KOFORD
ENGINEERING, LLC

2.3 inch (60 mm) Series

- High performance slotless brushless servomotors for military, aerospace, medical, and industrial applications.
- Highest power density
- Up to 94% efficiency
- Cog free non saturating design with linear behavior ideal for precision motion
- 2 pole housed and frameless designs
- High speed designs up to 25,104 rpm and 1.385 kW continuous power
- Low speed designs with no load speeds down to 3,864 rpm
- High temperature 240°C ML wire and Kapton® polyimide ground insulation along with TFE lead insulation used for the greatest possible durability
- Available with hall sensors, sensorless, and integral electronics
- Long life premium synthetic bearing lube with -73C to 149C temperature range
- Contact factory for encoders or custom gearboxes

KOFORD ENGINEERING, LLC

2.3" (60mm) Slotless Brushless Motor. 2 pole 24V windings

• 3,864 to 19,570 rpm no load **•up to 1,049 watts continuous**

High power density high efficiency slotless design is cog free, cost effective, quiet, and provides high efficiency and cool operation. 240°C ML wire and Kapton® polyimide ground insulation are used for the ultimate in ruggedness. 200°C Neo magnets are used along with hardened and ground 440C stainless shaft, and high temp TFE insulated lead wires. Slotless design eliminates cog and reduces bearing loads due to air gap asymmetries compared to conventional slotted motors. Unit are supplied either with 120° halls rated at 150°C, or for pumps, blowers, sensorless versions are available. Custom windings can be supplied upon request. Thermistor temperature sensors are offered as an option. Encoders, gearboxes and integral electronics can be supplied on custom order.

Motor Data

Winding		161	361	522	805
Rated supply voltage	volts	24	24	24	24
No load speed	rpm±12%	3,864	8,664	12,528	19,320
Speed/torque slope	rpm/oz-in	18	24	30	39
Maximum efficiency	%	86	90	92	93
Continuous torque heat sink/no h.s.	oz-in*	90/51	87/46	86/44	90/43
Rated power heat sink/no heat h.s.	watts*	148/110	422/256	630/366	1,049/560
Speed at rated power	rpm	2,244/2,946	6,575/7,560	9,948/11,196	15,810/17,643
Rated current	amps	11/6.1	24/14	34/18	54/26
Motor constant Km	oz-in/√w	9.4	9.4	9.4	9.4
Winding resistance#	ohm±15%	.80	.158	.076	.032
No load current	amp±50%	.16	.44	.58	.71
Damping factor	oz-in/krpm	.14	.11	.08	.04
Static friction	oz-in	.8	.7	.5	.4
Velocity constant	rpm/volt±12%	161	361	522	805
Torque constant Kt	oz-in/amp	8.39	3.74	2.59	1.67
Winding inductance	mH	.72	.13	.062	.027
Mechanical time constant	ms	3.3	3.3	3.3	3.3
Rotor inertia	10^{-4}oz-in-sec^2	20.5	20.5	20.5	20.5
Thermal res. winding to housing	°C/W	.64	.64	.64	.64
Thermal res. housing to ambient	°C/W	2.1	2.1	2.1	2.1

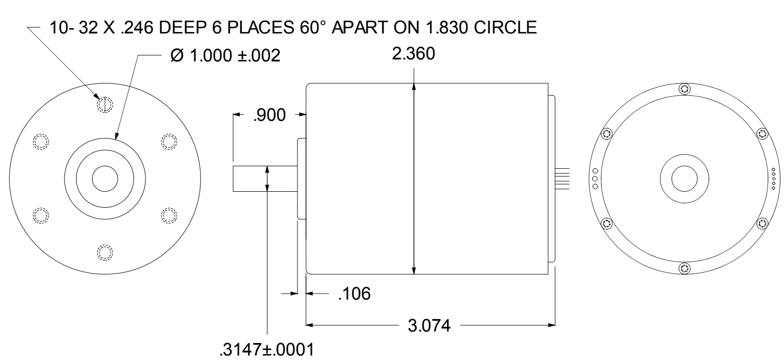
Ambient temperature range -73C to 149C

Weight 2.2 lb. maximum winding temp. 200C Data is for winding and magnet temperature of 20°C

*Case held to 60°C with customer supplied heat sinking or cooling jacket /still air and no heat sink 20°C ambient.

#Lead wires resistance 11.8mΩ if used at full length

Leads are 12" minimum Phase leads are 18 gauge, hall leads are 28 gauge, all TFE



Leads	
Blue	Phase A
White	Phase B
Brown	Phase C
Red	+5 volts
Black	Ground
Yellow	Sensor A
Orange	Sensor B
Green	Sensor C

Ordering Information: mail@koford.com•phone 937-695-1275•fax 937-695-0237•www.koford.com

Example: Part Number 60 H 805 A

Motor type — 60

Type S=sensorless H=120°halls — H

Winding number — 805

Modifications A=none, T=thermistor O=overtemperature protection — A

Test Data
Total System Performance
60S805A with S28V40A Controller at 24 Volts

Rpm	Torque Oz-in	Watts Out	Efficiency %	Amps
19612	0.00	0.0	0.0	0.70
19435	4.56	65.4	77.0	3.54
19258	9.16	130.1	85.1	6.37
19081	13.74	193.3	87.6	9.19
18904	18.32	255.4	88.5	12.02
18727	22.90	316.2	88.7	14.85
18550	27.48	375.9	88.6	17.68
18373	32.06	434.4	88.2	20.51
18196	36.64	491.6	87.8	23.34
18019	41.22	547.7	87.2	26.17
17842	45.80	602.6	86.6	29.00
17665	50.38	656.3	85.9	31.83
17486	54.96	708.7	85.0	34.72

Dyno test results of a motor and drive combination with voltage held to 24v at input of drive using remote voltage sense on the power supply. Winding temperature is held below 40C by running test quickly and/or allowing motor to cool between tests. Motor leads were left at full length and not shortened to minimum length to increase efficiency. Test were conducted at 24°C.

Test Data
Total System Performance
60H161A with S28V40A Controller at 24 Volts

Rpm	Torque oz-in	Watts Out	Efficiency %	Amps
3720	0.00	0.00	0.0	0.30
3422	13.92	35.36	73.6	2.00
3113	32.16	74.08	77.2	4.00
2809	50.24	104.48	72.6	6.00
2508	67.68	125.76	65.5	8.00
2141	85.60	135.52	56.5	10.00
1730	104.32	133.70	46.4	12.00

Dyno test results of a motor and drive combination with voltage held to 24v at input of drive using remote voltage sense on the power supply. Winding temperature is held below 40C by running test quickly and/or allowing motor to cool between tests. Motor leads were left at full length and not shortened to minimum length to increase efficiency. Test were conducted at 24°C.

KOFORD
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2.3" (60mm) Slotless Brushless Motor. 2 pole 48V windings

• 17,373 to 25,104 rpm no load **•up to 1,385 watts continuous**

High power density high efficiency slotless design is cog free, cost effective, quiet, and provides high efficiency and cool operation. 240°C ML wire and Kapton® ground insulation are used for the ultimate in ruggedness. 200°C Neo magnets are used along with hardened and ground 440C stainless shaft, and high temp TFE insulated lead wires. Slotless design eliminates cog and reduces bearing loads due to air gap asymmetries compared to conventional slotted motors. Unit are supplied either with 120° halls rated at 150°C, or for pumps, blowers, sensorless versions are available. Custom windings can be supplied upon request. Thermistor temperature sensors are offered as an option. Encoders, gearboxes and integral electronics can be supplied on custom order.

Motor Data

Winding		162	362	523
Rated supply voltage	volts	48	48	48
No load speed	rpm±12%	7,776	17,376	25,104
Speed/torque slope	rpm/oz-in	24	36	47
Maximum efficiency	%	89	93	94
Continuous torque heat sink/no h.s.	oz-in*	90/52	90/44	90/37
Rated power heat sink/no heat h.s.	watts*	372/249	938/512	1,385/637
Speed at rated power	rpm	5,601/6,511	14,136/15,792	20,874/23,365
Rated current	amps	11/6.3	24/12	35/15
Motor constant Km	oz-in/√w	9.4	9.4	9.4
Winding resistance#	ohm±15%	.80	.158	.076
No load current	amp±50%	.19	.30	.59
Damping factor	oz-in/krpm	.11	.04	.04
Static friction	oz-in	.7	.41	.41
Velocity constant	rpm/volt±12%	162	362	523
Torque constant Kt	oz-in/amp	8.39	3.73	2.58
Winding inductance	mH	.72	.13	.062
Mechanical time constant	ms	3.3	3.3	3.3
Rotor inertia	10^{-4}oz-in-sec^2	20.5	20.5	20.5
Thermal res. winding to housing	°C/W	.64	.64	.64
Thermal res. housing to ambient	°C/W	2.1	2.1	2.1

Ambient temperature range -73C to 149C

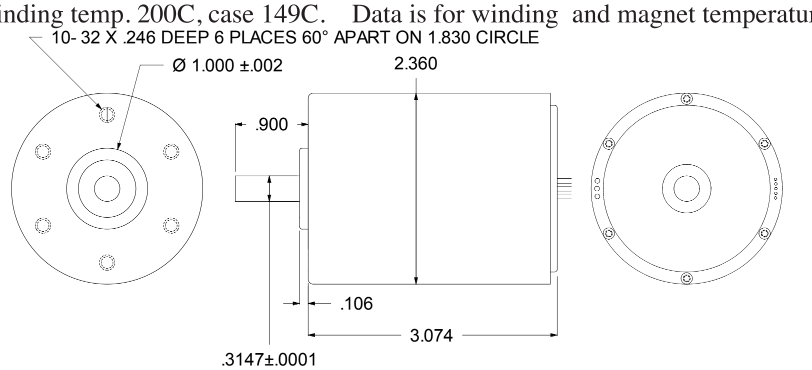
Weight 2.2 lbs, maximum winding temp. 200C, case 149C. Data is for winding and magnet temperature of 20°C

*Case held to 60°C with customer supplied heat sinking or cooling jacket /still air and no heat sink 20°C ambient.

#Lead wires resistance 11.8mΩ if used at full length

Leads are 12" minimum

Phase leads are 18 gauge, hall leads are 28



Leads	
Blue	Phase A
White	Phase B
Brown	Phase C
Red	+5 volts
Black	Ground
Yellow	Sensor A
Orange	Sensor B
Green	Sensor C

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Example: Part Number 60 H 523 A

Motor type — 60

Type S=sensorless H=120°halls — H

Winding number — 523

Modifications A=none, T=thermistor, O=overtemperature protection — A

Test Data
Total System Performance
60H162A with H48V20A Controller at 48 Volts

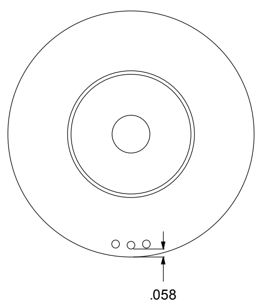
Rpm	Torque oz-in	Watts Out	Efficiency %	Amps
7427	0.00	0.00	0.0	0.40
7167	9.92	52.80	68.7	1.60
6937	21.76	111.68	77.5	3.00
6364	49.12	231.52	80.4	6.00
5800	75.84	325.28	75.3	9.00
5246	103.84	403.52	70.0	12.00
4457	130.82	431.52	59.9	15.00
3638	158.72	427.52	49.5	18.00

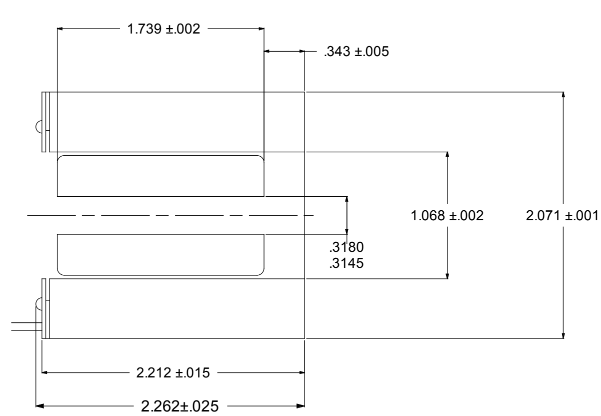
Dyno test results of a motor and drive combination with voltage held to 48v at input of drive using remote voltage sense on the power supply. Winding temperature is held below 40C by running test quickly and/or allowing motor to cool between tests. Motor leads were left at full length and not shortened to minimum length to increase efficiency. Test were conducted at 24°C.

KOFORD ENGINEERING, LLC

2.3" (60 mm) Frameless Slotless Brushless Motors

Frameless motors are used for the construction of pumps, hermetic compressors, high performance gearmotors for applications like military robots and high speed spindles using air or magnetic bearings. Frameless motor can be provided with or without out sensors. Sensorless applications include refrigeration compressors and pumps, The windings and all materials are suitable for use exposed to the working fluid in hermetic compressors, however it can also be used with a liner as long as the liner is insulated from with windings by epoxy powder coating or a mylar lining. When these motors are used with air or magnetic bearings the large air gap due to the slotless design greatly reduces the negative magnetic stiffness improving bearing performance and stability. In these applications a user supplied resolver, encoder or magnetic sensor mounted on the customer supplied shaft may be used. The stator should be attached to the housing with epoxy using a bond gap of around .001”. The minimum bondline thickness of the epoxy to be used must be determined as some material contain large particle size fillers and cannot achieve a .001” bondline. For heat cure (recommended) Koford Engineering has a line of high performance epoxies (see the epoxy section of our web site), for room temperature cure 3M DP-460 works well as long as care is taken to ensure the correct mix ratio (don’t use the static mixer and dispense a large enough quantity of material that the correct amount from both components is dispensed). If the stator must be removable a heat shrink mounting is recommended but careful fitting is required to achieve the correct interference and prevent the stator from spinning. Do not attempt press fitting as this will destroy the stator. The same adhesives can be used to bond the rotor magnet. Do not press fit! Press fitting will destroy the magnet. The data provided in this catalog can be used as a guide to motor performance, however some variations will result since your motor bearings, housing clearances, and thermal resistances may not be the same as ours. For the best performance the motor housing should be nonmagnetic and have the maximum practical clearance to the rotor magnet. The motor bearings should also be spaced as far away from the rotor as possible to reduce eddy and hysteresis drag. If a hall sensor mounted to the stator is required it can be provided with a through bore configuration, however efficiency will be several percentage points less then the standard housed configuration. Contact the factory for 12mm bore part numbers. Custom winds and rotors for other shaft sizes can be provided. For sensorless applications or hall applications where a customer supplied magnet and hall board are used, or where an encoder with phase output is used then the sensorless type of frameless motor should be used. If halls need to be included in the frameless then the hall configuration needs to be used. None that the hall configuration does not provide through rotor clearance. The hall board reads the end of the magnet and since the hall is spaced away from the windings performance is better then with a through bore design. The motor is more compact and has reduced inertia compared to a motor with a seperate hall magnet. Designs using a seperate hall magnets will require a time consuming alignment of the sensor magnet to the hall board (or the hall magnet to the motor magnet).

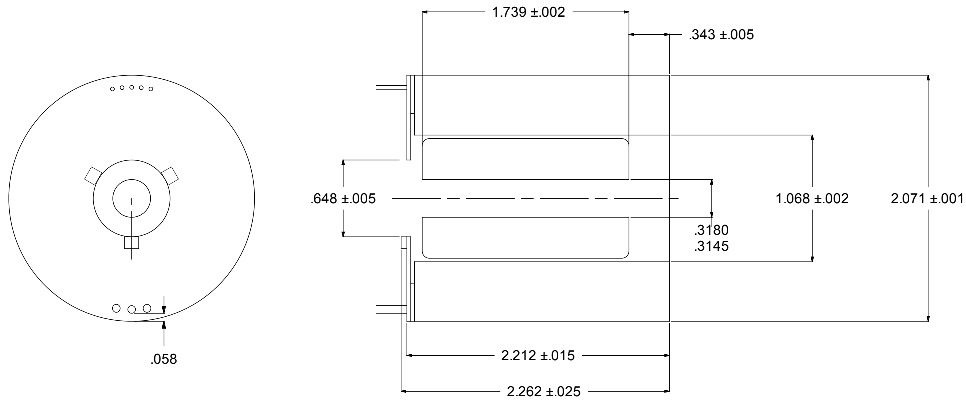




1lb 8 oz

Sensorless frameless motor. Add F to catalog part number. Example 60FS805A

2.3" (60mm) Frameless Slotless Hall Sensor Brushless Motors



1lb 8 oz

Hall sensor frameless motor. Add F to catalog part number. Example 60FH805A

Through bore frameless hall sensor motor can be ordered on special request. Efficiency will be reduced by about 2% and motor operation may not be as smooth at high load as with the standard configuration. Motor dimension are unchanged except for the bore diameter.

Thermistor resistance for Koford motors

Temp [degree C]	Temp [degree F]	Rt/R25	Temp Coef [%/C]	Resistance [ohm]
-50	-58	66.970	7.10	334850
-45	-49	47.250	6.86	236250
-40	-40	33.740	6.62	168700
-35	-31	24.370	6.40	121850
-30	-22	17.800	6.19	89000
-25	-13	13.130	5.99	65650
-20	-4	9.776	5.80	48880
-15	5	7.347	5.63	36735
-10	14	5.570	5.46	27850
-5	23	4.257	5.30	21285
0	32	3.279	5.10	16395
5	41	2.550	4.95	12750
10	50	1.998	4.81	9990
15	59	1.576	4.68	7880
20	68	1.252	4.55	6260
25	77	1.000	4.43	5000
30	86	0.804	4.31	4019
35	95	0.650	4.20	3249
40	104	0.528	4.09	2641
45	113	0.432	3.99	2158
50	122	0.355	3.74	1773
55	131	0.295	3.63	1474
60	140	0.247	3.54	1233
65	149	0.207	3.44	1035
70	158	0.175	3.35	874
75	167	0.148	3.26	741
80	176	0.126	3.18	631
85	185	0.108	3.10	539
90	194	0.092	3.03	462
95	203	0.080	2.95	398
100	212	0.069	2.86	344
105	221	0.060	2.78	299
110	230	0.052	2.70	261
115	239	0.046	2.63	228
120	248	0.040	2.56	200
125	257	0.035	2.50	177
130	266	0.031	2.44	156
135	275	0.028	2.37	138
140	284	0.025	2.31	123
145	293	0.022	2.26	110
150	302	0.020	2.20	98

Unit conversions

°F -32 ÷1.8=°C example: 212°F=100°C, °C x1.8+32=°F example: 100°C=212°F, in x 25.40=mm, mm x.03937= in., oz x 28.3495=g, oz-in x 7.06=mNm, mNm x .142=oz-in, Nm x .142=oz-in, Ncm x 1.42=oz-in, rpm x .1047=rad s^{-1}, V/R/S x .1047=volts/rpm, 746 watts=1hp, lb-in^2 x .04144=oz-in-sec^2

Understanding Data Sheets

When comparing Koford motors to data sheets for other motors be careful to note the conditions associated with the rated torque listed. For example many manufactures list continuous torque at stall or at rpm less then the maximum. Usually this is because these motors will overheat if run continuously at full speed even with no load.

Hall Sensors

Like other semiconductor components hall sensors are electrostatic sensititive. Hall motors are supplied in electrostatic safe packaging and should be kept in the packaging until use. When trimming wire length, adding connectors, and hooking up motors, workers should be grounded to prevent electrostatic damage to the sensors.

Balancing

Components attached to the motor shaft should be dynamicially balanced to G6.3 or better and located as close to the motor body as possible. This is especially critical over 20,000 rpm. G6.3 is equal to 0.64 x weight (oz.)/rpm=unbalance in milli oz-in. If the components have appreciable length they must be balance in 2 planes.

Motor technology

The Koford 60mm brushless series of motors are slotless sintered rare earth permanent magnet motors with unique technology. Compared to brush motors they have much longer life (up to 25,000 hours +), much higher speed capability (25,000+rpm), can operate in a vacuum, and will not introduce comtamination from brush dust. Compared to conventional slotted bonded rare earth magnet with the same no load speed and phase resistance Koford motors are smaller, lighter, have higher efficiency, higher peak torque (equal to stall torque), and are cog free. Compared to other slotless motors they have higher speed capabilities, better efficiency, lighter weight and more durable construction (ML Class 220C wire insulation bonded with high temperature epoxy resin) compared to the low temp bondable wire used in other slotless motors which will soften and fail under thermal overload.

Operating speed

Motors can be operated at any lower voltage and also at somewhat higher voltages and speeds then shown on the data sheet. For example 24 volt motors can be run on 28 volt system. Running a 24 volt motor at 36 volts is not recommended.

Motor selection

Motors for continuous duty applications such as pumps, blowers etc. should in most cases be selected to operate at about 10% of stall torque. This point is close to peak efficiency. Keep in mind that the drive used has a great effect on motor operating temperature. The lowest motor temperature rise will occur with the drive pwm duty cycle at 100% (maximum speed). Using a higher speed winding then necessary and reducing the speed through the drive will result in higher motor and drive operating temperatures then if a winding is selected that will run as close as possible to full speed. During variable speed operation, when the motor is operating at less then full speed, both the motor and drive operating temperature will be influenced by the drive frequency. Drive pwm frequencies of 37kHz or higher are recommended for best performance. Drives which operate at lower frequencies may need to be operated at slightly reduced load due to higher motor operating temperatures.

For variable speed applications where the motor does not operate continuously, the safest approach is to specify the motor with the continuous operating torque equal to the maximum load. If the maximum load is not known then the continuous motor current rating should be equal or more then the current limit of the drive. This will prevent the possibility of overload. For example if the current rating of the drive is 5 amps, the motor Kt is 3.0

and the no load current is 1.0 amps, continuous torque rating should be more then (5-1.0) x 3.0=12 oz-in. If the duty cycle is known then the equivalent continuous torque can be estimated. Keep in mind that the resistance losses are a function of the current squared so reducing the duty cycle to fifty percent will only allow the torque to be increased by 41% not 100%.

When comparing Koford motors to data sheets for other motors be careful to note the conditions associated with the rated torque listed. For example many manufactures list continuous torque at stall or at 10,000 rpm. Usually this is because these motors will overheat if run continuously at full speed even with no load.

Selection of Hall, Sensorless, or integral electronics

The most common motor configuration is the hall sensor design. They will operate down to zero speed and have no start up delay. Sensorless motors have only three leads which can be helpful in applications where the motor must be located a distance from the drive, it also reduces the labor required to connector the motor and reduces motor cost. For integral electronics contact the factory.

Linear characteristics

Koford motors exhibit highly linear behavior. This is not the case with slotted motors and even some slotless motors. A slotted motor with the same rpm and phase resistance may only be capable of less then half of the peak torque of a Koford motor with the same specifications. The use of slotted motors with sensorless drives is especially problematic and reduced torque capabilities should be expected. The stall torque of Koford motors is equal to the Kt times the current. However keep in mind that at stall the winding will heat up rapidly increasing the resistance so the full stall torque may only be available for a fraction of a second. Also when calculating stall torque the resistance value to use is the total resistance of the motor, drive and all associated wiring. Some drives do not apply full voltage to the drive so that must be considered also. In most cases the current limit of the drive is much less then the stall current so this is not an issue.

Speed torque calculations

A motors no load speed is equal to the supply voltage times the velocity constant (rpm/v). Under load the rpm will drop. To determine the approximate speed, use dyno data if listed, or use the speed torque slope from the data sheet. For example if the supply voltage is 28 volts and the rpm/volt is 500 then the no load speed will be 14,000 rpm. If the speed torque slope is 800 rpm/oz-in and a 5 oz-in load is applied to the shaft then the speed will be 14,000-(5 x 800) = 10,000 rpm. If there is extra wiring between the drive and the motor, or the supply and the drive, then the speed will drop at a more rapid rate due to the voltage drop in the wiring. A design margin of at least 15% should be used to allow for motor tolerances, so for example with the above motor the rpm can be expected to be a minimum of 8,500 rpm.

Motor cooling

The continuous output torque which can be achieved from a motor is limited by the allowable maximum temperature. This in turn is determined by the cooling provided by the user, and the ambient temperature. In the case of some high speed motors the continuous output torque is shown as zero if the motor does not have heat sinking. In these cases the motor can only be used in intermittent duty applications unless appropriate heatsinking is used. If the ambient temperature is above 20°C then the continuous duty torque shown must be reduced. Many Koford motors are available with temperature sensors and this can be especially useful during prototyping to evaluate cooling. The actual limitation is the rotor (magnet) temperature, but since the windings surround the rotor, the temperature can be assumed to be the same in most cases. One exception is in pump applications (frameless or housed) where the interior of the motor is filled with oil, refrigerant or water/glycol. In these applications the rotor temperature can be expected to closely follow the fluid temperature. For applications in air the allowable output torque can be increased by mounting the motor to a thick aluminum plate with surface area several times larger then the surface area of the motor. Further improvements can be obtained with the use of a fan directed at the body of the motor. Even higher performance can be obtained by the use of a refrigerant cooled sleeve around the outside diameter of the motor coupled with heatsink grease. If the motor housing can be cooled below 20°C then improved performance above data sheet values can be obtained. If only natural convection is used and the motor is mounted to plastic or a low thermal conductivity material such as steel then consideration should be given to ensuring free flow of air over the motor. Placing the motor in a small enclosed space with poor thermal connection to the outside ambient can result in considerable reduction in the amount of output power possible without overheating. When performing temperature rise calculations remember that the resistance of the copper windings increases with temperature. You must use the resistance at the operating temperature not at 20C. For example at 150°C the winding resistance is 1.51 times the resistance at 20°C, so this higher value must be used when calculating copper losses.

Frameless motors

Frameless motors are useful for certain specialized applications where housed motors cannot be used. These include air bearing or magnetic bearing motors, and pump applications where the rotor and impeller are part of a single assembly with the working fluid inside of the motor. All Koford motors can withstand continuous exposure to refrigerants. Frameless motors should be avoided for any application where a housed motor can be used. The use of water inside the motor requires special magnets or the magents must be canned in stainess steel. In many cases ceramic sleeve bearings are used with water instead of ball bearings so as to prevent corrosion and the possibilities of particles from jamming the ball bearings.

Vacuum Applications

All Koford motors are suitable for low vacuum applications. For high vacuum applications (option V) contact the factory. Vacuum grade motors are made with low outgassing material and baked before shipping. A vacuum bake by the customer immediately prior to use may be desirable to reduce pump down time. An important consideration is that in a vacuum there is no heat removal by air contacting the motor housing. Therefore the mounting of the motor should be made of highly thermally conductive material, such as copper or aluminum, should be of as heavy a cross section as possible, and should connect to a large surface exposed to the outside air.

Motor hook up

Koford hall sensor motors typically separate the phase and sensor wires. These wires should be kept apart and away from other wires. The leads should be trimmed as short as possible to reduce EMI and power losses. Where electrical noise is a consideration the phase wires may be twisted or braided with each other or enclosed in a shielded jacket. The same can be done with the hall leads to prevent their picking up EMI from noise sources.

EMI

Koford drives and motors have low levels of emi relative to other motors but in sensitive applications the following steps are suggested. First keep the phase wires as short as physically possible and twist or braid them together and if necessary add a shield jacket terminated at one end. Add a 5,000μF cap at the input to the drive along with a common mode inductor or an off the shelf EMI line filter may be used. Also consider enclosing the drive or motor and drive in a metal enclosure. If even better results are required then a custom EMI filter designed for the spec requirments and the load may be required.

Sine Drives

Koford motors are especially suitable for sine drives due to their exceptionally low harmonic distortion (typically well under 1%). Sine drives are useful for very accurate motion around zero speed. At higher speeds e.g. above 3,000 rpm there is not any noticable difference in noise/vibration/velocity accuracy with sine drives. The use of Sine drives results in lower power output and reduced efficiency compared to standard drives (block commutation) when compared with the same motor.

Permanent Magnet Synchronous motors, DC Brushless motors, AC Permanent Magnet motors, Brushless motors

These are all different names for the same kind of motor.

These are different from an AC motor (also know as an AC induction motor) which is a motor which can run from utility 60 hz AC voltage. These motors can only operate at the utility frequency and do not have adjustable speed unless the utility voltage is converted to DC and then back to a different voltage and frequency.

System efficiency

The system efficiency is different then the motor efficiency. The system efficiency takes into account motor losses, drive losses, wiring losses, and gearbox losses. The choice of a drive will make a large difference in the total system efficiency. The data sheet value for maximum motor efficiency is at maximum speed. If the speed is turned down then efficiency will be reduced. For example if a motor is operated at 12 volts with the speed control turned all of the way up, the efficiency will be better then if the motor is operated with 24 volts into the drive and the speed set at 50%. Although the motor speed is the same, there are additional losses in the drive and motor to drop the 24 volts down to 12 volts. The amount of these losses is determined by the drive and motor design. High frequency drives (37 kHz or above) provide slightly better overall efficiency then 18khz drives. Drives with a pwm frequency below 18kHz are not recommended for slotless motors.

PWM basics

Variable speed drives operate using PWM where the voltage to the motor is rapidly turned on and off. This is the same as a switching power supply where the motor is the filter. A PWM drive operates like a transformer, so the motor voltage is lower then the power supply voltage unless the speed pot it turned to maximum in which case they are the same. For example if the power supply voltage is 36 volts and the speed is turned down to 1/3 of maximum, then the motor voltage is12 volts. If a load is applied to the motor shaft which results in a 20 amp motor current then the input current to the drive will be 12/36 x 20 or 6.66 amps (neglecting losses). Because of this when using for example a 20 amp drive, the 20 amps can be pulled from the power suppply only when the speed pot is set to maximum.