Conductivity Circuit

EZO ™

EZO™ class embedded Electrical Conductivity circuit

V 3.4
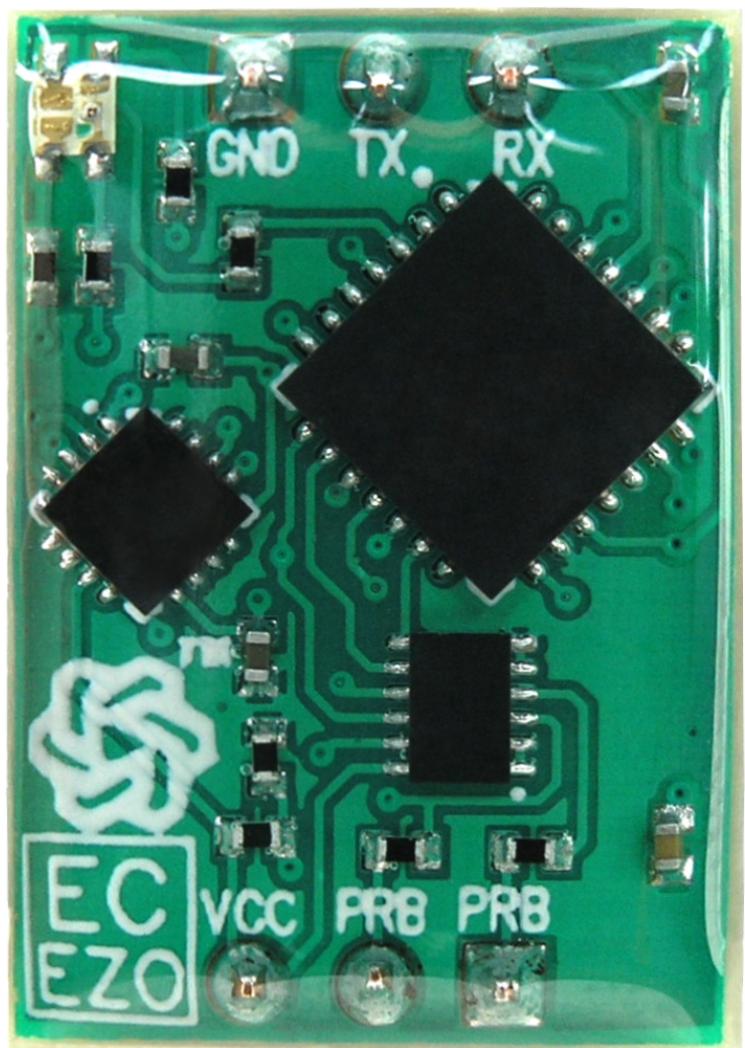This is an evolving document check back for updates.

Features

Reads
- Conductivity
- Total dissolved solids
- Practical salinity units
- Specific gravity of sea water
- Accuracy +/- 2%
- Full E.C. range from 0.07 µs/cm to 500,000+ µs/cm
- Temperature dependent or temperature independent readings
- Flexible calibration protocol supports single point or dual point calibration
- Calibrate to any E.C. value
- Calibration required only once per year
- **Data format is ASCII**

Two data protocols
- UART asynchronous serial connectivity (RX/TX voltage swing 0-VCC)
- I^{2}C (default I^{2}C 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

RoHS

LEAD FREE COMPLIANT

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.

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Environmental Robotics
Conductivity Circuit
EZO ™

STOP

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

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

Atlas**Scientific**™
Environmental Robotics

Conductivity Circuit
EZO™

Contents

UART Mode

I²C Mode

Circuit identification

EZO™ Class Circuit
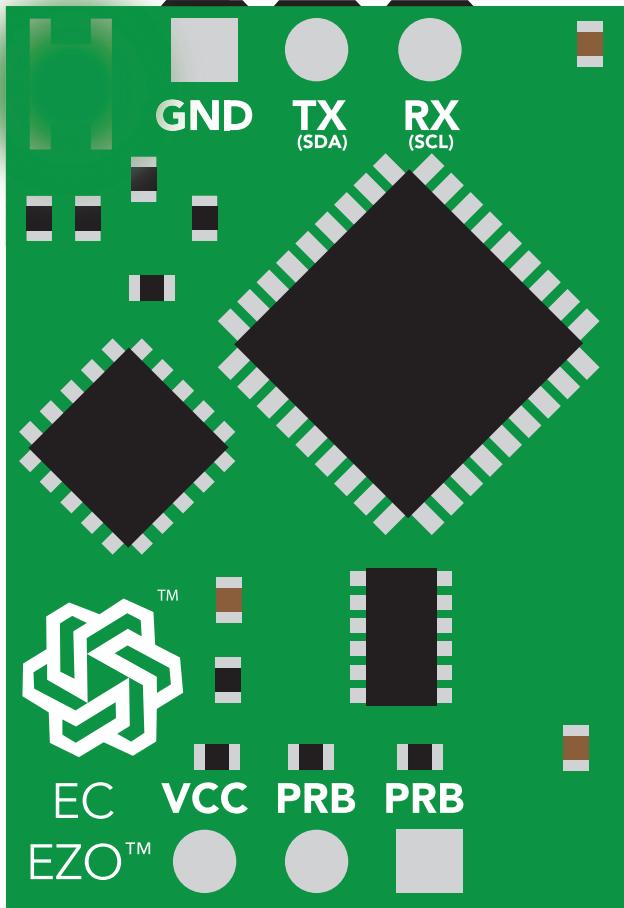
Legacy Circuit

If your Atlas Scientific™ Conductivity Circuit says "EC EZO" you are viewing the correct datasheet.

If your Atlas Scientific™ Conductivity Circuit says "E.C. 2.0, or 3.0" you are viewing the incorrect datasheet. Many functions will not will not work on legacy circuits.
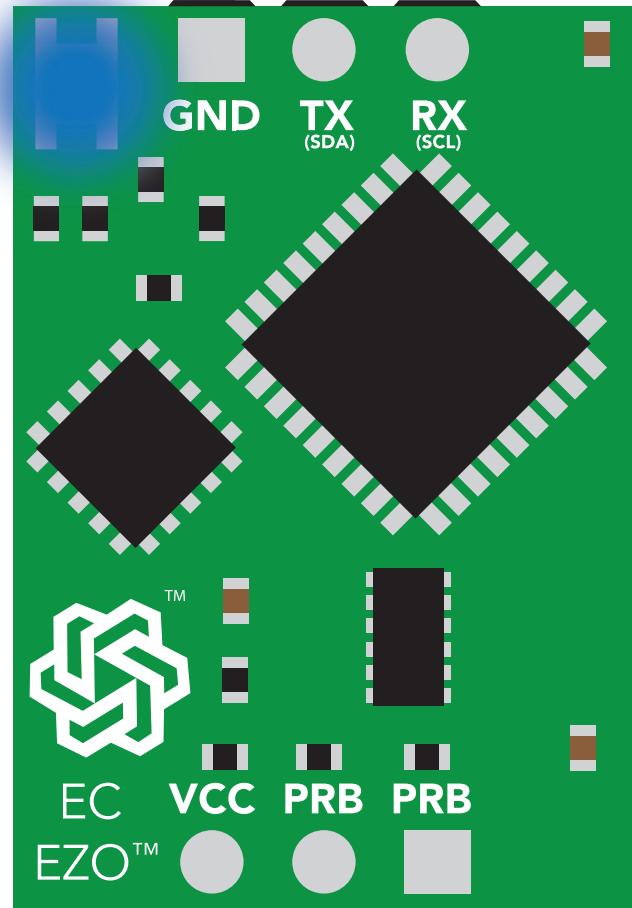
To view the legacy datasheet **click here**.

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AtlasScientific™

Environmental Robotics

Conductivity Circuit
EZO™

UART Mode

I²C Mode

System overview

The EZO™ 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™ class conductivity circuit can only be used to take measurements in liquids where the solvent is water.

The EZO™ 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™ 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™EZO™ class embedded electrical conductivity circuit is discharging a small electrical current into the water. 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. 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. It is best practice to electrically isolate the EZO™ class conductivity circuit from other devices.

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

Power consumption

	LED	MIN	MAX	STANDBY	SLEEP
5V	ON	22.5 mA	50 mA	18.14 mA	0.7 mA
	OFF	17.5 mA	45 mA	15.64 mA	
3.3V	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™ conductivity circuit)	-60 °C		150 °C
Operational temperature (EZO™ conductivity circuit)	-40 °C	25 °C	125 °C
VCC	3.3V	5.0V	5.5V

*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^{2}C mode

The default state is UART mode. In UART mode, this pin acts as the transmit (TX) line. The default baud rate is 9600, 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^{2}C mode, this pin acts as the Serial Data Line (SDA). The I^{2}C protocol requires an external pull up resistor on the SDA line (resistor not included).
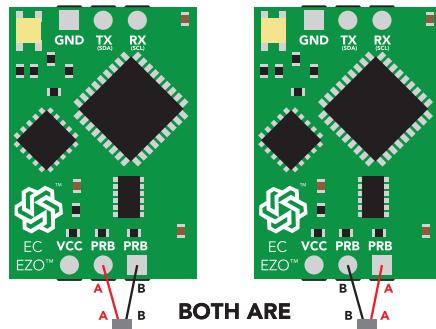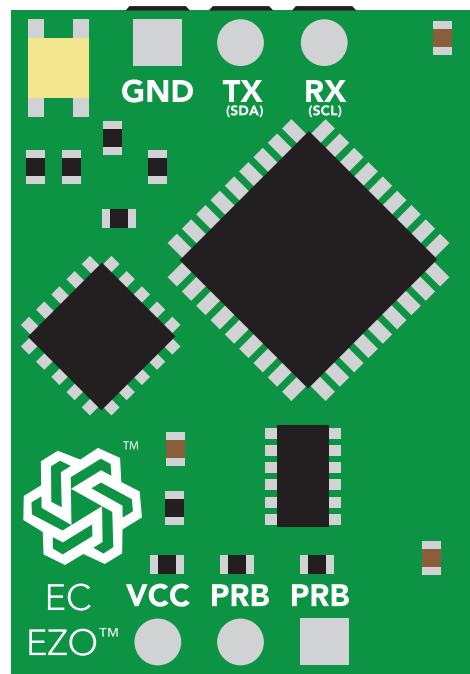
RX / SCL   All EZO™ class circuits can operate in either UART mode, or I^{2}C mode.

The default state is UART mode. In UART mode, this pin acts as the receive (RX) line. If the device is in I^{2}C mode, this pin acts as the Serial Clock Line (SCL). The I^{2}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.

GND TX (SDA) RX (SCL)

EC EZO™ VCC PRB PRB

GND TX (SDA) RX (SCL)
EC EZO™ VCC PRB PRB
A B
A B
BOTH ARE CORRECT

GND TX (SDA) RX (SCL)
EC EZO™ VCC PRB PRB
B A
B A

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 1 second. Once the device has booted up the circuit will output:

*RS<CR>
*RE<CR>
Indicating the device is ready for operation.

The LED will enter its default blink pattern *(see page 10)* indicating the device is operational and actively taking readings.

Default state

Mode
UART

Baud rate
9600 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 blink per data packet = Continues data streaming
Cyan = taking a reading

Data output
Conductivity, Total Dissolved Solids, Salinity, Specific Gravity

Units
E.C. = µS/cm
TDS = mg/L
SAL = PSS–78 (no defined units)
SG = Dimensionless unit

Format
CSV String

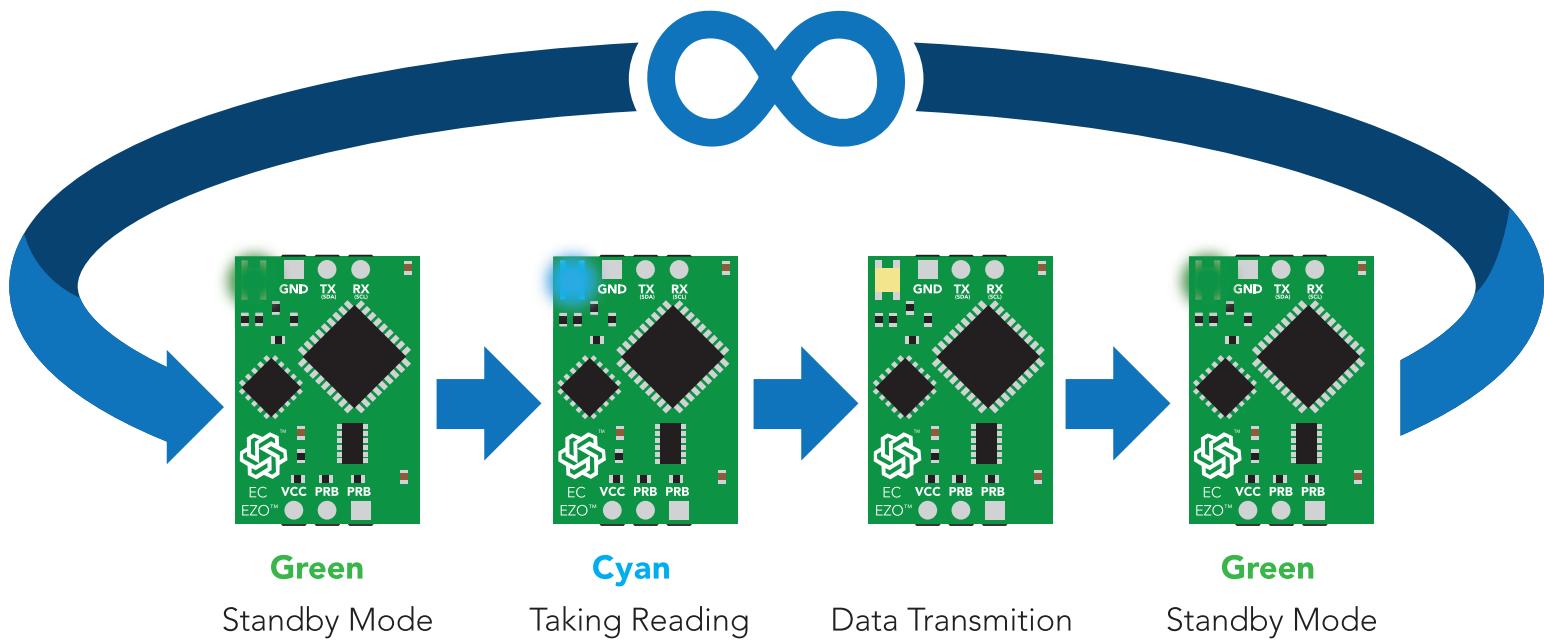**Data Type**
Floating point

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.
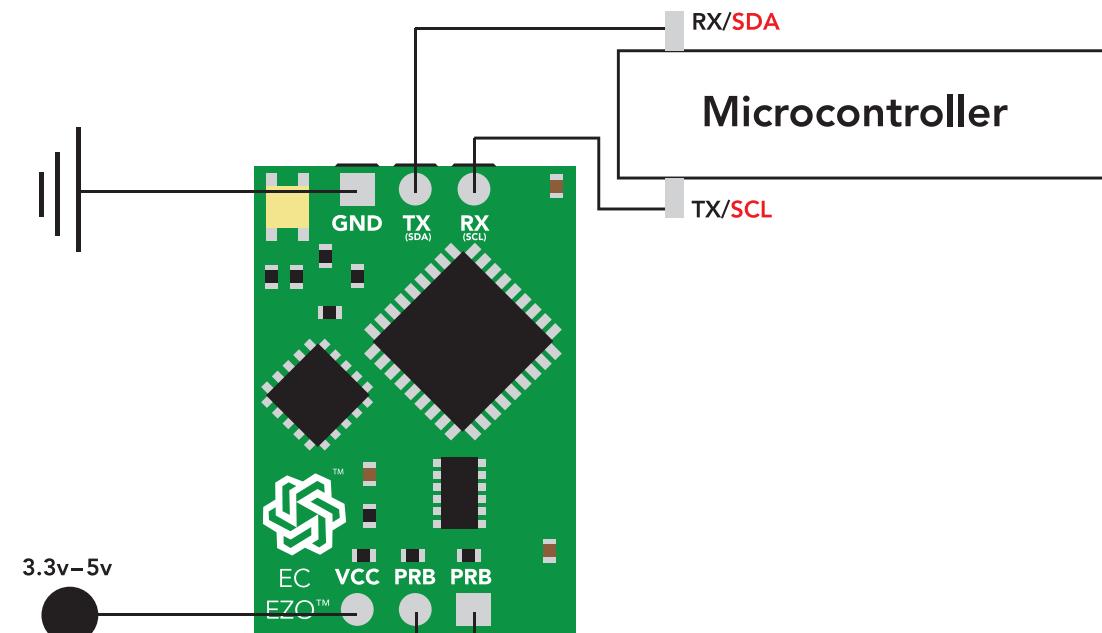
Default LED blink pattern

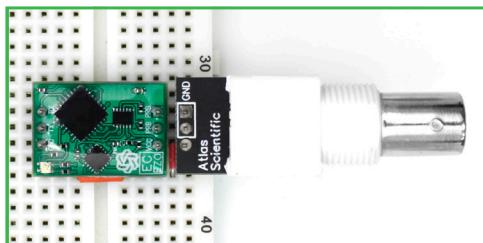| **Green**	**Cyan**		**Green**
Standby Mode	Taking Reading	Data Transmition	Standby Mode

This is the LED pattern for Continous Mode (which is the default state)

Wiring diagram
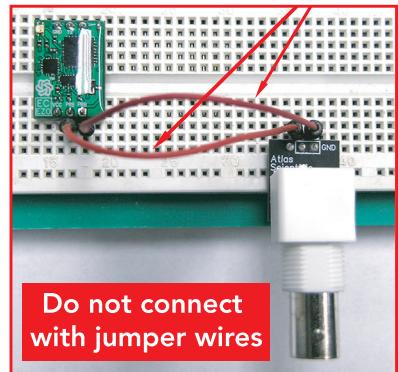
- To connect the Circuit to your microcontroller, follow the diagram below.
- Make sure your Circuit and microcontroller share a common ground.
- TX on your Circuit connects to RX on your microcontroller.
- If in I²C mode connect SDA to SDA and SCL to SCL
- *4.7k pull up resistor on SDA and SCL may be required

RX/SDA

Microcontroller

TX/SCL

GND   TX   RX
       (SDA)   (SCL)

3.3v–5v

EC   VCC PRB PRB
EZO™

center   sheild

BNC

Correct

Incorrect

Do not connect
with jumper wires

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

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	0.07 µS to 50,000 µS
K=1.0	accurate reading range	5 µS to 200,000+ µS
K=10	accurate reading range	10 µS to 1S

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.

0.07 to 99.99
Resolution = **0.01 µS**

100.1 to 999.9
Resolution = **0.1 µS**

1,000 to 9,999
Resolution = **1 µS**

10,000 to 99,990
Resolution = **10 µS**

100,000 to 999,900
Resolution = **100 µS**

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.

Calibration must be done using your indented operational voltage. If the device is calibrated while it is running at 5 volts but embedded into a system using 3.3 volts the device must be recalibrated. Calibration must be done using your intended operational voltage.

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.

Example - *Monitoring of sea water*
A single point calibration to a 50,000µS solution would provide highly accurate readings for any sea water; natural or manmade and in any ocean around the world.

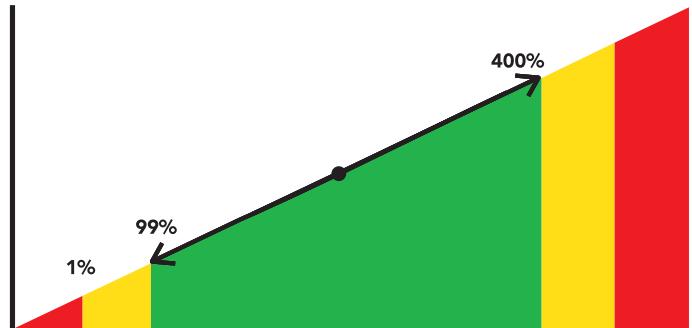**Example** - *Monitoring of drinking water*
A single point calibration to 84µS can be used to monitor drinking water.

**To Calibrate the EZO™ Conductivity Circuit in UART Mode please go to page 24.
To Calibrate the EZO™ Conductivity Circuit in I²C Mode please go to page 44.**

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 µS	1440 µS	12880 µS
1%	Min: 8.4 µS	Min: 14.4 µS	Min: 128.80 µS
400%	Max: 336 µS	Max: 5760 µS	Max: 51520 µS

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 µS to 200,000+ µS
To get it to read from 5 µS to ~ 100,000 µS

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 12,880µS
3. High calibrate to 80,000µS

When performing a two point calibration you will not see any changes to the E.C. reading after calibrating against the low point. Both the high point and the low point calibration must be done for the calibration to take effect.

Tested two point calibrations

K 0.1
Low point = 84 µS
High point = 1,413 µS
Range: 0.5 µS to 50,000+ µS

K 1.0
Low point = 12,880 µS
High point = 80,000 µS
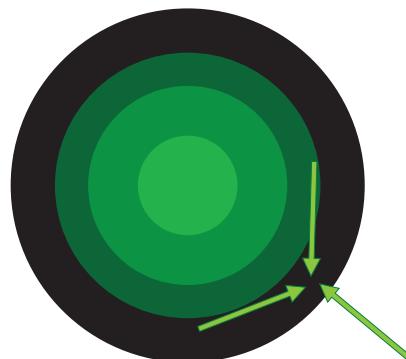Range: 5 µS to 100,000+ µS

K 10
Low point = 12,880 µS
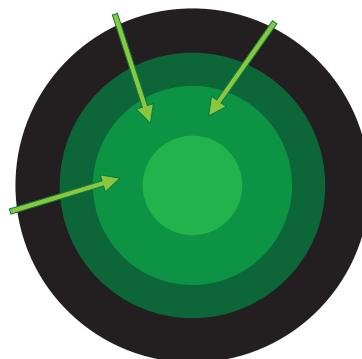High point = 150,000 µS
Range: 10 µS to 300,000+ µS

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

Low accuracy but high precision

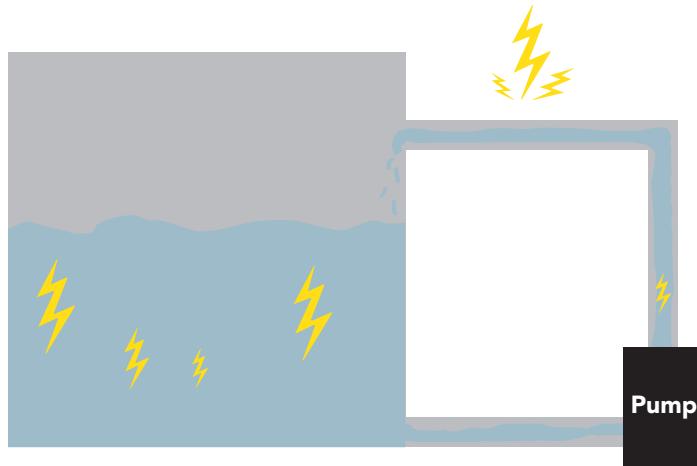**Higher accuracy but low precision**

High accuracy and high precision
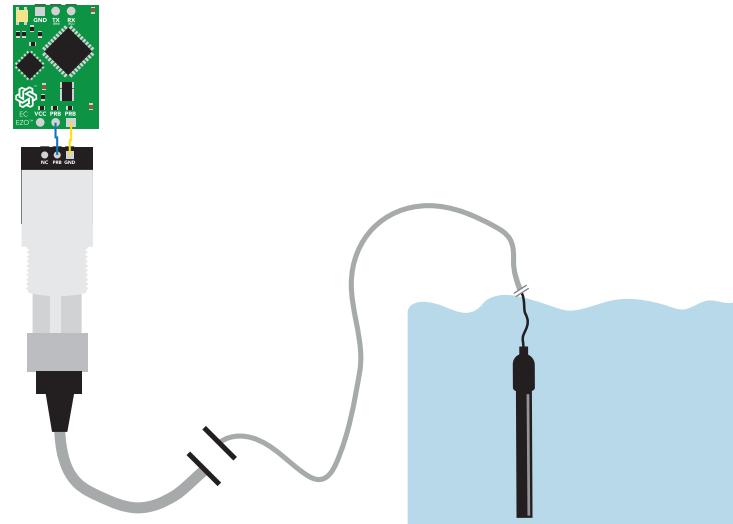
Design considerations

The Atlas Scientific EZO™ Conductivity circuit is a micro-computer system that is specifically designed to be embedded into a larger system. The EZO™ Conductivity circuit is not a completed product. The embedded systems engineer is responsible for building a completed working product.

Power and data isolation

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

Pump

When electrical noise is interfering with the Conductivity readings it is common to see rapidly fluctuating readings or readings that are consistently off. To verify that electrical noise is causing inaccurate readings place the Conductivity probe in a cup of water by itself. The readings should stabilize quickly, confirming that electrical noise was the issue.
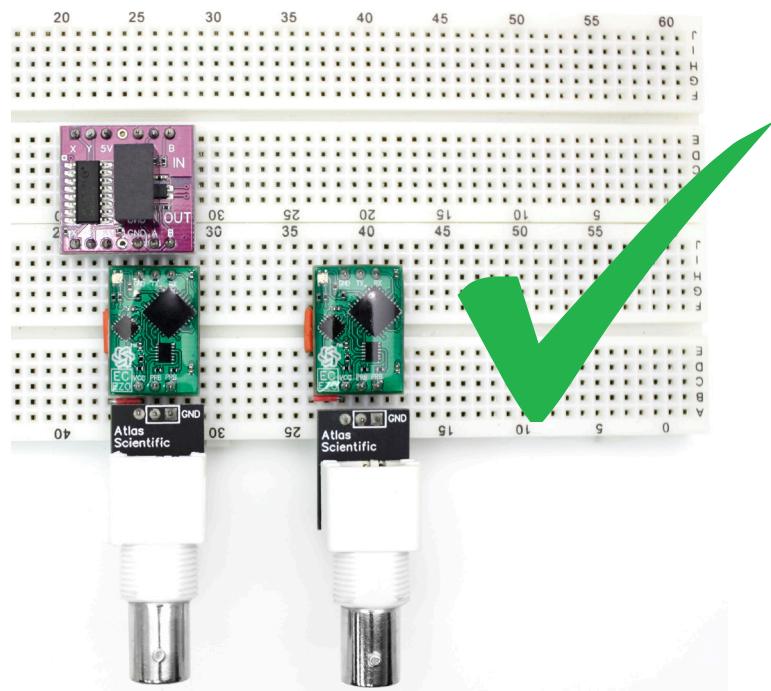
When reading from two conductivity circuits, it is strongly recommended that one of them is electrically isolated

Without isolation, conductivity readings will effect each other.

Incorrect

Correct
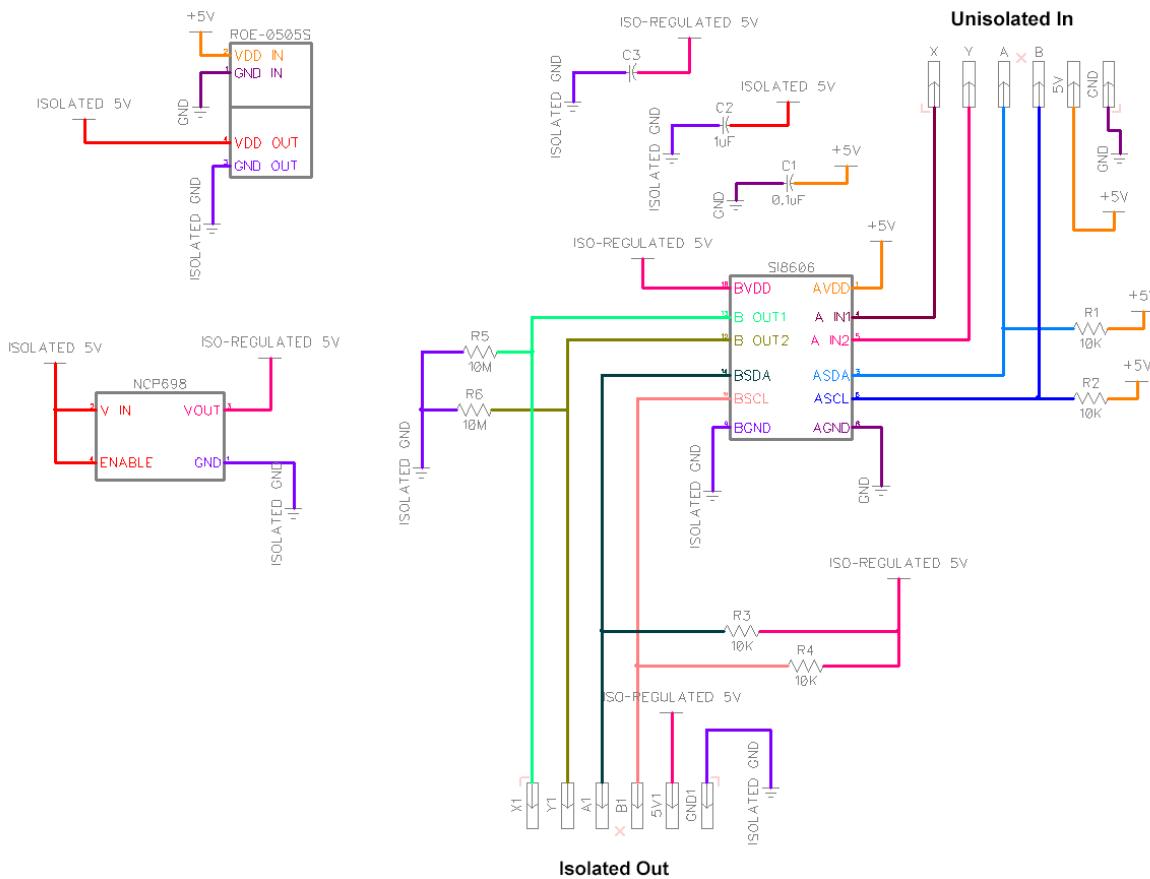
To correct this problem the power and data lines need to be electrically isolated. There is no one single method of doing this. This is just one of many ways to do so.

This schematic shows exactly how we isolate data and power using two parts, the data isolator part # SI8606, and the Power isolator part # ROE-0505S.

The SI8606 is a digital isolator with two bidirectional channels, which makes it excellent for use with I2C and UART protocols. This Part requires isolated power and pull ups on both channels on the isolated and non-isolated inputs. Pull up resistors can be anything from 3k to 10k.

The ROE-0505s is an isolated DC/DC converter that can handle 5V @ 1W. This part uses a Transformer that provides a 1:1 ratio (5V in and 5v out) however we have seen that 5V in produces 5.4V out and we recommend using a 5V regulator on its output. We use part# NCP698SQ50T1G.

Note: the Isolated Ground is different from the non-isolated Ground, these two lines should not be connected together.
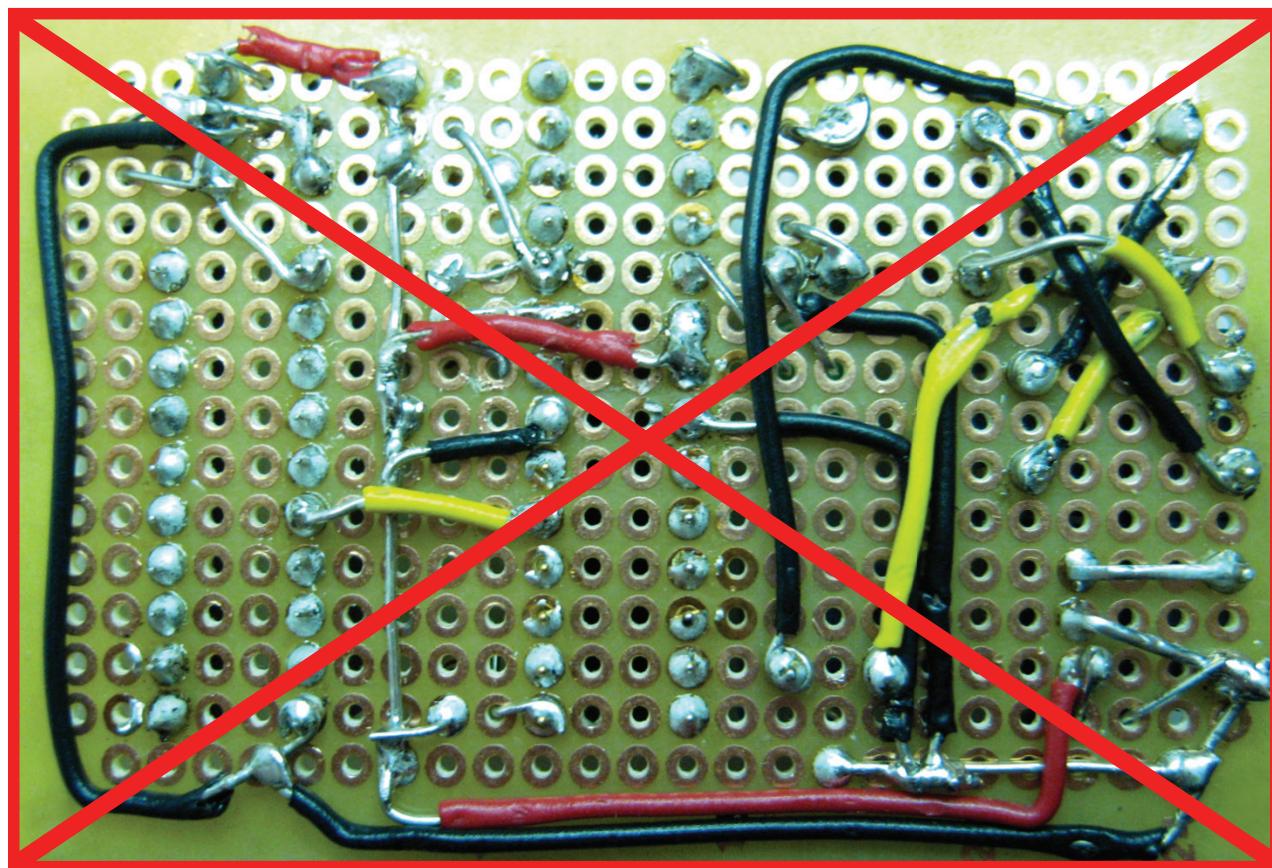
Board mounting

The Atlas Scientific EZO™ Conductivity circuit should be tested in a **_bread board_** with different colored jumper wires connecting to each pin of the EZO™ Conductivity circuit.

The EZO™ Conductivity circuit should not have wires for other devices in your system laying on top of it.

If long term use is desired a PCB should be made to hold the device.

Perfboards _(sometimes called Protoboards)_ should never be used.

Micro-shorts and bleeding voltages are very common when using such boards. Achieving stable reading can be quite difficult or impossible.

Perfboards _(sometimes called Protoboards)_ will void your devices warranty. No support will be given.

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UART Mode

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UART mode command quick reference

There are a total of 16 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	Enable / Disable or Query continuous readings (pg.24)	Enabled
Cal	Performs calibration (pg.30)	User must calibrate
Factory	Factory reset (pg.38)	N/A
I	Device information (pg.33)	N/A
I2C	Sets the I^{2}C ID number (pg.39)	Not set
K	Set or Query the probe K constant (pg.26)	K 1.0
L	Enable / Disable or Query the LEDs (pg.23)	LEDs Enabled
Name	Set or Query the name of the device (pg.32)	Not set
O	Enable / Disable or Query parts of the output string (pg.28)	All Enabled
Plock	Enables / Disables the protocol lock feature (pg.41)	Disabled
R	Returns a single reading (pg.24)	N/A
Response	Enable / Disable or Query response code (pg.34)	Enabled
Serial	Set the baud rate (pg.37)	9600
Sleep	Enter low power sleep mode (pg.36)	N/A
Status	Retrieve status information (pg.35)	N/A
T	Set or Query the temperature compensation (pg.27)	25℃

UART command definitions

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

LED control

All EZO™ 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
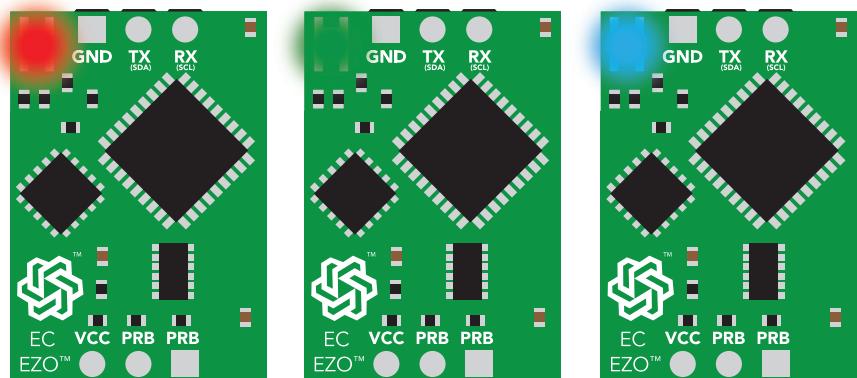
Command syntax

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

Device response

L,1 <CR>
(If the response code is enabled, the EZO™ class circuit will respond "*OK<CR>")
The Led will be enabled and the green power on/ standby LED will turn on

L,0 <CR>
(If the response code is enabled, the EZO™ class circuit will respond "*OK<CR>")
The Led will be disabled

L,? <CR>
(If the response code is enabled, the EZO™ class circuit will respond "*OK<CR>")
?L,1<CR> if the LED is enabled
?L,0<CR> if the LED is disabled

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 <CR>
(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 <CR>
(If the response code is enabled, the EZO™ class circuit will respond "*OK<CR>")
Continuous data transmission will cease.

C,? <CR>
(If the response code is enabled, the EZO™ class circuit will respond "*OK<CR>")
?C,1<CR> if continuous mode is enabled.
?C,0<CR> if continuous mode is disabled.

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)

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 a 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

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

To enable an output

Example

O,SG,1<CR>
This will enabled 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 output 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 a 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>   **This command must always be given first when calibrating. Be sure the probe is dry**

Cal,one,n<CR>   Single point calibration, where n is any E.C. value expressedin microsiemens. After issuing this command calibration is complete

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

Cal,high,n<CR>   Dual point calibration to the high end, where n is any E.C. value expressed in microsiemens.

Cal,? <CR>   Query the calibration

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

If not calibrated:	?CAL,0<CR>
If single point calibration:	?CAL,1<CR>
If dual point calibration:	?CAL,2<CR>

<CR> represents a 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 characters, 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>

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

Where EC = device type
1.0 = firmware version number

<CR> represents a 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

*ER An unknown command has been sent
*OV The circuit is being overvolted (VCC>= 5.5V)
*UV The circuit is being undervolted (VCC<= 3.1V)
*RS The circuit has reset

*RE The circuit has completed boot up
*SL The circuit has been put to sleep
*WA The circuit has woken up from sleep

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
RESPONSE,?<CR>   Query the response code

Device response

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

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

RESPONSE,?<CR>

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

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 a 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.**

After the device is woken up, **4** consecutive readings should be taken before the readings are considered valid.

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 a 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

9600 bps
8 data bits
1 stop bit
no parity
no flow control

Baud rate changes will be retained even if power is cut.

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
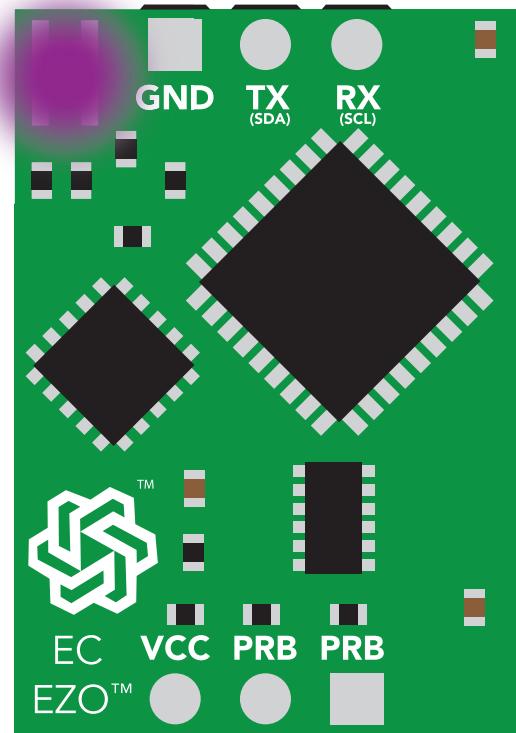7. 57600 bps
8. 115200 bps

Command syntax
(Using an example baud rate of 38400)
SERIAL,38400<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.

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
Factory<CR>   Factory reset

Command syntax
(If the response code is enabled, the EZO™ class circuit will respond "*OK<CR>")
The EZO™ class circuit will respond: *RE<CR>

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

Switch from UART mode to I²C mode

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

Command syntax
(Using an example an I²C ID number of 100)
I2C,100<CR>

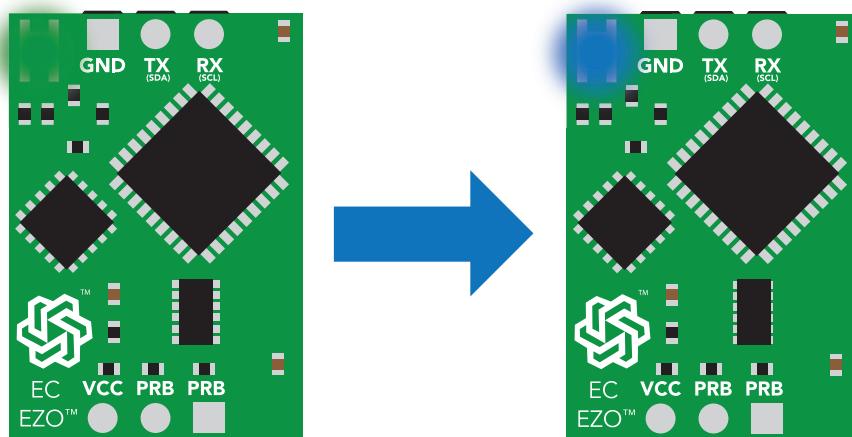**Device response**
If an address >127 is given
*ER<CR> Indicating an error has occurred

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 I²C mode

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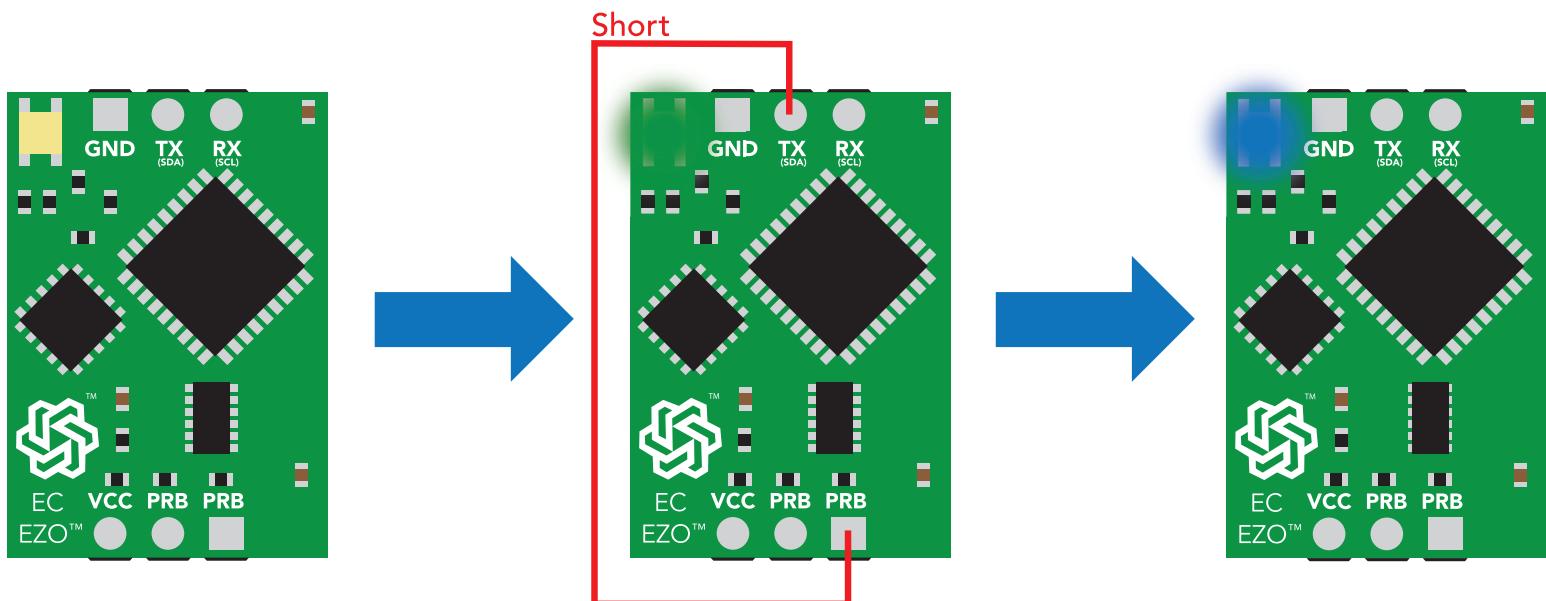and awaiting an instruction will now change to **Blue**.

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

Manual switching to I²C mode

All EZO™ class circuits can be manually switched from UART mode, to I²C mode. **If this is done the EZO™ class conductivity circuit, will set its I²C address to 100 (0X64).**

1. Cut the power to the device

2. Disconnect any jumper wires going from TX and RX to the master micro controller

3. Short the right probe pin to the TX pin

4. Power the device

5. Wait for LED to change from **Green** to **Blue**

6. Remove the short from the probe pin to the TX pin

7. Power cycle the device

8. The device is now I²C mode

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

Protocol lock

This feature is available on All EZO™ class circuits running firmware version 1.95 or higher.

When the protocol lock feature is enabled all changes to the communication protocol are blocked. This means that whatever communication mode the device is in (I^2C or UART); that communication protocol cannot be changed by any means. Furthermore, changes to the devices baud rate or I^2C address also cannot be changed.

By default the protocol lock is: **DISABLED**
Changes to this setting are retained even if the power is cut.

Command syntax
PLOCK,1<CR>   Enables the protocol lock feature
PLOCK,0<CR>   Disables the protocol lock feature
PLOCK,?<CR>   Query the state of the lock

Device response
PLOCK,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.

PLOCK,0<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.

PLOCK,?<CR>
(If the response code is enabled, the EZO™ class circuit will respond "*OK<CR>")
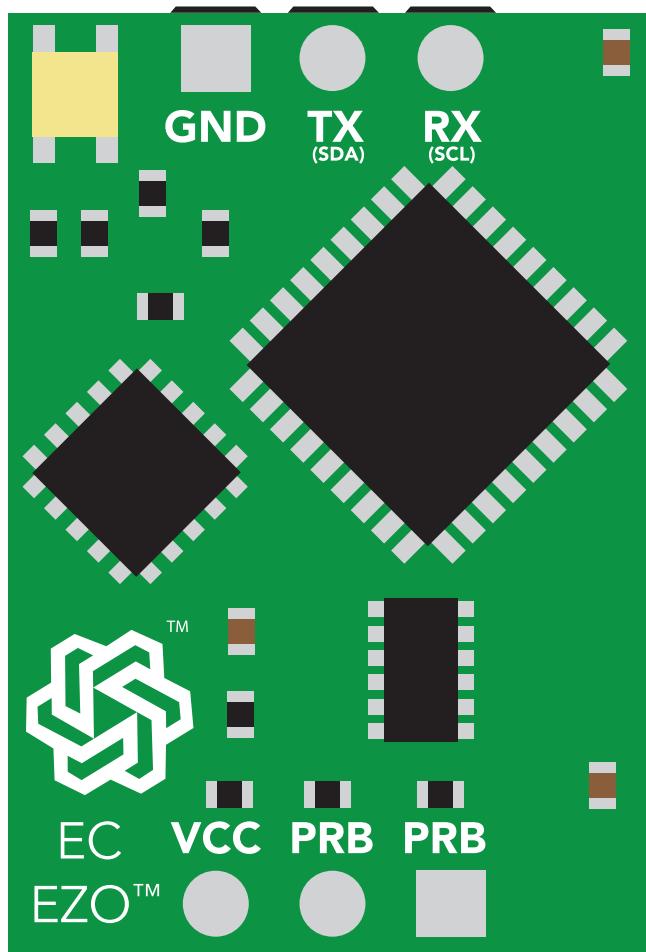?PLOCK,1<CR>   if the lock in enabled
?PLOCK,0<CR>   if the lock in disabled

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

Once the protocol lock is enable the following commands / actions will no longer work

Manual switching to I²C or UART mode
Software switching from I²C or UART mode
UART baud rate change
I²C address change

If the protocol lock is enabled attempting to manually switch to UART or I²C mode will have no effect. If any of the software commands are issued to switch mode, baud rate or I²C address the EZO class device will return *ER<CR>
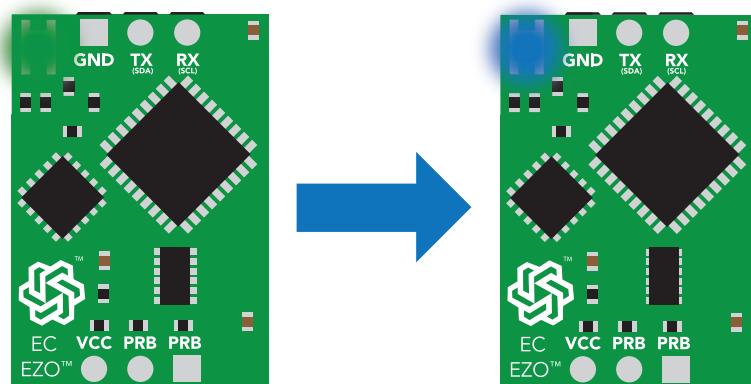
GND   TX   RX
      (SDA) (SCL)

EC
EZO™   VCC PRB PRB

Atlas**Scientific**

Environmental Robotics

Conductivity Circuit

EZO™

I²C Mode

I²C mode

An I²C address can be any number from 1-127. If the EZO™ Class Conductivity circuit was put into I²C mode by jumping PRB to TX, the I²C address is 100(0x64).

Once an EZO™ class device has been put into I²C 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 I²C mode.

The I²C protocol is considerably more complex than the UART (RS-232) protocol. Atlas Scientific assumes the embedded systems engineer understands this protocol.

Communication to the EZO™ class device is controlled by the master. The EZO™ class device as an I²C slave. The slave device is not able to initiate any data transmissions.

An I²C write event is defined as such

| start | write command to device address | instruction | stop |

In order to get the response from device, it is necessary to initiate a read command. The I²C protocol does not permit the slave device to initiate any data transmissions.

An I²C read event is defined as such

| start | read command to device address | data byte | data byte | data byte | stop |

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	**No Data** – there is no pending request, so there is no data to return from the circuit
254	**Pending** – the request is still being processed. Ensure that you have waited the minimum time to guarantee a response
2	**Failed** – the request failed
1	**Success** – the requested information is ready for transmission. 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.

| 255 | null | (every byte read after the first byte will be NULL) | stop |

All I²C 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

12.34 ≠ float   12.34 =byte[7]

Byte[0]= 1	(decimal 1)
byte[1]= "1"	(ASCII 49)
byte[2]= "2"	(ASCII 50)
byte[3]= "."	(ASCII 46)
byte[4]= "3"	(ASCII 51)
byte[5]= "4"	(ASCII 52)
byte[6]= NULL	(ASCII 0)

I²C 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 I²C 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.

I²C command quick reference

There are a total of 12 different commands that can be given to the EZO™ class conductivity circuit.

Command	Function
Cal	Performs calibration (pg.52)
Factory	Factory reset (pg.62)
I	Device information (pg.57)
K	Set or Query the probe K constant (pg.50)
L	Enable / Disable or Query the LEDs (pg.48)
O	Enable / Disable or Query parts of the output string (pg.55)
Plock	Enables / Disables the protocol lock feature (pg.64)
R	Returns a single reading (pg.49)
Serial	Switch back to UART mode (pg.61)
Sleep	Enter low power sleep mode (pg.60)
Status	Retrieve status information (pg.58)
T	Set or Query the temperature compensation (pg.51)

I²C LED control

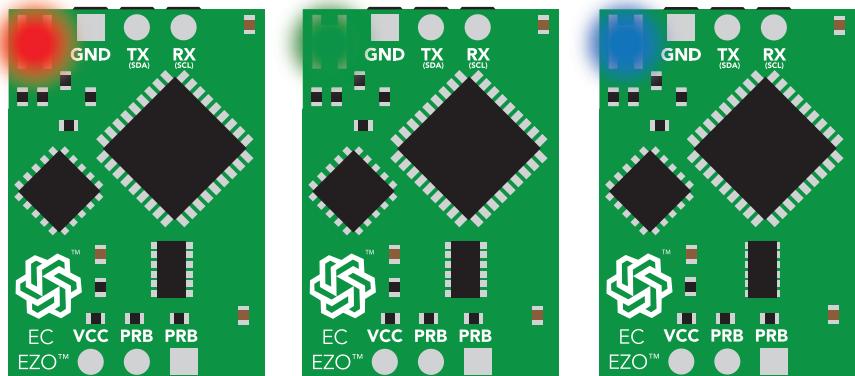All EZO™ class circuits have a tri-color LED used to indicate device operation.

I²C mode LED color definitions:
Steady **Blue** = Power on/ standby
Red double blink = Command received and not understood
Blue blink = Data transmission sent
Green = taking a reading

Command syntax
L,1   LED enable
L,0   LED disable
L,?   Query the LED

Device response
L,1
The Led will be enabled and the blue power on/ standby LED turn on.
After 300ms, an I²C read command can be issued to get the response code. A decimal 1 would indicate the command has been successfully processed.

| 1 | null |

L,0
The Led will be disabled
After 300ms, an I²C read command can be issued to get the response code. A decimal 1 would indicate the command has been successfully processed.

| 1 | null |

L,?
After 300ms, an I²C read command can be issued to get the response code.

| 1 | ? | L | , | 1 | null | (?L,1)   if the LED is enabled
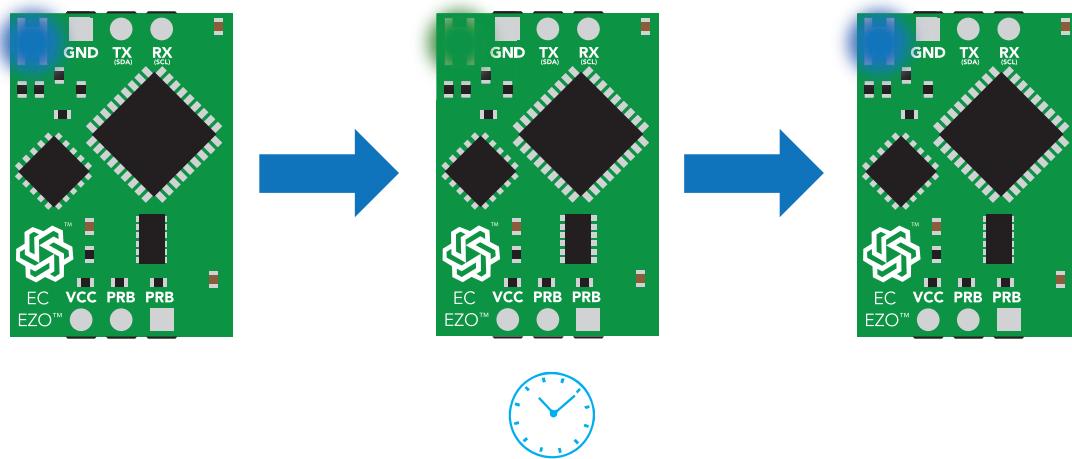| 1 | ? | L | , | 0 | null | (?L,0)   if the LED is disabled

I²C take reading

When a reading is taken, the LED (if enabled) will turn **Green**, 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 I²C read command can be issued to get the response:

| 1 | EC | , | TDS | , | SAL | , | SG | null |

Each parameter represents many bytes.
The string will be no longer than 32 bytes.

I²C 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
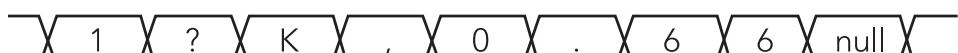

Time until instruction is processed 300ms

Device response

After 300ms an I²C read command can be issued, to get the response:
A decimal 1 would indicate the command has been successfully processed.

1	null

K,?
After 300ms an I²C read command can be issued, to get the response
?,K,[floating point K value]

1	?	K	,	0	.	6	6	null

?K,0.66

I²C 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.

Command syntax
(Using an example temperature 19.5)

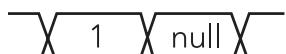T,19.5   Where the temperature is any value; floating point, or int, in ASCII form

T,?   Query the set temperature

Time until instruction is processed: 300ms
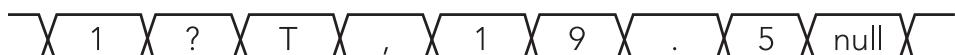
Device response
T,19.5
After 300ms, an I²C read command can be issued to get the response code.
A decimal 1 would indicate the command has been successfully processed.

1	null

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

1	?	T	,	1	9	.	5	null

(?T,19.5)

I²C 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: 2.0s

Cal,one,n   Single point calibration, where n is any E.C. value value expressed in microsiemens.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. value expressed in microsiemens **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. value expressed in microsiemens

Time until instruction is processed: 1.3s

Cal,?   Query the calibration

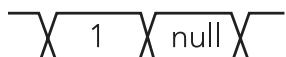Time until instruction is processed: 300ms

Device response

Cal,clear
After 300 ms, an I^{2}C read command can be issued to get the response code:
A decimal 1, would indicate the command has been successfully processed.

| 1 | null |

There is no other output associated output with this command.

Cal,dry
After 1.3s, an I^{2}C read command can be issued to get the response code:
A decimal 1, would indicate the command has been successfully processed.

| 1 | null |

The LED will turn **Cyan** during the calibration.

Cal,one,n
After 1.3s, an I^{2}C read command can be issued to get the response code:
A decimal 1, would indicate the command has been successfully processed.

| 1 | null |

The LED will turn **Cyan** during the calibration.

Cal,low,n
After 1.3s, an I^{2}C read command can be issued to get the response code:
A decimal 1, would indicate the command has been successfully processed.

| 1 | null |

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^{2}C read command can be issued to get the response code:
A decimal 1, would indicate the command has been successfully processed.

1	null

The LED will turn **Cyan** during the calibration.

Cal,?
After 300ms an I^{2}C read command can be issued, to get the response code:
A decimal 1, would indicate the command has been successfully processed.

1	null

If not calibrated

| ? | C | A | L | , | 0 | null | ?CAL,0
|---|---|---|---|---|---|------|

If single point calibration

| ? | C | A | L | , | 1 | null | ?CAL,1
|---|---|---|---|---|---|------|

If dual point calibration

| ? | C | A | L | , | 2 | null | ?CAL,2
|---|---|---|---|---|---|------|

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 enabled the specific gravity output

O,SG,1

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

1	null

O,?

After 300ms, an I^{2}C read command can be issued to get the response

1	?	O	,	E	C	,	T	D	S	,	S	,	S	G	null

?O,EC,TDS,S,SG
(If all are enabled)

I²C 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 I²C read command can be issued to get the response

?I,EC,1.0

Where EC = device type
1.0 = firmware version number

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 I²C 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

I²C Address change

Transmitting the command I2C,[n] while the EZO™ class circuit is already in I²C mode will change the devices I²C address. **Where [n] represents any number from 1-127.**

Warning!

After changing the I²C address the EZO™ class circuit will no longer be able respond to any commands from the master device until its code has been updated with the new I²C address

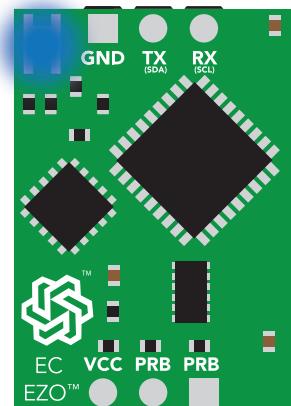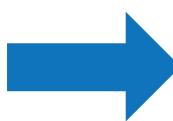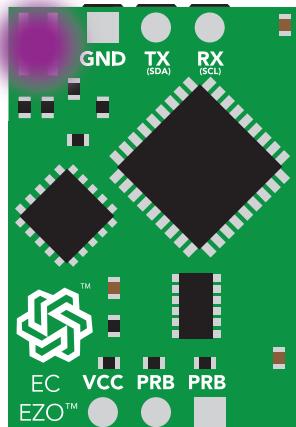## Command syntax

I2c,[n]

Device response

If an address >0 and <128 is given

	1	null	

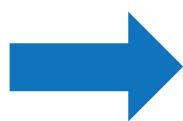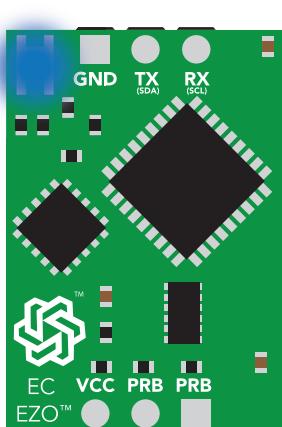If an address of 0 or and address of > 127 is given EZO™ class circuit will issue an error response and not change the I²C address.

The blue led used to indicate the device is in I²C mode will turn purple then the device will restart using its new I²C address.

No calibration information will be lost by changing the I²C address

I²C 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.**

> After the device is woken up, **4** consecutive readings should be taken before the readings are considered valid.

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 I²C mode to UART mode

Transmitting the command serial,<n> will set the EZO™ class circuit into UART mode from I²C mode. Where [n] represents any of one the 8 available baud rates.

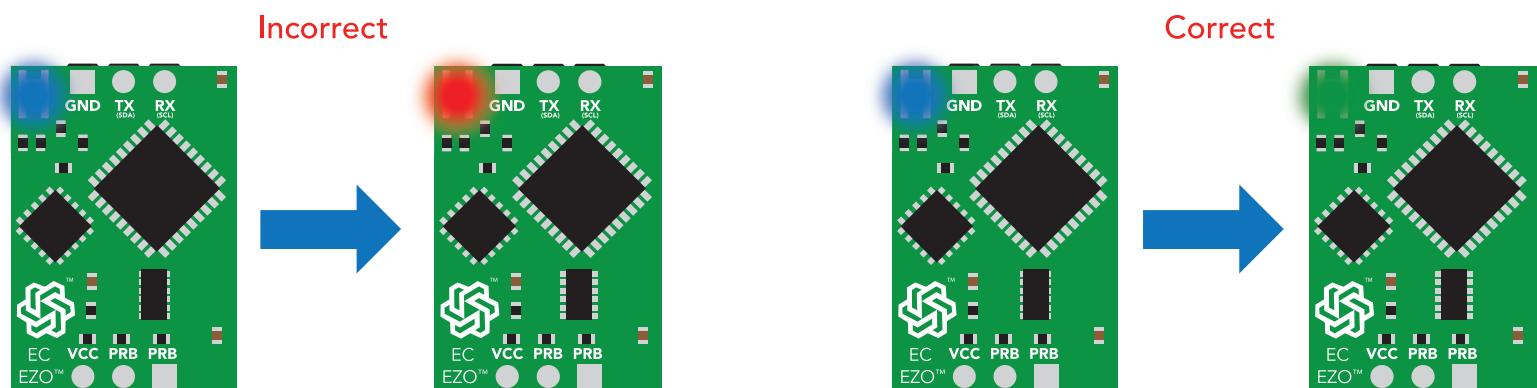## Command syntax
(Using an example an baud rate of 9600)
SERIAL,9600

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**.

Incorrect

Correct

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
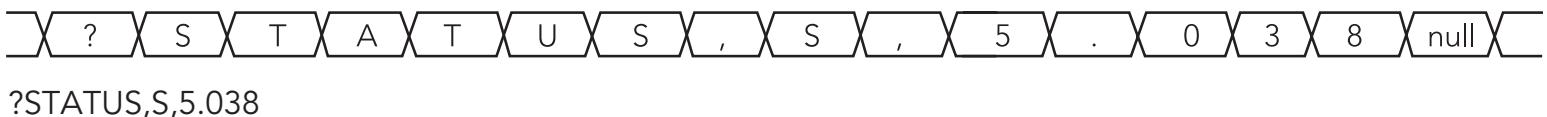Set debugging LED to on.
Enable response codes

This command will not change the set I²C address

Command syntax
Factory   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

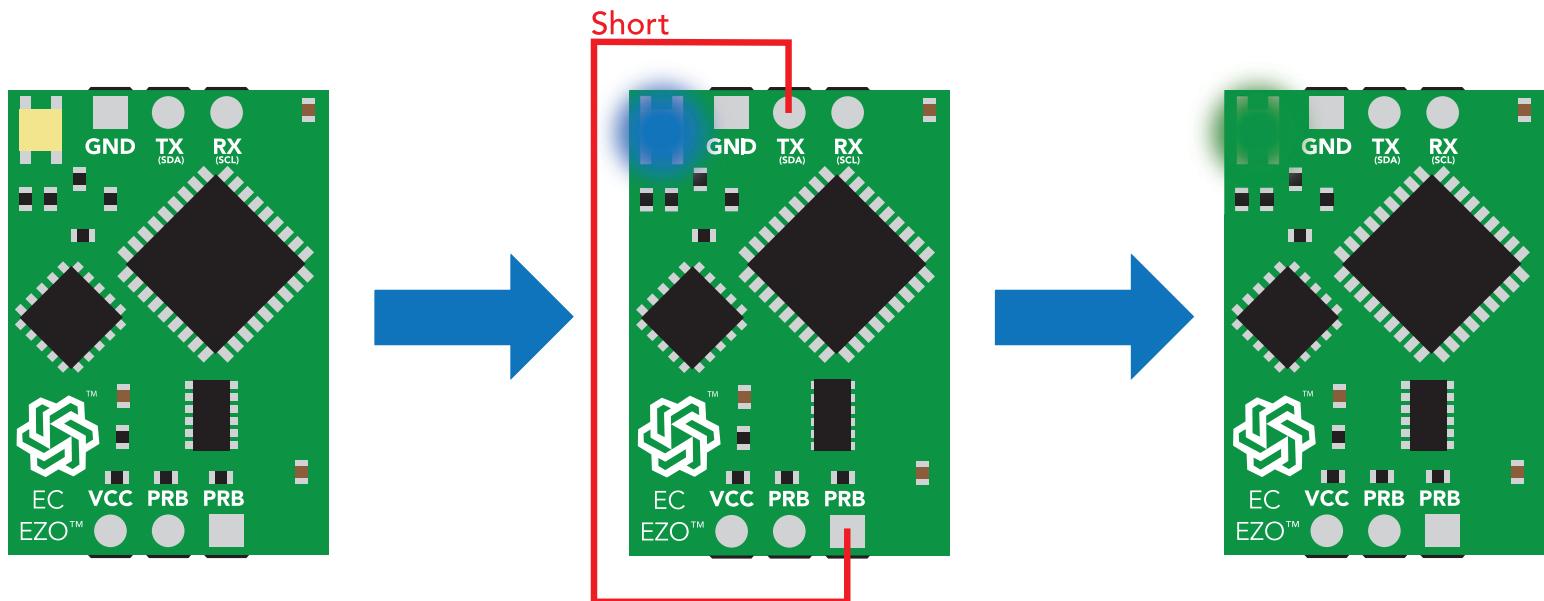Where: S is the reason for the last reset event (software reset)
Where: 5.038 is the its voltage at the VCC

Manual switching to UART mode

All EZO™ class circuits, can be manually switched from I^{2}C mode to UART mode.
If this is done, the EZO™ class conductivity circuit, will set its baud rate to 9600.

1. Cut the power to the device
2. Disconnect any jumper wires going from TX and RX to the master micro controller
3. Short the right probe pin to the TX pin
4. Power the device
5. Wait for LED to change from **Blue** to **Green**
6. Remove the short from the probe pin to the TX pin
7. Power cycle the device
8. The device is now UART mode

Protocol lock

This feature is available on All EZO™ class circuits running firmware version 1.95 or higher.

When the protocol lock feature is enabled all changes to the communication protocol are blocked. This means that whatever communication mode the device is in (I^2C or UART); that communication protocol cannot be changed by any means. Furthermore, changes to the devices baud rate or I^2C address also cannot be changed.

By default the protocol lock is: **DISABLED**
Changes to this setting are retained even if the power is cut.

Command syntax

PLOCK,1   Enables the protocol lock feature
PLOCK,0   Disables the protocol lock feature
PLOCK,?   Query the state of the lock

Device response

PLOCK,1
After 300ms, an I^2C read command can be issued to get the response code.
A decimal 1 would indicate the command has been successfully processed.
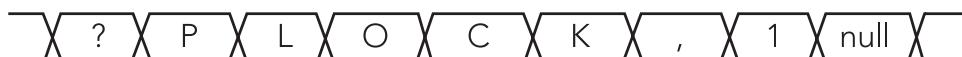
$$\boxed{1}\ \boxed{null}$$

PLOCK,0
After 300ms, an I^2C read command can be issued to get the response code.
A decimal 1 would indicate the command has been successfully processed.

$$\boxed{1}\ \boxed{null}$$

PLOCK,?
After 300ms, an I^2C read command can be issued to get the response code.

If locked

$$\boxed{?}\ \boxed{P}\ \boxed{L}\ \boxed{O}\ \boxed{C}\ \boxed{K}\ \boxed{,}\ \boxed{1}\ \boxed{null}$$

(?PLOCK,1)

If unlocked

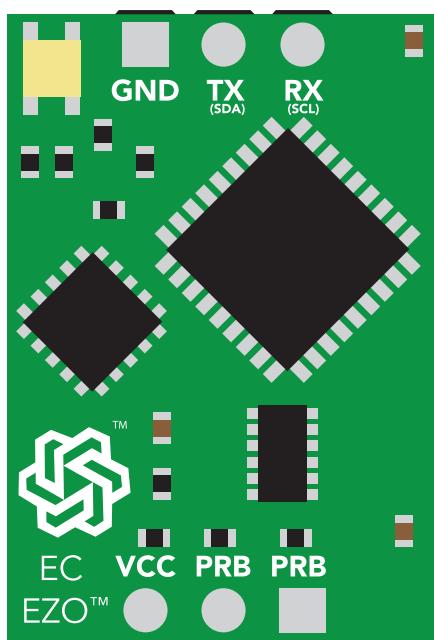| ? | P | L | O | C | K | , | 0 | null |

(?PLOCK,0)

Once the protocol lock is enable the following commands / actions will no longer work

Manual switching to I²C or UART mode
Software switching from I²C or UART mode
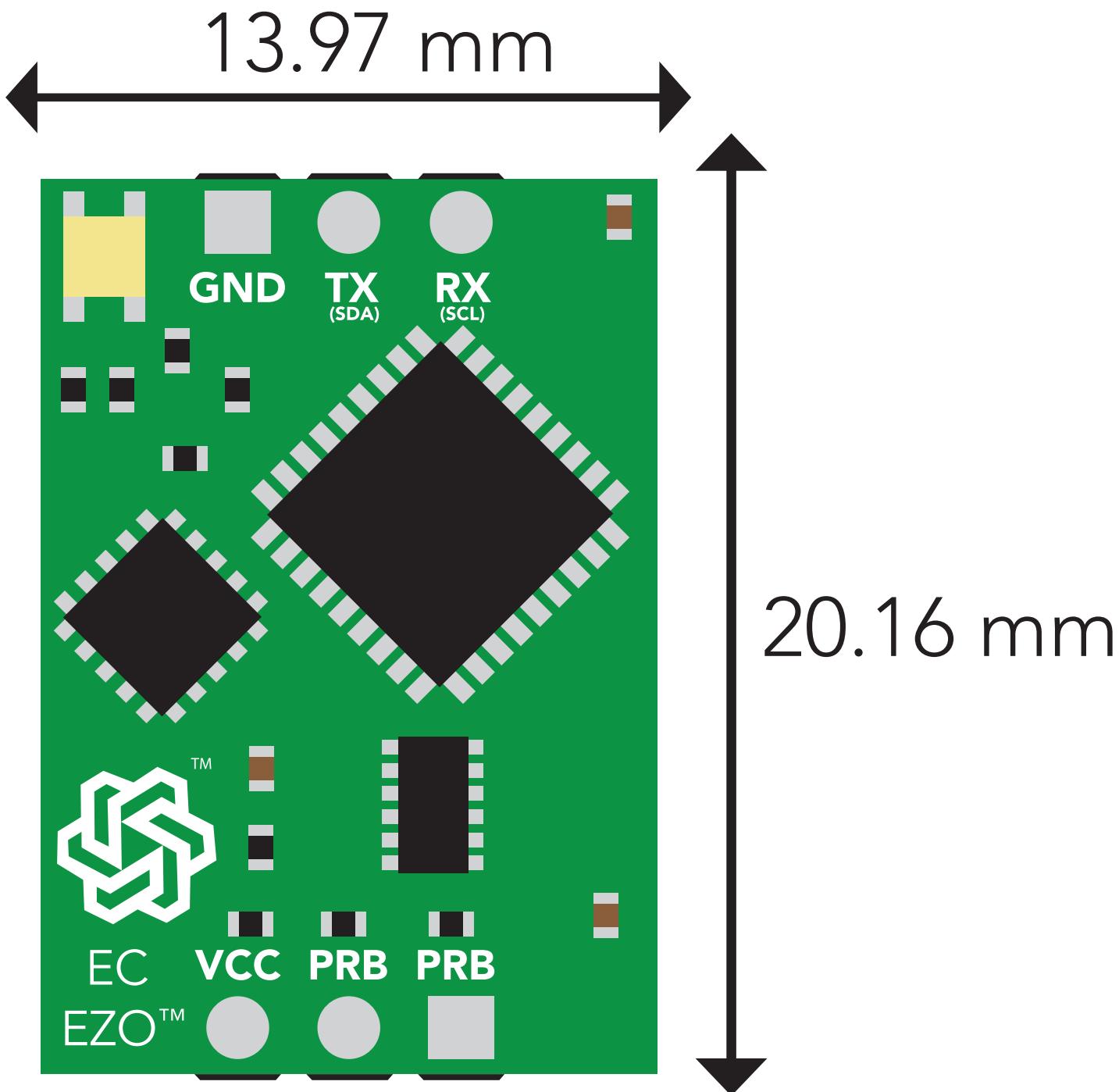**UART baud rate change**
I²C address change

If the protocol lock is enabled attempting to manually switch to UART or I²C mode will have no effect. If any of the software commands are issued to switch mode, baud rate or I²C address the EZO class device will return:

| 2 | null |

Indicating that the request failed.

Circuit dimensions

13.97 mm

20.16 mm

GND TX RX
(SDA) (SCL)

EC
EZO™ VCC PRB PRB

![AtlasScientific — Environmental Robotics logo]

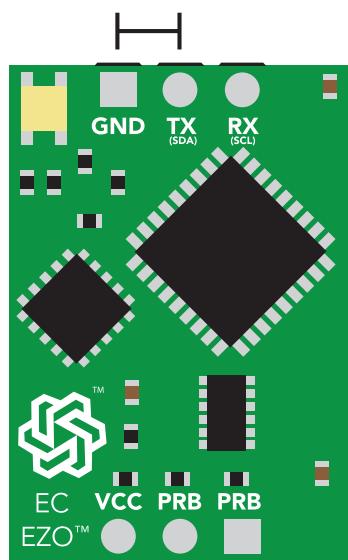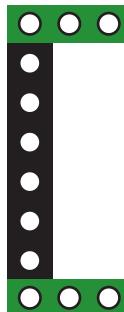# How to make a footprint for the Atlas Scientific™ EZO™ conductivity circuit

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.

2.54 mm (0.1")

17.78 mm (0.7")

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.

17.78 mm (0.7")

Datasheet change log

Datasheet V 3.4

Added Protocol Lock function on pages 41 and 64.

Datasheet V 3.3

Moved Wiring Diagram to page 11 and revised photos on pages 11 and 18.

Datasheet V 3.2

Added I^2C address change command on pg 56.

Datasheet V 3.1

Corrected

Cal,dry "Time until instruction is processed:" changed from 1.3s to 2.0s

Datasheet V 3.0

Added

"After the device is woken up, 4 consecutive readings should be taken before the readings are considered valid." to pages 30 and 51

"Circuit identification" on page 4.

Replaced

"X" command to "Factory"

Datasheet change log

Conductivity circuit firmware changes

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)
• Fix I2C bug where the circuit may inappropriately respond when other I2C devices
  are connected.

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

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. 56. 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™ 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.

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 statingc 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.

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