Senior Project
UAV Quadcopter
Spring 2021

California State Polytechnic University, Pomona

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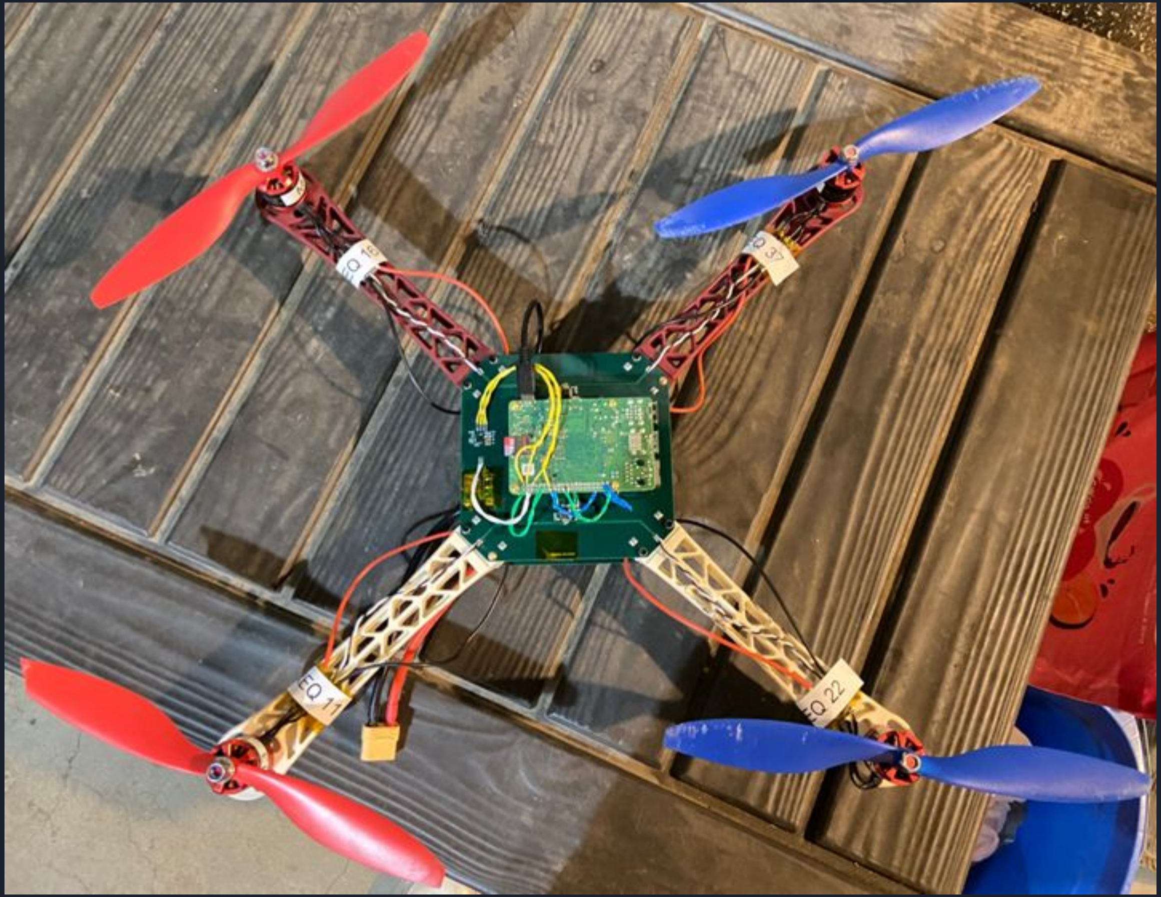
Overview:

1. Raspberry Pi “RPi”
2. Python Programming
3. Power
4. ESCs, DC Brushless Motors, & PWM
5. MPU6050 Gyro/Accel/Temp Sensor
6. Printed Circuit Board “DPIE” - Digital Power Interface Electronics
7. Tests and Results



GitHub used for Documentation

https://github.com/ryanchad22/UAV_Quad

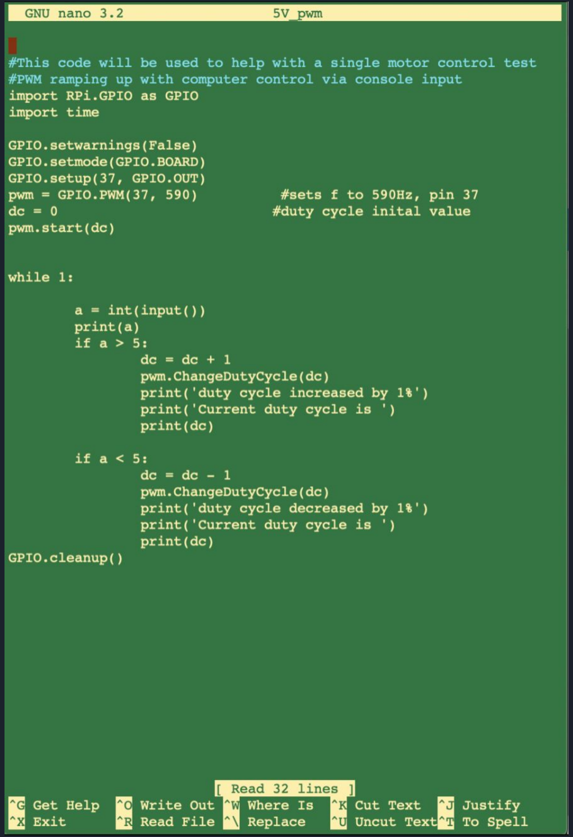
Raspberry Pi (RPi)

-Setup guide was created for initializing a new Raspberry Pi along with all necessary equipment to control the terminal via SSH.

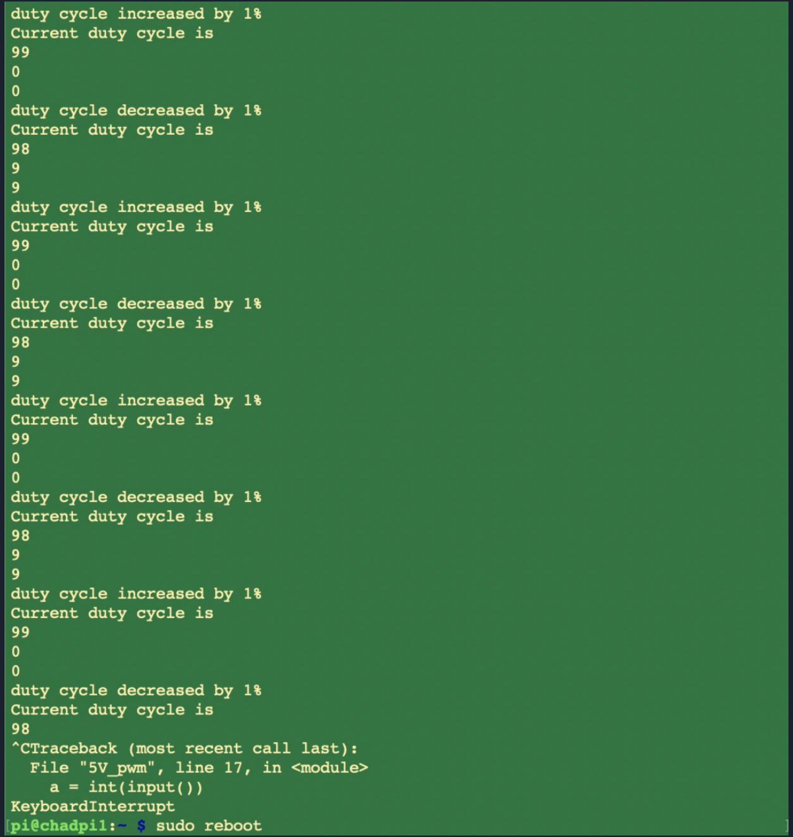
-Some research was done on how to program in Python, especially with how to program the GPIO’s of the RPi.

-Two tests have been completed using PWM generated from the RPi inputting into the ESC (Electronic Speed Controller). Both tests have validated successful PWM behavior from the RPi.

Raspberry Pi Programming



```
  GNU nano 3.2                    5V_pwm

#This code will be used to help with a single motor control test
#PWM ramping up with computer control via console input
import RPi.GPIO as GPIO
import time

GPIO.setwarnings(False)
GPIO.setmode(GPIO.BOARD)
GPIO.setup(37, GPIO.OUT)
pwm = GPIO.PWM(37, 590)          #sets f to 590Hz, pin 37
dc = 0                           #duty cycle inital value
pwm.start(dc)


while 1:

        a = int(input())
        print(a)
        if a > 5:
                dc = dc + 1
                pwm.ChangeDutyCycle(dc)
                print('duty cycle increased by 1%')
                print('Current duty cycle is ')
                print(dc)

        if a < 5:
                dc = dc - 1
                pwm.ChangeDutyCycle(dc)
                print('duty cycle decreased by 1%')
                print('Current duty cycle is ')
                print(dc)
GPIO.cleanup()

                         [ Read 32 lines ]
^G Get Help  ^O Write Out ^W Where Is  ^K Cut Text  ^J Justify
^X Exit      ^R Read File ^\ Replace   ^U Uncut Text^T To Spell
```



```
duty cycle increased by 1%
Current duty cycle is
99
0
0
duty cycle decreased by 1%
Current duty cycle is
98
9
9
duty cycle increased by 1%
Current duty cycle is
99
0
0
duty cycle decreased by 1%
Current duty cycle is
98
9
9
duty cycle increased by 1%
Current duty cycle is
99
0
0
duty cycle decreased by 1%
Current duty cycle is
98
9
9
duty cycle increased by 1%
Current duty cycle is
99
0
0
duty cycle decreased by 1%
Current duty cycle is
98
^CTraceback (most recent call last):
  File "5V_pwm", line 17, in <module>
    a = int(input())
KeyboardInterrupt
pi@chadpi1:~ $ sudo reboot
```

Purchasing Equipment

-After researching Batteries, ESC’s, and Motors, we purchased the following equipment:

-Motor:
https://www.amazon.com/XUSUYUNCHUANG-Racing-Brushless-Helicopter-Accessories/dp/B08FZLG56D

-Battery:

https://www.amazon.com/gp/product/B087R1RQ3M/ref=ppx_yo_dt_b_asin_title_o01_s00?ie=UTF8&psc=1

-ESC:

https://www.getfpv.com/spedix-is30-2-4s-30a.html

- Raspberry Pi 4
- MPU6050
- ESC

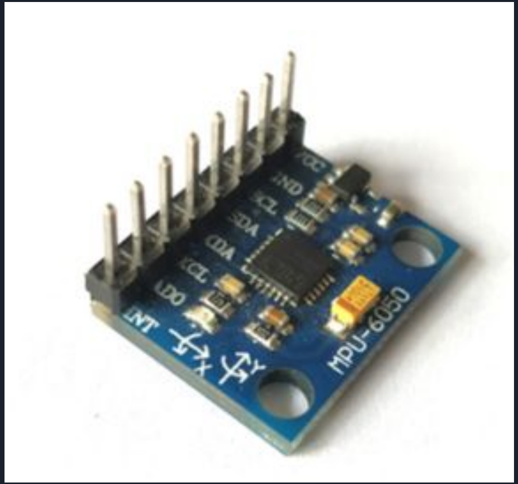
Kory Shopp

Raspberry Pi 4

- Supports Python code
- Supporting code for ESC
- SSH
- Headless mode

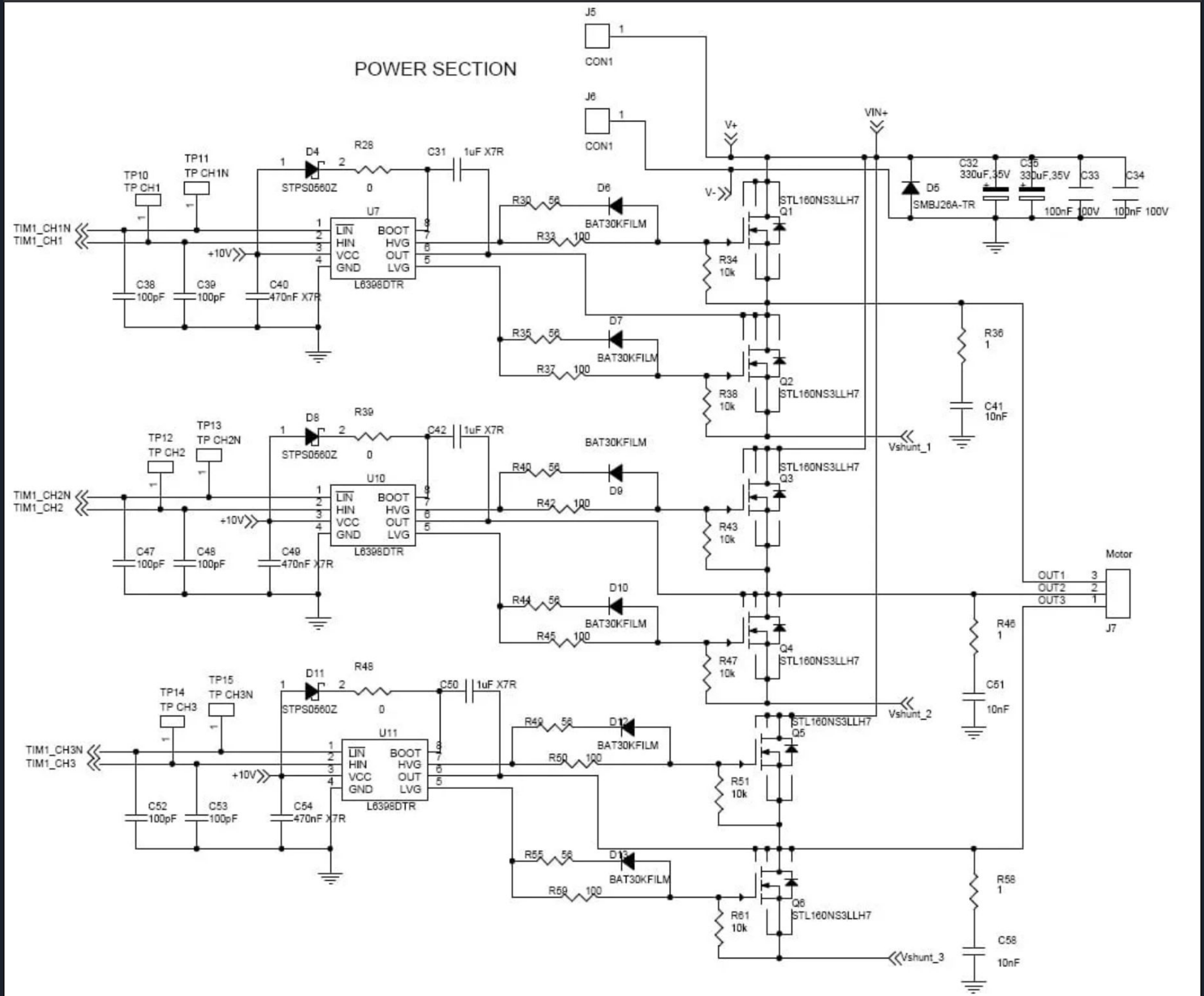
MPU6050

- Accelerometer and Gyroscope
- Measure acceleration, velocity, orientation, and displacement
- Two main components
  - Accelerometer
  - Gyroscope
- Communicates using I2C protocol



ESC

- Electronic Speed Controllers
- Control/adjust speed of the motors
- Inside brushless motor
- MOSFETs inside ESC


POWER SECTION
J5
1
CON1
J6
1
CON1
V+
VIN+
V-
D4
STPS0560Z
R28
0
C31
1uF X7R
TP10
TP CH1
TP11
TP CH1N
TIM1_CH1N
TIM1_CH1
+10V
U7
LIN
HIN
VCC
GND
BOOT
HVG
OUT
LVG
L6398DTR
C38
100pF
C39
100pF
C40
470nF X7R
R30 56
D6
BAT30KFILM
R33 100
R34
10k
Q1
STL160NS3LLH7
D5
SMBJ26A-TR
C32
330uF,35V
C35
330uF,35V
C33
100nF 100V
C34
100nF 100V
R35 56
D7
BAT30KFILM
R37 100
R38
10k
Q2
STL160NS3LLH7
R36
1
C41
10nF
Vshunt_1
D8
STPS0560Z
R39
0
C42
1uF X7R
TP12
TP CH2
TP13
TP CH2N
TIM1_CH2N
TIM1_CH2
+10V
U10
L6398DTR
C47
100pF
C48
100pF
C49
470nF X7R
R40 56
D9
BAT30KFILM
R42 100
R43
10k
Q3
STL160NS3LLH7
R44 56
D10
BAT30KFILM
R45 100
R47
10k
Q4
STL160NS3LLH7
Motor
OUT1
OUT2
OUT3
J7
R46
1
C51
10nF
Vshunt_2
D11
STPS0560Z
R48
0
C50
1uF X7R
TP14
TP CH3
TP15
TP CH3N
TIM1_CH3N
TIM1_CH3
+10V
U11
L6398DTR
C52
100pF
C53
100pF
C54
470nF X7R
R49 56
D12
BAT30KFILM
R50 100
R51
10k
Q5
STL160NS3LLH7
R55 56
D13
BAT30KFILM
R59 100
R61
10k
Q6
STL160NS3LLH7
R58
1
C58
10nF
Vshunt_3

Motor & Propellers

Peter Tiet

Motor

BR2216 Motor

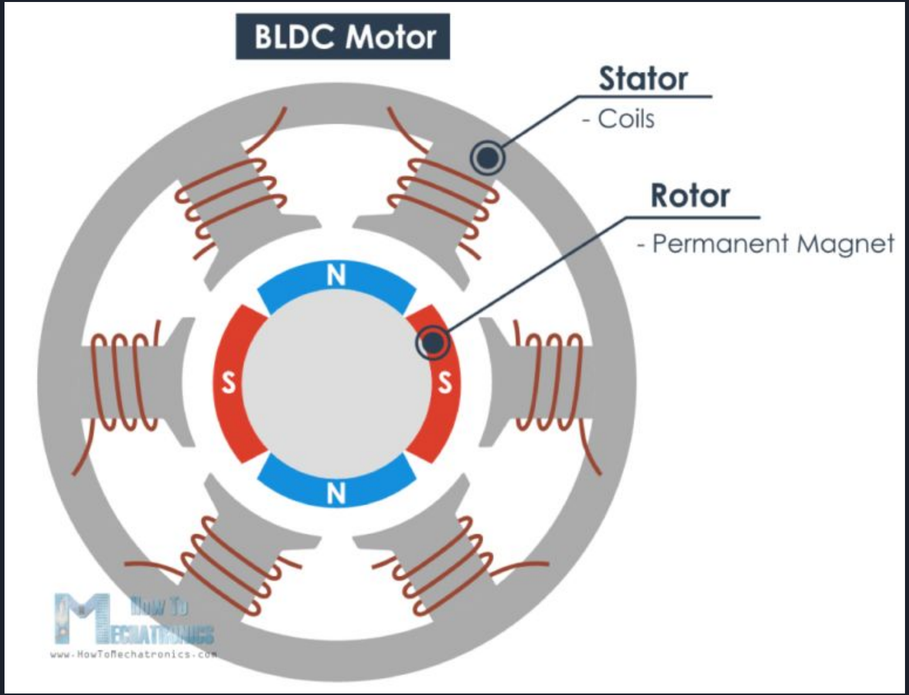
- 810 kV Brushless DC motor

Specs:

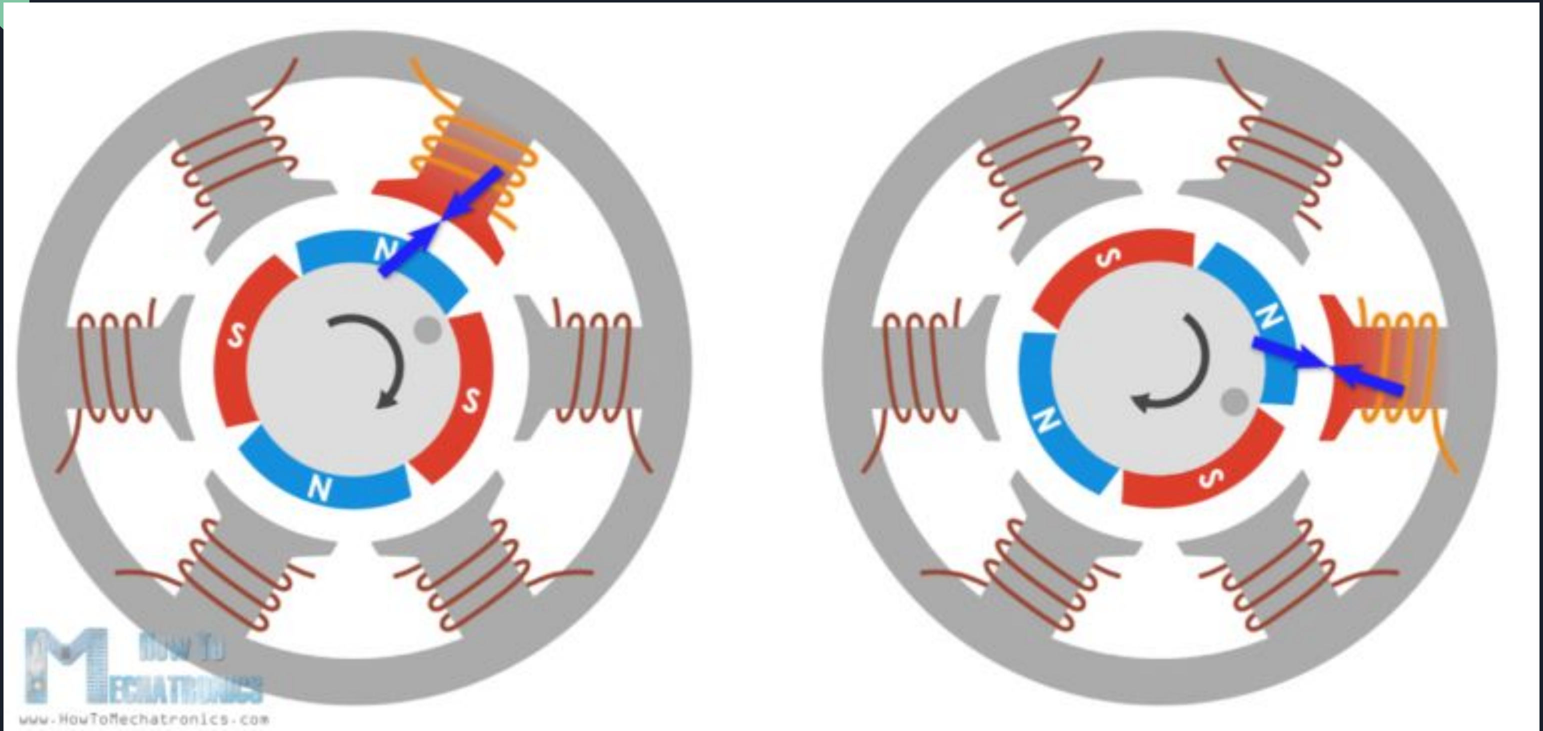
- Height: 45 mm
- Width: 27.7 mm
- Weight: about 66 g
- Voltage: 7.4 V- 14.8V

- Clockwise (Red) & Counterclockwise (Black)

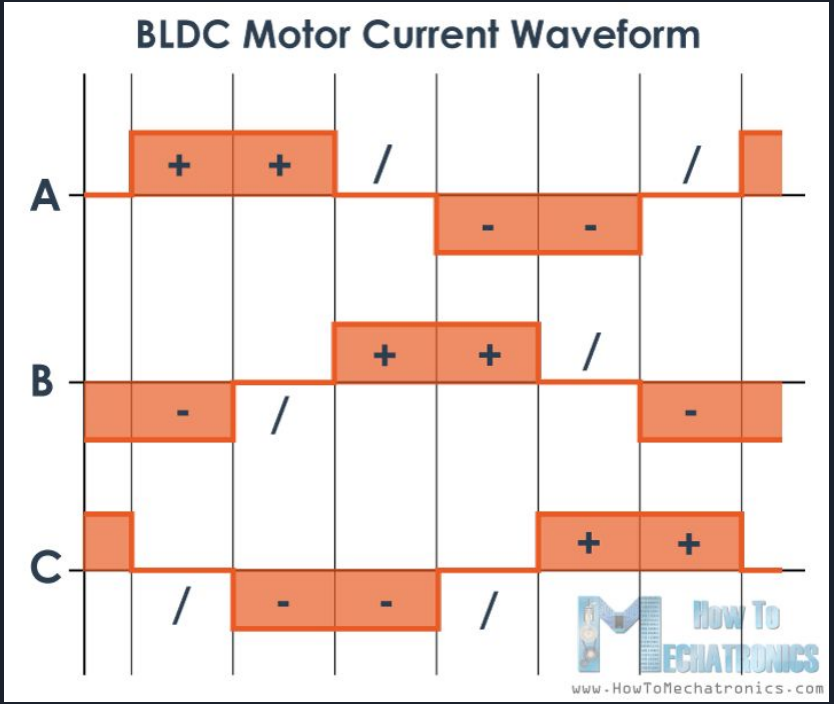
Brushless DC Motor



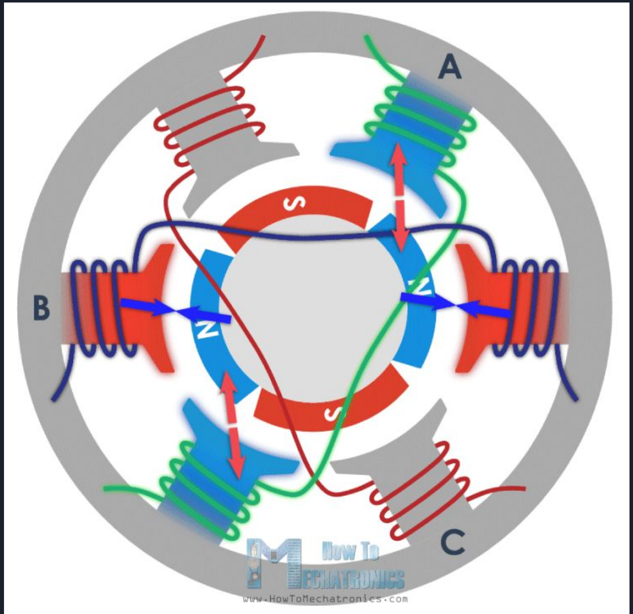
Rotation



Current Waveform



Full motor rotation

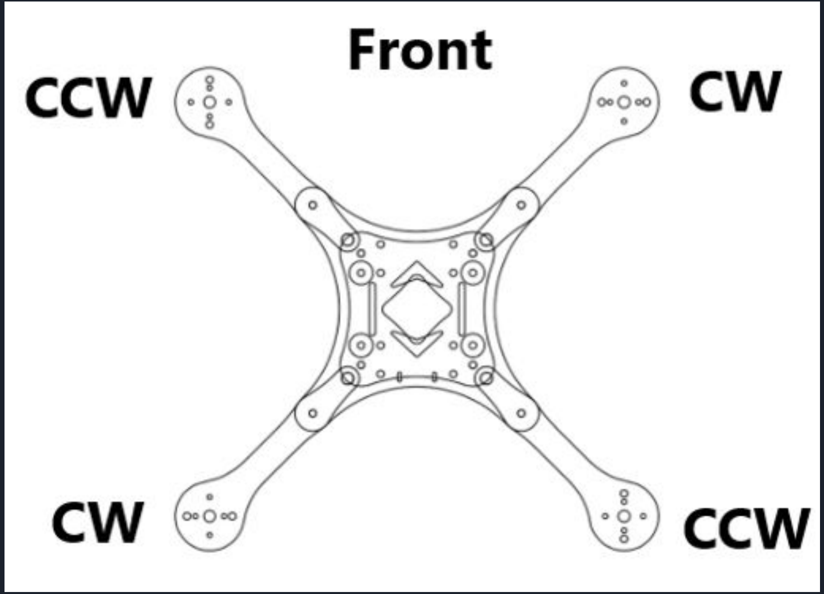


BR2216 Motor

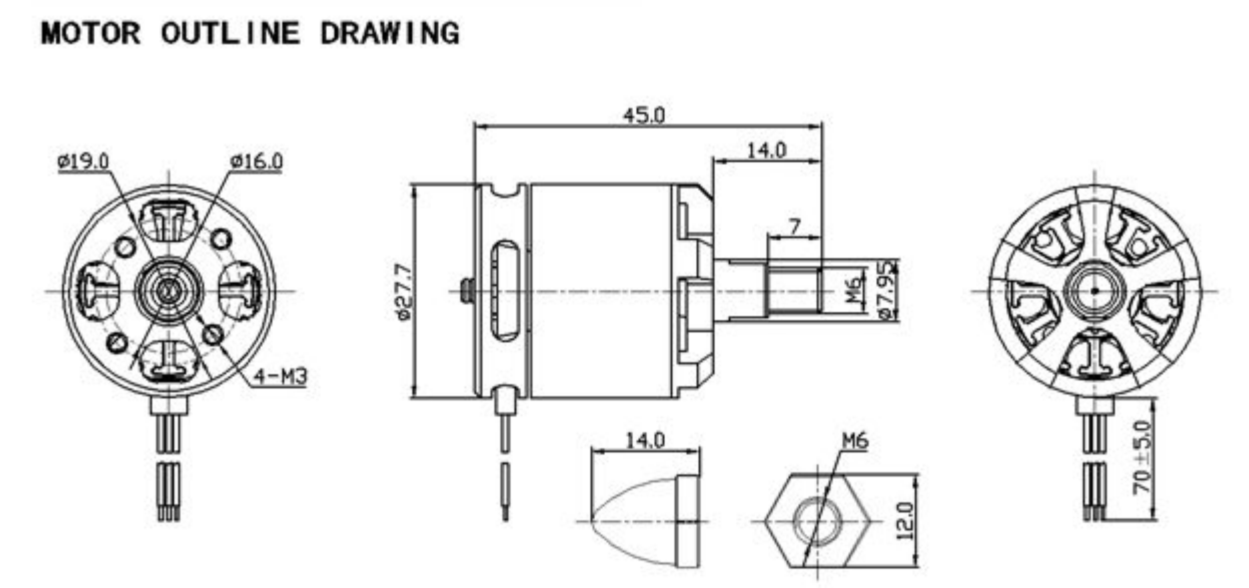
- Light and efficient
- Can be controlled continuously at maximum torque
- Motor controllability
- High durability

- Most efficient for devices that run continuously

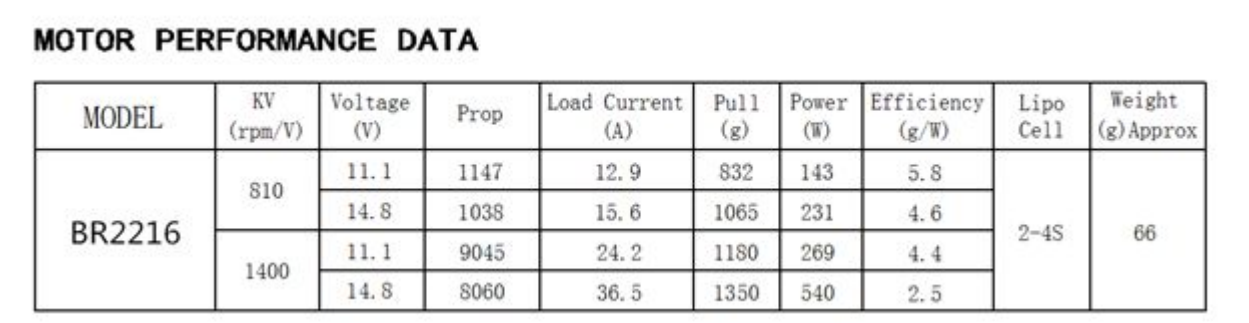
Placement of Motors



Motor Schematic



Datasheet



MOTOR PERFORMANCE DATA

MODEL	KV (rpm/V)	Voltage (V)	Prop	Load Current (A)	Pull (g)	Power (W)	Efficiency (g/W)	Lipo Cell	Weight (g)Approx
BR2216	810	11. 1	1147	12. 9	832	143	5. 8	2-4S	66
		14. 8	1038	15. 6	1065	231	4. 6		
	1400	11. 1	9045	24. 2	1180	269	4. 4		
		14. 8	8060	36. 5	1350	540	2. 5		

Propellers

RAYCorp 10-inch quadcopters performance propellers

- 10 inch diameter
- 4.5 shaft diameter
- 2 blade Propellers
- Plastic Propellers
- Hybrid bullnose (HBN)

- Clockwise (Red) and Counterclockwise (Black)

Size

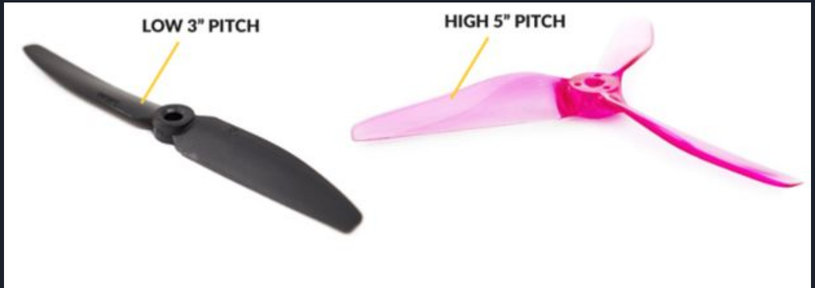
- 10 inch diameter

Long Propellers

- Increased Thrust
- Better “grip” during hover
- Better movement control

Pitch

- 4.5 shaft diameter



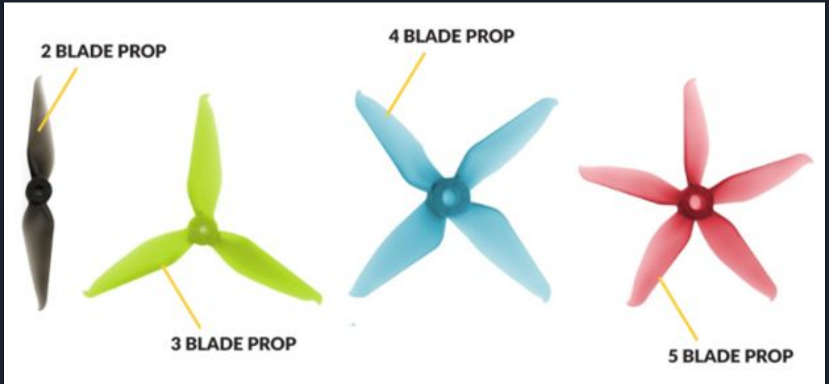
Higher pitch propellor

- Increased thrust
- Better top end speed
- Efficient when drone is moving quickly

Blade configuration

2 blade Propellers

- Faster motor response
- Reduced power consumption
- More efficiency of each blades while maintaining balance



*Increasing propellor size is more efficient than increasing the number of blades

Material

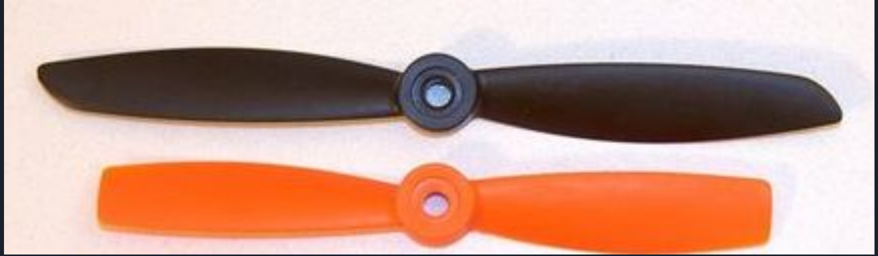
Plastic Propellers

- Stiff
- Lightweight
- Durable

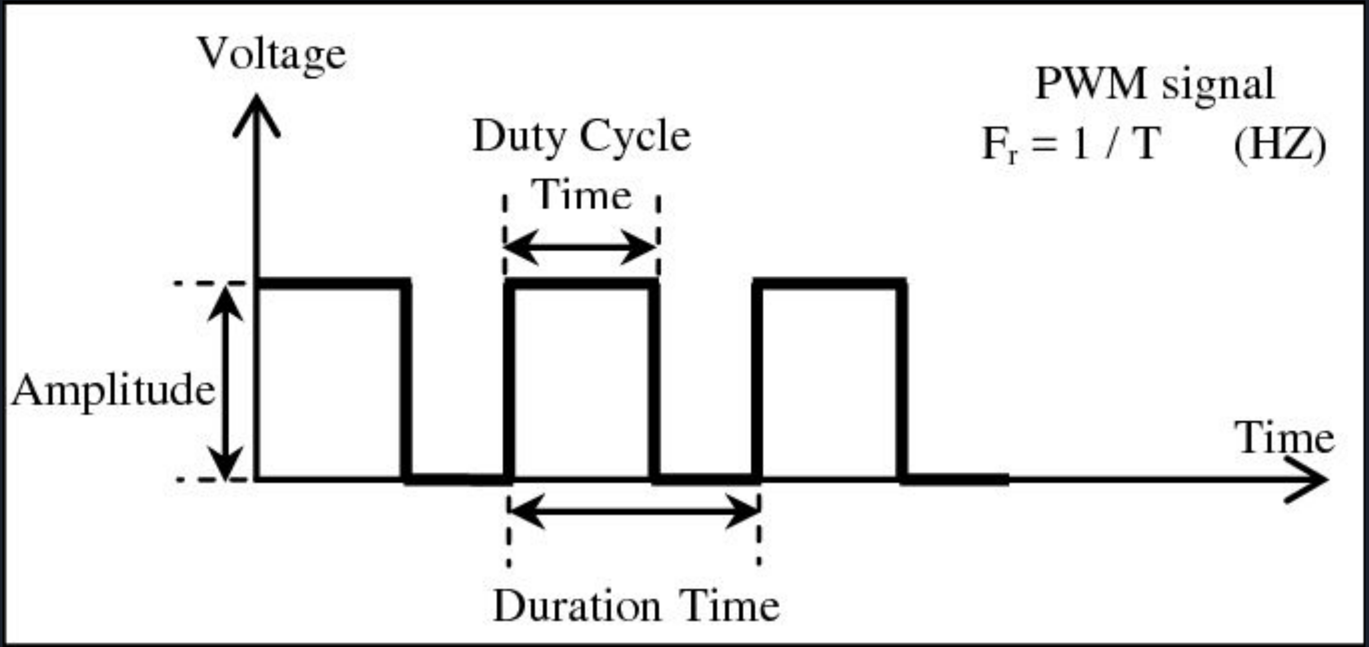
Shape

Hybrid bullnose (HBN)

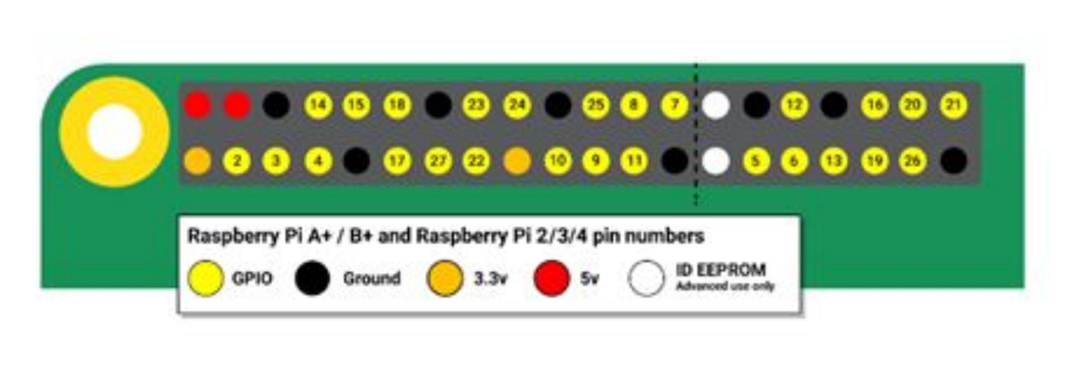
- Most efficient shape
- Generates less thrust

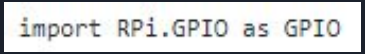


Pulse Width Modulation (PWM)

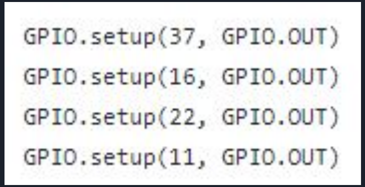


Raspberry Pi PWM

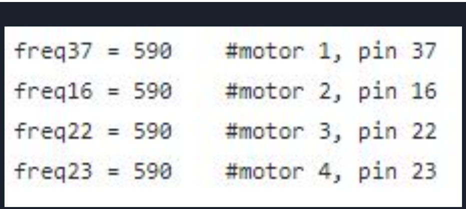




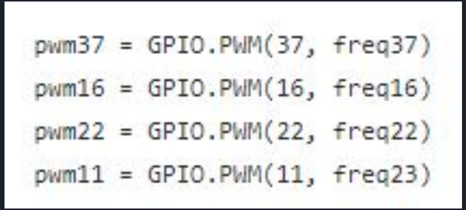
```
import RPi.GPIO as GPIO
```



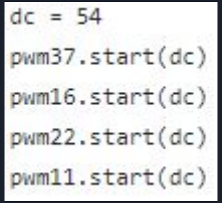
```
GPIO.setup(37, GPIO.OUT)
GPIO.setup(16, GPIO.OUT)
GPIO.setup(22, GPIO.OUT)
GPIO.setup(11, GPIO.OUT)
```



```
freq37 = 590     #motor 1, pin 37
freq16 = 590     #motor 2, pin 16
freq22 = 590     #motor 3, pin 22
freq23 = 590     #motor 4, pin 23
```

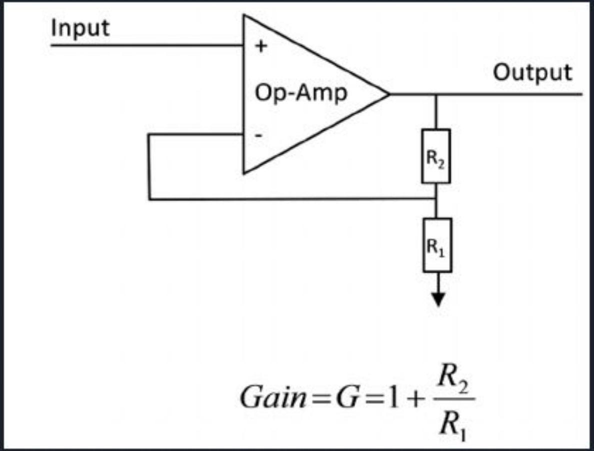


```
pwm37 = GPIO.PWM(37, freq37)
pwm16 = GPIO.PWM(16, freq16)
pwm22 = GPIO.PWM(22, freq22)
pwm11 = GPIO.PWM(11, freq23)
```

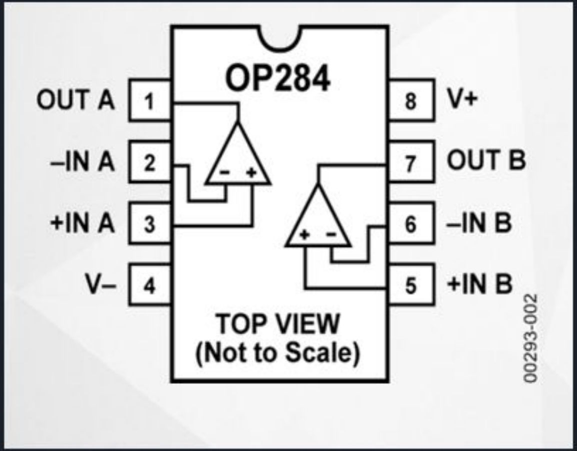


```
dc = 54
pwm37.start(dc)
pwm16.start(dc)
pwm22.start(dc)
pwm11.start(dc)
```

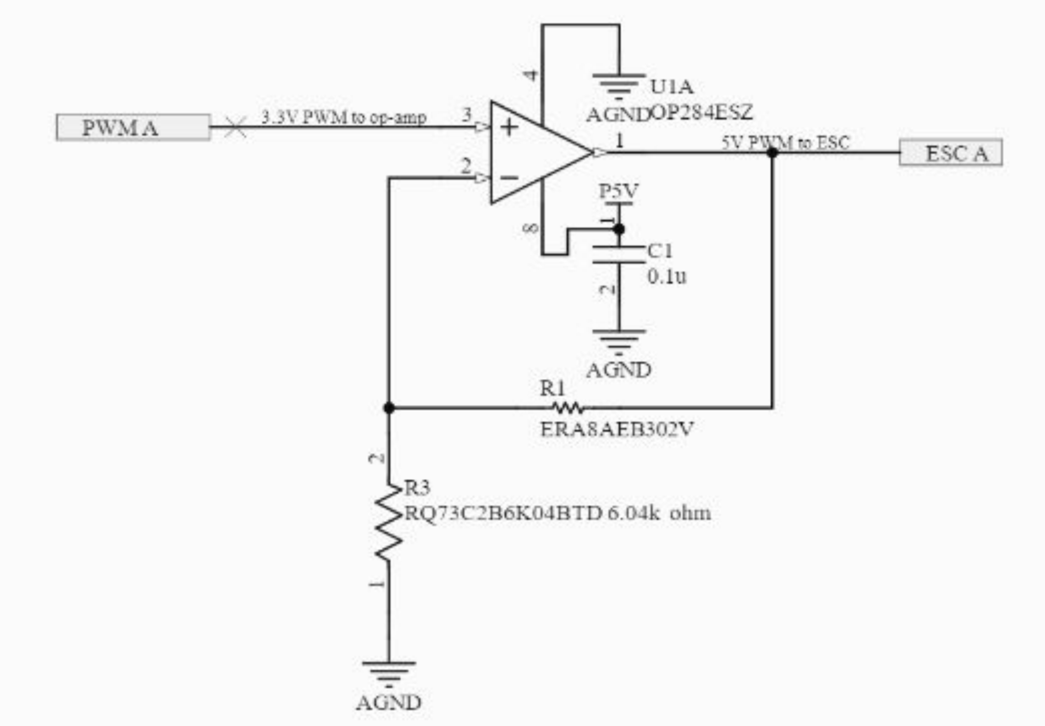
PWM Amplifier



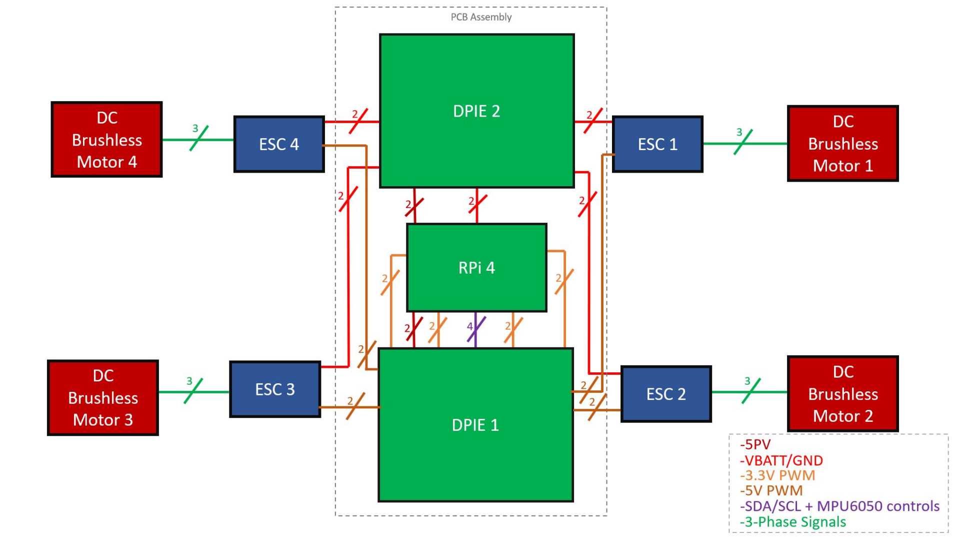
$$Gain = G = 1 + \frac{R_2}{R_1}$$



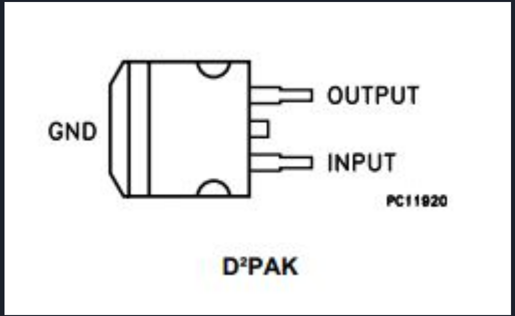
PWM Amplifier Cont.

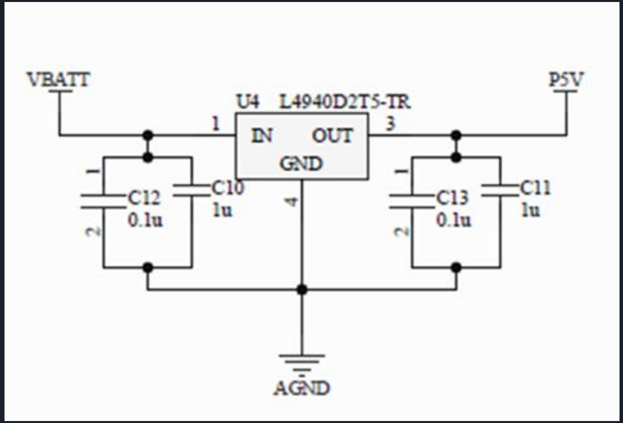


Voltage Regulator

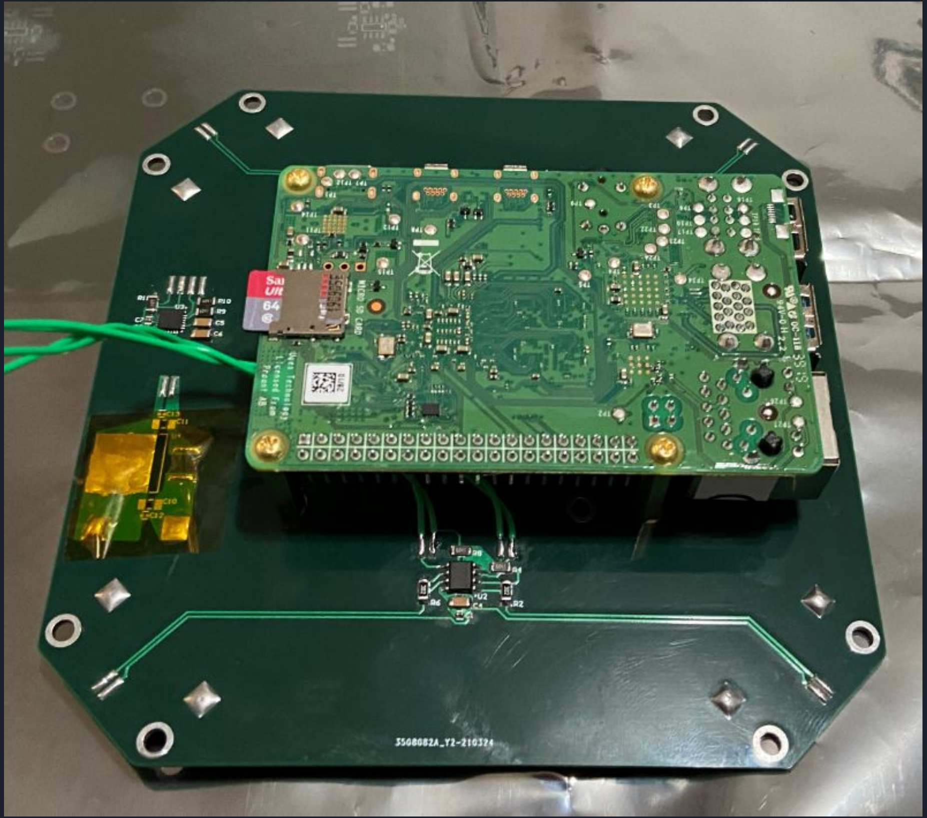


Voltage Regulator Cont.

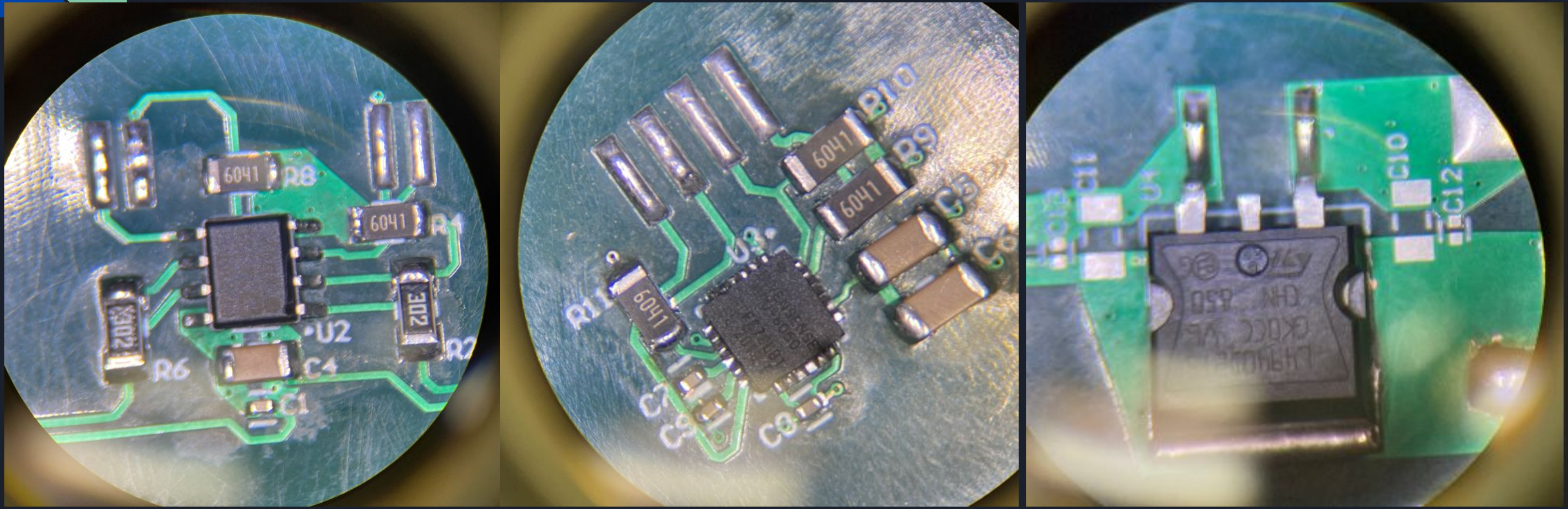




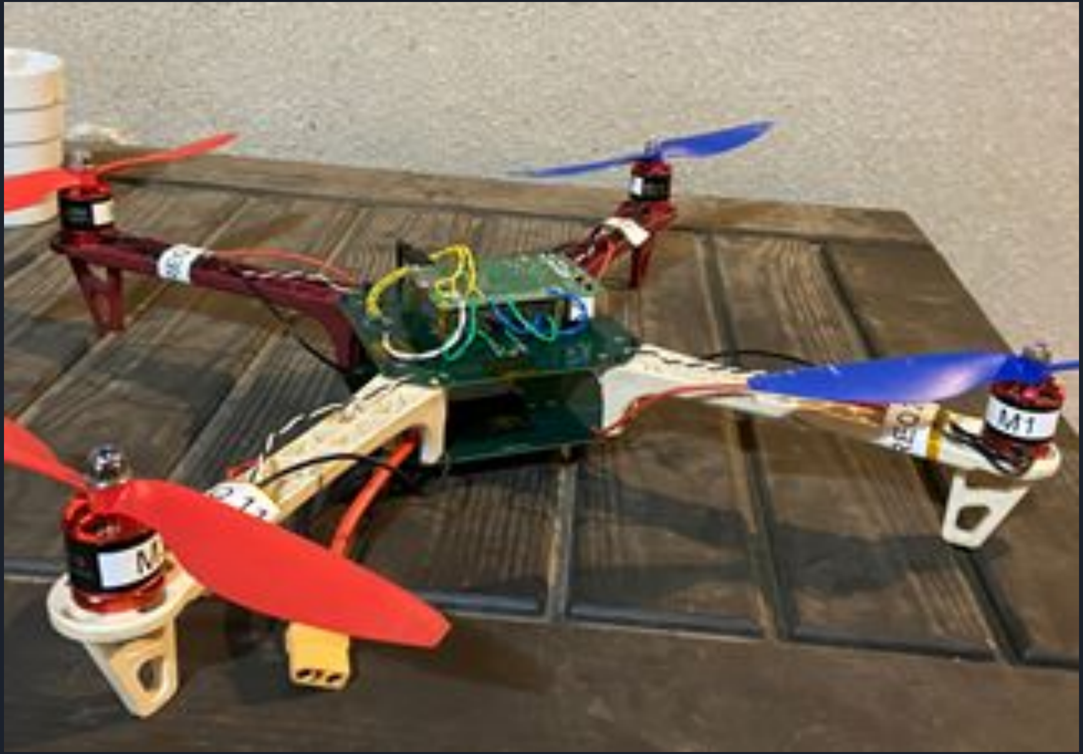
DPIE - Digital Power Interface Electronics + RPi 4



Workmanship



Final Assembly (without Battery)



Final Tests

Thank you for your time

Special thanks to Dr. Kang and the EE Department

- If you have any questions, please contact any of the members below
  - Chad Ryan
    Email: cpryan@cpp.edu
  - Kory Shopp
    Email: kshopp@cpp.edu
  - Peter Tiet
    Email: ptiet@cpp.edu
  - Liam Yeargin
    Email: lnyeargin@cpp.edu

CalPolyPomona

Music thanks to Bensound
Website: bensound.com