection of the units is made using the "XCR" and "XUC" command:

"**aXCR+k!"** **"aXRCR!"**	set conductivity range (0-7), 0 is auto-range. (uS/cm) Read the conductivity range

k	Min	Max
+0	Auto Range	
+1	0.01	35.0
+2	30.0	150.0
+3	120.0	880.0
+4	720.0	5,500.0
+5	4500.0	22,000.0
+6	18,000.0	107,000.0
+7	87,300.0	200,000.0

"aXUC+k!" **"aXRUC!"**	Set conductivity units index for : Siemens, Resistance, TDS, Salinity Read conductivity sensor units.

k	Units	Type
+0	S (Seimens)	Conductivity
+1	S/cm	Conductivity
+2	mS/cm	Conductivity
+3	uS/cm (default)	Conductivity
+4	Mohm*cm	Resistance
+5	mg/l	TDS
+6	ppt	Salinity

For example, the following command to sensor "0":

0XUC+3!

will specify the output to be in the default units (uS/cm) with a resolution of 2 decimal places.

SETTING USER UNITS

If you want the sensor to read out in units other than feet of water, psi, kPa, centimeters of water, meters of water, or millimeters of water 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 = psi * slope + offset

Where slope and offset are values you can enter into the system.

The "**XUU**" command is used to enter the user-defined scale factors. The format is:

aXUUso!	Where "s" is the signed *slope* and "o" is the signed *offset*.

For example, the following command will set the slope to 70.32 and the offset to 0.0 for sensor "0," which are the proper values to convert the psi to cm of water:

0XUU+70.32+0!

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

NOTE: REMEMBER THAT BOTH AN "XUU" AND AN "XUP" COMMAND ARE REQUIRED FOR THE SENSOR TO REPORT IN USER-DEFINED UNITS.

FIELD CALIBRATION

The sensor may have a change in the calibration over time. The most common change is a change in sensor zero (value read when the pressure is 0). The sensor has two commands that can be used to adjust for this change in zero. The "**XE**" command allows direct setting of an offset which will be added to the measurement to compensate for this drift:

aXEou!	Where "o" is the signed *field calibration offset value* with *units* "u:" +0=feet, +1=psi, +2=kPa, +3=cm, +4=m, +5=mm, and +9=user units.

For example, the command:

0XE+0.02+0!

would set the offset pressure of sensor at address "0" to 0.02 feet (u=+0).

The other command used to set the offset is the "**XS**" command, and it has two forms. The first form causes the sensor to make pressure readings and automatically compute a new offset:

aXS!	**Use this form of command only if you vent the sensor to the atmosphere.**

Use the second form when the sensor is at a stable known pressure.

aXSpu!	Where "p" represents the signed *known pressure value* and "u"= signed *units*.

For example, after venting the sensor at address "0" to the atmosphere, the following command would cause a new offset to be computed:

0XS!

If the same sensor was under pressure and stable at 4.65 feet of H_20, the following command would adjust the offset to ensure the 4.65-foot offset:

0XS+4.65+0!

If the same sensor was under pressure and stable at 5.00 psi, the following command would adjust the offset to ensure the 5.00-psi offset:

0XS+5.00+1!

When the sensor has completed self-calibration, the new offset is stored into memory. A response:

attt1

is returned by any of the above command forms. It indicates that command last send to sensor at address "a" will be complete in "ttt" seconds, and one (1) value (offset in units of psi) will be returned in the response to a subsequent "**D0**" command. The offset can also be displayed at any time using the "**M3**" command.

REMEMBER: THE UNITS FOR THE DISPLAYED FIELD CALIBRATION OFFSET WILL BE PSI, REGARDLESS OF THE UNITS YOU USED IN THE XSDU! COMMAND.

CONFIGURING THE AVERAGING TIME

The sensor supports user selectable averaging time for SDI-12 readings. The time period in seconds is specified with the following command

aXTt!	Where "t" is the signed *time in seconds*

The example command:

0XT+10!

will set the averaging time to 10 seconds for a sensor at address "0."

ALPHABETIC COMMAND REFERENCE

This section documents all the commands supported by the digital transducer. All commands are listed alphabetically in a large table with four (4) columns containing the following information:

Command	a 1-3 letter abbreviation (operation code) for the command,
Function	a functional description of the command,
Syntax	a complete rendering of the command's structure,
Sensor Response	a description of the response(s) returned by sensor.

Some commands require another special ***Get Data*** command ("**D0**") to follow them (*immediately* or after a delay of "ttt" seconds, as indicated by a parameter in the "main" response). Also, some command responses generate a "main" response, which is followed "ttt" seconds later by a second response: called the ***Service Request*** response. In both cases, a standalone colon (**:**) will indicate this required *following* relationship between two commands and two responses. To avoid unnecessary repetition of frequently-used parameter descriptions in the table entries, each occurrence of a simple "a" item always represents the ***address*** of the sensor. Also, "ttt" represents a common parameter of a "main" response: ***time in seconds*** until data will be ready to read with a following "**D0**" command. All responses end with a non-printable ***<CR><LF>*** character pair, which is not shown in the table.

Command	Function	Syntax	Sensor Response
a	***Acknowledge Active***	**a!**	a
?	***Get Unknown Address***	**?!**	a
		New in Version 1.2 of SDI-12 spec.	**Note:** Sensor must be only sensor on SDI-12 bus when this command given. Otherwise, a communications collision occurs when multiple sensors respond.

Command	Function	Syntax	Sensor Response
C or **C0**	***Start Concurrent Pressure Measurement*** **:** after which you must send the ***Get Data*** command:	**aC!** **:** **aD0!**	attt02 "02" is *number values* in "**D0**" resp: apu "p" is ± *pressure value*. "u" is *signed units* indicator. Units set by **"XUP"** command. If "**XUM + 1**" command executed then ± temperature value and units code (tu) also appended.
C1	***Start Concurrent Factory Pressure Measurement*** (pressure in psi, the factory calibrated value).	**aC1!** **:** **aD0!**	attt01 "01" is *number values* in "**D0**" resp: ap "p" is ± *pressure value* (psi).
C2	***Start Concurrent Temperature Measurement***	**aC2!** **:** **aD0!**	attt02 "02" is *number values* in "**D0**" resp.: atu "t" is *signed temperature*. "u" is *units*: +0=Celsius and +1=Fahrenheit. Use **"XUT"** command to set units.
C3	***Start Concurrent Scale Factor Measurement*** (user slope, user offset, and field calibration offset)	**aC3!** **:** **aD0!**	a00103 "03" is *number values* in "**D0**" resp.: asoc "s" is signed *user slope*. "o" is signed *user offset* (psi). "c" is signed *field cal. offset* (psi).
C4	***Start Concurrent Standards Lab Scale Factors Measurement*** (*calibration slope* and *calibration offset*)	**aC4!** **:** **aD0!**	a00102 "02" is *number values* in "**D0**" resp.: aso "s" is signed *cal. slope.* "o" is signed *cal. offset* (psi).

C5	***Start Concurrent High- Accuracy Temperature***	**aC5!** **:** **aD0!**	attt02 "02" is *number values* in "**D0**" resp.: atu "t" is signed *temperature*. "u" is *units*: +0=Celsius, +1=Fahrenheit. Use **"XUT"** command to set units.
C6	***Start Concurrent Battery Voltage Measurement***	**aC6!** **:** **aD0!**	a00201 "01" is *number values* in "**D0**" resp.: av "v" is signed *battery voltage*.
C7	***Start Concurrent Pressure and Temperature Measurement***	**aC7!** **:** **aD0!**	attt04 04 is *number values* in **D0** resp: aputu p is ±*pressure value*, 1st u is +*units* index. Units set by **"XUP"** command. t is ±*temperature value*, 2nd u is +0=Celsius or +1=Fahrenheit. Use **"XUT"** command to set units.
C8	**Start Concurrent Conductivity Measurement**	**aC8!**	attt02 "02" is *number values* in "**D0**" resp.: acu "c" is ± conductivity value, "u" is units: +3=µS/cm Use **"XUC"** command to set units
C9	***Start Concurrent Conductivity Probe Temperature Measurement***	**aC9!**	attt02 "02" is *number values* in "**D0**" resp.: atu "t" is *signed temperature*. "u" is *units*: +0=Celsius and +1=Fahrenheit. Use **"XUT"** command to set units.

D0	***Get Data***	**aD0!** **NOTE:** This command is only issued after a ***Start Measurement*** *(various* "**M**[v]" or "**C**[v]"*)* command. It should ***not*** be issued until *measurement time* (returned in response) has expired (or extra ***Service Request*** response has been received after a ***Start Non-Concurrent Measurement*** *(various* "**M**[v]"*)* command is issued. Example: **0D0!** (Send ***Get Data*** command to sensor "0")	av or apu avu or aputu or avv or avvv p is ± pressure value. t is ± temperature value. "v" is other non-specific value "u" is +*units* indicator (see pressure units tables for D0 in Section 5.5). Example: 0+10.23+0 If previous measurement command was an "**M**" or **"C"** above example response would be the "avu" form and would indicate that the water level of sensor "0" is at 10.23 feet. **NOTE:** If address is returned alone with no data and unit values, this indicated that there is no data available. Either a ***Start Measurement*** command was not issued, the command was aborted by sending a new command before the measurement time expired, or an expected ***Service Request*** response was not yet received.
I	***Identify Sensor***	**aI!**	a13-KPSI---500---hhh-ssssss-vvv 13 - Supports **SDI Version 1.3 commands** KPSI - Manufacturer 500 - Model number Hhh - ***Hardware revision*** Ssssss - Serial number vvv - Software revision

M **or** **M0**	***Start Non-Concurrent Pressure Measurement***	**aM!** **:** **aD0!**	attt2 : a (***Service Request*** response) "2" is *number values* in"**D0**" resp: apu or aputu "P" is ± *pressure* value "u" is +*units* indicator. Use **"XUP"** command to set units. If "**XUM +1**" command executed then ± temperature value and units code (tu) also appended.
M1	***Start Non-Concurrent Factory Pressure Measurement*** (factory calibrated value always in psi)	**AM1!** **:** **aD0!**	attt1 : a (***Service Request*** response) "1" is *number values* in"**D0**" resp: ap "p" is ± *pressure* value (psi)
M2	***Start Non-Concurrent Temperature Measurement***	**aM2!** **:** **aD0!**	attt2 : a (***Service Request*** response) "2" is *number values* in"**D0**" resp: atu "t" is signed *temperature* "u" is +*units*: 0=Celsius, 1=Fahrenheit. Use "**XUT** command to set units.
M3	***Start Non-Concurrent Scale Factor Measurement*** (user slope, user offset, and field calibration offset)	**aM3!** **:** **aD0!**	a0013 : a (***Service Request*** response) "3" is *number values* in"**D0**" resp: asoc "s" is signed *user slope* "o" is signed *user offset* (psi) "c" is signed *field cal. offset* (psi)

M4	***Start Non-Concurrent Standards Lab Scale Factor Measurement*** (standards lab *calibration slope* and *calibration offset*)	**aM4!** **:** **aD0!**	a0012 : a (***Service Request*** response) "2" is *number values* in"**D0**" resp: aso "s" is signed *cal. slope* "o" is signed *cal. offset* (psi)
M5	***Start Non-Concurrent High-Accuracy Temperature***	**aM5!** **:** **aD0!**	attt2 : a (***Service Request*** response) "2" is *number values* in"**D0**" resp: atu "t" is signed *temperature* "u" is +*units*: 0=Celsius, 1=Fahrenheit. Use "**XUT** command to set units.
M6	***Start Non-Concurrent Battery Voltage Measurement***	**aM6!** **:** **aD0!**	a0021 : a (***Service Request*** response) "01" is *number values* in"**D0**" resp: av "v" is the battery voltage.
M7	***Start Non-Concurrent Pressure and Temperature Measurement***	**aM7!** **:** **aD0!**	attt4 4 is *number values* in **D0** resp: aputu p is ±*pressure value*, 1st u is +*units* index. Units set by **"XUP"** command. t is ±*temperature value*, 2nd u is +0=Celsius or +1=Fahrenheit. Use **"XUT"** command to set units.

M8	***Start Non-Concurrent Conductivity Measurement***	**aM8!** **:** **aD0!**	attt2 : a (Service Request response) “2" is number values in“D0" resp: acu “c” is ± conductivity value, “u” is units: +3=µS/cm Use **“XUC”** command to set units
M9	***Start Non-Concurrent Conductivity Probe Temperature Measurement***	**aM9!** **:** **aD0!**	attt2 : a (***Service Request*** response) “2" is *number values* in“**D0**" resp: atu “t” is signed *temperature* “u” is +*units*: 0=Celsius, 1=Fahrenheit. Use “**XUT** command to set units.
R0 **R1** **.** **.** **.** **R9**	***Start Continuous Measurements*** (unimplemented)	**aR0!** **aR1!** **.** **.** **.** **AR9!**	a ***Note: address return indicates unimplemented command***
V	***Initiate Verify Sequence***	**aV!** **:** **aD0!**	a0013 : a (***Service Request*** response) aefg “e” is *executed:* +1=YES, +0=NO “f” is +*number unexpected interrupts* “g” is +*interrupt code* Example: a +1 + 0 + 0 is normal

XE	***Set Field Calibration Offset***	**aXEou!** "o" is signed *offset*. "u" is *units*: +0=feet of water, +1=psi. **:** **aD0!** Example: **aXE-0.05+0!** (set offset to -0.05 feet)	a0011 **:** a (***Service Request*** response) ***Service Request*** resp. returned in 001 seconds. "1" is *number values* in"**D0**" resp: ao "o" = signed *offset* value (psi)
XCR	***Set Conductivity Range***	**aXCR+k!** "k" is conductivity range (0-7). See chart under "Changing the Units – Conductivity"	a0032 : a (***Service Request*** response) ***Service Request*** resp. returned in 001 seconds. "1" is *number values* in"**D0**" resp:
XRCR	***Read Conductivity Range***	**aXRCR!** **:** **aD0!**	a00301 : a (Service Request response) Service Request resp. returned in 001 seconds. "1" is number values in"D0" resp: ao "o" = signed *range* value
XRUC	***Read Conductivity Sensor Units***	**aXRUC!** **:** **aD0!**	a00031 : a (Service Request response) Service Request resp. returned in 001 seconds. "1" is number values in"D0" resp: ao "o" = signed *unit* value

XS	***Recalculate Field Calibration Offset***	**aXS!** or **aXSdu!** "d" and "u" are optional signed values. When omitted, sensor is assumed to be vented to atmosphere. When supplied, "d" is desired reading for sensor and in units indicated by "u." The sensor will make a measurement and recalculate the field offset to ensure reading matches values entered. **:** **aD0!**	attt1 **:** a (***Service Request*** response) ***Service Request*** resp. returned in ttt seconds. "1" is *number values* in"**D0**" resp: ao "o" is new *offset* (psi).
XT	***Set Averaging Time***	**aXTt!** "t"= +*averaging time* in seconds (0 to 25)**:** **:** **aD0!**	a0011 **:** a (***Service Request*** response) ***Service Request*** resp. returned in 001 seconds. "1" is *number values* in "**D0**" resp.: as "s" = number samples to be averaged during selected time
XUC	***Set Conductivity Units***	**aXUC+k!** "k" is *conductivity units* (0-6). See chart under "Changing the Units – Conductivity"	a (Service Request response) Service Request resp. returned in 001 seconds.

XUM	***Set /Read Measurement Mode of M/M0, C/C0, MC/MC0, CC/CC0 Commands*** Drop optional argument [m] to Read mode	**aXUM[m]!** m=missing to read mode or m=+0 to set mode for *pressure data* only (default) or m=+1 to set mode for *pressure data* **and** *temperature data* just like **M7**/**C7**/**MC7**/**CC7** commands **:** **aD0!**	attt1 : a {***Service Request*** response) ***Service request*** resp. returned in m seconds. 1 is *number values* in **D0** resp. am m=+0 (Press.only) or m=+1(Press. and Temp)
XUP	***Set Pressure Units***	**aXUPn[d]!** n=+0 feet of water n=+1 psi n=+2 kPa n=+3 cm of water n=+4 m of water n=+5 mm of water n=+9 user units [+d=optional number of places to right of the decimal point] **:** **aD0!**	a0012 **:** a (***Service Request*** response) ***Service Request*** resp. returned in 001 seconds. "2" is *number values* in"**D0**" resp: **NOTE:** Make sure you use **XUU** command to set the slope and offset for the desired user units. aud "u" is +*units* selected. "d" is +*number of digits to right of decimal point*.
XUT	***Set Temperature Units***	**aXUTu!** "u"=+0: Celsius "u"=+1: Fahrenheit **:** **aD0!** Example: **aXUT+1!** (Set units =Fahrenheit)	a0011 **:** a (***Service Request*** response) ***Service Request*** resp. returned in 001 seconds. "1" is *number values* in"**D0**" resp: au "u" is +units selected.

XUU	***Set User Units***	**aXUUso!** “s” is signed *user slope*. “o” is signed *user offset*. User output = (psi) * user slope + user offset. **:** **aD0!** Example: **aXUU+27.63+0!** (27.63 inches per psi)	a0012 **:** a (***Service Request*** response) ***Service Request*** resp. returned in 001 seconds. “2” is *number values* in“**D0**” resp: aso “s” is user slope. “o” is user offset. **NOTE:** A slope of 0 is invalid. **NOTE:** Be sure units of pressure (“**XUP”**) are set to user units (9).

CALIBRATION

The sensors undergo a rigorous screening and testing at the factory before they are shipped, to ensure that they meet their accuracy specifications over temperature. Any drift in the zero of the unit can be easily checked by exposing the unit to atmosphere and performing a measurement. Any drift can be nulled out via the “**XS**” command. For optimum accuracy the offset drift should be nulled out at least every 6 months. The thermal calibration will remain accurate for the life of the transducer.

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.
	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 SDI-12 commands are capital letters. Make sure address is proper case and commands are upper case.
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, 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 field calibration offset using the M3 command and verify it. Re-calibrate the offset.
	Erroneous user slope and offset entered -- display the user slope and offset using the M3 command and verify.

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