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A Guide to Selecting the Right Miniature DC Motor

Introduction

Miniature DC motors (2mm to 80mm diameter) are used in a wide variety of applications.
But not all miniature DC motors are created equal. Furthermore not all types of DC motors are suitable for all applications.

When selecting an appropriate miniature DC motor, there are a number of factors to consider including torque, speed, operating mode, operating environment. At the same time, there are many considerations such as cost, precision and lifetime that may affect suitability.

A working knowledge of the various motor technologies and their applications will greatly improve your likelihood for success.

Know your system

Naturally, for any application – be it agricultural, scientific, military, medical or industrial – you are looking for the most efficient solution. For example the reliability and lifetime of the motor must justify the financial outlay.

By doing the required research in advance, you can ensure the best possible outcome, reducing the risk of costly maintenance further down the track. It can also save time in getting your system running smoothly and your product to market.

So what do I need to know?

First and foremost, it is important to match your motor to the application. You need to know your system and your objectives. Once this is established, selecting an optimum motor becomes a lot more straightforward. It may seem self-explanatory, but there are many key points to consider when selecting a DC motor:

- Type of Motion – Linear or Rotational.
- Power – Typically referring to output/mechanical power, but could also refer to input/electrical power. Will the motor be able to provide enough power to meet your requirement? Will gearing be required?
- Torque (M) – limited by current draw and is measured in Nm.
- Speed (n) – limited by voltage and is measured in rpm.
- Speed vs. Torque n/M – With any motor, there is a trade-off between torque and speed. This is

sometimes referred to as the n/M (rpm/Nm) curve. As speed increases, torque will decrease.

- Size Constraints – there is only a finite amount of power that can be harnessed from a certain motor package size. Limiting the dimensions of a motor may impact output power.
- Operating Mode & Duration – Motors can sometimes be taken past their normal limits, but only for a short duration. This is why it is important to understand if you intend to use a motor continuously, cyclically, or only for short/sporadic durations. The defining limitation is often due to thermal dissipation. Excessive heat can severely shorten a motors lifetime.
- Environmental Conditions – As already mentioned, thermal dissipation can reduce lifetime. Therefore it is best to ensure sufficient heat dissipation around the motor and through the motor mount. Other conditions that may be necessary to address include: Mechanical stress (shock, Vibration), IP-rating, suitability for vacuum, Noise (both mechanical and electrical) and RFI / EMI.
- But what do you do when there are unknowns? Especially during the R&D phase of a project, there is typically limited knowledge about the requirements. In this situation it is best to define what is necessary and what is advantageous.

For instance, you may require high rotational speed but want the motor to run off the same low voltage as the rest of the project. If for example the necessity is for high rotational speed, it would be an advantage if you could supply it using the existing power supply.

With many projects you may know only one set of requirements. If you know the output power requirements of a motor, you can make an assumption about the input requirements. As long as the assumptions are recorded and checked as the project progresses, then there shouldn't be any issues. This type of design process can often decrease time to market.

By understanding the key requirements of your project, you can help to manage the flow of information. This helps to ensure that you don't become bogged down in datasheets or overwhelmed by motor characteristics.

What is important to you?

Something that may not be commonly understood is that there are a wide variety of technologies that can be employed for a DC motor. For example; there are steppers, brushed & brushless, motors, linear actuators and many more. Furthermore within those classes of motors there are also a wide variety of ways to achieve commutation.

Many may be able to meet your requirements, but what are the trade-offs?

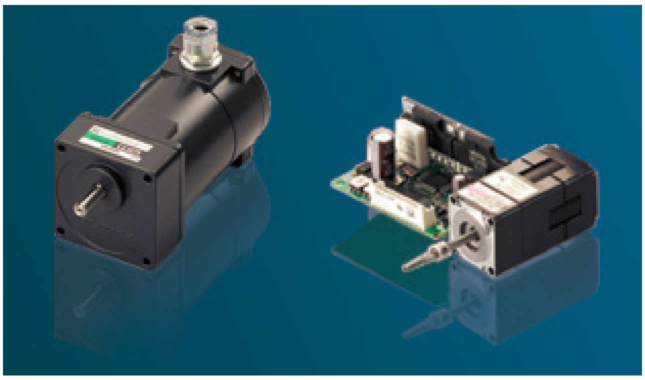
Precision

There are two main points to precision, accuracy and repeatability. Accuracy determines how close you get to your target operating point. Repeatability is your ability to reliably perform the same operation, time after time. Depending on the situation, one may be more critical than the other.

Lifetime vs. Operating Point

Motor service life largely depends on the torque and speed demands of the application. As torque increases, so does current through the armature. This increases current density, causing erosion which limits its service life. High rotational speeds similarly curtail service life by accelerating mechanical wear[1].

We have already talked about the available power in small motors, but there are other considerations. Running a motor near its limits for extended periods decreases lifetime.



In turn the type of bearing and commutation system selected may have a significant effect on what is possible near the limits of the motor. How the coils are wound, how the armature and bearings are seated, as well as brush construction all define what the motor will absorb mechanically and thermally.

For example if we look at the characteristics of a small Faulhaber Series 3257 12V DC Brushed motor. This motor is 32mm in diameter and 57 mm long has graphite brush commutation and sintered front bearings at the base of the shaft. We have made calculations for two different operating points.

1. Operating point 1, Motor needs to generate 33.27 mNm of torque at 3,400 rpm
2. Operating point 2, Motor needs to generate 63 mNm of torque at 7000 rpm

Graph 1 and the table below shows that there is a significant difference in coil temperature between operating point 1 and operating point 2.

Series 3257-012CR Motor Calculations		
	Operating Point 1	Operating Point 2
Motor Voltage [V]	7.7	15.8
Motor Current [A]	2	3.5
Motor Torque [mNm]	33.27	63
Motor Speed [rpm]	3400	7000
Motor Power [W]	11.8	46.2
Coil Temperature [°C]	39.6	87.4
Housing Temp [°C]	36.0	74.3

In Graph 1 its clear that operating point 2 is near the continuous limits for this motor. The motor will run continuously at this point but lifetime will be significantly reduced compared to operating point 1.

In general the ideal operating point for a miniature DC motor is typically around 10-15% of its stall torque. This is also the region where the motor is most efficient. For the motor we just made calculations for operating point 1 is a safer mode of operation for continuous use (see Graph 2).

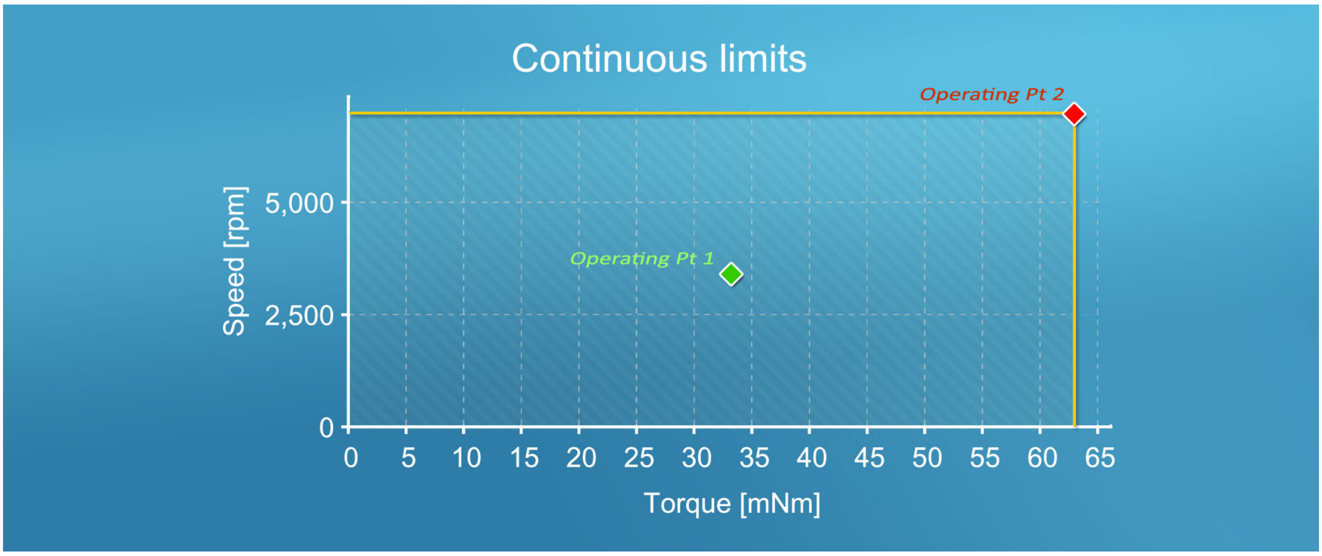
Other factors that can decrease life of the motors include:
- Start/stop operation
- Shock loading or vibration
- High torque or speed
- High ambient temperatures
- Using Pulse Width Modulation (PWM) to drive a motor, with switching speeds less than 20kHz

Some manufacturers may provide a general estimate of motor lifetime but many will not at all. In reality all of the factors we have discussed above can make a significant difference. The only true way of knowing is to test.

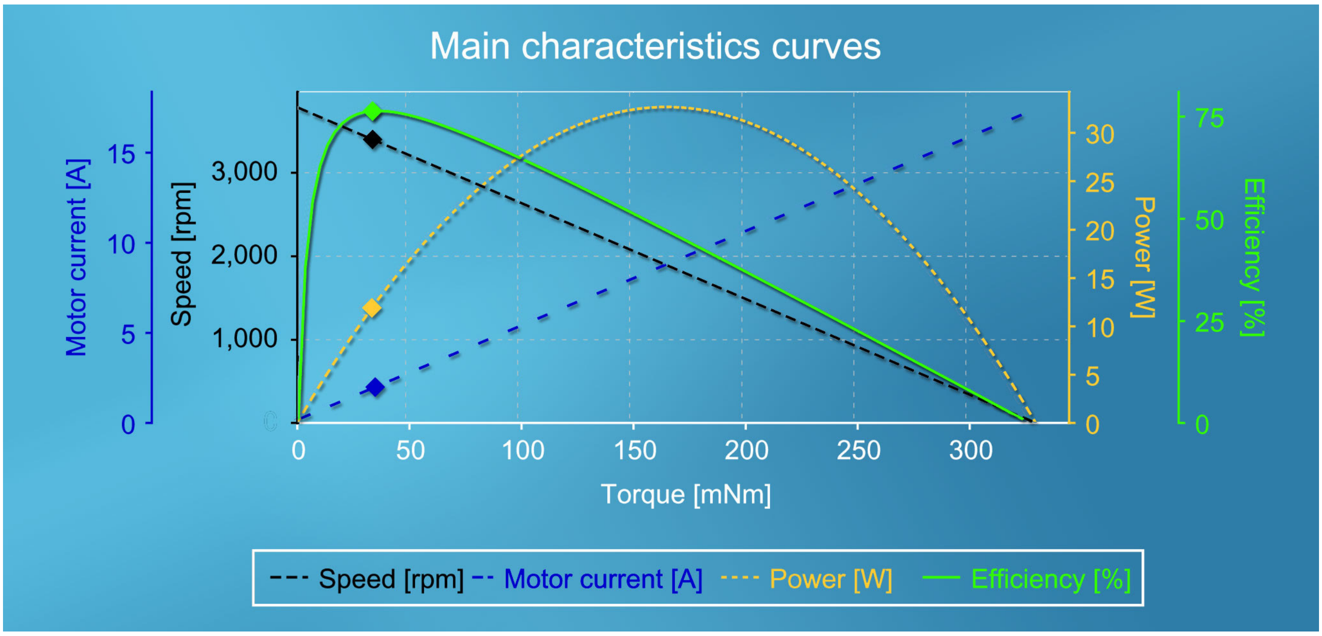
If the operating point is not too close to the continuous limit a general guide for some common types of DC motor types is:

- Precious Metal Brush Motors: 1'000-1'500 hours
- Carbon Graphite Brush Motors: 3'000-5'000 hours
- Brushless Motors: >10'000 hours

By using a motor which only just meets your operating point, you may be able to save money during production. However this needs to be balanced against the



Graph 1



Graph 2

cost of breakdowns and poorer reliability as the motor wears out.

Decreased time to market vs. Cost

Custom solutions to a problem are always possible, but not always viable. To design a custom solution takes time and money. The benefit being that you are likely to produce a higher quality product.

Even if your application allows for the design of a new drive system, you may want to consider standard parts for prototyping. This way you can test the validity of your system and decrease time to market.

Conclusion

Selecting a small DC motor can be a simple process if you have the right information. If you can understand your system and system objectives it's easier to discern which trade-offs you may need to make for a viable solution. In particular knowing the output speed & torque will allow you to gauge what a particular motor can do with some simple calculations.

Erntec: power and precision

Erntec supplies high-end miniature drives and can offer a range of engineered solutions for all miniature DC motor requirements. Erntec aims to work with customers to understand the application and operating point then assist in determining how a motor will perform prior to installation.

Erntec's experienced team can help account for all considerations to meet the specific needs and will discuss any trade-offs of any given application. In the case of challenging projects, custom design and construction solutions are available.

Erntec is an Australian owned company specialising in the manufacture of electrical and electronic enclosure solutions, including high quality, precision miniature DC drives.

1:Selecting a dc micromotor, p36
http://fab.cba.mit.edu/classes/MIT/961.04/topics/choosing_DCmicromotor.pdf