The Basics of Motor Selection

A designer's guide to motor types and customizations

A Groschopp, Inc. White Paper

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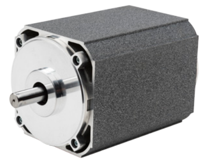
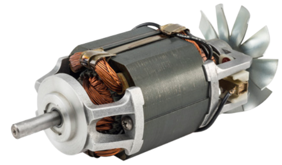
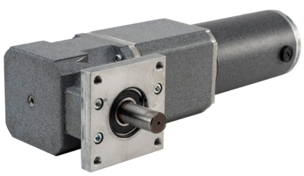
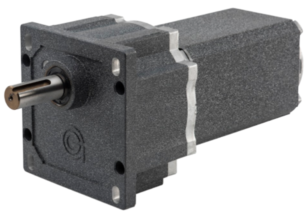

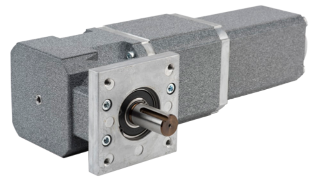


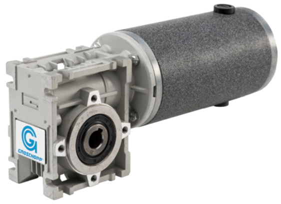
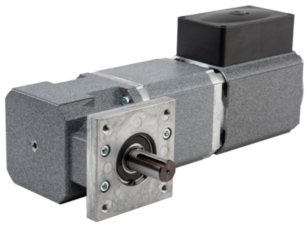

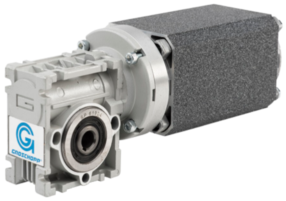
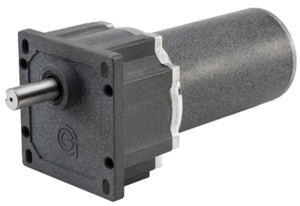


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I. OVERVIEW

Motor selection is often a complicated process that takes a lot of work with various vendors and time to sort and evaluate quotes. Groschopp engineers share knowledge and expertise about the motor selection process. Focusing on four broad motor types, care is taken to meticulously evaluate the characteristics, advantages, and drawbacks of each. Critical considerations include: power source, environment, motor specifications and motor performance. These considerations will provide designers with direction in regards to gathering the specifications for the application as well as the characteristics that each motor possesses. With that knowledge designers can more easily match a motor type with an application.

II. MOTOR BASICS

The purpose of a motor, regardless of the application, is to change electrical power to mechanical power in order to provide rotational movement. Every application will have its own distinct parameters for input and output power. The diagram in Figure 1 provides a visual representation of the input and output parameters of a motor. The input electrical power can be in the form of a DC battery, AC line voltage, rectified AC line voltage, or a wide variety of controls. Affected by application and environmental constraints along with the necessary power needed to move a load, the input power will be volts, amps, and frequency. The output power is the motor speed and torque response required to accomplish the task.

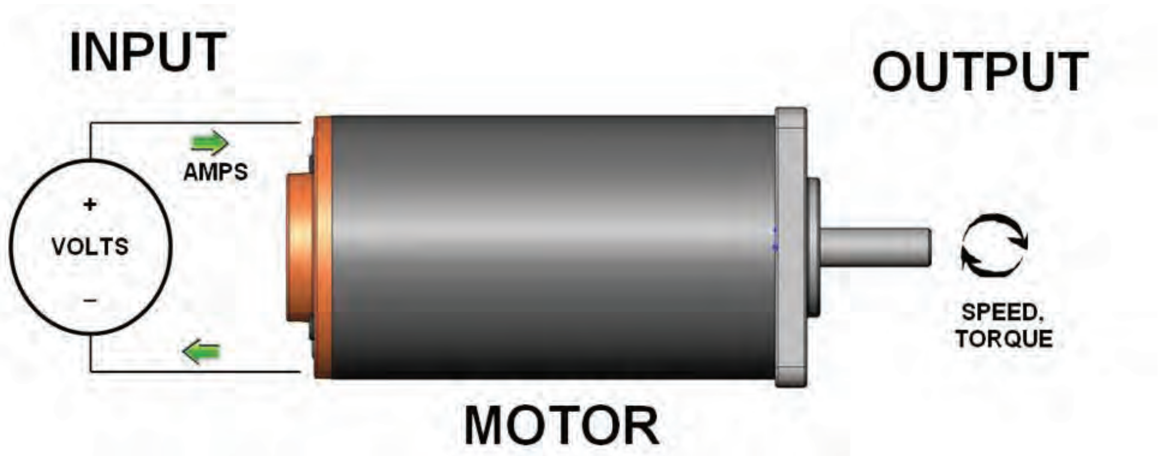

Figure 1: Motor Input and Output Functions

III. APPLICATION CONSIDERATIONS

The motor selection process begins with evaluating the application and ensuring the motor chosen will properly match the needs of the application. Though often overlooked by design engineers, the items on the Application Considerations Checklist (Figure 2) are critical to OEM motor design and a successful overall system solution. Using the Application Checklist to collect the application data, and then prioritizing it in order of importance will give a designer direction going forward with motor selection and system design. It is important to note that each application will have its own unique performance requirements that need to be evaluated using the checklist. While the items on the Application Checklist may not be the only factors to evaluate, from Groschopp engineer's long-term experience working with OEMs, the checklist covers the majority of application considerations.

Application Considerations Checklist

Input Power Source ☑

- ☐ Voltage
- ☐ Frequency
- ☐ Current (Efficiency)
- ☐ Control Type

Environment ☐

- ☐ Ingress Protection (IP) Rating
- ☐ Temperature (indoor/outdoor)

Motor Specs ☐

- ☐ Size and Weight
- ☐ Motor Life Expectancy / Maintenance
- ☐ Noise

Motor Performance ☐

- ☐ Speed and Torque
- ☐ Starting / Stall Torque
- ☐ Duty Cycle & Load Profile

Figure 2: Application Considerations Checklist

A. Input Power Source

Designers should pay attention to maximum allowable current early in the selection process, as it is a consideration that oftentimes goes unnoticed. For example, if an application such as a medical patient lift uses a standard electrical wall outlet as the power source, it is generally necessary to limit the currents to 15 amps to avoid overloading the electrical circuit. As mentioned previously, the input power will be a known quantity and is easy to specify in the form of voltage, current, and frequency. Some applications will have a maximum allowable current draw which needs to be closely monitored. For applications sensitive to high current draw situations, the selection of the motor is critical. Choosing a motor that runs at maximum efficiency at the application load point allows the designer to optimize performance to lessen current draw. If motor optimization alone does not work, the use of a control with current limiting capabilities can also be used to minimize the issue.

B. Environment

Most off-the-shelf motors are constructed for a clean, dry, room temperature environment. If the requirements of the project subject the motor to elements such as dust or water contamination, a designer should consider a motor constructed for environmentally sensitive applications. To more uniformly denote industry standard gearmotor sealing, the Ingress Protection (IP) chart (Table 1) was created to assist designers with selecting the proper IP rating for an application. The ingress rating of the motor enclosure is given a number rating in the form of IPXX. The first X indicates protection against solid objects and the second X denotes protection against liquids. For example, most totally enclosed motors would meet an IP44 rating which is protection against objects over 1 millimeter and liquid spray from all directions.

Ambient temperature is also an important factor to take into consideration when choosing a motor. UL dictates maximum allowable temperatures for each insulation class (Table 2), providing designers with an understanding of how hot the winding temperature of a motor can be at a continuous rating. For example, temperature class "B" means that the insulation system is designed not to exceed a maximum temperature of 130°C, if the internal motor temperature exceeds 130°C, the motor life will be shortened. Most motor windings are tested assuming that ambient temperatures will remain between 20°C and 40°C. If the application requires the motor to run at temperatures above 40°C, the motor must be run at a derated load in order to maintain the integrity of the insulation system over the life of the product.

INGRESS PROTECTION [IP] RATINGS			
FIRST NO.	PROTECTION AGAINST SOLIDS	SECOND NO.	PROTECTION AGAINST LIQUIDS
0	No protection	**0**	No protection
1	Objects over 50 mm (hand)	**1**	Vertically falling drops of water
2	Objects over 12 mm (finger)	**2**	Direct sprays up to 15° from vertical
3	Objects over 2.5 mm (tools and wires)	**3**	Direct sprays up to 60° from vertical
4	Objects over 1 mm (small tools and wires)	**4**	Sprays from all directions, limited ingress
5	Dust-limited ingress (no harmful deposit)	**5**	Low pressure jets of water from all directions, limited ingress
6	Totally protected against dust	**6**	Strong jets of water from all directions, limited ingress
		7	Temporary immersion (30 minutes) between 15 centimeters and 1 meter
		8	Long periods of immersion under pressure

Table 1: Ingress Protection (IP) Rating Chart

TEMPERATURE (INSULATION) CLASS	
UL 1466 TEMP CLASSES	MAX TEMP AT HOTTEST SPOT
B	130°C (266°F)
F	155°C (311°F)
H	180°C (356°F)
N	200°C (392°F)
R	220°C (428°F)
S	240°C (464°F)
> 240°C	over 240°C (over 464°F)

Table 2: UL Temperature Classes for Motor Insulation Systems

For every **10°C** that an application exceeds the maximum temperature rating, the motor life is cut in half.

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C. Motor Specs

When looking at new projects, one of the early considerations needs to be motor housing design. In order to meet application needs the designer must understand the size and weight restrictions of the product. One application may require a long skinny motor whereas the next application could utilize a short fat motor. Additionally, if the application is a portable product there might be a maximum allowable weight associated with the design, thus affecting the type of motor that should be selected.

Application life requirements are another key consideration in the selection process. Does the application require 10,000 hours of maintenance free running or will the motor only run 200 hours in the next 20 years? The key components that could pose a concern to the life of a motor include the bearings, the brushes, and the commutator. The brushes and the commutator create the electrical connection in brush type motors; as the motor runs these components tend to wear down. Generally, in limited use applications, a brush type motor will be an economical choice. In fact, there are many designs available with replaceable brushes to increase longevity of more economical brush-type motors. For longer life applications, it is best to select a motor design that does not require brushes; therefore the only factor limiting motor life is the bearings.

For many design engineers noise is an important factor to consider when specifying a motor and designing a system. Noise is typically measured in decibels (dB); however, decibel readings do not take into consideration what types of noises are good or bad. Decibel readings measure all frequencies the same way but the human ear does not hear all frequencies the same way. Noise is subjective because the human ear interprets pitch and intensity as noise. Therefore; one motor can sound louder than another even though a noise test result read both motors at the same dB level. Be aware that sound can be a complicated issue and it may take some time to work out exactly what noise limitations are needed in the application. Over the past several years sound has gotten more attention, to the point that many motor manufacturers, including Groschopp, have invested in sound equipment and quiet rooms to better quantify sounds and associate them with the responsible component.

D. Motor Performance

Up until this point the focus has been on the characteristics of an application that might constrain the motor type selection. Now, motor performance needs to be addressed. In other words, what does the motor need to do in the application?

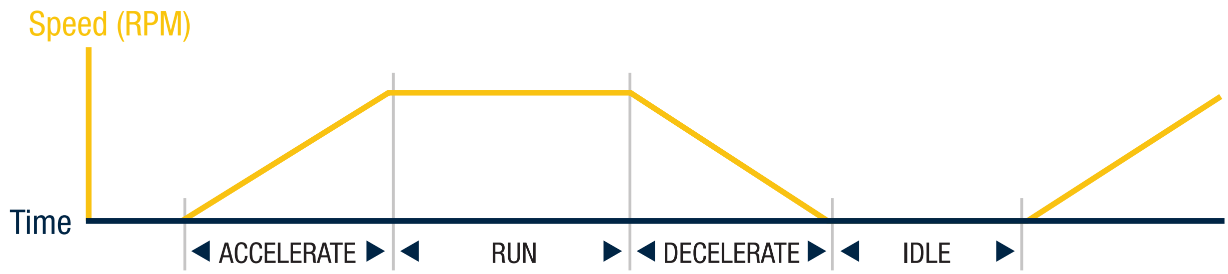


Figure 3: Motor Performance Load Profile Chart

Motor performance has been broken down into three key parameters:

1. Speed and Torque
2. Starting/Stall Torque
3. Duty Cycle or Load Profile

It is important to note that these parameters are not independent – they are, in fact, co-dependent and should be viewed somewhat "simultaneously" to develop the best motor for an application.

Speed and torque represent the output that will be required to power the application and will affect the size of the motor. A speed and torque rating is the starting point in selecting a motor once the initial constraints are determined. Size can also be impacted by minimum requirements for starting or stall torques and duty cycle. A motor that is run continuously will need to be larger than a motor running at the same load at a 10% duty cycle.

The advantage of OEM applications is that a motor supplier does not need to take a standard motor right off the shelf and fit it into an application. Rather, the motor can be optimized in the application by devoting special attention to the rating and operating characteristics of the motor design, allowing the opportunity to optimize the entire application. The ability to modify many motor characteristics to meet application requirements exemplifies the importance of prioritizing application considerations before the motor selection and customization process begins.*

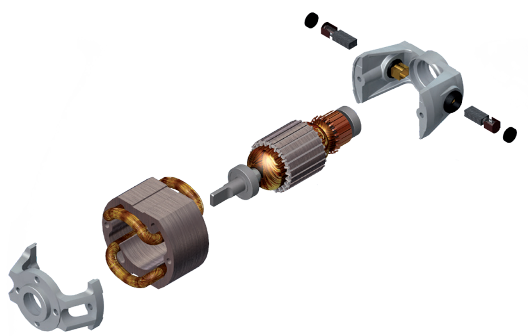
IV. MOTOR TYPES

There are four specific motor types that are covered in the motor selection process. Keep in mind that there will be trade-offs between the different motor types and sometimes the best choice is not readily apparent. Each motor type will be explained in a way that aids in a good understanding of the advantages and trade-offs, making the choices easier. The explanation of Universal (UM), Permanent Magnet DC (PMDC), AC Induction and Brushless DC motors (BLDC) will cover the construction, motor characteristics, advantages and disadvantages. Tips for interpreting the performance curves for speed, torque and efficiency will also help designers better understand motors and motor characteristics.

A. UNIVERSAL MOTORS

The diagram in Figure 4 shows the basic components of a Universal Motor. The armature is the rotating component and the field is the stationary component. Both the armature and field are wound with magnet wire and the electrical connection is made both to the armature (through the brushes) and the field. There are two characteristics that differentiate the Universal Motor from most other motor types making it ideally suited for a few specialized applications. First, the motor can run by either an AC or DC power source, which is where it derives the name *Universal*. Second, the Universal motor is capable of running at high speeds, faster than most other motors types. The high no-load speeds are due to the weaker field at light current draws. Designs over 30,000 RPM have successfully been achieved, although extra care must be taken in the design, component selection and balance as these factors become critical to motor reliability.

**Note: price, quality and delivery were not included in the Applications Consideration checklist. Though these factors are important, the focus is selecting the best motor from an overall performance standpoint. From Groschopp's engineering experience, it's best to review price, quality and delivery early in the design process then revisit them in depth during the vendor selection process, once the motor is designed.*



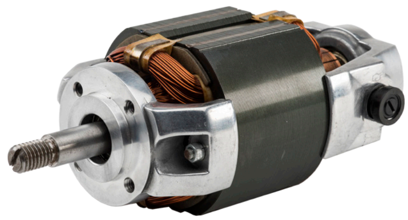


Figure 4: Universal Motor Construction

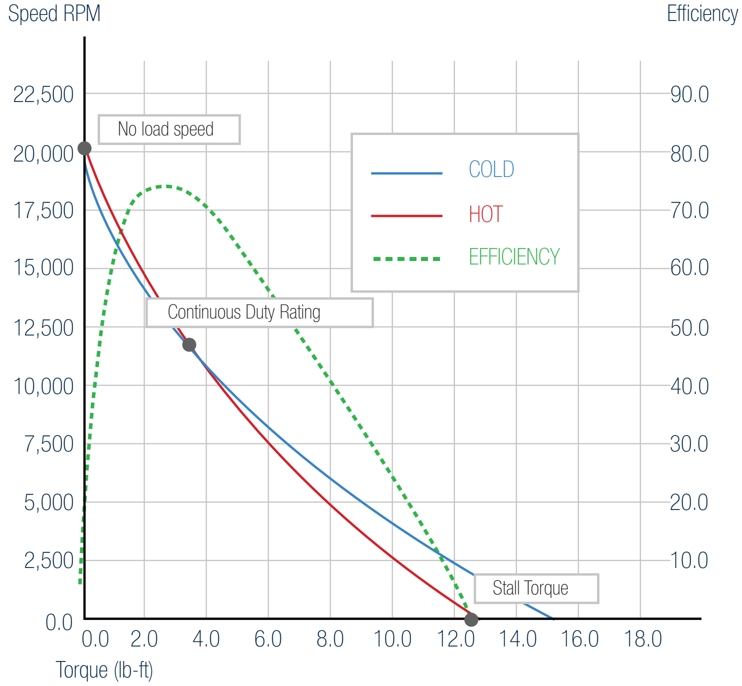
Characteristics:

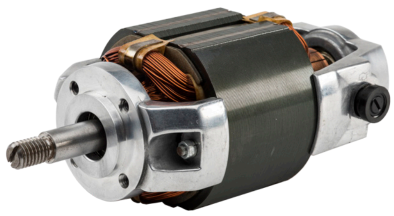
- Operates on AC and DC power
- Efficiency between 55% and 70% small to large
- High speed 8,000-20,000+ rpm (speed is independent of frequency)
- High starting torque, 4-6 times rated torque
- Life 500-2000 hours.

Frequently, the primary advantage (Table 3) of using the Universal motor is its high power density. It is not uncommon for the Universal Motor to have over twice the continuous output power as an AC Induction motor of similar size. The high power density of a Universal motor is the result of the high speed and generous fan cooling. The trade off for this high power density is that the motor is fairly noisy compared to most other motor types. On the low voltage side of Universal Motors; if a UM operates under 100 volts the motor efficiency can be quite low. So, when dealing with something like a battery input source, the universal motor could quickly drain a battery. In general, alternate motor options should be considered for low voltage situations.

Advantages	Disadvantages
High power density Excellent choice for portable applications No control required Low cost	High maintenance due to brushes Little speed regulation Requires air through for cooling Noisy Cogging at low speeds Less efficient at low voltages (less than 100V) High speed limits gearbox usage Burns out quickly in stall condition

Table 3: Advantages and Disadvantages of a Universal Motor





MOTOR TYPE
Universal Motor

UM 8104

Speed: 12,000 rpm
Torque: 3.5 lb-in
Current: 5.96 amps
Output: 492 watts
Output: 0.6594 HP
Voltage: 115V 60Hz

Figure 5: Speed, Torque and Efficiency Curves for a Universal Motor

Looking at a typical performance curve for a Universal Motor (Figure 5) notice the high no load speed that quickly drops off as additional load and current are applied. The shape of the UM curve is due to the additional field magnetics generated as current movement through the windings increases. Notice the difference in performance as the motor temperature changes. For a given torque point, the motor will run a little slower as it heats up. Finally, take note of the motor's efficiency curve, the green dashed line. Under ideal circumstances, the motor's efficiency will peak very near the maximum operating torque.

B. Permanent Magnet DC Motors

The PMDC motor (Figure 6), similar to the UM motor, has a wound armature providing commutation through the brushes and commutator. The difference between a UM and a PMDC motor lies in the field. UM motors have a wound field that varies in strength with the current draw of the motor, whereas PMDC motors use a constant strength, permanent magnet field – giving them their name. The constant field strength yields a motor with a more linear speed-torque curve, higher starting torque and much lower no-load speeds. Because it runs only on DC voltage, the PMDC motor requires the use of a rectifier or a control to be operated in a system with AC line voltage.

Characteristics:

- Straight line speed-torque curve
- Medium speed operation 1,000-5,000 rpm
- Efficiency 60%-75% (small to large)
- High starting torque (8-10 times rated torque)
- Operation on DC voltage
- Life 2,000+ hours
- Totally enclosed construction typical

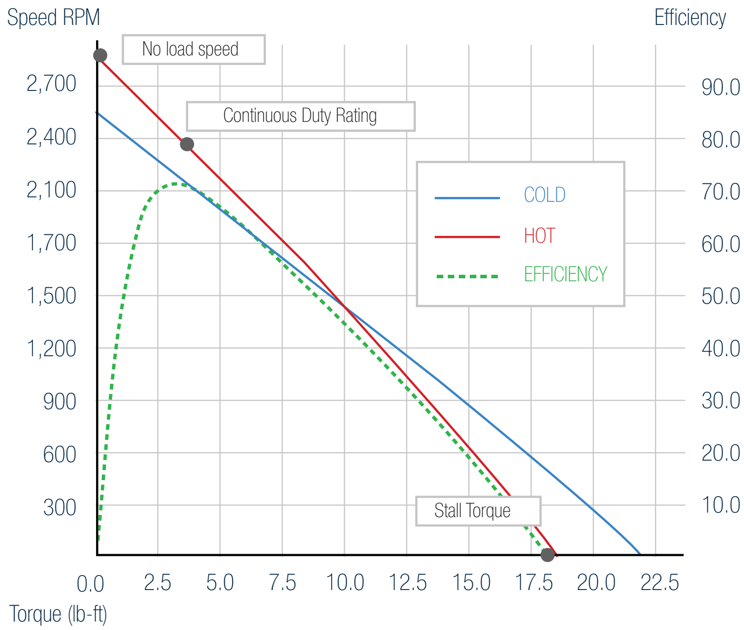
Figure 6: Permanent Magnet DC Motor Construction

One advantage of the PM motor is the lower operating speeds, making them ideal for use with gear reducers and allowing for much quieter operation (Table 4). However, compared to a similarly sized UM motor, the power density of a PM motor is not as high. From a maintenance standpoint, both Universal and PM motors have brushes density that must be periodically inspected and replaced to maximize motor life.

Advantages	Disadvantages
Works well with gearboxes Operates on DC without control Speed regulation attainable with inexpensive controls Low cost	High maintenance due to brushes Medium noise due to brushes Cogging at low speeds (less than 300 rpm) Less of significant power on full wave rectified voltage High starting torque can damage gearboxes

Table 4: Advantages and Disadvantages of a PM Motor

The generally linear speed-torque curve for a PMDC motor is shown in Figure 7. This linearity makes it very easy to control the torque output of the motor by simply monitoring the current draw. Additionally, the PMDC motor has a low no-load speed and a high starting torque. Looking closely at the hot motor curve, notice that as the motor temperature is elevated, the no-load speed is increased and the stall torque is decreased. This is due to the effect that heat has on the magnets. As the motor cools down, the speed will return to normal. The efficiency curve is very similar in shape to the Universal Motor.

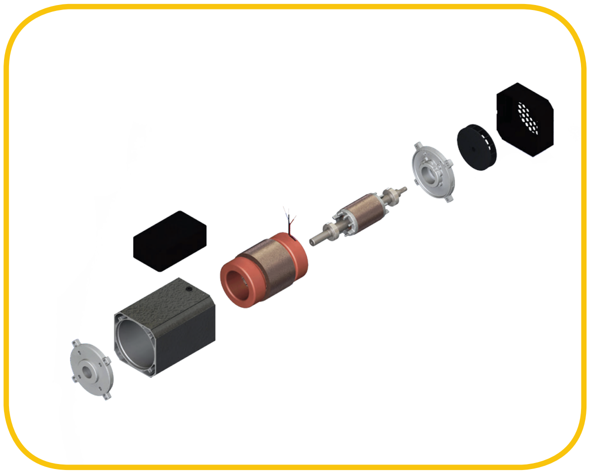


MOTOR TYPE
Permanent Magnet DC (PMDC)

Figure 7: Speed, Torque and Efficiency Curves of a PMDC Motor

C. AC Induction Motors

The AC Induction Motor is constructed and functions differently than both the UM and PMDC motor. The main difference is the elimination of a wound armature and the brushes that perform the commutation. The AC motor construction has a wound stator and a cast rotor. The rotor itself is very simple in construction, consisting of laminations, cast aluminum, and a shaft. While the construction is much different than the UM and PMDC motors, the concept is still the same, a magnetic field is generated and rotates around the motor through a process called commutation. In an induction motor, the winding takes advantage of the alternating current of an AC power source to do the commutation rather than having the rotating armature (in a UM & PMDC) and brushes doing this process. The current in the windings creates the magnetic field that turns the shaft by inducing a magnetic field in the rotor. The stator winding actually determines most of the performance characteristics of the AC motor.



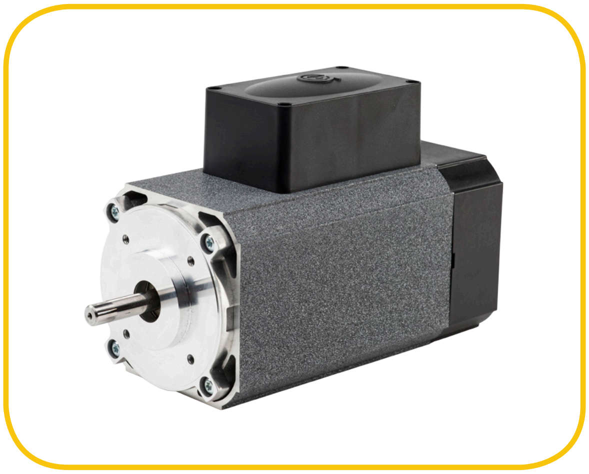


Figure 8: AC Motor Construction

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Characteristics:

- Relatively fixed speed operation (without a control), typically limited to 3,400 rpm
- Efficiency 60%-90% (small to large)
- Low (single phase) to medium (three phase) starting torque
- Operates on AC line voltage
- Life 20,000+ hours
- Totally enclosed construction is typical

The AC Induction Motor, depending on the construction, can run off of either a single phase or a three-phase AC power source. The output speed of the motor is fairly fixed and is dependent only on the number of poles with which the stator is wound and the frequency of the input voltage. Unlike a PMDC or UM motor, the value of the input voltage does not affect the speed, only the frequency of the input source. There are many different types of single-phase motors available: capacitor start, split phase, permanent split capacitor, shaded pole and others. Groschopp focuses on the permanent split capacitor (PSC) and three-phase motor designs.

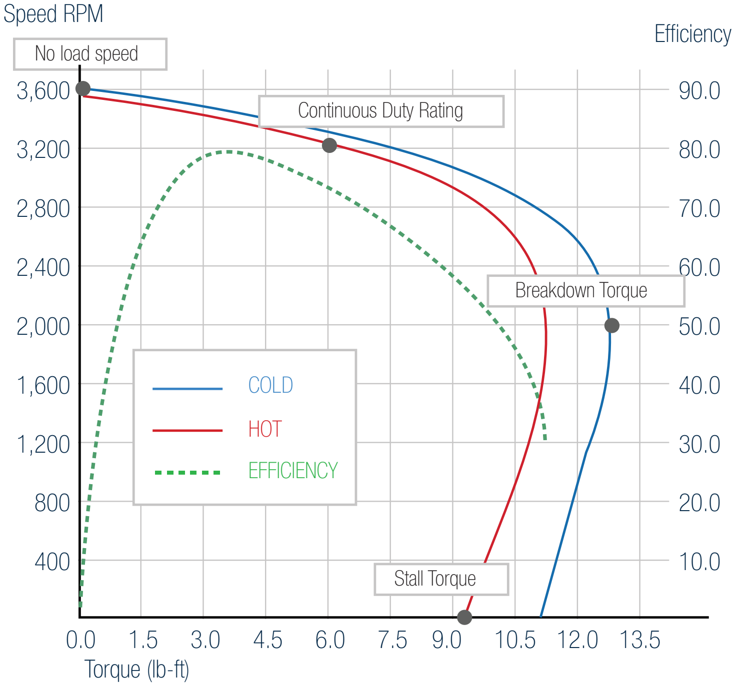
The primary advantage of an AC induction motor (Table 5) is that it does not have common wear parts such as brushes and commutators. The absence of these parts allows for long life potential and low maintenance. In fact, if properly applied, the life of an AC induction motor is only limited by the bearings.

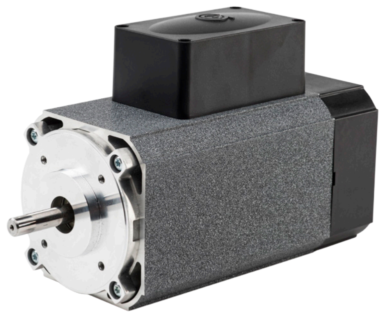
Advantages	Disadvantages
Long life No control needed Maintains speed over wide range of torque Works well with gearboxes Low starting current Suitable for speed control Quiet	Requires capacitor (single phase only) Can have difficulty starting (single phase) Not suitable for portable applications Low power levels for size High cost per horsepower

Table 5: Advantages and Disadvantages of an AC Motor

The lack of brushes, combined with a relatively low speed, makes the AC motor a great choice for applications requiring quiet operation. On the other hand, they have a significantly lower starting torque than PMDC or Universal Motors, a factor that should be considered during the motor selection process. In *three*-phase AC motors the starting torque is higher, but many PSC *single*-phase motors will actually have less starting torque than their rated torque. If the application requires starting under load, a PSC motor may not be a good choice.

Figure 9 portrays a typical *three*-phase AC induction motor performance curve. This curve is fairly linear until the breakdown torque is reached. After breakdown, the torque drops off sharply and even folds back a bit. In a single-phase PSC motor, the fold back is even more pronounced. The relationship of the cold and hot motor curves closely resembles the Universal motor, in that, higher motor temperatures lead to lower output speeds for a given torque.





MOTOR TYPE
AC Induction Motor

AC9060 3PH. TEFC

Speed: 3,244 rpm
Torque: 5.9 lb-in
Current: 0.94 amps
Output: 227 watts
Output: 0.304 HP
Voltage: 230V 60Hz

Figure 9: Speed, Torque & Efficiency Curves of an AC Induction Motor

D. Brushless DC Motors

Looking at the brushless DC (BLDC) stator construction, a designer will notice it is similar to that of an AC Motor. The rotor is constructed of a steel hub wrapped with permanent magnets; typically composed of a high energy, rare earth material. In a six step or trapezoidally operated motor, there will quite often be a lower grade magnet for use with the Hall Effect commutation encoder. These sensors tell the control when to fire the stator coils, replacing the commutator and brushes found on UM and PMDC motors. Like AC Induction Motors, when the parts are properly applied the only wear will be on the bearings.

Characteristics:

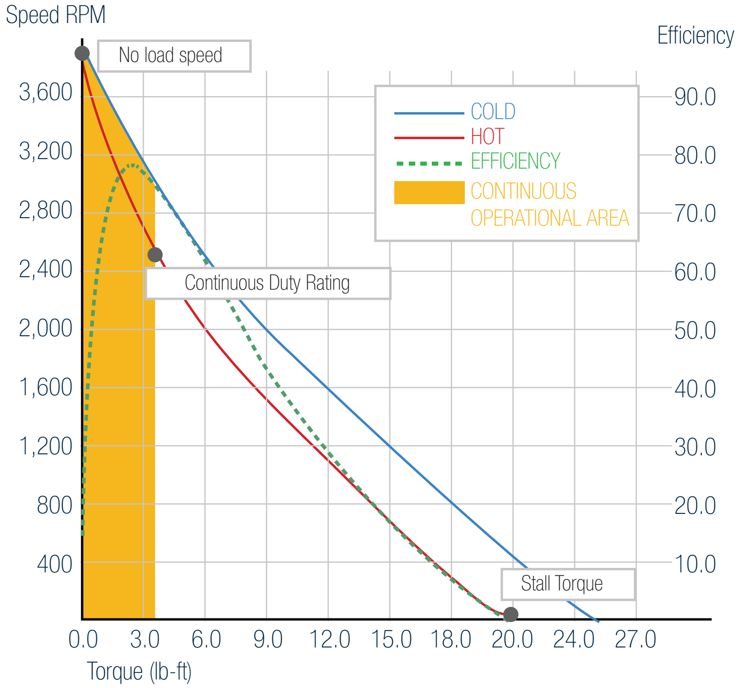
- Variable speed operation
- High efficiency between 70%-95% (small to large)
- High starting torque
- Requires a control to operate
- Life 20,000+ hours
- Similar speed torque characteristics to PMDC

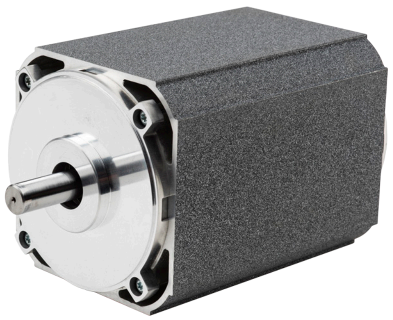
The performance of a BLDC motor looks very similar to that of a PMDC motor in that the speed-torque curve has a very linear progression from no load to stall. While the performance curve looks similar, the efficiency and power density of the BLDC motor are superior to that of the PMDC. BLDC motors are becoming a more popular choice in applications as the price and size of control electronics are reduced. A recent challenge to the advancement of BLDC motors is the volatility of the rare materials used in the magnets. While the price and supply issues of 2011 have subsided, the overall cost of the material has stabilized at a higher rate than the historical averages. For this reason, it is important to work with the motor manufacturer to ensure the motor design effectively balances performance and cost.

Advantages	Disadvantages
Totally enclosed typical Long life Low maintenance High power levels for size Works well with gearboxes Could be used in variable speed applications	High cost due to rare earth magnets Requires control to operate Cogging at low speeds (less than 300 rpm)

Table 6: Advantages and Disadvantages of a Brushless Motor

The brushless motor construction combines the long life and low maintenance benefits of an AC induction motor, and the desirable speed-torque curve of a PMDC motor. When it comes to power density, the BLDC motor is second only to the Universal motor. All of the attractive features: long life, low maintenance and higher power density come at a price. Even with the higher cost per motor compared to UM, PMDC, and AC; there are certainly applications where the benefits of the BLDC motor make it a cost-effective choice.





MOTOR TYPE
Brushless DC Motor

BL6540 TENV

Speed: 2,500 rpm
Torque: 3.4 lb-in
Current: 0.95 amps
Output: 102 watts
Output: 0.136 HP
Voltage: 125V

Figure 10: Speed, Torque, Efficiency Curves of a BLDC motor

The BLDC speed-torque curve seen in Figure 10 is very similar to the PM motor. This curve represents the motor performance with full voltage applied, without the control providing speed regulation. Because a control is always used with a BLDC motor, there is more flexibility in the application of a standard motor winding. Rather than only operating up and down the curve as the torque changes, the use of a speed control allows the designer to apply a motor anywhere within the operational region of the performance curve. Take a look at the gold shaded area on the curve, the motor can be operated anywhere within this area. Caution should be used when BLDC motors are applied at low speed or in torque mode applications, these applications will require proper selection of encoder resolution and the use of AC brushless controls.

V. MOTOR COMPARISON

Looking at the curves for the different motor types individually, it is difficult to accurately compare each motor's performance against the others. The Motor Types Graph (Figure 11) maps the speed-torque curves of all four motor types on one graph, using the same scale to clearly illustrate the differences between the motors. This comparison shows the dramatically higher no-load speed of a universal and the significantly higher starting torques of PMDC and BLDC motors. Interestingly, all four of these motors are roughly the same physical size despite their significantly different performance curves. The Motors Quick Reference Guide (Table 7) chart is a good starting point when comparing the different motor types to help determine the optimal motor type for an application.

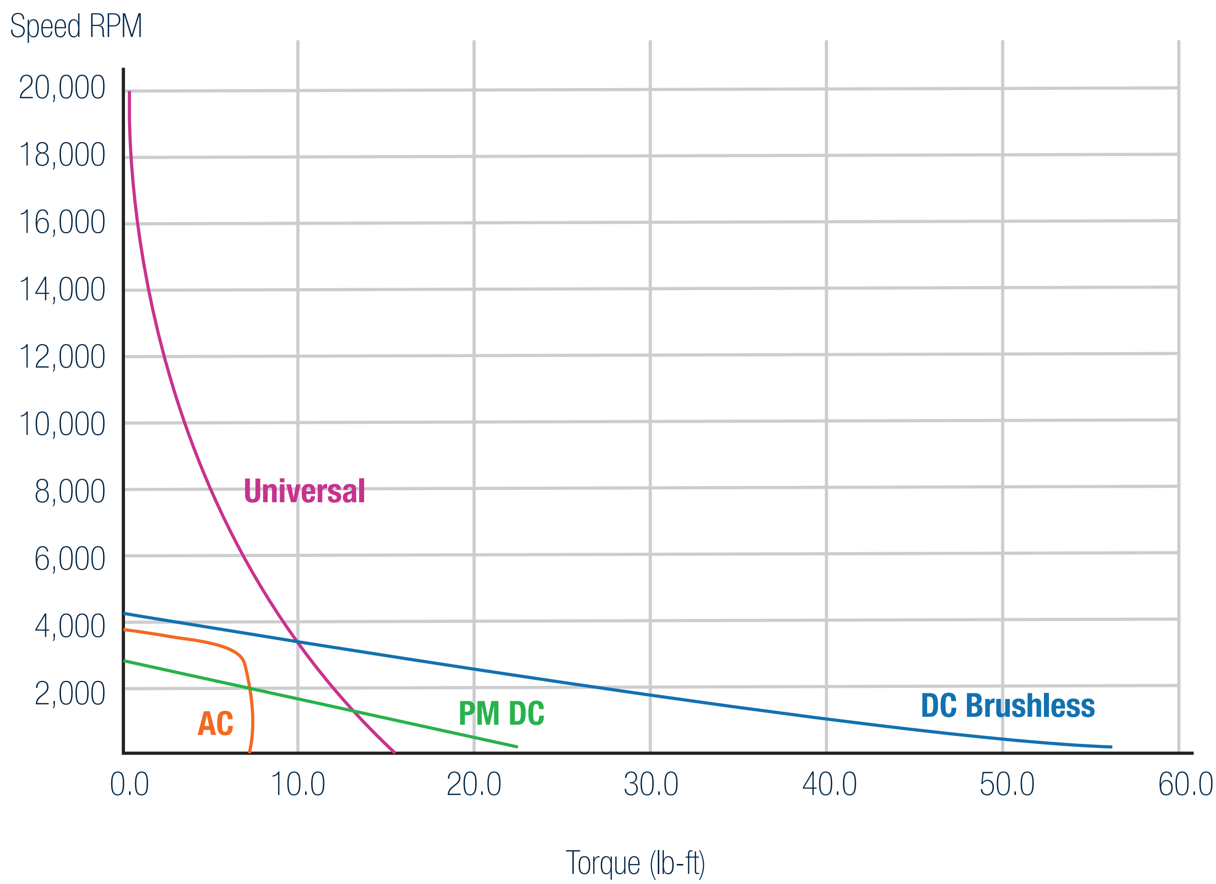
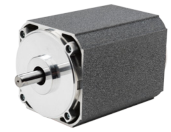


Figure 11: All Motor Types Speed vs. Torque Comparison

	UNIVERSAL	DC	AC	BRUSHLESS
Voltage	AC, DC	DC	AC	AC, DC
Speed	8000-20000+	350--6000	1200-3400	2300-3800
Horsepower	Very High	Medium	Low-Medium	High
Efficiency	55-70%	60-70%	40-80%	65-80%
Life	Low	Medium	Very High	Very High
Maintenance	High	Medium	Very Low	Very Low
Noise	Noisy	Medium	Quiet	Very Quiet
Speed Regulation	Poor	Fair	Good	Excellent
Starting Torque	High	Very High	Low-Medium	Very High

Table 7: Quick Reference Guide Motors

VI. CUSTOMIZATION

When working with a motor manufacturer, being a high volume OEM allows a designer the opportunity to perfectly "match" a motor to the application. Most motor manufacturers have standard tooling for various frame sizes. Since the tooling for motor windings are costly, utilizing a manufacturer's standard frame size is usually the most cost effective way to buy a motor. It is important to note that the use of a standard frame size is simply a guide in terms of winding, there are many other items on the motor that can be changed and accessories added to change motor performance and physical characteristics.

TECH TIP

When talking with a motor manufacturer, specify whether the application is intermittent duty or continuous duty.

For intermittent duty applications, often a smaller motor can be used compared to the motor size needed for the same application running constantly. This translates to significant cost savings and the ability to increase output horsepower without making the motor any larger.

Customizing a Standard Motor	"Blank Sheet" Custom Design
Output Shaft End brackets/mounting face Housing Foot Mount Custom winding/performance Accessories (brake, encoder, power cord, etc.)	New Lamination Significant tooling expense "No compromise" designs Most cost effective for higher volume applications

Table 8: Customizing a standard motor vs. Blank sheet custom design

OEM's have freedom to tailor the motor performance and mechanical interface without investing in new frame sizes and thus incurring high custom tooling costs. Using a standard, "pre-tooled" frame size can also significantly speed up the delivery time for the initial production process.

Sometimes it is necessary to create a "blank sheet design" if a customer's needs are too specialized for a modified standard motor. In these instances it makes the most sense to design a completely custom motor, exactly suited for the application. Although the initial investment in tooling can be significant, often the lower cost of production motors leads to a relatively short payback time by paying for only the motor needed. The tooling investment for a blank sheet design can be very significant, ranging anywhere from tens of thousands of dollars to a half-million dollars. Unless there is a fairly high volume application involved, it could be hard to justify the tooling cost. An experienced motor designer can tweak motor performance by changing the winding to create custom speed or torque points without altering the physical size of the motor. This weighing of the "Customized Standard" versus the "Blank Sheet Custom Design" is important to consider. The motor manufacturer can assist with calculating cost benefits and return on investment analysis.

VII. CONCLUSION

Though there are many options and considerations to keep in mind when selecting a motor it all boils down to the application specifications. The application needs to be on the forefront of a designers mind when selecting a motor. Selecting a motor based independently on price, packaging or performance does not allow a designer to optimize the most effective design for the application. Though various parameters should be considered, it may be necessary to compromise on some of the specifications in order to optimize the entire performance and cost package to best meet the project parameters. With several motor types to choose from, varying performance characteristics and the additional option of customization the process can get burdensome. When in doubt contact the motor manufacturer, many times a representative can walk through specifications and options to ensure a designer receives the proper motor that best meshes with the application.

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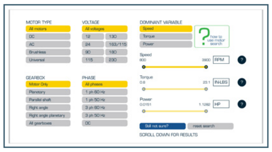
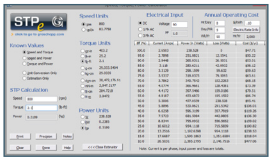


MOTOR SEARCH TOOL

- Web based software
- Sophisticated algorithms to calculate and match various search parameters
- 8000 proven product platforms and over 154,000 possible product configurations
- Allows a specific range for searching speed, torque and power

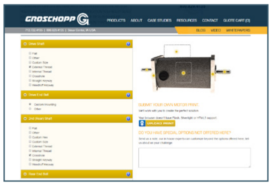


STPe CALCULATOR: SPEED, TORQUE AND POWER

- Web based tool that is available for download
- Simplifies fractional horsepower motor and gearmotor selection for our engineers.
- Quickly calculates speed, torque and power
- Conversions are automatically and accurately generated

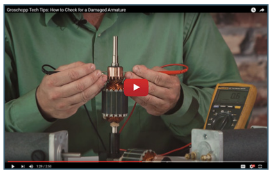
DATA SHEETS AND OUTLINE DRAWINGS

- Program developed by Groschopp engineers
- Provide a comprehensive overview of a motor or gearmotor's specifications.
- Calculates speed-torque curves in reference to different temperatures, efficiency curves, and additional specification breakdowns.



ONLINE CUSTOMIZATIONS

- Match the motor to your application as closely as possible
- Working from a standard frame size is typically the most cost effective approach when customizing a motor
- Delivery times are quicker when basing off of a standard frame size



VIDEOS, WHITEPAPERS & BLOGS

- Resources to help you understand our company and what we do
- Helpful tips for motor care and preservation