Determining Electric Motor Specifications for a LEGO NXT project

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Abstract

There are many electric motors that are available commercially. Deciding which one to use for a given application can sometimes be daunting. For instance, a layman might consider a servo motor to be special type of motor built in a unique way to give it its precise control. The goal of this Application Note is to give guidance to an individual seeking to find a motor candidate for building a servo motor. A general overview of various motor types is given. The focus of this paper discusses the process for choosing a motor to be used for a precise speed, and position function. This paper assumes the reader is familiar with basic circuit theory and signal processing as well as the physical phenomena used to describe the operation of motors.

Keywords:

Rotor
Stator
Encoder
Power
Torque

Introduction

Two characteristics above all others determine the specification of a motor: the power of the motor, and how fast the rotor turns. This Application Note begins by introducing several common electric motor types, and some methods for controlling them. The focus of the application note will be process of determining the specifications of a DC motor that is to be controlled as a servo motor by a microcontroller, in this case, a LEGO NXT brick.

Common Motor Types

DC Motor

The DC motor is what will be used in the servo motor. The DC motor is common in small load applications because they work with batteries without the need for additional control mechanisms. The primary disadvantage of a DC motor is that the rotor speed is very high in comparison to other electric motors. This problem is often over come through the use of gear trains, which have the added benefit of increasing torque.

Stepper Motor

The stepper motor is a motor made specifically for precise control. The rotor has many teeth and has a shape similar to that of a gear. The stator is made from windings that are electrically independent of each other and spaced evenly around the rotor. An electronic control mechanism turns on the windings one at time which a produce a magnetic field that draws the nearest tooth on the rotor to align with the stator. The teeth of the rotor are spaced so that they are always out of position with the next in line winding. These motors have the disadvantage of having decreased torque as the rotor speed increases.

Induction Motors

These two or three phase AC motors have been used extensively in industry. For the purpose of building a servo mechanism a two phase system would be the simpler solution. These motors deliver maximum torque at frequency below the frequency of the supply. To operate induction to produce maximum torque at any frequency requires the use on an inverter.

Synchronous Motor

These polyphase motors can be similar to induction motors in construction. The motors differ in how torque is created. The induction motors induces an AC current in the windings of the rotor. Synchronous machines develop torque between the rotating magnetic field of the stator and a stationary magnetic field in the rotor. The stationary field can be created from a DC electromagnet or a permanent magnet.

The Problem:

You have a system which requires a precise and accurate motor control system. The speed of the system is of importance, and there is a high torque requirement, bigger than a LEGO NXT servo motor can provide. Also, the control system of this motor drive has already been determined to be the LEGO NXT brick. All control for the motor will have to be compatible with this system. Therefore, the challenge is find a motor that matches or exceeds torque and power requirement, and is compatible with the given control system. The first step in designing the system is to determine the power and torque requirements of the motor. These two specifications will determine the size of the motor.

Determining Power and Torque Requirements

The two equations for determining torque and power are shown below:

$$Torque = Force * Length\ of\ Moment\ Arm$$

$$Power = Torque * Angular\ Velocity = Voltage * Current$$

If you have a known load that the motor must be capable of turning it is possible to measure the torque requirement for the motor. There are several ways to do this such as using a torque wrench, but for the poor man there is also a solution. A string can be tied to the axle of the load. The radius of the axle will be length of the moment arm. By tying a known mass at end of the string the torque required to move the load can be determined by the size of the mass used. It is recommended that a safety factor be added to the torque requirement. While the smallest mass possible might turn the load, it would not rotate fast, and the motor purchased with the minimum torque most likely would not operate well for most practical purposes.

Now that the torque requirement of the system is known it is possible to calculate the mechanical power necessary to rotate the load at the maximum desired speed. Now that the mechanical power is known this value transfers directly into the power the motor will be required to output.

Creating a servo motor

The LEGO NXT comes with three servo motors. These servos are powered by a DC motor, controlled through a through a closed loop transfer function through a rotary encoder, and through PWM power control. After measuring the torque and power requirements of the system the size of the motor can be determined. By taking apart a LEGO servo motor it is possible to remove the rotary encoder from the motor. Using this as the control mechanism the new DC motor is automatically compatible with the LEGO NXT control format. There are now two things to consider. First, the gear train of the LEGO servo motor reduces the mechanical frequency of the system from that of the rotor frequency. Therefore, in the new control program the desired mechanical speed will be a product of the rotor speed times the LEGO NXT's reduction ratio divided the reduction ratio of any gear train that the new motor may have. The second thing to consider is how to supply power to motor that is beyond the 9VDc the NXT brick is capable of providing. This problem can be solved by using MOSFETs in an H-Bridge as switches to a larger power supply. The PWM signal from the NXT brick then becomes a control signal instead of a power supply and controls the MOSFETs.

References

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