AtlasScientific™
Environmental Robotics

V 6.3

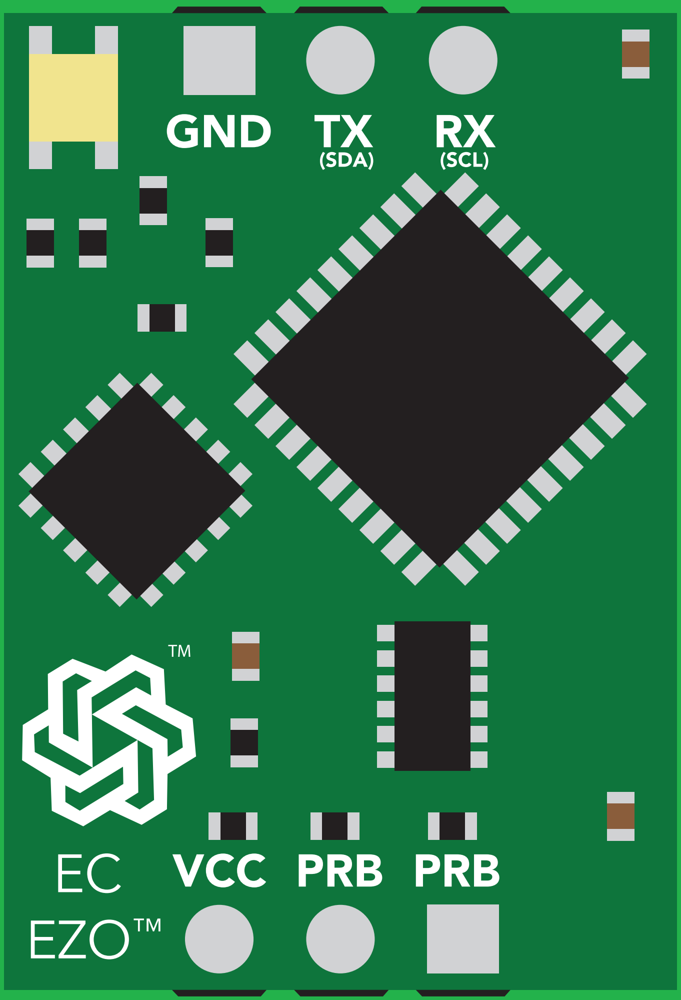
Revised 10/21

EZO-EC™

Embedded Conductivity Circuit

ISO 7888 Compliant

Reads	Conductivity = μS/cm Total dissolved solids = ppm Salinity = PSU (ppt) 0.00 – 42.00 Specific gravity *(sea water only)* = 1.00 – 1.300
Range	0.07 – 500,000+ μS/cm
Accuracy	+/– 2%
Response time	1 reading per sec
Supported probes	K 0.1 – K 10 any brand
Calibration	1 or 2 point
Temp compensation	Yes
Data protocol	UART & I²C
Default I²C address	100 (0x64)
Operating voltage	3.3V – 5V
Data format	ASCII



RoHS COMPLIANT

PATENT PROTECTED

Written by Jordan Press
Designed by Noah Press

This is an evolving document, check back for updates.

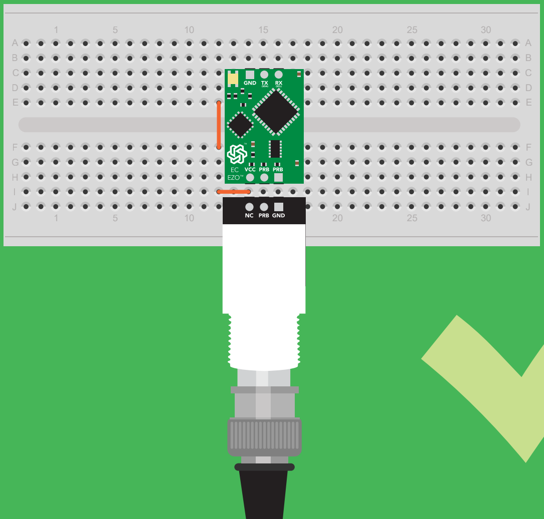
STOP

SOLDERING THIS DEVICE VOIDS YOUR WARRANTY.

This is sensitive electronic equipment. Get this device working in a solderless breadboard first. Once this device has been soldered it is no longer covered by our warranty.

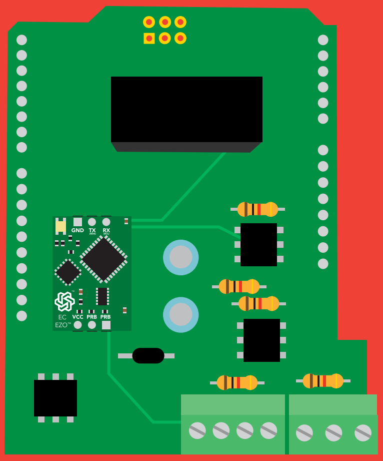
This device has been designed to be soldered and can be soldered at any time. Once that decision has been made, Atlas Scientific no longer assumes responsibility for the device's continued operation. The embedded systems engineer is now the responsible party.

Get this device working in a solderless breadboard first!



✓

Do not embed this device without testing it in a solderless breadboard!



✗

r 0.1

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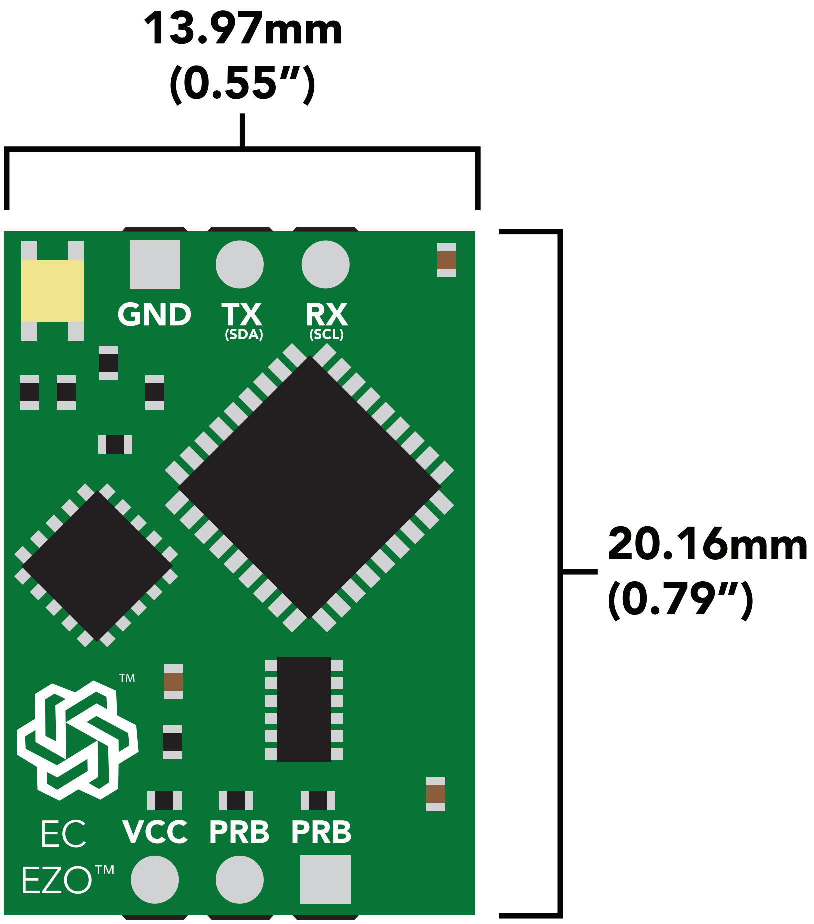
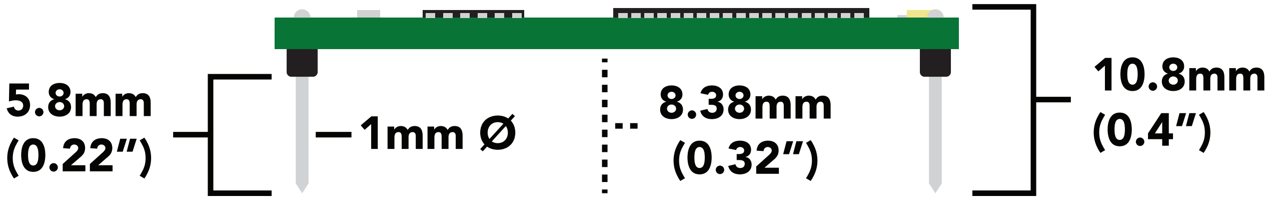
UART

I^{2}C

EZO™ circuit dimensions





Power consumption

	LED	MAX	STANDBY	SLEEP
5V	ON	50 mA	18.14 mA	0.7 mA
	OFF	45 mA	15.64 mA	
3.3V	ON	35 mA	16.85 mA	0.4 mA
	OFF	34 mA	15.85 mA	

Absolute max ratings

Parameter	MIN	TYP	MAX
Storage temperature (EZO™ Conductivity)	-60 °C		150 °C
Operational temperature (EZO™ Conductivity)	-40 °C	25 °C	125 °C
VCC	3.3V	5V	5.5V

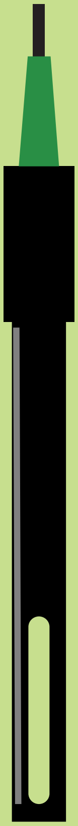
Conductivity probe range

The EZO™ Conductivity circuit is capable of connecting to any two-conductor conductivity probe, ranging from:

K 0.01 → **K 10**

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

K 0.1



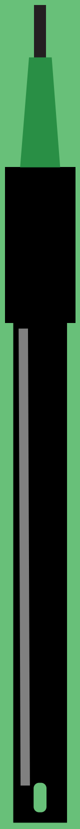
accurate reading range

0.07μS/cm – 50,000μS/cm

TDS *(ppm)* 0 – 25,000

Salinity *(ppt)* 0 – 33

K 1.0



accurate reading range

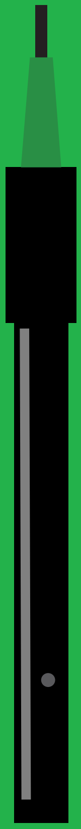
5μS/cm – 200,000+μS/cm

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. Determining the accurate reading range of such probes, i.e. **K 2.6**, or **K 0.66**, is the responsibility of the embedded systems engineer.

Resolution

The EZO™ Conductivity circuit, employs a method of scaling resolution. As the conductivity increases the resolution between readings decreases.

The EZO™ Conductivity circuit will output conductivity readings where the first **4 digits** are valid and the others are set to 0. This excludes conductivity readings that are less than 9.99. In that case, only 3 conductivity digits will be output.

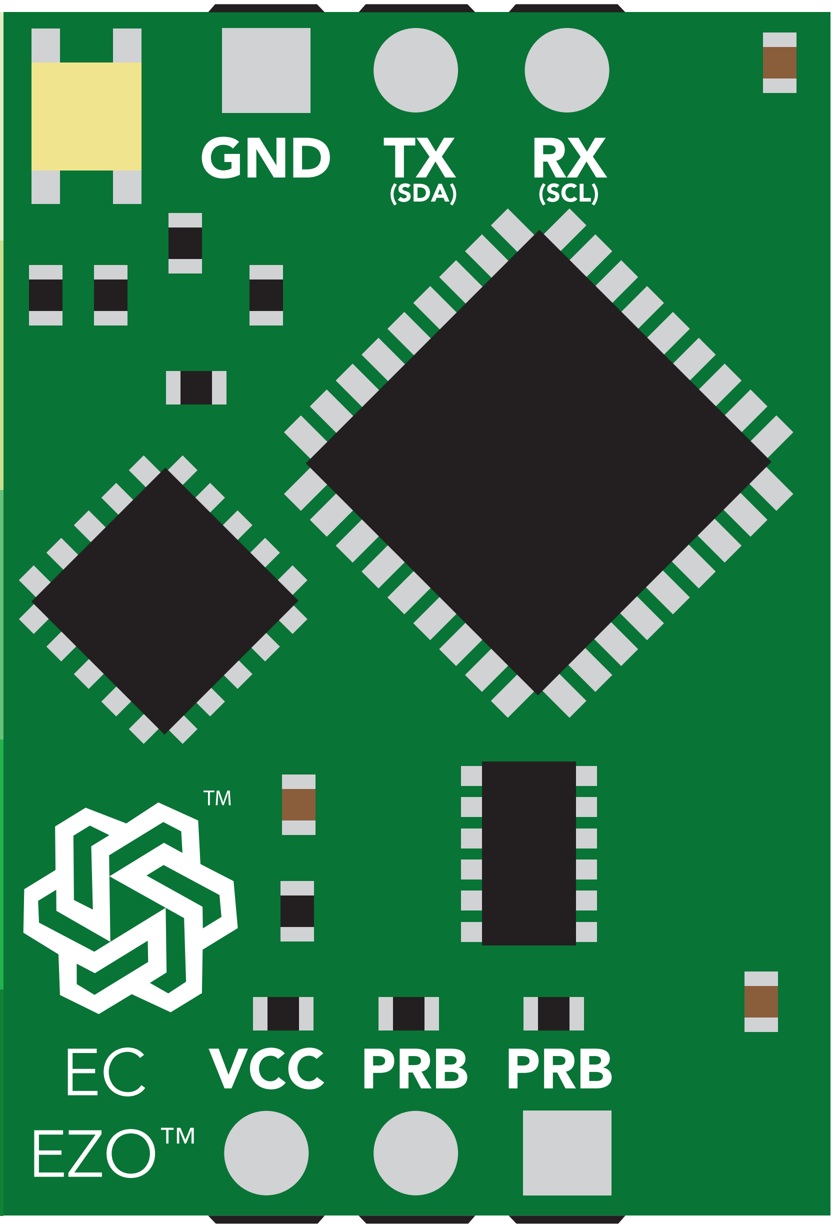
0.07 – 99.99
Resolution = **0.01μS/cm**

100.1 – 999.9
Resolution = **0.1μS/cm**

1,000 – 9,999
Resolution = **1.0μS/cm**

10,000 – 99,990
Resolution = **10μS/cm**

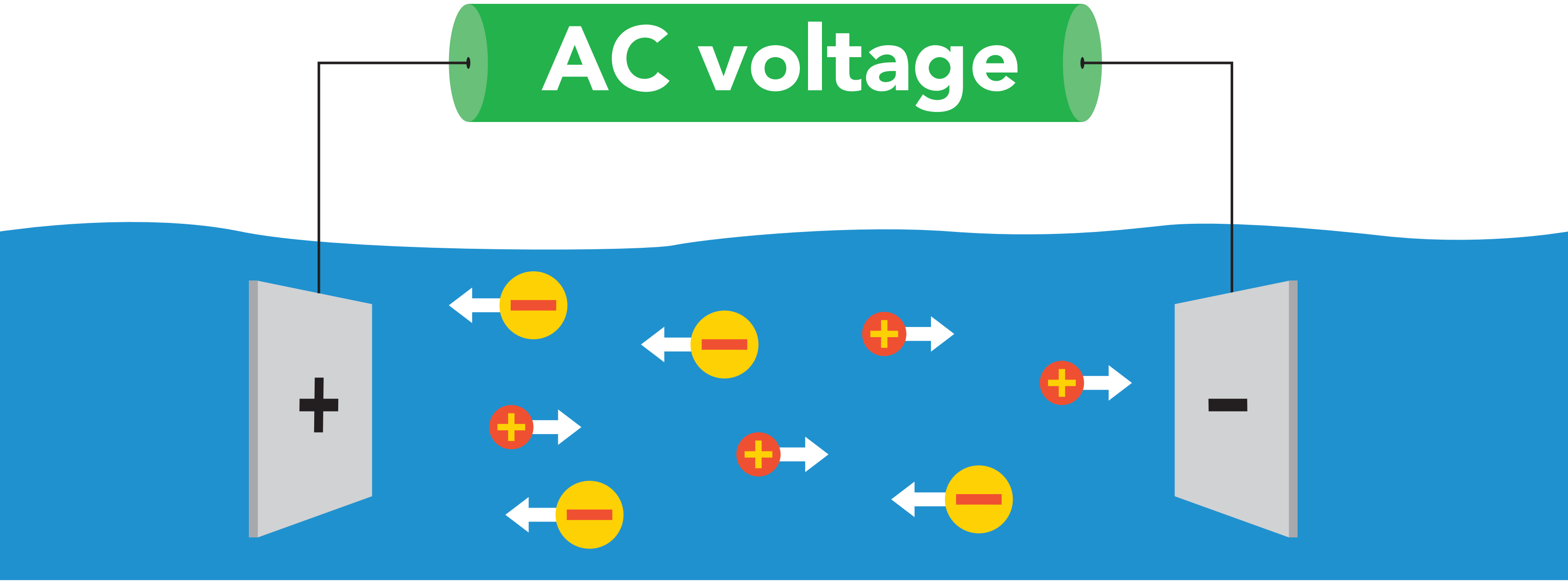
100,000 – 999,900
Resolution = **100μS/cm**

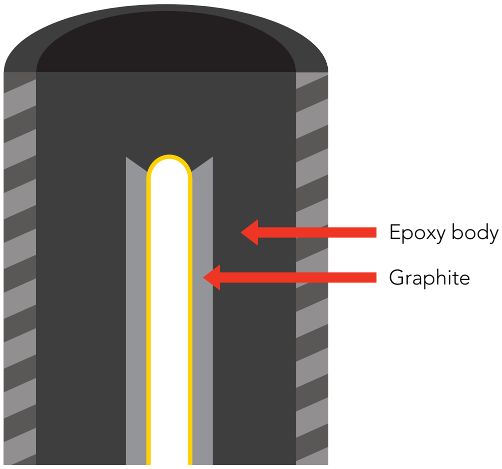


Operating principle

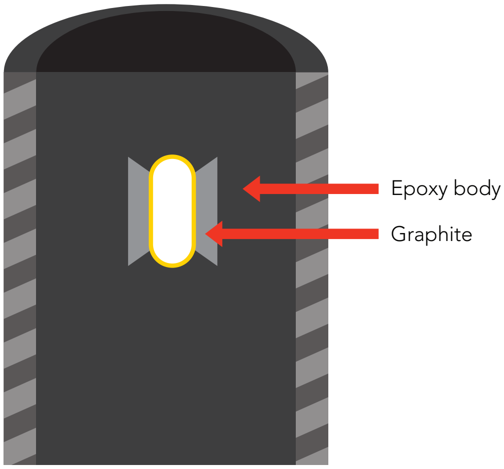
An E.C. ***(electrical conductivity)*** probe measures the electrical conductivity in a solution. It is commonly used in hydroponics, aquaculture and freshwater systems to monitor the amount of nutrients, salts or impurities in the water.

Inside the conductivity probe, two electrodes are positioned opposite from each other, an AC voltage is applied to the electrodes causing cations to move to the negatively charged electrode, while the anions move to the positively electrode. The more free electrolyte the liquid contains, the higher the electrical conductivity.

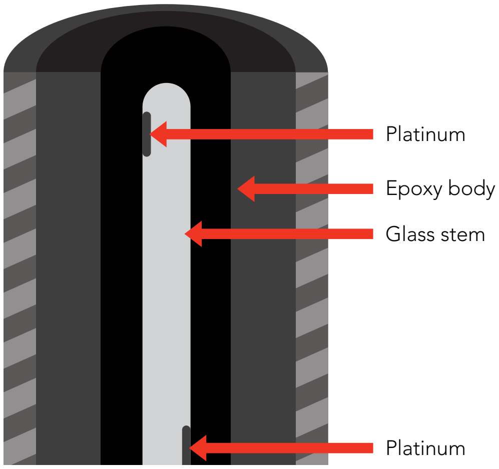




K 0.1
Graphite electrode



K 1.0
Graphite electrode



K 10
Platinum electrode

Output units

By default, EZO™ Conductivity circuits with firmware version 2.10 and above will *only* output EC. To enable these parameters see page 35 for UART, and 62 for I^2C.

The EZO™ Conductivity circuit also has the capability to read:

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

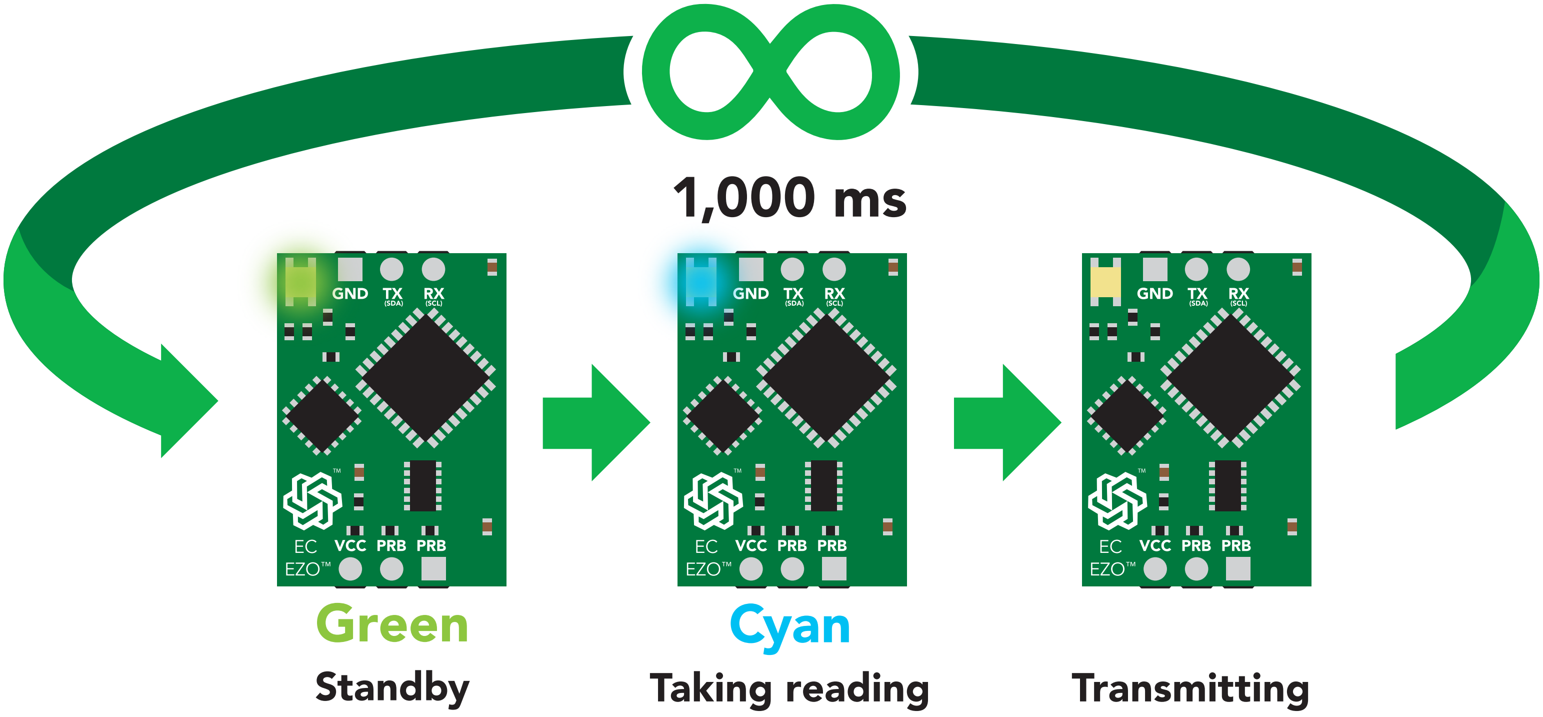
These parameters must be individually enabled within the device. See page **35** to enable each parameter in UART mode, and on page **62** for I^2C mode.

Once these parameters have been enabled, output will be a CSV string.

Example
EC,TDS,SAL,SG

Default LED blink pattern

This is the LED pattern for Continous Mode *(default state)*
This can only happen when the device is in **UART** mode.



Green
Standby

Cyan
Taking reading

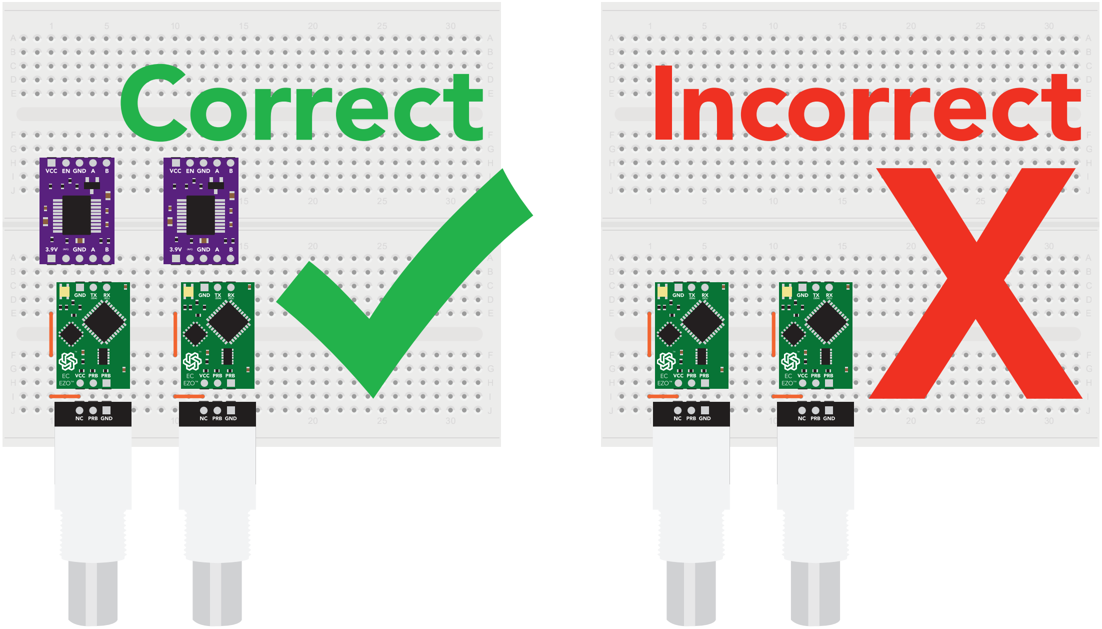
Transmitting

Power and data isolation

The Atlas Scientific EZO™ Conductivity circuit is a very sensitive device. This sensitivity is what gives the Conductivity circuit its accuracy. This also means that the Conductivity circuit is capable of reading micro-voltages that are bleeding into the water from unnatural sources such as pumps, solenoid valves or other probes/sensors.

When electrical noise is interfering with the Conductivity readings it is common to see rapidly fluctuating readings or readings that are consistently off. To verify that electrical noise is causing inaccurate readings, place the Conductivity probe in a cup of water by itself. The readings should stabilize quickly, confirming that electrical noise was the issue.

When reading from two EZO™ Conductivity circuits, it is ***strongly recommended*** that they are electrically isolated from each other.



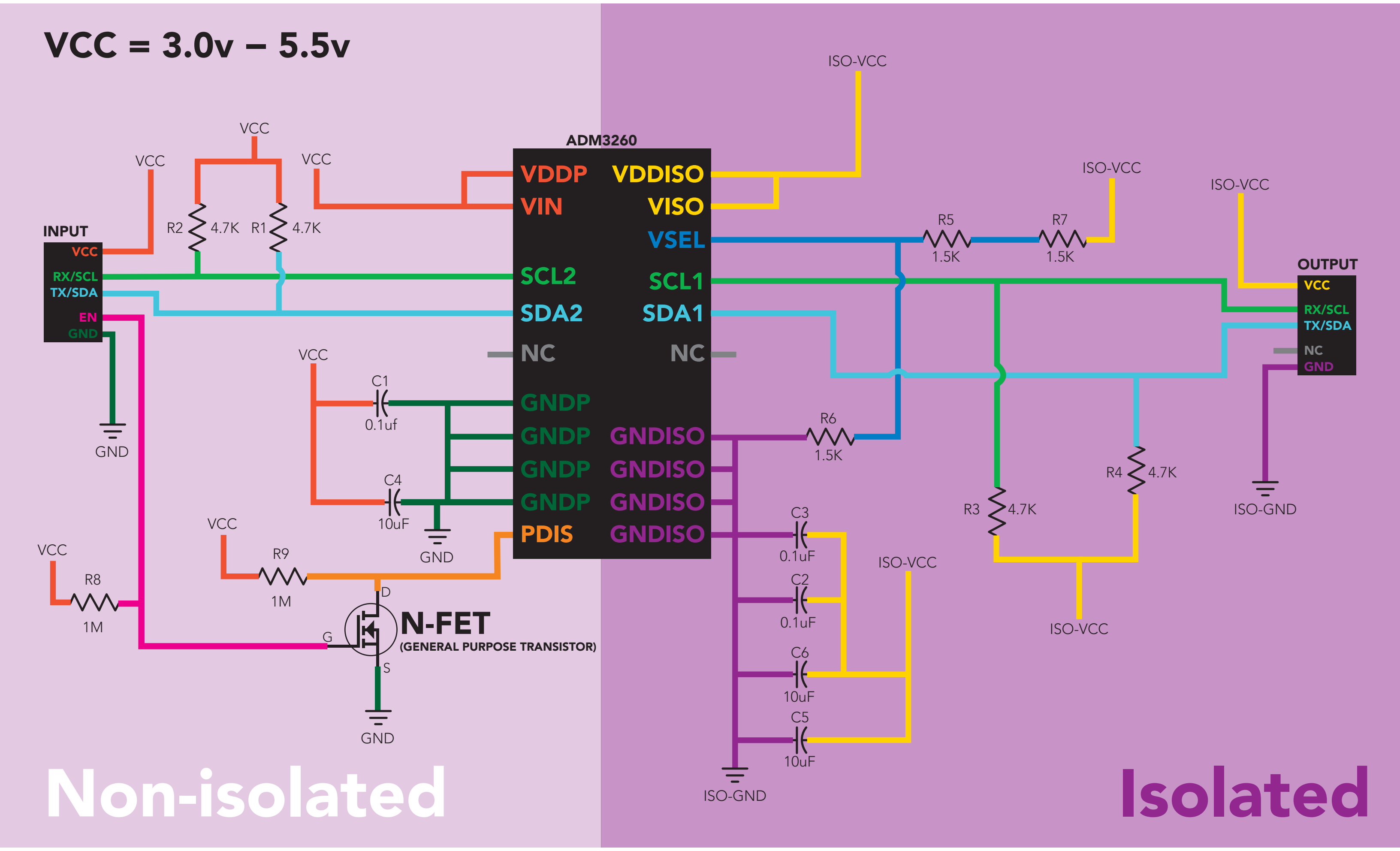
Basic EZO ™ Inline Voltage Isolator

Without isolation, Conductivity readings will effect each other.

This schematic shows exactly how we isolate data and power using the and a few passive components. The ADM3260 can output isolated power up to 150 mW and incorporates two bidirectional data channels.

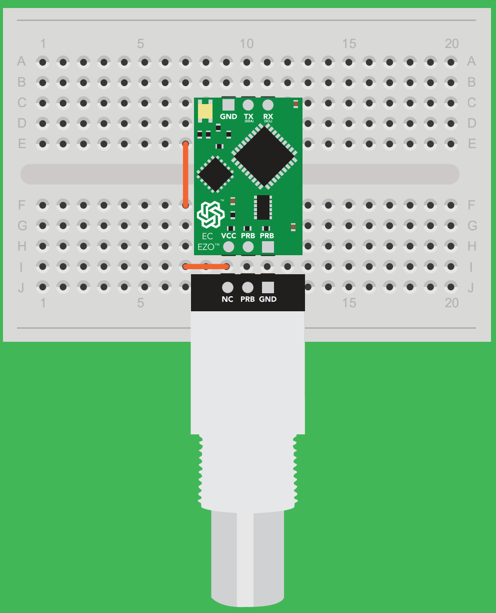
This technology works by using tiny transformers to induce the voltage across an air gap. PCB layout requires special attention for EMI/EMC and RF Control, having proper ground planes and keeping the capacitors as close to the chip as possible are crucial for proper performance. The two data channels have a 4.7kΩ pull up resistor on both the isolated and non-isolated lines (R1, R2, R3, and R4) The output voltage is set using a voltage divider (R5, R6, and R7) this produces a voltage of 3.9V regardless of your input voltage.

Isolated ground is different from non-isolated ground, these two lines should not be connected together.

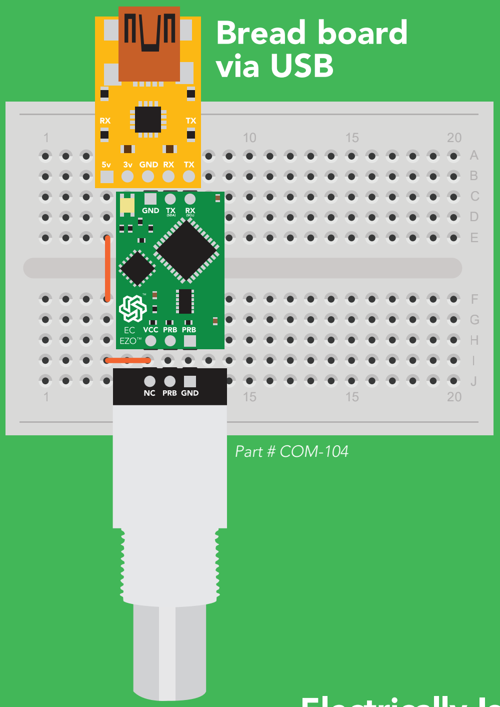


✓ Correct wiring

Bread board

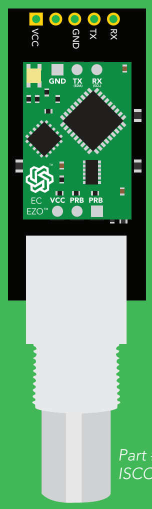


Bread board via USB



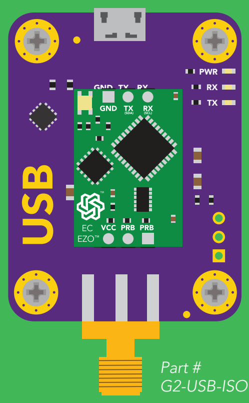
Part # COM-104

Carrier board



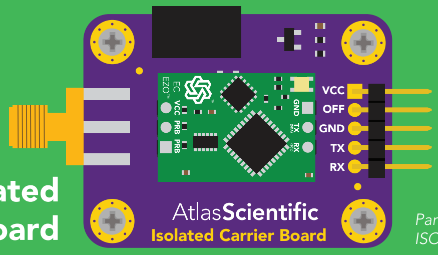
Part # ISCCB

USB carrier board



Part # G2-USB-ISO

Electrically Isolated EZO™ Carrier Board



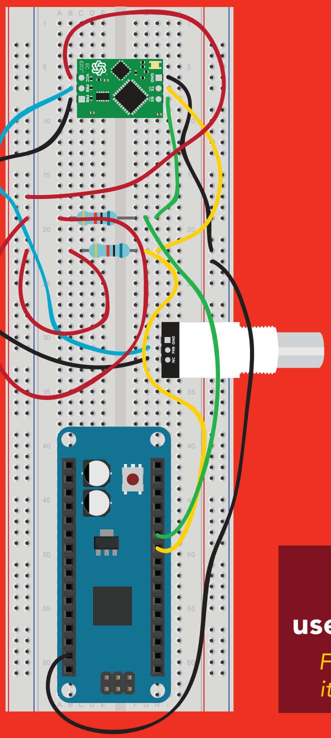
Part # ISCCB-2

X Incorrect wiring

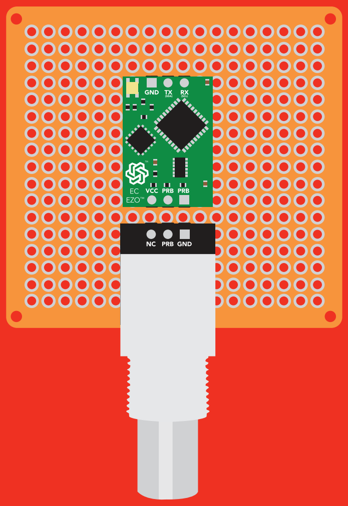
Extended leads

GND TX RX
EC VCC PRB PRB
EZO™
NC PRB GND

Sloppy setup



Perfboards or Protoboards

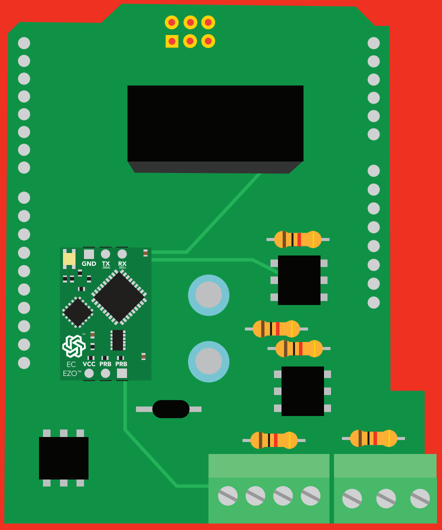


NEVER

use Perfboards or Protoboards

Flux residue and shorting wires make it very hard to get accurate readings.

*Embedded into your device



***Only after you are familar with EZO™ circuits operation**

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r 0.1

Calibration theory

Simple calibration

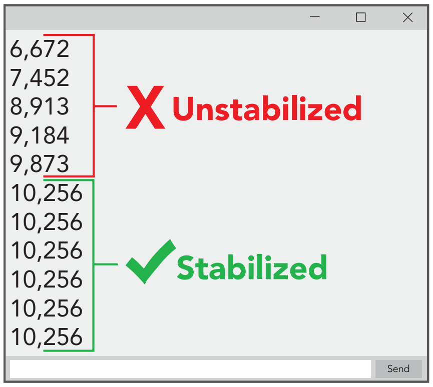
UART mode

Continuous readings

Advanced calibration

I²C mode

Continuously request readings



```
6,672
7,452
8,913
9,184
9,873
10,256
10,256
10,256
10,256
10,256
10,256
```

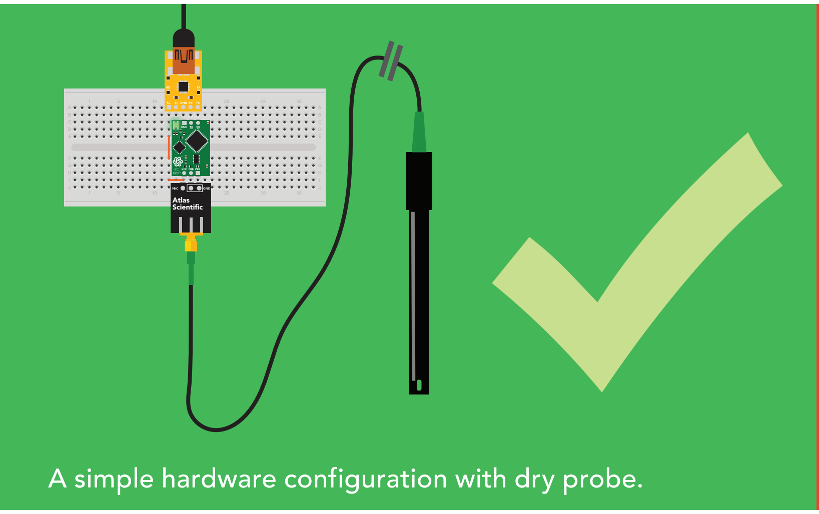
The most important part of calibration is watching the readings during the calibration process.

It's easiest to calibrate the device in its default state (UART mode, with continuous readings enabled).

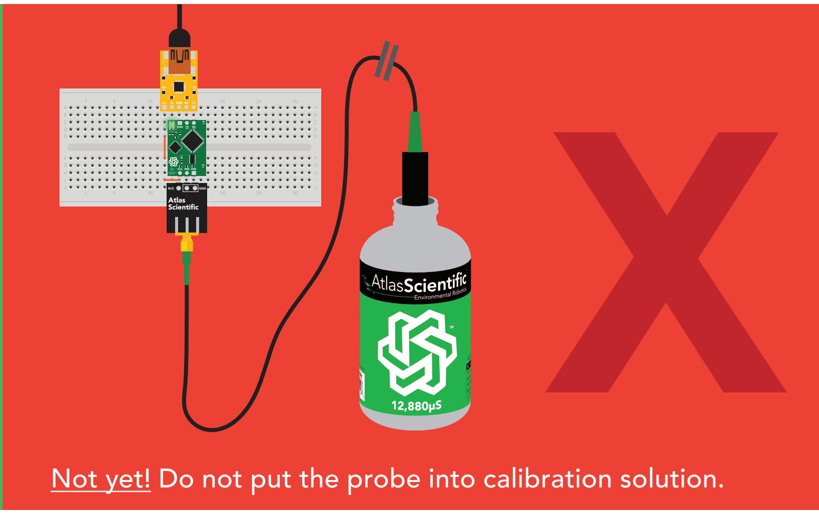
Switching the device to I²C mode after calibration ***will not*** affect the stored calibration. If the device must be calibrated in I²C mode be sure to ***continuously request readings*** so you can see the output from the probe.

1. Pre-calibration setup

Connect the dry conductivity probe and take continous readings.



A simple hardware configuration with dry probe.



Not yet! Do not put the probe into calibration solution.

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 **33** or **60**.

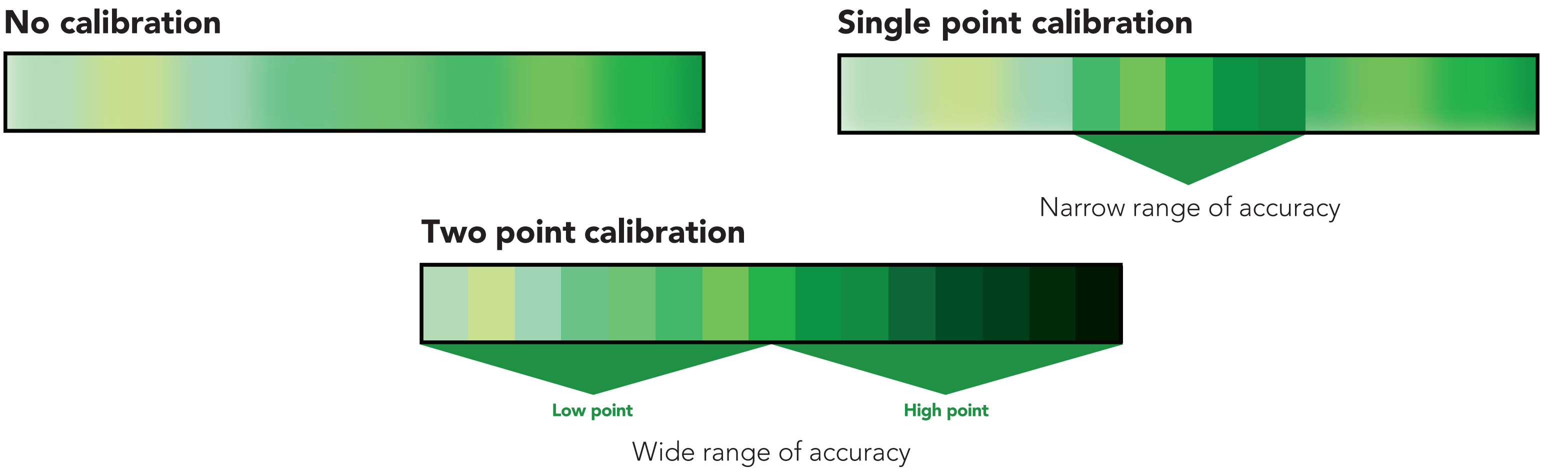
3. Dry calibration

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

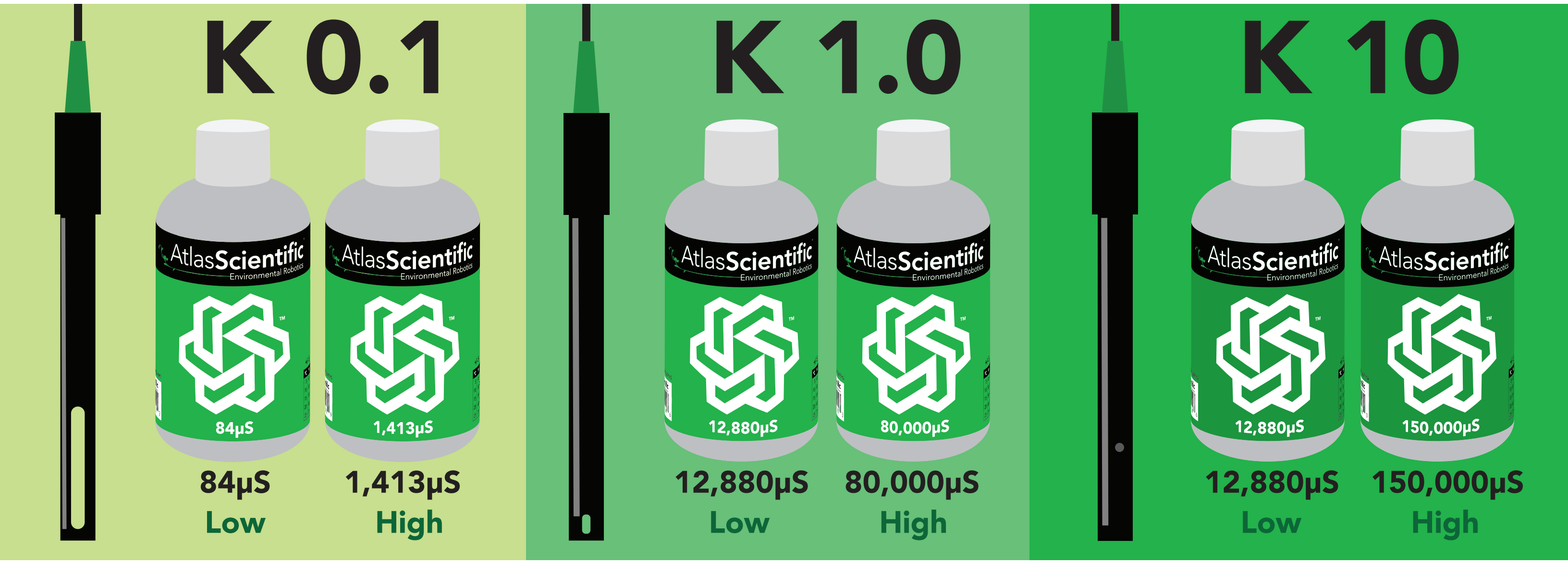
00.00 ➡ "Cal,dry" ➡ 0.00 ✓ Correct

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

4. Single point or Two point calibration



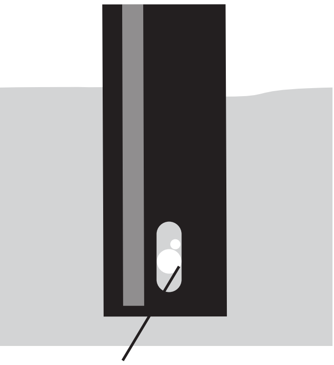
Recommended calibration points



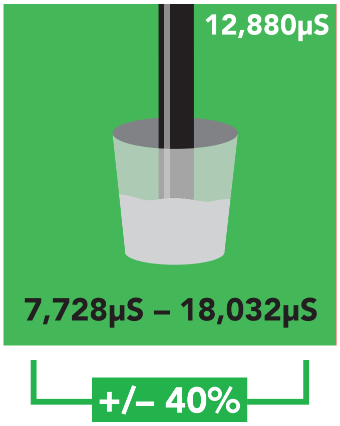
When calibrating, Atlas Scientific recommends using the above µS values. However, you can use any µS values you want.

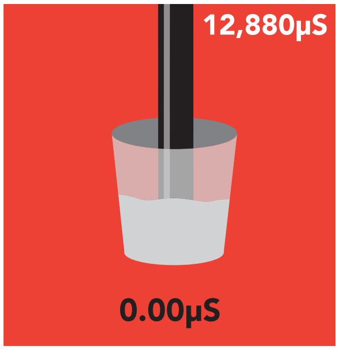
Two point calibration - low point

Pour a small amount of the low point calibration solution into a cup. Shake the probe to make sure you do not have trapped air bubbles in the sensing area. You should see readings that are off by **1 – 40%** from the stated value of the calibration solution. Wait for readings to stabilize *(small movement from one reading to the next is normal)*.

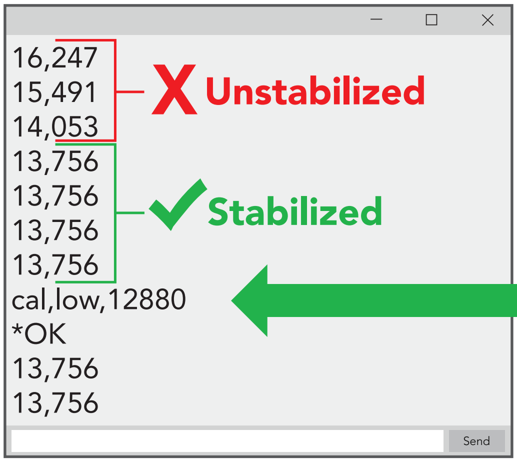


Trapped air in sensing area (shake to remove)





check probe connection, you cannot calibrate to 0.

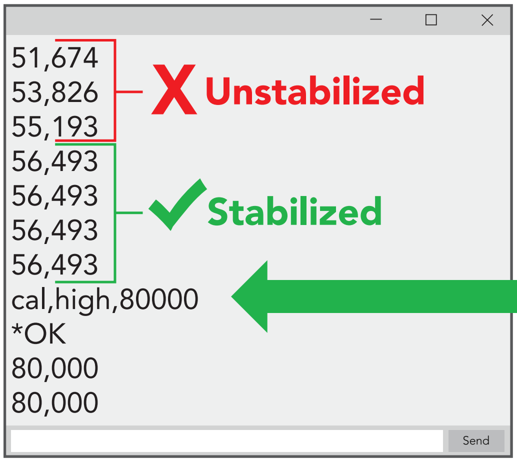


```
16,247
15,491
14,053
13,756
13,756
13,756
13,756
cal,low,12880
*OK
13,756
13,756
```

Once the readings stabilize, issue the low point calibration command.**"cal,low,12880"** *(Readings will **NOT** change)*

Two 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.

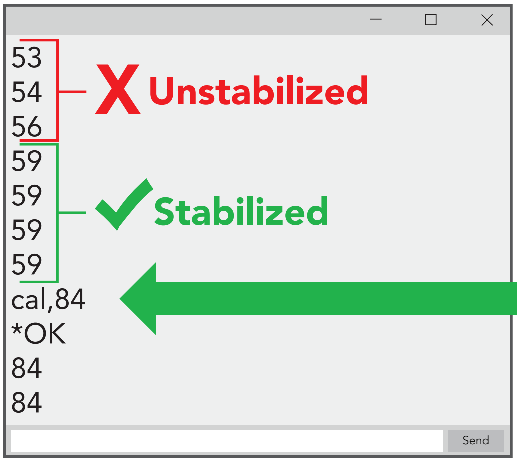


```
51,674
53,826
55,193
56,493
56,493
56,493
56,493
cal,high,80000
*OK
80,000
80,000
```

Once the readings stabilize, issue the high point calibration command.**"cal,high,80000"** *(Readings **will** change, calibration complete).*

Single point calibration

- Pour a small amount of calibration solution into a cup *(μS value of your choice)*.
- Shake the probe to remove trapped air.
- Readings may be off by +/- 40%
- Wait for readings to stabilize.



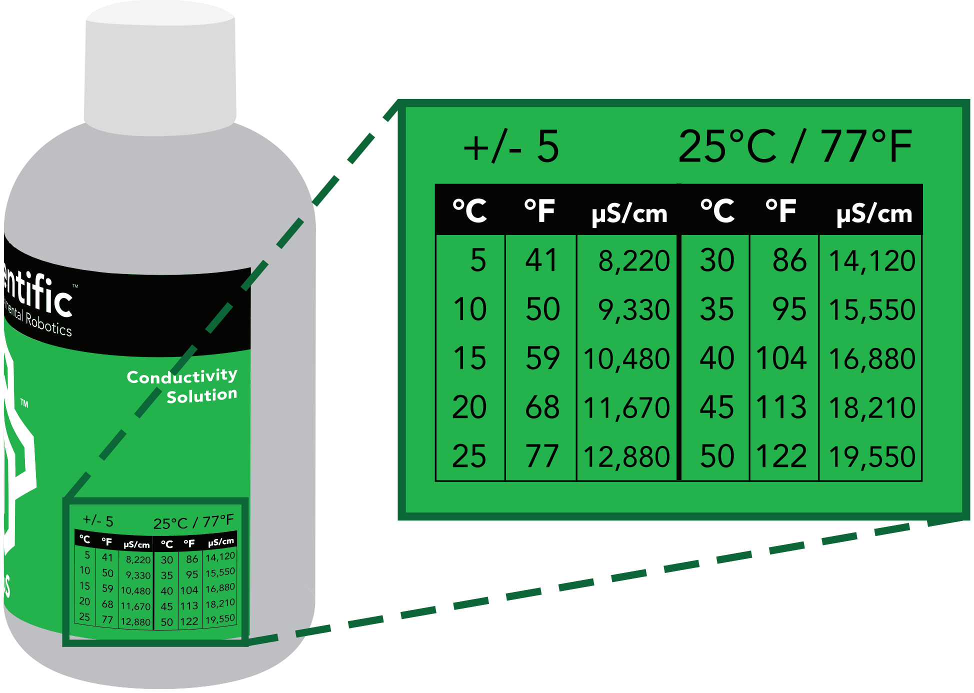
```
53
54
56
59
59
59
59
cal,84
*OK
84
84
```

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

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**.

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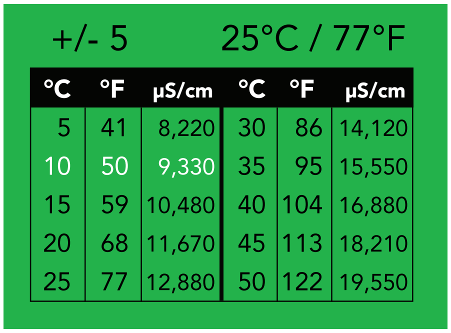
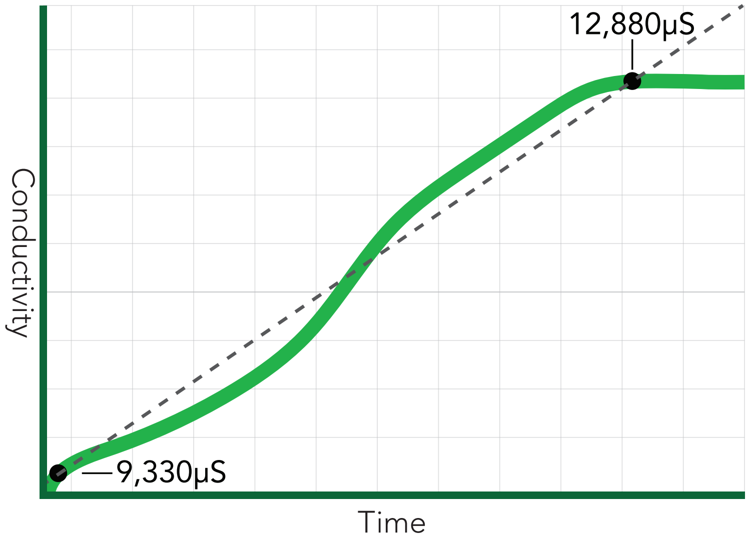
Environmental Robotics
12,880μS
10°C



+/- 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.

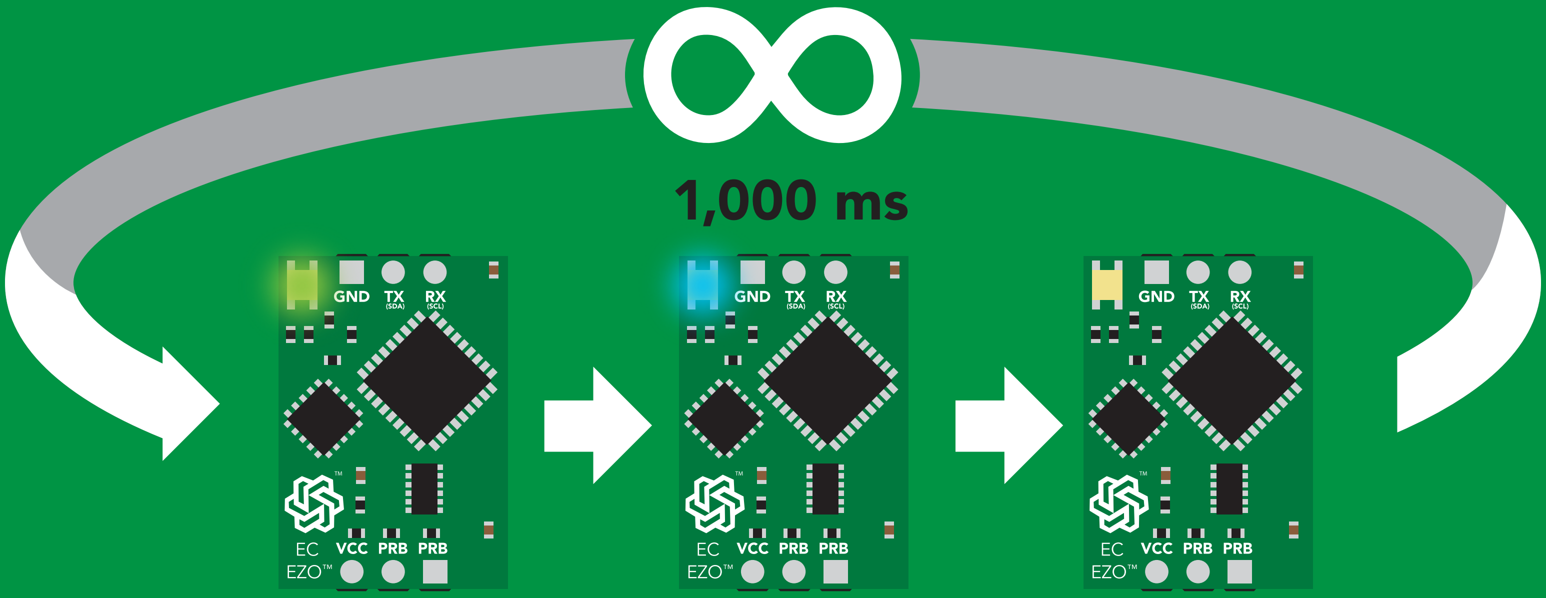
See pages **34** or **61** for more information.



Default state

UART mode

Baud	9,600
Readings	continuous
Units	µS/cm
Speed	1 reading per second
LED	on



1,000 ms

Green
Standby

Cyan
Taking reading

Transmitting

✓ Available data protocols

UART

Default

I^{2}C

✗ Unavailable data protocols

SPI

Analog

RS-485

Mod Bus

4–20mA

UART mode

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

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Environmental Robotics

r 0.2

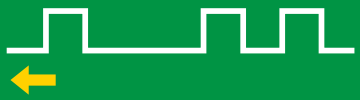
UART mode

8 data bits	no parity
1 stop bit	no flow control

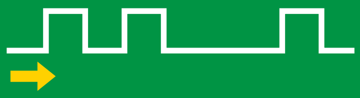
Baud

- 300
- 1,200
- 2,400
- **9,600 default**
- 19,200
- 38,400
- 57,600
- 115,200

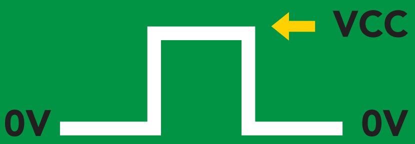
RX
Data in

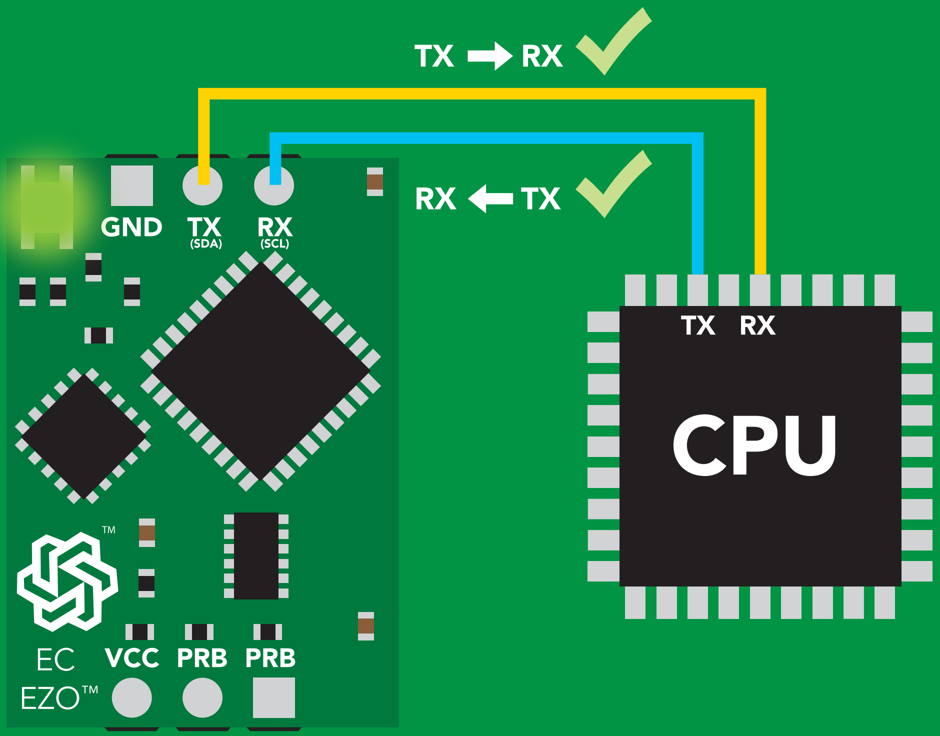


TX
Data out



Vcc 3.3V – 5.5V





Data format

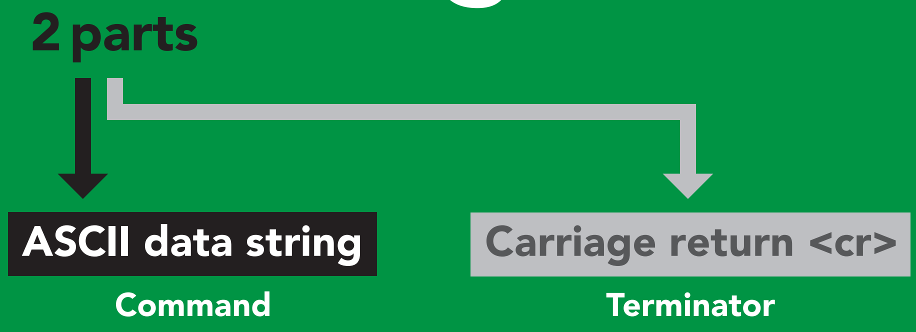
Reading

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

Units	EC,TDS,SAL,SG
Encoding	ASCII
Format	string

Terminator	carriage return
Data type	floating point
Decimal places	3
Smallest string	3 characters
Largest string	40 characters

Receiving data from device

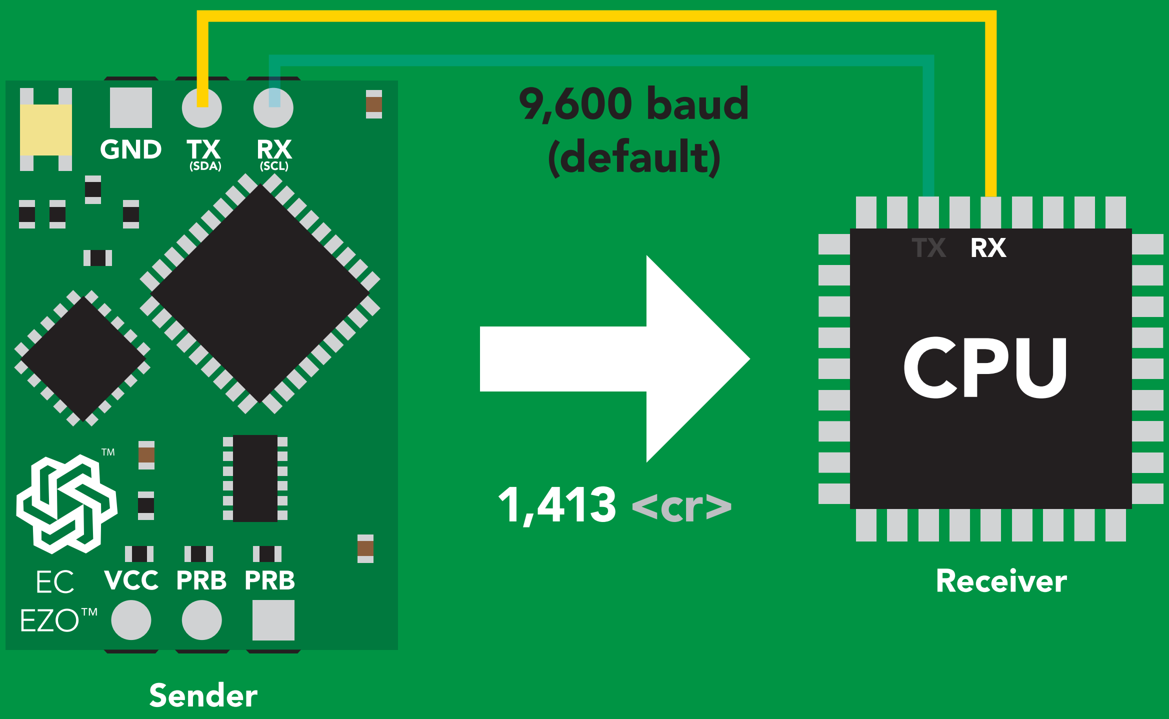

2 parts

ASCII data string

Command

Carriage return <cr>

Terminator



9,600 baud (default)

1,413 <cr>

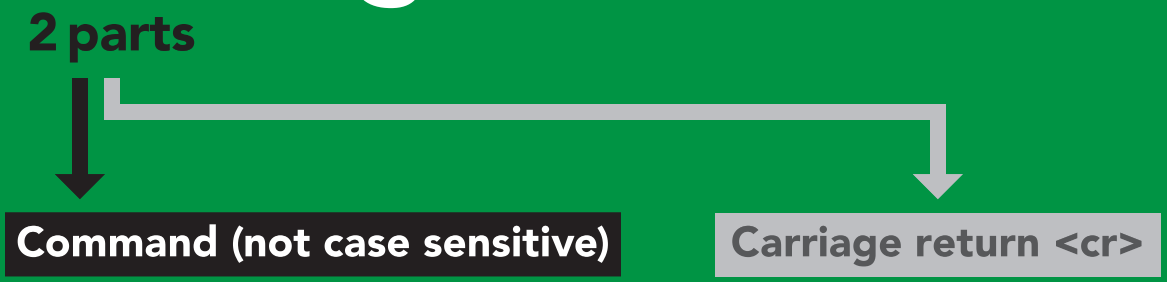
Sender

Receiver

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



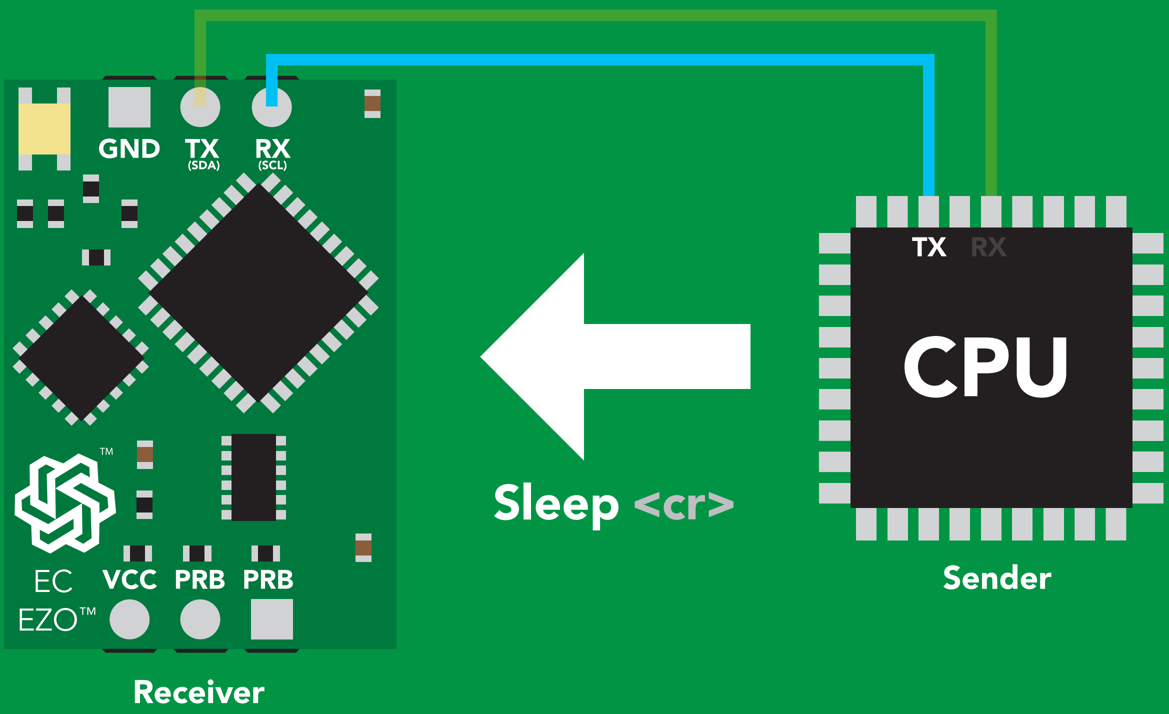
2 parts

Command (not case sensitive)

ASCII data string

Carriage return <cr>

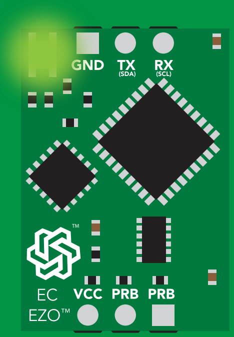
Terminator



Advanced

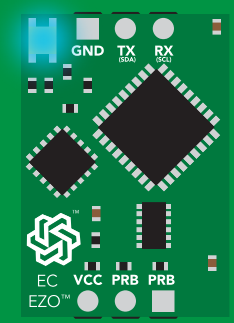
ASCII:	S	l	e	e	p	<cr>
Hex:	53	6C	65	65	70	0D
Dec:	83	108	101	101	112	13

LED color definition



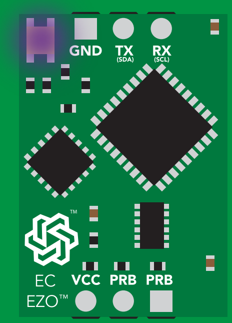
Green

UART standby



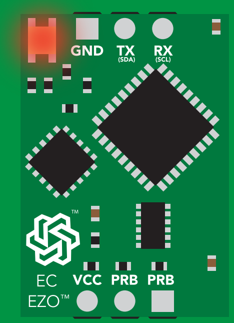
Cyan

Taking reading



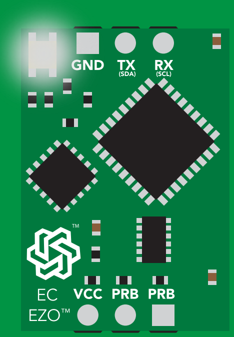
Purple

Changing baud rate



Red

Command not understood



White

Find

	LED ON
5V	**+2.5 mA**
3.3V	**+1 mA**

UART mode

command quick reference

All commands are ASCII strings or single ASCII characters.

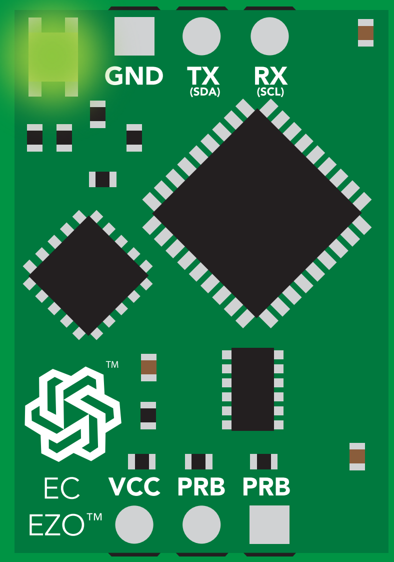
Command	Function		Default state
Baud	change baud rate	pg. 41	9,600
C	enable/disable continuous reading	pg. 27	enabled
Cal	performs calibration	pg. 29	n/a
Export	export calibration	pg. 31	n/a
Factory	enable factory reset	pg. 43	n/a
Find	finds device with blinking white LED	pg. 26	n/a
i	device information	pg. 37	n/a
I2C	change to I^2C mode	pg. 44	not set
Import	import calibration	pg. 32	n/a
K	Set probe type	pg. 33	K 1.0
L	enable/disable LED	pg. 25	enabled
Name	set/show name of device	pg. 36	not set
O	enable/disable parameters	pg. 35	all enabled
Plock	enable/disable protocol lock	pg. 42	disabled
R	returns a single reading	pg. 28	n/a
Sleep	enter sleep mode/low power	pg. 40	n/a
Status	retrieve status information	pg. 39	enable
T	temperature compensation	pg. 34	25°C
TDS	change the TDS conversion factor	pg. 30	n/a
*OK	enable/disable response codes	pg. 38	enable

LED control

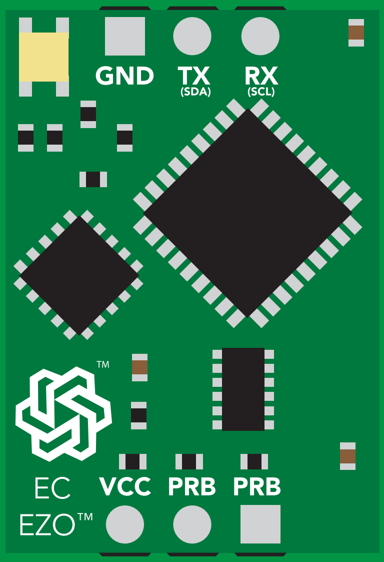
Command syntax

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

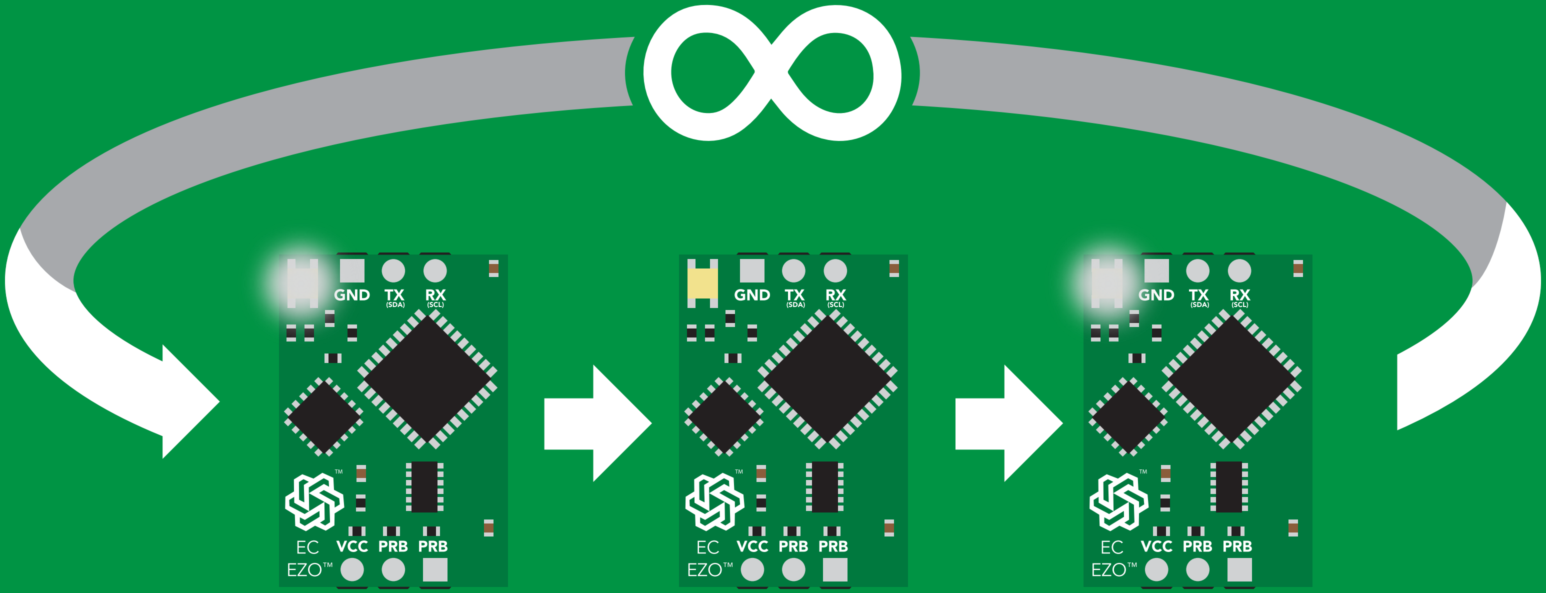
Find

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?

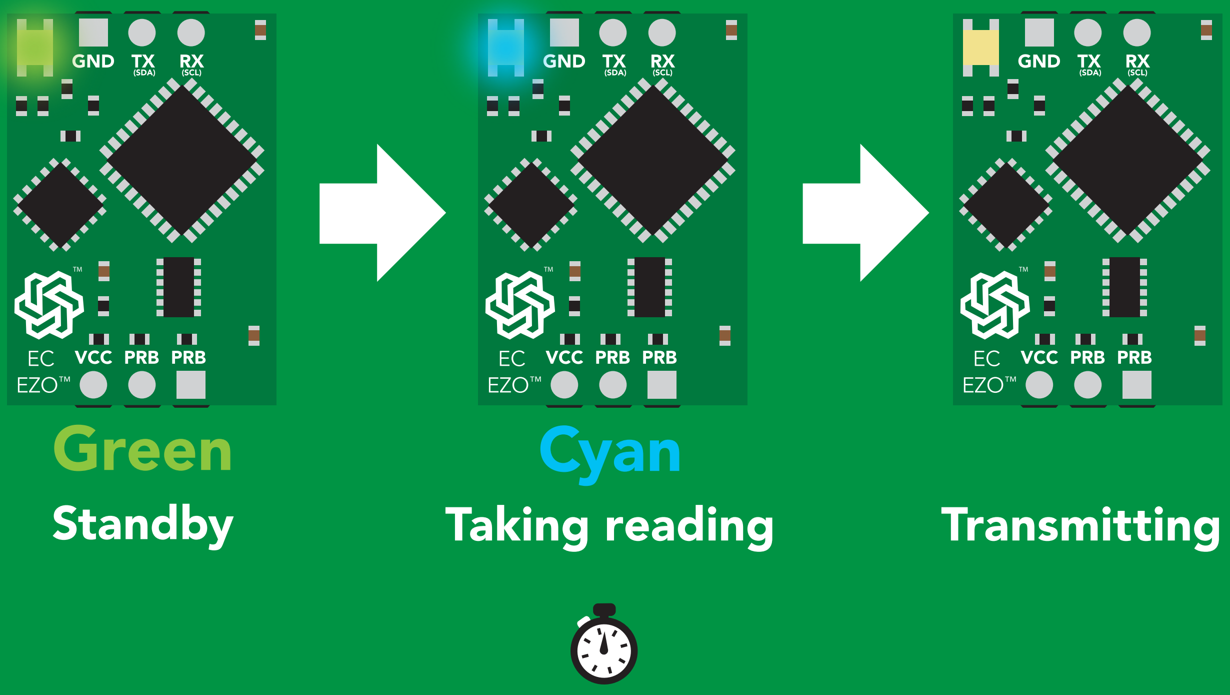
Example	Response
C,1 <cr>	*OK <cr> EC,TDS,SAL,SG (1 sec) <cr> EC,TDS,SAL,SG (2 sec) <cr> EC,TDS,SAL,SG (3 sec) <cr>
C,30 <cr>	*OK <cr> EC,TDS,SAL,SG (30 sec) <cr> EC,TDS,SAL,SG (60 sec) <cr> EC,TDS,SAL,SG (90 sec) <cr>
C,0 <cr>	*OK <cr>
C,? <cr>	?C,1 <cr> or ?C,0 <cr> or ?C,30 <cr> *OK <cr>

Single reading mode

Command syntax

R <cr> **takes single reading**

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



Green
Standby

Cyan
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> or ?CAL,2 one point two point *OK <cr>

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

Two 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

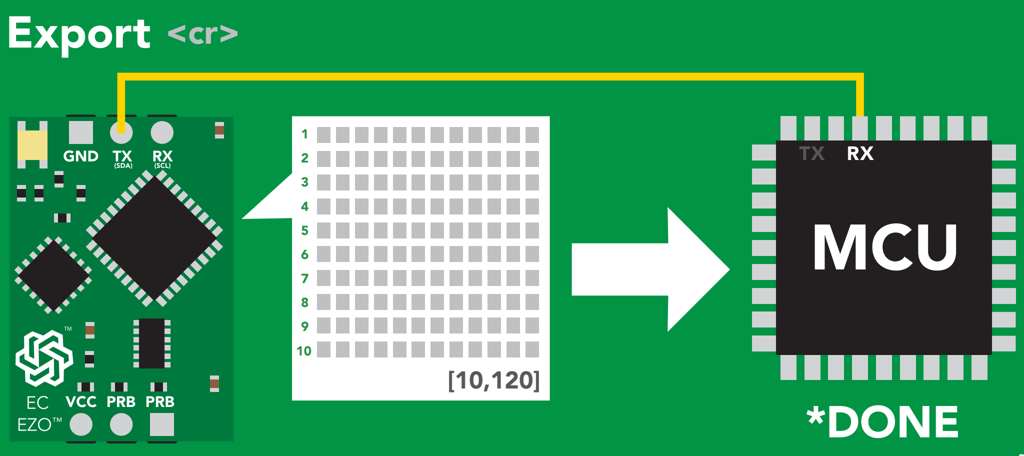
10 → # of strings to export

120 → # 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



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r 0.2

Import calibration

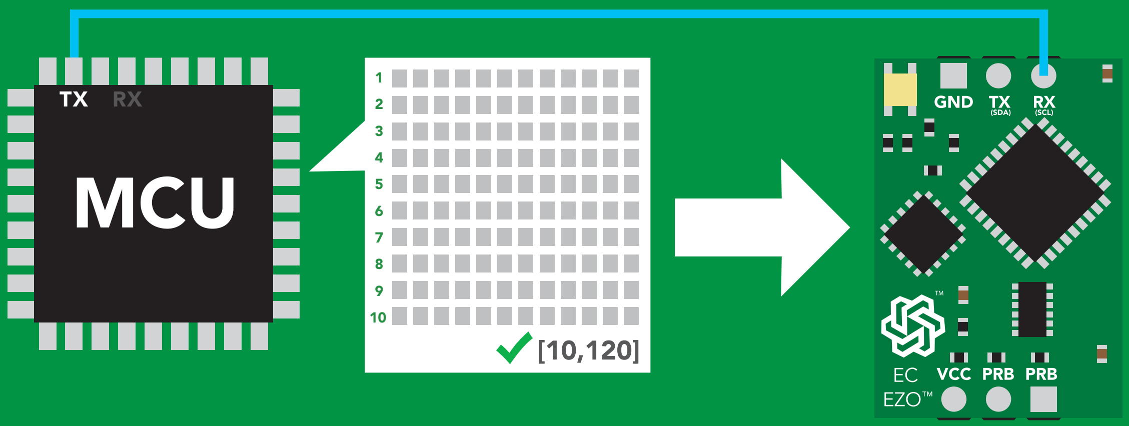
Command syntax

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

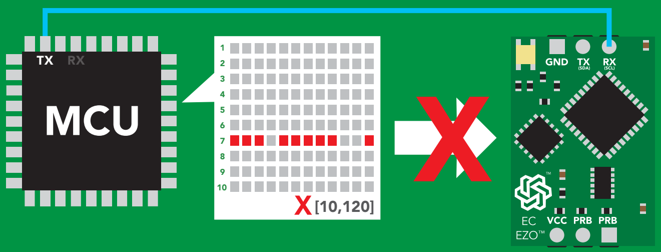
Import,n <cr> **import calibration string to new device**

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.**

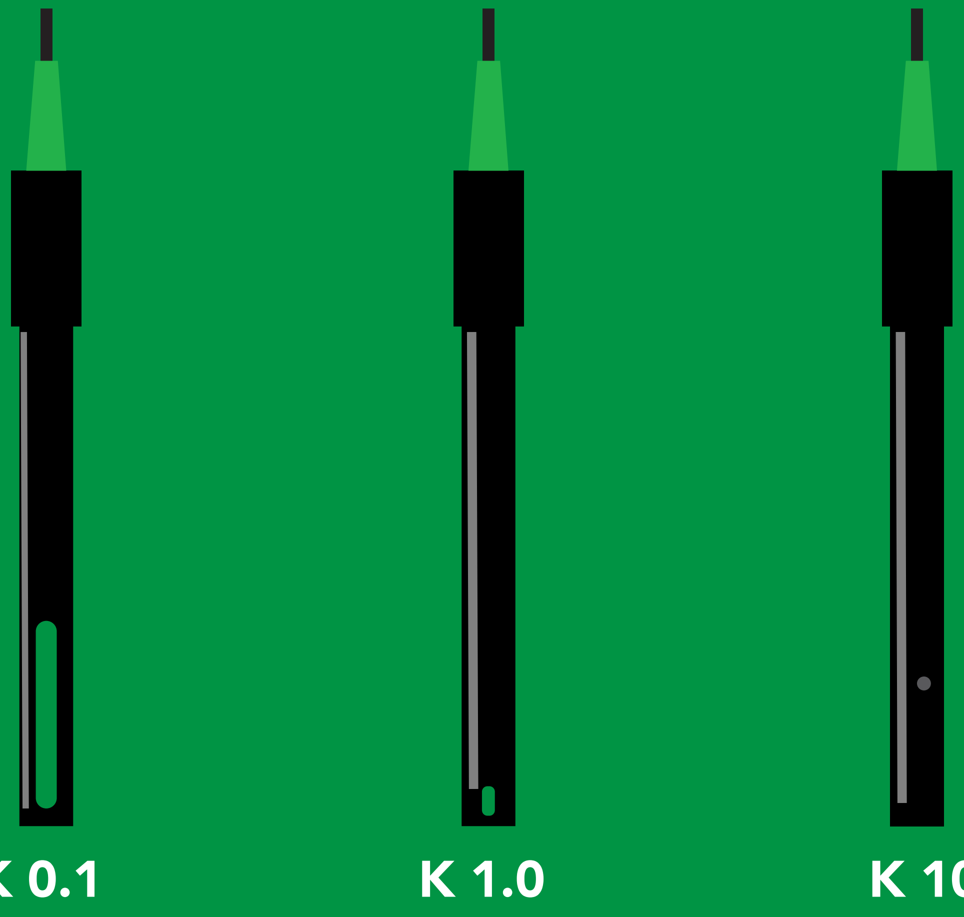
Setting the probe type

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>



Temperature compensation

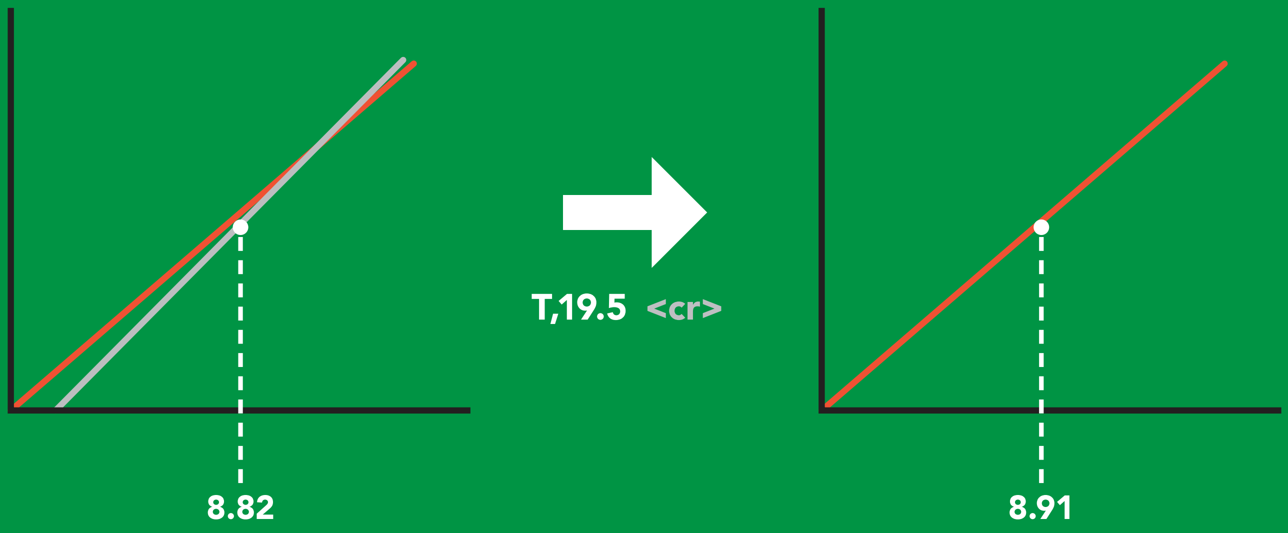
Command syntax

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*

* This is a new command for firmware V2.13

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>



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
TDS	total dissolved solids
S	salinity
SG	specific gravity

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

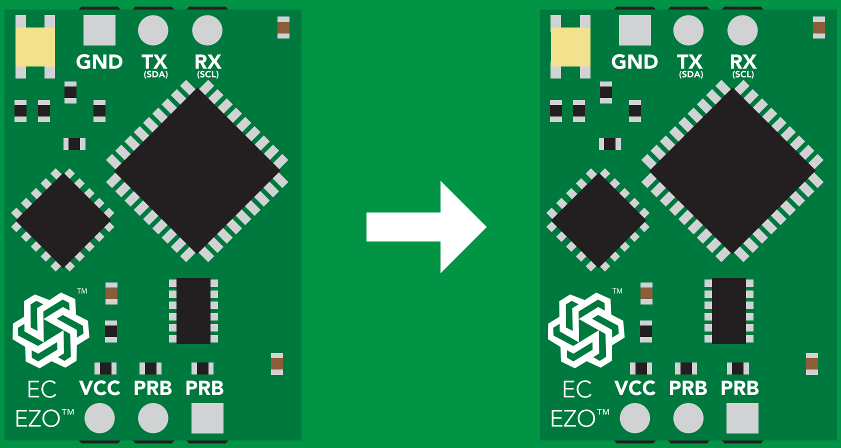
n = _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16

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>

Device information

Command syntax

```
i <cr>  device information
```

Example	Response
i <cr>	?i,EC,2.10 <cr> *OK <cr>

Response breakdown

```
?i,   EC,      2.10
      ↑        ↑
      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

Sleep mode/low power

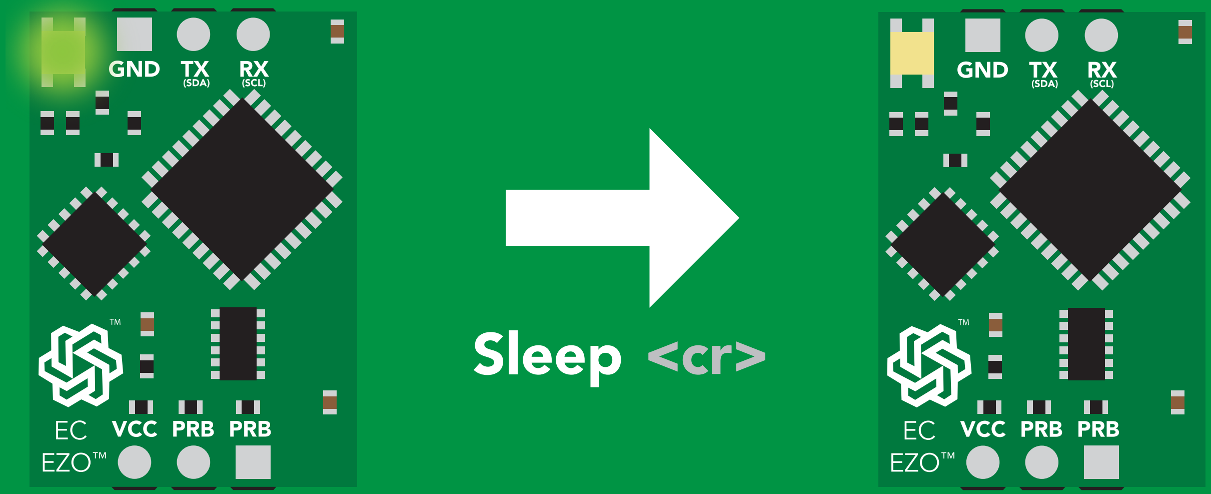
Command syntax

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



Sleep <cr>

Standby
18.14 mA

Sleep
0.7 mA

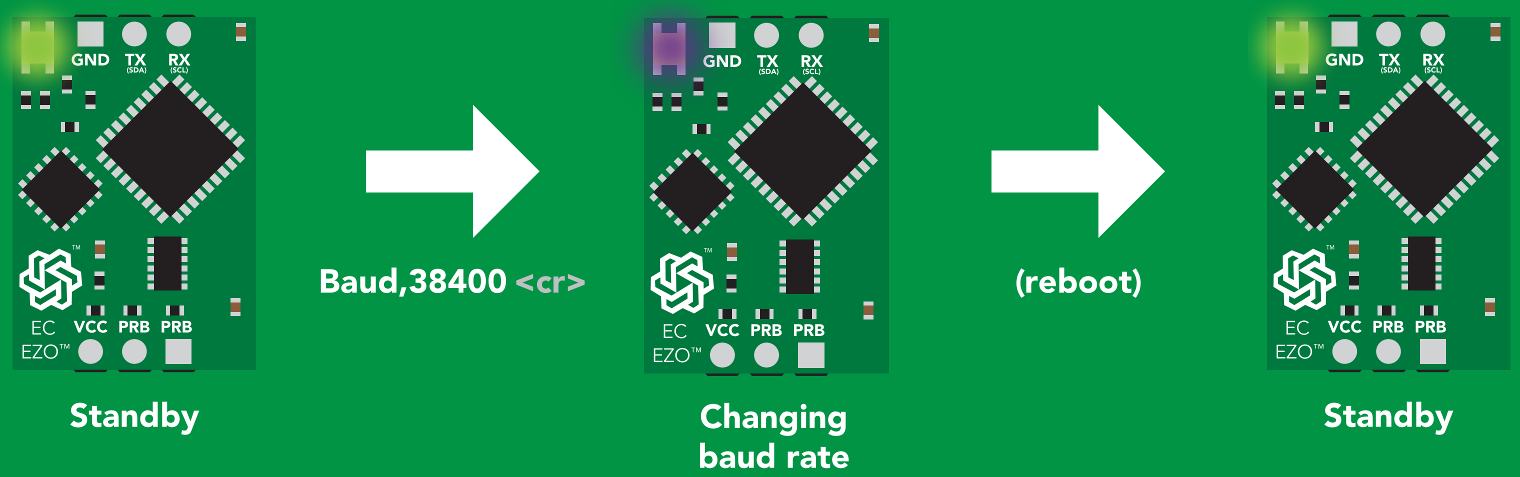
Change baud rate

Command syntax

Baud,n <cr> **change baud rate**

Example	Response
Baud,38400 <cr>	*OK <cr>
Baud,? <cr>	?Baud,38400 <cr> *OK <cr>

n =
- 300
- 1200
- 2400
- 9600 default
- 19200
- 38400
- 57600
- 115200



Standby

Changing baud rate

*OK <cr>

Standby

Protocol lock

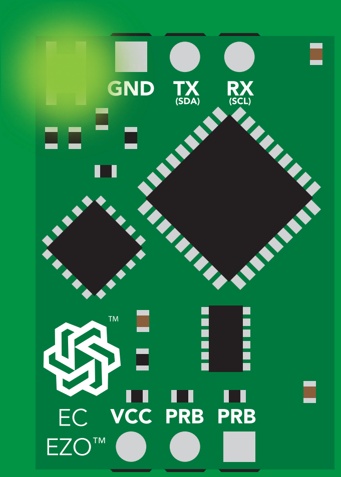
Command syntax

Locks device to UART mode.

Plock,1	<cr>	enable Plock	
Plock,0	<cr>	disable Plock	default
Plock,?	<cr>	Plock on/off?	

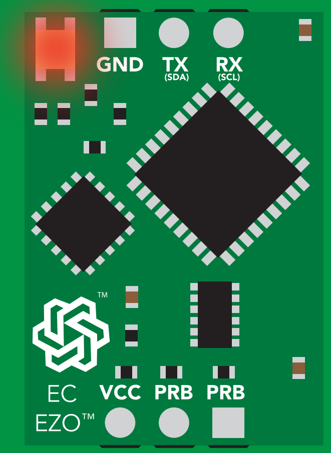
Example	Response
Plock,1 <cr>	*OK <cr>
Plock,0 <cr>	*OK <cr>
Plock,? <cr>	?Plock,1 <cr> or ?Plock,0 <cr>

Plock,1



*OK <cr>

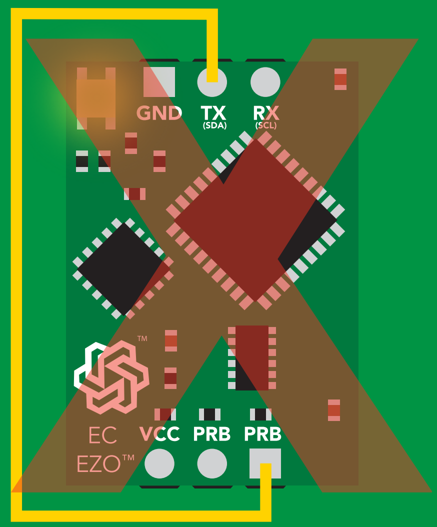
I2C,100



cannot change to I²C

*ER <cr>

Short



cannot change to I²C

Factory reset

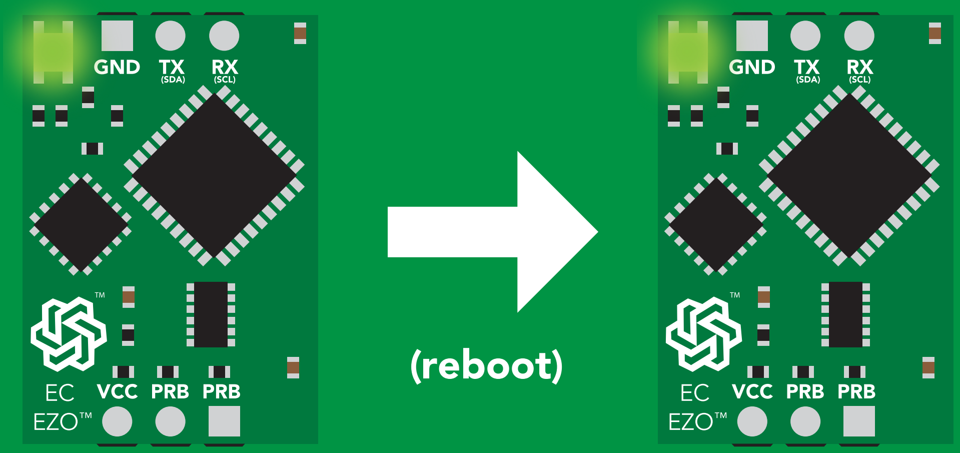
Command syntax

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

Change to I²C mode

Command syntax

Default I²C address 100 (0x64)

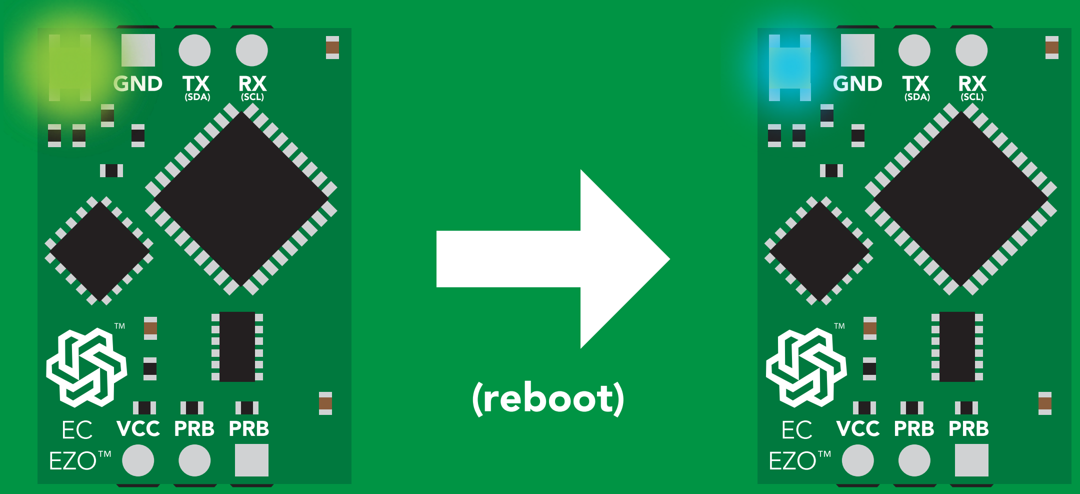
I2C,n <cr> sets I²C address and reboots into I²C mode

n = any number 1 – 127

Example	Response
I2C,100 <cr>	*OK (reboot in I²C mode)

Wrong example	Response
I2C,139 <cr> n ≯ 127	*ER <cr>

I2C,100



(reboot)

Green

*OK <cr>

Blue

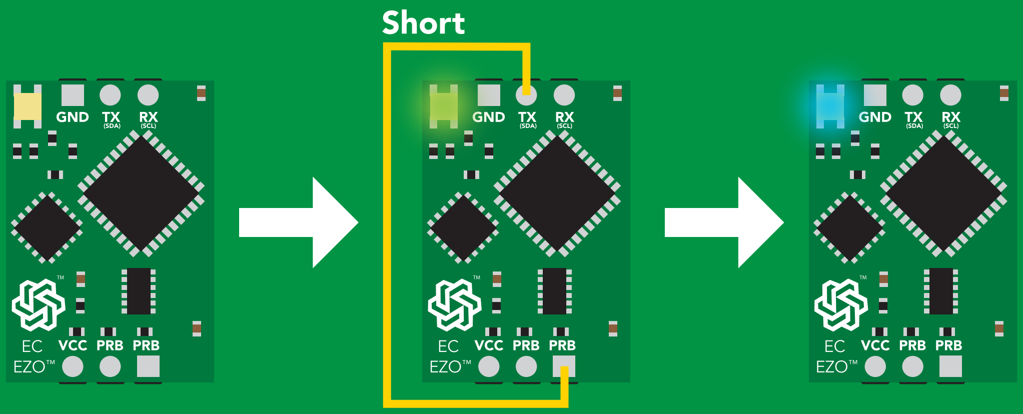
now in I²C mode

Manual switching to I²C

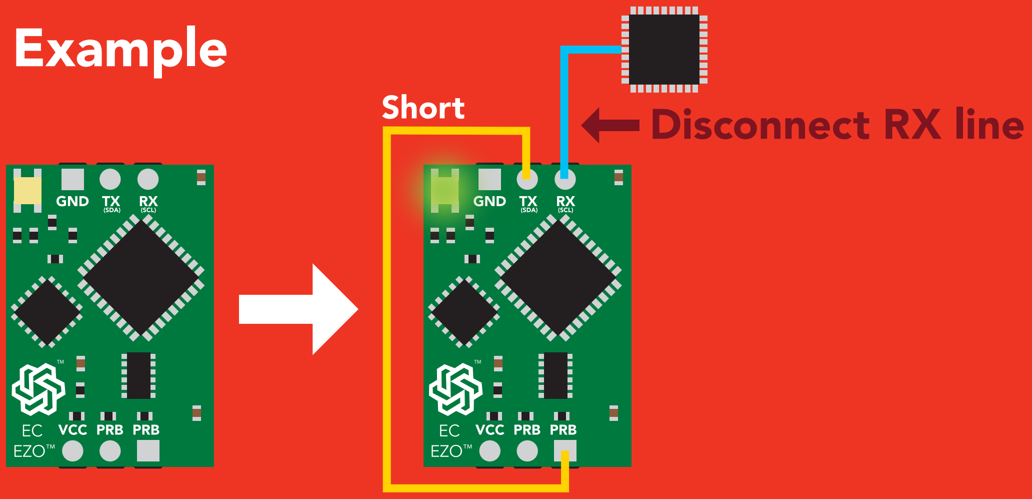
- Disconnect ground (power off)
- Disconnect TX and RX
- Connect TX to the right PRB
- Confirm RX is disconnected
- Connect ground (power on)
- Wait for LED to change from Green to Blue
- Disconnect ground (power off)
- Reconnect all data and power

Manually switching to I²C will set the I²C address to 100 (0x64)

Example



Wrong Example



I^2C mode

The I^2C protocol is *considerably more complex* than the UART (RS–232) protocol. Atlas Scientific assumes the embedded systems engineer understands this protocol.

To set your EZO™ device into I^2C mode click here

Settings that are retained if power is cut

Calibration
Change I^2C address
Enable/disable parameters
Hardware switch to UART mode
LED control
Protocol lock
Software switch to UART mode

Settings that are *NOT* retained if power is cut

Find
Sleep mode
Temperature compensation

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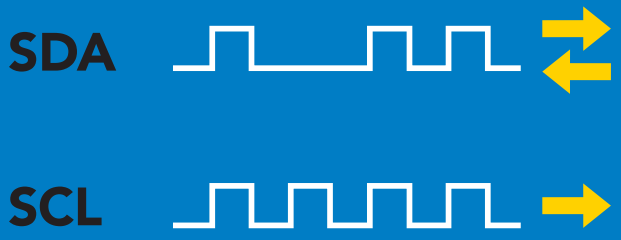
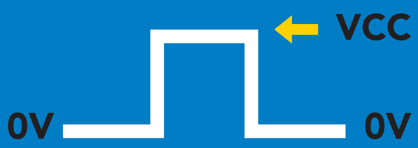
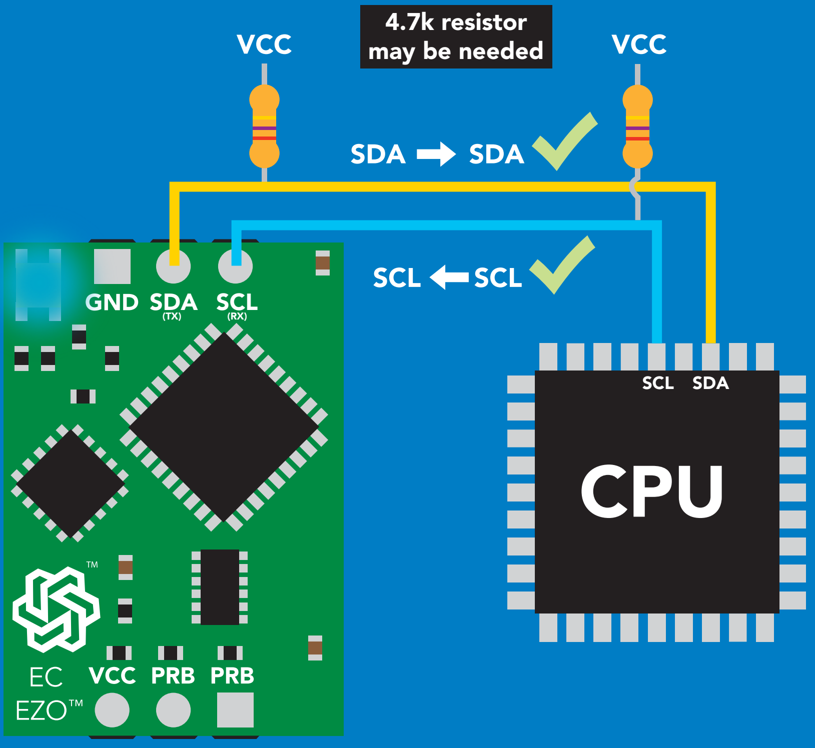
r 0.2

I^{2}C mode

I^{2}C address	(0x01 – 0x7F) 100 (0x64) default
Vcc	3.3V – 5.5V
Clock speed	100 – 400 kHz







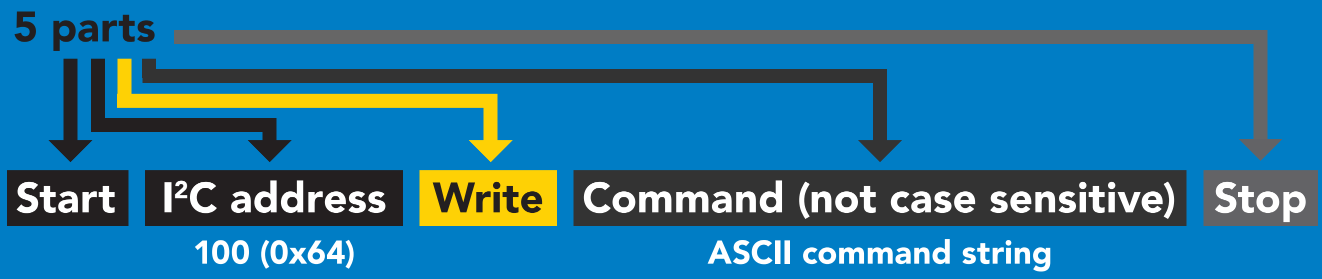
Data format

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

Units	EC,TDS,SAL,SG
Encoding	ASCII

Format	string
Data type	floating point
Decimal places	3
Smallest string	3 characters
Largest string	40 characters

Sending commands to device



5 parts

Start | I^{2}C address | Write | Command (not case sensitive) | Stop

100 (0x64)

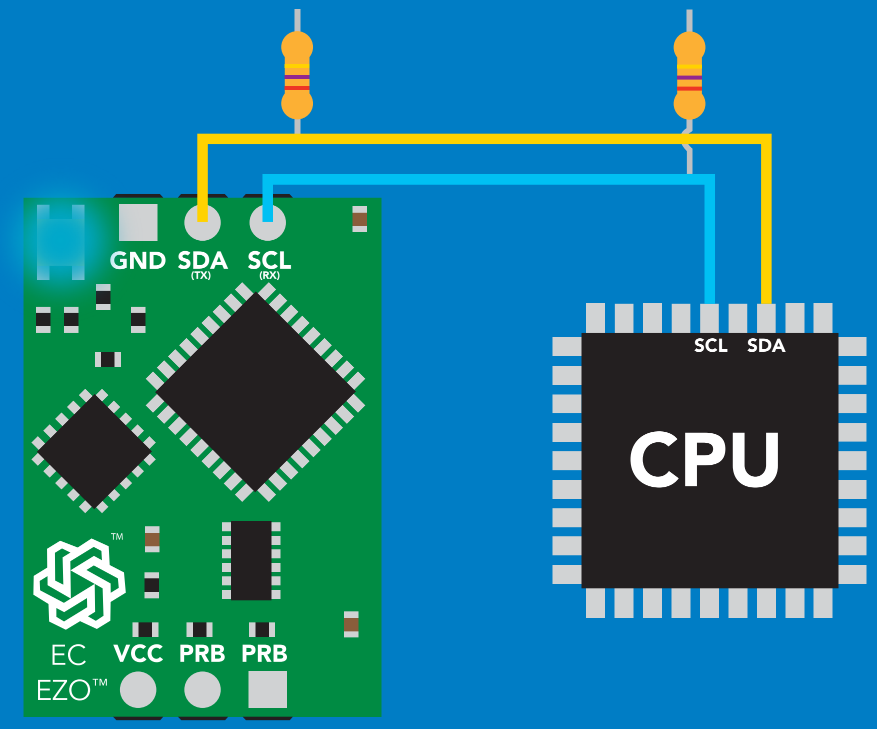
ASCII command string

Example

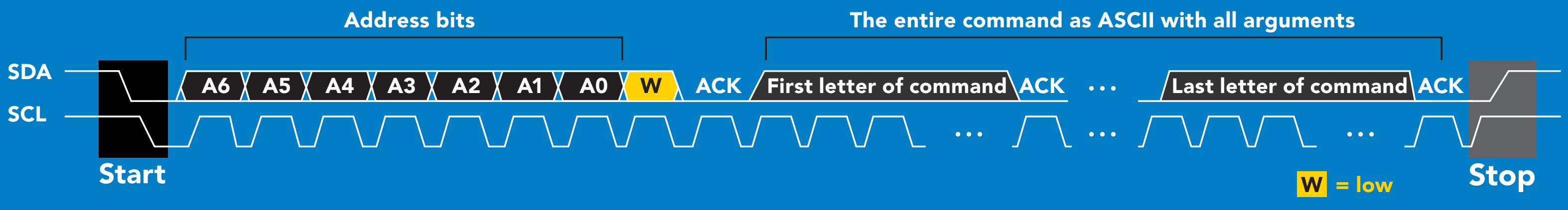
Start | 100 (0x64) | Write | Sleep | Stop

I^{2}C address

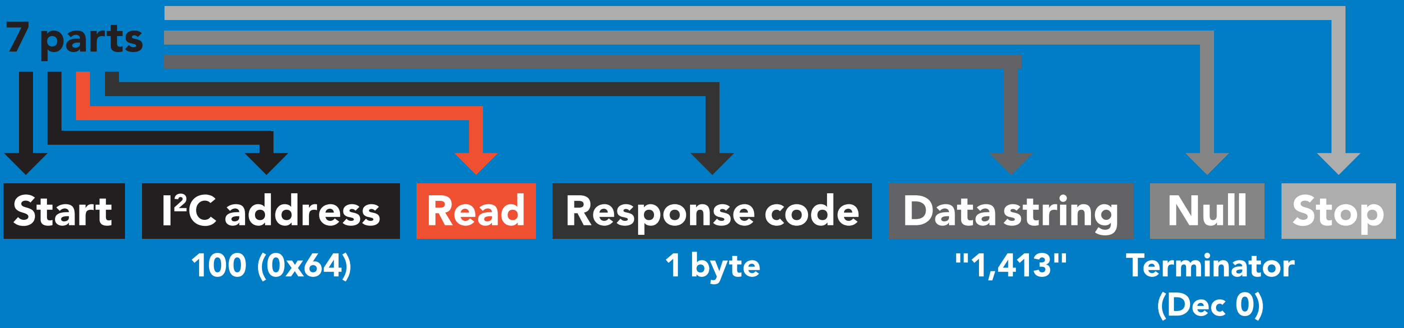
Command



Advanced



Requesting data from device



7 parts

Start

I^2C address
100 (0x64)

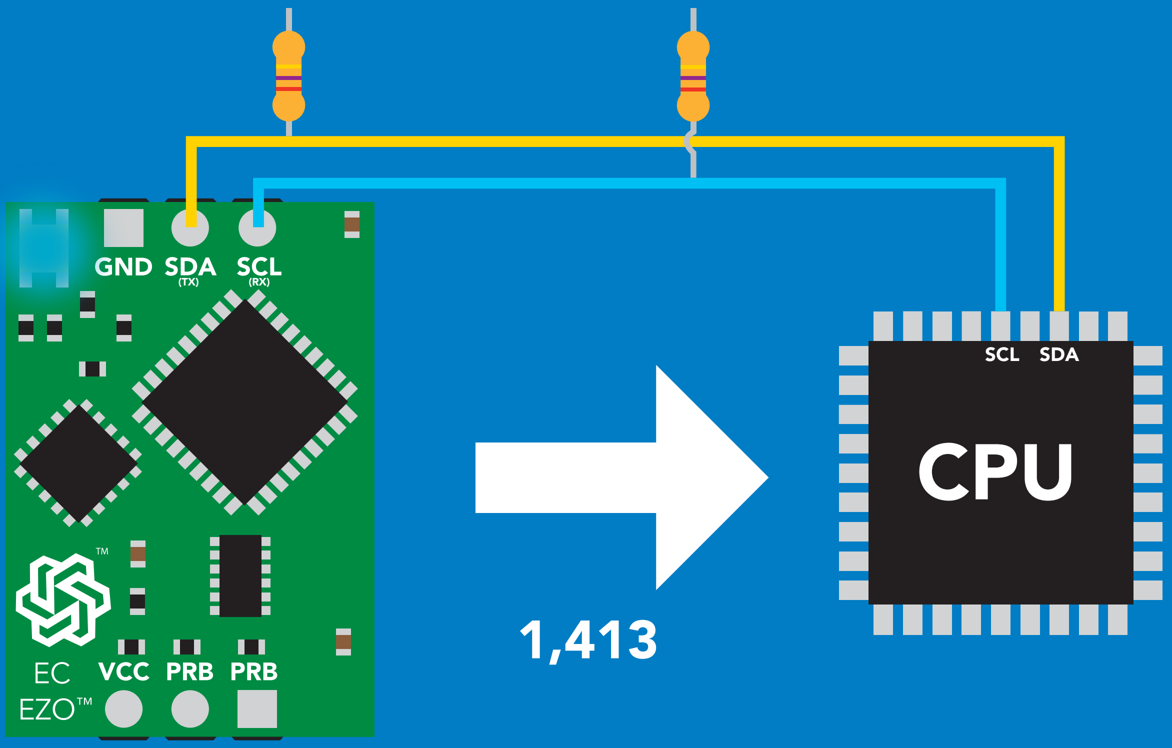
Read

Response code
1 byte

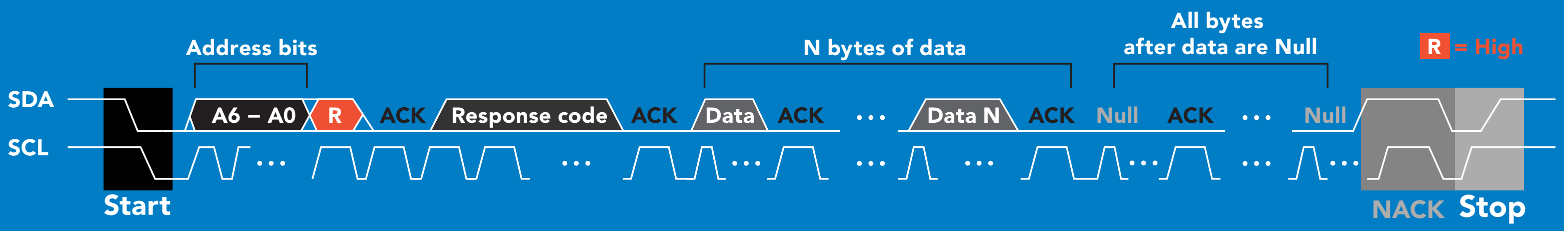
Data string
"1,413"

Null
Terminator
(Dec 0)

Stop



Advanced



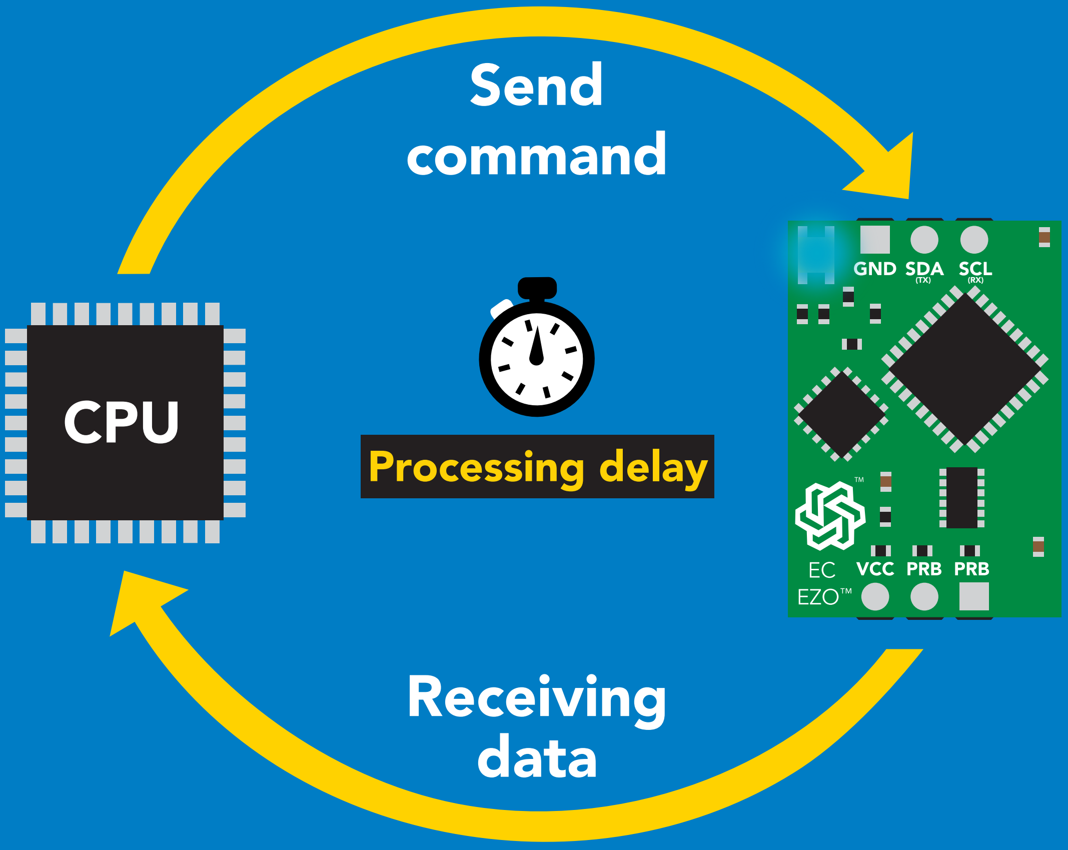
1 49 44 52 49 51 0 = 1,413

Dec ASCII Dec

Response codes

After a command has been issued, a 1 byte response code can be read in order to confirm that the command was processed successfully.

Reading back the response code is completely optional, and is not required for normal operation.



Example

```
I2C_start;
I2C_address;
I2C_write(EZO_command);
I2C_stop;

delay(300);   Processing delay

I2C_start;
I2C_address;
Char[ ] = I2C_read;
I2C_stop;
```

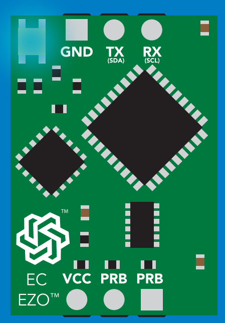
The response code will always be 254, if you do not wait for the processing delay.

Response codes

Single byte, not string

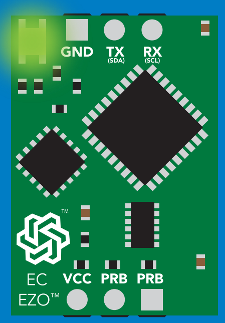
255	no data to send
254	still processing, not ready
2	syntax error
1	successful request

LED color definition



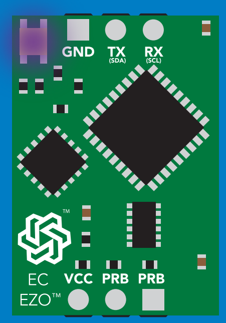
Blue

I²C standby



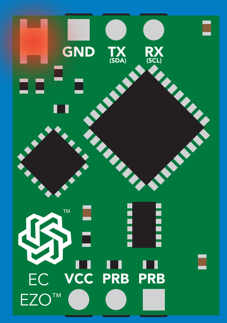
Green

Taking reading



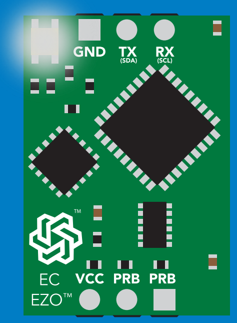
Purple

Changing I²C address



Red

Command not understood



White

Find

	LED ON
5V	**+2.5 mA**
3.3V	**+1 mA**

I^{2}C mode

command quick reference

All commands are ASCII strings or single ASCII characters.

Command	Function	
Baud	switch back to UART mode	pg. 70
Cal	performs calibration	pg. 56
Export	export calibration	pg. 58
Factory	enable factory reset	pg. 69
Find	finds device with blinking white LED	pg. 54
i	device information	pg. 64
I2C	change I^{2}C address	pg. 68
Import	import calibration	pg. 59
K	set probe type	pg. 60
L	enable/disable LED	pg. 53
Name	set/show name of device	pg. 63
O	enable/disable parameters	pg. 62
Plock	enable/disable protocol lock	pg. 67
R	returns a single reading	pg. 55
Sleep	enter sleep mode/low power	pg. 66
Status	retrieve status information	pg. 65
T	temperature compensation	pg. 61
TDS	change the TDS conversion factor	pg. 57

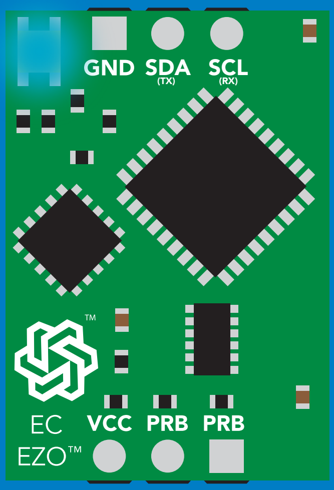
LED control

Command syntax

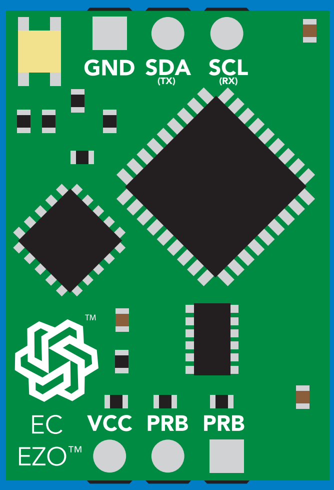
300ms ⏱ processing delay

L,1	LED on	default
L,0	LED off	
L,?	LED state on/off?	

Example	Response
L,1	⏱ Wait 300ms 1 Dec 0 Null
L,0	⏱ Wait 300ms 1 Dec 0 Null
L,?	⏱ Wait 300ms 1 Dec ?L,1 ASCII 0 Null or 1 Dec ?L,0 ASCII 0 Null



L,1



L,0

Find

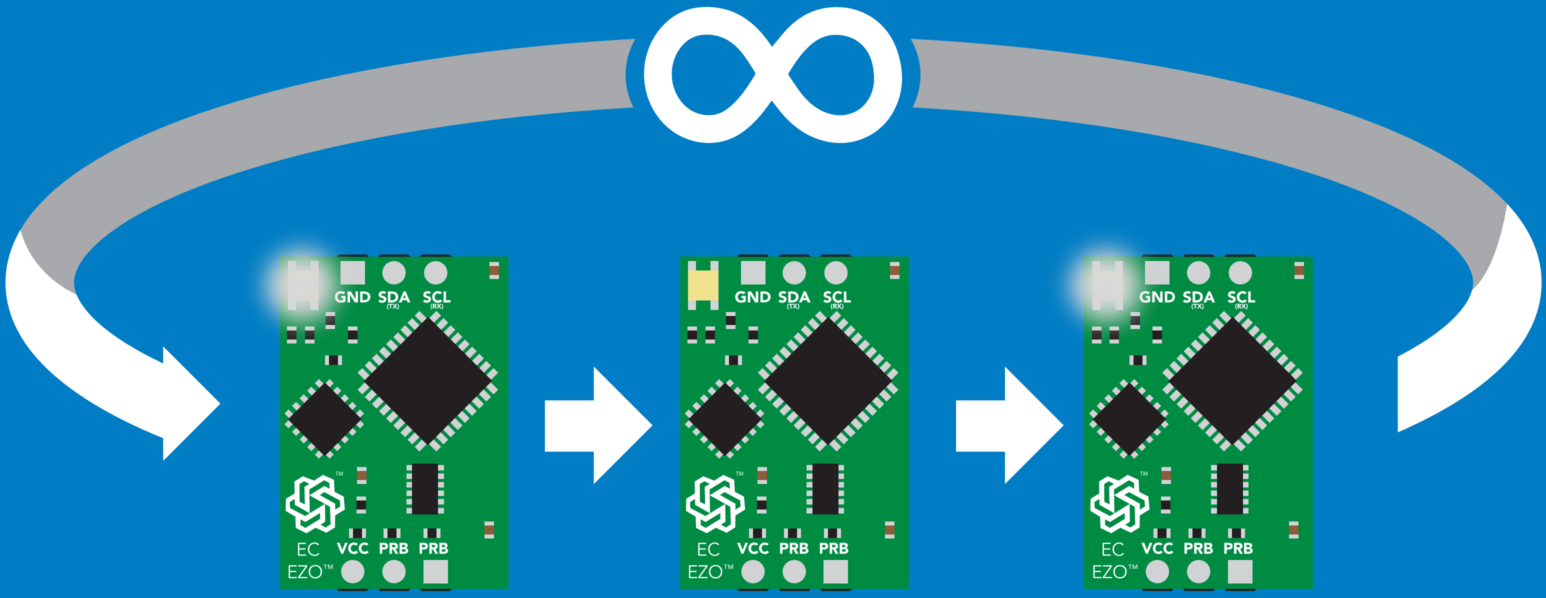
300ms ⏱ processing delay

Command syntax

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

Find	LED rapidly blinks white, used to help find device

Example	Response
Find	⏱ Wait 300ms 1 Dec 0 Null



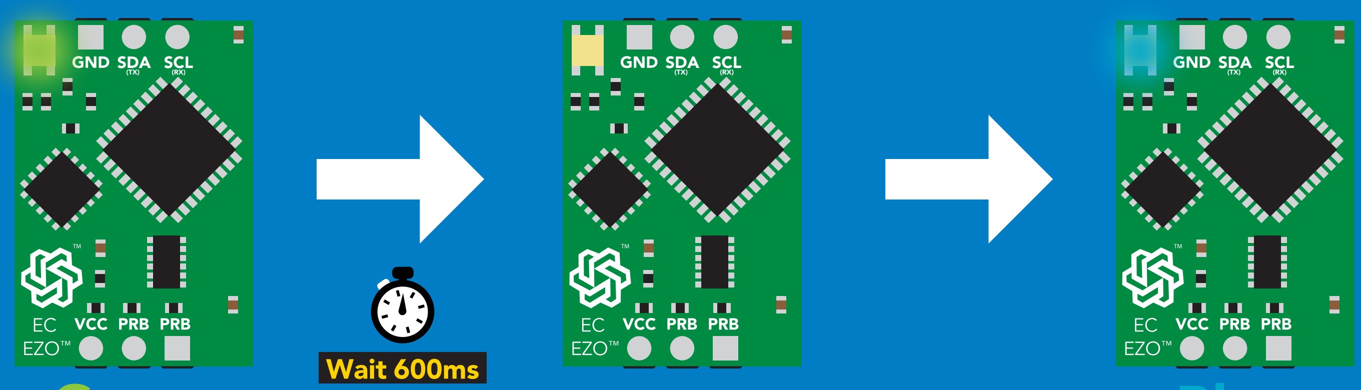
Taking reading

Command syntax

600ms ⏱ processing delay

R	return 1 reading

Example	Response
R	⏱ Wait 600ms 1 Dec 1,413 ASCII 0 Null



Green
Taking reading

Transmitting

Blue
Standby

Calibration

600ms processing delay

Command syntax

Dry calibration must always be done first!

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

Example	Response
Cal,dry	Wait 600ms 1 Dec 0 Null
Cal,84	Wait 600ms 1 Dec 0 Null
Cal,low,12880	Wait 600ms 1 Dec 0 Null
Cal,high,80000	Wait 600ms 1 Dec 0 Null
Cal,clear	Wait 300ms 1 Dec 0 Null
Cal,?	Wait 300ms 1 Dec ?CAL,0 ASCII 0 Null or 1 Dec ?CAL,1 ASCII one point 0 Null or 1 Dec ?CAL,2 ASCII two point 0 Null

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

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

Changing the TDS (ppm) conversion factor

300ms ⏱ processing delay

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

Example	Response
TDS,?	Wait 300ms 1 ?TDS,0.54 0 Dec ASCII Null
R	Wait 300ms EC TDS ↓ ↓ 1 100,54 0 Dec ASCII Null
TDS,0.46	Wait 300ms 1 0 Dec Null
R	Wait 300ms EC TDS ↓ ↓ 1 100,46 0 Dec ASCII Null

Common conversion factors

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

Formula

EC x conversion factor = TDS

AtlasScientific™
Environmental Robotics

Export calibration

300ms ⏱ processing delay

Command syntax

Export: Use this command to download calibration settings

Export,?	calibration string info
Export	export calibration string from calibrated device

Example	Response
Export,?	⏱ Wait 300ms · 1 Dec · 10,120 ASCII · 0 Null
Export	⏱ Wait 300ms · 1 Dec · 59 6F 75 20 61 72 ASCII · 0 Null (1 of 10)
Export	⏱ Wait 300ms · 1 Dec · 65 20 61 20 63 6F ASCII · 0 Null (2 of 10)
(7 more)	⋮
Export	⏱ Wait 300ms · 1 Dec · 6F 6C 20 67 75 79 ASCII · 0 Null (10 of 10)
Export	⏱ Wait 300ms · 1 Dec · *DONE ASCII · 0 Null

Response breakdown

10, 120

↑ # of strings to export ↑ # of bytes to export

Export strings can be up to 12 characters long

Import calibration

300ms processing delay

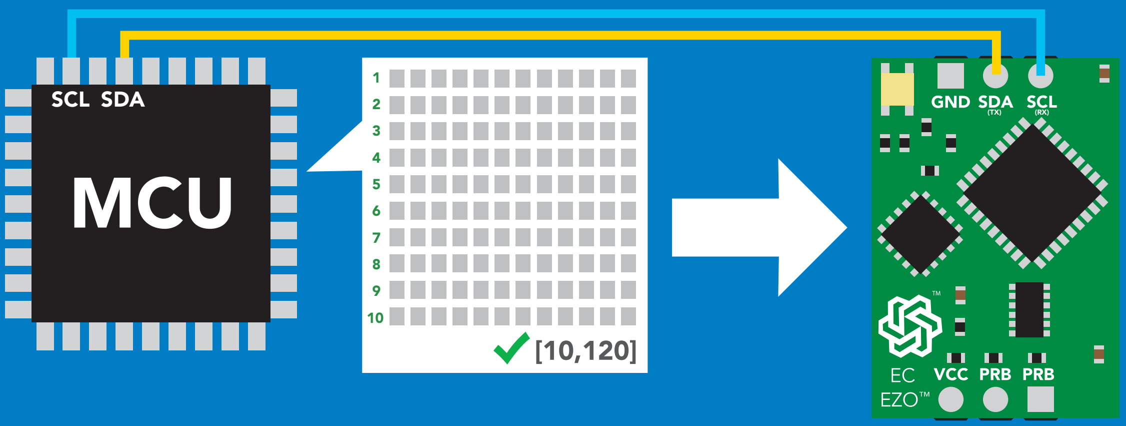
Command syntax

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

Import,n	import calibration string to new device

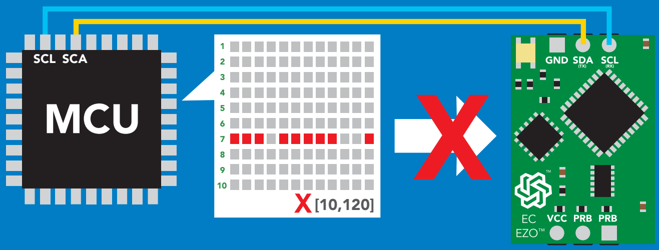
Example		Response
Import, 59 6F 75 20 61 72	(1 of 10)	Wait 300ms 1 Dec 0 Null
Import, 65 20 61 20 63 6F	(2 of 10)	Wait 300ms 1 Dec 0 Null
⋮		⋮
Import, 6F 6C 20 67 75 79	(10 of 10)	Wait 300ms 1 Dec 0 Null

Import,n



1	*Pending	0
Dec	ASCII	Null

system will reboot



reboot

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

Setting the probe type

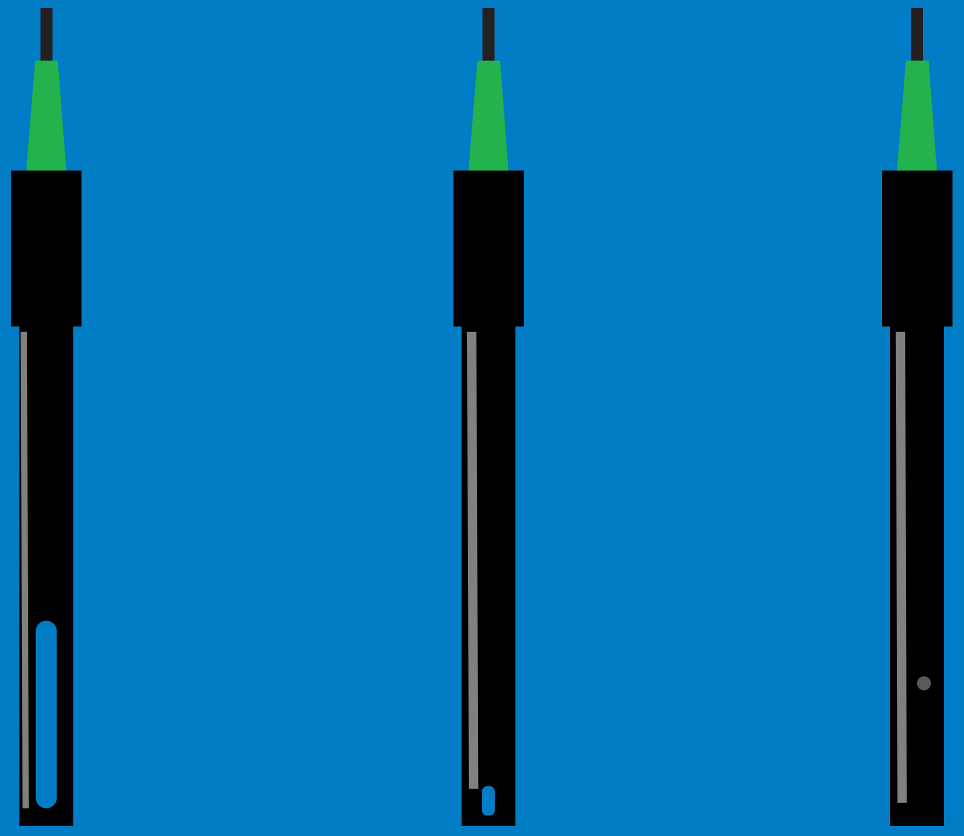
Command syntax

300ms processing delay

K,n	n = any value; floating point in ASCII
K,?	probe K value?

K 1.0 is the default value

Example	Response
K,10	Wait 300ms 1 Dec 0 Null
K,?	Wait 600ms 1 Dec K,10 ASCII 0 Null



Temperature compensation

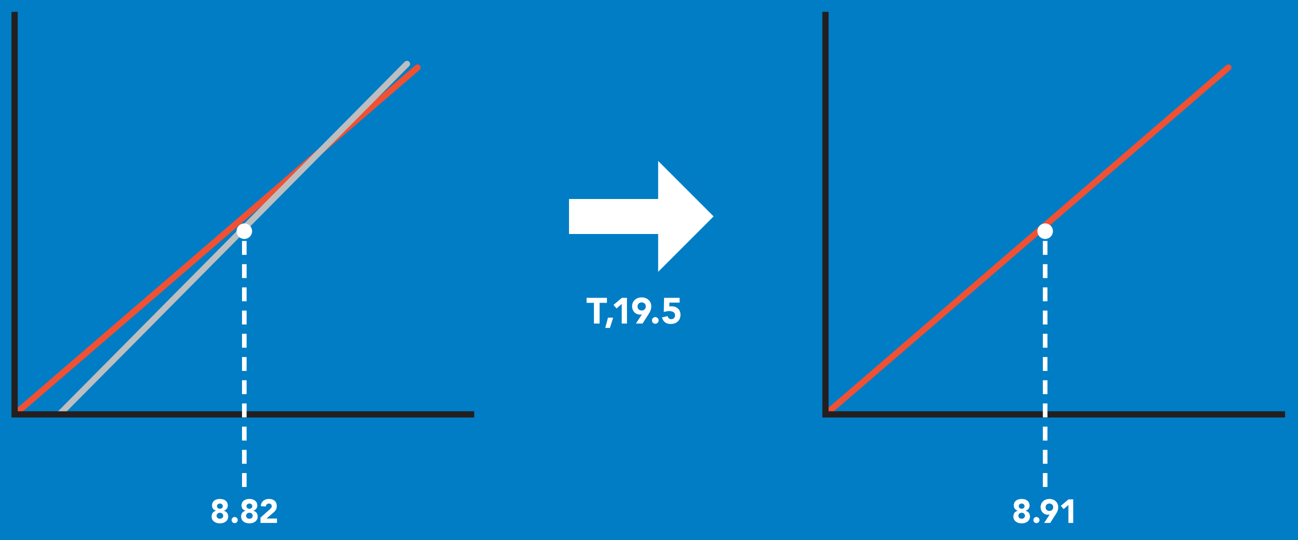
Default temperature = 25°C
Temperature is always in Celsius
Temperature is not retained if power is cut

Command syntax

T,n	n = any value; floating point or int	300ms ⏱ processing delay
T,?	compensated temperature value?	
RT,n	set temperature compensation and take a reading*	

* This is a new command for firmware V2.13

Example	Response
T,19.5	⏱ Wait 300ms · 1 Dec · 0 Null
RT,19.5	⏱ Wait 900ms · 1 Dec · 8.91 ASCII · 0 Null
T,?	⏱ Wait 300ms · 1 Dec · ?T,19.5 ASCII · 0 Null



Enable/disable parameters from output string

Command syntax

300ms processing delay

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

Example	Response			
O,EC,1 / O,EC,0	Wait 300ms	1 Dec	0 Null	enable / disable conductivity
O,TDS,1 / O,TDS,0	Wait 300ms	1 Dec	0 Null	enable / disable total dissolved solids
O,S,1 / O,S,0	Wait 300ms	1 Dec	0 Null	enable / disable salinity
O,SG,1 / O,SG,0	Wait 300ms	1 Dec	0 Null	enable / disable specific gravity
O,?	Wait 300ms	1 Dec	?,O,EC,TDS,S,SG ASCII	0 Null
				if all are enabled

Parameters

EC	conductivity
TDS	total dissolved solids
S	salinity
SG	specific gravity

Followed by 1 or 0

1	enabled
0	disabled

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

Naming device

300ms ⏱ processing delay

Command syntax

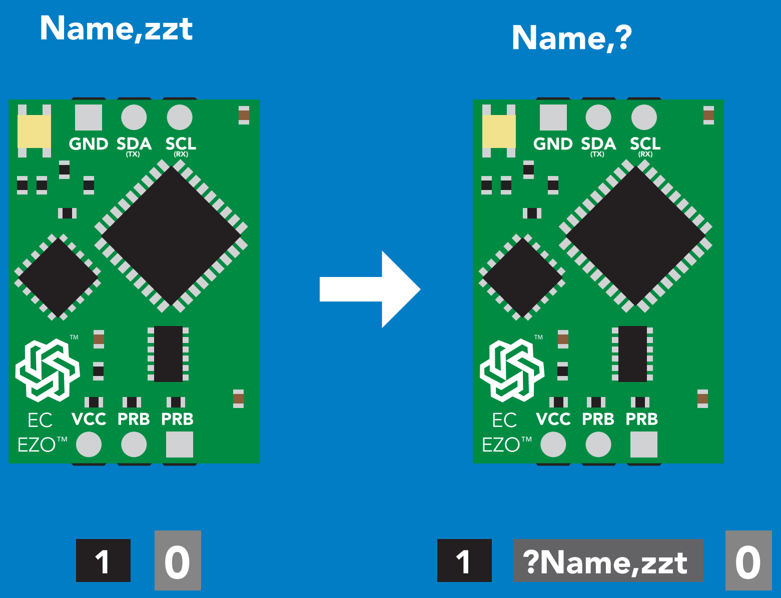
Do not use spaces in the name

Name,n	set name
Name,	clears name
Name,?	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,	⏱ Wait 300ms 1 Dec 0 Null name has been cleared
Name,zzt	⏱ Wait 300ms 1 Dec 0 Null
Name,?	⏱ Wait 300ms 1 Dec ?Name,zzt ASCII 0 Null


Name,zzt

Name,?

1 0

1 ?Name,zzt 0

Device information

Command syntax

300ms ⏱ processing delay

i device information

Example

i

Response

⏱ Wait 300ms

1	?i,EC, 2.10	0
Dec	ASCII	Null

Response breakdown

?i, EC, 2.10

EC, ↑ Device

2.10 ↑ Firmware

Reading device status

Command syntax

300ms ⏱ processing delay

Status	voltage at Vcc pin and reason for last restart

Example	Response
Status	⏱ Wait 300ms 1 Dec ?Status,P,5.038 ASCII 0 Null

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

Sleep mode/low power

Command syntax

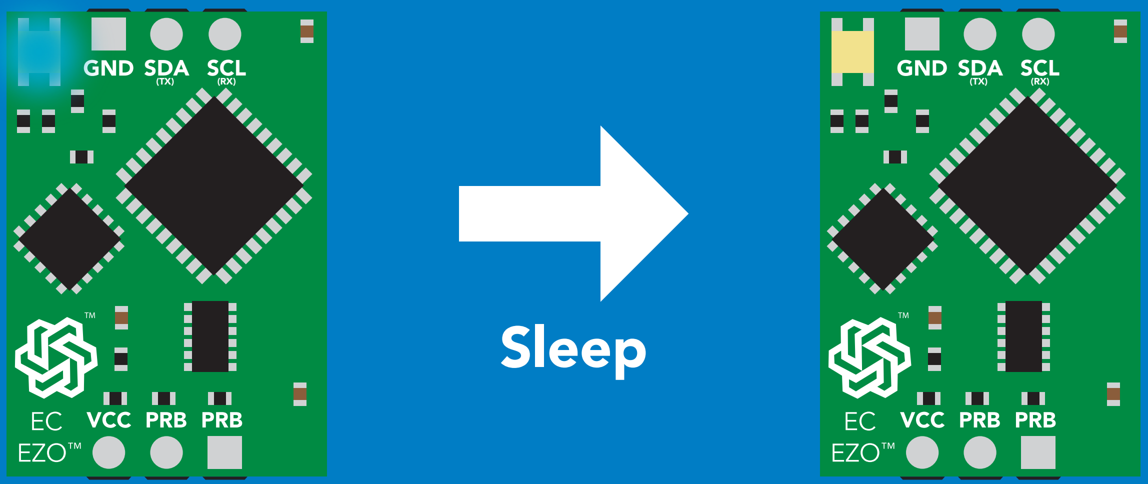
Sleep enter sleep mode/low power

Send any character or command to awaken device.

Example	Response
Sleep	no response
Any command	wakes up device

Do not read status byte after issuing sleep command.

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



Standby

Sleep

Protocol lock

Command syntax

300ms ⏱ processing delay

Plock,1 enable Plock

Plock,0 disable Plock **default**

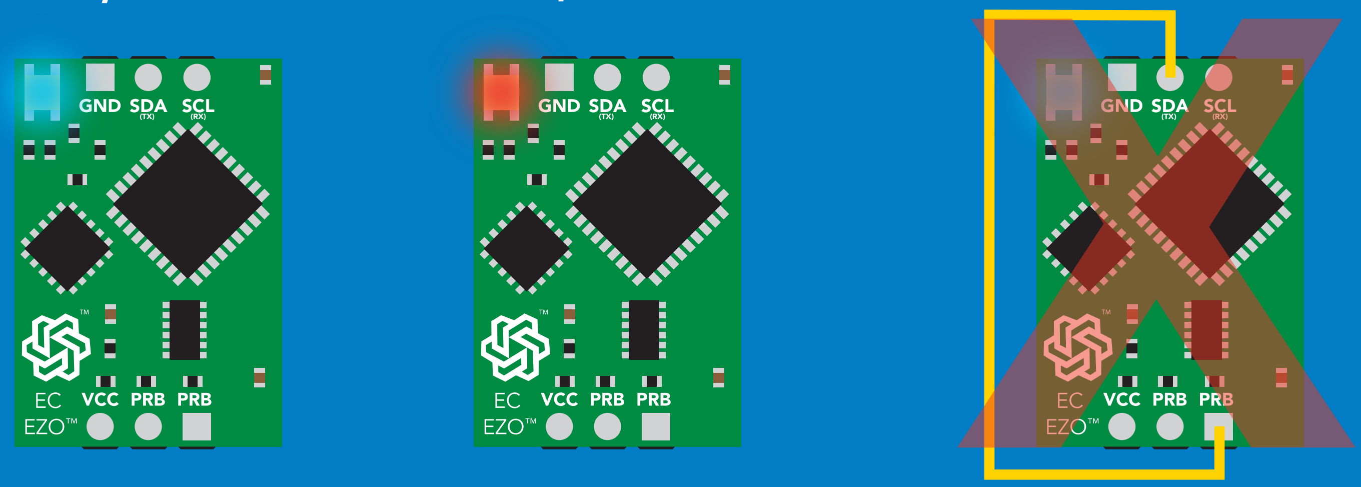
Plock,? Plock on/off?

Locks device to I²C mode.

Example	Response
Plock,1	⏱ Wait 300ms · 1 Dec · 0 Null
Plock,0	⏱ Wait 300ms · 1 Dec · 0 Null
Plock,?	⏱ Wait 300ms · 1 Dec · ?Plock,1 ASCII · 0 Null

Plock,1

Baud, 9600



cannot change to UART

cannot change to UART

I²C address change

Command syntax

300ms processing delay

I2C,n sets I²C address and reboots into I²C mode

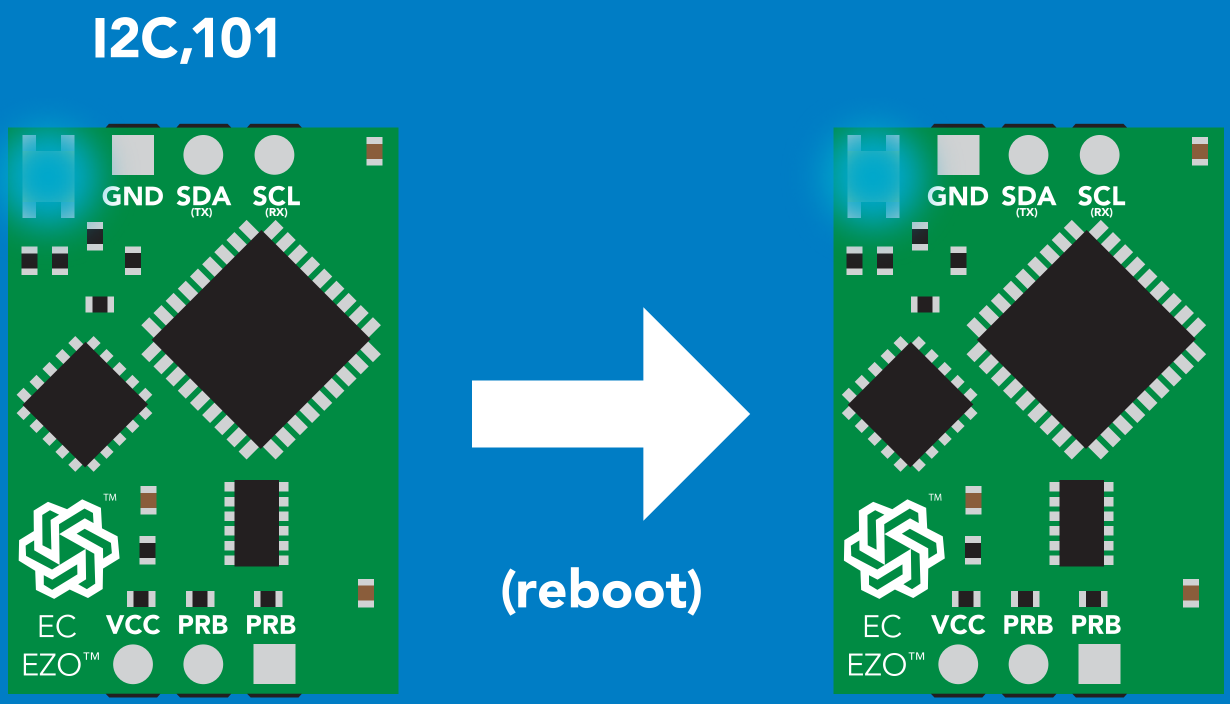
Example	Response
I2C,101	device reboot (no response given)

n = any number 1 – 127

Warning!

Changing the I²C address will prevent communication between the circuit and the CPU until your CPU is updated with the new I²C address.

Default I²C address is 100 (0x64).



Factory reset

Command syntax

Factory reset will not take the device out of I²C mode.

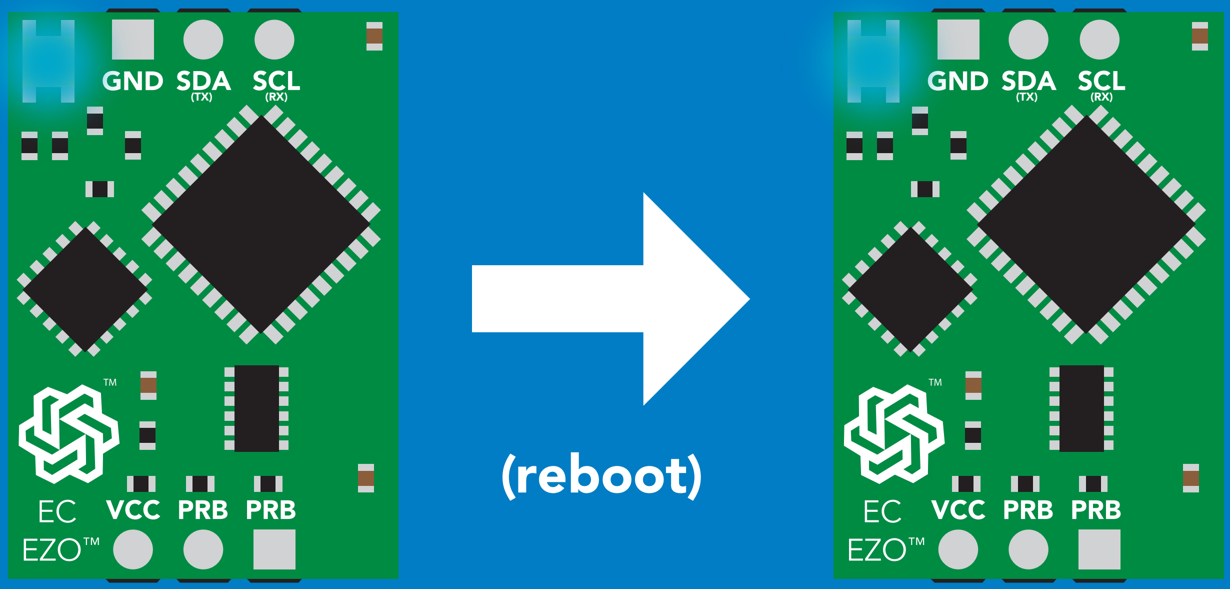
I²C address will not change

Factory	**enable factory reset**

Example	Response
Factory	**device reboot** **(no response given)**

Clears calibration
LED on
Response codes enabled

Factory



Change to UART mode

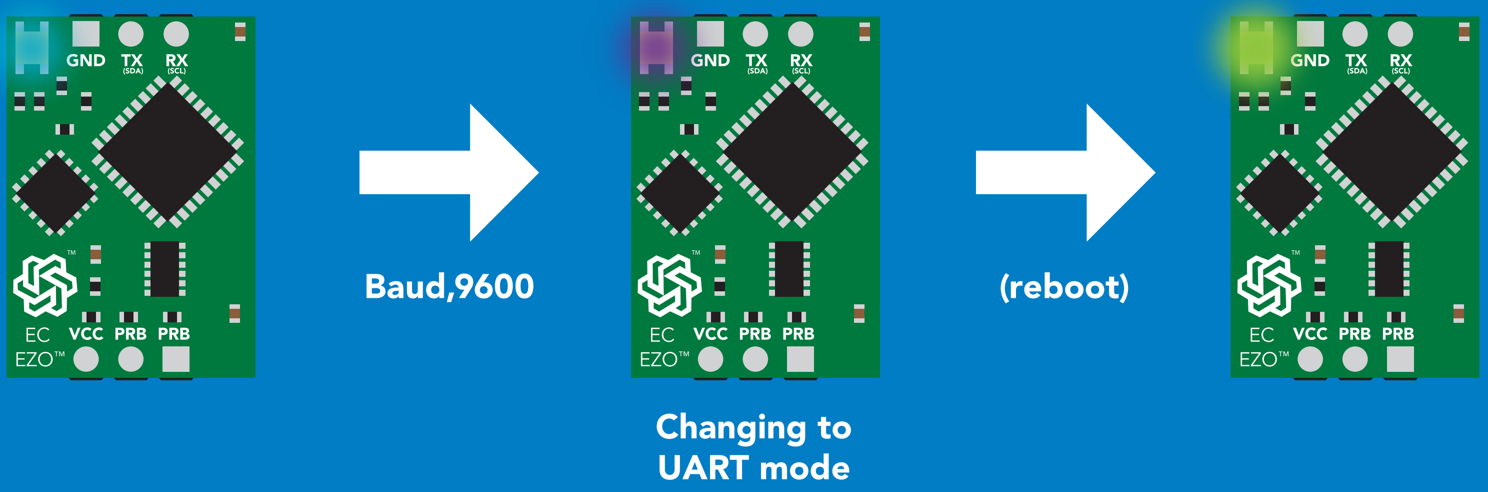
Command syntax

Baud,n	**switch from I^2C to UART**

Example	Response
Baud,9600	**reboot in UART mode** (no response given)

n =

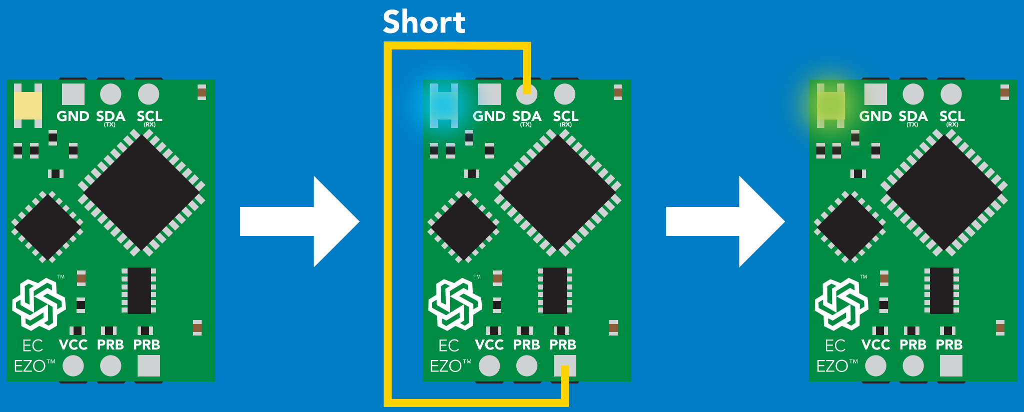
- 300
- 1200
- 2400
- 9600
- 19200
- 38400
- 57600
- 115200



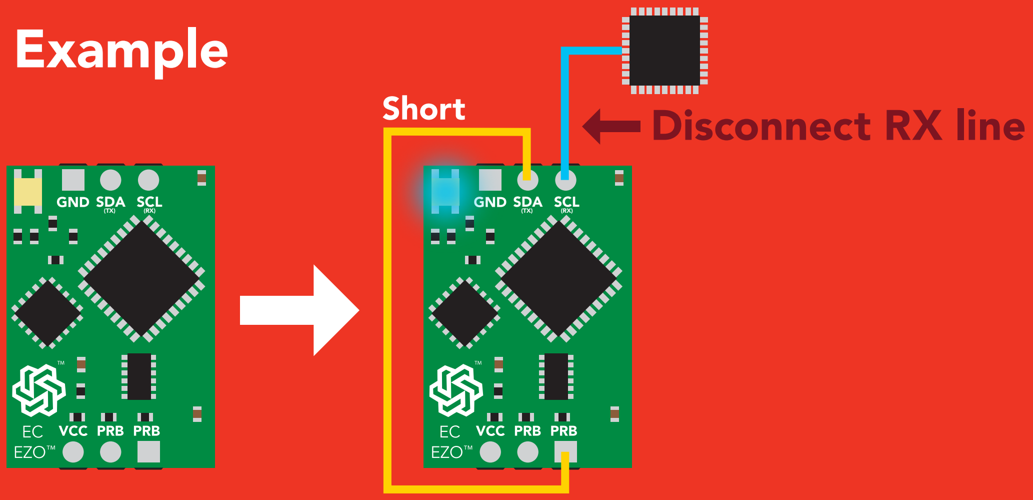
Manual switching to UART

- **Disconnect ground (power off)**
- **Disconnect TX and RX**
- **Connect TX to the right PRB**
- **Confirm RX is disconnected**
- **Connect ground (power on)**
- **Wait for LED to change from Blue to Green**
- **Disconnect ground (power off)**
- **Reconnect all data and power**

Example

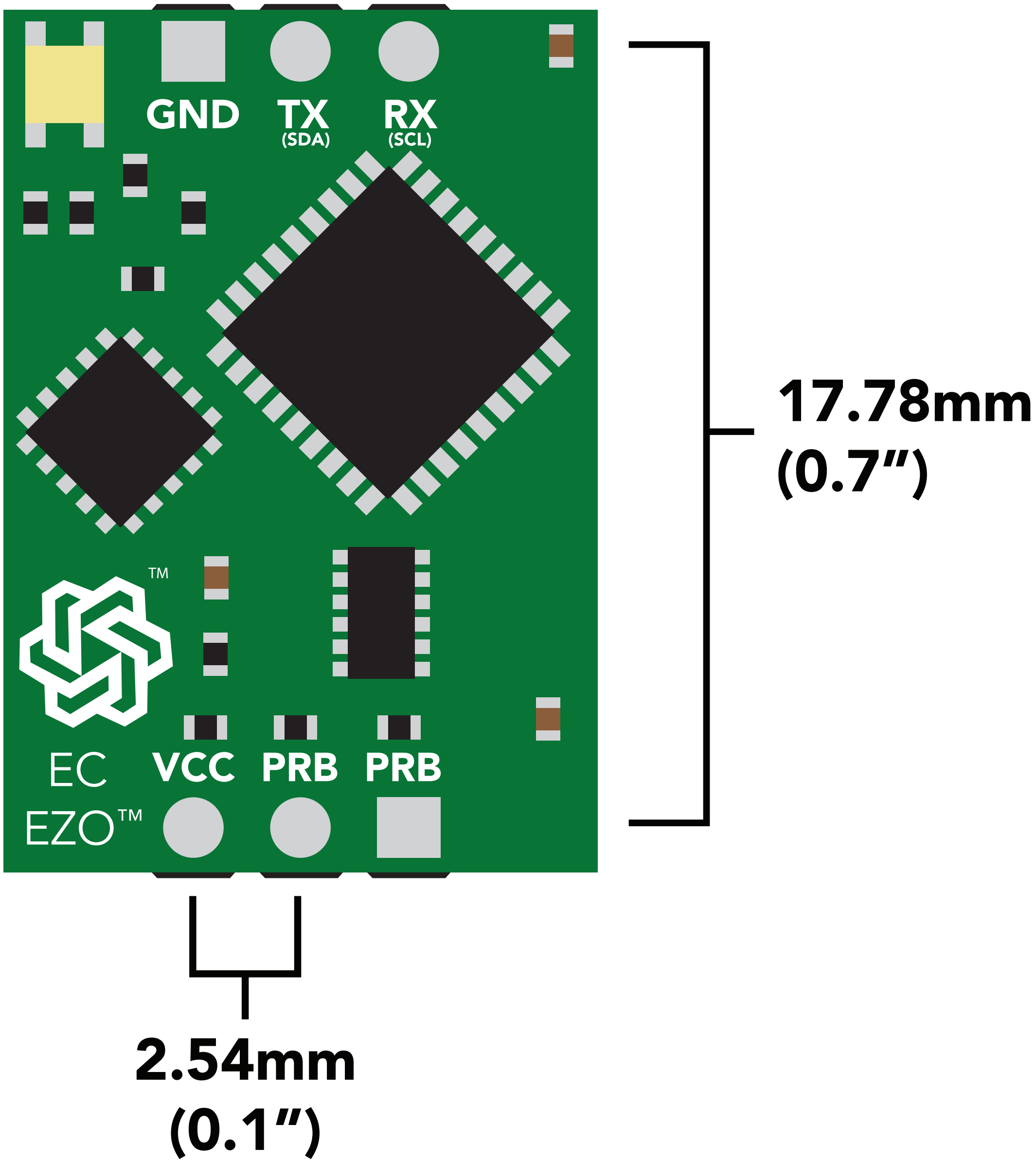


Wrong Example



Disconnect RX line

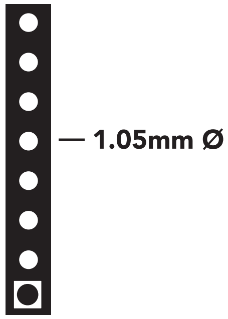
EZO™ circuit footprint

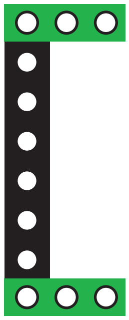


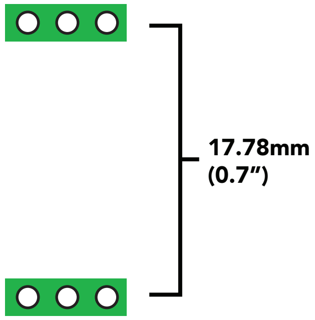
1 In your CAD software, place a 8 position header.

2 Place a 3 position header at both top and bottom of the 8 position.

3 Delete the 8 position header. The two 3 position headers are now 17.78mm (0.7″) apart from each other.







Datasheet change log

Datasheet V 6.3

Revised naming device info on pages 36 & 63.

Datasheet V 6.2

Added new command:
"TDS,n" Changing the TDS (ppm) conversion factor on pages 30 (UART) & 57 (I^2C).

Datasheet V 6.1

Corrected typos within the datasheet.

Datasheet V 6.0

Changed the K value range from 0.1 to 0.01 on pg 5.

Datasheet V 5.9

Moved Default state to pg 17.

Datasheet V 5.8

Revised conductivity probe range information on pg 5.

Datasheet V 5.7

Revised response for the sleep command in UART mode on pg 39.

Datasheet V 5.6

Added more information on the Export calibration and Import calibration commands.

Datasheet V 5.5

Revised calibration theory pages, added information on temperature compensation on pg. 15, moved data isolation to pg 9, and correct wiring to pg 11.

Datasheet V 5.4

Revised isolation schematic on pg. 13

Datasheet V 5.3

Added new command:
"RT,n" for Temperature compensation located on pages 30 (UART) & 55 (I^2C).
Added firmware information to Firmware update list.

Datasheet V 5.2

Revised calibration information on pages 27 & 52.

Datasheet V 5.1

Added more information about temperature compensation on pages 30 & 55.

Datasheet V 5.0

Changed "Max rate" to "Response time" on cover page.

Datasheet V 4.9

Removed note from certain commands about firmware version.
Added steps to calibration command pages 27 (UART) and 52 (I^2C).

Datasheet V 4.8

Revised definition of response codes on pg 46.

Datasheet V 4.7

Revised cover page art.

Datasheet V 4.6

Updated calibration processing delay time on pg.52.

Datasheet V 4.5

Revised Enable/disable parameters information on pages 31 & 56.

Datasheet V 4.4

Updated High point calibration info on page 11.

Datasheet V 4.3

Updated calibration info on pages 27 (UART) and 52 (I^2C).

Datasheet V 4.2

Revised Plock pages to show default value.

Datasheet V 4.1

Corrected I²C calibration delay on pg. 52.

Datasheet V 4.0

Revised entire datasheet.

Firmware updates

V1.0 – Initial release (April 17, 2014)

V1.1 – (June 2, 2014)
- Change specific gravity equation to return 1.0 when the uS reading is < 1000 (previously returned 0.0)
- Change accuracy of specific gravity from 2 decimal places to 3 decimal places
- Don't save temperature changes to EEPROM

V1.2 – (Aug 1, 2014)
- Baud rate change is now a long, purple blink

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

V1.6 – I2C bug (Dec 1, 2014)
- Fixed I^2C bug where the circuit may inappropriately respond when other I2C devices are connected

V1.8 – Factory (April 14, 2015)
- Changed "X" command to "Factory"

V1.95 – Plock (March 31, 2016)
- Added protocol lock feature "Plock"

V1.96 – EEPROM (April 26, 2016)
- Fixed bug where EEPROM would get erased if the circuit lost power 900ms into startup
  This would cause the EZO circuit to revert back to UART mode if set to I2C

V2.10 – (April 12, 2017)
- Added "Find" command.
- Added "Export/import" command.
- Modified continuous mode to be able to send readings every "n" seconds.
- Default output changed from CSV string of 4 values to just conductivity; Other values must be enabled

V2.11 – (April 28, 2017)
- Fixed "Sleep"bug, where it would draw excessive current.

V2.12 – (May 9, 2017)
- Fixed bug in sleep mode, where circuit would wake up to a different I^2C address.

V2.13 – (July 16, 2018)
- Added "RT" command to Temperature compensation

V2.14 – (Nov 26, 2019)
- The K value range has been extended to 0.01

V2.15 – (June 29, 2020)
- Fixed bug where output doesnt always round to 0

Firmware updates

V2.16 – (Dec 14, 2021)

- Internal update for new part compatibility.

Warranty

Atlas Scientific™ Warranties the EZO™ class Conductivity circuit to be free of defect during the debugging phase of device implementation, or 30 days after receiving the EZO™class Conductivity circuit (which ever comes first).

The debugging phase

The debugging phase as defined by Atlas Scientific™ is the time period when the EZO™ class Conductivity circuit is inserted into a bread board, or shield. If the EZO™ class Conductivity circuit is being debugged in a bread board, the bread board must be devoid of other components. If the EZO™ class Conductivity circuit is being connected to a microcontroller, the microcontroller must be running code that has been designed to drive the EZO™ class Conductivity circuit exclusively and output the EZO™ class Conductivity circuit data as a serial string.

It is important for the embedded systems engineer to keep in mind that the following activities will void the EZO™ class Conductivity circuit warranty:

- **Soldering any part of the EZO™ class Conductivity circuit.**
- **Running any code, that does not exclusively drive the EZO™ class Conductivity circuit and output its data in a serial string.**
- **Embedding the EZO™ class Conductivity circuit into a custom made device.**
- **Removing any potting compound.**

Reasoning behind this warranty

Because Atlas Scientific™ does not sell consumer electronics; once the device has been embedded into a custom made system, Atlas Scientific™ cannot possibly warranty the EZO™ class Conductivity circuit, against the thousands of possible variables that may cause the EZO™ class Conductivity circuit to no longer function properly.

Please keep this in mind:

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

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

3. **All Atlas Scientific™ devices can be soldered into place, however you do so at your own risk.**

Atlas Scientific™ is simply stating that once the device is being used in your application, Atlas Scientific™ can no longer take responsibility for the EZO™ class Conductivity circuits continued operation. This is because that would be equivalent to Atlas Scientific™ taking responsibility over the correct operation of your entire device.