Atlas Scientific™
Environmental Robotics

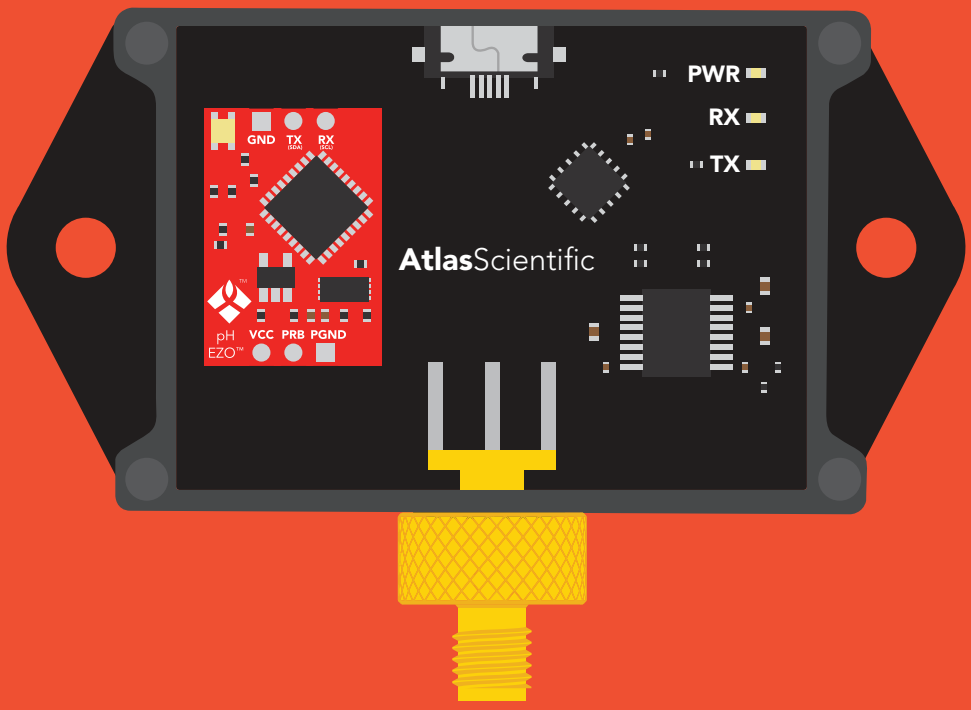
V 1.1
Revised 10/23

EZO Complete-pH™

USB pH meter

Datasheet for engineers

ISO 10523 Compliant
(determination of pH)



Reads	**pH**
Normal range	**.001 – 14.000**
Extended range	**-1.600 – 15.600**
Accuracy	**+/– 0.002**
pH reading time	**800ms**
Supported probes	**Any type & brand**
Calibration	**1, 2, 3 point**
Recalibration frequecy	**~8 – 12 months**
Data protocol	**Serial data through FTDI virtual comport**
Temp compensation	**Yes**
Data format	**ASCII**
Ingress protection	**IP62**

RoHS COMPLIANT

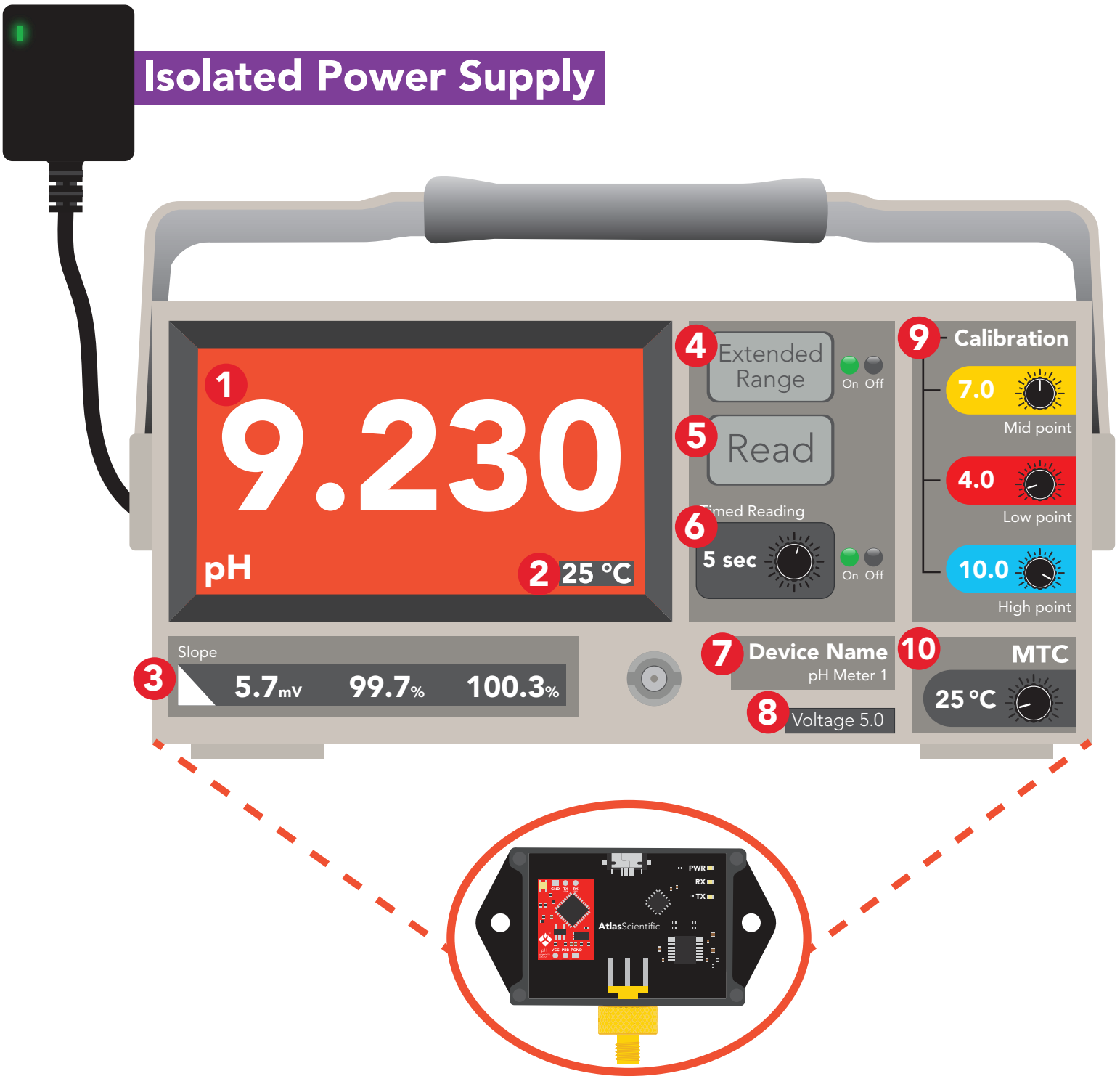
Written by Jordan Press
Designed by Noah Press

PATENT PROTECTED

This is an evolving document, check back for updates.

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

Isolated Power Supply



1 Three decimal pH reading
2 Temperature used for reading
3 Calibration slope
4 Extended range capability
5 Immediate reading
6 Timed readings
7 Set device name
8 Voltage usage
9 Multi-point variable calibration
10 Manual Temperature compensation

The EZO Complete-pH™ is compatible with any brand of pH probe.

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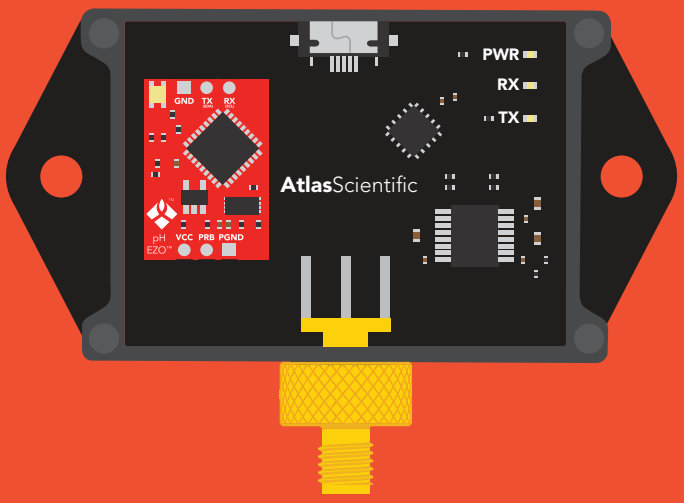

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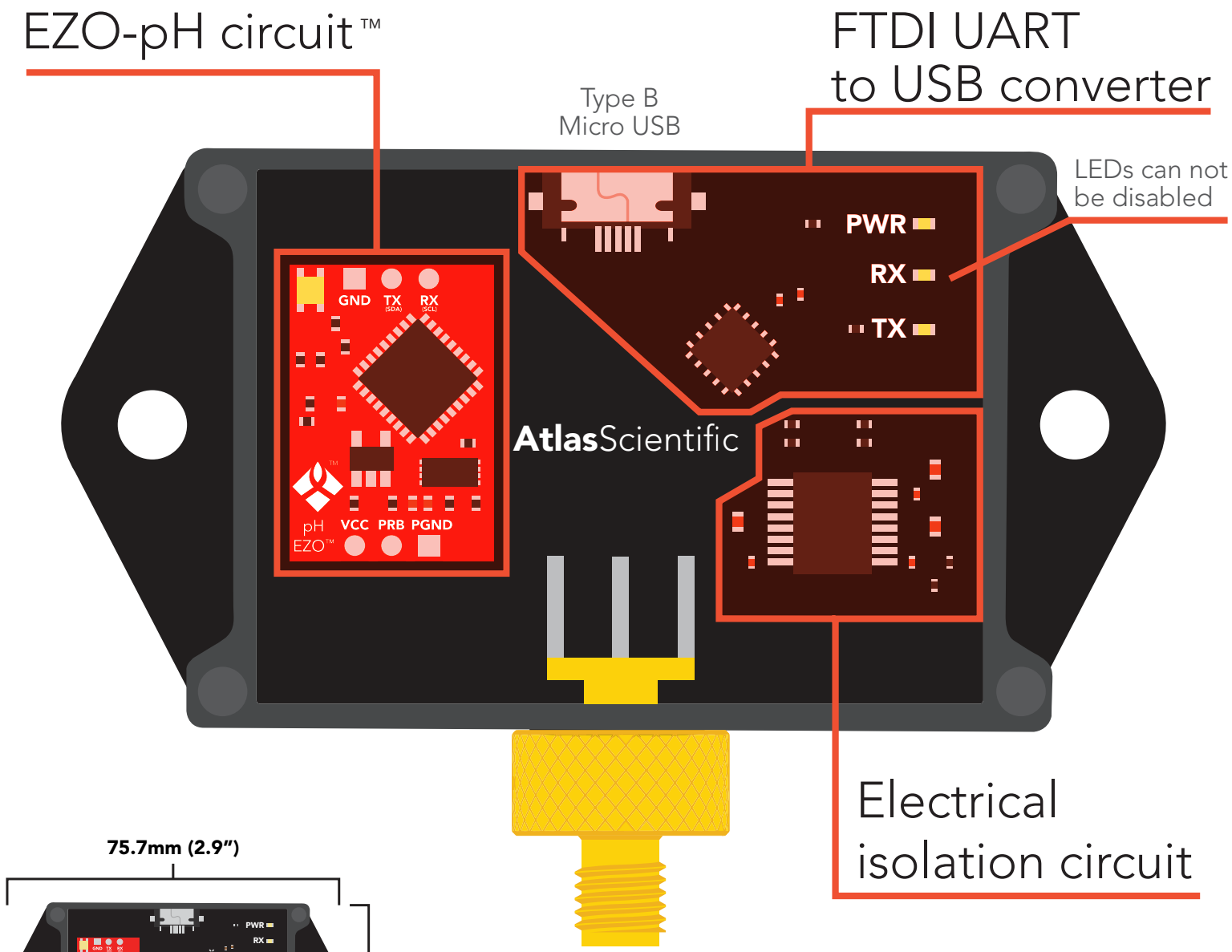
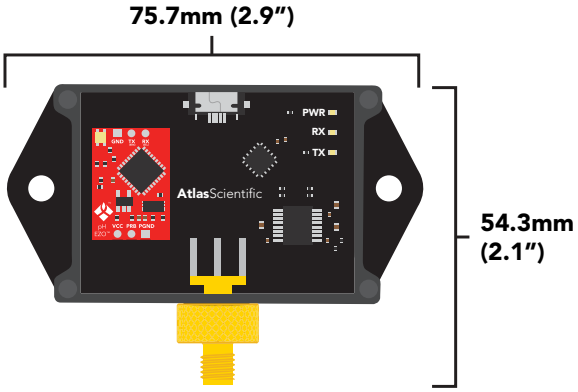
The EZO Complete-pH™ consists of 3 major components.





Power consumption

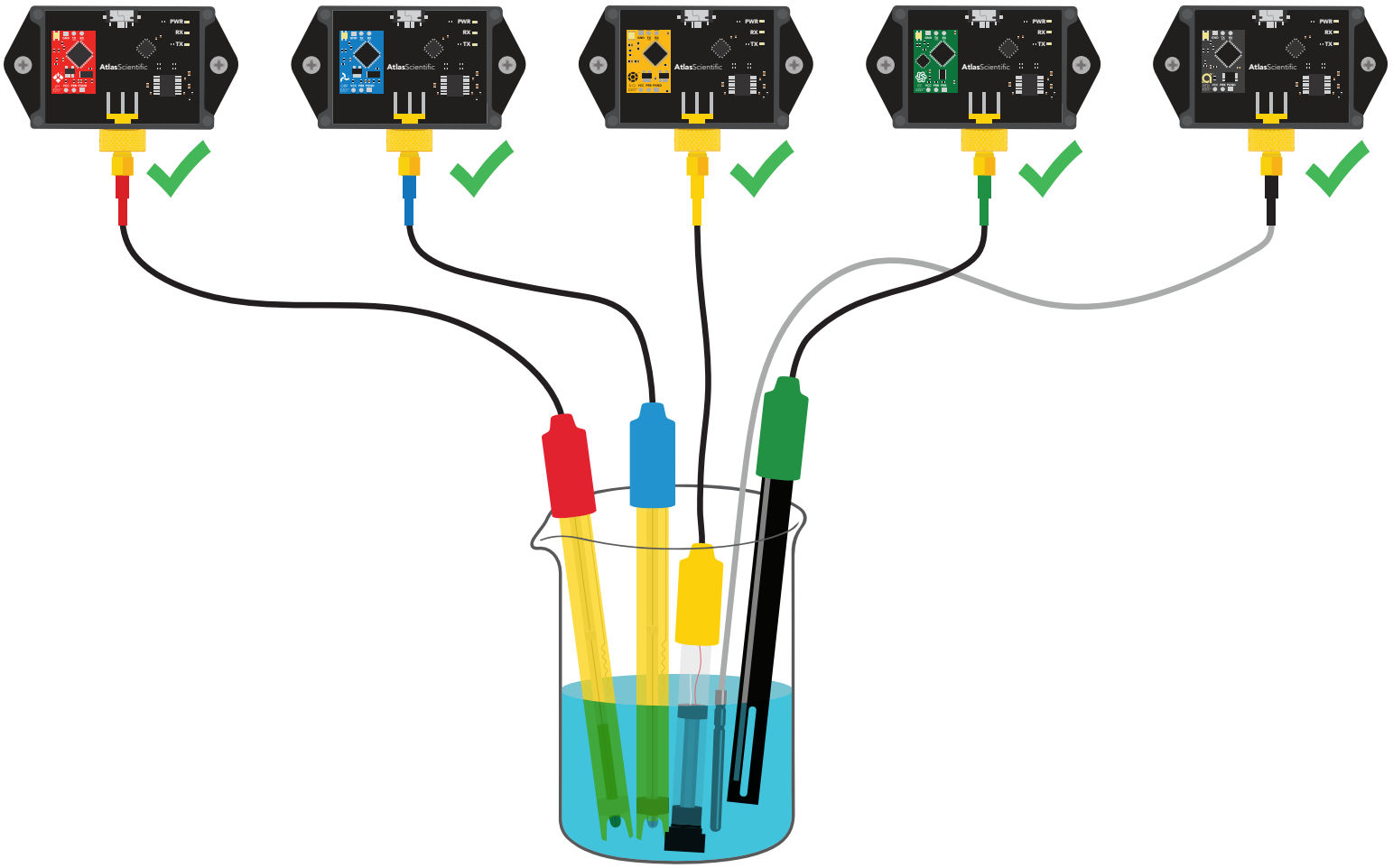
	MAX	STANDBY	SLEEP
5V USB	37.0 mA	36.8 mA	22.6 mA

Absolute max ratings

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

Interference free

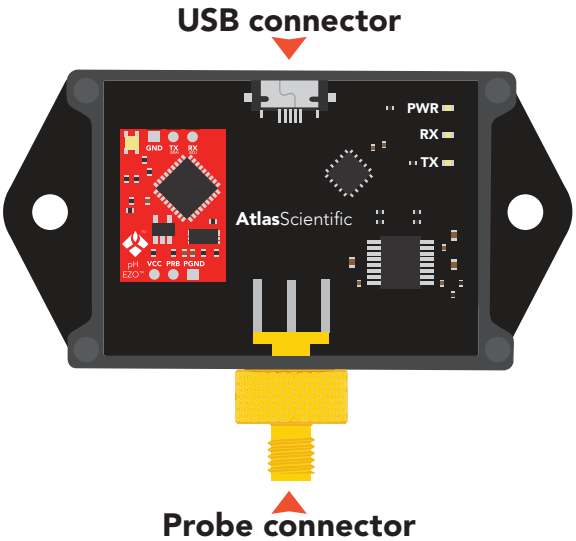
The EZO complete readings are unaffected by other sensors in the same water.



Ingress protection – IP62

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

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



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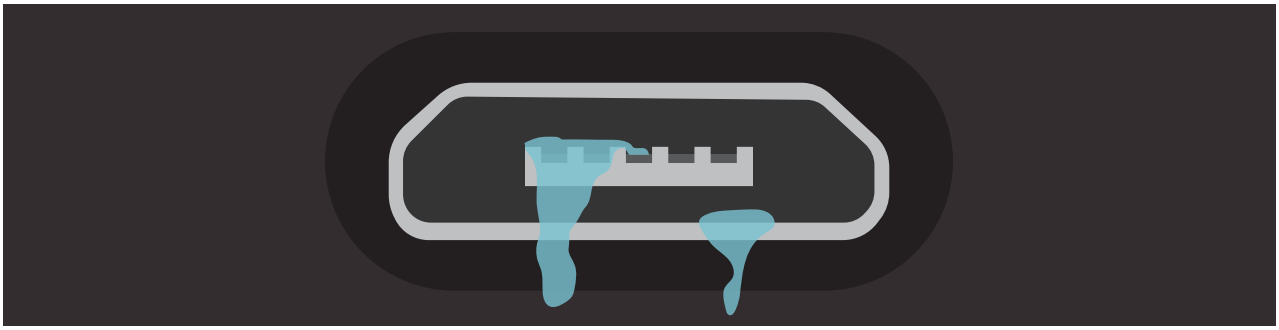
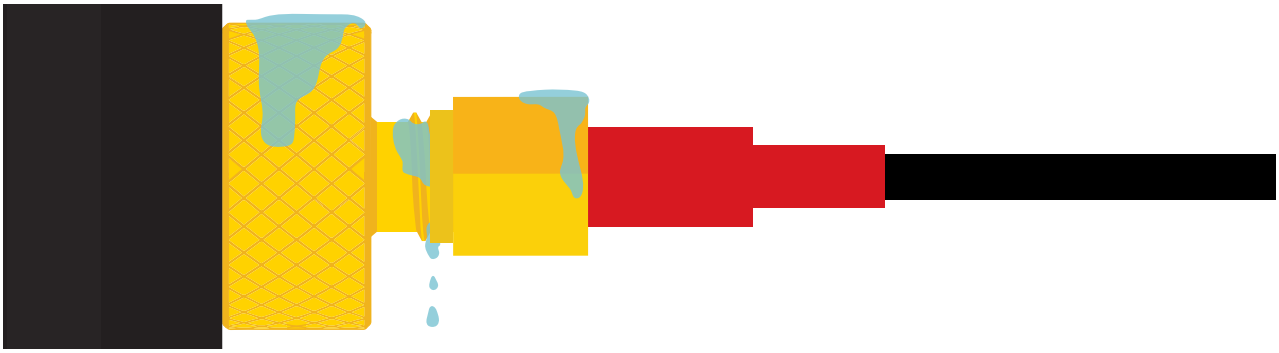
Ingress protection – IP62

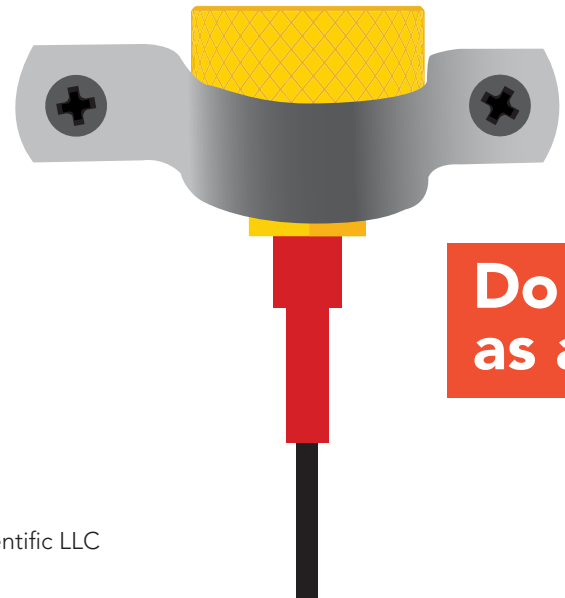
An electrical short can occur if water enters the USB connector. A USB short could permanently damage the EZO-Complete. A USB short is not covered under warranty.



A connector short can occur if water enters the SMA connector. A connector short will cause the pH readings to pin to 0, 14, or the probe will respond slowly to changes in pH. A connector short is reversible and will not damage the EZO-Complete. However, frequent shorts will eventually damage the pH 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!

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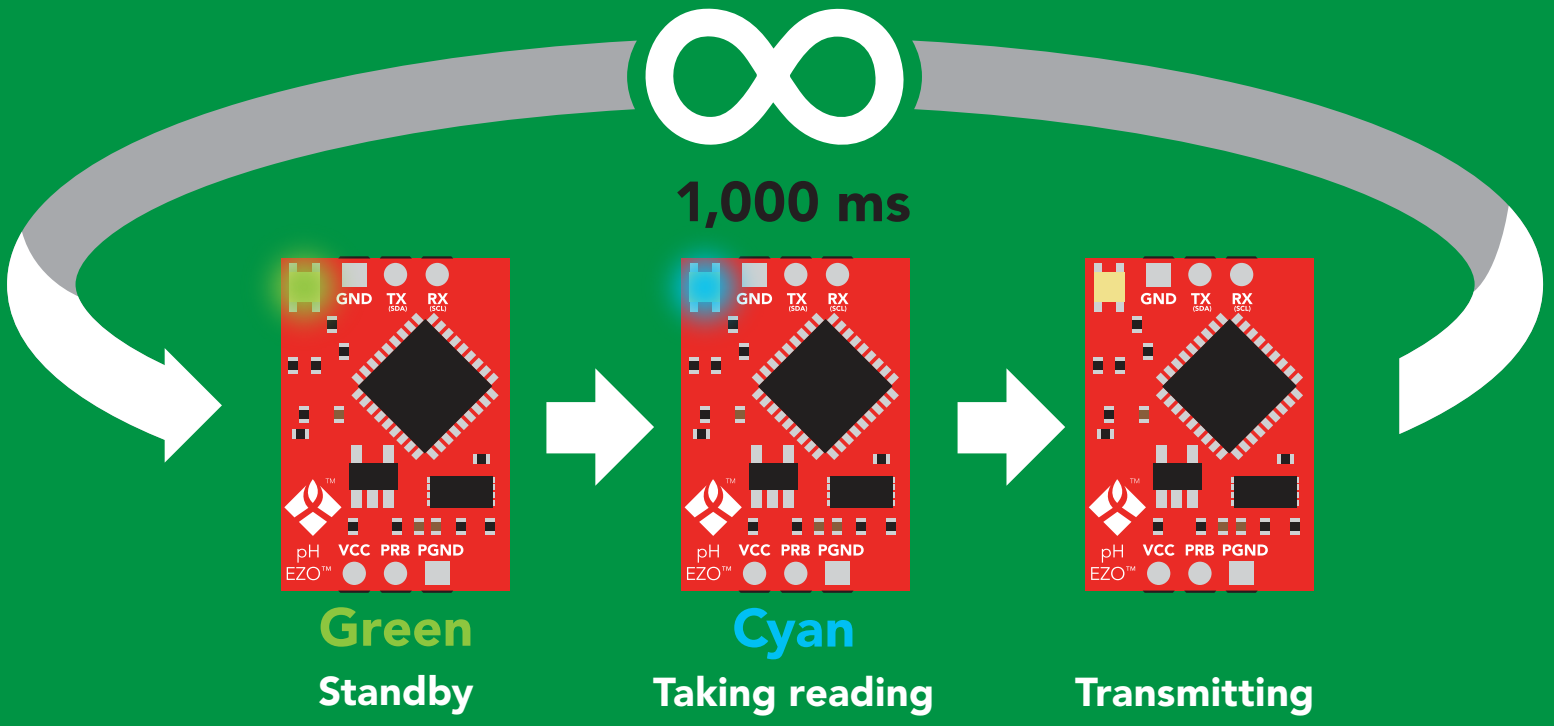
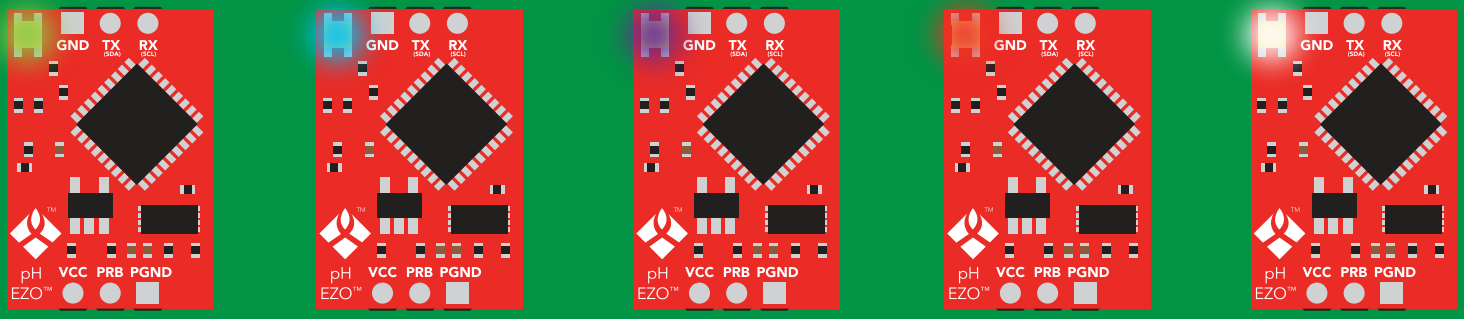
Default state

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

Calibration
Continuous mode
Device name
Enable/disable response codes
LED control
Protocol lock

Settings that are *NOT* retained if power is cut

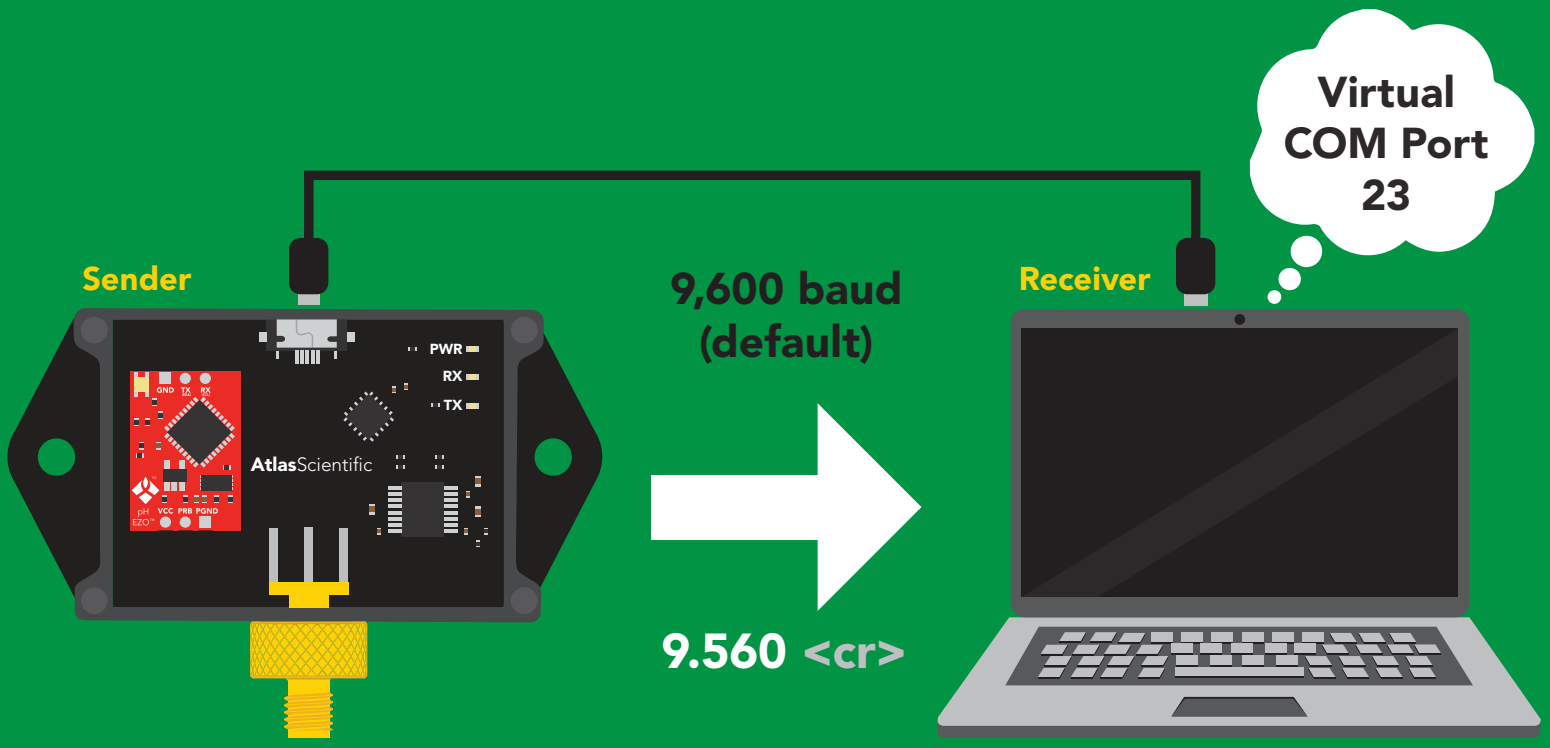
Find
Sleep mode
Temperature compensation

Receiving data from device

2 parts

ASCII data string
Command

Carriage return <cr>
Terminator



(COM Port numbers are determined by the computer)

Advanced

ASCII:	9	.	5	6	0	<cr>
Hex:	39	2E	35	36	30	0D
Dec:	57	46	53	54	48	13

Sending commands to device

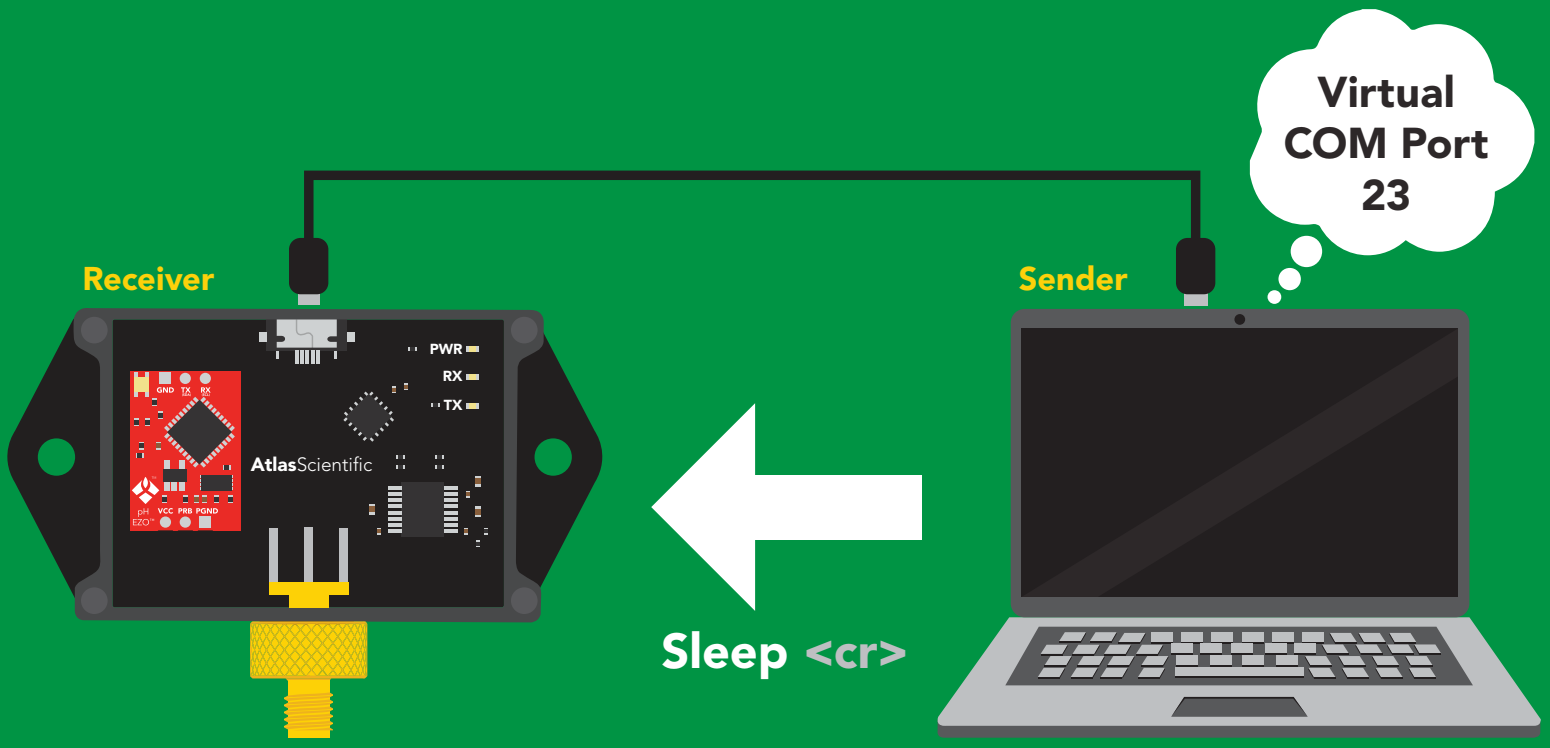
2 parts

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

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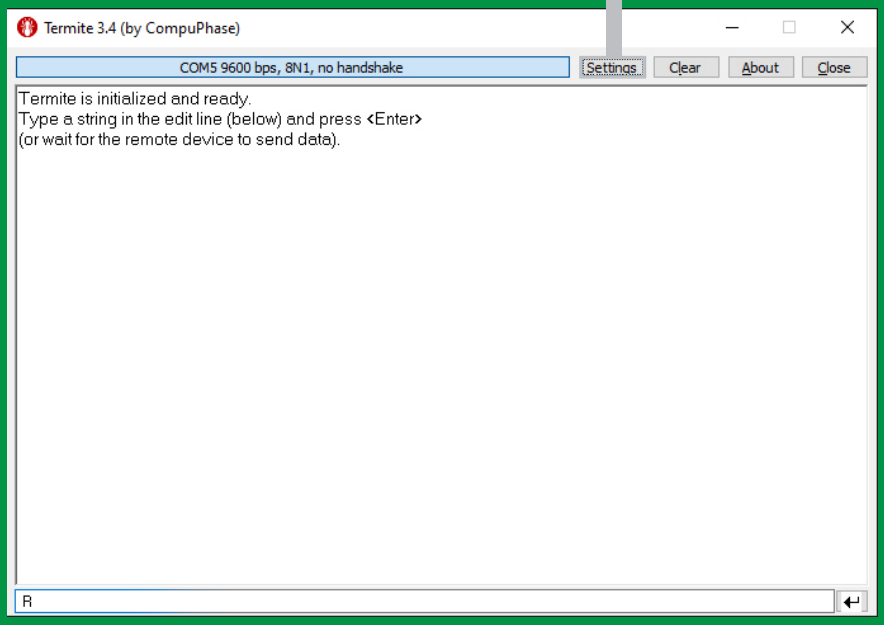
Looking for a simple serial monitor for debugging?

Termite: a simple RS232 terminal

Click here to download

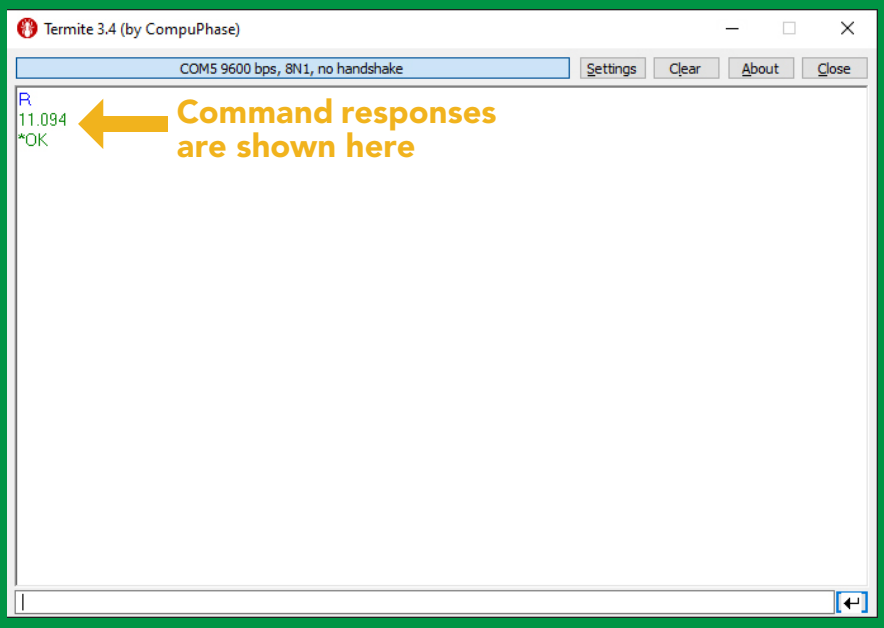


Settings

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

Transmitted text append CR

Enter commands here



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Command quick reference

All commands are ASCII strings or single ASCII characters.

Command	Function		Default state
C	enable/disable continuous reading	pg. 15	enabled
Cal	performs calibration	pg. 17	n/a
Export	export calibration	pg. 18	n/a
Factory	enable factory reset	pg. 28	n/a
Find	finds device with blinking white LED	pg. 14	n/a
i	device information	pg. 24	n/a
Import	import calibration	pg. 19	n/a
L	enable/disable LED	pg. 13	enabled
Name	set/show name of device	pg. 23	not set
pHext	enable/disable extended pH scale	pg. 21	disabled
R	returns a single reading	pg. 16	n/a
Sleep	enter sleep mode/low power	pg. 27	n/a
Slope	returns the slope of the pH probe	pg. 20	n/a
Status	retrieve status information	pg. 26	enable
T	temperature compensation	pg. 22	25˚C
*OK	enable/disable response codes	pg. 25	enable

LED control

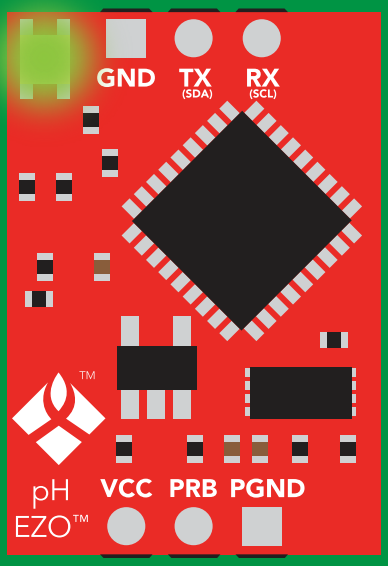
Command syntax

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

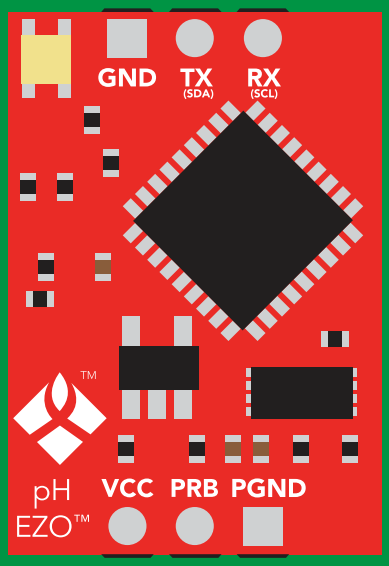
L,0 <cr> LED off

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

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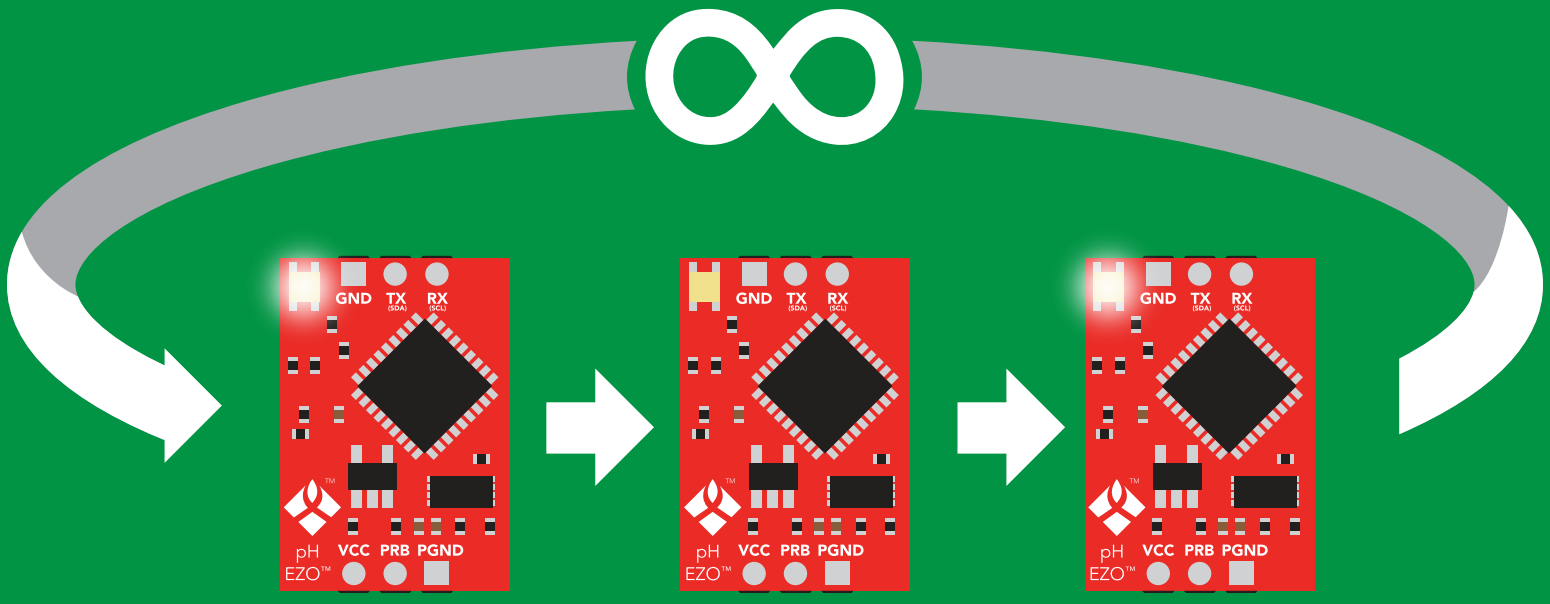
Find

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>



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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> pH (1 sec) <cr> pH (2 sec) <cr> pH (n sec) <cr>
C,30 <cr>	*OK <cr> pH (30 sec) <cr> pH (60 sec) <cr> pH (90 sec) <cr>
C,0 <cr>	*OK <cr>
C,? <cr>	?C,1 <cr> or ?C,0 <cr> or ?C,30 <cr> *OK <cr>

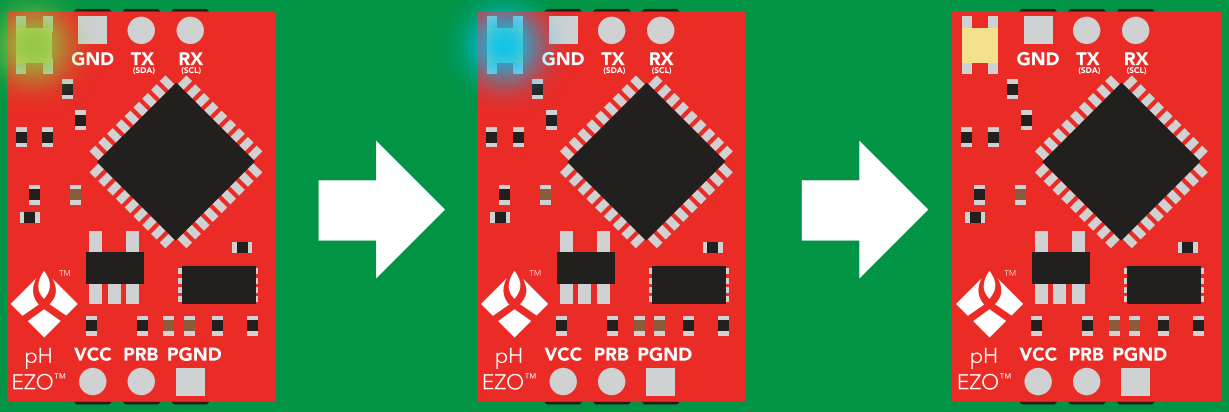
Single reading mode

Command syntax

A single reading takes 800ms

R <cr> takes single reading

Example	Response
R <cr>	9.560 <cr> *OK <cr>



Green
Standby

Cyan
Taking reading

Transmitting

800 ms

Calibration

Command syntax

Issuing the cal,mid command after the EZO™ pH circuit has been calibrated, will clear the other calibration points. Full calibration will have to be redone.

Cal,mid,n	<cr>	single point calibration at midpoint
Cal,low,n	<cr>	two point calibration at lowpoint
Cal,high,n	<cr>	three point calibration at highpoint
Cal,clear	<cr>	delete calibration data
Cal,?	<cr>	device calibrated?

Example	Response
Cal,mid,7.00 <cr>	*OK <cr>
Cal,low,4.00 <cr>	*OK <cr>
Cal,high,10.00 <cr>	*OK <cr>
Cal,clear <cr>	*OK <cr>
Cal,? <cr>	?Cal,0 <cr> or ?Cal,1 <cr> (one point) or ?Cal,2 <cr> (two point) or ?Cal,3 <cr> (three point) *OK <cr>

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>

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>

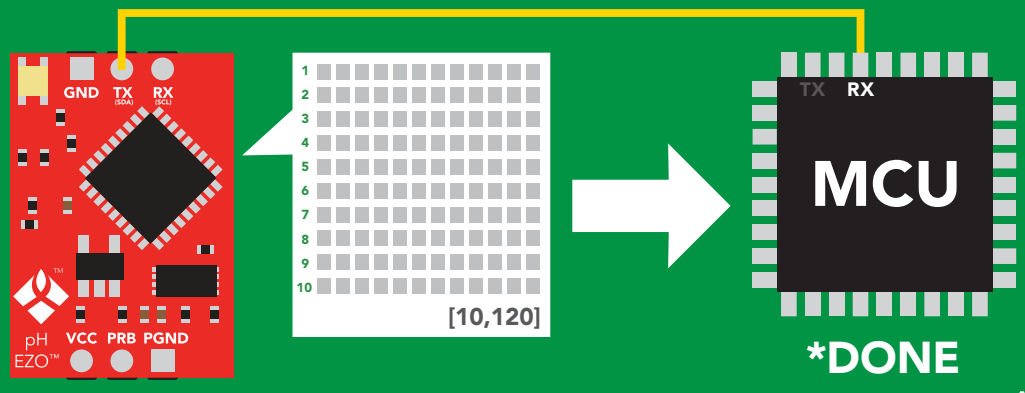
6F 6C 20 67 75 79 <cr> **(10 of 10)**

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

Import, 59 6F 75 20 61 72 <cr> (1 of 10)

Import, 65 20 61 20 63 6F <cr> (2 of 10)

⋮

Import, 6F 6C 20 67 75 79 <cr> (10 of 10)

Response

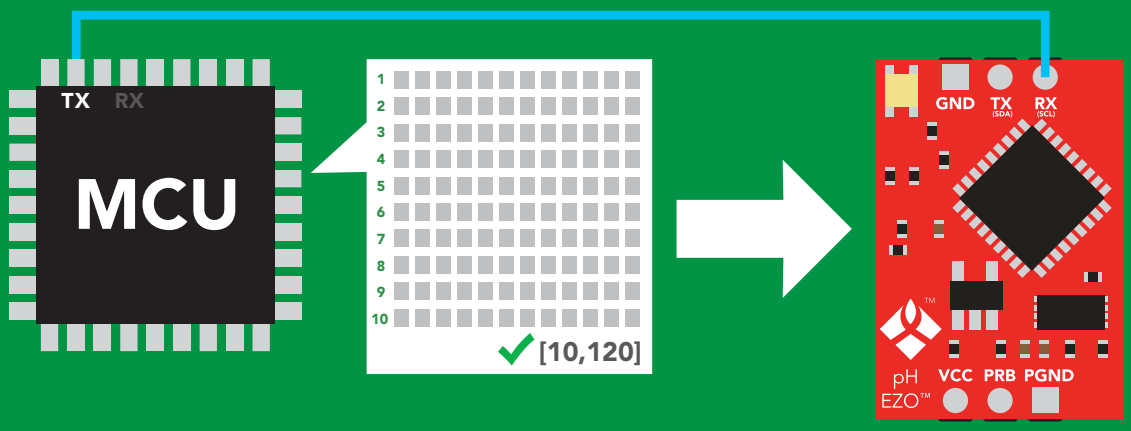
*OK <cr>

*OK <cr>

⋮

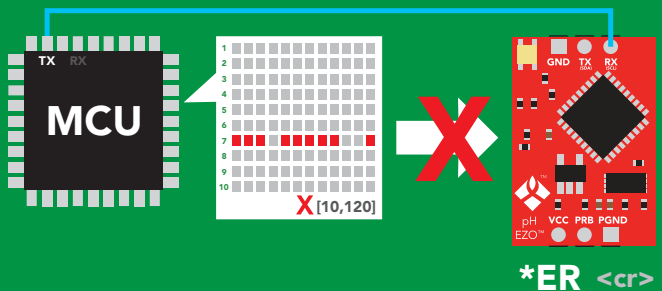
*OK <cr>

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.**

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Slope

Command syntax

After calibrating a pH probe issuing the slope command will show how closely (in percentage) the calibrated pH probe is working compared to the "ideal" pH probe.

Slope,? <cr> returns the slope of the pH probe

Example	Response
Slope,? <cr>	?Slope,99.7,100.3, -0.89 <cr> *OK <cr>

Response breakdown

?Slope,

99.7

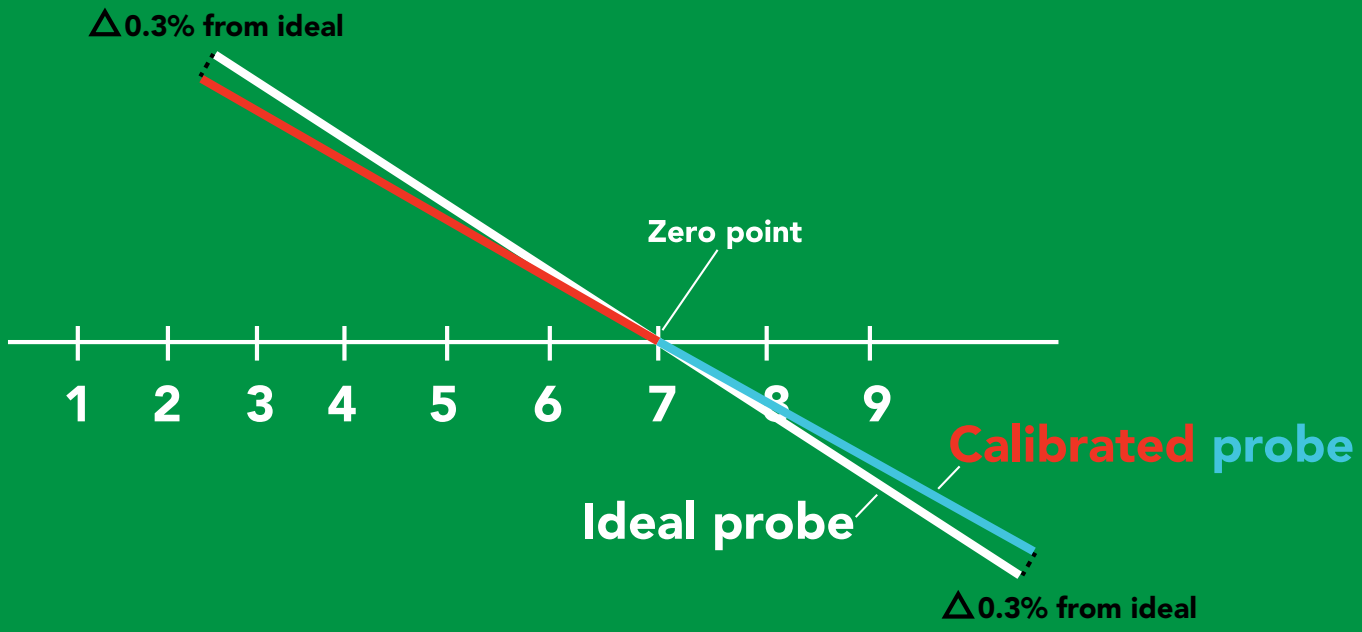
99.7% is how closely the slope of the **acid** calibration line matched the "ideal" pH probe.

100.3

100.3% is how closely the slope of the **base** calibration matches the "ideal" pH probe.

-0.89

This is how many millivolts the zero point is off from true 0.



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Extended pH scale

Very strong acids and basses can exceed the traditional pH scale. This command extends the pH scale to show below 0 and above 14.

Lowest possible reading: **-1.6**
Highest possible reading: **15.6**

Command syntax

pHext,0 <cr>	extended pH scale off (0–14)	**default**
pHext,1 <cr>	extended pH scale on (-1.6–15.6)	
pHext,? <cr>	extended pH scale on/off?	

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

pHext,0

pH = 0.000

pHext,1

pH = -1.220

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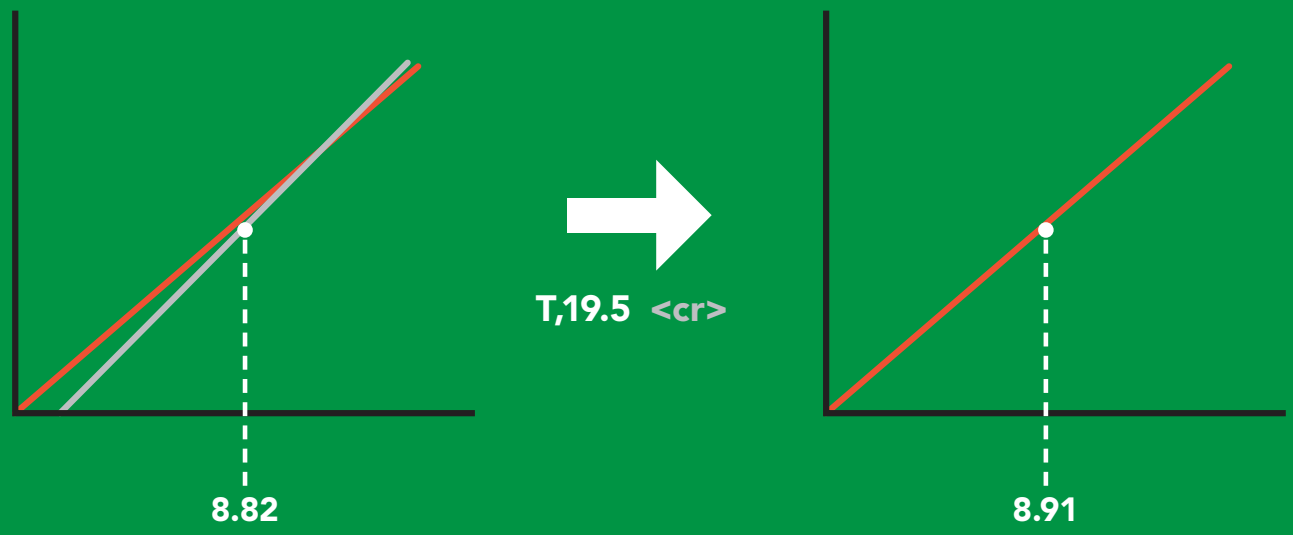
Temperature compensation

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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Naming device

Command syntax

Do not use spaces in the name

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

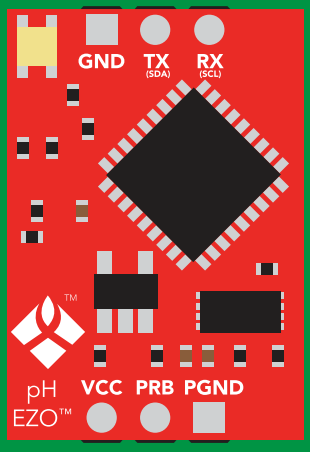
n =

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

Up to 16 ASCII characters

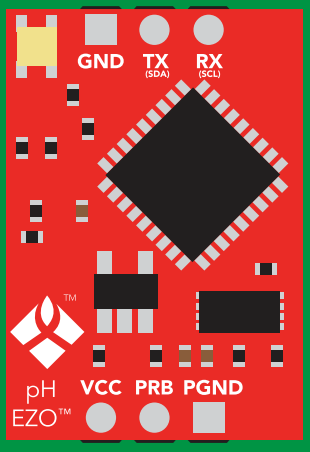
Example		Response	
Name,	<cr>	*OK <cr>	name has been cleared
Name,zzt	<cr>	*OK <cr>	
Name,?	<cr>	?Name,zzt <cr> *OK <cr>	

Name,zzt



*OK <cr>

Name,?



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

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Device information

Command syntax

i <cr> **device information**

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

Response breakdown

?i, pH, 2.16

pH, → Device

2.16 → 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>	9.560 <cr> *OK <cr>
*OK,0 <cr>	no response, *OK disabled
R <cr>	9.560 <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

- P: Reason for restart
- 5.038: Voltage at Vcc

Restart codes

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

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	16 mA	1.16 mA
3.3V	13.9 mA	0.995 mA

Standby
16 mA

Sleep
1.16 mA

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Factory reset

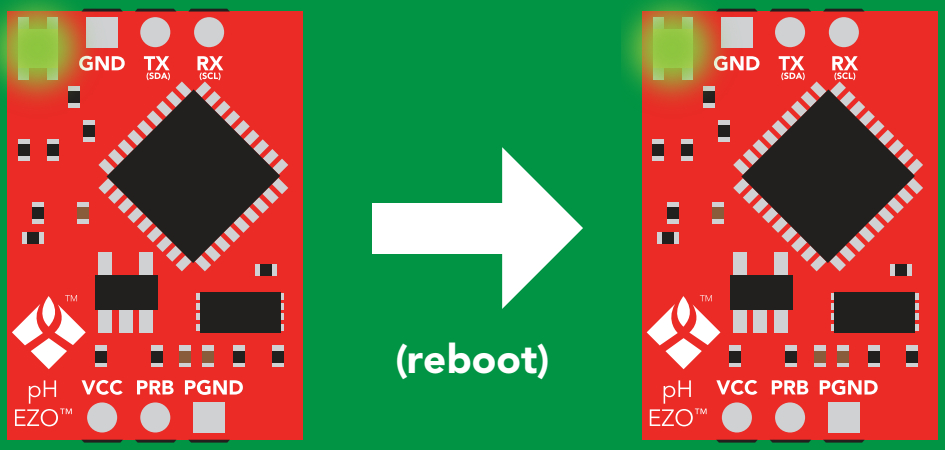
Command syntax

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>

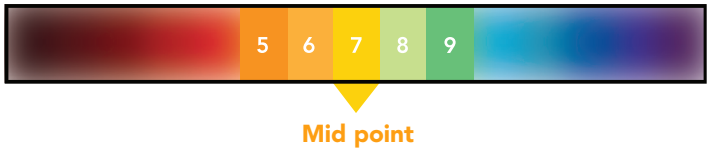
Baud rate will not change

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).

Single, Two point, or Three point calibration accuracy

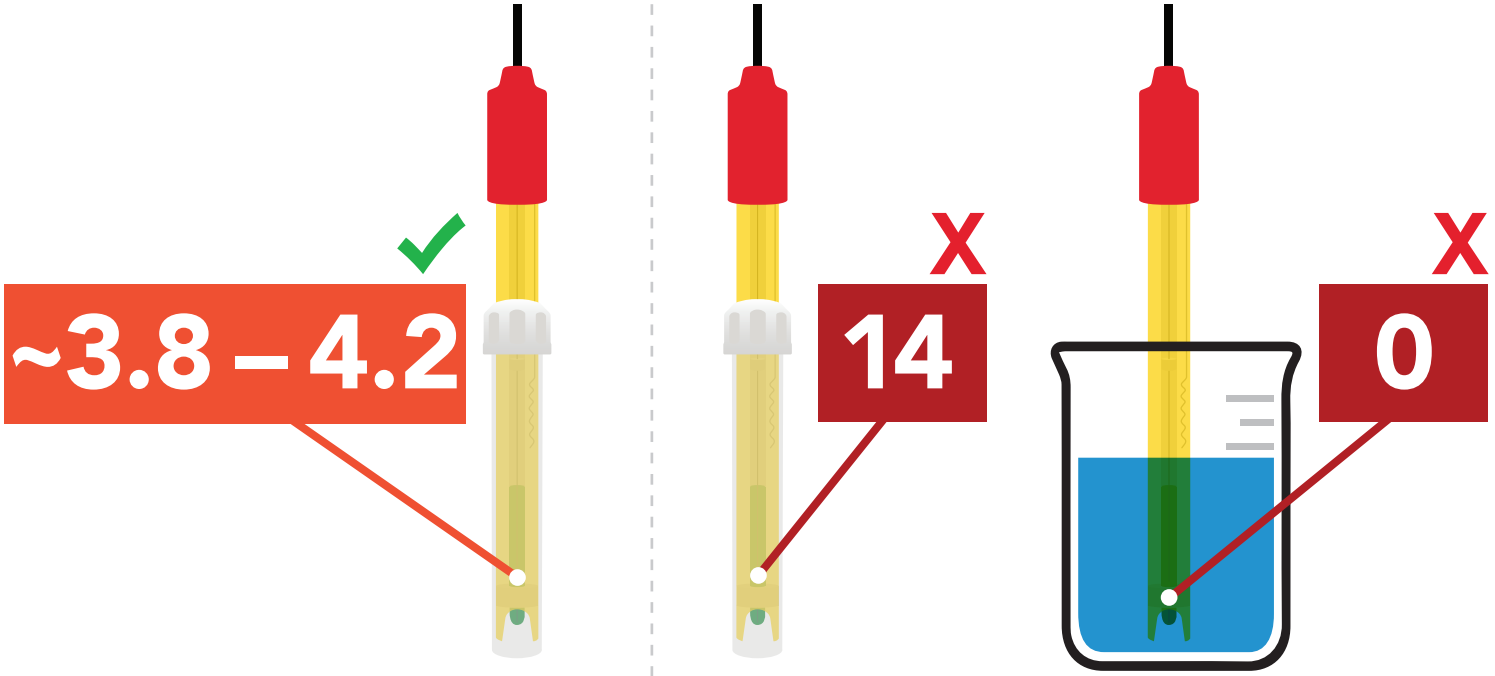
Single point calibration



Two point calibration

Three point calibration

Confirm the pH probe is working correctly



A new Atlas Scientific pH probe, still in its soaker bottle will read a pH of ***~3.4 – 3.8***

If your pH probe gives a reading of ***zero***, ***seven*** or ***14*** continuously and that reading cannot be changed no matter what solution the probe is in, your probe cannot be calibrated and may be damaged.

Contact Atlas Scientific customer support for assistance.

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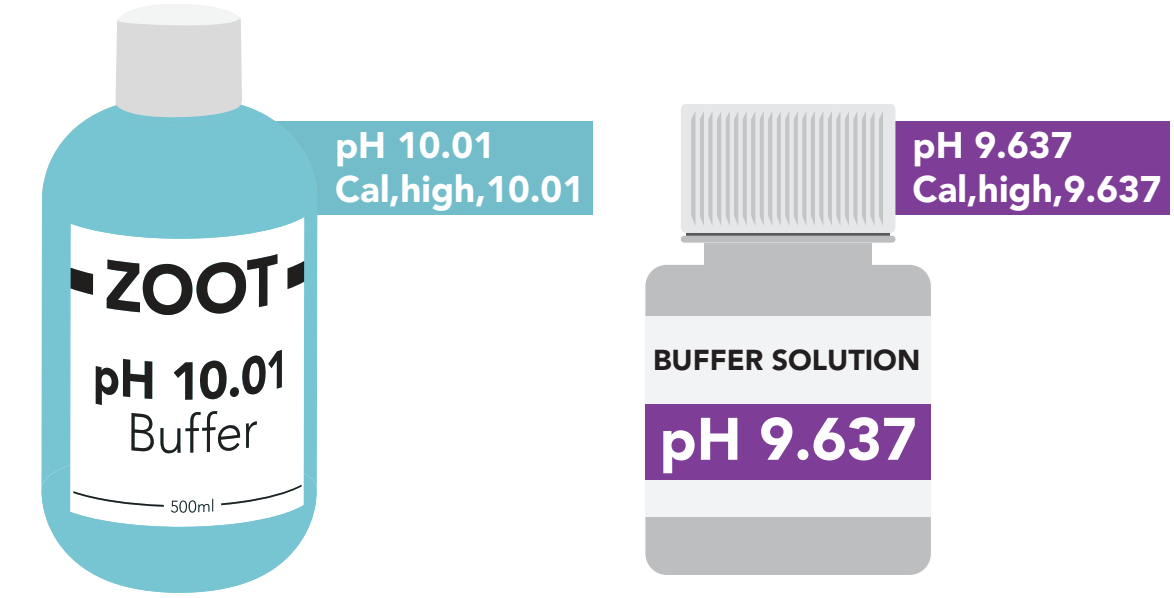
Calibration order

If this is your first time calibrating the EZO Complete-pH, we recommend following this calibration order.

1 **Mid point** 2 **Low point** 3 **High point**

Calibration solutions

The Atlas Scientific EZO Complete-pH can work with any brand or value of calibration solution. ***We recommend using calibration solutions that have simple values.***



✓ **Simple value** X **Complex value**

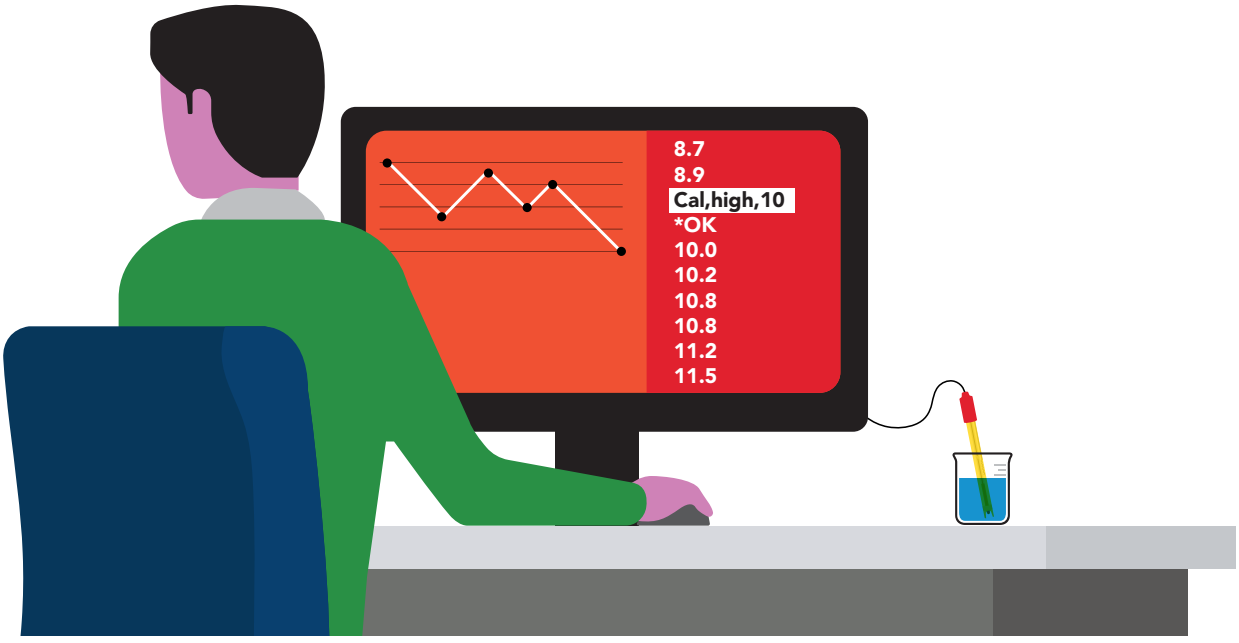
While you can use calibration solutions that have complex values, we recommend avoiding unnecessary complexity. ***Unusually specific calibration values should be treated with suspicion.***

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.



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Best practices for calibration

Avoid extended stabilization time.

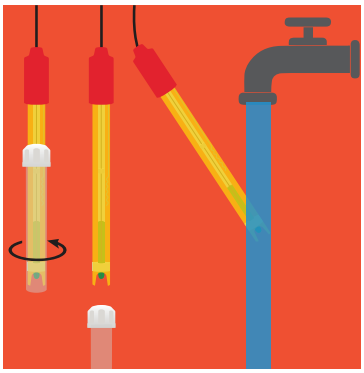
Letting the probes pre-calibrtion readings stabilize over an extended period will cause your calibrated readings to take a long time to stabilize.

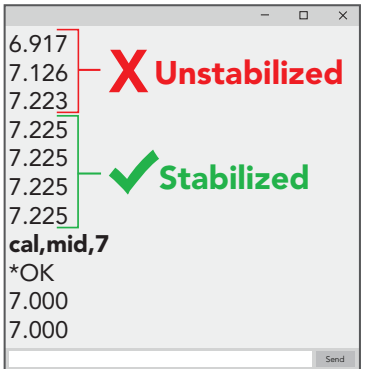
Avoid frequent recalibrations.

if it ain't broke, don't fix it.

pH probes loose accuracy slowly. Frequent recalibrations to insure high accuracy will often have the opposite effect. It is far more llikly that you will misscalibrate the probe rather then improve its accuracy.

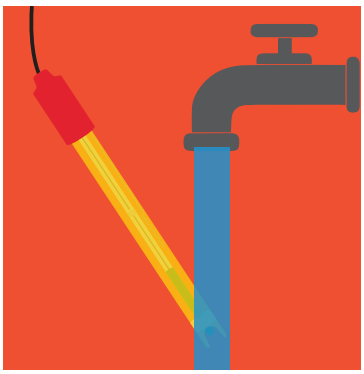
1. Mid point calibration

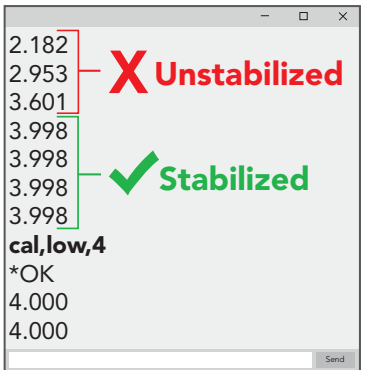




Mid point calibrated

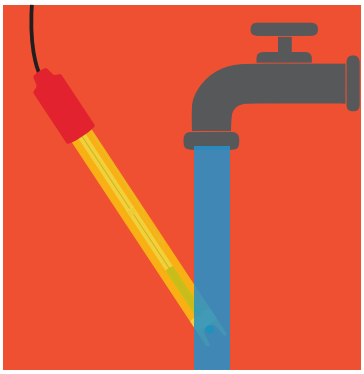
2. Low point calibration

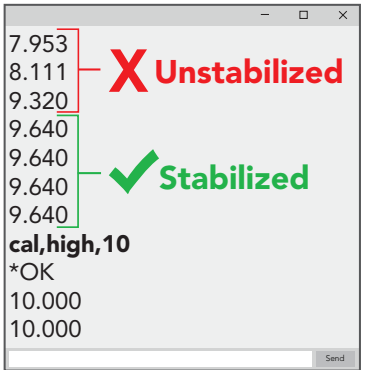




Low point calibrated

3. High point calibration





High point calibrated

Optional steps:

Confirm your calibration accuracy using the slope command.
Recalibrate a single point if required.

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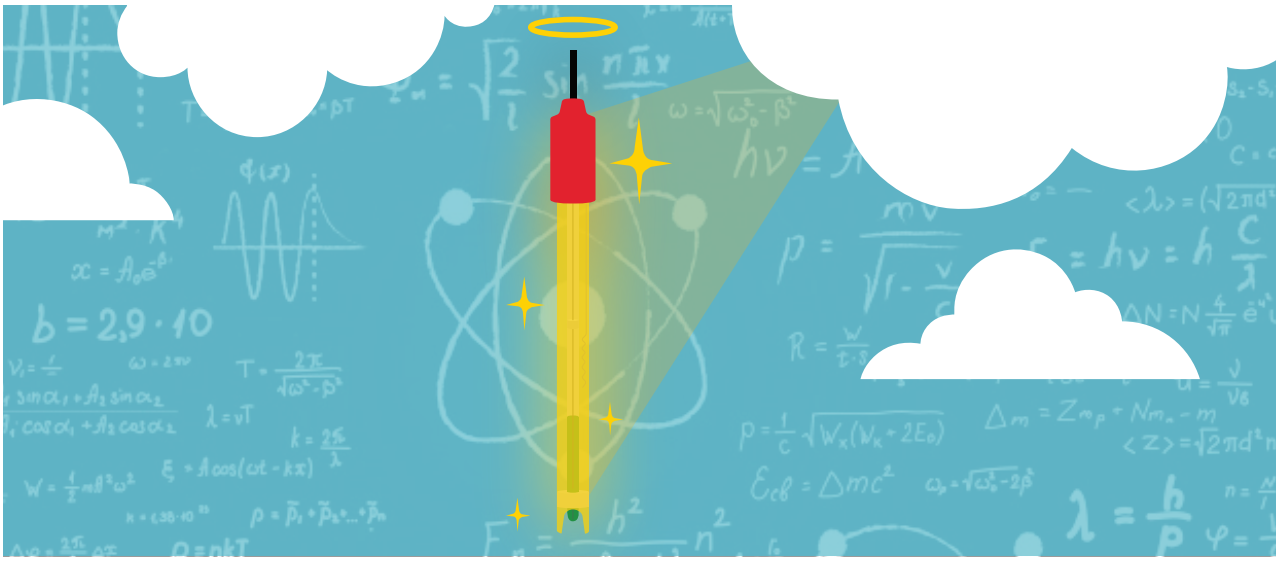
Understanding pH slope

The slope function is a powerful tool used to verify calibration and determine the overall health of a pH probe. By evaluating the slope of a pH probe's response curve, you can determine how well a pH probe was calibrated or when that probe is reaching end of life.

Slope and calibration are directly related. The slope is updated when a calibration command is given. The slope does not update automatically.

Generally speaking, all pH probes behave the same way. This means a probe's response to calibration can be compared to a simulated pH probe that is mathematically perfect in all ways.



The slope is broken into three sections; acid, base, and neutral.
Each section is evaluated separately.

Acid (pH 1 – 6.9)
Base (pH 7.1 – 14)
Neutral (pH 7)

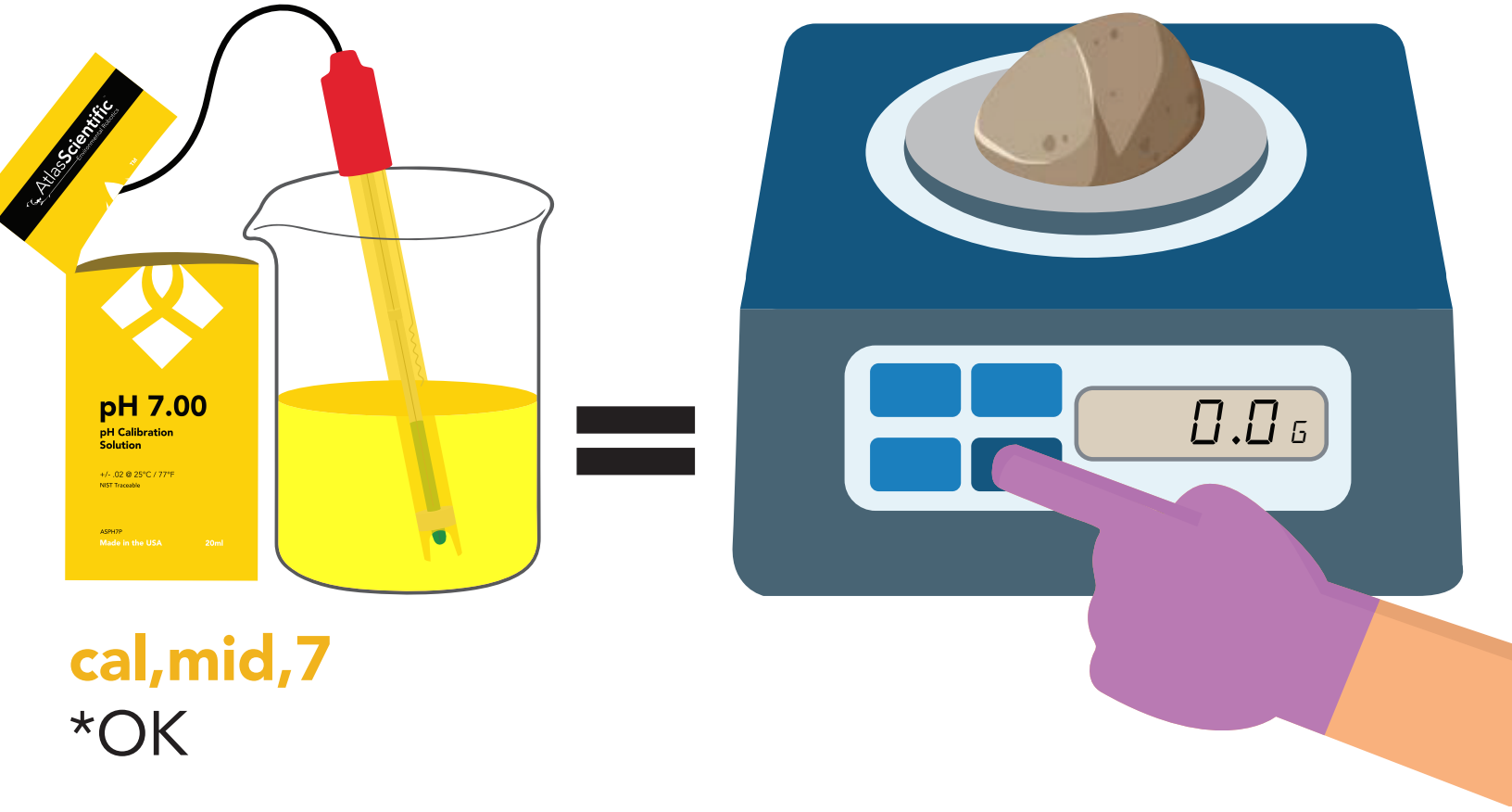
An uncalibrated pH probe will have a mathematically perfect slope. Because no pH probe is mathematically perfect, the slope can be used to determine if the pH was calibrated.

Uncalibrated slope: 100, 100, 0 (acid, base, neutral)
% % mV

The first two numbers are percentages, and the third is millivolts. The slope shows that the probe's response to acid and base is 100% correct, and it detects 0 mv in a pH 7. Because such perfection does not exist in the real world, we know this probe was not calibrated.

Understanding pH slope

pH 7 is the absence of pH; it is not an acid or a base. Therefore it should always be your first calibration point. It is equivalent to the tare function on a scale because it establishes the probe's zero point.



cal,mid,7
*OK

After pH 7 calibration, use the slope command to see how the probe performed during calibration.

The slope after pH 7 calibration: 100, 100, -1.2

Here we see the probe reads -1.2mV in pH 7. The closer this number is to 0, the better. A new pH probe should give a millivolt offset no greater than -5mV to 5mV. Over time this number's distance to 0 may increase; the larger the number, the lower the accuracy. A reading >10mV will result in noticeable performance issues.

It is important to remember that a high number is not definitive evidence that the probe is inaccurate or malfunctioning. It is very common to see a high number if the calibration solution was contaminated and not actually its stated value.

Understanding pH slope

The next two calibration points *(pH 4 and pH 10)* report their slope in percentage. A new pH probe should have a slope of >95%.

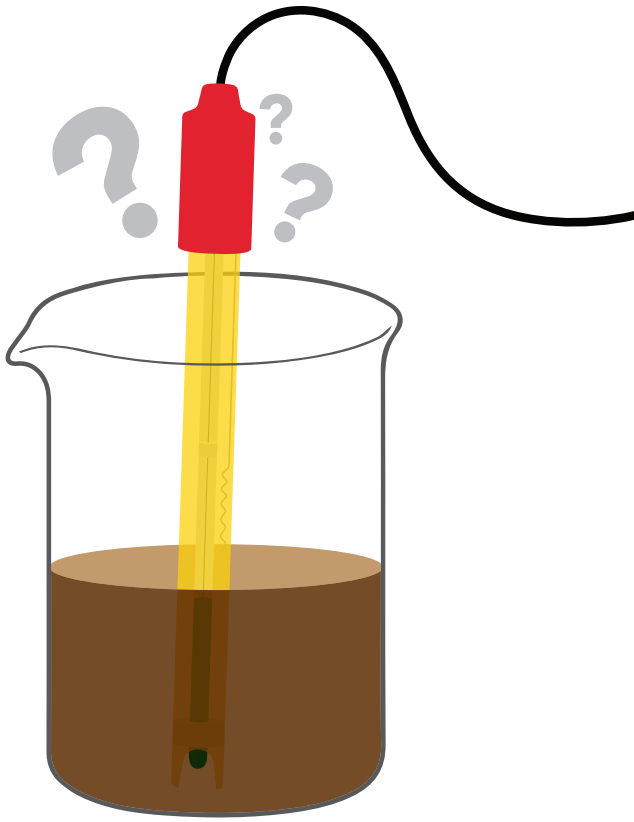
The slope after pH 4 calibration: 98.2, 100, -1.2

The slope after pH 10 calibration: 98.2, 97.8, -1.2

Tips:

Throughout this explanation, we have looked at the slope after each calibration event. This is unnecessary; in reality, it is best to fully calibrate the probe and look at the slope once calibration has been completed.

To gain a deeper understanding of how slope affects the stability and accuracy of a pH probe, intentionally miscalibrate the probe and see how it affects the slope.



Datasheet change log

Datasheet V 1.1

Revised probe artwork.

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.