AtlasScientific™
Environmental Robotics

V 6.5

Revised 5/24

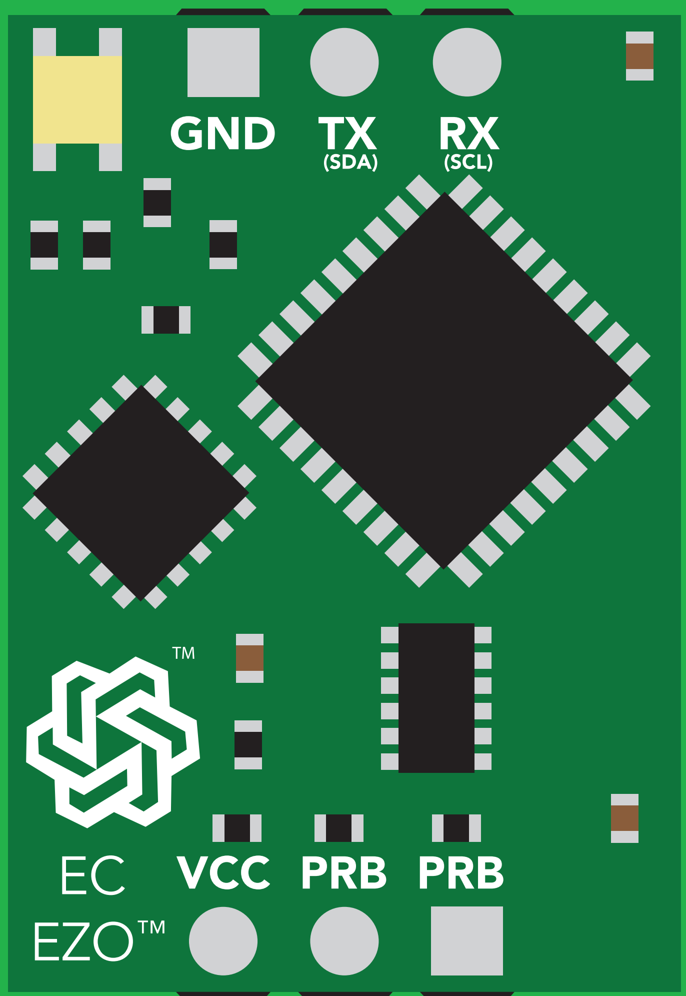
EZO-EC™

Embedded Conductivity Circuit

ISO 7888 Compliant

(determination of electrical conductivity)

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%**
EC reading time	**600ms**
Supported probes	**K 0.01 – K 10.2 any brand**
Calibration	**2 or 3 point**
Temp compensation	**Yes**
Data protocol	**UART & I²C**
Default I²C address	**100 (0x64)**
Operating voltage	**3.3V – 5V**
Data format	**ASCII**

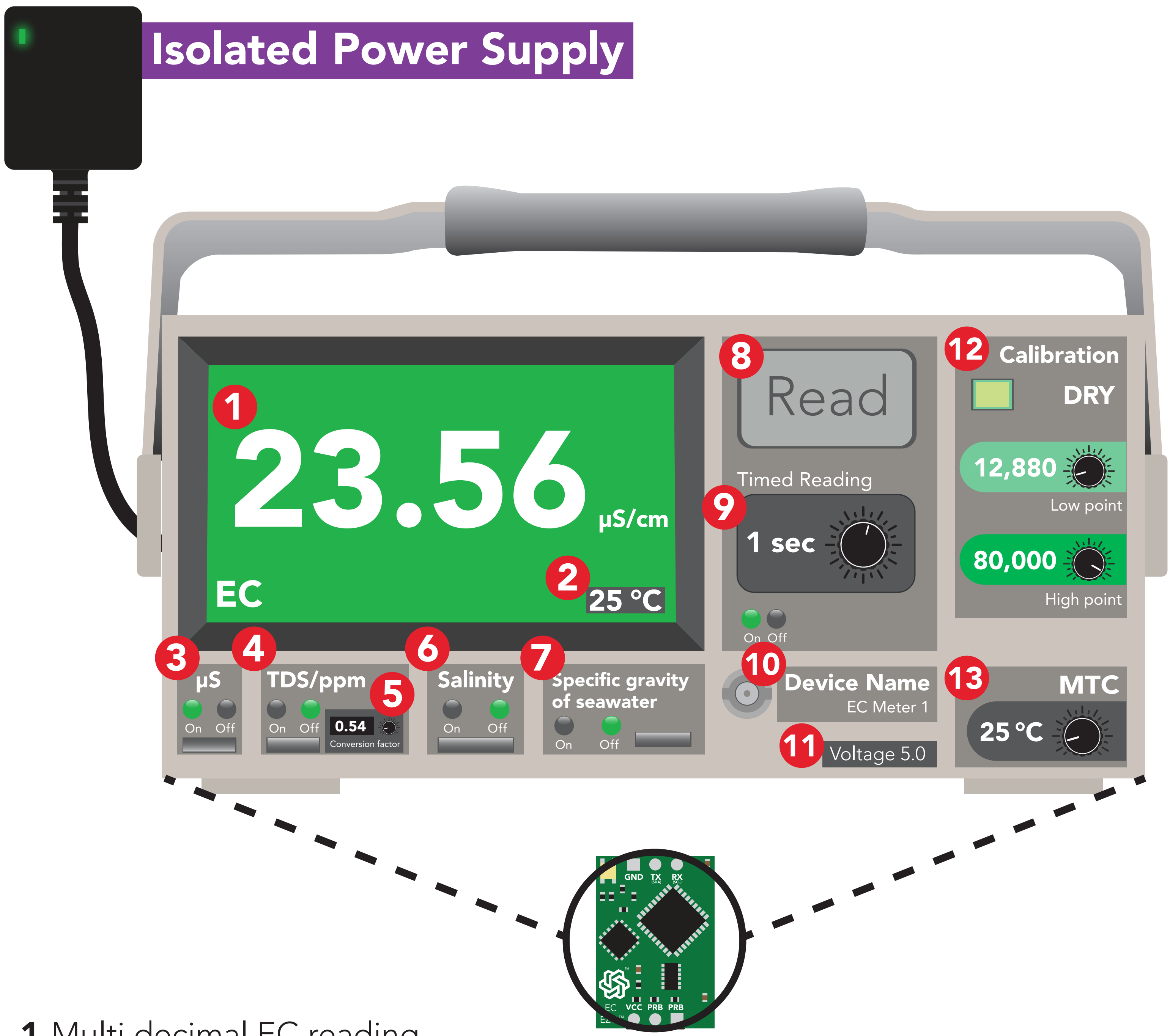


PATENT PROTECTED

Written by Jordan Press
Designed by Noah Press

This is an evolving document, check back for updates.

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



1 Multi decimal EC reading

2 Temperature used for reading

3 Enable EC readings

4 Enable TDS/ ppm readings

5 Variable TDS conversion factor

6 Enable salinity readings

7 Enable specific gravity readings

8 Immediate reading

9 Timed readings

10 Set device name

11 Voltage usage

12 Multi-point variable calibration

13 Temperature compensation

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

Conductivity probe range

The EZO™ Conductivity circuit is compatible with any brand of two-conductor conductivity probe, ranging from:

K 0.01 → K 10.2

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

K 0.1	K 1.0	K 10
accurate reading range	**accurate reading range**	**accurate reading range**
0.07μS/cm – 50,000μS/cm	**5μS/cm – 200,000+μS/cm**	**10μS/cm – 1S/cm**
TDS *(ppm)* 0 – 25,000	TDS *(ppm)* 2 – 100,000	TDS *(ppm)* 5 – 500,000
Salinity *(ppt)* 0 – 33	Salinity *(ppt)* 0 – 42*	Salinity *(ppt)* 0 – 42*
	***salinity scale cannot go any higher**	***salinity scale cannot go any higher**

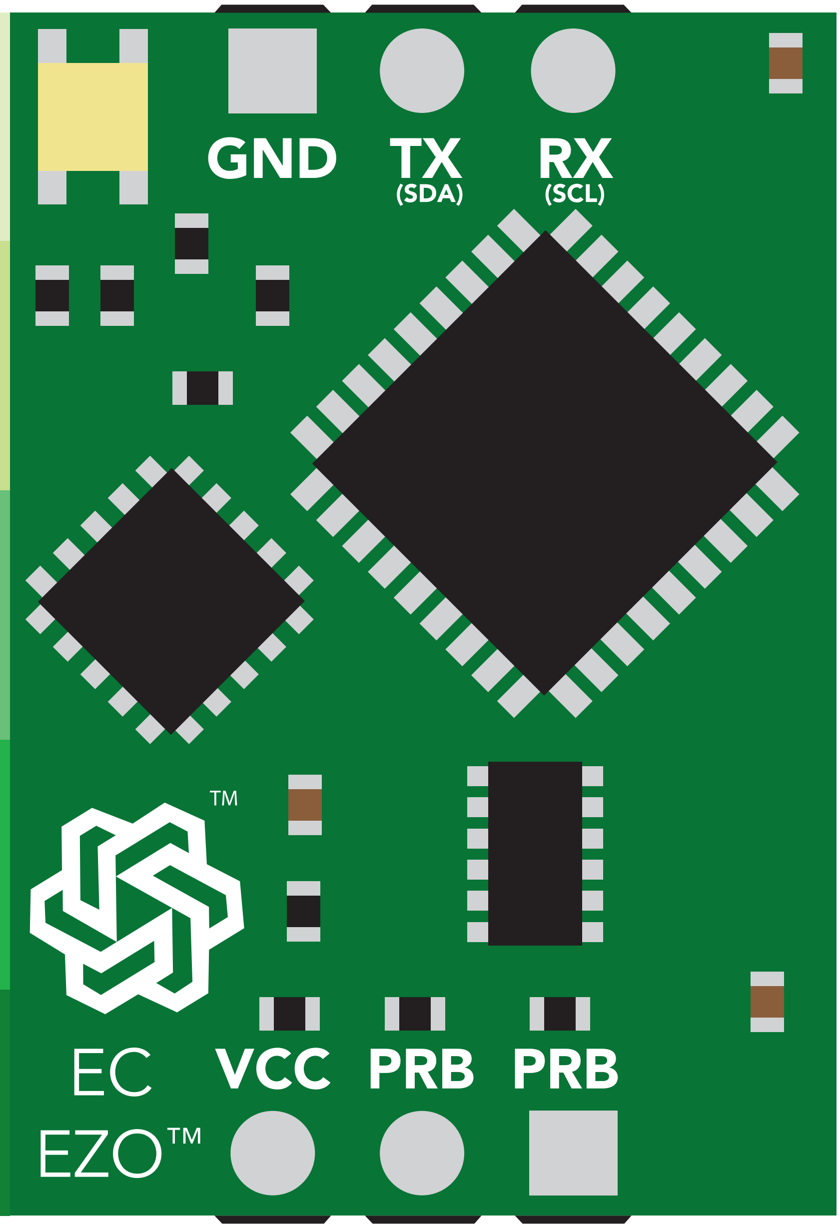
Atlas Scientific™ does not know what the accurate reading range would be for conductivity probes, other than the above mentioned values. Determining the accurate reading range of such probes, i.e. **K 2.6**, or **K 0.66**, is the responsibility of the embedded systems engineer.

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**



Available data protocols

UART

Default

I^2C

Unavailable data protocols

SPI

Analog

RS-485

Mod Bus

4–20mA

STOP

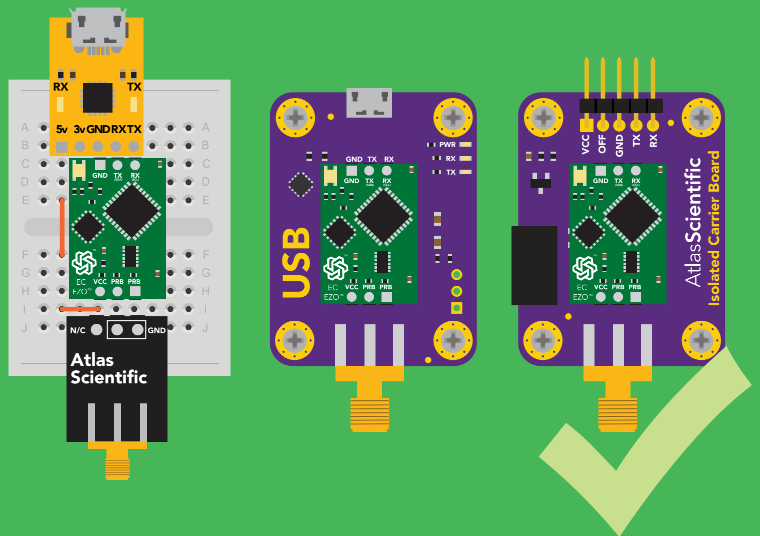
SOLDERING THIS DEVICE VOIDS YOUR WARRANTY.

Are there specific soldering instructions? **Yes, see page 73.**

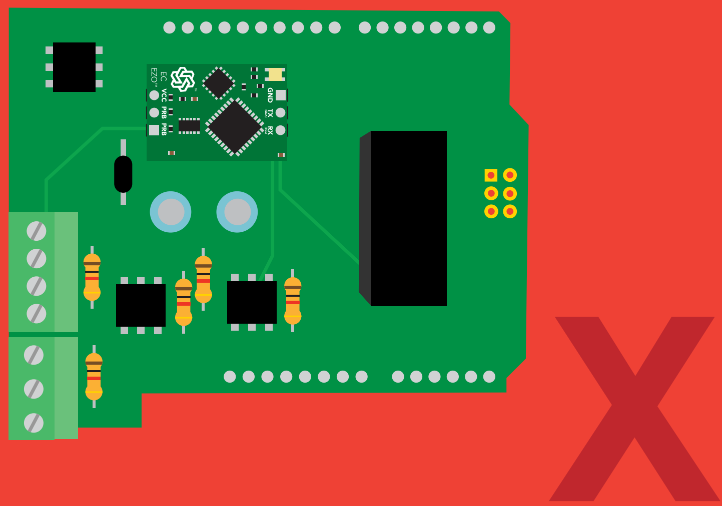
Can you make a warranty claim after soldering? **No.**

If you have not used this product before; Observe how a properly working sensor behaves *BEFORE* embedding it into your PCB.

Get this device working using one of these methods first.



Do not embed before you have experience with this sensor.



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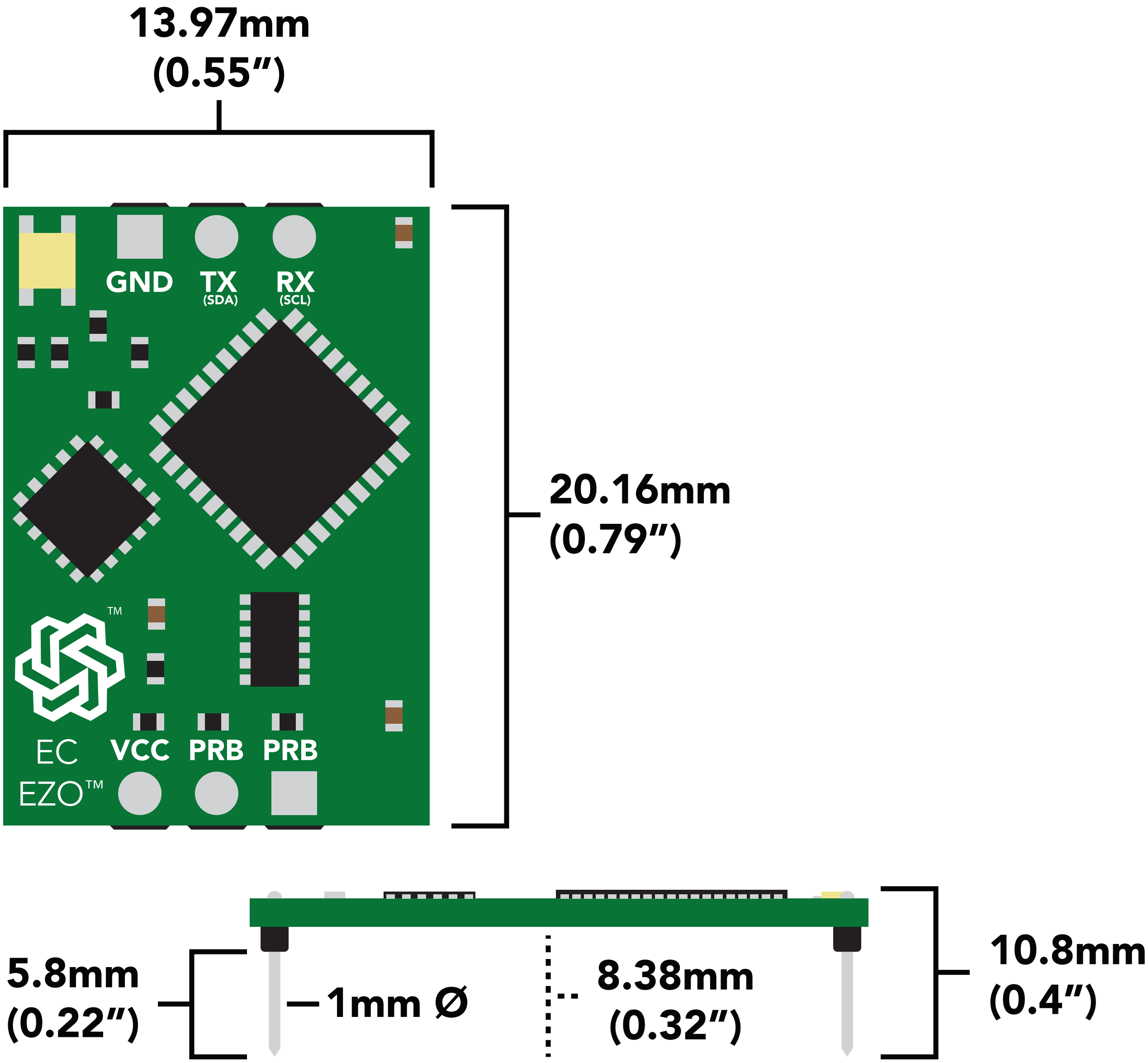
UART

I²C

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	

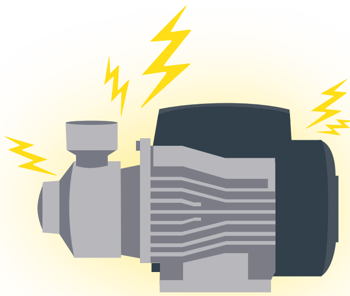
Absolute max ratings

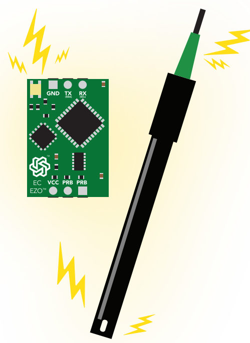
Parameter	MIN	TYP	MAX
Storage temperature (EZO™ Conductivity)	-60 °C		150 °C
Operational temperature (EZO™ Conductivity)	-40 °C	25 °C	125 °C
VCC	3.3V	5V	5.5V

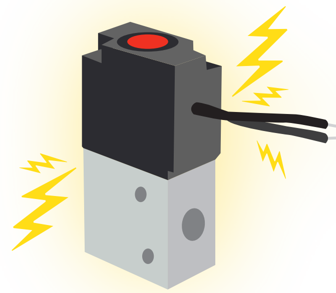
Electrical isolation

Conductivity readings will introduce significant electrical interference into your water. This electrical interference will affect other sensors, such as pH, ORP, and dissolved oxygen. Electrical isolation is 100% effective in preventing this electrical interference.

Unlike other probes, a conductivity probe provides a low-resistance pathway from your water to your electronics. If an accidental electrical surge passes through your water, it will travel up your conductivity probe and into your electronics. Electrical isolation is 100% effective at stopping an accidental electrical surge from destroying your computer system.



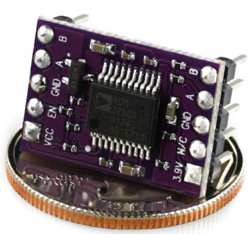




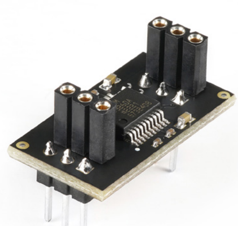
Advice:

When reading conductivity along with other sensors, electrical isolation is strongly recommended.
Never build a commercial product without electrical isolation.

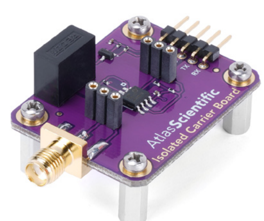
Atlas Scientific offers several different electrical isolation products that can be used in your design. Select the electrical isolation product that works best for your design.



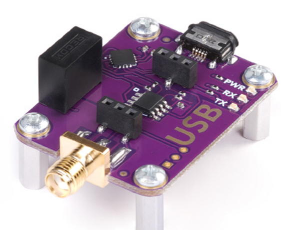
Basic EZO™
Inline Voltage Isolator



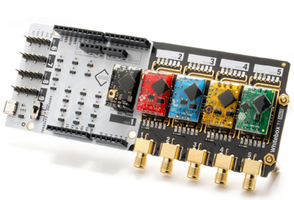
Vertical Isolator



Electrically Isolated
EZO™ Carrier Board

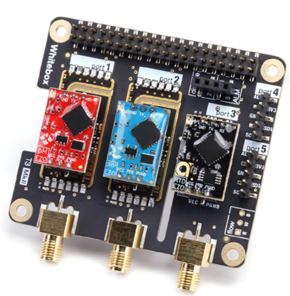


Gen 2 Electrically Isolated
USB EZO™ Carrier Board



Whitebox T1

Whitebox T3



Whitebox T3

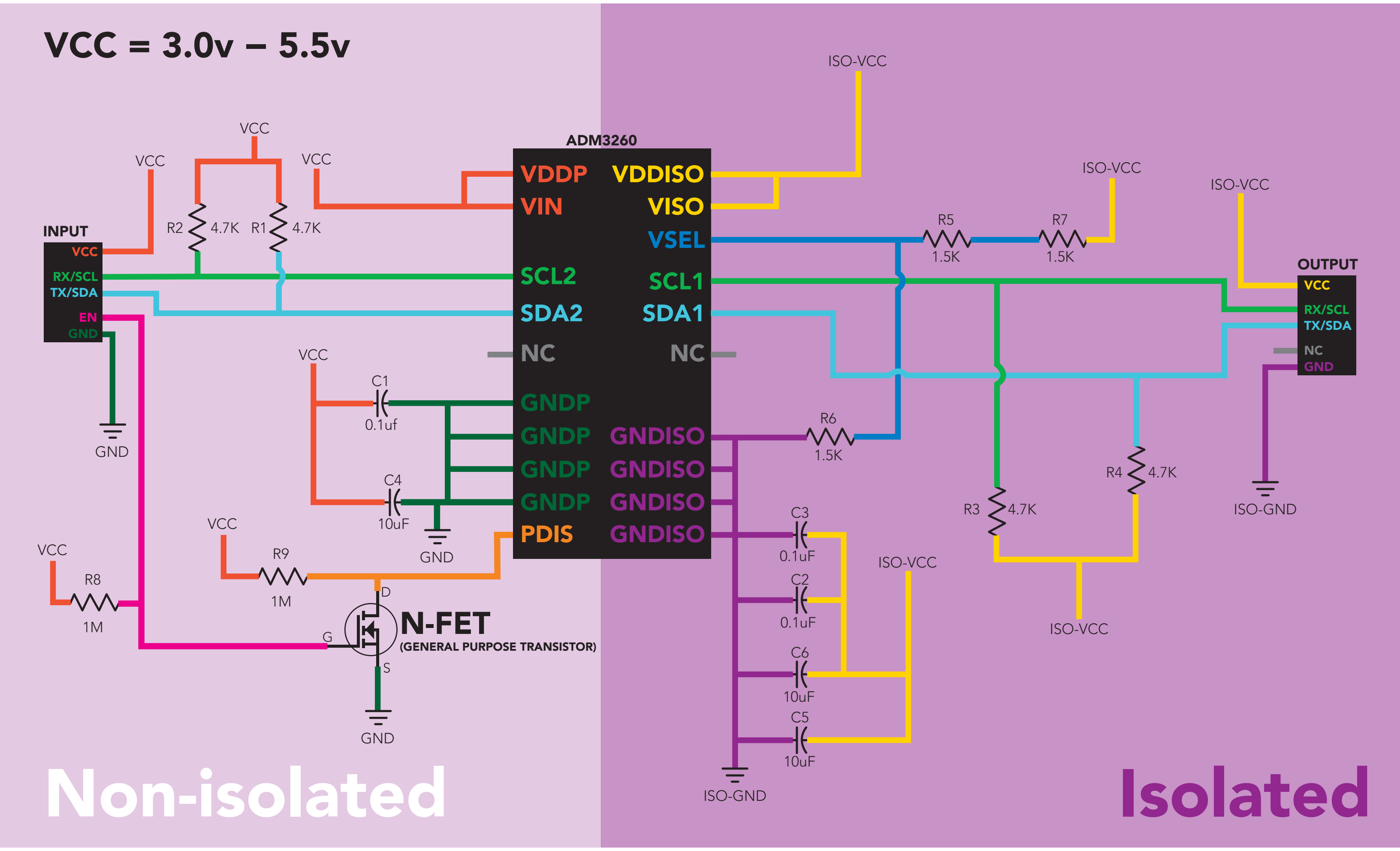
Electrically Isolated EZO™
Carrier Board (old style)

For various reasons, you may need to build your own electrical isolator. Because electrical isolation is so important, we have published our isolation schematic for anyone to use.

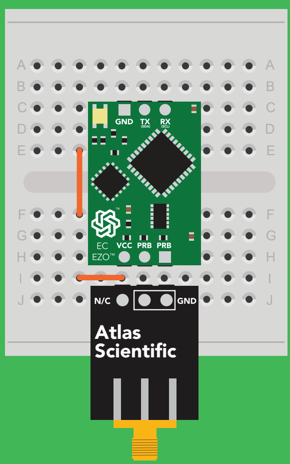
This isolation schematic is based on the ADM3260, which can output up to 150 mW of isolated power. PCB layout requires special attention for EMI/EMC and RF Control. Having good ground planes and keeping the capacitors as close to the chip as possible are crucial for proper performance.

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.

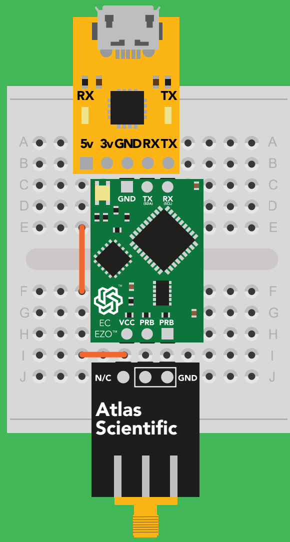
Isolated ground is different from non-isolated ground, these two lines should not be connected together.



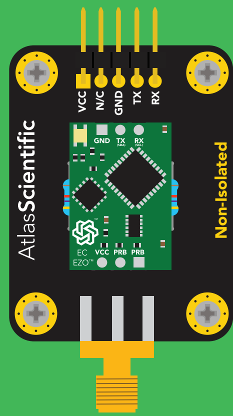
✓ Correct wiring



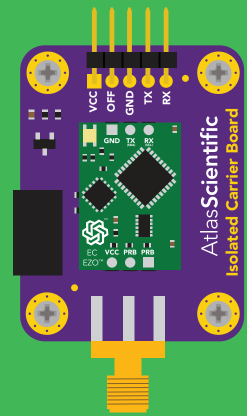
Bread board



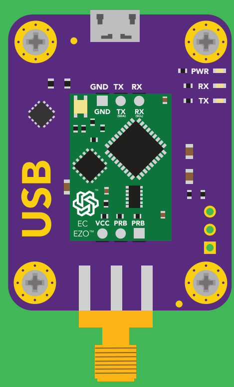
Bread board via USB



Non-Isolated EZO™ Carrier Board



Electrically Isolated EZO™ Carrier Board

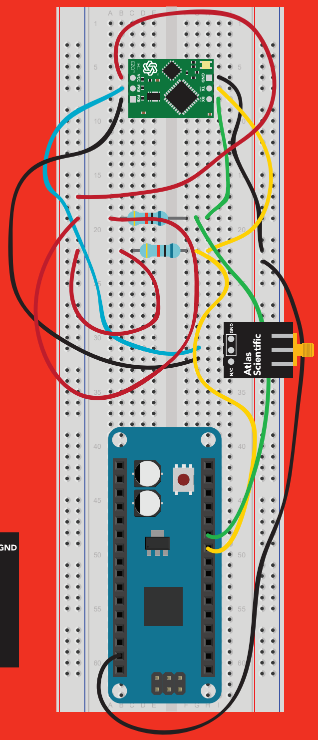


USB carrier board

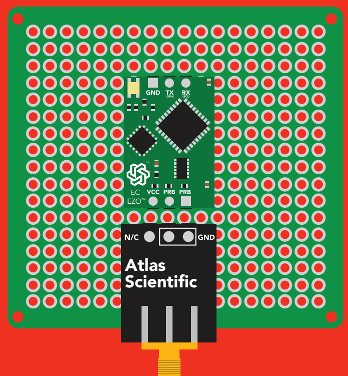
X Incorrect wiring

Extended leads

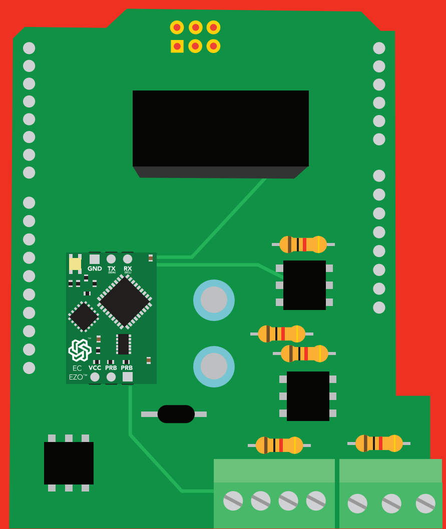
Sloppy setup



Perfboards or Protoboards



*Embedded into your device



NEVER
use Perfboards or Protoboards
Flux residue and shorting wires make it very hard to get accurate readings.

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

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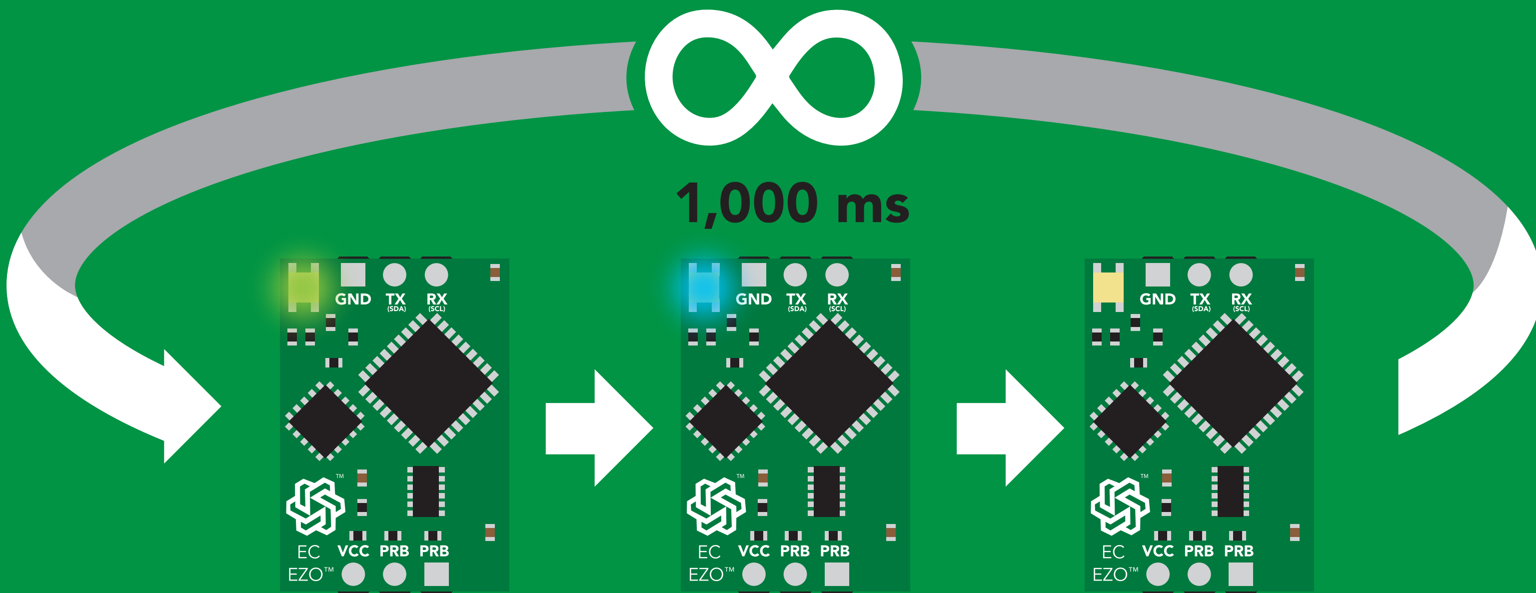
Default state
UART mode

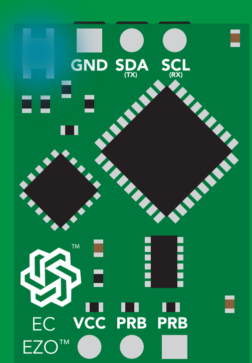
Baud	9,600
Readings	continuous
Units	μS/cm
Speed	1 reading per second
LED	on



Green
Standby

Cyan
Taking reading

Transmitting



Solid Blue LED
in I²C mode
Not UART ready

AtlasScientific
Environmental Robotics

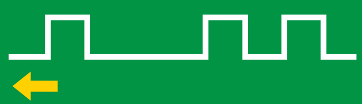
UART mode

8 data bits	no parity
1 stop bit	no flow control

Baud

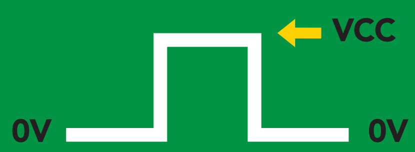
300
1,200
2,400
9,600 default
19,200
38,400
57,600
115,200

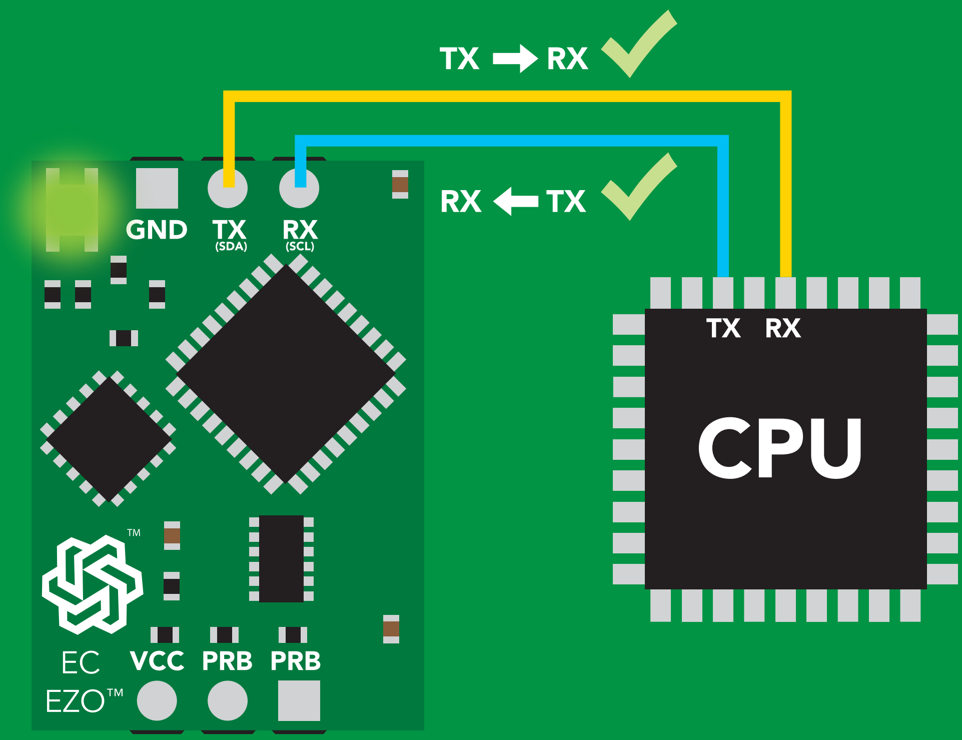
RX
Data in



TX
Data out

Vcc 3.3V – 5.5V





Data format

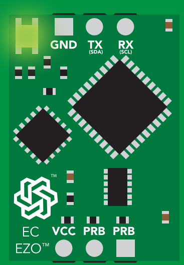
Reading

Conductivity = Deafult

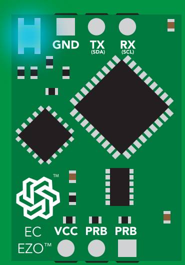
Total dissolved solids
Salinity
Specific gravity
} = Must be enabled

Order	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

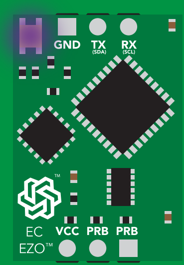
LED color definition



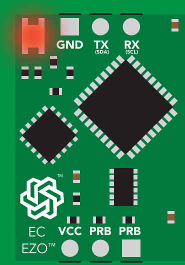
Green
UART standby



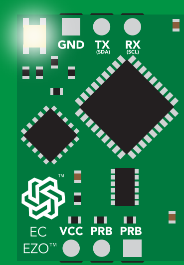
Cyan
Taking reading



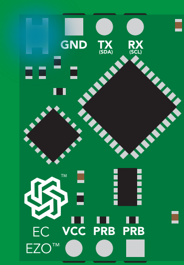
Purple
Changing baud rate



Red
Command not understood



White
Find



Blue
I2C standby

	LED ON
5V	**+2.5 mA**
3.3V	**+1 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
Sleep mode
Temperature compensation

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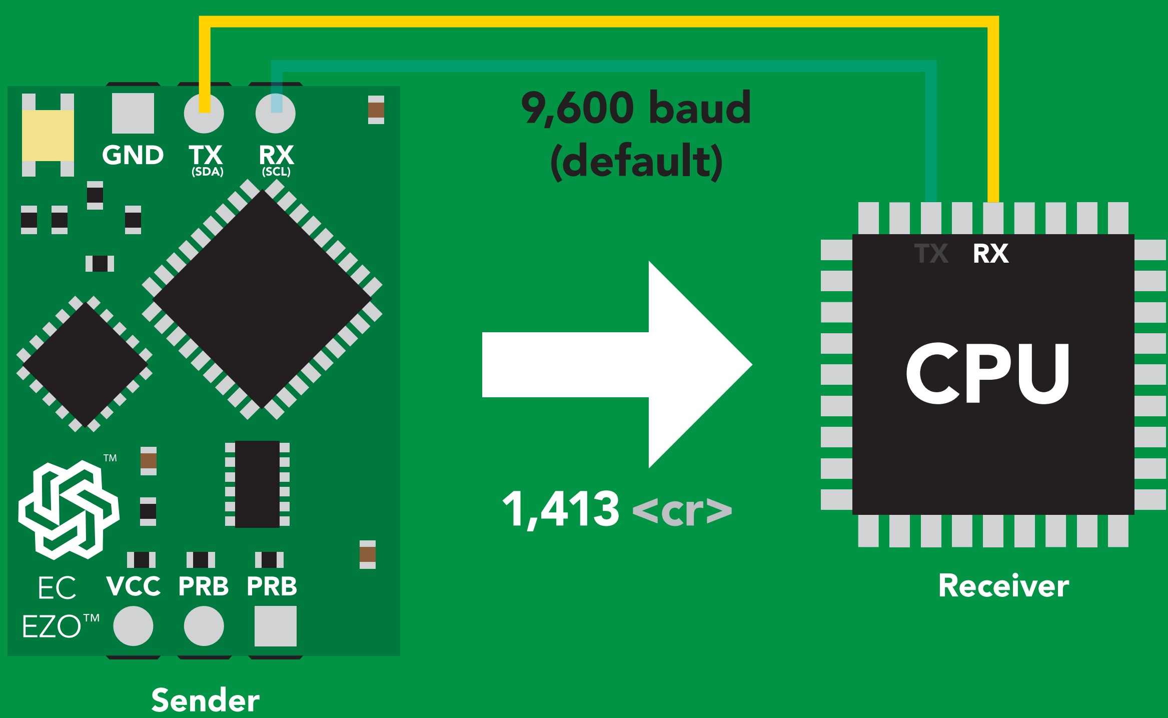
Receiving data from device



Advanced

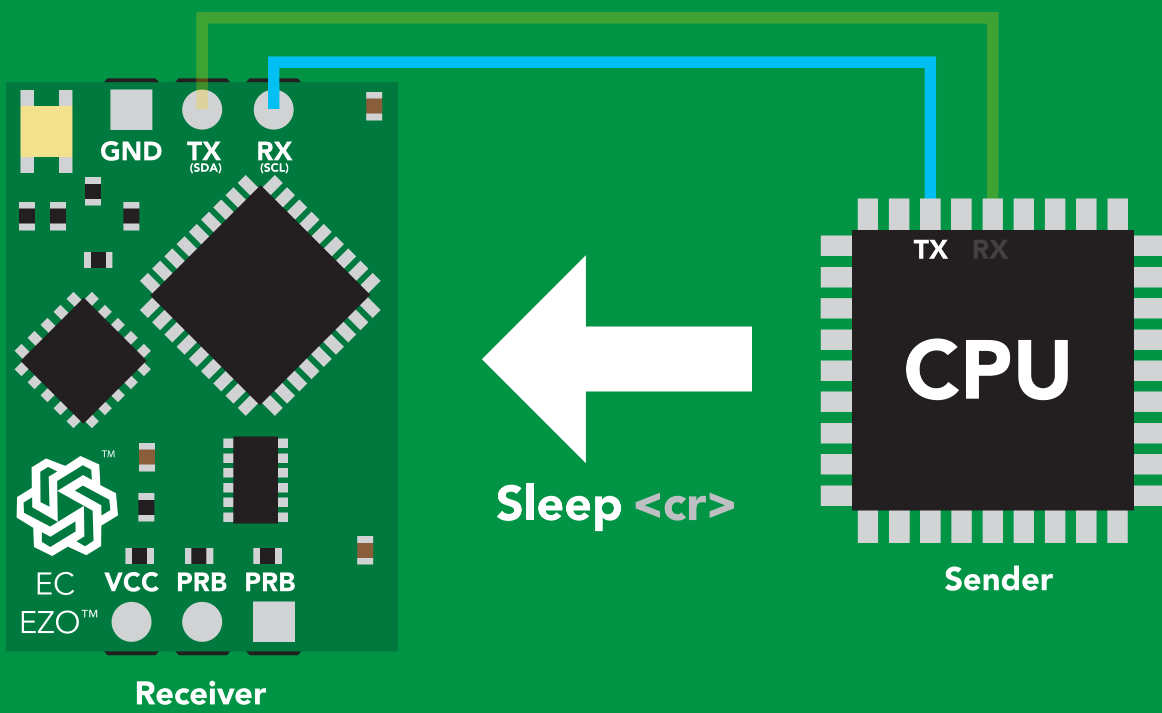
ASCII:	1	,	4	1	3	<cr>
Hex:	31	2C	34	31	33	0D
Dec:	49	44	52	49	51	13

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

UART mode

command quick reference

All commands are ASCII strings or single ASCII characters.

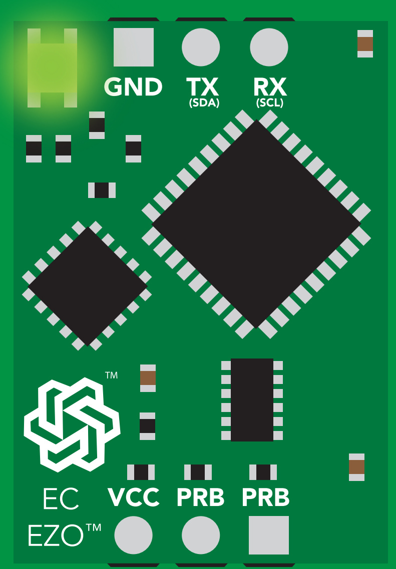
Command	Function		Default state
Baud	change baud rate	pg. 34	9,600
C	enable/disable continuous reading	pg. 20	enabled
Cal	performs calibration	pg. 22	n/a
Export	export calibration	pg. 24	n/a
Factory	enable factory reset	pg. 36	n/a
Find	finds device with blinking white LED	pg. 19	n/a
i	device information	pg. 30	n/a
I2C	change to I²C mode	pg. 37	not set
Import	import calibration	pg. 25	n/a
K	Set probe type	pg. 26	K 1.0
L	enable/disable LED	pg. 18	enabled
Name	set/show name of device	pg. 29	not set
O	enable/disable parameters	pg. 28	all enabled
Plock	enable/disable protocol lock	pg. 35	disabled
R	returns a single reading	pg. 21	n/a
Sleep	enter sleep mode/low power	pg. 33	n/a
Status	retrieve status information	pg. 32	enable
T	temperature compensation	pg. 27	25°C
TDS	change the TDS conversion factor	pg. 23	0.54
*OK	enable/disable response codes	pg. 31	enable

LED control

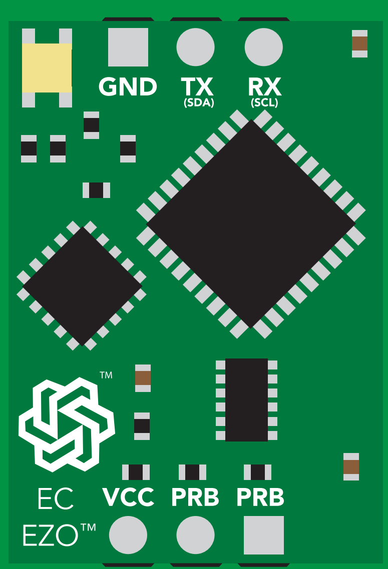
Command syntax

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

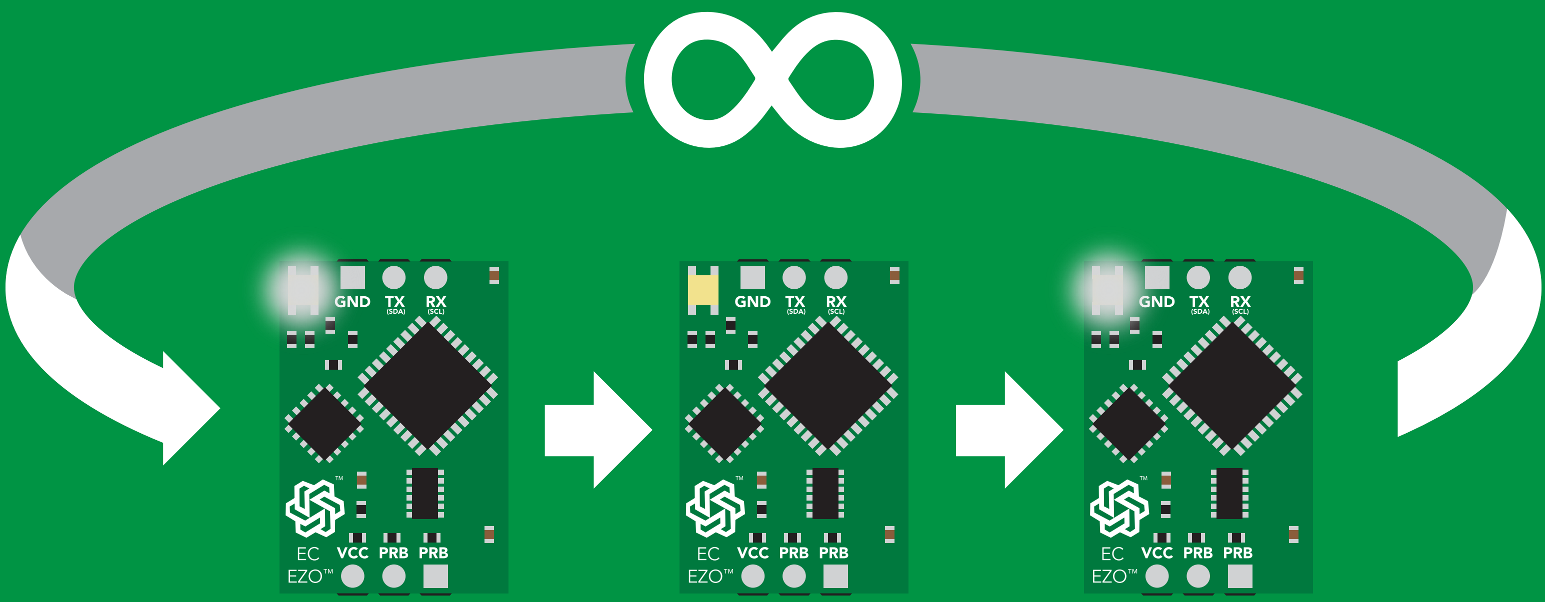
Find

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?

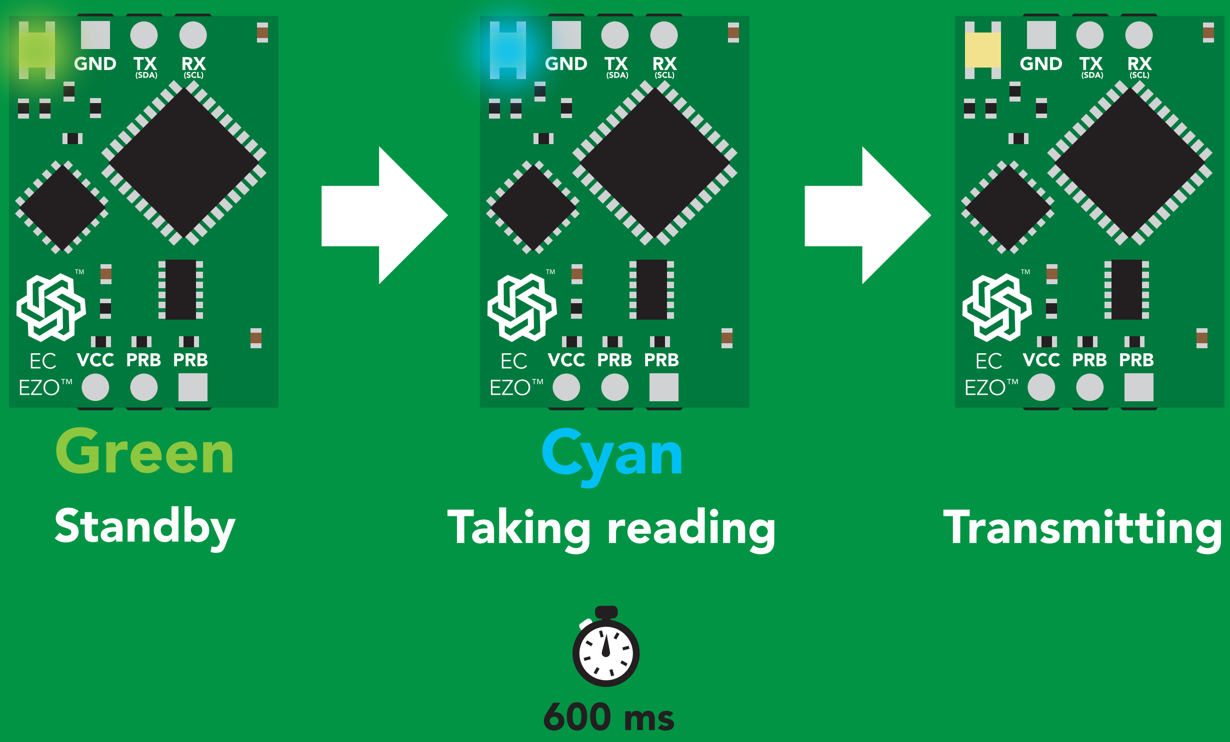
Example	Response
C,1 <cr>	*OK <cr> EC,TDS,SAL,SG (1 sec) <cr> EC,TDS,SAL,SG (2 sec) <cr> EC,TDS,SAL,SG (3 sec) <cr>
C,30 <cr>	*OK <cr> EC,TDS,SAL,SG (30 sec) <cr> EC,TDS,SAL,SG (60 sec) <cr> EC,TDS,SAL,SG (90 sec) <cr>
C,0 <cr>	*OK <cr>
C,? <cr>	?C,1 <cr> or ?C,0 <cr> or ?C,30 <cr> *OK <cr>

Single reading mode

Command syntax

R <cr> **takes single reading**

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



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 (two point) <cr> or ?CAL,2 (three point) *OK <cr>

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

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

Changing the TDS (ppm) conversion factor

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

Command syntax

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

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

Common conversion factors

NaCl	0.47 – 0.50
KCL	0.50 - 0.57
"442"	0.65 – 0.85

Formula

EC x conversion factor = TDS

Export calibration

Command syntax

Export: Use this command to download calibration settings

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

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

Response breakdown

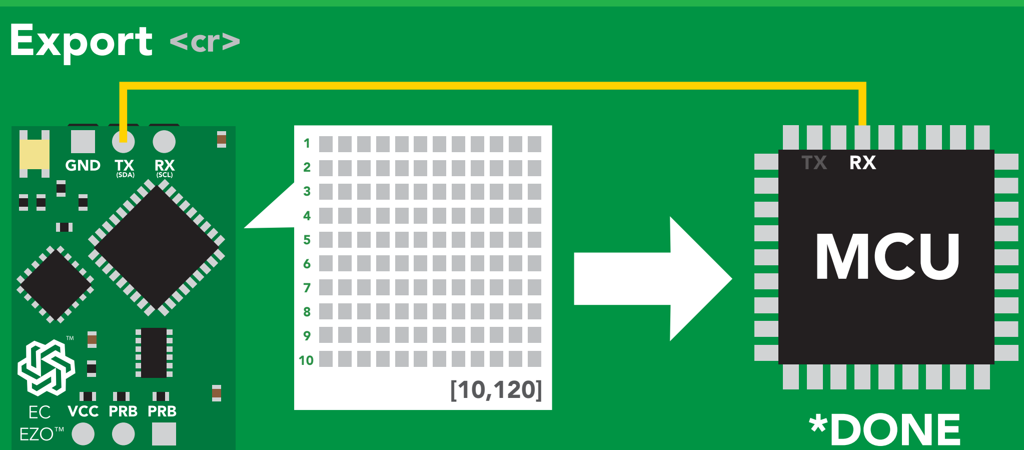
10, 120

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

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

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

Disabling *OK simplifies this process



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Import calibration

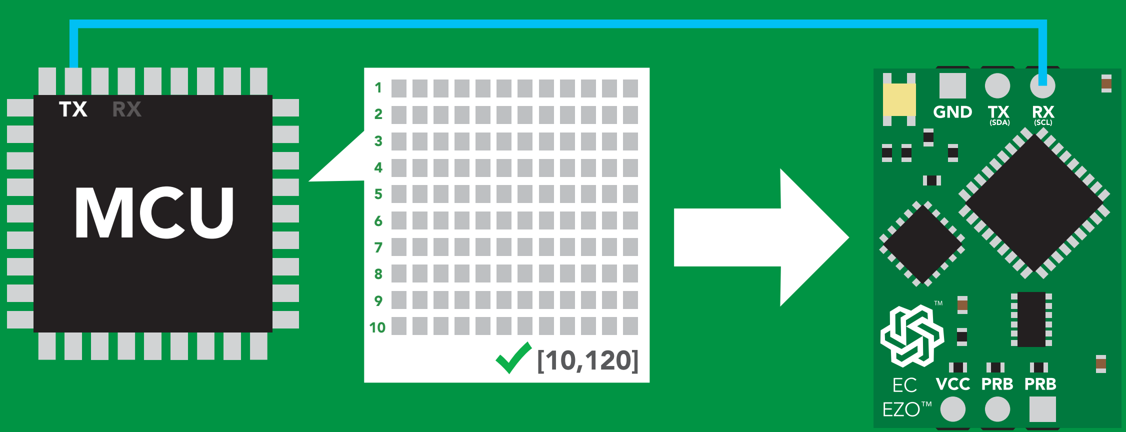
Command syntax

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

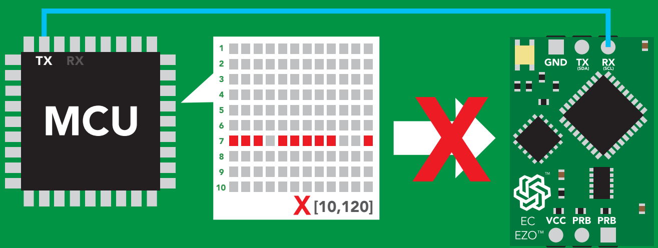
Import,n	<cr>	import calibration string to new device

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

Import,n <cr>



*OK <cr>
system will reboot



*ER <cr>

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

Setting the probe type

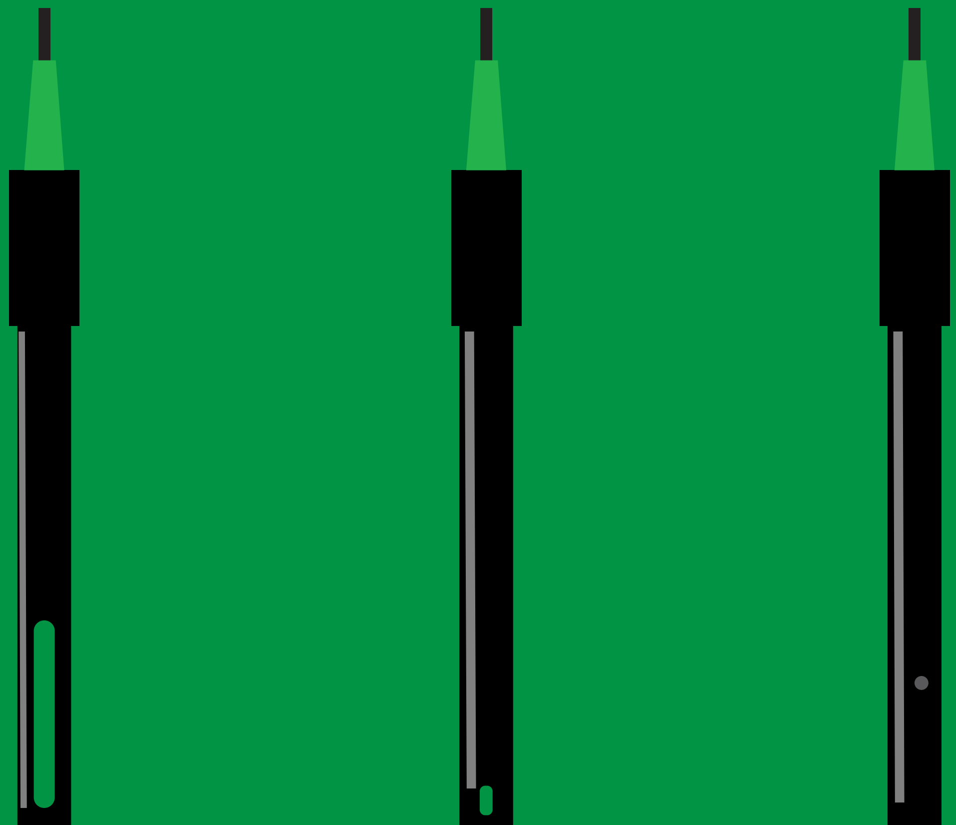
Command syntax

K 1.0 is the default value

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

K,? <cr> probe K value?

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



K 0.1 K 1.0 K 10

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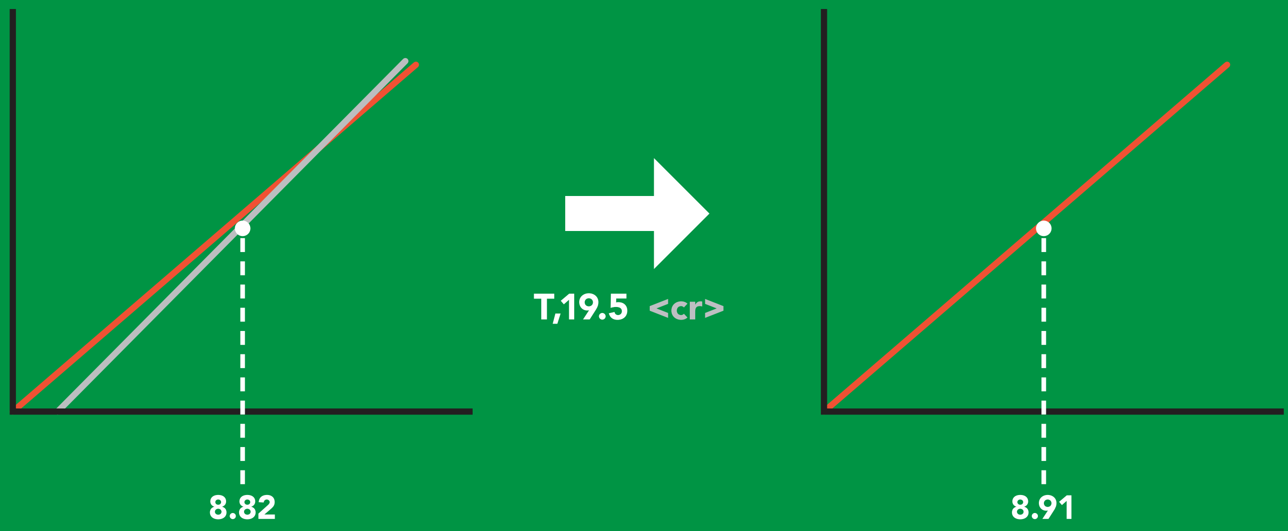
Temperature compensation

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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Enable/disable parameters from output string

Command syntax

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

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

Parameters

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

Followed by 1 or 0

1	enabled
0	disabled

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

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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

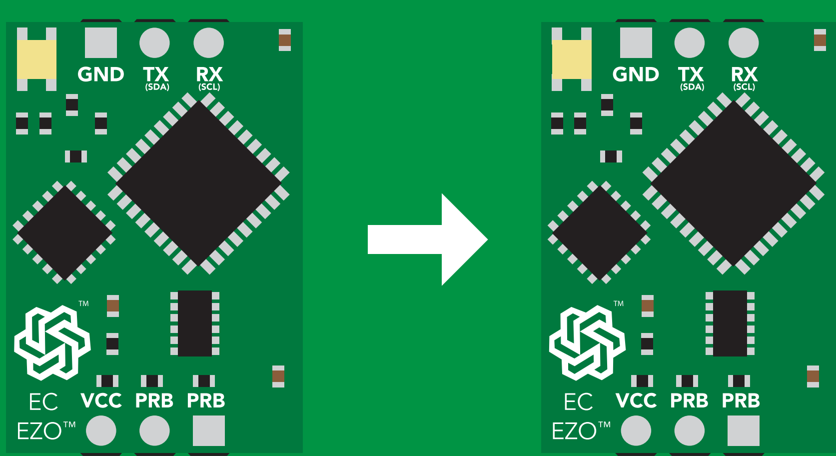
n = _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16

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

Name,?



*OK <cr>

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

Device information

Command syntax

i <cr> **device information**

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

Response breakdown

?i,	EC,	2.16
	Device	Firmware

Response codes

Command syntax

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

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

Other response codes

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

These response codes cannot be disabled

Reading device status

Command syntax

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

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

Response breakdown

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

Restart codes

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

Sleep mode/low power

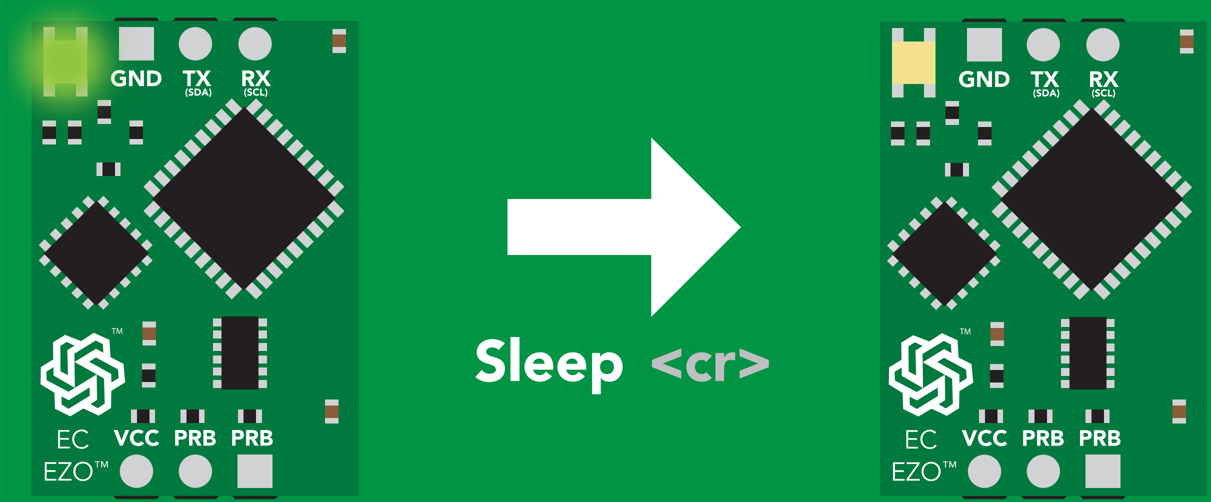
Command syntax

Send any character or command to awaken device.

Sleep <cr> enter sleep mode/low power

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

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



Standby
18.14 mA

Sleep
0.7 mA

Change baud rate

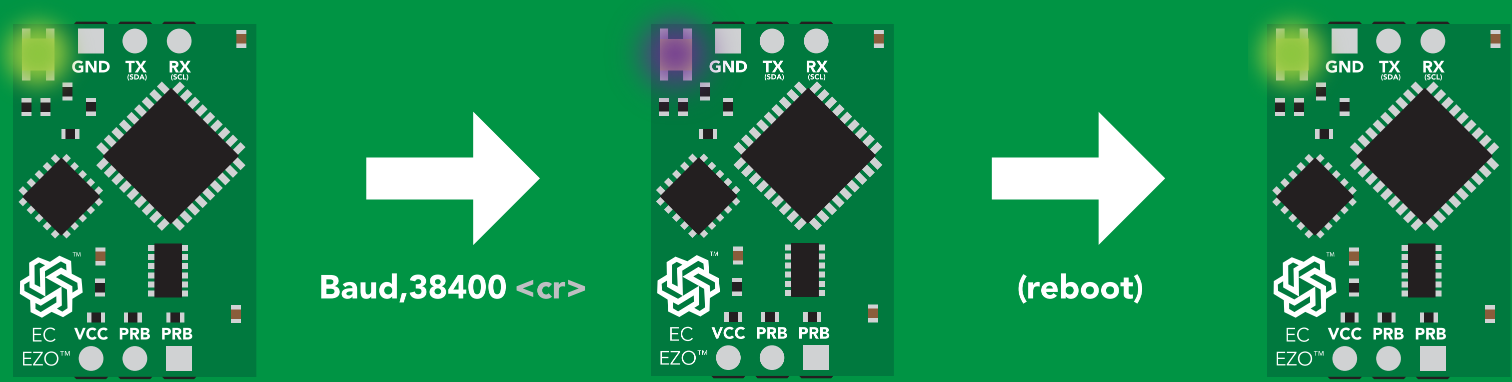
Command syntax

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

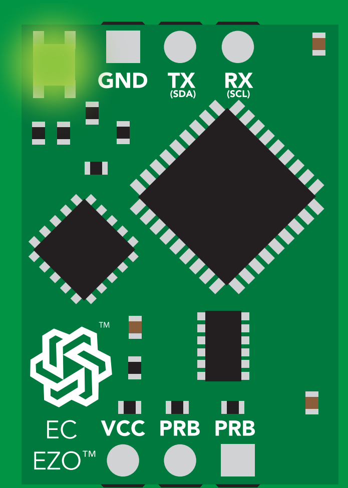
Command syntax

Locks device to UART mode.

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

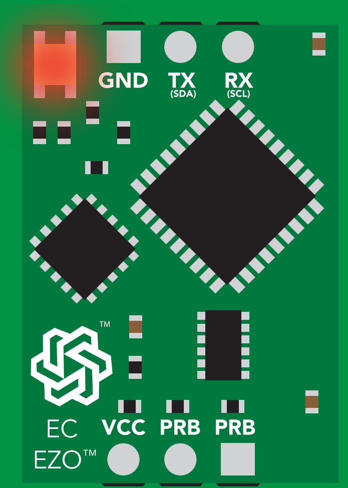
Example	Response
Plock,1 <cr>	*OK <cr>
Plock,0 <cr>	*OK <cr>
Plock,? <cr>	?Plock,1 <cr> or ?Plock,0 <cr>

Plock,1



*OK <cr>

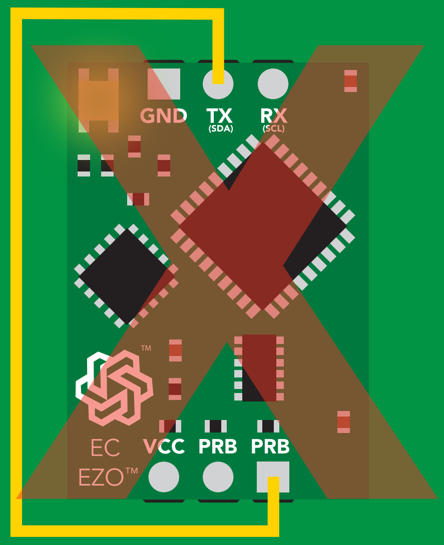
I2C,100



cannot change to I²C

*ER <cr>

Short



cannot change to I²C

Factory reset

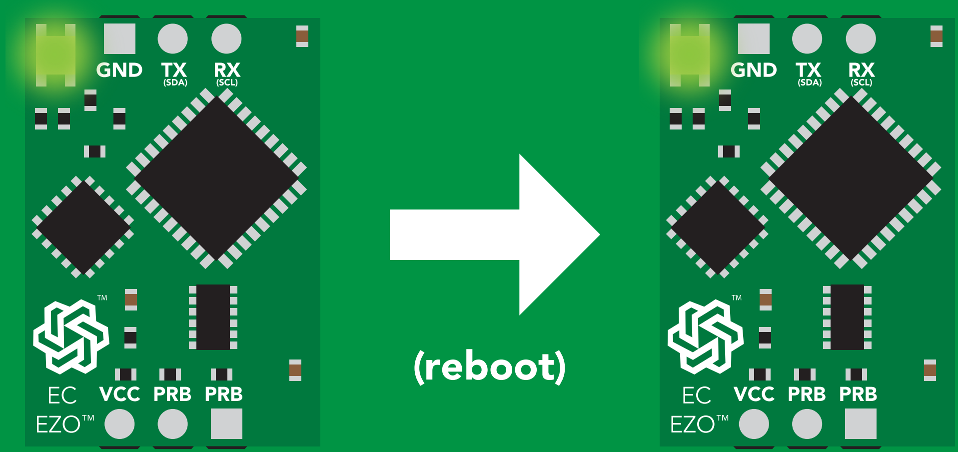
Clears calibration
LED on
"*OK" enabled

Command syntax

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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Change to I^{2}C mode

Command syntax

Default I^{2}C address 100 (0x64)

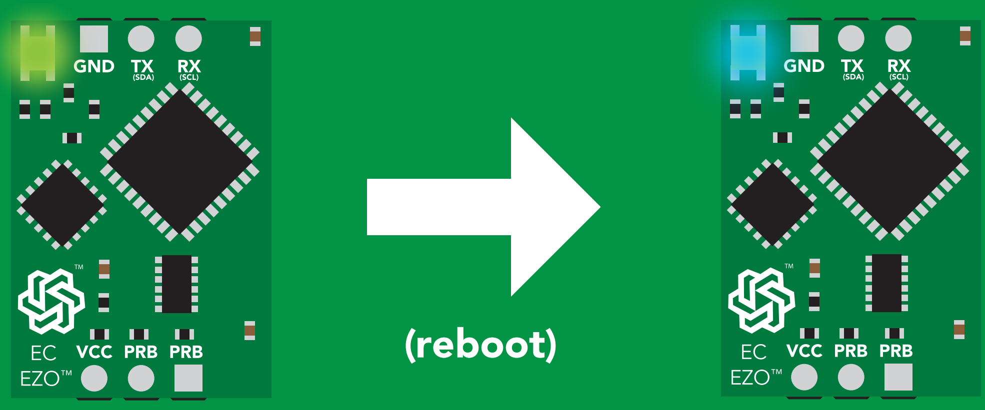
I2C,n <cr> sets I^{2}C address and reboots into I^{2}C mode

n = any number 1 – 127

Example	Response
I2C,100 <cr>	*OK (reboot in I^{2}C mode)

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

I2C,100



Green
*OK <cr>

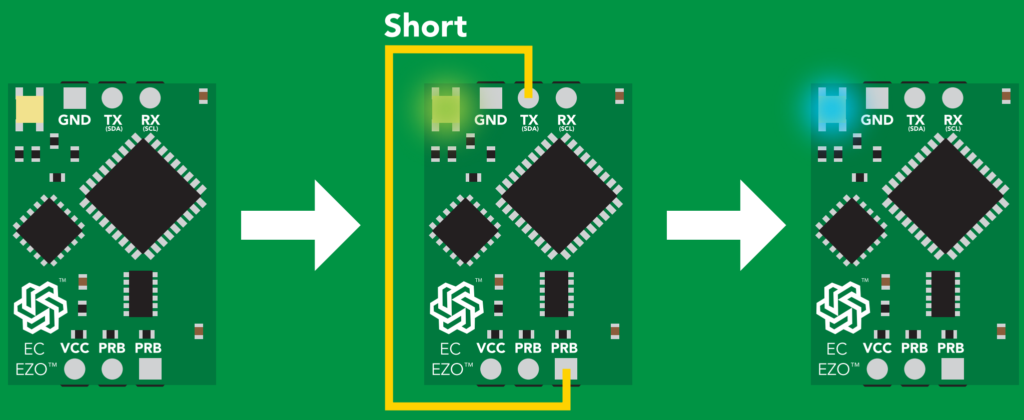
Blue
now in I^{2}C mode

Manual switching to I²C

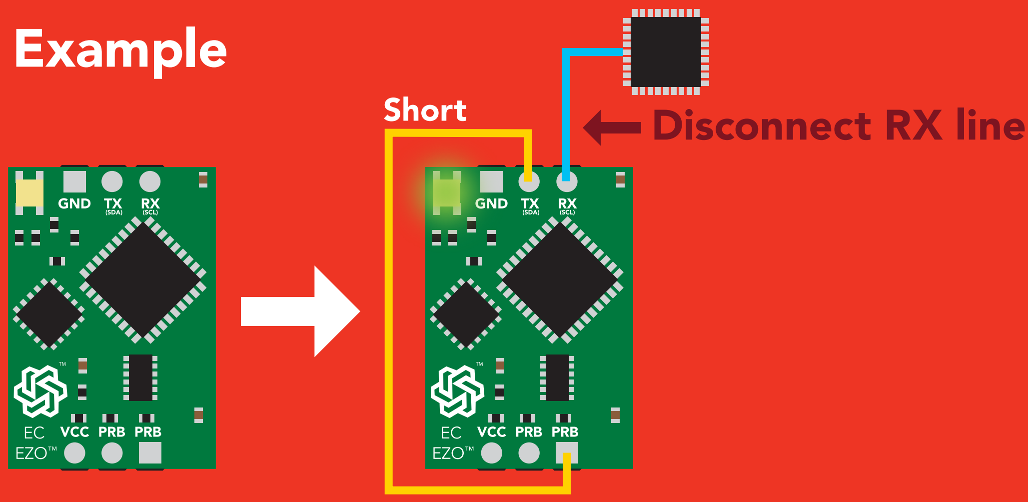
- Disconnect ground (power off)
- Disconnect TX and RX
- Connect TX to the right PRB
- Confirm RX is disconnected
- Connect ground (power on)
- Wait for LED to change from Green to Blue
- Disconnect ground (power off)
- Reconnect all data and power

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

Example



Wrong Example



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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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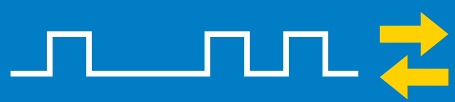
I²C mode

I²C address (0x01 – 0x7F)
100 (0x64) default

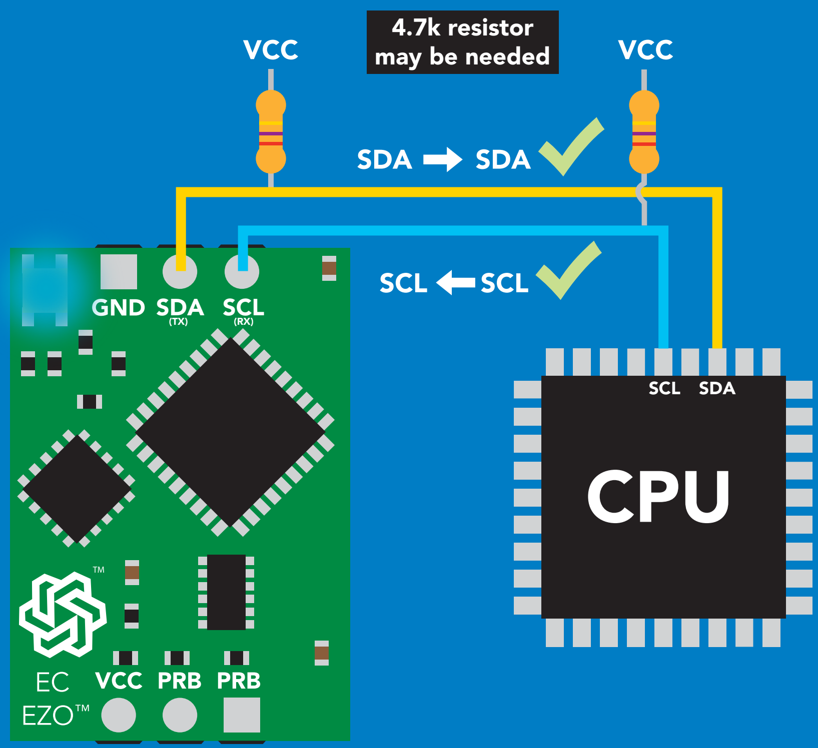
Vcc 3.3V – 5.5V

Clock speed 100 – 400 kHz

SDA



SCL



Data format

Reading

Conductivity = Deafult

Total dissolved solids
Salinity
Specific gravity
} = Must be enabled

Order EC,TDS,SAL,SG

Encoding ASCII

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

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Sending commands to device

5 parts

Start | I²C address | Write | Command (not case sensitive) | Stop

I²C address: 100 (0x64)

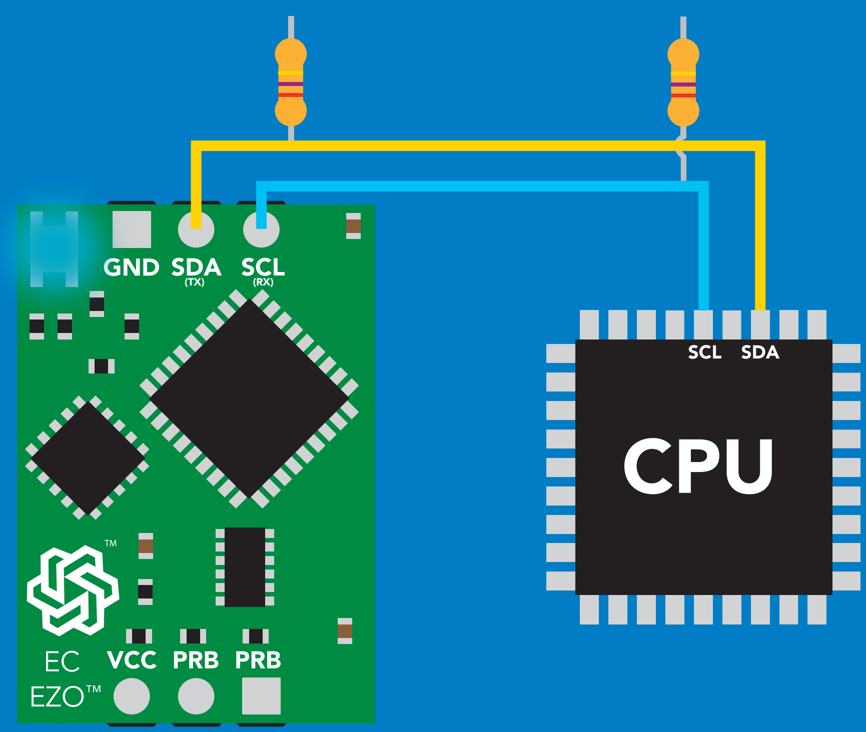
Command: ASCII command string

Example

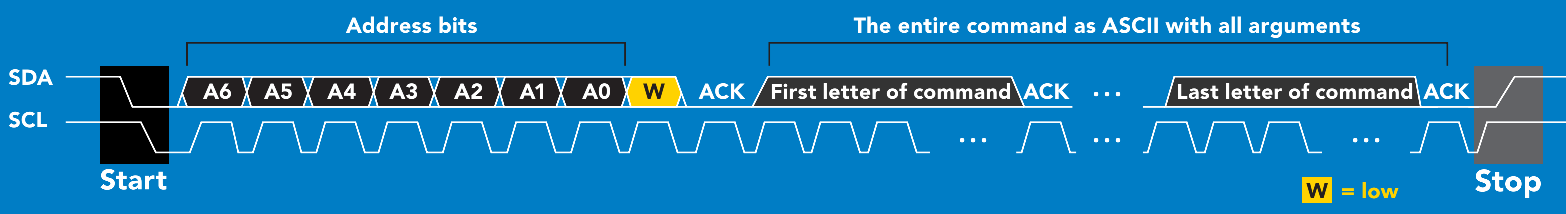
Start | 100 (0x64) | Write | Sleep | Stop

I²C address: 100 (0x64)

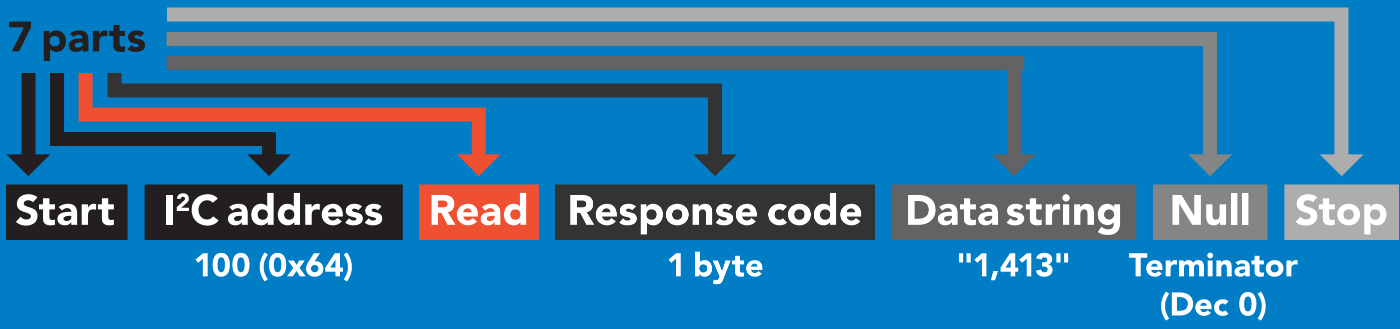
Command: Sleep

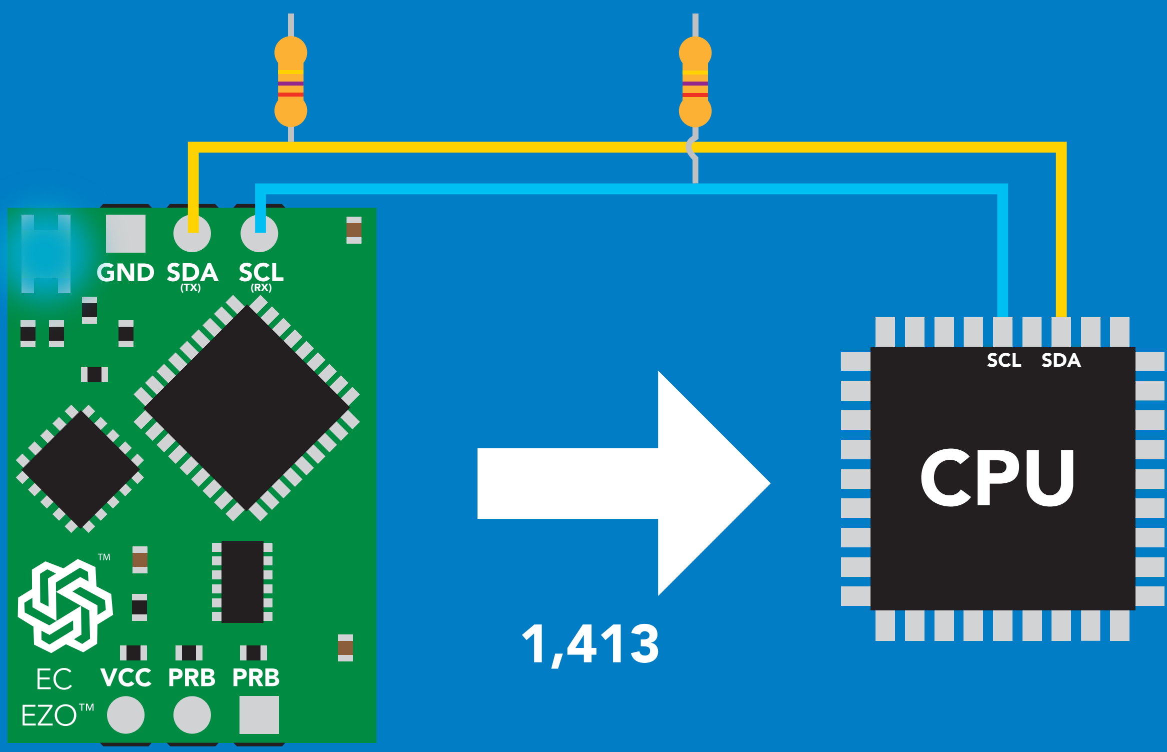


Advanced

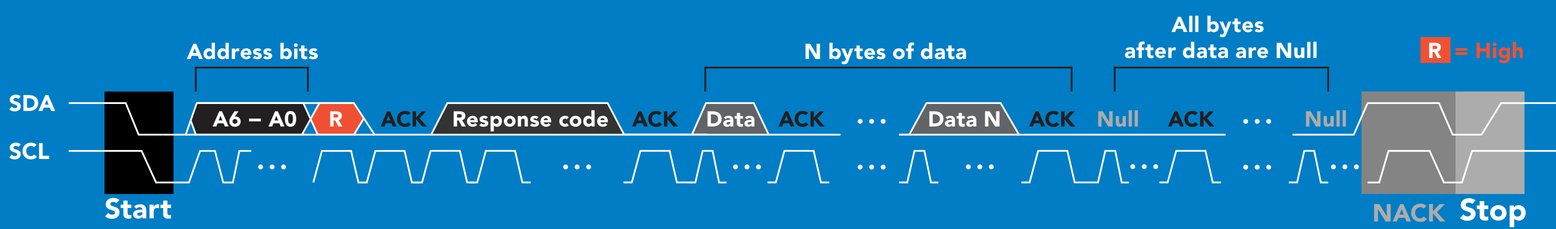


Requesting data from device





Advanced



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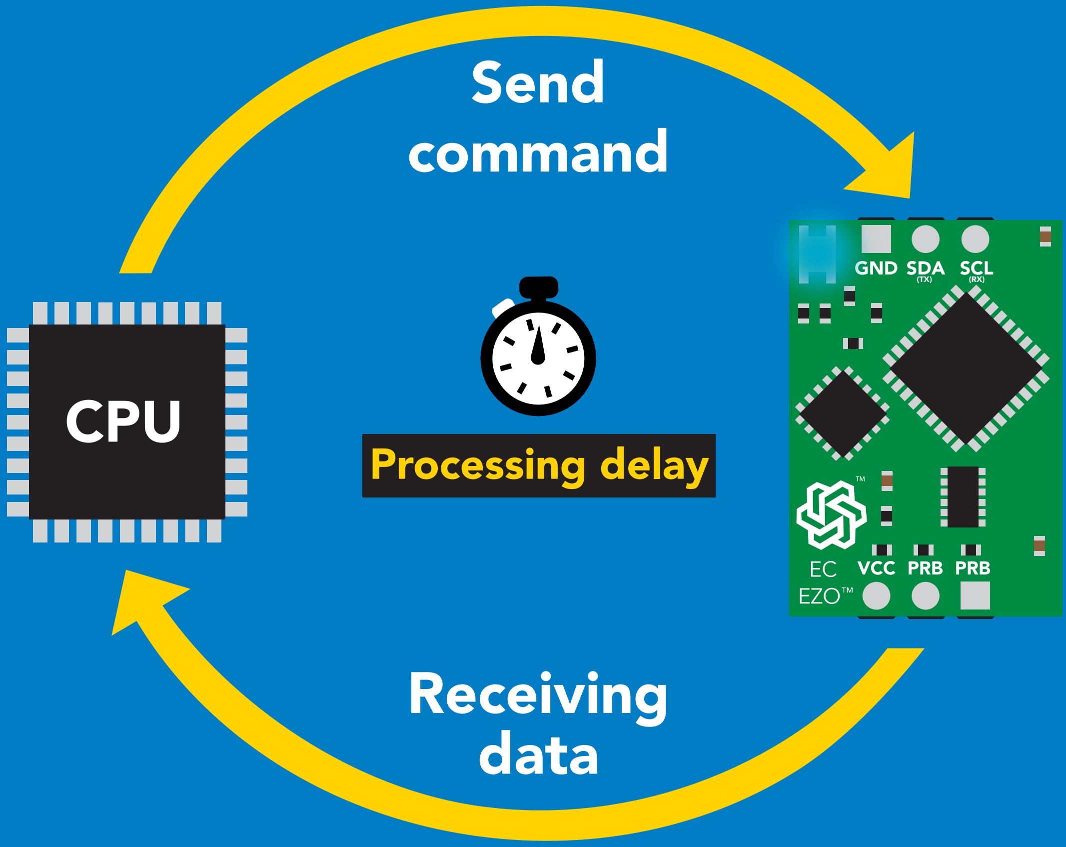
Response codes

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;
```

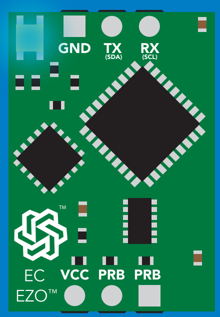
The response code will always be 254, if you do not wait for the processing delay.

Response codes

Single byte, not string

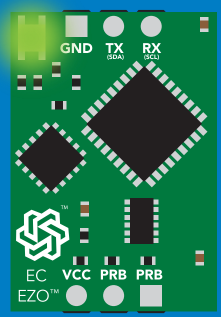
255	no data to send
254	still processing, not ready
2	syntax error
1	successful request

LED color definition



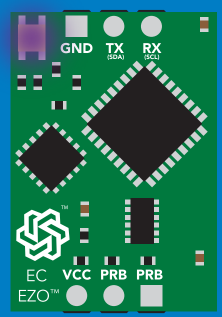
Blue

I²C standby



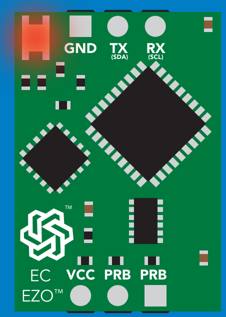
Green

Taking reading



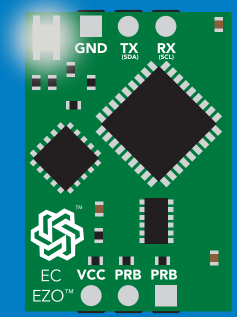
Purple

Changing I²C address



Red

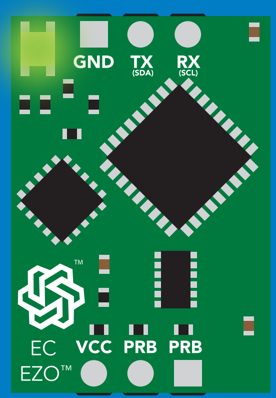
Command not understood



White

Find

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



Solid Green LED

in UART mode
Not I²C ready

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I^2C mode
command quick reference

All commands are ASCII strings or single ASCII characters.

Command	Function	
Baud	switch back to UART mode	pg. 63
Cal	performs calibration	pg. 49
Export	export calibration	pg. 51
Factory	enable factory reset	pg. 62
Find	finds device with blinking white LED	pg. 47
i	device information	pg. 57
I2C	change I^2C address	pg. 61
Import	import calibration	pg. 52
K	set probe type	pg. 53
L	enable/disable LED	pg. 46
Name	set/show name of device	pg. 56
O	enable/disable parameters	pg. 55
Plock	enable/disable protocol lock	pg. 60
R	returns a single reading	pg. 48
Sleep	enter sleep mode/low power	pg. 59
Status	retrieve status information	pg. 58
T	temperature compensation	pg. 54
TDS	change the TDS conversion factor	pg. 50

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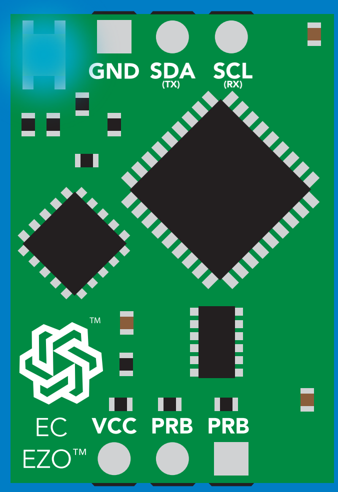
LED control

Command syntax

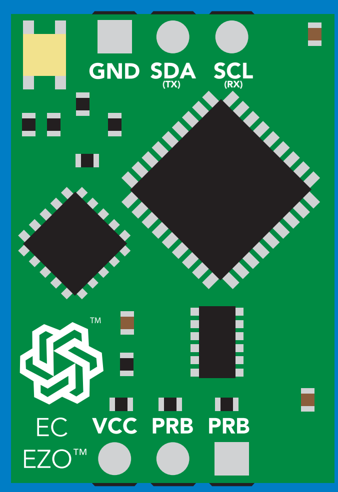
300ms processing delay

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

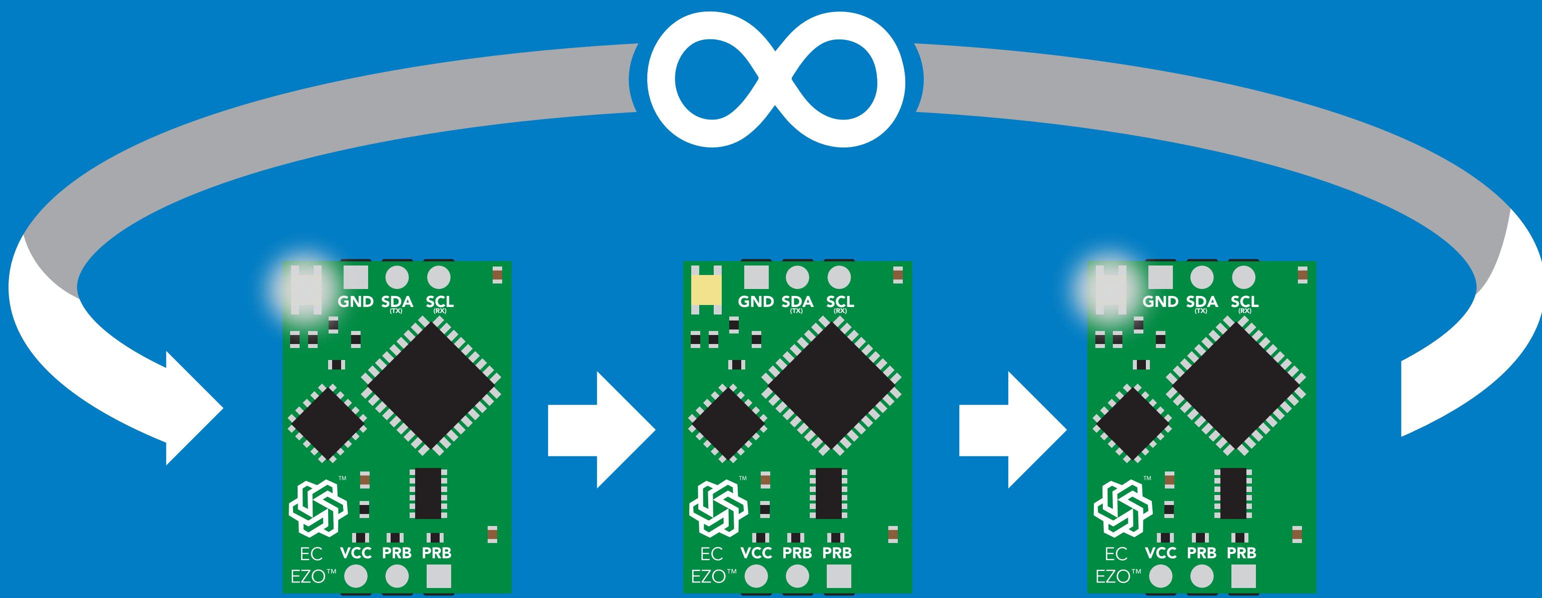
300ms processing delay

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



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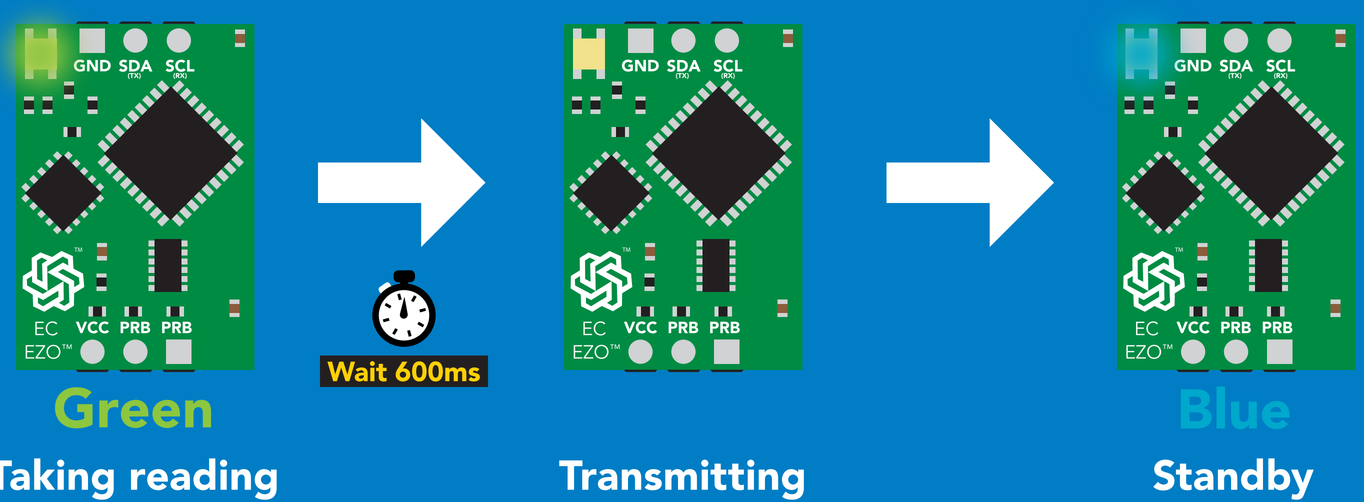
Taking reading

Command syntax

600ms processing delay

R return 1 reading

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



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 (two point) · 0 Null **or** 1 Dec · ?CAL,2 ASCII (three point) · 0 Null

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

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

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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 (Dec) ?TDS,0.54 (ASCII) 0 (Null)
R	Wait 300ms — 1 (Dec) 100,54 (ASCII: EC = 100, TDS = 54) 0 (Null)
TDS,0.46	Wait 300ms — 1 (Dec) 0 (Null)
R	Wait 300ms — 1 (Dec) 100,46 (ASCII: EC = 100, TDS = 46) 0 (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

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

10 = # of strings to export

120 = # of bytes to export

Export strings can be up to 12 characters long

Import calibration

300ms processing delay

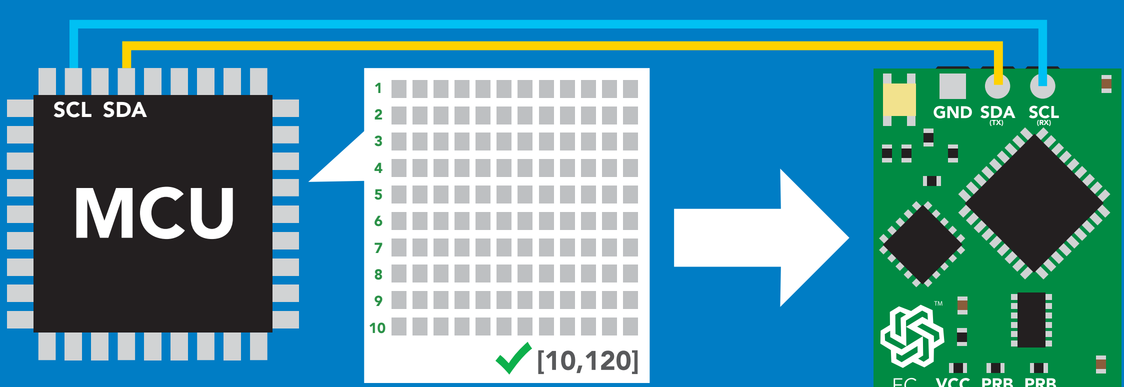
Command syntax

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

Import,n import calibration string to new device

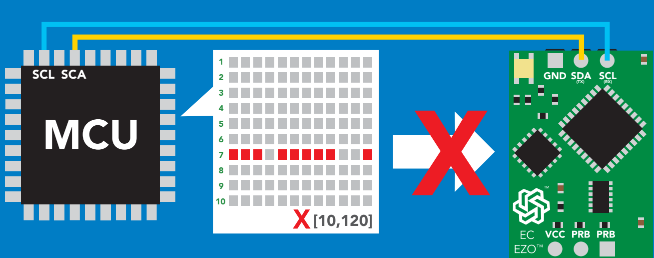
Example		Response
Import, 59 6F 75 20 61 72	(1 of 10)	Wait 300ms 1 Dec 0 Null
Import, 65 20 61 20 63 6F	(2 of 10)	Wait 300ms 1 Dec 0 Null
⋮		⋮
Import, 6F 6C 20 67 75 79	(10 of 10)	Wait 300ms 1 Dec 0 Null

Import,n



1 Dec | *Pending ASCII | 0 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

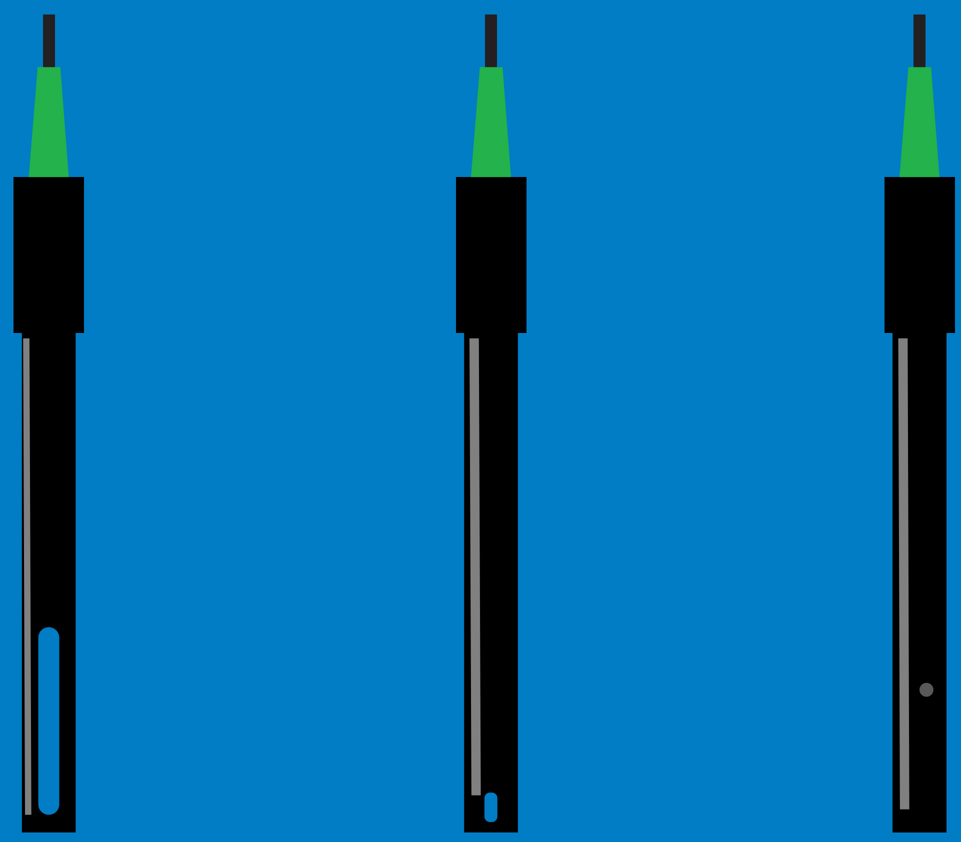
300ms processing delay

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)



K 0.1 K 1.0 K 10

AtlasScientific Environmental Robotics

Temperature compensation

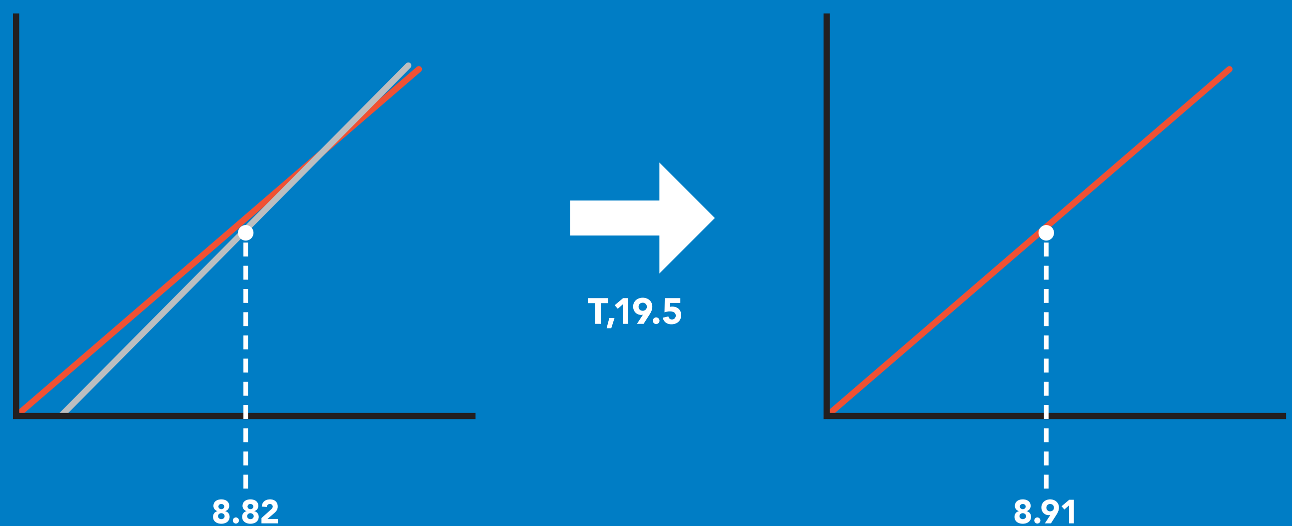
Command syntax

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

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

300ms processing delay

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)



AtlasScientific Environmental Robotics

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

Followed by 1 or 0

1	enabled
0	disabled

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

AtlasScientific™ Environmental Robotics

Naming device

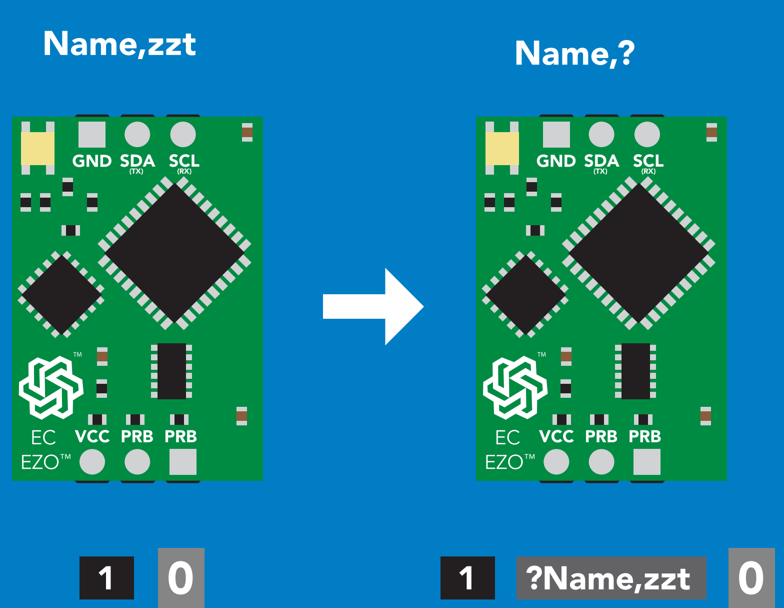
300ms processing delay

Command syntax

Do not use spaces in the name

Name,n	set name	n = _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ (1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16) Up to 16 ASCII characters
Name,	clears name	
Name,?	show name	

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



AtlasScientific™ Environmental Robotics

Device information

Command syntax

300ms processing delay

i	device information

Example	Response
i	Wait 300ms · 1 (Dec) · ?i,EC, 2.16 (ASCII) · 0 (Null)

Response breakdown

?i, EC, 2.16

EC, → Device

2.16 → 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

P — Reason for restart

5.038 — Voltage at Vcc

Restart codes

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

Atlas Scientific
Environmental Robotics

Sleep mode/low power

Command syntax

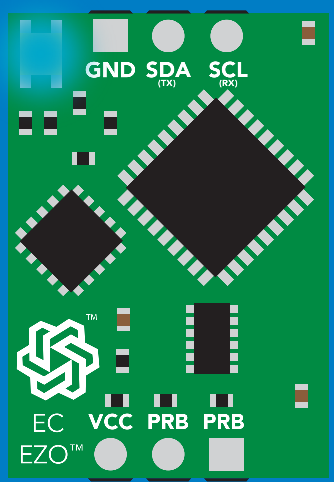
Sleep enter sleep mode/low power

Send any character or command to awaken device.

Example	Response
Sleep	no response
Any command	wakes up device

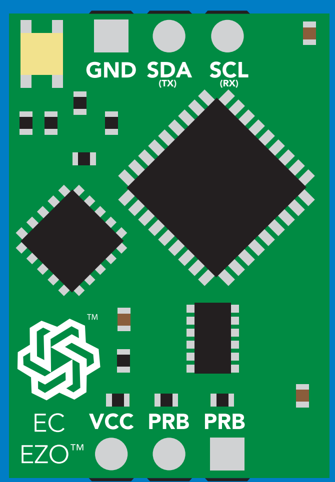
Do not read status byte after issuing sleep command.

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



Standby

Sleep



Sleep

AtlasScientific
Environmental Robotics

Protocol lock

Command syntax

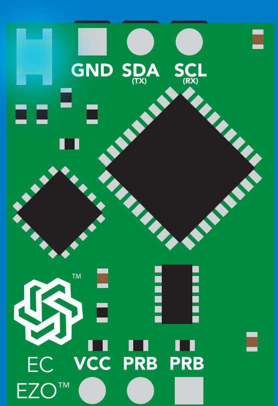
300ms processing delay

Plock,1	enable Plock	
Plock,0	disable Plock	default
Plock,?	Plock on/off?	

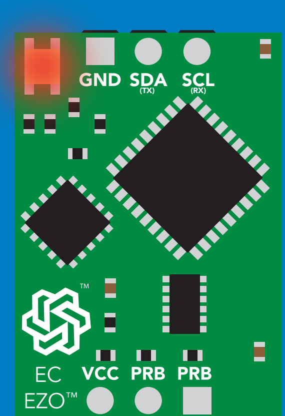
Locks device to I²C mode.

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)

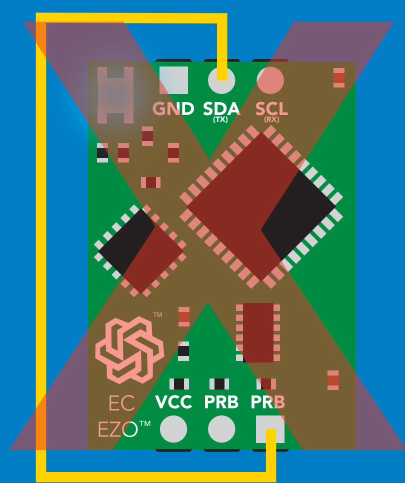
Plock,1



Baud, 9600



cannot change to UART



cannot change to UART

Atlas Scientific Environmental Robotics

I²C address change

Command syntax

300ms processing delay

I2C,n sets I²C address and reboots into I²C mode

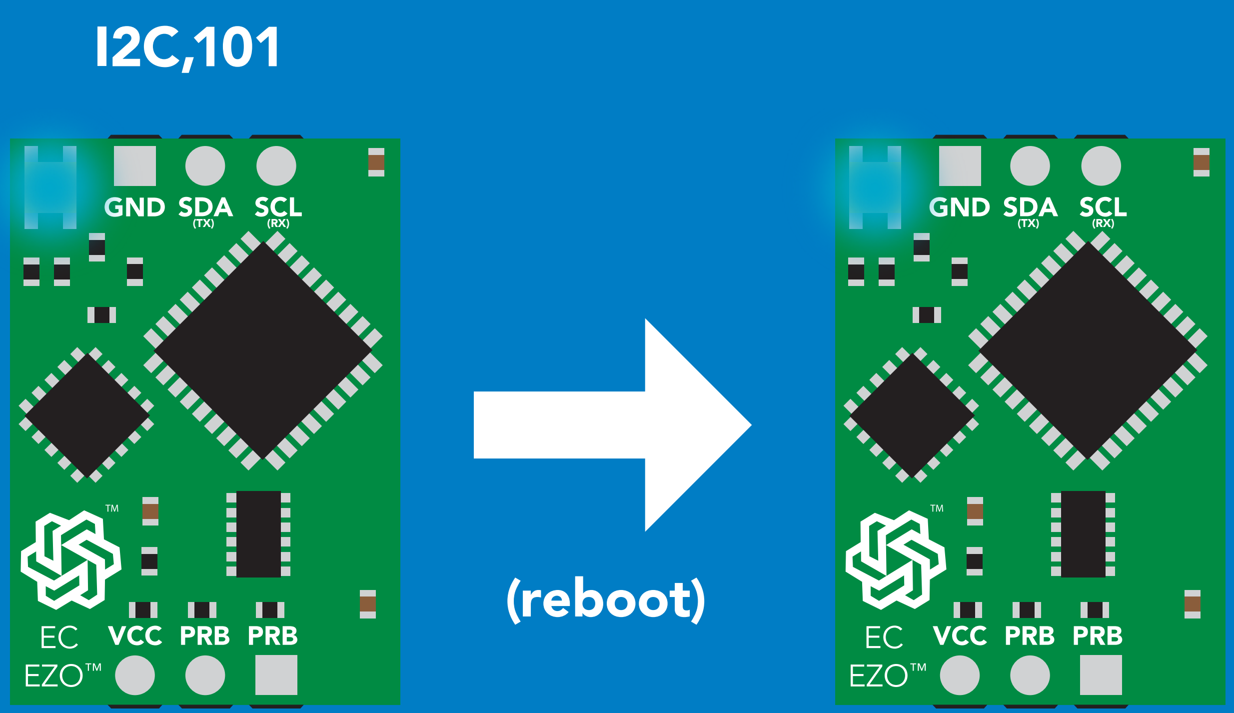
Example	Response
I2C,101	device reboot (no response given)

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).

n = any number 1 – 127



Factory reset

Command syntax

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

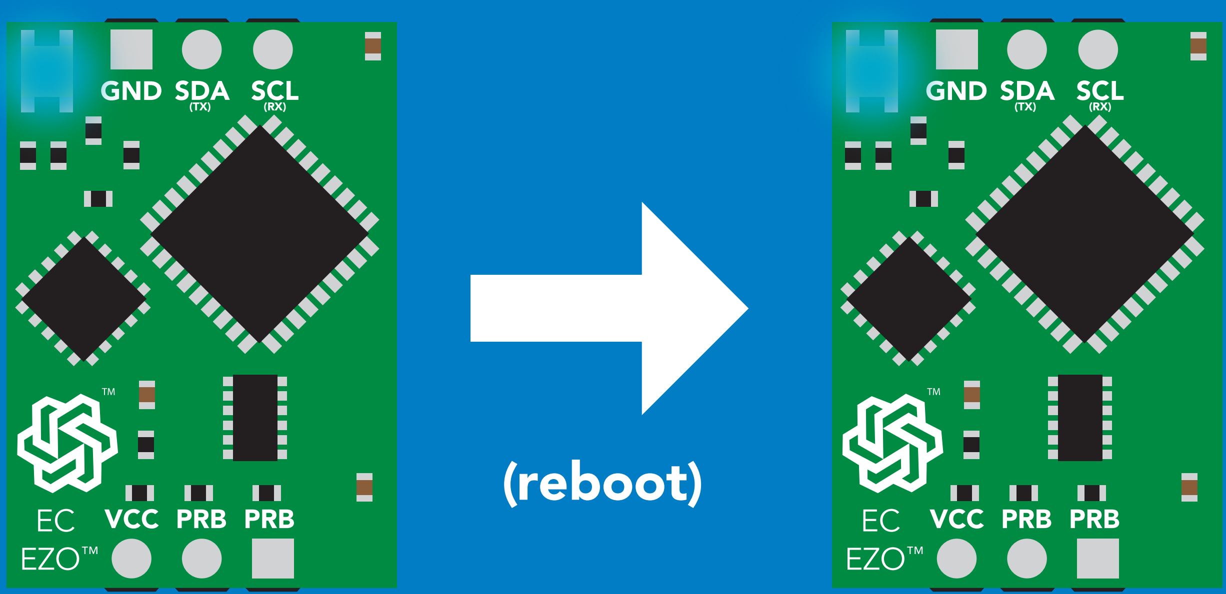
Factory enable factory reset

I²C address will not change

Example	Response
Factory	device reboot (no response given)

Clears calibration
LED on
Response codes enabled

Factory



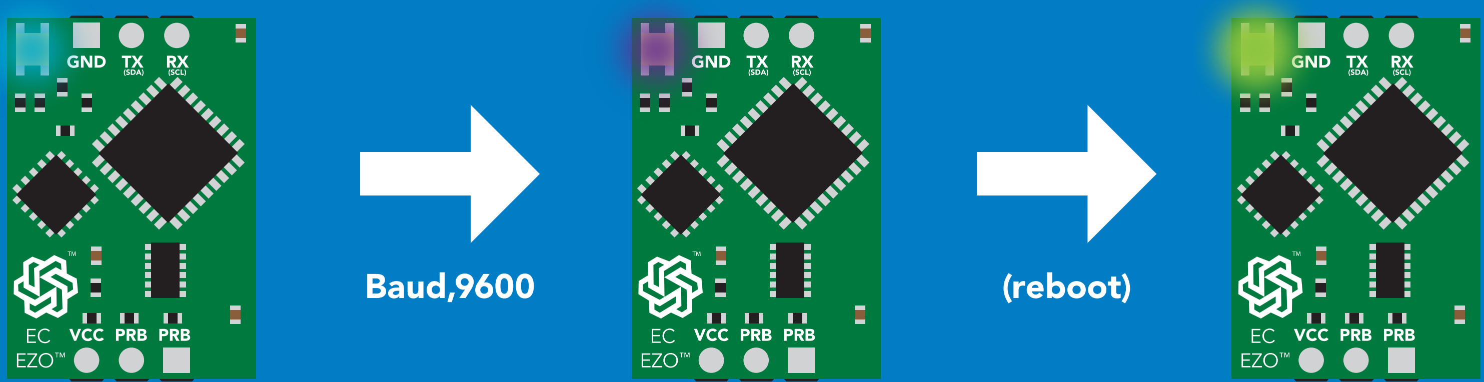
Change to UART mode

Command syntax

Baud,n	**switch from I²C to UART**

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

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

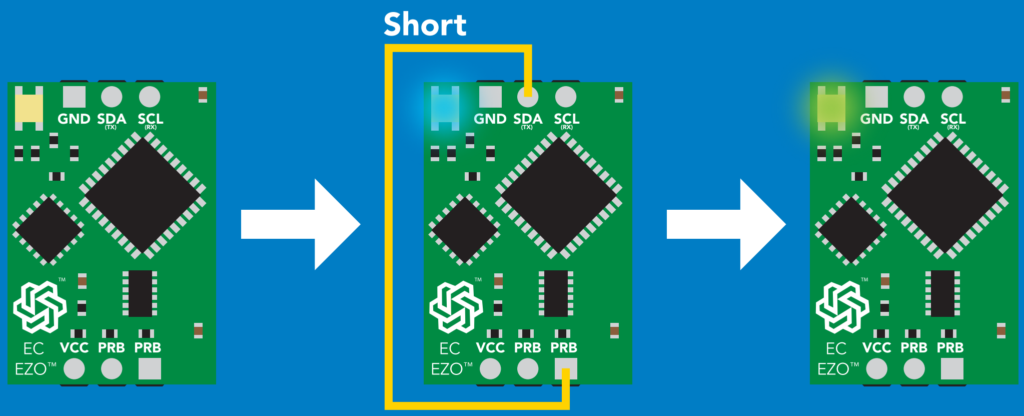


Changing to UART mode

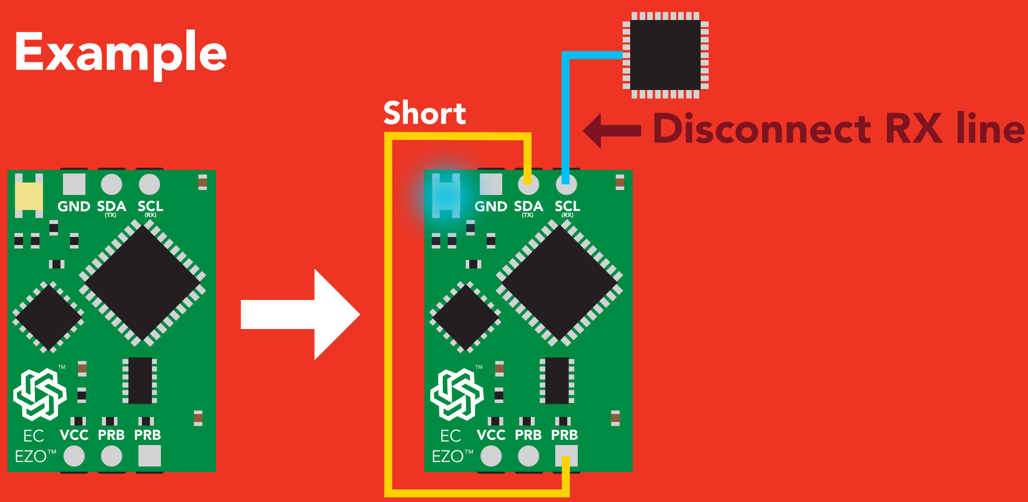
Manual switching to UART

- 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



Calibration theory

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

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

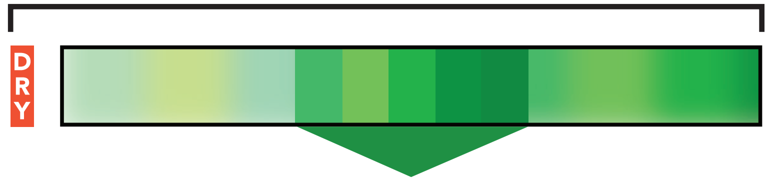
However, changing the cable length of the probe or moving the EZO-EC circuit from one machine to another may require recalibration. This is because such actions will change the electrical properties of the probe or EC circuit.

Two point or Three point calibration

No calibration

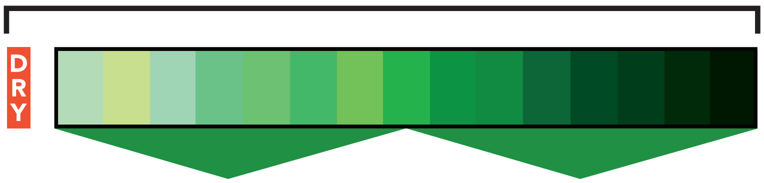
Approximation

Two point calibration



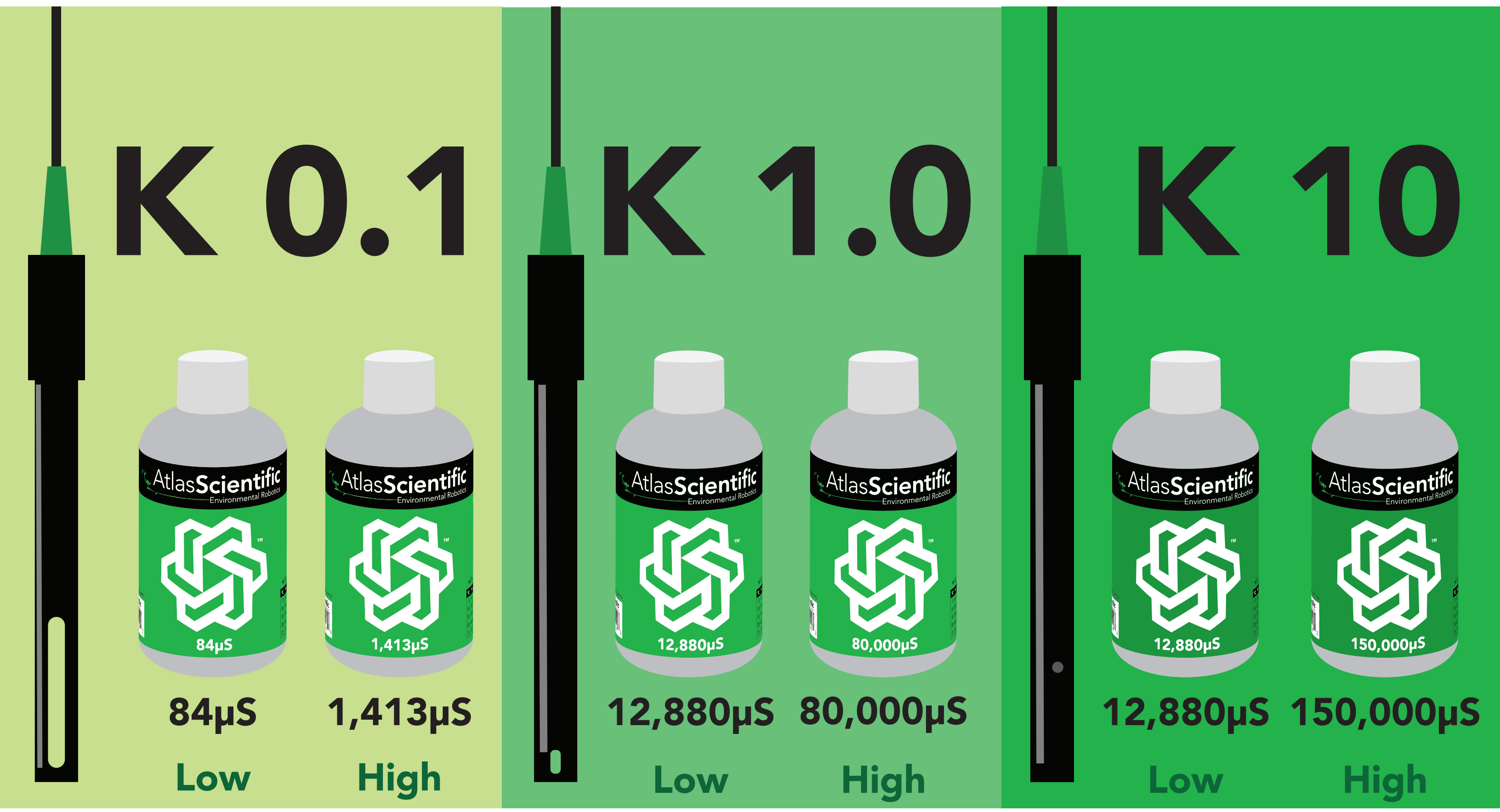
Narrow band accuracy

Three point calibration



Wide range accuracy

Recommended calibration points



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

AtlasScientific Environmental Robotics

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.***

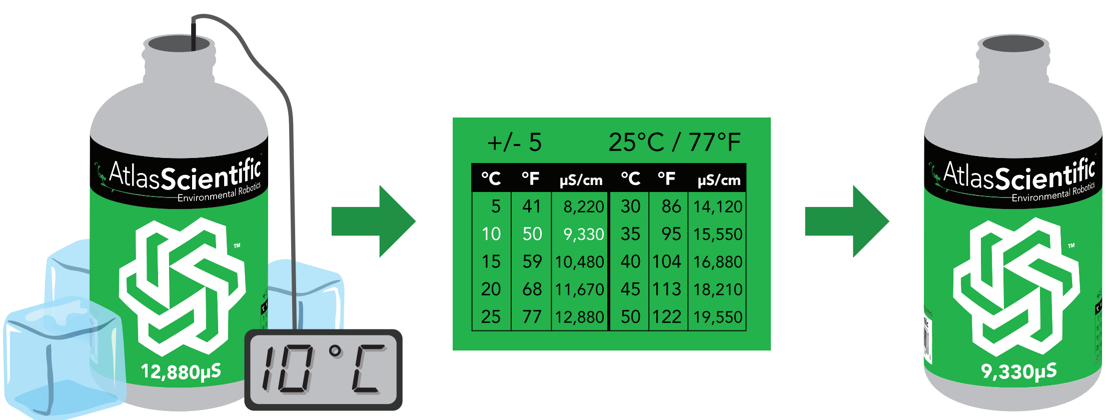
If the solution is +/- 5° C *(or more)*, refer to the chart on the bottle, and calibrate to that value.

+/- 5 25°C / 77°F

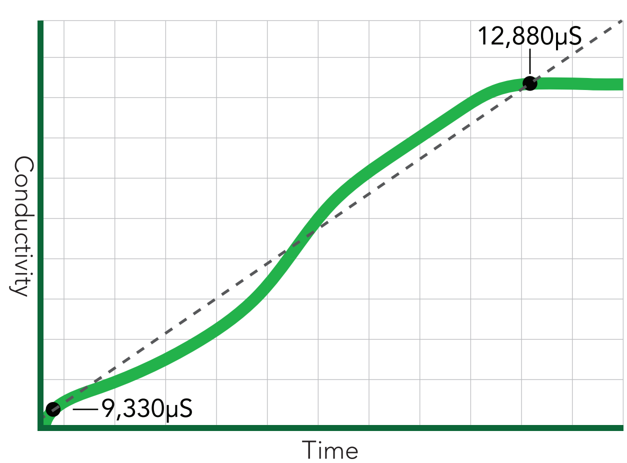
°C	°F	µS/cm	°C	°F	µS/cm
5	41	8,220	30	86	14,120
10	50	9,330	35	95	15,550
15	59	10,480	40	104	16,880
20	68	11,670	45	113	18,210
25	77	12,880	50	122	19,550

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**.



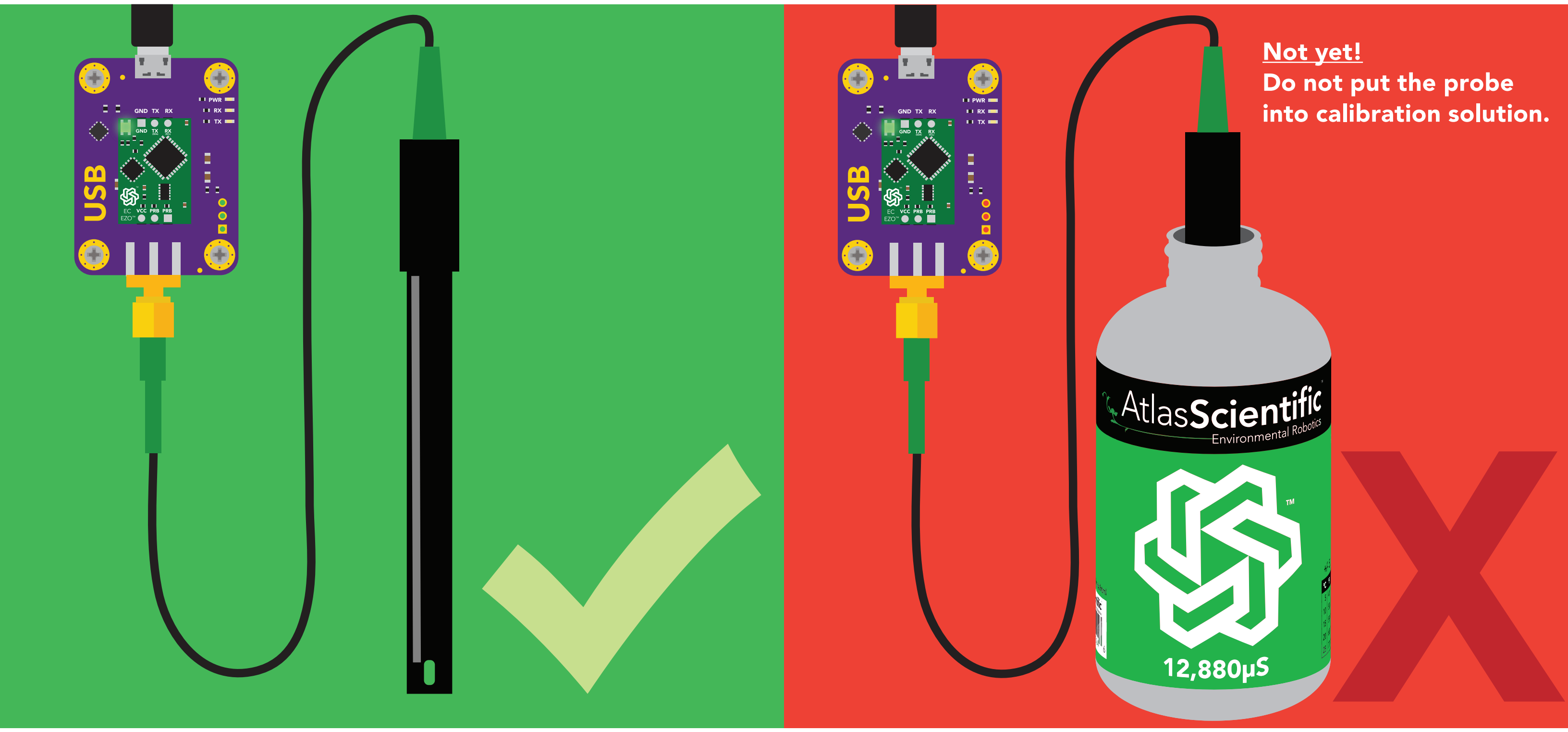
Over time, the readings will normalize as the solution warms to 25° C.



See pages **27** or **54** for more information.

1. Pre-calibration setup

Connect the dry conductivity probe and take continous readings.



2. Set probe type

If your probe ≠ K 1.0 *(default)*, then set the probe type by using the **"K,n"** command. *(where n = K value of your probe)* for more information, see page **26** or **53**.

3. Dry calibration

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

00.00 → **"Cal,dry"** → 0.00 ✓ **Correct**

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

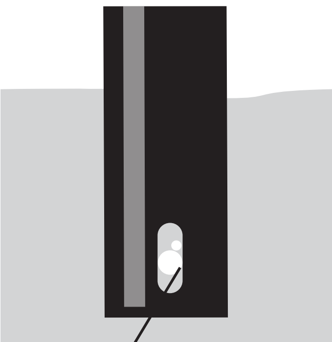
4. Calibration

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

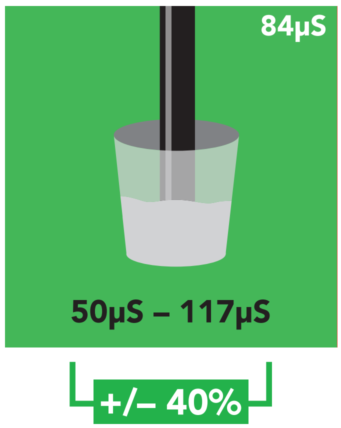
To perform a two or three point calibration, follow the instructions below.

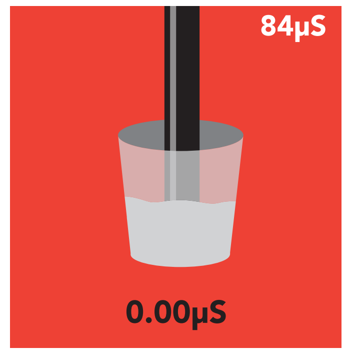
Two point calibration

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

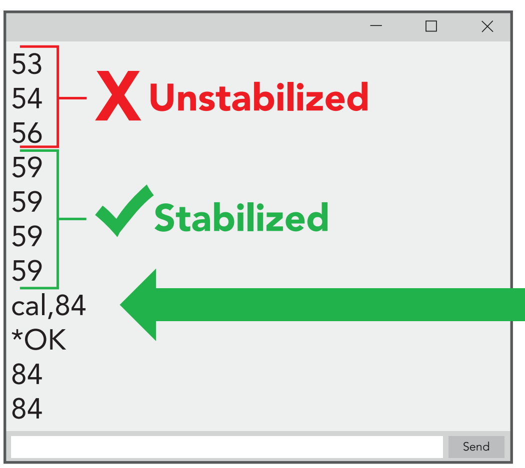


Trapped air in sensing area (shake to remove)





check probe connection, you cannot calibrate to 0.

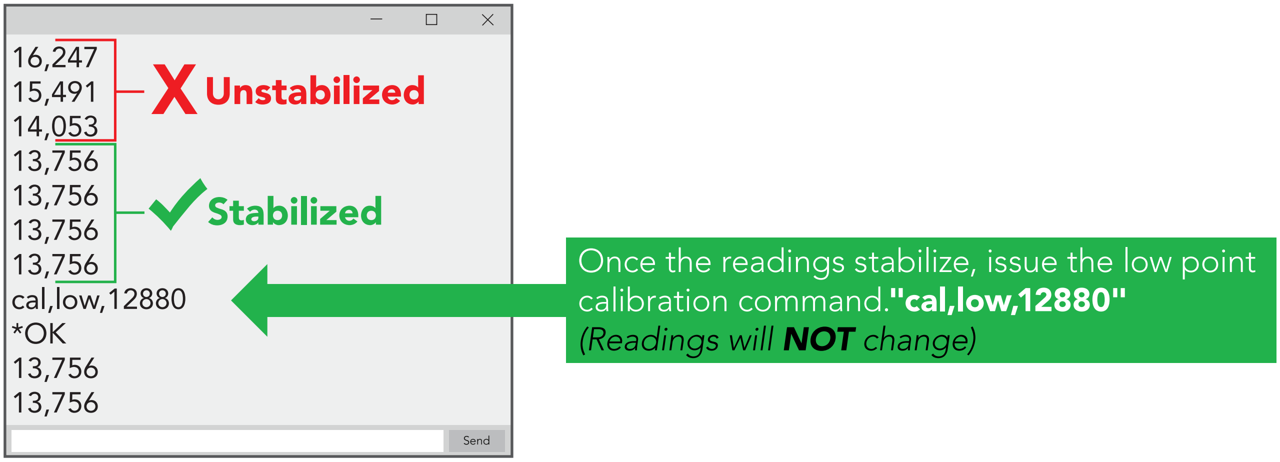


Once the readings stabilize, issue the single point calibration command.**"cal,n"** where n = any value. *(Readings **will** change, calibration complete).a*

Calibration complete!

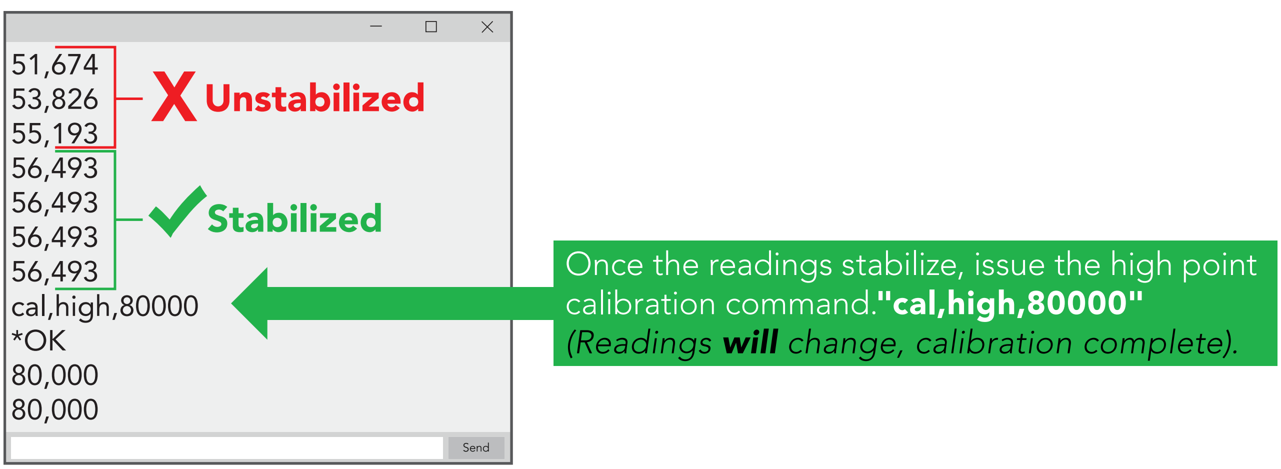
Three point calibration - low point

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



Three point calibration - high point

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

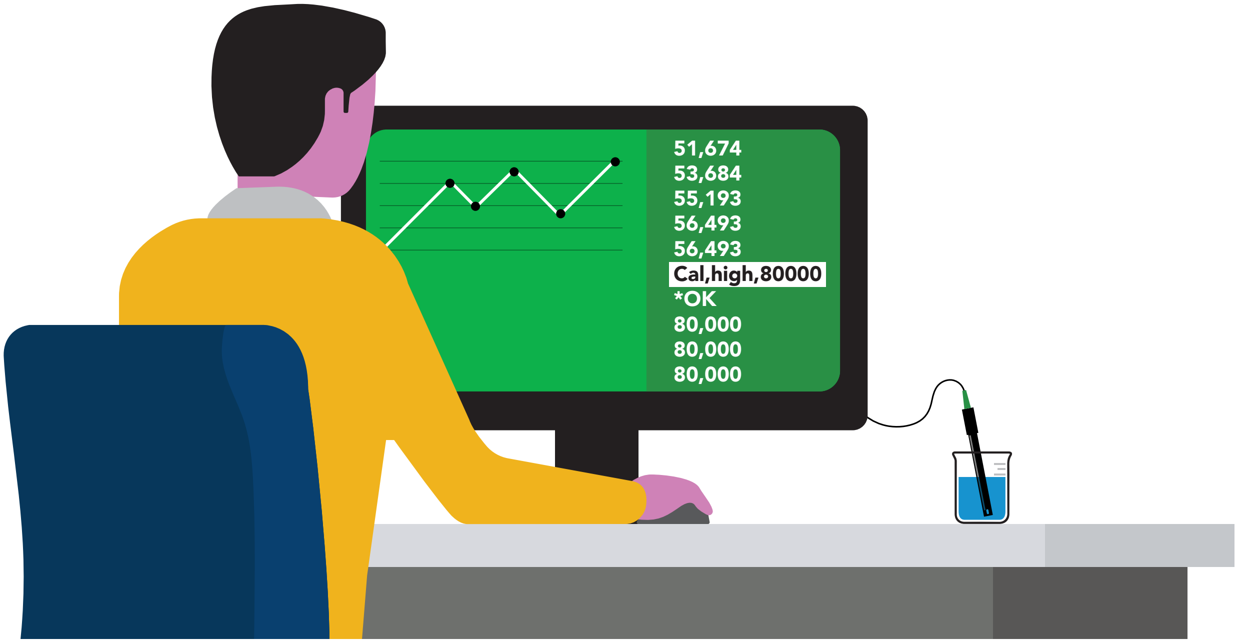


Calibration complete!

AtlasScientific Environmental Robotics

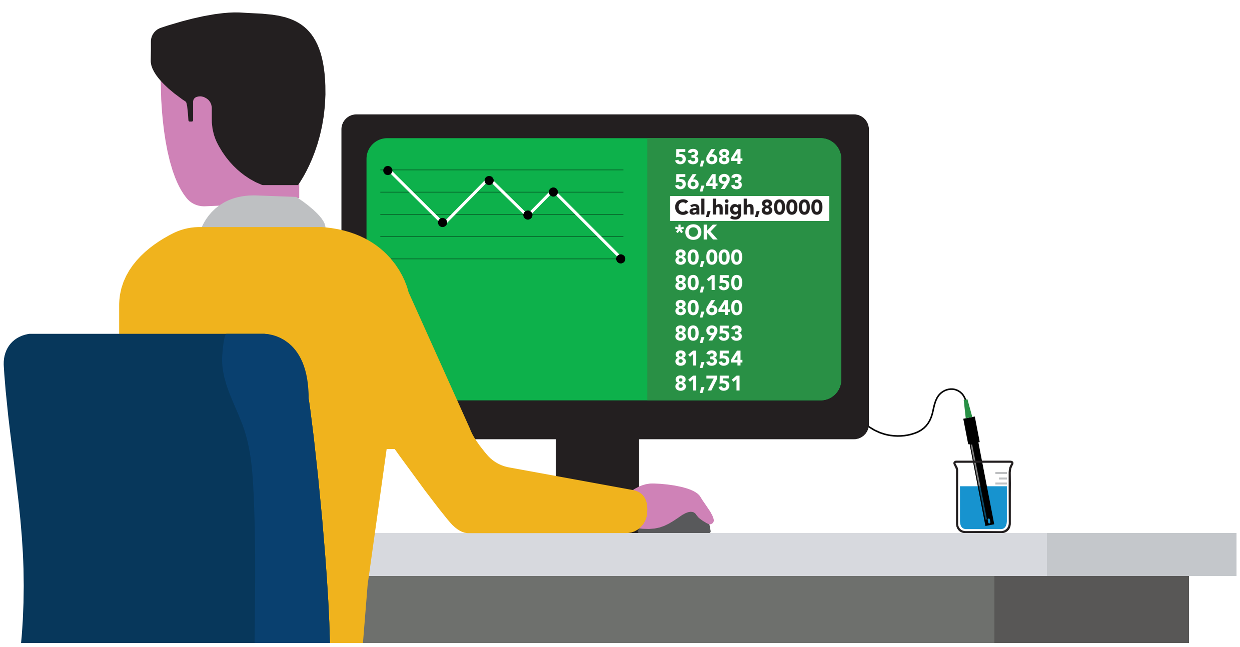
Best practices for calibration

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



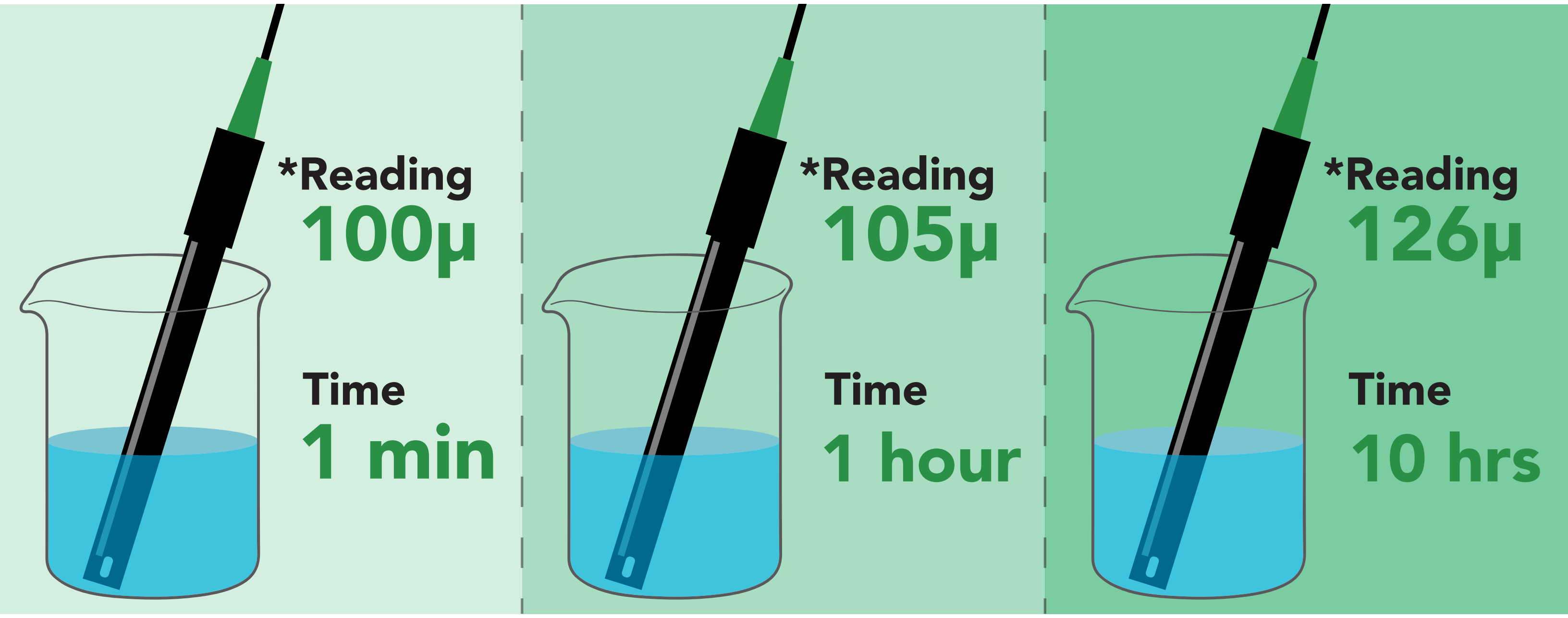
⚠ Never do a blind calibration! ⚠

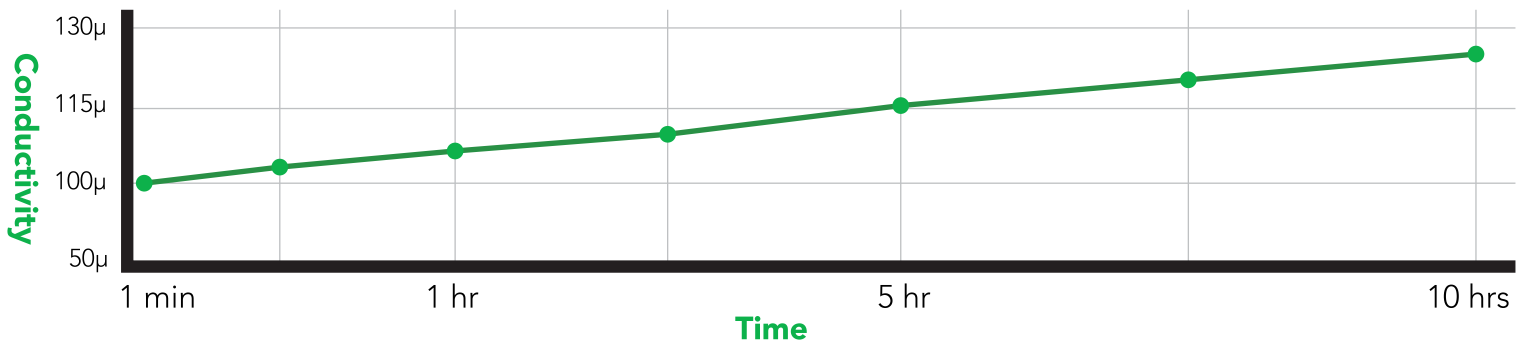
Issuing a calibration command before the readings stabilize will result in drifting readings.



Long-term conductivity measurements in stagnant water

Taking continuous conductivity readings in stagnant water:





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

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

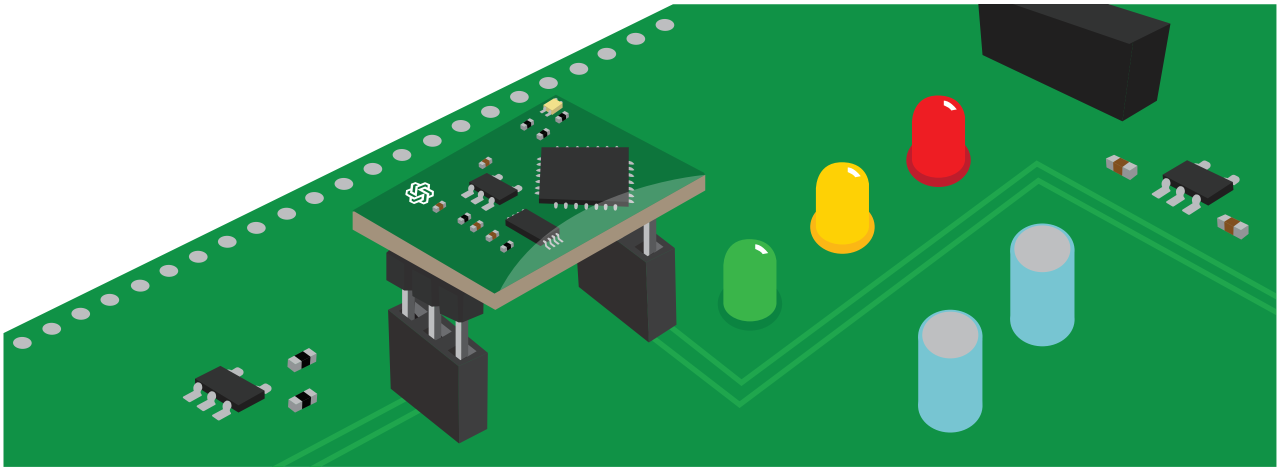
These are example readings; there is no way to predict how the readings will change over time.

AtlasScientific Environmental Robotics

Soldering

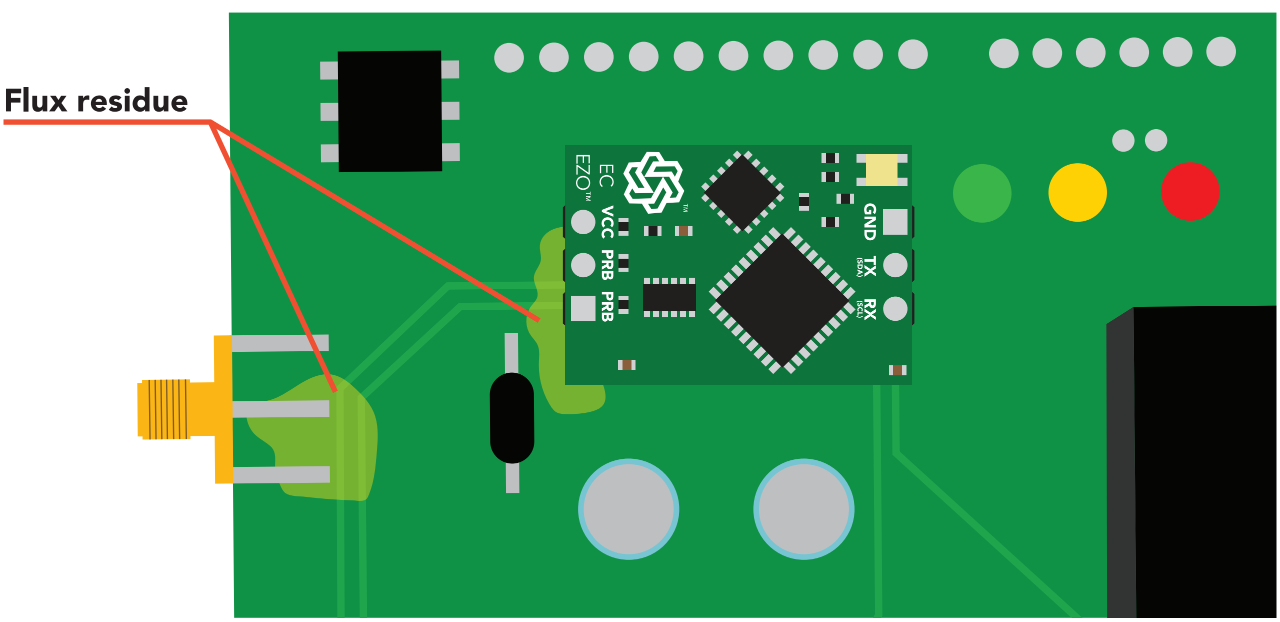
Do not directly solder an EZO circuit to your PCB. If something goes wrong during the soldering process it may become impossible to correct the problem. It is simply not worth the risk.

Instead, solder female header pins to your PCB and place the EZO device in the female headers.



Avoid using rosin core solder.
Use as little flux as possible.

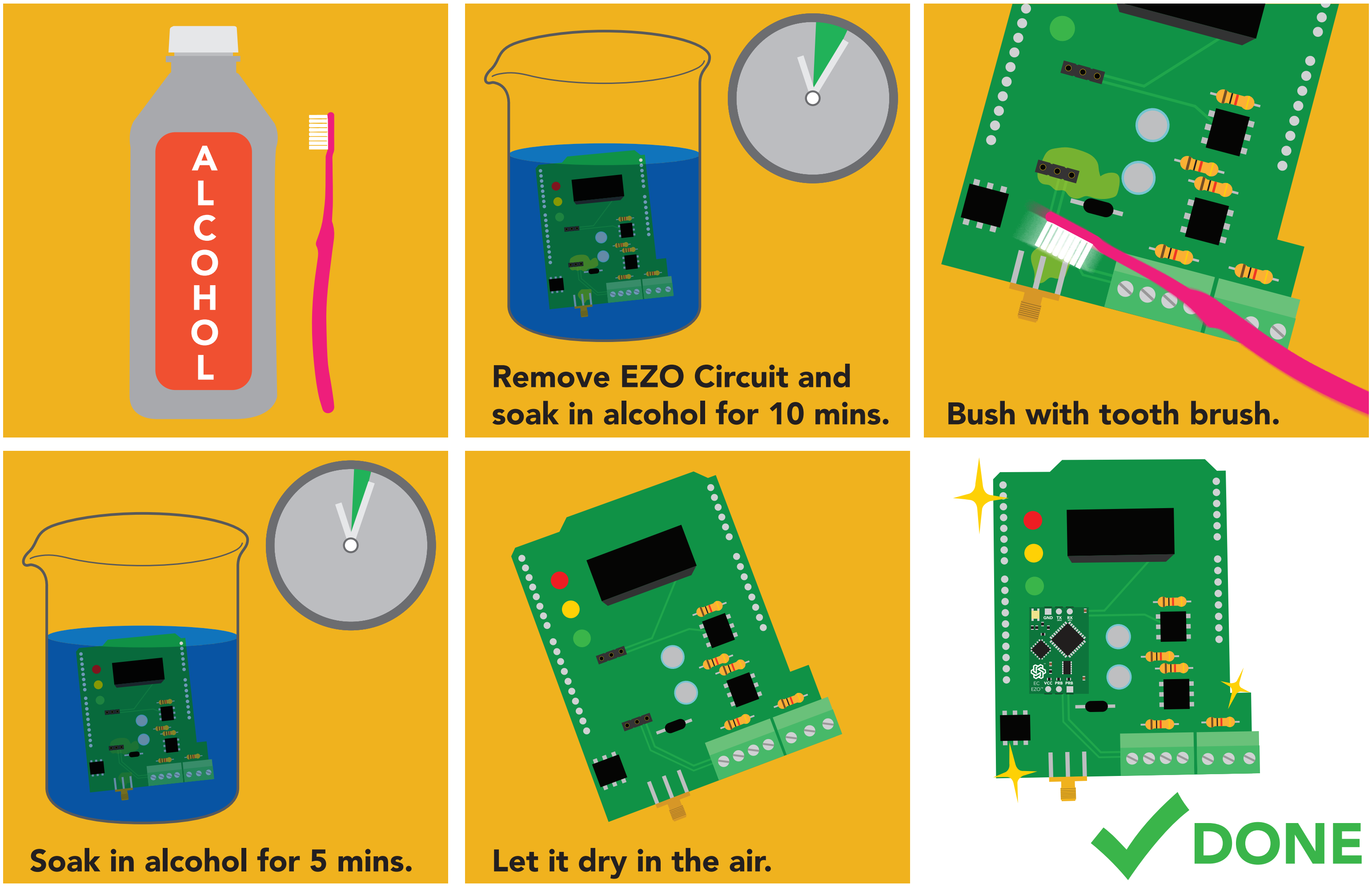
Flux residue will severely affect your readings. Any Flux residue that comes in contact with the PRB pins or your probes connector will cause a “flux short”.



You ***MUST*** remove all the flux residue from your PCB after soldering.

Soldering

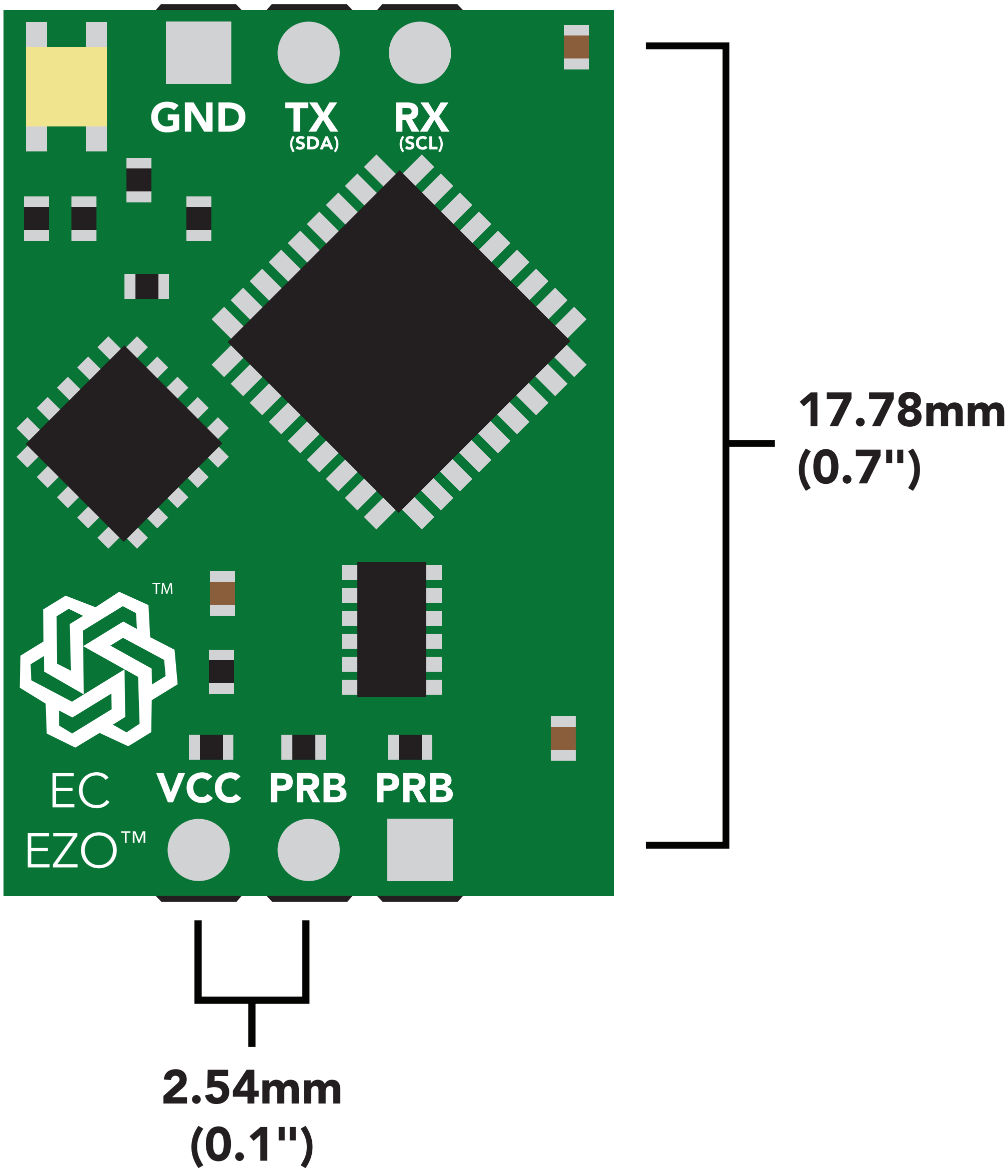
Removing flux residue can be done with commercially available products such as flux off or you can use alcohol and a tooth brush.



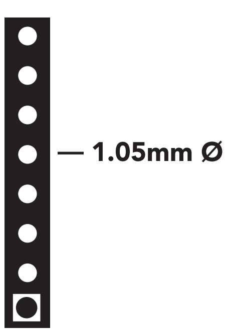
What does a flux short look like?

Readings move slowly and take serval minutes to reach the correct value.

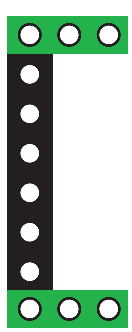
EZO™ circuit footprint



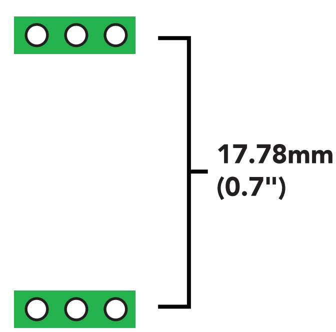
1 In your CAD software, place a 8 position header.



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 6.5

Revised calibration theroy on pages 65 - 70.

Datasheet V 6.4

Revised entire document.

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 I^2C 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 micro-controller, 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.