EN2532 Robot Design and Competition
User Guide - 01

Title: Understanding practical usage of Brushed DC motors

1. Introduction

Brushed DC motors are the most convenient to be used in ground mobile robots as propulsion units. The specifications for the provided motors can be found via the link, https://www.pololu.com/product/3216/specs.

2. Theoretical Background

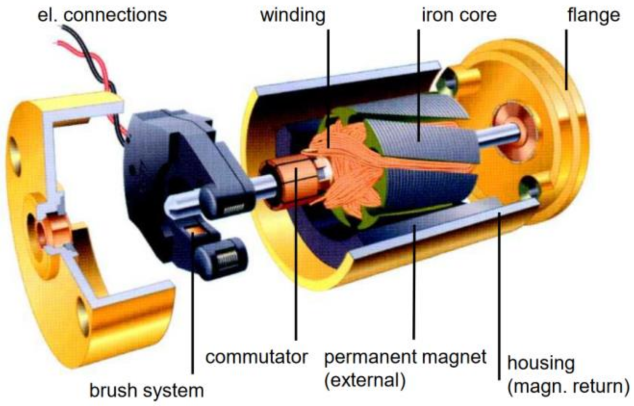

Figure 01: Internal architecture of a conventional brushed DC motor.
Reference: https://www.maxongroup.com/medias/sys_master/8803450421278.pdf

When the current is passing through, the winding of a brushed DC motor generates the electromagnetic torque that is required to turn the rotor (moving component of the motor consisting winding, iron core and commutator as in Figure 01). However, when the rotor is stalled, there is no back electromotive force acting on the winding unlike when the rotor is turning, therefore, the winding current as a result of the supplied voltage divided by the winding resistance becomes the maximum (stall current). Then the supplied energy is purely dissipated as heat. The winding of the motor has a very low heating capacity therefore can quickly rise in temperature due to the joule power losses (I^2R power losses).

The housing of the motor has a better heating capacity, therefore will not rise in temperature quickly. Therefore, even if you unsafely operate the motor in near stall conditions, it is impossible to observe the winding temperature through the housing temperature. Overheating can cause immediate and irreversible damage to the motor winding, thus resulting in low performing or a burned motor.

According to Pololu motors, a good general rule of thumb is to keep the continuous load on a DC motor from exceeding approximately ***20% to 30% of the stall torque***.

3. Underpowering the motors

Even though the motor is ***rated for 12V***, you are expected to underpower the motor at a lesser voltage during the testing and evaluation stages. The purpose of underpowering is to reduce the stall currents if the condition ever occurs. However, you must make sure that stall conditions do not occur throughout any stage of operations.

The stall current at 12V is 5.6A but will be reduced to approximately 3.6A at 9V, 4.2A at 10V and 4.8A at 11V.

4. General guidelines for using the motors provided by the university

- ❖ The motors are QR coded, appropriately tested, and recorded before handing over to your group. Proper care must be taken to return them again in the same condition given to you.

- ❖ As mentioned above, operating the motor at 20% to 30% of the stall current conditions is a guarantee from the manufacturer that the motor can be run indefinitely without burning out the internal winding. Usually that percentage is calculated assuming the environment is kept constant at 25^0C and motor is not covered by any enclosure. Since those conditions are always not achievable, 20% is a good margin you can operate.

- ❖ That does not mean that you cannot exceed 20% of stall current for any reason. When you exceed the value, you no longer can operate the motor indefinitely and should limit the on-time and let the winding cool down afterwards. At the extreme condition of 100% stall current, it is usually seconds before the winding heats up exceeding the rated temperature and burning out. You can theoretically stall a motor for a very small time, but avoiding the condition is the safest.

- ❖ It is a good practice to use a ***DC-DC switch mode voltage*** converter to power the motor. Since it can regulate the voltage, behavior of a motor for a given PWM value will approximately be constant irrespective of the primary battery charge level. The DC-DC converter should be rated considering the stall conditions of the motors for the safety of the converter.

- ❖ Understand the difference between a motor controller and a motor driver. An example motor driver that can be used to power the provided motors by Pololu is shown in the Figure 02. It is mandatory in robotic applications to compare and match the ratings of the motor and the motor driver. The connections shown in Figure 02 are fundamentally required to basic operations of the motor. However, depending on the motor driver of your choice, optional functionality may be available. For example, ‘CS’ in the Figure 02 stands for ‘current sensing’ and can provide a feedback to the microcontroller regarding the instantaneous motor current drawn by the motor.

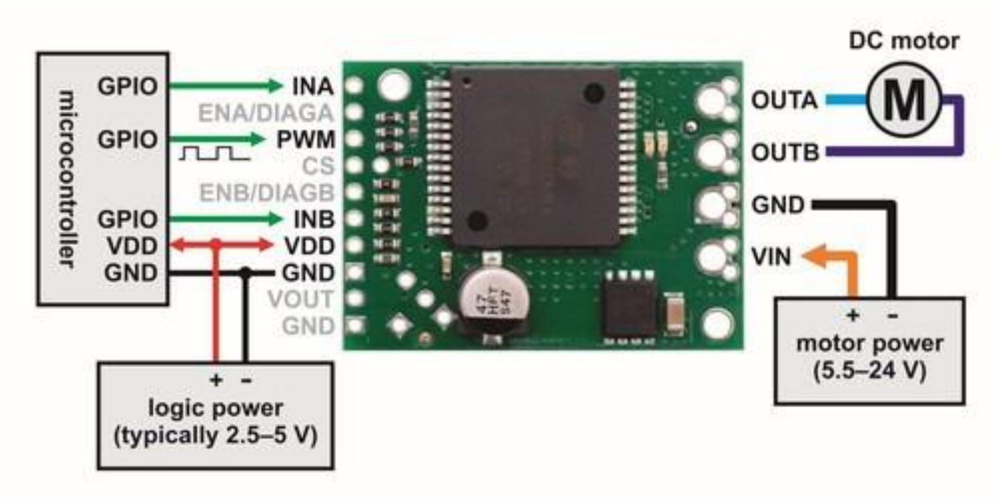

Figure 02: A Pololu motor driver and the connection diagram

Reference: https://www.pololu.com/product/1451

❖ The motor driver should be rated considering the stall conditions of the attached motor for the safety of the motor driver.

❖ When you are giving commands to the motor via the microcontroller, it is a good practice to give smooth commands rather than step like commands. Gradual incrementations in the command values starting from the initial conditions is vital to avoid current spikes generating inside the motor, therefore, to the safety of the motor. An S-curve profile is argued to be a good commanding profile for the velocity of a motor and is shown in the Figure 03. In this profile, velocity increases from zero and gradually rises to the maximum velocity and then gradually descends.

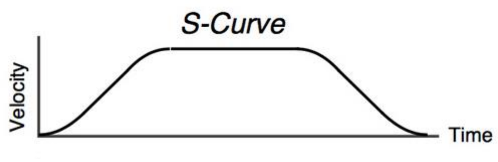

Figure 03: S-curve velocity command profile

Reference: https://www.linearmotiontips.com/how-to-reduce-jerk-in-linear-motion-systems/

We encourage you to do your own research and utilize a safe and innovative power subsystem for your robot. Please contact the respective instructors for any clarification.