AtlasScientific™
Environmental Robotics

V 6.1

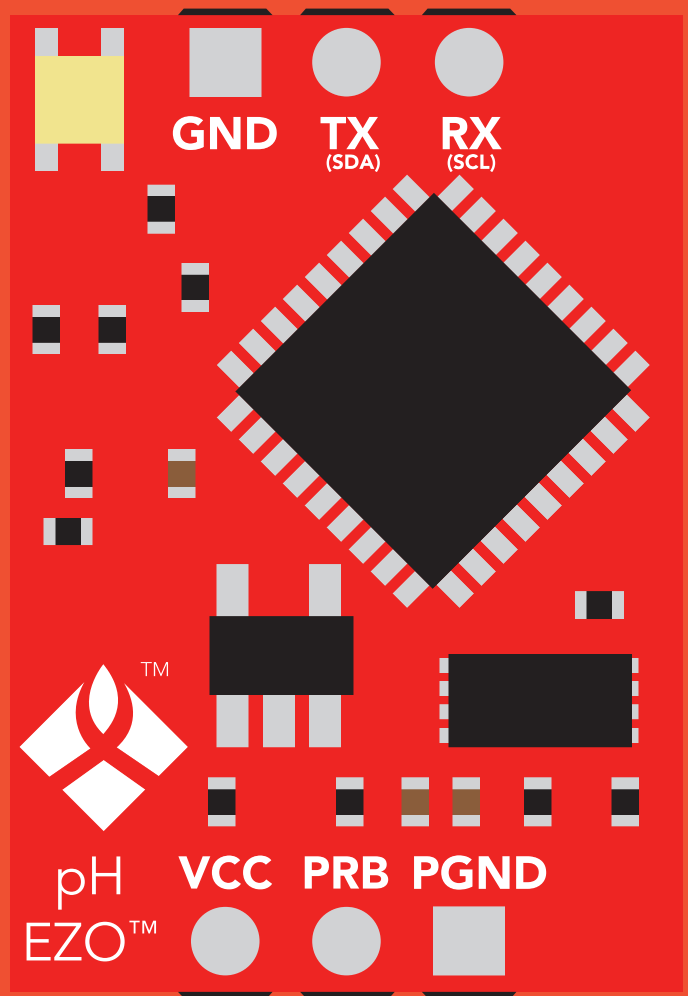
Revised 5/23

EZO-pH™

Embedded pH Circuit

ISO 10523 Compliant
(determination of pH)

Reads	**pH**
Range	**.001 – 14.000**
Resolution	**.001**
Accuracy	**+/– 0.002**
pH reading time	**800ms**
Supported probes	**Any type & brand**
Calibration	**1, 2, 3 point**
Temp compensation	**Yes**
Data protocol	**UART & I^2C**
Default I^2C address	**99 (0x63)**
Operating voltage	**3.3V – 5V**
Data format	**ASCII**

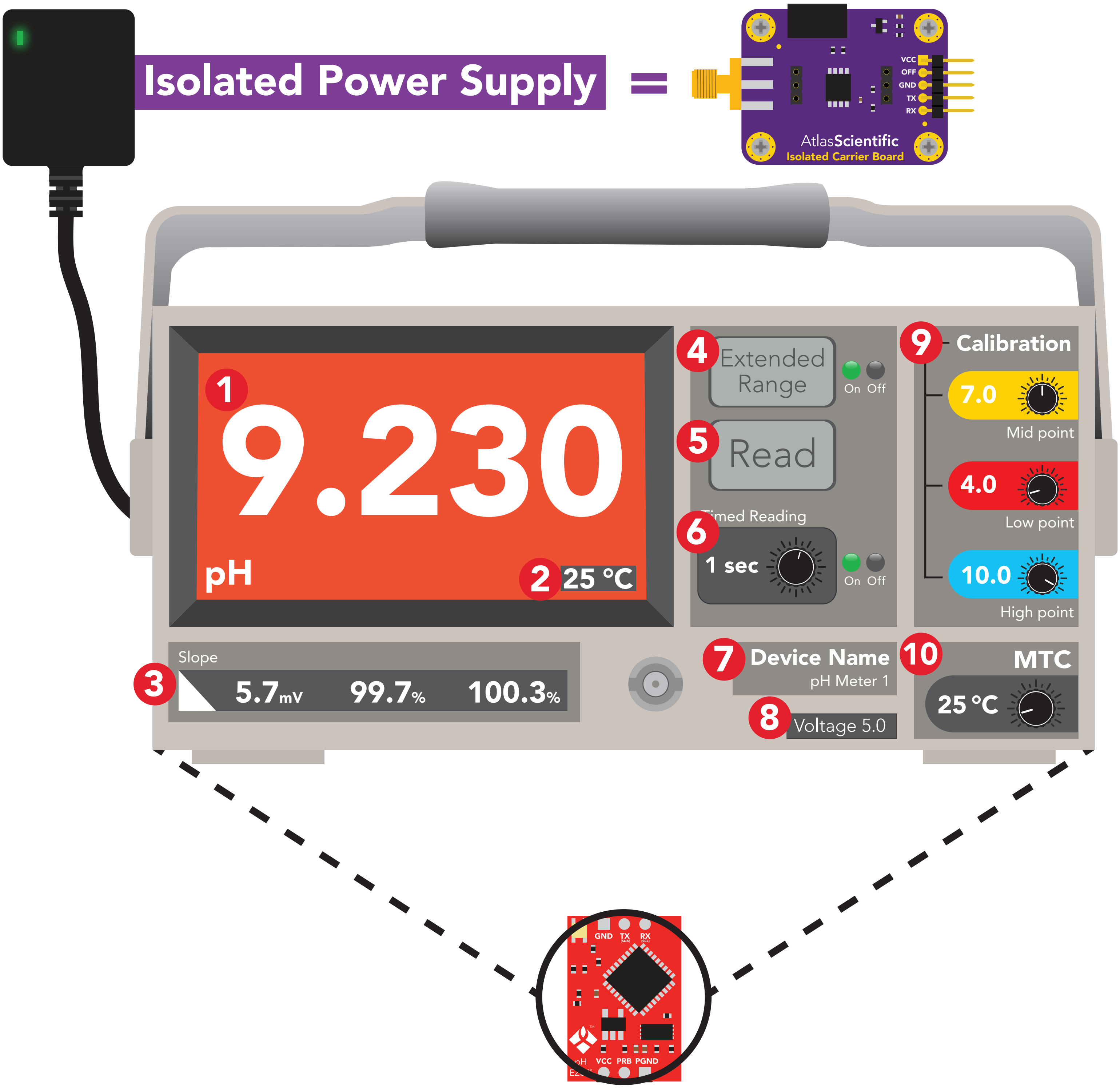


PATENT PROTECTED

Written by Jordan Press
Designed by Noah Press

This is an evolving document, check back for updates.

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



1 Three decimal pH reading

2 Temperature used for reading

3 Calibration slope

4 Extended range capability

5 Immediate reading

6 Timed readings

7 Set device name

8 Voltage usage

9 Multi point calibration

10 Manual temperatue compensation

The EZO™ pH Circuit is compatible with any brand of pH probe.

✓ Available data protocols

UART

Default

I²C

X Unavailable data protocols

SPI

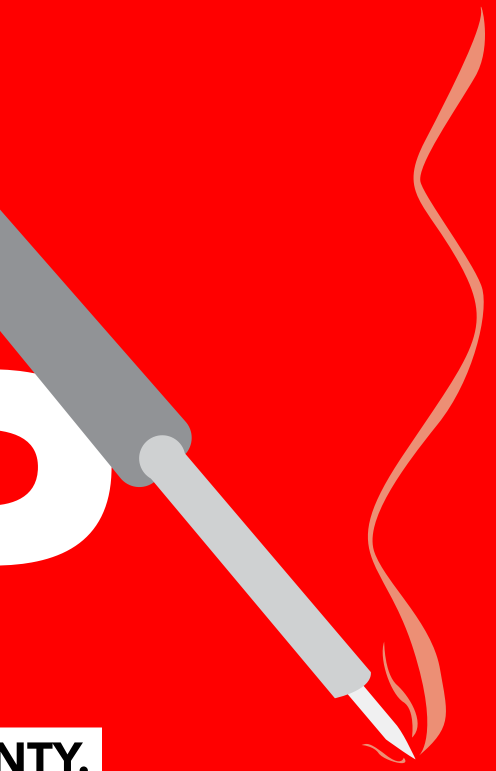
Analog

RS-485

Mod Bus

4–20mA

STOP



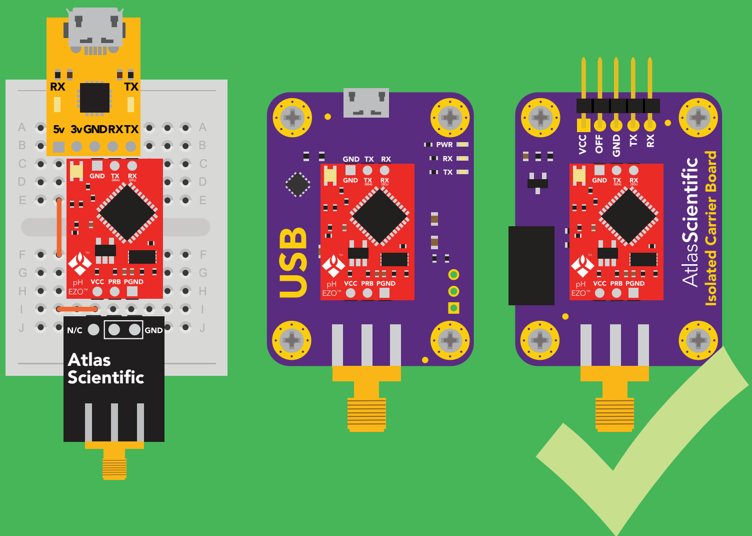
SOLDERING THIS DEVICE VOIDS YOUR WARRANTY.

Are there specific soldering instructions? **Yes, see page 71.**

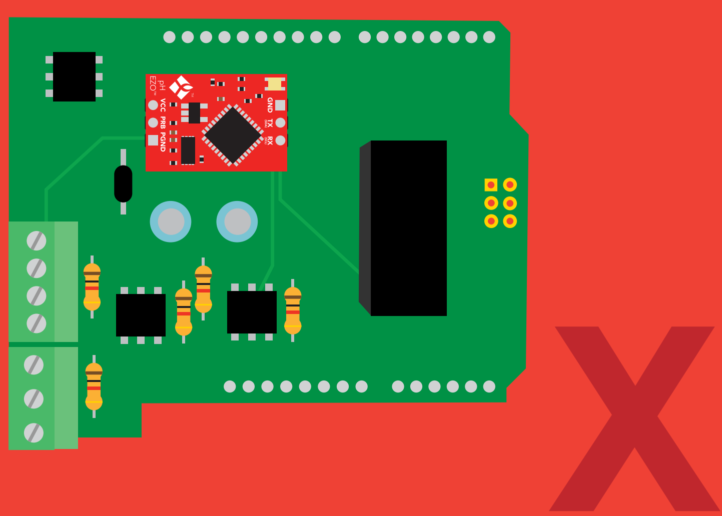
Can you make a warranty claim after soldering? No.

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

Get this device working using one of these methods first.



Do not embed before you have experience with this sensor.



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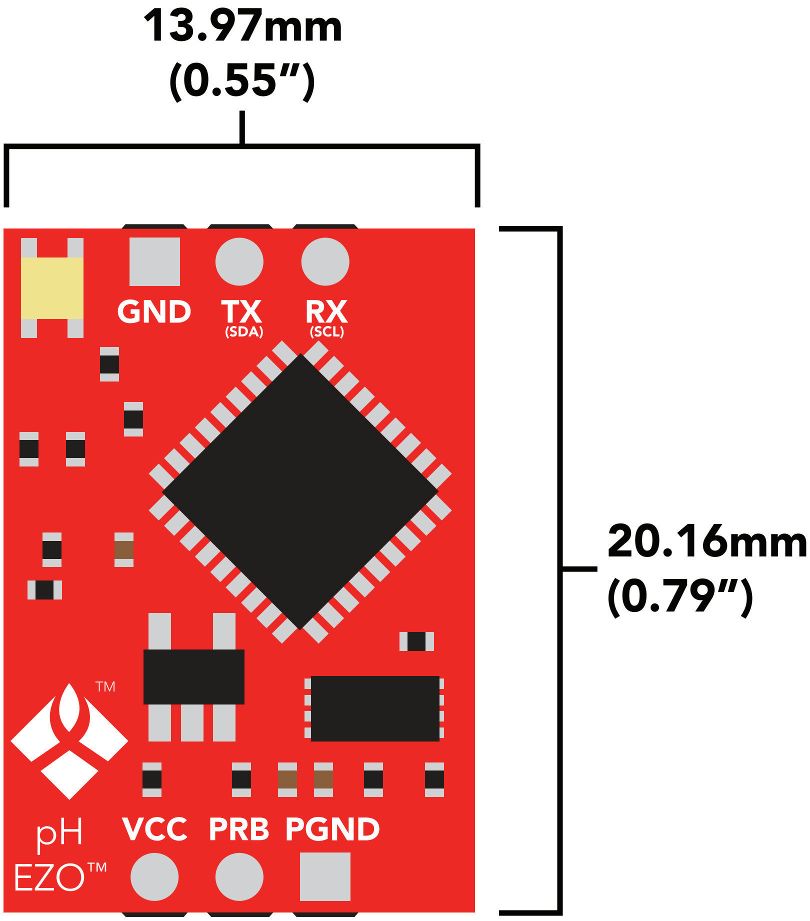
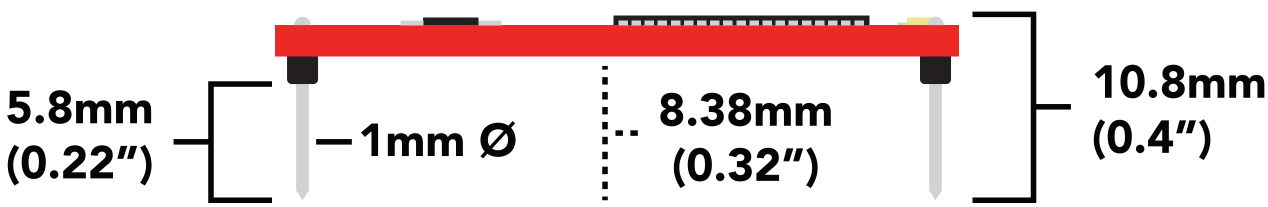
EZO™ circuit dimensions





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 max ratings

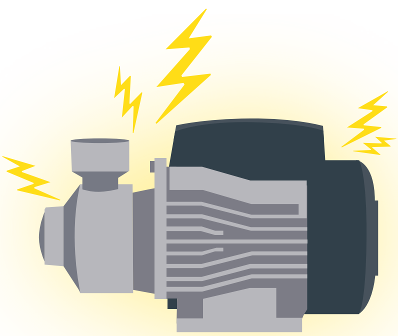
Parameter	MIN	TYP	MAX
Storage temperature (EZO™ pH)	-65 °C		125 °C
Operational temperature (EZO™ pH)	-40 °C	25 °C	85 °C
VCC	3.3V	5V	5.5V

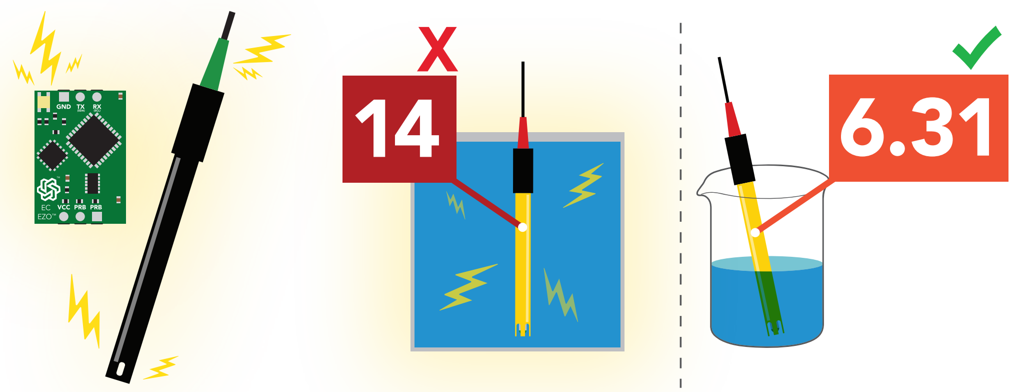
AtlasScientific™ Environmental Robotics

Electrical isolation

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

When electrical noise interferes with the pH readings, it is common to see rapidly fluctuating readings or readings that are pinned to 14 or 0. To verify that electrical noise is causing inaccurate readings, place the pH probe in a cup of water by itself. The readings should stabilize quickly, confirming that electrical noise was the issue.

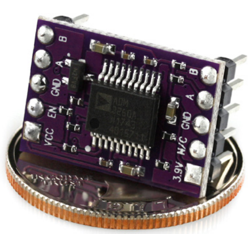




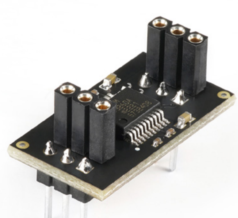
Advice:

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

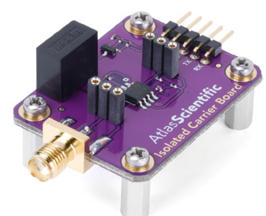
Atlas Scientific offers several different electrical isolation products that can be used in your design. Select the electrical isolation product that works best for your design.



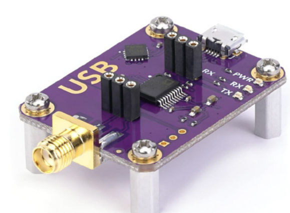
Basic EZO™
Inline Voltage Isolator



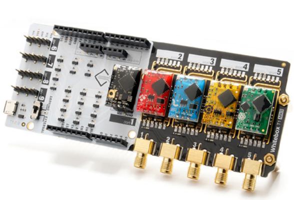
Vertical Isolator



Electrically Isolated
EZO™ Carrier Board

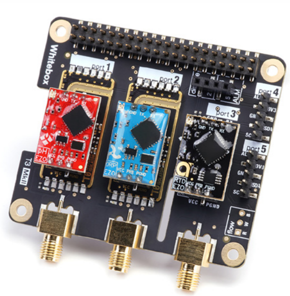


Gen 2 Electrically Isolated
USB EZO™ Carrier Board



Whitebox T1

Whitebox T3



Whitebox T3

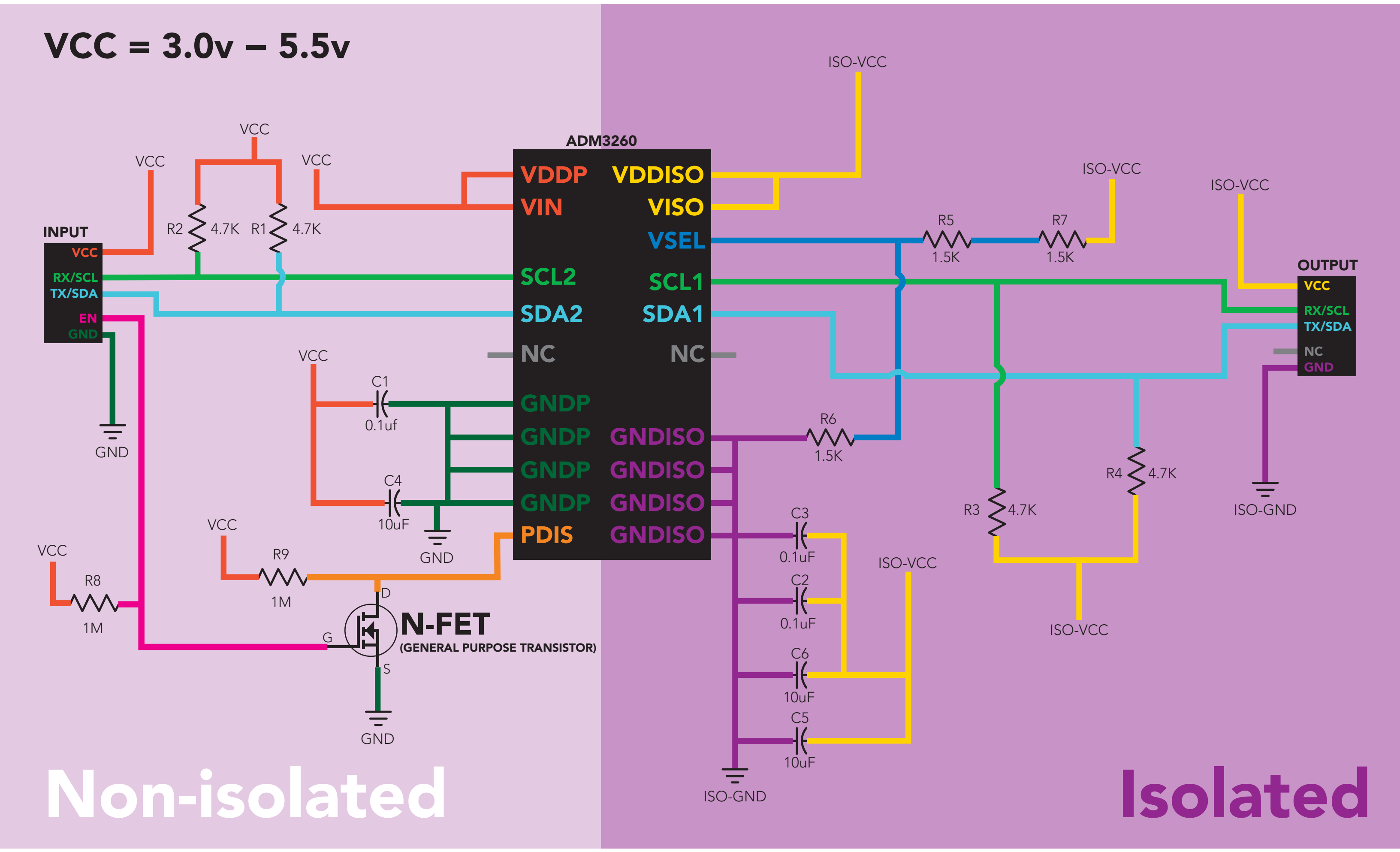
Electrically Isolated EZO™
Carrier Board (old style)

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

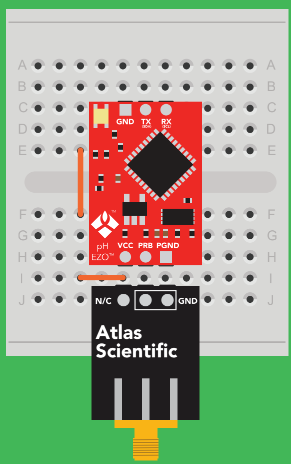
This isolation schematic is based on the ADM3260, which can output up to 150 mW of isolated power. PCB layout requires special attention for EMI/EMC and RF Control. Having good ground planes and keeping the capacitors as close to the chip as possible are crucial for proper performance.

The two data channels have a 4.7kΩ pull-up resistor on both the isolated and non-isolated lines (R1, R2, R3, and R4). The output voltage is set using a voltage divider (R5, R6, and R7). This produces a voltage of 3.9V regardless of your input voltage.

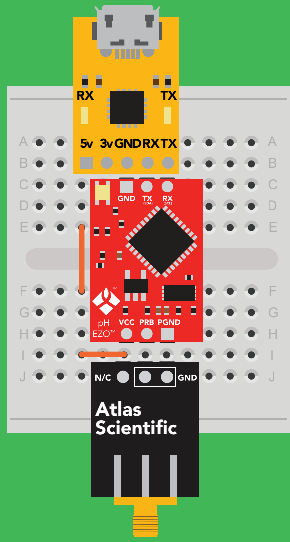
Isolated ground is different from non-isolated ground, these two lines should not be connected together.



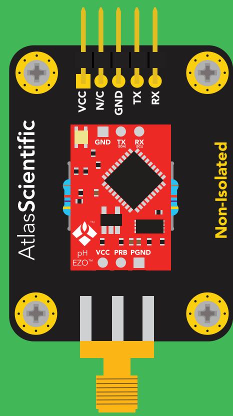
Correct wiring



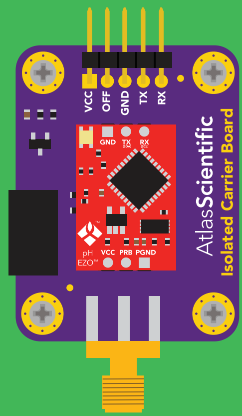
Bread board



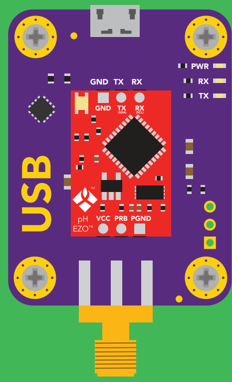
Bread board via USB



Non-Isolated EZO™ Carrier Board



Electrically Isolated EZO™ Carrier Board

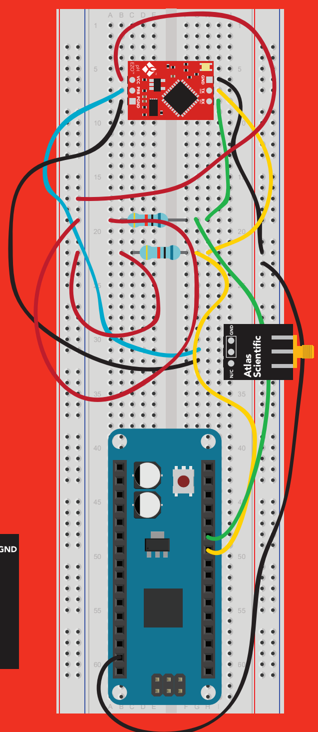


USB carrier board

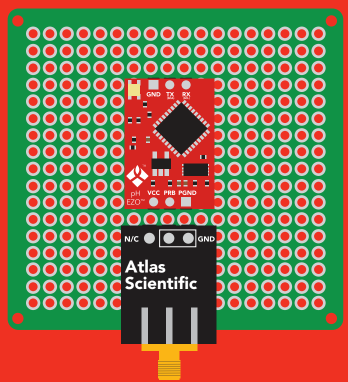
Incorrect wiring

Extended leads

Sloppy setup

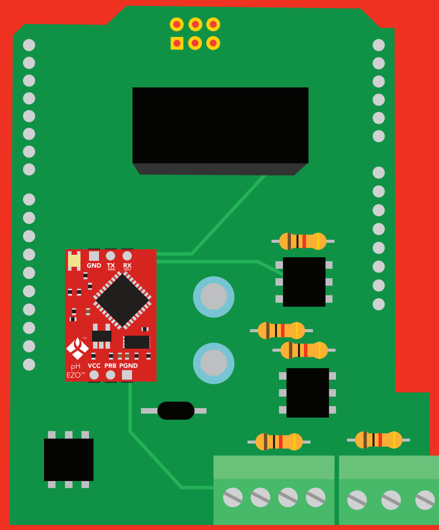


Perfboards or Protoboards



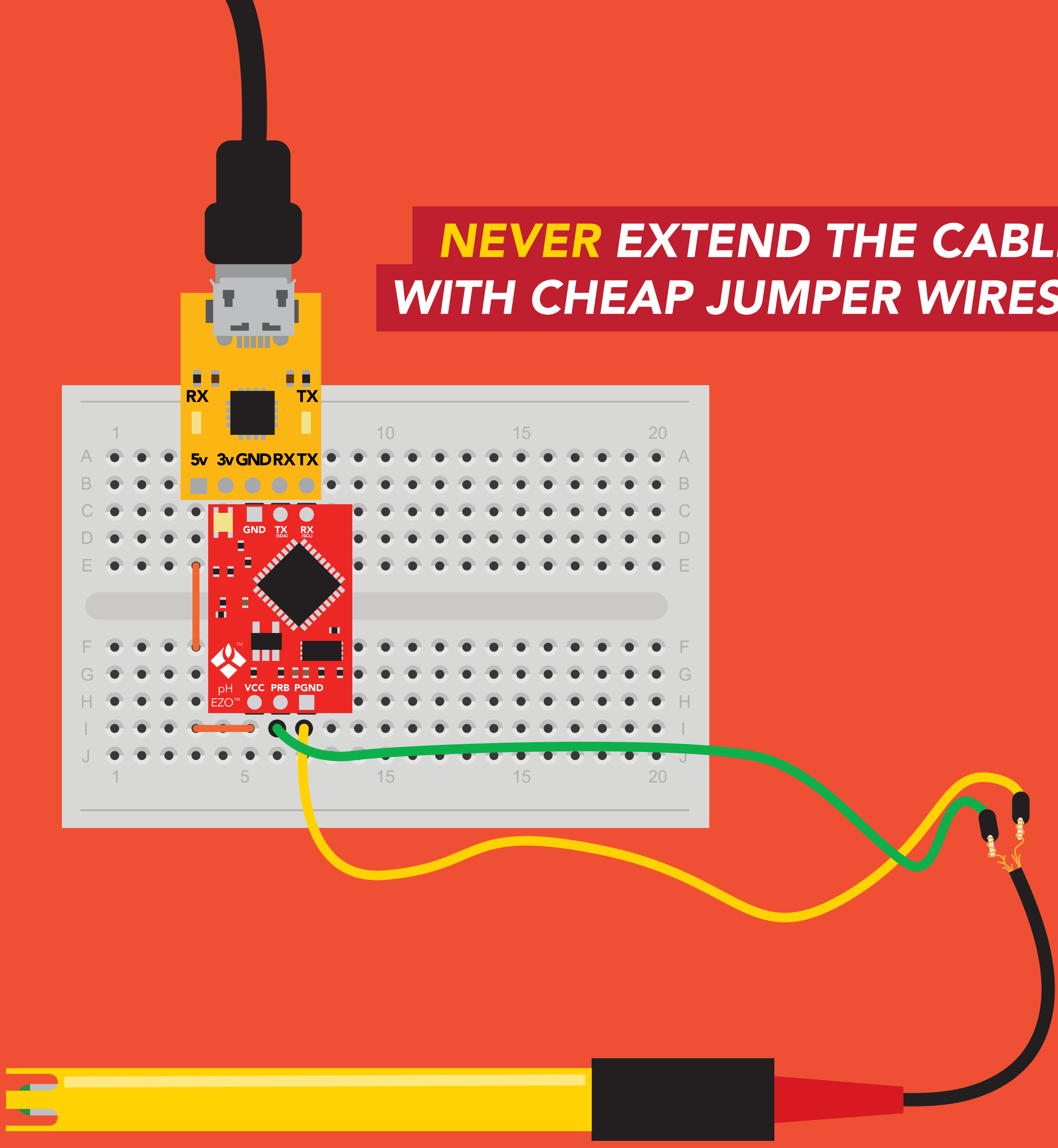
NEVER
use Perfboards or Protoboards
Flux residue and shorting wires make it very hard to get accurate readings.

*Embedded into your device



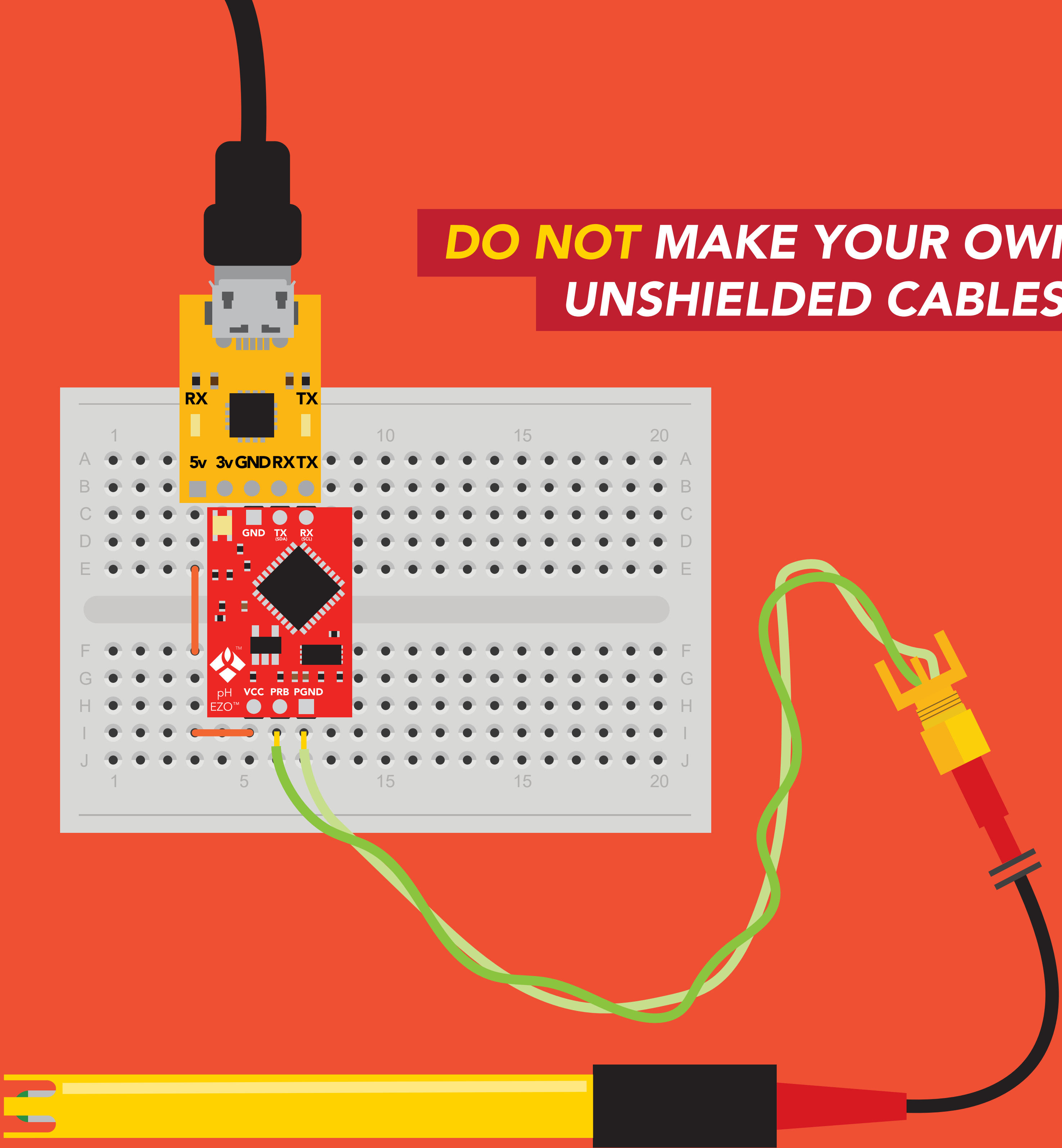
***Only after you are familar with EZO™ circuits operation**

NEVER EXTEND THE CABLE WITH CHEAP JUMPER WIRES!



DO NOT CUT THE PROBE CABLE WITHOUT REFERING TO THIS DOCUMENT!

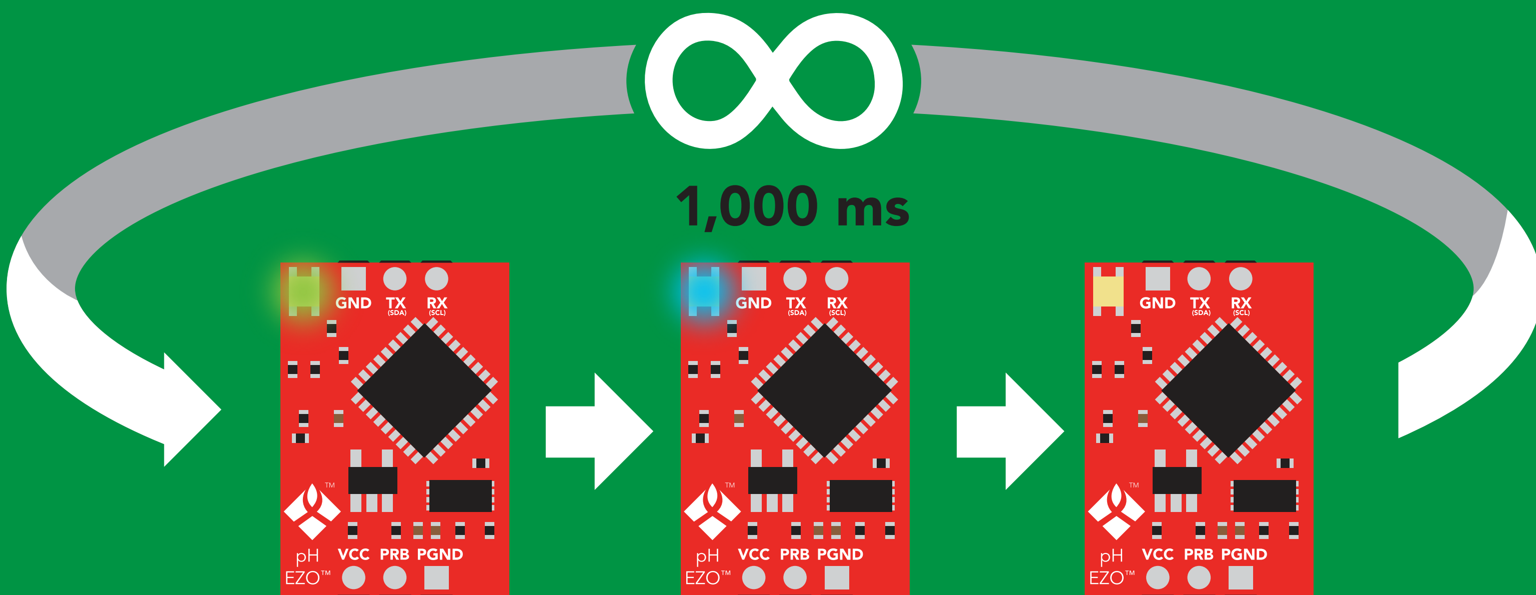
DO NOT MAKE YOUR OWN UNSHIELDED CABLES!



ONLY USE SHIELDED CABLES.

Default state
UART mode

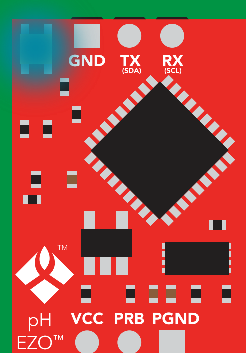
Baud	**9,600**
Readings	**continuous**
Units	**pH**
Speed	**1 reading per second**
LED	**on**



Green
Standby

Cyan
Taking reading

Transmitting



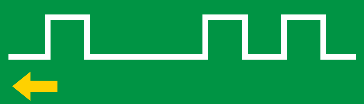
Solid Blue LED
in I²C mode
Not UART ready

UART mode

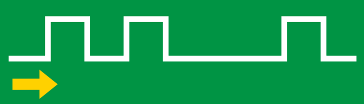
8 data bits	no parity
1 stop bit	no flow control

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

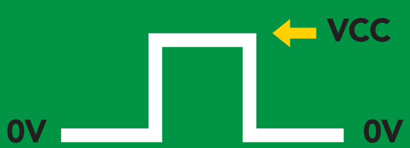
RX
Data in

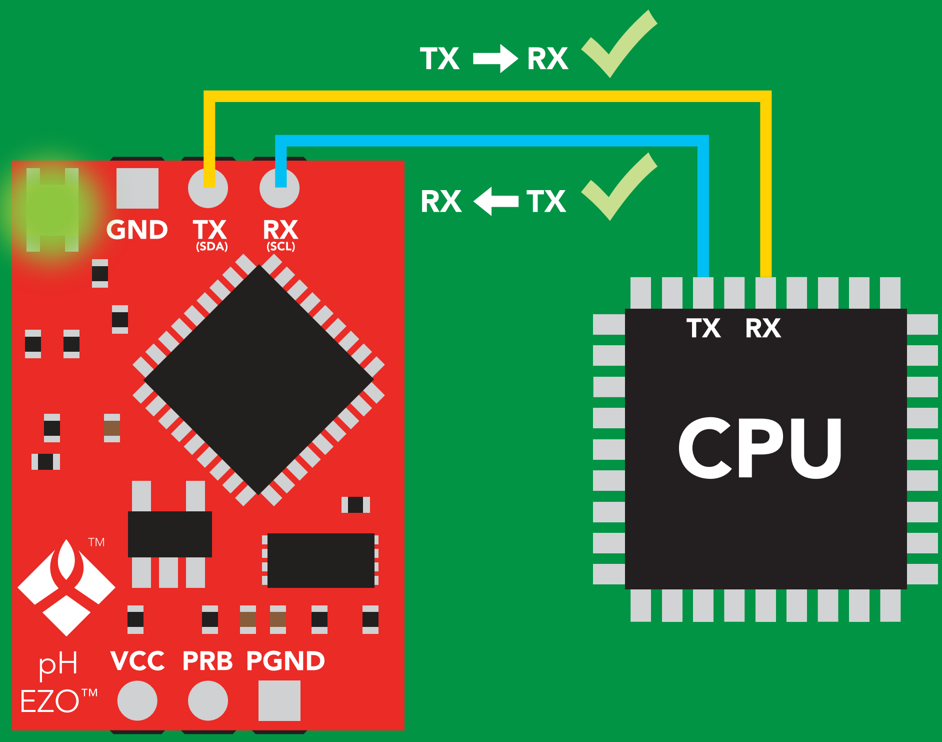


TX
Data out



Vcc 3.3V – 5.5V

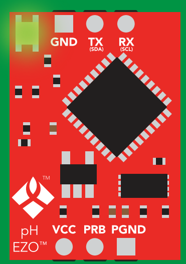




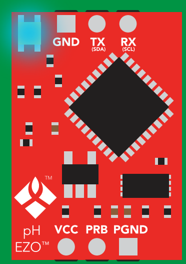
Data format

Reading	pH	Data type	floating point
Encoding	ASCII	Decimal places	3
Format	string	Smallest string	4 characters
Terminator	carriage return	Largest string	40 characters

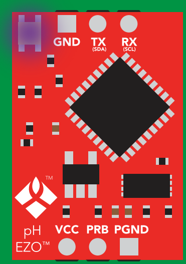
LED color definition



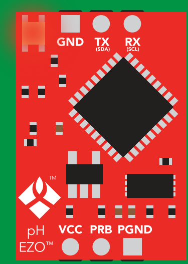
Green
UART standby



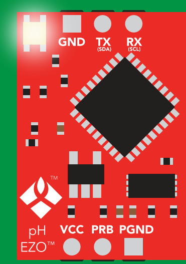
Cyan
Taking reading



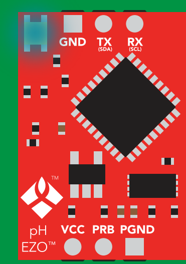
Purple
Changing baud rate



Red
Command not understood



White
Find



Blue
I2C standby

	LED ON
5V	**+2.2 mA**
3.3V	**+0.6 mA**

Settings that are retained if power is cut

Baud rate
Calibration
Continuous mode
Device name
Enable/disable response codes
Hardware switch to I²C mode
LED control
Protocol lock
Software switch to I²C mode

Settings that are *NOT* retained if power is cut

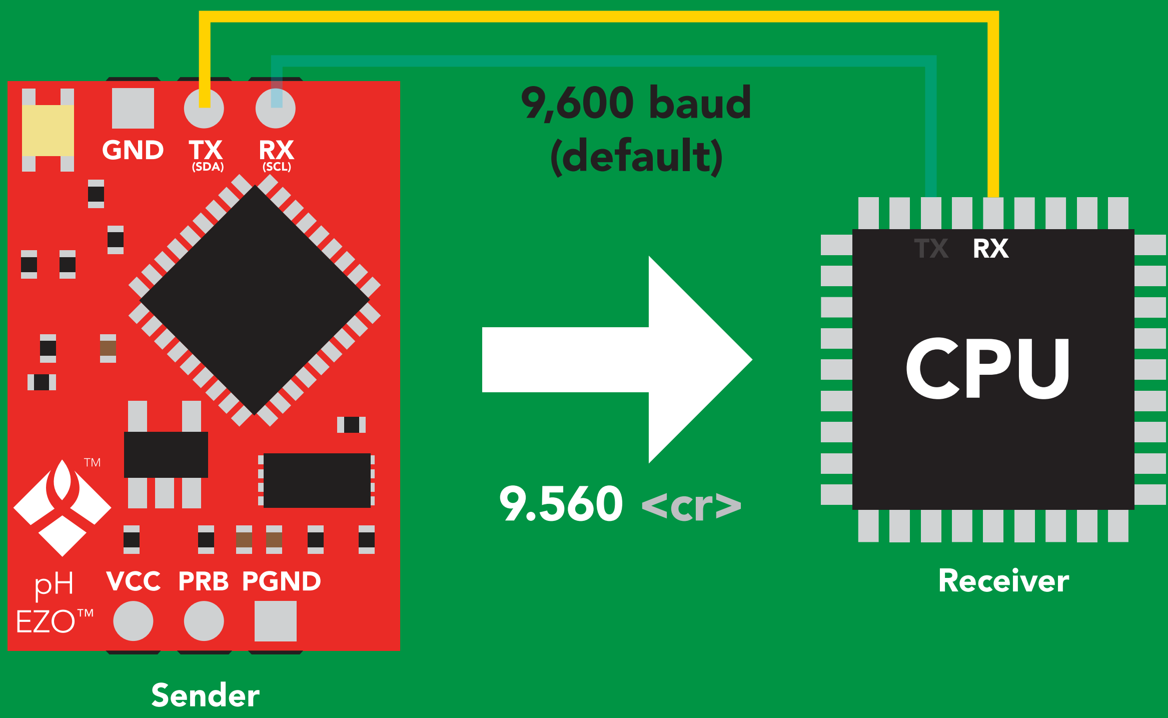
Find
Sleep mode
Temperature compensation

Receiving data from device

2 parts

ASCII data string — Command

Carriage return <cr> — Terminator



Advanced

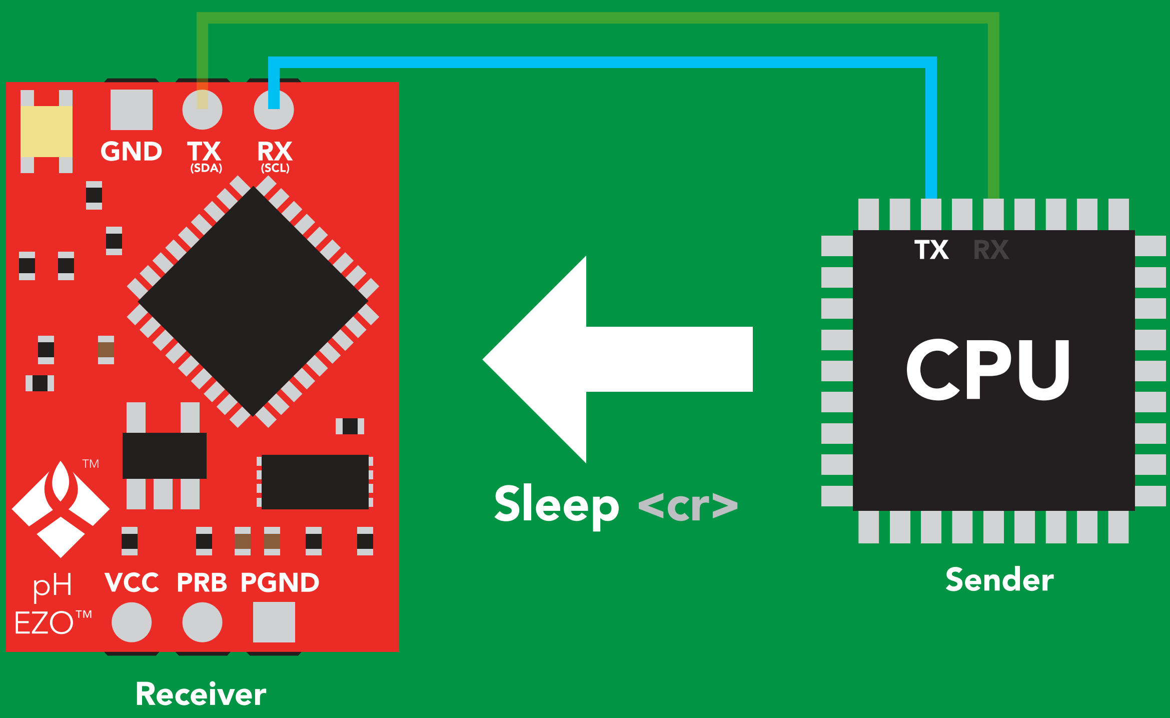
ASCII:	9	.	5	6	0	<cr>
Hex:	39	2E	35	36	30	0D
Dec:	57	46	53	54	48	13

AtlasScientific™ Environmental Robotics

Sending commands to device

2 parts

Command (not case sensitive)	Carriage return <cr>
ASCII data string	Terminator



Advanced

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

UART mode
command quick reference

All commands are ASCII strings or single ASCII characters.

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

LED control

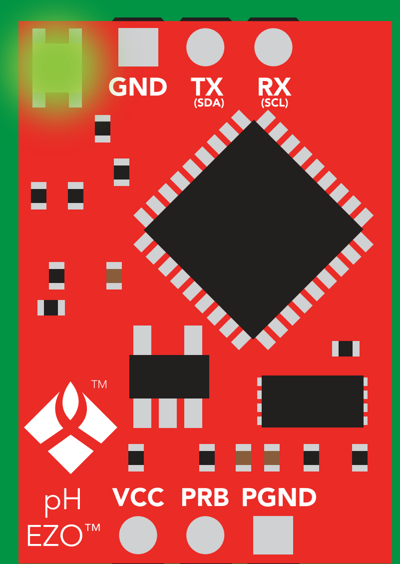
Command syntax

L,1 <cr> **LED on** **default**

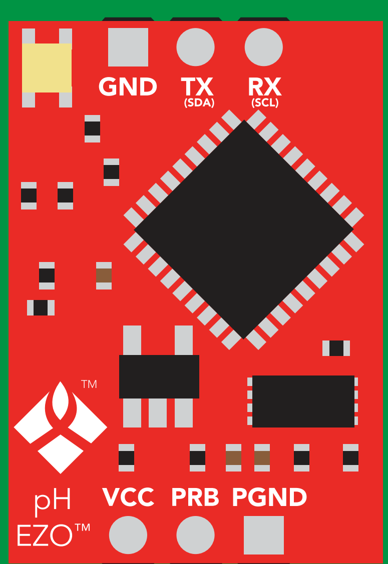
L,0 <cr> **LED off**

L,? <cr> **LED state on/off?**

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



L,1



L,0

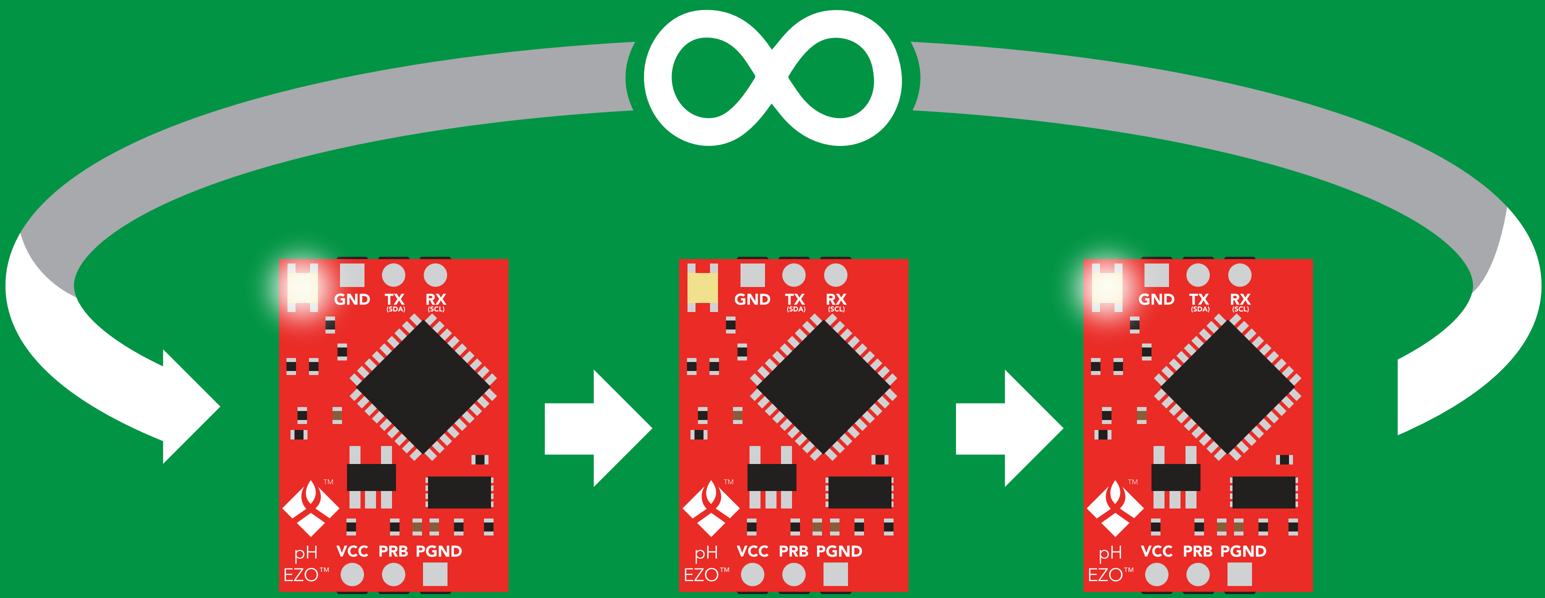
Find

Command syntax

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

Find <cr> **LED rapidly blinks white, used to help find device**

Example	Response
Find <cr>	*OK <cr>



Continuous reading mode

Command syntax

C,1	<cr>	enable continuous readings once per second **default**
C,n	<cr>	continuous readings every n seconds (n = 2 to 99 sec)
C,0	<cr>	disable continuous readings
C,?	<cr>	continuous reading mode on/off?

Example	Response
C,1 <cr>	*OK <cr> pH (1 sec) <cr> pH (2 sec) <cr> pH (n sec) <cr>
C,30 <cr>	*OK <cr> pH (30 sec) <cr> pH (60 sec) <cr> pH (90 sec) <cr>
C,0 <cr>	*OK <cr>
C,? <cr>	?C,1 <cr> or ?C,0 <cr> or ?C,30 <cr> *OK <cr>

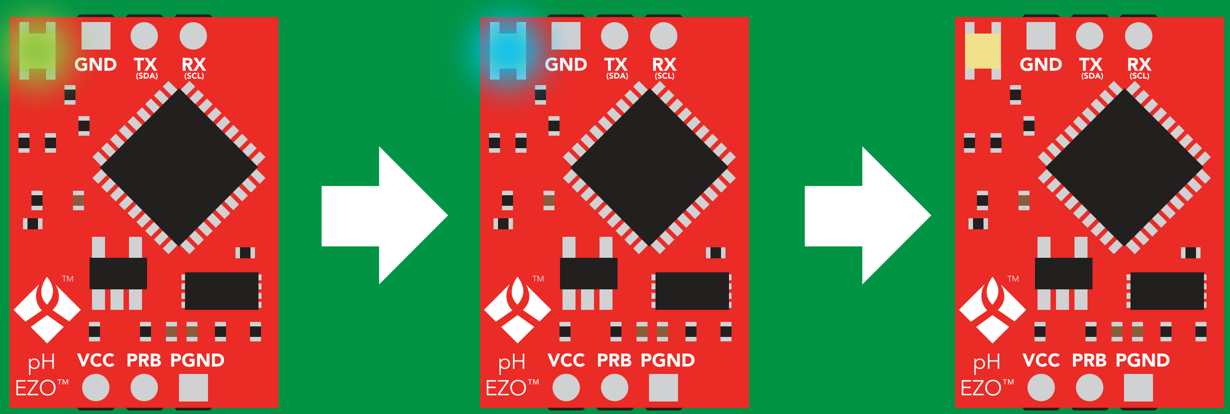
Single reading mode

Command syntax

A single reading takes 800ms

R <cr> takes single reading

Example	Response
R <cr>	9.560 <cr> *OK <cr>



Green	Cyan	
Standby	Taking reading	Transmitting

800 ms

Calibration

Command syntax

Issuing the cal,mid command after the EZO™ pH circuit has been calibrated, will clear the other calibration points. Full calibration will have to be redone.

Cal,mid,n	<cr>	single point calibration at midpoint
Cal,low,n	<cr>	two point calibration at lowpoint
Cal,high,n	<cr>	three point calibration at highpoint
Cal,clear	<cr>	delete calibration data
Cal,?	<cr>	device calibrated?

Example	Response
Cal,mid,7.00 <cr>	*OK <cr>
Cal,low,4.00 <cr>	*OK <cr>
Cal,high,10.00 <cr>	*OK <cr>
Cal,clear <cr>	*OK <cr>
Cal,? <cr>	?Cal,0 <cr> or ?Cal,1 <cr> (one point) or ?Cal,2 <cr> (two point) or ?Cal,3 <cr> (three point) *OK <cr>

Export calibration

Command syntax

Export: Use this command to download calibration settings

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

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

Response breakdown

10, 120

10: # of strings to export

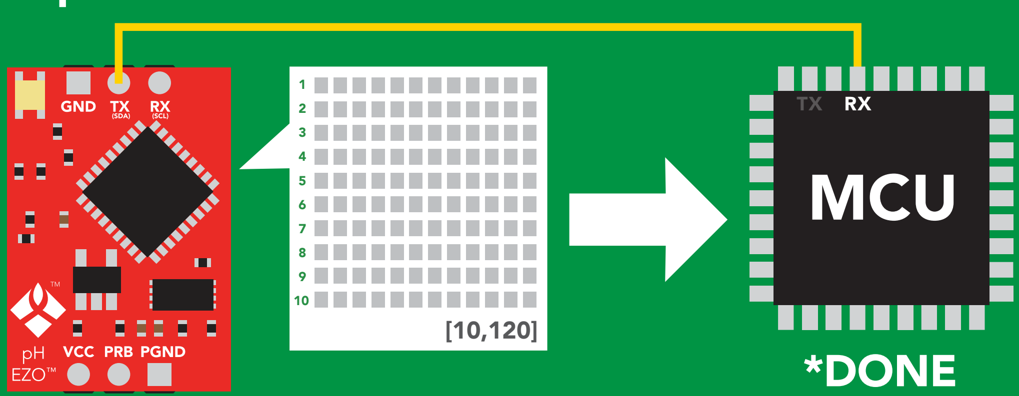
120: # of bytes to export

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

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

Disabling *OK simplifies this process

Export <cr>



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Import calibration

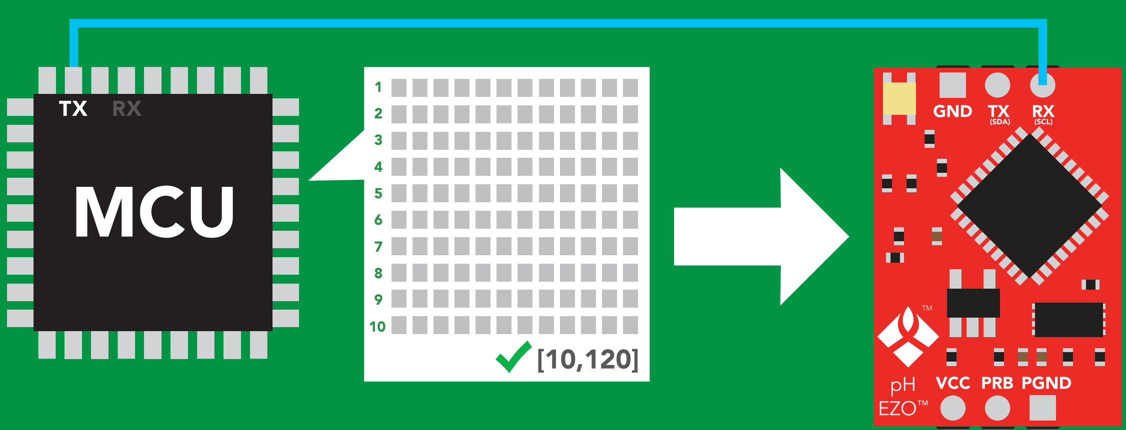
Command syntax

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

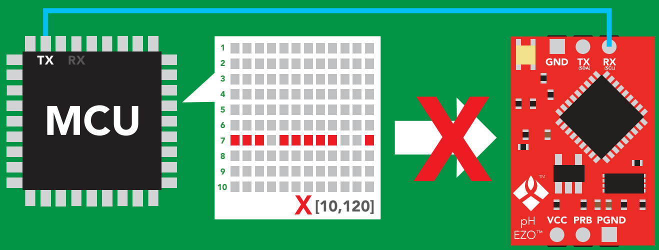
Import,n	<cr>	import calibration string to new device

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

Import,n <cr>



*OK <cr>
system will reboot



*ER <cr>

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

Slope

Command syntax

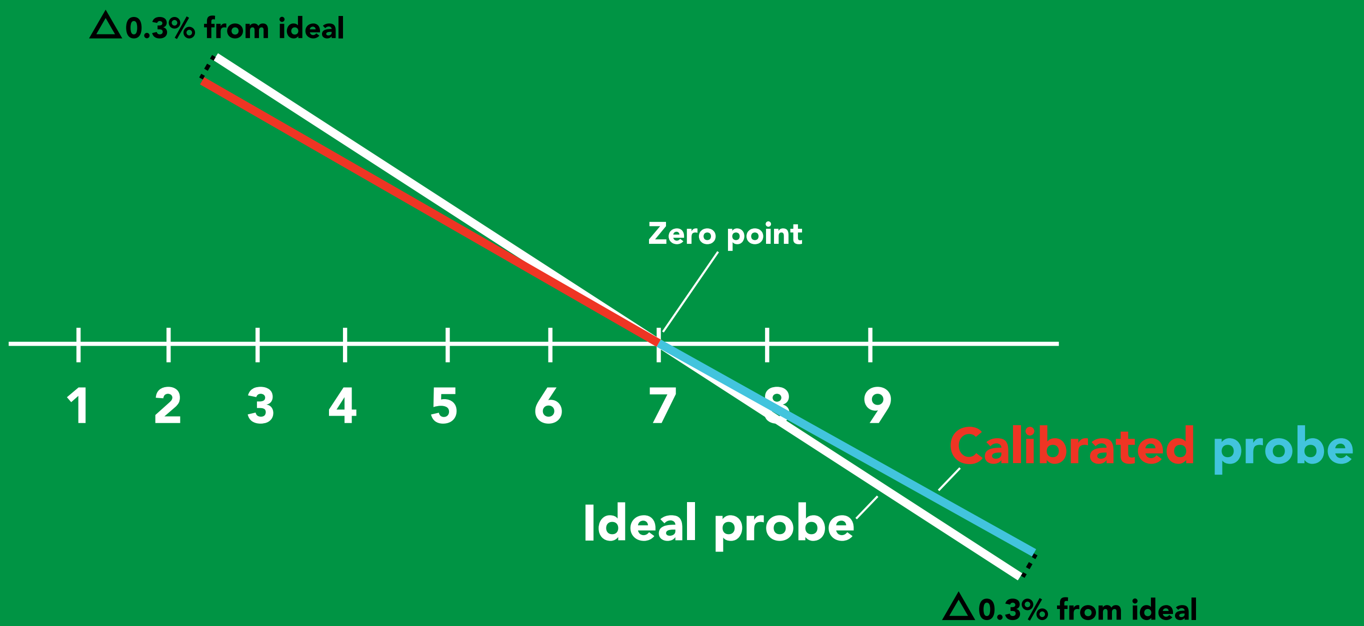
After calibrating a pH probe issuing the slope command will show how closely (in percentage) the calibrated pH probe is working compared to the "ideal" pH probe.

Slope,? <cr> returns the slope of the pH probe

Example	Response
Slope,? <cr>	?Slope,99.7,100.3, -0.89 <cr> *OK <cr>

Response breakdown

?Slope,	99.7	100.3	-0.89
	99.7% is how closely the slope of the **acid** calibration line matched the "ideal" pH probe.	100.3% is how closely the slope of the **base** calibration matches the "ideal" pH probe.	This is how many millivolts the zero point is off from true 0.



Extended pH scale

Very strong acids and basses can exceed the traditional pH scale. This command extends the pH scale to show below 0 and above 14.

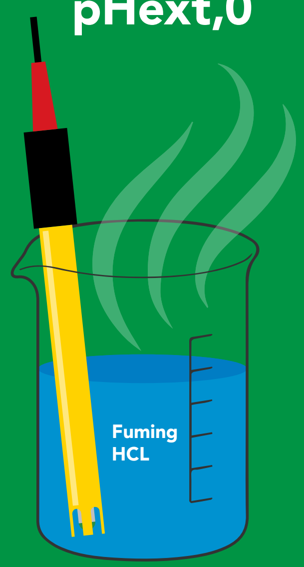
Lowest possible reading: **-1.6**
Highest possible reading: **15.6**

Command syntax

pHext,0	<cr>	extended pH scale off (0 – 14) **default**
pHext,1	<cr>	extended pH scale on (-1.6 – 15.6)
pHext,?	<cr>	extended pH scale on/off?

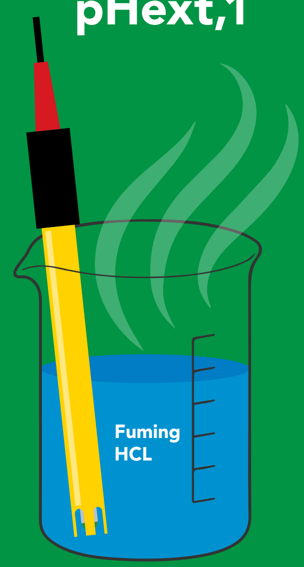
Example	Response
pHext,1 <cr>	*OK <cr>
pHext,0 <cr>	*OK <cr>
pHext,? <cr>	?pHext,1 <cr> or ?pHext,0 <cr>

pHext,0



pH = 0.000

pHext,1



pH = -1.220

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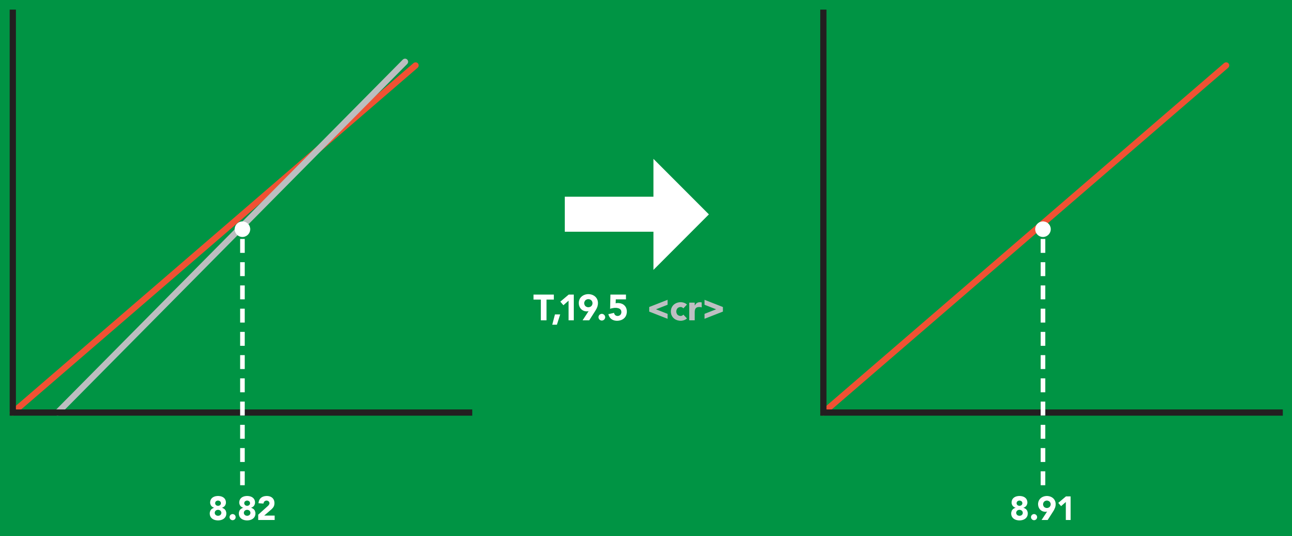
Temperature compensation

Command syntax

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

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

Example	Response
T,19.5 <cr>	*OK <cr>
RT,19.5 <cr>	*OK <cr> 8.91 <cr>
T,? <cr>	?T,19.5 <cr> *OK <cr>



Naming device

Command syntax

Do not use spaces in the name

Name,n	<cr>	set name
Name,	<cr>	clears name
Name,?	<cr>	show name

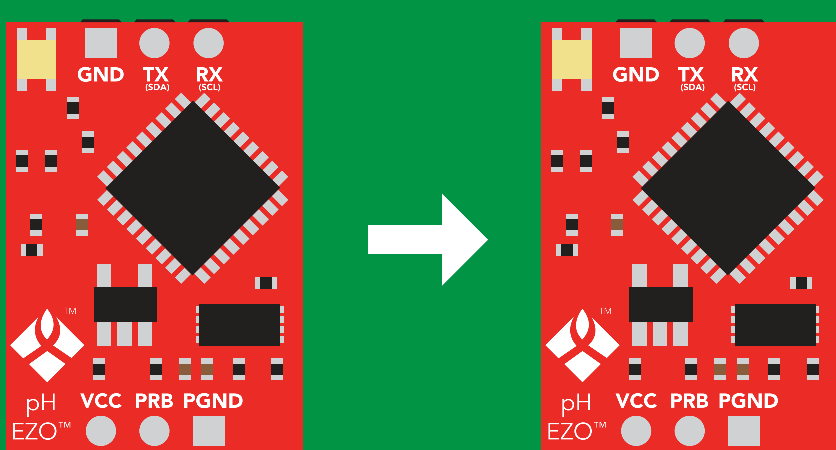
n = _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16

Up to 16 ASCII characters

Example	Response
Name, <cr>	*OK <cr> name has been cleared
Name,zzt <cr>	*OK <cr>
Name,? <cr>	?Name,zzt <cr> *OK <cr>

Name,zzt

Name,?



*OK <cr>

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

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Device information

Command syntax

i <cr> **device information**

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

Response breakdown

?i,	pH,	2.16
	Device	Firmware

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Response codes

Command syntax

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

Example	Response
R <cr>	9.560 <cr> *OK <cr>
*OK,0 <cr>	no response, *OK disabled
R <cr>	9.560 <cr> *OK disabled
*OK,? <cr>	?*OK,1 <cr> or ?*OK,0 <cr>

Other response codes

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

These response codes cannot be disabled

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Reading device status

Command syntax

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

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

Response breakdown

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

Restart codes

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

Sleep mode/low power

Command syntax

Send any character or command to awaken device.

Sleep <cr> enter sleep mode/low power

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

	STANDBY	SLEEP
5V	16 mA	1.16 mA
3.3V	13.9 mA	0.995 mA

Standby
16 mA

Sleep
1.16 mA

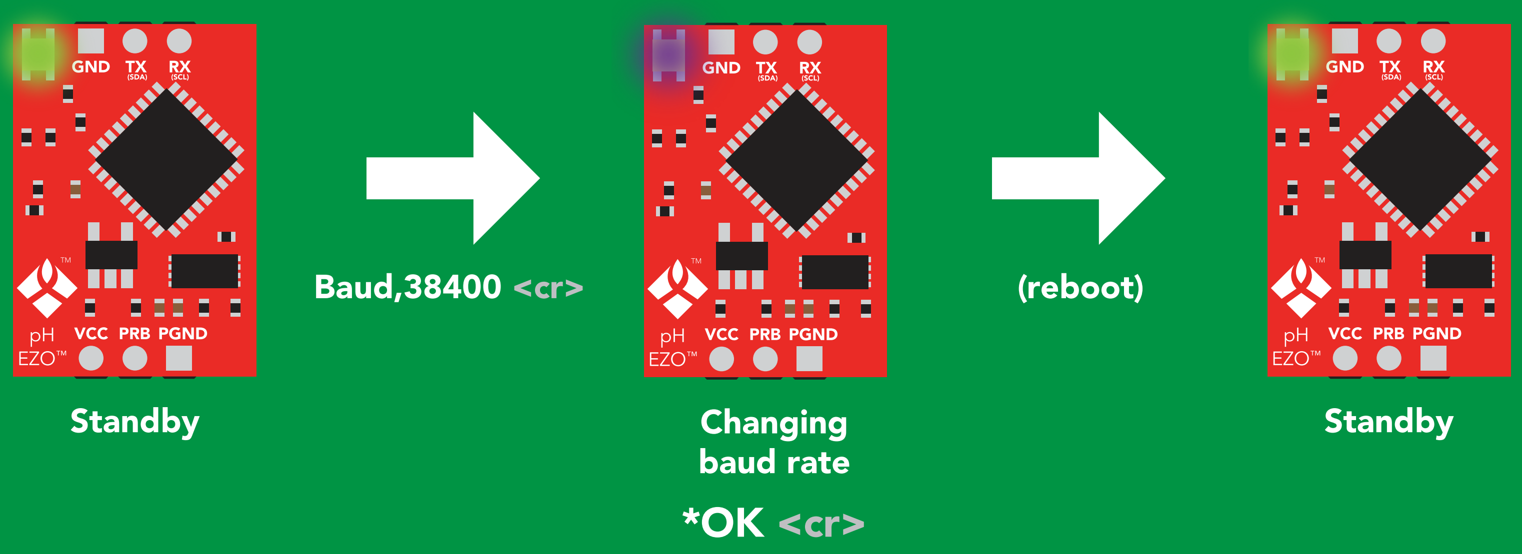
Change baud rate

Command syntax

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

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

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



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Protocol lock

Command syntax

Locks device to UART mode.

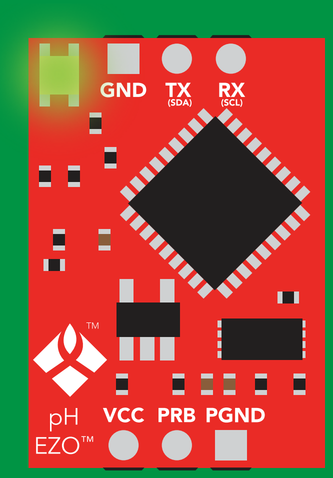
Plock,1 <cr> enable Plock

Plock,0 <cr> disable Plock **default**

Plock,? <cr> Plock on/off?

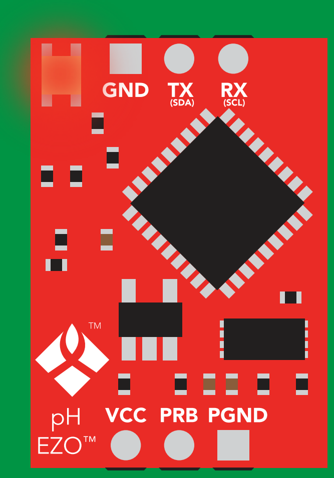
Example	Response
Plock,1 <cr>	*OK <cr>
Plock,0 <cr>	*OK <cr>
Plock,? <cr>	?Plock,1 <cr> or ?Plock,0 <cr>

Plock,1



*OK <cr>

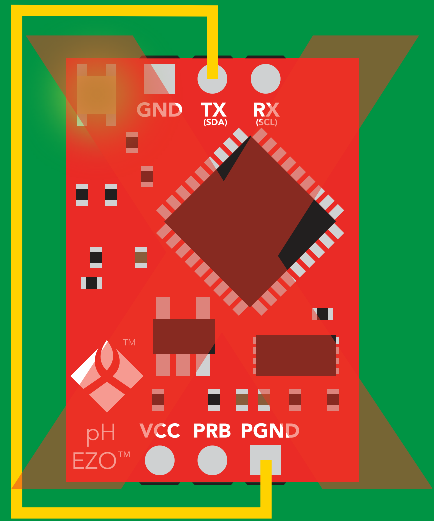
I2C,100



cannot change to I²C

*ER <cr>

Short



cannot change to I²C

Factory reset

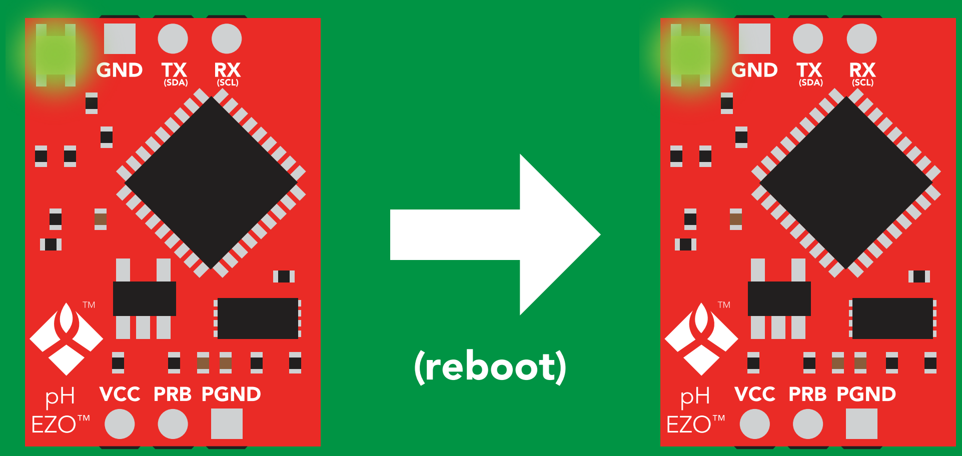
Clears calibration
LED on
"*OK" enabled

Command syntax

Factory	<cr>	**enable factory reset**

Example	Response
Factory <cr>	***OK** <cr>

Factory <cr>



***OK** <cr>

***RS** <cr>
***RE** <cr>

Baud rate will not change

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Change to I^{2}C mode

Command syntax

Default I^{2}C address 99 (0x63)

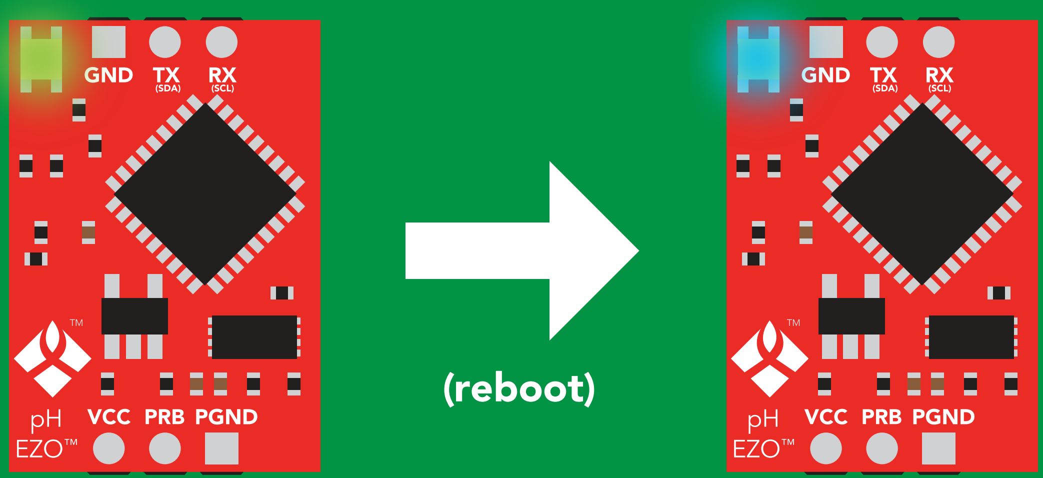
I2C,n <cr> sets I^{2}C address and reboots into I^{2}C mode

n = any number 1 – 127

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

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

I2C,100



Green
*OK <cr>

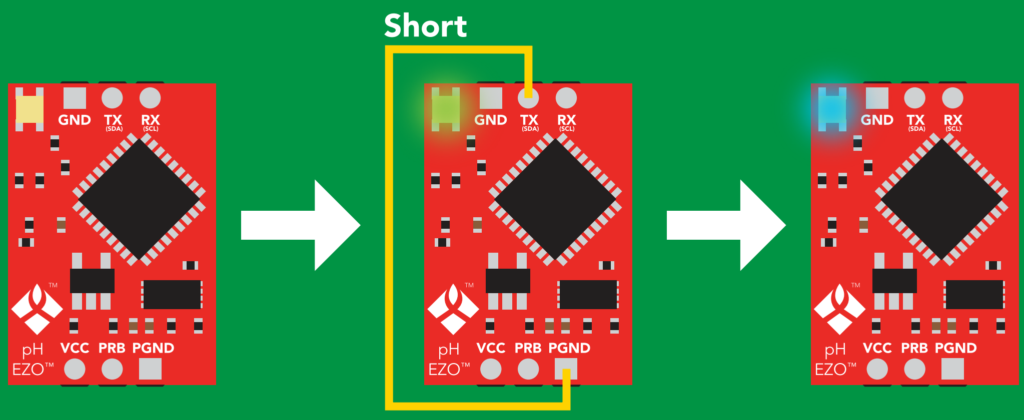
Blue
now in I^{2}C mode

Manual switching to I²C

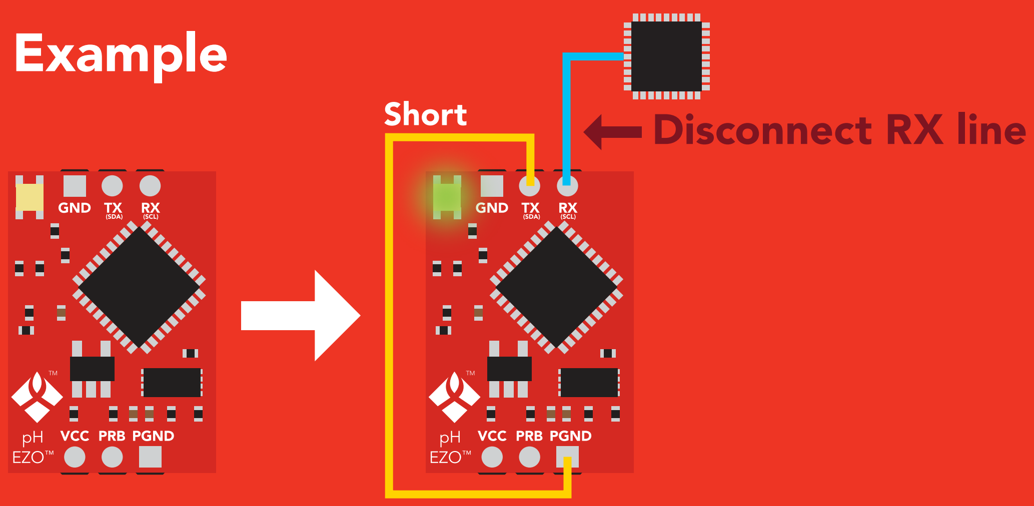
- Disconnect ground (power off)
- Disconnect TX and RX
- Connect TX to PGND
- Confirm RX is disconnected
- Connect ground (power on)
- Wait for LED to change from Green to Blue
- Disconnect ground (power off)
- Reconnect all data and power

Manually switching to I²C will set the I²C address to 99 (0x63)

Example



Wrong Example



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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.

To set your EZO™ device into I²C mode click here

Settings that are retained if power is cut

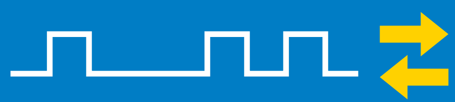
Calibration
Change I²C address
Hardware switch to UART mode
LED control
Protocol lock
Software switch to UART mode

Settings that are *NOT* retained if power is cut

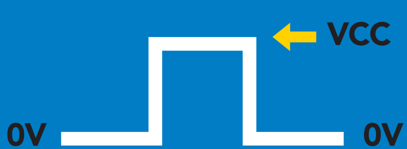
Find
Sleep mode
Temperature compensation

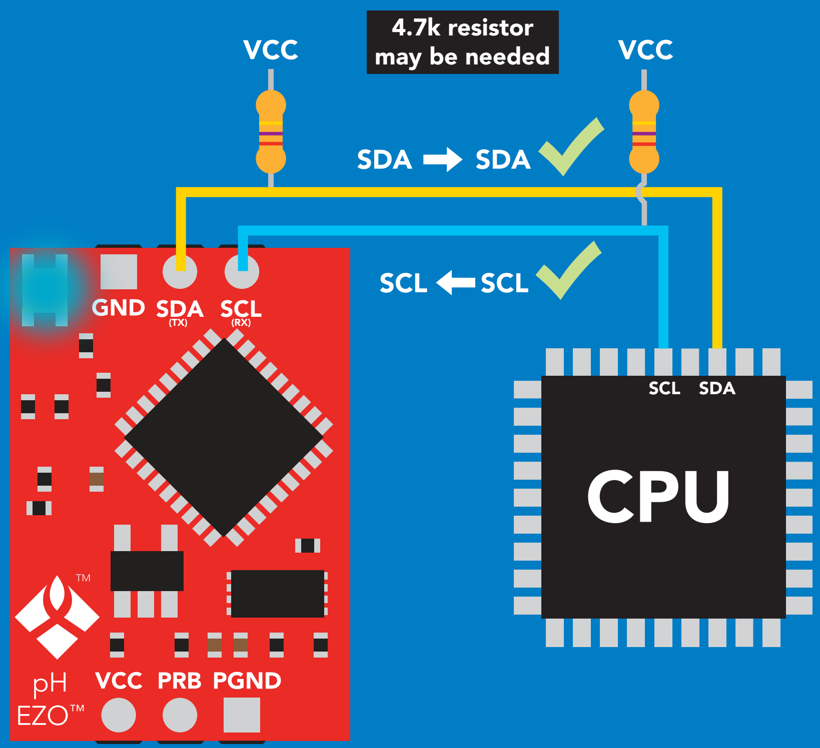
I^2C mode

I^2C address	(0x01 – 0x7F)
	99 (0x63) default
Vcc	3.3V – 5.5V
Clock speed	100 – 400 kHz

SDA 

SCL 





Data format

Reading	pH	Data type	floating point
Units	pH	Decimal places	3
Encoding	ASCII	Smallest string	4 characters
Format	string	Largest string	40 characters

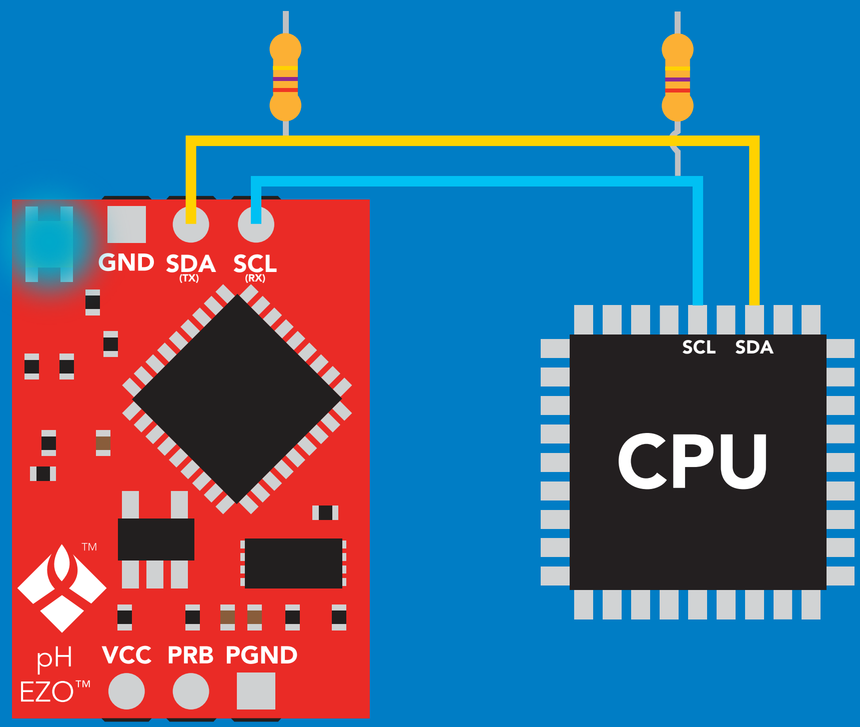
Sending commands to device

5 parts

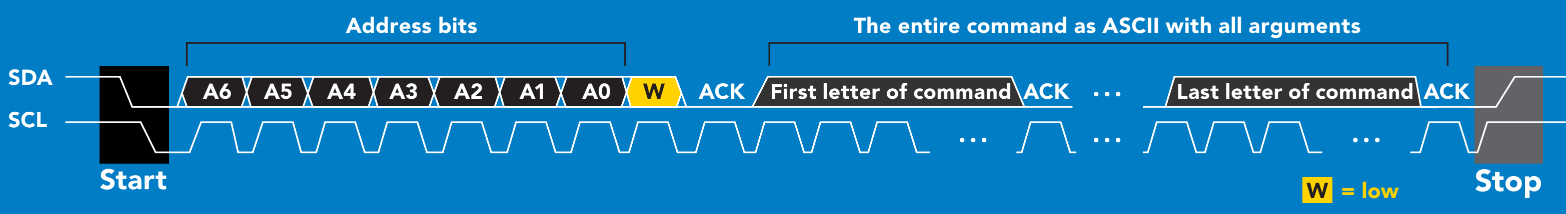
Start	I^2C address	Write	Command (not case sensitive)	Stop
	99 (0x63)		ASCII command string	

Example

Start	99 (0x63)	Write	Sleep	Stop
	I^2C address		Command	



Advanced



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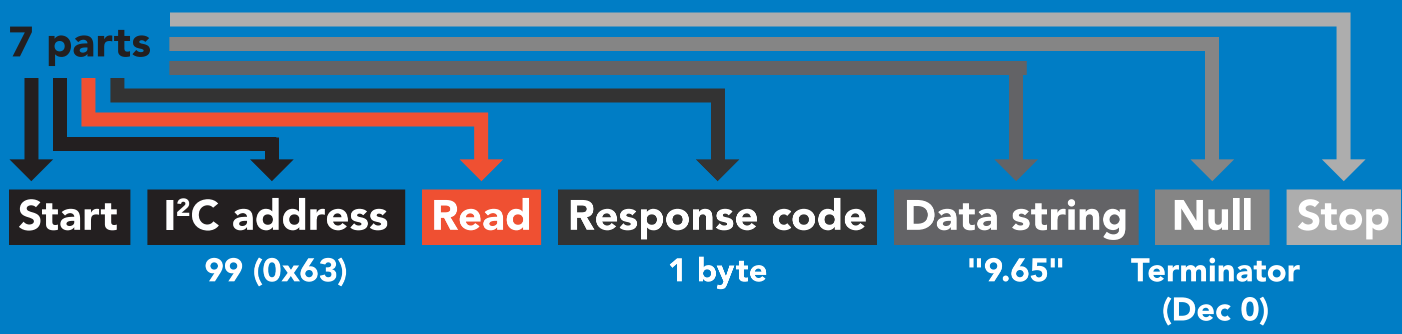
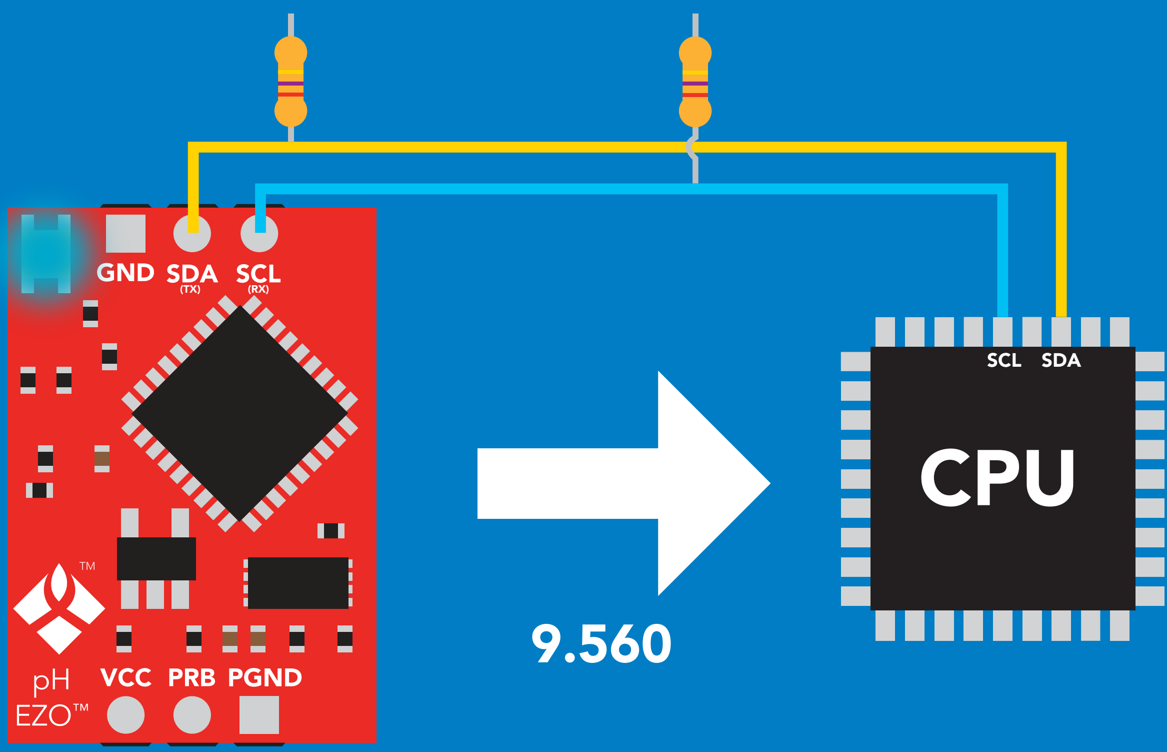
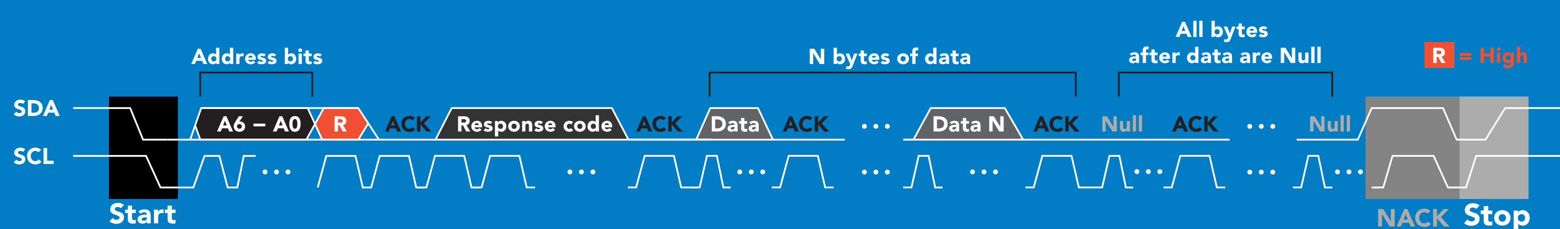
Requesting data from device





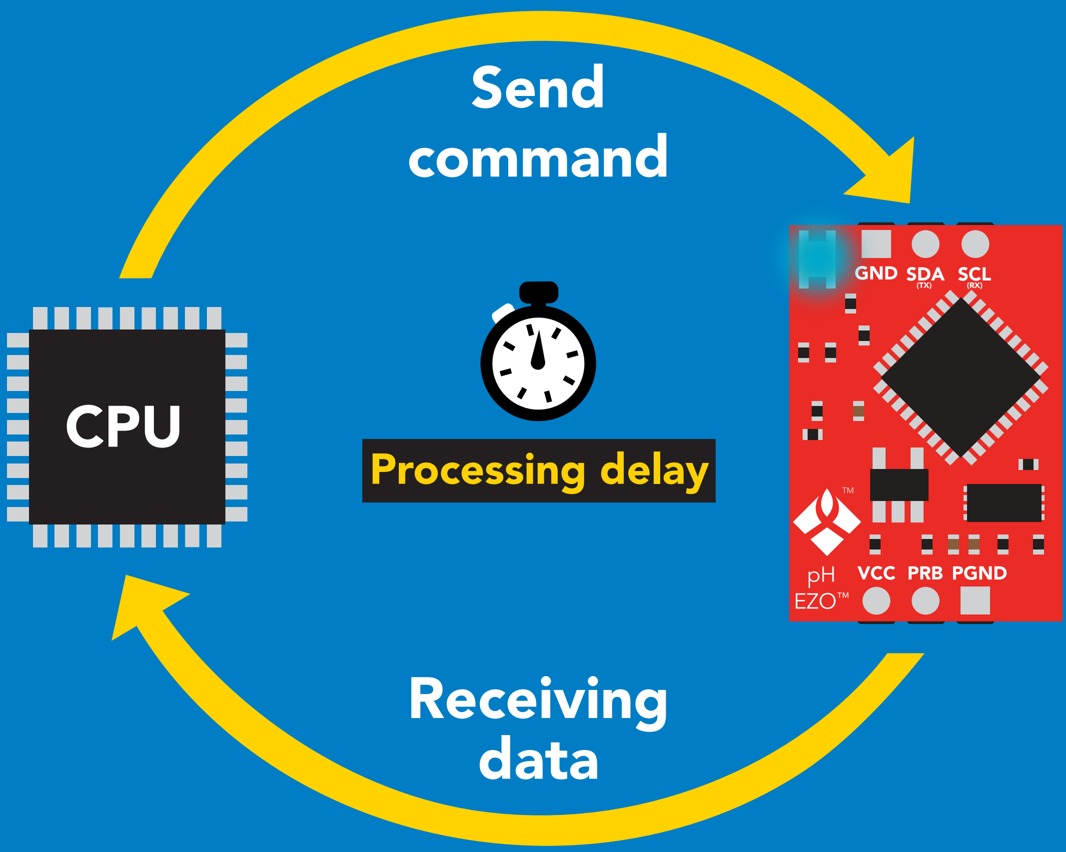
Advanced



Response codes

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

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



Example

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

delay(300);
```


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

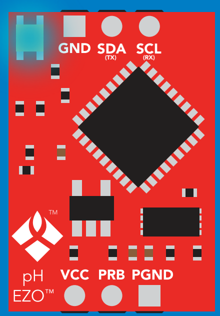
If there is no processing delay or the processing delay is too short, the response code will always be 254.

Response codes

Single byte, not string

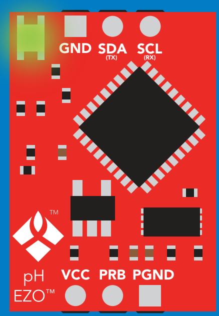
255	no data to send
254	still processing, not ready
2	syntax error
1	successful request

LED color definition



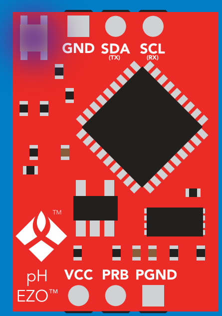
Blue

I²C standby



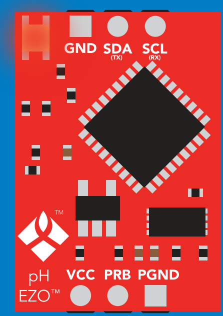
Green

Taking reading



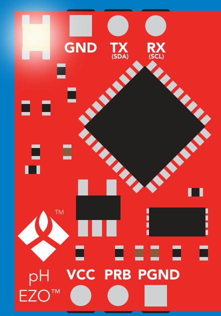
Purple

Changing I²C address



Red

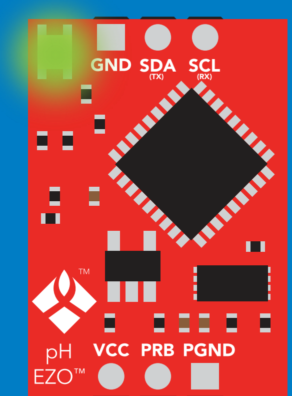
Command not understood



White

Find

	LED ON
5V	**+2.2 mA**
3.3V	**+0.6 mA**



Solid Green LED

in UART mode
Not I²C ready

I²C mode

command quick reference

All commands are ASCII strings or single ASCII characters.

Command	Function	
Baud	switch back to UART mode	pg. 61
Cal	performs calibration	pg. 48
Export	export calibration	pg. 49
Factory	enable factory reset	pg. 60
Find	finds device with blinking white LED	pg. 46
i	device information	pg. 55
I2C	change I²C address	pg. 59
Import	import calibration	pg. 50
L	enable/disable LED	pg. 45
Name	set/show name of device	pg. 54
pHext	enable/disable extended pH scale	pg. 52
Plock	enable/disable protocol lock	pg. 58
R	returns a single reading	pg. 47
Sleep	enter sleep mode/low power	pg. 57
Slope	returns the slope of the pH probe	pg. 51
Status	retrieve status information	pg. 56
T	temperature compensation	pg. 53

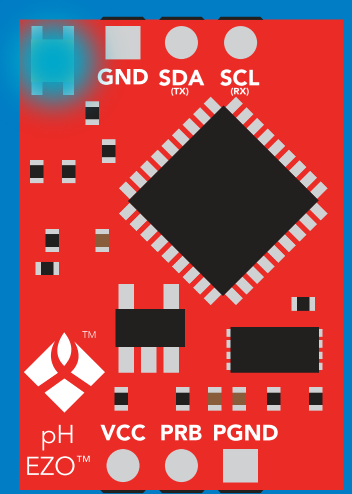
LED control

Command syntax

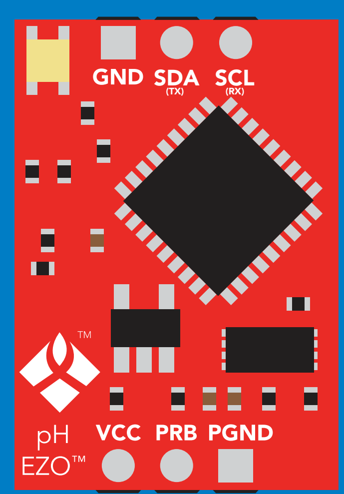
300ms processing delay

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

Example	Response
L,1	Wait 300ms — 1 (Dec) 0 (Null)
L,0	Wait 300ms — 1 (Dec) 0 (Null)
L,?	Wait 300ms — 1 (Dec) ?L,1 (ASCII) 0 (Null) or 1 (Dec) ?L,0 (ASCII) 0 (Null)



L,1



L,0

Find

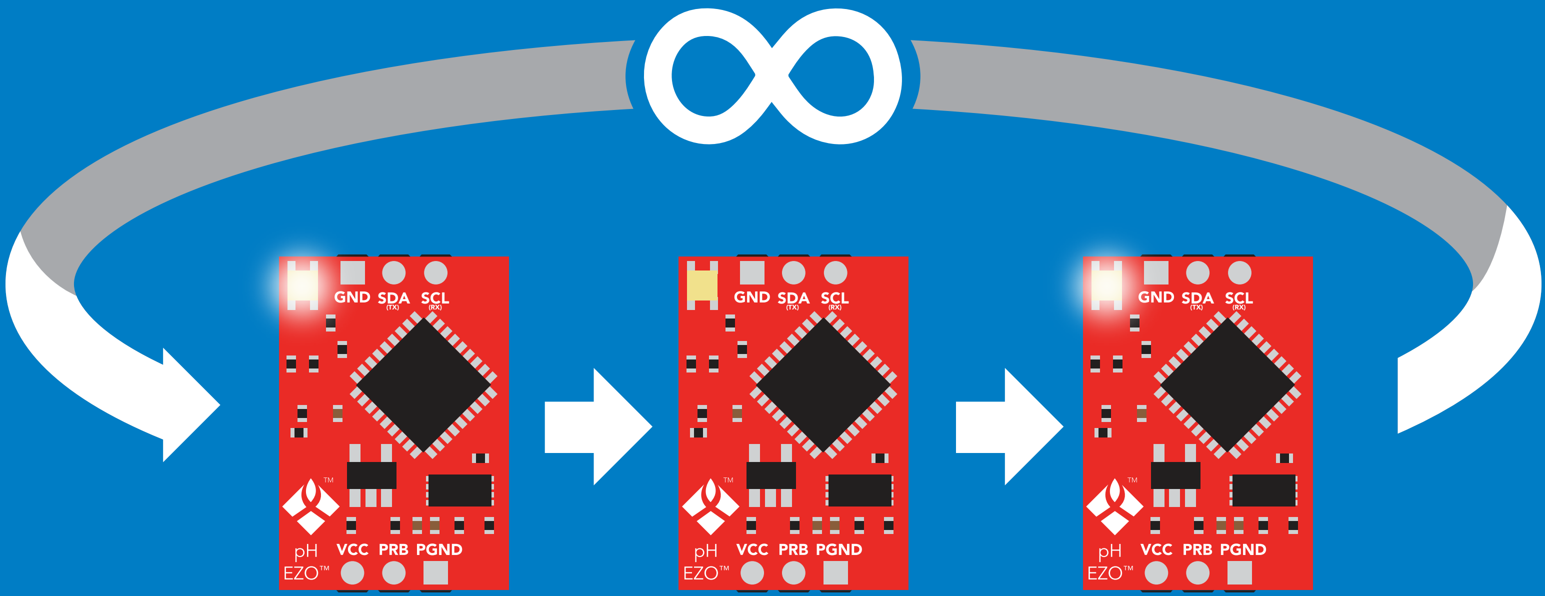
300ms processing delay

Command syntax

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

Find	LED rapidly blinks white, used to help find device

Example	Response
Find	Wait 300ms 1 Dec 0 Null



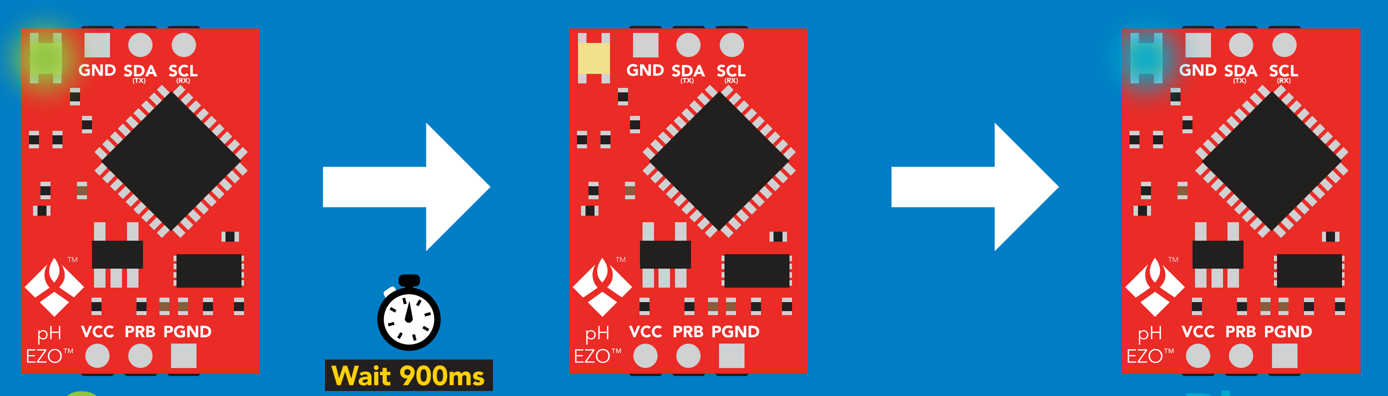
Taking reading

Command syntax

900ms processing delay

R return 1 reading

Example	Response
R	Wait 900ms — 1 (Dec) 9.560 (ASCII) 0 (Null)



Green
Taking reading

Transmitting

Blue
Standby

Calibration

900ms processing delay

Issuing the cal,mid command after the EZO™ pH circuit has been calibrated, will clear the other calibration points. Full calibration will have to be redone.

Command syntax

Cal,mid,n	single point calibration at midpoint
Cal,low,n	two point calibration at lowpoint
Cal,high,n	three point calibration at highpoint
Cal,clear	delete calibration data
Cal,?	device calibrated?

Example	Response
Cal,mid,7.00	Wait 900ms — 1 (Dec) 0 (Null)
Cal,low,4.00	Wait 900ms — 1 (Dec) 0 (Null)
Cal,high,10.00	Wait 900ms — 1 (Dec) 0 (Null)
Cal,clear	Wait 300ms — 1 (Dec) 0 (Null)
Cal,?	Wait 300ms — 1 (Dec) ?Cal,0 (ASCII) 0 (Null) or 1 (Dec) ?Cal,1 (ASCII, one point) 0 (Null); 1 (Dec) ?Cal,2 (ASCII, two point) 0 (Null) or 1 (Dec) ?Cal,3 (ASCII, three point) 0 (Null)

Export calibration

300ms processing delay

Command syntax

Export: Use this command to download calibration settings

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

Example / Response

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

Response breakdown

10, 120

10 = # of strings to export; 120 = # of bytes to export

Export strings can be up to 12 characters long

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Import calibration

300ms processing delay

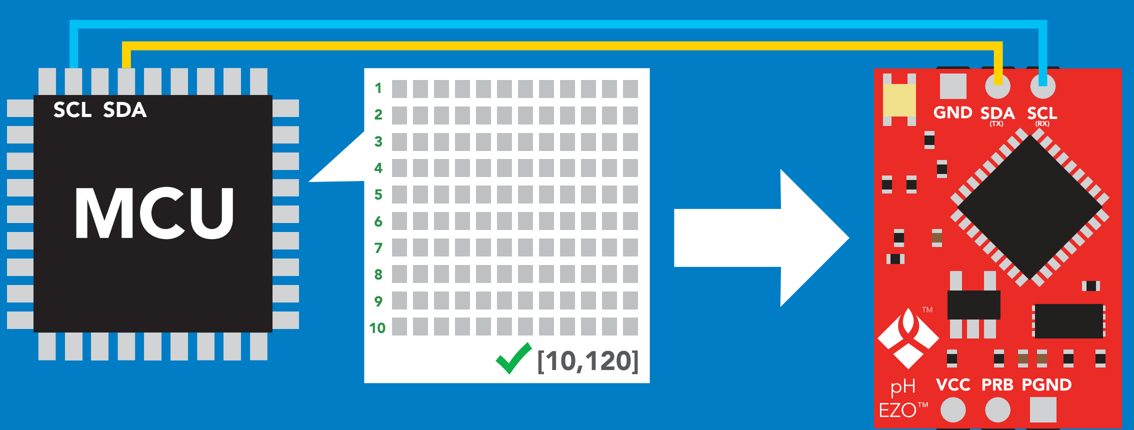
Command syntax

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

Command	Description
Import,n	import calibration string to new device

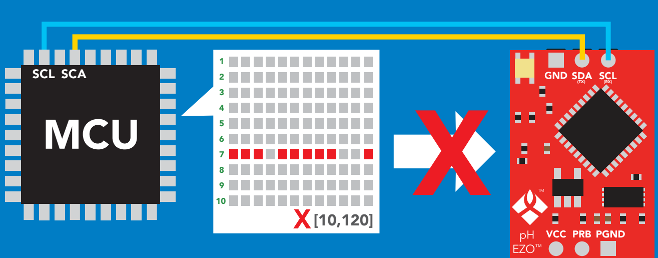
Example		Response
Import, 59 6F 75 20 61 72	(1 of 10)	Wait 300ms · 1 Dec · 0 Null
Import, 65 20 61 20 63 6F	(2 of 10)	Wait 300ms · 1 Dec · 0 Null
⋮		⋮
Import, 6F 6C 20 67 75 79	(10 of 10)	Wait 300ms · 1 Dec · 0 Null

Import,n



1 Dec · *Pending ASCII · 0 Null

system will reboot



reboot

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

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Slope

300ms processing delay

After calibrating a pH probe issuing the slope command will show how closely (in percentage) the calibrated pH probe is working compared to the "ideal" pH probe.

Command syntax

Slope,?	**returns the slope of the pH probe**

Example

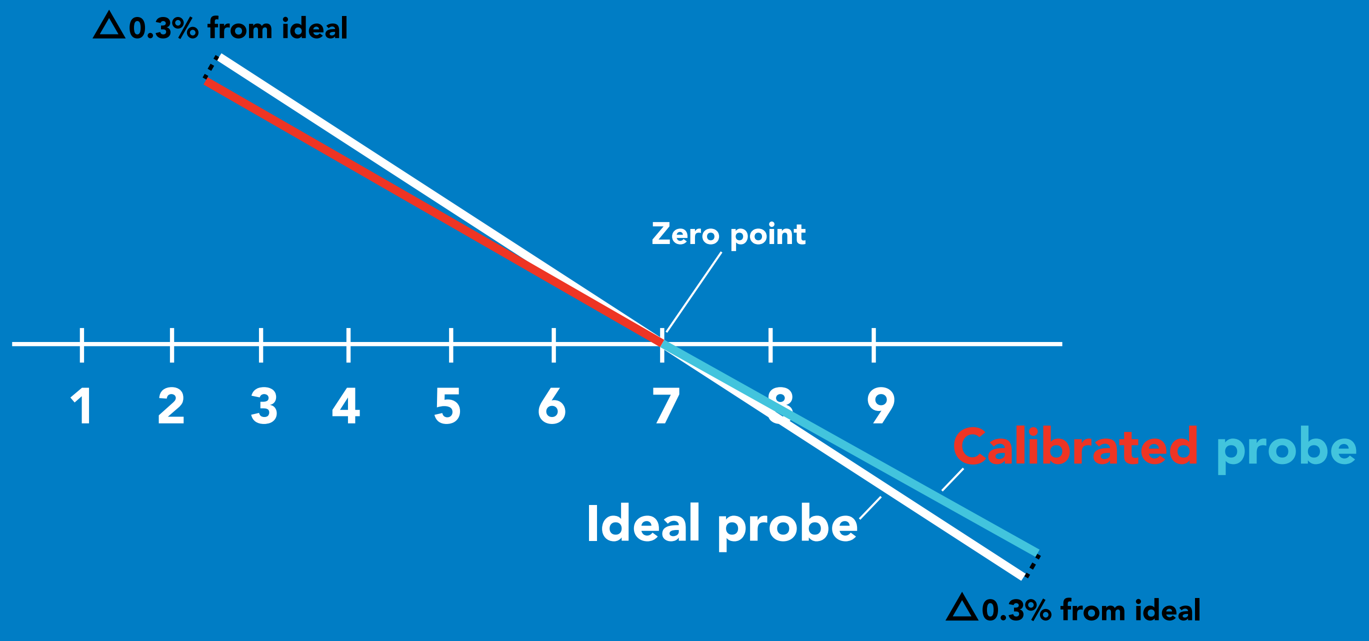
Slope,?

Response

Wait 300ms | 1 (Dec) | ?Slope,99.7,100.3, -0.89 (ASCII) | 0 (Null)

Response breakdown

?Slope,	99.7	100.3	-0.89
	99.7% is how closely the slope of the **acid** calibration line matched the "ideal" pH probe.	100.3% is how closely the slope of the **base** calibration matches the "ideal" pH probe.	This is how many millivolts the zero point is off from true 0.



Extended pH scale

300ms processing delay

Very strong acids and basses can exceed the traditional pH scale. This command extends the pH scale to show below 0 and above 14.

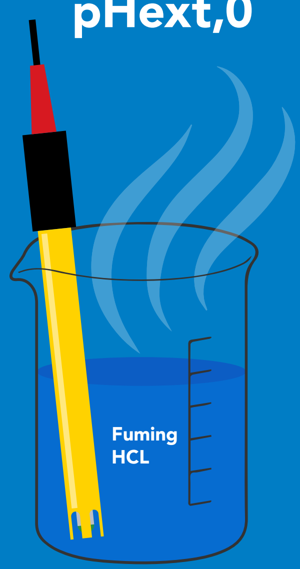
Lowest possible reading: **-1.6**
Highest possible reading: **15.6**

Command syntax

pHext,0	extended pH scale off (0 – 14)	**default**
pHext,1	extended pH scale on (-1.6 – 15.6)	
pHext,?	extended pH scale on/off?	

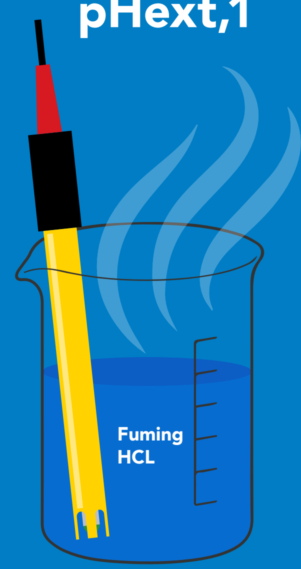
Example	Response
pHext,1	Wait 300ms · 1 (Dec) · 0 (Null)
pHext,0	Wait 300ms · 1 (Dec) · 0 (Null)
pHext,?	Wait 300ms · 1 (Dec) · ?pHext,1 (ASCII) · 0 (Null) **or** 1 (Dec) · ?pHext,0 (ASCII) · 0 (Null)

pHext,0



pH = 0.000

pHext,1



pH = -1.220

Temperature compensation

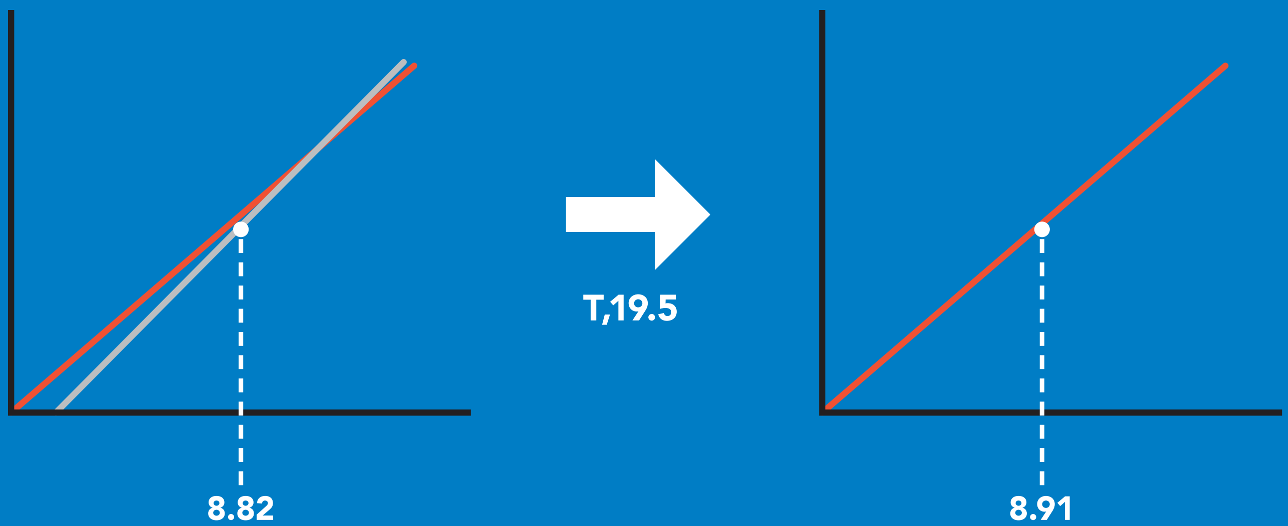
Command syntax

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

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

300ms processing delay

Example	Response
T,19.5	Wait 300ms — 1 (Dec) 0 (Null)
RT,19.5	Wait 900ms — 1 (Dec) 8.91 (ASCII) 0 (Null)
T,?	Wait 300ms — 1 (Dec) ?T,19.5 (ASCII) 0 (Null)



Naming device

300ms processing delay

Command syntax

Do not use spaces in the name

Name,n	set name
Name,	clears name
Name,?	show name

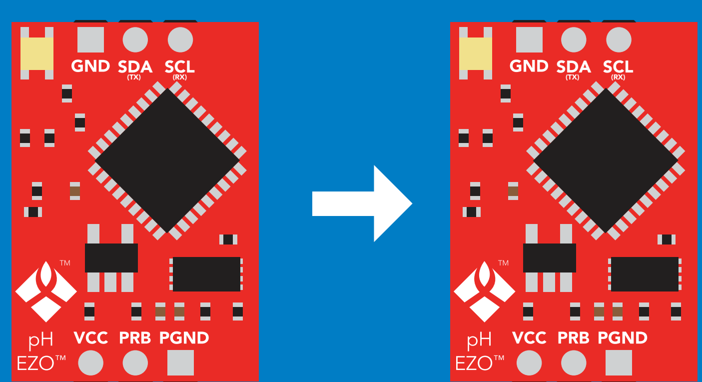
n = _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16

Up to 16 ASCII characters

Example	Response
Name,	Wait 300ms — 1 (Dec) 0 (Null) name has been cleared
Name,zzt	Wait 300ms — 1 (Dec) 0 (Null)
Name,?	Wait 300ms — 1 (Dec) ?Name,zzt (ASCII) 0 (Null)

Name,zzt

Name,?



1 0

1 ?Name,zzt 0

AtlasScientific Environmental Robotics

Device information

Command syntax

300ms processing delay

i device information

Example	Response
i	Wait 300ms · 1 (Dec) · ?i,pH,1.98 (ASCII) · 0 (Null)

Response breakdown

?i, pH, 1.98

pH = Device

1.98 = Firmware

Reading device status

Command syntax

300ms processing delay

Status	**voltage at Vcc pin and reason for last restart**

Example	Response
Status	Wait 300ms · 1 (Dec) · ?Status,P,5.038 (ASCII) · 0 (Null)

Response breakdown

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

Restart codes

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

Sleep mode/low power

Command syntax

Sleep enter sleep mode/low power

Send any character or command to awaken device.

Example	Response
Sleep	no response
Any command	wakes up device

Do not read status byte after issuing sleep command.

	STANDBY	SLEEP
5V	16 mA	1.16 mA
3.3V	13.9 mA	0.995 mA

Standby   Sleep

AtlasScientific Environmental Robotics

Protocol lock

Command syntax

300ms processing delay

Plock,1 enable Plock

Plock,0 disable Plock **default**

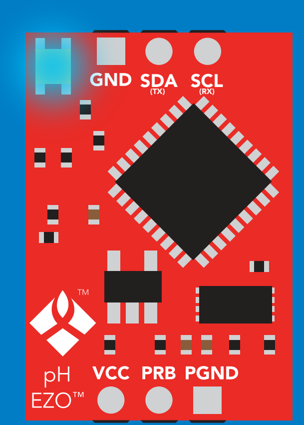
Plock,? Plock on/off?

Locks device to I²C mode.

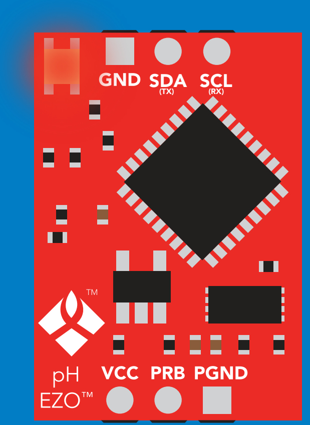
Example / Response

Example	Response
Plock,1	Wait 300ms — 1 (Dec) 0 (Null)
Plock,0	Wait 300ms — 1 (Dec) 0 (Null)
Plock,?	Wait 300ms — 1 (Dec) ?Plock,1 (ASCII) 0 (Null)

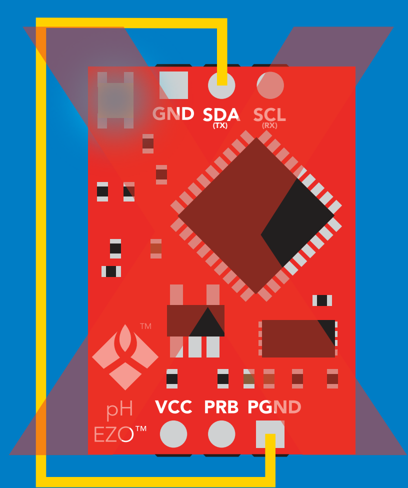
Plock,1



Baud, 9600



cannot change to UART



cannot change to UART

Atlas Scientific Environmental Robotics

I^2C address change

Command syntax

300ms processing delay

I2C,n sets I^2C address and reboots into I^2C mode

Example	Response
I2C,100	device reboot (no response given)

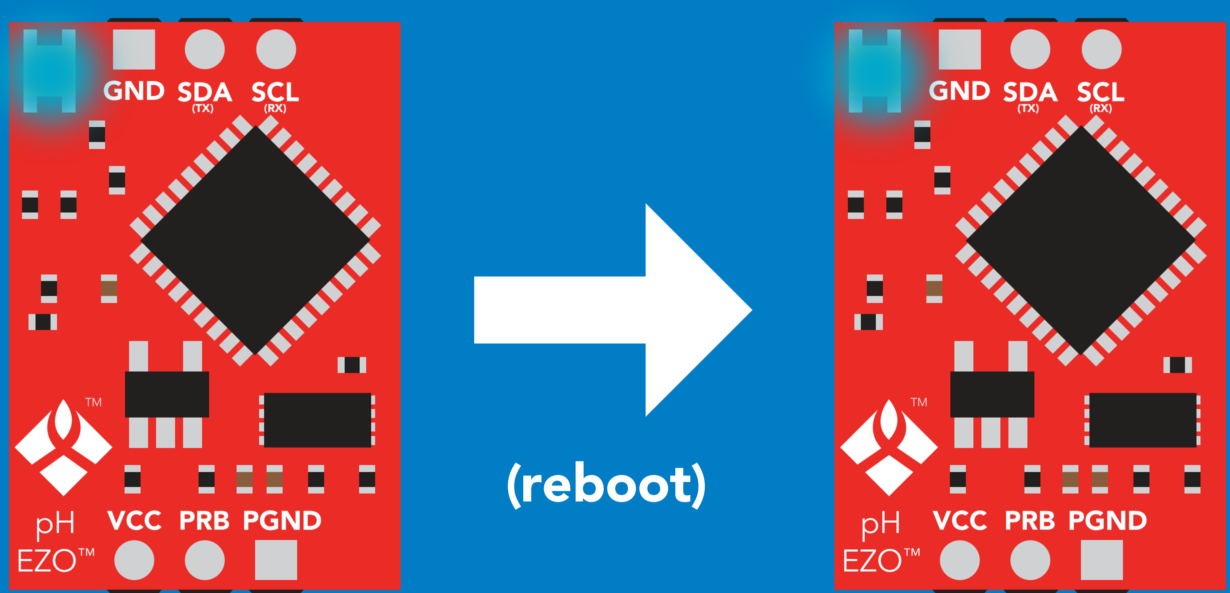
Warning!

Changing the I^2C address will prevent communication between the circuit and the CPU until the CPU is updated with the new I^2C address.

Default I^2C address is 99 (0x63).

n = any number 1 – 127

I2C,100



Factory reset

Command syntax

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

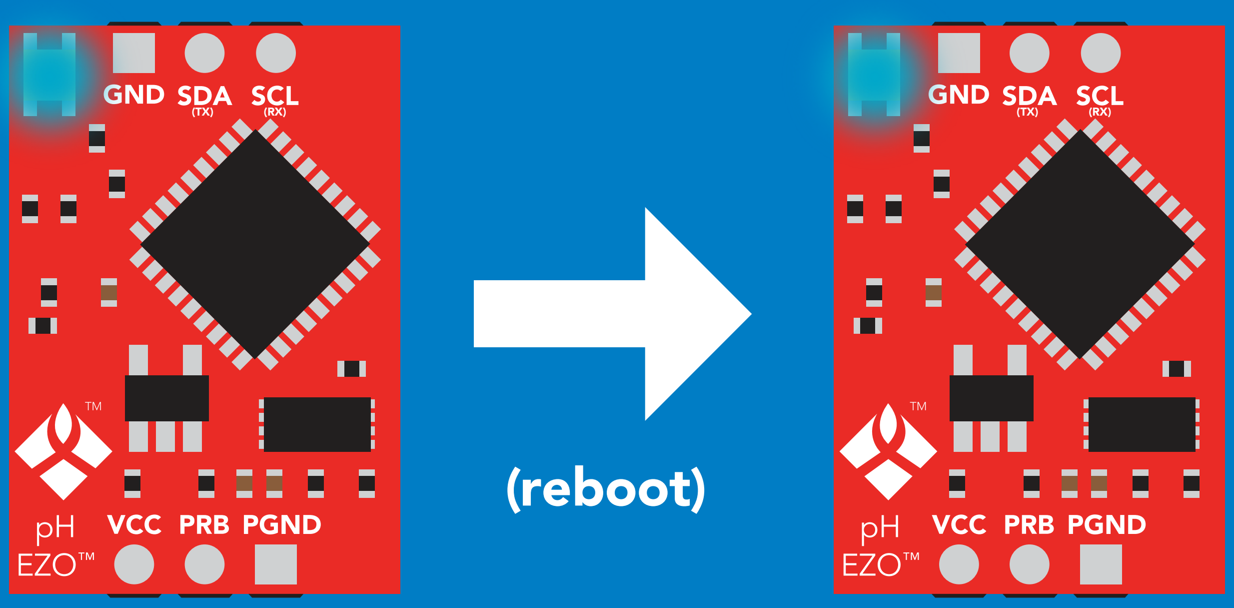
Factory enable factory reset

I²C address will not change

Example	Response
Factory	device reboot (no response given)

Clears calibration
LED on
Response codes enabled

Factory



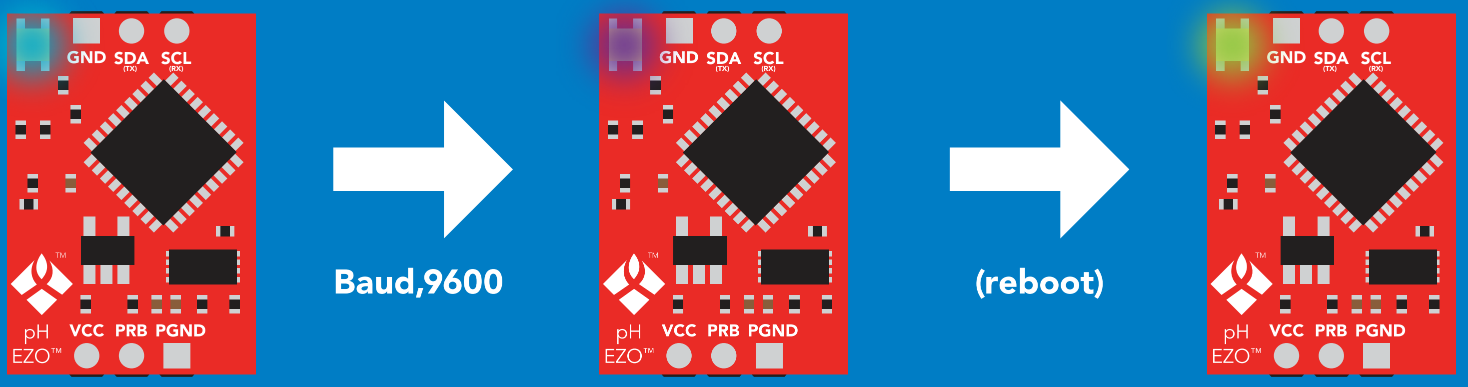
Change to UART mode

Command syntax

Baud,n switch from I^2C to UART

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

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

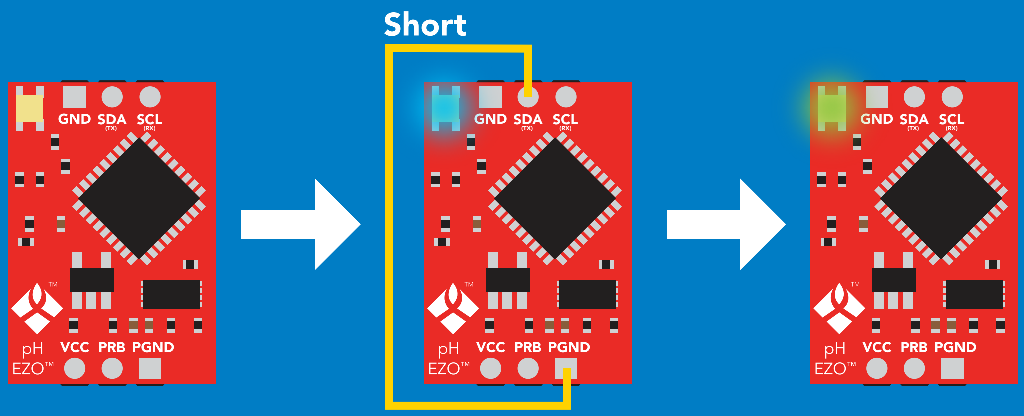


Changing to UART mode

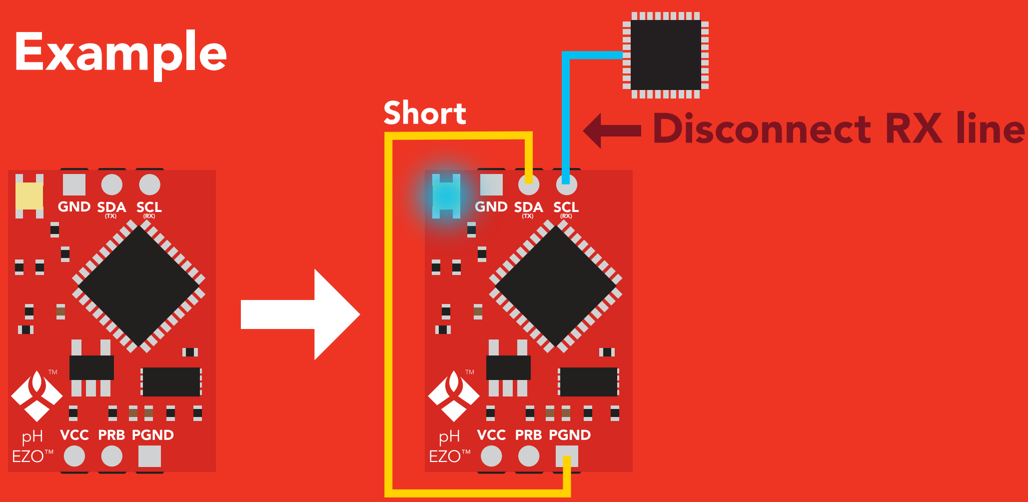
Manual switching to UART

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

Example



Wrong Example

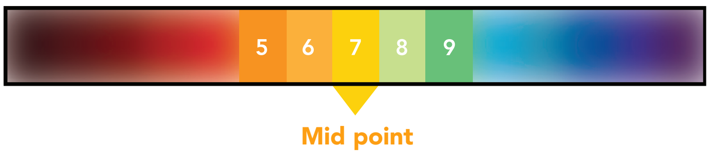


Calibration theory

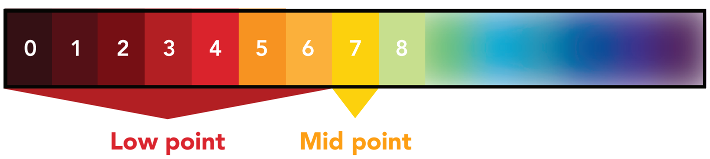
The accuracy of your readings is directly related to the quality of your calibration.
(Calibration is not difficult, and a little bit of care goes a long way).

Single, Two point, or Three point calibration accuracy

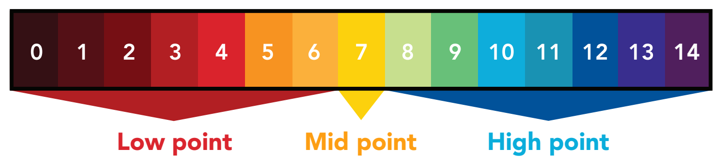
Single point calibration



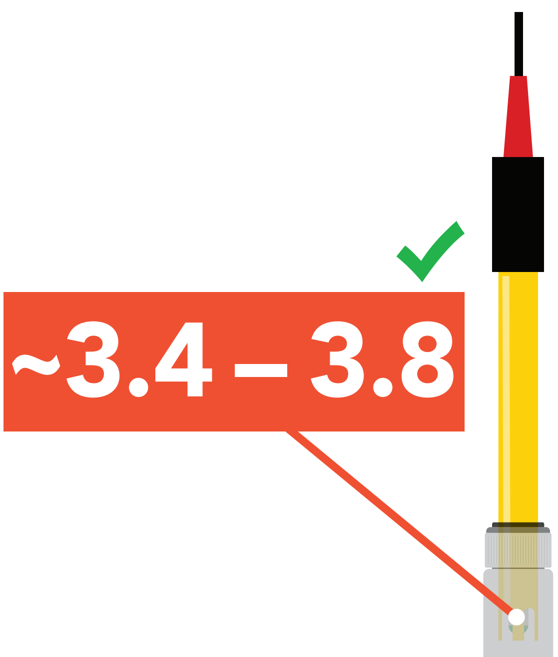
Two point calibration



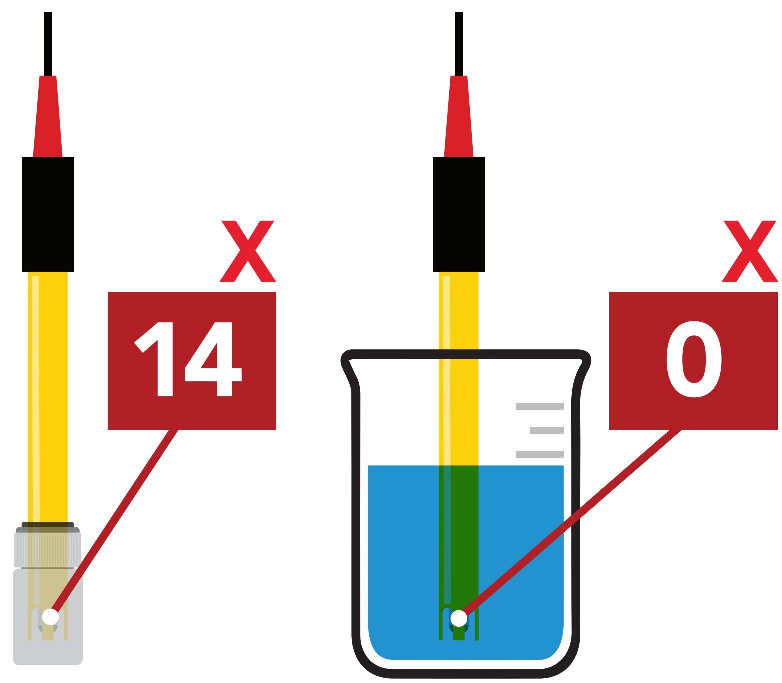
Three point calibration



Confirm the pH probe is working correctly



A new Atlas Scientific pH probe, still in its soaker bottle will read a pH of ***~3.4 – 3.8***

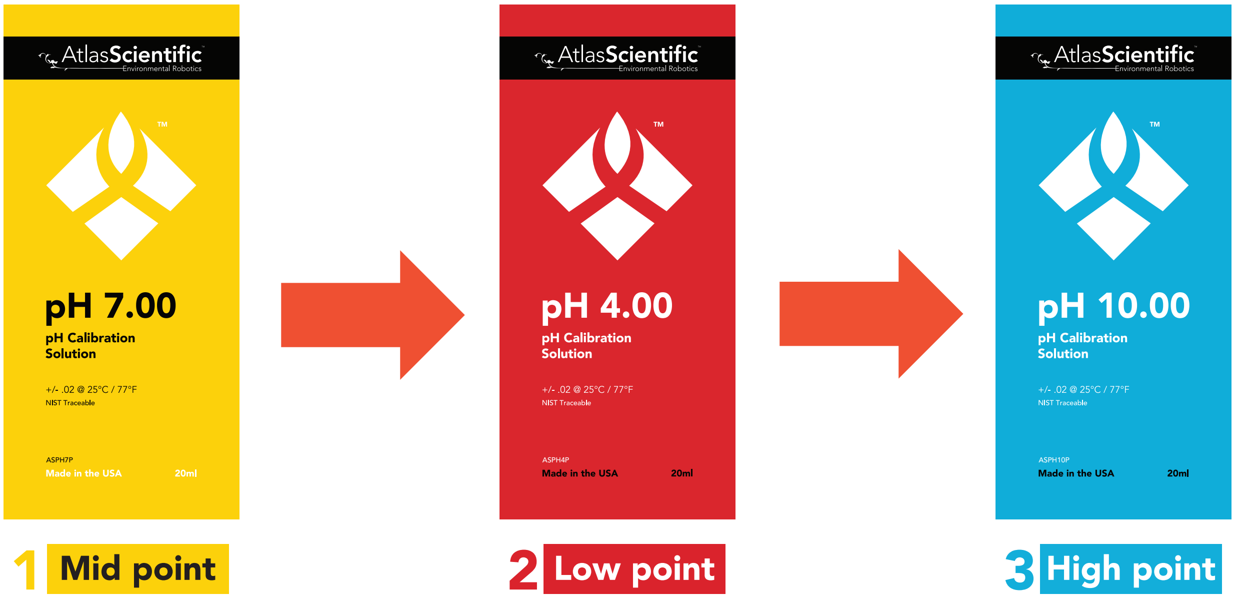


If your pH probe gives a reading of ***zero***, ***seven*** or ***14*** continuously and that reading cannot be changed no matter what solution the probe is in, your probe cannot be calibrated and may be damaged.

Contact Atlas Scientific customer support for assistance.

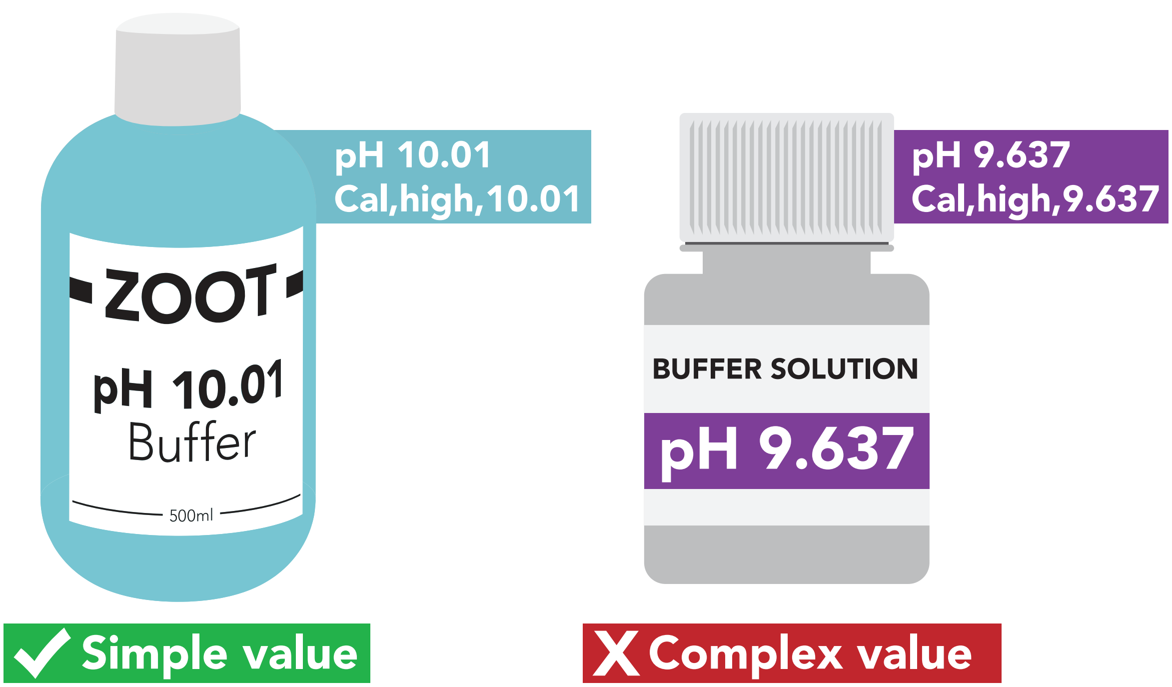
Calibration order

If this is your first time calibrating the EZO™ pH circuit, we recommend that you follow this calibration order.



Calibration solutions

The Atlas Scientific EZO™ pH circuit can work with any brand or value of calibration solution. ***We recommend using calibration solutions that have simple values.***



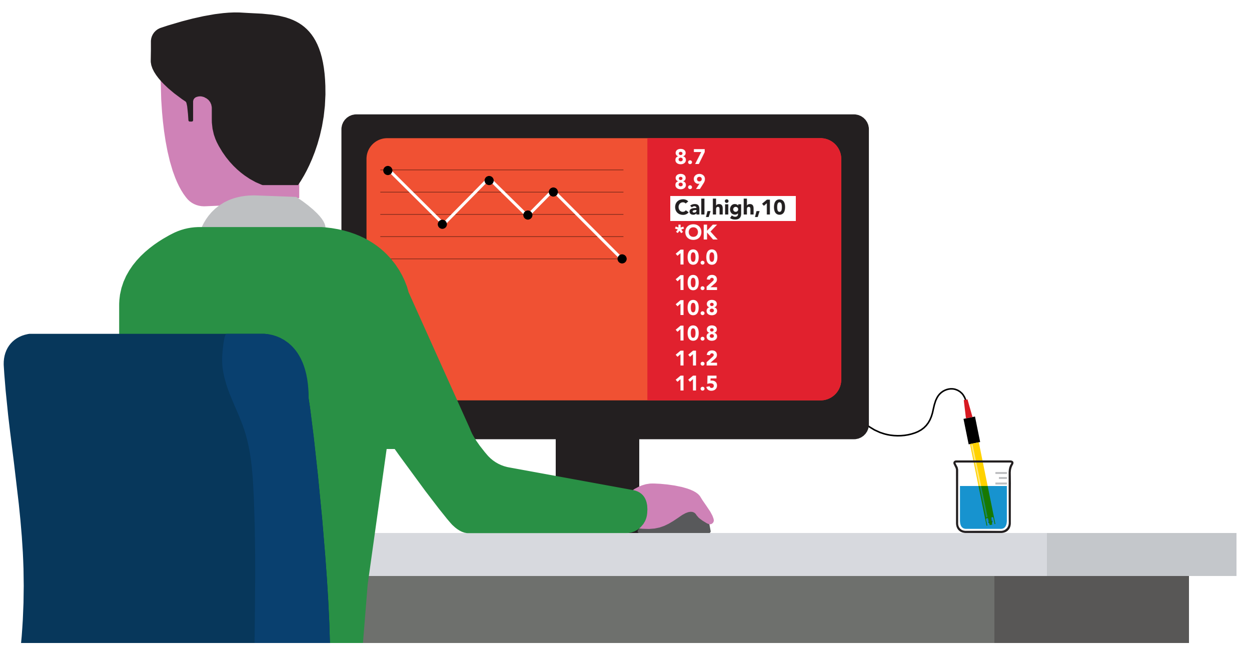
While you can use calibration solutions that have complex values, we recommend avoiding unnecessary complexity. ***Unusually specific calibration values should be treated with suspicion.***

Best practices for calibration

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

⚠ Never do a blind calibration! ⚠

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



Best practices for calibration

Avoid extended stabilization time.

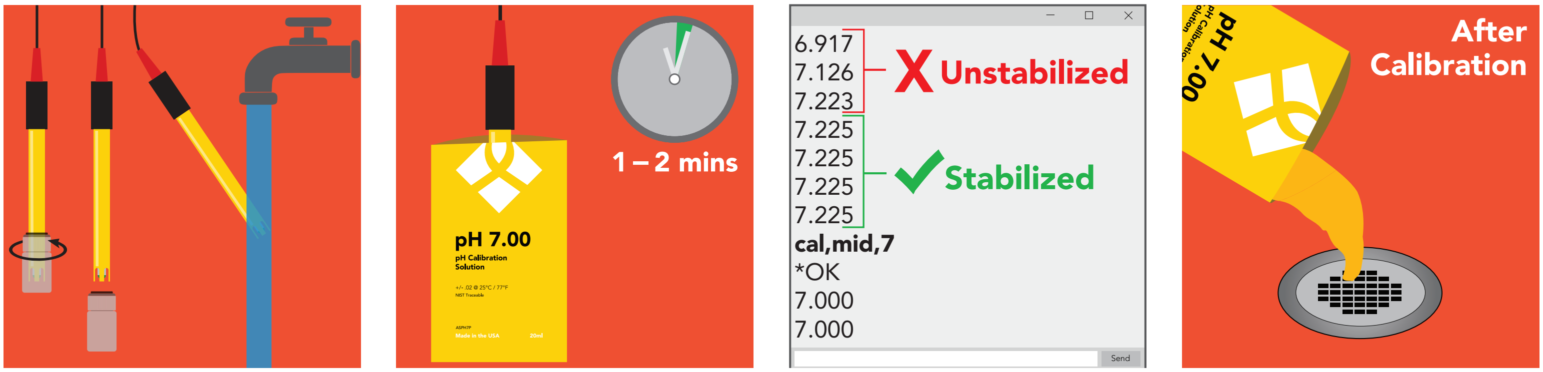
Letting the probes pre-calibrtion readings stabilize over an extended period will cause your calibrated readings to take a long time to stabilize.

Avoid frequent recalibrations.

if it ain't broke, don't fix it.

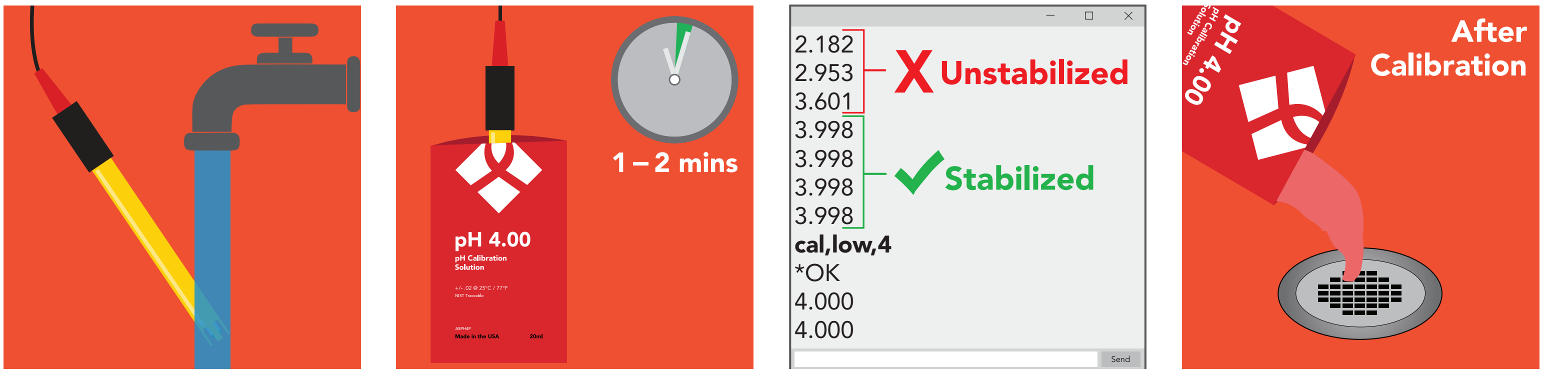
pH probes loose accuracy slowly. Frequent recalibrations to insure high accuracy will often have the opposite effect. It is far more llikly that you will misscalibrate the probe rather then improve its accuracy.

1. Mid point calibration



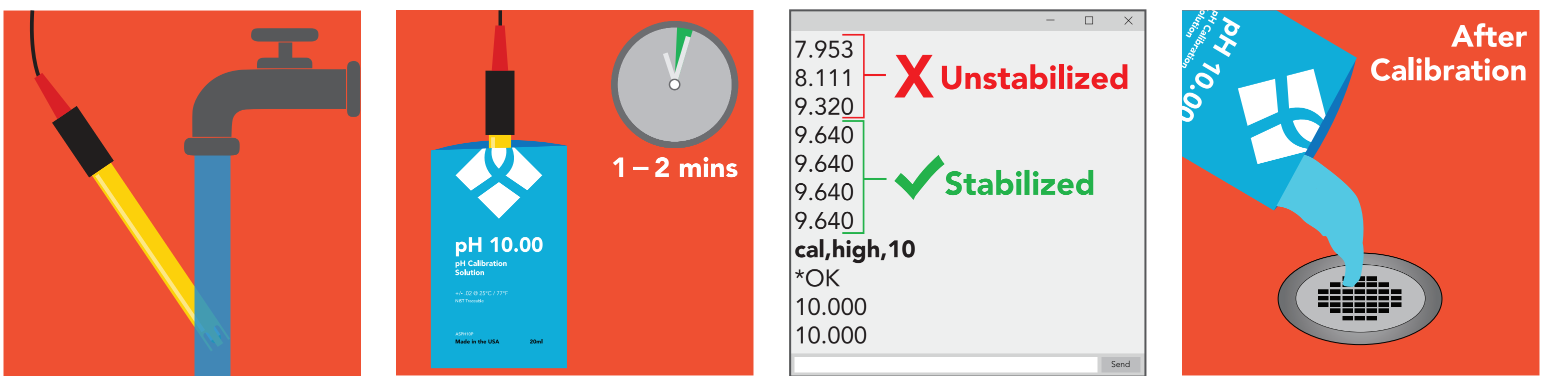
Mid point calibrated

2. Low point calibration



Low point calibrated

3. High point calibration



High point calibrated

Optional steps:

Confirm your calibration accuracy using the slope command.
Recalibre a single point if required.

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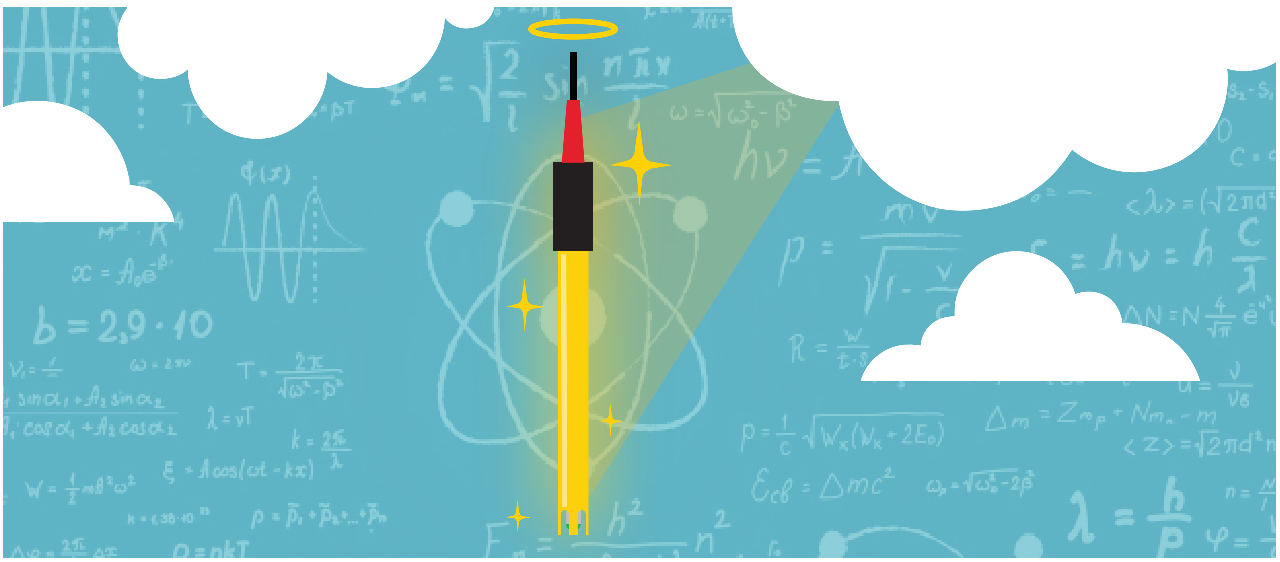
Understanding pH slope

The slope function is a powerful tool used to verify calibration and determine the overall health of a pH probe. By evaluating the slope of a pH probe's response curve, you can determine how well a pH probe was calibrated or when that probe is reaching end of life.

Slope and calibration are directly related. The slope is updated when a calibration command is given. The slope does not update automatically.

Generally speaking, all pH probes behave the same way. This means a probe's response to calibration can be compared to a simulated pH probe that is mathematically perfect in all ways.



The slope is broken into three sections; acid, base, and neutral.
Each section is evaluated separately.

Acid (pH 1 – 6.9)
Base (pH 7.1 – 14)
Neutral (pH 7)

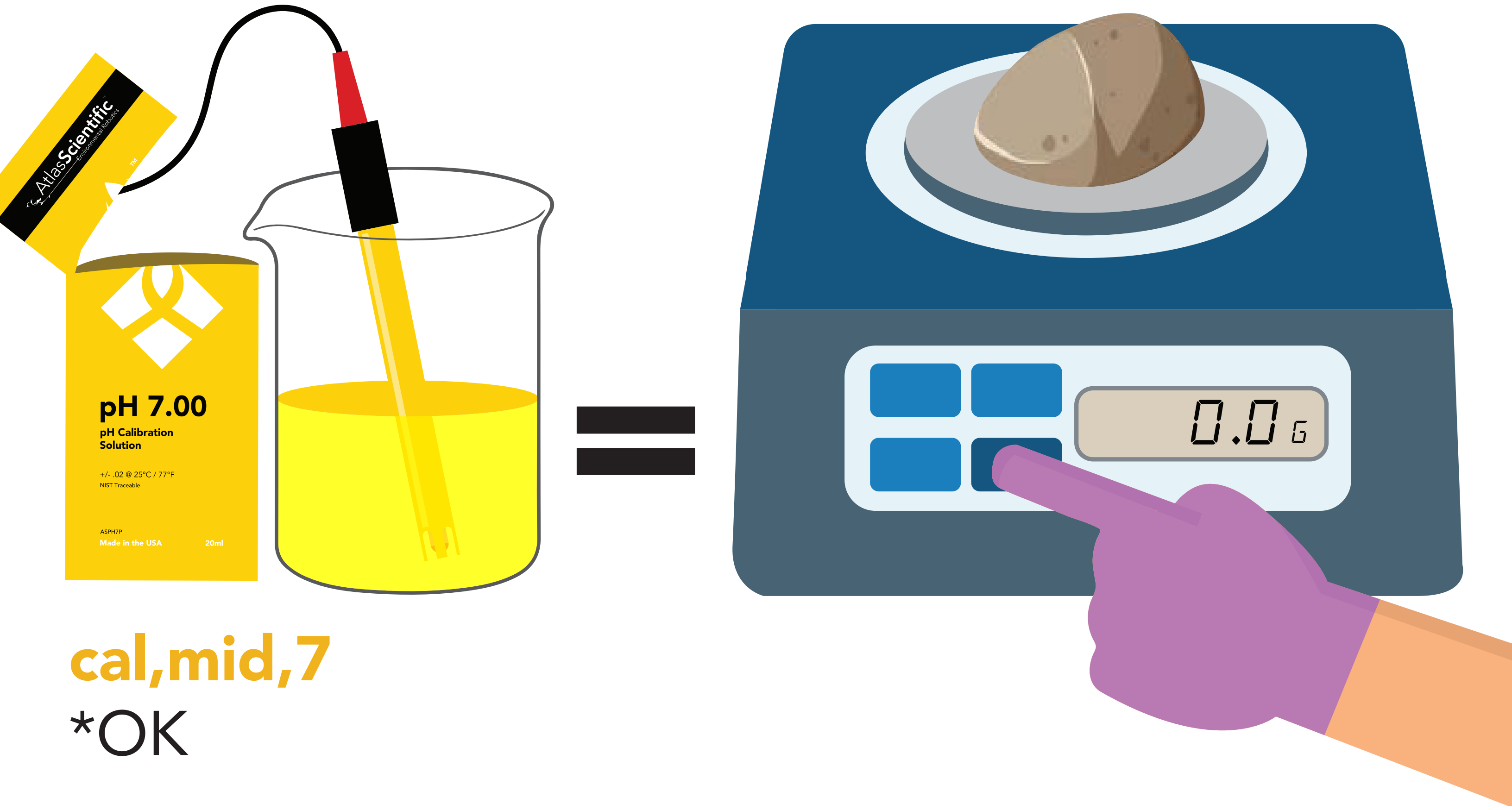
An uncalibrated pH probe will have a mathematically perfect slope. Because no pH probe is mathematically perfect, the slope can be used to determine if the pH was calibrated.

Uncalibrated slope: 100, 100, 0 (acid, base, neutral)
% % mV

The first two numbers are percentages, and the third is millivolts. The slope shows that the probe's response to acid and base is 100% correct, and it detects 0 mv in a pH 7. Because such perfection does not exist in the real world, we know this probe was not calibrated.

Understanding pH slope

pH 7 is the absence of pH; it is not an acid or a base. Therefore it should always be your first calibration point. It is equivalent to the tare function on a scale because it establishes the probe's zero point.



cal,mid,7

*OK

After pH 7 calibration, use the slope command to see how the probe performed during calibration.

The slope after pH 7 calibration: 100, 100, -1.2

Here we see the probe reads -1.2mV in pH 7. The closer this number is to 0, the better. A new pH probe should give a millivolt offset no greater than -5mV to 5mV. Over time this number's distance to 0 may increase; the larger the number, the lower the accuracy. A reading >10mV will result in noticeable performance issues.

It is important to remember that a high number is not definitive evidence that the probe is inaccurate or malfunctioning. It is very common to see a high number if the calibration solution was contaminated and not actually its stated value.

Understanding pH slope

The next two calibration points *(pH 4 and pH 10)* report their slope in percentage. A new pH probe should have a slope of >95%.

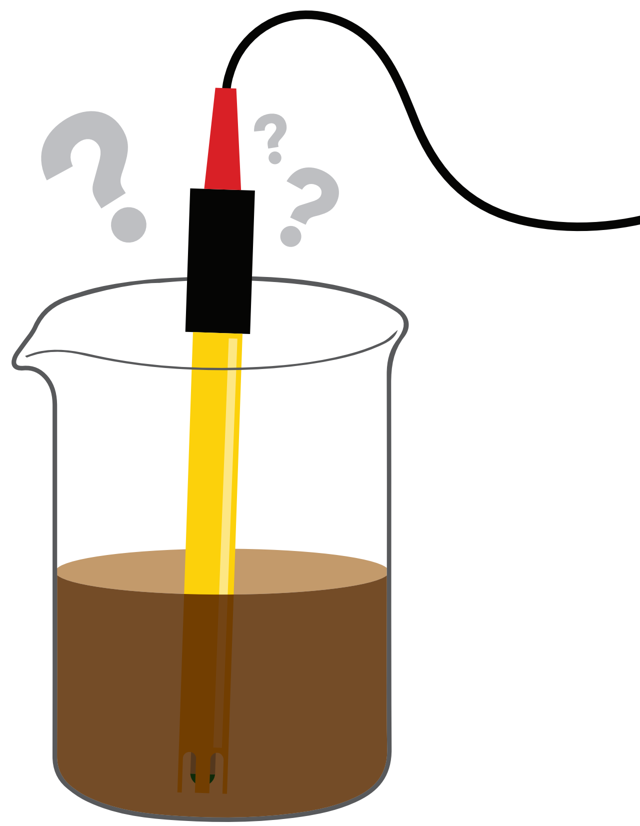
The slope after pH 4 calibration: 98.2, 100, -1.2

The slope after pH 10 calibration: 98.2, 97.8, -1.2

Tips:

Throughout this explanation, we have looked at the slope after each calibration event. This is unnecessary; in reality, it is best to fully calibrate the probe and look at the slope once calibration has been completed.

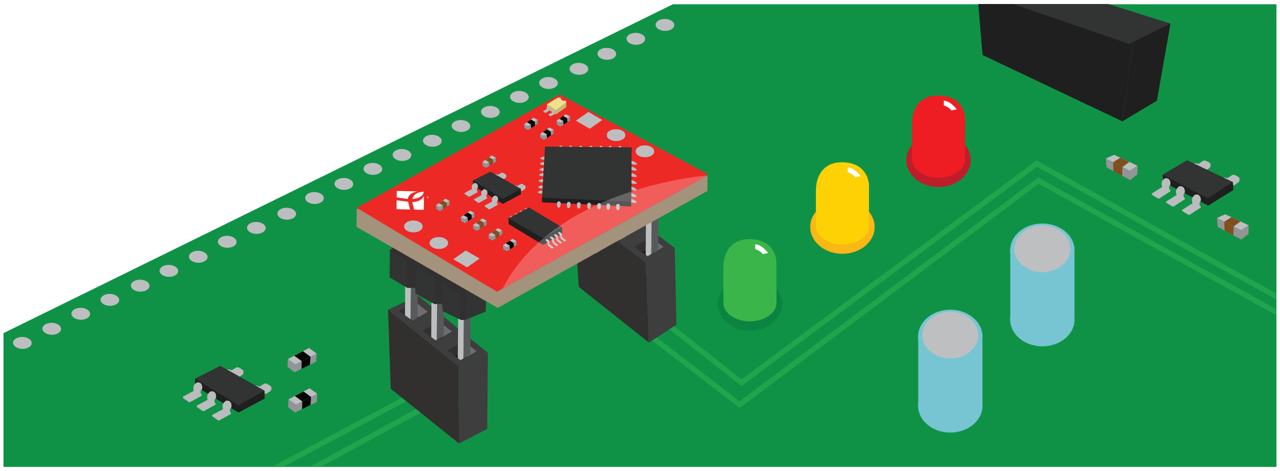
To gain a deeper understanding of how slope affects the stability and accuracy of a pH probe, intentionally miscalibrate the probe and see how it affects the slope.



Soldering

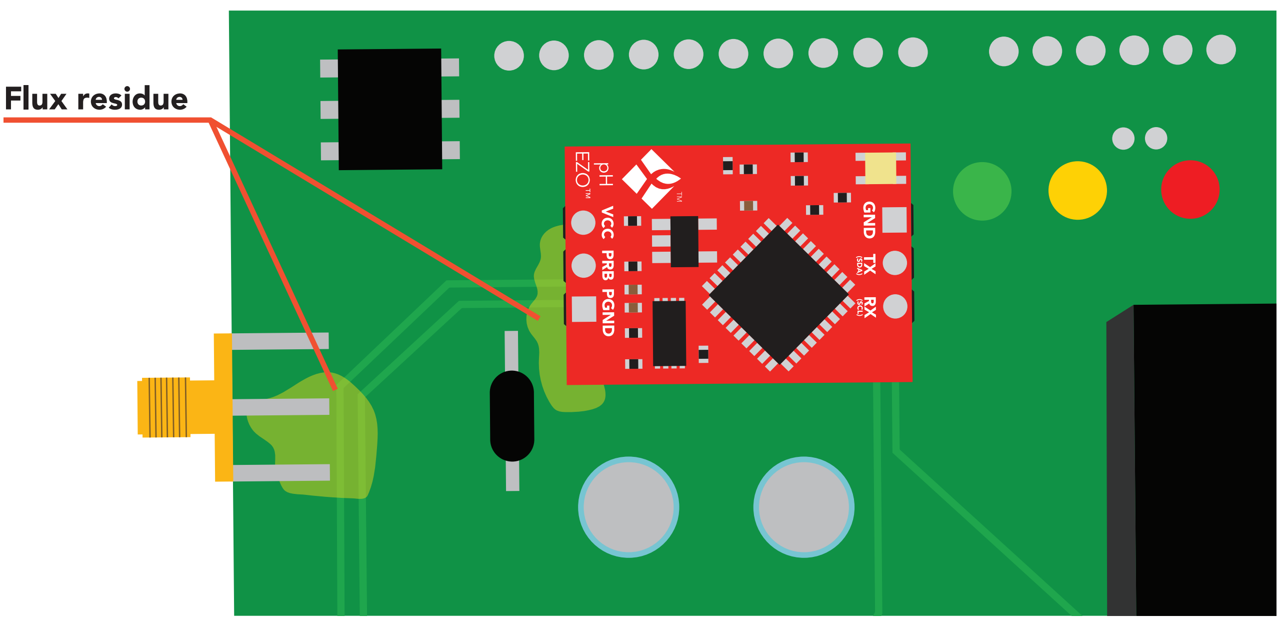
Do not directly solder an EZO circuit to your PCB. If something goes wrong during the soldering process it may become impossible to correct the problem. It is simply not worth the risk.

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



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

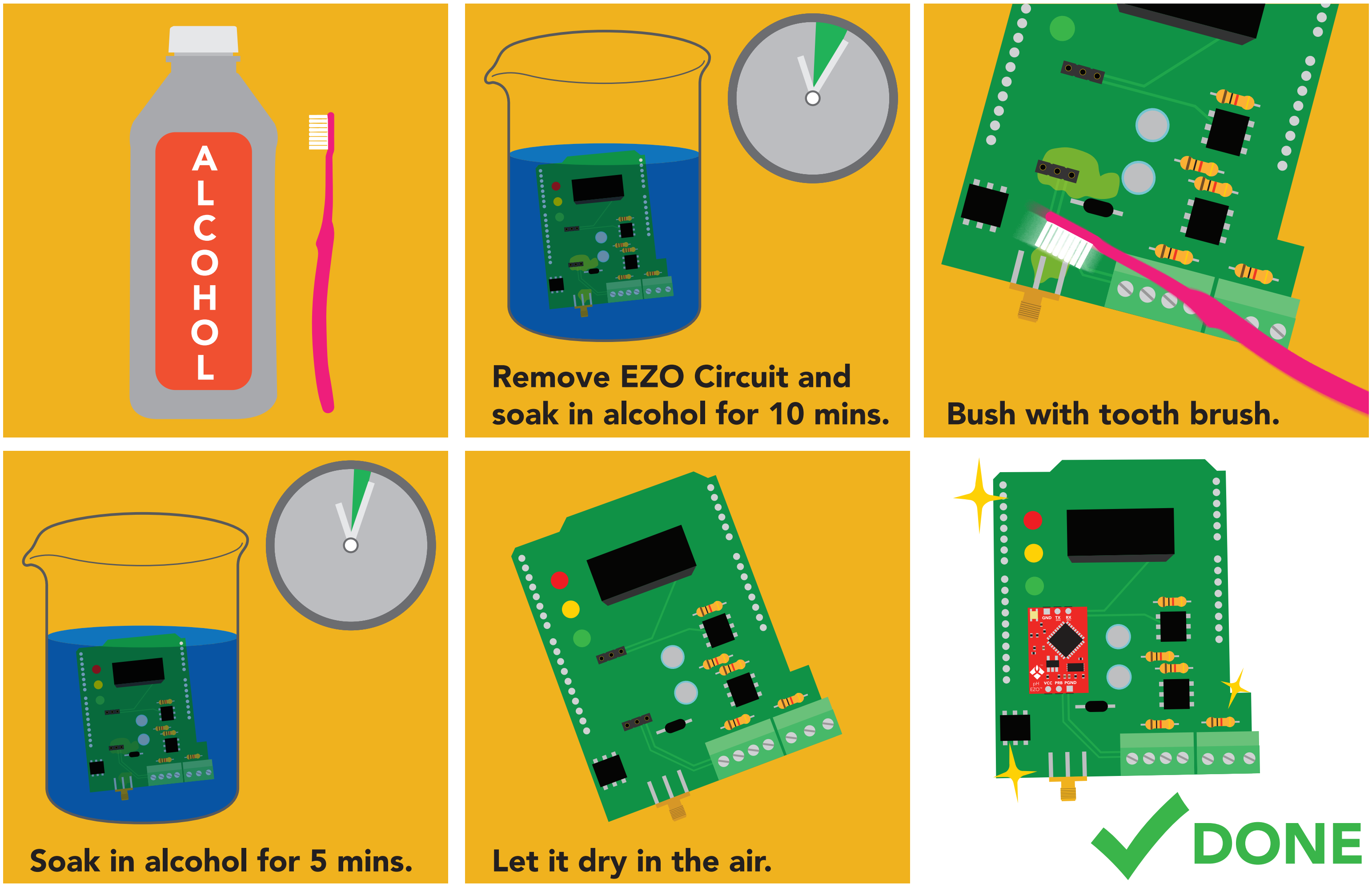
Flux residue will severely affect your readings. Any Flux residue that comes in contact with the PRB pins or your probes connector will cause a “flux short”.



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

Soldering

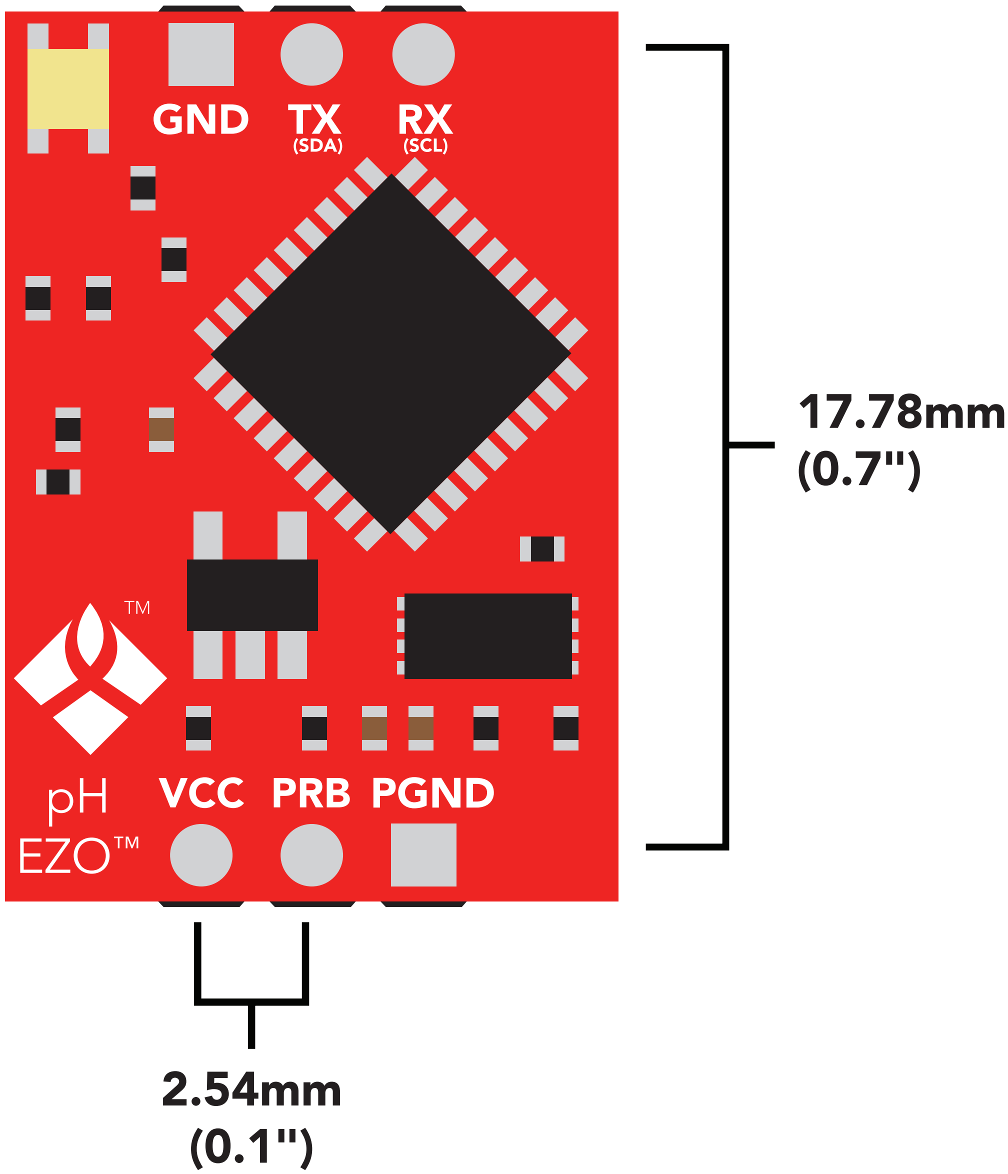
Removing flux residue can be done with commercially available products such as flux off or you can use alcohol and a tooth brush.



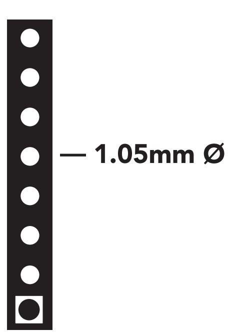
What does a flux short look like?

1: Readings move slowly and take serval minutes to reach the correct value.
2: Readings are pinned to 0, 7 or 14.

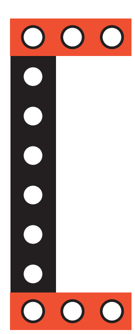
EZO™ circuit footprint



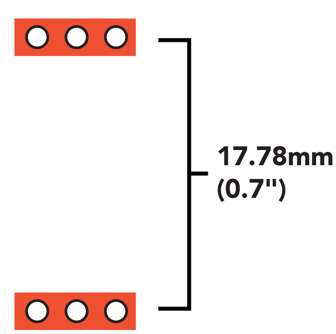
1 In your CAD software place a 8 position header.



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



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



Datasheet change log

Datasheet V 6.1

Revised electrical isolation section on page 7.

Datasheet V 6.0

Revised entire document.

Datasheet V 5.9

Revised naming device info on pages 32 & 58.

Datasheet V 5.8

Revised calibration info and art on pages 11 & 12.

Datasheet V 5.7

Added new command:
"Extended pH Scale" pages 30 (UART) & 56 (I^2C).

Datasheet V 5.6

Revised information on the slope command found on pages 29 & 54.

Datasheet V 5.5

Revised artwork within datasheet.

Datasheet V 5.4

Moved the Default state to pg 14.

Datasheet V 5.3

Revised response for the sleep command in UART mode on pg 35.

Datasheet V 5.2

Revised calibration theory on page 11, and added more information on the Export calibration and Import calibration commands.

Datasheet V 5.1

Revised isolation schematic on pg 10.

Datasheet V 5.0

Added more information about temperature compensation on pages 29 & 53.

Datasheet V 4.9

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

Datasheet V 4.8

Added new command:
"RT,n" for Temperature compensation located on pages 29 (UART) & 53 (I^2C).
Added firmware information to Firmware update list.

Datasheet V 4.7

Removed note from certain commands about firmware version.

Datasheet V 4.6

Added information to calibration theory on pg 7.

Datasheet V 4.5

Revised definition of response codes on pg 44.

Datasheet V 4.4

Added resolution range to cover page.

Datasheet V 4.3

Revised isolation information on pg 9.

Datasheet V 4.2

Revised Plock pages to show default value.

Datasheet V 4.1

Added new commands:
"Find" pages 23 (UART) & 46 (I^2C).
"Export/Import calibration" pages 27 (UART) & 49 (I^2C).
Added new feature to continous mode "C,n" pg 24.

Datasheet V 4.0

Added accuracy range on cover page, and revised isolation info on pg. 10.

Datasheet V 3.9

Revised calibration theory on pg. 7.

Datasheet V 3.8

Revised entire datasheet.

Firmware updates

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

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

V1.7 – Factory (April 14, 2015)
- Changed "X" command to "Factory"

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

V1.96 – EEPROM (April 26, 2016)
- Fixed bug where EEPROM would get erased if the circuit lost power 900ms into startup

V1.97 – EEPROM (Oct 10, 2016)
- Added the option to save and load calibration.

V1.98 – EEPROM (Nov 14, 2016)
- Fixed bug during calibration process.

V2.10 – (May 9, 2017)
- Added "Find" command.
- Added "Export/import" command.
- Modified continuous mode to be able to send readings every "n" seconds.

V2.11 – (June 12, 2017)
- Fixed "I" command to return "pH" instead of "PH".

V2.12 – (April 16, 2018)
- Fixed "cal,clear" was not clearing stored calibration in EEPROM.
- Added "RT" command to Temperature compensation.

V2.13 – (June 25, 2019)
- Added calibration offset to slope.
- Added calibration with temperature compensation.

V2.14 – (June 10, 2020)
- Added extended pH scale.

v2.15 – (Nov 3, 2021)
- Internal update for new part compatibility.

v2.16 – (Nov 19, 2021)
- Fixed bug in I2C mode with timing and sleep mode.

Warranty

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

The debugging phase

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

- **Soldering any part of the EZO™ class pH circuit.**
- **Running any code, that does not exclusively drive the EZO™ class pH circuit and output its data in a serial string.**
- **Embedding the EZO™ class pH 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 pH circuit, against the thousands of possible variables that may cause the EZO™ class pH 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 pH circuits continued operation. This is because that would be equivalent to Atlas Scientific™ taking responsibility over the correct operation of your entire device.

