

# EZO™ class embedded electrical conductivity circuit

### v1.6

This is an evolving document  
check back for updates.

## Features

### Reads

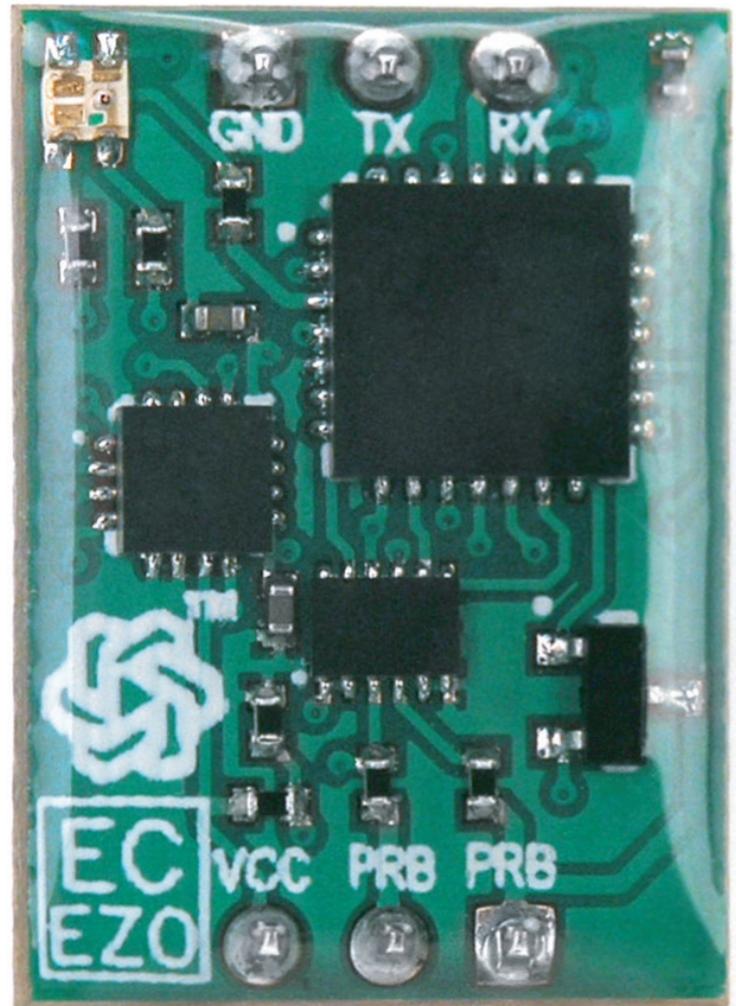
- Conductivity
- Total dissolved solids
- Practical salinity units
- Specific gravity of sea water
  
- E.C. readings +/- 2  $\mu\text{s}/\text{cm}$
- Full E.C. range from 0.55  $\mu\text{s}/\text{cm}$  to 500,000+  $\mu\text{s}/\text{cm}$
- Temperature dependent or temperature independent readings
- Flexible calibration protocol supports single point or dual point calibration
- Calibrate to any E.C. value

### Two data protocols

- UART asynchronous serial connectivity (RX/TX voltage swing 0-VCC)
- I2C (default I2C address 0x64)
  
- Operating voltage: 3.3V to 5V
  
- Works with any off-the-shelf two conductor conductivity probe
- Works with any K value from K=0.1 to K=10

### Sleep mode power consumption

- 0.4mA\* at 3.3V



Patent pending



## Description

The Atlas Scientific™ EZO™ class embedded electrical conductivity circuit is our 6th generation embedded electrical conductivity circuit. The EC-EZO™ electrical conductivity circuit can work with any off-the-shelf two conductor conductivity probe from K=0.1 to K=10. This includes any value between K=0.1 and K=10 such as K=0.66 or K=4.78. **This device reads electrical conductivity from an E.C. probe/sensor/electrode. This device does not include an E.C. probe/sensor/electrode.**

## Contents

System overview .....	3
Power consumption .....	4
Pin out .....	5
Device operation .....	6
Conductivity probe range .....	7
Resolution .....	8
Calibration theory .....	9
Calibartion UART Mode .....	21
Calibartion I <sup>2</sup> C Mode .....	41

## UART Mode

UART command quick reference ...	13
L,<1 0 ?> .....	14
C,<1 0 ?> .....	15
R .....	16
K,<nn.nn ?> .....	17
T,<XX.XX ?> .....	18
O, <parameter, (1 0)> .....	19
Cal,<type nnn> .....	21
Name,<nnn ?> .....	23
I .....	24
Response,<1 0 ?> .....	25
Status .....	26
Sleep .....	27
Serial,<nnn> .....	28
X .....	29
I2C,nnn .....	30
Manual switching to I <sup>2</sup> C mode ...	31

Circuit dimensions .....	52
Circuit Footprint .....	53

## I<sup>2</sup>C Mode

I <sup>2</sup> C mode .....	33
Data from a read back event .....	34
I <sup>2</sup> C timing .....	35
I <sup>2</sup> C command quick reference .....	36
L,<1 0 ?> .....	37
R .....	38
K,<nn.nn ?> .....	39
T,<XX.XX ?> .....	40
Cal,<type nnn> .....	41
O, <parameter, (1 0)> .....	44
I .....	46
Status .....	47
Sleep .....	48
Serial,<nnn> .....	49
X .....	50
Manual switching to UART mode ..	51

Wiring diagram .....	54
Warranty information .....	55

## System overview

The EZO<sup>™</sup> class conductivity circuit, is a small footprint computer system that is specifically designed to be used in robotics applications where the embedded systems engineer requires accurate and precise measurements of Electrical Conductivity (EC), Total Dissolved Solids (TDS), Salinity and Specific Gravity (SG) of sea water. It is important to keep in mind that the EZO<sup>™</sup> class conductivity circuit can only be used to take measurements in liquids where the solvent is water.

The EZO<sup>™</sup> class conductivity circuit, is an extremely complex device consisting of multiple layers. The first layer of the device is the conductivity probe driver. A conductivity probe is a passive device that outputs no electrical signal. The EZO<sup>™</sup> class conductivity circuit transmits an alternating current square wave at varying frequencies. The varying frequencies (23.81 Hz to 41.27 KHz) of the alternating current square wave is absolutely critical to accurately reading the conductivity.

It is important for the embedded systems engineer to keep in mind that the Atlas Scientific<sup>™</sup> EZO<sup>™</sup> class embedded electrical conductivity circuit, is discharging a small electrical current into the water when actively taking a reading. This small current creates an interference field that can be detected by other devices such as a pH probe. This may make other devices inaccurate when the EZO<sup>™</sup> class conductivity circuit is actively taking a reading and for a short time directly after. Because of a wide range of factors that are unique for each implementation of the device, it is not possible for Atlas Scientific to know the size of this interference field. When the device is not taking a reading, no interference field is generated.

The second layer of the EZO<sup>™</sup> class conductivity circuit, is the analog signal processing layer. This layer is also known as the convolution layer. This is where the input signal is combined with the system's functions to find the output signal. Where convolution is mathematically defined as:

$$y(t) = (x * h)(t) = \int_{\{a\}}^{\{b\}} x(\tau)h(t - \tau), d\tau$$

The third layer of the EZO<sup>™</sup> class conductivity circuit, is the operating system and communications layer. In this layer, a master device communicates with the EZO<sup>™</sup> class conductivity circuit, via asynchronous serial communication (UART/RS232 with a voltage swing 0-VCC), or an I<sup>2</sup>C communications protocol.

## Power consumption

	LED	MIN	MAX	STANDBY	SLEEP
<b>5V</b>	ON	22.5 mA	50 mA	18.14 mA	0.7 mA
	OFF	17.5 mA	45 mA	15.64 mA	
<b>3.3V</b>	ON	20 mA	35 mA	16.85 mA	0.4 mA
	OFF	19 mA	34 mA	15.85 mA	

## Absolute maximum ratings\*

Parameter	MIN	TYP	MAX
Storage temperature (EZO <sup>TM</sup> conductivity circuit)	-40 C°		125C°
Operational temperature (EZO <sup>TM</sup> conductivity circuit)	1 C°	25 C°	35C°
VCC	3.3 V	3.3 V	5.5 V

**\*Note:** Stresses above those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. Exposure to maximum rating conditions for extended periods may affect device reliability

## Pin out

**GND** Return for the DC power supply

**Vcc** Operates on 3.3V – 5.5V

**TX / SDA** All EZO™ class circuits can operate in either UART mode or I<sup>2</sup>C mode

The default state is UART mode.

In UART mode, this pin acts as the transmit (TX) line.

The default baud rate is 38400, 8 bits, no parity, no flow control, one stop bit. If standard RS232 voltage levels are desired, connect an RS232 converter such as a MAX232.

If the device is in I<sup>2</sup>C mode, this pin acts as the Serial Data Line (SDA). The I<sup>2</sup>C protocol requires an external pull up resistor on the SDA line (resistor not included).

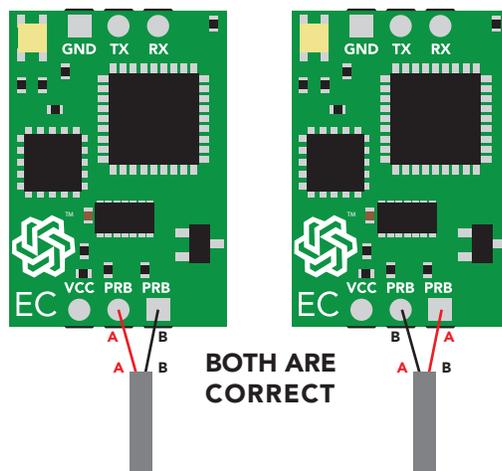
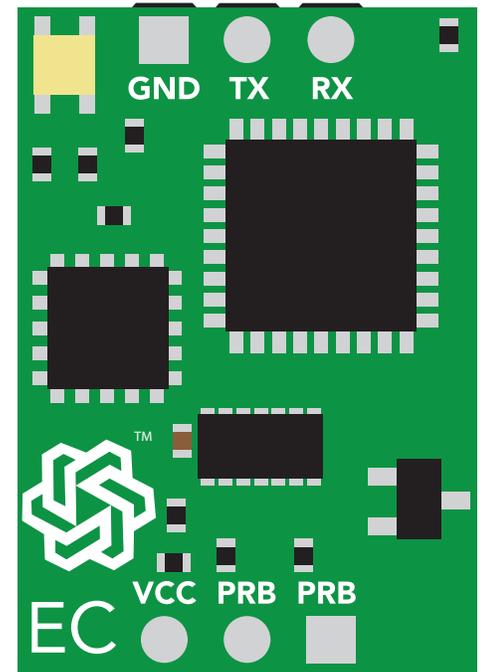
**RX / SCL** All EZO™ class circuits can operate in either UART mode, or I<sup>2</sup>C mode.

The default state is UART mode.

In UART mode, this pin acts as the receive (RX) line.

If the device is in I<sup>2</sup>C mode, this pin acts as the Serial Clock Line (SCL). The I<sup>2</sup>C protocol requires an external pull up resistor on the SCL line (resistor not included).

**PRB** Two pins are marked PRB. These pins are to be connected to an E.C. probe. It makes **no difference** which lead of the E.C. probe is connected to the two probe pins.



## Device operation

When an EZO™ class circuit is first powered up the boot sequence will begin. This is indicated by the LED moving from **Red** to **Green** to **Blue**. The boot up sequence takes 1s. Once the device has booted up the circuit will output:

\*RE<CR>

Indicating the device is ready for operation.

The **green** LED will also stay lit, indicating that the EZO™ class circuit is now operational in its default state.

## Default state

### Mode

UART

### Baud rate

38,400 bps  
8 data bits  
1 stop bit  
no parity  
no flow control

### Reading time

1 reading every second

### Probe type

K=1.0

### LEDs

Enabled

Steady **Green** = Power on/ standby

**Red** double blink = Command received and not understood

**Green** double blink per data packet = Continues data streaming

**Cyan** = taking a reading

### Data output

CSV: EC,TDS,Salinity,SG

Encoding: ASCII characters followed by a carriage return <CR>

Maximum string length: 48 characters

If the response code is enabled the EZO™ class circuit will respond "\*OK<CR>" after a command is acknowledged.

If an unknown command is sent the E.C. Circuit will respond "\*ER<CR>" this will happen whether or not response codes are enabled.

## Conductivity probe range

The Atlas Scientific™ EZO™ class embedded electrical conductivity circuit is capable of connecting to any two conductor conductivity probe from

**K=0.1**  **K=10**

Atlas Scientific™ has tested 3 different K value probe types

**K=0.1**      **accurate reading range**      **0.5  $\mu$ s to 50,000  $\mu$ s**

**K=1.0**      **accurate reading range**      **5  $\mu$ s to 200,000+  $\mu$ s**

**K=10**      **accurate reading range**      **10  $\mu$ s to 1 S**



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, such as a **K=2.6**, or **k=0.66**, is the responsibility of the embedded systems engineer.



## Resolution

The Atlas Scientific™ EZO™ class electrical conductivity circuit, employs a method of scaling resolution. As the conductivity increases the resolution between readings decreases.

The EZO™ class electrical 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.

### Example

1.23  
Resolution = 0.01  $\mu$ s

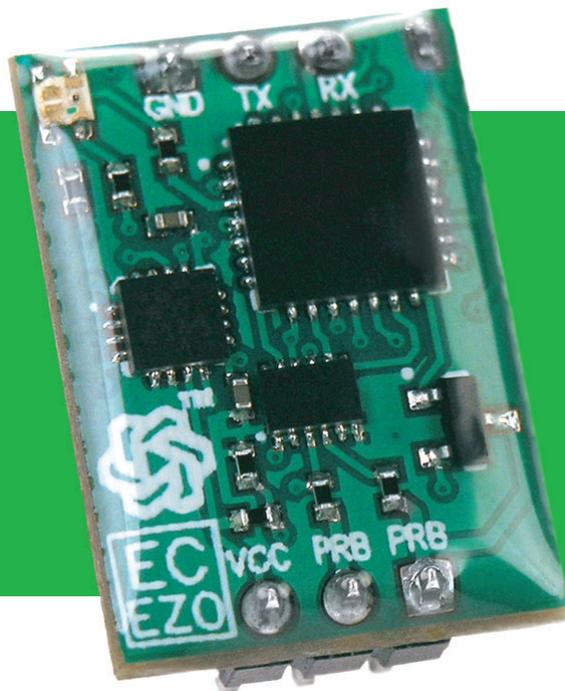
12.34  
Resolution = 0.01  $\mu$ s

123.40  
Resolution = 0.1  $\mu$ s

1,234.00  
Resolution = 1  $\mu$ s

12,340  
Resolution = 10  $\mu$ s

123,400  
Resolution = 100  $\mu$ s



## Calibration theory

The calibration steps should be:

### Two point calibration (Very Accurate)

Dry calibration  
Low point Calibration  
High point Calibration

### Single point calibration (Accurate)

Dry calibration  
Point calibration

**This device has no set calibration values.  
It can be calibrated to any value.**

The Atlas Scientific™ EZO™ class embedded electrical conductivity circuit, offers a flexible calibration protocol that can be used to best suit your intended operation. If the intended use is in a solution that will remain relatively constant, a single point calibration can be used. The accurate range will not be as wide in comparison to a two point calibration.

### Examples of single point calibration

Dry calibration must always be done.  
When performing dry calibration, the probe must be dry.  
Even a few drops of water on the probe will affect the calibration.

#### Monitoring of sea water

A single point calibration to a 50,000 $\mu$ s solution would provide highly accurate readings for any sea water; natural or manmade and in any ocean around the world.

#### Monitoring of drinking water

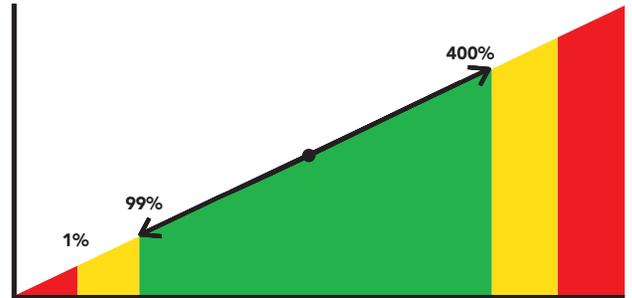
A single point calibration to 84 $\mu$ s, can be used to monitor drinking water.

**To Calibrate the EZO™ Conductivity Circuit in UART Mode please go to page 21.**

**To Calibrate the EZO™ Conductivity Circuit in I<sup>2</sup>C Mode please go to page 41.**

### Single point calibration range

With a single point calibration, the accurate range starts at 1% of the calibrated value, to 400% above the calibrated value.



### Example (using K=1.0 probe)

calibrate to	84 $\mu\text{s}$	1440 $\mu\text{s}$	12880 $\mu\text{s}$
1%	Min: 8.4 $\mu\text{s}$	Min: 14.4 $\mu\text{s}$	Min: 128.80 $\mu\text{s}$
400%	Max: 336 $\mu\text{s}$	Max: 5760 $\mu\text{s}$	Max: 51520 $\mu\text{s}$

A two point calibration can be used to monitor the conductivity of water over a wide range. The two calibration points are a low point calibration, and a high point calibration. Because the Atlas Scientific™ EZO™ class embedded electrical conductivity circuit, can use any probe type from K=0.1 to K=10 there is no set calibration solution to use. It is only necessary that two calibration points be sufficiently apart between one another. The low point calibration should be ~ 10-15% above the lowest point that will be read, and the high point calibration should be ~ 15-20% below the highest point.

### Example

A K=1.0 probe can read from 5  $\mu\text{s}$  to 200,000+  $\mu\text{s}$   
 To get it to read from 5  $\mu\text{s}$  to ~ 100,000  $\mu\text{s}$

1. Dry calibrate

When performing dry calibration the probe must be dry.  
 Even a few drops of water on the probe will affect the calibration.

2. Low calibrate to 12,880 $\mu\text{s}$
3. High calibrate to 80,000 $\mu\text{s}$

When performing a two point calibration you will not see any changes to the E.C. reading after calibrating against the low point.

### Tested two point calibrations

#### K=0.1

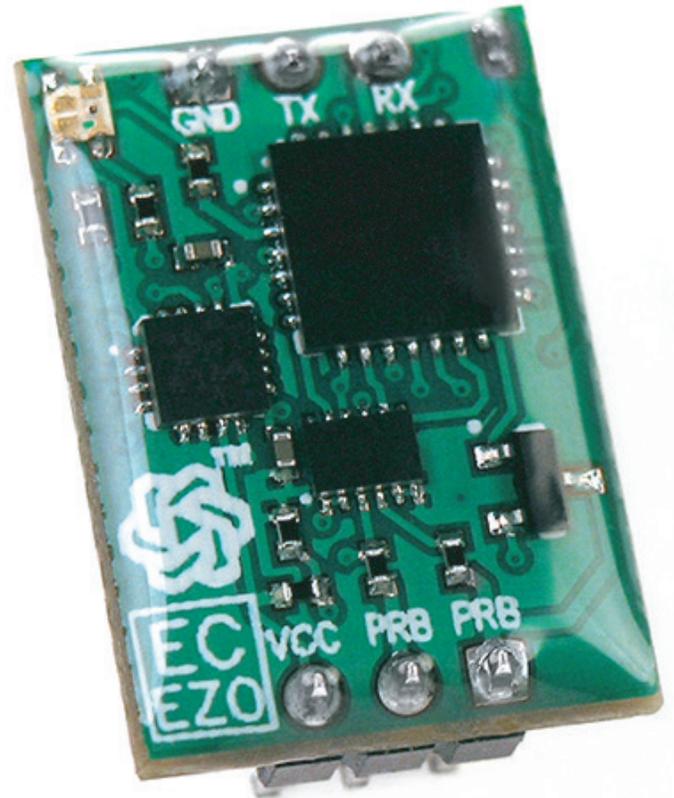
Low point = 84  $\mu\text{s}$   
 High point = 1,413  $\mu\text{s}$   
 Range: 0.5  $\mu\text{s}$  to 50,000+  $\mu\text{s}$

#### K=1.0

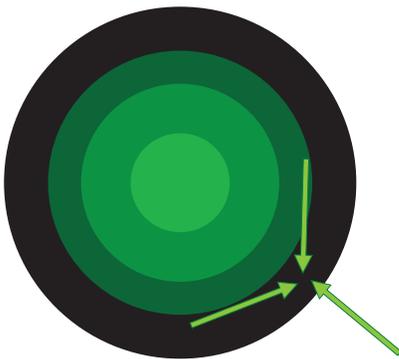
Low point = 12,880  $\mu\text{s}$   
 High point = 80,000  $\mu\text{s}$   
 Range: 5  $\mu\text{s}$  to 100,000+  $\mu\text{s}$

#### K=10

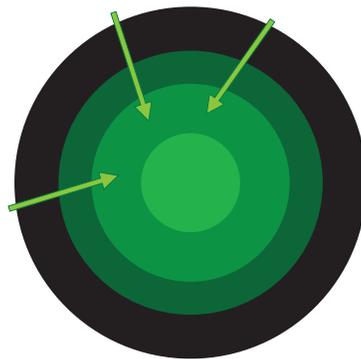
Low point = 12,880  $\mu\text{s}$   
 High point = 150,000  $\mu\text{s}$   
 Range: 10  $\mu\text{s}$  to 300,000+  $\mu\text{s}$



Proper calibration will lead to high accuracy/high precision readings.



**Low accuracy  
but high precision**



**Higher accuracy  
but low precision**



**High accuracy and  
high precision**

# UART Mode



# UART mode command quick reference

There are a total of 15 different commands that can be given to the EZO™ class conductivity circuit.

**All commands are ASCII strings or single ASCII characters**

Command	Function	Default state
C,<1 0 ?>	Enable / Disable or Query continuous readings (pg.15)	Enabled
Cal,<type,nnn>	Performs calibration (pg.21)	User must calibrate
I	Device information (pg.24)	N/A
I2C,<nnn>	Sets the I <sup>2</sup> C ID number (pg.30)	Not set
K,<nn.nn ?>	Set or Query the probe K constant (pg.17)	K=1.0
L,<1 0 ?>	Enable / Disable or Query the LEDs (pg.14)	LEDs Enabled
Name,<nnn ?>	Set or Query the name of the device (pg.23)	Not set
O, <parameter>,<1 0>	Enable / Disable or Query parts of the output string (pg.19)	All Enabled
R	Returns a single reading (pg.16)	N/A
Response,<1 0 ?>	Enable / Disable or Query response code (pg.25)	Enabled
Serial,<nnn>	Set the baud rate (pg.28)	38400
Sleep	Enter low power sleep mode (pg.27)	N/A
Status	Retrieve status information (pg.26)	N/A
T,<XX.XX ?>	Set or Query the temperature compensation (pg.18)	25°C
X	Factory reset (pg.29)	N/A

# UART command definitions

<CR> represents carriage return (ASCII 13). The user does not transmit the literal string "<CR>". Commands are not case sensitive.

## LED control

All EZO<sup>™</sup> class circuits have a tri color LED used to indicate device operation.

UART mode LED color definitions:

Steady **Green** = Power on/ standby

**Red** double blink = Command received and not understood

**Green** blink = Data transmission sent

**Cyan** = taking a reading

### Command syntax

L,1<CR> LED enable  
 L,0<CR> LED disable  
 L,?<CR> Query the LED

### Device response

L,1

(If the response code is enabled, the EZO<sup>™</sup> class circuit will respond "\*OK<CR>")  
 The LED will be enabled and the green power on/ standby LED will turn on.

L,0

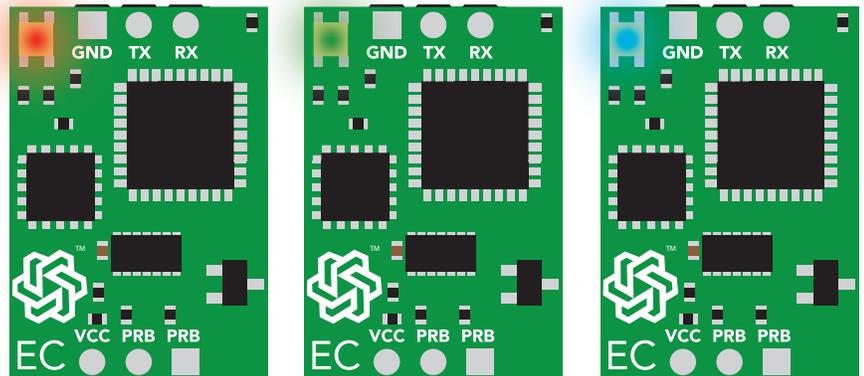
(If the response code is enabled, the EZO<sup>™</sup> class circuit will respond "\*OK<CR>")  
 The LED will be disabled.

L,?

(If the response code is enabled, the EZO<sup>™</sup> class circuit will respond "\*OK<CR>")

?L,1<CR> if the LED is enabled

?L,0<CR> if the LED is disabled



**<CR> represents carriage return (ASCII 13). The user does not transmit the literal string "<CR>".  
Commands are not case sensitive.**

## Continuous reading mode

All EZO™ class circuits are capable of continuous mode operation. In continuous mode the device will output its readings, one after the other continuously until the continuous mode disable command has been issued. All EZO™ class circuits are defaulted to operate in continuous mode. If the LEDs are enabled, each time a data transmission occurs the green LED will blink.

### Command syntax

C,1<CR>    continuous mode enable  
C,0<CR>    continuous mode disable  
C,?<CR>    query continuous mode

### Device response

C,1

(If the response code is enabled the EZO™ class circuit will respond "\*OK<CR>")

The EZO™ class E.C. circuit will output a CSV string containing all measured values once per second.

EC,TDS,SAL,SG<CR> (1 second)

EC,TDS,SAL,SG<CR> (2 seconds)

EC,TDS,SAL,SG<CR> (n\* seconds)

C,0

(If the response code is enabled the EZO™ class circuit will respond "\*OK<CR>")

Continuous data transmission will cease.

C,?

(If the response code is enabled the EZO™ class circuit will respond "\*OK<CR>")

?C,1<CR> if continuous mode is enable.

?C,0<CR> if continuous mode is disabled.

**<CR> represents carriage return (ASCII 13). The user does not transmit the literal string "<CR>".  
Commands are not case sensitive.**

## Single reading mode

All EZO™ class circuits are capable of taking a single reading upon request. If the LEDs are enabled each time a data transmission occurs the green LED will blink.

### Command syntax

R<CR> Returns a single reading

### Device response

(If the response code is enabled, the EZO™ class circuit will respond "\*OK<CR>")

The EZO™ class conductivity circuit, will output a single CSV string containing all enabled values 1 second after the command was issued.

EC,TDS,SAL,SG<CR> (1 second)

**<CR> represents carriage return (ASCII 13). The user does not transmit the literal string "<CR>".  
Commands are not case sensitive.**

## Setting the probe type

The Atlas Scientific EZO™ class conductivity circuit can read electrical conductivity, total dissolved solids, salinity and the specific gravity of sea water, using any off the shelf two conductor conductivity probe. The K value can range from K=0.1 to K=10. This includes any K value between K=0.1, to K=10. The default value is set to K=1.0.

### Command syntax

K,[floating point K value in ASCII]<CR>	Sets the K value of the E.C. probe
K,<CR>	Query the probe type

### Device response

K,0.66<CR>

(If the response code is enabled, the EZO™ class circuit will respond "\*OK<CR>")  
There is no other output associated output with this command.

K,<CR>

(If the response code is enabled, the EZO™ class circuit will respond "\*OK<CR>")  
?K,[floating point K value]<CR> ?K,0.66 <CR>

**<CR> represents carriage return (ASCII 13). The user does not transmit the literal string "<CR>".  
Commands are not case sensitive.**

## Temperature compensation

In order to achieve the most accurate possible readings, the temperature of the liquid being measured must be transmitted to the EZO™ class conductivity circuit. The embedded systems engineer must keep in mind that the EZO™ class conductivity circuit, cannot read the temperature from a conductivity probe or from a temperature probe. Another device must be used to read the temperature. The EZO™ class conductivity circuit, has its default temperature set at 25°C. The temperature at which to compensate against can be changed at any time using the "T" command.

### Temperature is always in Celsius

#### Command syntax

(Using an example temperature 19.5)

T,19.5<CR>	Where the temperature is any value; floating point or int, in ASCII form
T,?<CR>	Query the set temperature

#### Device response

T,19.5<CR>  
(If the response code is enabled, the EZO™ class circuit will respond "\*OK<CR>")  
There is no other output associated output with this command.

T,?<CR>  
(If the response code is enabled, the EZO™ class circuit will respond "\*OK<CR>")  
?T,19.5

<CR> represents carriage return (ASCII 13). The user does not transmit the literal string "<CR>".  
Commands are not case sensitive.

## Removing parameters from the output string

The Atlas Scientific™ EZO™ class circuit will output a CSV string, containing all parameters by default.

### Example

```
EC,TDS,Salinity,SG<CR>
```

Using the "O" command, you are able to control what parameters are output from the EZO™ class circuit. **You are not able to control the order.**

### Command syntax

```
O,[parameter],[1,0]<CR>    Enable or disable an output parameter  
O,?<CR>                    Query the enabled outputs
```

Where parameter is

EC	electrical conductivity
TDS	Total dissolved solids
S	Salinity
SG	Specific gravity of sea water

Followed by a 1 or a 0

Where: 1= enabled  
0= disabled

### Example

```
O,SG,0<CR>
```

This will disable the specific gravity output

**<CR> represents carriage return (ASCII 13). The user does not transmit the literal string "<CR>".  
Commands are not case sensitive.**

To enable an output

### Example

O,SG,1<CR>

This will enable the specific gravity output

### Device response

O,SG,1<CR>

(If the response code is enabled, the EZO™ class circuit will respond "\*OK<CR>")

There is no other output associated with this command

O,?<CR>

(If the response code is enabled, the EZO™ class circuit will respond "\*OK<CR>")

?O,EC,TDS,S,SG

(If all are enabled)

<CR> represents carriage return (ASCII 13). The user does not transmit the literal string "<CR>".  
Commands are not case sensitive.

## Calibration

The EZO™ class E.C. circuit can be calibrated using a single point, or dual point calibration. **Dry calibration must always be done first.** In dual point calibration, first calibrate to the low end value (there will be no change to the E.C. after low point calibration) then calibrate to the high end value. If single point calibration has been done and two point calibration is desired, clear the previous calibration data using the Cal,clear command.

### Command syntax

Cal,clear<CR>	Clears all calibration data
Cal,dry<CR>	<b>This command must always be given first when calibrating. Be sure the probe is dry</b>
Cal,one,n<CR>	Single point calibration, where n is any E.C. value. After issuing this command calibration is complete
Cal,low,n<CR>	Dual point calibration to the lower end, where n is any E.C. <b>After entering in the command the E.C. value will not change.</b>
Cal,high,n<CR>	Dual point calibration to the high end, where n is any E.C.
Cal,? <CR>	Query the calibration

**<CR> represents carriage return (ASCII 13). The user does not transmit the literal string "<CR>".  
Commands are not case sensitive.**

### Device response

Cal,clear<CR>

(If the response code is enabled, the EZO™ class circuit will respond "\*OK<CR>")

There is no other output associated with this command.

Cal,dry<CR>

(If the response code is enabled, the EZO™ class circuit will respond "\*OK<CR>")

The LED will turn cyan during the calibration.

Cal,one,n<CR>

(If the response code is enabled, the EZO™ class circuit will respond "\*OK<CR>")

The LED will turn cyan during the calibration.

Cal,low,n<CR>

(If the response code is enabled, the EZO™ class circuit will respond "\*OK<CR>")

The LED will turn cyan during the calibration.

The read E.C. values will not change until high calibration has been done.

Cal,high,n<CR>

(If the response code is enabled, the EZO™ class circuit will respond "\*OK<CR>")

The LED will turn cyan during the calibration.

Cal,?

(If the response code is enabled, the EZO™ class circuit will respond "\*OK<CR>")

If not calibrated:                   ?CAL,0

If single point calibration:       ?CAL,1

If dual point calibration:         ?CAL,2

**<CR> represents carriage return (ASCII 13). The user does not transmit the literal string "<CR>".  
Commands are not case sensitive.**

## Device identification

All EZO™ class circuits are capable of being assigned a name. This is a simple way to identify the device in a system that consists of multiple EZO™ class circuits. A name can consist of any combination of ASCII character, with a length of 1 to 16 characters long, *no blank spaces*.

### Command syntax

NAME,nnn<CR>      Sets the device name, where nnn is the given name.  
NAME,?<CR>        Query the device name

### Device response

NAME,DEVICE\_1<CR>

(If the response code is enabled, the EZO™ class circuit will respond "\*OK<CR>")  
There is no other output associated output with this command.

NAME,?<CR>

(If the response code is enabled, the EZO™ class circuit will respond "\*OK<CR>")  
?NAME, DEVICE\_1<CR>

**<CR> represents carriage return (ASCII 13). The user does not transmit the literal string "<CR>".  
Commands are not case sensitive.**

## Device information

The EZO™ class circuit can identify itself by device type and firmware version. This is done by transmitting the "I" command.

### Command syntax

I<CR>          Device information

### Device response

?I,EC,1.0

(If the response code is enabled, the EZO™ class circuit will respond "\*OK<CR>")

**<CR> represents carriage return (ASCII 13). The user does not transmit the literal string "<CR>". Commands are not case sensitive.**

## Response codes

The Atlas Scientific EZO™ class circuits, have 7 response codes to help the user understand how the device is operating, and to aid in the construction of a state machine to control the EZO™ class circuit. All EZO™ class devices indicate a response code has been triggered, by transmitting a string with the prefix "\*" and ending with a carriage return <CR>.

### A list of response codes

<b>*ER</b>	An unknown command has been sent	<b>*RE</b>	The circuit has completed boot up
<b>*OV</b>	The circuit is being overvolted ( $VCC \geq 5.5V$ )	<b>*SL</b>	The circuit has been put to sleep
<b>*UV</b>	The circuit is being undervolted ( $VCC \leq 3.1V$ )	<b>*WA</b>	The circuit has woken up from sleep
<b>*RS</b>	The circuit has reset		

Only the response code "\*OK" can be disabled.  
Disabling this response code is done using the "response" command.

### Command syntax

RESPONSE,1<CR>	Enable response code (default)
RESPONSE,0<CR>	Disable response code (default)
RESPONSE,?<CR>	Query the response code(default)

### Device response

RESPONSE,1<CR>  
EZO™ class circuit will respond "\*OK<CR>"

RESPONSE,0<CR>  
There is no response to this command

RESPONSE,?

?RESPONSE,1<CR> If the response code is enabled  
?RESPONSE,0<CR> If the response code is disabled

**<CR> represents carriage return (ASCII 13). The user does not transmit the literal string "<CR>".  
Commands are not case sensitive.**

## Reading the status of the device

The Atlas Scientific™ EZO™ class circuit is able to report its voltage at the VCC pin and the reason the device was last restarted.

### Restart codes

P power on reset  
S software reset  
B brown out reset  
W watchdog reset  
U unknown

### Command syntax

STATUS<CR>

### Device response

?STATUS,P,5.038<CR>

(If the response code is enabled, the EZO™ class circuit will respond "\*OK<CR>")

Where: P is the reason for the last reset event

Where: 5.038 is the its voltage at the VCC

<CR> represents carriage return (ASCII 13). The user does not transmit the literal string "<CR>".  
Commands are not case sensitive.

## Low power state

To conserve energy in between readings, the Atlas Scientific™ EZO™ class circuit, can be put into a low power sleep state. This will turn off the LEDs and shut down almost all of the internal workings of the EZO™ class circuit. The power consumption will be reduced to 1.18 mA at 5V and 0.72 mA at 3.3V. **To wake the EZO™ class circuit, send it any character.**

### Command syntax

SLEEP<CR>      Enter low power sleep state

### Device response

(If the response code is enabled the EZO™ class circuit will respond "\*OK<CR>")  
\*SL<CR>

Device response upon wake up:  
\*WA<CR>

<CR> represents carriage return (ASCII 13). The user does not transmit the literal string "<CR>".  
Commands are not case sensitive.

## Change baud rate

The Atlas Scientific EZO™ class circuit, has 8 possible baud rates it can operate at.  
The default baud rate is

**38400 bps**  
**8 data bits**  
**1 stop bit**  
**no parity**  
**no flow control**

**Data bits, stop bits, parity and flow control are fixed and cannot be changed.**

1. 300 bps
2. 1200 bps
3. 2400 bps
4. 9600 bps
5. 19200 bps
6. 38400 bps
7. 57600 bps
8. 115200 bps

### Command syntax

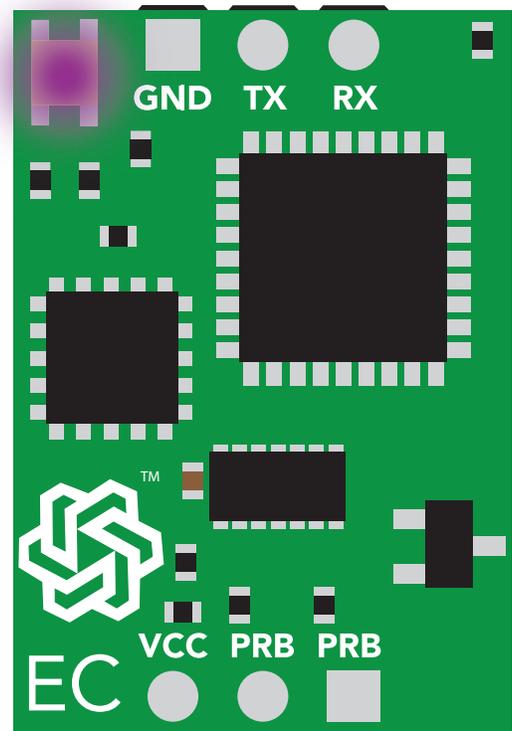
(Using an example baud rate of 9600)

SERIAL,9600<CR>

### Device response

(If the response code is enabled the EZO™ class circuit will respond "\*OK<CR>") The EZO™ class circuit will respond with a **Purple** LED double blink.

The LED blink will happen even if the LEDs are disabled.



**<CR> represents carriage return (ASCII 13). The user does not transmit the literal string "<CR>".  
Commands are not case sensitive.**

## Factory reset

All EZO™ class circuits, are capable of resetting themselves to the original factory settings. Issuing a factory reset will:

- Reset the calibration back to factory default
- Reset probe type to K=1.0
- Reset default temperature to 25°C
- Set debugging LED to on.
- Enable response codes

**This command will not change the set baud rate.**

### Command syntax

X<CR>      Factory reset

### Device response

(If the response code is enabled, the EZO™ class circuit will respond "\*OK<CR>")

The EZO™ class circuit, will respond: \*RE<CR>

<CR> represents carriage return (ASCII 13). The user does not transmit the literal string "<CR>".  
Commands are not case sensitive.

## Switch from UART mode to I<sup>2</sup>C mode

Transmitting the command I2C,[n] will set the EZO™ class circuit into I<sup>2</sup>C mode from UART mode. **Where [n] represents any number from 1-127.** The I<sup>2</sup>C address is sent in decimal ASCII form. Do not send the address in hexadecimal ASCII form.

### Command syntax

(Using an example an I<sup>2</sup>C ID number of 100)

I2C[100]<CR>

### Device response

If an address >127 is given

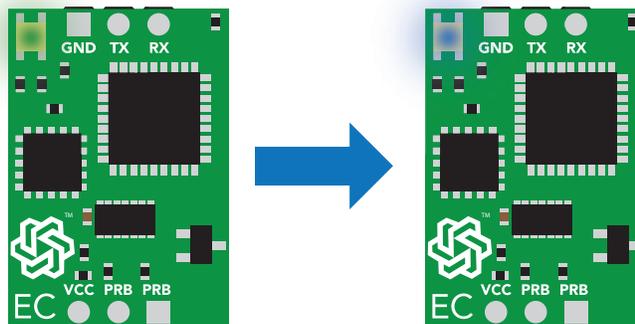
\*ER            Indicating an error has occurred.

If an address >0 and <128 is given

(If the response code is enabled the EZO™ class circuit will respond "\*OK<CR>")

\*RS<CR>        The device will restart in I<sup>2</sup>C mode.

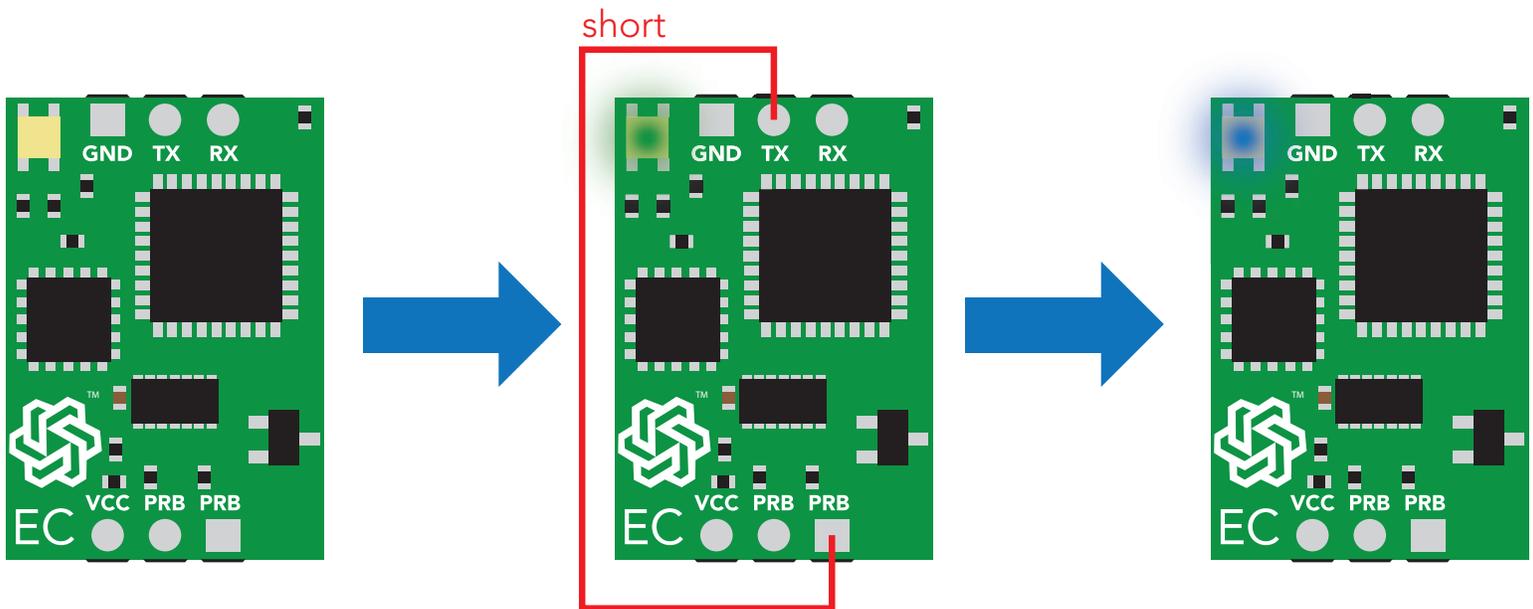
The **green** LED used to indicate that the device is powered and awaiting an instruction will now change to **blue**.



## Manual switching to I<sup>2</sup>C mode

All EZO™ class circuits can be manually switched from UART mode, to I<sup>2</sup>C mode.  
**If this is done the EZO™ class conductivity circuit, will set its I<sup>2</sup>C address to 0XEC.**

1. Cut the power to the device
2. Short the right probe pin to the TX pin
3. Power the device
4. Wait for LED to change from **green** to **blue**
5. Remove the short from the probe pin to the TX pin
6. Power cycle the device
7. The device is now I<sup>2</sup>C mode



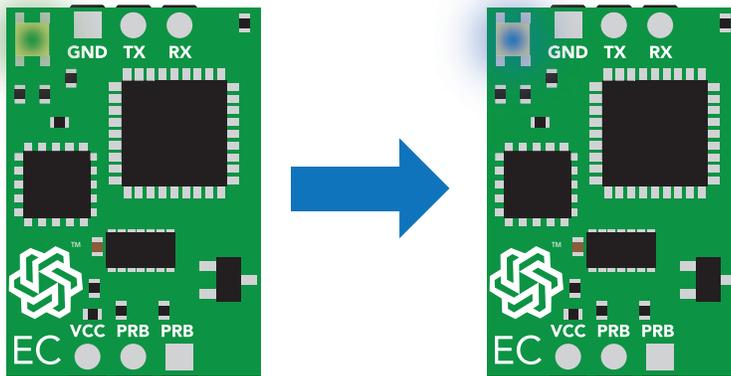
# I<sup>2</sup>C Mode



## I<sup>2</sup>C mode

An I<sup>2</sup>C address can be any number from 1-127. If the EZO™ Class Conductivity circuit was put into I<sup>2</sup>C mode by jumping PRB to TX, the I<sup>2</sup>C address is 100(0x64).

Once an EZO™ class device has been put into I<sup>2</sup>C mode the green power LED that was used in UART mode will now switch to a **blue** LED. This indicates the device is now in I<sup>2</sup>C mode.



The I<sup>2</sup>C protocol is considerably more complex than the UART (RS-232) protocol. Atlas Scientific assumes that the embedded systems engineer understands this protocol.

Communication to the EZO™ class device is controlled by the master. The EZO™ class device is an I<sup>2</sup>C slave. The slave device is not able to initiate any data transmissions.

### An I<sup>2</sup>C write event is defined as such



In order to get the response from the device, it is necessary to initiate a read command. The I<sup>2</sup>C protocol does not permit the slave device to initiate any data transmissions.

### An I<sup>2</sup>C read event is defined as such



## Data from a read back event

The first byte of the data read back, is the response code. This byte informs the master of the status of the data about to be read back. For all commands, the first byte of the read data is the response code, which is defined as

Value	Meaning
255	<b>No Data</b> – there is no pending request, so there is no data to return from the circuit
254	<b>Pending</b> – the request is still being processed. Ensure that you have waited the minimum time to guarantee a response
2	<b>Failed</b> – the request failed
1	<b>Success</b> – the requested information is ready for transmit. There may be more bytes following this which are returned data.

The bytes transmitted after that, will be the requested data. When all the data has been transmitted each additional byte will be a NULL.

### Example

A read request when no command has been given.



All I<sup>2</sup>C mode responses are in ASCII format however, they do not terminate with a <CR> rather, they terminate with a NULL. The Null termination makes data manipulation easier once it has been received.

### Example

EZO™ class device responds to a request for a reading

12.3 ≠ float	12.3 = byte[5]	
	<b>byte[0] = 1</b>	(decimal 1)
	<b>byte[0] = "1"</b>	(ASCII 49)
	<b>byte[1] = "2"</b>	(ASCII 50)
	<b>byte[2] = "."</b>	(ASCII 46)
	<b>byte[3] = "3"</b>	(ASCII 51)
	<b>byte[4] = NUL</b>	(ASCII 0)

## I<sup>2</sup>C timing

When a command is issued to the EZO™ class device, a certain amount of time must be allowed to pass before the data is ready to be read. Each command specifies the delay needed before the data can be read back. EZO™ class devices do not support I<sup>2</sup>C clock stretching. All commands are sent to the EZO™ class device in the same ASCII format as in UART mode however, there is no <CR> sent at the end of the transmission.

## I<sup>2</sup>C command quick reference

There are a total of 11 different commands that can be given to the EZO™ class conductivity circuit.

Command	Function
Cal,<type>,<nnn>	Performs calibration ( <a href="#">pg.41</a> )
I	Device information ( <a href="#">pg.46</a> )
K,<nn.nn ?>	Set or Query the probe K constant ( <a href="#">pg.39</a> )
L,<1 0 ?>	Enable / Disable or Query the LEDs ( <a href="#">pg.37</a> )
O,<parameter>,<1 0>	Enable / Disable or Query parts of the output string ( <a href="#">pg.44</a> )
R	Returns a single reading ( <a href="#">pg.38</a> )
Serial,<nnn>	Switch back to UART mode ( <a href="#">pg.49</a> )
Sleep	Enter low power sleep mode ( <a href="#">pg.48</a> )
Status	Retrieve status information ( <a href="#">pg.47</a> )
T,<XX.XX ?>	Set or Query the temperature compensation ( <a href="#">pg.40</a> )
X	Factory reset ( <a href="#">pg.50</a> )

## I<sup>2</sup>C LED control

All EZO™ class circuits have a tri color LED used to indicate device operation.

I2C mode LED color definitions:

Steady **Blue**= Power on/ standby

**Red** double blink = Command received and not understood

**Blue** blink=Data transmission sent

**Cyan**= taking a reading

### Command syntax

- L,1<CR> LED enable
- L,0<CR> LED disable
- L,?<CR> Query the LED

### Device response

L,1

The LED will be enabled and the blue power on/ standby LED turn on. After 300ms an I<sup>2</sup>C read command can be issued to get the response code. A decimal 2 would indicate the command has been successfully processed.



L,0

The Led will be disabled. After 300ms, an I<sup>2</sup>C read command can be issued to get the response code. A decimal 2 would indicate the command has been successfully processed.



L,?

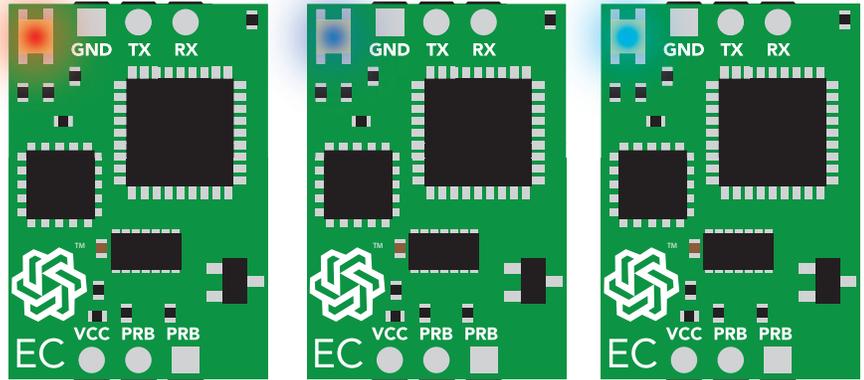
After 300ms, an I<sup>2</sup>C read command can be issued to get the response code.



if the LED is enabled



if the LED is disabled



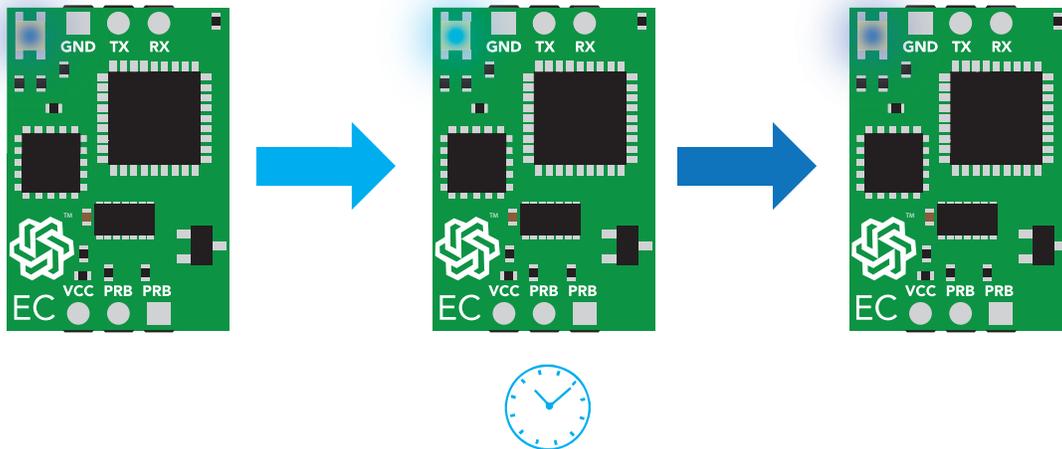
## I<sup>2</sup>C Take reading

When a reading is taken, the LED (if enabled) will turn **cyan**, indicating that a reading is being taken. Once the reading has been taken, the LED will turn back to **blue**.

### Command syntax

R Returns a single reading

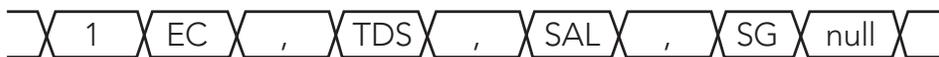
Time until instruction is processed: 1 Second



1 Second time has passed

### Device response

After 1 second, an I<sup>2</sup>C read command can be issued, to get the response.



Each parameter represents many bytes.

The string will be no longer than 32 bytes.

## I<sup>2</sup>C Setting the probe type

The Atlas Scientific™ E.C. EZO™ class circuit, can read electrical conductivity, total dissolved solids, salinity and the specific gravity of sea water, using any off the shelf, two conductor conductivity probe. The K value can range from K=0.1, to K=10. This includes any K value between K=0.1 and K=10. The default value is set to K=1.0.

### Command syntax

K,[floating point K value in ASCII]                      Sets the K value of the E.C. probe  
 K,?    Query the probe type

Time until instruction is processed 300ms

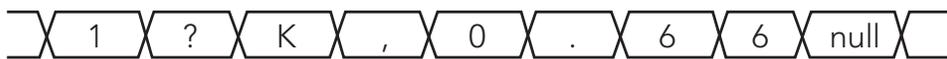
### Device response

After 300ms an I<sup>2</sup>C read command can be issued, to get the response:  
 A decimal 1 would indicate the command has been successfully processed.



K,?

After 300ms an I<sup>2</sup>C read command can be issued, to get the response  
 ?,K,[floating point K value]



?K,0.66

## I<sup>2</sup>C Temperature compensation

In order to achieve the most accurate possible readings, the temperature of the liquid being measured must be transmitted to the EZO™ class conductivity circuit. The embedded systems engineer must keep in mind that the EZO™ class conductivity circuit, cannot read the temperature from a conductivity probe, or from a temperature probe. Another device must be used to read the temperature. EZO™ class conductivity circuit, has its default temperature set at 25°C. The temperature, at which to compensate against, can be changed at any time using the "T" command.

### Temperature is always in Celsius

#### Command syntax

(Using an example temperature 19.5)

T,19.5      Where the temperature is any value; floating point or int, in ASCII form  
 T,?          Query the set temperature

Time until instruction is processed: 300ms

#### Device response

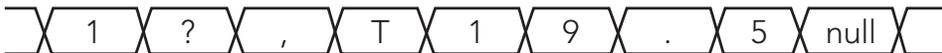
T,19.5

After 300ms, an I<sup>2</sup>C read command can be issued to get the response code. A decimal 1, would indicate the command has been successfully processed.



T,?

After 300ms, an I<sup>2</sup>C read command can be issued to get the response



?T,19.5

## I<sup>2</sup>C Calibration

The EZO™ class, conductivity circuit, can be calibrated using a single point or dual point calibration. **Dry calibration must always be done first.** In dual point calibration first calibrate to the low end value (there will be no change to the E.C. after low point calibration) then calibrate to the high end value. If single point calibration has been done and two point calibration is desired, clear the previous calibration data, using the Cal,clear command.

### Command syntax

Cal,clear                      Clears all calibration data

Time until instruction is processed: 300ms

Cal,dry                        **This command must always be given first when calibrating.  
Be sure the probe is dry**

Time until instruction is processed: 1.3s

Cal,one,n                    Single point calibration, where n is any E.C. value.  
After issuing this command, calibration is complete.

Time until instruction is processed: 1.3s

Cal,low,n                    Dual point calibration to the lower end, where n is any E.C.  
**After entering in the command, the E.C. value will not change.**

Time until instruction is processed: 1.3s

Cal,high,n                    Dual point calibration to the high end, where n is any E.C.

Time until instruction is processed: 1.3s

Cal,?                        Query the calibration

Time until instruction is processed: 300ms

### Device response

Cal,clear

After 300 ms, an I<sup>2</sup>C read command can be issued to get the response code:  
A decimal 1, would indicate the command has been successfully processed.



There is no other output associated output with this command.

Cal,dry

After 1.3s, an I<sup>2</sup>C read command can be issued to get the response code:  
A decimal 1, would indicate the command has been successfully processed.



The LED will turn cyan during the calibration.

Cal,one,n

After 1.3s, an I<sup>2</sup>C read command can be issued to get the response code:  
A decimal 1, would indicate the command has been successfully processed.



The LED will turn cyan during the calibration.

Cal,low,n

After 1.3s, an I<sup>2</sup>C read command can be issued to get the response code:  
A decimal 1, would indicate the command has been successfully processed.



The read E.C. values will not change, until high calibration has been done.  
The LED will turn cyan during the calibration.

Cal,high,n

After 1.3s, an I<sup>2</sup>C read command can be issued to get the response code:  
A decimal 1, would indicate the command has been successfully processed.



The LED will turn cyan during the calibration.

Cal,?

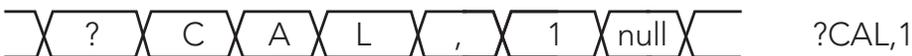
After 300ms an I<sup>2</sup>C read command can be issued, to get the response code:  
A decimal 1, would indicate the command has been successfully processed.



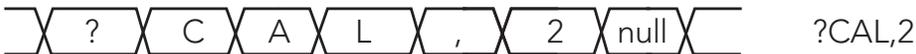
If not calibrated



If single point calibration



If dual point calibration



## Removing parameters from the I2C output string

The Atlas Scientific™ EZO™ class circuit, will output a CSV string, containing all parameters by default.

### Example

```
EC,TDS,Salinity,SG<null>
```

Using the “O” command, you are able to control what parameters are output from the EZO™ class circuit. **You are not able to control the order.**

### Command syntax

O,[parameter], [1,0]	Enable or disable an output parameter
O,?<CR>	Query the enabled outputs

Where parameter is

EC	electrical conductivity
TDS	Total dissolved solids
S	Salinity
SG	Specific gravity of sea water

Followed by a 1 or a 0

Where: 1= enabled  
0= disabled

### Example

```
O,SG,0  
This will disable the specific gravity output
```

To enable an output

### Example

O,SG,1

This will enable the specific gravity output

### Device response

O,SG,1

After 300ms, an I<sup>2</sup>C read command can be issued to get the response code. A decimal 1, would indicate the command has been successfully processed.



O,?

After 300ms, an I2C read command can be issued to get the response



?O,EC,TDS,S,SG

(If all are enabled)

## I<sup>2</sup>C Device information

The EZO™ class circuit, can identify itself by device type and firmware version. This is done by transmitting the “I” command.

### Command syntax

I                    Device information

Time until instruction is processed 300ms

### Device response

After 300ms, an I<sup>2</sup>C read command can be issued to get the response



?I,EC,1.0

# Reading the status of the device in I2C mode

The Atlas Scientific™ EZO™ class circuit is able to report its voltage at the VCC pin and the reason the device was last restarted.

## Restart codes

- P power on reset
- S software reset
- B brown out reset
- W watchdog reset
- U unknown

## Command syntax

STATUS

Time until instruction is processed: 300ms

## Device response

After 300ms, an I<sup>2</sup>C read command can be issued, to get the response

```
? S T A T U S , P , 5 . 0 3 8 null
```

?STATUS,P,5.038

Where: P is the reason for the last reset event

Where: 5.038 is the its voltage at the VCC

## I<sup>2</sup>C Low power state

To conserve energy in between readings, the Atlas Scientific™ EZO™ class circuit can be put into a low power sleep state. This will turn off the LEDs and shut down almost all of the internal workings of the EZO™ class circuit. The power consumption will be reduced to 0.7 mA at 5V and 0.4 mA at 3.3V. **To wake the EZO™ class circuit send it any command.**

### Command syntax

SLEEP            Enter low power sleep state

Time until instruction is processed 300ms

### Device response

If the LEDs are enabled, the **blue** LED will blink and then turn off.  
There is no other output associated with this command.

## Switch from I<sup>2</sup>C mode to UART mode

Transmitting the command serial,<n> will set the EZO<sup>TM</sup> class circuit into UART mode from I<sup>2</sup>C mode. **Where [n] represents any of one the 8 available baud rates.**

### Command syntax

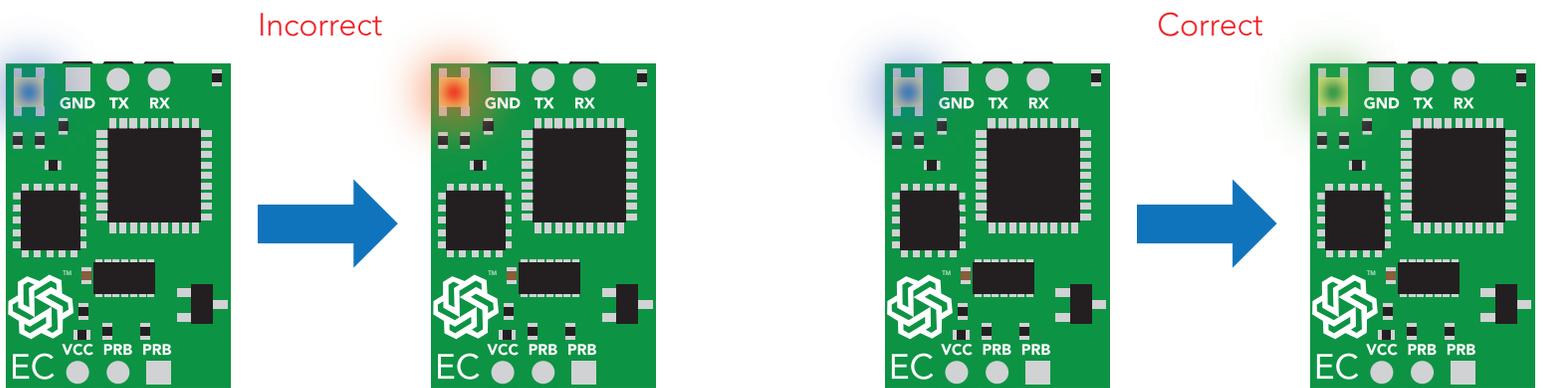
(Using an example an baud rate of 9600)

```
SERIAL,9600
```

### Device response

If an incorrect baud rate is sent the device will not switch into UART mode and the **red** LED will flash.

If a correct baud rate is given:  
The **blue** LED used to indicate that the device is powered and awaiting an instruction will now change to **green**.



## Factory reset

All EZO™ class circuits, are capable of resetting themselves to the original factory settings. Issuing a factory reset will:

- Reset the calibration back to factory default
- Reset probe type to K=1.0
- Reset default temperature to 25°C
- Set debugging LED to on.
- Enable response codes

**This command will not change the set baud rate.**

### Command syntax

X            Factory reset

### Device response

After 300ms, the STATUS command can be issued to see that the device was reset.

?	S	T	A	T	U	S	,	S	,	5	.	0	3	8	null
---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	------

?STATUS,S,5.038

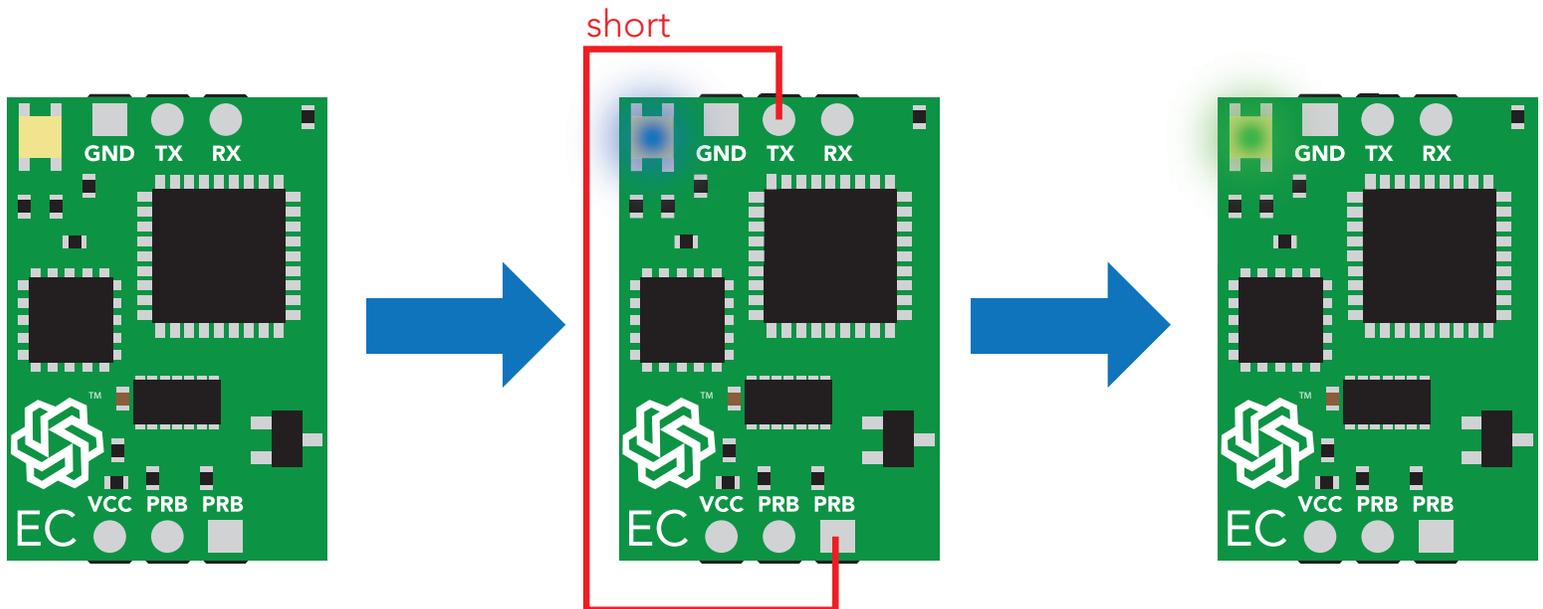
Where: S is the reason for the last reset event (software reset)

Where: 5.038 is the its voltage at the VCC

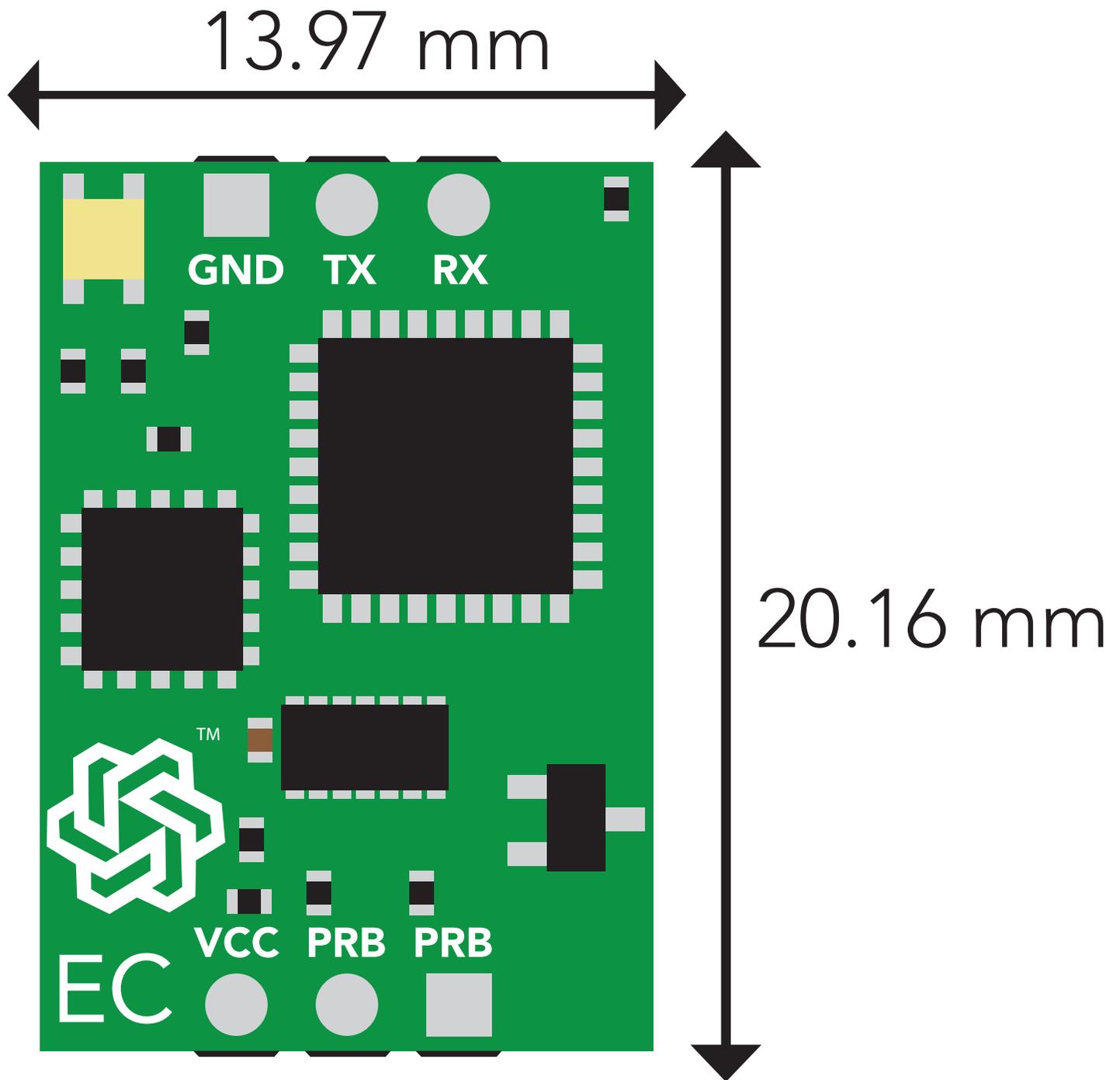
## Manual switching to UART mode

All EZO™ class circuits, can be manually switched from I<sup>2</sup>C mode to UART mode.  
**If this is done, the EZO™ class conductivity circuit, will set its baud rate to 38400.**

1. Cut the power to the device
2. Short the right probe pin to the TX pin
3. Power the device
4. Wait for LED to change from **blue** to **green**
5. Remove the short from the probe pin to the TX pin
6. Power cycle the device
7. The device is now UART mode



## Circuit dimensions

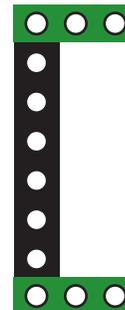


# How to make a footprint for the Atlas Scientific™ EZO™ conductivity circuit

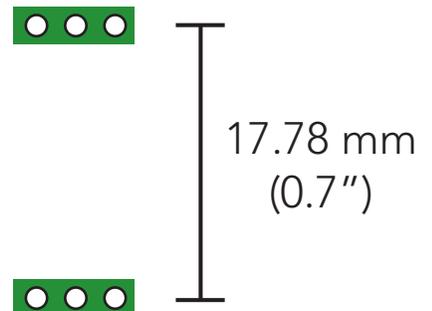
1. In your CAD software place an 8 position header.



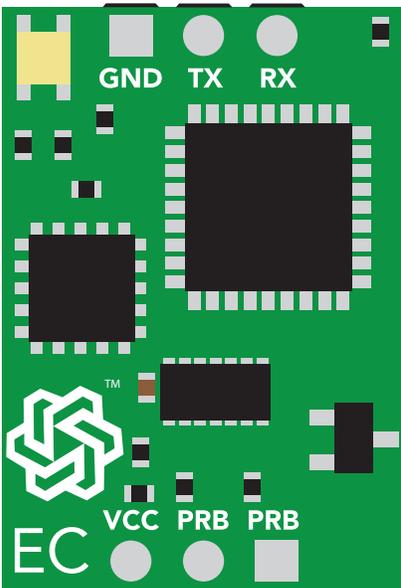
2. Place a 3 position header at both top and bottom of the 8 position header as shown.



3. Once this is done, you can delete the 8 position header. Make sure that the two 3 position headers are 17.78mm (0.7") apart from each other.



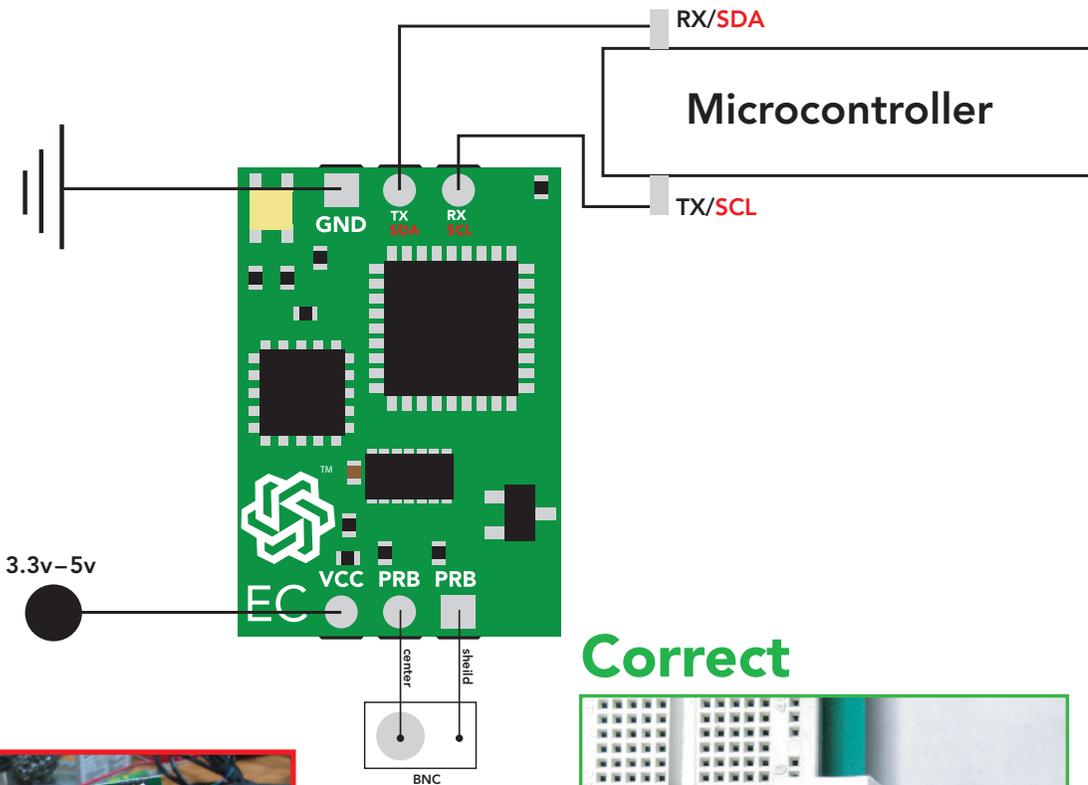
2.54 mm (0.1")



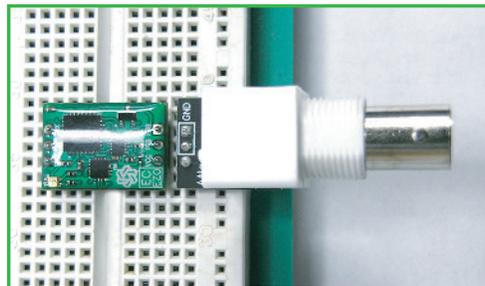
17.78 mm  
(0.7")

## Wiring diagram

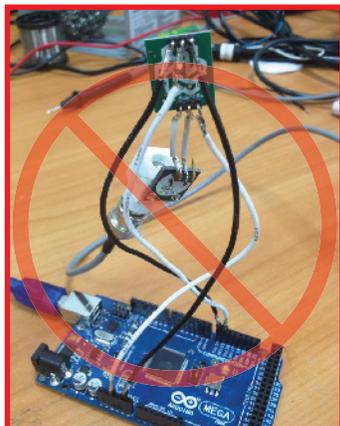
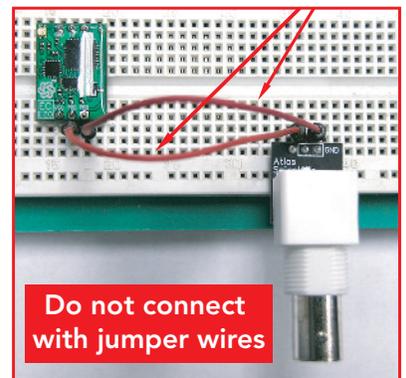
- To connect the Circuit to your microcontroller, follow the diagram below.
- The BNC shield can be connected to any ground line.
- Make sure your Circuit and microcontroller share a common ground.
- TX on your Circuit connects to RX on your microcontroller.
- *If in I<sup>2</sup>C mode connect SDA to SDA and SCL to SCL*
- *\*4.7k pull up resistor on SDA and SCL may be required*



**Correct**



**Incorrect**



The Atlas Scientific™ EZO™ class conductivity circuit is a piece of sensitive equipment. Debugging should be done in a bread board; Not like what is show in this photo.

## 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, and is connected to a microcontroller according to the wiring diagram on pg. 54. Reference this wiring diagram for a connection to USB debugging device, or if a shield is being used, when it is connected to its carrier board.

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

### **Please keep this in mind:**

- 1. All Atlas Scientific<sup>TM</sup> devices have been designed to be embedded into a custom made system by you, the embedded systems engineer.**
- 2. All Atlas Scientific<sup>TM</sup> devices have been designed to run indefinitely without failure in the field.**
- 3. All Atlas Scientific<sup>TM</sup> devices can be soldered into place, however you do so at your own risk.**

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





TM