Atlas Scientific™
Environmental Robotics

Dissolved Oxygen Circuit

EZO™

EZO™ class embedded Dissolved Oxygen circuit

V 2.0
This is an evolving document check back for updates.

Features

Reads

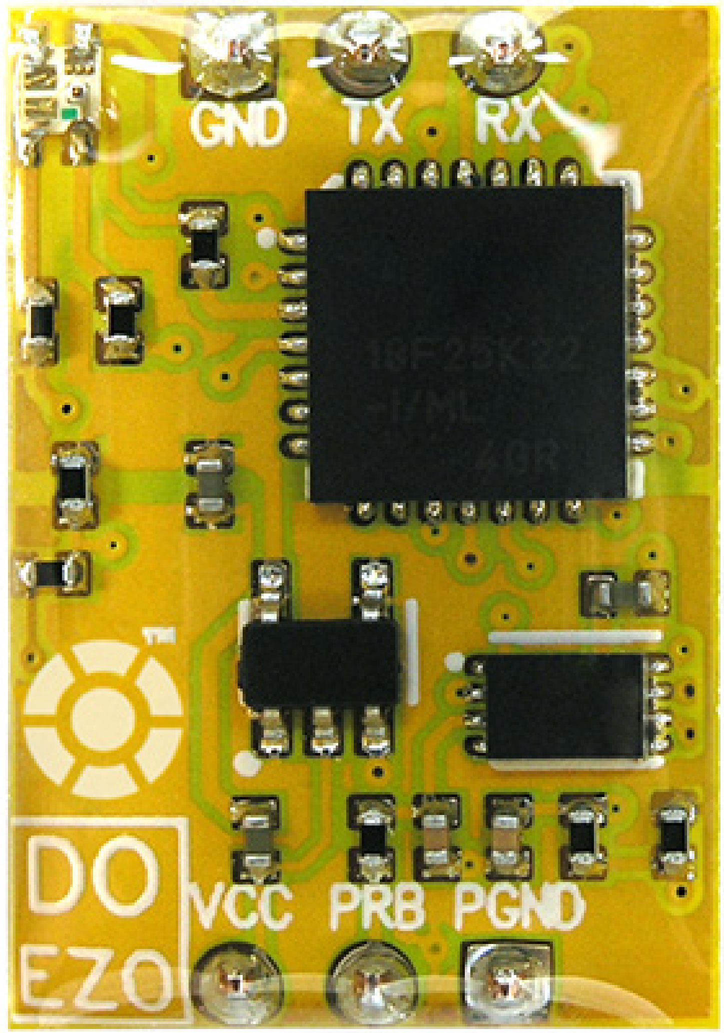
- Full range dissolved oxygen readings from 0.01 to +35.99 mg/L
- Accurate dissolved oxygen readings down to the hundreds place **(+/- 0.2)**
- Temperature compensation
- Salinity compensation
- Pressure compensation
- Flexible calibration protocol supports one point or two calibration
- Calibration required only once per year with an Atlas Scientific™ D.O. probe
- Single reading or continuous reading modes
- **Data format is ASCII**

Two data protocols

- UART asynchronous serial connectivity
- (RX/TX voltage swing 0-VCC)
- I²C (default I²C address 0x61)
- Compatible with any microprocessor that supports UART, or I²C protocol
- Operating voltage: 3.3V to 5V
- Works with any off-the-shelf galvanic HDPE dissolved oxygen probe

Sleep mode power consumption

- 0.995mA at 3.3V



Patent pending

Description

The Atlas Scientific™ EZO™ class embedded D.O. circuit, is our 6th generation embedded dissolved oxygen circuit. This EZO class D.O. circuit, offers the highest level of stability and accuracy. With proper configuration the EZO class D.O. circuit, can meet, or exceed the accuracy and precision found in most bench top laboratory grade dissolved oxygen meters. The EZO™ D.O. circuit, can work with any off-the-shelf galvanic HDPE dissolved oxygen probe/sensor/electrode. This device reads the D.O. from a D.O. probe/sensor/electrode. This device does not include a D.O. probe/sensor/electrode.

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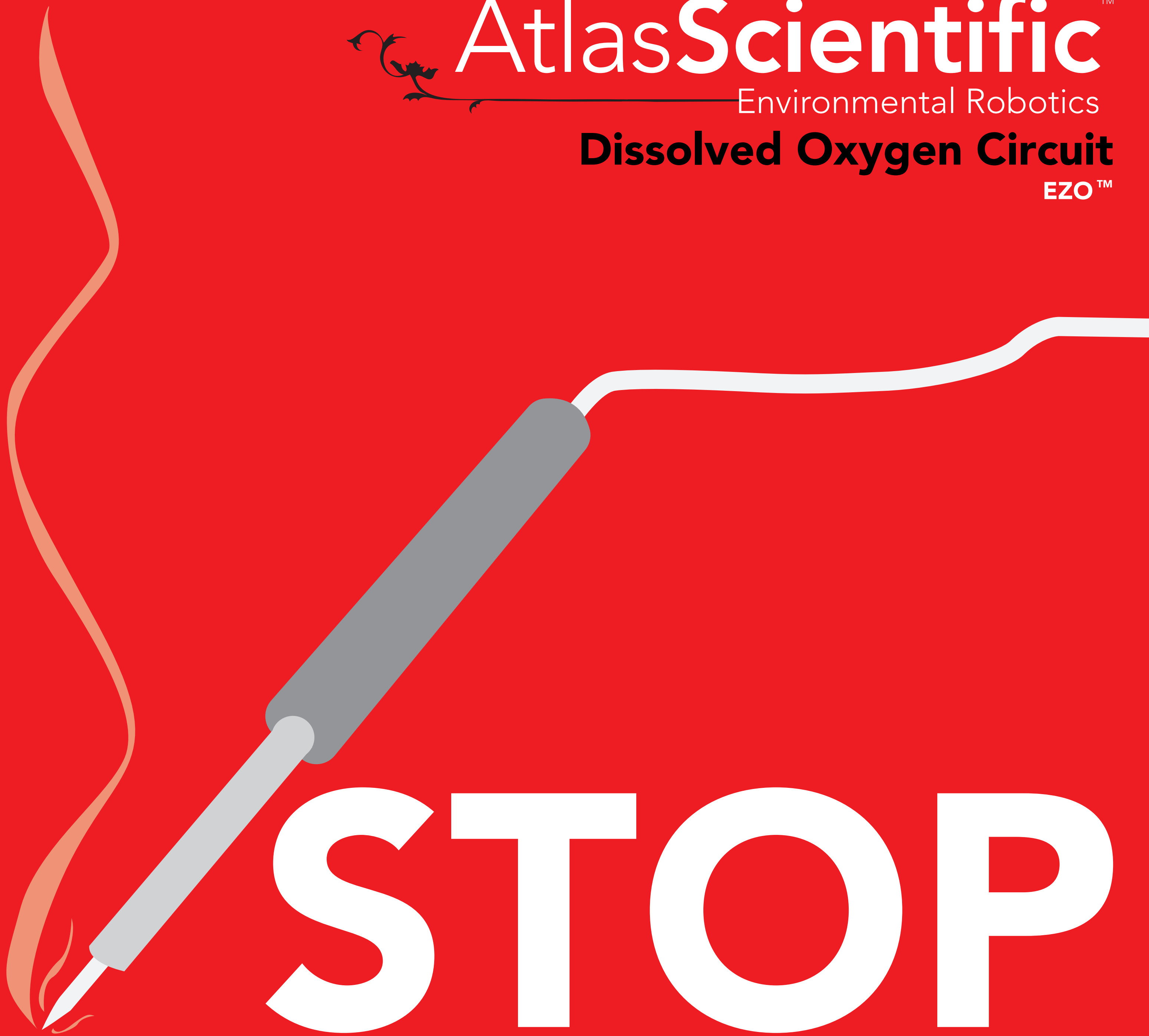

STOP

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.

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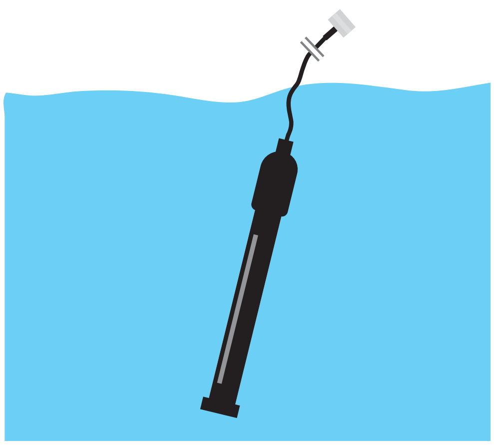
System overview

The Atlas Scientific EZO™ class dissolved oxygen 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 the dissolved oxygen in water.

The EZO™ class D.O. circuit is an extremely complex device that takes into account temperature, salinity and pressure to derive the concentration of dissolved oxygen in water. The signal coming off a galvanic HDPE probe is fairly strait forward; 0mV means no oxygen and a voltage from 36mV to 54 mV means 100% oxygen.



0 mV

36mV to 54mV

$$\%\ \text{saturation}\ \frac{mV\ in\ water}{Mv\ in\ air} X\ 100$$

To determine very basic information about the percentage of saturation we take the mV coming off the D.O. probe when it is in water and divide that by the mV coming off the D.O. probe when it is in air.

This tells us the percentage of oxygen saturation relative to the air. Although this information is important it tells us very little about the water's ability to hold oxygen. Temperature, pressure and salinity are the 3 major factors that change waters ability to hold oxygen. These three major factors are far from linear. Many very large calculations are needed in order to correctly derive the waters ability to hold oxygen. Further processing is then needed to turn a saturation percentage into mg/L. The Atlas Scientific EZO™ class dissolved oxygen circuit is specifically designed to perform these calculations and quickly determine the waters dissolved oxygen in mg/L.

How to take an accurate Dissolved Oxygen reading

Out of the 3 parameters we compensate for (temperature, salinity and pressure), temperature by far has the greatest effect. The D.O. circuit has its temperature compensation set to 20˚C by default. If the temperature is more than 2˚ or 3˚ from 20˚, the temperature should be transmitted to the device.

Salinity has a significate, but lesser effect on the waters ability to hold oxygen. If the water has a conductivity of less than 2,500μs it can be considered insignificant and omitted. If the salinity of the water is constant it can be set once and left alone. This is because small fluctuations in salinity will have no effect on the readings.

Pressure is the least used parameter. The EZO™ class D.O. circuit assumes that it is operating at atmospheric pressure. Sure, the probe is under water and cannot be at atmospheric pressure however, we are not talking about small differences. Pressure should be used when the probe is reading in 10+ meters of water, or it is connected to a pipe and that pipe is pressurized.

Adjusting theses three parameters as needed will insure accurate D.O. readings.

Salinity and pressure settings are stored in the devices EEPROM and will not be lost if the power is cut. Temperature is not stored and will be lost if the power is cut. It will return to its default of 20 C.

Calibration should be done once per year.
It may need more frequent calibration depending on your accuracy needs and specific use case.

Power consumption

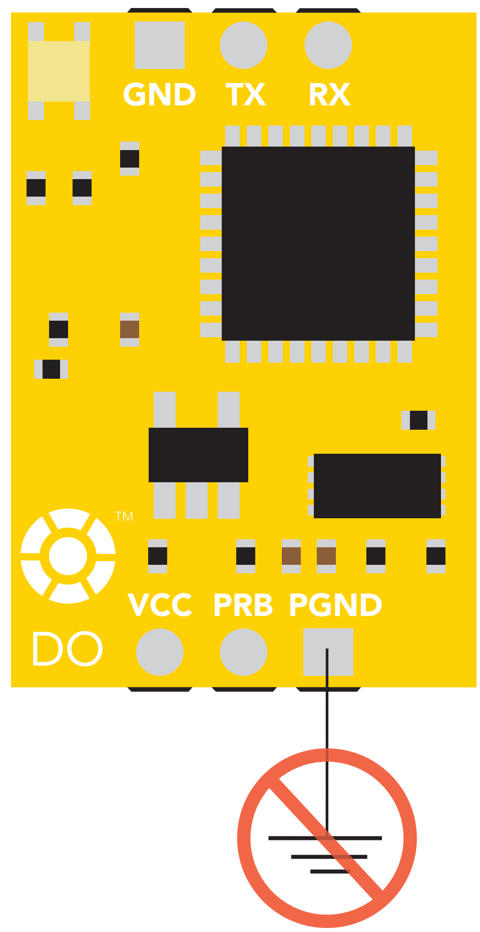
	LED	MAX	STANDBY	SLEEP
5V	ON	18.3 mA	16 mA	1.16 mA
	OFF	13.8 mA	13.8 mA	
3.3V	ON	14.5 mA	13.9 mA	0.995 mA
	OFF	13.3 mA	13.3 mA	

Absolute maximum ratings*

Parameter	**MIN**	**TYP**	**MAX**
Storage temperature (EZO™ D.O. circuit)	-40 C°		125 C°
Operational temperature (EZO™ D.O. circuit)	1 C°	25 C°	35 C°
VCC	3.3V	3.3V	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 I²C 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 I2C mode, this pin acts as the Serial Data Line (SDA). The I2C 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 I²C mode.

The default state is UART mode. In UART mode, this pin acts as the receive (RX) line. If the device is in I²C mode, this pin acts as the Serial Clock Line (SCL). The I²C protocol requires an external pull up resistor on the SCL line (resistor not included).

PRB This pin connects to the output lead of a D.O. probe/ sensor/electrode

PGND This pin connects to the ground lead of a D.O. probe/ sensor/electrode

This pin is not ground.
Do not tie this pin to system ground

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:

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

Data output: String
Encoding: ASCII characters followed by a carriage return <CR>
Maximum string length: 14 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 D.O. Circuit will respond "*ER<CR>" this will happen whether or not response codes are enabled

Reading time
1 reading every second

Probe type
Any off the shelf galvanic HDPE dissolved oxygen probe/sensor/electrode

LEDs:
Enabled
Steady **Green**= Power on/ standby
Red double blink = Command received and not understood
Green double blink per data packet = Continuous data streaming
Cyan = taking a reading

Calibration theory

Calibration should be done once per year.
It may need more frequent calibration depending on your accuracy needs and specific use case.

The Atlas Scientific EZO™ class D.O. circuit, has a flexible calibration protocol, allowing for single point or dual point calibration.

It is mandatory to calibrate the EZO™ class D.O. circuit to the atmospheric oxygen concentration at the altitude where it will be used. You would not want to calibrate the D.O. circuit at sea level, but deploy it on a mount top. Although it is not necessary, sending the EZO™ class D.O. circuit the air temperature just before calibration will result in higher accuracy readings.

On the opposite side, do not be overly concerned with small changes in altitude. An altitude change of less than 100 meters from calibration to deployment would be significant.

The second point that can be calibrated against is 0 mg/L. This calibration point is not necessary but it will give higher resolution for D.O. values from 1.0mg/L to 0.1mg/L.

Calibration steps
1. Remove cap from D.O. probe
2. Dip D.O. probe in fresh water. This is so the sensing area of the probe is wet.
(do not use salt water to wet the sensing area of the probe)
3. Let the probe sit in air for around 3-5 min.
4. Calibrate.

Optional step
1. Place the probe in a 0 D.O. solution.
2. Let the readings drop and stabilize.
3. If they are not at 0 (but are close) calibrate.

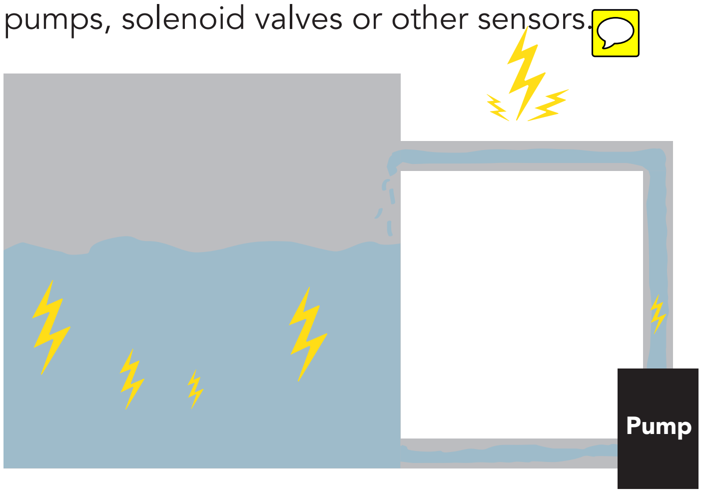
If the readings do not go to less than 1 mg/L the calibration solution may no longer be good. **DO NOT CALIBRATE**. Zero D.O. calibration solution will start to go bad once the bottle has been opened.

Design considerations

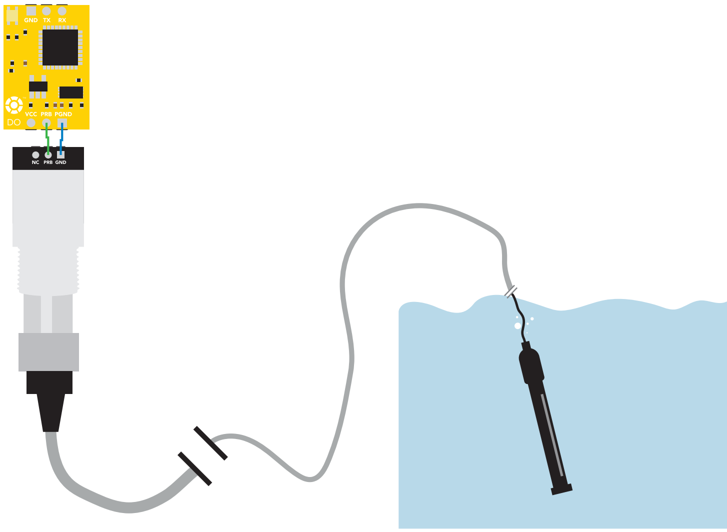
The Atlas Scientific EZO™ D.O. circuit is a micro-computer system that is specifically designed to be embedded into a larger system. The EZO™ D.O. circuit is not a completed product. The embedded systems engineer is responsible for building a completed working product.

Power and data isolation

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



When electrical noise is interfering with the D.O. 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 D.O. probe in a cup of water by itself. The readings should stabilize quickly, confirming that electrical noise was the issue.

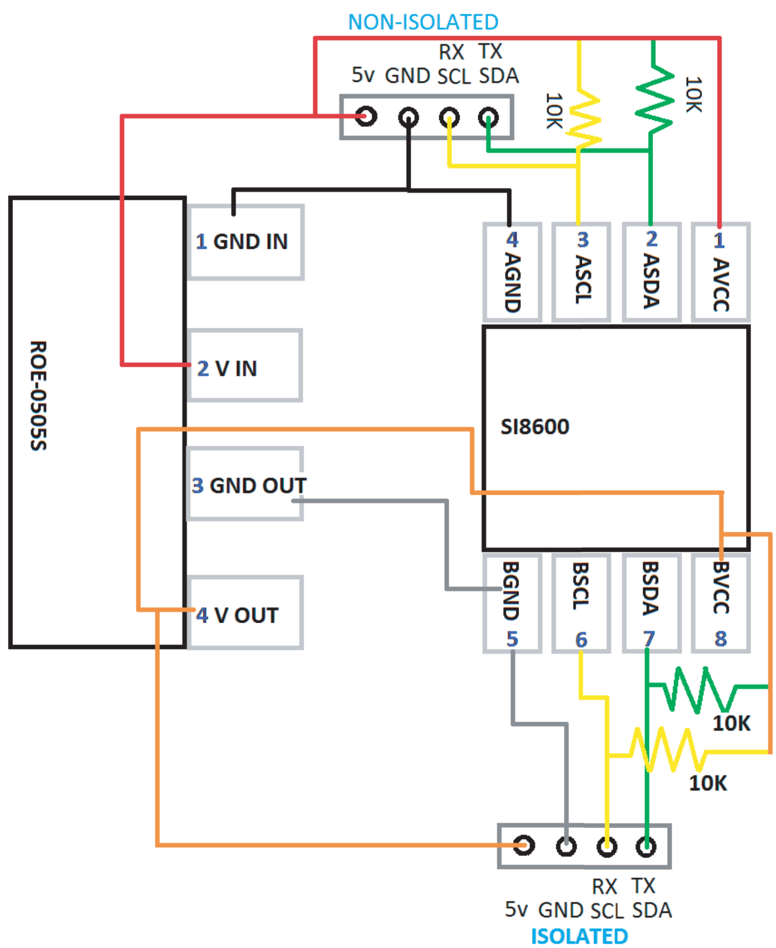


To correct this problem the power and data lines need to be electrically isolated. There is no one single method of doing this. This is just one of many ways to do so.

The SI8600 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.

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



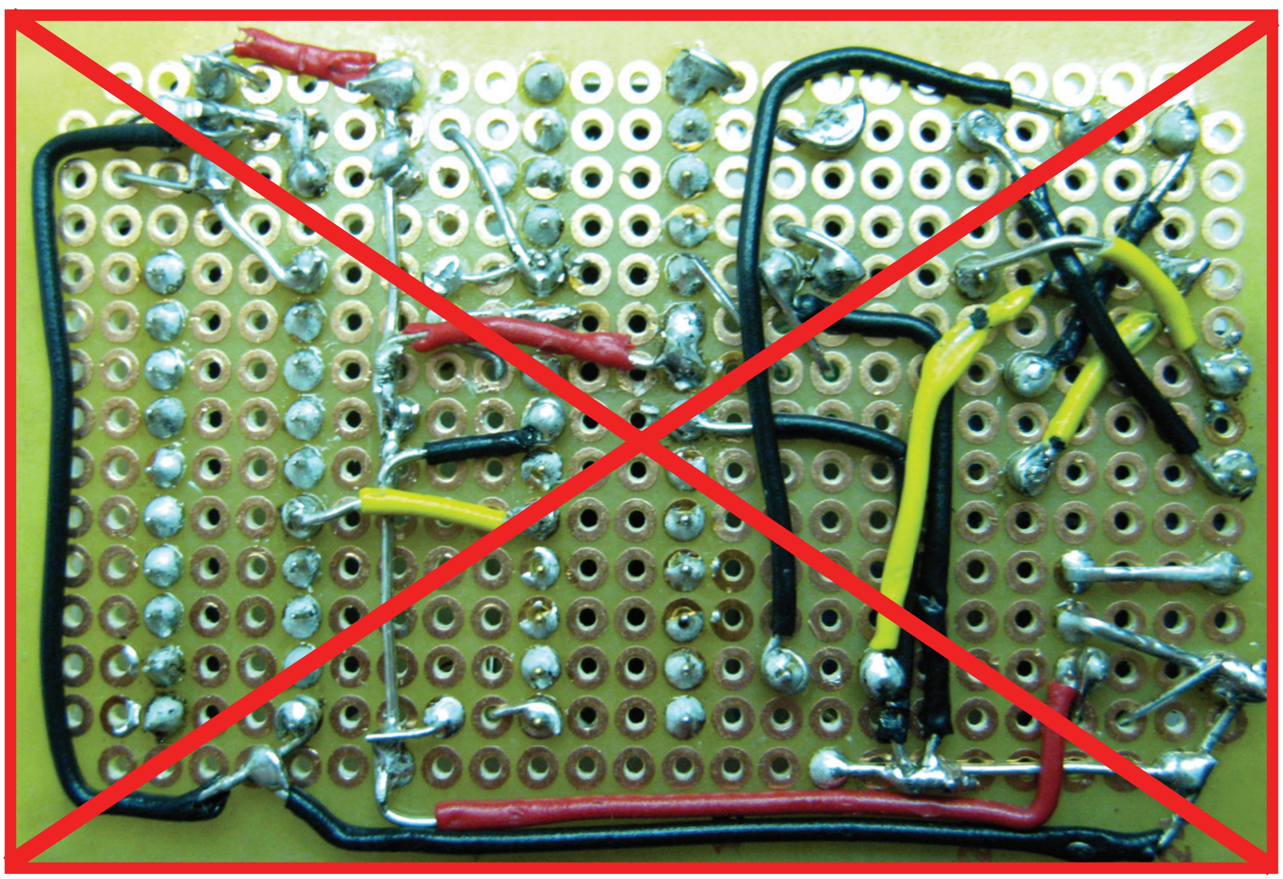
Board mounting

The Atlas Scientific EZO™ D.O. circuit should be tested in a bread board with different colored jumper wires connecting to each pin of the EZO™ D.O. circuit.

The EZO™ D.O. 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.

Protoboards or Perfboards 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.

Using Protoboards or Perfboards will void your devices warranty.
No support will be given.

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UART Mode

™

UART mode command quick reference

There are a total of 16 different commands that can be given to the EZO™ class D.O. circuit.

All commands are ASCII strings or single ASCII characters

Command	Function	Default state
C	Enable / Disable or Query continuous readings (pg.16)	Enabled
Cal	Performs calibration (pg.23)	User must calibrate
I	Device information (pg.24)	N/A
I2C	Sets the I^2C ID number (pg.30)	Not set
L	Enable / Disable or Query the LEDs (pg.15)	LEDs Enabled
Name	Set or Query the name of the device (pg.24)	Not set
O	Enable / Disable or Query parts of the output string (pg.21)	Dissolved Oxygen
P	Pressure compensation (pg.20)	0
R	Returns a single reading (pg.17)	N/A
Response	Enable / Disable or Query response code (pg.25)	Enabled
S	Salinity compensation (pg.19)	0
Serial	Set the baud rate (pg.28)	9600
Sleep	Enter low power sleep mode (pg.27)	N/A
Status	Retrieve status information (pg.26)	N/A
T	Temperature compensation (pg.18)	20° C
X	Factory reset (pg.29)	N/A

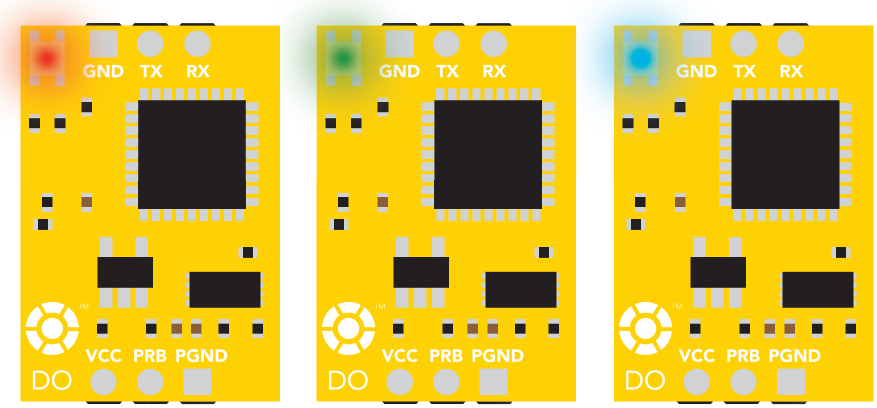
UART command definitions

<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

<CR> represents a 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 <CR>
(If the response code is enabled, the EZO™ class circuit will respond "*OK<CR>")
The EZO™ class D.O. circuit, will output a numeric string containing the D.O. once per second

D.O.<CR> (1 second)
D.O.<CR> (2 seconds)
D.O.<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.

<CR> represents a 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 D.O. circuit, will output a single string containing a D.O. reading 1 second after the command was issued.

D.O.<CR> (1 second)

<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 D.O. circuit. The embedded systems engineer must keep in mind that the EZO™ class D.O. circuit, cannot read the temperature from a D.O. probe or from a temperature probe. Another device must be used to read the temperature. EZO™ class D.O. circuit, has its default temperature set at 20°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 with this command

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

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

Salinity compensation

If the conductivity of your water is less than 2,500µs this command is irrelevant

In order to achieve the most accurate possible readings, the salinity or conductivity of the liquid being measured can be transmitted to the EZO™ class D.O. circuit. The default salinity/conductivity is set to 0. The salinity at which to compensate against can be changed at any time using the "S" command.

Salinity or conductivity can be in microsiemens or PPT

Command syntax

(Using an example salinity 50,000µs or 36.7 PPT)

S,50000<CR>	Using conductivity in µs to set salinity
or	
S,37.5,PPT<CR>	Using PPT to set salinity must be in this format "S,XXX,PPT"
S,?<CR>	Query the set salinity

Device response

S,50000<CR>
(If the response code is enabled, the EZO™ class circuit will respond "*OK<CR>")
There is no other output associated with this command

S,37.5,PPT<CR>
(If the response code is enabled, the EZO™ class circuit will respond "*OK<CR>")
There is no other output associated with this command

S,?<CR>
(If the response code is enabled, the EZO™ class circuit will respond "*OK<CR>")
?S,50000,µs<CR>
or
?S,37.5,ppt<CR>

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

Pressure compensation

This is to be used for the pressure of the water.
Not atmospheric pressure at altitude.

In order to achieve the most accurate possible readings, the pressure of the liquid being measured can be transmitted to the EZO™ class D.O. circuit. This parameter can be omitted if the water is less than 10 meters deep. The default pressure used is 101.325 kPa.

Command syntax

(Using an example pressure of 202.65 kPa)

P,202.65<CR>	Set the pressure to 202.65 kPa
P,?<CR>	Query the set pressure

Device response

P,202.65<CR>
(If the response code is enabled, the EZO™class circuit will respond "*OK<CR>")
There is no other output associated with this command.

P,?<CR>
(If the response code is enabled, the EZO™class circuit will respond "*OK<CR>")
?,P,202.65<CR>

<CR> represents a 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
saturation percentage, DO<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
% saturation percentage
DO dissolved oxygen

Followed by a 1 or a 0
Where: 1= enabled
0= disabled

Example
O,%,0<CR>
This will disable the saturation percentage output

To enable an output
Example
0,%,1<CR>
This will enable the saturation percentage output

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

Device response

O,%,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,%,DO<CR>
(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 D.O. circuit can be calibrated to atmospheric oxygen levels and 0 dissolved oxygen. Calibration to 0 dissolved oxygen is optional.

Command syntax

Cal, clear<CR>	Clears all calibration data
Cal<CR>	Calibrate the device to atmospheric oxygen levels
Cal,0<CR>	Calibrate the device to 0 dissolved oxygen
Cal,?<CR>	Query the calibration

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<CR>
(If the response code is enabled, the EZO™ class circuit will respond "*OK<CR>")
The LED will turn **Cyan** during the calibration.

Cal,0<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 two 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 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,D.O.,1.0<CR>
(If the response code is enabled, the EZO™ class circuit will respond "*OK<CR>")

<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

<CR> represents a 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 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

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

?STATUS,P,5.038<CR>

Where: P is the reason for the last reset event
Where: 5.038 is 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 1.16 mA at 5V and 0.995 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 to 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.

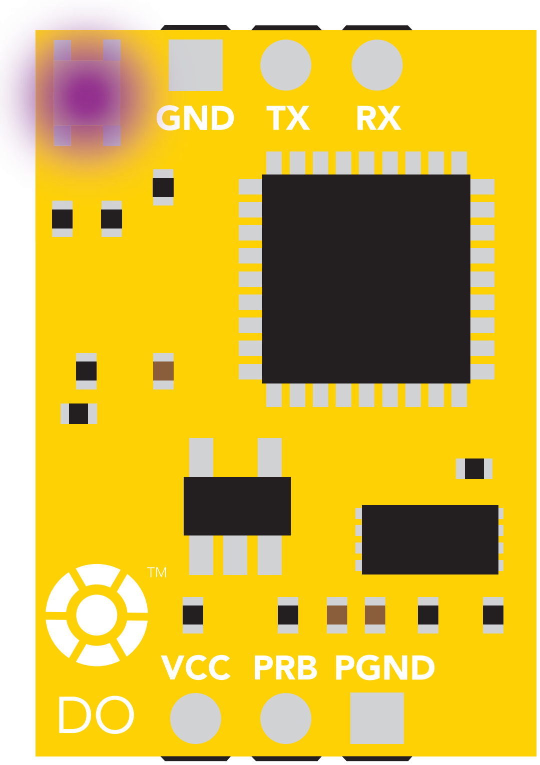
Change baud rate

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

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 EZO™ class circuit will then restart at the new baud rate.

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

<CR> represents a 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 temperate back to 20°C
Reset salinity back to 0
Reset pressure back to 101 kPa
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 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 as example an I²C ID number of 97)
I2C,[97]<CR>

Device response

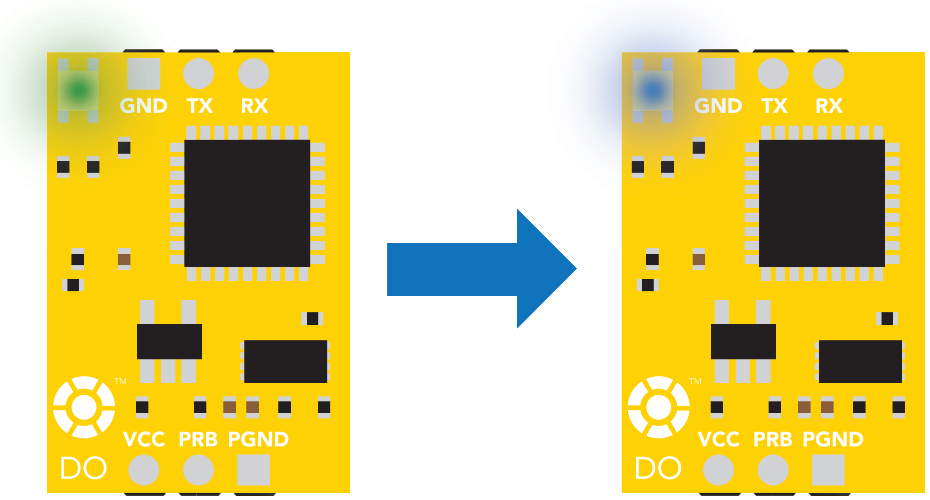
If an address > 127 is given

*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 I²C mode

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

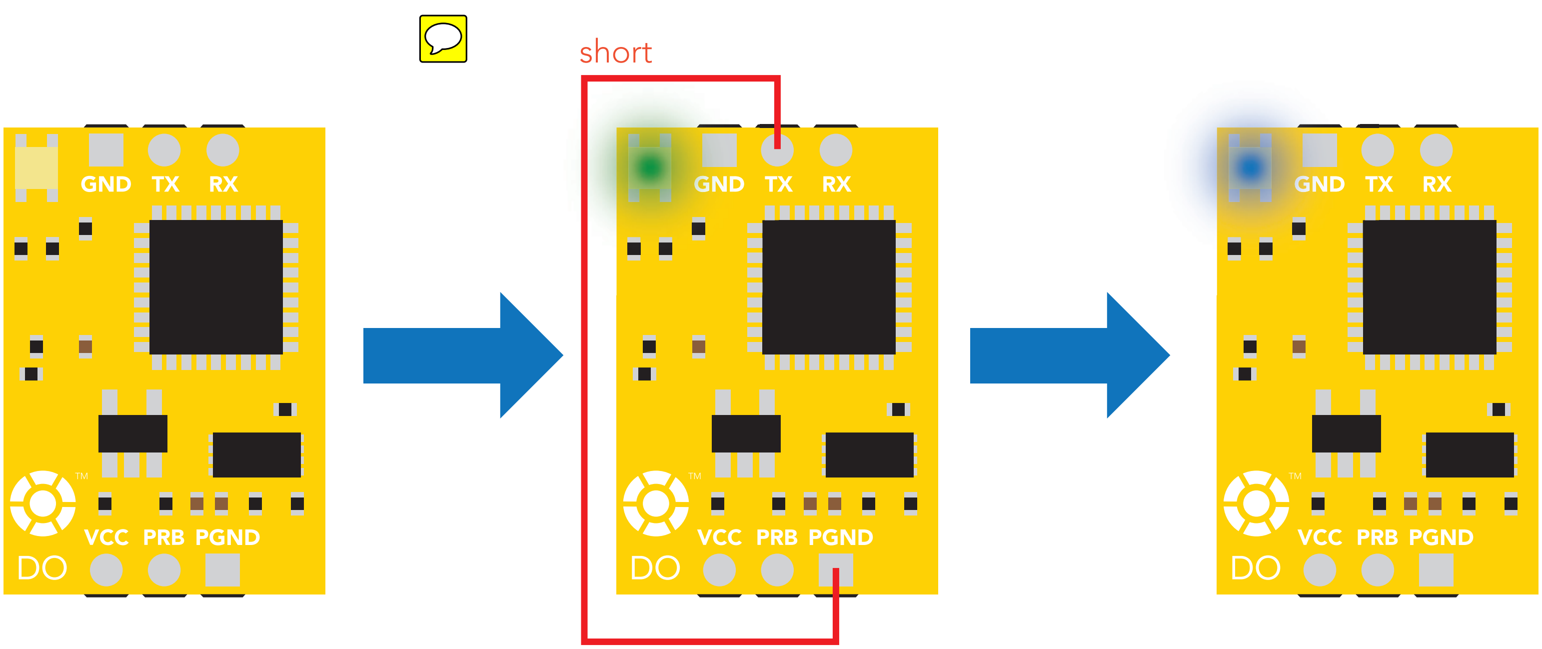


<CR> represents a carriage return (ASCII 13). The user does not transmit the literal string "<CR>". Commands are not case sensitive.

Manual switching to I^{2}C mode

All EZO™ class circuits can be manually switched from UART mode, to I^{2}C mode. **If this is done the EZO™ class D.O. circuit, will set its I^{2}C address to 97 (0x61).**

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^{2}C mode.



AtlasScientific™
Environmental Robotics

Dissolved Oxygen Circuit
EZO™

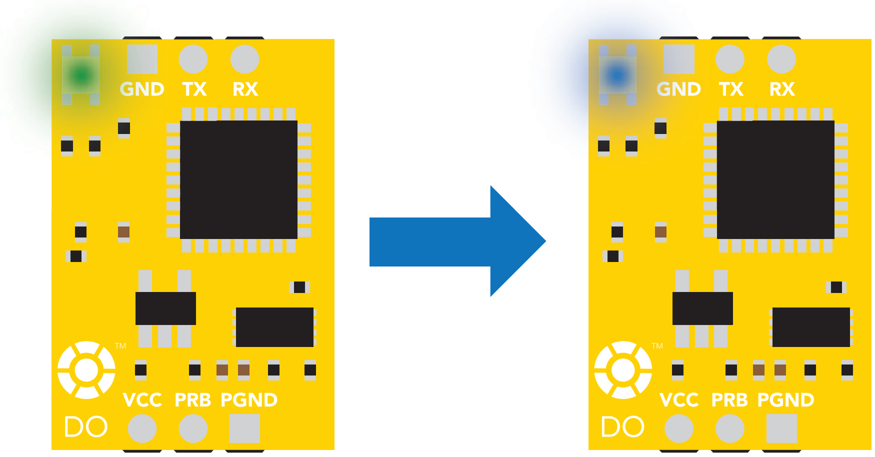
I²C Mode

™

I²C mode

An I²C address can be any number from 1-127. If the EZO™ Class D.O. circuit was put into I²C mode by jumping PRB to TX, the I²C address is 97(0x61).

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 is 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[6]	
	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

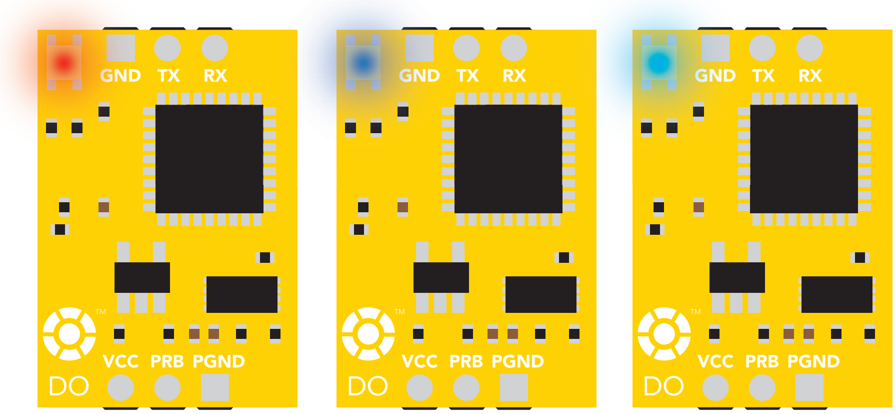
There are a total of 13 different commands that can be given to the EZO™ class D.O. circuit.

Command	Function
Cal	Performs calibration (pg.44)
I	Device information (pg.45)
L	Enable / Disable or Query the LEDs (pg.37)
O	Enable / Disable or Query parts of the output string (pg.42)
P	Pressure compensation (pg.41)
R	Returns a single reading (pg.38)
S	Salinity compensation (pg.40)
Serial	Set the baud rate (pg.48)
Sleep	Enter low power sleep mode (pg.47)
Status	Retrieve status information (pg.46)
T	Temperature compensation (pg.39)
X	Factory reset (pg.49)

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
Cyan= 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 |

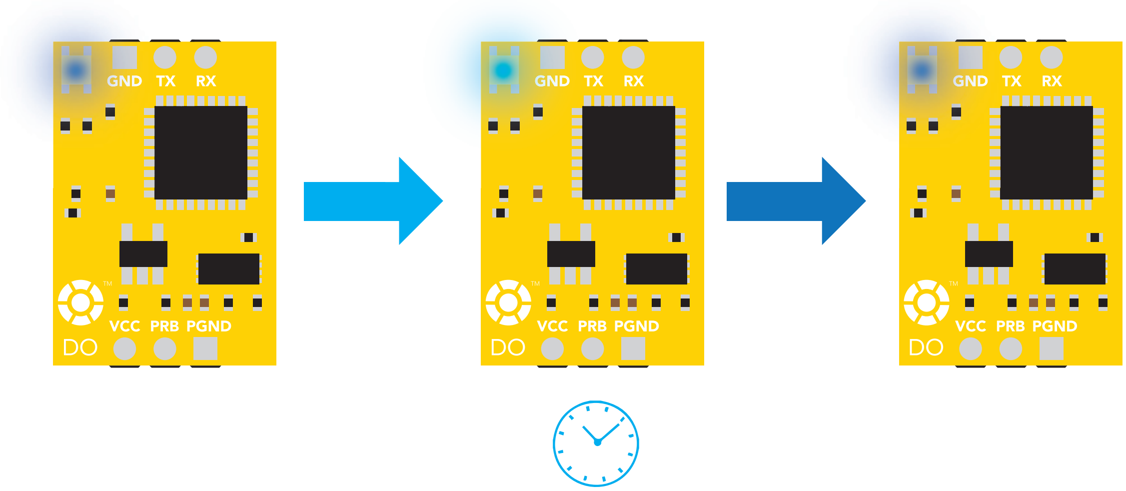
I²C take reading

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

D.O. represents many bytes.

The string will be no longer than 14 bytes.

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 D.O. circuit. The embedded systems engineer must keep in mind that the EZO™ class D.O. circuit, cannot read the temperature from a D.O. probe, or from a temperature probe. Another device must be used to read the temperature. EZO™ class D.O. circuit, has its default temperature set at 20˚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)

Salinity compensation

If the conductivity of your water is less than 2,500µs this command is irrelevant

In order to achieve the most accurate possible readings, the salinity, or conductivity of the liquid being measured can be transmitted to the EZO™ class D.O. circuit. The default salinity/conductivity is set to 0. The salinity at which to compensate against can be changed at any time using the "S" command. Salinity, or conductivity can be in microsiemens, or PPT

Command syntax

(Using an example salinity 50,000µs or 36.7 PPT)

S,50000	Using conductivity in µs to set salinity
or	
S,37.5,PPT	Using PPT to set salinity must be in this format "S,XXX,PPT"
S,?	Query the set salinity

Device response

S,50000<CR>
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.

1	null

S,37.5,PPT<CR>
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.

1	null

S,?<CR>
After 300ms, an I^2C read command can be issued to get the response code.
?S,50000,µs
or
?S,37.5,ppt

1	?	S	,	3	7	.	5	,	P	P	T	null

Pressure compensation

This is to be used for the pressure of the water.
Not atmospheric pressure at altitude.

In order to achieve the most accurate possible readings, the pressure of the liquid being measured can be transmitted to the EZO™ class D.O. circuit. This parameter can be omitted if the water is less than 10 meters deep. The default pressure used is 101.325 kPa.

Command syntax

(Using an example pressure of 202.65 kPa)

P,202.65 Set the pressure to 202.65 kPa

P,? Query the set pressure

Device response

P,202.65
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

P,?
After 300ms, an I2C read command can be issued to get the response
?,P,202.65

1	?	,	P	,	2	0	2	.	6	5	null

Removing parameters from the output string

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

Example
saturation percentage

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,?	Query the enabled outputs

Where parameter is

%	saturation percentage
DO	dissolved oxygen

Followed by a 1 or a 0
Where: 1= enabled
0= disabled

Example
O,%,0
This will disable the saturation percentage output

To enable an output
Example
0,%,1
This will enable the saturation percentage output

Device response

O,%,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.

O,?

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

?,O,%,DO

I²C Calibration

The EZO™class D.O. circuit can be calibrated to atmospheric oxygen levels and 0 dissolved oxygen. Calibration to 0 dissolved oxygen is optional.

Command syntax

Cal, clear	Clears all calibration data
Cal	Calibrate the device to atmospheric oxygen levels
Cal,0	Calibrate the device to 0 dissolved oxygen
Cal,?	Query the calibration

Device response

Cal,clear
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 |

Cal
The LED will turn **Cyan** during the calibration.
After 1.3 seconds, 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 |

Cal,0
The LED will turn **Cyan** during the calibration.
After 1.3 seconds, 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 |

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

If not calibrated

?	C	A	L	,	0	null

(?CAL,0)

If single point calibration

?	C	A	L	,	1	null

(?CAL,1)

If two point calibration

?	C	A	L	,	2	null

(?CAL,2)

I²C Device Info

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 300 ms

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

1	?	I	,	D	O	,	1	.	0	null

?I,D.O.,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 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 Low power state

To conserve energy in between readings, the Atlas Scientific D.O. 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 1.16 mA at 5V and 0.995 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 I²C mode to UART mode

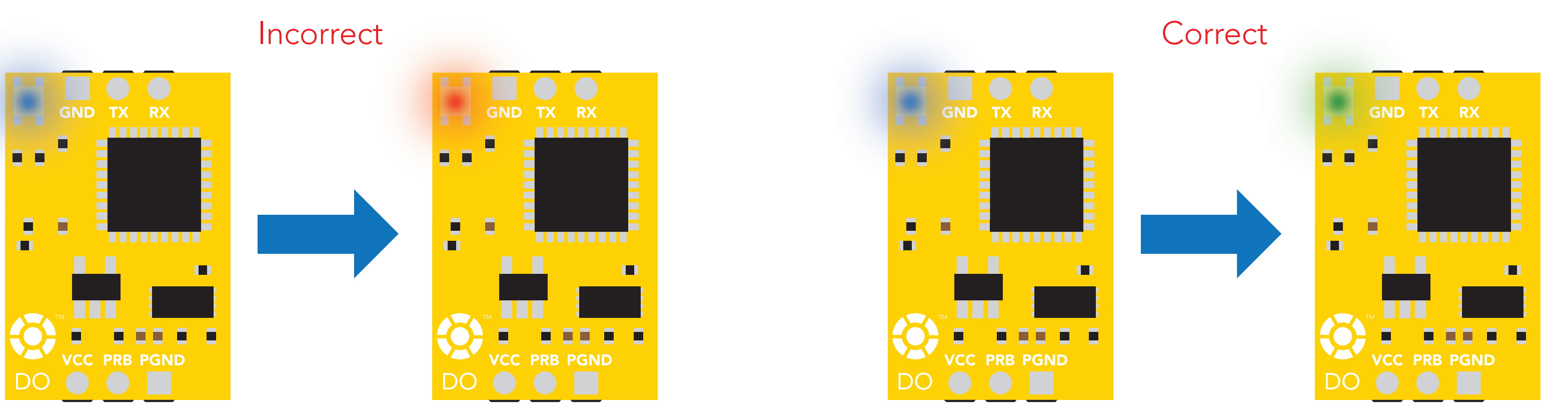
Transmitting the command serial,<n> will set the EZO™ class circuit into UART mode from I²C mode. **Where [n] represents any one of the 8 available baud rates.**

Command syntax
(Using as example a 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 temperate back to 20˚C
Reset salinity back to 0
Reset pressure back to 101 kPa
Set debugging LED to on
Enable response codes

This command will not change the set I²C address

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

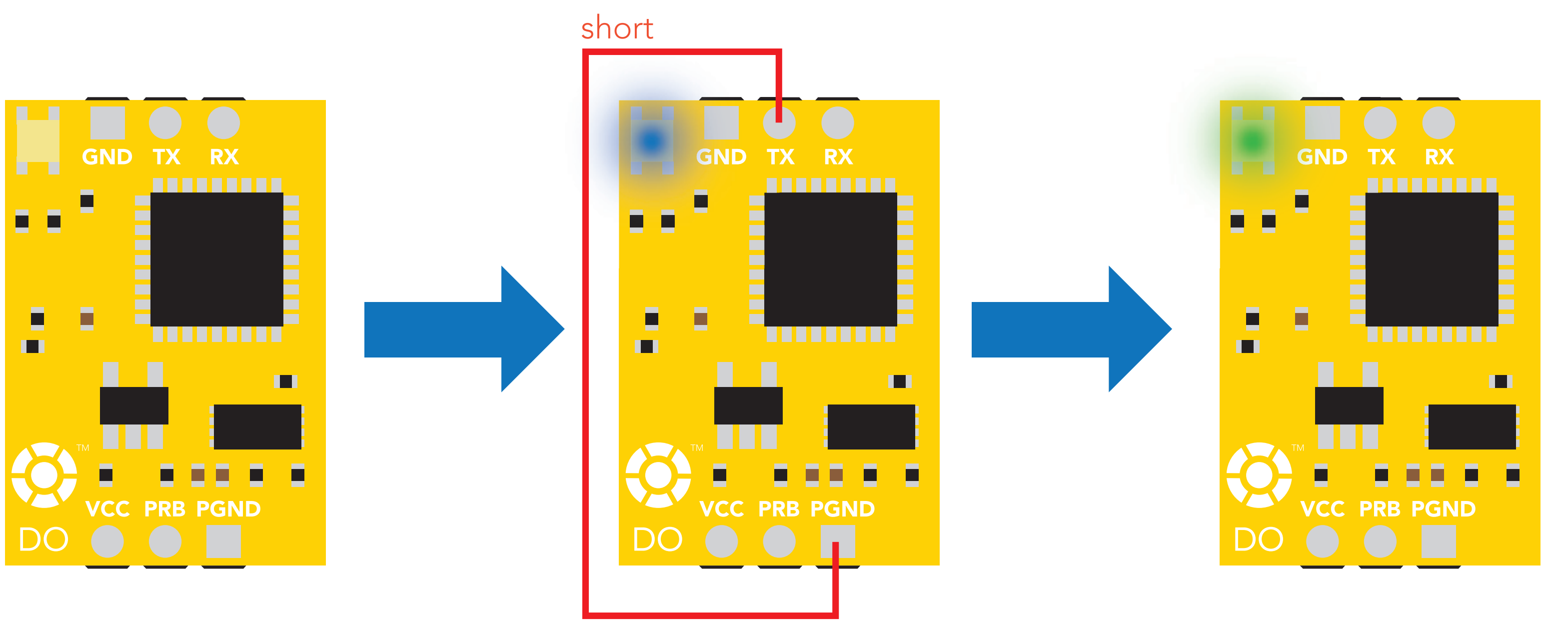
?STATUS,S,5.038

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

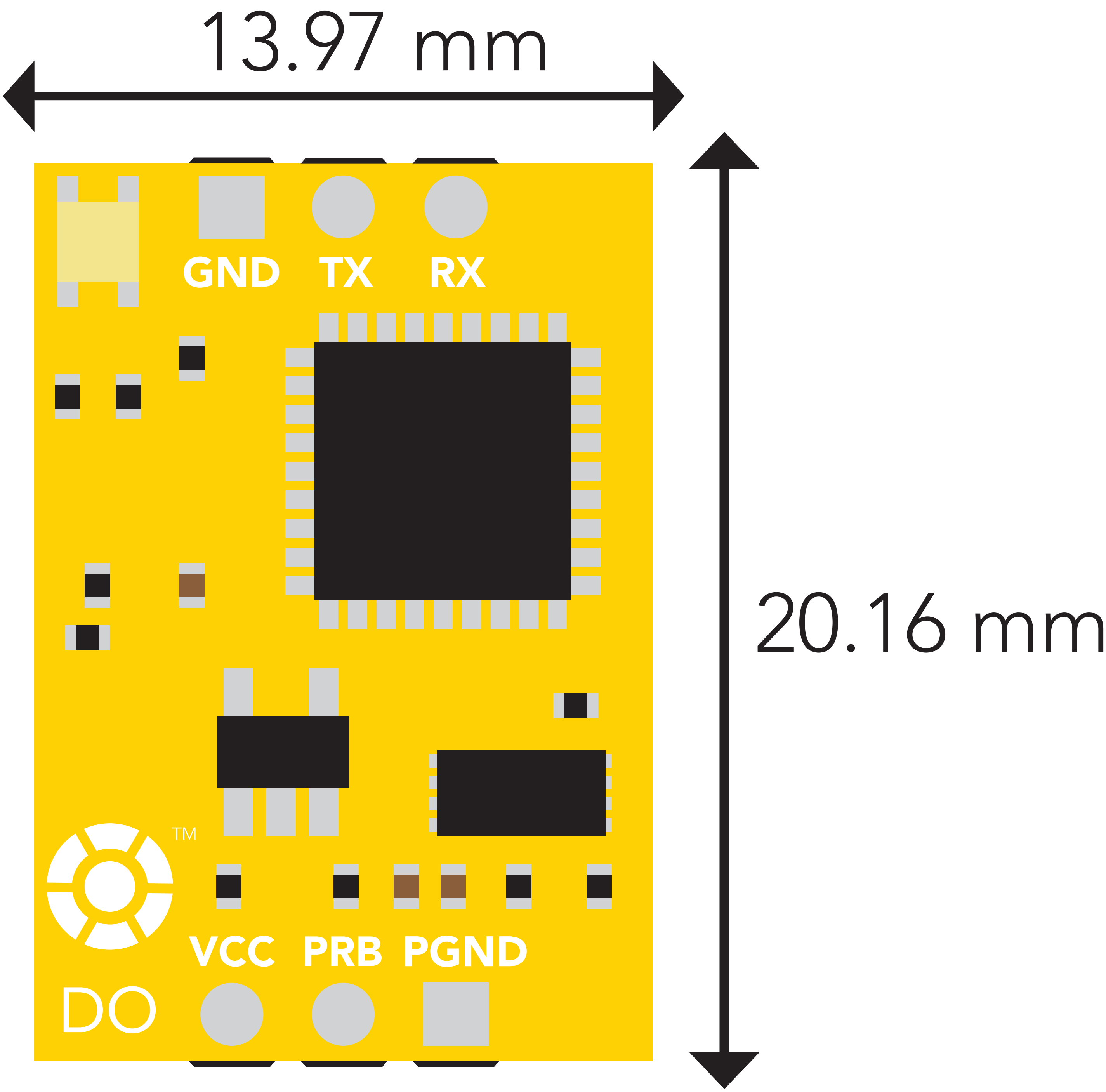
Manual switching to UART mode

All EZO™ class circuits, can be manually switched from I²C mode to UART mode.
If this is done, the EZO™ class D.O. circuit, will set its baud rate to 9600.

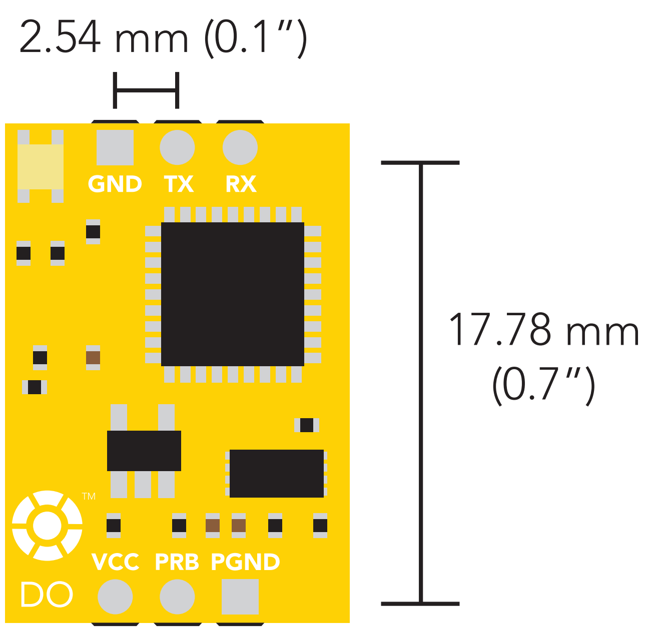
1. Cut the power to the device
2. Short the right probe pin to the TX pin
3. Power the device
4. Wait for LED to change from **Blue** to **Green**
5. Remove the short from the probe pin to the TX pin
6. Power cycle the device
7. The device is now UART mode



Circuit dimensions

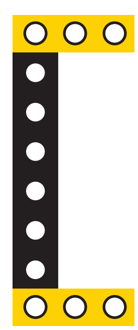


How to make a footprint for the Atlas Scientific™ EZO™ D.O. circuit

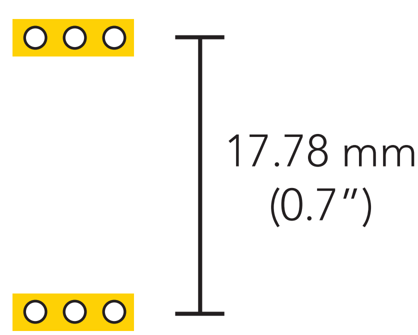


1. In your CAD software place an 8 position header.

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

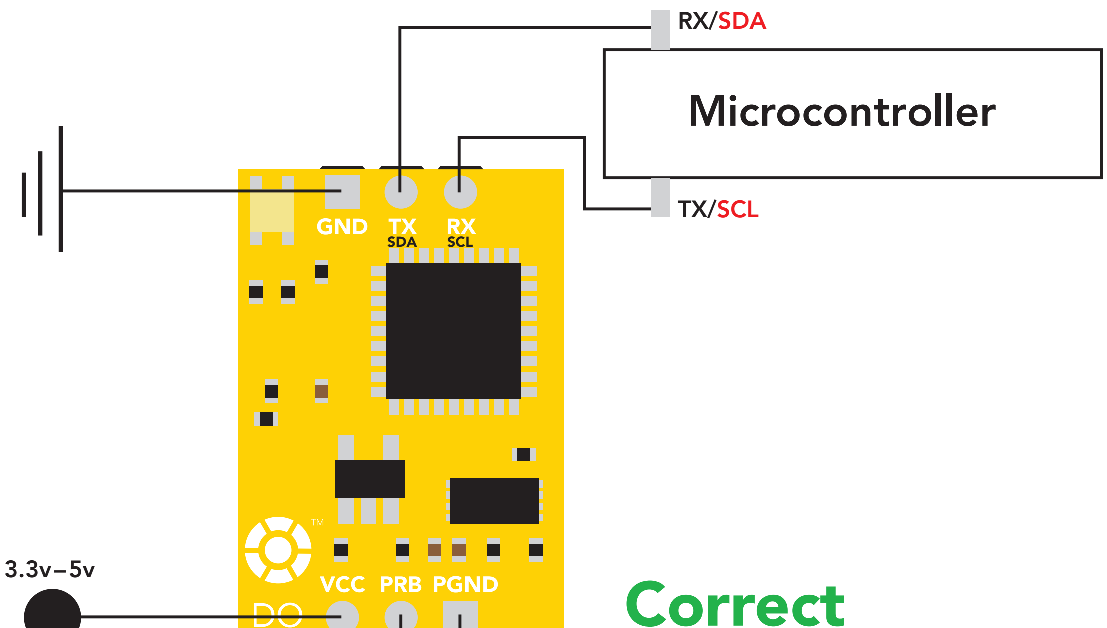


3. Once this is done, you can delete the 8 position header. Make sure that the two 3 position headers are 17.78mm (0.7″) apart from each other.

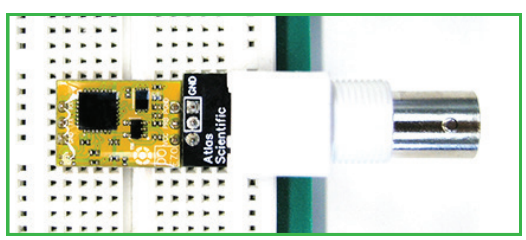


Wiring diagram

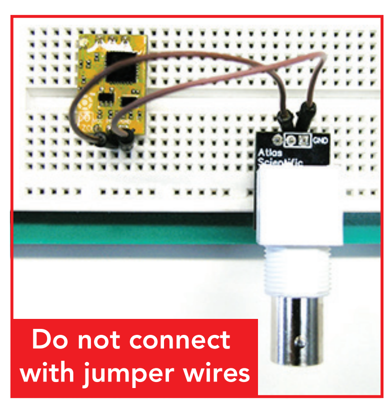
- To connect the Circuit to your microcontroller, follow the diagram below.
- The BNC shield can be connected to any ground line.
- Make sure your Circuit and microcontroller share a common ground.
- TX on your Circuit connects to RX on your microcontroller.
- If in I²C mode connect SDA to SDA and SCL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

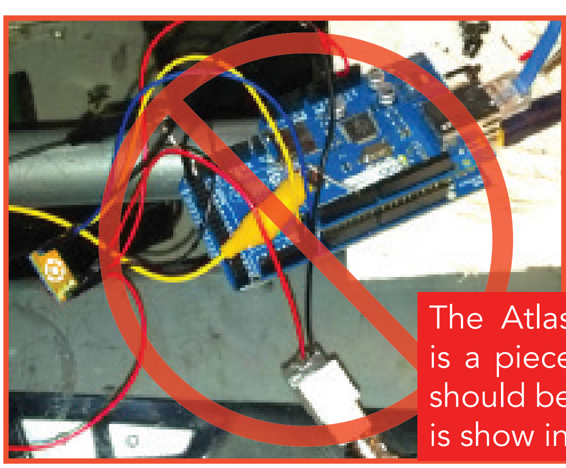


Correct



Incorrect





The Atlas Scientific™ EZO™ class D.O. 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 D.O. circuit to be free of defect during the debugging phase of device implementation, or 30 days after receiving the EZO™class D.O. circuit (whichever comes first).

The debugging phase

The debugging phase as defined by Atlas Scientific™, is the time period when the EZO™ class D.O. circuit is inserted into a bread board, or shield, and is connected to a microcontroller according to the wiring diagram on pg. 47. 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 D.O. circuit is being debugged in a bread board, the bread board must be devoid of other components. If the EZO™ class D.O. circuit is being connected to a microcontroller, the microcontroller must be running code that has been designed to drive the EZO™ class D.O. circuit exclusively and output the EZO™ class D.O. 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 D.O. circuit warranty:

- **Soldering any part of the EZO™ class D.O. circuit**
- **Running any code, that does not exclusively drive the EZO™ class D.O. circuit and output its data in a serial string**
- **Embedding the EZO™ class D.O. 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 D.O. circuit, against the thousands of possible variables that may cause the EZO™ class D.O. circuit to no longer function properly.
Please keep this in mind:

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

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

TM