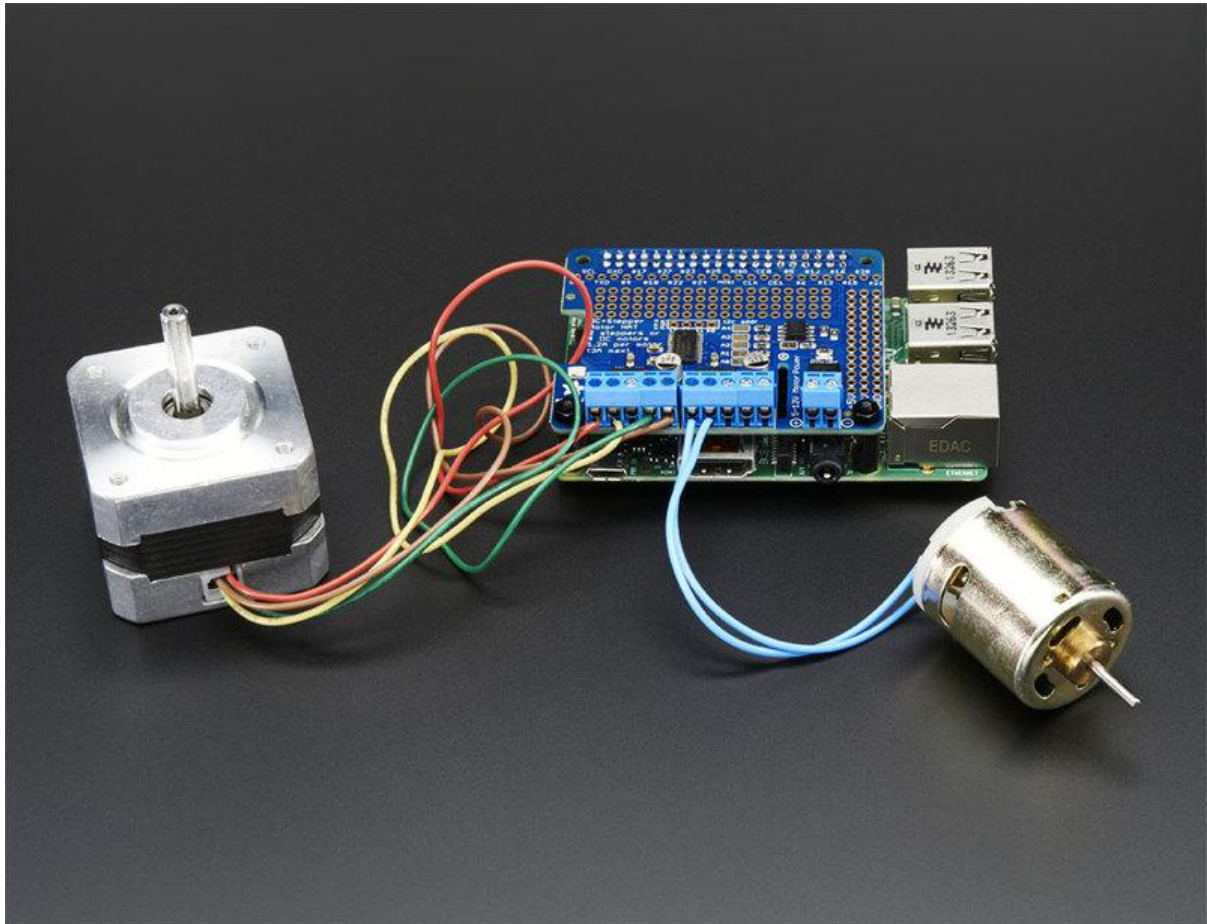




# Adafruit DC and Stepper Motor HAT for Raspberry Pi

Created by lady ada



<https://learn.adafruit.com/adafruit-dc-and-stepper-motor-hat-for-raspberry-pi>

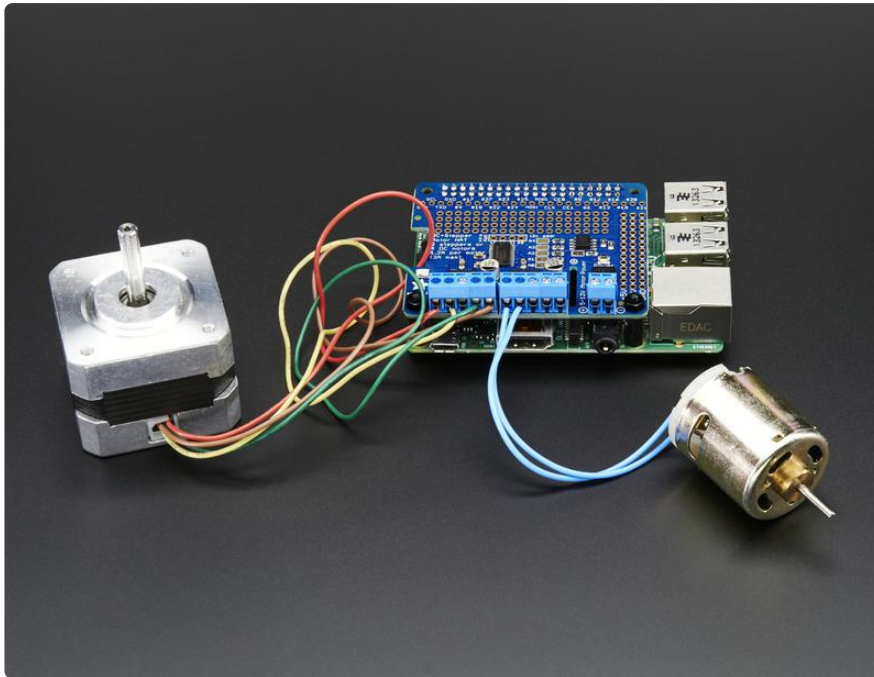
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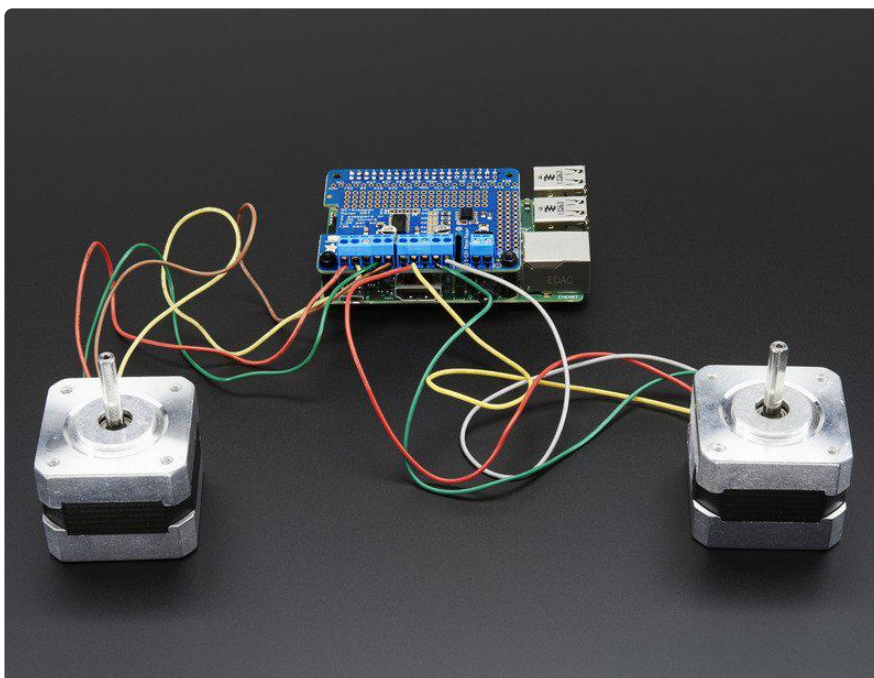
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# Overview



Let your robotic dreams come true with the new DC+Stepper Motor HAT from Adafruit. This Raspberry Pi add-on is perfect for any motion project as it can drive up to 4 DC or 2 Stepper motors with full PWM speed control.

Raspberry Pi and motors are not included

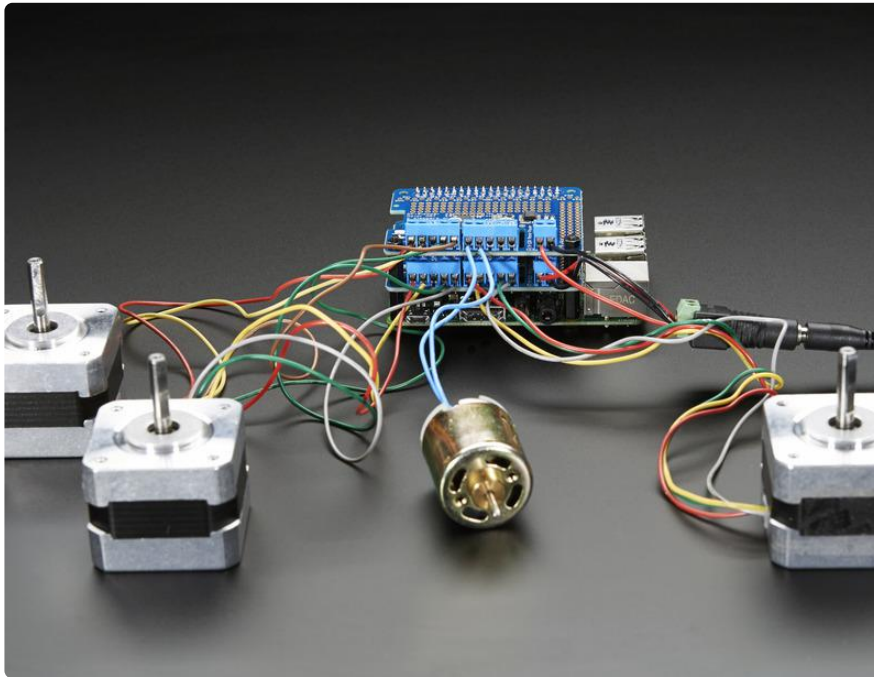


Since the Raspberry Pi does not have a lot of PWM pins, we use a fully-dedicated PWM driver chip onboard to both control motor direction and speed. This chip

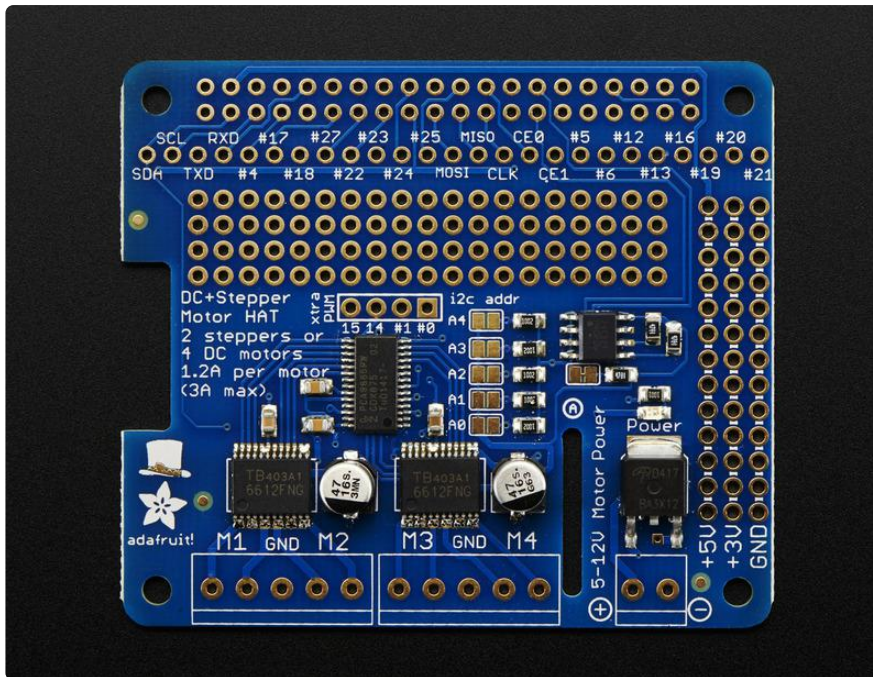
handles all the motor and speed controls over I2C. Only two GPIO pins (SDA & SCL) are required to drive the multiple motors, and since it's I2C you can also connect any other I2C devices or HATs to the same pins.

In fact, you can even stack multiple Motor HATs, up to 32 of them, for controlling up to 64 stepper motors or 128 DC motors - just remember to purchase and solder in a stacking header instead of the one we include.

If connecting the Hat off-the-Pi via jumpers, you will need to connect GND and 3.3v in addition to SDA and SCL.



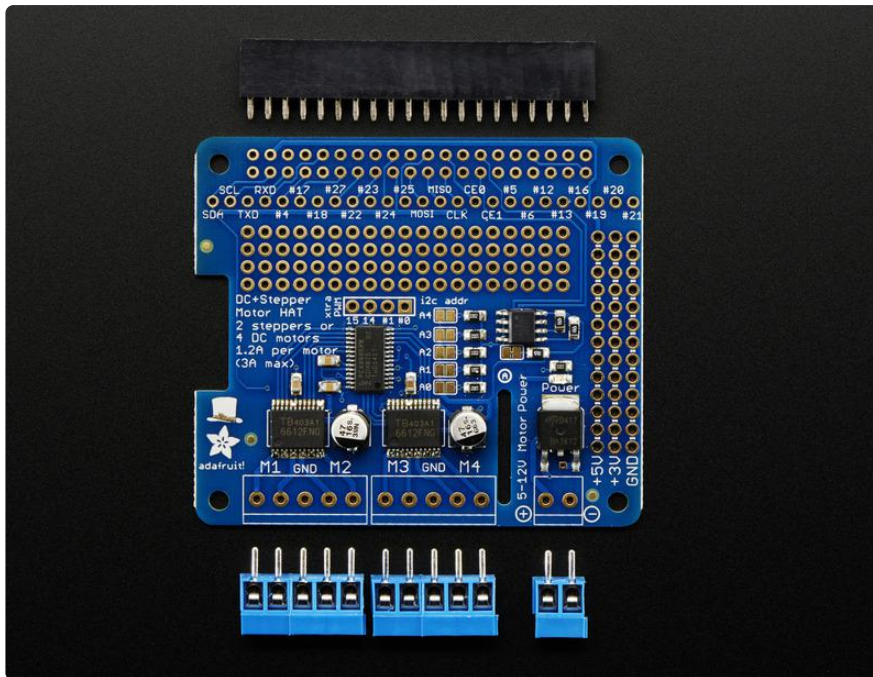
Motors are controlled TB6612 MOSFET driver: with 1.2A per channel current capability (20ms long bursts of 3A peak), a big improvement over L293D drivers and there are built-in flyback diodes as well.



We even had a little space so we added a polarity protection FET on the power pins and a bit of prototyping area. And the HAT is assembled and tested here at Adafruit so all you have to do is solder on the included 2x20 plain header and the terminal blocks.

Lets check out these specs again:

- 4 H-Bridges: TB6612 chipset provides 1.2A per bridge (3A brief peak) with thermal shutdown protection, internal kickback protection diodes. Can run motors on 4.5VDC to 13.5VDC.
- Up to 4 bi-directional DC motors with individual 8-bit speed selection (so, about 0.5% resolution)
- Up to 2 stepper motors (unipolar or bipolar) with single coil, double coil, interleaved or micro-stepping.
- Big terminal block connectors to easily hook up wires (18-26AWG) and power
- Polarity protected 2-pin terminal block and jumper to connect external 5-12VDC power
- Works best with Raspberry Pi model B+ and A+, [but can be used with a model A or B if you purchase a 2x13 extra-tall header and solder that instead of the 2x20 \(https://adafru.it/eib\)](https://adafru.it/eib)
- Install the easy-to-use Python library, check out the examples and you're ready to go!



Comes with an assembled & tested HAT, terminal blocks, and 2x20 plain header. Some soldering is required to assemble the headers on. [Stacking header not included, but we sell them in the shop so if you want to stack HATs, please pick one up at the same time. \(http://adafru.it/2223\)](http://adafru.it/2223)

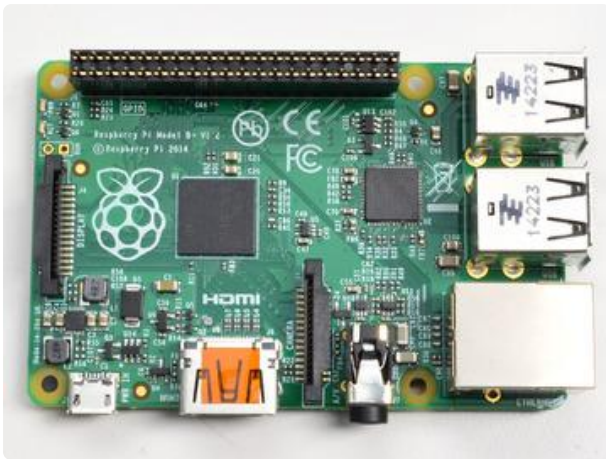
Raspberry Pi and motors are not included but we have lots of motors in the shop and all our DC motors, and stepper motors work great.

---

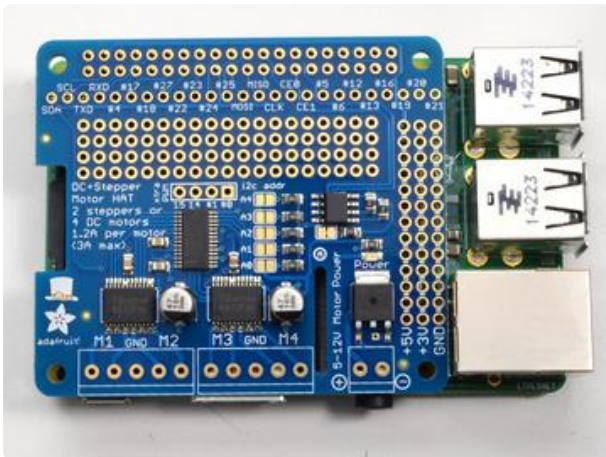
## Assembly

### Solder on Headers and Terminal Block

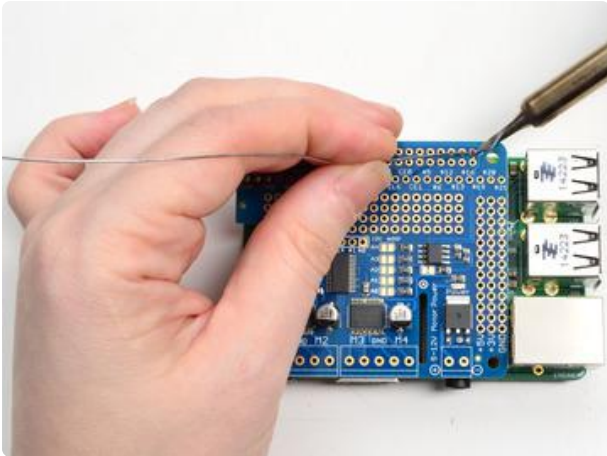
Before we can motorin' there's a little soldering to be done. This step will attach the 2x20 socket header so that we can plug this HAT into a Raspberry Pi, and the terminal blocks so you can attach external power and motors.



Start by plugging the 2x20 header into a Raspberry Pi, this will keep the header stable while you solder. Make sure the Pi is powered down!



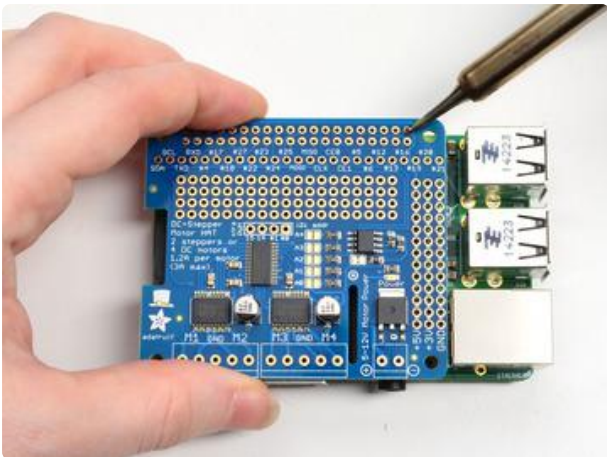
Place the HAT on top so that the short pins of the 2x20 header line up with the pads on the HAT



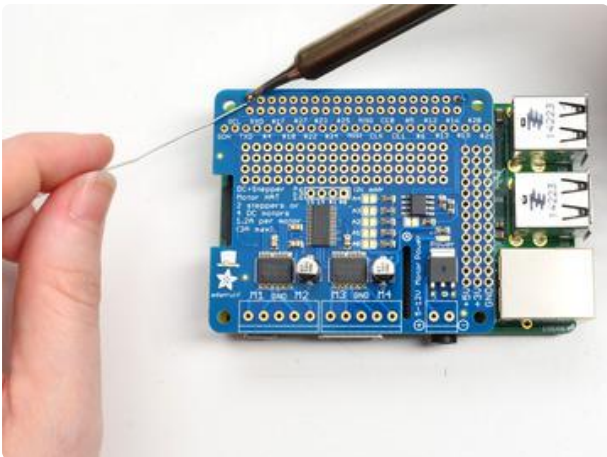
## And Solder!

Heat up your iron and solder in one header connection on the right.

Once it is soldered, put down the solder and reheat the solder point with your iron while straightening the HAT so it isn't leaning down

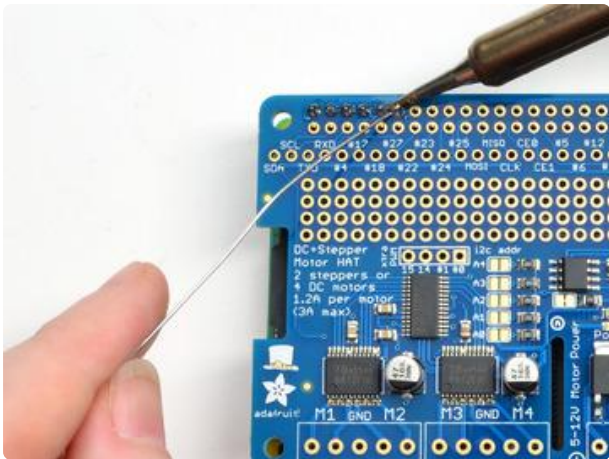


(For tips on soldering, be sure to check out our [Guide to Excellent Soldering](https://adafru.it/aTk) (<https://adafru.it/aTk>)).

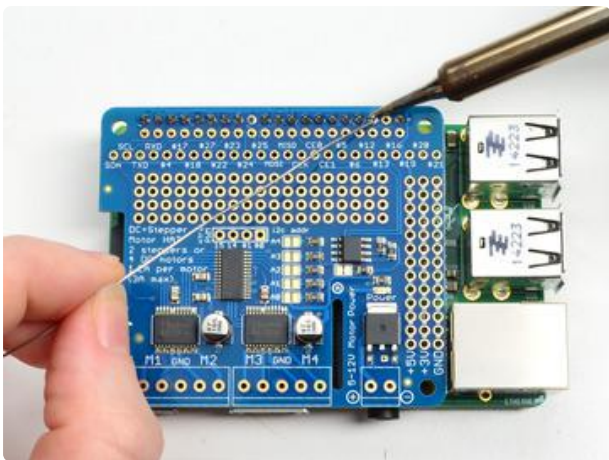
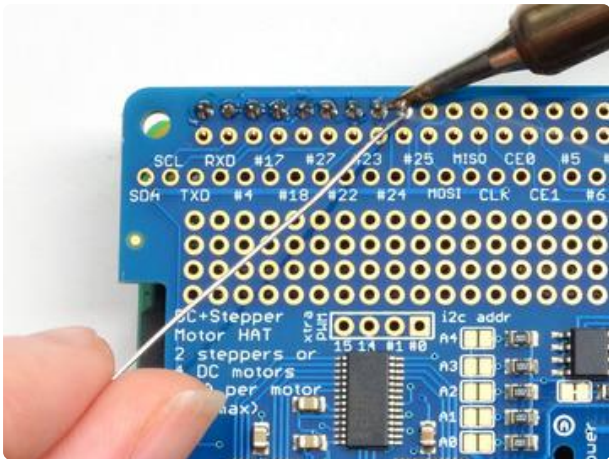


Solder one point on the opposite side of the connector

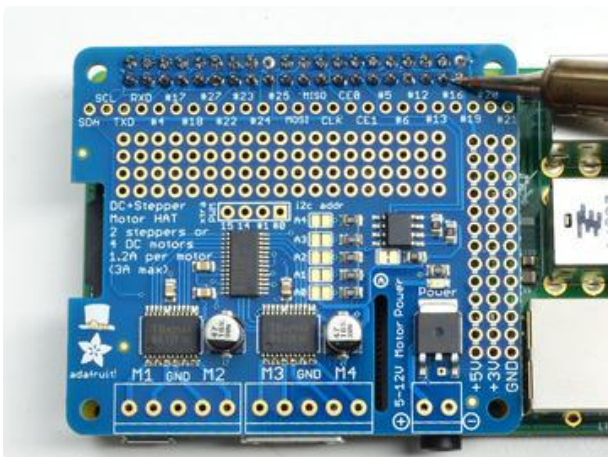
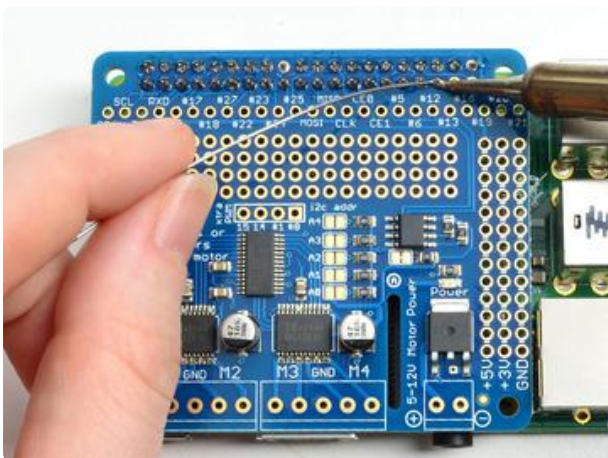
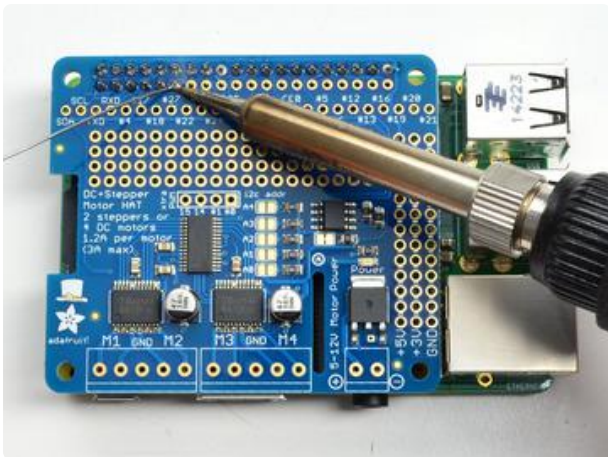
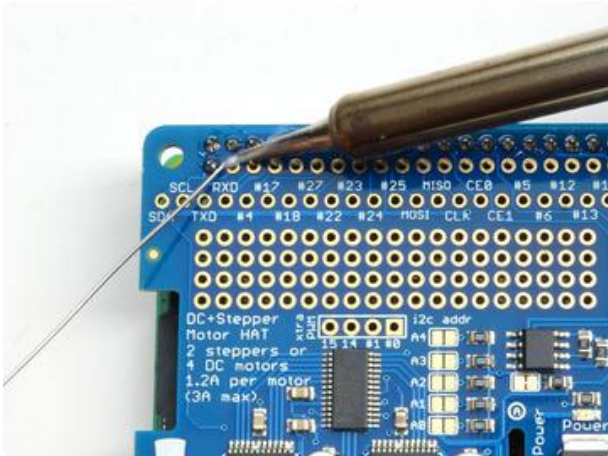


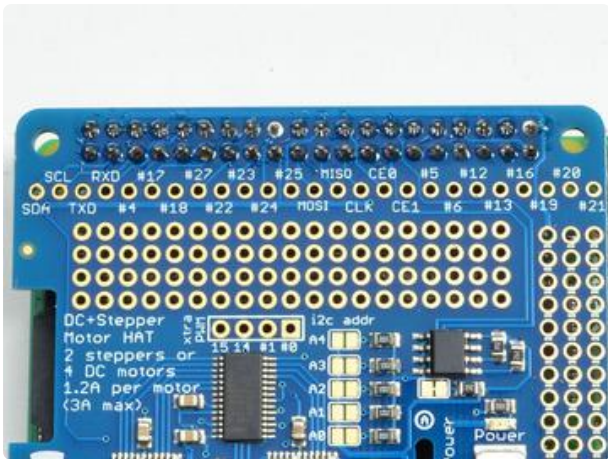


Solder each of the connections for the top row



Flip the board around and solder all the connections for the other half of the 2x20 header





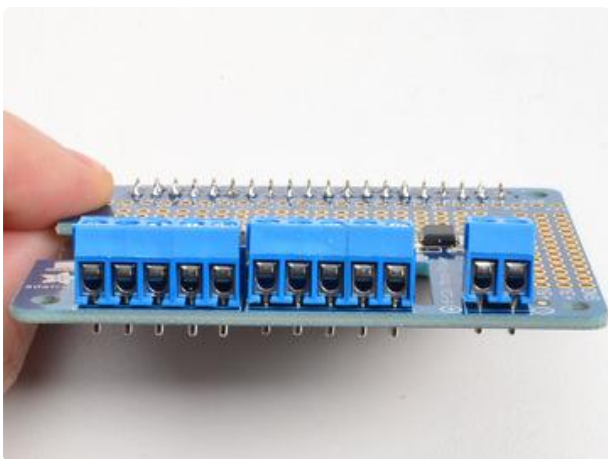
Check over your work so far, make sure each solder point is shiny, and isn't bridged or dull or cracked



Now grab the 3.5mm-spaced terminal blocks. These will let you quickly connect up your motor and power supply using only a screw driver

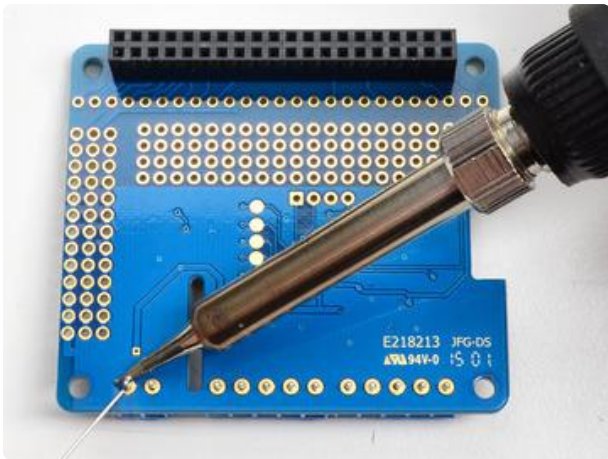
You will have 3 x 2-pin terminal blocks and 2 x 3-pin terminal blocks

Slide each of the 3-pin terminal blocks into a 2-pin to create two 5-pin blocks

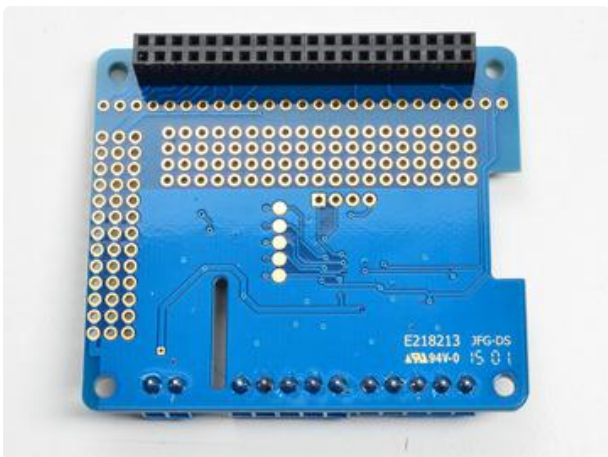
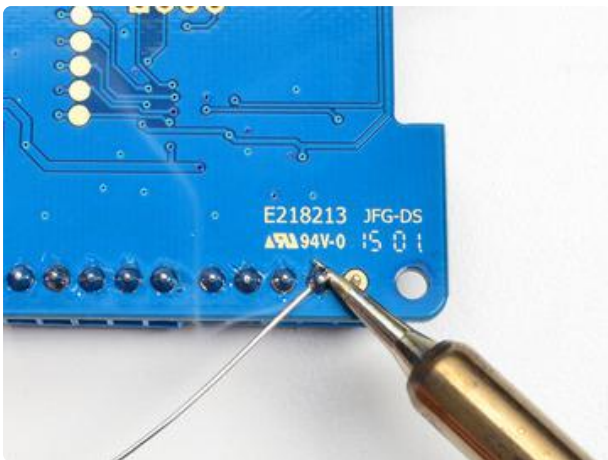
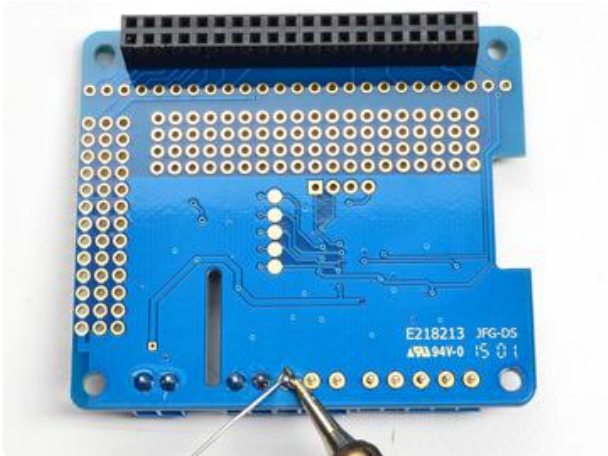


Slide the terminal blocks along the edge of the HAT, so that the 'mouth' of each block is facing out.

You can use scotch or other plain tape to keep the terminal blocks flat against the PCB while you solder



Flip over the board and solder in all of the terminal block pins



Check over your work so far, make sure each solder point is shiny, and isn't bridged or dull or cracked

You're done! You can now move onto the software side

---

# Powering Motors

Motors need a lot of energy, especially cheap motors since they're less efficient.

## Voltage requirements:

The first important thing to figure out what voltage the motor is going to use. If you're lucky your motor came with some sort of specifications. Some small hobby motors are only intended to run at 1.5V, but its just as common to have 6-12V motors. The motor controllers on this HAT are designed to run from 5V to 12V.

**MOST 1.5-3V MOTORS WILL NOT WORK or will be damaged by 5V power**

## Current requirements:

The second thing to figure out is how much current your motor will need. The motor driver chips that come with the kit are designed to provide up to 1.2 A per motor, with 3A peak current. Note that once you head towards 2A you'll probably want to put a heat-sink on the motor driver, otherwise you will get thermal failure, possibly burning out the chip.

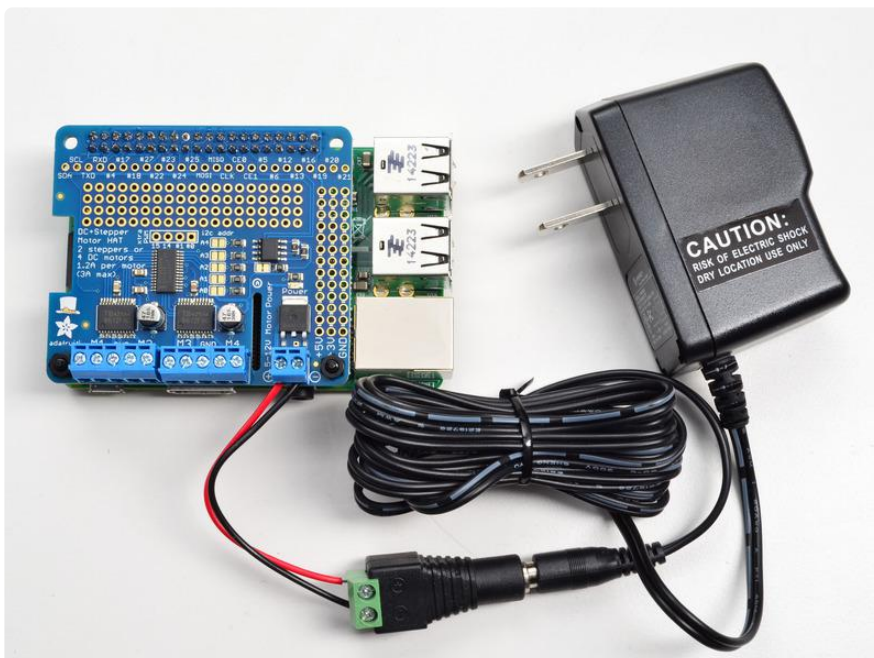
**You can't run motors off of a 9V battery so don't waste your time/batteries!**

Honestly, for portable we recommend you use a big Lead Acid or multiple-AA NiMH battery pack - use 4 to 8 batteries to vary the voltage from about 6V to 12V as your motors require



If you don't have to take your project on the go, a [9V 1A](https://adafru.it/dO6) (<https://adafru.it/dO6>), [12V 1A](https://adafru.it/eny) (<https://adafru.it/eny>), or [12V 5A w](https://adafru.it/enz) (<https://adafru.it/enz>) will work nicely

99% of 'weird motor problems' are due to having a voltage mismatch (too low a voltage, too high a voltage) or not having a powerful enough supply! Even small DC motors can draw up to 3 Amps when they stall.



# Power it up

Wire up your battery pack to the Power terminal block on the right side of the HAT. It is polarity protected but still its a good idea to check your wire polarity. Once the HAT has the correct polarity, you'll see the green LED light up

Please note the HAT does not power the Raspberry Pi, and we strongly recommend having two seperate power supplies - one for the Pi and one for the motors, as motors can put a lot of noise onto a power supply and it could cause stability problems!

---

## Installing Software

We've written a handy CircuitPython library for the DC Motor and Stepper Pi Hat Kit called [Adafruit CircuitPython MotorKit \(https://adafru.it/DdU\)](https://adafru.it/DdU) that handles all the complicated setup for you. All you need to do is import the appropriate class from the library, and then all the features of that class are available for use.

You can use this kit with a Raspberry Pi and Python [thanks to Adafruit\\_Blinka, our CircuitPython-for-Python compatibility library \(https://adafru.it/BSN\)](https://adafru.it/BSN).

## Enable I2C

The Adafruit DC and Stepper Motor Pi Hat kit uses I2C to communicate with your Raspberry Pi. [You will have to make I2C support work on your Pi before you begin. Please visit our tutorial to enable I2C in the kernel! \(https://adafru.it/dEO\)](https://adafru.it/dEO)

## Python Installation of MotorKit Library


You'll need to install the Adafruit\_Blinka library that provides the CircuitPython support in Python. This will require enabling I2C on your Raspberry Pi and verifying you are running Python 3. [Since Linux changes often, please visit the CircuitPython on Linux guide to get your computer ready \(https://adafru.it/BSN\)](https://adafru.it/BSN)!

Once that's done, from your command line run the following command:

- `sudo pip3 install adafruit-circuitpython-motorkit`

If your default Python is version 3 you may need to run `pip` instead. Just make sure you aren't trying to use CircuitPython on Python 2.x, it isn't supported!

This will install the Adafruit CircuitPython MotorKit library along with the necessary dependencies.



```
(.env) pi@cppt:~/CircuitPython $ pip install adafruit-circuitpython-motorkit
Collecting adafruit-circuitpython-motorkit
  Downloading https://files.pythonhosted.org/packages/ff/ca/ff273c68aa704c84c1efb030f19c8a5453c26c69792f2fd443fdb88b149/adafruit_circu
itpython_motorkit-1.1.2-py3-none-any.whl
Collecting adafruit-circuitpython-motor (from adafruit-circuitpython-motorkit)
  Downloading https://www.pywheels.org/simple/adafruit-circuitpython-motor/adafruit_circuitpython_motor-1.3.3-py3-none-any.whl
Collecting adafruit-circuitpython-pca9685 (from adafruit-circuitpython-motorkit)
  Downloading https://www.pywheels.org/simple/adafruit-circuitpython-pca9685/adafruit_circuitpython_pca9685-3.2.3-py3-none-any.whl
Collecting adafruit-circuitpython-busdevice (from adafruit-circuitpython-motorkit)
  Downloading https://www.pywheels.org/simple/adafruit-circuitpython-busdevice/adafruit_circuitpython_busdevice-2.2.7-py3-none-any.whl
Collecting adafruit-circuitpython-register (from adafruit-circuitpython-motorkit)
  Downloading https://www.pywheels.org/simple/adafruit-circuitpython-register/adafruit_circuitpython_register-1.3.2-py3-none-any.whl
Collecting Adafruit-Blinka (from adafruit-circuitpython-motorkit)
  Downloading https://www.pywheels.org/simple/adafruit-blinka/Adafruit-Blinka-0.4.0-py3-none-any.whl
Collecting rpi-ws281x>=4.0.0; platform_machine == "armv7L" or platform_machine == "armv6L" (from Adafruit-Blinka->adafruit-circuitpyth
on-motorkit)
  Downloading https://files.pythonhosted.org/packages/dc/46/934508cf2f68c63842839ae7584225c95a18749ca1b8d3da2a38f3930d4/rpi_ws281x-4.
1.0-cp35-cp35m-linux_armv7L.whl (95kB)
100% |#####| 102kB 1.4MB/s
Collecting Adafruit-GPIO (from Adafruit-Blinka->adafruit-circuitpython-motorkit)
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it)
  Downloading https://www.pywheels.org/simple/rpi-gpio/RPi.GPIO-0.6.5-cp35-cp35m-linux_armv7L.whl (66kB)
100% |#####| 71kB 342kB/s
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  Downloading https://www.pywheels.org/simple/adafruit-pureio/Adafruit-PureIO-0.2.3-py3-none-any.whl
Collecting spidev (from Adafruit-GPIO->Adafruit-Blinka->adafruit-circuitpython-motorkit)
  Downloading https://www.pywheels.org/simple/spidev/spidev-3.2-cp35-cp35m-linux_armv7L.whl
Installing collected packages: rpi-ws281x, adafruit-pureio, spidev, Adafruit-GPIO, RPi.GPIO, Adafruit-Blinka, adafruit-circuitpython-m
otor, adafruit-circuitpython-busdevice, adafruit-circuitpython-register, adafruit-circuitpython-pca9685, adafruit-circuitpython-motork
it
Successfully installed Adafruit-Blinka-0.4.0 Adafruit-GPIO-1.0.3 RPi.GPIO-0.6.5 adafruit-circuitpython-busdevice-2.2.7 adafruit-circu
itpython-motor-1.3.3 adafruit-circuitpython-motorkit-1.1.2 adafruit-circuitpython-pca9685-3.2.3 adafruit-circuitpython-register-1.3.2 a
dafruit-pureio-0.2.3 rpi-ws281x-4.1.0 spidev-3.2
(.env) pi@cppt:~/CircuitPython $
```

## Using DC Motors

DC motors are used for all sort of robotic projects.

The Motor HAT can drive up to 4 DC motors bi-directionally. That means they can be driven forwards and backwards. The speed can also be varied at 0.5% increments using the high-quality built in PWM. This means the speed is very smooth and won't vary!

Note that the H-bridge chip is not meant for driving continuous loads over 1.2A or motors that peak over 3A, so this is for small motors. Check the datasheet for information about the motor to verify its OK!

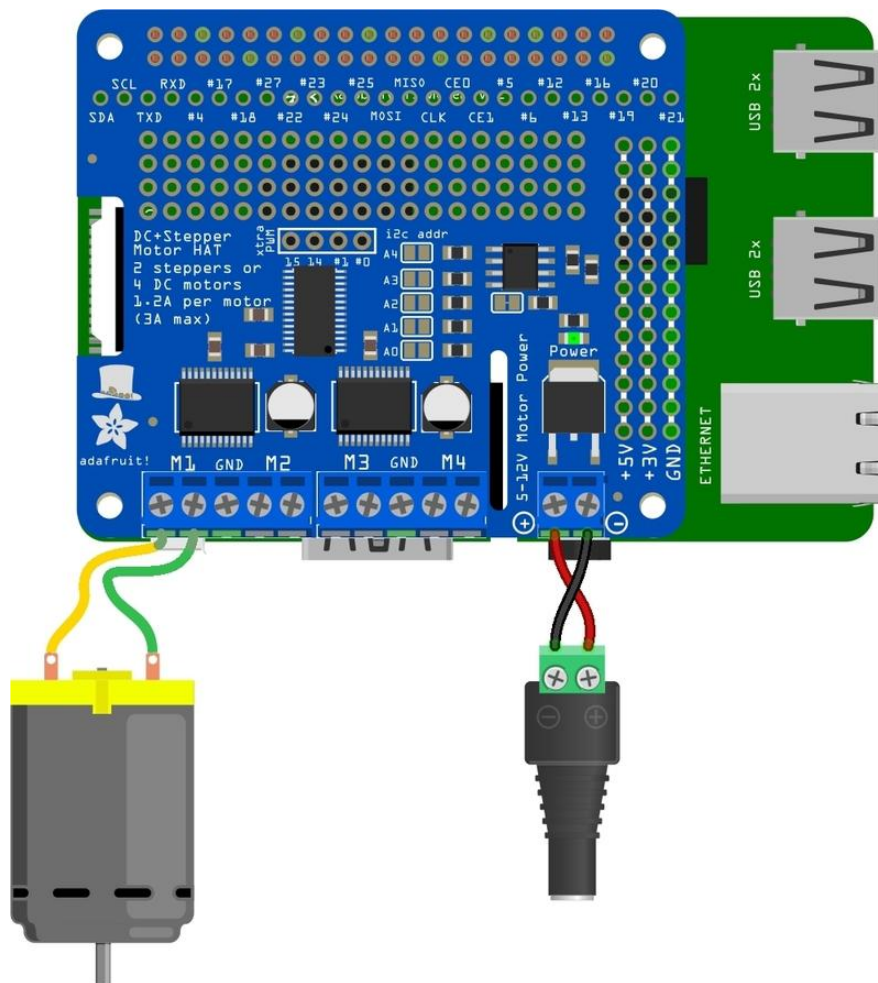
## Connecting DC Motors

To connect a motor, simply solder two wires to the terminals on the motor (if they're not already there!) and then connect them to either the M1, M2, M3, or M4 terminal blocks on the Pi hat. If your motor is running 'backwards' from the way you expect, swap the wires in the terminal block



For this demo, please connect it to M1.

Run `python3` to get to the Python REPL.



## Controlling DC Motors

To demonstrate the usage, we'll initialise the library and use Python code to control a DC motor from the Python REPL.

First you'll need to import and initialize the `MotorKit` class.

```
from adafruit_motorkit import MotorKit
kit = MotorKit()
```

The four motor spots on the Pi hat are available as `motor1`, `motor2`, `motor3`, and `motor4`.

In this example we'll use `motor1`.

Now to move a motor you can set the `throttle` attribute. We don't call it speed because it doesn't correlate to a particular number of revolutions per minute (RPM). RPM depends on the motor and the voltage which is unknown.

For example to drive motor M1 forward at a full speed you set it to `1.0`:

```
kit.motor1.throttle = 1.0
```

To run the motor at half throttle forward use a decimal:

```
kit.motor1.throttle = 0.5
```

Or to reverse the direction use a negative throttle:

```
kit.motor1.throttle = -0.5
```

You can stop the motor with a throttle of `0`:

```
kit.motor1.throttle = 0
```

To let the motor coast and then spin freely set throttle to `None`.

```
kit.motor1.throttle = None
```

That's all there is to controlling DC motors with the Adafruit CircuitPython MotorKit library! With DC motors you can build fun moving projects like robots or remote controlled cars that glide around with ease.

## Full Example Code

```
# SPDX-FileCopyrightText: 2021 ladyada for Adafruit Industries
# SPDX-License-Identifier: MIT

"""Simple test for using adafruit_motorkit with a DC motor"""
import time
import board
from adafruit_motorkit import MotorKit

kit = MotorKit(i2c=board.I2C())

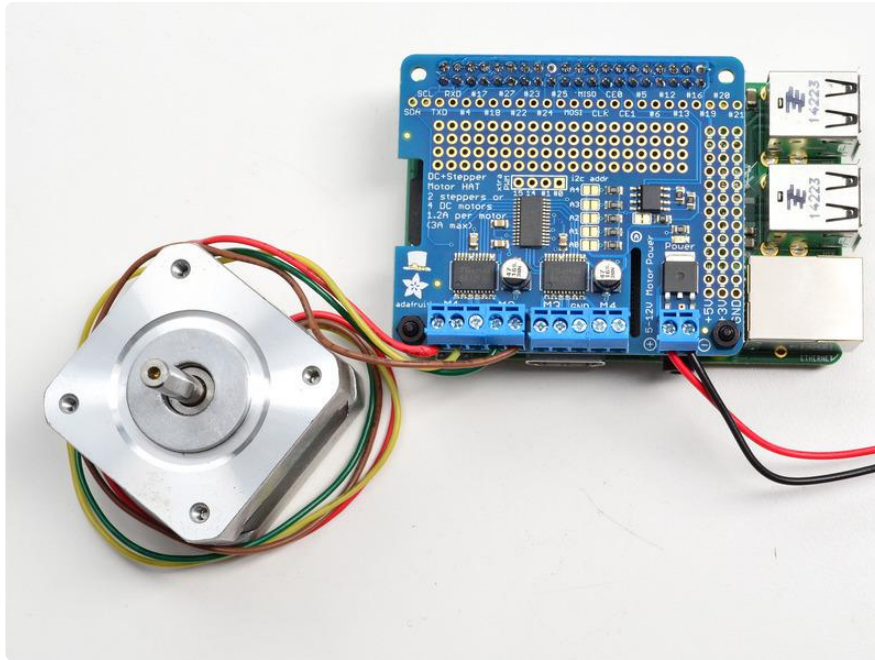
kit.motor1.throttle = 1.0
time.sleep(0.5)
kit.motor1.throttle = 0
```

---

# Using Stepper Motors

Stepper motors are great for (semi-)precise control, perfect for many robot and CNC projects. This HAT supports up to 2 stepper motors. The python library works identically for bi-polar and uni-polar motors.

Running a stepper is a little more intricate than running a DC motor but its still very easy.



## Connecting Stepper Motors

For unipolar motors: to connect up the stepper, first figure out which pins connected to which coil, and which pins are the center taps. If its a 5-wire motor then there will be 1 that is the center tap for both coils. [Theres plenty of tutorials online on how to reverse engineer the coils pinout. \(https://adafruit.it/aOO\)](https://adafruit.it/aOO) The center taps should both be connected together to the center GND terminal on the Motor HAT output block. then coil 1 should connect to one motor port (say M1 or M3) and coil 2 should connect to the other motor port (M2 or M4).

For bipolar motors: its just like unipolar motors except there's no 5th wire to connect to ground. The code is exactly the same.

For this demo, please connect it to M1 and M2

Run `python3` to get to the Python REPL.

## Controlling Stepper Motors

To demonstrate the usage, we'll initialise the library and use Python code to control a DC motor from the Python REPL.

First you'll need to import and initialize the `MotorKit` class.

```
from adafruit_motorkit import MotorKit
kit = MotorKit()
```

Similar DC motors, stepper motors are available as `stepper1` and `stepper2`. `stepper1` is made up of the M1 and M2 terminals, and `stepper2` is made up of the M3 and M4 terminals.

We'll use `stepper1` in our example.

The most basic function (and the default) is to do one single coil step.

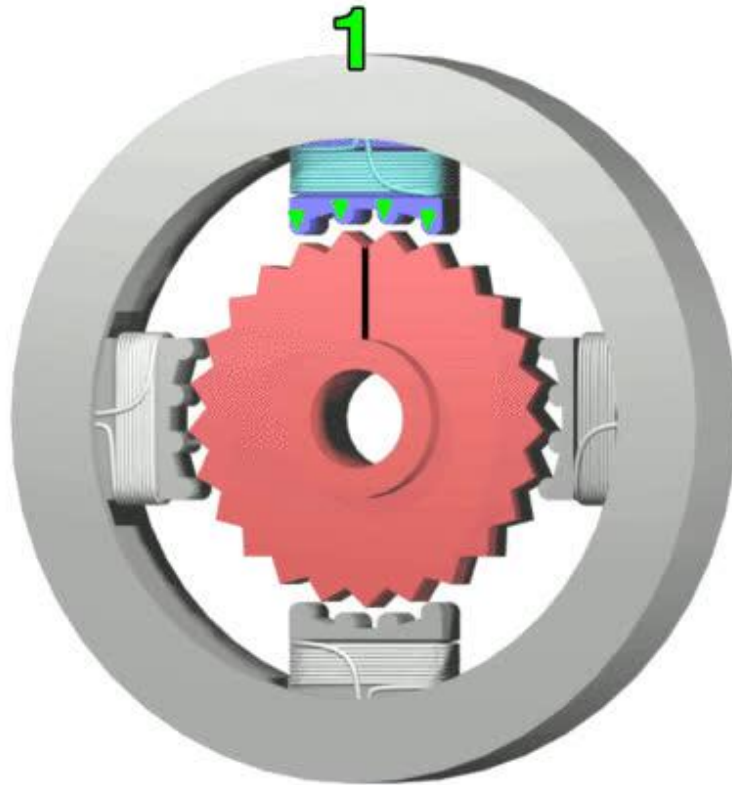
```
kit.stepper1.onestep()
```

There are a number of optional features available for the `onestep()` function. Let's take a look!

## Stepping

Stepper motors differ from DC motors in that the controller (in this case, Raspberry Pi) must tick each of the 4 coils in order to make the motor move. Each two 'ticks' is a step. By alternating the coils, the stepper motor will spin all the way around. If the coils are fired in the opposite order, it will spin the other way around.

If the python code or Pi crashes or stops responding, the motor will no longer move. Compare this to a DC motor which has a constant voltage across a single coil for movement.



["StepperMotor" by Wapcaplet; Teravolt. \(https://adafru.it/enC\)](https://adafru.it/enC)

There are four essential types of steps you can use with your Motor HAT. All four kinds will work with any unipolar or bipolar stepper motor

1. Single Steps - this is the simplest type of stepping, and uses the least power. It uses a single coil to 'hold' the motor in place, as seen in the animated GIF above
2. Double Steps - this is also fairly simple, except instead of a single coil, it has two coils on at once. For example, instead of just coil #1 on, you would have coil #1 and #2 on at once. This uses more power (approx 2x) but is stronger than single stepping (by maybe 25%)
3. Interleaved Steps - this is a mix of Single and Double stepping, where we use single steps interleaved with double. It has a little more strength than single stepping, and about 50% more power. What's nice about this style is that it makes your motor appear to have 2x as many steps, for a smoother transition between steps
4. Microstepping - this is where we use a mix of single stepping with PWM to slowly transition between steps. It's slower than single stepping but has much higher precision. We recommend 8 microstepping which multiplies the # of steps your stepper motor has by 8.

You can call the `onestep` function with two optional keyword arguments. To use these, you'll need to `import stepper` as well.

```
from adafruit_motor import stepper
```

Then you have access to the following options:

- `direction`, which should be one of the following constant values:
  - `stepper.FORWARD` (default)
  - `stepper.BACKWARD`
- `style`, which should be one of the values:
  - `stepper.SINGLE` (default) for a full step rotation to a position where one single coil is powered
  - `stepper.DOUBLE` for a full step rotation to position where two coils are powered providing more torque
  - `stepper.INTERLEAVE` for a half step rotation interleaving single and double coil positions and torque
  - `stepper.MICROSTEP` for a microstep rotation to a position where two coils are partially active
- `release()` which releases all the coils so the motor can free spin, and also won't use any power

The function returns the current step 'position' in microsteps which can be handy to understand how far the stepper has moved, or you can ignore the result.

To take a double-coil step backward call:

```
kit.stepper1.onestep(direction=stepper.BACKWARD, style=stepper.DOUBLE)
```

You can even use a loop to continuously call `onestep` and move the stepper, for example a loop of `200` microsteps forward for smooth movement:

```
for i in range(200):  
    kit.stepper1.onestep(style=stepper.MICROSTEP)
```

That's all there is to controlling a stepper motor from CircuitPython! Steppers are handy motors for when you need smooth or precise control of something--for example 3D printers and CNC machines use steppers to precisely move tools around surfaces.

# Full Example Code

```
# SPDX-FileCopyrightText: 2021 ladyada for Adafruit Industries
# SPDX-License-Identifier: MIT

"""Simple test for using adafruit_motorkit with a stepper motor"""
import time
import board
from adafruit_motorkit import MotorKit

kit = MotorKit(i2c=board.I2C())

for i in range(100):
    kit.stepper1.onestep()
    time.sleep(0.01)
```

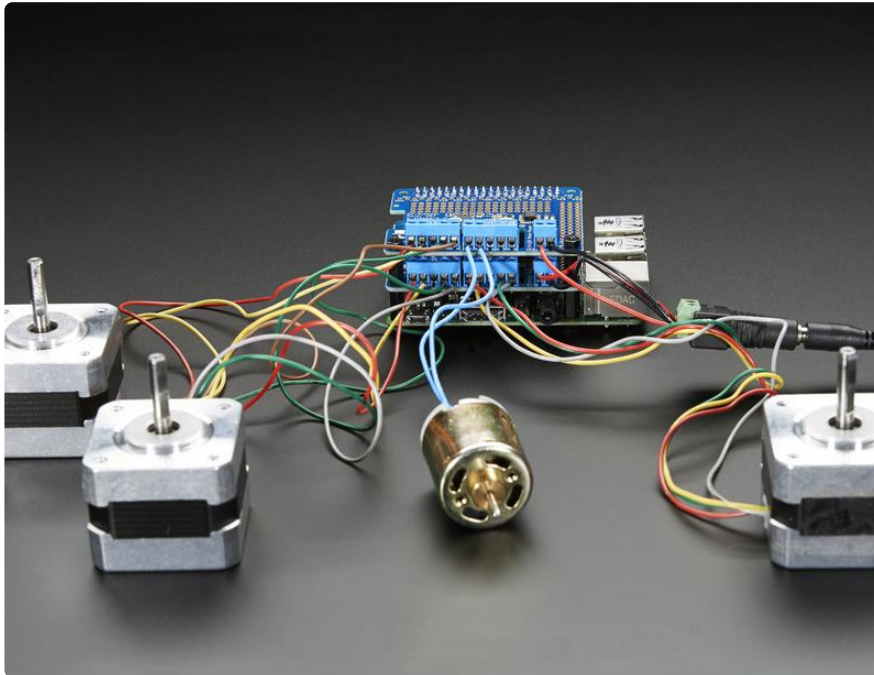
---

## Python Docs

[Python Docs \(https://adafru.it/DeE\)](https://adafru.it/DeE)

---

## Stacking HATs



One of the cool things about this HAT design is that it is possible to stack them. Every HAT you stack can control another 2 steppers or 4 DC motors (or a mix of the two)

You can stack up to 32 HAT for a total of 64 steppers or 128 DC motors! Most people will probably just stack two or maybe three but hey, you never know. (PS if you drive 64 steppers from one Raspberry Pi send us a photo, OK?)

[If you need to control a bunch of servos as well, you can use our 16-channel servo HAT and stack it with this HAT to add a crazy large # of servos. \(https://adafru.it/enA\)](https://adafru.it/enA)

Stacking HATs is very easy. [Each HAT you want to stack on top of must have stacking headers installed. \(http://adafru.it/2223\)](http://adafru.it/2223) The top HAT does not have to have stacking headers unless you eventually want to put something on top of it.

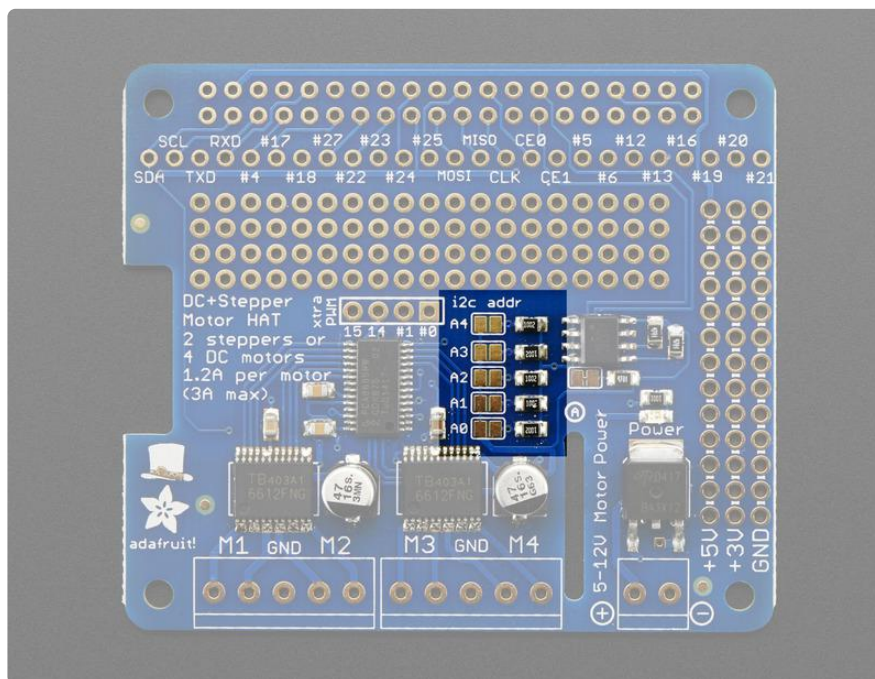
The only thing to watch for when stacking HATs is every HAT must have a unique I2C address. The default address is 0x60. You can adjust the address of the motor HATs to range from 0x60 to 0x80 for a total of 32 unique addresses.

## Addressing the HATs

Each board in the stack must be assigned a unique address. This is done with the address jumpers on the left side of the board. The I2C base address for each board is 0x60. The binary address that you program with the address jumpers is added to the base I2C address.

To program the address offset, use a drop of solder to bridge the corresponding address jumper for each binary '1' in the address.

The bottom-most jumper is address bit #0, then the one above of that is address bit #1, etc up to address bit #5





Board 0: Address = 0x60 Offset = binary 0000 (no jumpers required)  
Board 1: Address = 0x61 Offset = binary 0001 (bridge A0)  
Board 2: Address = 0x62 Offset = binary 0010 (bridge A1, the one above A0)  
Board 3: Address = 0x63 Offset = binary 0011 (bridge A0 & A1, two bottom jumpers)  
Board 4: Address = 0x64 Offset = binary 0100 (bridge A2, middle jumper)

etc.

Note that address 0x70 is the "all call" address for the controller chip on the HAT. All boards will respond to address 0x70 - regardless of the address jumper settings.

## Stacking in Code

Now that you've changed the I2C address on the hardware, you need to set it in your code. When you initialise the class, you can set the address.

```
from adafruit_motorkit import MotorKit
# Initialise the first hat on the default address
kit1 = MotorKit()
# Initialise the second hat on a different address
kit2 = MotorKit(address=0x61)
```

Then you can use `kit1` and `kit2` to control the motors attached to the associated hat.

---

## Downloads

### Motor ideas and tutorials

- [Wikipedia has tons of information \(https://adafru.it/aOF\)](https://adafru.it/aOF) on steppers
- [Jones on stepper motor types \(https://adafru.it/aOH\)](https://adafru.it/aOH)
- [Jason on reverse engineering the stepper wire pinouts \(https://adafru.it/aOI\)](https://adafru.it/aOI)

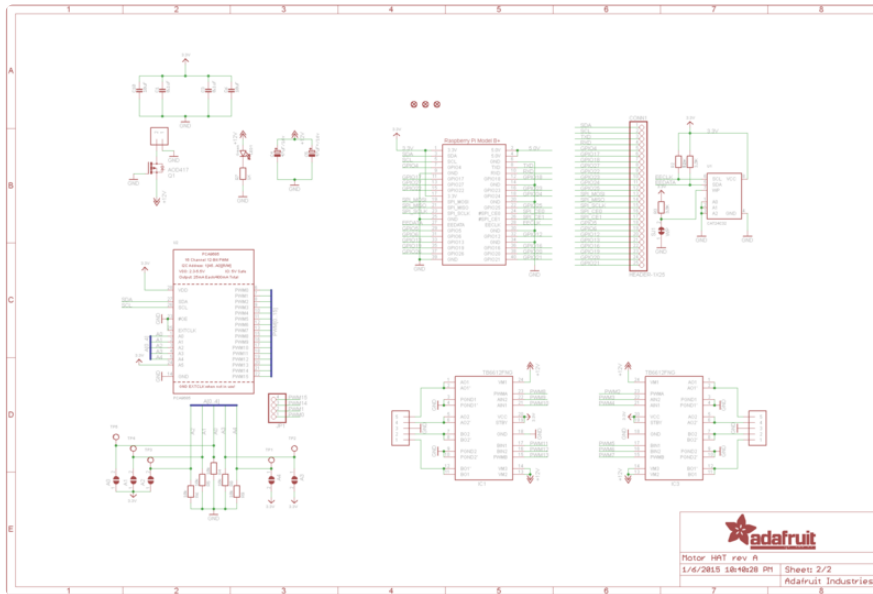
## Files

- [PCA9685 PWM driver \(https://adafru.it/emJ\)](https://adafru.it/emJ)
- [TB6612 Motor driver \(https://adafru.it/emK\)](https://adafru.it/emK)
- [PCB files on GitHub \(https://adafru.it/rEN\)](https://adafru.it/rEN)
- [HAT Fritzing object in the Adafruit Fritzing Library \(https://adafru.it/aP3\)](https://adafru.it/aP3)

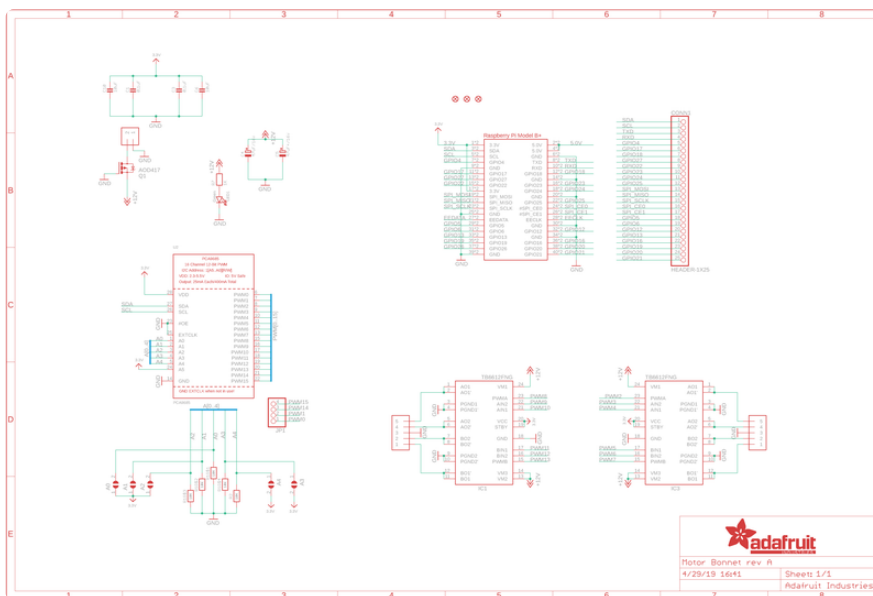
- [Bonnet Fritzing object in the Adafruit Fritzing Library \(https://adafru.it/F52\)](https://adafru.it/F52)

# Schematic

Click to embiggen

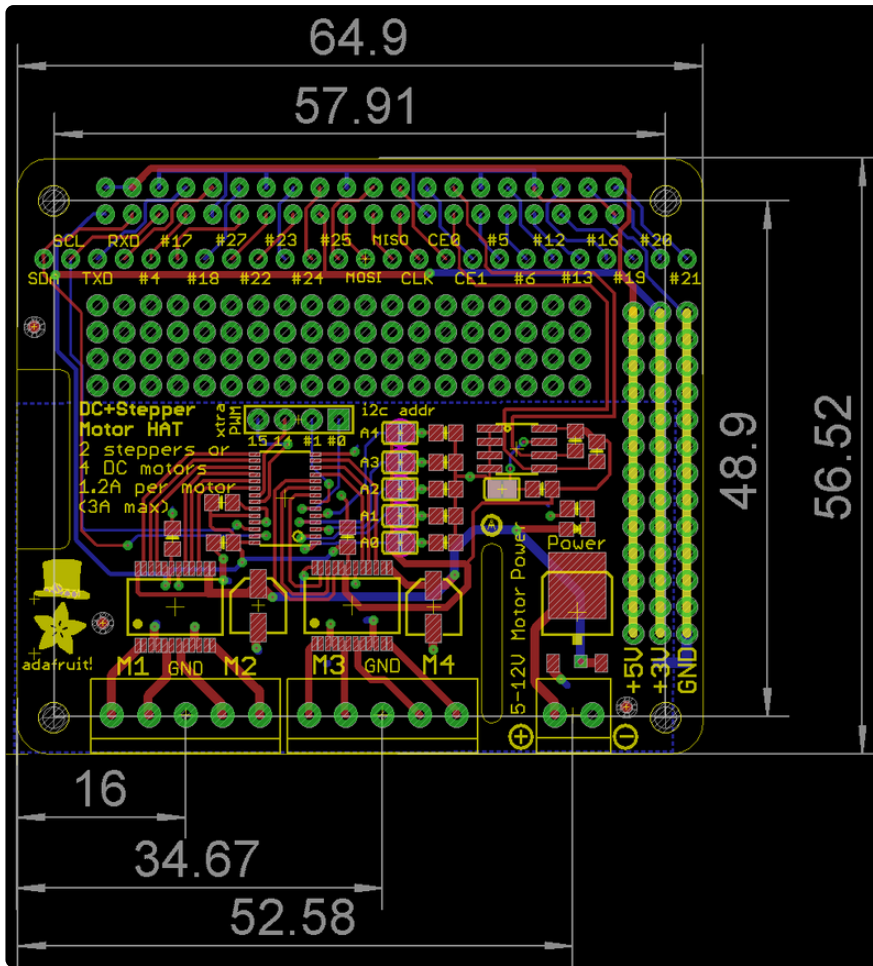


Bonnet!

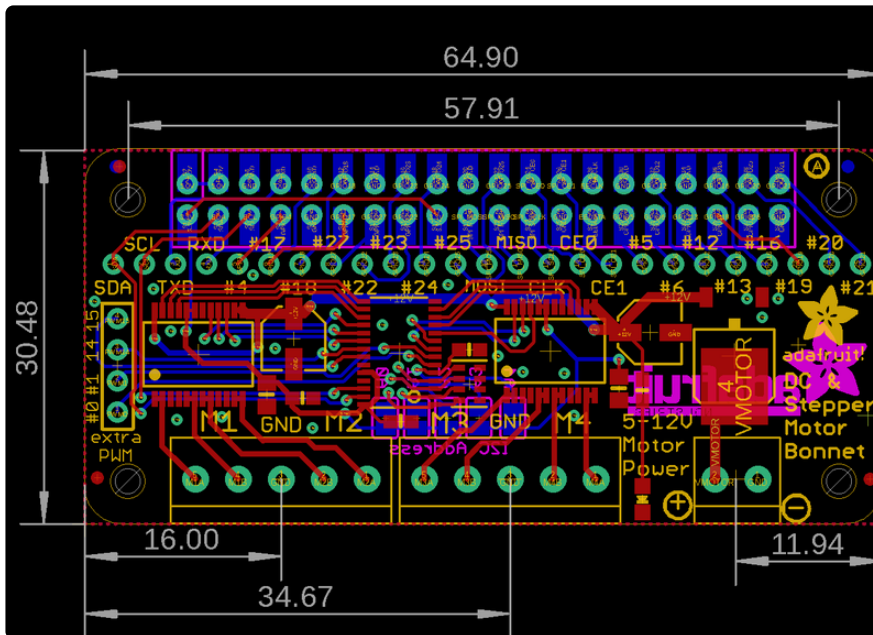


# Fabrication Print

This is a 'HAT mechanical standard' compatible!



Bonnet!



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