KOFORD ENGINEERING, LLC

1.9" (48mm) Slotless Brushless Air Cooled Bearing Motor.

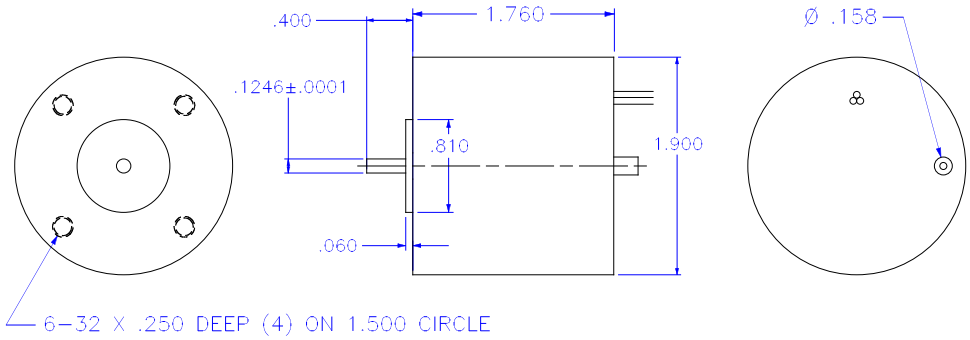
•24V windings •Sensorless •Up to 300,000 rpm •Maximum continuous power to 100 watts

Quiet and cool operation. Slotless design is cog free, and provides high efficiency. Air cooled high speed ceramic hybrid bearings for longest life. Continuous duty up to 300,000 rpm. Uses 1.25-3 psi air at .1 cfm from plant air or a 24 volt 5 watt miniature air compressor (see next page). A winding temperature sensor is available. The motor features a hardened stainless shaft, Teflon insulated lead wires, 240°C magnet wire, precison balance, anodized machined aluminum housing. For applications such as beam chopper which need to operate in a vacuum chamber at reduced pressure to avoid excessive drag, a standard diaphram vacuum pump can achieve a 90% reduction in pressure even with .1 cfm air cooling. The air cools both the windings and the bearings, reducing or eliminating the need for other cooling provisions. High rpm applications require safety precautions including operation only within containment structures which will contain the object attached to the motor shaft in the case of failure. The object mounted to the motor shaft should be light in weight, should not extend past the end of the shaft, and be balanced to G2.5 or better after mounting on the motor shaft. Special modifications are possible such as hollow shafts, custom shaft lengths, and custom rpm/v windings. For 8333, 5284 and 6785 windings use S24V5A-4G drive. For 12500 winding use S24V5A-4I drive. The Topward 3303D power supply is recommended. 24 volt DC and 120 volt AC air pumps for applications where plant air is not available or convenient are listed on the next page.

Motor Data

Winding		12500	8333	6785	5284
Nominal supply voltage	volts	24	24	24	24
no load speed	rpm ±12%	300,000	200,000	162,841	126.818
speed/torque slope	rpm/oz-in	54,000	26,650	22,600	18,162
Rated speed	rpm	273,000	184,010	144,761	112,288
Rated torque*	oz-in	.5	.6	.8	.8
Rated current*	amps	5.0	4.1	4.4	3.7
Rated. power*	watts	100	81	85	82
Motor constant Km	oz-in/√w	.20	.30	.32	.33
Winding resistance not including leads	ohm±15%	.11	.12	.37	.62
Torque at 5 amps	oz-in	.5	.7	.9	1.2
No load current	amp±50%	.50	.40	.29	.21
Damping factor	oz-in/krpm	.00014	.00026	.00028	.00032
Static friction	oz-in	.012	.012	.012	.012
Velocity constant	rpm/volt	12,500	8,333	6,785	5284
Torque constant Kt	oz-in/amp	.108	.162	.199	.255
Maximum efficiency	%	91	91	87	86
Winding inductance	mH	.009	.011	.017	.027
Thermal res. winding to ambient .1cfm	°C/W	5.0	5.0	5.0	5.0

Weight 8 oz. Maximum winding temperature 125°C. Values based on winding and magnet temperature of 20°C. *Continuous torque values assume operation in 20°C still air. Phase lead are 12" minimum and untrimmed lead resistance is .052Ω. Excess lead length should be trimmed. Phase leads are 24 gauge stranded TFE insulated. Axial force on bearing including during installation should not exceed 20 lb.



Leads	
Blue	Phase A
White	Phase B
Brown	Phase C

Ordering Information: contact us at mail@koford.com

Example: Part Number 4845 S 8333 A

- 4845 — Motor dia.
- S — Type S=sensorless
- 8333 — Winding number
- A — Modifications T=Thermistor, H=.040 bore hollow shaft

KOFORD ENGINEERING, LLC

Air pumps for 1.9" (48mm) Slotless Air Cooled Bearing Brushless Motors

Ordering Information: contact us at mail@koford.com

AP1-24 24v DC air pump kit, includes compressor mounted on antivibration mount, air filter and hose.

AP1-120 120v AC air pump kit, includes wall plug power supply and compressor mounted on antivibration mount, air filter and hose.

1.9" (48mm) Slotless Brushless DC motor.

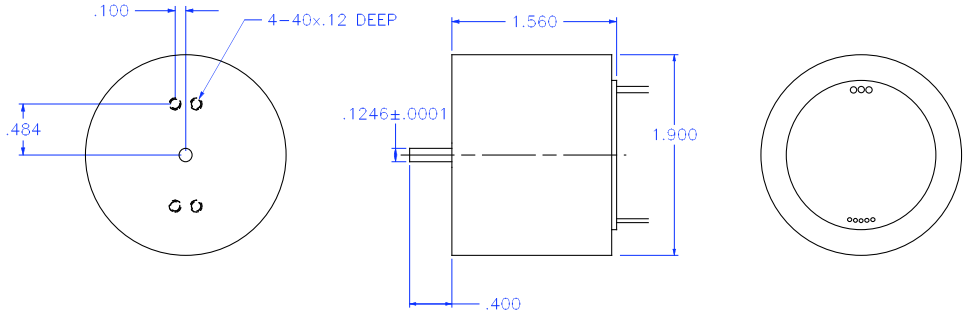
•Vacuum compatable •24V windings •Sensorless •Up to 200,000 rpm •Maximum continuous power to 60 watts

Quiet and cool operation. Slotless design is cog free, and provides high efficiency. High speed ceramic hybrid bearings for longest life. Intermittent duty up to 200,000 rpm, continuous duty up to 81,408 rpm. Constructed using all non outgassing materials suitable for high vacuum use. Water, refrigerant or heat pipe cooling is required for continuous vacuum operation since there is no cooling by ambient air. A winding temperature sensor is available. The motor features a hardened stainless shaft, Teflon insulated lead wires, 240°C magnet wire, precison balance, anodized machined aluminum housing. Special modifications are possible such as hollow shafts, custom shaft lengths, and custom windings. For 8333, 5284 and 6785 use S24V5A-4G drive, for 3392 use S24V5A-4F drive.

Motor Data

Winding		8333	6785	5284	3392
Nominal supply voltage	volts	24	24	24	24
no load speed	rpm ±12%	200,000	162,841	126.818	81,408
speed/torque slope	rpm/oz-in	26,650	22,600	18,162	13,723
Continuous torque case 20°C/no h.s.*	oz-in	.5/0	-	-	1.2/.75
Continuous current case 20°C/no h.s.*	amps	-	-	-	3.1/2.0
Maximum cont. power case 20°C/no h.s.*	watts	-	-	-	57/39
Motor constant Km	oz-in/√w	.30	.32	.33	.33
Winding resistance not including leads	ohm±15%	.30	.37	.62	1.5
Torque at 5 amps	oz-in	.7	.9	1.2	2.0
No load current	amp±50%	.40	.29	.21	.10
Damping factor	oz-in/krpm	.00026	.00028	.00032	.00032
Static friction	oz-in	.012	.012	.012	.012
Velocity constant	rpm/volt	8,333	6,785	5284	3,392
Torque constant Kt	oz-in/amp	.162	.199	.255	.398
Maximum efficiency	%	86	87	86	85
Winding inductance	mH	.011	.017	.027	.068
Rotor inerta	10^{-4}oz-in-sec^2	.111	.111	.111	.111
Thermal res. winding to case	°C/W	5.2	5.2	5.2	5.2
Thermal case to ambient	°C/W	4.3	4.3	4.3	4.3

Weight 7 oz. Maximum winding temperature 125°C. Values based on winding and magnet temperature of 20°C. *Continuous torque values assume operation in 20°C still air. Phase lead are 12" minimum and untrimmed lead resistance is .052Ω. Excess lead length should be trimmed. Phase leads are 24 gauge stranded TFE insulated. Axial force on bearing including during installation should not exceed 20 lb.



Leads	
Blue	Phase A
White	Phase B
Brown	Phase C

Ordering Information: contact us at mail@koford.com

Example: Part Number 48 S 5284 A

Motor dia.
Type S=sensorless
Winding number
Modifications A=none, V=Vacuum compatable, T=Thermistor, H=.040 bore hollow shaft

1.9" (48mm) Slotless Brushless DC motor.

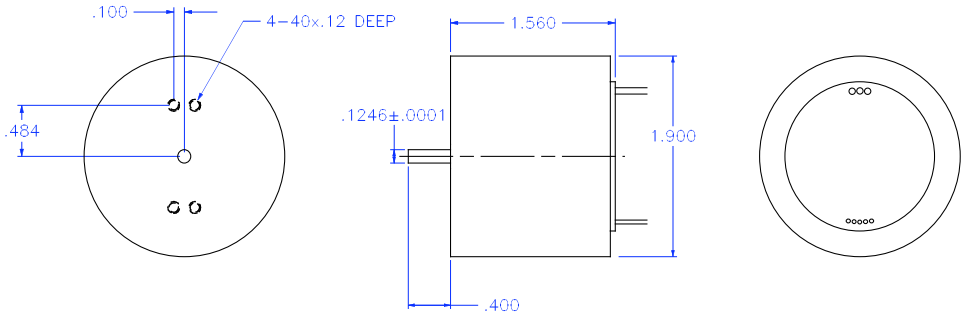
24V winding **• 40,332 rpm** **•Maximum continuous power 31 watts**

Slotless design is cog free, provides high efficiency, and cool quiet operation at high speed. Stainless ball bearings with high performance lube are standard. Available with 120° hall sensors or sensorless. Hall sensors recomended for positioning or where a large inertial load is attached to the shaft. The V (vacuum compatable option) has all non outgassing materials suitable for vacuum use and ceramic hybrid ball bearings. Water or refrigerant cooling is required for continuous vacuum operation since there is no cooling by ambient air. Special modifications are possible such as custom shaft lengths, and custom windings. The encoder is usefull where higher position resolution is desired then is available from the hall or sensorless drive.

Motor Data

Winding		1680
Nominal supply voltage	volts	24
no load speed	rpm ±12%	40,320
speed/torque slope	rpm/oz-in	5,613
Stall torque (theoretical)	oz-in	10.9
Continuous torque case 20°C/no h.s.*	oz-in	2.1/1.3
Continuous current case 20°C/no h.s.*	amps	4.0/1.7
Maximum cont. power case 20°C/no h.s.*	watts	44/31
Motor constant Km	oz-in/√w	.51
Winding resistance not including leads	ohm±15%	5.6
No load current	amp±50%	.06
Damping factor	oz-in/krpm	.0016
Static friction	oz-in	.012
Velocity constant	rpm/volt	1,680
Torque constant Kt	oz-in/amp	.80
Stall current	amps	10.9
Maximum efficiency	%	78
Winding inductance	mH	.28
Mechanical time constant	ms	6
Rotor inerta	10^{-4}oz-in-sec^2	.111
Thermal res. winding to case	°C/W	5.2
Thermal case to ambient	°C/W	4.3

Weight 7 oz. Maximum winding temperature 125°C. Values based on winding and magnet temperature of 20°C. *20°C case continuous torque values require refrigerant cooling on outside diameter of motor housing, no heat sink continuous torque values assume operation in still air. Phase lead are 12" minimum and untrimmed lead resistance is .052Ω. Excess lead length should be trimmed. Phase leads are 24 gauge stranded TFE insulated, and hall leads are 28 gauge, TFE insulated.Axial force on bearing including during installation should not exceed 25 lb.



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: contact us at mail@koford.com

Example: Part Number 48 H 1680 A / A5

Motor dia.
Type S=sensorless H=120°halls
Winding number
Modifications A=none, V=Vacuum compatable, T=Thermistor (sensorless only), H=.040" bore hollow shaft
Encoder A5=500lines(2,000 count)

KOFORD ENGINEERING, LLC

1.9" (48mm) Slotless Brushless DC motor.

12V windings •Sensorless • Up to 151,200 rpm •Maximum continuous power 43 watts

Slotless design is cog free, and provides high efficiency, with cool and quiet operation at high speed. High speed ceramic hybrid bearings for longest life. Intermittent duty at 151,200 rpm or continuous duty at 90,792 rpm. The V (vacuum compatable option) is constructed using all non outgassing materials suitable for vacuum use. Water or refrigerant cooling is required for continuous vacuum operation since there is no cooling by ambient air. A winding temperature sensor is available. The motor features a hardened stainless shaft, Teflon insulated lead wires, 240°C magnet wire, precison balance, anodized machined aluminum housing. Special modifications are possible such as hollow shafts, custom shaft lengths, and custom windings. For 12600 use S24V5A-4G drive, for 7566 use S24V5A-4F drive.
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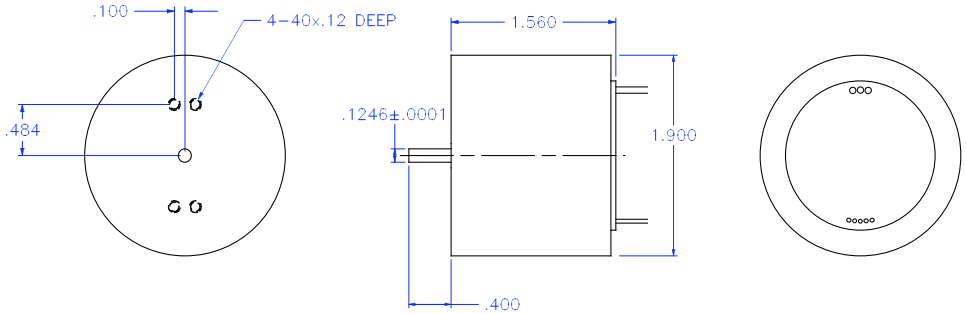
Motor Data

Winding		12600	7566
Nominal supply voltage	volts	12	12
no load speed	rpm ±12%	151,200	90,792
speed/torque slope	rpm/oz-in	21,372	14,746
Continuous torque *.	oz-in	-	.74
Continuous current case *	amps	-	4.3
Maximum cont. power *	watts	-	43
Motor constant Km	oz-in/√w	.30	.31
Winding resistance not including leads	ohm±15%	.13	.32
Torque at 5 amps	oz-in	.48	.85
No load current	amp±50%	.51	.23
Damping factor	oz-in/krpm	.00028	.00032
Static friction	oz-in	.012	.012
Velocity constant	rpm/volt	12,600	7,566
Torque constant Kt	oz-in/amp	.107	.178
Maximum efficiency	%	86	85
Winding inductance	mH	.005	.014
Rotor inerta	10^{-4}oz-in-sec^2	.111	.111
Thermal res. winding to case	°C/W	5.2	5.2
Thermal case to ambient	°C/W	4.3	4.3

Weight 7 oz. Maximum winding temperature 125°C. Values based on winding and magnet temperature of 20°C. *20°C case continuous torque values require refrigerant cooling on outside diameter of motor housing, no heat sink continuous torque values assume operation in still air. Phase lead are 12" minimum and untrimmed lead resistance is .052Ω. Excess lead length should be trimmed. Phase leads are 24 gauge stranded TFE insulated, and hall leads are 28 gauge, TFE insulated.Axial force on bearing including during installation should not exceed 25 lb.



Leads	
Blue	Phase A
White	Phase B
Brown	Phase C

Ordering Information: contact us at mail@koford.com

Example: Part Number 48 S 2575 T

Motor dia.
Type S=sensorless
Winding number
Modifications A=none, V=Vacuum compatable, T=Thermistor (sensorless only)

1.9" (48mm) Slotless Brushless DC motor.

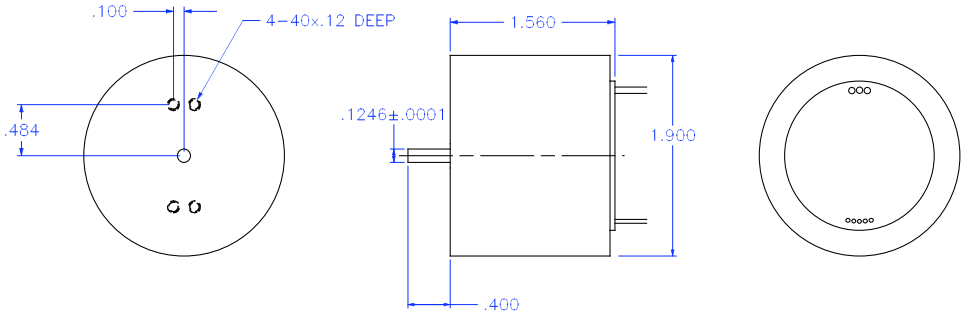
12V winding **• 40,692 rpm** **•Maximum continuous power 31 watts**

Slotless design is cog free, provides high efficiency, and cool quiet operation at high speed. Stainless ball bearings with high performance lube are standard. Available with 120° hall sensors or sensorless. Hall sensors recomended for positioning or where a large inertial load is attached to the shaft. The V (vacuum compatable option) has all non outgassing materials suitable for vacuum use and ceramic hybrid ball bearings. Water or refrigerant cooling is required for continuous vacuum operation since there is no cooling by ambient air. Special modifications are possible such as custom shaft lengths, and custom windings. The encoder is usefull where higher position resolution is desired then is available from the hall or sensorless drive (6 or 3 pulses per revolution).

Motor Data

Winding		3391
Nominal supply voltage	volts	12
no load speed	rpm ±12%	40,692
speed/torque slope	rpm/oz-in	5,613
Stall torque (theoretical)	oz-in	10.9
Continuous torque case 20°C/no h.s.*	oz-in	2.1/1.3
Continuous current case 20°C/no h.s.*	amps	4.2/2.6
Maximum cont. power case 20°C/no h.s.*	watts	44/31
Motor constant Km	oz-in/√w	.51
Winding resistance not including leads	ohm±15%	1.48
No load current	amp±50%	.10
Damping factor	oz-in/krpm	.0016
Static friction	oz-in	.023
Velocity constant	rpm/volt	3,391
Torque constant Kt	oz-in/amp	.40
Stall current	amps	8.1
Maximum efficiency	%	78
Winding inductance	mH	.07
Mechanical time constant	ms	6
Rotor inerta	10^{-4}oz-in-sec^2	.111
Thermal res. winding to case	°C/W	5.2
Thermal case to ambient	°C/W	4.3

Weight 7 oz. Maximum winding temperature 125°C. Values based on winding and magnet temperature of 20°C. *20°C case continuous torque values require refrigerant cooling on outside diameter of motor housing, no heat sink continuous torque values assume operation in still air. Phase lead are 12" minimum and untrimmed lead resistance is .052Ω. Excess lead length should be trimmed. Phase leads are 24 gauge stranded TFE insulated, and hall leads are 28 gauge, TFE insulated. Axial force on bearing including during installation should not exceed 25 lb.



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: contact us at mail@koford.com

Example: Part Number 48 H 3391 A / A5

Motor dia.
Type S=sensorless H=120°halls
Winding number
Modifications A=none, V=Vacuum compatable
T=Thermistor (sensorless only)
Encoder A5=500lines(2,000 count)

KOFORD
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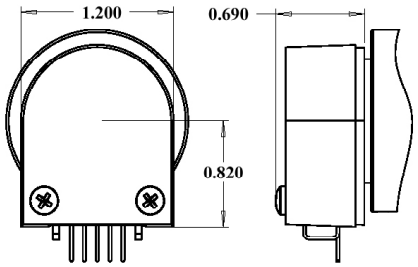
Optical Encoders

Mating connector AMP103977-4. Supply voltage 5±.5V. Rpm 50,000 max. Weight .5 oz, inertia .08 x10^{-4}oz-in-sec^2



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, 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

The parameters shown are for sensorless commutation. For operation up to around 60,000 rpm the performance of the hall sensor motor will match that of the sensorless motor (except for increased drive power consumption due to the halls). Above 60,000 rpm the current consumption of hall motors begains to increase above that for a sensorless version and for that reason higher speed motors are offered only in the sensorless form. For motors where Hall sensors are offered, they are recommended if very fast start up (less then 1-2 seconds to full speed) a speed range wider then 2 or 3 to one, or operation at speeds near zero or holding postion at zero rpm are required. 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 dynamically balanced to G6.3 or better (G2.5 is prefered) and located as close to the motor body as possible. 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 balanced in 2 planes. Parts mounted to the motor shaft should not extend past the end of the motor shaft. For operation at 120,000 rpm or higher the rotor should be balanced again after mounting to the motor shaft.

Motor technology

The Koford 48HS brushless series of motors are high speed slotless sintered rare earth permanent magnet motors with unique technology. Compared to other brushless motors they have higher speed capabilities, better efficiency, lighter weight and more durable construction (ML Class 220C wire insulation bonded with Class 205 thermoset resin) compare 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 voltages lower then the specified voltage. Motors must not be operated over the maximum speed listed. To obtain speeds over 100,000 rpm a high speed drive must be used. Hall drives are not recommended for speeds over 60,000 rpm.

Motor selection

Hall sensor motor can start large inertial loads. For this reason they are most suitable for applications such as beam choppers providing that a speed above 60,000 rpm is not required. If higher speeds are required then a sensorless motor must be used with a sensorless drive.

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 24 volts and the rpm/volt is 8,333 then the no load speed will

be 199,992 (±12%) rpm. If the speed torque slope is 26,650 rpm/oz-in and a 0.1 oz-in load is applied to the shaft then the speed will be 199,992-(0.1 x 26,650) = 197,327 rpm (±12%). 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% on rpm under load should be used to allow for motor, load and power supply tolerances, so for example with the above motor would be suitable for an application where the speed needs to be a minimum of 173,906 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 (if any), and the ambient temperature. For the air cooled bearing motors no additional cooling is required but if the ambient temperature is elevated the continuous torque will be reduced linearly between a 20°C and 125°C ambient. The 20°C continuous torque values for non air cooled bearing motors are based on the motor housing being held to 20°C by such means as a refrigerated cooling jacket clamped to the OD of the motor. If the ambient temperature is above 20°C then the continuous duty torque is reduced.

Vacuum Applications

Standard motors and air cooed bearing motors are suitable for low (soft) vacuum applications. For high vacuum applications use option V. 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 initial pump down time. An important consideration is that in a vacuum there is no heat removal by air contacting the motor housing. Therefore cooling of the motor OD or of an aluminum or copper mounting plate by means of a water or refrigerant cooling system or a heat pipe should be used for continuous operation. Operation for a few minutes at a time may be possible without cooling. The use of the temperature sensor (thermistor) option T is recommended so that the winding temperature can be monitered and motor damage avoided.

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 such as the phase wires.

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. An off the shelf EMI filter rated for the drive current (5 amps) connected between the power source and the drive will reduce conducted emissions. Mounting the drive inside of a metal enclosure and using shielded cable and connectors will reduce radiated emissions.

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, for example if the motor pulls 20 amps at 12 volts and the input to the drive is 36 volts then the input current to the drive will be 12/36 x 20 or 6.66 amps (neglecting losses). A drive rated at 20 amps will only pull 20 amps from the power supply or battery if the speed is turned all of the way up (no PWM).

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