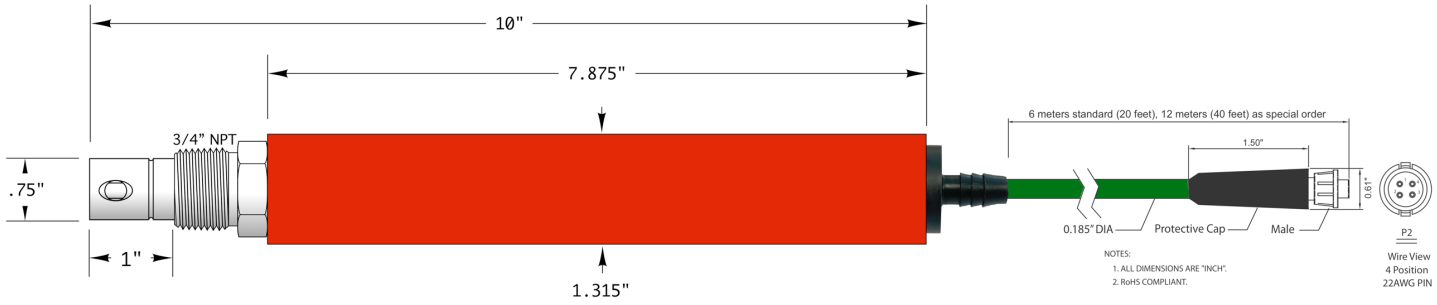
AST41 Smart *HiQDT* Conductivity Sensors Optimized for Low-Range at Pressure to 500 psig & Temperature to 205°C



Drawing for K= 0.05, 0.10, 0.20, 0.50, 1.0 & 2.0 /cm cells. ***Longer 2.25" insertion depth is available with 11.3" overall length.***

- Smart Digital Conductivity Sensors with Isolated RS-485 MODBUS RTU interfaces directly with any suitable PLC
- Windows software for configuration, calibration and testing of ***HiQDT*** smart digital sensors is provided free of charge
  - **Sensor stores temperature & cell constant calibrations including days in use since they were performed**
- AST41 was designed for high pressure & temperature conductivity measurement and an ideal choice applications like:
  - Blowdown control, condensate monitoring & leak detection on heat exchangers & steam purity measurements
  - Boiler condensate and blowdown control and/or monitoring in installation locations without coolers
- High temperature and pressure water and steam is a severe environment for any elastomer requiring special features:
  - Dual EPDM O-ring seals ensure reliability (Viton & Kalrez Optional). Front seal absorbs brunt of chemical attack, allowing rear O-ring to operate in protected environment ensuring continued sealing & long service.
- Compact design for ¾" NPT inline process interface with longer insertion depths available as special-order option
- WPIT sealing option allows for use in areas with high levels of moisture, washdowns, rain or corrosive environment
- Wetted insulator materials of construction are PEEK insulator with 316SS sensor body and inner electrode as standard.
- Available cell constants of K=0.05/cm, K=0.1/cm, K=0.2/cm, K=1.0/cm & K=2.0/cm for lower conductivity ranges.
  - K=0.05/cm can be used from 0.1-10 µS/cm in ultralow range mode at 25°C
  - K=0.1/cm can be used from 0.2-20 µS/cm in ultralow range mode at 25°C
  - K=0.2/cm can be used from 0.4-40 µS/cm in ultralow range mode at 25°C
  - K=1.0/cm can be used from 2.0-200 µS/cm in ultralow range mode at 25°C
  - K=2.0/cm can be used from 4.0-400 µS/cm in ultralow range mode at 25°C
- Computed MegaOhms (MΩ) units using linear user adjustable ATC coefficients or the non-linear ultrapure water ATC
- Special configuration available for K=0.1/cm cell constant for use in ultrapure water (UPW) applications. This version has the characteristic non-linear temperature compensation curve necessary for pure water measurement as well as providing the computed resistivity units of MegaOhms (MΩ) which are most commonly used for such applications
- Cable terminated with quick-disconnect waterproof NEMA 6P snap connector. Max 3,280 feet (1,000 meters) length.

AST41 Smart *HiQDT* MODBUS RTU Conductivity Sensor Specs

Measurement Range: See table below for **ultralow range optimized version** of each cell constant

Operating Temperature Inline Use: -35 to +205 °C (-31 to +401 °F) **

Operating Pressure: Max 500 psig @ 100°C or 250 psig @ 205°C with front 316SS Threads

Process Connections: ¾"MNPT 316SS Front Threads

Wetted Materials of Construction:

- Insulator: PEEK
- O-Rings: EPDM (Standard) or Viton/Aflas/Kalrez (Optional), Redundant
- Electrodes: 316SS Standard
- Sensor Body (Front): 316SS Standard
- Rear Nipple: CPVC or KYNAR (PVDF)

Temperature Element: Pt1000 temperature sensor (included standard, required for all ***HiQDT*** sensors)

Temperature Input Range: -40 to +210 °C (-31 to +410 °F) ±0.3°C *Limited by actual sensor specs* **

Cell Constants Available for AST41: K = 0.05, 0.1, 0.2, 1.0 or 2.0 **/cm**

Cable Length Limits: Standard 20 feet (6 meters), Max 3,280 feet (1,000 meters) with 12VDC supply

End of Cable Terminations: 4-pole waterproof & corrosion-resistant NEMA 6P rated HiQ4M snap connector

Storage and Shelf-Life: One (1) year from date of dispatch from factory when stored at ambient.

Dimensional Details: See following pages for drawing of each particular cell constant configuration.

Sealing Hose Options: Braid reinforced vinyl tubing or NORPRENE tubing is available

** *Contact factory for applications where the measurement is below 0°C or else above 175°C prior to purchase.*

Temperature compensated conductivity ranges shown below at each °C assumes typical 2% per °C coefficient (for ultrapure water temp. comp. scheme differs). If alternate temp. comp. coefficient is used recommended conductivity ranges will vary accordingly.

Cell Constant of AST41	Full Range of Raw Conductivity Input	Temp. Compensated Conductivity @ **25°C**	Temp. Compensated Conductivity @ **75°C**	Temp. Compensated Conductivity @ **125°C**	Temp. Compensated Conductivity @ **175°C**
K=0.05/cm Ultralow	0.100-10 µS/cm 0.100-10.000 MΩ	0.100-10 µS/cm 0.100-10.000 MΩ	0.050-5 µS/cm 0.200-20.000 MΩ	0.033-3.333 µS/cm 0.300-33.333 MΩ	0.025-2.5000 µS/cm 0.400-40.000 MΩ
K=0.1/cm Ultralow	0.200-20 µS/cm 0.050-5.000 MΩ	0.200-20 µS/cm 0.050-5.000 MΩ	0.100-10 µS/cm 0.100-10.000 MΩ	0.067-6.667 µS/cm 0.150-15.000 MΩ	0.050-5 µS/cm 0.200-20.000 MΩ
K=0.2/cm Ultralow	0.400-40 µS/cm 0.025-2.500 MΩ	0.400-40 µS/cm 0.025-2.500 MΩ	0.200-20 µS/cm 0.050-5.000 MΩ	0.133-13.333 µS/cm 0.075-7.500 MΩ	0.100-10 µS/cm 0.100-10.000 MΩ
K=1.0/cm Ultralow	2.0-200 µS/cm 0.005-0.500 MΩ	2.0-200 µS/cm 0.005-0.500 MΩ	1.0-100 µS/cm 0.010-1.00 MΩ	0.667-66.667 µS/cm 0.015-1.500 MΩ	0.050-5 µS/cm 0.200-20.000 MΩ
K=2.0/cm Ultralow	4.0-400 µS/cm 0.0025-0.250 MΩ	4.0-400 µS/cm 0.0025-0.250 MΩ	2.0-200 µS/cm 0.005-0.500 MΩ	1.333-133.33 µS/cm 0.0075-0.750 MΩ	1.0-100 µS/cm 0.010-1.00 MΩ

HiQDT-CON-ISO-L-10X SENSOR CELL & RANGE TABLE FOR ULTRALOW-10X HARDWARE

ULTRA-LOW RANGE MODE 10X * - in microSiemens/cm

Range Scaling Factor	2			Max Temp. Compensated Conductivity using 2% per °C Coefficient			
Nominal Cell Int **	**ACTUAL** Cell Constant	Max Raw Input Limit	Resolution ***	Lowest Recommended Measurement @ 25°C	@ 25°C	@ 75°C	@ 125°C
50	0.05	100	0.002	1.0	100	50	33.333
100	0.10	200	0.004	2.0	200	100	66.667
200	0.20	400	0.008	4.0	400	200	133.33
1000	1.00	2,000	0.04	20.0	2,000	1,000	666.667
2000	2.00	4,000	0.08	40.0	4,000	2,000	1,333.33

* Range mode defined by register 40018. When register 40018 is 2 then range scaling factor is ultralow mode. **This register 40018 is read only for the ultralow mode sensor type.**

** The nominal cell constant of conductivity sensor is found by dividing integer obtained from register 40019 by 100.

*** The resolution is always 50,000 steps no matter the nominal cell constant of sensor or range mode that is in operation.

If sensor used is only ever just one cell constant and range mode, then simple scaling of 0-50,000 steps to conductivity range is possible. Procedure below supports any cell constant in any range mode without changing programming of MODBUS RTU master PLC device:

1) Converting registers 30001 & 30003 for conductivity sensors into µS/cm conductivity units

To display calibrated & temperature compensated conductivity in µS/cm units, use the following formula:

uS/cm = ((REG30001 * REG40019) * REG40018) / 50,000

To display calibrated raw conductivity in µS/cm units use register 30003 instead of 30001 in formula above.

2) Converting µS/cm conductivity units into native 0-50,000 step sensor resolution units

When performing the autocalibration calls on the conductivity sensor you will need to convert from the engineered µS/cm conductivity units to the 0 to 50,000 native resolution units of the conductivity sensor using this formula:

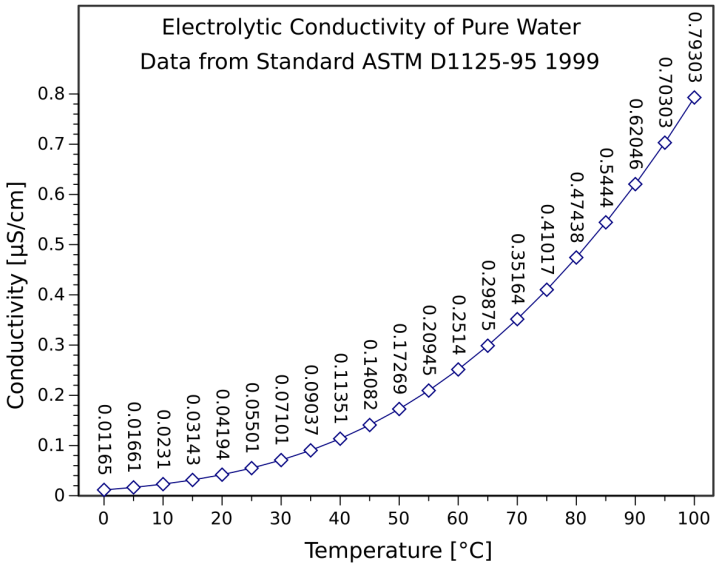
Native 0-50,000 sensor resolution units = (uS/cm * 50,000) / (REG40019 * REG40018)

Native 0-50,000 sensor resolution units are what is sent to register 40011 (ultralow slope).

SPECIAL NOTES ABOUT ULTRALOW-10X STYLE SPECIAL ORDER SENSORS:

It is not possible to tell whether the sensor that you have is the Ultralow style or the Ultralow-10X style simply from looking at register 40018 since this would be 2 in both cases. The only way to tell that you have the Ultralow-10X style hardware is that the nominal cell constant detailed in register 40019 will be 10 times higher than the actual cell constant as indicated on the sensor label. This ten-fold deviation between the nominal and the actual cell constant is what is to be expected if you have purchased the Ultralow-10X style sensor. The range of the Ultralow-10X follows what would be expected if the actual cell constant was ten times higher for the same ultralow sensor configuration. Contact factory if you should have any questions or concerns prior to ordering.

Ultralow Range Conductivity Sensors for Ultrapure Water (UPW)



The conductivity of pure water varies significantly with temperature in a well defined but non-linear fashion as detailed in the graph to left. This behavior is preprogrammed into the HiQDT-CON-L MODBUS RTU conductivity sensors for the automatic temperature compensation feature to make it suitable for ultrapure water (UPW) type applications.

Although the recommended cell constant for performing conductivity measurement in UPW is K=0.01/cm for best resolution and lower bounds of measurement there may be situations where this K=0.01/cm cell constant cannot be used for the planned installation location because of limitations such as piping arrangement and low-flow. The higher cell constants of K=0.05/cm or K=0.10/cm can be used instead in such cases albeit they require the sample to be at a higher temperature to ensure best results. Table below details recommended minimum temperature for various cell constants for use in UPW. The minimum temperature for UPW measurement for each cell is determined based upon the lowest absolute conductivity value for which the cell constant is recommended & temperature at which this conductivity occurs for UPW. Resistivity are computed units are the inverse of the measured conductivity value.

ULTRA-LOW RANGE MODE - MicroSiemens/cm unless otherwise indicated

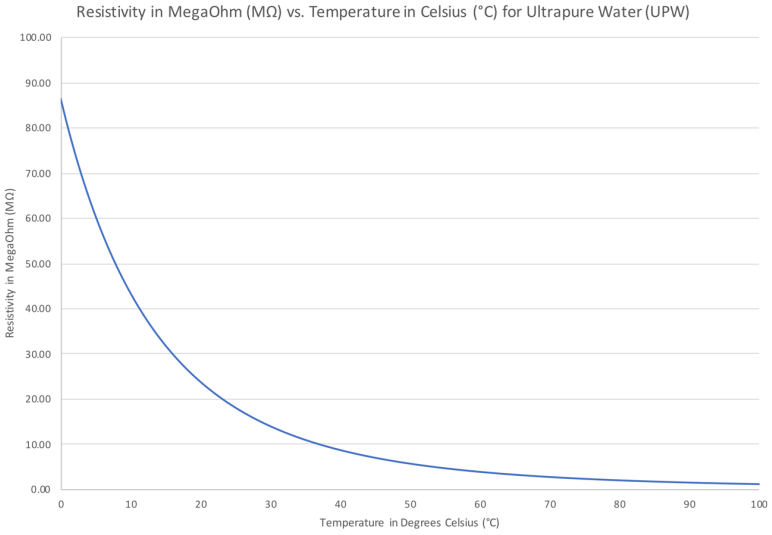
Range Scaling Factor 2

Cell Constant (K)	Raw Max Input @ 25°C	Resolution	Lowest Recommended Absolute Measurement	Minimum Temp °C *	Absolute MegaOhm (MΩ) @ Min Recommended °C *
~~0.01~~	~~2~~	~~0.00004~~	~~0.02~~	~~8~~	~~50~~
0.05	10	0.0002	0.1	40	10
0.10	20	0.0004	0.2	55	5

** Minimum recommended temperature is conductivity of UPW which is 1% of ultralow range mode for the given cell and the associated MegaOhm units. Measurements can be performed below the recommended minimum temperature with an associated higher uncertainty for those situations.*

For ultralow range conductivity sensors the 5th read input register (30005) sends the computed resistivity MegaOhm (MΩ) using the user defined linear automatic temperature compensation (ATC) while the 6th read input register (30006) sends computed resistivity MegaOhm (MΩ) using the special non-linear ultrapure water style automatic temperature compensation. The resistivity values sent as 0 to 50,000 steps corresponding to 0.000-50.000 MegaOhm (MΩ) for both the 5th (30005) & 6th (30006) read input registers. Theoretical temperature compensated resistivity value can never go above 18.18 MegaOhm (MΩ) for uncontaminated pure water since this is the ideal value at 25 degrees Celsius.

Temperature compenated conductivity & resistivity referenced back to the 25 °C for all ATC. Ultrapure water with no contaminants has value of 0.055 µS/cm conductivity or 18.18 MΩ in resistivity. Common units for measurement of pure water is resistivity (MΩ) MegaOhm due to high resolution & convenient scaling in the low conductivity levels. Temperature compensated conductivity and computed resistivity values sent for the ultralow range mode smart digital HiQDT-CON-L style MODBUS RTU conductivity sensors as well as the raw conductivity.



Graph above shows relationship between the resistivity of pure water at various temperatures. Computed resistivity MegaOhm (MΩ) units are the inverse of measured conductivity and so are the mirror image of the conductivity at various temperatures for ultrapure water (UPW). The graph above shows absolute raw resistivity at various temperatures. Resistivity values sent include ATC referencing reading to 25 °C state.

Technical Specifications for Smart *HiQDT* AST41 MODBUS RTU Conductivity Sensors with Cell Constants 0.05, 0.1, 0.2, 1.0 & 2.0

BENEFITS OF SMART DIGITAL HiQDT MODBUS CONTACTING CONDUCTIVITY SENSORS

- **Integral RS-485 MODBUS RTU interfaces all-modern PLC controllers & data acquisition systems.**
- **Communicator provides easy management of field installations** without the cost of a mating transmitter. This is ideal for locations where a local display is not necessary or possible due to installation limitations.
- **Windows software for setup and calibration of HiQDT conductivity sensors is free allowing for easy and low-cost field commissioning for setup & pre-calibration of sensors** without the cost of a transmitter. Ideal for installation locations where a local display is not needed or possible due to site specific needs.
- **Intelligent management of sensor calibrations and service life-cycle** for efficient commissioning & maintenance. All aspects of installation are completely portable from the shop to the field site location.
- **The 'Days in Use' since calibration was performed is stored** allowing for optimal maintenance planning.
- **All digital sensors ensure** reliable operation even in noisy process environments.
- **No degradation in digital output** even with very long cable runs. **Max of 1,000 meters (3,280 feet) with 12VDC power** supply to support for remote installation sites and consolidation of collected data.
- Bridging connections & modifying installations easily without loss of signal quality with **NEMA 6P & IP67 rated quick disconnect waterproof and corrosion-resistant dual snap connector**. Simple plug and play operation for intelligent maintenance planning & smart management of sensor installations and stocking.
- **Low-cost snap digital extension cables** facilitate consolidation of very many HiQDT sensors outputs into one panel enclosure where very many remote field installations can all be conveniently all viewed at once.
- **All Extension cables for HiQ & HiQDT sensors are intercompatible**. Uniform extension cables minimize stocking. Separate field installation guide details available options to commission & exchange sensors.

Mechanical & Thermal

Housing:	316SS (Front) & CPVC/KYNAR (Rear)
Mounting:	Inline Only; ¾" NPT Process Connection
Connector:	NEMA 6P rated HiQ4M male snap connector for HiQDT snap extension cables; Extension cables for 3TX-HiQ platform can also be used for HiQDT type smart digital sensors as well
Max Cable:	Up to 2,000 feet (610 meters) using 22 AWG leads when employing 12VDC power supply
Temp.:	Inline max per sensor specs
Pressure:	Up to 500 psig inline use
Weight:	Per Sensor, Typically 0.6-2.0 kg (1.3-4.4 lbs)
Dimensions:	¾" MNPT Process Connection for inline installations; Length is 10.0 to 11.3 inches Excluding any hose sealing installed

Electrical

Operating VDC:	8.0 to 13.0 VDC at sensor board
Power Supply:	Isolated & Regulated 9V or 12V DC
Current draw:	Max 35mA Absolute, Typical ~25mA
Conductivity Range:	See Conductivity Range Table on Page 2 for Each Cell Constant Type
Temp Sensor:	Integral Platinum 1000Ω TC Element
Temp Range:	-40 to +210°C ±0.3°C *(limited by actual sensor specifications)* Max Temp is +85°C at sensor board
Temp. Comp.:	Automatic for all measurements
Digital Output:	Isolated RS-485 MODBUS RTU
Baud rate:	9600 or 19,200 kbps (selectable)
Compatibility:	For use with ASTI HiQDT Handheld or ASTI HiQDT Windows software or any PLC with isolated RS-485 input that can serve as a MODBUS RTU master to HiQDT sensor slave
CE mark:	EN61326A

RoHS COMPLIANT

HiQDT SMART DIGITAL CONDUCTIVITY SENSOR FEATURES & BASIC USAGE

The smart digital HiQDT conductivity sensor with integral RS-485 MODBUS RTU communications allows for a simple and fully portable installation. The sensor may be calibrated anywhere (lab, shop or field) and interfaced with any data acquisition or control system in the field via the RS-485 MODBUS RTU output. Temperature & cell constant calibrations can be done with sensor left in service if grab sample adjustments are desired to agree with reference values. Waterproof and corrosion-resistant NEMA 6P HiQ4M snap connectors come standard for easy seamless hot-swap of sensors from service for cleaning, recalibration and other maintenance requirements as well as eventual replacement in time.

SENSOR SERIAL NUMBER, ITEM NUMBER & TOTAL TIME IN FIELD SERVICE

Systematic tracking is achieved with factory digitally stamped serial number and item number as well as the build date of sensor. The internal clock on the HiQDT sensor board is incremented when sensor is continuous energized for one-hour period to monitor the total number of days in active field service. If the sensor is disconnected the incrementing of the time in service will stop. When the sensor is energized the incrementing of time in service will once again resume. The number of days in service is always the actual real-time total usage. The total days in use is shown in days and equally accurate for continuous or intermittent service such that the time in service is accurate even if the sensor is taken in & out of use for cleaning & re-calibration and/or swapped between different installations. The total time in service since each calibration was performed is shown when the 'View' key is pressed for 3 to 5 seconds in the given calibration LED mode.

CALIBRATION OF HiQDT MODBUS RTU CONTACTING CONDUCTIVITY SENSORS

- Calibrate modes of the HiQDT Windows software & handheld communicator allows for the following adjustments:
  - Temperature offset adjustment (typically only required at initial time of commissioning)
  - Dry in air zero calibration in 'Offset' calibrate mode (typically only required at initial time of commissioning)
  - 'Slope' calibration adjusts conductivity to grab sample or standard to give the effective apparent cell constant
- Calibration values are stored inside the HiQDT smart digital conductivity sensor in EEPROM such that sensor can be powered down or moved without loss of calibration resulting in a true plug and play low maintenance installation.
- Grab sample offset type calibration is done with sensor left in service after stabilized. A grab sample is analyzed offline by the preferred method. The inline field reading is made to agree with any grab sample analysis. The value of the sensor installed in service is adjusted in gain calibration mode to agree with the reference determined value.

COMPUTED UNITS BASED UPON MEASURED CONDUCTIVITY

Units of measure are native conductivity expressed as either µS/cm or mS/cm for all cell constants depending upon particular range of interest. For the ultralow range optimized sensors the computed units of resistivity are available from 0.000 to 20.000 MegaOhms (MΩ) with a resolution of 0.001 MΩ through the entire range. Resistivity is computed both using standard linear user defined temperature compensation as well as special non-linear preprogrammed ultrapure water (UPW) temperature compensation. **Contact factory for assistance if measurement of ultrapure water is planned.**

IMPORTANT NOTE FOR POWERING HiQDT SMART DIGITAL SENSORS

- Although RS-485 MODBUS RTU communications from HiQDT conductivity sensors is isolated, the mating PLC serving as MODBUS Master should still have an isolated RS-485 input port for ensure best results in field use.
  - The power source that energizes sensor should be isolated (dedicated & separate from all other devices) or
  - DC/DC isolator can be added to the existing power supply employed to accomplish the same net result as having a dedicated and isolated 9V or 12V to DC power source.

NOTES ON ADJUSTABLE SMOOTHING DAMPENER & OUTPUT DELAY:

- Dampener LED when HiQDT conductivity sensor is connected allows for display & modification of the variable that is used to set the number of seconds used for the smoothing dampener and delay from boot to send the output values
- For intermittent operation, it is recommended to set this dampener & output delay variable to a low number in order to minimize power consumption while from battery power sources and maximize sampling time of process output

MODBUS RTU setup of HiQDT sensor is available to enable all functionality detailed below:

READ-ONLY Data	Core Process Value Description	READ-ONLY Data	Analytic Sensor Value Description
Calibrated & Temperature Compensated Conductivity & Temperature for HiQDT AST41 Smart Sensors **See table on page 2 for recommended low and high conductivity levels for use at various temperatures for each cell constant** Computed Values	K=0.05/cm Ultralow Range Range 0 to 10 µS/cm K=0.1/cm Ultralow Range Range 0 to 20 µS/cm K=0.2/cm Ultralow Range Range 0 to 40 µS/cm K=1.0/cm Ultralow Range Range 0 to 200 µS/cm K=2.0/cm Ultralow Range Range 0 to 400 µS/cm sent All cell constants have temperature range of -40.0 to +210.0 °C MegaOhm (MΩ) resistivity units sent with 0.001 resolution through entirety of range.	Sensor Serial Number Sensor Diagnostics	Unique Serial Number Designation: YY.M-A.DD ** Sensor Item Number Software Revision Max Temp in Use Min Temp in Use Hours in Field Use
Raw Process Values	Same as the calibrated and temperature compensated conductivity and temperature for each cell constant configuration. Max recommended temperature compensated conductivity range depends upon cell constant, range mode and temperature.	Calibration Values	Temperature Offset Hours since Temp Offset Cal Zero Dry in Air Offset Hours since Dry in Air Zero Offset Cal Cell Constant Wet Gain Calibration Time since Wet Gain (Span) Cal

** *Serial number format YY is the last digits of year M is month with A=Oct, B= Nov & C=Dec A is a letter from A to Z (as permissible) DD is value from 0 to 255*

READ/WRITE Type	Adjustable Calibration Description	READ/WRITE Type	Adjustable Parameter Description
Offset Adjust Temperature	**Calibrated Temperature Value Limit ±25.0 °C * from raw value**	Reset Calibrations	Will reset all user adjustable sensor calibrations back to factory default values
Zero Dry in Air Offset	Conductivity Reading Adjusted to Zero for dry in air condition	Dampener & Delay from Boot	Time averaging of process value 1, 2, 3, 4, 5, 8, 10, 15, 20 or 30 Seconds
Wet Gain Calibration to determine effective apparent cell constant	Calibrated Conductivity Value **±70% from nominal cell constant**	Step Change	Increment value for stepwise calibration on the handheld communicator: 0.05, 0.10, 0.20, 0.5, 1.0 or 2.0 %
Range Mode	Ultralow Range Mode operation is fixed for this sensor type.	Special - Temp Compensation	0.00 to 9.99 % per degree Celsius (Default 2.10%)

NOTE 1: All MODBUS devices on network must use the same baudrate and have a unique node address. Handheld Communicator (HHC) is MODBUS master while all HiQDT sensors are MODBUS slaves. To interface HHC with HiQDT sensor, either removed it from the network, or else bypass with a bridge box with switch scheme. Access any given HiQDT sensor on the MODBUS network with HHC is possible if the existing MODBUS master is disconnected or powered down. If node of HiQDT sensor is not known, use Widows Software or HHC search feature to find it. Please see HiQDT installation guide and HiQDT controller manual for additional recommendations & details about commissioning, calibration and troubleshooting.

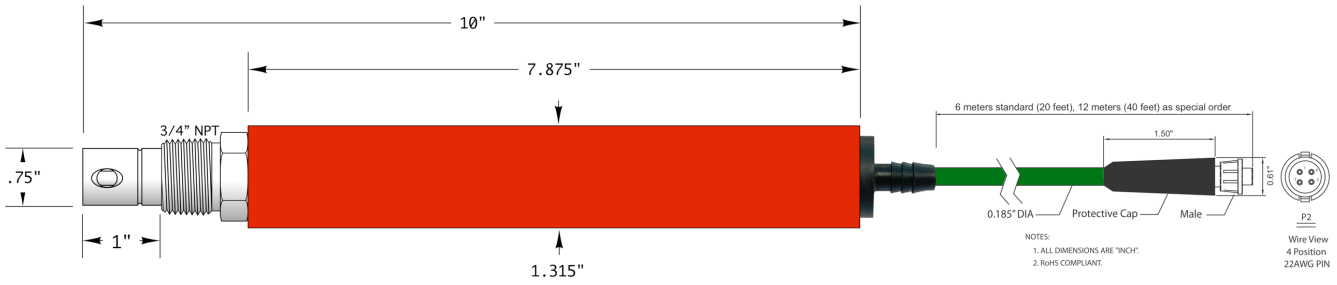
NOTE 2: Access to **READ** values in *Core Process Value Column* gained through MODBUS function code (04).

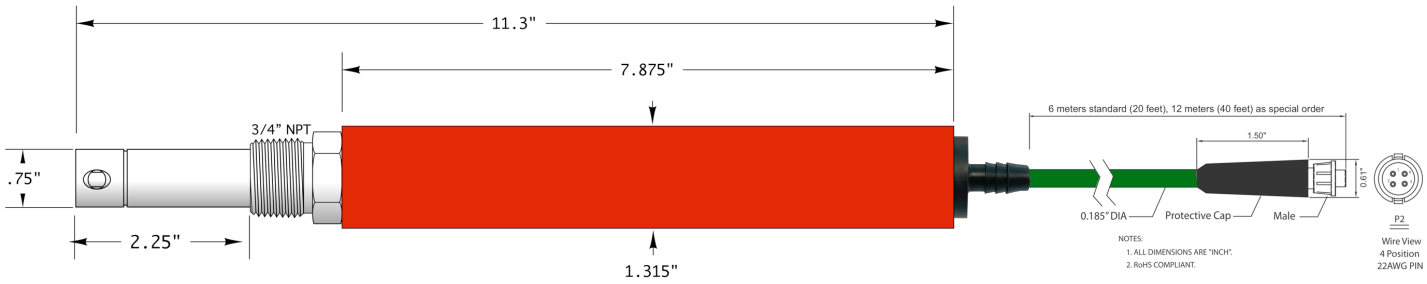
NOTE 3: Access to **READ** parameters in the *Analytic Sensor Value Column, Adjustable Calibration Column & Adjustable Parameters Column* gained through MODBUS function code (03).

NOTE 4: Access to **WRITE** parameters in the *Analytic Sensor Value Column, Adjustable Calibration Column & Adjustable Parameters Column* gained through MODBUS function code (16).

Last Revised Janaury 8, 2021

Dimensions for *HiQDT* AST41 Cell Constants 0.05. 0.1, 0.2. 1.0 & 2.0





NOTES:

1) All cell constants are available in both the standard 1.0 and extended 2.25 insertion depth configurations.
2) The wetted materials of construction for the front portion of the sensor are 316SS for metal electrodes and PEEK for the insulator
3) The material of construction for the rear eight (8) inch nipple is either CPVC or KYNAR (PVDF).
    a. For inline installations using the front ¾"MNPT threads only the 316SS & PEEK materials of construction are wetted.
4) The sensors may be installed at any orientation as desired. Care should be taken that the installation scheme is such that the measuring cell is always completed full at all times (no entrapped air bubbles or times when this part of the line is dry).
5) For batch operations where the tank is drained, installation with the sensor tip to the top of the tank (inverted style) is preferred.
6) For inline installations, the vent hole should be entirely in the path of flow and unobstructed by the compression fitting to ensure that the sample in the measuring cell is representative of the process fluid at all times. Alternatively, if the vent hole cannot be installed to be entirely in the flow the tip should be installed into the direction of flow typically at an elbow in the piping.
7) For low-flow installations please contact the factory for additional assistance. Custom insertion depth may be available for selected sensor configurations as special order options upon request.
8) Dimensions for all drawings are in inches.