RoboClaw Tutorial Report

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ME 14

1. Getting Started

Learning Objective: By the end of this section, you will gain familiarity with how brushed motors are typically spec'd, which will help you in later classes when it comes time to select your own motors for projects. Each group will be supplied with a 30-Amp or 60-Amp Dual Channel Roboclaw and brushed motors. Before interacting with these components, please answer/complete the following questions:

1. *Install BasicMicro Motion Studio using this link.*

2. *Report the following specifications associated with your Roboclaw:*

   The data was found in the following document:
   https://downloads.basicmicro.com/docs/roboclaw_datasheet_2x30A.pdf
   - Peak Current per Channel: 120 A
   - Continuous Current per Channel: 60 A
   - Max Voltage: 34 V

3. *Compare brushed and brushless motors. Which applications are brushed motors better suited for, and which applications are brushless motors better suited for?*

   - Brush motors use physical brushes to transfer electrical energy into the motion of the rotation. As was discussed in lectures, the brushed motors have a commutator ring which rotates and in its rotation interacts with different magnetic and electric fields. These interactions lead to the continuous motor motion while for a brushless motor, it uses a permanent magnet instead of the brushes.
   - Brushed motors are cost-effective but they require more maintenance as the brushes can get worn over a long time of using the motor. Brushless motors are a bit more expensive but require less maintenance when considering the operation over time. This means brushless are typically better for a longer lasting application.
   - Brushed motors have high torque which makes them good for applications where there would be a higher torque requirement. For example, if a motor was being used to pull an object, that requires high torque, and a brushed motor would be good to use.
   - Brushed motors have a lower speed range (due to the limitation of the electrical input it is taking in and friction within itself), while brushless motors have a slightly higher speed range so the brushless motor should be used for high speed applications.
   - Finally, brushless motors also tend to give more efficiency so the power input to output is better.

4. *Define the following quantities for brushed motors:*

- no-load speed: the maximum speed the motor can read when no load torque is applied
- no-load current: the lowest current through a motor at which no load torque is applied
- stall torque: the maximum torque a motor can generate at which the motor has no speed
- stall current: the maximum current that occurs at the stall torque

5. *Find the above quantities associated with this brushed motor (https://banebots.com/m7-rs775-24/) and graph the corresponding motor performance curves (speed vs. torque, current vs. torque, output power vs. torque, and efficiency vs. torque). What is the motor's maximum efficiency, and what is its speed at maximum efficiency?*

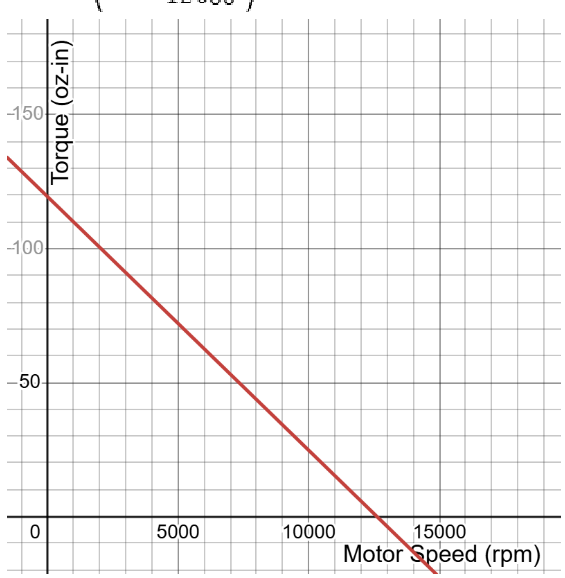
   Based on the motor specifications document the following are the no-load speed, the no-load current, the stall torque, and the stall current for the brushed RS775 Motor - 24V:

   - no-load speed: 12600 rpm
   - no-load current: 0.85 A
   - stall torque: 119.43 oz-in
   - stall current: 59A

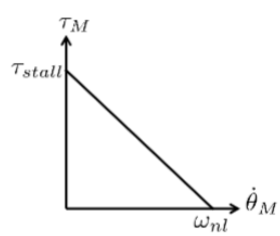
   Graph equations for the graphs are here: Lecture 17 and Lecture 19 slides
   https://caltech.instructure.com/courses/8378/files/1896530?module_item_id=323387
   https://caltech.instructure.com/courses/8378/files/1897430?module_item_id=323717

Speed vs. Torque

$$119.43\left(1-\frac{x}{12600}\right)$$



Motor Torque-Speed Curve



$$\boxed{\tau_m = \tau_{stall}\left(1-\frac{\dot{\theta}_m}{\omega_{nl}}\right)} \quad (12)$$

where: τ_M = motor torque

$\dot{\theta}_M$ = motor speed

τ_{stall} = stall torque

ω_{nl} = no load speed

Left: graph for the motor specified and Right: Professor Mello notes on speed vs. torque

Current vs. Torque

7.1 Current as a Function of Torque

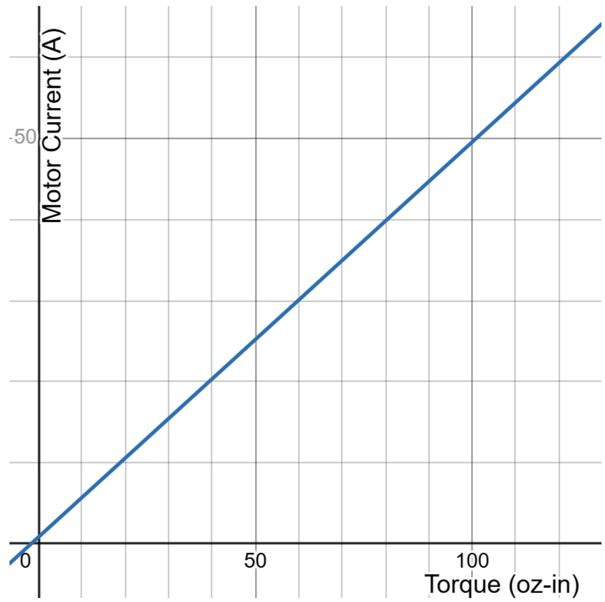
From standard linear approximations of brushed DC motor behavior, the current draw increases linearly with torque:

$$\boxed{i_M = i_0 + (i_s - i_0)\frac{T_M}{T_s}} \tag{24}$$

where:

- i_0 is the no-load current,
- i_s is the stall current,
- T_M is the motor torque at a given instant,
- T_s is the stall torque.

$$0.85 + \frac{(59 - 0.85)}{119.45}x$$



Left: Professor Mello notes on current vs. torque and Right: graph for torque vs current

Output Power vs. Torque

$\boxed{P_{out} = -K_m^2\omega_m^2 + \left(\frac{K_t}{R}u\right)\omega_m}$ (14) restated

Output power of a motor: $P = T_m\omega_m$

Combining with $\frac{\omega_m}{\omega_0} + \frac{T_m}{T_s} = 1$

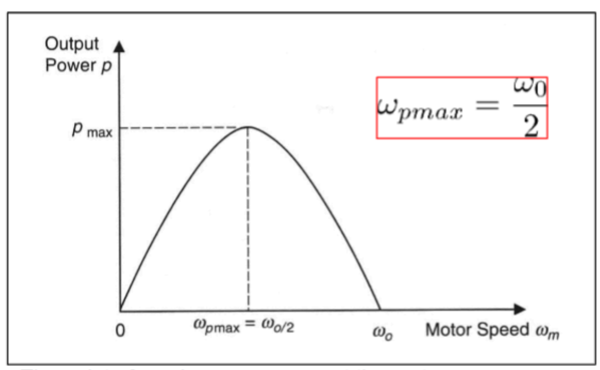
Yields:

$$p = T_s\left(1 - \frac{\omega_m}{\omega_o}\right)\omega_m$$

Quadratic profile recovered

Maximum Power: $\boxed{p_{max} = T_s\omega_0}$

("Take derivative of p and set = 0")

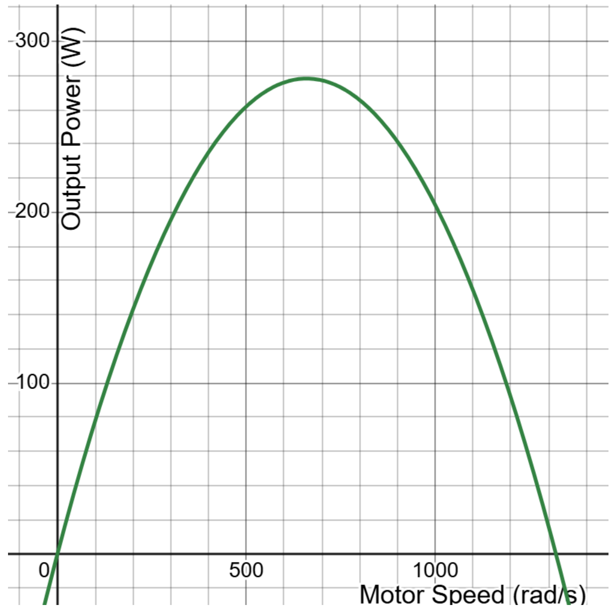


The point of maximum power as at the vertex of the curve.

Above: Professor Mello notes on speed vs. power output

Stall torque: 0.843361133 N-m, no-load speed: 1319.468913 rad/s

$$0.843361133\left(1-\frac{x}{1319.468913}\right)x$$



Above: The graph of output power vs motor speed

Solving for motor output power vs. motor torque:

$P = \tau_m w_m$

$\dfrac{w_m}{w_o} + \dfrac{\tau_m}{\tau_s} = 1$

$w_m = \dfrac{P_{out}}{\tau_m}$ so combining

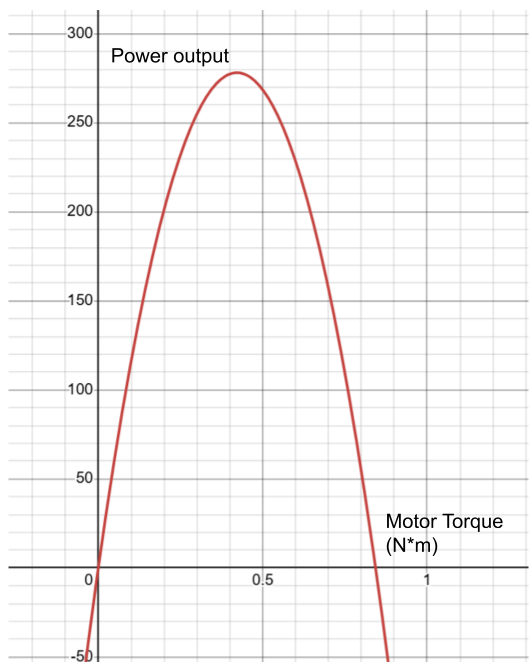
$$\frac{P_{out}}{\tau_m(w_o)} + \frac{\tau_m}{\tau_s} = 1$$

$$\frac{P_{out}}{\tau_m(w_o)} = 1 - \frac{\tau_m}{\tau_s}$$

$$P_{out} = \tau_m (w_o)\left(1 - \frac{\tau_m}{\tau_s}\right)$$

$w_o = 1319.46$ rad/s

$\tau_s = 0.84336$ N.m



Above: The graph of output power vs motor torque

Efficiency vs. Torque

9.3 Efficiency as a Function of Torque

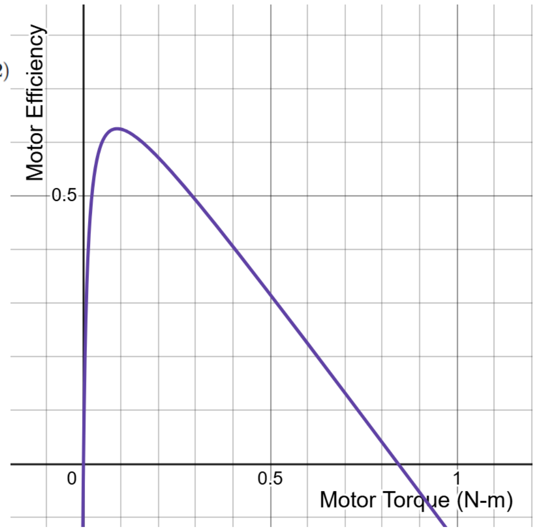
An alternative but equally practical approach is to express efficiency in terms of motor torque. Starting from:

$$\omega = \omega_0 \left(1 - \frac{T}{T_s}\right),$$

we substitute this into the original definition of efficiency:

$$\eta(T) = \frac{T\omega_0 \left(1 - \frac{T}{T_s}\right)}{V\left[i_0 + (i_s - i_0)\frac{T}{T_s}\right]} \tag{32}$$

$$\frac{1319.468913x\left(1 - \frac{x}{0.843361133}\right)}{24\left(0.85 + \frac{(59 - 0.85)x}{0.843361133}\right)}$$



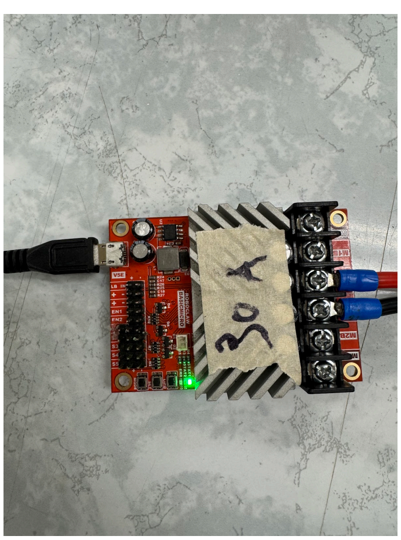
Left: Professor Mello notes on efficiency vs. torque and Right: graph for efficiency vs torque

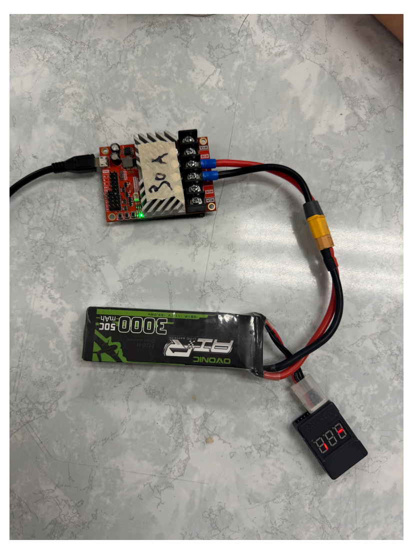
The maximum efficiency of the motor is 62.6% of the input power. Torque at maximum efficiency is 0.09038 N-m, so the speed at maximum efficiency is 11250 rpm.

2. Gaining Control with Motion Studio

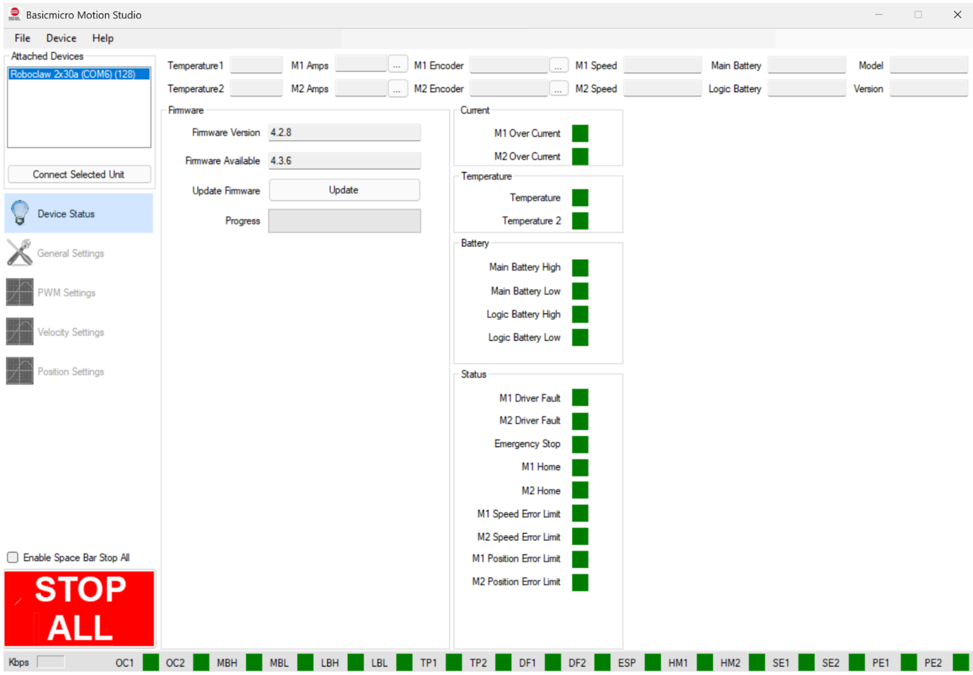
1. Powering your Roboclaw. Please submit a picture of your setup and the LEDs on your Roboclaw.

- a. *Ensure that the voltage being supplied by your Lipo does not exceed the max voltage of your Roboclaw.*
- b. *The positive lead from the battery must go to the ”+” terminal and the negative lead to the ”-” terminal. Reversing these will damage the Roboclaw.*
- c. *After connecting your battery, verify that STAT1 LED is green. If it is not, or if ERR is red, disconnect and seek help.*

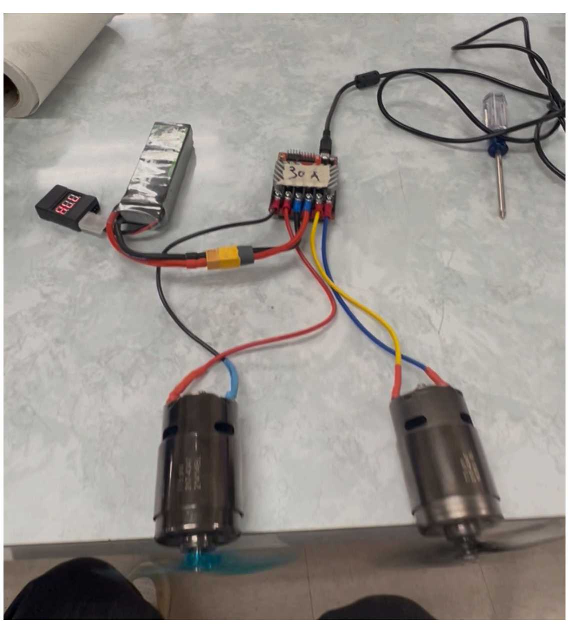


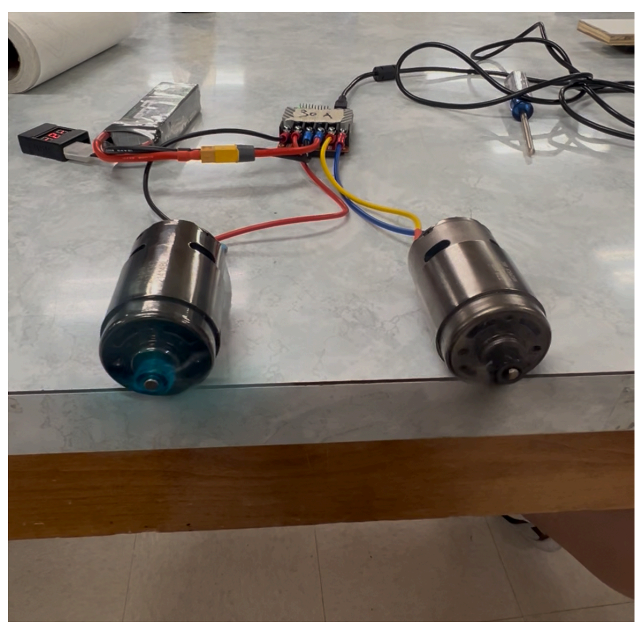


2. *Connect your Roboclaw to your computer using a micro USB cable. Open Motion Studio and verify that you see your Roboclaw in the upper left pane of the application. Submit a screenshot showing this.*



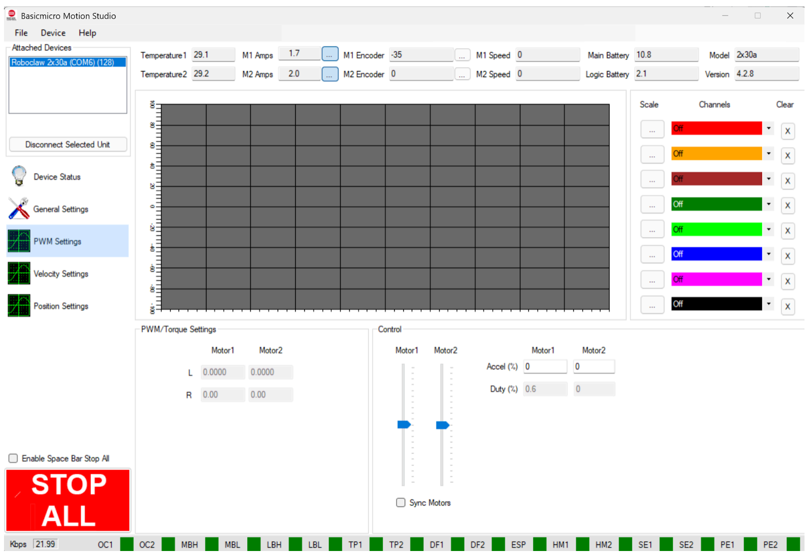
3. *Disconnect your Roboclaw from your computer and from the Lipo.*
4. *Wire both motors to the two motor channels on your Roboclaw (see Figure 1). Please submit a picture of your setup.*
    a. *The A/B terminal polarity determines direction. Incorrect wiring will not damage anything—it just reverses polarity.*





Video of our roboclaw:
https://drive.google.com/file/d/1w0cgb2NzFtORET0ZEG-i_tiqfyUSlA6p/view?usp=sharing

5. *Reconnect your Roboclaw to the Lipo and computer. Open Motion Studio and click "Connect Selected Unit." Under General Settings, find "M1 Max Current" and "M2 Max Current." Set both at or below the continuous current rating.*
6. *Control your motors using Motion Studio. Verify that both motors are running in the same direction.*
    a. *Go to "PWM Settings" in the left-hand panel. Slide the sliders for Motor 1 and Motor 2 (see Figure 2).*
    b. *If motors spin opposite directions, switch the leads for one motor (after disconnecting power).*



3. Understanding Motion Studio Settings

Learning Objective: By the end of this section, you will understand the different settings used to control motors with a microcontroller.

1. *Compare "Packet Serial Mode" and "Simple Serial Mode" on the Roboclaw. Refer to tutorials linked at the bottom of this website and the user manual. (https://resources.basicmicro.com/roboclaw-motor-controllers-getting-started-guide/ and https://downloads.basicmicro.com/docs/roboclaw_user_manual.pdf)*

   Simple serial mode consists of single-byte one-way commands from the controller to the Roboclaw. Simple serial mode is limited to only basic motor control which means commands are sent to the motor but it is limited in that data is not being sent back so there is no error checking. Packet serial mode consists of multi-byte packets for communication and supports two-way communication as the controller can send commands and receive data from the motor as well. This configuration may involve a microcontroller and compared to the serial mode allows for more error checking (as data is also received back and can be reviewed) and this allows for overall more control of the motor.

2. *Describe the differences between "RC Mode" and the serial modes. What are the benefits/drawbacks of RC Mode versus serial control?*

   RC mode has the motor controlled by an RC radio or a controller generating PWM signals (such as the servo pulses which are mentioned in the roboclaw user manual). Both serial modes involve controlling the motor using bytes. The benefit to using the RC mode is that it allows for real-time remote control of the motor so the motor could be a distance away from where the signal is sent from to turn it on. However, the drawbacks are that there is no motor feedback to the controller which leads to slightly more limited motor control. Serial modes have more complex motor control with feedback if using packets for communication, but the packet serial mode is more complex to set up.