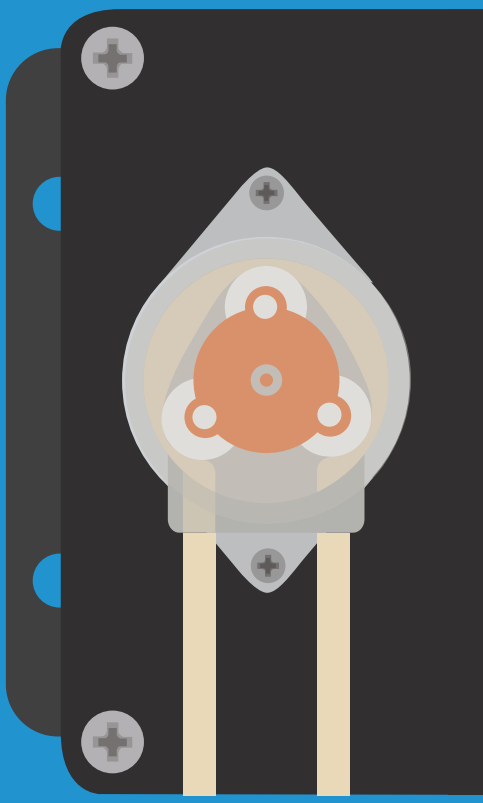
Atlas Scientific™
Environmental Robotics

V 1.1

Revised 4/22

TRI-PMP-BX™

Flow rate (per pump)	**0.5ml to 105ml/min**
Accuracy (per pump)	**+/- 1%**
Pump head (per pump)	**8.1 meters (26.5')**
Tubing size	**Any 5mm O.D. tubing**
Calibration	**Single point**
Modes of operation	**Continuous dispensing** **Volume dispensing** **Dose over time** **Constant flow rate** **Dispense at startup**
Data protocol	**I²C**
Default I²C address	**56 (0x38)** **57 (0x39)** **58 (0x3A)**
Data format	**ASCII**
Operating voltage	**12V 3 amp**

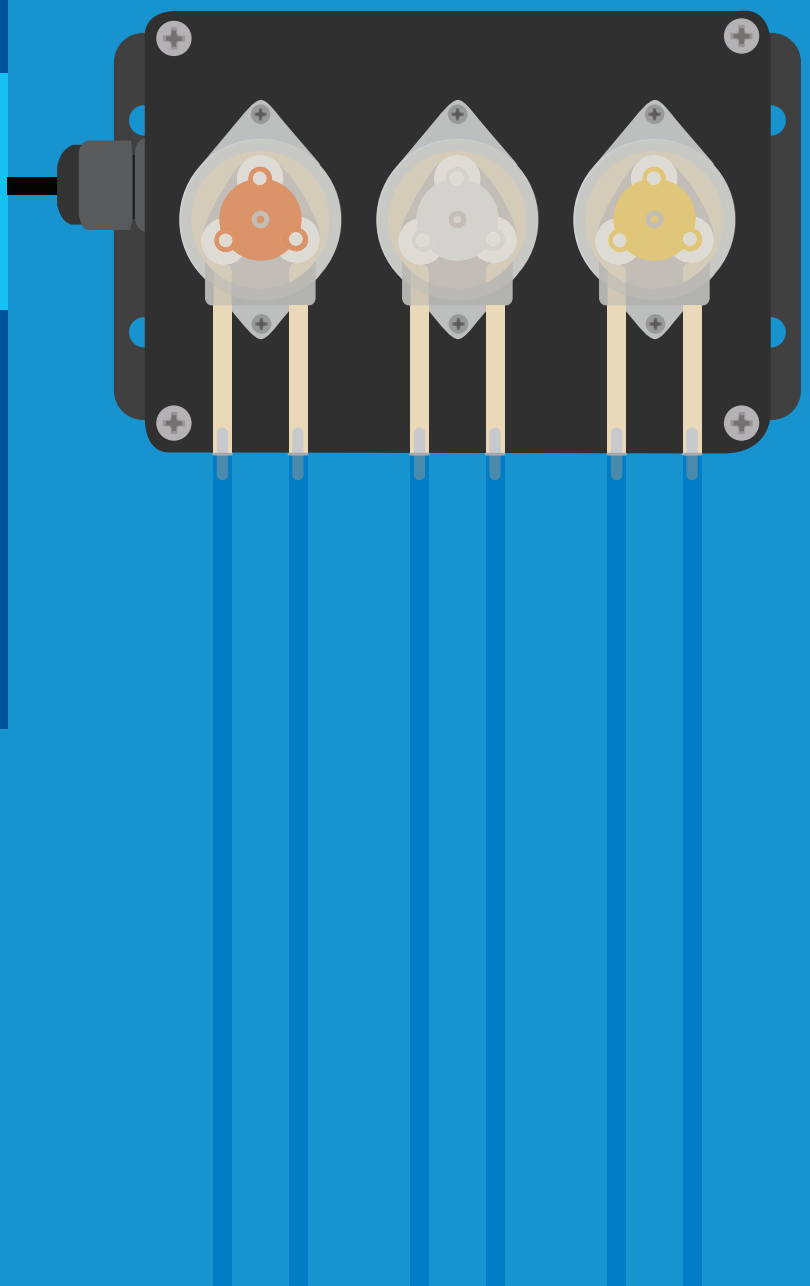


RoHS COMPLIANT

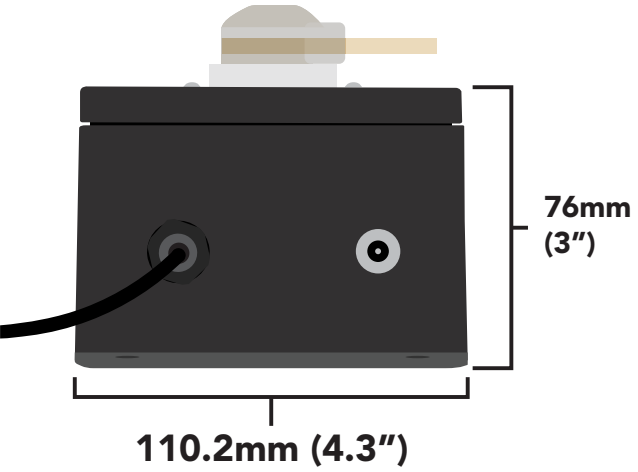
Written by Jordan Press
Designed by Noah Press

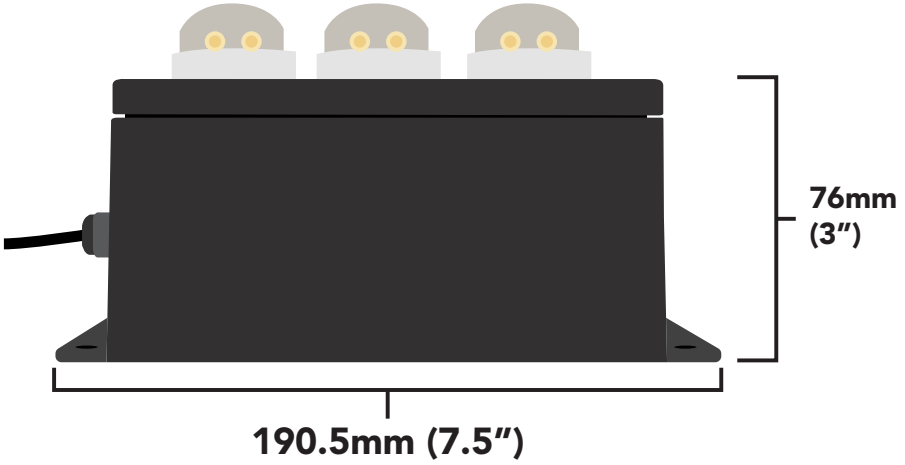
This is an evolving document, check back for updates.

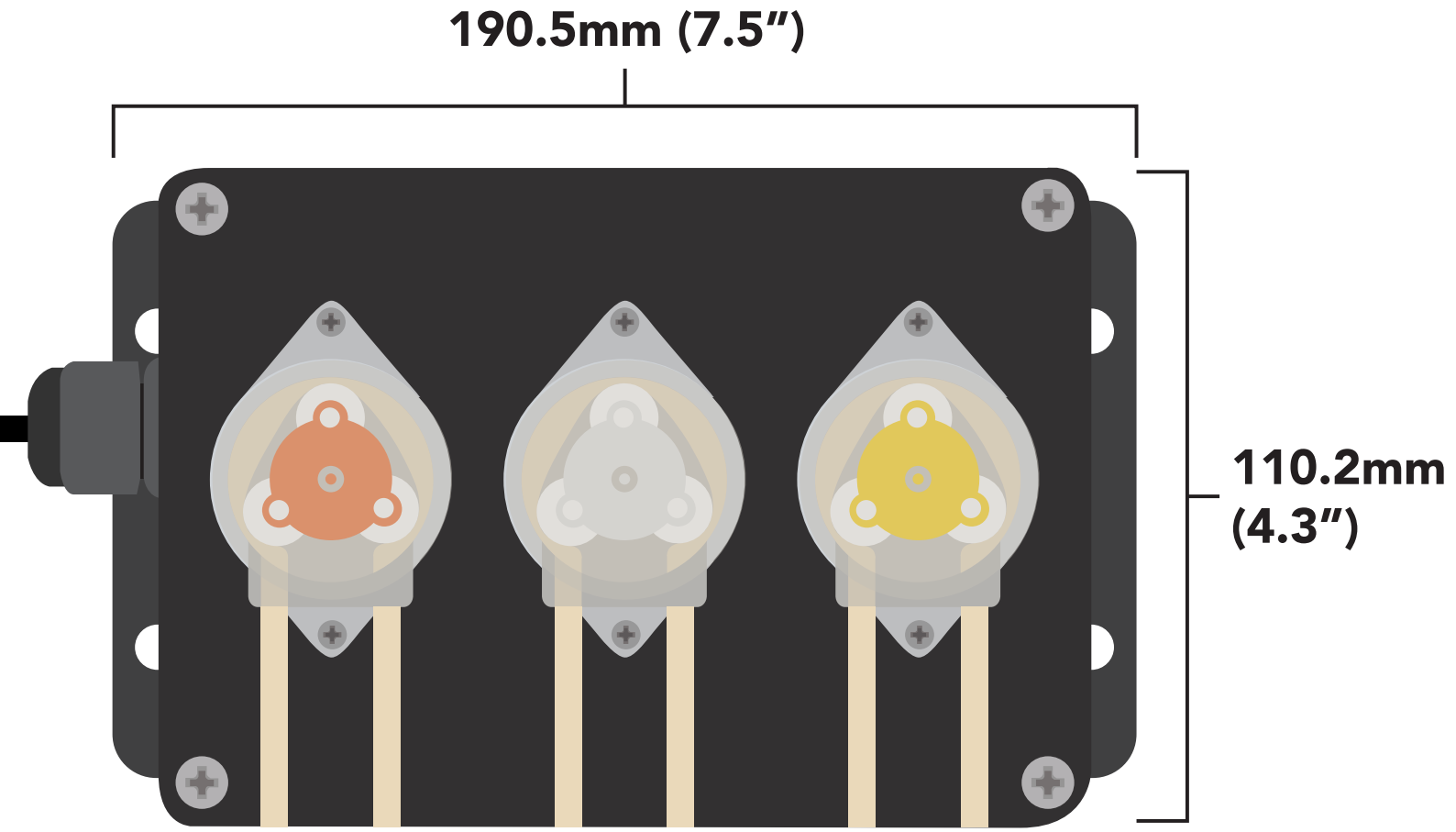
Table of contents



TRI-PMP-BX™ dimensions







I²C addresses

56 (0x38)	57 (0x39)	58 (0x3A)

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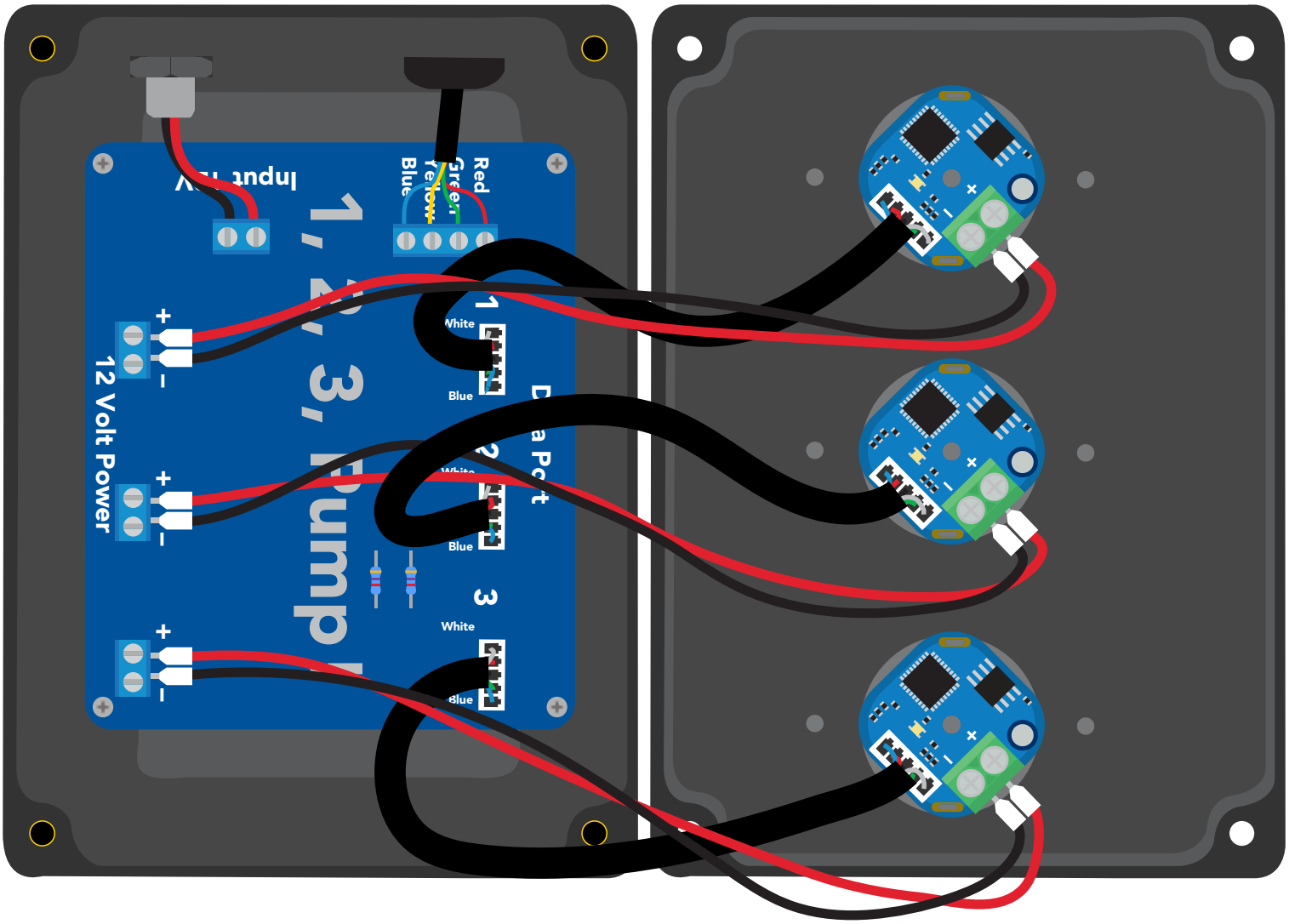
Operating principle

The TRI-PMP-BX™ system consists of three individually controllable pumps that are connected together through a single I²C data line. It's best to think of this device as three individual smart pumps in one enclosure.



Power consumption

Logic	~40 mA (for all 3 pumps)
Motor	400 mA per pump when running

Absolute max ratings

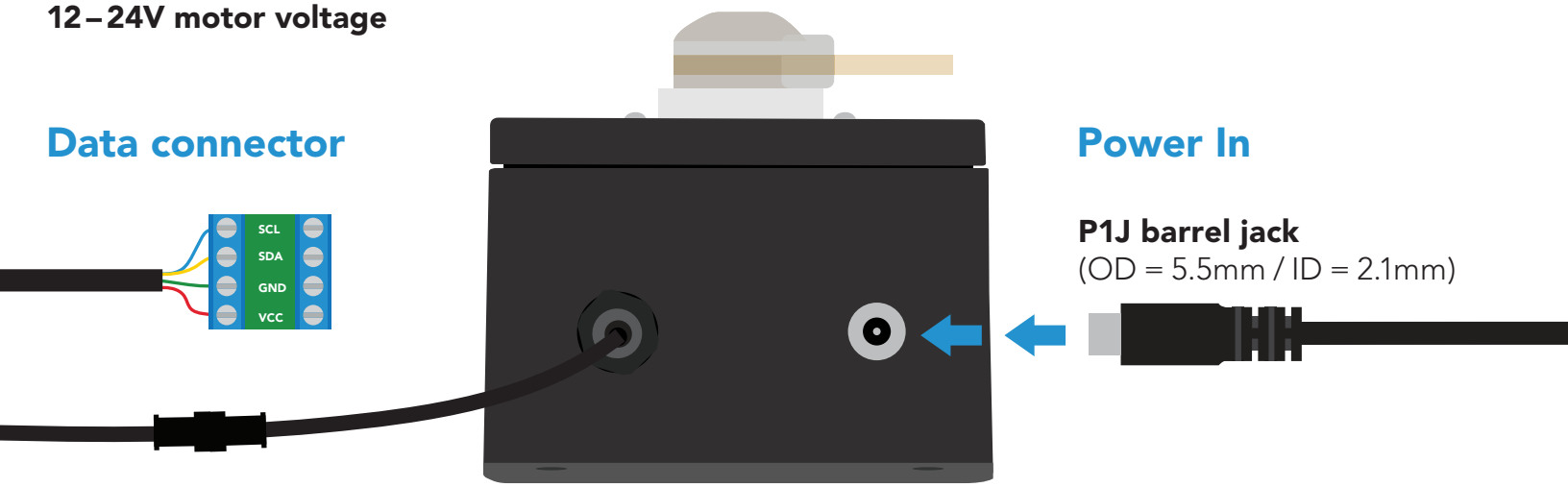
Parameter	MIN	TYP	MAX
Storage temp (EZO-PMP™)	-65 °C		125 °C
Operational temp (EZO-PMP™)	-40 °C	25 °C	85 °C

Tubing life span	+1,000 hrs.
Cassette life span	+1,500 hrs.
Motor life span	+5,000 hrs.

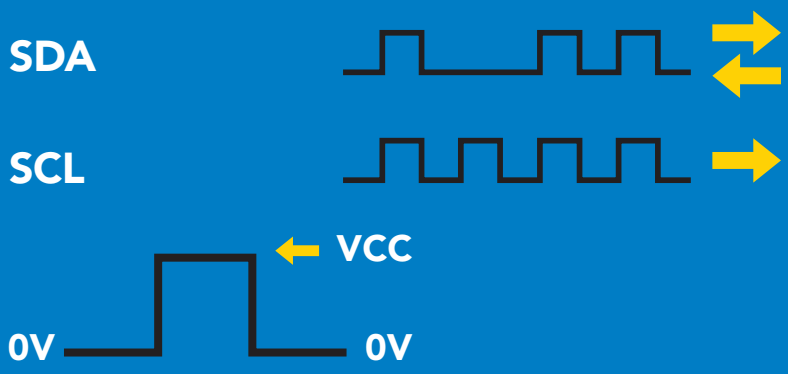
Connectors

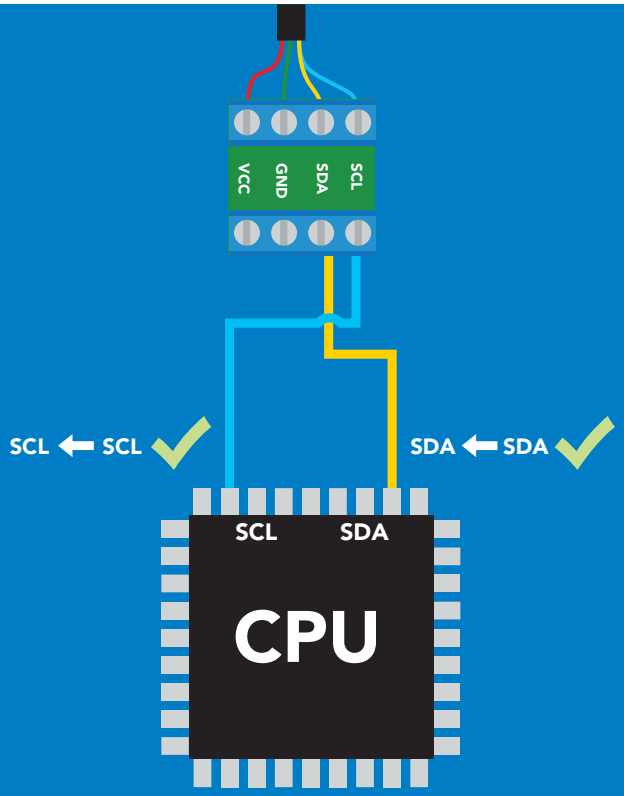
The TRI-PMP-BX™ system requires two power sources:

3.3v – 5v logic voltage
12 – 24V motor voltage



I2C addresses	56 (0x38) 56 (0x38) 56 (0x38)
Vcc	3.3V – 5.5V
Clock speed	100 – 400 kHz

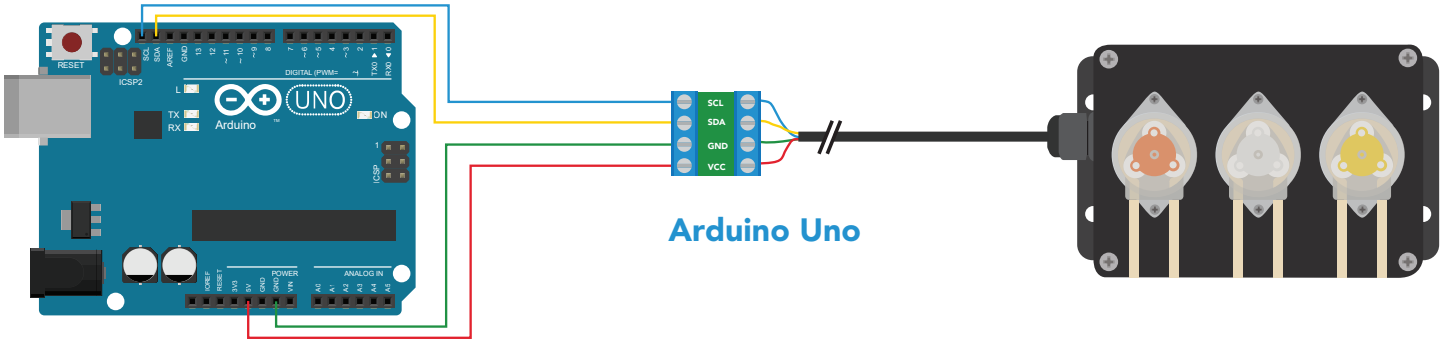




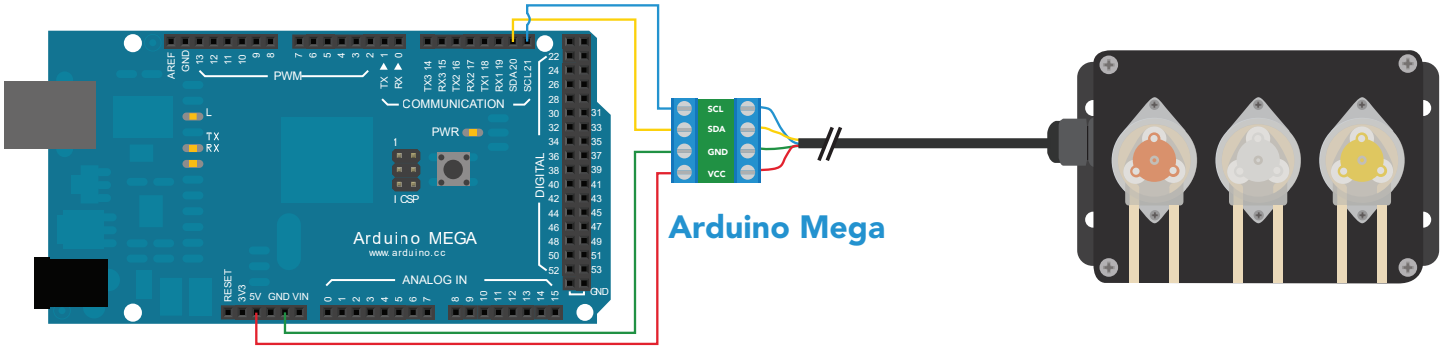
Data format

Readings	volume	Data type	floating point
Units	ml	Decimal places	2
Encoding	ASCII	Smallest string	3 characters
Format	string	Largest string	39 characters

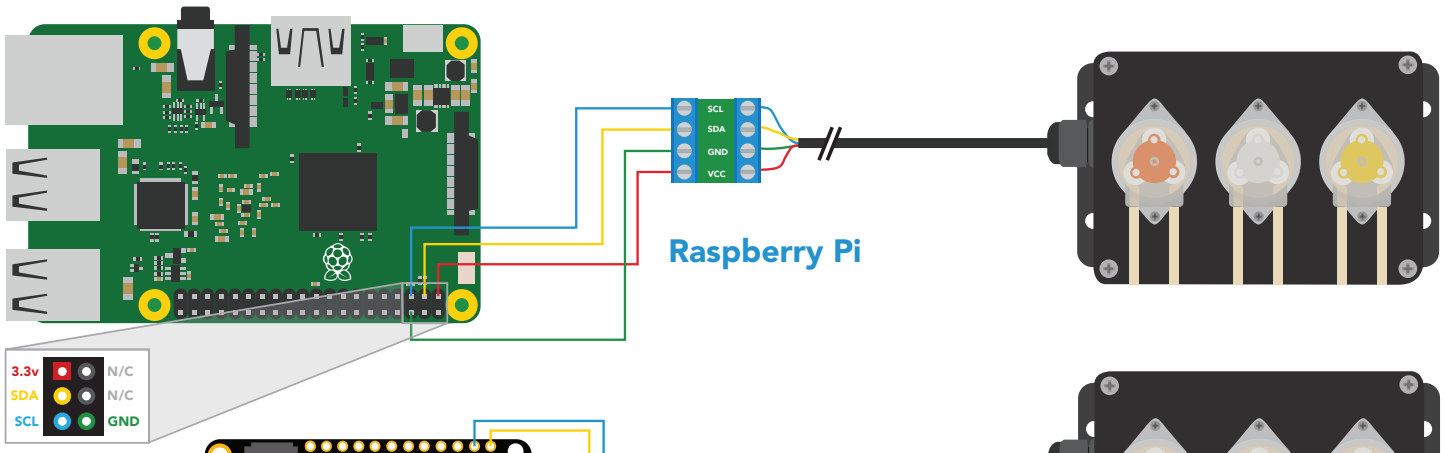
Connections to common CPUs



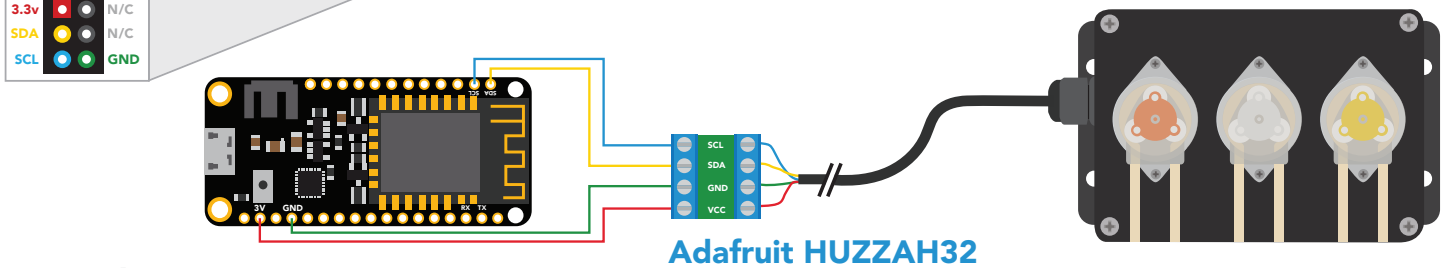
Arduino Uno



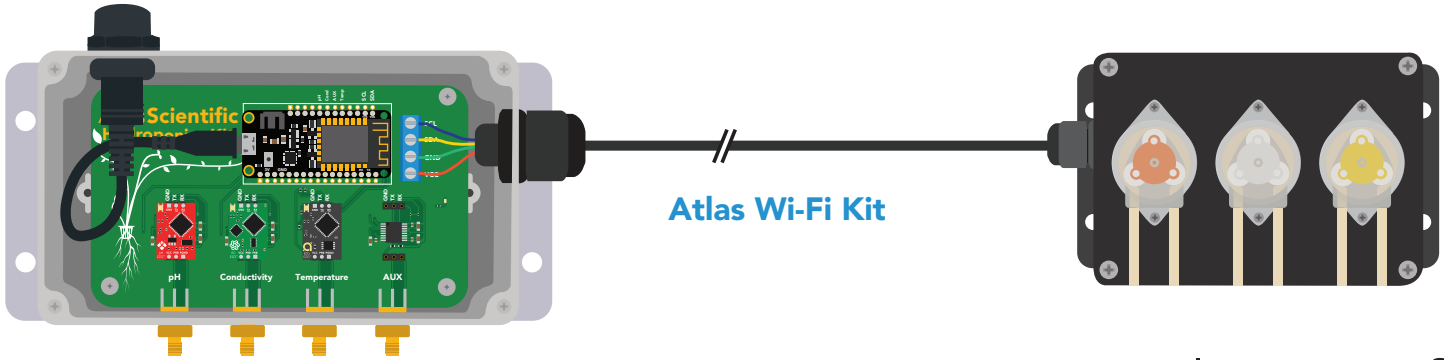
Arduino Mega



Raspberry Pi



Adafruit HUZZAH32



Atlas Wi-Fi Kit

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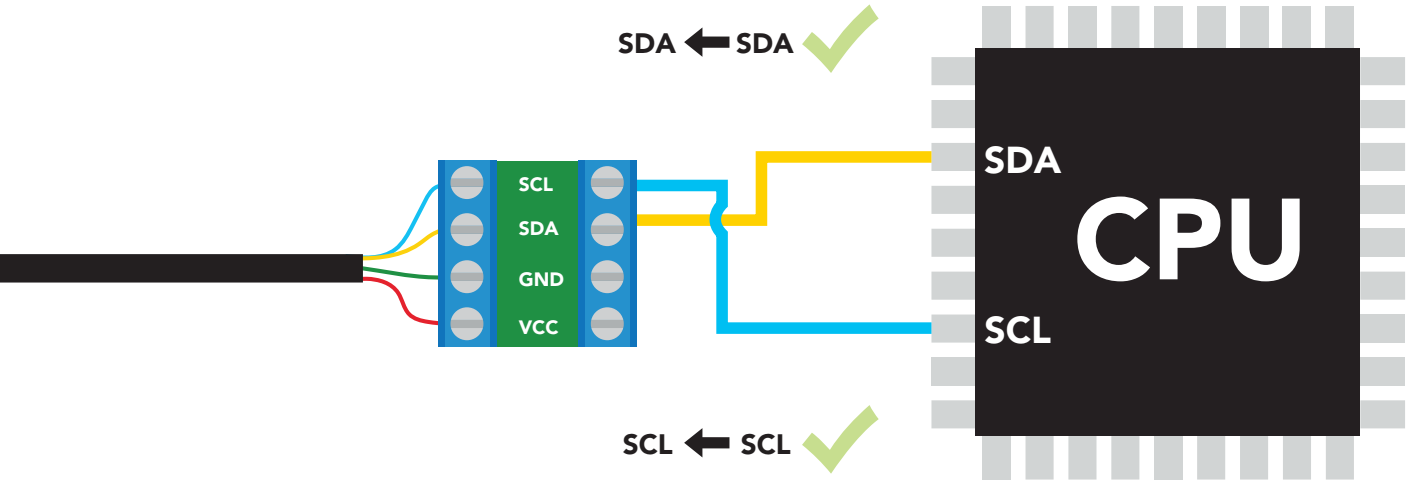
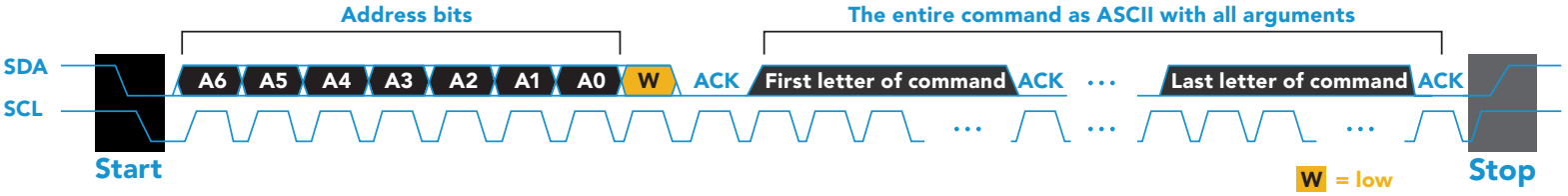
Sending commands to device

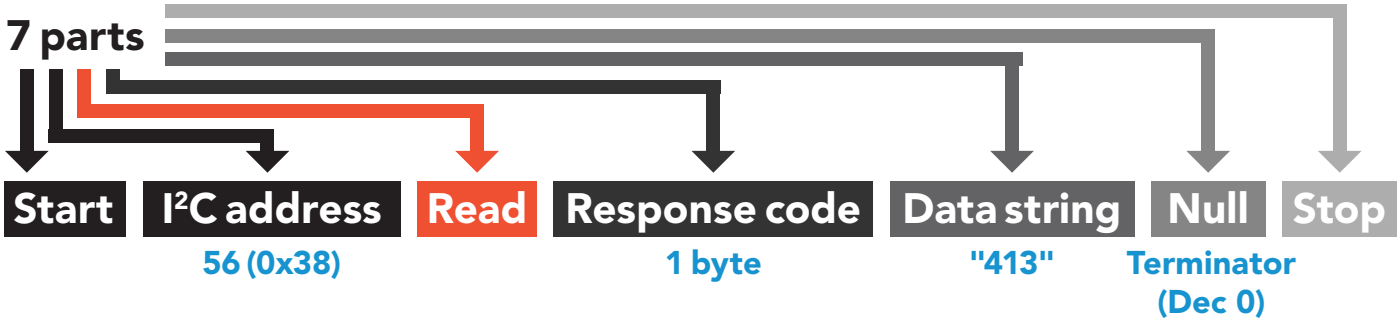
Example

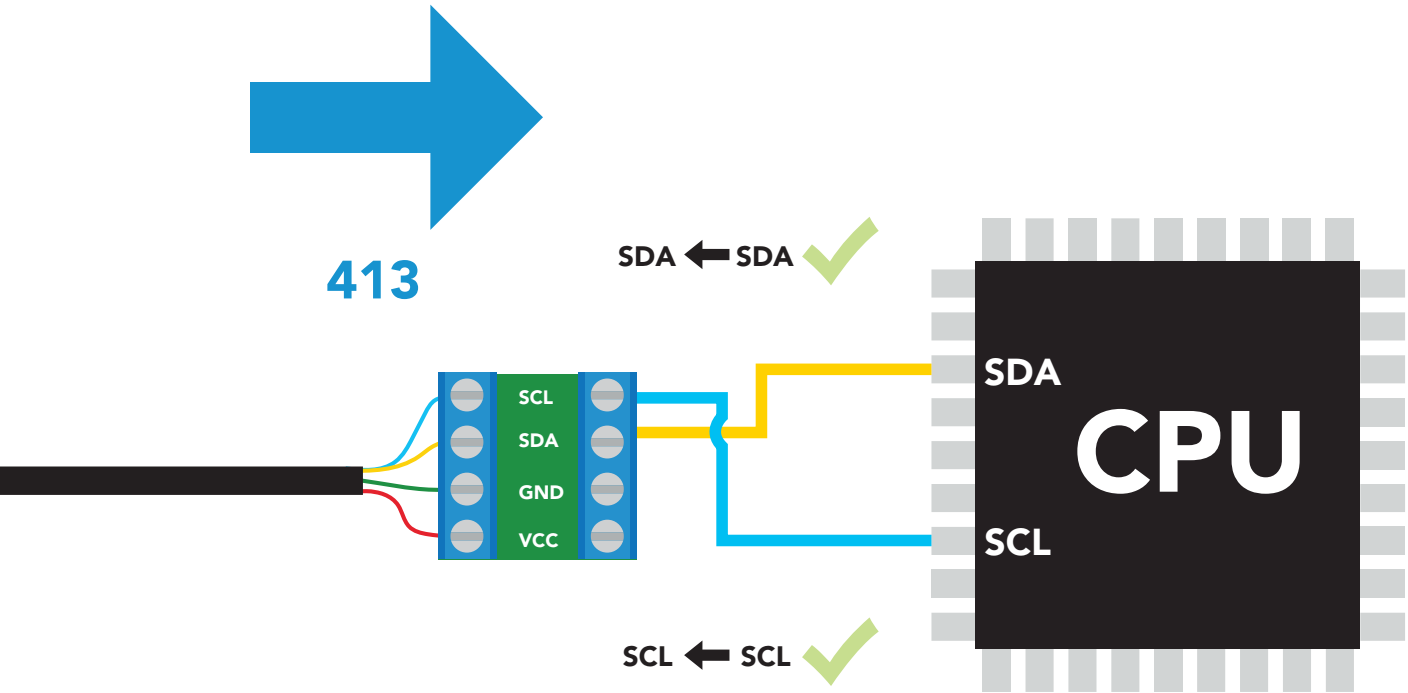


Advanced

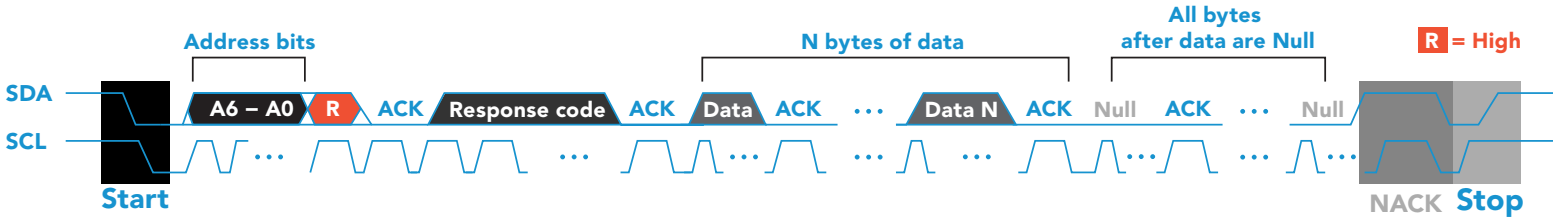


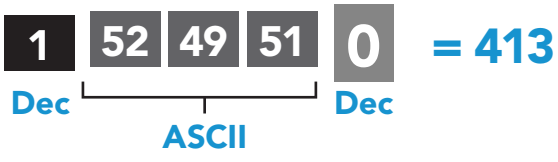
Requesting data from device





Advanced





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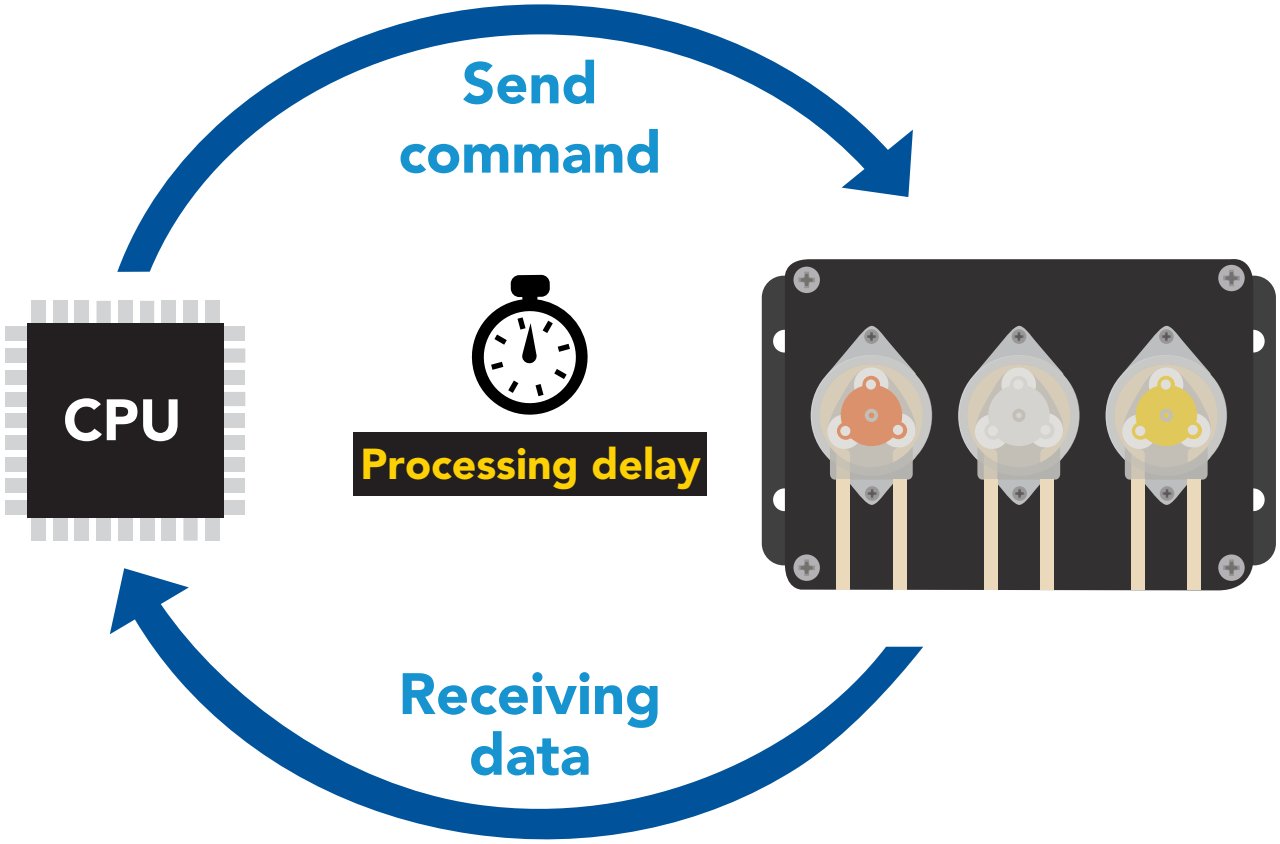
Response codes

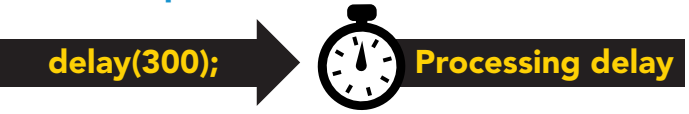
After a command has been issued, a 1 byte response code can be read in order to confirm that the command was processed successfully.

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



Example

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




```
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

Command quick reference

All commands are ASCII strings or single ASCII characters.

Command	Function	
Cal	performs calibration	pg. 23
D	dispense modes	pg. 12 – 18
i	device information	pg. 25
Invert	invert dispensing direction	pg. 21
I2C	change I²C address	pg. 26
O	enable/disable parameters	pg. 24
P	pauses the pump during dispensing	pg. 19
R	returns a single reading	pg. 11
Tv	total volume dispensed	pg. 22
X	stop dispensing	pg. 20

Single report mode

Command syntax

300ms processing delay

R returns a single value showing dispensed volume

Example	Response
R	Wait 300ms — 1 (Dec) 2.50 (ASCII) 0 (Null) (If issued half way through dispensing 5ml)
	Wait 300ms — 1 (Dec) 5.00 (ASCII) 0 (Null) (If issued once dispensing has stopped)

Continuous dispensing

Pump on/pump off

300ms processing delay

Command syntax

After running in continuous mode for 20 days the EZO-PMP™ will reset.

D,*	dispense until the stop command is given
D,-*	dispense in reverse until the stop command is given
D,?	dispense status

Example	Response
D,*	Wait 300ms → 1 (Dec) 0 (Null) — pump will continuously run at ~105ml/min (with supplied tubing)
D,-*	Wait 300ms → 1 (Dec) 0 (Null) — pump will continuously run in reverse at ~105ml/min (with supplied tubing)
D,?	Wait 300ms → 1 (Dec) ?D,10.00,1 (ASCII) 0 (Null)

Response breakdown

?D,*,1

- ? — last volume requested
- 1 — pump on

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Volume dispensing

Pump a specific volume

300ms processing delay

Command syntax

where [ml] is any volume in millimeters >= 0.5

D,[ml]	dispense [this specific volume]
D,[-ml]	dispense [*in reverse* this specific volume]
D,?	dispense status

Example	Response
D,15	Wait 300ms → 1 (Dec) 0 (Null) — 15 ml will be dispensed
D,-40.5	Wait 300ms → 1 (Dec) 0 (Null) — 40.5 ml will be dispensed *in reverse*
D,?	Wait 300ms → 1 (Dec) ?D,-40.50,0 (ASCII) 0 (Null)

Response breakdown

?D,-40.50,0

- -40.50 ↑ last volume dispensed
- 0 ↑ pump off

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Dose over time

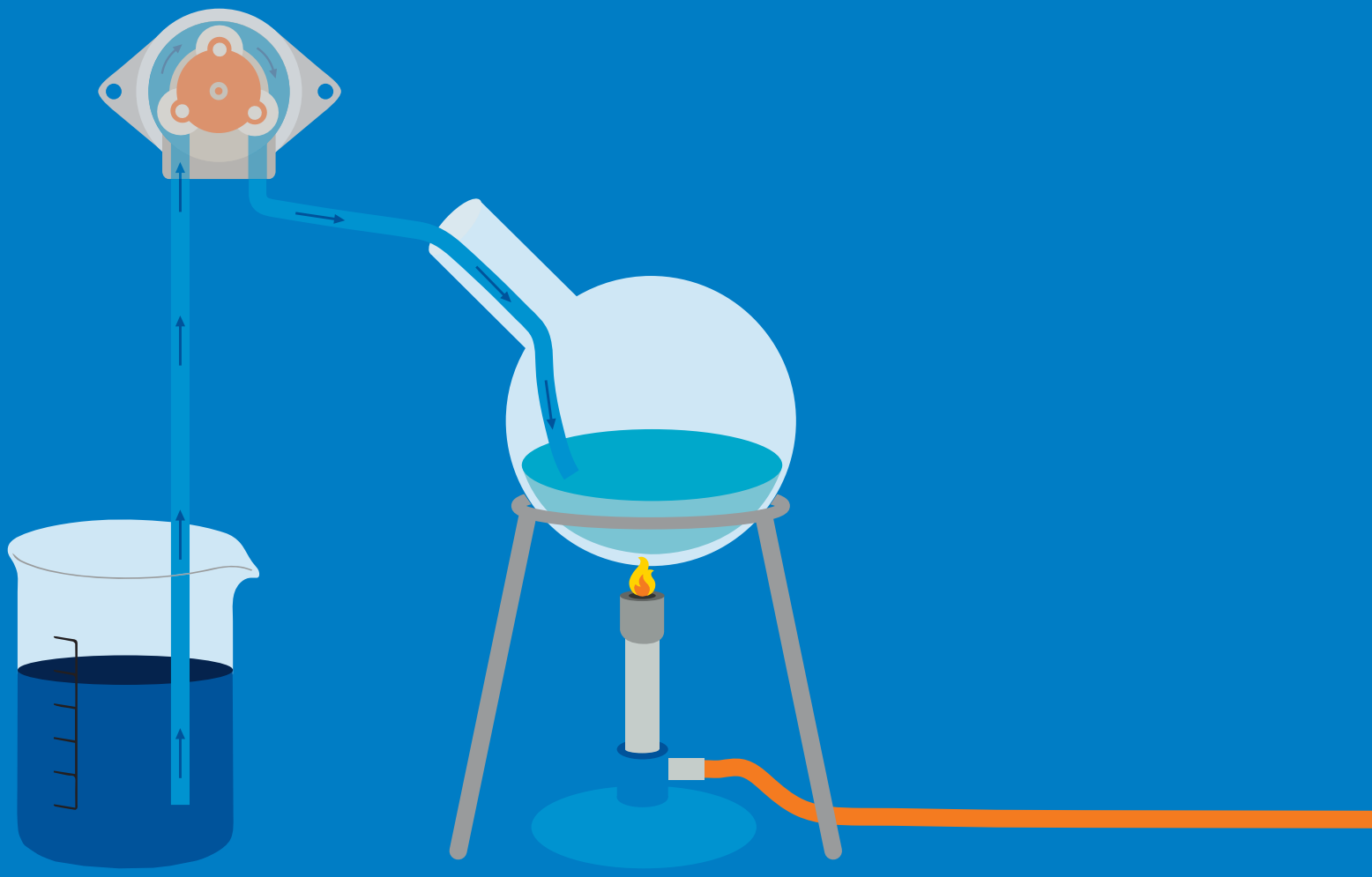
Pump a fixed volume over a fixed time

Command syntax

300ms processing delay

D,[ml],[min]	Dispense [this volume], [over this many minutes]

Example	Response
D,85,10	Wait 300ms; 1 Dec; 0 Null; Dispense 85ml over 10 mins



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Constant flow rate

Maintain a constant flow rate

300ms processing delay

Command syntax

After running in continuous mode for 20 days the EZO-PMP™ will reset.

DC,[ml/min], [min or *] [maintain this rate], [for this much time]

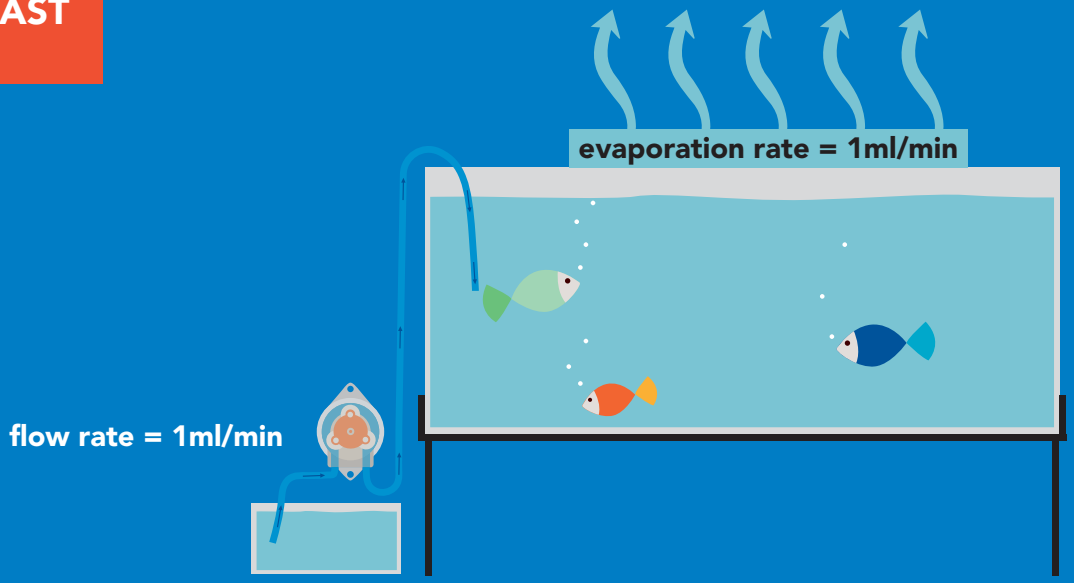
DC,? reports maximum possible flow rate

[ml/min] = a single number (int or float) representing the desired flow rate
[min or *] = the number of minutes to run or (*) indefinitely
A negative value for ml/min = reverse

Example	Response
DC,25,40	Wait 300ms → 1 (Dec) 0 (Null) — Dispense 25ml per minute for 40 minutes
DC,?	Wait 300ms → 1 (Dec) ?maxrate,58.5 (ASCII) 0 (Null)

The maximum flow rate is determined after calibration.
If the flowrate entered is too fast the EZO-PMP™ will send an error.

***TOOFAST**
***ER**



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r 0.1

Dispense at startup

Pump a specific volume at startup and then stop

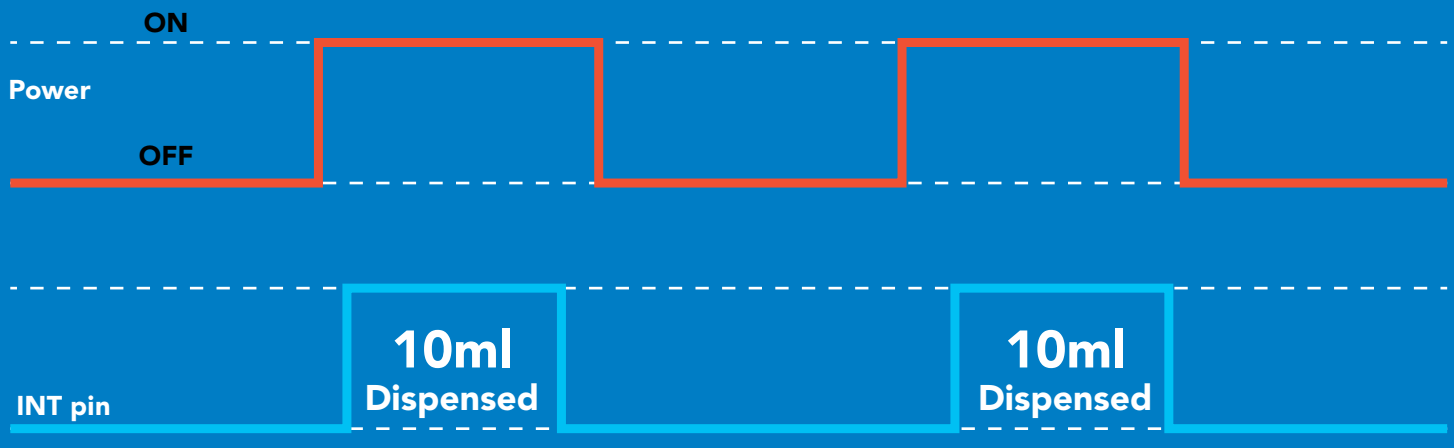
Use this command to make a simple fixed-volume pump

Command syntax

300ms processing delay

Dstart,[ml]	dispense [this specific volume] at startup
Dstart,off	disables dispense at startup mode
Dstart,?	startup dispense status

Example	Response
Dstart,10	Wait 300ms · 1 Dec · 0 Null
Dstart,off	Wait 300ms · 1 Dec · 0 Null
D,?	Wait 300ms · 1 Dec · ?Dstart,10 ASCII · 0 Null **or** Wait 300ms · 1 Dec · ?Dstart,0 ASCII · 0 Null



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Continuous dispensing at startup

Pump on & continuously dispense

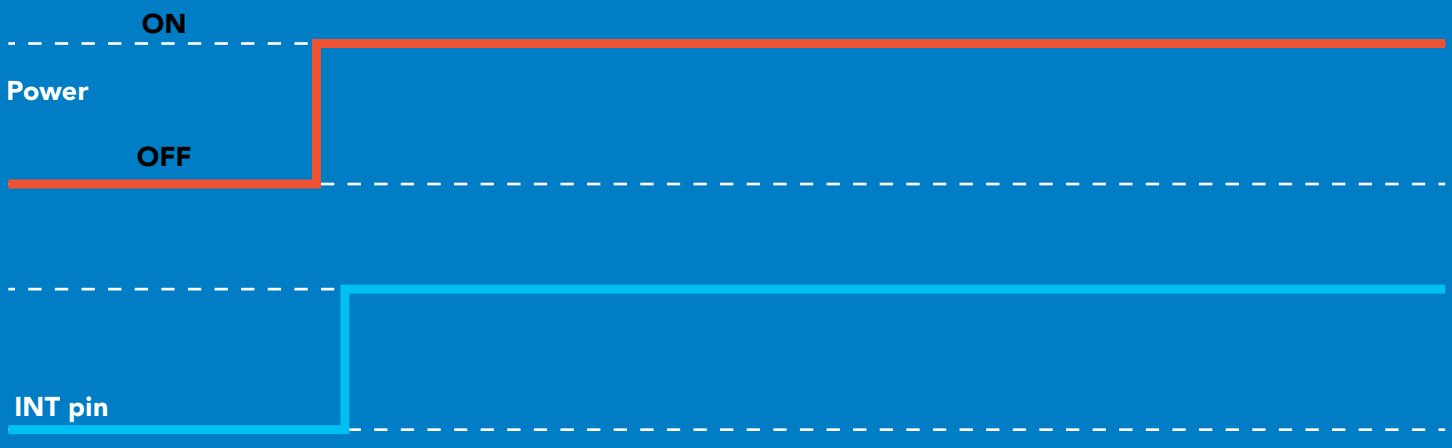
300ms processing delay

Command syntax

After running in continuous mode for 20 days the EZO-PMP™ will reset.

Dstart,*	dispense at startup until the stop command is given
Dstart,-*	dispense in reverse at startup until the stop command is given
Dstart,?	startup dispense status

Example	Response
Dstart,*	Wait 300ms → 1 (Dec) 0 (Null) — Pump will startup and continuously run at ~105ml/min (with supplied tubing)
Dstart,-*	Wait 300ms → 1 (Dec) 0 (Null) — Pump will startup and continuously run in reverse at ~105ml/min (with supplied tubing)
Dstart,?	Wait 300ms → 1 (Dec) ?Dstart,* (ASCII) 0 (Null)



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Dose Over time at startup

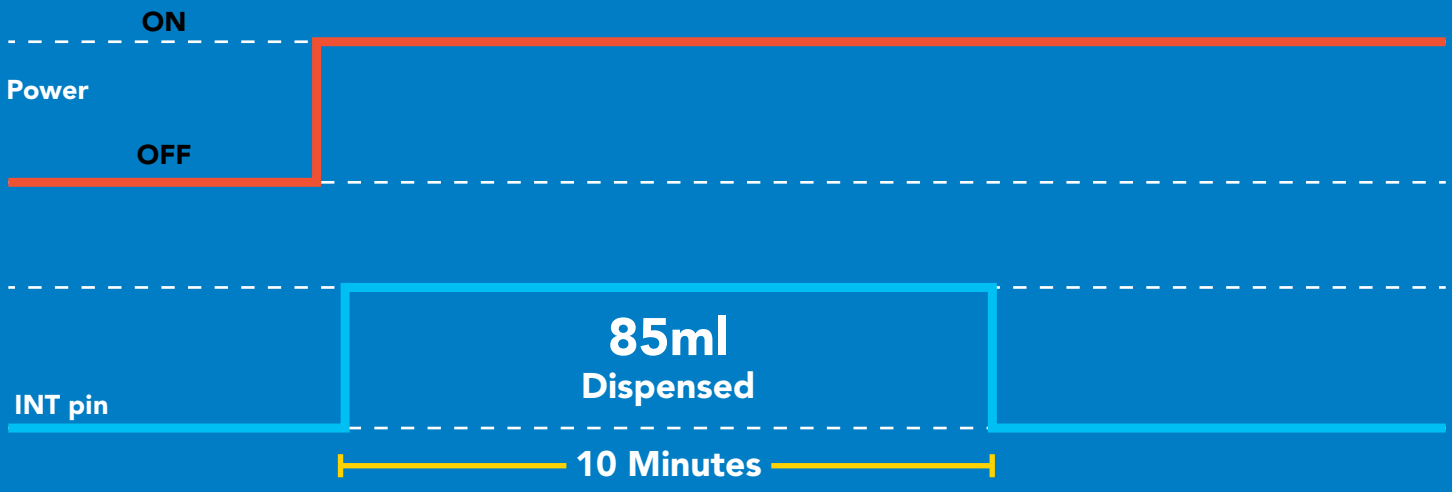
Pump a fixed volume over a fixed time at startup

Command syntax

300ms processing delay

D,[ml],[min]	Dispense [this volume], [over this many minutes] at startup

Example	Response
Dstart,85,10	Wait 300ms · 1 (Dec) · 0 (Null) — Pump will startup and dispense 85ml over 10 minutes
Dstart,?	Wait 300ms · 1 (Dec) · ?Dstart,85.00,10.00 (ASCII) · 0 (Null)



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Pause dispensing

Command syntax

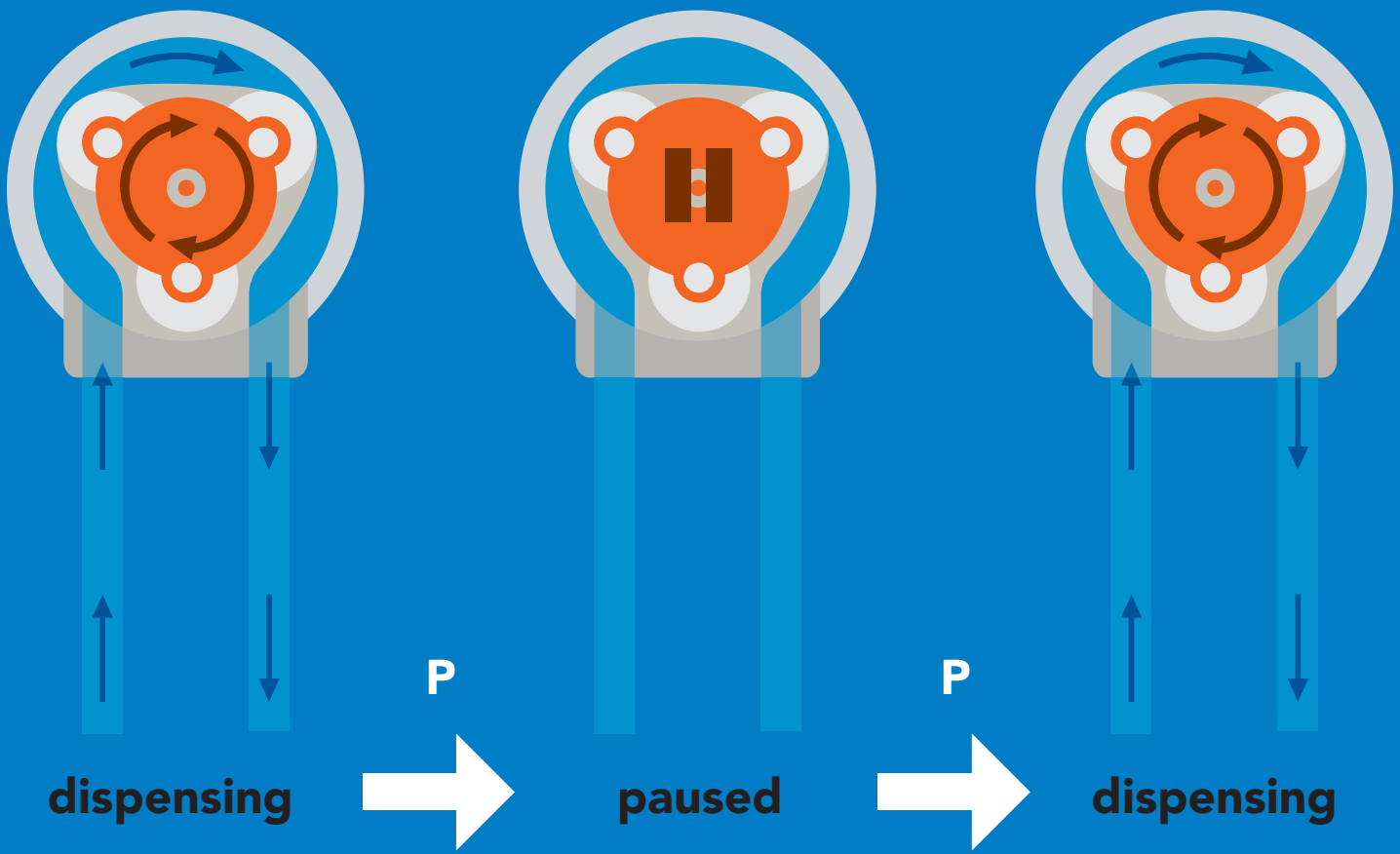
300ms processing delay

Issue the command again to resume dispensing

P pauses the pump during dispensing

P,? pause status

Example	Response
P	Wait 300ms — 1 Dec — 0 Null
P,?	Wait 300ms — 1 Dec — ?P,1 ASCII paused — 0 Null **or** Wait 300ms — 1 Dec — ?P,0 ASCII unpaused — 0 Null



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r 0.1

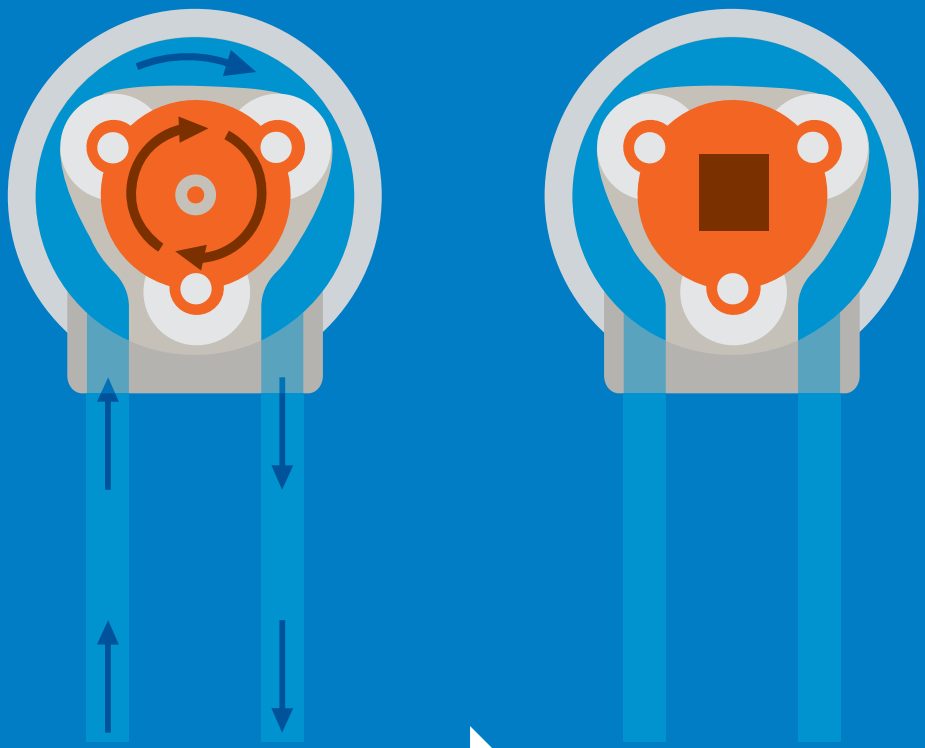
Stop dispensing

Command syntax

300ms processing delay

X stop dispensing

Example	Response
X	Wait 300ms · 1 (Dec) · *DONE,v (ASCII) · 0 (Null) · v = volume dispensed



X
dispensing

*DONE,10.15
Stopped

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r 0.1

Invert dispensing direction

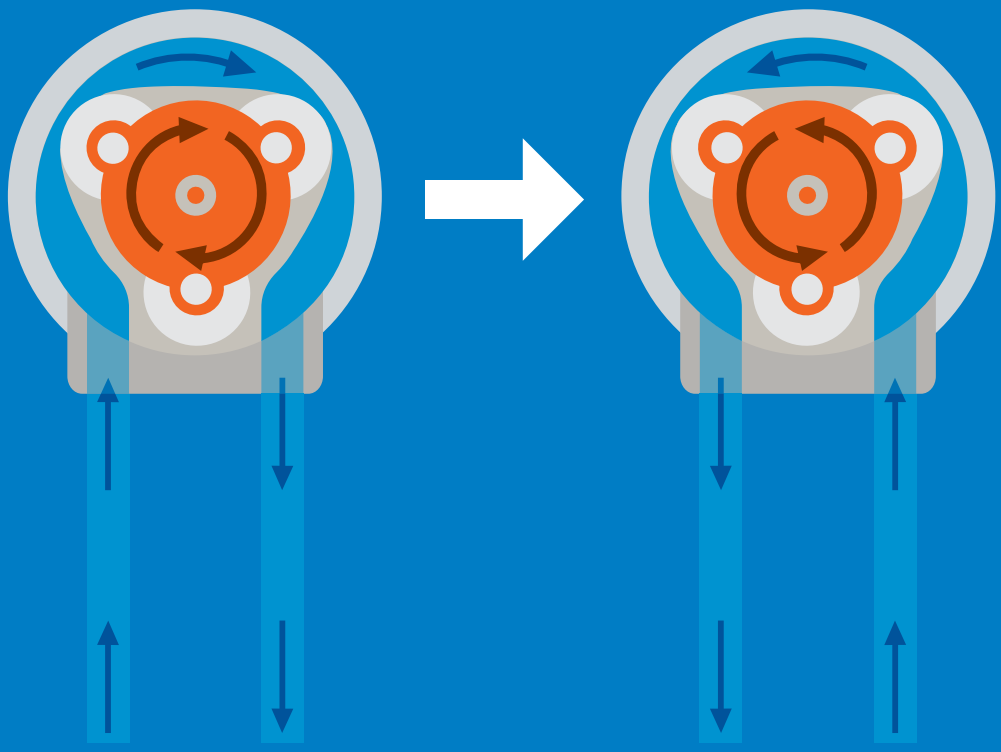
300ms processing delay

Command syntax

Invert direction will be retained if power is cut

Invert	changes dispensing direction of pump

Example	Response
Invert	Wait 300ms — 1 (Dec) — 0 (Null)
Invert,?	Wait 300ms — 1 (Dec) — ?Invert,1 (ASCII inverted) — 0 (Null) **or** Wait 300ms — 1 (Dec) — ?Invert,0 (ASCII uninverted) — 0 (Null)



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Total volume dispensed

Command syntax

300ms processing delay

TV,?	shows total volume dispensed
ATV,?	absolute value of the total volume dispensed
Clear	clears the total dispensed volume

Example	Response
TV,?	Wait 300ms — 1 Dec — ?TV,623.00 ASCII — 0 Null
ATV,?	Wait 300ms — 1 Dec — ?ATV,434.50 ASCII — 0 Null
clear	Wait 300ms — 1 Dec — 0 Null — total now 0.00

This data will be lost if the power is cut.

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Calibration

Command syntax

300ms processing delay

Calibrate to the actual volume dispensed.

Cal,v	v = corrected volume
Cal,clear	delete calibration data
Cal,?	device calibrated?

Example	Response
Cal,24.01	Wait 300ms → 1 (Dec) 0 (Null)
Cal,clear	Wait 300ms → 1 (Dec) 0 (Null)
Cal,?	Wait 300ms → 1 (Dec) ?Cal,1 (ASCII, fixed volume) 0 (Null) **or** Wait 300ms → 1 (Dec) ?Cal,2 (ASCII, volume/time) 0 (Null) Wait 300ms → 1 (Dec) ?Cal,3 (ASCII, both) 0 (Null) **or** Wait 300ms → 1 (Dec) ?Cal,0 (ASCII, uncalibrated) 0 (Null)

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Enable/disable parameters from output string

Command syntax

300ms processing delay

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

Example	Response
O,V,1	Wait 300ms — 1 Dec — 0 Null — enable volume being pumped
O,TV,0	Wait 300ms — 1 Dec — 0 Null — disable total volume pumped
O,ATV,1	Wait 300ms — 1 Dec — 0 Null — enable absolute volume pumped
O,?	Wait 300ms — 1 Dec — ?,O,V,TV,ATV ASCII — 0 Null — if all three are enabled

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r 0.1

Device information

Command syntax

300ms processing delay

i device information

Example

i

Response

1 Dec

?i,PMP, 1.1 ASCII

0 Null

Response breakdown

?i, PMP, 1.1

PMP: Device

1.1: Firmware

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I²C address change

Command syntax

300ms processing delay

I2C,n sets I²C address and reboots into I²C mode

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

Warning!

Changing the I²C address will prevent communication between the circuit and the CPU until the CPU is updated with the new I²C address.

n = any number 1 – 127

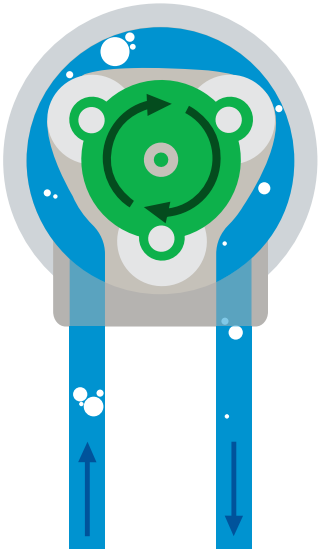
Default I²C address are:
56 (0x38), 57 (0x39), 58 (0x3A)

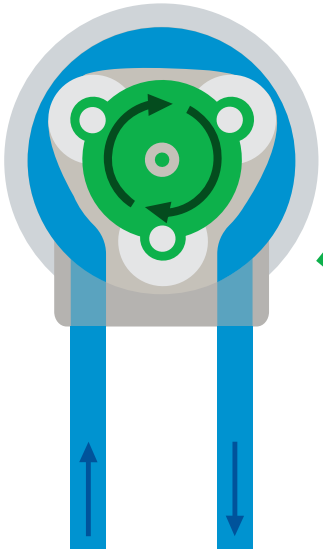
Calibration theory

Uncalibrated accuracy +/- 5%
Calibrated accuracy +/- 1%

Before calibration is attempted all the air bubbles should be removed from the tubing. This is done by running the pump while tapping the tubing. If air bubbles are not removed from the tubing they will slowly group together into larger air bubbles. Over time this will lead to accuracy issues.

Not ready for calibration X





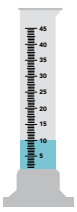
Ready for calibration ✓

Calibration types

Volume calibration
Volume over time calibration

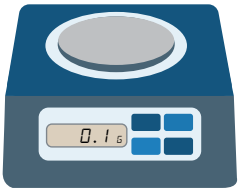
Calibration is optional. Both types of calibration are independent of each other and can be done at any time. Calibration can be done at any volume however; Atlas Scientific recommends using volumes above 5ml.

Equipment needed for calibration



An accurate graduated cylinder of at least 10ml.

Or



An accurate scale with a resolution of at least 0.1 grams

1 gram of water = 1ml
23.56 grams of water = 23.56ml

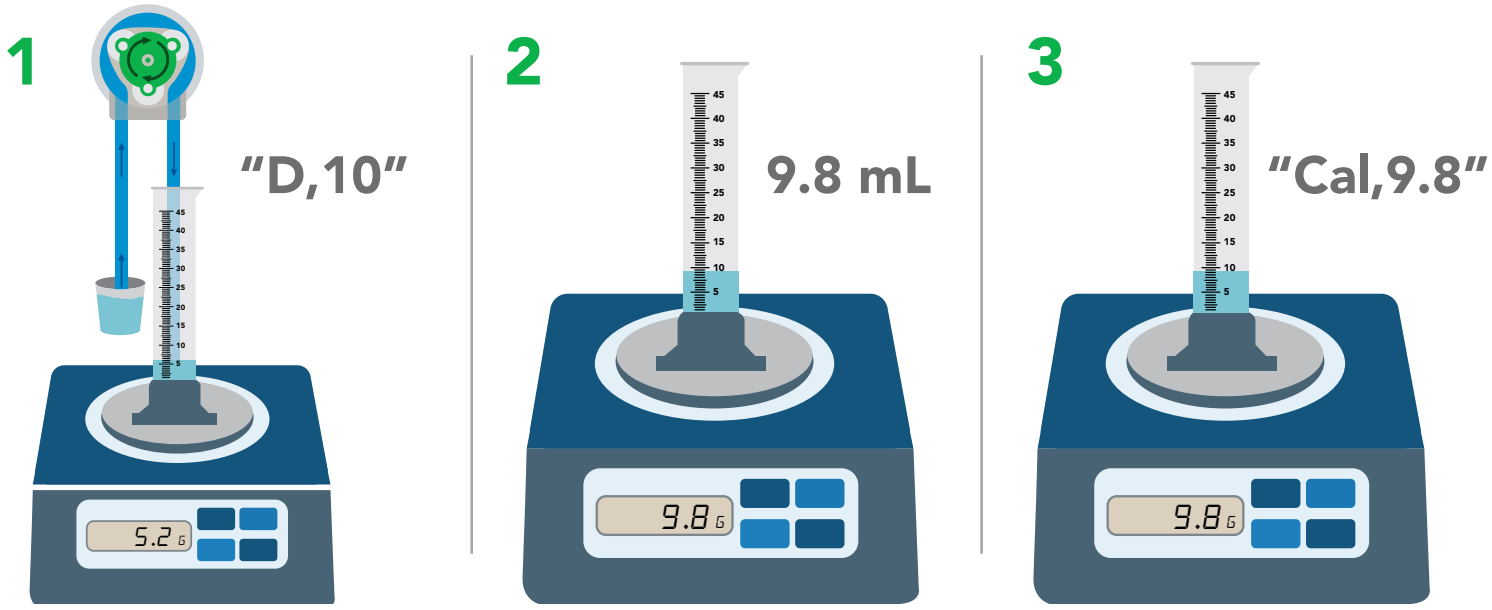
Calibration procedure

Calibration should be done with water and not a chemical

Make sure the tubing is full of water and has no bubbles before calibrating.

1. Instruct the pump to dispense a volume of water.
2. Measure the dispensed amount to determine how much water was actually dispensed.
3. Calibrate the pump by sending it the volume of liquid you have measured.

Example
Calibrate the pump by dispensing 10ml



1. Instruct the pump to dispense 10ml into a graduated cylinder or beaker on a scale.
2. Measure the amount of liquid that was actually dispensed.
3. Inform the pump how much liquid was actually dispensed.
4. Calibration is now complete.

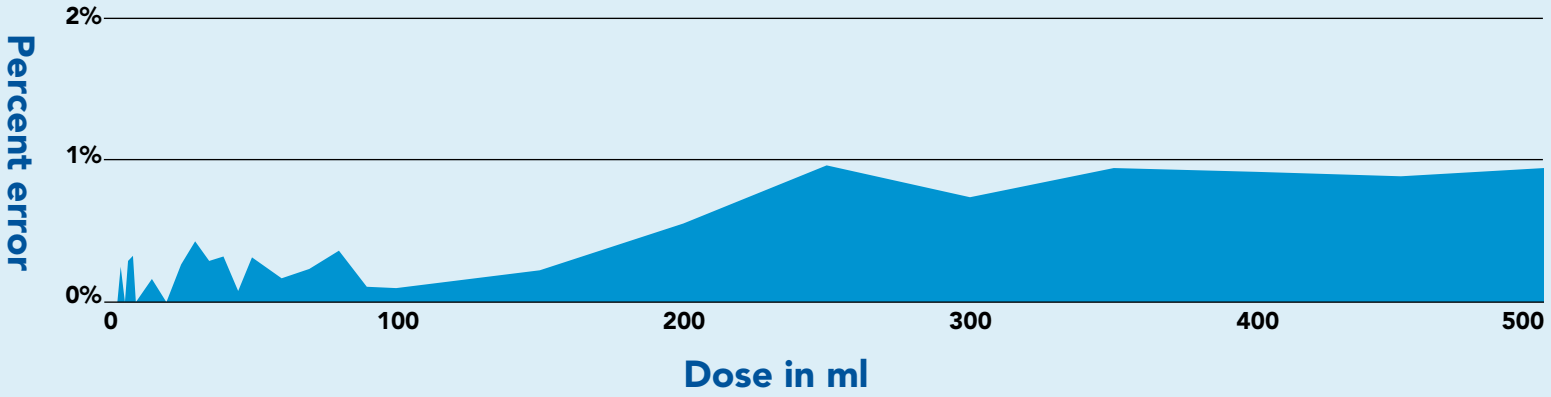
Once the pump has been calibrated, it will accurately dispense any volume of liquid. Use the same procedure to perform a volume over time calibration.

Accuracy

Uncalibrated accuracy +/- 5%
Calibrated accuracy +/- 1%

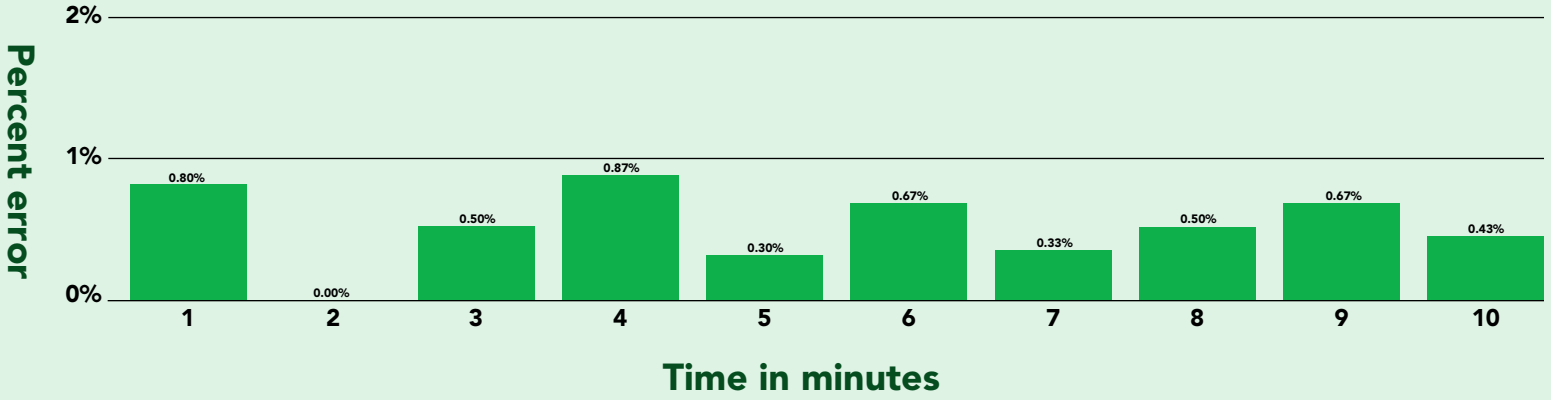
Volume dispensing mode

calibrated at 10ml



Dose over time mode

calibrated at 10ml over 90 seconds



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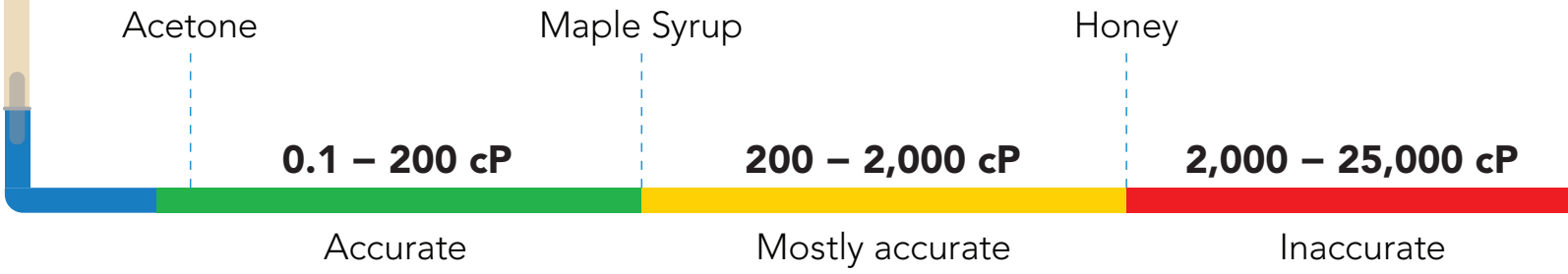
Viscosity

The EZO-PMP™ is capable of pumping liquids within a viscosity range of **0.1 – 2,000 cP**.

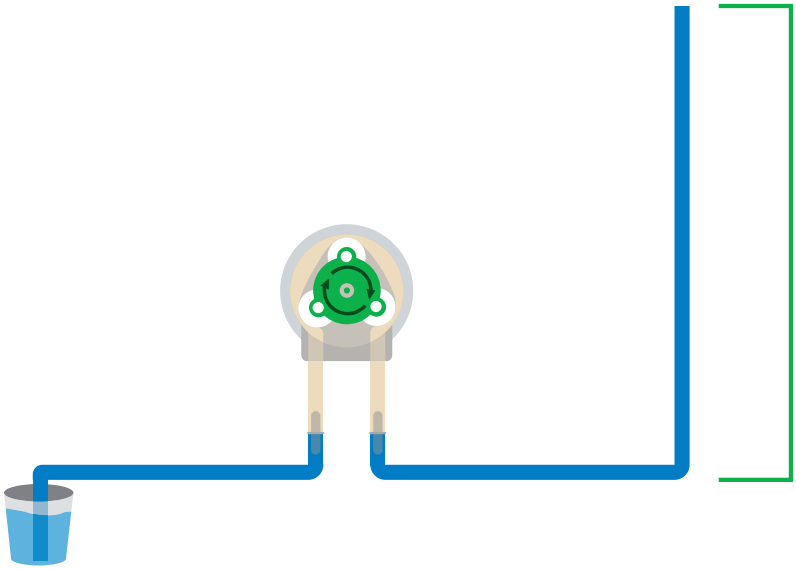
0.6	=	Acetone
1	=	Water
10	=	Kerosene
100	=	Corn Syrup
200	=	Maple Syrup
2,000	=	Honey
10,000	=	Hershey Chocolate Syrup

Dispense accuracy



Pump head

Pump head refers to the maximum vertical height a pump can dispense.
The EZO-PMP™ has a pump head of 8.1 meters *(26.5')*.



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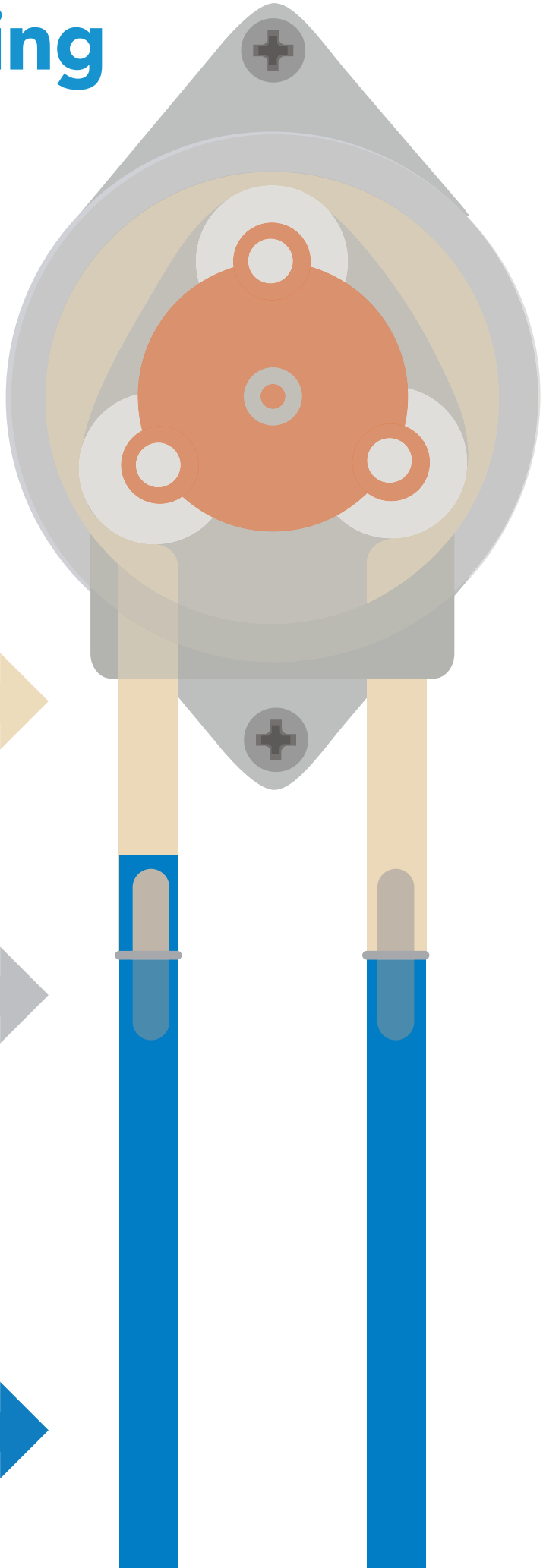
EZO-PMP™ tubing



Tan tubing
Saint-Gobain™ PharMed™ BPT tubing
Length: 15.24cm
Outer diameter: 5mm
Inner diameter: 3mm

This tubing is highly chemically resistant and has 30X more resistant to mechanical wear than silicone tubing.

Food safe ✓

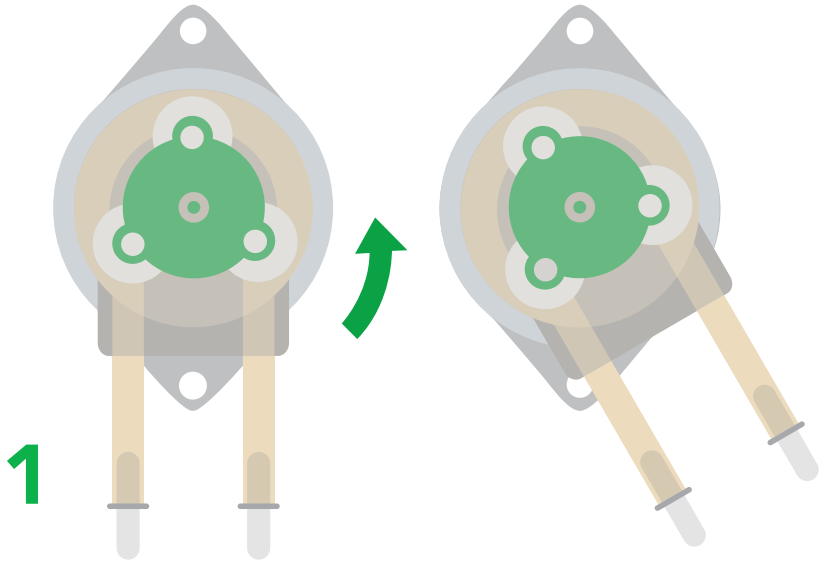
Inline tubing connectors
HDPE
Length: 2.54cm
Outer diameter: 8mm
Inner diameter: 2.8mm

Food safe ✓

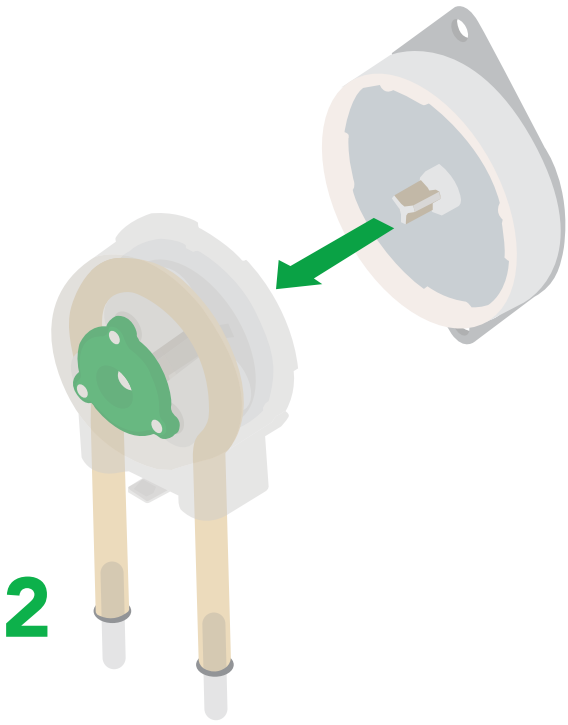
Blue tubing
Silicone
Length: 2x 30.48cm
Outer diameter: 5mm
Inner diameter: 3mm
Bend radius: 15mm
Temperature -67°C to 200°C
Max pressure: 69 kPa (10 PSI)

Food safe ✓

Removing cassette



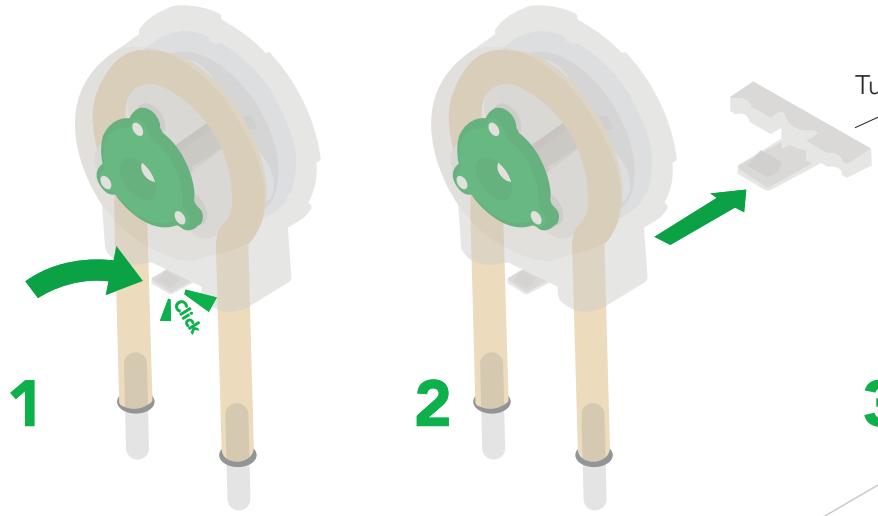
Turn cassette counterclockwise until it stops.



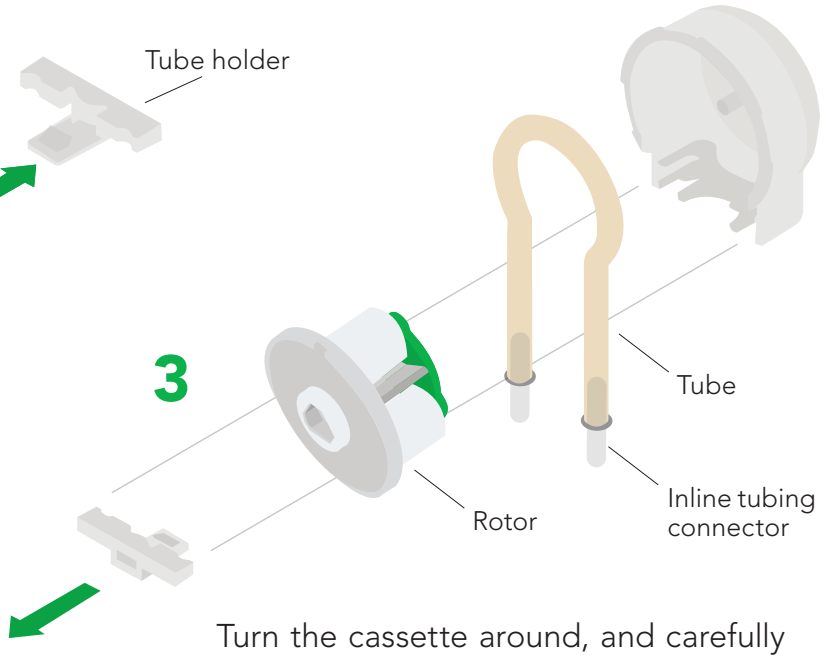
Pull cassette off the motor.

Removing tube assembly

The inner workings of the cassette are fragile and must be dismantled by hand. Using tools can damage or break the cassette.



Gently push down the tube holder until it clicks, then remove.



Turn the cassette around, and carefully remove rotor and pump tube.

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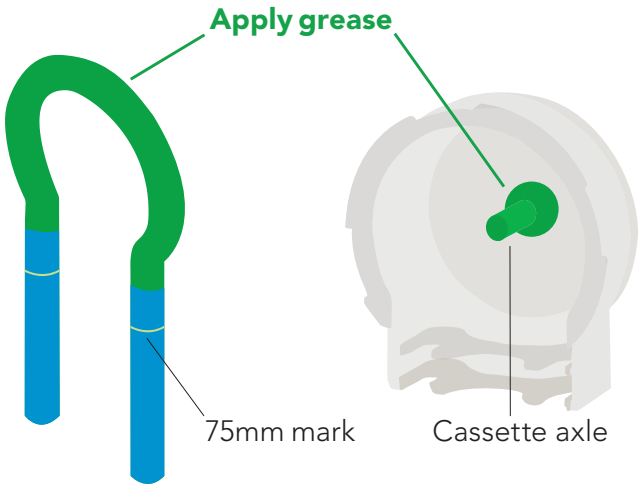
Installing new tube assembly

1

Measure 75mm of pump tubing, and mark both ends with a soft-tip pen or marker.

2

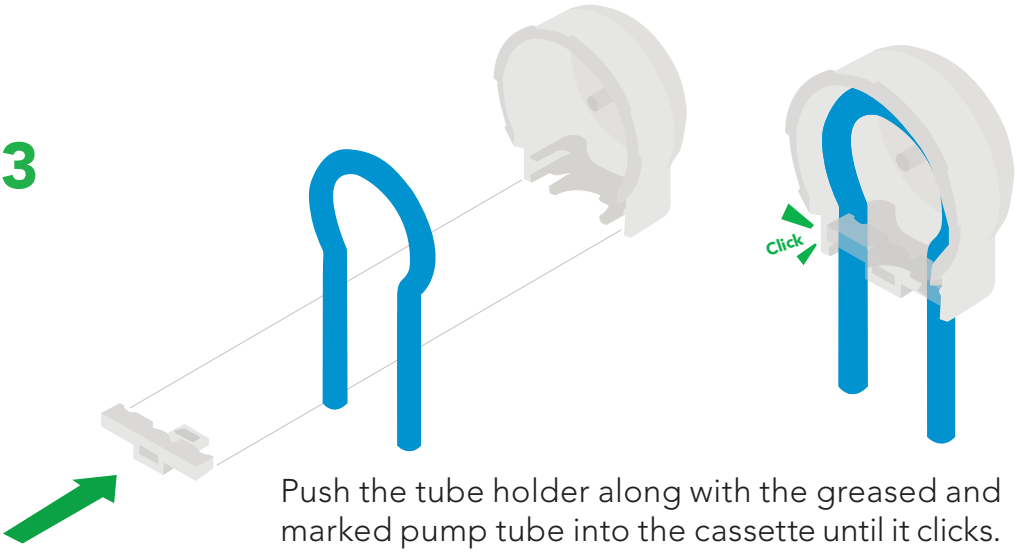


Apply silicone lubricating grease to the marked areas on both the tubing and cassette axle.

Do not operate this device without lubrication!

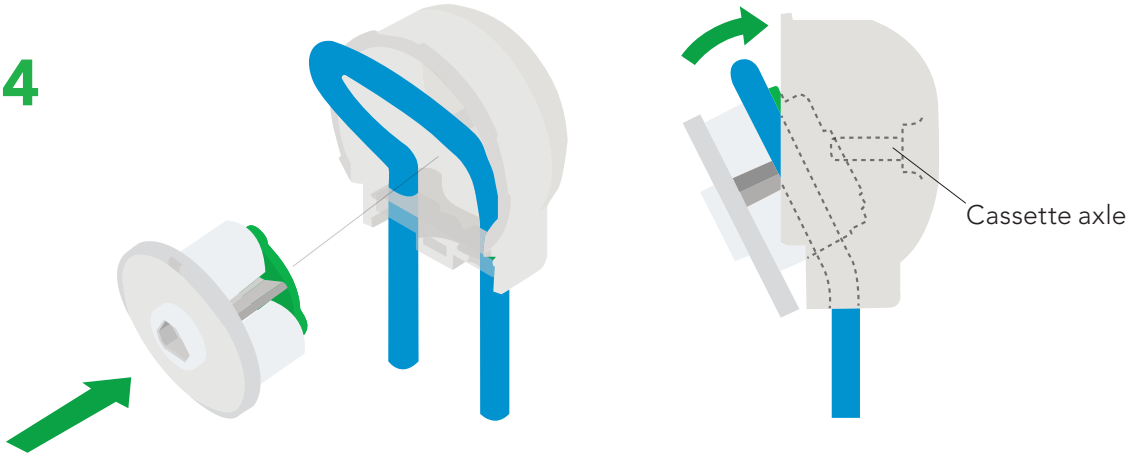
*Atlas Scientific recommends using **Super Lube** silicone lubricating grease.*

3

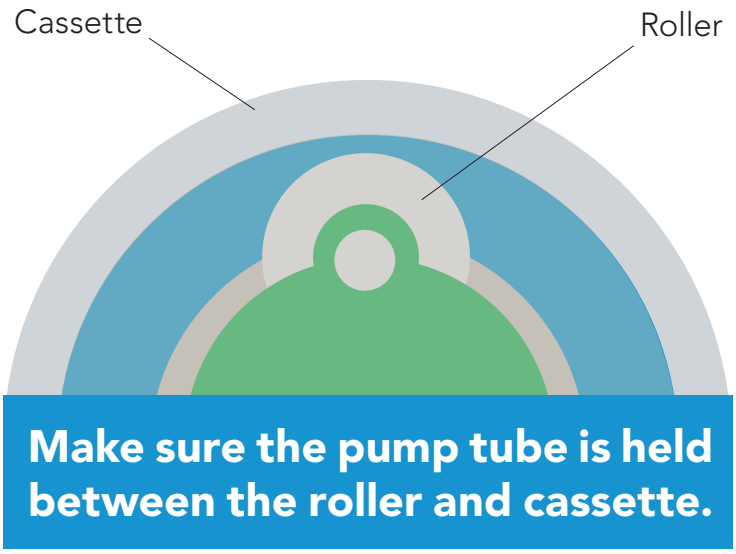


Push the tube holder along with the greased and marked pump tube into the cassette until it clicks.

4

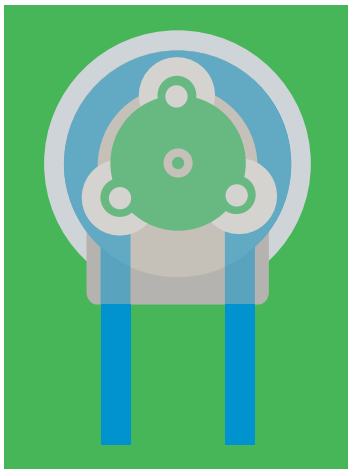


Gently pull out the pump tube, and insert the rotor into the pump tube. Align pump tube and rotor with the cassette axle.

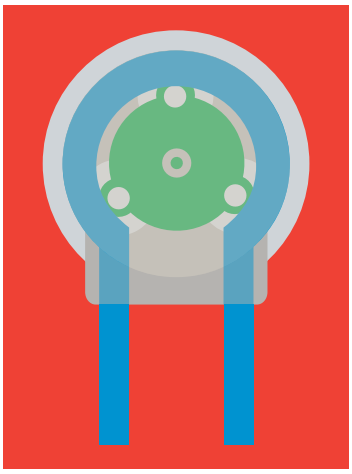


Make sure the pump tube is held between the roller and cassette.

✓ Correct



X Incorrect



Once the tubing has been replaced, run the pump for 3–5 minutes to break in the new tubing. **Remember, this pump can be run dry and does not need to pump liquid for the 3–5 minute break in period.**

Warranty

Atlas Scientific™ Warranties the TRI-PMP-BX™ to be free of defect during the debugging phase of device implementation, or 30 days after receiving the TRI-PMP-BX™(which ever comes first).

The debugging phase

The debugging phase as defined by Atlas Scientific™ is the time period when the TRI-PMP-BX™ is inserted into a bread board, or shield. If the TRI-PMP-BX™ is being debugged on a bread board, the bread board must be devoid of other components. If the TRI-PMP-BX™ is being connected to a microcontroller, the microcontroller must be running code that has been designed to drive the TRI-PMP-BX™ exclusively and output the TRI-PMP-BX™ data as a serial string.

It is important for the embedded systems engineer to keep in mind that the following activities will void the TRI-PMP-BX™ warranty:

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

