Laser Technology, Inc.

TruSense® Sx00 & Sx10 Series

SDI-12 User's Manual

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1. INTRODUCTION

The Laser Technology, Inc. (LTI) TruSense® S-Series (TruSense S200, TruSense S210, TruSense S300 and TruSense S310) laser sensors for distance measurement, in addition to a standard serial RS-232 for configuration and reporting interface, also provide a standardized SDI-12 serial interface for measurement reporting and some configuration.

This manual provides a detailed description of the LTI-implemented SDI-12 commands of the SDI-12 communications protocol for the S200/S210/S300/S310. For more information on the SDI-12 basic commands, please refer to [2]. See [1] for the user's manual for additional information on the S200/S210/S300/S310 laser sensor operation and configuration.

The primary target audience for this manual is developers / O.E.M. systems integrators incorporating LTI S200/S210/S300/S310 laser sensors into end-systems solutions.

2. References

[1] Laser Technology, Inc., TruSense® S200 Series User's Manual, 7th Edition – 2014,
Laser Technology, Inc., TruSense® S300 Series User's Manual, 1th Edition – 2017
http://www.lasertech.com/TruSense-Laser-Sensor.aspx.

[2] SDI-12 – A **S**erial-**D**igital **I**nterface Standard for Microprocessor-Based Sensors, Version 1.3, January 28, 2016, http://www.sdi-12.org/.

3. S200 / S210 / S300 / S310 SDI-12 Configuration

To use the SDI-12 interface of the S200/S210/S300/S310 laser sensors, the sensors must first be configured to enable the SDI-12 interface. This configuration must be done via the standard serial interface commands (see [1]). The following outlines the S200/S210/S300/S310 configuration process to enable the SDI-12 communications:

1. If pass word is enabled enter the password (assumes default password) with "**`$PW,admin`**"
2. Enable the SDI-12 interface with the "**`$TG,5`**" command
3. Set the desired Measurement Mode with the "**`$MM`**" command (must be "**`$MM,0`**" to "**`$MM,2`**")
4. Set the desired Measurement Units and optional reported number of digits after the decimal point with the "**`$MU`**" command (the undocumented optional number of digits is configured with "**`$MM,u,n`**" with „u" setting the units and „n" setting the number of digits, „0" to „3")
5. Ensure the Target Mode is valid with the "**`$DM`**" command (must be "**`$DM,2`**" to "**`$DM,8`**")
6. The sensor Warm-up Period ("**`$WU`**") may also need to be adjusted to give a reasonable measurement start time
7. The pulses-per-measurement setting ("**`$OP`**") may also need to be adjusted to give a reasonable measurement response time, especially when making multiple measurements for each measurement request
8. Optionally enable SDI-12 debugging log output to the serial interface with the "**`$FK,1`**" command (the debugging log output can be disabled with the "**`$FK,0`**" command)
9. Save the settings with the "**$SU**" command

The S200/S210/S300/S310 laser sensor will reset and its SDI-12 interface is now configured for SDI-12 communications. Note that any SDI-12 initiated measurements are also reported on the serial interface as well, using the Target Mode "**`$DM`**" command configured format. See the user's manual [1] for the wiring diagrams to connect the S200/S210/S300/S310 sensor to an SDI-12 bus.

The SDI-12 configuration can be subsequently further refined using the LTI extended SDI-12 configuration commands "**`aXWn!`**" to set number of measurements to make for each measurement request and "**`aXCn!`**" to enable auto-start if continuous measurements are going to be used – see sections 4.4.35 and 4.4.29.

4. SDI-12 Data Communications

SDI-12 is a standard for interfacing data recorders with microprocessor-based sensors. SDI-12 stands for serial/digital interface at 1200 baud. It can connect multiple sensors with a single data recorder on one cable. It supports up to 200 feet (60 meter) of cable between a sensor and a data logger. This section describes the protocol for communications between the LTI S200/S210/S300/S310 laser sensors and SDI-12 data recorders complying with Version 1.3 of the SDI-12 standard[2].

4.1 S200 /S210 /S300 / S310 Measurement Retrieval Using SDI-12

The LTI S200/S210/S300/S310 laser sensors report the following types of distance measurement data: "**First #1**", "**Second #2**", "**Third #3**", "**Strongest**", and "**Last**" (plus its on-board temperature) Using the SDI-12 bus, the measurement data is obtained via two means:

- Indirectly, using a start measurement command followed by a retrieve measurement command (known as standard and concurrent measurements in SDI-12 terminology)
- Directly, using a request measurement command (known as continuous measurements in SDI-12 terminology)

The measurement data flow of the 5 types of S200/S210/S300/S310 measurement data (and temperature) associated with using the SDI-12 indirect and direct measurement data reporting is as follows: (see Figure A on Page 26)

- Indirect measurement data retrieval: (non-concurrent and concurrent measurements)
    1. a non-concurrent or concurrent measurement SDI-12 command must first be issued to take the measurement(s) for the specific measurement type
    2. the sensor reports how long it will take and how many measurements will be made
    3. the measurement(s) are placed in measurement buffer(s)
    4. after the time has expired, SDI-12 command(s) are then sent to retrieve the data from the measurement buffer(s) until all measurement data has been retrieved
- Direct measurement data retrieval: (continuous measurements)
    1. the S200/S210/S300/S310 sensor must be taking continuous measurements (i.e. Auto-start enabled – see 4.4.29)
    2. a continuous measurement SDI-12 command is issued to retrieve a specific measurement
    3. the latest available measurement data is returned as a response to the request

A distinct difference in the two methods of retrieving measurement data is in the certainty of the time origin of the measurement data. In the indirect measurement retrieval, the measurement data from **all** measurements requested can be retrieved (up to the limit of the room provided for in the measurement buffers). In the direct (continuous) measurement retrieval, only the latest available measurement is retrievable. All other prior measurements are no longer available. This also means that if the sensor is configured to take measurements at a very slow rate, the latest available measurement could be quite stale.

Note: The verification data ("aV!" command) is only available using the indirect measurement way.

4.2 SDI-12 Data Packet Formats

The S200/S210/S300/S310 responds to commands sent to it by an SDI-12 data recorder. Command packets should have the format:

<**a**><**command-data**>**!**

where:

- <**a**> is the S200/S210/S300/S310's SDI-12 address character (valid values are ASCII "`0` to `9`, `A` to `Z`, `a` to `z`", "`?`")
- <**command-data**> is a string of zero or more command dependent data characters (values in the range 0x20-0x7E {ASCII „space" to "~"}, excluding 0x21 (ASCII "`!`"))
- the packet command is terminated by 0x21 (ASCII "`!`")

NOTE: ALL SDI-12 COMMANDS ARE UPPER CASE.

Response packets have the format:

<**a**><**response-data**>[<**CRC**>]<**CR**><**LF**>

where:

- <**a**> is the S200/S210/S300/S310's SDI-12 address character
- <**response-data**> is a string of zero or more command dependent data characters (values in the range 0x20-0x7E {ASCII „space" to „~"})
- <**CRC**>, optionally available only with measurement responses, but when present, is a string of 3 characters encoding the 16-bit cyclic redundancy check of the response data from the address character through the character preceding the 1st CRC character (1st CRC character is in the range 0x40-0x4F, 2nd and 3rd CRC characters are in the range 0x40-0x7F)
- the packet is terminated by a carriage return followed by a line feed

The formats of the individual command/response packets that the S200/S210/S300/S310 supports are described in the following subsections.

S200/S210/S300/S310 SDI-12 Commands Implementation Notes:

- '`?`' can be used for '`a`' in any commands as a wildcard SDI-12 address if only 1 device is on the SDI-12 bus
- '`0`' is implied and can be left off of commands "`aD0!`", "`aR0!`", and "`aRC0!`"
- "`aM0!`" can be used in place of "`aM!`"
- "`aMC0!`" can be used in place of "`aMC!`"
- "`aC0!`" can be used in place of "`aC!`"
- "`aCC0!`" can be used in place of "`aCC!`"
- specified measurements ID:
  - "0" measurement is "**First #1**" measurement data
  - "1" measurement is "**Second #2**" measurement data
  - "2" measurement is "**Third #3**" measurement data
  - "3" measurement is "**Strongest**" measurement data
  - "4" measurement is "**Last**" measurement data
  - "5" measurement is on-board **Temperature** data

4.3 SDI-12 Commands Summary

LTI S200/S210/S300/S310 Supported SDI-12 Commands Summary.

Command	Response	Description
?!	a<CR><LF> *where*: a = sensor SDI-12 address	Address Query - Query for **any** device on the bus There must be only one device on the SDI-12 bus and it will respond with its SDI-12 address.
a!	a<CR><LF> *where*: a = sensor SDI-12 address	Acknowledge Active - Query for a **specific** device on the bus – there is no response if the specific device is not on the SDI-12 bus.
aI!	annccccccccmmmmmmvvvxxxxxxxxxxxxx<CR><LF> *where*: a = sensor SDI-12 address nn = SDI-12 compatibility version number (n.n) cccccccc = company name mmmmmm = sensor model vvv = sensor FW version number xxxxxxxxxxxx = sensor serial number	Query Identification - Query for sensor ID info example: "013LASERTECS200 476000403" address = 0 SDI-12 Version 1.3 LASERTEC S200 FW: 1.14-76 S/N: DS000403
aAb!	a<CR><LF> *where*: a = sensor's new SDI-12 address	Change Address - Change sensor's SDI-12 address This changes the sensor's SDI-12 address from address „a" to address „b".
aM! (aM0!)	atttn<CR><LF> *where*: a = sensor SDI-12 address ttt = the specified time, in seconds, until the sensor will have the data ready n = the number of measurement items Followed by, if „ttt" is non-zero, before „ttt" seconds: a<CR><LF> (i.e. service request – data ready) *where*: a = sensor SDI-12 address	Start Measurement "First #1" Use the "aD0!" command to retrieve up to the first 5 measurements of the "First #1" measurement data, then the "aD1!" command to retrieve up to the next 5 measurements of the "First #1" measurement data, then the "aD2!" command to retrieve up to the next 5 measurements of the "First #1" measurement data, then the "aD2!" command etc. until all measurements are retrieved
aM1!	The same as the "aM!" response.	Start Measurement "Second #2" The same as the "aM!" description except it's for the "Second #2" measurements.
aM2!	The same as the "aM!" response.	Start Measurement "Third #3" The same as the "aM!" description except it's for the "Third #3" measurements.
aM3!	The same as the "aM!" response.	Start Measurement "Strongest" The same as the "aM!" description except it's for the "Strongest" measurements.
aM4!	The same as the "aM!" response.	Start Measurement "Last" The same as the "aM!" description except it's for the "Last" measurements.
aM5!	The same as the "aM!" response.	Start Measurement "Temperature" The same as the "aM!" description except it's for the "Temperature" data.
aM6! – aM9!	a0000<CR><LF> *where*: a = sensor SDI-12 address 0000 = indication that these measurements are not supported	Start Additional Measurement (not supported)
aMC! (aMC0!)	The same as the "aM!" response.	Start Measurement "First #1" w/CRC The same as the "aM!" description except it's for the "First #1" measurements with CRC.
aMC1!	The same as the "aM!" response.	Start Measurement "Second #2" w/CRC The same as the "aM!" description except it's for the "Second #2" measurements with CRC.
aMC2!	The same as the "aM!" response.	Start Measurement "Third #3" w/CRC The same as the "aM!" description except it's for the "Third #3" measurements with CRC.
aMC3!	The same as the "aM!" response.	Start Measurement "Strongest" w/CRC The same as the "aM!" description except it's for the "Strongest" measurements with CRC.

Command	Response	Description
aMC4!	The same as the "aM!" response.	Start Measurement "Last" w/CRC The same as the "aM!" description except it's for the "Last" measurements with CRC.
aMC5!	The same as the "aM!" response.	Start Measurement "Temperature" w/CRC The same as the "aM!" description except it's for the "Temperature" data with CRC.
aMC6! – aMC9!	a0000<CR><LF> *where*: a = sensor SDI-12 address 0000 = indication that these measurements are not supported	Start Additional Measurement w/CRC (not supported)
aC! (aC0!)	atttnn<CR><LF> *where*: a = sensor SDI-12 address ttt = the specified time, in seconds, until the sensor will have the data ready nn = the number of measurement items	Start Concurrent Measurement "First #1" The same as the "aM!" description except it's for the "First #1" concurrent measurements.
aC1!	The same as the "aC!" response.	Start Concurrent Measurement "Second #2" The same as the "aM!" description except it's for the "Second #2" measurements.
aC2!	The same as the "aC!" response.	Start Concurrent Measurement "Third #3" The same as the "aM!" description except it's for the "Third #3" concurrent measurements.
aC3!	The same as the "aC!" response.	Start Concurrent Measurement "Strongest" The same as the "aM!" description except it's for the "Strongest" concurrent measurements.
aC4!	The same as the "aC!" response.	Start Concurrent Measurement "Last" The same as the "aM!" description except it's for the "Last" concurrent measurements.
aC5!	The same as the "aC!" response.	Start Concurrent Measurement "Temperature" The same as the "aM!" description except it's for the "Temperature" concurrent measurements.
aC6! – aC9!	a00000<CR><LF> *where*: a = sensor SDI-12 address 00000 = indication that these measurements are not supported	Start Additional Concurrent Measurement (not supported)
aCC! (aCC0!)	The same as the "aC!" response.	Start Concurrent Measurement "First #1" w/CRC The same as the "aM!" description except it's for the "First #1" measurements.
aCC1!	The same as the "aC!" response.	Start Concurrent Measurement "Second #2" w/CRC The same as the "aM!" description except it's for the "Second #2" measurements.
aCC2!	The same as the "aC!" response.	Start Concurrent Measurement "Third #3" w/CRC The same as the "aM!" description except it's for the "Third #3" measurements.
aCC3!	The same as the "aC!" response.	Start Concurrent Measurement "Strongest" w/CRC The same as the "aM!" description except it's for the "Strongest" measurements.
aCC4!	The same as the "aC!" response.	Start Concurrent Measurement "Last" w/CRC The same as the "aM!" description except it's for the "Last" measurements.
aCC5!	The same as the "aC!" response.	Start Concurrent Measurement "Temperature" w/CRC The same as the "aM!" description except it's for the "Temperature" measurements.
aCC6! – aCC9!	a00000<CR><LF> *where*: a = sensor SDI-12 address 00000 = indication that these measurements are not supported	Start Additional Concurrent Measurement w/CRC (not supported)

Command	Response	Description
aR0! (aR!)	a<value><CR><LF> *where*: a = sensor SDI-12 address <value> = pn.d *where*: p = the polarity sign („+" or „–„) n = numeric digits before the decimal point „." = the decimal point d = the numeric digits after the decimal point	Start Continuous Measurement "First #1" The maximum number of digits for a data value is 7. The minimum number of digits for a data value is 1. The maximum number of characters in a data value is 9 (polarity sign + 7 digits + decimal point).
aR1!	The same as the "aR0!" response.	Start Continuous Measurement "Second #2" The same as the "aR0!" description except it's for the "Second #2" measurements.
aR2!	The same as the "aR0!" response.	Start Continuous Measurement "Third #3" The same as the "aR0!" description except it's for the "Third #3" measurements.
aR3!	The same as the "aR0!" response.	Start Continuous Measurement "Strongest" The same as the "aR0!" description except it's for the "Strongest" measurements.
aR4!	The same as the "aR0!" response.	Start Continuous Measurement "Last" The same as the "aR0!" description except it's for the "Last" measurements.
aR5!	a+nn.n<CR><LF> *where*: a = sensor SDI-12 address + = sign of the on-board temperature value nn.n = the on-board temperature (°C)	Start Continuous Measurement "Temperature" The same as the "aR0!" description except it's for the "Temperature" data.
aR6! – aR9!	a<CR><LF> *where*: a = sensor SDI-12 address and nothing else indicating that these measurements are not supported	Start Additional Continuous Measurement (not supported)
aRC0! (aRC!)	a<values><CRC><CR><LF> *where*: a = sensor SDI-12 address <values> = pn.d *where*: p = the polarity sign („+" or „–„) and measurement separator character n = numeric digits before the decimal point „." = the decimal point d = the numeric digits after the decimal point <CRC> = the 3 character encoded 16-bit CRC of the response	Retrieve Continuous Measurement "First #1" w/CRC The maximum number of digits for a data value is 7. The minimum number of digits for a data value is 1. The maximum number of characters in a data value is 9 (polarity sign + 7 digits + decimal point).
aRC1!	The same as the "aRC0!" response.	Retrieve Continuous Measurement "Second #2" w/CRC The same as the "aRC0!" description except it's for the "Second #2" measurements.
aRC2!	The same as the "aRC0!" response.	Retrieve Continuous Measurement "Third #3" w/CRC The same as the "aRC0!" description except it's for the "Third #3" measurements.
aRC3!	The same as the "aRC0!" response.	Retrieve Continuous Measurement "Strongest" w/CRC The same as the "aRC0!" description except it's for the "Strongest" measurements.
aRC4!	The same as the "aRC0!" response.	Retrieve Continuous Measurement "Last" w/CRC The same as the "aRC0!" description except it's for the "Last" measurements.
aRC5!	a+nn.n<CRC><CR><LF> *where*: a = sensor SDI-12 address + = sign of the on-board temperature value nn.n = the on-board temperature (°C) <CRC> = the 3 character encoded 16-bit CRC of the response	Retrieve Continuous Measurement "Temperature" w/CRC The same as the "aRC0!" description except it's for the "Temperature" data.

Command	Response	Description
aRC6! – aRC9!	a<CRC><CR><LF> *where*: a = sensor SDI-12 address and nothing else indicating that these measurements are not supported <CRC> = the 3 character encoded 16-bit CRC of the response	Retrieve Additional Continuous Measurement w/CRC (not supported)
aD0! (aD!)	a<values><CR><LF> -or- a<values><CRC><CR><LF> *where*: a = sensor SDI-12 address <values> = pn.d where: p = the polarity sign („+" or „–„) and measurement separator character n = numeric digits before the decimal point „." = the decimal point d = the numeric digits after the decimal point <CRC> = the 3 character encoded 16-bit CRC of the response, appended if the data was requested with the "aMCn!" or "aCCn!" commands	Send Data – 1st Buffer of Measurement(s) or vendor-specific data from the "aV!" command The maximum number of digits for a data value is 7. The minimum number of digits for a data value is 1. The maximum number of characters in a data value is 9 (polarity sign + 7 digits + decimal point).
aD1! – aD6	The same as the "aD0!" response.	Send Data – Additional Buffers of Measurements (for up to 32 measurements) The same as the "aD0!" description.
aD7! – aD9	a<CR><LF> -or- a<CRC><CR><LF> *where*: a = sensor SDI-12 address and nothing else indicating that these measurements are not supported <CRC> = the 3 character encoded 16-bit CRC of the response, appended if the data was requested with the "aMCn!" or "aCCn!" commands	Send Data – Additional Buffers (not supported)
aV!	atttn<CR><LF> *where*: a = sensor SDI-12 address ttt = the specified time, in seconds, until the sensor will have the data ready n = the number of data items	Start Verification - Query for vendor-specific data example: "30006" *where*: 3 = sensor SDI-12 address 000 = ready immediately (0 seconds) 6 items Use the "aD0!" command to retrieve the vendor data example: "8+5+100+22+2+4+0" *where*: 8 = sensor SDI-12 address 5 = number of measurements to take 100 = 10.0 seconds between measurements 22 = "aXV22!" (i.e. "$WU,22") 2 = "$LS,2" (always weaker target) 4 = "$OP,16" (P.P.M. / 4) 0 = "$MM,0" (Standard Range)

Table 1. LTI S200/S210/S300/S310 Supported SDI-12 Standard Commands.

LTI S200/S210/S300/S310 Supported Extended SDI-12 Commands Summary.

Command	Response	Description
aXCn!	an<CR><LF> *where*: a = sensor SDI-12 address n = auto-start enabled (1), disabled (0)	Enable/disable auto-start n = 0 disables auto-start n = non-zero enables auto-start
aXMn!	an<CR><LF> *where*: a = sensor SDI-12 address n = number of measurements to make	Set/Get number of measurements to make n = 1 to 32
aXP!	ann<CR><LF> *where*: a = sensor SDI-12 address nn = period between measurements (1/10th secs)	Get measurement update period (currently, read-only) n = tenths of seconds
aXR!	aRESET<CR><LF> *where*: a = sensor SDI-12 address RESET = sensor reset confirmation	Reset sensor
aXS!	aSAVE<CR><LF> *where*: a = sensor SDI-12 address SAVE = sensor save settings confirmation	Save current configuration settings and reset sensor
aXVn!	aV0<CR><LF> *where*: a = sensor SDI-12 address V0 = ???	Turn the alignment laser pointer on/off (S210) Note: No programmatic indication of the laser pointer on/off status is available – only visual observation
aXWn!	an<CR><LF> *where*: a = sensor SDI-12 address n = number of discarded initial measurements	Set warm-up period – i.e. discarded initial measurements count n = 1 to 99 (cannot set to 0 to disable it, use "$WU,0" serial command)

Table 2. LTI S200/S210/S300/S310 Supported SDI-12 LTI–Extended Commands.

Measurement Data	SDI-12 Measurement Request Commands
"First" #1	"aC!", "aCC!", "aM!", "aMC!", "aR0!", "aRC0!"
"Second" #2	"aC1!", "aCC1!", "aM1!", "aMC1!", "aR1!", "aRC1!"
"Third" #3	"aC2!", "aCC2!", "aM2!", "aMC2!", "aR2!", "aRC2!"
"Strongest"	"aC3!", "aCC3!", "aM3!", "aMC3!", "aR3!", "aRC3!"
"Last"	"aC4!", "aCC4!", "aM4!", "aMC4!", "aR4!", "aRC4!"
Temperature	"aC5!", "aCC5!", "aM5!", "aMC5!", "aR5!", "aRC5!"
Verification	"aV!"
Any Buffered Data	"aD0!" to "aD9!"

Table 3. Summary of LTI S200/S210/S300/S310 SDI-12 Measurement Request/Retrieval Commands. (See Figure A on Page 26)

4.4 SDI-12 Commands Detailed Descriptions

This subsection provide detailed descriptions of the SDI-12 command support for the LTI S200/S210/S300/S310 laser sensors. Examples identify the command sent to the sensor is shown in **BLUE**, and the response is shown in **GREEN**.

4.4.1 "?!" Address Query

This command queries for **any** devices on the SDI-12 bus. There should only be one device on the SDI-12 bus when this command is issued as all devices will respond with their address, resulting in a corrupted received response if more than one device is responding.

Command: **?!** Response: **a<CR><LF>**

where: **?** = wildcard SDI-12 address
! = SDI-12 command termination character
a = responding sensor's SDI-12 address

Example: **?!8<CR><LF>** The responding sensor's SDI-12 address is "8".

4.4.2 "a!" Acknowledge Active

This command queries for a **specific** device on the SDI-12 bus by its address. If no device is on the SDI-12 bus at the specified address, there will be no response.

Command: **a!** Response: **a<CR><LF>**

where: a = specified sensor's SDI-12 address
! = SDI-12 command termination character

Example: **8!8<CR><LF>** The specified sensor responded.

4.4.3 "aI!" Send Identification

This command queries the S200/S210 for its SDI-12 compatibility level, company name, model number, firmware version, and serial number.

Command: **aI!** Response: **annccccccccmmmmmmvvvxxxxxxxxxxxxxx<CR><LF>**

where: a = specified sensor's SDI-12 address
I = Send Identification SDI-12 command
! = SDI-12 command termination character
nn = SDI-12 compatibility version number (n.n)
cccccccc = company name
mmmmmm = sensor model
vvv = sensor FW version number
xxxxxxxxxxxxx = sensor serial number

Example: **8I!813LASERTECS200 476000403<CR><LF>**.

where: sensor's SDI-12 address = "8"
SDI-12 version = "1.3"
company name = "LASERTEC"
sensor model = "S200" FW
version = "1.14-76"
serial number = "DS000403"

4.4.4 "aAb!" Change Address

This command is used to change the SDI-12 for the S200/S210/S300/S310 sensor. The S200/S210/S300/S310 sensor will reset after its SDI-12 address is changed.

Command: **aAb!** Response: **b<CR><LF>**

where: a = specified sensor's current SDI-12 address
A = Change Address SDI-12 command
b = sensor's new SDI-12 address ("0 to 9, A to Z, a to z")
! = SDI-12 command termination character

Example: **8A5!5<CR><LF>** The sensor's SDI-12 address changed from "8" to "5".

4.4.5 "aM!" Start Measurement for "First #1"

This command is used to request measurement(s) for the "First #1" measurement data. The "aD0!" command will then be used to retrieve the data when it's ready.

Command: **aM!** Response: **attt<CR><LF>**

where:
- a = specified sensor's current SDI-12 address
- **M** = Start Measurement for "First #1" measurement data SDI-12 command
- **!** = SDI-12 command termination character
- ttt = the specified time, in seconds, until the sensor will have data ready
- n = the number of measurements being accumulated

Example: **8M!80025<CR><LF>** The sensor will have 5 "First #1" measurements in 2 seconds. followed by: (in approximately 2 seconds)

8<CR><LF> Service Request – the measurements are ready.

4.4.6 "aM1!" Start Measurement for "Second #2"

This command is used to request measurement(s) for the "Second #2" measurement data. The "aD0!" command will then be used to retrieve the data when it's ready.

Command: **aM1!** Response: **attt<CR><LF>**

where:
- a = specified sensor's current SDI-12 address
- **M1** = Start Measurement for "First #2" measurement data SDI-12 command
- **!** = SDI-12 command termination character
- ttt = the specified time, in seconds, until the sensor will have data ready
- n = the number of measurements being accumulated

Example: **8M1!80025<CR><LF>** The sensor will have 5 "Second #2" measurements in 2 seconds. followed by: (in approximately 2 seconds)

8<CR><LF> Service Request – the measurements are ready.

4.4.7 "aM2!" Start Measurement for "Third #3"

This command is used to request measurement(s) for the "Third #3" measurement data. The "aD0!" command will then be used to retrieve the data when it's ready.

Command: **aM!** Response: **attt<CR><LF>**

where:
- a = specified sensor's current SDI-12 address
- **M2** = Start Measurement for "First #3" measurement data SDI-12 command
- **!** = SDI-12 command termination character
- ttt = the specified time, in seconds, until the sensor will have data ready
- n = the number of measurements being accumulated

Example: **8M2!80025<CR><LF>** The sensor will have 5 "Third #3" measurements in 2 seconds. followed by: (in approximately 2 seconds)

8<CR><LF> Service Request – the measurements are ready.

4.4.8 "aM3!" Start Measurement for "Strongest"

This command is used to request measurement(s) for the "Strongest" measurement data. The "aD0!" command will then be used to retrieve the data when it's ready.

Command: **aM3!** Response: **attt<CR><LF>**

where:
- a = specified sensor's current SDI-12 address
- **M3** = Start Measurement for "Strongest" measurement data SDI-12 command
- **!** = SDI-12 command termination character
- ttt = the specified time, in seconds, until the sensor will have data ready
- n = the number of measurements being accumulated

Example: **8M3!80025<CR><LF>** The sensor will have 5 "Strongest" measurements in 2 seconds. followed by: (in approximately 2 seconds)

8<CR><LF> Service Request – the measurements are ready.

4.4.9 "aM4!" Start Measurement for "Last"

This command is used to request measurement(s) for the "Last" measurement data. The "aD0!" command will then be used to retrieve the data when it's ready.

Command: **aM4!** Response: **atttn<CR><LF>**

where:
- a = specified sensor's current SDI-12 address
- **M4** = Start Measurement for "Last" measurement data SDI-12 command
- **!** = SDI-12 command termination character
- ttt = the specified time, in seconds, until the sensor will have data ready
- n = the number of measurements being accumulated

Example: **8M4!80025<CR><LF>** The sensor will have 5 "Last" measurements in 2 seconds.

followed by: (in approximately 2 seconds)

8<CR><LF> Service Request – the measurements are ready.

4.4.10 "aM5!" Start Measurement for "Temperature"

This command is used to request measurement(s) for the "Temperature" data. The "aD0!" command will then be used to retrieve the data when it's ready.

Command: **aM5!** Response: **atttn<CR><LF>**

where:
- a = specified sensor's current SDI-12 address
- **M5** = Start Measurement for "Temperature" measurement data SDI-12 command
- **!** = SDI-12 command termination character
- ttt = the specified time, in seconds, until the sensor will have data ready
- n = the number of measurements being accumulated

Example: **8M5!80015<CR><LF>** The sensor will have 5 "Temperature" data in 1 second.

followed by: (in approximately 1 second)

8<CR><LF> Service Request – the measurements are ready.

4.4.11 "aMCn!" Start Specified Measurement with CRC

These commands are used to request specified measurement(s) for the "First #1" "Second #2" "Third #3" "Strongest" "Last" measurement and temperature data and include the CRC when it's retrieved. The "aD0!" command will then be used to retrieve the data with the included CRC when it's ready. These commands are the same as the "aM!" through "aM5!" commands except that when the measurement data is retrieved, it will include a CRC.

Command: **aMCn!** Response: **atttn<CR><LF>**

where:
- a = specified sensor's current SDI-12 address
- **MCn** = Start Measurement for specified measurement data with CRC SDI-12 command (n = "0" to "5")
- **!** = SDI-12 command termination character
- ttt = the specified time, in seconds, until the sensor will have data ready
- n = the number of measurements being accumulated

Example: **8MC!800205<CR><LF>** The sensor will have 5 "First #1" measurements in 2 seconds.

followed by: (in approximately 2 seconds)

8<CR><LF> Service Request – the measurements are ready with CRC.

4.4.12 "aC!" Start Concurrent Measurement for "First #1"

This command is used to request concurrent measurement(s) for the "First #1" measurement data. The "aD0!" command will then be used to retrieve the data when it's ready.

Command: **aC!** Response: **atttnn<CR><LF>**

where:
- a = specified sensor's current SDI-12 address
- **C** = Start Concurrent Measurement for "First #1" measurement data SDI-12 command
- **!** = SDI-12 command termination character
- ttt = the specified time, in seconds, until the sensor will have data ready
- nn = the number of measurements being accumulated

Example: **8C!800205<CR><LF>** The sensor will have 5 "First #1" measurements in 2 seconds.

4.4.13 "aC1!" Start Concurrent Measurement for "Second #2"

This command is used to request concurrent measurement(s) for the "Second #2" measurement data. The "aD0!" command will then be used to retrieve the data when it's ready.

Command: **aC1!** Response: **atttnn<CR><LF>**

where:
- a = specified sensor's current SDI-12 address
- **C1** = Start Concurrent Measurement for "First #2" measurement data SDI-12 command
- **!** = SDI-12 command termination character
- ttt = the specified time, in seconds, until the sensor will have data ready
- nn = the number of measurements being accumulated

Example: **8C1!800205<CR><LF>** The sensor will have 5 "Second #2" measurements in 2 seconds.

4.4.14 "aC2!" Start Concurrent Measurement for "Third #3"

This command is used to request concurrent measurement(s) for the "Third #3" measurement data. The "aD0!" command will then be used to retrieve the data when it's ready.

Command: **aC2!** Response: **atttnn<CR><LF>**

where:
- a = specified sensor's current SDI-12 address
- **C2** = Start Concurrent Measurement for "First #3" measurement data SDI-12 command
- **!** = SDI-12 command termination character
- ttt = the specified time, in seconds, until the sensor will have data ready
- nn = the number of measurements being accumulated

Example: **8C2!800205<CR><LF>** The sensor will have 5 "Third #3" measurements in 2 seconds.

4.4.15 "aC3!" Start Concurrent Measurement for "Strongest"

This command is used to request concurrent measurement(s) for the "Strongest" measurement data. The "aD0!" command will then be used to retrieve the data when it's ready.

Command: **aC3!** Response: **atttnn<CR><LF>**

where:
- a = specified sensor's current SDI-12 address
- **C3** = Start Concurrent Measurement for "Strongest" measurement data SDI-12 command
- **!** = SDI-12 command termination character
- ttt = the specified time, in seconds, until the sensor will have data ready
- nn = the number of measurements being accumulated

Example: **8C3!800205<CR><LF>** The sensor will have 5 "Strongest" measurements in 2 seconds.

4.4.16 "aC4!" Start Concurrent Measurement for "Last"

This command is used to request concurrent measurement(s) for the "Last" measurement data. The "aD0!" command will then be used to retrieve the data when it's ready.

Command: **aC4!** Response: **atttnn<CR><LF>**

where:
- a = specified sensor's current SDI-12 address
- **C4** = Start Concurrent Measurement for "Last" measurement data SDI-12 command
- **!** = SDI-12 command termination character
- ttt = the specified time, in seconds, until the sensor will have data ready
- nn = the number of measurements being accumulated

Example: **8C4!800205<CR><LF>** The sensor will have 5 "Last" measurements in 2 seconds.

4.4.17 "aC5!" Start Concurrent Measurement for "Temperature"

This command is used to request concurrent measurement(s) for the "Temperature" data. The "aD0!" command will then be used to retrieve the data when it's ready.

Command: **aC5!** Response: **atttnn<CR><LF>**

where:
- a = specified sensor's current SDI-12 address
- **C5** = Start Concurrent Measurement for "Temperature" measurement data SDI-12 command
- **!** = SDI-12 command termination character
- ttt = the specified time, in seconds, until the sensor will have data ready
- nn = the number of measurements being accumulated

Example: **8C4!800105<CR><LF>** The sensor will have 5 "Temperature" data in 1 second.

4.4.18 "aCCn!" Start Specified Concurrent Measurement with CRC

These commands are used to request specified concurrent measurement(s) for the "First #1" "Second #2" "Third #3" "Strongest" "Last" measurement and temperature data and include the CRC when it's retrieved. The "aD0!" command will then be used to retrieve the data with the included CRC when it's ready. These commands are the same as the "aC!" through "aC5!" commands except that when the measurement data is retrieved, it will include a CRC.

Command: **aCCn!** Response: **atttnn<CR><LF>**

where:
- a = specified sensor's current SDI-12 address
- **CCn** = Start Concurrent Measurement for specified measurement data with CRC SDI-12 command (n = "0" to "5")
- **!** = SDI-12 command termination character
- ttt = the specified time, in seconds, until the sensor will have data ready
- nn = the number of measurements being accumulated

Example: **8CC!800205<CR><LF>** The sensor will have 5 "First #1" measurements in 2 seconds.

4.4.19 "aR0!" Start Continuous Measurement for "First #1"

This command is used to request a continuous measurement for the "First #1" measurement data. The sensor must be in Auto-start continuous measurement mode.

Command: **aR0!** Response: **a<value><CR><LF>**

where:
- a = specified sensor's current SDI-12 address
- **R0** = Start Continuous Measurement for "First #1" measurement data SDI-12 command
- **!** = SDI-12 command termination character
- **<value>** = pn.d

  where:
  - p = the polarity sign ("+" or "–")
  - n = the numeric digits before the decimal point
  - „." = the decimal point
  - d = the numeric digits after the decimal point

Example: **8R0!8+14.029<CR><LF>** The measurement value is "+14.029".

4.4.20 "aR1!" Start Continuous Measurement for "Second #2"

This command is used to request a continuous measurement for the "Second #2" measurement data. The sensor must be in Auto-start continuous measurement mode.

Command: **aR1!** Response: **a<value><CR><LF>**

where:
- a = specified sensor's current SDI-12 address
- **R1** = Start Continuous Measurement for "First #2" measurement data SDI-12 command
- **!** = SDI-12 command termination character
- **<value>** = pn.d
  where:
  - p = the polarity sign ("+" or "–")
  - n = the numeric digits before the decimal point
  - "." = the decimal point
  - d = the numeric digits after the decimal point

Example: **8R1!8+14.029<CR><LF>** The measurement value is "+14.029".

4.4.21 "aR2!" Start Continuous Measurement for "Third #3"

This command is used to request a continuous measurement for the "Third #3" measurement data. The sensor must be in Auto-start continuous measurement mode.

Command: **aR2!** Response: **a<value><CR><LF>**

where:
- a = specified sensor's current SDI-12 address
- **R2** = Start Continuous Measurement for "First #3" measurement data SDI-12 command
- **!** = SDI-12 command termination character
- **<value>** = pn.d
  where:
  - p = the polarity sign ("+" or "–")
  - n = the numeric digits before the decimal point
  - "." = the decimal point
  - d = the numeric digits after the decimal point

Example: **8R2!8+14.029<CR><LF>** The measurement value is "+14.029".

4.4.22 "aR3!" Start Continuous Measurement for "Strongest"

This command is used to request a continuous measurement for the "Strongest" measurement data. The sensor must be in Auto-start continuous measurement mode.

Command: **aR3!** Response: **a<value><CR><LF>**

where:
- a = specified sensor's current SDI-12 address
- **R3** = Start Continuous Measurement for "Strongest" measurement data SDI-12 command
- **!** = SDI-12 command termination character
- **<value>** = pn.d
  where:
  - p = the polarity sign ("+" or "–")
  - n = the numeric digits before the decimal point
  - "." = the decimal point
  - d = the numeric digits after the decimal point

Example: **8R3!8+14.029<CR><LF>** The measurement value is "+14.029".

4.4.23 "aR4!" Start Continuous Measurement for "Last"

This command is used to request a continuous measurement for the "Last" measurement data. The sensor must be in Auto-start continuous measurement mode.

Command: **aR4!** Response: **a<value><CR><LF>**

where:
- a = specified sensor's current SDI-12 address
- **R4** = Start Continuous Measurement for "Last" measurement data SDI-12 command
- **!** = SDI-12 command termination character
- **<value>** = pn.d
  where:
  - p = the polarity sign („+" or „–„)
  - n = the numeric digits before the decimal point
  - „." = the decimal point
  - d = the numeric digits after the decimal point

Example: **8R4!8+14.029<CR><LF>** The measurement value is "+14.029".

4.4.24 "aR5!" Start Continuous Measurement for "Temperature"

This command is used to request a continuous "Temperature" data. The sensor must be in Auto-start continuous measurement mode.

Command: **aR5!** Response: **a<value><CR><LF>**

where:
- a = specified sensor's current SDI-12 address
- **R5** = Start Continuous Measurement for "Temperature" data SDI-12 command
- **!** = SDI-12 command termination character
- **<value>** = pn.d
  where:
  - p = the polarity sign („+" or „–„)
  - n = the numeric digits before the decimal point
  - „." = the decimal point
  - d = the numeric digits after the decimal point

Example: **8R5!8+37.3<CR><LF>** The temperature value is "+37.3 °C".

4.4.25 "aRCn!" Start Specified Continuous Measurement with CRC

These commands are used to request specified continuous measurements for the "Last" the "First #1" "Second #2" "First #3" "Strongest" "Last" measurement and temperature data and include the CRC. The sensor must be in Auto-start continuous measurement mode.

Command: **aRCn!** Response: **a<value><CRC><CR><LF>**

where:
- a = specified sensor's current SDI-12 address
- **RCn** = Start Continuous Measurement for specified measurement data with CRC SDI-12 command (n = „0" to „5")
- **!** = SDI-12 command termination character
- **<value>** = pn.d
  where:
  - p = the polarity sign („+" or „–„)
  - n = the numeric digits before the decimal point
  - „." = the decimal point
  - d = the numeric digits after the decimal point
- **<CRC>** = the 3 character encoded 16-bit CRC of the response

Example: **8RC4!8+14.017CQq<CR><LF>** The "Last" measurement value is "+14.017" with "CQq" the encoded CRC.

4.4.26 "aD0!" Send Data

This command is used to request the first measurement buffer data after measurement(s) are completed after an "aM!", "aMCn!", "aC!", "aCCn!", or "aV!" command. The amount of measurement data returned depends on the number of measurements taken. "aM!" and "aMCn!" commands can report up to 5 measurements. "aC!" and "aCCn!" commands can report up to 10 measurements. The "aV!" command reports 6 items.

Command: **aD0!** Response: **a<values><CR><LF>**

–or–

Response: **a<values><CRC><CR><LF>**

where: a = specified sensor's current SDI-12 address

D0 = Send Data SDI-12 command for first measurement buffer

! = SDI-12 command termination character

<values> = pn.d

where:

p = the polarity sign („+" or „–„) and measurement separator character

n = the numeric digits before the decimal point

„." = the decimal point

d = the numeric digits after the decimal point

<CRC> = the 3 character encoded 16-bit CRC of the response

Example: **8D0!8+14.012+14.022+0.125+14.017+14.010<CR><LF>**

The measurement values are "+14.012", "+14.022", "+0.125", ."+14.017", "+14.010".

Example: **8D0!+14.023+14.016+14.021+14.025Cbp<CR><LF>**

The measurement values are "+14.023", "+14.016", "+14.021", "+14.025" and the encoded CRC is "Cbp".

Example: **8D0!8+5+100+10+2+20+0<CR><LF>** The "aV!" verification values are:

8 = sensor SDI-12 address
5 = number of measurements to take
100 = 10.0 seconds between measurements
10 = "aXV10!" (i.e. "$WU,10")
2 = "$LS,2" (always weaker target)
20 = "$OP,80" (P.P.M. / 4)
0 = "$MM,0" (Standard Range)

4.4.27 "aD1!" to "aD9!" Send Additional Data

These commands are used to request the additional measurement buffer data after measurement(s) are completed after an "aM!", "aMCn!", "aC!", or "aCCn!" command. The amount of measurement data returned depends on the number of measurements taken. "aM!" and "aMCn!" commands can report up to 5 measurements per buffer. "aC!" and "aCCn!" commands can report up to 10 measurements per buffer. A data request for a buffer that is empty will return nothing but its SDI-12 address (and the CRC if the previous measurement request specified a CRC). The S200/S210 sensor can take up to 32 measurements per measurement request. The measurements data is placed into the D0 buffer first, and then when it is full, additional measurements data is placed into the D1 buffer until it is full, followed by the D2 buffer, etc. until all measurements (up to 32) have been stored in the measurements buffers.

Command: **aDn!** Response: **a<values><CR><LF>**
–or–
Response: **a<values><CRC><CR><LF>**

where: a = specified sensor's current SDI-12 address
Dn = Send Data SDI-12 command for the specified measurement buffer (n = „1" to „9")
! = SDI-12 command termination character
<values> = pn.d (or nothing if the buffer is empty)
where:
p = the polarity sign („+" or „–„) and measurement separator character
n = the numeric digits before the decimal point
„." = the decimal point
d = the numeric digits after the decimal point
<CRC> = the 3 character encoded 16-bit CRC of the response

Example: **8D0!8+14.012+14.022+0.125+14.017+14.010<CR><LF>**
The measurement values are "+14.012", "+14.022", "+0.125", "+14.017", "+14.010".

Example: **8D0!+14.023+14.016+14.021+14.025Cbp<CR><LF>**
The measurement values are "+14.023", "+14.016", "+14.021", "+14.025" and the encoded CRC "Cbp".

Example: **8D4!8<CR><LF>** The buffer is empty.

Example: **8D4!8MHA<CR><LF>** The buffer is empty and the encoded CRC is "MHA".

4.4.28 "aV!" Start Verification

This command is used to request various S200/S210/S300/S310 configuration settings. The "aD0!" command will then be used to retrieve the data when it's ready.

Command: **aV!** Response: **atttn<CR><LF>**

where: a = specified sensor's current SDI-12 address
V = Start Verification SDI-12 command
! = SDI-12 command termination character
ttt = the specified time, in seconds, until the sensor will have data ready
n = the number of items being accumulated

Example: **8M!80006<CR><LF>** The sensor has 6 items ready immediately. See section 4.4.26 for example configuration settings data.

The six configuration settings items returned are:

1. the current measurement iteration count ("aXMn!" or „n" in "$GO,n,m")
2. the current measurement update period („m" in "$GO,n,m" – in tenths of seconds)
3. the current warm-up period ("aXWn!" or "$WU")
4. the current long range scan mode ("$LS")
5. the current P.P.M. value divided by 4 ("$OP")
6. the current measurement mode ("$MM")

4.4.29 "aXCn!" Enable/Disable Auto-Start Mode

This LTI-proprietary SDI-12 extended command enables or disables auto-starting of continuous measurements by the S200/S210/S300/S310. To obtain measurement data with the "aRn" continuous measurements commands, the S200/S210/S300/S310 sensor must have its auto-start mode enabled. The S200/S210/S300/S310 sensor will reset after its auto-start mode is changed. This corresponds to the "$MA,ma" serial command.

Command: **aXCn!** Response: **an<CR><LF>**

where:	a	= specified sensor's current SDI-12 address
	XC	= Enable/Disable Auto-Start Mode extended SDI-12 command
	n	= enable/disable value ("0" = disable, non-0 = enable – responds with "1")
	!	= SDI-12 command termination character

Example: **8XC1!81<CR><LF>** The sensor's auto-start mode has been enabled.

Note: Do **not** send "aXC!" (without the "n" value) in an attempt to query for the current Auto-Start setting. This will actually enable the Auto-Start mode!

4.4.30 "aXMn!" Set Number of Measurements to Make

This LTI-proprietary SDI-12 extended command configures the number of measurements that should be made by the S200/S210 sensor when a start measurement request is issued. This allows multiple measurements to be reported after a measurement request. This corresponds to the „n" in the "$GO,n,m" serial command.

Command: **aXMn!** Response: **an<CR><LF>**

where:	a	= specified sensor's current SDI-12 address
	XM	= Set Number of Measurements to Make extended SDI-12 command
	n	= the number of measurements to make (1 to 32)
	!	= SDI-12 command termination character

Example: **8XM12!812<CR><LF>** The sensor is set to make 12 measurements.

Note: Sending "aXM!" (without the „n" value) can be used to query for the current number of measurements to make setting.

4.4.31 "aXP!" Get Measurement Update Period

This LTI-proprietary SDI-12 extended command reports the period between measurements setting that is used by the S200/S210 sensor configured for multiple measurements per measurement request when a start measurement request is issued. This currently is only a read-only value. This corresponds to the "m" (in tenths of seconds, however) in the "$GO,n,m" serial command.

Command: **aXP!** Response: **an<CR><LF>**

where:	a	= specified sensor's current SDI-12 address
	XP	= Get Measurement Update Period extended SDI-12 command
	n	= the period between multiple measurements (in tenths of seconds)
	!	= SDI-12 command termination character

Example: **8XP15!815<CR><LF>** The sensor is set to make measurements every 1.5 seconds.

4.4.32 "aXR!" Reset Instrument

This LTI-proprietary extended command resets the S200/S210/S300/S310 sensor. This corresponds to the "$PD" serial command.

Command: **aXR!** Response: **aRESET<CR><LF>**

where:	a	= specified sensor's SDI-12 address
	XR	= Reset Instrument extended SDI-12 command
	!	= SDI-12 command termination character
	RESET	= confirmation that the reset is about to occur

Example: **8XR!8RESET<CR><LF>** The sensor has reset.

4.4.33 "aXS!" Save Current Settings

This LTI-proprietary SDI-12 extended command saves the current configuration settings in non-volatile memory in the S200/S210/S300/S310 sensor. The sensor is reset after the settings are saved. This corresponds to the "$SU" serial command.

Command:	**aXS!**		Response: **aSAVE<CR><LF>**
	where:	a	= specified sensor's SDI-12 address
		XS	= Save Settings extended SDI-12 command
		!	= SDI-12 command termination character
		SAVE	= confirmation that the configuration settings are about to be saved
	Example:	**8XS!8SAVE<CR><LF>**	The sensor has saved its settings and reset.

4.4.34 "aXVn!" Turn Alignment Laser Pointer On/Off

This LTI-proprietary SDI-12 extended command turns the alignment laser pointer on the S210/S310 sensor on or off. This corresponds to the "$V0" and "$VF" serial commands. This command is for the S210/S310 laser sensors only – the S200/S300 does not have an alignment laser pointer. (Note: No mechanism, SDI-12 or serial command, is provided to determine the current status of the laser pointer – except visually!)

Command:	**aXVn!**		Response: **aV0<CR><LF>**
	where:	a	= specified sensor's current SDI-12 address
		XV	= Alignment Turn Laser Pointer On/Off extended SDI-12 command
		n	= on/off value ("1" = on, other digit = off)
		!	= SDI-12 command termination character
		V0	= confirmation that the command was accepted
	Example:	**8XV1!8V0<CR><LF>**	The S210 sensor turned on the laser pointer.

Note: Do **not** send "aXV!" (without the "n" value) in an attempt to query for the current alignment laser pointer setting. This will actually turn off the alignment laser pointer!

4.4.35 "aXWn!" Set Warm-Up Period

This LTI-proprietary SDI-12 extended command configures number of initial measurement laser firings which will be discarded before the first measurement is available. This corresponds to the "$WU,n" serial command. Note: The warm-up period cannot be disabled by this command – the serial "$WU,0" command must be used to do that.

Command:	**aXWn!**		Response: **an<CR><LF>**
	where:	a	= specified sensor's current SDI-12 address
		XW	= Set Warm-Up Period extended SDI-12 command
		n	= the number of initial discarded measurement laser firings (1 to 99)
		!	= SDI-12 command termination character
	Example:	**8XW10!810<CR><LF>**	The sensor is set to a warm-up period of 10 discarded measurement laser firings.

Note: Sending "aXW!" (without the "n" value) can be used to query for the current warm-up period setting.

5. S200 / S210 /S300 / S310 SDI-12 FAQ & Troubleshooting

1. No measurement data reported with the "aRn!" command
   - S200/S210/S300/S310 not in continuous measurement auto-start (“aXC1!” or "$GO,0") mode
2. How to read the on-board temperature
   - use "aM5!" command to get temperature measurement followed by "aD0!" to retrieve the temperature
   - if in continuous measurement auto-start (“aXC1!” or "$GO,0") mode, use "aR5!" command to get temperature
3. How to read the vender verification data
   - use "aV!" command to request to get the data followed by "aD0!" to retrieve it
   - (note: currently (FW 1.14-76), "aD0!" to "aD9!" all retrieve the same data)
4. How to request and read multiple measurements
   - use "aXMn!" command to specify 'n' measurements to be made on each request
   - use "aMn!" command to request the specified 'n'-type measurements
     i. (the response will indicate how long it will take and the # measurements to be made
   - note: the # measurements is not entirely accurate!)
   - use "aD0!" retrieve first few measurements of the data (35 characters maximum)
   - use "aD1!" retrieve next few measurements of the data (35 characters maximum)
   - use "aD2!" retrieve next few measurements of the data (35 characters maximum)
   - etc. until all measurements (no buffer data) have been retrieved
5. How to request and read specific LTI S200/S210.S300/S310 measurements
   - the S200/S210/S300/S310 can report 5 types of measurements plus on-board temperature
     - "First" #1, "First" #2, "First" #3, "Strongest", "Last"
   - for standard non-concurrent measurements:
     - use "aM!" command to request "First" #1 measurements followed by "aD0!" to retrieve them
     - use "aM1!" command to request "First" #2 measurements followed by "aD0!" to retrieve them
     - use "aM2!" command to request "First" #3 measurements followed by "aD0!" to retrieve them
     - use "aM3!" command to request "Strongest" measurements followed by "aD0!" to retrieve them
     - use "aM4!" command to request "Last" measurements followed by "aD0!" to retrieve them
     - use "aM5!" command to request the on-board temperature value followed by "aD0!" to retrieve it
   - for concurrent measurements:
     - use "aC!" command to request "First" #1 measurements followed by "aD0!" to retrieve them
     - use "aC1!" command to request "First" #2 measurements followed by "aD0!" to retrieve them
     - use "aC2!" command to request "First" #3 measurements followed by "aD0!" to retrieve them
     - use "aC3!" command to request "Strongest" measurements followed by "aD0!" to retrieve them
     - use "aC4!" command to request "Last" measurements followed by "aD0!" to retrieve them
     - use "aC4!" command to request "Last" measurements followed by "aD0!" to retrieve them
     - use "aC5!" command to request the on-board temperature value followed by "aD0!" to retrieve it

- for continuous measurements:
  - use "aR!" command to request and retrieve the latest "First" #1 measurement
  - use "aR1!" command to request and retrieve the latest "First" #2 measurement
  - use "aR2!" command to request and retrieve the latest "First" #3 measurement
  - use "aR3!" command to request and retrieve the latest "Strongest" measurement
  - use "aR4!" command to request and retrieve the latest "Last" measurement
  - use "aR5!" command to request and retrieve the on-board temperature value

Note: The measurement data is stored in measurement data buffers (D0 to D9), which can hold up to a maximum of 5 measurements each for standard non-concurrent measurements and can hold up to a maximum of 10 measurements each for concurrent measurements. If the "aXMn!" command's specified number of measurements to make for each measurement request exceeds the number of measurements which can be held in a single buffer, subsequent "aD1!", "aD2!", etc. requests must be made to get the additional measurements data.

9. Which SDI-12 responses contain a CRC?

- all "aDn!" responses following a previous "aCCn" and "aMCn" measurement requests
- all "aRCn!" responses

10. How to detect if a CRC is in an SDI-12 response

- The CRC is the last 3 characters in a "aDn!" or "aRCn!" response. These characters will be ASCII characters '@' to '~' and DEL (0x40 to 0x7f), while the actual measurement response values are polarity, decimal point, and digit characters ('+', '-', '.', '0' to '9'). The CRC encompasses all response characters beginning at the address character up to, but not including, the first CRC character.

11. How to parse the returned measurement data

- The "aDn!" responses can contain multiple items of measurement data. Each item is in the form of “pn.d” when „p‟ is the polarity sign, „n‟ is the numeric digits before the decimal point, „.‟ is the decimal point, and „d‟ is the numeric digits after the decimal point. When multiple items are returned, the polarity sign is also the item separator character (e.g. the beginning of a data item).

12. What is the difference between the non-concurrent measurement "aM!", "aM1!" to "aM9!" commands and the concurrent measurement "aC!", "aC1!" to "aC9!" commands?

- With the non-concurrent measurement commands, if the "ttt" value in "atttn" response is non-zero, a Service Request is sent by the sensor when the measurement data is ready, at which time the data logger can retrieve the measurement data. The data logger cannot access any devices on the SDI-12 bus during the measurement in progress as that will abort the measurement. Also, the measurement data measurement data buffers (D0 to D9) can only hold up to a maximum of 5 non-concurrent measurements each.
- With the concurrent measurement commands, no Service Request is sent by the sensor and the data logger cannot retrieve the measurement data until the "ttt" time in "atttnn" response has been elapsed. However, the data logger can access other devices on the SDI-12 bus in the interim, but cannot access a device that has measurement in progress as that will abort the measurement for that device. Also, the measurement data measurement data buffers (D0 to D9) can hold up to a maximum of 10 concurrent measurements each.

13. What SDI-12 addresses are supported by the LTI S200/S210 laser sensors?

- All valid SDI-12 addresses are supported: '0' to '9', 'A' to 'Z', and 'a' to 'z'. The wildcard address „?‟ can also be used to communicate SDI-12 commands to the S200/S210 if it is the only device on the SDI-12 bus.

14. What is the amount of time needed for measurements to occur?

- The "ttt" value in the "atttn" response to non-concurrent "aMn!" and the "atttnn" response to concurrent measurements ("aCn!") depends on many factors in the configuration of the laser sensor:
  - the number of measurements made per measurement request ("aXMn!")
  - the sensor Warm-up Period ("aXWn!")
  - the pulses-per-measurement setting ("$OP")
  - the measurement update period (the "p.p" value in "$GO,n,p.p" as reported by the "aXP!" command)
  - the reflective quality and distance of the measured target(s)

- possibly the measurement mode ("$MM")
- possibly the long-range scan mode ("$LS")

Note: The values of several of these settings can be requested by the "aV!" command followed by the "aD0!" command to retrieve them.

15. What are the units of the retrieved measurements data?

- The units and number of decimal places reported are determined by the "$MU" serial command.

6. S200 / S210 /S300 / S310 SDI-12 Operational Issues

This document is based on the observations of the SDI-12 operational behavior of an S200 with FW 1.4-76 (and an S210 with FW 1.4-68) and several non-conforming SDI-12 issues and other unexpected behavior were noticed. This section describes those issues and behaviors.

1. If a measurement reports no data in replies to the M/MC commands, there is an immediate Service Request (primarily noticeable in the M6/MC6 to M9/MC9 commands)
   - this is out of compliance with the SDI-12 spec. [2] (see: section 4.4.6 last paragraph, last sentence)
2. The M/MC commands replies do **not** report the total number of measurements expected (only up to 5, but additional measurements can be read using the D1, D2, etc. commands)
   - this is out of compliance with the SDI-12 spec. [2] (see: sections 4.4.5 and 4.4.8 and 4.4.8.4 example c)
3. The **first** M/MC commands replies after the P.P.M. ($OP) is changed do **not** correctly reflect the change in the ready time reported, but the actual time before the Service Request is issued is correct
   - this is out of compliance with the SDI-12 spec. [2] (see: sections 4.4.5 and 4.4.6 and 4.4.7)
   - This is reproduced by:
     a. set number of measurements to take to 12 with "aXM12" b. set wake-up to 0 with "$WU,0"
     b. set P.P.M. to 8 with "$OP,8"
     c. take the measurements with "aM!"
     d. take the measurements with "aM!", with response of "00019"
     e. set P.P.M. to 80 with "$OP,80"
     f. take the measurements with "aM!", with response of "00019" - 1 second is **not** correct!
     g. take the measurements again with "aM!", with response of "00079" - 7 seconds **is** correct!
4. It was expected after using any of the M6/MC6 to M9/MC9 commands that report no measurements were done, the result of the “aD0!” command to read the result would indicate no data.
5. After storing non-concurrent or concurrent measurements in the “aDn” measurements buffers, doing a “$GO,0” on the S200/S210 serial followed by a “ST” (or taking “aRn!” continuous measurements before the "$ST"), the data in the "aDn" buffers may be changed or cleared. This was not expected since the “aRn!” continuous measurements do not appear to go through the “aDn” measurements buffers. This does **not** occur when the “aDn” measurement buffers contain the results of the “aV!” command.
6. The “aAb!” command without or invalid new address 'b' spews some garbage in response.
7. A CRC is incorrectly added to the "aDn!" response to the 'aV!' command if a prior non-continuous measurement (non-concurrent or concurrent) requested a CRC.
8. The “aV!” command populates all D0 to D9 data buffers with the same data.
9. The “aXP” command only reports the measurement update period, but does not allow it to be set.
10. The “aXWn” command does not allow the warm-up period to be disabled with a “0” value.
11. Aborting a non-concurrent measurement (section 4.4.5.1 of the SDI-12 spec. [2]) does not appear to work correctly.
12. When requesting multiple measurements, and aborting using any SDI-12 command after measurements start occurring, as observed on the serial output, the measurements correctly stop occurring, but the measurements that have occurred incorrectly show up in the “aD0!” buffer. The buffer should be empty!

13. Aborting a concurrent measurement (section 4.4.6 of the SDI-12 spec. [2]) does not appear to work correctly. Any attempt to abort a concurrent measurement incorrectly appears to be ignored as observed on the serial output and retrieved from the measurement buffers. From the SDI-12 debug output by the S200/S210/S300/S310, it appears that while a concurrent measurement request is in progress, the SDI-12 input is ignored!

14. The S200/S210/S300/S310 gets into a state when continuous measurements are running in which any SDI-12 command on the SDI-12 bus stops the continuous measurements. This is reproduced by:
    a. take a concurrent measurement with "aC!"
    b. start continuous mode with "GO,0" (observe measurements occurring on serial port)
    c. send a "?!" – this stops the continuous mode (observe measurements stop occurring on serial port)
    d. take a non-concurrent measurement with "aM!" or retrieve vendor data with "aV!"
    e. start continuous mode with "GO,0" (observe measurements occurring on serial port)
    f. send a "?!"– the continuous mode continues (observe measurements still occurring on serial port)

    It appears that if continuous mode is started from a sensor reset (i.e. auto-start), this bad state does not occur unless a “ST” is done from the serial port followed by a concurrent measurement and followed by a “$GO,0”, causing the bad state to be entered where any SDI-12 command addressed to the sensor cause the continuous mode to stop! The work-around is to always do a non-concurrent measurement after any continuous measurement to prevent this problem.

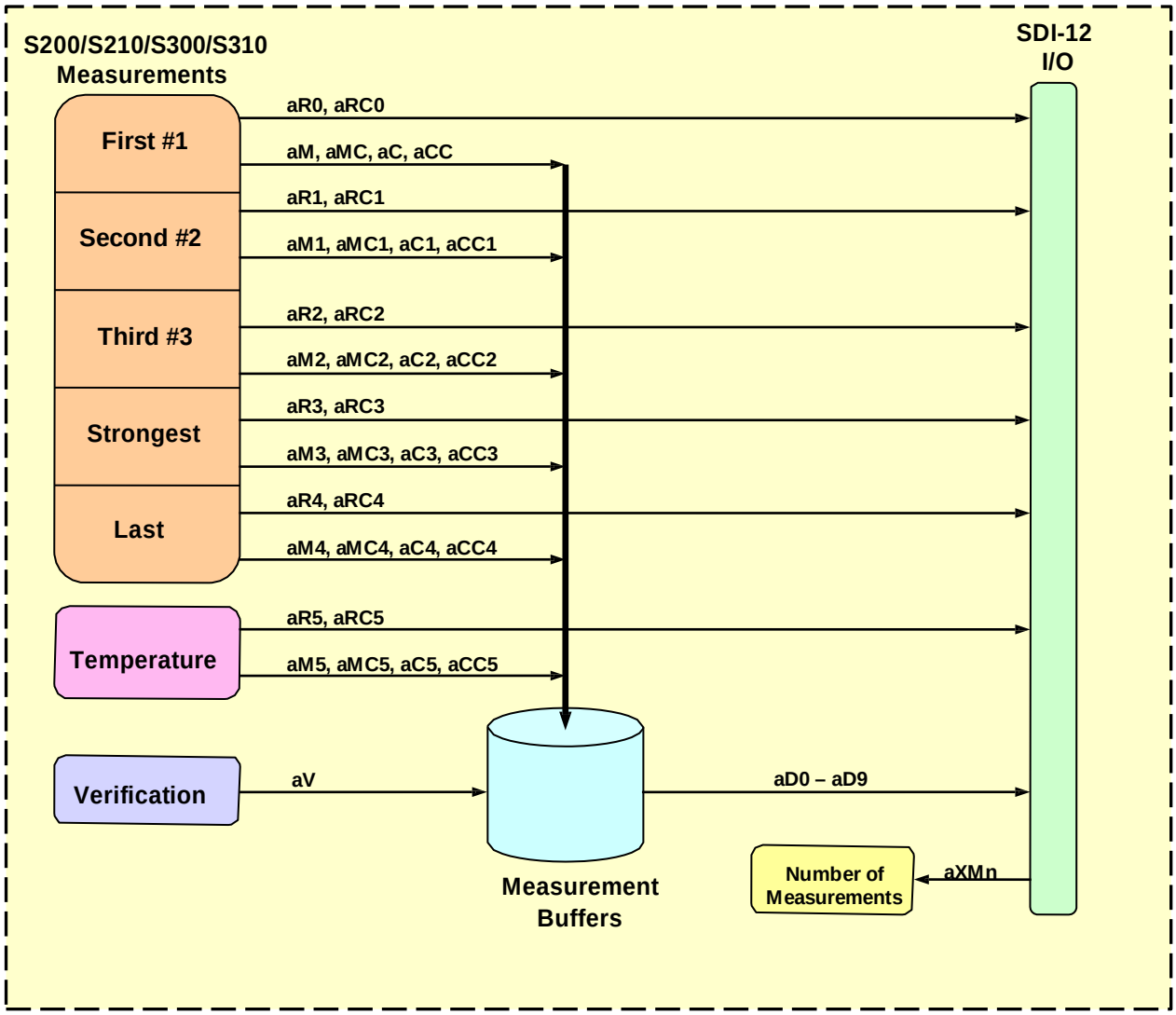

Figure A: S200 / S210 / S300 / S310 SDI-12 Measurement Retrieval Architecture