AtlasScientific™
Environmental Robotics

V 1.3

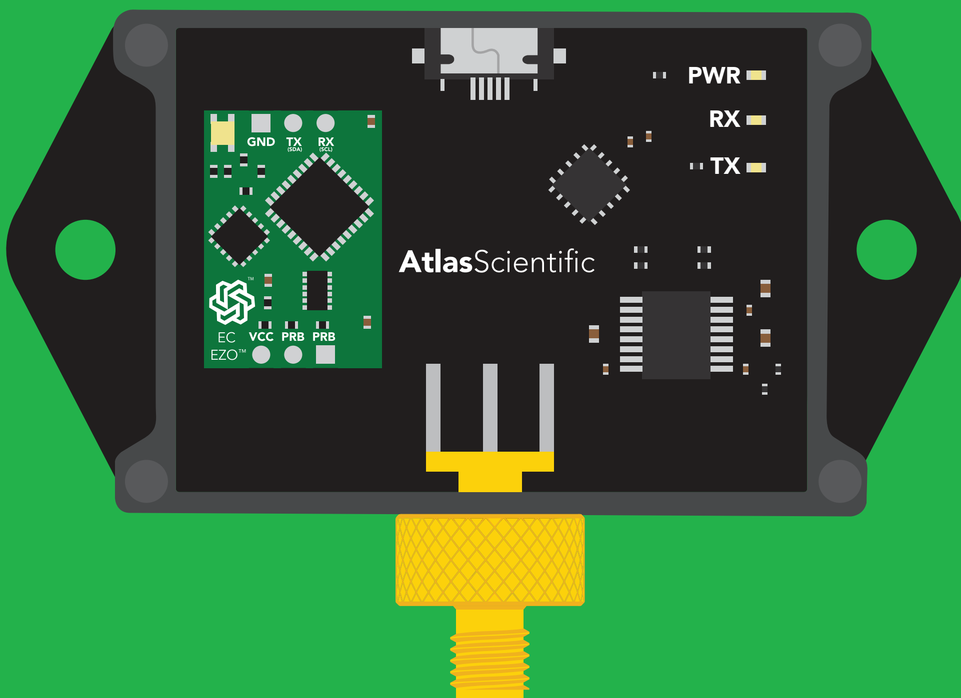
Revised 10/24

EZO Complete-EC™

USB Conductivity meter

Datasheet for engineers

ISO 7888 Compliant
(determination of electrical conductivity)



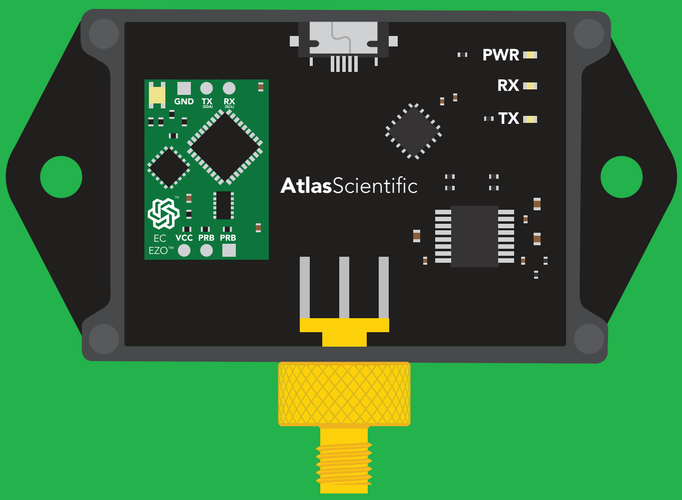
Reads	**Conductivity = μS/cm or ms/cm** **Total Dissolved Solids = ppm** **Salinity = PSU (ppt) 0.00 – 42.00** **Specific gravity = 1.00 – 1.300** ***(sea water only)***
Range	**0.07 – 500,000+ μS/cm** ***(depending on probe type)***
Accuracy	**+/- 2% of reading**
Reading time	**600ms**
Supported probes	**K 0.01 – K10.2**
Calibration	**3 point**
Recalibration frequecy	**Not necessary**
Temp compensation	**Automatic or manual**

Written by Jordan Press
Designed by Noah Press

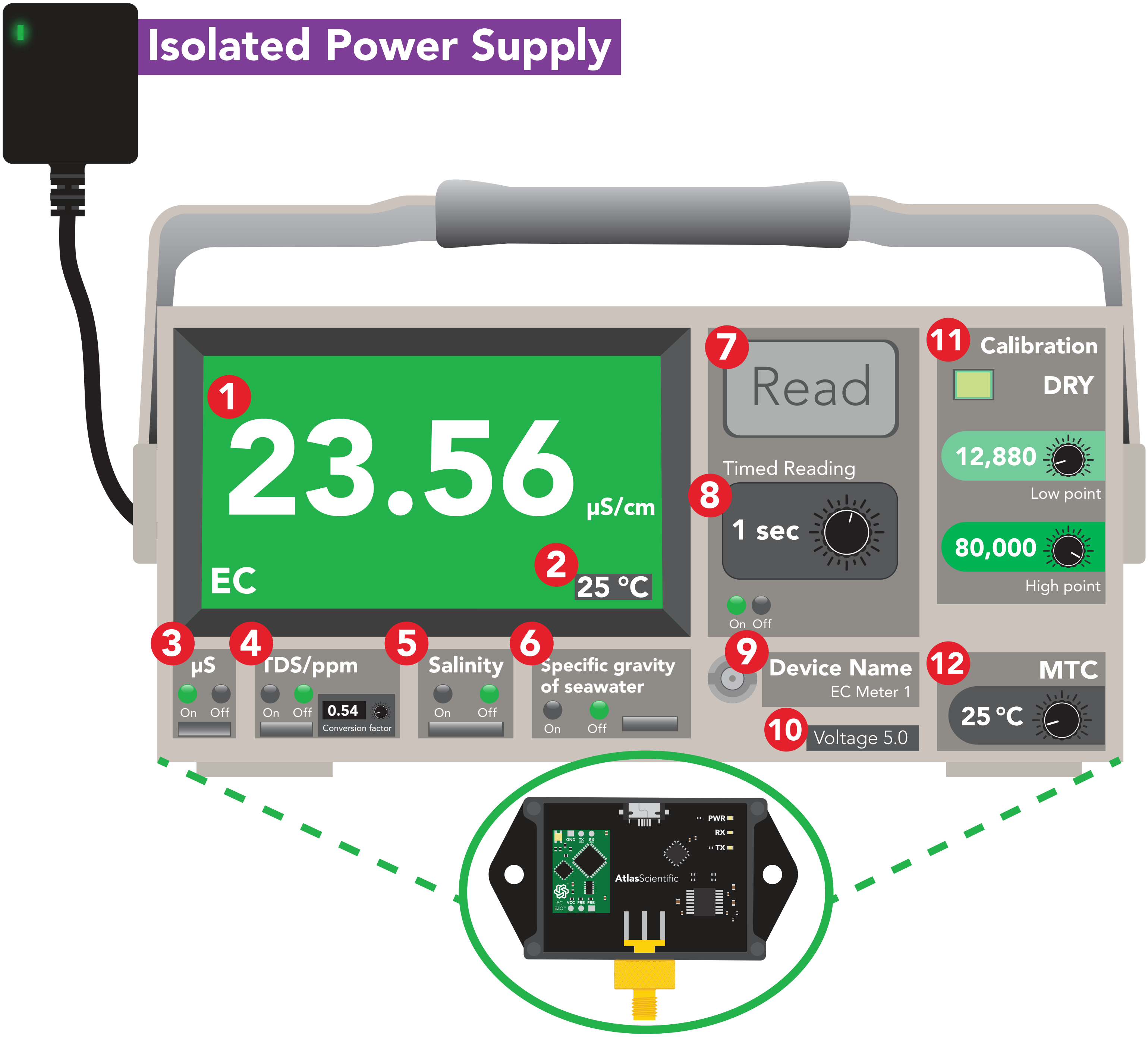
PATENT PROTECTED

This is an evolving document, check back for updates.

Table of contents



The EZO Complete-EC™ has all the features of this bench top meter.



1 Variable decimal conductivity reading

2 Temperature used for reading

3 Readings in μS/cm or mS/cm

4 TDS/ ppm readings

5 Salinity readings

6 Specific gravity readings

7 Immediate reading

8 Timed readings

9 Set device name

10 Voltage usage

11 Three point calibration

12 Temperature compensation

The EZO Complete-EC™ is compatible with any brand of EC probe from K 0.01 – K10.2

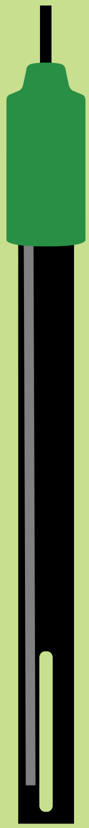
Conductivity probe range

The EZO Complete-EC is capable of connecting to any two-conductor conductivity probe, ranging from:

K 0.01 → K 10.2

Atlas Scientific™ has tested three different K value probe types:

K 0.1



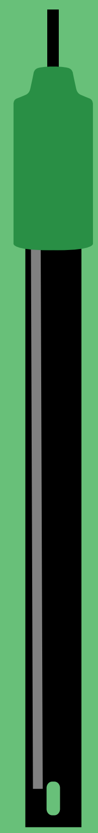
accurate reading range

0.07μS/cm – 50,000μS/cm

TDS *(ppm)* 0 – 25,000

Salinity *(ppt)* 0 – 33

K 1.0



accurate reading range

5μS/cm – 200,000+μS/cm

TDS *(ppm)* 2 – 100,000

Salinity *(ppt)* 0 – 42*

****salinity scale cannot go any higher***

K 10

accurate reading range

10μS/cm – 1S/cm

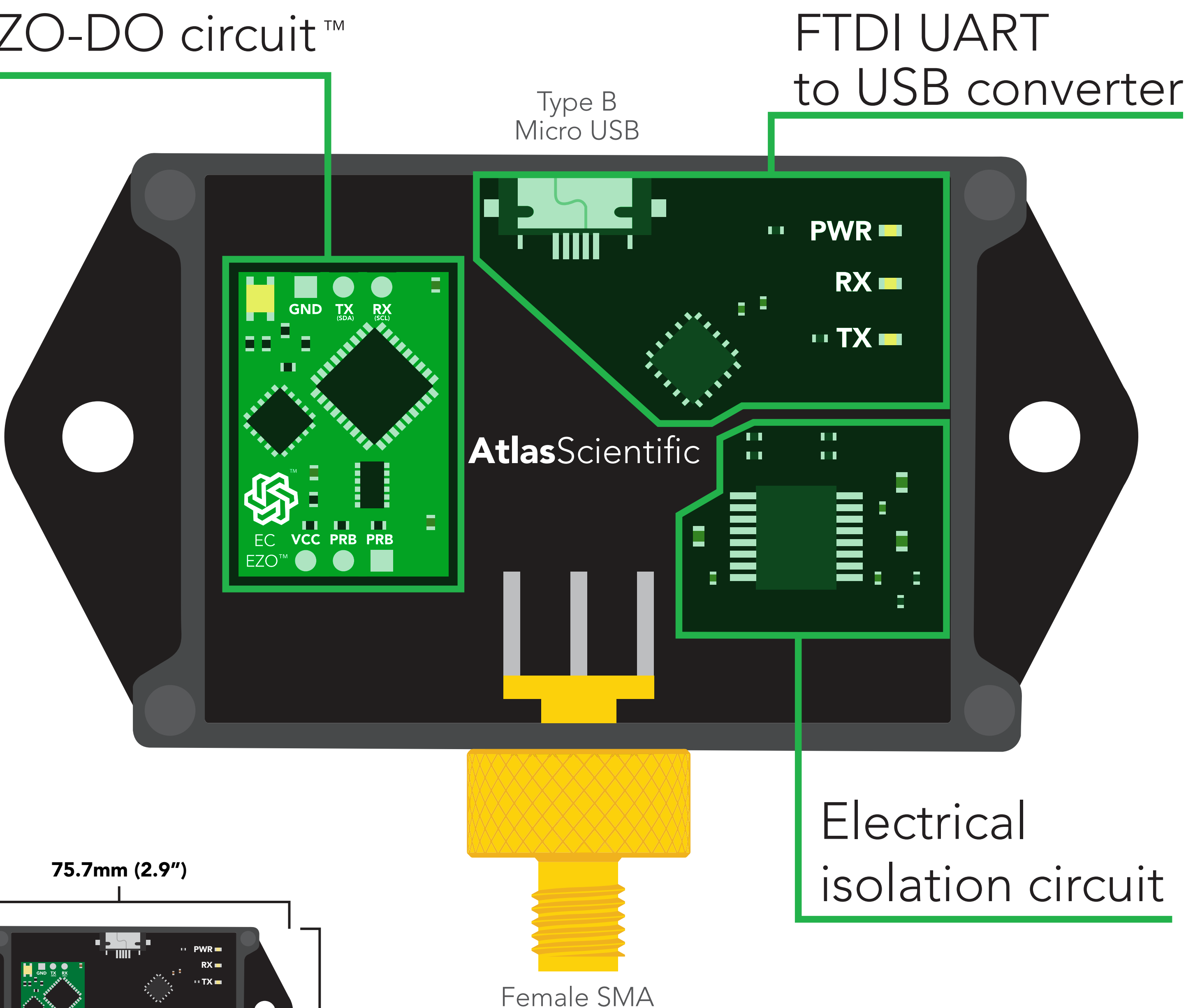
TDS *(ppm)* 5 – 500,000

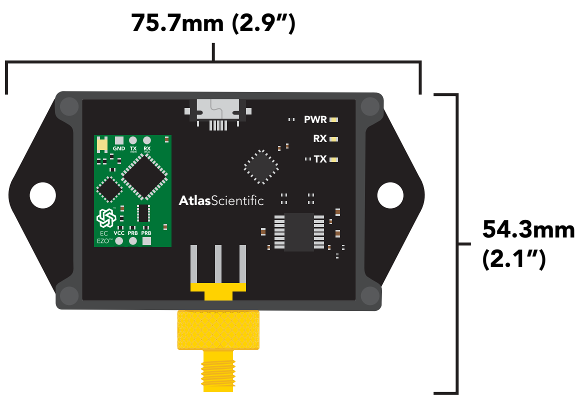
Salinity *(ppt)* 0 – 42*

****salinity scale cannot go any higher***

Atlas Scientific™ does not know what the accurate reading range would be for conductivity probes, other than the above mentioned values.

The EZO Complete-EC™ consists of 3 major components.





Power consumption

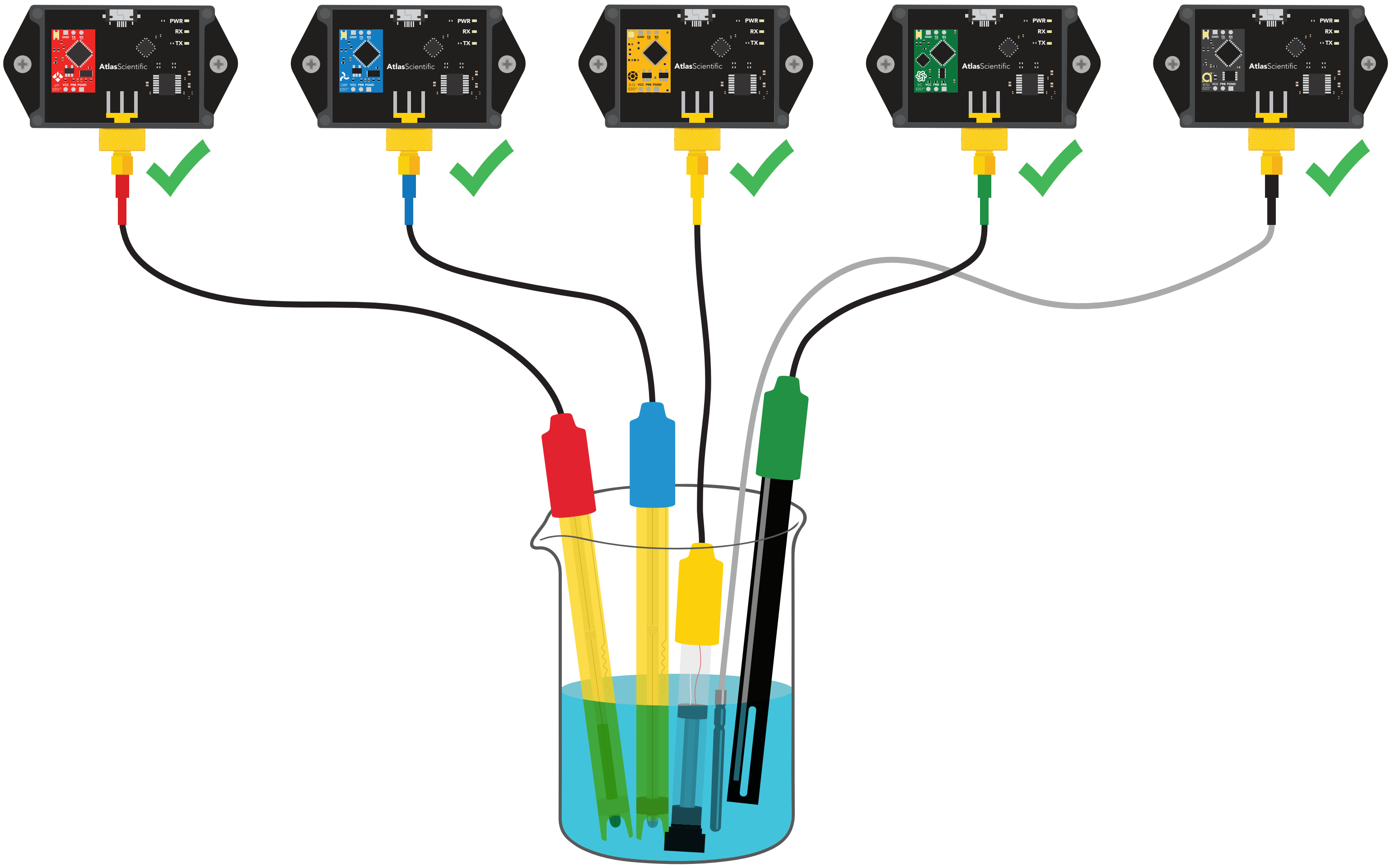
5V USB	MAX	STANDBY	SLEEP
	50 mA	35 mA	21 mA

Absolute max ratings

Parameter	MIN	TYP	MAX
Storage temperature	-65 °C		125 °C
Operational temperature	-40 °C	25 °C	85 °C

Interference free

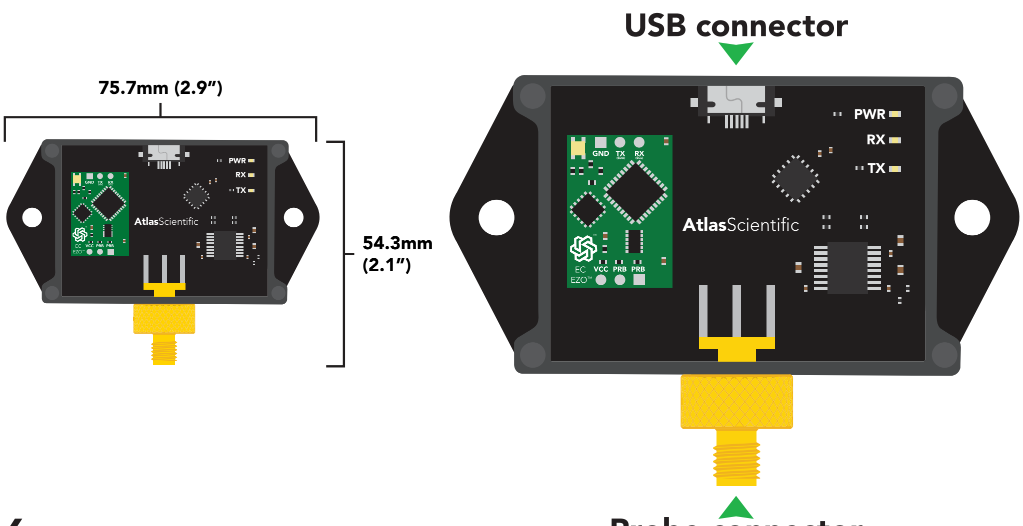
The EZO complete readings are unaffected by other sensors in the same water.



Ingress protection – IP62

The EZO Complete-EC ™ is dust proof and resistant to splashing water.

Two areas of concern are the *USB connector* and the *probe connector.*



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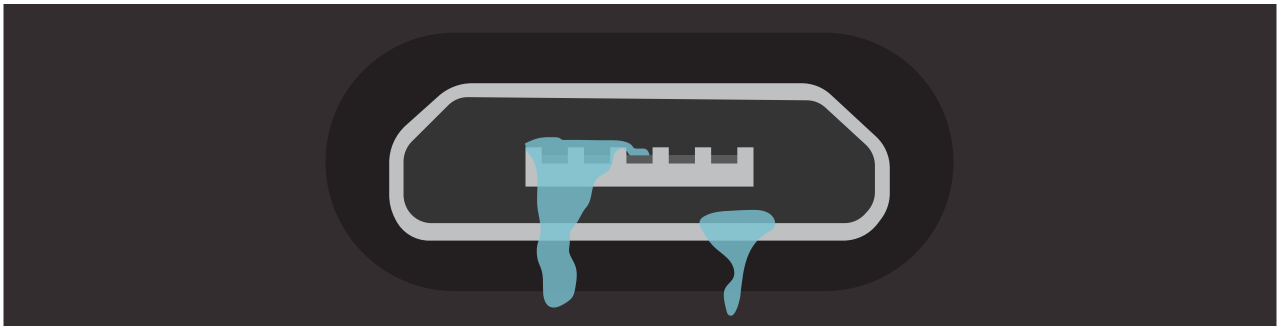
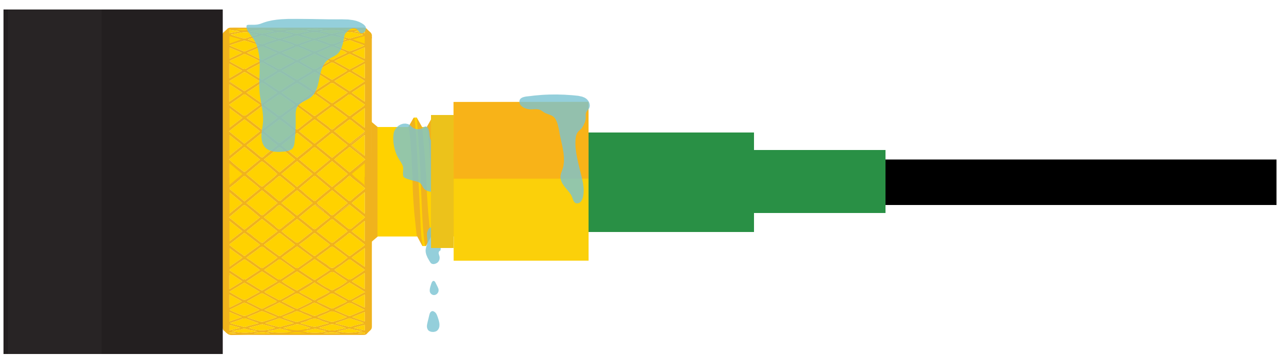
Ingress protection – IP62

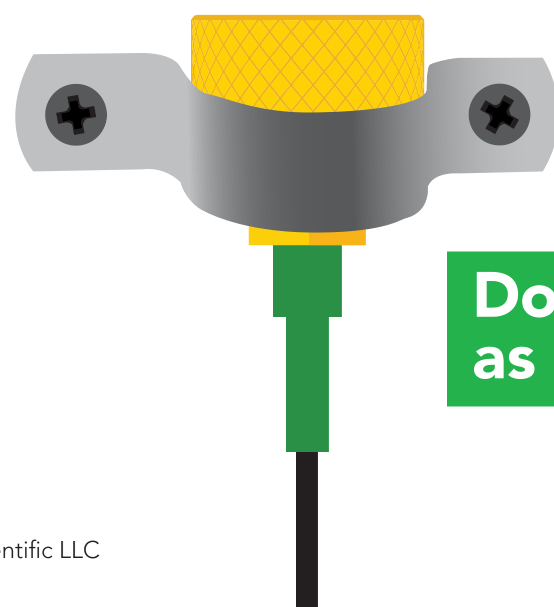
An electrical short can occur if water enters the USB connector. A USB short could permanently damage the EZO-Complete. A USB short is not covered under warranty.



A connector short can occur if water enters the SMA connector. A connector short will cause the conductivity readings to go to 0 or to lock on a specific value and not change. A connector short is reversible and will not damage the EZO-Complete. However, frequent shorts will eventually damage the probe.



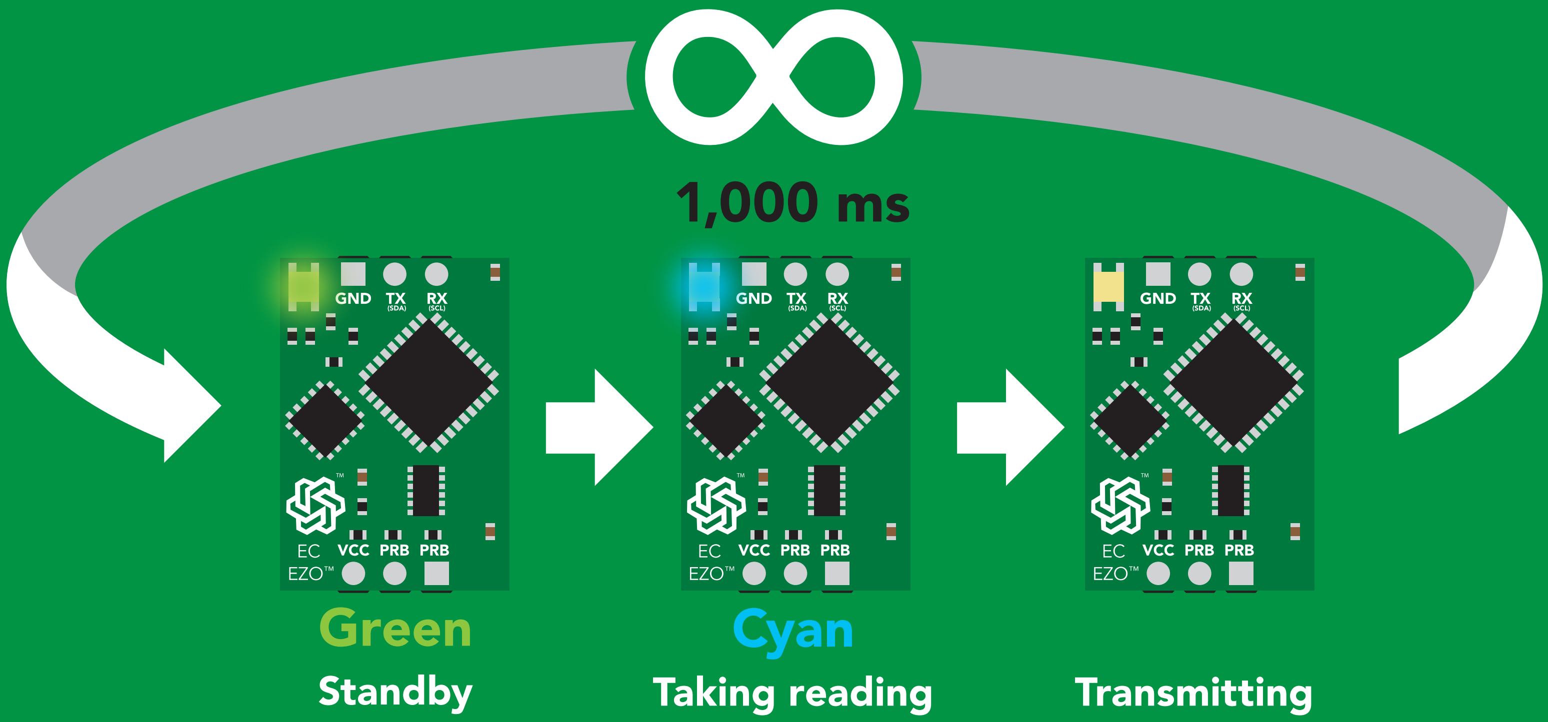
The SMA connector is part of your probe; Nothing should be in contact with this part.



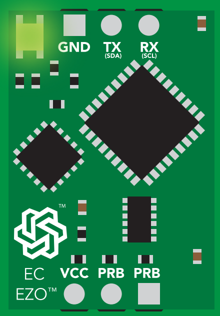
Do not use this as a mounting point!

Default state

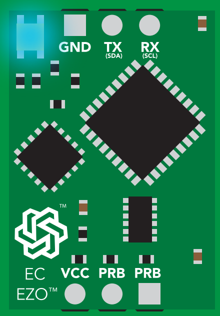
Baud	**9,600**
Readings	**continuous**
Speed	**1 reading per second**



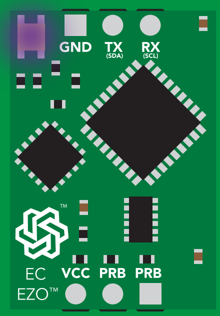
LED color definition



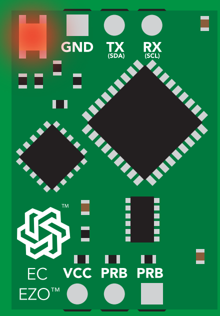
Green
UART standby



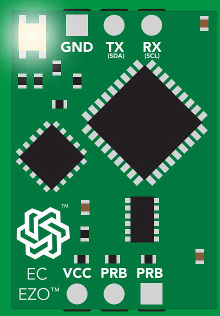
Cyan
Taking reading



Purple
Changing baud rate



Red
Command not understood



White
Find

	LED ON
5V	**+2.2 mA**
3.3V	**+0.6 mA**

Settings that are retained if power is cut

Baud rate
Calibration
Continuous mode
Device name
Enable/disable parameters
Enable/disable response codes
Hardware switch to I²C mode
LED control
Protocol lock
Software switch to I²C mode

Settings that are *NOT* retained if power is cut

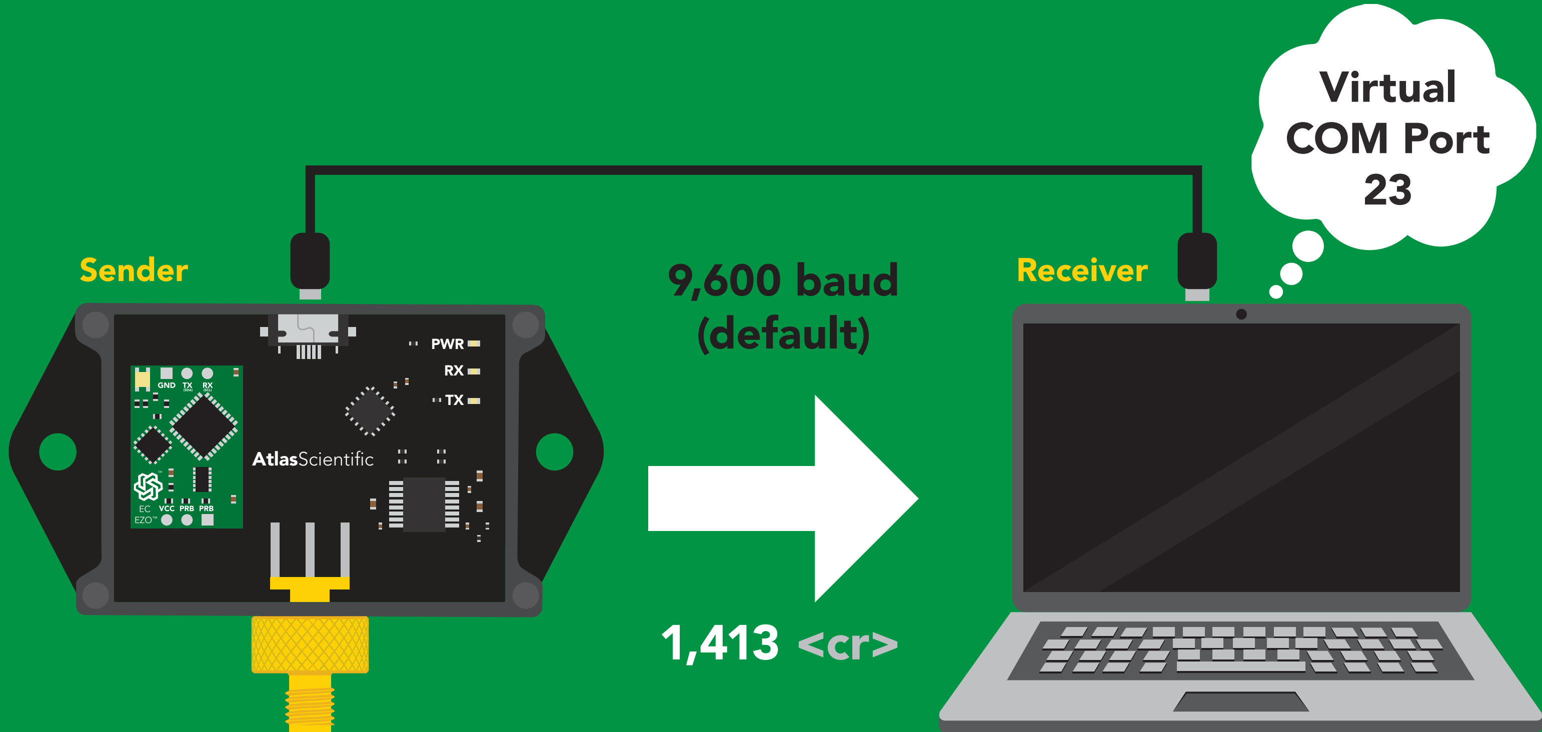
Find
Sleep mode
Temperature compensation

Receiving data from device

2 parts

ASCII data string — Command

Carriage return <cr> — Terminator



(COM Port numbers are determined by the computer)

Advanced

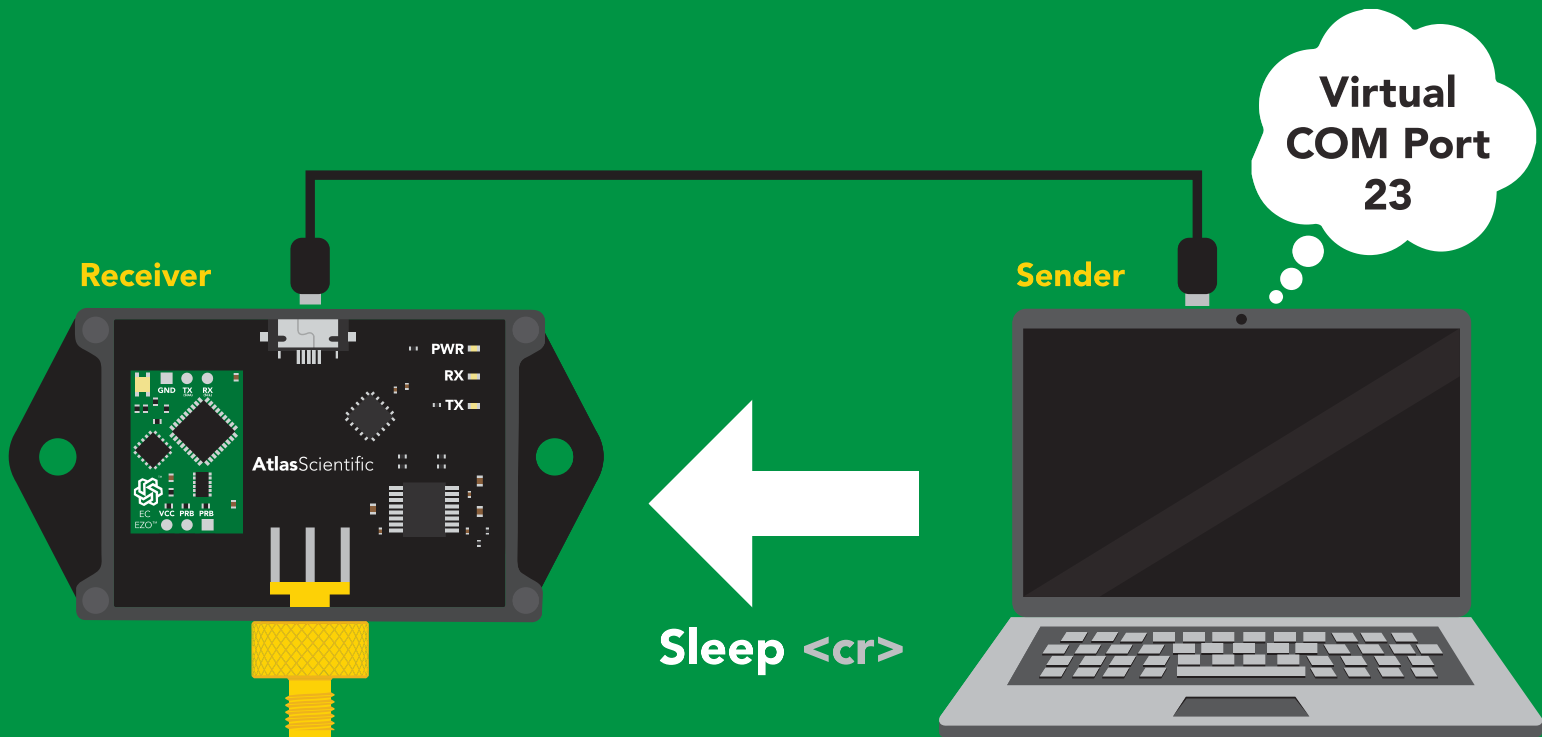
ASCII:	1	,	4	1	3	<cr>
Hex:	31	2C	34	31	33	0D
Dec:	49	44	52	49	51	13

Sending commands to device

2 parts

Command (not case sensitive)
ASCII data string

Carriage return <cr>
Terminator



(COM Port numbers are determined by the computer)

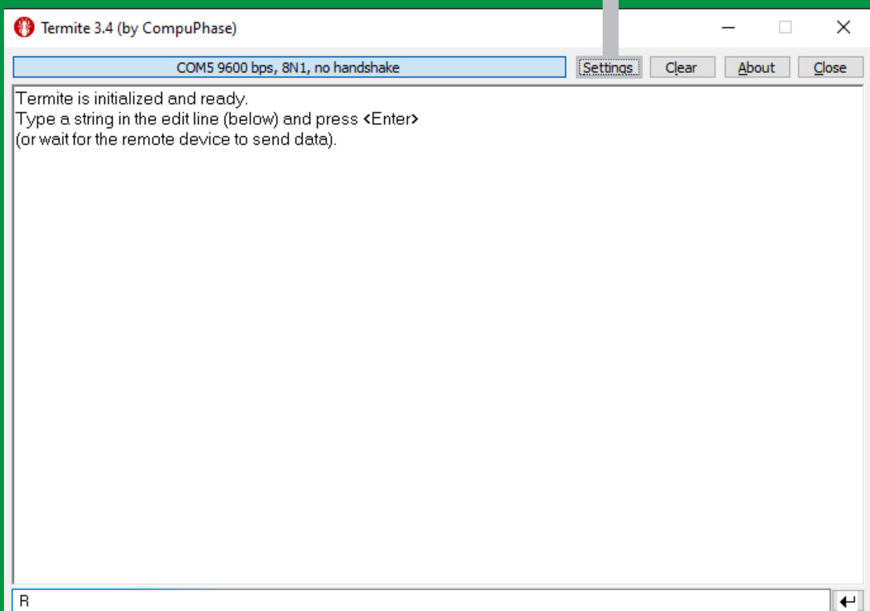
Advanced

ASCII:	S	l	e	e	p	<cr>
Hex:	53	6C	65	65	70	0D
Dec:	83	108	101	101	112	13

Looking for a simple serial monitor for debugging?

Termite: a simple RS232 terminal

Click here to download

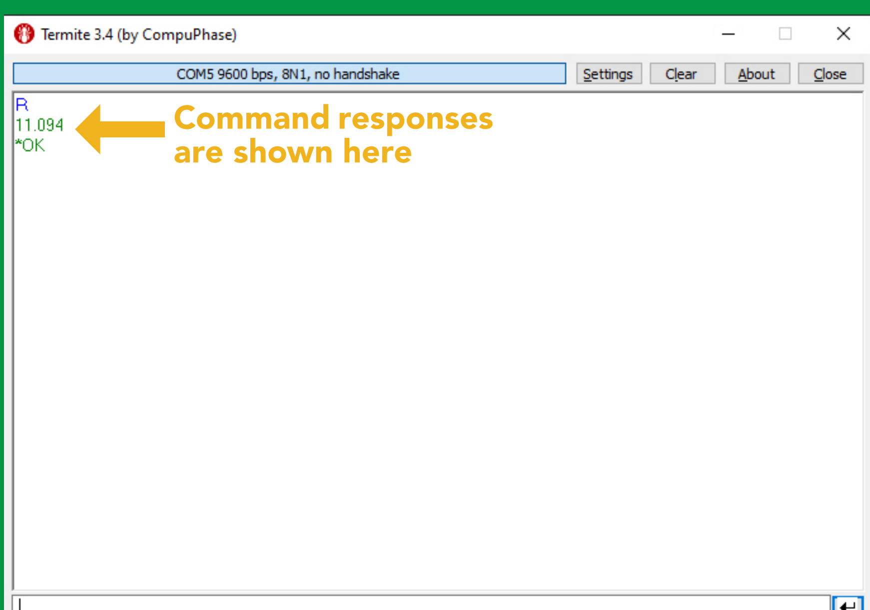


Enter commands here

Settings

Baud 9600	**Parity** none
Data bits 8	**flow control** none
Stop bits 1	**Forward** none

Transmitted text append CR



Command quick reference

All commands are ASCII strings or single ASCII characters.

Command	Function		Default state
C	enable/disable continuous reading	pg. 16	enabled
Cal	performs calibration	pg. 18	n/a
Export	export calibration	pg. 20	n/a
Factory	enable factory reset	pg. 30	n/a
Find	finds device with blinking white LED	pg. 15	n/a
i	device information	pg. 26	n/a
Import	import calibration	pg. 21	n/a
K	Set probe type	pg. 22	K 1.0
L	enable/disable LED	pg. 14	enabled
Name	set/show name of device	pg. 25	not set
O	enable/disable parameters	pg. 24	all enabled
R	returns a single reading	pg. 17	n/a
Sleep	enter sleep mode/low power	pg. 29	n/a
Status	retrieve status information	pg. 28	enable
T	temperature compensation	pg. 23	25°C
TDS	change the TDS conversion factor	pg. 19	0.54
*OK	enable/disable response codes	pg. 27	enable

LED control

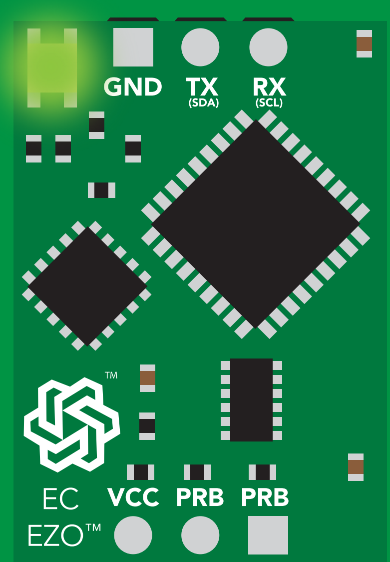
Command syntax

L,1 <cr> LED on **default**

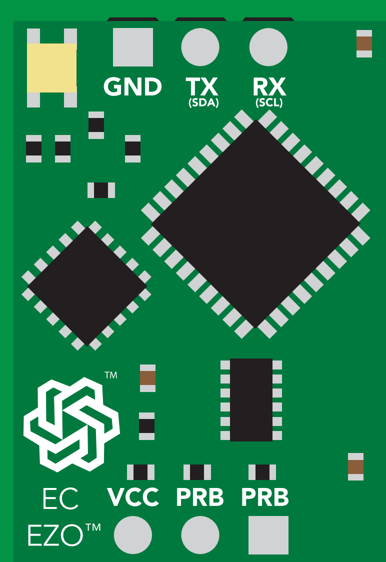
L,0 <cr> LED off

L,? <cr> LED state on/off?

Example	Response
L,1 <cr>	*OK <cr>
L,0 <cr>	*OK <cr>
L,? <cr>	?L,1 <cr> or ?L,0 <cr> *OK <cr>



L,1



L,0

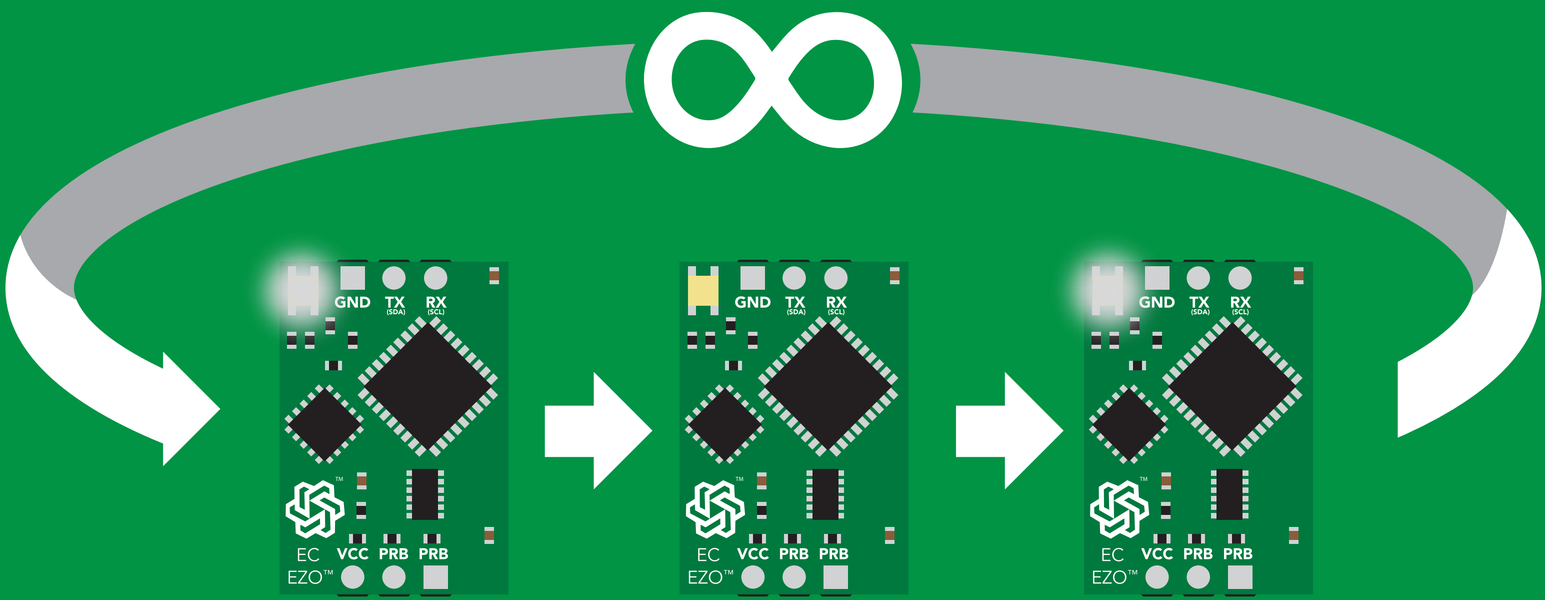
Find

Command syntax

This command will disable continuous mode
Send any character or command to terminate find.

Find <cr>	LED rapidly blinks white, used to help find device

Example	Response
Find <cr>	*OK <cr>



Continuous reading mode

Command syntax

C,1	<cr>	enable continuous readings once per second **default**
C,n	<cr>	continuous readings every n seconds (n = 2 to 99 sec)
C,0	<cr>	disable continuous readings
C,?	<cr>	continuous reading mode on/off?

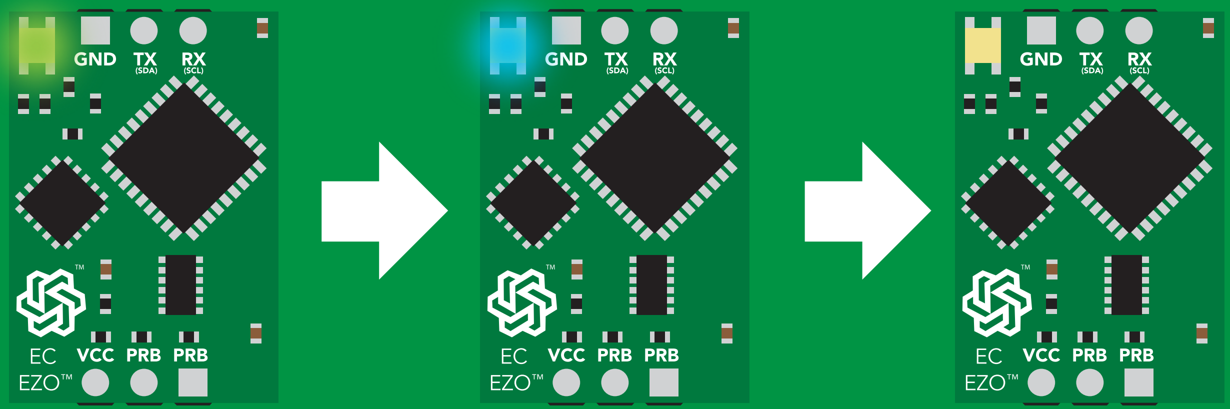
Example	Response
C,1 <cr>	*OK <cr> EC,TDS,SAL,SG (1 sec) <cr> EC,TDS,SAL,SG (2 sec) <cr> EC,TDS,SAL,SG (3 sec) <cr>
C,30 <cr>	*OK <cr> EC,TDS,SAL,SG (30 sec) <cr> EC,TDS,SAL,SG (60 sec) <cr> EC,TDS,SAL,SG (90 sec) <cr>
C,0 <cr>	*OK <cr>
C,? <cr>	?C,1 <cr> or ?C,0 <cr> or ?C,30 <cr> *OK <cr>

Single reading mode

Command syntax

R <cr> **takes single reading**

Example	Response
R <cr>	1,413 <cr> *OK <cr>



Green	Cyan	
Standby	Taking reading	Transmitting

600 ms

Calibration

Command syntax

Dry calibration must always be done first!

Cal,dry	<cr>	dry calibration
Cal,n	<cr>	single point calibration, where n = any value
Cal,low,n	<cr>	low end calibration, where n = any value
Cal,high,n	<cr>	high end calibration, where n = any value
Cal,clear	<cr>	delete calibration data
Cal,?	<cr>	device calibrated?

Example	Response
Cal,dry <cr>	*OK <cr>
Cal,84 <cr>	*OK <cr>
Cal,low,12880 <cr>	*OK <cr>
Cal,high,80000 <cr>	*OK <cr>
Cal,clear <cr>	*OK <cr>
Cal,? <cr>	?CAL,0 <cr> or ?CAL,1 <cr> (two point) or ?CAL,2 (three point) *OK <cr>

Two point calibration:
Step 1. "cal,dry"
Step 2. "cal,n"
Calibration complete!

Three point calibration:
Step 1 "cal,dry"
Step 2 "cal,low,n"
Step 3 "cal,high.n"
Calibration complete!

Changing the TDS (ppm) conversion factor

There are several different conversion factors used to read TDS(ppm). For some applications, it may be necessary to use a conversion factor other than the default value of 0.54

Command syntax

TDS,n	<cr>	set custom conversion factor, n = any value between 0.01 – 1.00
TDS,?	<cr>	conversion factor being used

Example	Response
TDS,? <cr>	?TDS,0.54 <cr> *OK <cr>
R <cr>	EC TDS 100,54 <cr> *OK <cr>
TDS,0.46 <cr>	*OK <cr>
R <cr>	EC TDS 100,46 <cr> *OK <cr>

Common conversion factors

NaCl	0.47 – 0.50
KCL	0.50 - 0.57
“442”	0.65 – 0.85

Formula

EC x conversion factor = TDS

Export calibration

Command syntax

Export: Use this command to download calibration settings

Export,?	<cr>	calibration string info
Export	<cr>	export calibration string from calibrated device

Example	Response
Export,? <cr>	10,120 <cr>

Response breakdown

10, 120

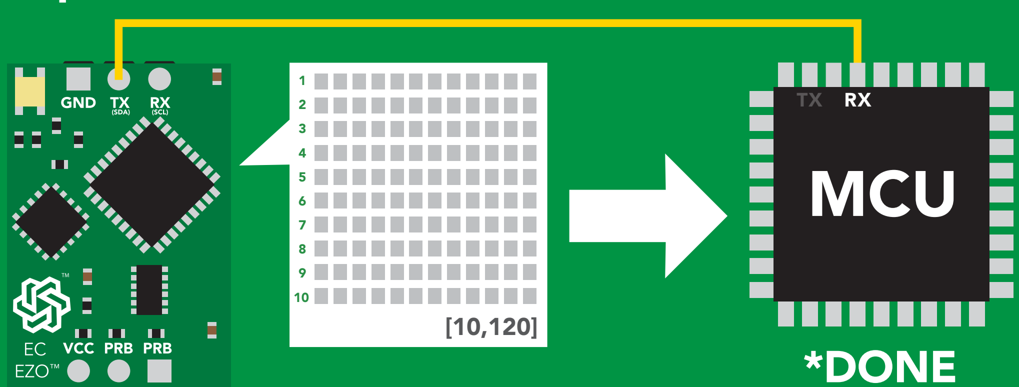
\# of strings to export — # of bytes to export

Export strings can be up to 12 characters long, and is always followed by <cr>

Example	Response	
Export <cr>	59 6F 75 20 61 72 <cr>	(1 of 10)
Export <cr>	65 20 61 20 63 6F <cr>	(2 of 10)
(7 more)	⋮	
Export <cr>	6F 6C 20 67 75 79 <cr>	(10 of 10)
Export <cr>	*DONE	

Disabling *OK simplifies this process

Export <cr>



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Import calibration

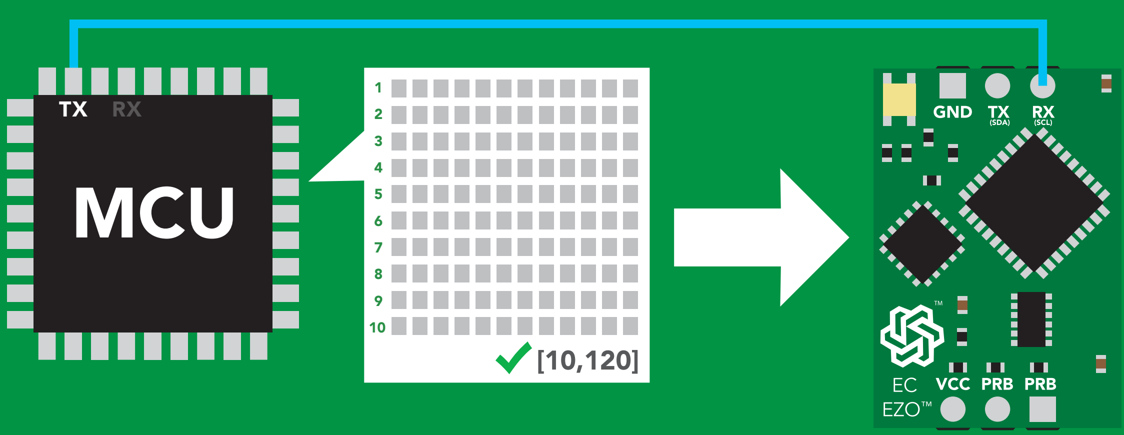
Command syntax

Import: Use this command to upload calibration settings to one or more devices.

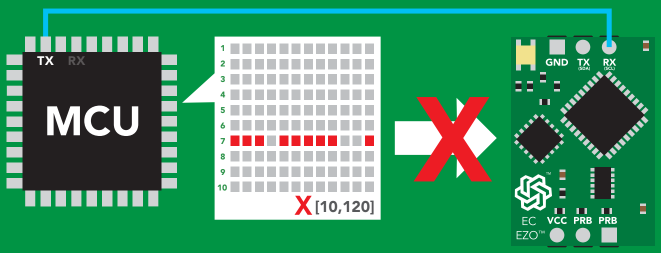
Import,n	<cr>	import calibration string to new device

Example		Response
Import, 59 6F 75 20 61 72 <cr>	(1 of 10)	*OK <cr>
Import, 65 20 61 20 63 6F <cr>	(2 of 10)	*OK <cr>
⋮		⋮
Import, 6F 6C 20 67 75 79 <cr>	(10 of 10)	*OK <cr>

Import,n <cr>



*OK <cr>
system will reboot



*ER <cr>

*** If one of the imported strings is not correctly entered, the device will not accept the import, respond with *ER and reboot.**

Setting the probe type

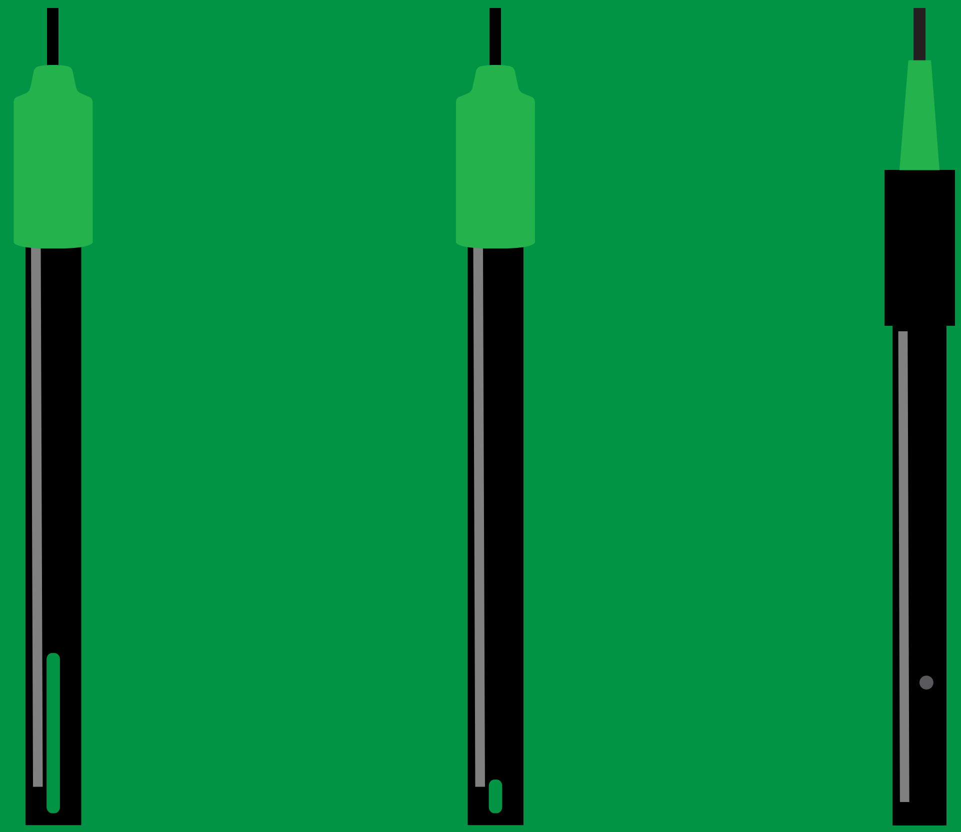
Command syntax

K 1.0 is the default value

K,n <cr> n = any value; floating point in ASCII

K,? <cr> probe K value?

Example	Response
K,10 <cr>	*OK <cr>
K,? <cr>	?K,10 <cr> *OK <cr>



K 0.1 K 1.0 K 10

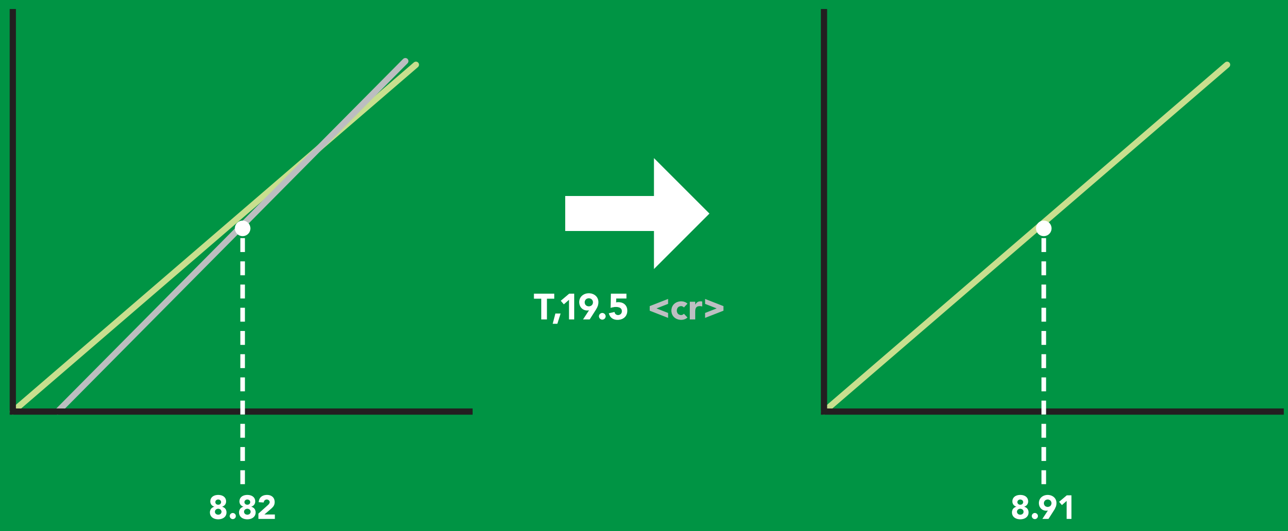
Temperature compensation

Command syntax

Default temperature = 25°C
Temperature is always in Celsius
Temperature is not retained if power is cut

T,n	<cr>	n = any value; floating point or int
T,?	<cr>	compensated temperature value?
RT,n	<cr>	set temperature compensation and take a reading

Example	Response
T,19.5 <cr>	*OK <cr>
RT,19.5 <cr>	*OK <cr> 8.91 <cr>
T,? <cr>	?T,19.5 <cr> *OK <cr>



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Enable/disable parameters from output string

Command syntax

O, [parameter],[1,0]	<cr>	enable or disable output parameter
O,?	<cr>	enabled parameter?

Example	Response
O,EC,1 / O,EC,0 <cr>	*OK <cr> enable / disable conductivity
O,TDS,1 / O,TDS,0 <cr>	*OK <cr> enable / disable total dissolved solids
O,S,1 / O,S,0 <cr>	*OK <cr> enable / disable salinity
O,SG,1 / O,SG,0 <cr>	*OK <cr> enable / disable specific gravity
O,? <cr>	?,O,EC,TDS,S,SG <cr> if all are enabled

Parameters

EC	Conductivity = µS/cm
TDS	Total dissolved solids = ppm
S	Salinity = PSU (ppt) 0.00 – 42.00
SG	Specific gravity (sea water only) = 1.00 – 1.300

Followed by 1 or 0

1	enabled
0	disabled

* If you disable all possible data types your readings will display "no output".

Naming device

Command syntax

Do not use spaces in the name

Name,n	<cr>	set name
Name,	<cr>	clears name
Name,?	<cr>	show name

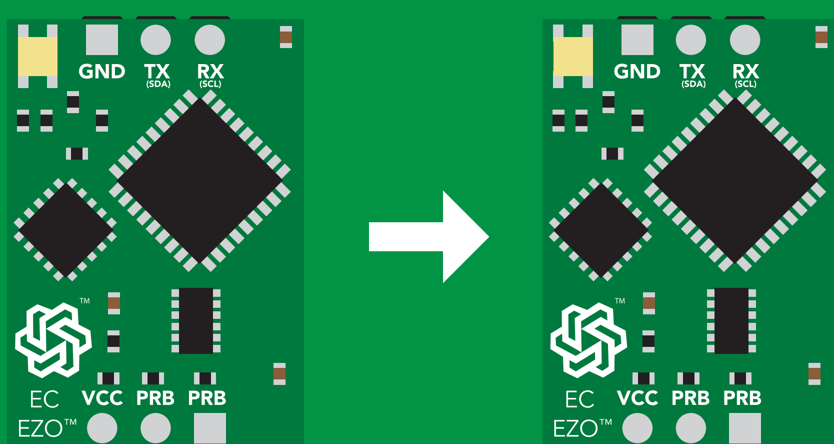
n = _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16

Up to 16 ASCII characters

Example	Response
Name, <cr>	*OK <cr> name has been cleared
Name,zzt <cr>	*OK <cr>
Name,? <cr>	?Name,zzt <cr> *OK <cr>

Name,zzt

Name,?



*OK <cr>

?Name,zzt <cr>
*OK <cr>

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Device information

Command syntax

i <cr> **device information**

Example	Response
i <cr>	?i,EC,2.16 <cr> *OK <cr>

Response breakdown

?i,	EC,	2.16
	Device	Firmware

Response codes

Command syntax

*OK,1 <cr>	enable response	**default**
*OK,0 <cr>	disable response	
*OK,? <cr>	response on/off?	

Example	Response
R <cr>	1,413 <cr> *OK <cr>
*OK,0 <cr>	no response, *OK disabled
R <cr>	1,413 <cr> *OK disabled
*OK,? <cr>	?*OK,1 <cr> or ?*OK,0 <cr>

Other response codes

*ER	unknown command
*OV	over volt (VCC>=5.5V)
*UV	under volt (VCC<=3.1V)
*RS	reset
*RE	boot up complete, ready
*SL	entering sleep mode
*WA	wake up

These response codes cannot be disabled

Reading device status

Command syntax

Status <cr> voltage at Vcc pin and reason for last restart

Example	Response
Status <cr>	?Status,P,5.038 <cr> *OK <cr>

Response breakdown

?Status,	P,	5.038
	Reason for restart	Voltage at Vcc

Restart codes

P	powered off
S	software reset
B	brown out
W	watchdog
U	unknown

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Sleep mode/low power

Command syntax

Send any character or command to awaken device.

Sleep <cr> **enter sleep mode/low power**

Example	Response
Sleep <cr>	*OK <cr> *SL <cr>
Any command	*WA <cr> wakes up device

	STANDBY	SLEEP
5V	**18.14 mA**	**0.7 mA**
3.3V	**16.85 mA**	**0.4 mA**

Standby
18.14 mA

Sleep
0.7 mA

Factory reset

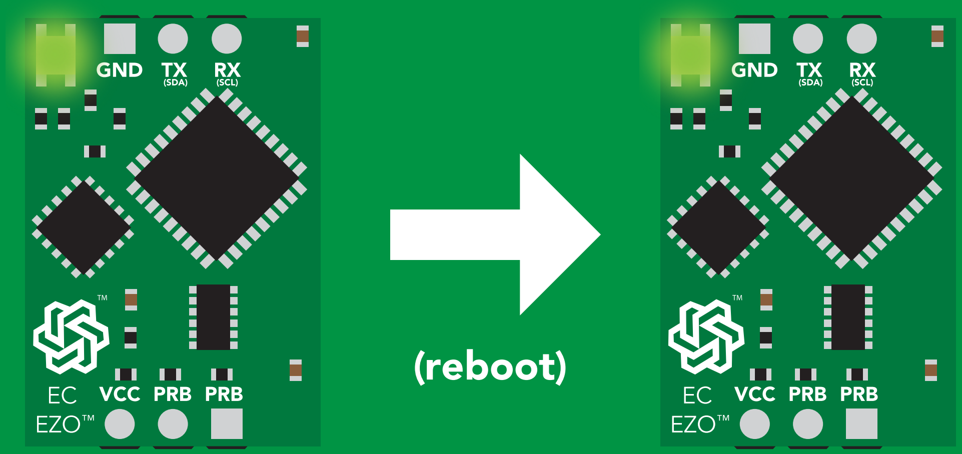
Command syntax

Clears calibration
LED on
"*OK" enabled

Factory <cr> **enable factory reset**

Example	Response
Factory <cr>	*OK <cr>

Factory <cr>



***OK** <cr>

***RS** <cr>
***RE** <cr>

Baud rate will not change

Calibration theory

The accuracy of your readings is directly related to the quality of your calibration. (Calibration is not difficult, and a little bit of care goes a long way)

A properly calibrated conductivity probe will never need recalibration. Once calibrated, you can use the probe continuously year after year without concern. This is because a conductivity probe does not contain any parts that wear out over time.

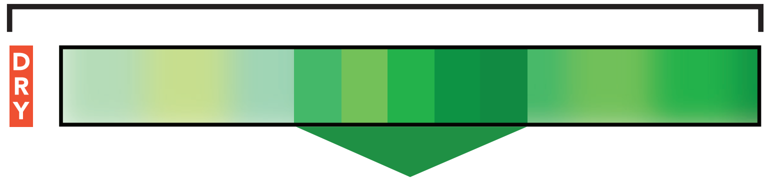
However, changing the cable length of the probe or moving the EZO-EC circuit from one machine to another may require recalibration. This is because such actions will change the electrical properties of the probe or EC circuit.

Two point or Three point calibration

No calibration

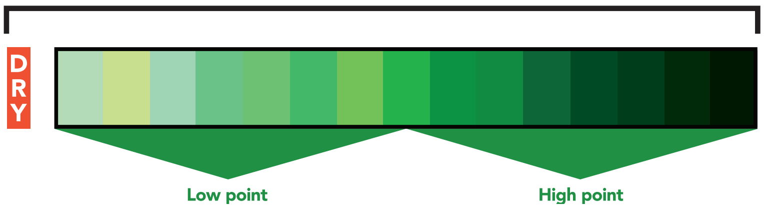
Approximation

Two point calibration



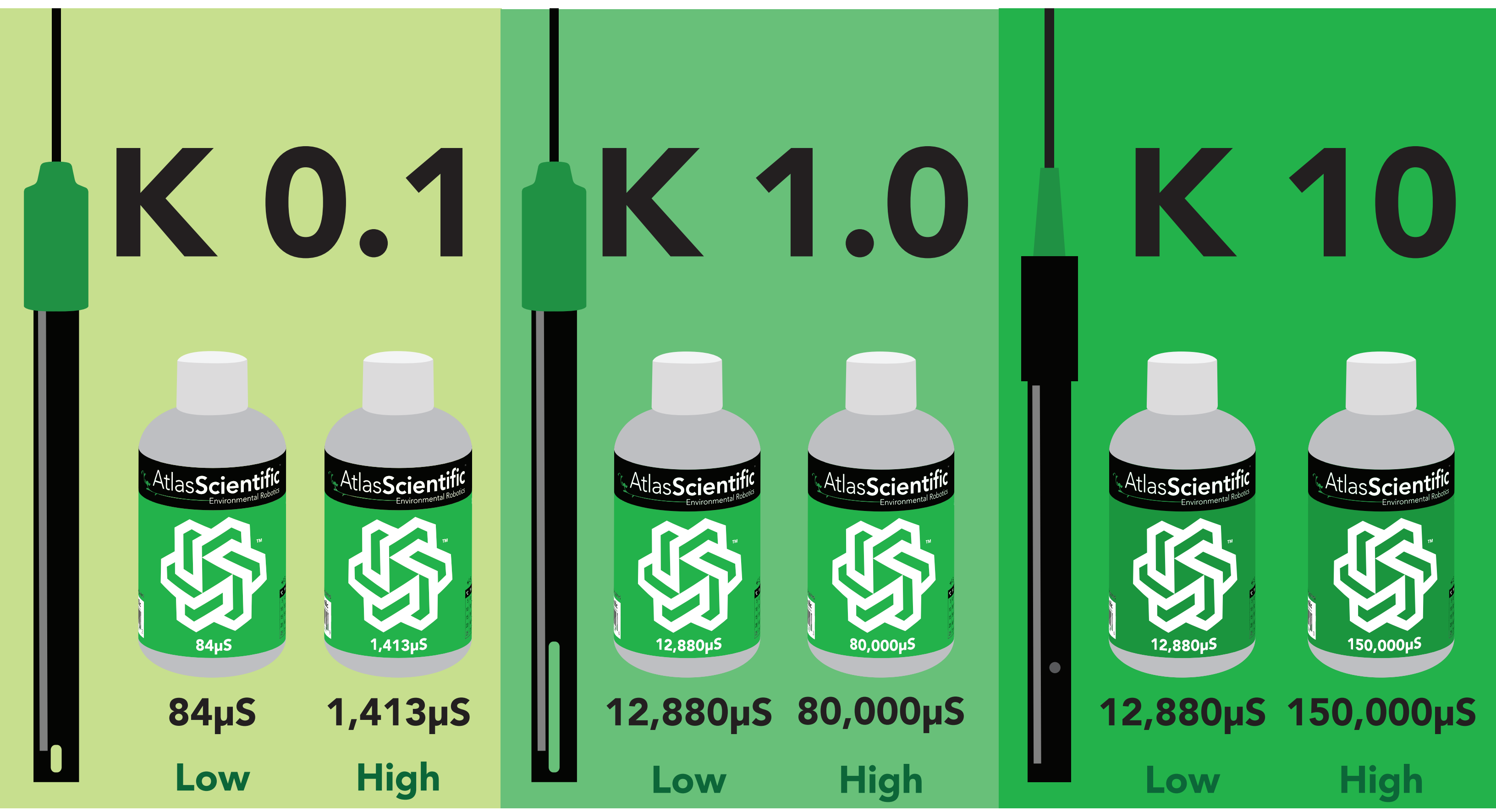
Narrow band accuracy

Three point calibration



Wide range accuracy

Recommended calibration points



When calibrating, Atlas Scientific recommends using the above µS values. However, you can use any µS values you want.

Temperature compensation during calibration

Temperature has a significant effect on conductivity readings. The EZO™ Conductivity circuit has its temperature compensation set to 25° C as the default. ***At no point should you change the default temperature compensation during calibration.***

If the solution is +/- 5° C *(or more)*, refer to the chart on the bottle, and calibrate to that value.

+/- 5 25°C / 77°F

°C	°F	µS/cm	°C	°F	µS/cm
5	41	8,220	30	86	14,120
10	50	9,330	35	95	15,550
15	59	10,480	40	104	16,880
20	68	11,670	45	113	18,210
25	77	12,880	50	122	19,550

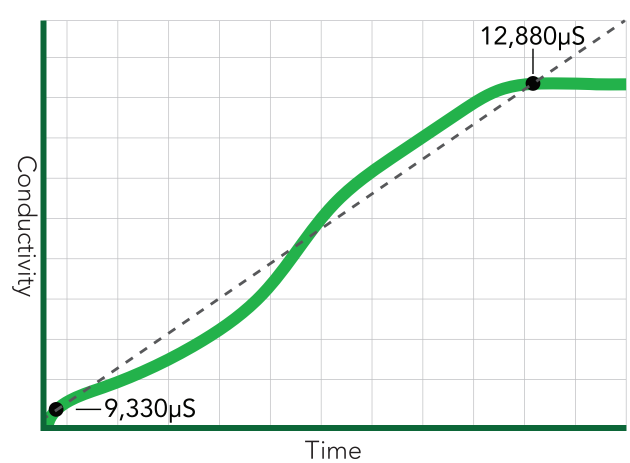
Temperature compensation example

For this example, we brought the temperature of the solution down to 10° C.
Referring to chart on the bottle, you can see the value you should calibrate to is **9,330µS**.

+/- 5 25°C / 77°F

°C	°F	µS/cm	°C	°F	µS/cm
5	41	8,220	30	86	14,120
10	50	9,330	35	95	15,550
15	59	10,480	40	104	16,880
20	68	11,670	45	113	18,210
25	77	12,880	50	122	19,550

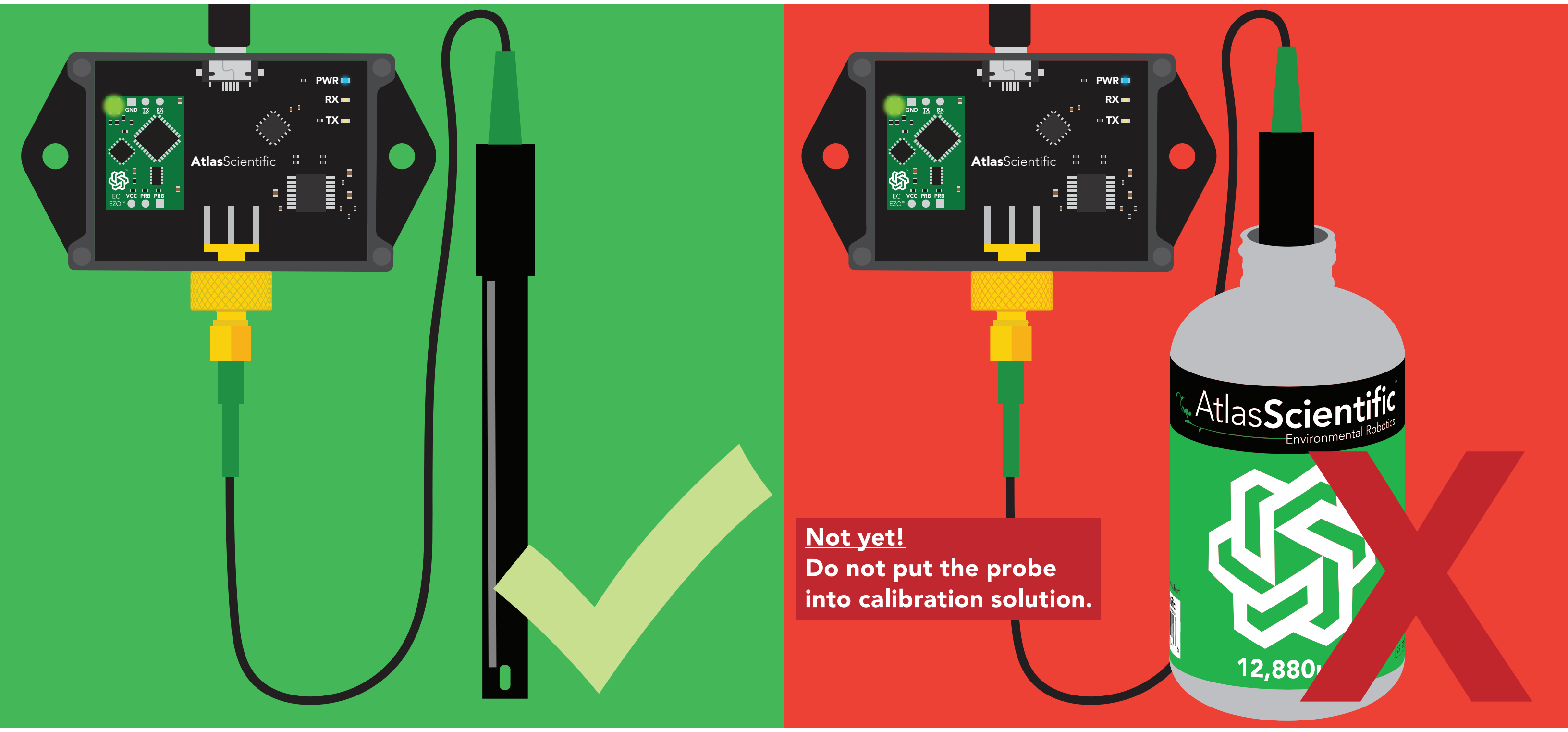
Over time, the readings will normalize as the solution warms to 25° C.



See pages **23** for more information.

1. Pre-calibration setup

Connect the dry conductivity probe and take continous readings.



2. Set probe type

If your probe ≠ K 1.0 *(default)*, then set the probe type by using the **"K,n"** command. *(where n = K value of your probe)* for more information, see page **22**.

3. Dry calibration

Perform a dry calibration using the command **"Cal,dry"** Even though you may see readings of 0.00 before issuing the **"Cal,dry"** command, it is still a necessary part of calibration.

00.00 → "Cal,dry" → 0.00 ✓ Correct

17.00 → "Cal,dry" → 0.00 ✓ Also correct

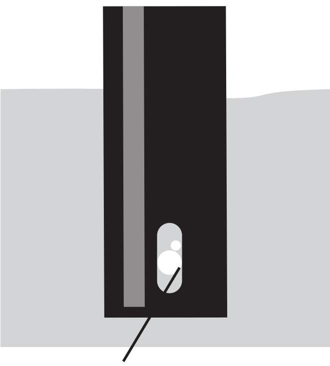
4. Calibration

Atlas Scientific recommends performing a three point calibration (*dry, low point & high point)* to obtain the greatest sensing range possible. However, depending on your situation a two point calibration may suffice.

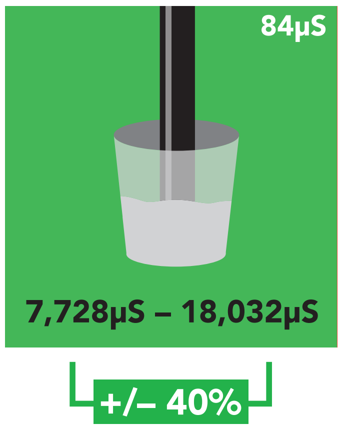
To perform a two or three point calibration, follow the instructions below.

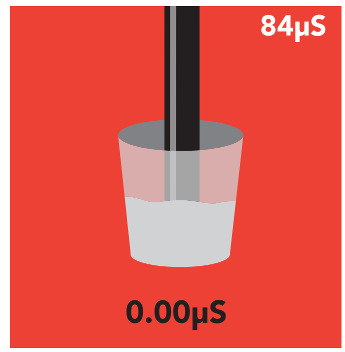
Two point calibration

After completing the dry calibration; Pour a small amount of calibration solution into a cup *(µS value of your choice)*. Shake the probe to make sure you do not have trapped air in the probe. You should see readings that are off by +/- 40% from the stated value of the calibration solution. Wait for readings to stabilize *(small movement from one reading to the next is normal)*.

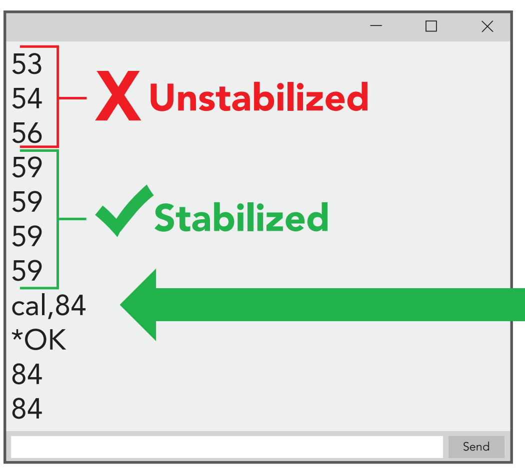


Trapped air in sensing area (shake to remove)





check probe connection, you cannot calibrate to 0.

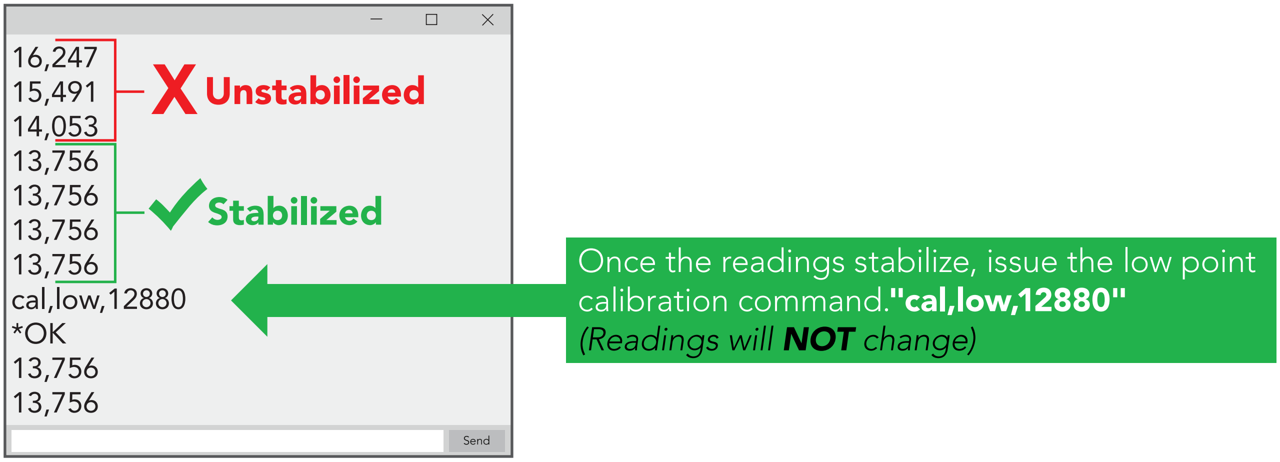


Once the readings stabilize, issue the single point calibration command.**"cal,n"** where n = any value. *(Readings **will** change, calibration complete).a*

Calibration complete!

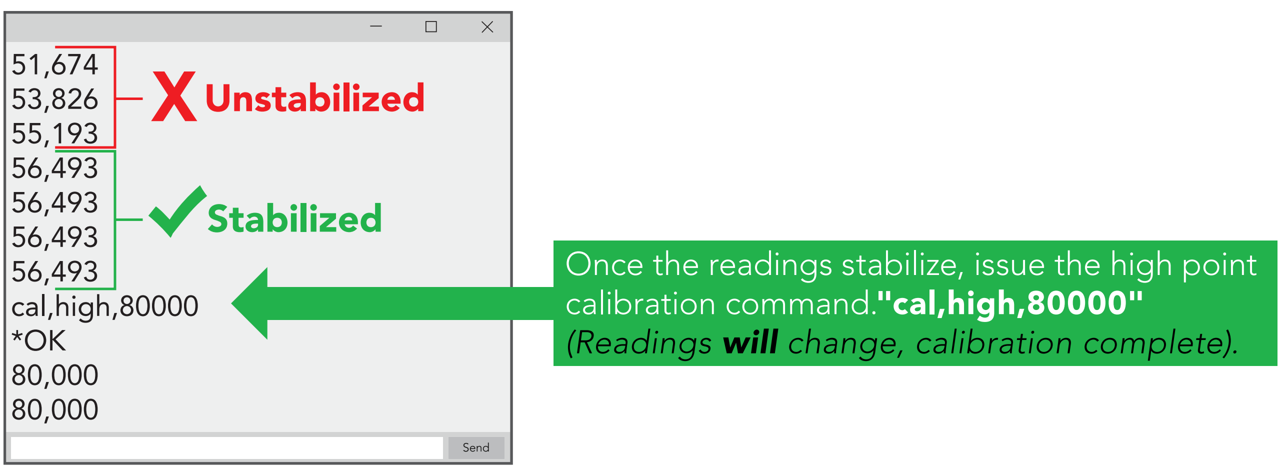
Three point calibration - low point

- Complete the dry calibration process first.
- Pour a small amount of the low point calibration solution into a cup.
- Shake the probe to remove trapped air.
- Readings may be off by +/- 40%
- Wait for readings to stabilize.



Three point calibration - high point

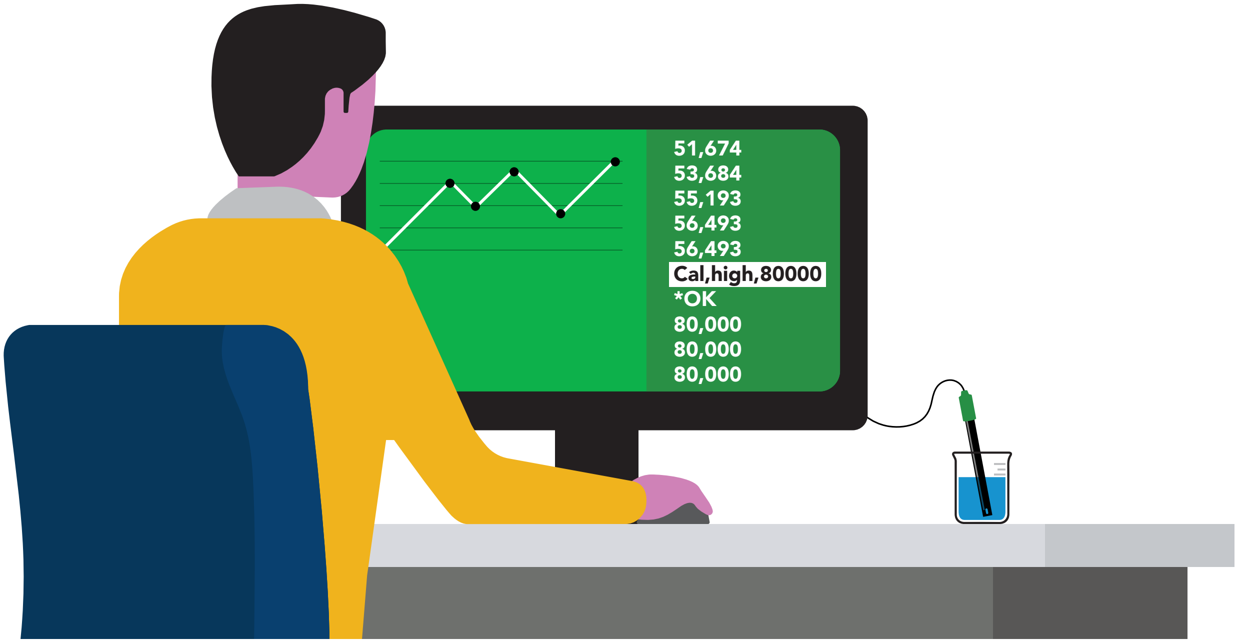
- Rinse off the probe before calibrating to the high point.
- Pour a small amount of the high point calibration solution into a cup.
- Shake the probe to remove trapped air.
- Readings may be off by +/- 40%
- Wait for readings to stabilize.



Calibration complete!

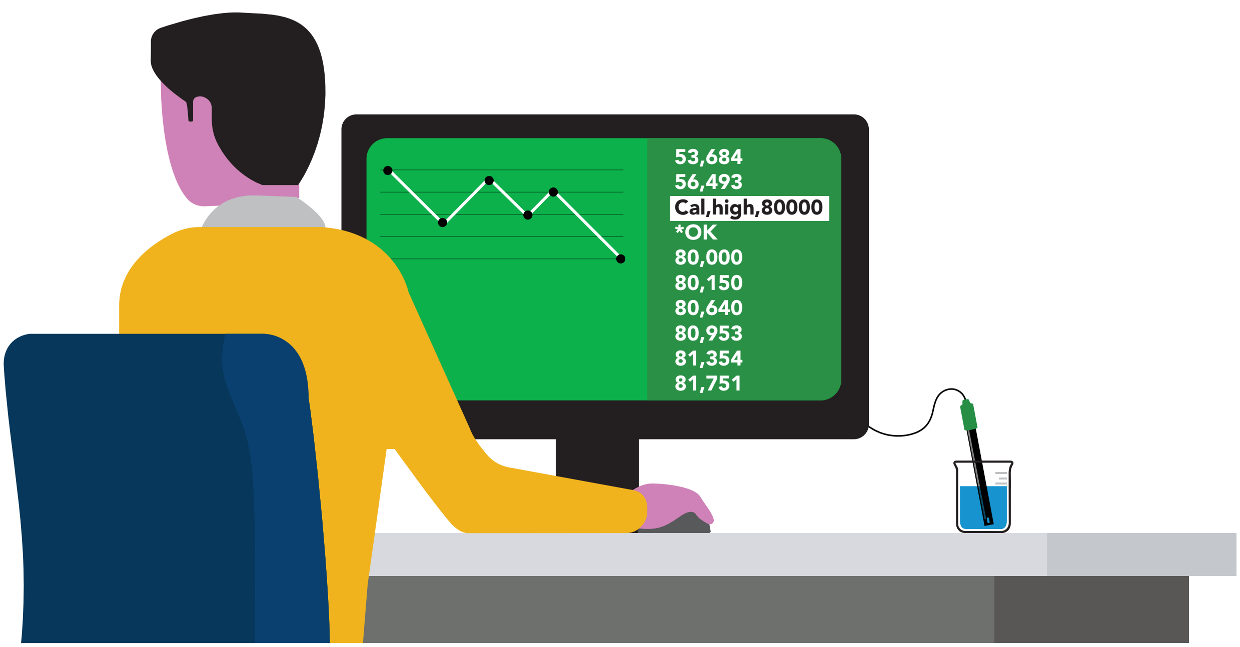
Best practices for calibration

Always watch the readings throughout the calibration process.
Issue calibration commands once the readings have stabilized.



⚠ Never do a blind calibration! ⚠

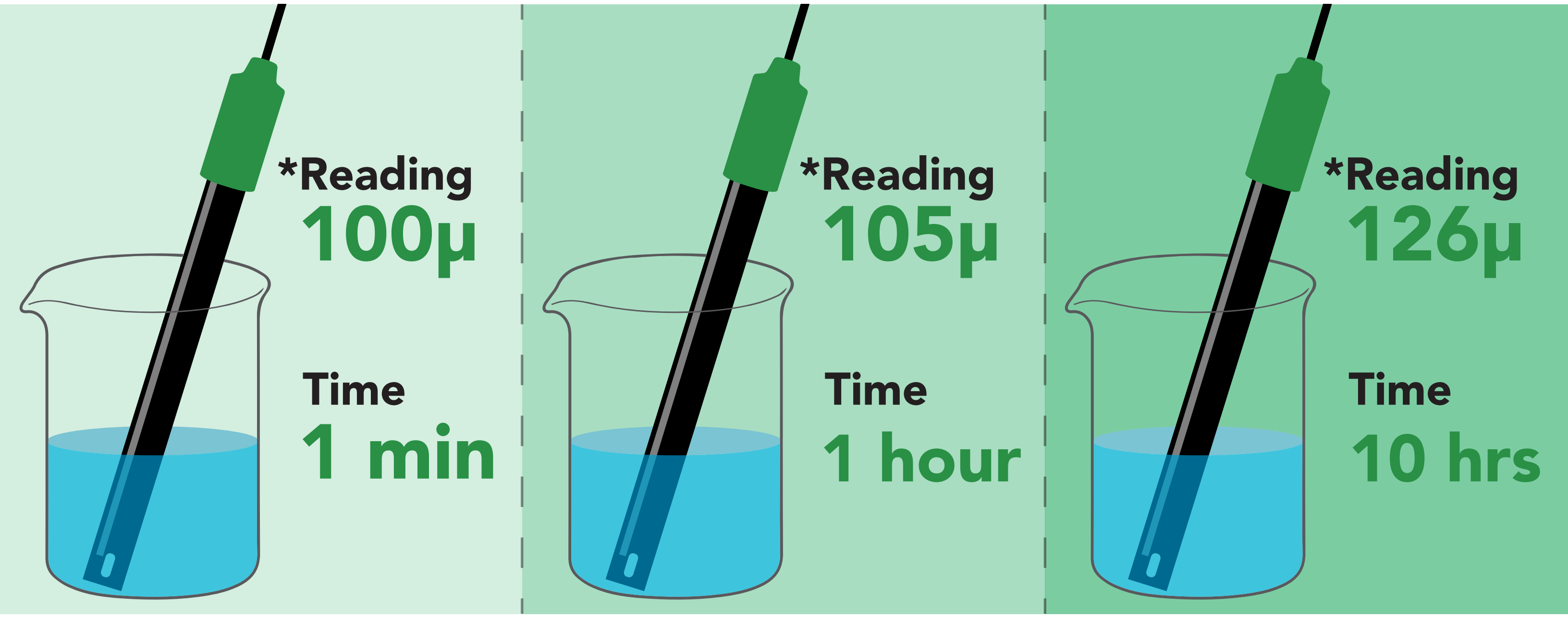
Issuing a calibration command before the readings stabilize will result in drifting readings.

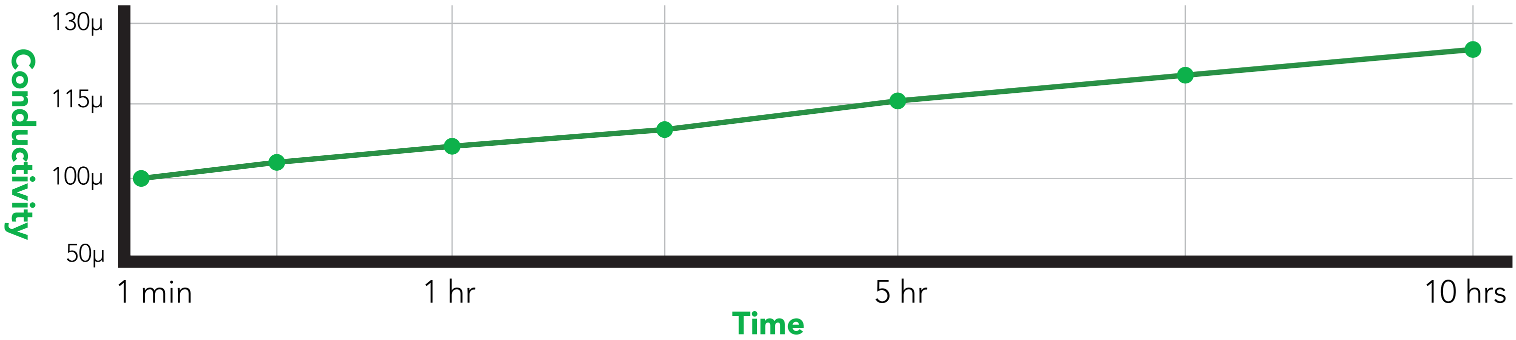


AtlasScientific
Environmental Robotics

Long-term conductivity measurements in stagnant water

Taking continuous conductivity readings in stagnant water:





A small amount of energy must be put into the water to measure conductivity. This small amount of energy will start to affect the readings in stagnant water. Over time, the energy passing through the stagnant water will start to align the dissolved salts along a path of least resistance. Lowering the resistance of the water will increase the water's conductivity.

Moving the probe or the water will disrupt this alignment and cause the readings to suddenly return to normal.

These are example readings; there is no way to predict how the readings will change over time.

Datasheet change log

Datasheet V 1.3

Revised probe artwork.

Datasheet V 1.2

Added info on Long-term conductivity measurements in stagnant water on pg 38.

Datasheet V 1.1

Revised calibration theory pages 31-38.

Datasheet V 1.0

Revised entire document.

Firmware updates

V1.5 – Baud rate change (Nov 6, 2014)
• Change default baud rate to 9600

Warranty

Atlas Scientific™ Warranties the EZO Complete device to be free of defects during the debugging phase of device implementation or 30 days after receiving the EZO Complete device *(whichever comes first)*.

The debugging phase

As defined by Atlas Scientific™, the debugging phase is when the EZO Complete device is connected to a computer to evaluate its output and/or is being integrated into custom software.

The following activities will void the EZO Complete device warranty:

- **Soldering any part of the EZO™ class device.**
- **Removing any potting compound.**
- **Embedding the EZO Complete device into a custom machine.**

Reasoning behind this warranty

Atlas Scientific™ does not sell consumer electronics. Once the device has been embedded into a custom-made machine, Atlas Scientific™ cannot possibly warranty the EZO Complete device against the thousands of possible variables that may cause the device to malfunction.

Please keep this in mind:

1. All Atlas Scientific™ devices have been designed to be embedded into a custom-made machine by you, the embedded systems engineer.

2. All Atlas Scientific™ devices have been designed to run indefinitely without failure in the field.

Atlas Scientific™ is simply stating that once the device is being used in your machine or application, Atlas Scientific™ can no longer take responsibility for the device's continued operation. Doing so would be equivalent to Atlas Scientific™ taking responsibility for the correct operation of your entire machine.

