23-06 220Kv Module

1 Features

Performance & Control

- Low power position control
- Multi-turn position control with tunable PID/FF
- Precise to 0.022°
- Field Estimated Control: Best-in-class efficiency
- Vibration minimization via anticogging software
- Closed-loop positioning, never skips or gets lost
- Built-in minimum jerk trajectories
- Built-in linear motion conversion
- Industry-leading response times
- Voltage, PWM, Coast, Brake modes
- No minimum speed
- Silent motion
- Backdrivable

System Integration

- Motor with built-in ESC & position sensor
- Serial (UART) w/ access to control parameters, 1-2ms PWM, and step/direction input
- Compatible with open-source hardware/Arduino

Safety & Reliability

- Over-current, over-voltage, & over-temperature protection
- Access to standard & custom telemetry
- Motor health monitoring
- Safe arming procedure

2 Applications

- Robotics
- Gimbals
- CNC machines
- 3D printers
- Laboratory devices
- Automated manufacturing machinery
- Haptic devices
- Hobby/Maker devices

3 Description

The 23-06 220Kv Module is an ultra-compact, light-weight module that tightly integrates a high-performance 23-06 motor with a 30A, 6S motor controller and position sensor. It has a wide range of position applications. Its performance is comparable to or better than other 23-06 sized (NEMA 11, 28mm stepper) motors and can operate at any speed between -4,800 and 4800 RPM thanks to its sensored control. Its closed-loop PID controller tracks targets across multiple revolutions, making it ideal for applications with transmissions, both rotary and linear. This sits on top of a voltage controller, which compensates for varying input voltages. Finally, the core is a raw PWM controller. Any of the above controllers can be used by the user.

The 23-06 220Kv Module has a built-in rotary to linear calculation converter, which allows the user to communicate to the firmware in native linear units. The onboard minimum jerk trajectory generator with 32 segment queue produces smooth, human like motions with minimal computation and communication overhead from the application controller.

4 Motor Specifications

Description	Symbol	Value	Unit	Notes
Speed Constant	K_v	220	RPM/V	
Torque/EMF Constant	K_t	0.053	$\mathrm{N\,m\,A^{-1}}$	
Resistance	R	4.7	Ω	25°C
Mass	m	37.4	g	Without wires/accessories
Continuous Torque	τ_c	65	N mm	25°C ambient
Continuous Torque	τ_c	130	N mm	In airflow, 25°C ambient
Continuous Current	I_S	1.3	A	Motor current, 25°C ambient
Continuous Current	I_S	2.5	A	Motor current, in airflow, 25°C ambient
Pulsed Current	I_{SP}	5.3	A	Maximum supply voltage limited
No Load Speed	ω_0	199	$\mathrm{rad\,s^{-1}}$	@$V_{CC} = 10\,\mathrm{V}$
No Load Current	I_0	0.02	A	@$V_{CC} = 10\,\mathrm{V}$

5 Electrical Specifications

Table 1: Absolute Maximum Ratings

Description	Symbol	Min	Max	Unit	Notes
Supply Voltage	V_{CC}	-0.3	30	V	
Digital Logic Voltage	V_L	-0.3	7.3	V	3.3 V system, 5 V tolerant
MCU Temperature	T_{MCU}	-20	105	°C	Controller will self-limit performance when approaching max temperature

Table 2: Recommended Operating Conditions

Description	Symbol	Min	Max	Unit	Notes
Battery Cells	S	2	6	S	Standard Li-on/po. Use w/ caution on 6S.
Power Supply Voltage	V_{CC}	5.4	24	V	Ensure motor regen does not exceed voltage limit. Use built in regen limiter or use an external load.
Ambient Temperature	T_a	-10	50	°C	Higher possible with reduced performance

6 Electrical Interface

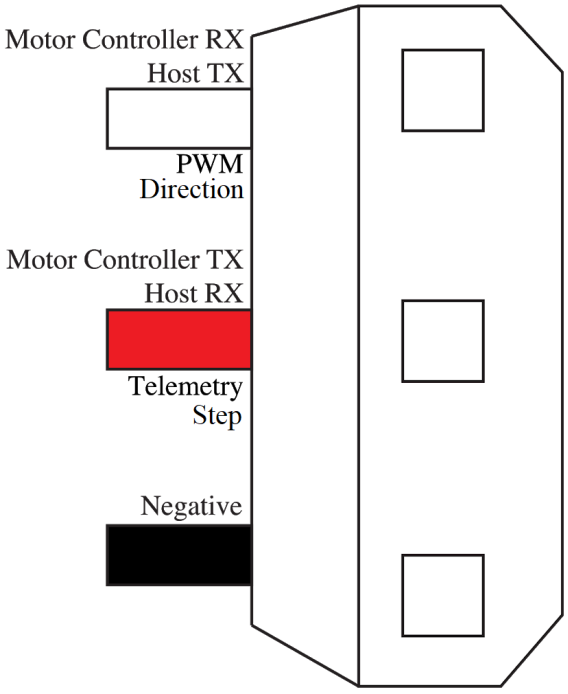


Figure 1: JR Servo Communication Connector

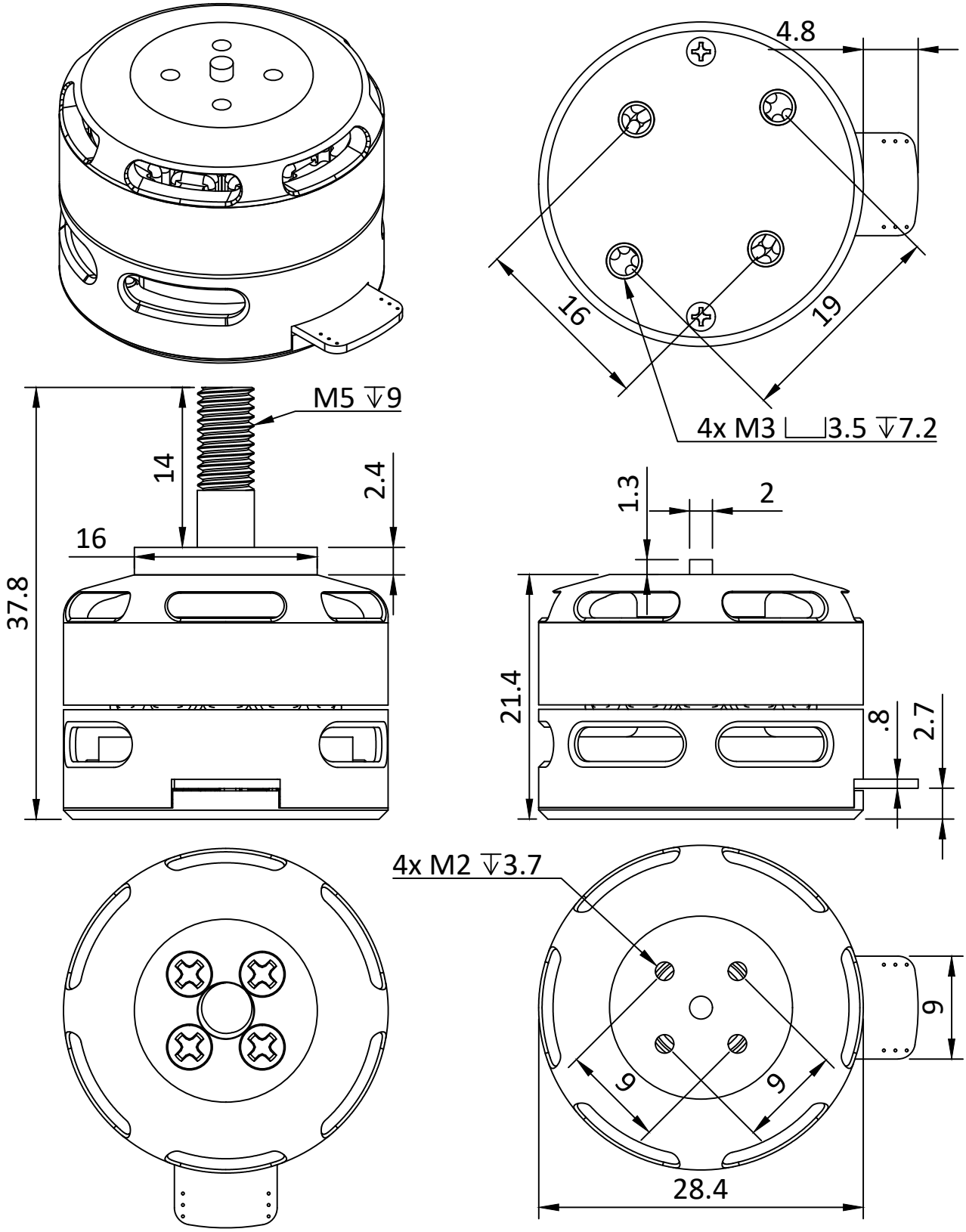
6.1 Communication Wiring

The standard communication connector is a JR type servo connector with 15cm of wire. These connectors have 0.1in spacing and can be inserted into standard perfboard and breadboards with a 3x1 0.1in male-to-male header. Black is minus (ground). Red is motor controller TX (host RX) and telemetry output. White is motor controller RX (host TX) and pwm input.

6.2 Supply Wiring

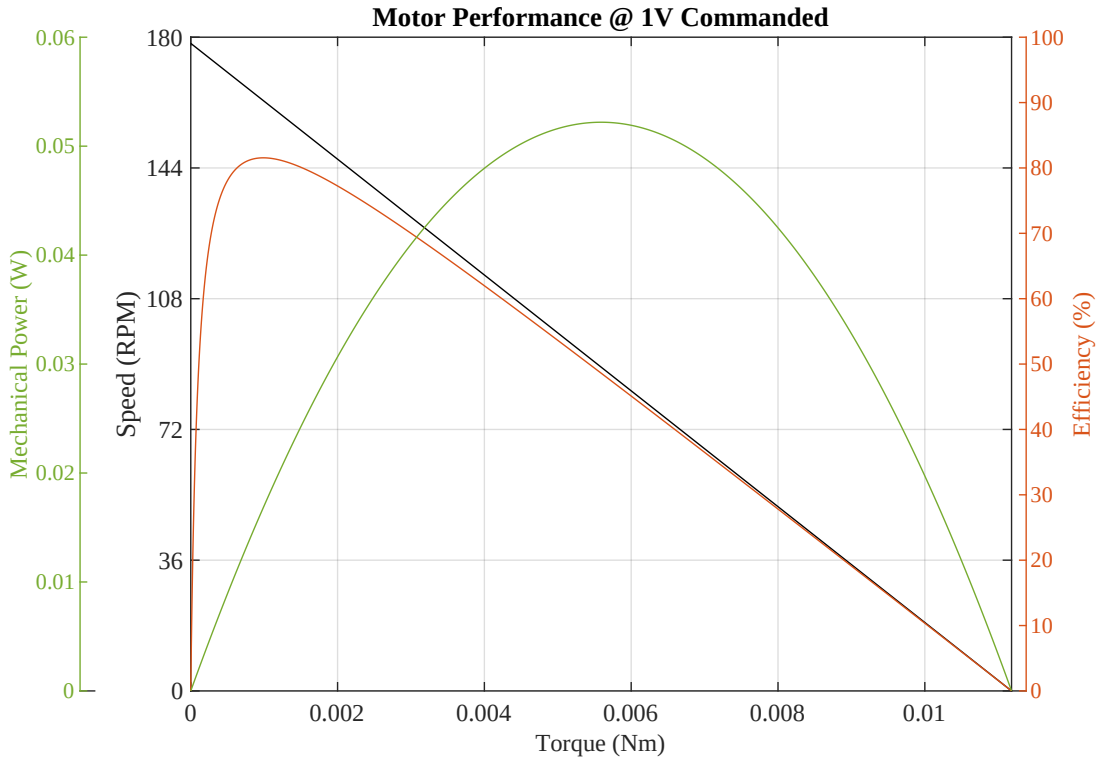
Power is transmitted to the 23-06 220Kv Module via the two supplied 16 AWG (1.31 mm^2), silicone encased, 15cm long wires. Black is minus (ground). Red is positive.

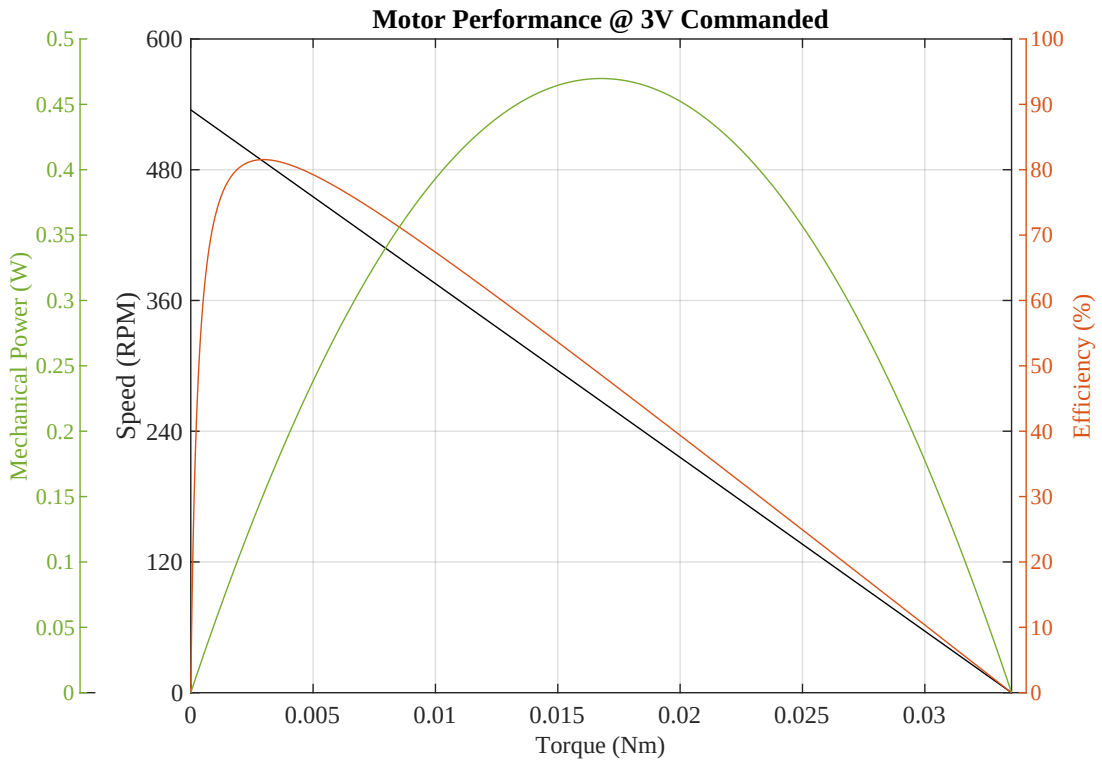
7 Mechanical Interface

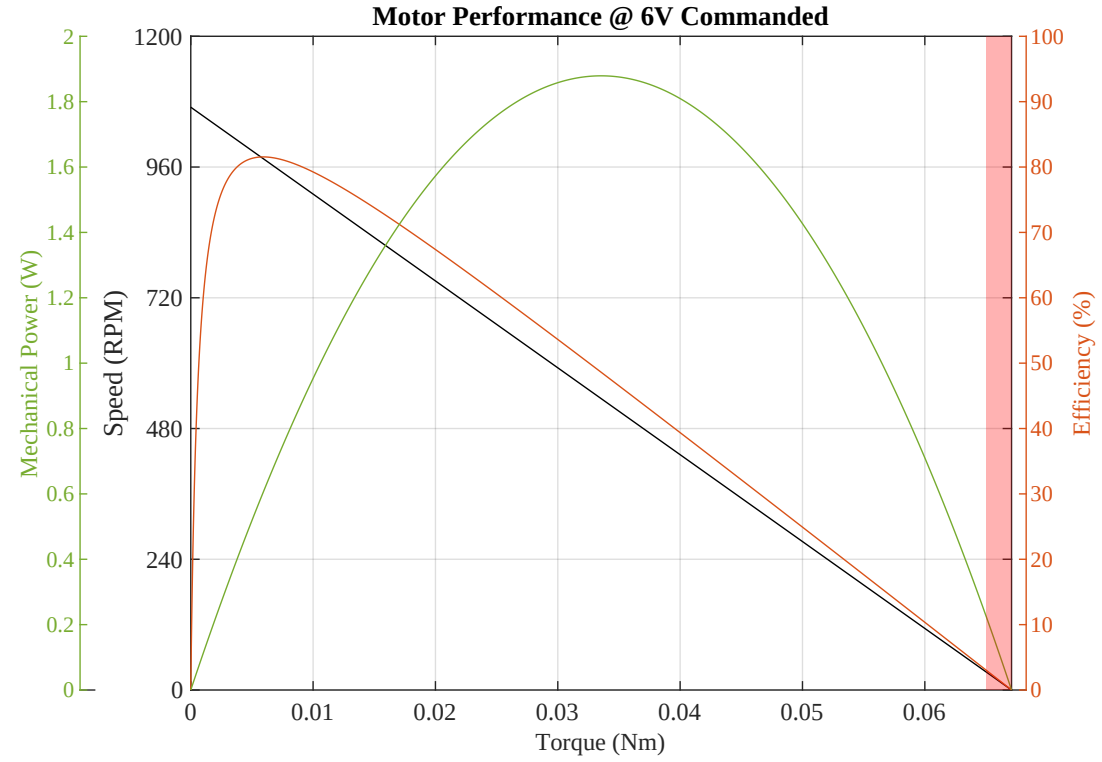


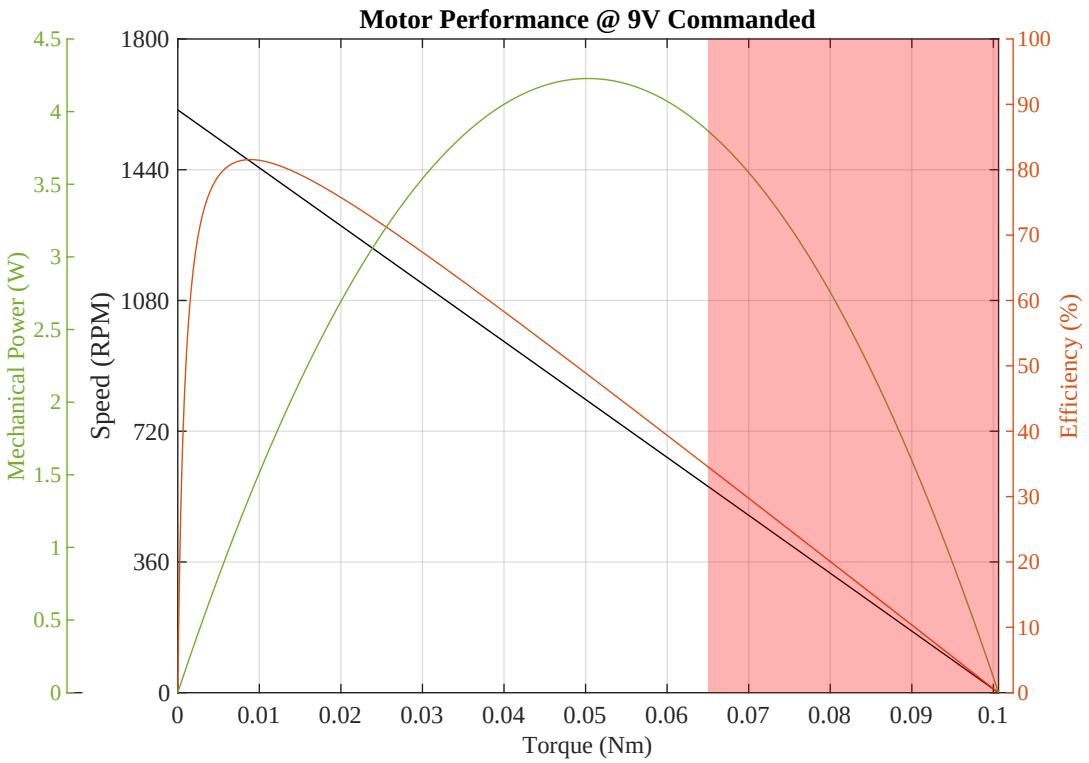
8 Motor Performance

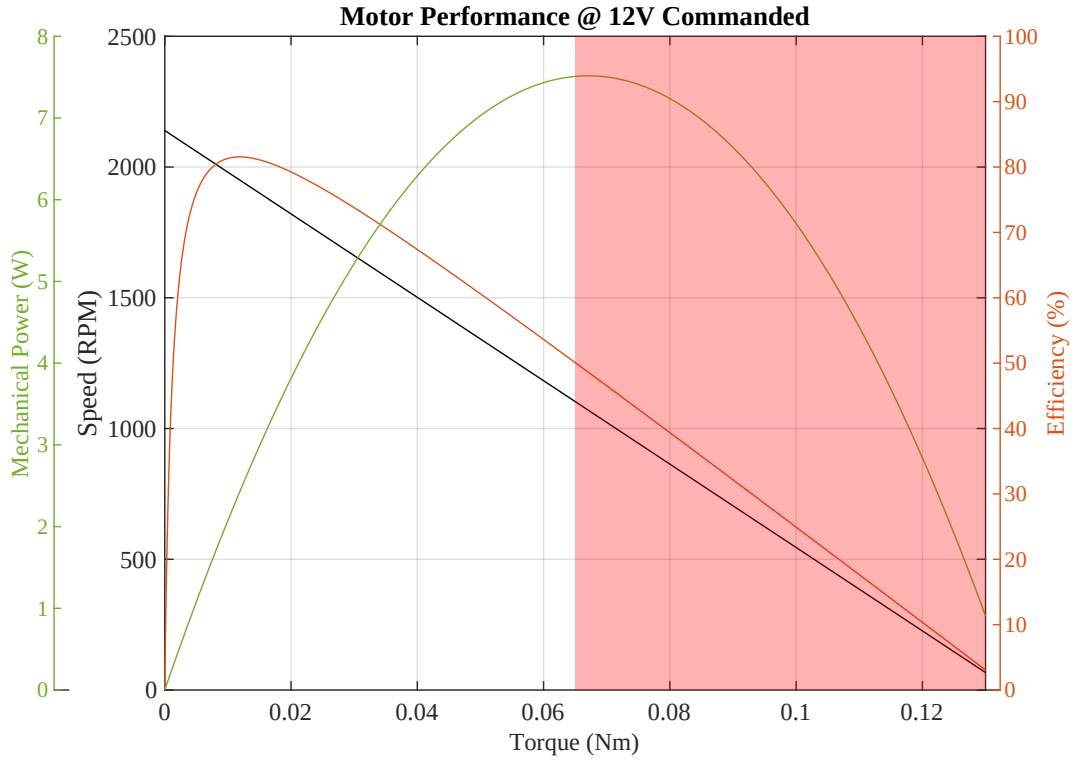
Meaning of colored area(s) on graphs:
Red area: Torque range above "still-air continuous." Note: users should be careful operating in the red area as the motor requires air cooling in this range and the amount of air flow depends heavily on the propeller.

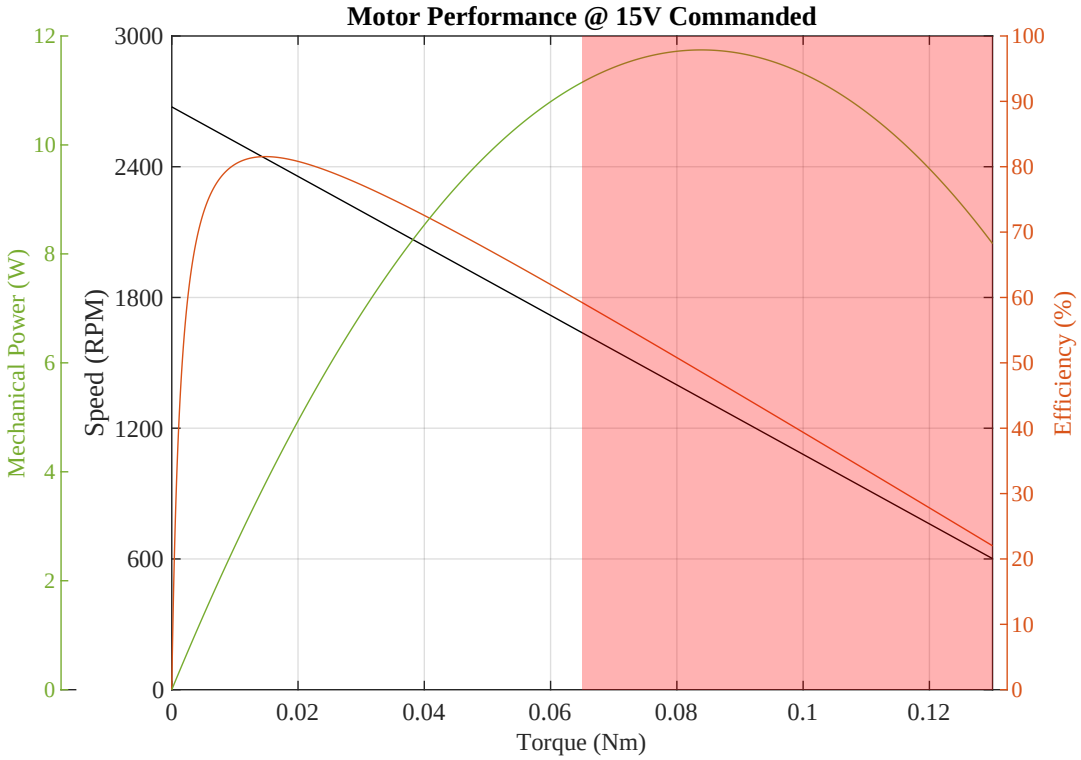


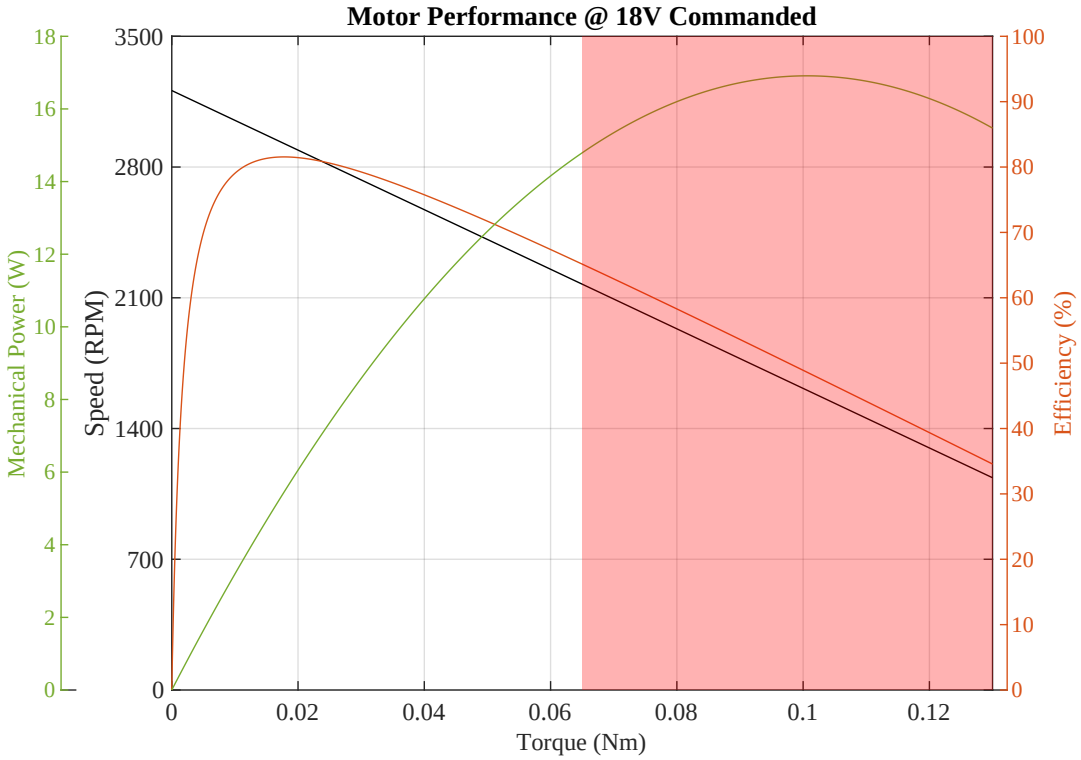

Motor Performance @ 3V Commanded
Mechanical Power (W)
Speed (RPM)
Efficiency (%)
Torque (Nm)
0
0.005
0.01
0.015
0.02
0.025
0.03
0
120
240
360
480
600
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5
0
10
20
30
40
50
60
70
80
90
100

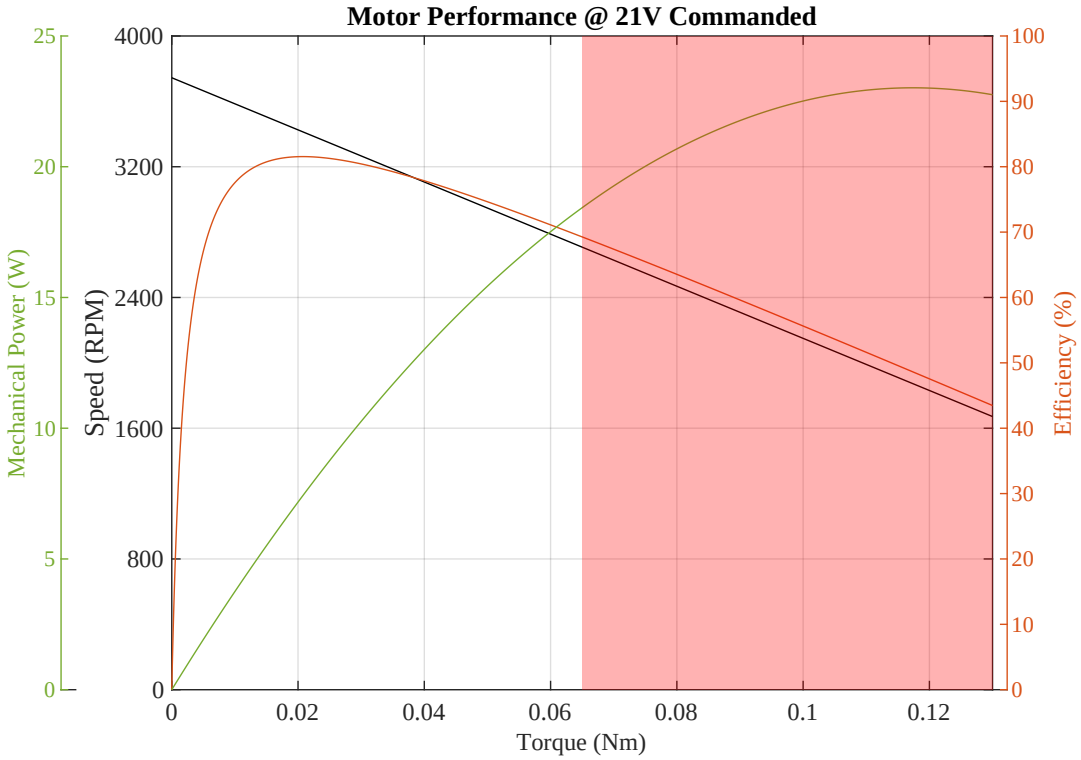

Motor Performance @ 6V Commanded
Mechanical Power (W)
Speed (RPM)
Efficiency (%)
Torque (Nm)
0
0.01
0.02
0.03
0.04
0.05
0.06
0
240
480
720
960
1200
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
0
10
20
30
40
50
60
70
80
90
100

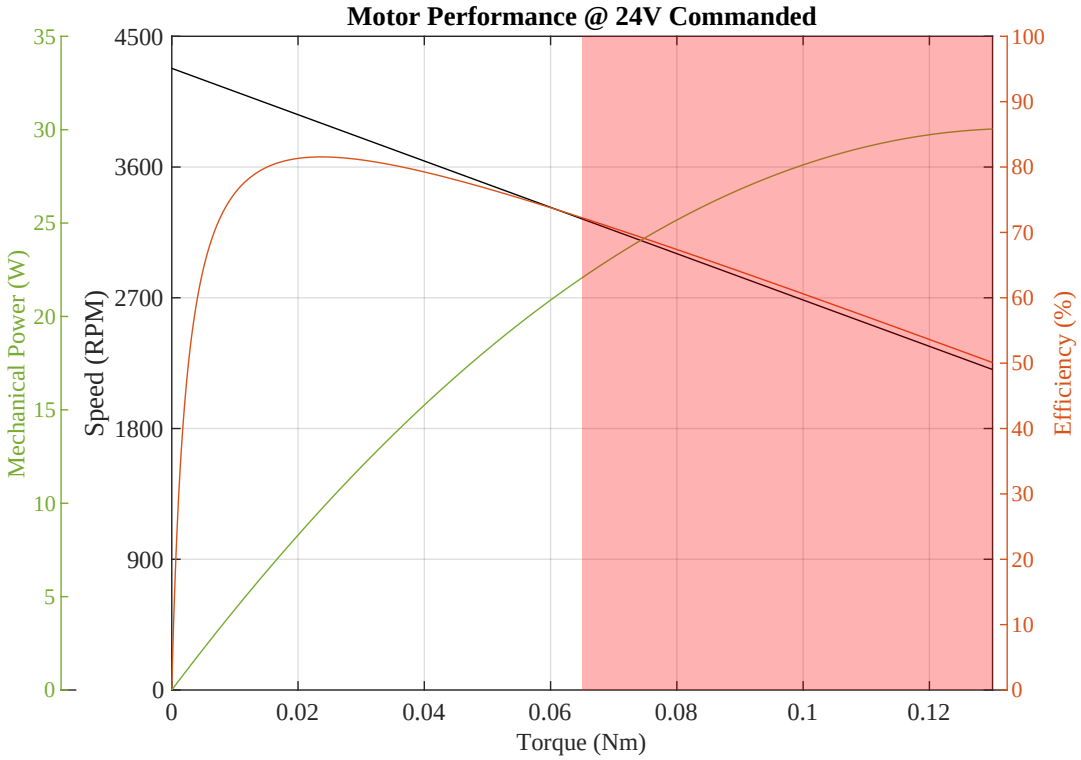

Motor Performance @ 9V Commanded
Mechanical Power (W)
Speed (RPM)
Efficiency (%)
Torque (Nm)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
360
720
1080
1440
1800
10
20
30
40
50
60
70
80
90
100
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.1


Motor Performance @ 12V Commanded
Mechanical Power (W)
Speed (RPM)
Efficiency (%)
Torque (Nm)
0
1
2
3
4
5
6
7
8
500
1000
1500
2000
2500
10
20
30
40
50
60
70
80
90
100
0.02
0.04
0.06
0.08
0.1
0.12


Motor Performance @ 15V Commanded
Mechanical Power (W)
Speed (RPM)
Efficiency (%)
Torque (Nm)
0
2
4
6
8
10
12
600
1200
1800
2400
3000
10
20
30
40
50
60
70
80
90
100
0.02
0.04
0.06
0.08
0.1
0.12


Motor Performance @ 18V Commanded
Mechanical Power (W)
Speed (RPM)
Efficiency (%)
Torque (Nm)
0
2
4
6
8
10
12
14
16
18
700
1400
2100
2800
3500
10
20
30
40
50
60
70
80
90
100
0.02
0.04
0.06
0.08
0.1
0.12


Motor Performance @ 21V Commanded
Mechanical Power (W)
Speed (RPM)
Efficiency (%)
Torque (Nm)
0
5
10
15
20
25
800
1600
2400
3200
4000
30
40
50
60
70
80
90
100
0.02
0.04
0.06
0.08
0.1
0.12


Motor Performance @ 24V Commanded
Mechanical Power (W)
Speed (RPM)
Efficiency (%)
Torque (Nm)
0
5
10
15
20
25
30
35
900
1800
2700
3600
4500
40
50
60
70
80
90
100
0.02
0.04
0.06
0.08
0.1
0.12

9 Safety Features

9.1 Over Current Protection

The ESC uses a predictive method for over current protection. The motor controller will not apply a voltage which would put the controller or motor at risk of over current. This is in contrast to a reactive current controller, which only performs limiting once large currents have been detected, and thus already put the hardware at risk.

9.2 Over Temperature Protection

The controller has an onboard temperature sensing circuit. If the temperature sensor detects a temperature that is approaching the controller's maximum temperature limit the controller will begin to derate, resulting in lower speeds and torques than expected. The controller will continue outputting as much power as possible without exceeding its thermal limit. If the temperature drops the controller will automatically exit derate mode and continue normal operation.

Though there is no temperature sensor in the motor's coils, the controller contains a predictive model which estimates the coil temperature. The same derating process as above is applied to the estimated coil temperatures, applying as much power as possible without causing damage. This protection ensures that large loads or stalled conditions do not overheat and damage the motor coils and magnets.

9.3 Over Speed Protection

A soft limiter will reduce the voltage applied to the motor once ω_{max} is exceeded. The farther the speed is above ω_{max} the lower the output voltage of the controller. In extreme overspeed situations the motor acts as a brake, effectively shorting the three phases of the motor together. This will protect the motor from extremely large load changes, poor PID tuning values, and the unlikely chance of a runaway condition. This feature will fight an externally applied load that causes an over speed, but is not able to guarantee the prevention of an over speed condition in this situation.

9.4 Regeneration Voltage Protection

The 23-06 220Kv Module is a four quadrant motor-controller, which means it can both motor and generate in both directions. One problem when the motor is generating is the voltage can spike if the connected electronics cannot absorb the energy that is being generated. Power supplies cannot generally absorb energy, while rechargable batteries and capacitors can. This leads to a voltage spike that may destroy the motor and any attached equipment.

The controller prevents these spikes from occurring by limiting the voltage applied to the motor. If an out of allowable range generation occurs, the motor will decrease its own generation, thereby protecting the circuitry. This protection does not prevent the damage from externally applied voltages.

9.5 Command Timeout Protection

A user settable timeout automatically puts the motor in to coast mode if it does not receive a message valid message within a specified amount of time. The normal operation resumes upon receiving a new message.

9.6 Input Connection Protection

All exposed pins are protected with ESD diodes and a small amount of reverse polarity protection. Do not knowingly or intentionally apply reverse polarity or out of limit voltages to the exposed pins.

9.7 Watchdog Protection

In case of an unlikely error in the controller that causes it to freeze, the controller will automatically reboot. While this may allow for a recovery, all normal startup procedures are re-performed and any arming sequence or auxiliary commands must be redone.

10 Revision History

Table 3: Revision History

Version	Date	Changes
1.0	2019-03-05	Initial Version
1.1	2022-08-24	Update images and description, add version history