BRUSH DC MOTORS

Brush DC 8mm

Motor Coil Cross Section

Brush DC 16mm

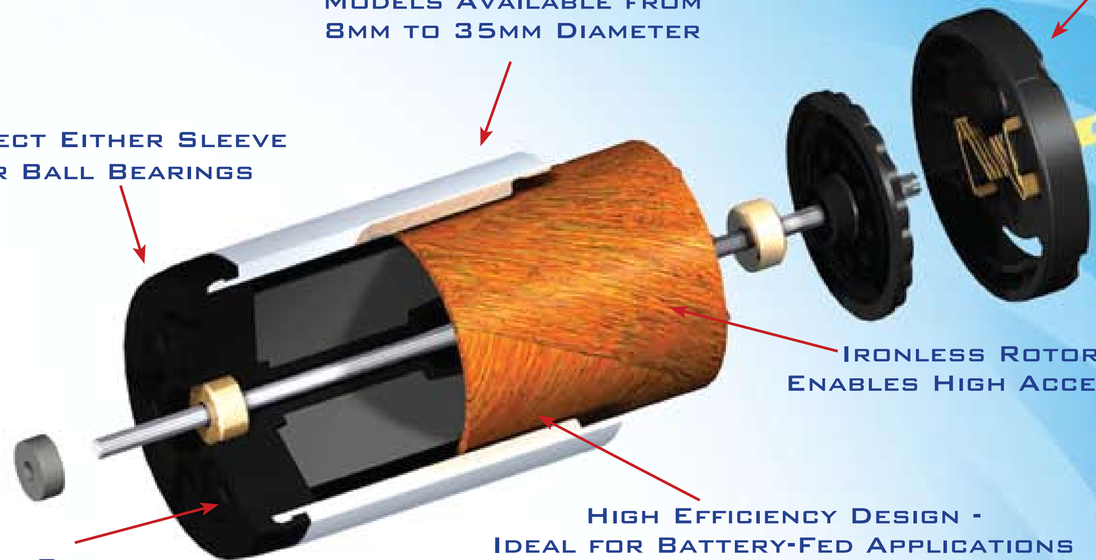
Brush DC 35mm

Portescap
A Danaher Motion Company

Your miniature motion challenges are unique and your ideas for meeting those challenges are equally unique. From medical to aerospace or security and access, Portescap's brush DC motion solutions are moving life forward worldwide in critical applications. The following Brush DC section features our high efficiency and high power density with low inertia coreless brush DC motor technology.

MOTION SOLUTIONS THAT MOVE LIFE FORWARD.™

Why a Brush DC motor



Innovation & Performance

Portescap's brush DC coreless motors incorporate salient features like low moment of inertia, no cogging, low friction, very compact commutation which in turn results in high acceleration, high efficiency, very low joule losses and higher continuous torque.

Ideal for portable and small devices, Portescap's coreless motor technologies reduce size, weight, and heat in such applications. This results in improved motor performance in smaller physical envelopes thus offering greater comfort and convenience for end-users. In addition, the coreless design enables long-life and higher energy efficiency in battery-powered applications.

Portescap continues innovating coreless technology by seeking design optimizations in magnetic circuit, self supporting coreless coil along with commutator and collector configurations.

Get your products to market faster through Portescap's rapid prototyping and collaborative engineering. Our R&D and application engineering teams can adapt brush DC coreless motors with encoders and gearboxes to perform in different configuration, environment, or envelope.

Standard Features

- **Max continuous torque ranging from 0.66 to 158.6 mNm**
- **Speed ranging from 11,000 RPM (8mm) to 5,500 RPM (35mm)**
- **Motor regulation factor(R/K^2) ranging from 1,900 to .3 10^3/Nms**

- **Brush DC commutation design**
  Longer commutator life because of the design.
- **REE system**
  Stands for Reduction of Electro Erosion. The electro erosion, caused by arcing during commutation, is greatly reduced in low inertia coreless DC motors because of the low inductivity of their rotors.
- **NEO magnet**
  The powerful Neodymium magnets along with enhanced air gap design thus giving higher electro-magnetic flux and a lower motor regulation factor.
- **Coreless rotor design**
  Optimized coil and rotor reduces the weight and makes it compact.

Your Custom Motor

- **Shaft extension and double shaft options**
- **Custom coil design (different voltages)**
- **Mounting plates**
- **Gear pulleys and pinion**
- **Shock absorbing damper and laser welding**
- **Special lubrication for Civil aviation and medical applications**
- **EMI filtering**
- **Cables and connectors**
- **Gearboxes**

SPOTLIGHT ON INNOVATION

Innovation is a passion at Portescap. It defines your success, and defines our future. We help you get the right products to market faster, through rapid prototyping and collaborative engineering. With experienced R&D and application engineering teams in North America, Europe, and Asia, Portescap is prepared to create high-quality precision motors, in a variety of configurations and frame sizes for use in diverse environments.

Demanding application?

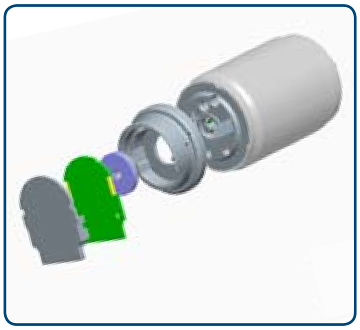
Portescap is up for the challenge. Take our latest innovation Athlonix in high power density motors. Ultra-compact, and designed for lower joule heating for sustainable performance over the life of your product, Portescap's Athlonix motors deliver unparalleled speed-to-torque performance. And better energy efficiency brings you savings while helping you achieve your green goals.

Athlonix motors are available in 12, 16, and 22mm.

More Endurance. Higher Power Density. Smaller Package

Looking for a lighter motor with more torque?

35GLT brush dc coreless motor from Portescap might be the solution for your needs. The 35GLT provides a 40% increase in torque-to-volume ratio over most average iron core motors. A featured multi-layer coil improves performance and offers insulating reinforcement, resulting in improved heat dissipation. Weighing in at only 360 grams and providing an energy efficiency of 85%, the 35GLT offers less power draw and excellent space savings.



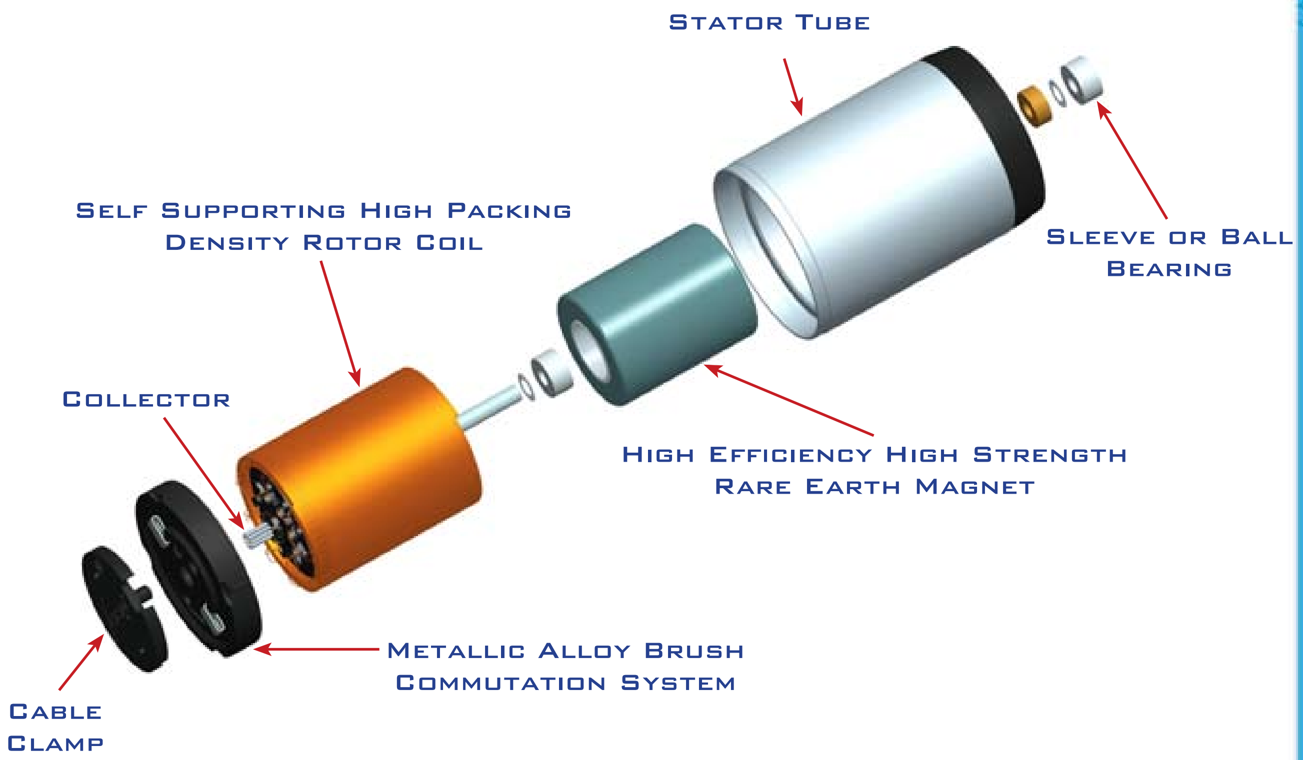
The quest for high-resolution feedback with accuracy in speed is the essence of Portescap's innovative **MR2 magneto resistive encoder**. These miniature encoders accommodate motors from frame sizes of 8mm to 35mm with superior integration schemes to facilitate a compact assembly with motors. And, with a resolution of 2 to 1024 lines, Portescap's MR2 encoders meet your application requirements today - while flexibly adapting to your evolving needs.

Brush DC Motor Basics

Construction of Portescap motors with iron less rotor DC motors

All DC motors, including the ironless rotor motors, are composed of three principle sub assemblies:

1. **Stator**
2. **Brush Holder Endcap**
3. **Rotor**



1. The stator

The stator consists of the central, cylindrical permanent magnet, the core which supports the bearings, and the steel tube which completes the magnetic circuit. All three of these parts are held together by the motor front plate, or the mounting plate. The magnetic core is magnetized diametrically after it has been mounted in the magnetic system

2. The Brush Holder Endcap

The Brush Holder Endcap is made of a plastic material. Depending on the intended use of the motor, the brush could be of two different types:

- Carbon type, using copper grahite or silver graphite, such as those found in conventional motors with iron rotors.
- Multiwire type, using precious metals.

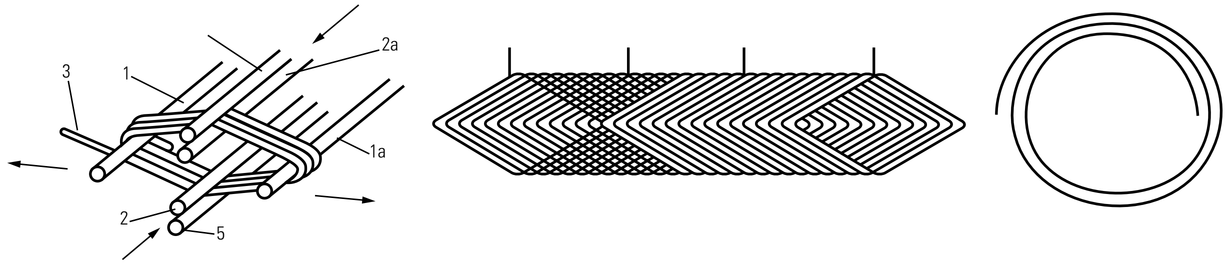
3. The Rotor

Of the three sub-assemblies, the one that is most characteristic of this type of motor is the ironless, bell-shaped rotor. There are primarily four different methods of fabricating these ironless armatures utilized in present-day technology.

A — In the conventional way, the various sections of the armature are wound separately, then shaped and assembled to form a cylindrical shell which is glass yarn reinforced, epoxy resin coated, and cured. It is of interest to note the relatively large coil heads which do not participate in the creation of any torque.

B — A method which avoids these coil heads uses an armature wire that is covered with an outer layer of plastic for adhesion, and is wound on a mobile lozenge-shaped support. Later, the support is removed, and a flat armature package is obtained, which is then formed into a cylindrical shape (Figure 1). The difficulty with this method lies in achieving a completely uniform cylinder. This is necessary for minimum ripple of the created torque, and for a minimum imbalance of the rotor.

Figure 1 - Continuous winding on mobile support



a) support arrangement

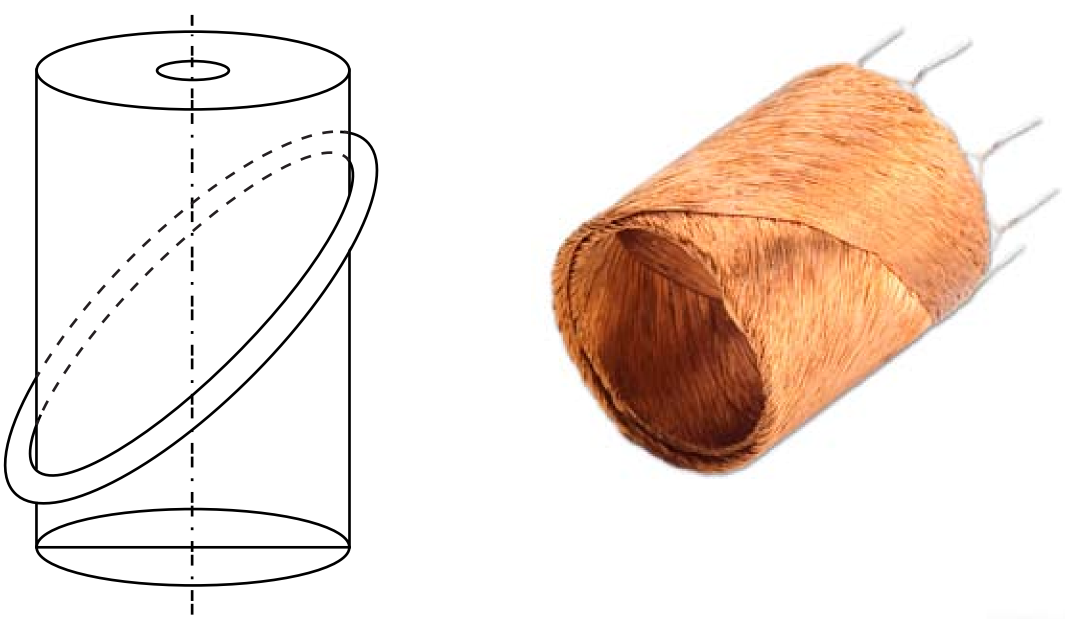
b) armature as flat package

c) forming of armature in cylindrical shape

C — A procedure which avoids having to form a perfect cylinder from a flat package consists of winding the wire directly and continuously onto a cylindrical support. This support then remains inside the rotor. Coil heads are reduced to a minimum.
Although a large air gap is necessary to accommodate the armature support; this method is, however, easily automated.

D — The Skew-Wound armature method utilizes the same two-layer plastic coated wire described in Method B. This Wire is directly and continuously wound onto a cylindrical support which is later removed, thus eliminating an excessive air gap and minimizing rotor inertia. In this type of winding, inactive coil heads are non-existent. (Figure 2). This kind of armature winding does require relatively complex coil winding machines. Portescap thru its proprietary know how has developed multiple automated winding machines for different frame sizes and continues to innovate in the space so that dense coil windings can be spun in these automated machines.

Figure 2



Features of Ironless Rotor DC Motors

The rotor of a conventional iron core DC motor is made of copper wire which is wound around the poles of its iron core. Designing the rotor in this manner has the following results:

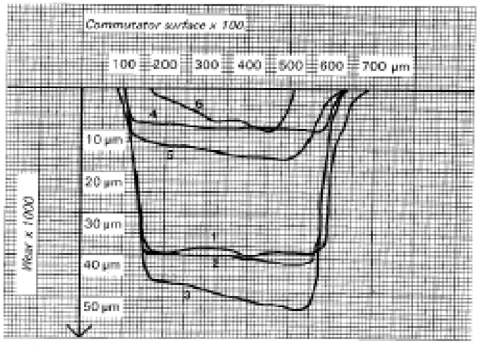
- A large inertia due to the iron mass which impedes rapid starts and stops
- A cogging effect and rotor preferential positions caused by the attraction of the iron poles to the permanent magnet.
- A considerable coil inductance producing arcing during commutation. This arcing is responsible on the one hand for an electrical noise, and on the other hand for the severe electro—erosion of the brushes. It is for the latter reason that carbon type brushes are used in the conventional motors.

A self supporting ironless DC motor from Portescap has many advantages over conventional iron core motors:

- high torque to — inertia ratio
- absence of preferred rotor positions
- very low torque and back EMF variation with armature positions
- essentially zero hysteresis and eddy current losses
- negligible electrical time constant
- almost no risk of demagnetization, thus fast acceleration
- negligible voltage drop at the brushes (with multiwire type brushes)
- lower viscous damping
- linear characteristics

REE System proven to increase motor life up to 1000 percent

The two biggest contributors to the commutator life in a brush DC motor are the mechanical brush wear from sliding contacts and the erosion of the electrodes due to electrical arcing. The superior surface finish, commutator precision along with material upgrades such as precious metal commutators with appropriate alloys has helped in reducing the mechanical wear of the brushes. To effectively reduce electro erosion in while extending commutator life Portescap innovated its proprietary REE (Reduced Electro Erosion) system of coils. The REE system reduces the effective inductivity of the brush commutation by optimization of the mutual induction of the coil segments. In order to compare and contrast the benefits of an REE system Portescap conducted tests on motors with and with out REE coil optimization. The commutator surface wear showed improvements ranging from 100 -300 percent as shown in Figure 5. Coils 4, 5 and 6 are REE reinforced while 1, 2 & 3 are without REE reinforcement.

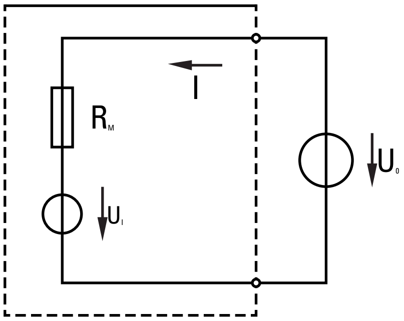


Brush DC Working Principles

The electromechanical properties of motors with ironless rotors can be described by means of the following equations:

1. The power supply voltage U_0 is equal to the sum of the voltage drop produced by the current I in the ohmic resistance R_M of the rotor winding, and the voltage U_i induced in the rotor :

$U_0 = I \times R_M + U_i$ (1)



2. The voltage U_i induced in the rotor is proportional to the angular velocity ω of the rotor :

$U_i = k_E \times \omega$ (2)

It should be noted that the following relationship exists between the angular velocity ω express in radians per second and the speed of rotation n express in revolutions per minute:

$$\omega = \frac{2\pi\, n}{60}$$

3. The rotor torque M is proportional to the rotor current I:

$M = k_T \times I$ (3)

It may be mentioned here that the rotor torque M is equal to the sum of the load torque M_L supplied by the motor and the friction torque M_f of the motor :

$M = M_L + M_f$

By substituting the fundamental equations (2) and (3) into (1), we obtain the characteristics of torque/angular velocity for the dc motor with an ironless rotor :

$U_0 = M \times R_M + k_E \times \omega$ (4)

By calculating the constant k_E and k_T from the dimensions of the motor, the number of turns per winding, the number of windings, the diameter of the rotor and the magnetic field in the air gap, we find for the direct-current micromotor with an ironless rotor:

$$\frac{M}{I} = \frac{U_i}{\omega} = k \qquad (5)$$

Which means that $k = k_E = k_T$

The identity $k_E = k_T$ is also apparent from the following energetic considerations:

The electric power $P_e = U_0 \times I$ which is supplied to the motor must be equal to the sum of the mechanical power $P_m = M \times \omega$ produced by the rotor and the dissipated power (according to Joule's law) $P_v = I^2 \times R_M$:

$P_e = U_0 \times I = M \times \omega + I^2 \times R_M$

$\quad = P_m + P_v$

Moreover, by multiplying equation (1) by I, we also obtain a formula for the electric power P_e:

$P_e = U_0 \times I = I^2 \times R_M + U_i \times I$

The equivalence of the two equations gives

$M \times \omega = U_i \times I$

or $\frac{U_i}{\omega} = \frac{M}{I}$ and $k_E = k_T = k$

Quod erat demonstrandum.

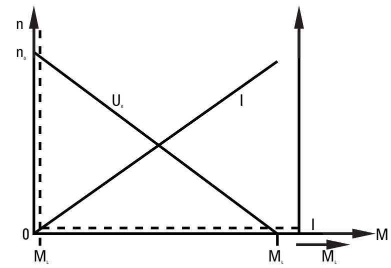
Using the above relationships, we may write the fundamental equations (1) and (2) as follows:

$U_0 = I \times R_M + k \times \omega$ (6)

and :

$$U_0 = M \times \frac{R_M}{k} + k \times \omega \qquad (7)$$

Graphic express "speed-torque" characteristic:



To overcome the friction torque M_f due to the friction of the brushes and bearings, the motor consumes a no-load current I_0. This gives

$M_f = k \times I_0$

and:

$U_0 = I_0 \times R_M + k \times \omega_0$ where

$$\omega_0 = \frac{2\pi \times n_0}{60}$$

hence:

$$k = \frac{U_0 - I_0 \times R_M}{\omega_0} \qquad (8)$$

Is it therefore perfectly possible to calculate the motor constant k with the no-load speed n_0, the no-load current I_0 and the rotor resistance R_M.

The starting-current I_d is calculated as follows:

$$I_d = \frac{U_0}{R_M}$$

It must be remembered that the R_M depends to a great extent on the temperature; in other words, the resistance of the rotor increases with the heating of the motor due to the dissipated power (Joule's law):

$R_M = R_{M0} (1 + \gamma \times \Delta T)$

Where γ is the temperature coefficient of copper (γ = 0.004/°C).

As the copper mass of the coils is comparatively small, it heats very quickly

Brush DC Working Principles

through the effect of the rotor current, particularly in the event of slow or repeated starting. The torque M_d produced by the starting-current I_d is obtained as follows:

$$M_d = I_d \times k - M_f = (I_d - I_0)k \qquad (9)$$

By applying equation (1), we can calculate the angular velocity ω produced under a voltage U_0 with a load torque M_L. We first determine the current required for obtaining the torque $M = M_L + M_f$:

$$I = \frac{M_L + M_f}{k}$$

Since $\frac{M_f}{k} = I_0$

we may also write (10)

$$I = \frac{M_L}{k} + I_0$$

For the angular velocity ω, we obtain the relationship

$$\omega = \frac{U_0 - I \times R_M}{k} \qquad (11)$$

$$= \frac{U_0}{k} - \frac{R_M}{k^2}(M_L + M_f)$$

In which the temperature dependence of the rotor resistance R_M must again be considered; in other words, the value of R_M at the working temperature of the rotor must be calculated. On the other hand, with the eqation (6), we can calculate the current I and the load torque M_L for a given angular velocity ω and a given voltage U_0 :

$$I = \frac{U_0 - k \times \omega}{R_M} = I_d - \frac{k}{R_M}\omega \qquad (12)$$

And with equation (10)

$$M_L = (I - I_0)k$$

We get the value of M_L:

$$M_L = (I - I_0)k - \frac{k^2}{R_M}\omega$$

The problem which most often arises is that of determining the power supply voltage U_0 required for obtaining a speed of rotation n for a given load torque M_L (angular velocity ω = n x 2π/60). By introducing equation (10) into (6) we obtain:

$$U_0 = \left(\frac{M_L}{k} + I_0\right) R_M + k \times \omega \qquad (13)$$

Practical examples of calculations

Please note that the International System of Units (S.I.) is used throughout.

1. Let us suppose that, for a Portescap® motor 23D21-216E, we wish to calculate the motor constant k, the starting current I_d and the starting torque M_d at a rotor temperature of 40°C. With a power supply voltage of 12V, the no-load speed is n_0 is 4900 rpm (ω_0 = 513 rad/s), the no-load current I_0 = 12 mA and the resistance R_{M0} = 9.5 Ω at 22°C.

By introducing the values ω_0, I_0, R_{M0} and U_0 into the equation (8), we obtain the motor constant k for the motor 23D21-216E:

$$k = \frac{12 - 0.012 \times 9.5}{15} = 0.0232 \text{ Vs}$$

Before calculating the starting-current, we must calculate the rotor resistance at 40°C. With ΔT = 18°C and R_{M0} = 9.5Ω, we obtain

$$R_M = (1 + 0.004 \times 18) = 9.5 \times 1.07$$
$$= 10.2\Omega$$

The starting-current I_d at a rotor temperature of 40°C becomes

$$I_d = \frac{U_0}{R_M} = \frac{12}{10.2} = 1.18\text{A}$$

and the starting-torque M_d, according to equation (9), is

$$M_d = k(I_d - I_0) = 0.0232\ (1.18 - 0.012)$$
$$= 0.027 \text{ Nm}$$

2. Let us ask the following question: what is the speed of rotation n attained by the motor with a load torque of 0.008 Nm and a power supply voltage of 9V at a rotor temperature of 40°C?

Using equation (10) we first calculate the current which is supplied to the motor under these conditions:

$$I = \frac{M_L}{k} + I_0 = \frac{0.008}{0.0232} + 0.012$$
$$= 0.357\text{A}$$

Equation (11) gives the angular velocity ω:

$$\omega = \frac{U_0 - I \times R_M}{k} = \frac{9 - 0.357 \times 10.2}{0.0232}$$
$$= 231 \text{ rad/s}$$

and the speed of rotation n:

$$n = \frac{60}{2\pi}\omega = 2200 \text{ rpm}$$

Thus the motor reaches a speed of 2200 rpm and draws a current of 357 mA.

3. Let us now calculate the torque M at a given speed of rotation n of 3000 rpm (ω = 314 rad/s) and a power supply voltage U_0 of 15V; equation (12) gives the value of the current:

$$I = \frac{U_0 - k \times \omega}{R_M} = I_d - \frac{k}{R_M} \times \omega$$
$$= 1.18 - \frac{0.0232}{10.2} \times 314 = 0.466\text{A}$$

and the torque load M_L:

$$M_L = k(I - I_0)$$
$$= 0.0232\ (0.466 - 0.012)$$
$$= 0.0105 \text{ Nm}$$
$$(M_L = 10.5 \text{ mNm})$$

4. Lastly, let us determine the power supply voltage U_0 required for obtaining a speed rotation n of 4000 rpm (ω = 419 rad/s) with a load torque of M_L of 0.008 Nm, the rotor temperature again being 40°C (R_M = 10.2Ω).
As we have already calculated, the current Í necessary for a torque of 0.008 Nm is 0.357 A

$$U_0 = I \times R_M + k \times \omega$$
$$= 0.357 \times 10.2 + 0.0232 \times 419$$
$$= 13.4 \text{ volt}$$

How to select your Coreless motor

PRODUCT RANGE CHART

FRAME SIZE		08GS	08G	13N	16C	16N28	16G
Max Continuous Torque	mNm (Oz-in)	0.66 (0.093)	0.87 (0.102)	3.33 (0.47)	1.0 (0.14)	2.4 (0.34)	5.4 (0.76)
Motor Regulation R/K^2	10^3/Nms	1900	1200	166	1523	380	77
Rotor Inertia	$Kgm^2\ 10^{-7}$	0.03	0.035	0.33	0.27	0.51	0.8
		17S	**17N**	**22S**	**22N28**	**22V**	**23L**
Max Continuous Torque	mNm (Oz-in)	2.6 (0.37)	4.85 (0.69)	9.5 (1.34)	7.3 (1.04)	8.13 (1.15)	6.2 (1.16)
Motor Regulation R/K^2	10^3/Nms	250	97	33	73	58	54
Rotor Inertia	$Kgm^2\ 10^{-7}$	0.5	0.8	1.9	3	2.4	3.6

FRAME SIZE		23V	23GST	25GST	25GT	26N	28L	28LT
Max Continuous Torque	mNm (Oz-in)	13 (1.8)	22 (3.1)	27 (3.8)	41 (5.8)	17.3 (2.4)	21.0 (2.97)	22.8 (3.23)
Motor Regulation R/K^2	10^3/Nms	30	11 (0.4)	8	4.2	18	12	13
Rotor Inertia	$Kgm^2\ 10^{-7}$	3.7	4.7	10	13	6	17.5	10.7
		28D	**28DT**	**30GT**	**35NT2R32**	**35NT2R82**	**35GLT**	
Max Continuous Torque	mNm (Oz-in)	33.6 (4.8)	41 (5.8)	93 (13.2)	58.3 (8.3)	115 (16.3)	158.6	
Motor Regulation R/K^2	10^3/Nms	6.69	5.9	1.1	3.12	0.83	0.39	
Rotor Inertia	$Kgm^2\ 10^{-7}$	17.6	20	33	52	71.4	70	

Motor Designation

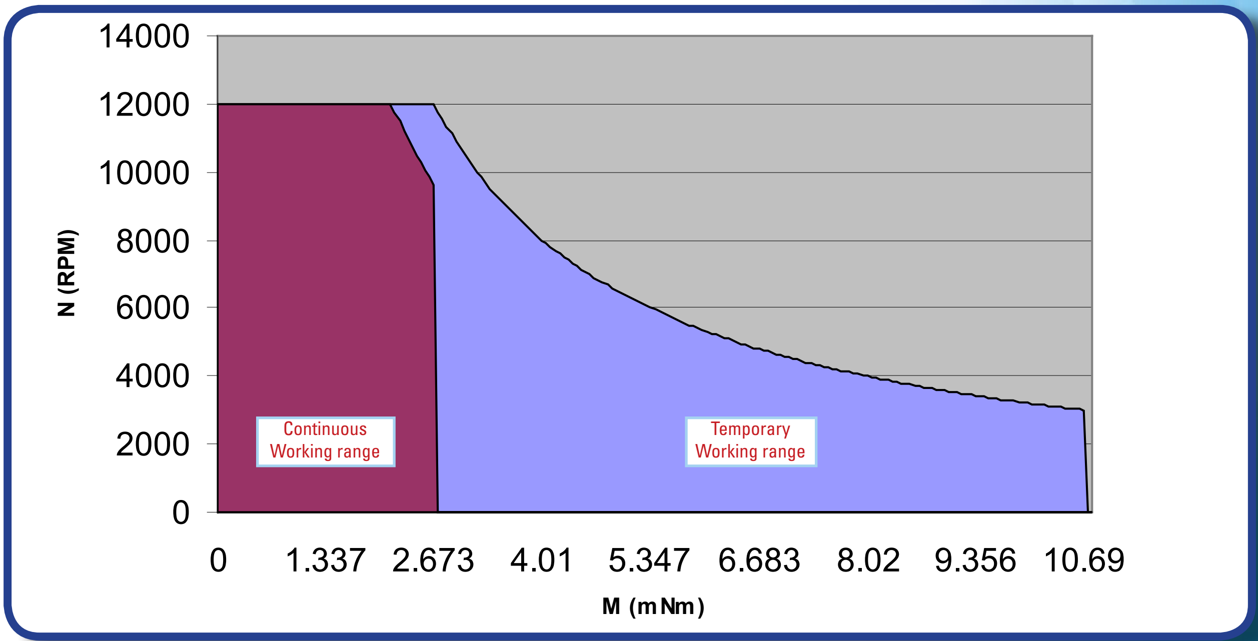
22 N 2R 2B - 210E 286

- 22: Motor diameter (in mm)
- N: Motor generation/ length:
  L, C = old generation (C: short, L: long), Alnico Magnet
  S, N, V = middle generation (S: short, N: normal, V: very long)
  G, GS = new generation (high power magnet), S: short version
- 2R: Bearing type:
  blank = with sleeve bearings
  2R = with front and rear ball bearings
- 2B: Commutation size & type/ magnet type:
  Alnico/ Precious Metal = 18, 28, 48, 58
  Alnico/ Graphite & Copper = 12
  NdFeB/ Precious Metal = 78, 88, 98
  NdFeB/ Graphite Copper = 82, 83
- 210E: Coil type:
  nb of layer
  wire size
  type connexion
- 286: Execution coding

Explanation of Specifications

MOTOR PART NUMBER		16N28 205E	EXPLANATION
MEASURING VOLTAGE	V	18	Is the DC voltage on the motor terminals and is the reference at which all the data is measured
NO LOAD SPEED	rpm	9600	This is the the speed at which motor turns when the measuring voltage is applied with out any load
STALL TORQUE	mNm (oz-in)	2.9 (0.41)	Minimum torque required to stall the motor or stop the motor shaft from rotating at measuring voltage
AVERAGE NO LOAD CURRENT	mA	4.9	The current drawn by the motor at no load while operating at the measured voltage
TYPICAL STARTING VOLTAGE	V	0.45	The minimum voltage at which the motor shaft would start rotating at no load
MAX RECOMMENDED VALUES			
MAX CONT CURRENT	A	0.15	The maximum current that can be passed through the motor with out overheating the coil
MAX CONT TORQUE	mNm (oz-in)	2.5 (0.35)	The maximum torque that can be applied without overheating the coil
MAX ANGULAR ACCELERATION	10^3 rad/s^2	182	The maximum feasible rotor acceleration to achieve a desired speed
INTRINSIC PARAMETERS			
BACK-EMF CONSTANT	V/1000 rpm	1.8	Voltage induced at a motor speed of 1000 rpm
TORQUE CONSTANT	mNm/A (oz-in/A)	17.3 (2.45)	Torque developed at a current of 1 A
TERMINAL RESISTANCE	ohm	109	Resistance of the coil at a temperature of 22 °C
MOTOR REGULARION	10^3 /Nms	360	It is the slope of speed torque curve
ROTOR INDUCTANCE	mH	3	Measured at a frequency of 1 kHz
ROTOR INERTIA	kgm^2 10^{-7}	0.55	Order of magnitude mostly dependent on mass of copper rotating
MECHANICAL TIME CONSTANT	ms	20	Product of motor regulation and rotor inertia

Speed vs Torque curve • 16N28 at 18V



Markets & Applications

MEDICAL

- Powered surgical instruments
- Dental hand tools
- Infusion, Volumetric & Insulin Pumps
- Diagnostic & scanning equipment

Benefits: Reduced footprint analyzers with high efficiency & precision sample positioning

SECURITY & ACCESS

- Security cameras
- Locks
- Bar code readers
- Paging systems

Benefits: Low Noise & Vibration, High Power & Superior Efficiency

AEROSPACE & DEFENSE

- Cockpit gauge
- Indicators
- Satellites
- Optical scanners

Benefits: Low Inertia, Compactness and Weight, High Efficiency

ROBOTICS & FACTORY AUTOMATION

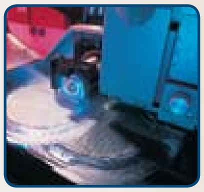
- Conveyors
- Remote controlled vehicles
- Industrial robots

Benefits: High Power & Low Weight

POWER HAND TOOLS

- Shears
- Pruning hand tools
- Nail guns

Benefits: High Efficiency, Compactness and Weight, Low Noise



OTHER

- Office equipment
- Semiconductors
- Model railways
- Document handling
- Optics
- Automotive
- Transportation
- Audio & video

Benefits: Low Noise, High Power, Better Motor Regulation

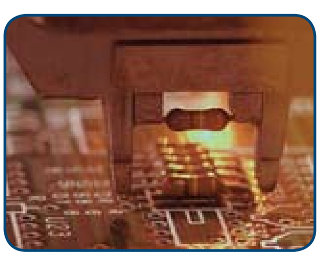
Brush DC Motors at Work

MEDICAL ANALYZERS

Portescap solves multiple application needs in analyzers, from sample draw on assays to rapid scanning and detection of molecular mechanisms in liquids and gases, with its coreless brush dc motors. For high throughput applications—those where over 1,000 assays are analyzed in an hour—high efficiency and higher speed motors such as brush DC coreless motors are a suitable choice. Their low rotor inertia along with short mechanical time constant makes them ideally suited for such applications. As an example, a Portescap 22-mm motor brush coreless DC motor offers no-load speed of 8,000 rpm and a mechanical time constant of 6.8 milliseconds. Another analyzer function that plays a vital role in their output is collecting samples from the vials or assays, and serving them up to measurement systems based on photometry, chromatography, or other appropriate schemes. Here again, a brush DC coreless motor is highly applicable due to the power density it packs in a small frame size. You can maximize your application's productivity with a 16 or 22mm workhorse from Portescap.

INFUSION PUMPS

Coreless brush DC motors offer significant advantages over their iron core brush counterparts for some of the critical care pump applications where, the benefits range from improved efficiency to higher power density, in a smaller frame size. One of the factors that deteriorates motor performance over long term usage is the heating of the motor with associated Joule loss. In motor terminology this is governed by the motor regulation factor determined by the coil resistance, R, and the torque constant, k. The lower the motor regulation factor (R/k^2) the better would the motor perform over its life while sustaining higher efficiencies. With some of the lowest motor regulation factors Portescap's latest innovation in Athlonix motors is already benefiting applications in the infusion pump space by offering a choice of a higher performance motor with less heat loss, higher efficiency and power density in compact packages.



ELECTRONICS ASSEMBLY SURFACE MOUNT EQUIPMENT

Portescap's versatile 35mm coreless motors with carbon brush commutation excel in electronic assembly, robotics and automated machinery equipment and have been a work horse in some of the pick and place machinery used in surface mount technology. Our 35mm low inertia motors can provide high acceleration, low electro magnetic interference, and frequent start stops that the machines need while maintaining smaller and light weight envelopes.