KOFORD ENGINEERING, LLC

1.4 inch (36mm) Series

- High performance slotless brushless motors for military, aerospace, medical, and commercial applications. Up to 100 watts and 30,000 rpm.
- Cog free design, low inductance and low inertia is ideal for precision servo applications
- 2 and 4 pole designs
- Highest power density
- High temperature 220°C ML insulation
- Available with hall sensors, sensorless, and integral electronics
- Up to 90% efficiency
- Available with planetary gearboxes featuring all case hardened alloy steel gears
- Needle bearings on planets and ball bearings on output shaft.
- Long life premium synthetic bearing lube with -73C to 149C temperature range

KOFORD
ENGINEERING, LLC

1.4" (36mm) Hi Performance 4 Pole Slotless Brushless DC motor.

•9,960 rpm no load **•Rated power 61 watts**

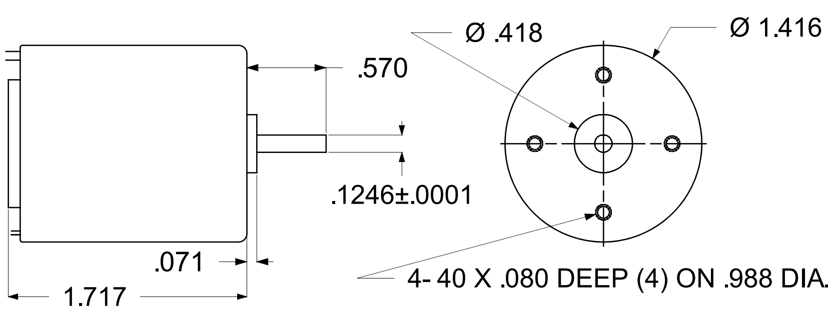
High performance design uses special low loss lamination material. Four pole design is optimum for positioning applications using hall signals for speed feedback because it offers twice the resolution, as well as increased power and speed compared to two pole motors. Slotless design is cog free for maximum smoothness and positioning accuracy. Thermistors are available on both hall and sensorless drives, and overtemperature protection which turns the motor off if the winding temperature exceeds 125°C is available on hall drives. 240°C insulation is used for the greatest possible durability. Available with optical encoders and gearheads. 150°C rated Neo rare earth magnets standard. These motors can be used with sinusoidal drives (brushless AC) to provide smooth ripple free torque at low speeds. Custom versions with modified shaft or custom windings can be provided on request. Contact us at mail@koford.com for assistance in specifying the best motor and drive for your application.

Motor Data

Winding		415
Nominal supply voltage	volts	24
No load speed	rpm	9,960
Speed/torque slope	rpm/oz-in	130
Maximum efficiency	%	90
Continuous torque heat sink/no h.s.	oz-in	23.7/9.5
Motor constant Km	oz-in/√w	3.66
Resistance	ohm±15%	.80
Peak output	watts	160
No load current	amp±50%	.12
Damping factor	oz-in/krpm	.03
Static friction	oz-in	.07
Velocity constant	rpm/volt±12%	415
Torque constant Kt	oz-in/amp	3.25
Stall current	amps	30
Stall torque	oz-in	97
Winding inductance	mH	.29
Mechanical time constant	ms	2.3
Rotor inertia	10^{-4}oz-in-sec^2	2.4
Thermal res. winding to case	°C/W	1.9
Thermal res case to ambient	°C/W	5.7
Bearing rating radial (dynamic)	lb.	71
Bearing rating axial (static)	lb.	29

Weight 7 oz. Maximum winding temperature 125°C

Values based on winding and magnet temp. of 20°C, heat sink values assume case cooled to 20C. Lead wire 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	
Brown	Phase C
Blue	Phase A
White	Phase B
Red	+5 volts
Black	Ground
Yellow	Sensor A
Orange	Sensor B
Green	Sensor C

Ordering Information: Please send your order to: mail@koford.com

Example: Part Number 36 H 415 A / A5 / P7

Gearhead P7=6.75:1, P46=45.56:1, P307=307.54:1
Encoder w index A5=500line(2000 count)
Modifications A=none, T=thermistor, O=overtemp protection
Motor dia.
Type S=sensorless H=120°halls
Winding number

Test Data
Total System Performance
36H415A with H24V10A Controller at 24 volts

Rpm	Torque Oz-in	Watts Out	Efficiency %	Amps
9600	0.00	0.00	0.00	0.13
9475	1.02	7.18	69.60	0.43
9345	2.01	13.87	80.30	0.72
9221	3.00	20.46	85.30	1.00
9090	4.03	27.12	86.90	1.30
8930	5.02	33.18	87.50	1.58
8802	6.03	39.29	87.54	1.87
8690	6.91	44.46	86.97	2.13
8540	8.02	50.71	86.95	2.43
8421	9.02	56.19	86.10	2.72
8296	10.01	61.36	85.79	2.98
8066	11.94	71.26	83.64	3.55
7820	13.88	79.71	81.80	4.06
7225	17.90	95.64	75.90	5.25
6642	22.06	108.42	70.70	6.39
6010	26.08	115.98	63.60	7.60

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. Test were conducted at room temperature. Motor leads are full untrimmed length.

KOFORD ENGINEERING, LLC

1.4" (36mm) Hi Output 4 Pole Slotless Brushless DC motor, 12 V

•up to 15,468 rpm no load **•Peak output up to 487 watts**

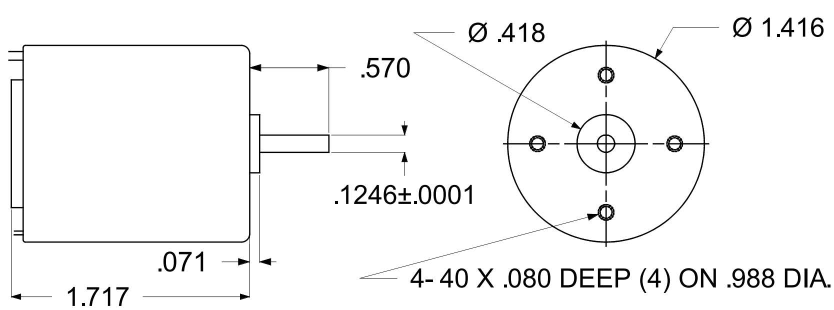
High performance design with high flux density design for maximum output. Uses include autoclavable surgical power tools. Four pole design is optimum for positioning applications using hall signals for speed feedback because it offers twice the resolution, as well as increased power compared to two pole motors. Slotless design is cog free for maximum smoothness and positioning accuracy. Thermistors are available on both hall and sensorless drives, and overtemperature protection which turns the motor off if the winding temperature exceeds 150C is available on hall drives. Wire insulation is 200°C. Available with optical encoders and gearheads. These motors can be used with sinusoidal drives (brushless AC) to provide smooth ripple free torque at low speeds. Custom versions with modified shaft or custom windings can be provided on request. Contact us at mail@koford.com for assistance in specifying the best motor and drive for your application.

Motor Data

Winding		866	1289	1630
Nominal supply voltage	volts	12	12	12
No load speed	rpm	10,392	15,468	19,560
Speed/torque slope	rpm/oz-in	103	114	131
Maximum efficiency	%	85	86	86
Continuous torque heat sink/no h.s.	oz-in	31/11	19/6	18/5
Motor constant Km	oz-in/√w	4.98	4.98	4.63
Resistance	ohm±15%	.093	.045	.032
Peak output	watts	217	435	487
No load current	amp±50%	.74	1.47	1.75
Damping factor	oz-in/krpm	.11	.11	.04
Static friction	oz-in	.076	.076	.076
Velocity constant	rpm/volt±12%	866	1,289	1630
Torque constant Kt	oz-in/amp	1.52	1.06	.828
Stall current	amps	129	267	375
Stall torque	oz-in	196	283	310
Winding inductance	mH	.016	.007	.004
Mechanical time constant	ms	1.7	1.7	1.7
Rotor inertia	10^{-4}oz-in-sec^2	3.1	3.1	3.1
Thermal res. winding to case	°C/W	1.9	1.9	1.9
Thermal res case to ambient	°C/W	5.7	5.7	5.7
Bearing rating radial (dynamic)	lb.	71	71	71
Bearing rating axial (static)	lb.	29	29	29

Weight 7 oz. Maximum winding temperature 150°C, at rpm above 15,000 winding temperature should not exceed 100°C

Values based on winding and magnet temp. of 20°C, heat sink values assume case cooled to 20C. Lead wire 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	
Brown	Phase C
Blue	Phase A
White	Phase B
Red	+5 volts
Black	Ground
Yellow	Sensor A
Orange	Sensor B
Green	Sensor C

Ordering Information: Please send your order to: mail@koford.com

Example: Part Number 36 H 866 A / A5 / P7

- Motor dia. — 36
- Type S=sensorless H=120°halls — H
- Winding number — 866
- Modifications A=none, T=thermistor, O=overtemp protection — A
- Encoder w index A5=500line(2000 count) — A5
- Gearhead P7=6.75:1, P46=45.56:1, P307=307.54:1 — P7

Test Data
Total System Performance
36H1630A-P46 with H24V10A Controller at 12 volts

RPM	Torque Oz-in	Watts out	Efficiency %	Amps
481	0.00	0.00	0.0	1.39
478	17.52	6.19	25.8	2.00
477	48.72	17.20	47.8	3.00
472	78.75	27.50	57.3	4.00
469	112.70	39.10	65.2	5.00
466	140.88	48.41	67.2	6.00
463	169.05	57.72	68.7	7.00
460	197.23	66.90	69.7	8.00
457	225.40	75.96	70.3	9.00
454	253.58	84.89	70.7	10.00

Dyno test results of a motor and drive combination with voltage held to 12v 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. Test were conducted at room temperature. Motor leads are full untrimmed length.

Test Data
Total System Performance
36H866A with H28V40A Controller at 12 volts

Rpm	Torque oz-in	Watts Out	Efficiency %	Amps
10970	0.00	0.00	0.0	0.62
10791	2.10	16.71	69.6	2.00
10635	3.62	28.39	78.9	3.00
10479	5.14	39.72	82.7	4.00
10323	6.66	50.70	84.5	5.00
10167	8.18	61.33	85.2	6.00
10011	9.70	71.61	85.2	7.00
9855	11.22	81.54	85.0	8.00
9700	12.74	91.13	84.4	9.00
9545	14.26	100.37	83.6	10.00
9389	15.78	109.25	82.8	11.00
9233	17.30	117.79	81.8	12.00
9077	18.82	125.97	80.7	13.00
8921	20.34	133.80	79.6	14.00
8765	21.86	141.29	78.5	15.00
8609	23.38	148.42	77.3	16.00
8453	24.90	155.21	76.1	17.00
8297	26.42	161.64	74.8	18.00
7985	29.46	173.46	72.3	20.00
7673	32.50	183.89	69.7	22.00
7361	35.54	192.91	67.0	24.00
7049	38.58	200.54	64.3	26.00
6737	41.62	206.76	61.5	28.00
6425	44.66	211.59	58.8	30.00
6113	47.70	215.02	56.0	32.00
5801	50.74	217.05	53.2	34.00
5489	53.78	217.68	50.4	36.00

Dyno test results of a motor and drive combination with voltage held to 12v 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. Test were conducted at room temperature. Motor leads are full untrimmed length.

KOFORD
ENGINEERING, LLC

1.4" (36mm) Hi Output 4 Pole Slotless Brushless DC motor, 18 V

•up to 15,588 rpm no load **•Peak output up to 487 watts**

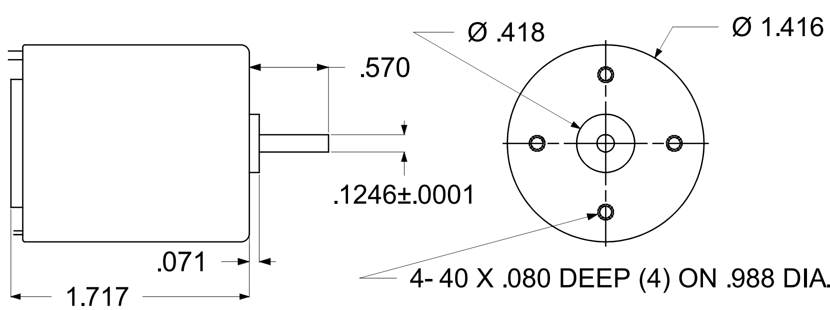
High performance high flux density design for maximum power density. Especially suitable for intermittent duty applications such as autoclavable surgical and other battery powered tools. Four pole design provides maximum power to weight ratio. Slotless design is cog free for maximum smoothness and positioning accuracy. Thermistors are available on both hall and sensorless drives. Steam autoclavable providing that housing is sealed or an autoclave bag is used. Wire insulation is 200°C. Available with optical encoders and gearheads. These motors can be used with sinusoidal drives (brushless AC) to provide smooth ripple free torque at low speeds. Custom versions with modified shaft or custom windings can be provided on request. Contact us at mail@koford.com for assistance in specifying the best motor and drive for your application.

Motor Data

Winding		667	866
Nominal supply voltage	volts	18	18
No load speed	rpm	12,000	15,588
Speed/torque slope	rpm/oz-in	100	118
Maximum efficiency	%	87	88
Continuous torque heat sink/no h.s.	oz-in	27/9	19/6
Motor constant Km	oz-in/√w	4.98	4.98
Resistance	ohm±15%	.157	.093
Peak output	watts	268	470
No load current	amp±50%	.41	.75
Damping factor	oz-in/krpm	.06	.06
Static friction	oz-in	.076	.076
Velocity constant	rpm/volt±12%	866	866
Torque constant Kt	oz-in/amp	2.02	1.52
Stall current	amps	91	193
Stall torque (theoretical)	oz-in	183	294
Winding inductance	mH	.032	.016
Mechanical time constant	ms	1.7	1.7
Rotor inertia	10^{-4}oz-in-sec^2	3.1	3.1
Thermal res. winding to case	°C/W	1.9	1.9
Thermal res case to ambient	°C/W	5.7	5.7
Bearing rating radial (dynamic)	lb.	71	71
Bearing rating axial (static)	lb.	29	29

Weight 7 oz. Maximum winding temperature 150°C, at rpm above 15,000 winding temperature should not exceed 100°C

Values based on winding and magnet temp. of 20°C, heat sink values assume case cooled to 20C. Lead wire 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	
Brown	Phase C
Blue	Phase A
White	Phase B
Red	+5 volts
Black	Ground
Yellow	Sensor A
Orange	Sensor B
Green	Sensor C

Ordering Information: Please send your order to: mail@koford.com

Example: Part Number 36 H 866 A / A5 / P7

Gearhead P7=6.75:1, P46=45.56:1, P307=307.54:1

Encoder w index A5=500line(2000 count)

Modifications A=none, T=thermistor, O=overtemp protection

Motor dia.

Type S=sensorless H=120°halls

Winding number

Test Data
Total System Performance
36H667A with H28V40A Controller at 18 volts

Rpm	Torque oz-in	Watts Out	Efficiency %	Amps
12000	0.00	0.00	0.0	0.44
11882	1.19	10.42	57.9	1.00
11611	3.32	28.43	79.0	2.00
11400	5.45	45.81	84.8	3.00
11188	7.58	62.54	86.9	4.00
10977	9.71	78.60	87.3	5.00
10766	11.84	94.00	87.0	6.00
10555	13.97	108.73	86.3	7.00
10343	16.10	122.79	85.3	8.00
10132	18.23	136.20	84.1	9.00
9921	20.36	148.95	82.8	10.00
9710	22.49	161.03	81.3	11.00
9498	24.62	172.43	79.8	12.00
9288	26.75	183.21	78.3	13.00
9076	28.88	193.28	76.7	14.00
8865	31.01	202.71	75.1	15.00
8654	33.14	211.48	73.4	16.00
8443	35.27	219.59	71.8	17.00
8232	37.40	227.03	70.1	18.00
8020	39.53	233.78	68.4	19.00
7809	41.67	239.95	66.7	20.00
7598	43.79	245.35	64.9	21.00
7387	45.92	250.13	63.2	22.00
7176	48.05	254.26	61.4	23.00
6964	50.18	257.69	59.7	24.00
6753	52.31	260.49	57.9	25.00

Dyno test results of a motor and drive combination with voltage held to 18v 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. Test were conducted at room temperature. Motor leads are full untrimmed length.

Test Data
Total System Performance
36H866A with H28V40A Controller at 18 volts

Rpm	Torque oz-in	Watts Out	Efficiency %	Amps
16940	0.00	0.00	0.0	0.78
16720	1.85	22.81	63.4	2.00
16540	3.37	41.10	76.1	3.00
16360	4.89	58.99	81.9	4.00
16180	6.41	76.48	85.0	5.00
16000	7.93	93.56	86.6	6.00
15820	9.45	110.24	87.5	7.00
15640	10.97	126.51	87.8	8.00
15460	12.49	142.38	87.9	9.00
15280	14.01	157.85	87.7	10.00
15100	15.53	172.92	87.3	11.00
14920	17.05	187.58	86.8	12.00
14740	18.57	201.84	86.3	13.00
14560	20.09	215.70	85.6	14.00
14380	21.61	229.15	84.9	15.00
14200	23.13	242.20	84.1	16.00
14020	24.65	254.84	83.3	17.00
13840	26.17	267.08	82.4	18.00
13660	27.69	278.92	81.6	19.00
13480	29.21	290.35	80.7	20.00
13300	30.73	301.38	79.7	21.00

Dyno test results of a motor and drive combination with voltage held to 18v 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. Test were conducted at room temperature. Motor leads are full untrimmed length.

KOFORD ENGINEERING, LLC

1.4" (36mm) Hi Output 4 Pole Slotless Brushless DC motor, 24 V

•up to 15,468 rpm no load **•Rated power up to 75 watts**

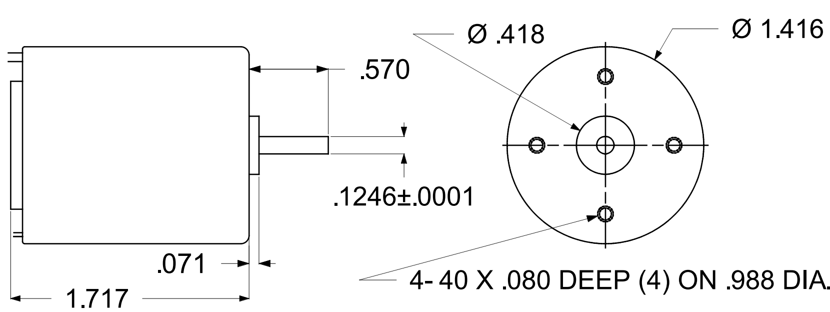
High performance design with high flux density design for maximum output. Four pole design is optimum for positioning applications using hall signals for speed feedback because it offers twice the resolution, as well as increased power compared to two pole motors. Slotless design is cog free for maximum smoothness and positioning accuracy. Thermistors are available on both hall and sensorless drives, and overtemperature protection which turns the motor off if the winding temperature exceeds 150C is available on hall drives. Wire insulation is 200°C. Available with optical encoders and gearheads. 150°C rated Neo rare earth magnets standard. These motors can be used with sinusoidal drives (brushless AC) to provide smooth ripple free torque at low speeds. Custom versions with modified shaft or custom windings can be provided on request. Contact us at mail@koford.com for assistance in specifying the best motor and drive for your application.

Motor Data

Winding		433	216
Nominal supply voltage	volts	24	24
No load speed	rpm	10,392	5,184
Speed/torque slope	rpm/oz-in	103	85
Maximum efficiency	%	85	85
Continuous torque heat sink/no h.s.	oz-in	31/11	33/15
Motor constant Km	oz-in/√w	4.98	4.98
Resistance	ohm±15%	.372	1.488
Peak output	watts	219	66
No load current	amp±50%	.37	.10
Damping factor	oz-in/krpm	.10	.11
Static friction	oz-in	.076	.076
Velocity constant	rpm/volt±12%	433	216
Torque constant Kt	oz-in/amp	3.04	6.08
Stall current	amps	64.5	16.1
Stall torque	oz-in	196	98
Winding inductance	mH	.064	.256
Mechanical time constant	ms	1.7	1.7
Rotor inertia	10^{-4}oz-in-sec^2	3.1	3.1
Thermal res. winding to case	°C/W	1.9	1.9
Thermal res case to ambient	°C/W	5.7	5.7
Bearing rating radial (dynamic)	lb.	71	71
Bearing rating axial (static)	lb.	29	29

Weight 7 oz. Maximum winding temperature 150°C

Values based on winding and magnet temp. of 20°C, heat sink values assume case cooled to 20C. Lead wire 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	
Brown	Phase C
Blue	Phase A
White	Phase B
Red	+5 volts
Black	Ground
Yellow	Sensor A
Orange	Sensor B
Green	Sensor C

Ordering Information: Please send your order to: mail@koford.com

Example: Part Number 36 H 866 A / A5 / P7

Gearhead P7=6.75:1, P46=45.56:1, P307=307.54:1

Encoder w index A5=500line(2000 count)

Modifications A=none, T=thermistor, O=overtemp protection

Motor dia.

Type S=sensorless H=120°halls

Winding number

KOFORD ENGINEERING, LLC

1.4" (36mm) 2 Pole Slotless Brushless DC motor.

•4,992 to 30,000 rpm no load **•Rated power 100 watts**

Slotless design is cog free, cost effective, and provides high efficiency and cool operation at high speed. 240°C ML insulation is used for the greatest possible durability. Available with optical encoders and gearheads. 150°C rated Neo rare earth magnets standard, 200°C magnets optional. The 2 pole design is prefered for higher speeds. Available with hall sensors for positioning and reversing applications or heavy inertial loads and sensorless for use with sensorless drives, with encoder controlled commutation or use as a generator. These motors exhibit exceptional smoothness when driven by encoder controlled sinusoidal drives. Motor can be wound to different rpm and voltages then the standard winds. Custom output shafts can be provided on request. Also available in frameless configuration. Contact us at mail@koford.com for assistance in specifying the best motor and drive for your application.

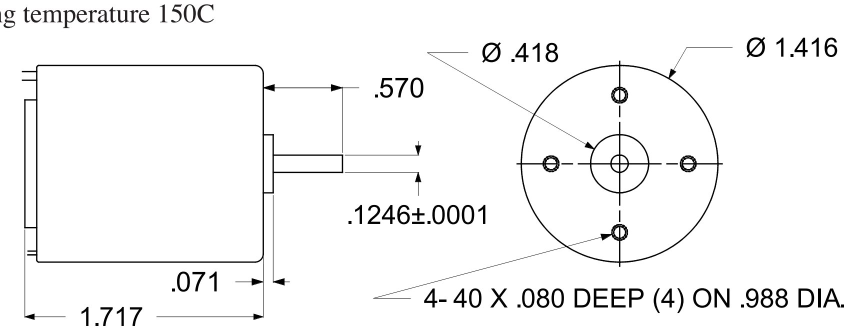
Motor Data

Winding		416	396	1250	2500	1251	792	417	396
Nominal supply voltage	volts	12	24	12	12	24	24	24	48
No load speed	rpm	4,992	9,504	15,000	30,000	30,000	19,000	10,000	19,000
Speed/torque slope	rpm/oz-in	139	183	229	351	351	269	185	269
Maximum efficiency	%	85	85	87	88	88	87	87	87
Continuous torque heat sink/no h.s.	oz-in	20/9.8	20/9.2	20/8.6	8.3/0	8.3/0	16/9	20/9.8	16/9
Motor constant Km	oz-in/√w	2.98	2.86	3.06	2.39	3.06	2.86	3.14	2.86
Winding resistance	ohm±15%	1.15	1.39	.122	.049	.122	.348	1.04	1.39
Peak output	watts	30.3	115	263	583	1,052	391	121	391
No load current	amp±50%	.07	.10	.43	1.5	.75	.33	.10	.17
Damping factor	oz-in/krpm	.028	.027	.026	.025	.025	.025	.025	.025
Static friction	oz-in	.076	.076	.076	.076	.076	.076	.076	.076
Velocity constant	rpm/volt±12%	416	396	1250	2,500	1251	792	417	396
Torque constant Kt	oz-in/amp	3.20	3.39	1.07	.53	1.07	1.69	3.20	3.39
Stall current	amps	10.4	17.2	98.4	245	196	68.9	23.0	68.9
Stall torque	oz-in	33.0	58.0	95.7	145	191	112	66.1	112
Winding inductance	mH	.432	.444	.059	.012	.059	.111	.432	.444
Mechanical time constant	ms	6	6	6	8	6	6	6	6
Rotor inerta	10^{-4}oz-in-sec^2	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1
Thermal res. winding to case	°C/W	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9
Thermal res case to ambient	°C/W	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7
Bearing rating dynamic	lb	71	71	71	71	71	71	71	71
Bearing rating axial (static)	lb	29	29	29	29	29	29	29	29

Weight 7 oz Maximum winding temperature 150C

Values based on winding and magnet temp. of 20°C heat sink values assume case cooled to 40C

Lead wires resistance 11.8mΩ if used at full length. Leads are 12" minimum Phase leads are 24 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: Please send your order to: mail@koford.com

Example: Part Number 36 H 417 A / A5 / P7 — Gearhead P7=6.75:1, P46=45.56:1, P307=307.54:1

Motor dia.

Type S=sensorless H=120°halls

Winding number

Encoder w index A5=500lines(2000 count)

Modifications A=none, T=thermistor, O=overtemp protection

Test Data
Total System Performance
36H792T/P7 gearmotor with H24V10A Controller at 24 volts

RPM	Torque Oz-in	Watts out	Efficiency %	Amps
2818	0.00	0.00	0.0	0.45
2703	8.22	16.44	56.6	1.21
2678	16.03	31.77	70.0	1.89
2633	24.27	47.29	74.4	2.65
2590	32.70	62.67	78.2	3.34
2553	40.12	75.81	79.2	3.99
2511	48.85	90.76	79.4	4.76
2489	51.53	94.94	79.9	4.95
2454	57.75	104.89	79.5	5.50
2423	66.03	118.39	79.0	6.24
2365	74.22	129.90	77.3	7.00
2318	82.26	141.13	75.4	7.80
2260	90.96	152.15	74.6	8.50
2220	95.15	156.36	72.4	9.00

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. Test were conducted at room temperature.

Test Data
Continuous Duty Total System Performance
36H792T/P7 gearmotor with H24V10A Controller at 24 volts

RPM	Torque oz-in	watts out	Efficiency (%)	Amps	∆T (° C)	Final temp(° C)
2773	5.09	10.45	48.4	0.90	32.5	55.9
2750	9.90	20.13	64.0	1.31	33.4	57.2
2732	14.81	29.84	71.5	1.74	35.2	59.3
2710	19.88	39.87	75.5	2.20	38.6	62.9
2689	25.03	49.85	78.1	2.66	41.7	66.1
2659	32.76	64.46	79.9	3.36	49.2	73.9
2613	41.11	79.52	79.6	4.16	56.0	81.6

Motor was run at load until winding temperature stabilized. Motor was attached to a heavy aluminum mounting bracket. Test was run at room ambient 23-26C. Note that there is no drop in output power as the motor heats up.

Test Data
Total System Performance
36H792A motor with H24V10A Controller at 24 volts

RPM	Torque Oz-in	Watts out	Efficiency %	Amps
19021	0.00	0.00	0.0	0.45
18445	1.30	17.68	60.9	1.21
18176	2.53	33.91	74.8	1.89
17873	3.83	50.48	80.0	2.63
17483	5.17	66.65	83.1	3.34
17233	6.34	80.57	84.1	3.99
16949	7.72	96.49	84.5	4.76
16800	8.14	100.84	84.5	4.97
16564	9.12	111.39	83.9	5.53
16255	10.43	125.02	83.5	6.24
15963	11.73	138.08	82.2	7.00
15647	13	150.00	80.5	7.76
15255	14.37	161.65	79.2	8.50
14985	15.03	166.08	77.7	8.91

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. Test were conducted at room temperature.

Test Data
Total System Performance
36H396A motor with H24V10A Controller at 24 volts

Rpm	Torque Oz-in	Watts Out	Efficiency %	Amps
9140	0.00	0.00	0.0	0.13
8948	1.17	7.75	64.6	0.50
8603	2.99	19.06	79.4	1.00
8299	4.73	29.04	80.7	1.50
7947	6.67	39.22	81.7	2.00
7668	8.57	48.12	80.2	2.50
7309	10.51	56.90	79.0	3.00
6971	12.21	63.01	75.0	3.50
6671	13.98	69.37	72.3	4.00
6314	15.90	74.68	69.1	4.50
6001	17.62	78.80	65.7	5.00
5600	19.67	81.55	61.8	5.50
5309	21.41	84.46	58.7	6.00
4986	23.10	84.68	54.3	6.50
4553	25.00	85.08	50.6	7.00
4252	26.68	83.98	46.7	7.50
3940	28.41	82.85	43.2	8.00

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. Test were conducted at room temperature.

KOFORD ENGINEERING, LLC

1.4" (36mm) Integral Electronics Slotless Brushless DC motor

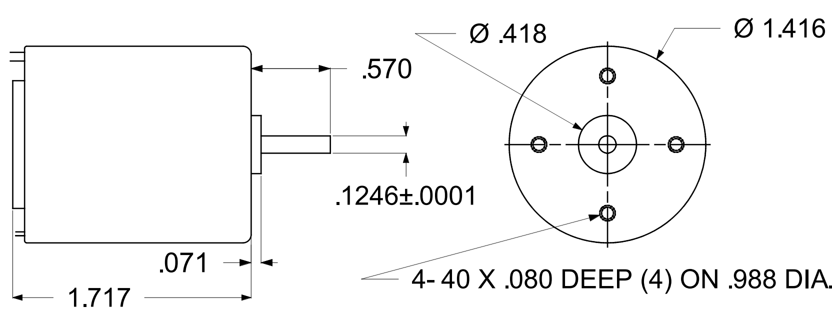
•Maximum rpm 10,100 **•Continuous torque 5 oz-in.**

Integral electronics operate at either 12 volts or 24 volts and are ideal for pump, blower and filter wheel, and beam chopper applications where long life is required, electrical noise cannot be tolerated, or brush dust is not acceptable. These units have higher continuous and maximum torque ratings then similarly sized integral electronic motors. Options are offered with clockwise, counterclockwise or bidirectional output. Two wire models (type O) have an output speed that varies with input voltage and drops under load. On special order two wire motors can be produced that run at a preprogramed speed which is independent of input voltage and load. With an additional wire the motor speed can be controlled with a 0-5v DC signal, with type D 0v=0% duty cycle and 5v=100% duty cycle, with type S speed is under closed loop control with 0v=0 rpm and 5v=maximum rated rpm, For type B this is modified so the 2.5v is 0rpm or duty cycle and 5v is maximum rpm or 100% duty cycle in the clockwise direction, while 0 volts is the same in the counterclockwise direction. If the tach option T is selected then a 5v 50% on time 6 pulse per revolution tach output is provided. Contact us at mail@koford.com for assistance in specifying the best motor and drive for your application.

Motor Data

Winding		I420	I210	I421
Nominal supply voltage	volts	12	24	24
Absolute maximum voltage	volts	30	30	30
No load speed	rpm±12%	5,000	5,000	10,000
Maximum torque	oz-in	5	11	5
Continuous torque case 50°C/no h.s.	oz-in	5/5	7/5	5/5
rpm gradient	rpm/oz-in	-327	-562	-327
Motor constant Km	oz-in/√w	2.0	1.8	2.0
Resistance	ohm	1.8	8.8	1.8
Peak output	watts	18	18	38
No load current	amp±50%	.2	.1	.3
Damping factor	oz-in/krpm	.1	.1	.1
Static friction	oz-in	.14	.14	.14
Velocity constant	rpm/volt	420	210	421
Torque constant Kt	oz-in/amp	3.21	6.42	3.21
Maximum current	amps	2.0	2.0	2.0
Thermal res. winding to case	°C/W	1.9	1.9	1.9
Thermal res case to ambient	°C/W	5.7	5.7	5.7
Bearing rating dynamic	oz	1136	1136	1136
Bearing rating axial (static)	oz	464	464	464

Weight 7 oz
Maximum winding temperature 125°C
Motor data based on winding and magnet temp. of 20°C



Ordering Information: Please send your order to: mail@koford.com

Example: Part Number 36 I420 F O T

Motor dia. — 36
Winding number — I420
F=clockwise, R=counterclockwise, B=Bidirectional
O=fixed speed, D=duty cycle control, S=closed loop speed control
T=tach

KOFORD
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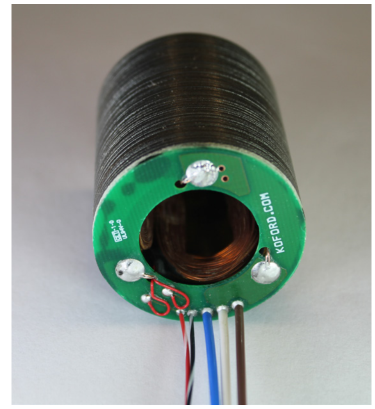
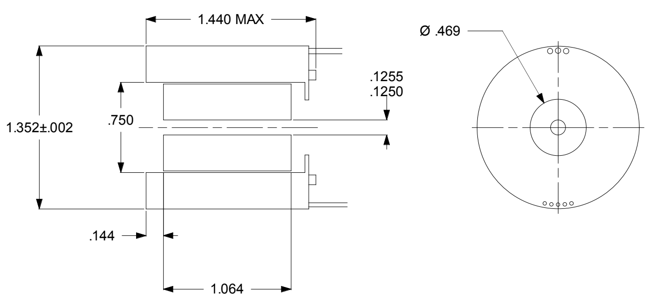
Custom Shafts and Housings

KOFORD
ENGINEERING, LLC

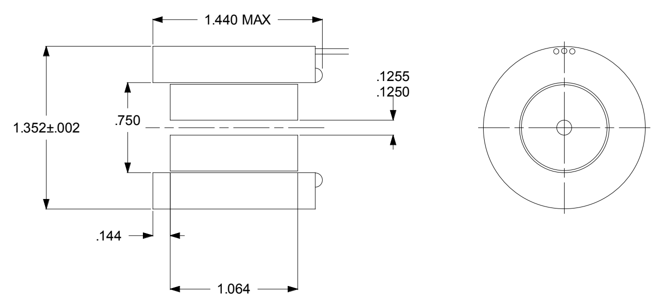
1.4" (36mm) Frameless Slotless Brushless motors



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. In the case of 2 pole designs a magnetized single piece magnet is supplied ready for the customer to epoxy to his shaft and balance (for higher speeds). In the case of 4 pole designs the magnets are bonded to a customer supplied shaft. Do not use Anaerobic or acrylic adhesives. Do not attempt press fitting, this will destroy the rotor. 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 data provided in this catalog can be used as a guide to motor performance, however some variations will result due to variations between motor bearings, housing clearances, and thermal resistances. For the best performance the motor housing should be 6061 Aluminum and have the maximum practical clearance to the stator. Heat shrinking works well as long as a low viscosity adhesive is applied to ythe joint after cooling. This will ensure the best heat transfer and a strong joint. The motor bearings should also be spaced as far away from the rotor as possible to reduce drag. Custom winds and rotors for other shaft sizes can be provided.



Hall Sensor Frameless Motor



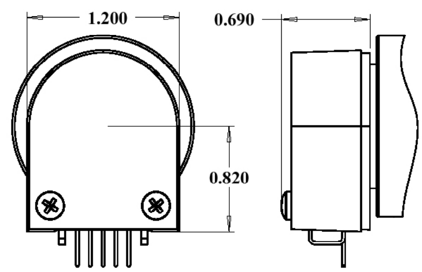
Sensorless Frameless Motor

For the frameless version of a motor use F in the winding number. Example 36FS416A

KOFORD
ENGINEERING, LLC

Optical Encoders

Supply voltage 5±.5V. Rpm 60,000 max. Weight .5 oz, inertia .08 $x10^{-4}$oz-in-sec^2, mating connector TYCO 103977-4, Temperature rating -40°C to +100°C.



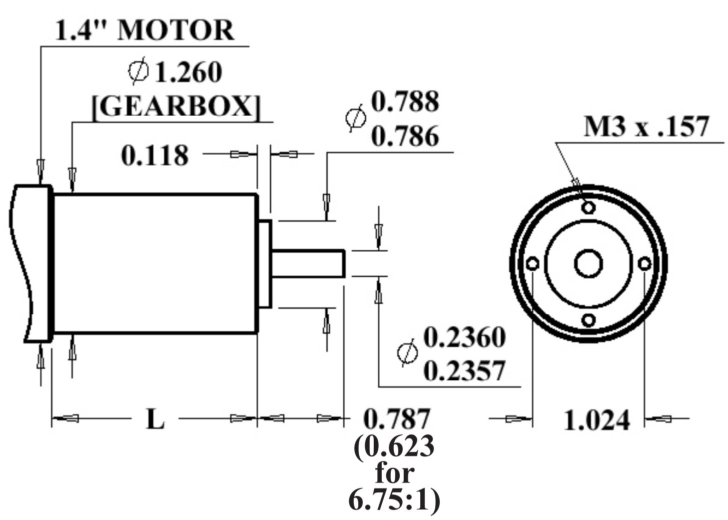
Planetary Gearheads

Construction is planetary with case hardened alloy steel gears, needle bearings on planets and double sheilded ball bearings on output. Bearing lube rated for -35C to 140C. Low temp lube rated for -60 to 130C available on special order.

For 1.4" (36mm) motors

6.75:1 L=1.136 159 oz-in peak/120 cont. 94% eff. Maximum input speed 60,000 rpm.
45.56:1 L=1.510 478 oz-in peak /319 cont. 89% eff. Maximum input speed 60,000 rpm.
307.54:1 L=1.884 957 oz-in peak /638 cont. 85%eff. Maximum input speed 60,000 rpm.

Weight 6.75:1=4.1 oz, 45.56:1=6.8 oz
307.54:1=8.4 oz
Maximum backlash 6.75:1=1.5°, 45.56:1=2°, 307.54:1=3°
inertia =.13 x 10^{-4}oz-in-sec^2
All gears are precision hobbed hardened alloy steel. Output is dual sheilded ball bearings.



Ordering Information: Please send your order to: mail@koford.com

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, 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

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 36 mm 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 (30,000 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 solventless Class 205 thermoset 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 on a 36 volts system 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 56kHz or higher are recommended for best performance. Drives which use ASIC's for transistor switching will perform better then drives which use DSP's or Micro's for this function due to more accurate phase switching. For the highest performance Koford drives are recommended. Drives which have a pwm frequency of less then 56kHz will need inductors for proper drive operation and to prevent overheating when used with higher speed motor. Koford drives do not require inductors.

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 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%.

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. Some manufactures also rate motors at a power which cannot be obtained at the nominal voltage.

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.

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 hundred or thousands of feet away from the drive. It also makes for a more flexible cable for surgical or dental handpieces. In addition sensorless motors operate with higher efficiency especially at speeds above 60,000 rpm. In certain frameless hermetic pump applications hall sensor designs are not possible and sensorless motors must be used. Integral electronic motors are available in some larger sizes and simplify connection and mounting. In general integral electronic motors will have a lower power rating for a given motor size.

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 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. 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 at least 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 is reduced. If the data sheet shows the heat rise at a given torque and rpm then that rise can be added to the ambient temperature to determine if the motor is suitable for the application. Keep in mind that the temperature rise tests are with the motor mounted to an thick aluminum bracket. Many motors are available with temperature sensors and this can be 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 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.

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 without corrosion inhibitors inside the motor requires special magnets. In many cases 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. Add small inductors to each of the phase wires. If possible vary the input voltage to the drive rather then using the speed control. Place the drive and motor as close together as possible. Also consider enclosing the drive or motor and drive in a metal enclosure.

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 in 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

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

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. At less then 100% speed 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, 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).