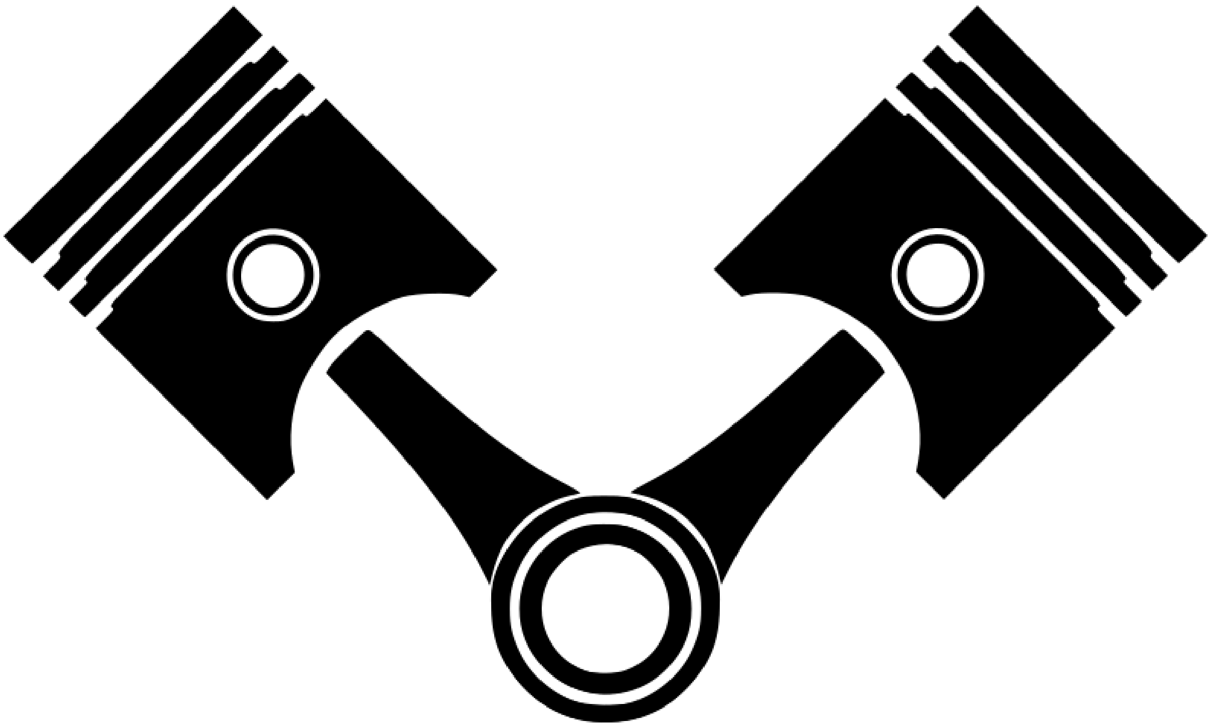
MotoZero

“Mechanics Manual”



Motor Controller Board

User Guide and Information

Product Page: **ThePiHut.com/motozero**

Guide Contents

Introduction

Congratulations on your purchase of the MotoZero motor driver board for the Raspberry Pi!

The MotoZero is designed to be a simple and easy way to get lots of motors moving with the Raspberry Pi, allowing anyone to make really cool robots!

The board allows you to control up to 4 motors in both directions, in the easiest way possible on a Raspberry Pi. It uses simple GPIO on/off commands to make it the perfect gentle introduction to robotics with the Pi.

Wiring and powering the board is simple too. Simply power your Pi in the usual way with a 5V power bank or battery box, then add power for the motors to the MotoZero and connect 4 motors.

This “Mechanics Manual” will take you through each step to get your robot moving from initial assembly and soldering, motor selection, wiring, power, code and frequently asked questions.

Design Features

- We’ve tried to make the MotoZero as visually appealing as possible, inspired by old-school motoring and brands
- We’ve sourced great quality terminal blocks with large solid flat-head screw fixings that won’t round-off like cheaper, smaller alternatives
- We’ve broken the motor terminals out to each end of the board where the motors are more likely to be
- We’ve included 2 motor drivers to allow the use of 4 motors
- We’ve chosen motor drivers that allow the use of super simple GPIO programming to make your robot move, and include built in protection from motor voltage spikes (“flyback”)
- The motor drivers can be removed from their sockets and replaced if accidentally damaged
- The board has been kept as symmetrical as possible to ensure your robot looks great
- We’ve used ENIG (gold) plating on the PCB to protect against oxidation and offer a good soldered contact.

Kit Contents

Like many Raspberry Pi add-on boards, the MotoZero is sold as a kit which requires soldering.

The following parts should be inside your kit bag:

1x MotoZero PCB

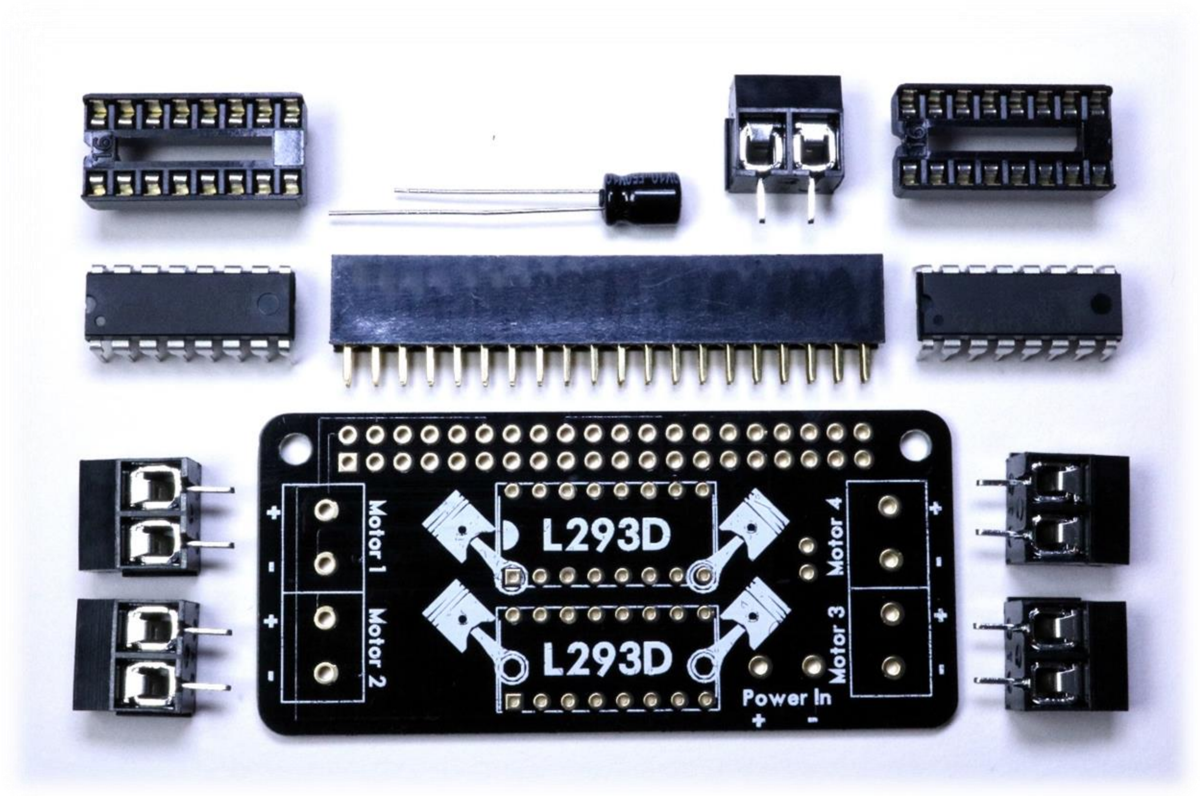
1x 40-pin GPIO header

2x 16-way IC Sockets

2x L293D Motor Driver ICs

5x Terminal Blocks

1x Capacitor



Assembly

Assembling the MotoZero involves soldering the provided components to the PCB.

Tools Required

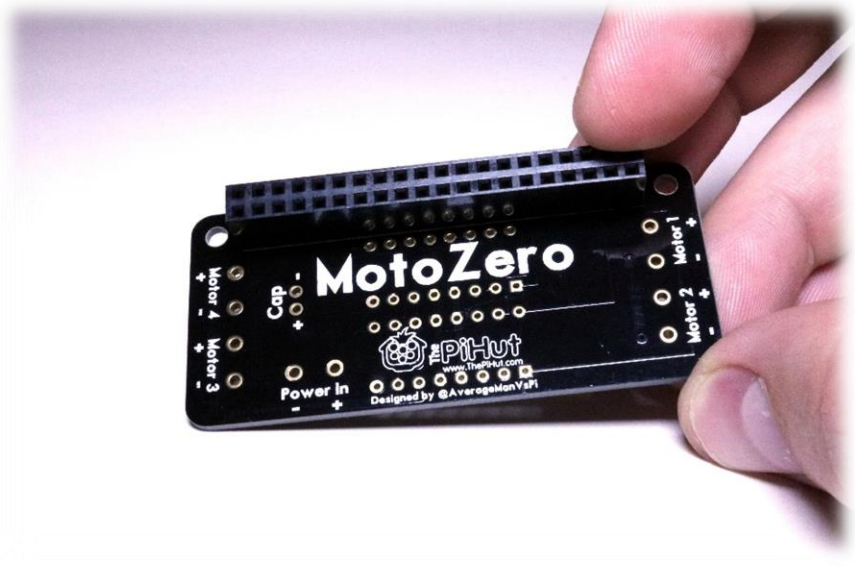
- Soldering Iron
- Solder
- Wire/Side cutters
- Wire Strippers
- Flat-head screwdriver (small)
- Protective eyewear

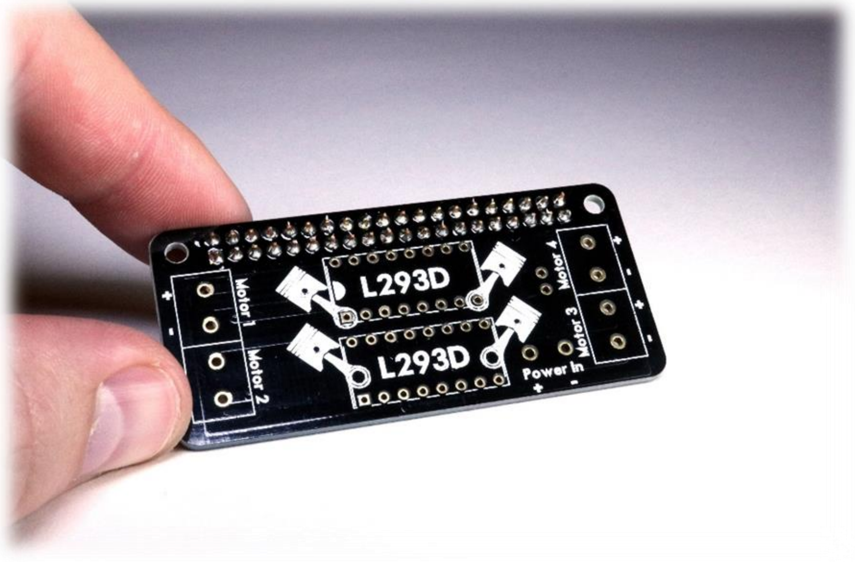
Before You Start

- Make sure you have all the parts required
- Read all steps through before starting, and take a good look at each image to confirm component positions before soldering.
- ALWAYS wear protective eyewear when soldering!

Assembly Steps

1. First solder the 40-pin GPIO header to the PCB. The plastic end of the header should be showing on the rear 'MOTOZERO' text side of the PCB:

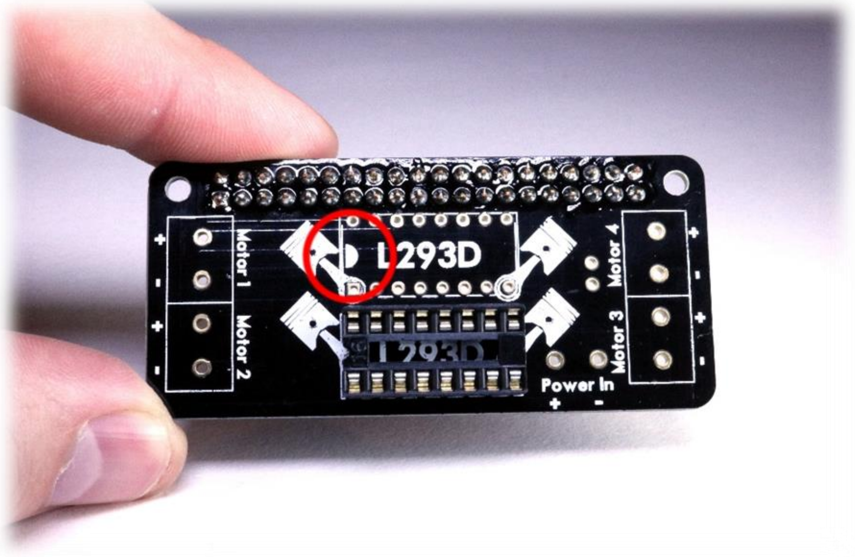


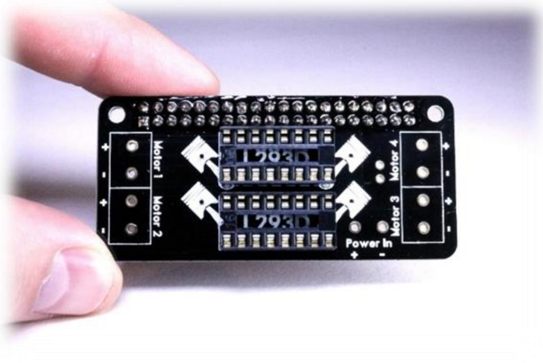


2. Next solder the two 16-way IC sockets to the PCB, making sure the notch is pointing to the left of the board.

   The plastic end of the sockets should be showing on the front of the board alongside the piston images.

   ***Note**: Soldering next to the 40-pin GPIO header can be tricky, however we assemble in this order as any accidental spoiling of the 40-pin GPIO header plastic will not be seen on the underside of the board.*

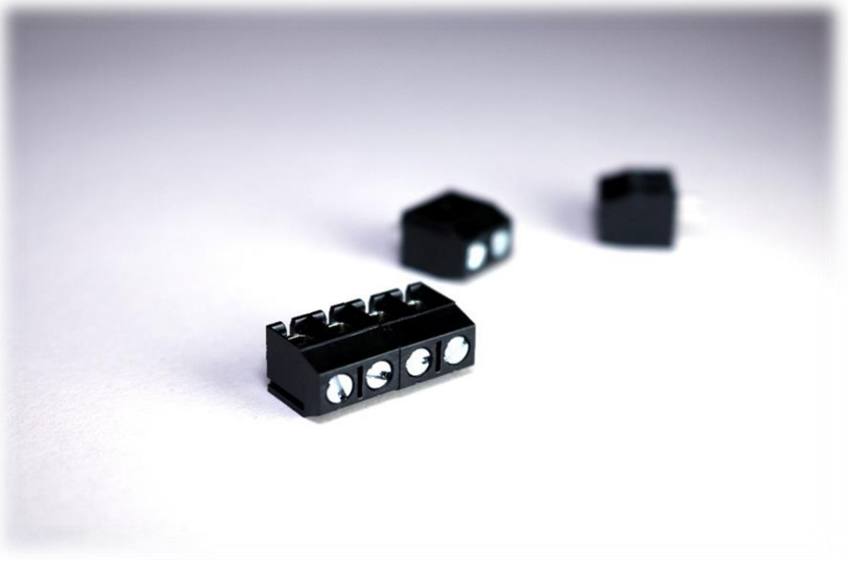


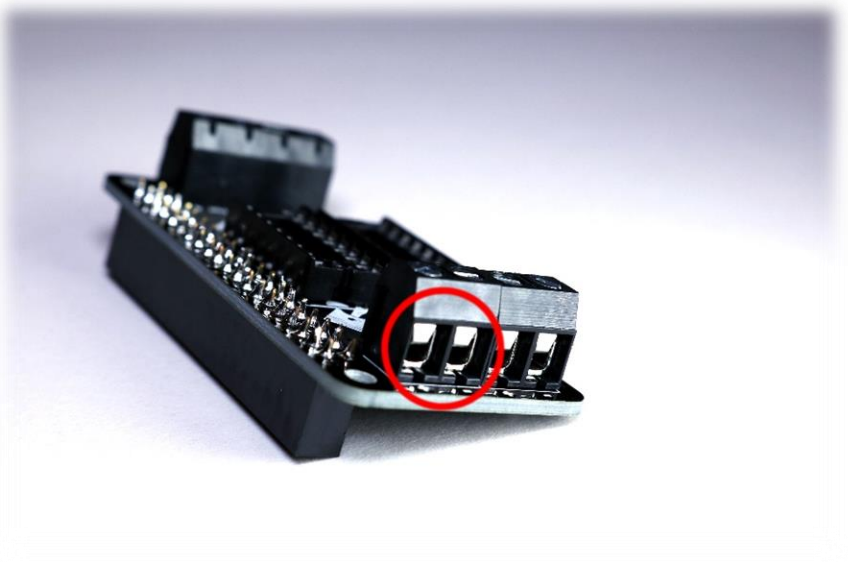


3. Next solder the 4 motor connection terminals. These are the two pairs of terminals at each end of the PCB, and should be fitted to the top of the board.

   Join the two pairs of terminals together by sliding the edge ridges together.

   <u>**Make sure the wire holes are facing outwards**</u>, and then solder in place.



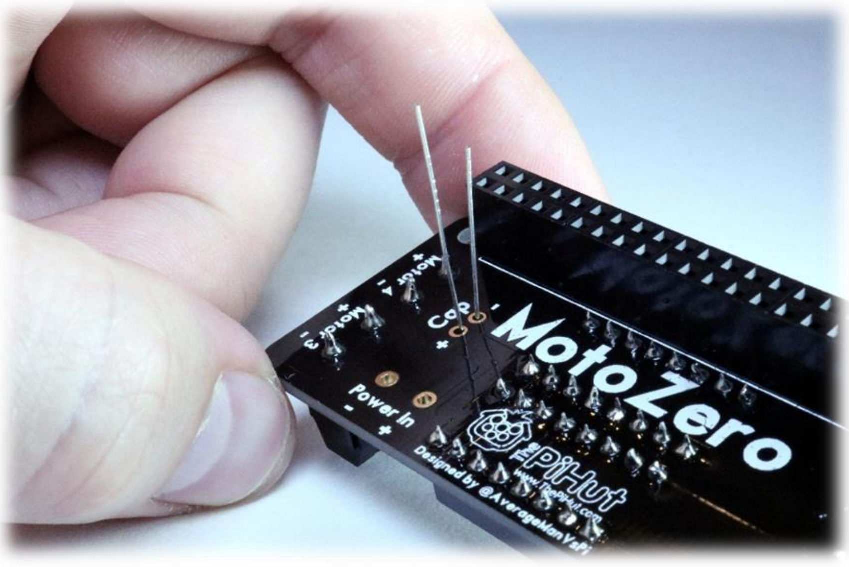


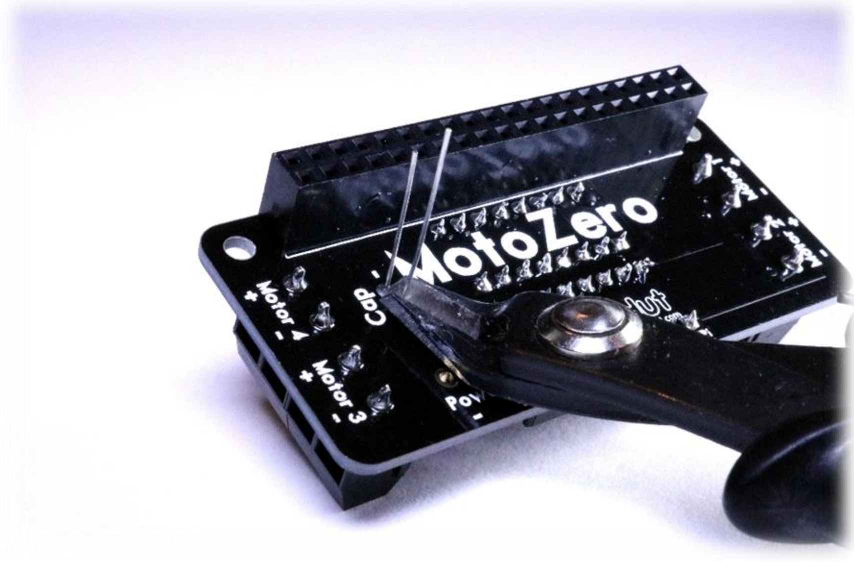
4. Next solder the capacitor to the right of the IC sockets, and snip off the remaining legs.

   IMPORTANT – the capacitor has a **set polarity**. The longer leg must be soldered to the '**+**' pad, and the shorter leg to the **'-'** pad.

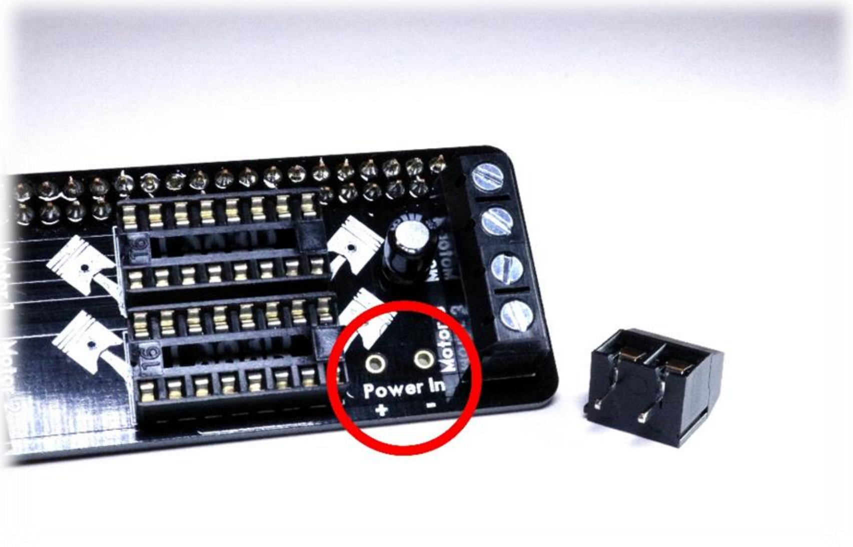
   The capacitor body should be showing to the front of the board.

   Tip*: You can also check polarity with the white stripe along the body of the capacitor. This is the '-' leg.*





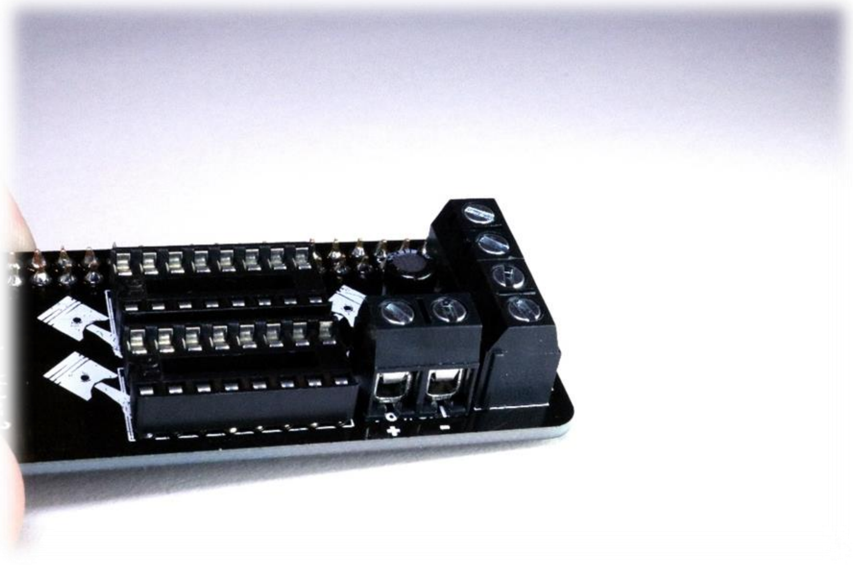
5. You now need to choose how you're going to connect motor power. The input power for the motors are the last remaining pads next to the motor 3 terminal.



A fifth terminal block is provided should you want to use it, or you can choose to directly solder wires from your chosen power supply.

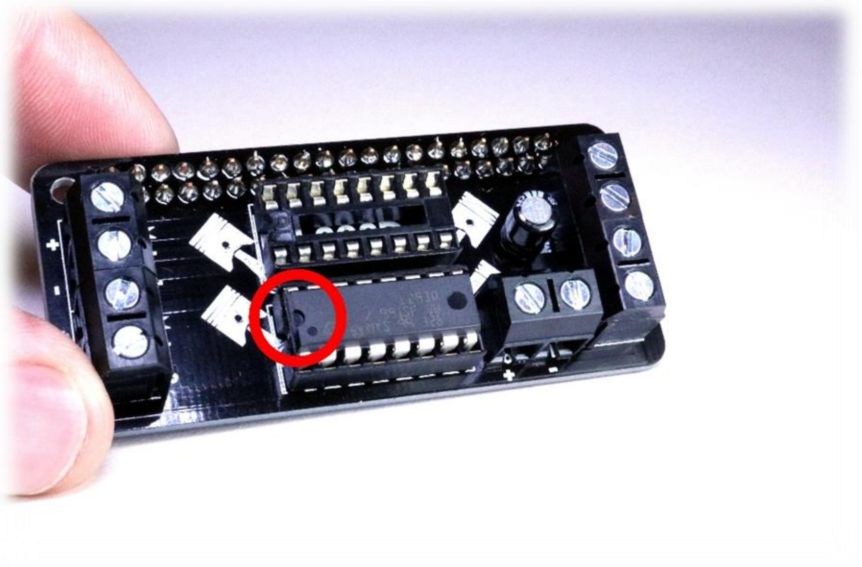
In this example we will use the terminal block, as this gives you greater flexibility to change power supplies in the future.

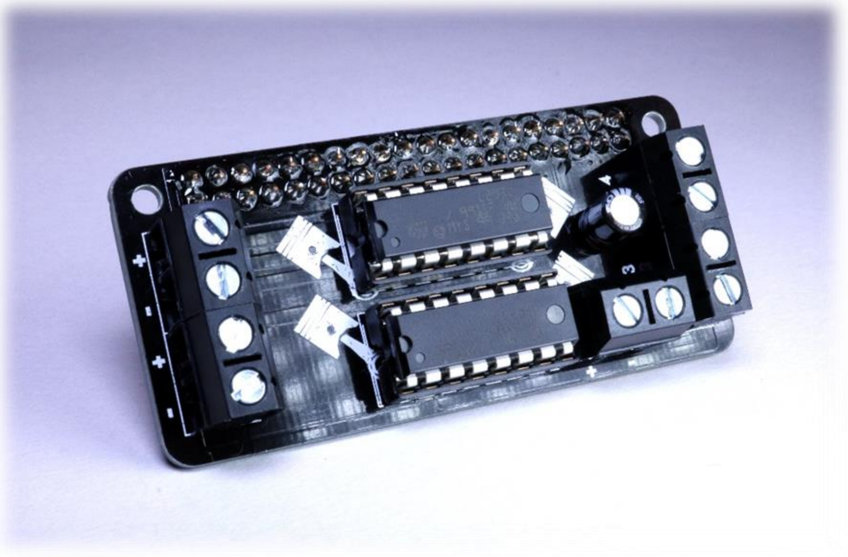
Fit the terminal through the pads so that the main body is on the front of the board (the same as the motor terminals) with the wire holes facing the edge of the PCB, then solder.



6. Lastly, fit the L293D motor driver ICs into the 2 IC sockets. You may need to bend the legs of each chip inwards to fit the socket.

   IMPORTANT – the notch on the ICs (looks like a 'D' at one end of the chip) should be positioned to the **left**, next to the Motor 1 and Motor 2 terminals.





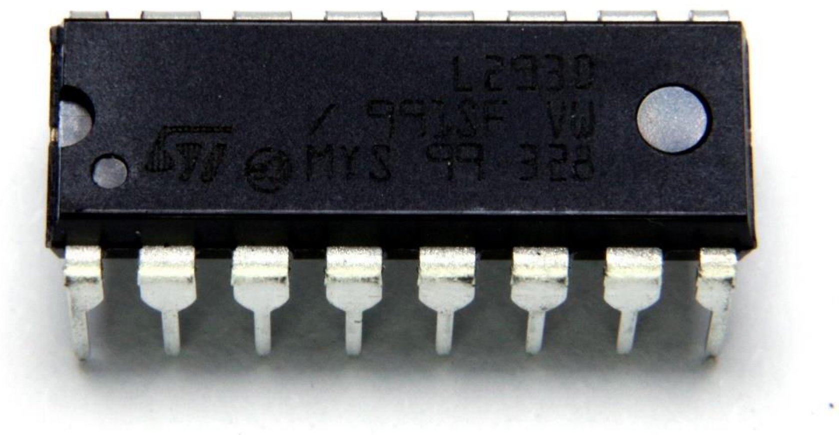
Assembly complete!

Motor Selection

You now have a completed MotoZero ready to control motors – but which motors can you use with this board?

This is determined by the L293D motor driver ICs used on the MotoZero.

Every motor driver IC has different limits to the motors they can drive. This is usually related to voltage used and the amount of current the IC can handle.



Why We Use The L293D

The L293D has been out a long time, however it's still a very popular choice due to its low cost, simplicity and internal protection. It's able to be controlled by basic GPIO commands (including GPIO Zero) which makes it a great choice for beginner boards like the MotoZero.

The L23D can handle a wide range of voltages, includes over-temperature protection and comes with integrated clamp/flyback diodes to protect from sudden voltage spikes ("flyback") from the motors.

The L293D DIP format, used with an IC socket, allows the user to easily replace the IC if they accidentally damage it.

L293D Headline Specifications

Let’s take a look at the key specifications for the L293D:

- 600mA **continuous** current per channel **(per motor)**
- 1.2A **peak** output current per channel **(per motor)**
- Supports voltages of 4.5V to 36V

Try to ignore that second 1.2A current figure when choosing motors – you want to avoid running the chips at peak!

A safe approach is to match your motor’s stall current to no more than the continuous current figure (600mA), allowing lots of breathing room for the odd current spike to peak if required (for example, if the motor stalls).

Example Motor Recommendation

With the specifications above in mind, let’s take a look a popular brand of motors available on the market to give you an idea of what to look for.

Micro Metal Gearmotors

There are lots of examples of these small 6V motors available online, ideal for making robots. One manufacturer offer these motors in 4 main power categories:

Category	**Stall Current**
High-Power Carbon Brushes	1600mA
High-Power	1600mA
Medium-Power	700mA
Low-Power	360mA

By looking at the stall currents of each of these categories, we can see that the low-power versions will be a good choice for the L293D, with a stall current of 360Ma.

The medium-power motors could also be selected, however as these run slightly over our target stall current at 700mA, so it would be wise to take necessary precautions to avoid stalling the motor. Temperature should also be monitored.

L293D Manufacturer Datasheet

The full L283D datasheet from the IC manufacturer can be found at: http://www.st.com/content/st_com/en/products/motor-drivers/brushed-dc-motor-drivers/l293d.html

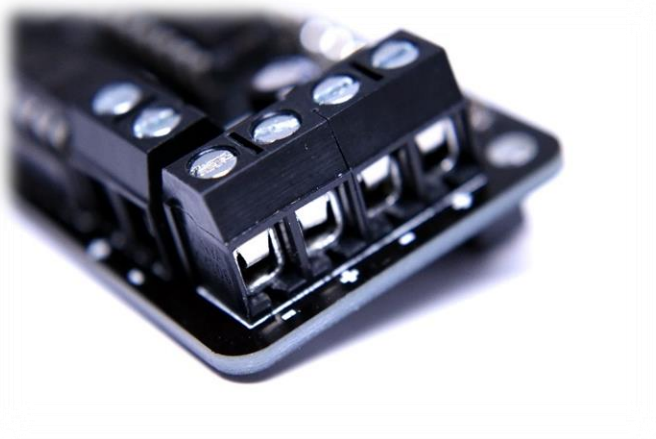
Wiring Up

With your board soldered and motors ready, it's time to connect everything to the MotoZero.

Connect Motors

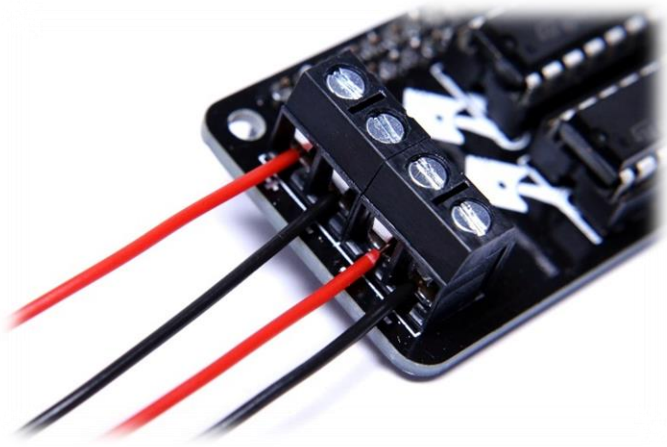
You can choose to wire 1, 2, 3 or 4 motors to the MotoZero at any one time. It doesn't make any difference how many you use, or which terminals you use.

Your motors connect to the 4 terminal blocks at each end of the MotoZero – each motor terminal has a pair of connections and are labelled '**Motor 1'**, '**Motor 2**', '**Motor 3**' and '**Motor 4**'.



Each motor terminal is labelled with '**+**' and '**-**' markings, however it doesn't matter which way round you wire the motors to each terminal.

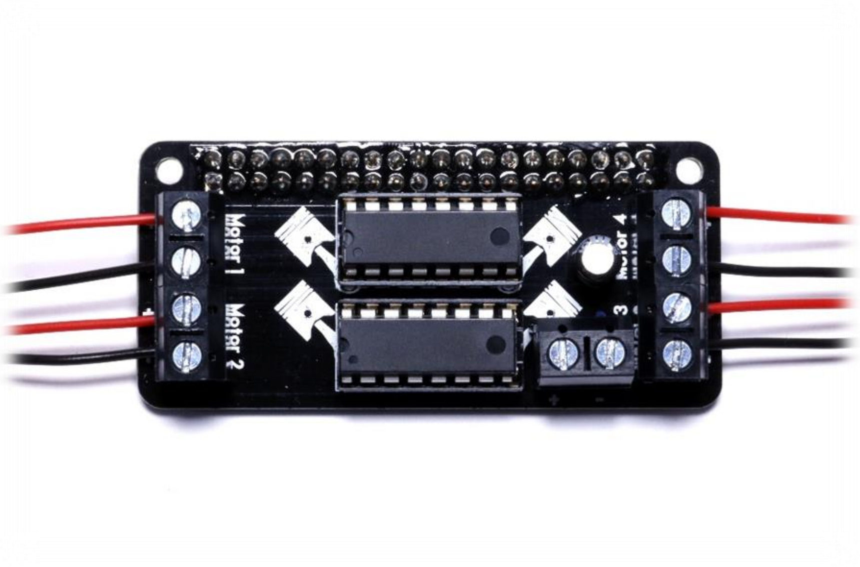
Insert the two wires from each motor in to the '**+**' and '**-**' of each terminal block.



Use your flat-head screwdriver to secure the wires – just finger tight will do.

The plastic body of the terminal block may twist slightly, this is normal and can be pushed back if needed.

If connecting 4 motors, it should look something like this:



Connect The Motor Power

***** WARNING *****

ENSURE YOUR MOTOR POWER SUPPLY IS WIRED WITH THE CORRECT POLARITY! ENSURE THE POSITIVE (USUALLY RED) WIRE IS CONNECTED TO THE '+' PAD/TERMINAL HOLE!

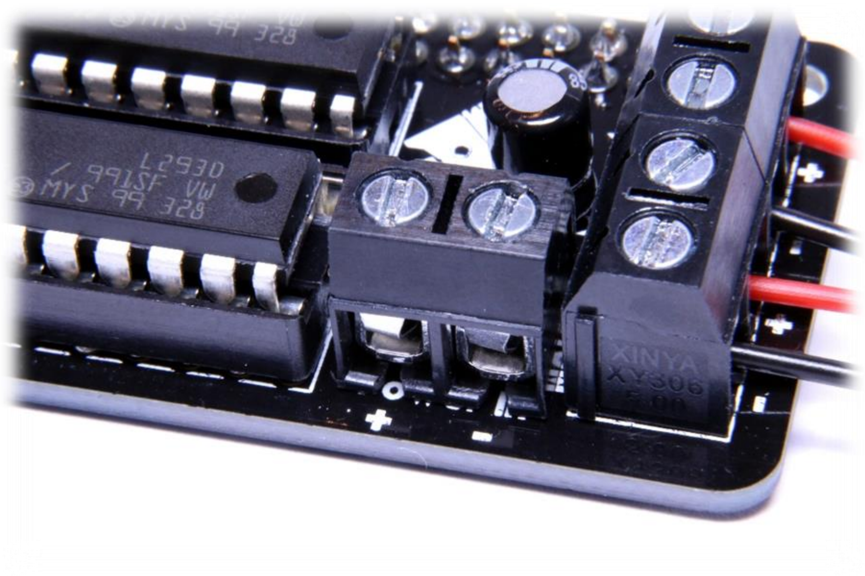
Let us stress that again…

MAKE SURE YOU CONNECT YOUR BATTERY THE RIGHT WAY ROUND!

The MotoZero is a simple and affordable motor controller add-on board, and therefore does not include any protection against incorrect battery polarity.

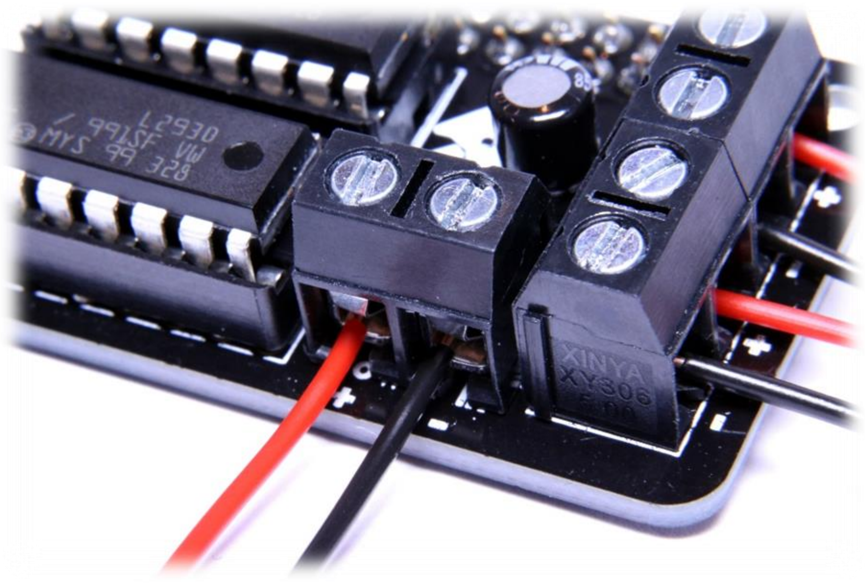
****

Motor power I connected to the MotoZero's 'Power In' section. We're using the supplied terminal block here:

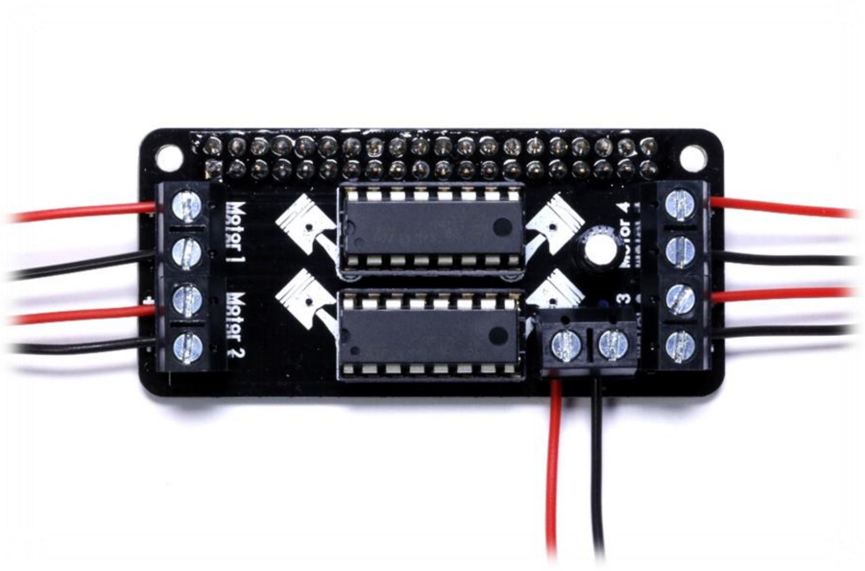


Turn your power supply off (or remove the batteries if it has no on/off switch).

Connect your battery wires to the MotoZero's 'power In' section, ensuring the positive wire is connected to the '**+**' terminal and the negative wire connected to the '**-**' terminal.



Your MotoZero should now look something like this:



Connect The Raspberry Pi Power Source

Your Raspberry Pi should be powered via the usual micro-USB port using either a wall plugged power supply (for testing at a workstation) or power bank/battery pack.

Turn the chosen power supply off and connect the cable to the Raspberry Pi.

Code and Control

Introduction

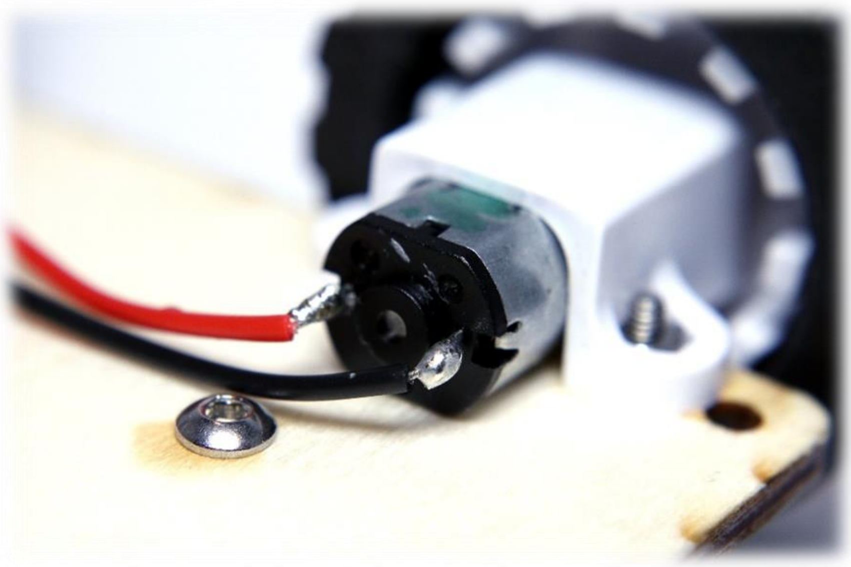
Controlling motors with the MotoZero is very easy thanks to simple GPIO 'on/off' control. If you've controlled an LED using the GPIO, you'll feel right at home with the MotoZero.

All examples in this document use the GPIO.BCM mode and the standard Raspbian Jessie image.

Turn on your Pi and motor power sources, then try some of the examples.

GPIO Control Explained

Each motor has 3 GPIO pins associated with it. One pin *enables* the motor (think of this as a "master on/off switch") and the other two pins control the power to the positive and negative wires of the motor.



To make the motor turn, we need to enable the motor (our "master switch") and then send power to one of the motor wires, and GND the other one. This will make the motor turn in one direction.

To make the motor turn in the other direction, we simply switch the code around so that we send power and ground to the opposite motor wires.

Let's show you an example, and then list the GPIOs used in the MotoZero.

One Motor One Direction Example

Here’s an example of making Motor 1 turn in one direction for 3 seconds. This example uses the exact same GPIO pins that the MotoZero uses:

- Motor 1 is enabled by GPIO 5 (our “Master Switch” or “Enable”)
- The Motor 1 ‘+’ motor terminal is linked to GPIO 27
- The Motor 1 ‘-‘ motor terminal is linked to GPIO 24

Our setup code imports the ‘GPIO’ and ‘sleep’ modules. It then sets the GPIO mode to BCM.

We then tell the code which GPIO pins we want to use for what (A and B are our motor terminal wires. E is for ‘Enable’). Lastly we set up each GPIO pin to be an output:

```
# Import GPIO
import RPi.GPIO as GPIO

# Import sleep
from time import sleep

# Set the GPIO mode
GPIO.setmode(GPIO.BCM)

# Define GPIO pins
Motor1A = 27
Motor1B = 24
Motor1Enable = 5

 # Set up defined GPIO pins
GPIO.setup(Motor1A,GPIO.OUT)
GPIO.setup(Motor1B,GPIO.OUT)
GPIO.setup(Motor1Enable,GPIO.OUT)
```

We then tell the code to turn certain pins on or off to make the motor move:

```
# Turn the motor on
GPIO.output(Motor1A,GPIO.HIGH) # GPIO high to send power to the + terminal
GPIO.output(Motor1B,GPIO.LOW)  # GPIO low to ground the - terminal
GPIO.output(Motor1Enable,GPIO.HIGH) # GPIO high to enable this motor

# Leave the motor on for 3 seconds
sleep(3)

# Stop the motor by 'turning off' the enable GPIO pin
GPIO.output(Motor1Enable,GPIO.LOW)

# Always end this script by cleaning the GPIO
GPIO.cleanup()
```

This will make the motor turn in one direction for 3 seconds then stop.

One Motor Two Directions Example

Here's an example of making Motor 1 turn in one direction for 3 seconds, then turn in the other direction for another 3 seconds.

We're using the exact same set up as the last example but will add a little more code to make the motor turn in the other direction.

The setup lines are the same:

```python
# Import GPIO
import RPi.GPIO as GPIO

# Import sleep
from time import sleep

# Set the GPIO mode
GPIO.setmode(GPIO.BCM)

# Define GPIO pins
Motor1A = 27
Motor1B = 24
Motor1Enable = 5

# Set up defined GPIO pins
GPIO.setup(Motor1A,GPIO.OUT)
GPIO.setup(Motor1B,GPIO.OUT)
GPIO.setup(Motor1Enable,GPIO.OUT)
```

However, we now add some lines after the 'sleep' to the turn the motor in the opposite direction for 3 seconds as well. To do this, we simply copy the same lines but swap the Motor1A and Motor1B GPIO directions:

```python
# Turn the motor on one way
GPIO.output(Motor1A,GPIO.HIGH) # GPIO high to send power to the + terminal
GPIO.output(Motor1B,GPIO.LOW)  # GPIO low to ground the - terminal
GPIO.output(Motor1Enable,GPIO.HIGH) # GPIO high to enable this motor

# Leave the motor on for 3 seconds
sleep(3)

# Turn the motor the other way
GPIO.output(Motor1A,GPIO.LOW)
GPIO.output(Motor1B,GPIO.HIGH)
GPIO.output(Motor1Enable,GPIO.HIGH)

# Leave the motor on for 3 seconds
sleep(3)

# Stop the motors by 'turning off' the enable GPIO pins
GPIO.output(Motor1Enable,GPIO.LOW)

# Always end this script by cleaning the GPIO
GPIO.cleanup()
```

Two Motors One Direction Example

Using more motors on the MotoZero is super simple and just a case of connecting the motors and a bit of '*copy and paste*'.

Let's go through the differences. You'll need to define the pins for the second motor– notice the Motor 2 block added below (we've skipped past the import section this time):

```
# Define GPIO pins
Motor1A = 24
Motor1B = 27
Motor1Enable = 5

Motor2A = 6
Motor2B = 22
Motor2Enable = 17
```

Then you'll need to set up the pins as outputs in the same way. We've added a black for motor 2 again:

```
# Set up defined GPIO pins
GPIO.setup(Motor1A,GPIO.OUT)
GPIO.setup(Motor1B,GPIO.OUT)
GPIO.setup(Motor1Enable,GPIO.OUT)

GPIO.setup(Motor2A,GPIO.OUT)
GPIO.setup(Motor2B,GPIO.OUT)
GPIO.setup(Motor2Enable,GPIO.OUT)
```

Same again when we turn on the motors, we just duplicate for motor 2:

```
# Turn the motor on one way
GPIO.output(Motor1A,GPIO.HIGH) # GPIO high to send power to the + terminal
GPIO.output(Motor1B,GPIO.LOW)  # GPIO low to ground the - terminal
GPIO.output(Motor1Enable,GPIO.HIGH) # GPIO high to enable this motor

GPIO.output(Motor2A,GPIO.HIGH)
GPIO.output(Motor2B,GPIO.LOW)
GPIO.output(Motor2Enable,GPIO.HIGH)
```

When we disable the motors, we add a line to turn off motor 2 as well:

```
# Leave the motors on for 3 seconds
sleep(3)

# Stop the motors by 'turning off' the enable GPIO pin
GPIO.output(Motor1Enable,GPIO.LOW)
GPIO.output(Motor2Enable,GPIO.LOW)

# Always end this script by cleaning the GPIO
GPIO.cleanup()
```

GPIO Zero Control

The ‘Motor’ and ‘OutputDevice’ functions within GPIO Zero provide an easy way to get your robot moving with the MotoZero, and also offers speed control!

Add this code to the start of your Python file to set up the motor pins:

```python
from gpiozero import Motor, OutputDevice
from time import sleep

motor1 = Motor(24, 27)
motor1_enable = OutputDevice(5, initial_value=1)
motor2 = Motor(6, 22)
motor2_enable = OutputDevice(17, initial_value=1)
motor3 = Motor(23, 16)
motor3_enable = OutputDevice(12, initial_value=1)
motor4 = Motor(13, 18)
motor4_enable = OutputDevice(25, initial_value=1)
```

Then use any of the example commands below to make your robot move.

***Tip**: Remember to change the code to match the number of your motor, for example motor**1**.forward() or motor**2**.reverse().*

```python
motor.forward()  # full speed forwards
motor.forward(0.5)  # half speed forwards

motor.backward()  # full speed backwards
motor.backward(0.5)  # half speed backwards

motor.stop()  # stop the motor

motor.value = 0.5  # half speed forwards
motor.value = -0.5  # half speed backwards
motor.value = 0  # stop

motor.reverse()  # reverse direction at same speed, e.g...

motor.forward(0.5)  # going forward at half speed
motor.reverse()  # now going backwards at half speed
```

It really is that simple!

GPIO Pins Used

The MotoZero PCB has GPIO pins pre-allocated for the twin L293D motor drivers.

You'll need to know which pins are assigned to which motor in order to be able to drive them properly (as demonstrated in the code examples).

***Tip**: No SPI, I2C or UART pins have been used, allowing you to use these connections alongside the MotoZero if desired.*

Motor 1

Enable Pin =	**5**
Positive (+) Terminal =	**24**
Negative (-) Terminal =	**27**

Motor 2

Enable Pin =	**17**
Positive (+) Terminal =	**6**
Negative (-) Terminal =	**22**

Motor 3

Enable Pin =	**12**
Positive (+) Terminal =	**23**
Negative (-) Terminal =	**16**

Motor 4

Enable Pin =	**25**
Positive (+) Terminal =	**13**
Negative (-) Terminal =	**18**

FAQs

Q. Can I use this with any Raspberry Pi?

A. The MotoZero can only be used with 40-pin Raspberry Pis (B+, A+, Pi2, Pi Zero and the Pi3).

Q. Is this a HAT?

A. No. HATs have a set specification including EEPROM chips and other standards. We didn't feel this product needed HAT features, so we prefer to call it an "add-on board".

Q. What motors can I use with this board?

A. Check the 'Motor Selection' section of this document. In general, aim for motors from 4.5V to 36V with a stall current not much greater than 600mA.

Q. What voltage battery should I use to power the motors?

A. Your battery voltage should match the voltage rating of your motors, and be within 4.5V to 36V.

Q. How big should my motor battery be?

A. Anything from AAA size battery packs should give reasonable running time. AA battery packs are most commonly used – however the voltage rating of your motors will determine the type and number of batteries to use.

Q. My motor isn't turning?

A. This could be due to a number of reasons. Is your wiring correct? Are the ICs the right way around? Is the battery charged and turned on? Does the motor work in another terminal? Does another motor work? Is your code correct?

Q. Why is my motor going the wrong way?

A. There is no right or wrong way with motors. However, if you want your motor to turn in the opposite direction you can either swap the wires over or reverse the code.

Q. Why isn't my wire going in to the terminal block?

A. After some usage, the gripping metal part inside terminal blocks can 'pull out'. Turn off and disconnect the MotoZero, unscrew the terminal block screws, then push a small screwdriver into the terminal block wire hole to bend the internal metal gripper back into position.

Q. Why are the LM293D ICs getting hot?

A. The ICs will get warm with normal usage, and even warmer depending on the voltage and current requirements of the motors. Make sure your motors are within the specification detailed in the 'Motor Selection' section, and avoid stalling.

Q. I made a cool project with the MotoZero, how can I show you?

A. We LOVE seeing MotoZero projects! Share your image with @ThePiHut and show us what you've made.