Atlas Scientific™
Environmental Robotics

V 1.1

Revised 10/24

EZO Complete-DO™

USB Dissolved Oxygen meter

Datasheet for engineers

ISO 5814 Compliant

(determination of dissolved oxygen)

Reads	**Dissolved Oxygen**
Normal range	**0.00 – 100 mg/L** **0 – 350% saturation**
Accuracy	**+/- 0.05**
Resolution	**.01**
DO reading time	**600ms**
Supported probes	**Any galvanic probe**
Calibration	**1 or 2 point**
Recalibration frequecy	**~8 – 12 months**
Temperature, salinity, and pressure compensation	**Yes**
Data protocol	**Serial data through FTDI virtual comport**
Data format	**ASCII**
Ingress protection	**IP62**

RoHS COMPLIANT

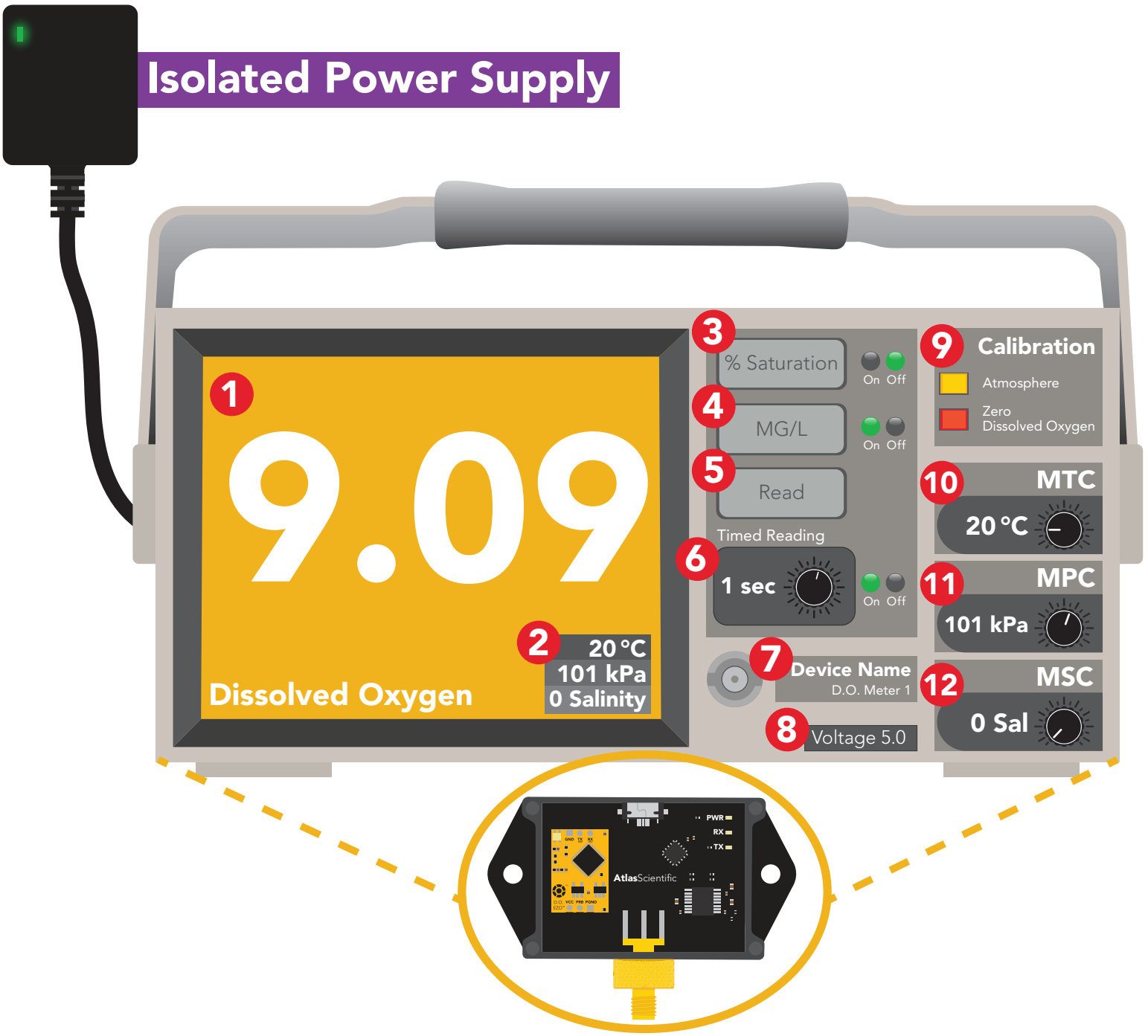
Written by Jordan Press
Designed by Noah Press

PATENT PROTECTED

This is an evolving document, check back for updates.

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

Isolated Power Supply



1 Two decimal D.O. reading

2 Temperature, pressure, and salinity compensation value

3 Percent saturation

4 Milligrams per liter

5 Immediate reading

6 Timed readings

7 Set device name

8 Voltage usage

9 Multi point calibration

10 Temperature compensation

11 Pressure compensation

12 Salinity compensation

The EZO Complete-DO™ is compatible with any brand of galvanic D.O. probe.

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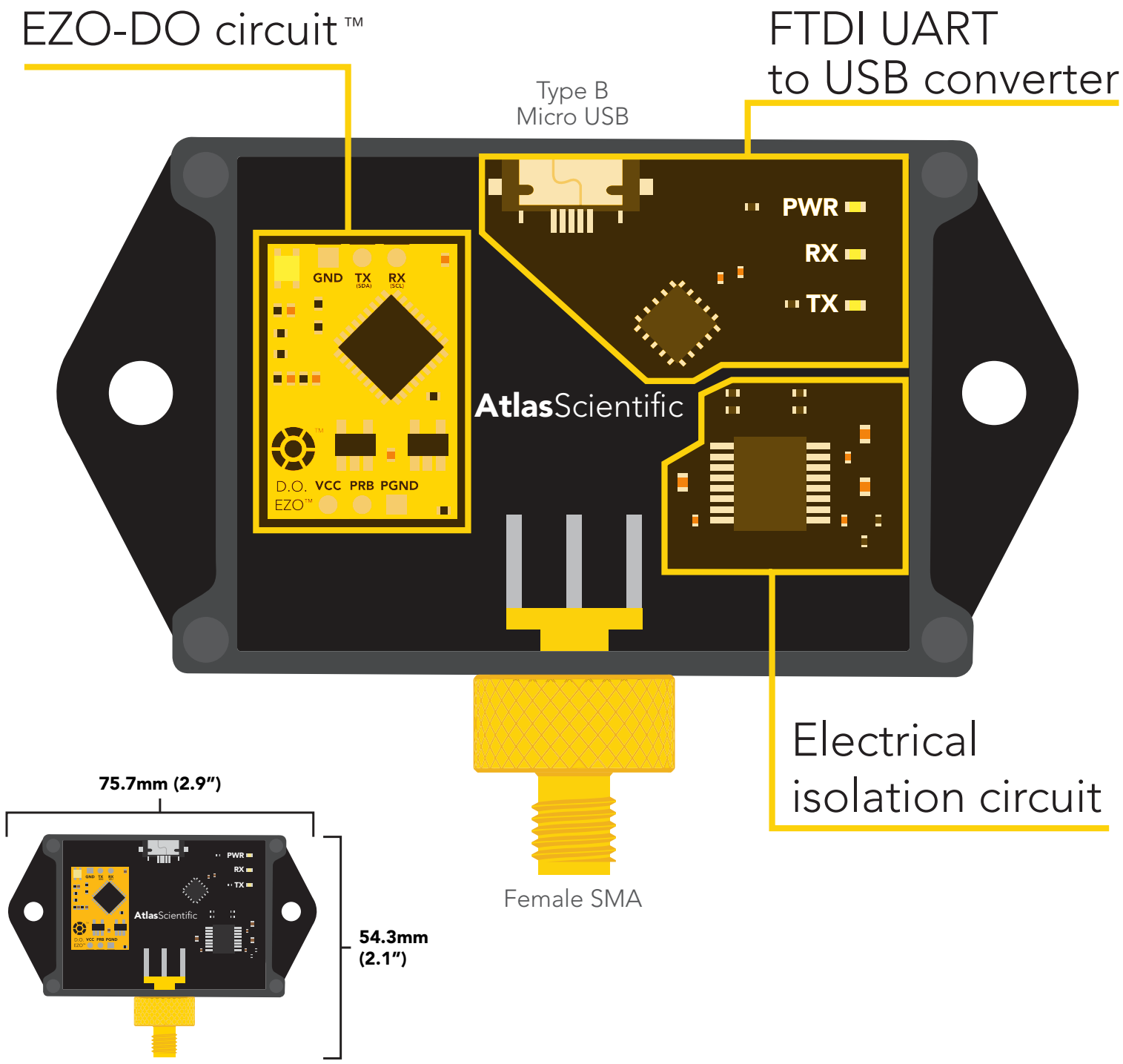
The EZO Complete-DO™ consists of 3 major components.



Power consumption

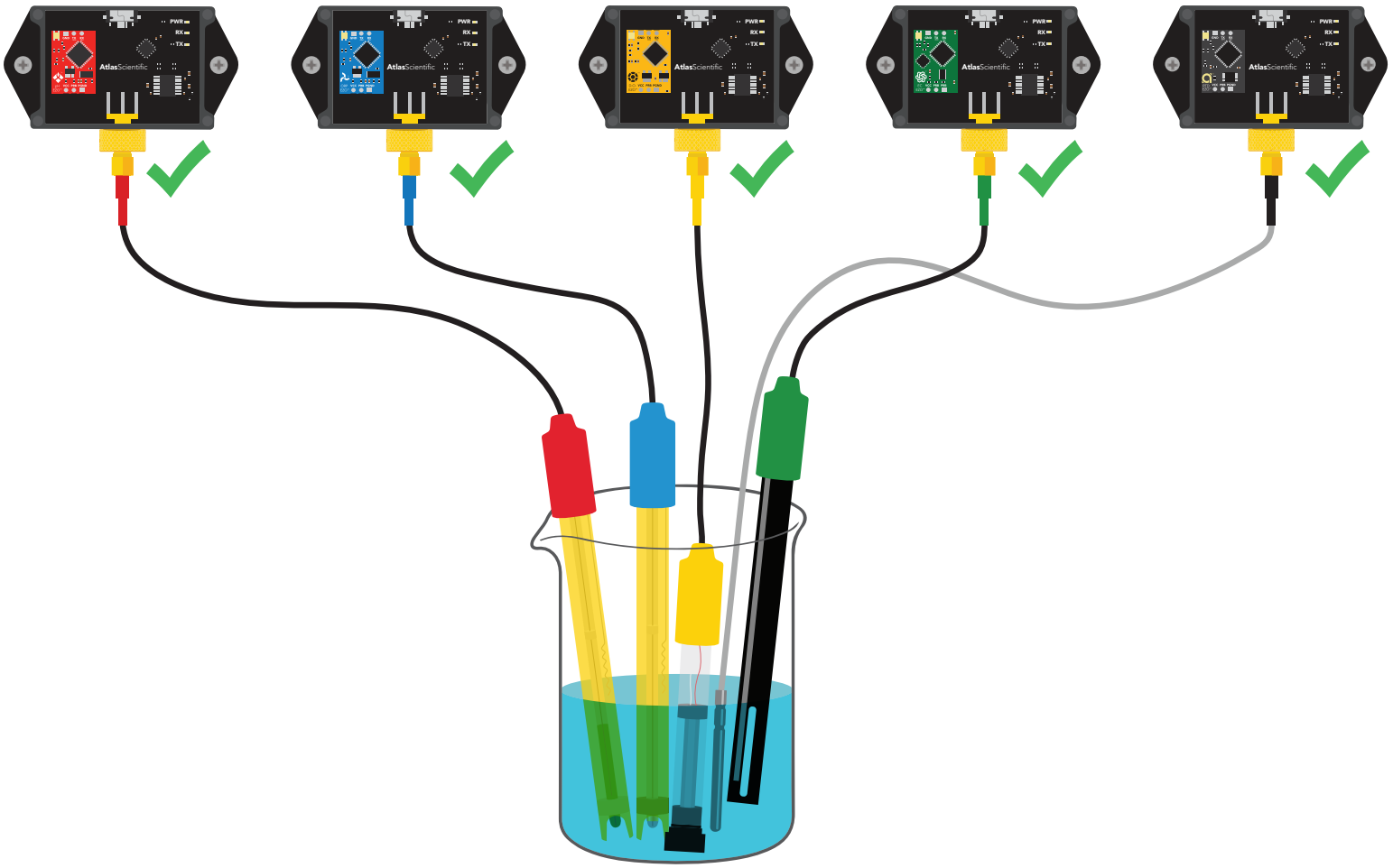
	MAX	STANDBY	SLEEP
5V USB	37.0 mA	36.8 mA	22.6 mA

Absolute max ratings

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

Interference free

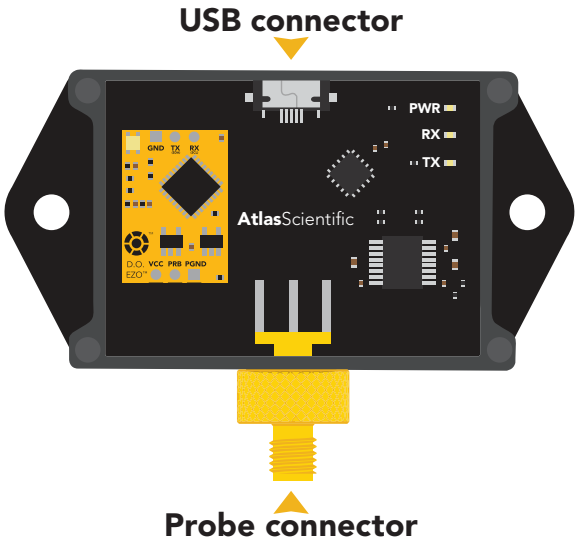
The EZO complete readings are unaffected by other sensors in the same water.



Ingress protection – IP62

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

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



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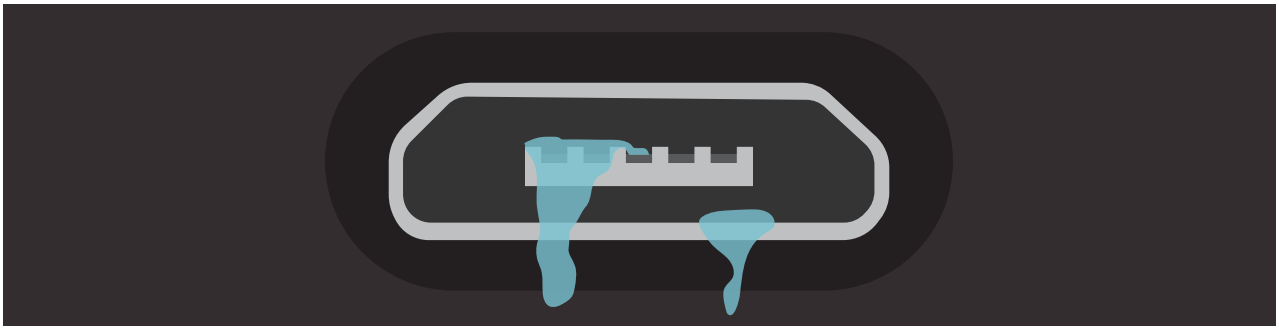
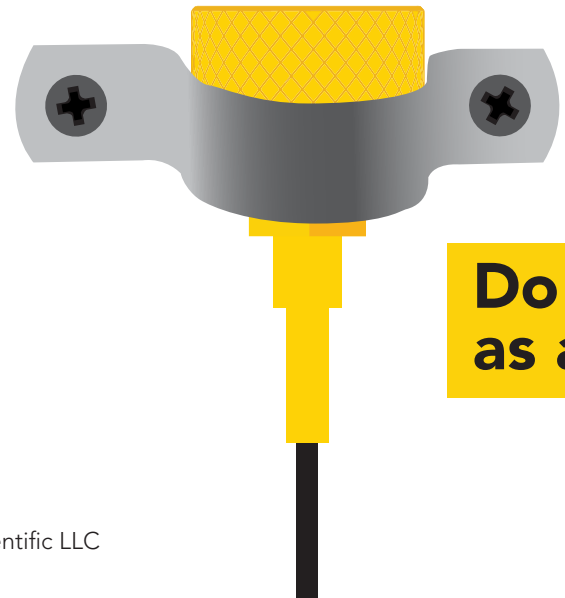
Ingress protection – IP62

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 DO readings to pin to 0, 35, or the probe will respond slowly to changes in DO. A connector short is reversible and will not damage the EZO-Complete. However, frequent shorts will eventually damage the DO 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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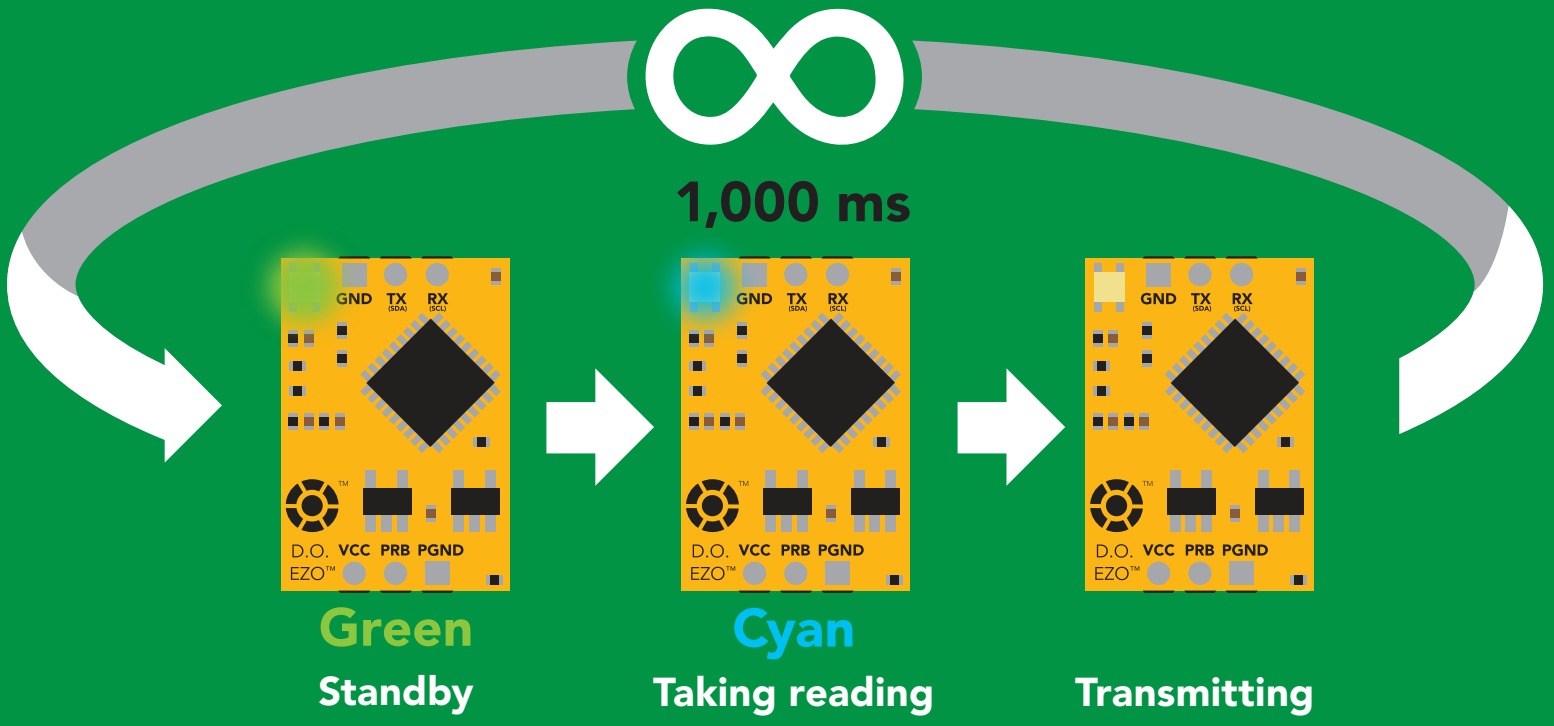
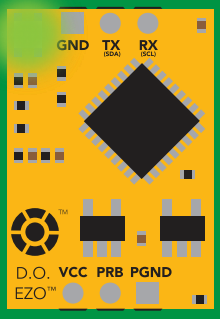
Default state

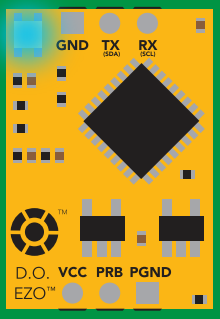
Baud	**9,600**
Readings	**continuous**
Speed	**1 reading per second**



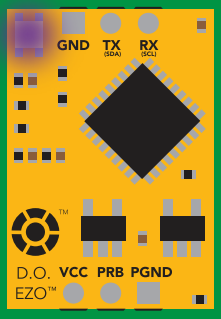
LED color definition



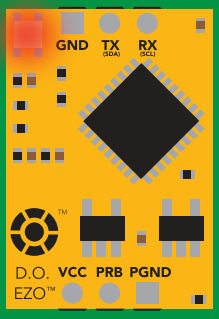
Green
UART standby



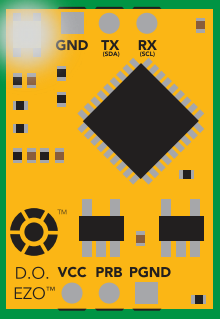
Cyan
Taking reading



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

Baud rate
Calibration
Continuous mode
Device name
Enable/disable parameters
Enable/disable response codes
Hardware switch to I^2C mode
LED control
Protocol lock
Software switch to I^2C mode

Settings that are NOT retained if power is cut

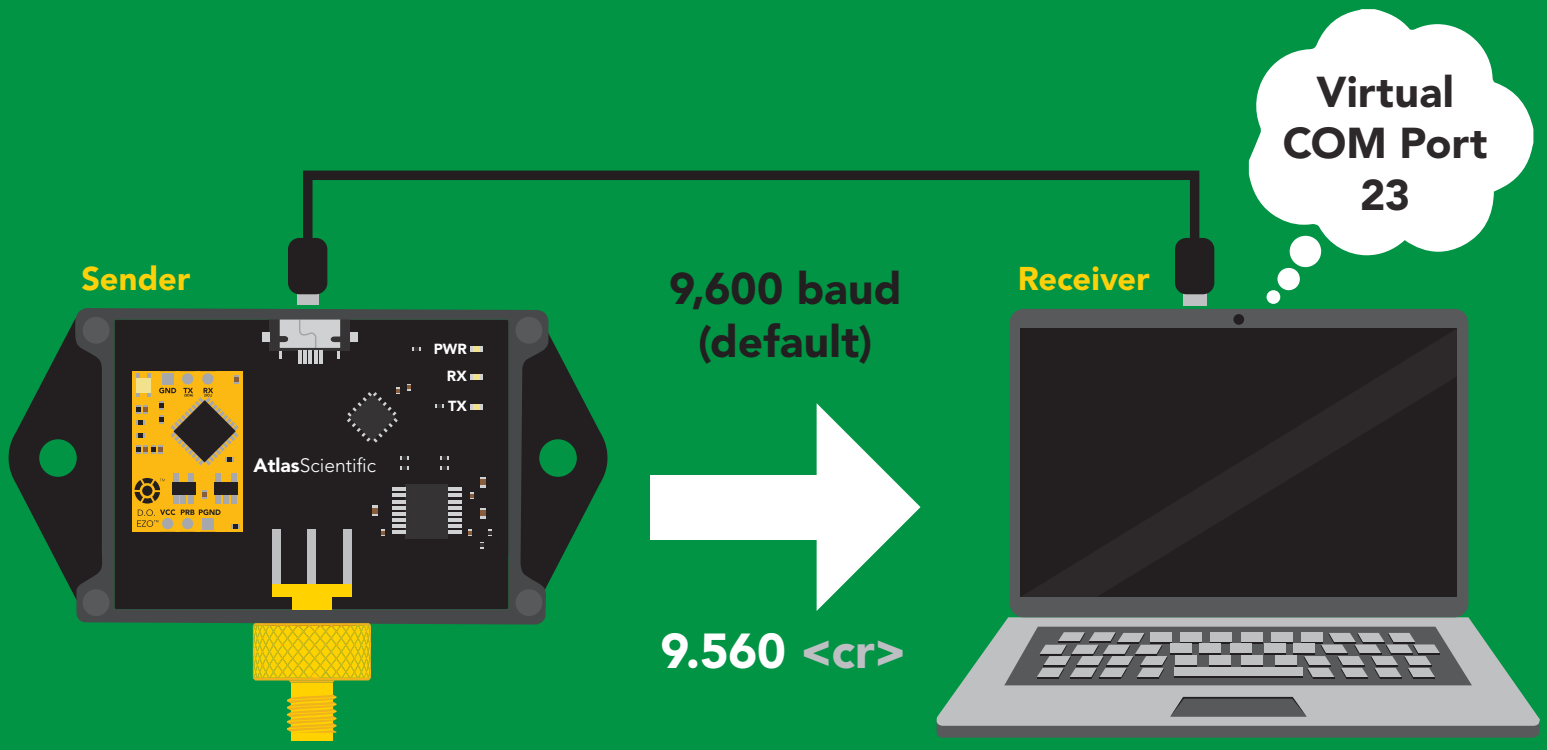
Find
Pressure compensation
Salinity compensation
Sleep mode
Temperature compensation

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

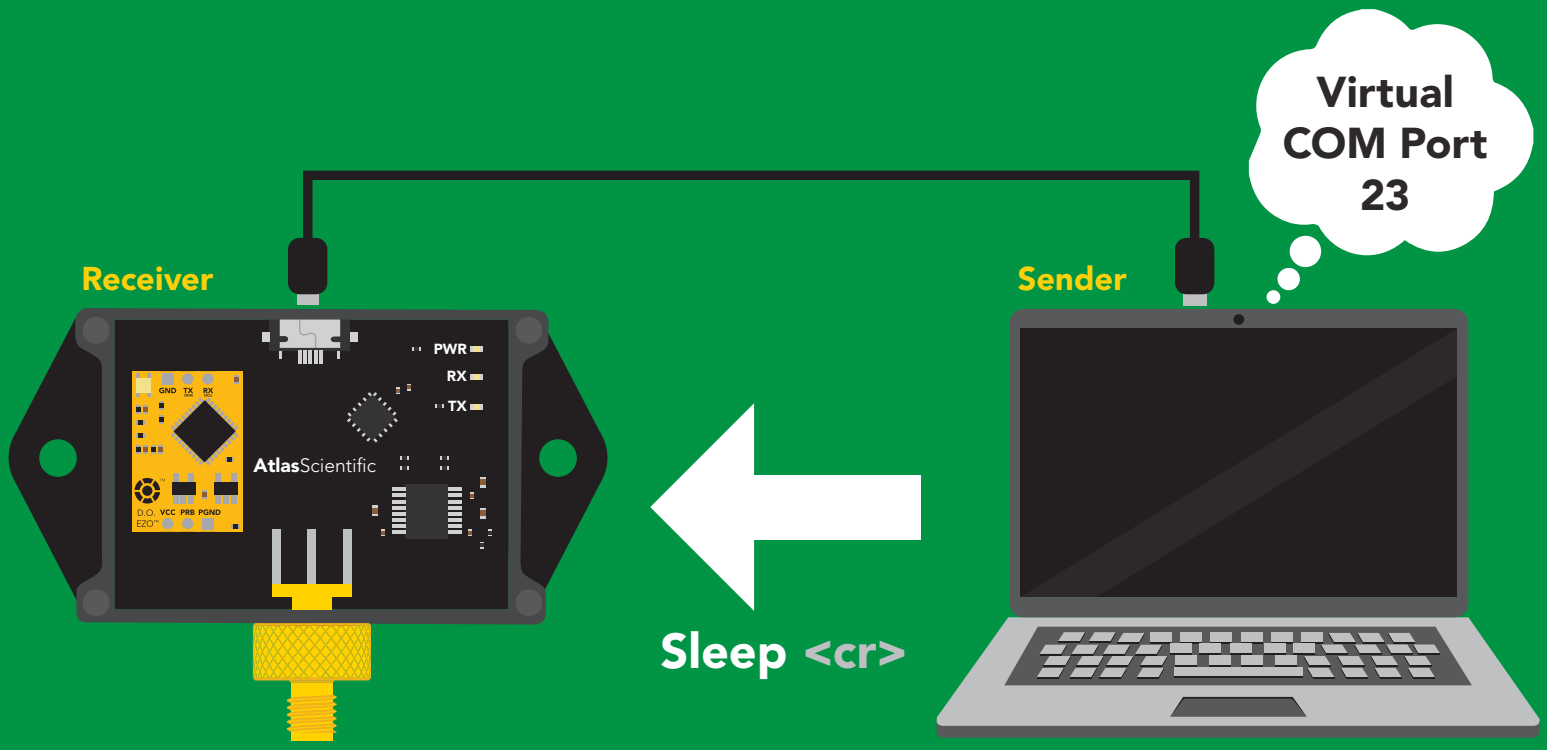
2 parts

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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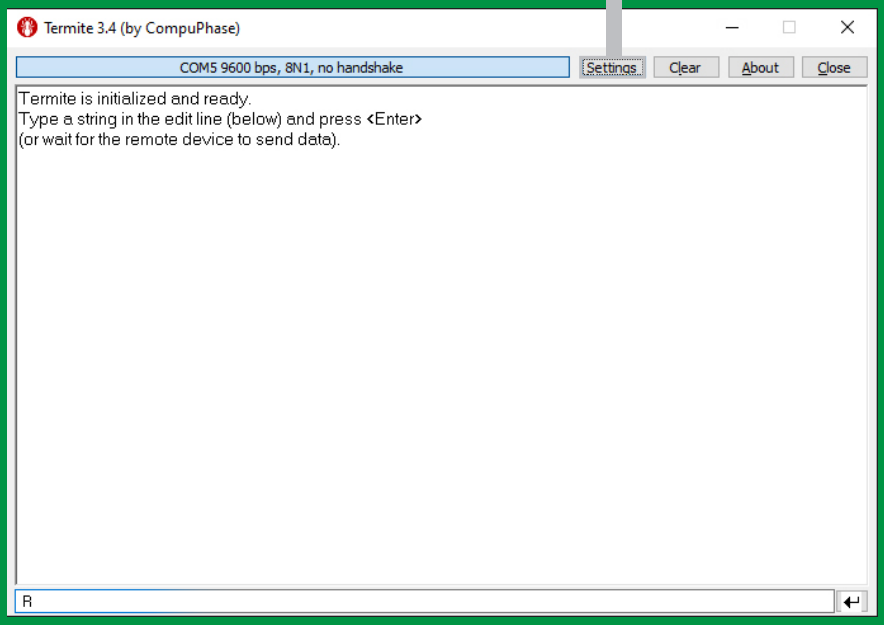
Looking for a simple serial monitor for debugging?

Termite: a simple RS232 terminal

Click here to download

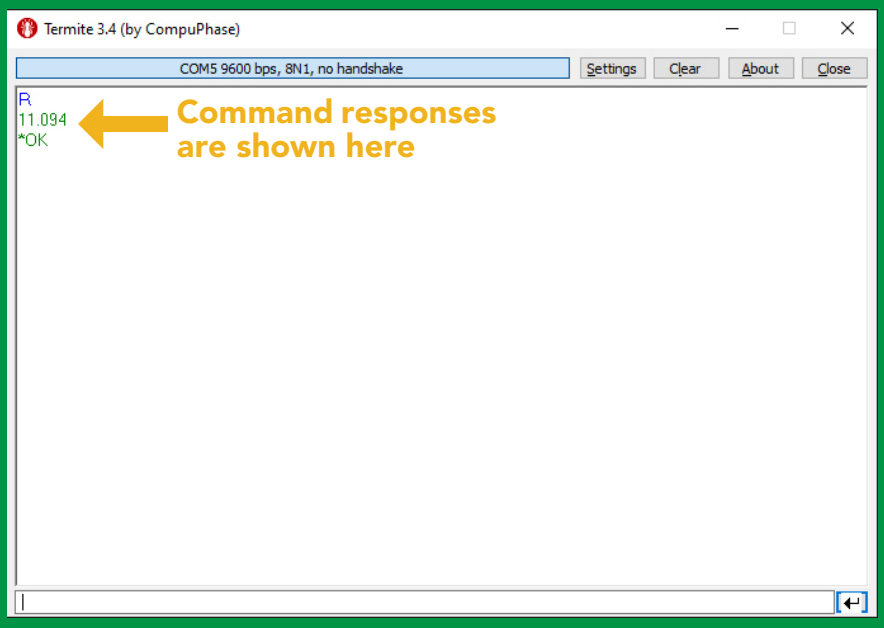


Settings

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. 29	n/a
Find	finds device with blinking white LED	pg. 14	n/a
i	device information	pg. 25	n/a
Import	import calibration	pg. 19	n/a
L	enable/disable LED	pg. 13	enabled
Name	set/show name of device	pg. 24	not set
O	enable/disable parameters	pg. 23	mg/L
P	atmospheric pressure compensation	pg. 22	101.3 kPa
R	returns a single reading	pg. 16	n/a
S	salinity compensation	pg. 21	n/a
Sleep	enter sleep mode/low power	pg. 28	n/a
Status	retrieve status information	pg. 27	n/a
T	temperature compensation	pg. 20	20°C
*OK	enable/disable response codes	pg. 26	enable

LED control

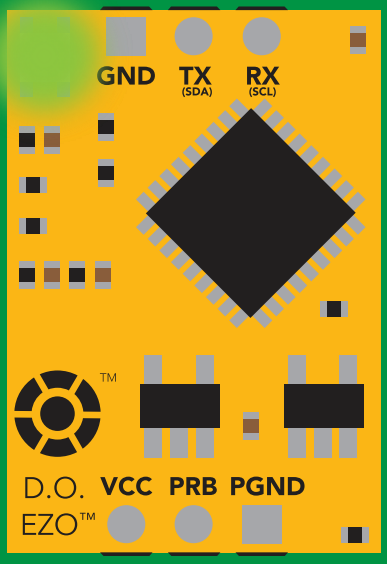
Command syntax

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

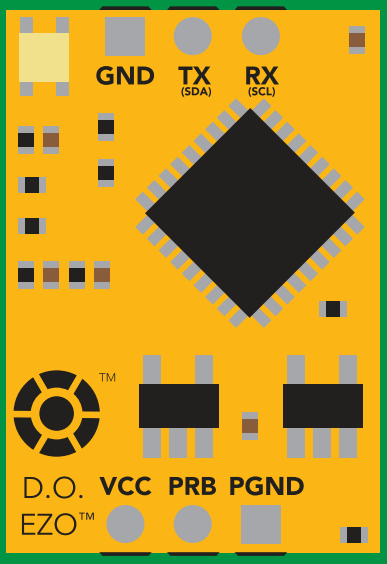
L,0 <cr> LED off

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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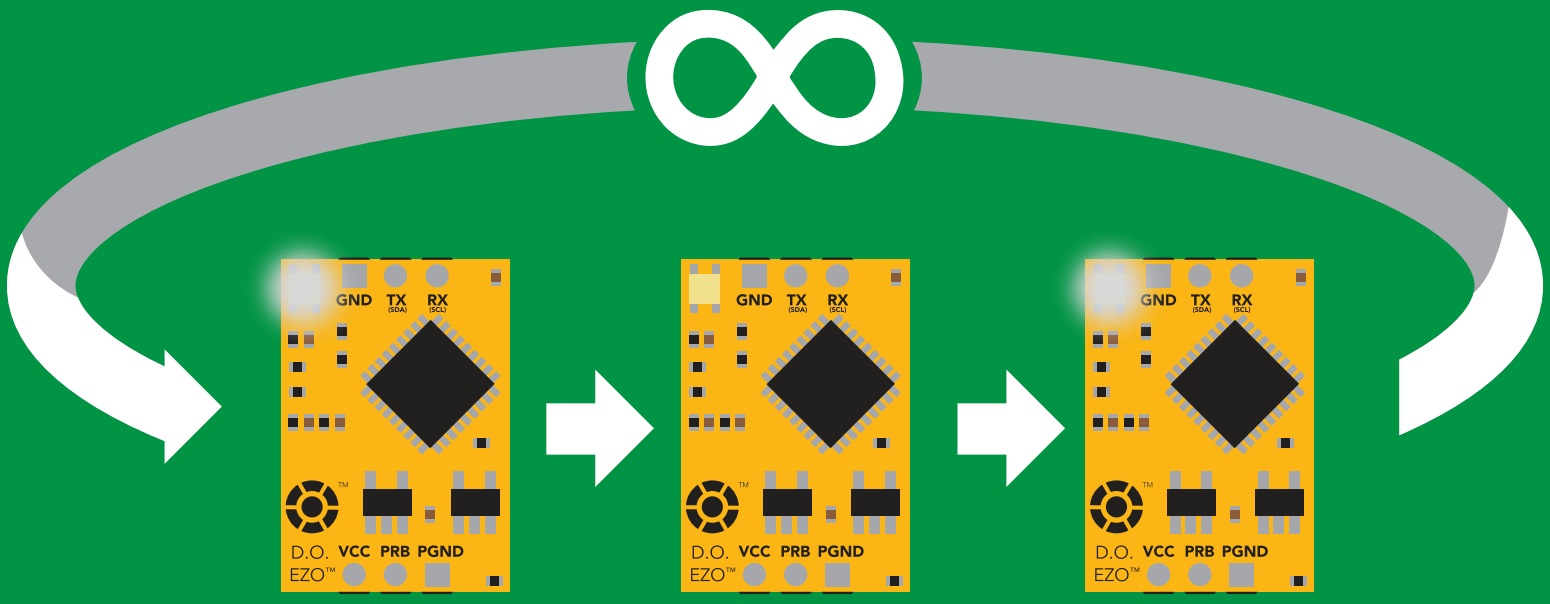
Find

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>



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?

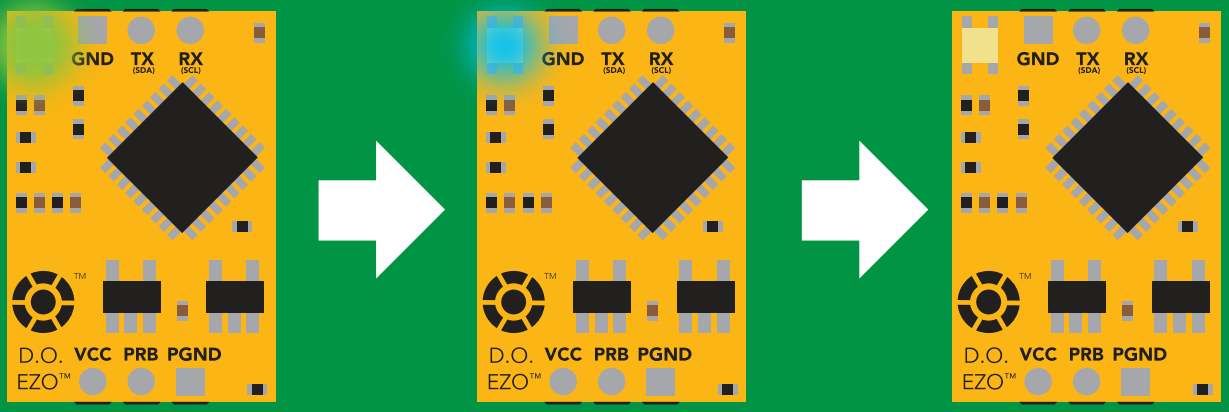
Example	Response
C,1 <cr>	*OK <cr> DO (1 sec) <cr> DO (2 sec) <cr> DO (3 sec) <cr>
C,30 <cr>	*OK <cr> DO (30 sec) <cr> DO (60 sec) <cr> DO (90 sec) <cr>
C,0 <cr>	*OK <cr>
C,? <cr>	?C,1 <cr> or ?C,0 <cr> or ?C,30 <cr> *OK <cr>

Single reading mode

Command syntax

R <cr> takes single reading

Example	Response
R <cr>	7.82 <cr> *OK <cr>



Green
Standby

Cyan
Taking reading

Transmitting

600 ms

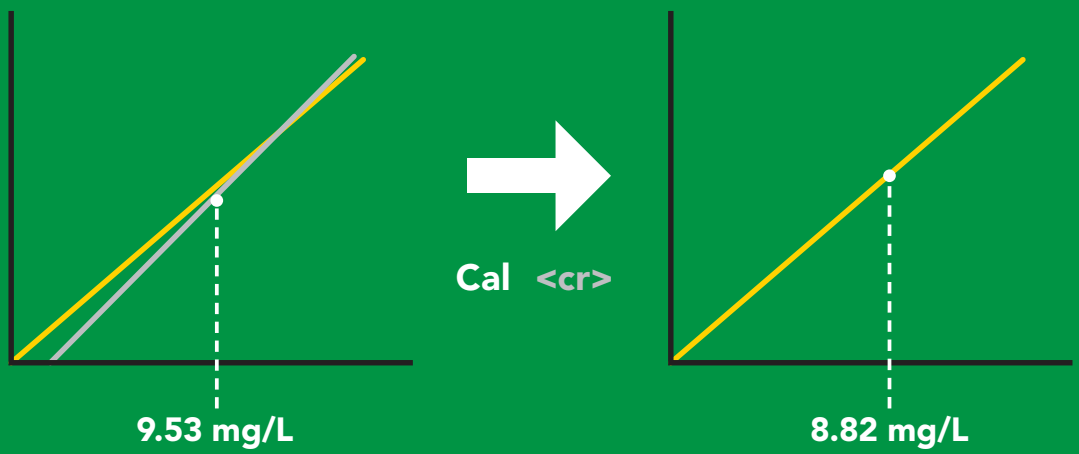
Calibration

Command syntax

The EZO™ Dissolved Oxygen circuit uses single and/or two point calibration

Cal	<cr>	calibrate to atmospheric oxygen levels
Cal,0	<cr>	calibrate device to 0 dissolved oxygen
Cal,clear	<cr>	delete calibration data
Cal,?	<cr>	device calibrated?

Example	Response
Cal <cr>	*OK <cr>
Cal,0 <cr>	*OK <cr>
Cal,clear <cr>	*OK <cr>
Cal,? <cr>	?Cal,0 <cr> or ?Cal,1 <cr> (single point) or ?Cal,2 <cr> (two point) *OK <cr>



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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)**

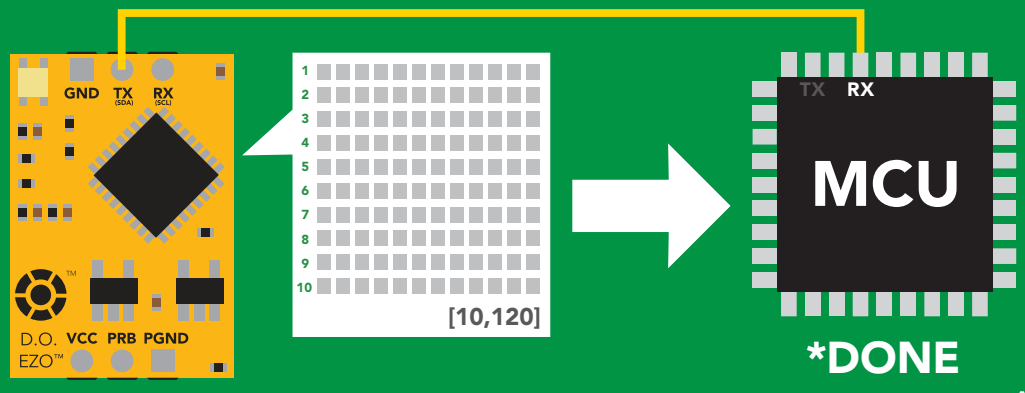
(7 more) — ⋮

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)

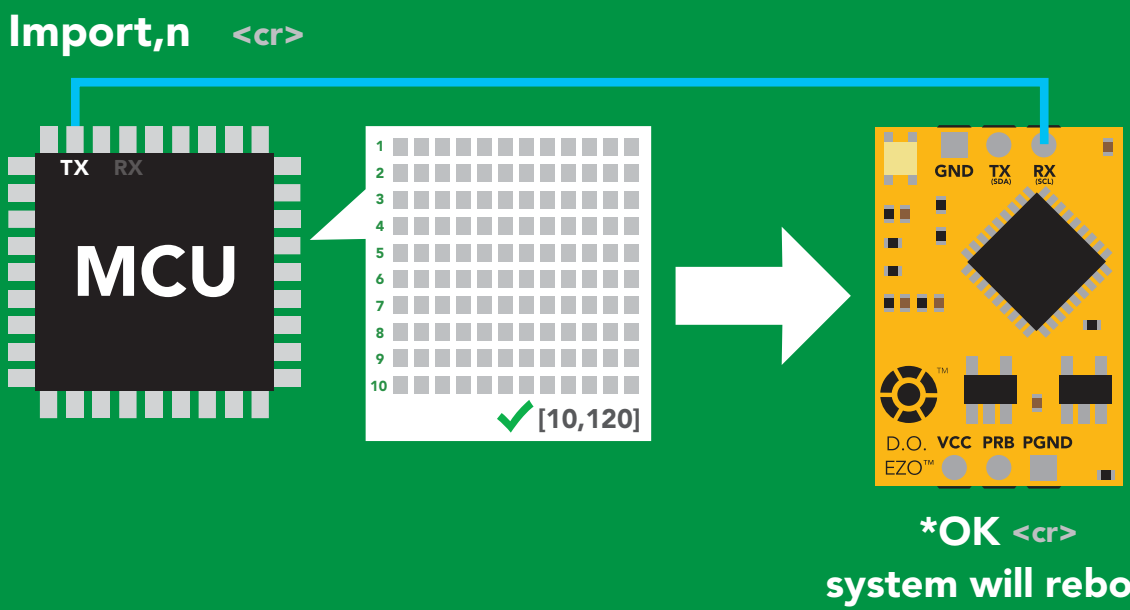
Response

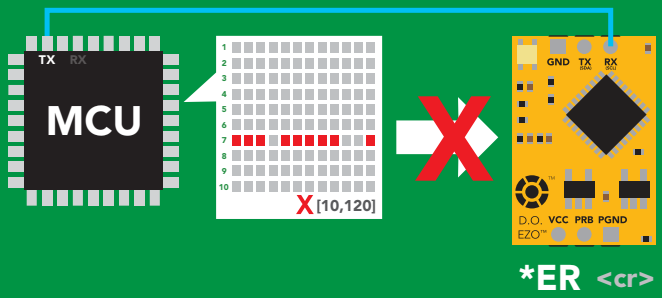
*OK <cr>

*OK <cr>

⋮

*OK <cr>





*** 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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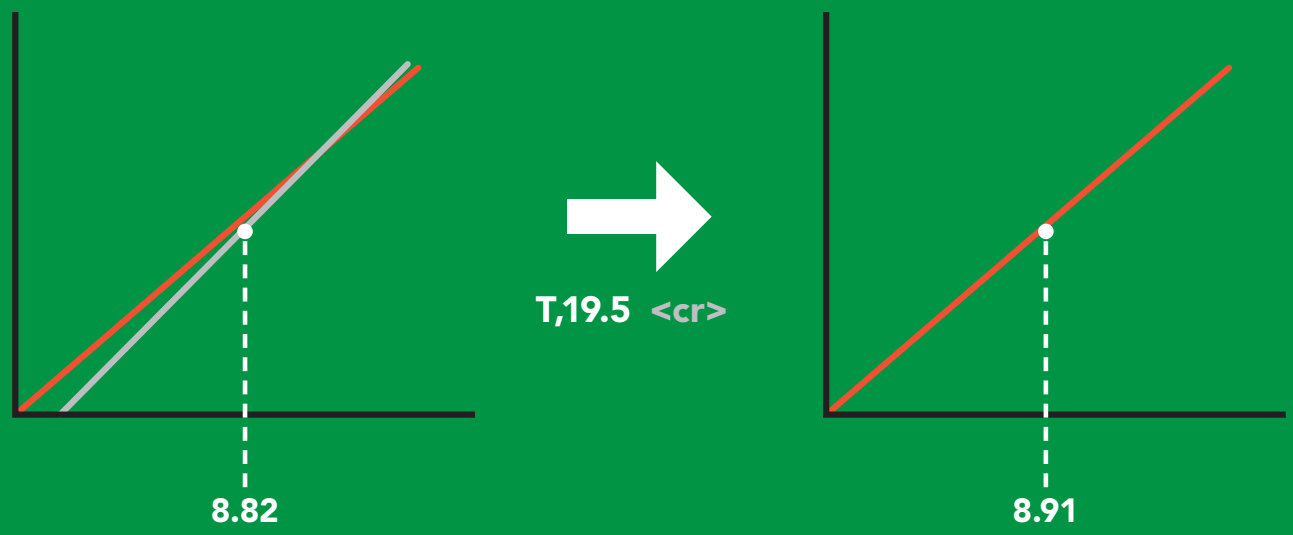
Temperature compensation

Command syntax

Default temperature = 20°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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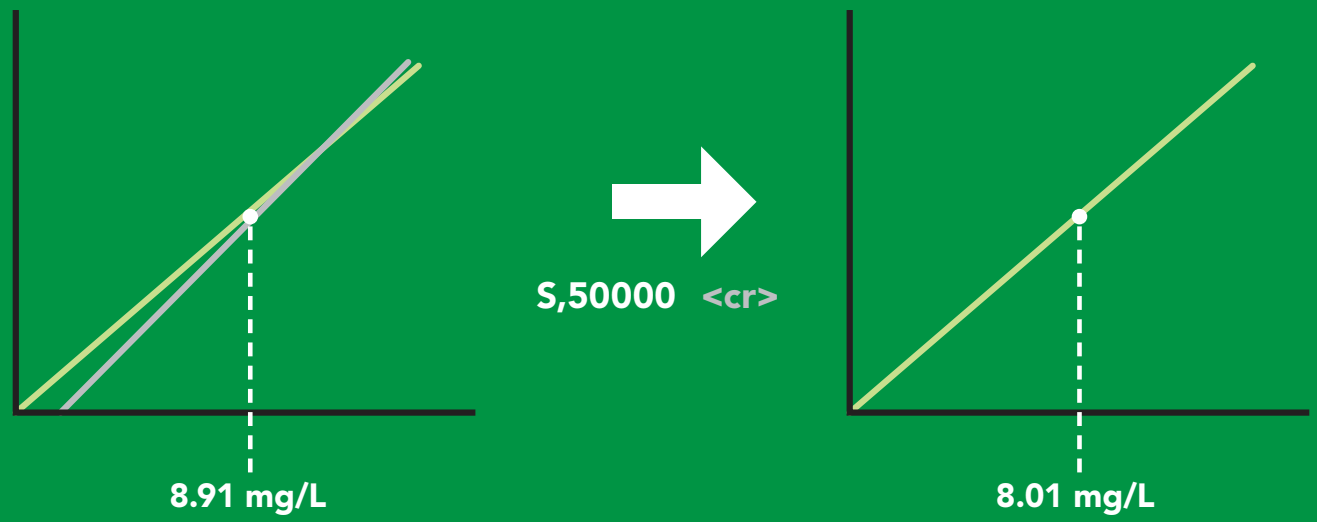
Salinity compensation

Command syntax

Default value = 0 µs
If the conductivity of your water is less than 2,500µS this command is irrelevant

S,n	<cr>	n = any value in microsiemens
S,n,ppt	<cr>	n = any value in ppt
S,?	<cr>	compensated salinity value?

Example	Response
S,50000 <cr>	*OK <cr>
S,37.5,ppt <cr>	*OK <cr>
S,? <cr>	?S,50000,µS <cr> or ?S,37.5,ppt <cr> *OK <cr>



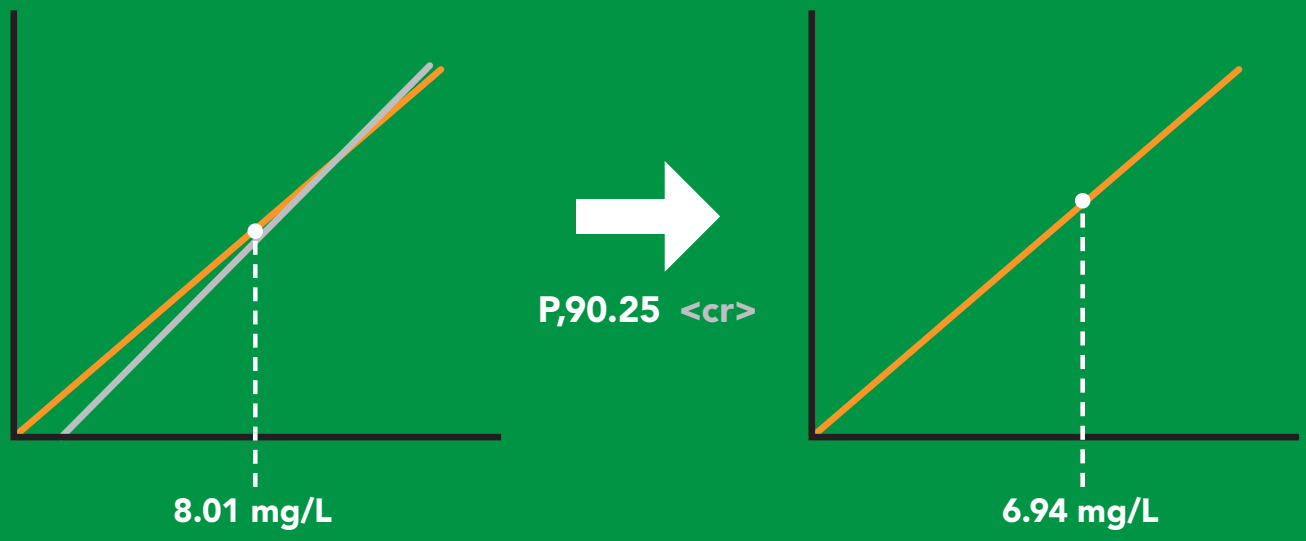
Atmospheric pressure compensation

Command syntax

P,n <cr> n = any value in kPa

P,? <cr> compensated pressure value?

Example	Response
P,90.25 <cr>	*OK <cr>
P,? <cr>	?,P,90.25 <cr> *OK <cr>



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,mg,1 / O,mg,0 <cr>	*OK <cr> enable / disable mg/L
O,%,1 / O,%,0 <cr>	*OK <cr> enable / disable percent saturation
O,? <cr>	?,O,%,mg <cr> if both are enabled

Parameters

mg	mg/L
%	percent saturation

Followed by 1 or 0

1	enabled
0	disabled

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

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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

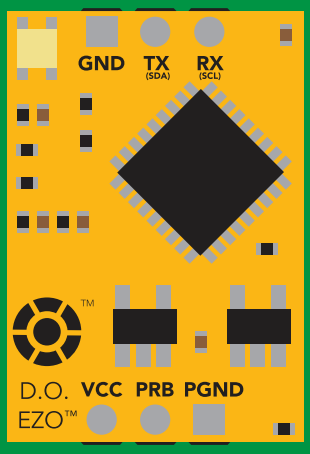
n =

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

Up to 16 ASCII characters

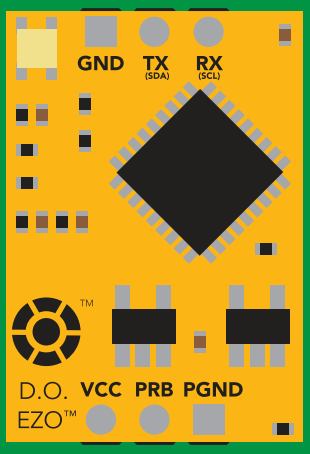
Example	Response
Name, <cr>	*OK <cr> name has been cleared
Name,zzt <cr>	*OK <cr>
Name,? <cr>	?Name,zzt <cr> *OK <cr>

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,D.O.,1.98 <cr> *OK <cr>

Response breakdown

?i, D.O., 1.98

D.O. → Device

1.98 → Firmware

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Response codes

Command syntax

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

Example	Response
R <cr>	7.82 <cr> *OK <cr>
*OK,0 <cr>	no response, *OK disabled
R <cr>	7.82 <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	13.1 mA	0.66 mA
3.3V	12 mA	0.3 mA

Standby
13.1 mA

Sleep
0.66 mA

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Factory reset

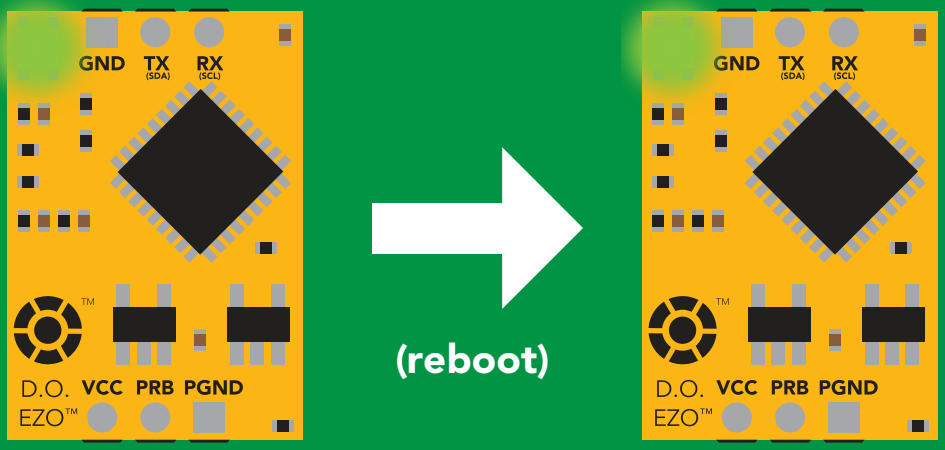
Command syntax

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

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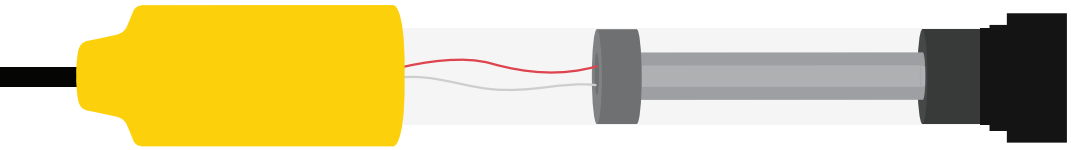
Calibration theory

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).

Confirm the D.O. probe is working correctly

Take readings in air first.



Readings > 10

Readings < 5 or > 25

Refer to probes datasheet for instructions.

Calibrate first, compensate later

Compensating for temperature, pressure, and salinity will change your calibrated readings to a value that cannot easily be predicted. This makes it difficult to know if the probe has been calibrated correctly.

Default compensation values	Known calibration value
Temp = 20 °C **Pressure = 101 kPa** **Salinity = 0**	**9.09 Mg/L**
Temp = 29 °C **Pressure = 93 kPa** **Salinity = 5** *(too many variables)*	**???** **(6.84 Mg/L)**

Best practices for calibration

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

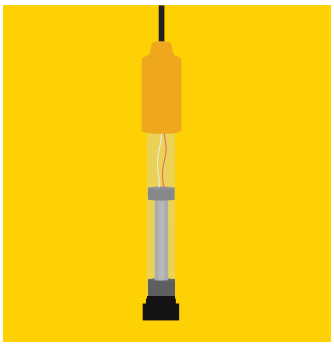
⚠ Never do a blind calibration! ⚠

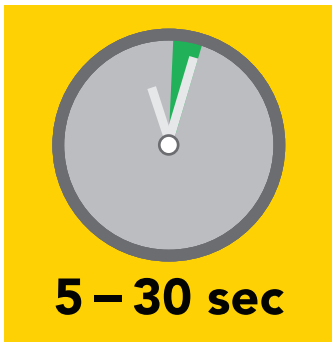
Issuing a calibration command before the readings stabilize will result in drifting readings.

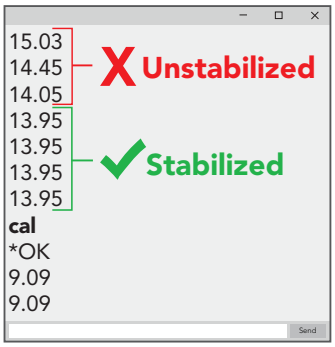
Calibration order

High point calibration

Remove the Dissolved Oxygen probe's cap and let the probe sit, exposed to air until the readings stabilize. *(small movement from one reading to the next is normal).*





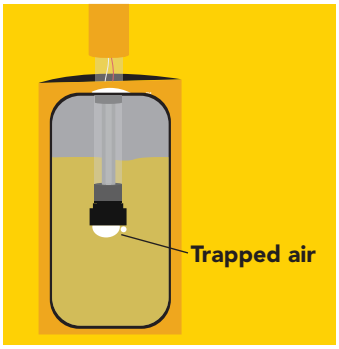


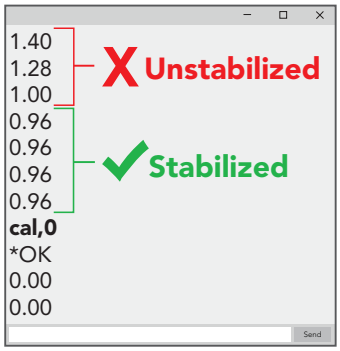
After calibration is complete, you should see readings between **9.09 – 9.1X mg/L.**
(only if temperature, salinity and pressure compensation are at default values)

High point calibrated

Low point calibration

After you have calibrated the EZO™ Dissolved Oxygen circuit using the "Cal" command; Remove the top of the Zero Dissolved Oxygen calibration solution pouch, and Insert the probe and stir it around to remove any trapped air (which could cause readings to go high). Let the probe sit in Zero D.O. calibration solution until readings stabilize.
(small movement from one reading to the next is normal).





Low point calibrated

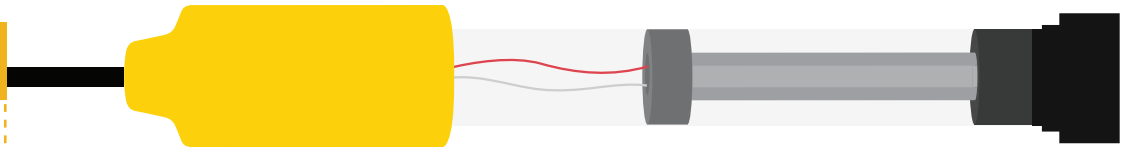
Advanced calibration

Probe temperature calibration

Probe temperature calibration ≠ Temperature compensation.

When a Dissolved Oxygen probe is calibrated, it is calibrated to the oxygen level and ambient temperature. As a D.O. probe is heated or cooled, its response curve will change. A small temperature change *(≤ 5 °C)* will not affect the probe. However, a large temperature change will be noticeable.

Calibrated probe

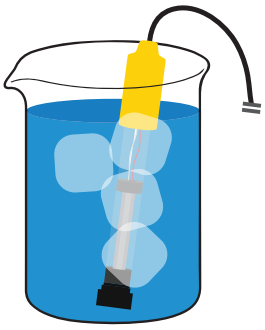


Air temperature

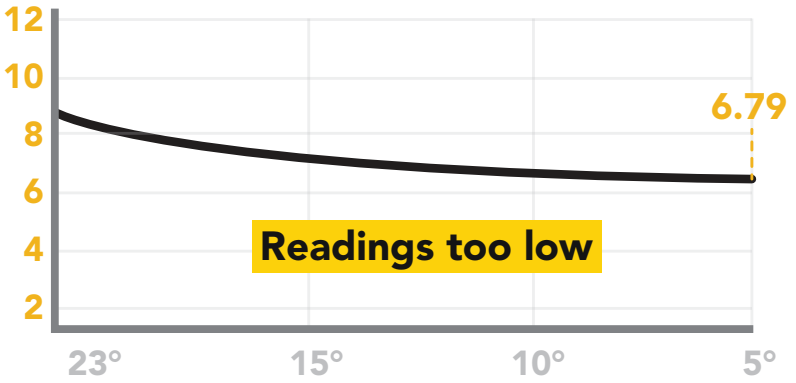
23°C

Air Reading

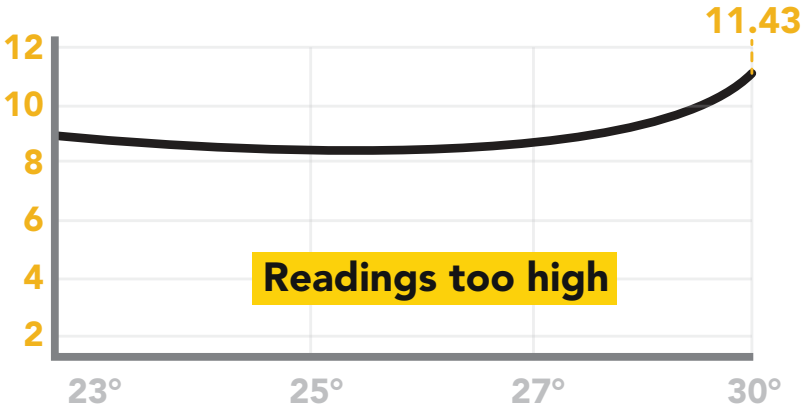
9.10 mg/L



5°C



30°C

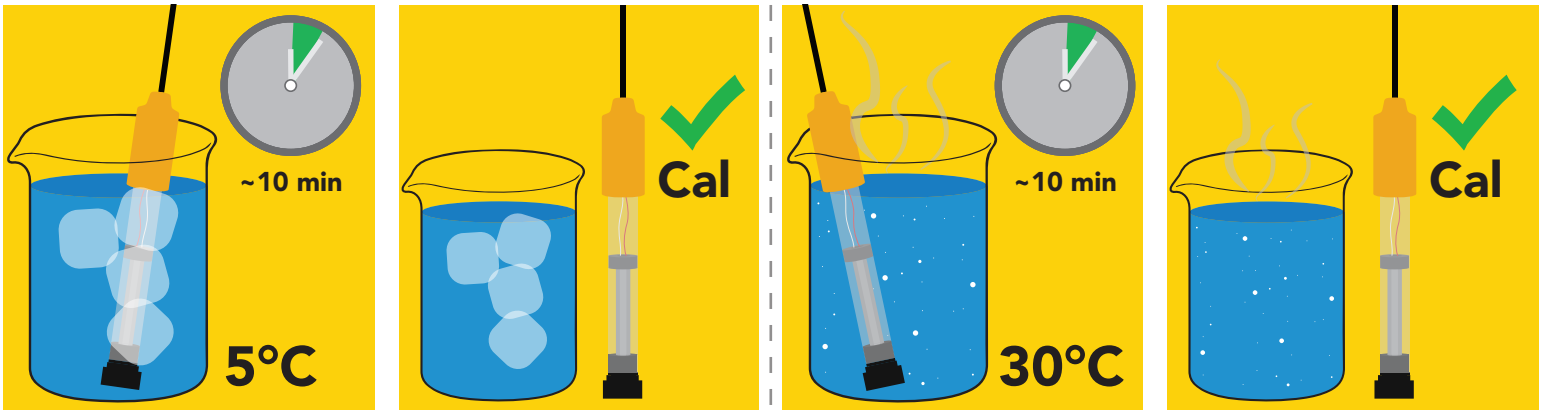


AtlasScientific™ Environmental Robotics

Advanced calibration

What to do:

After the Dissolved Oxygen probe has been properly calibrated, another calibration can be done to account for the probe temperature.

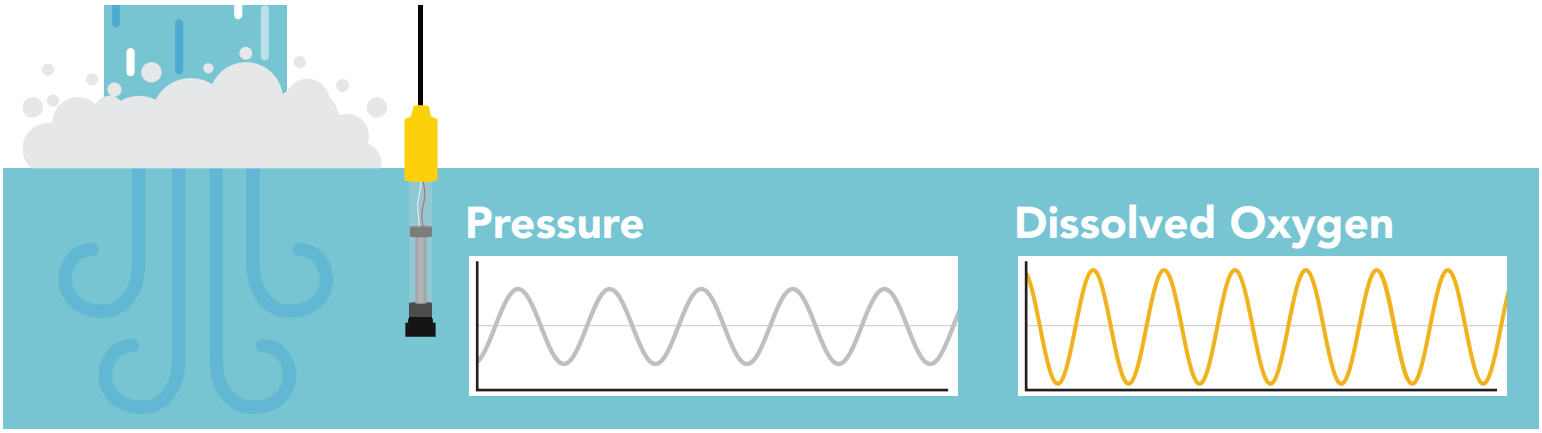


Let the probe acclimate to its operating temperature and then recalibrate. Once the probe has been calibrated at its intended operating temperature, using temperature compensation will give accurate readings.

Understanding D.O. measurements

Most chemical sensors do not directly measure the parameter they are designed for. Dissolved oxygen is no exception. A galvanic D.O. probe is actually an oxygen pressure sensor. It only measures the partial pressure of oxygen.

Keep this in mind when choosing a spot to place the probe.



It just so happens that partial pressure of oxygen is the same in water as it is in air.

(While the pressure is the same, the amount is not. Pure water at sea level can only hold ~9 mg/L of oxygen, while the atmosphere holds ~300mg/L)

By comparing oxygens pressure to its solubility in water, the mg/L are derived.

There are three factors that affect waters ability to hold oxygen.

Temperature
Salinity
Atmospheric Pressure

Temperature

Water temperature has the largest effect; the colder the water, the more oxygen it holds. As water heats up, its ability to hold oxygen goes down.

Pure water at 1°C can hold 14.2 mg/L

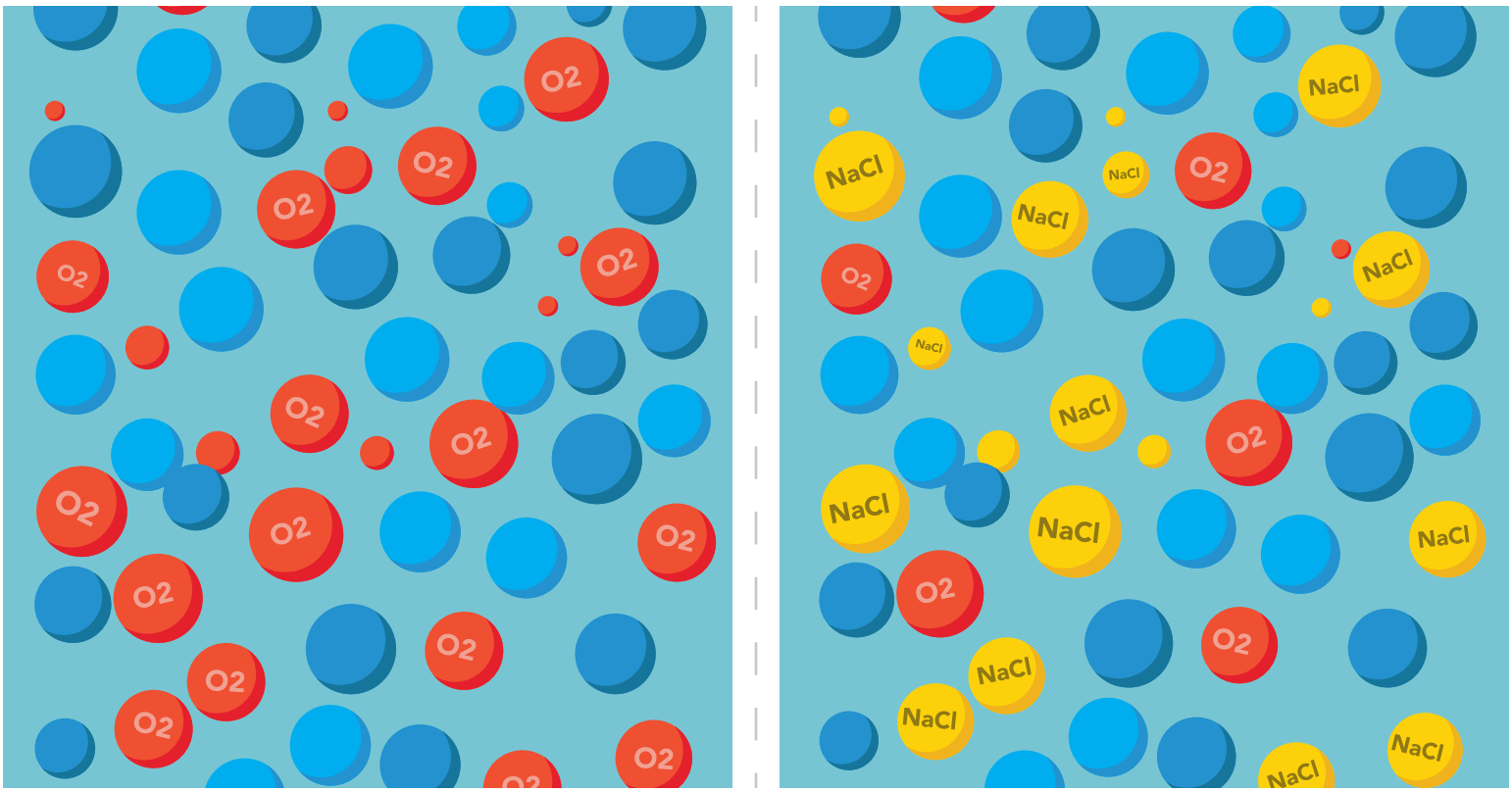
And at 40°C it can only hold 6.4 mg/L

Understanding D.O. measurements

Salinity

When salt is added to water, it drives out oxygen by competing for the same space.

Sea water at 1°C can only hold 10.7 mg/L
Pure water at 1°C can hold 14.2 mg/L



Atmospheric Pressure

A D.O. probe is an oxygen pressure sensor.

Dissolved oxygen pressure cannot be higher than atmospheric oxygen pressure. This is why the probe is calibrated to the atmosphere; it defines the probe's response to the maximum oxygen pressure available. However, oxygen pressure does not tell us how much oxygen is available to dissolve in the water. That information is derived from atmospheric pressure (where atmospheric pressure = altitude).

As altitude increases, oxygen concentration decreases, and because D.O. readings are expressed in Mg/L, the oxygen concentration must be known.

At sea level, 1°C pure water can hold 14.2 mg/L

At 1,500 meters, 1°C pure water can hold 11.7 mg/L

At -1,200 meters, 1°C pure water can hold 16.2 mg/L

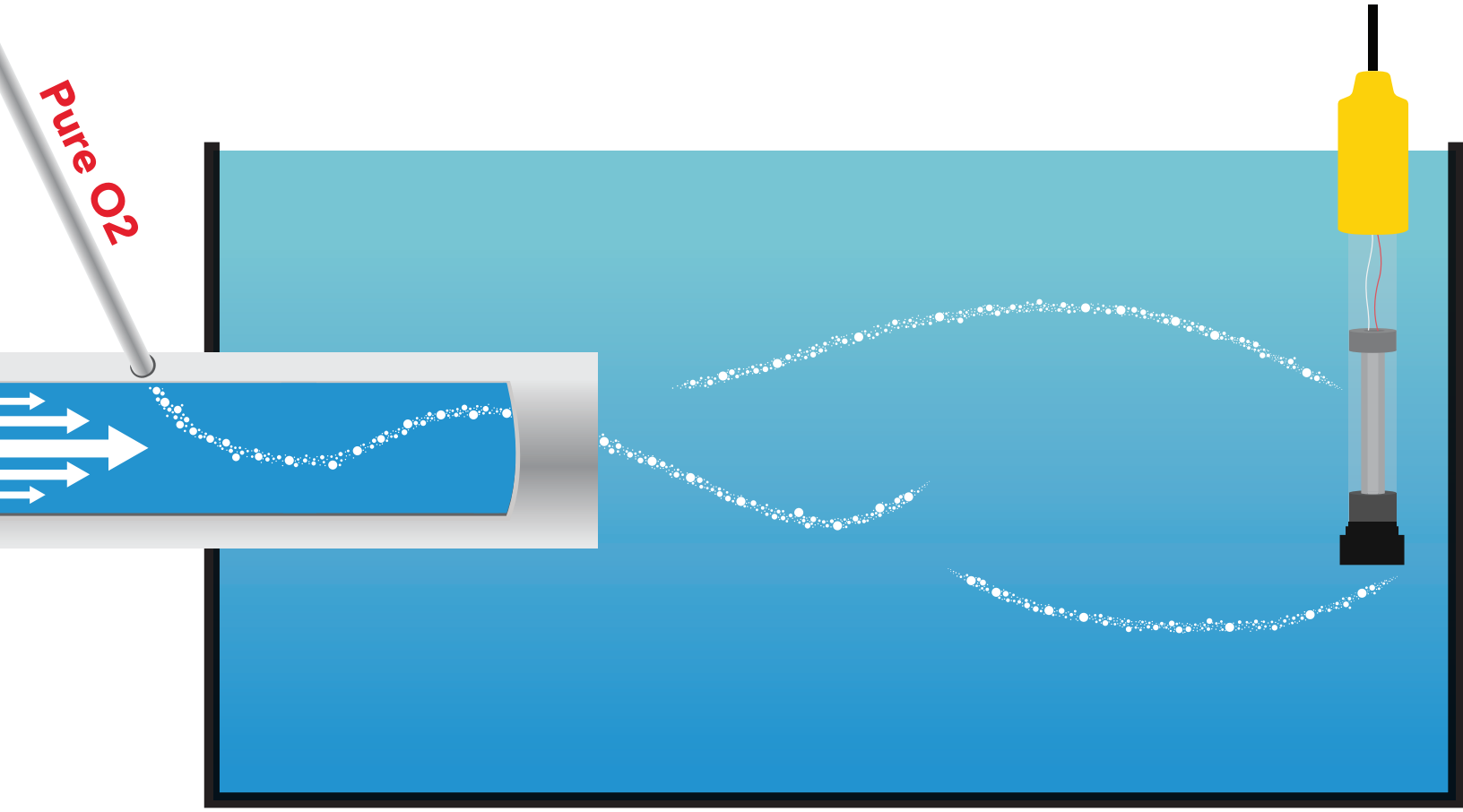
Atlas Scientific™
Environmental Robotics

Hyper saturation with pure oxygen

Dissolved oxygen measurements are based on natural occurring oxygen levels. However, some applications may require pure oxygen to achieve extremely high saturation levels. Because injecting pure oxygen into water is not a naturally occurring event, you will need to change some compensation parameters to achieve extremely high readings.

To reach 100mg/L and a saturation of 350%

Set pressure compensation to: **202 kPa**
Set temperature compensation to: **1°C**



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.

