KOFORD
ENGINEERING, LLC

1.6 inch (42mm) Series

- High performance slotless brushless servomotors for military, aerospace, medical, scientific research, and industrial applications.
- Cog free non saturating design with linear behavior ideal for precision motion
- 2 and 4 pole, housed and frameless designs
- Highest power density, up to 94% efficiency
- High speed designs up to 104,297 rpm, rated power up to 1,000 watts.
- Vacuum compatible, temperature sensors, ceramic hybrid bearing, corrosion resistant wet hydrogen/autoclavable and hollow shaft versions available
- Low speed designs with no load speeds down to 1,560 rpm
- High temperature 240°C ML wire and Kapton® ground insulation is 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
- Planetary gearboxes with all antifriction bearings and nitrided gears available
- Matching sensorless and hall sensor drives available

KOFORD ENGINEERING, LLC

1.6" (42mm) Slotless Brushless motor. 2 pole 24V and 48V windings

• 3,120 to 22,848 rpm no load **•Rated power 400 watts**

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. Leads are Teflon® insulated. 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 and beam choppers, sensorless versions are available. Custom windings can be supplied upon request. Units with gearboxes and encoders can also be supplied. Integral 2 wire electronic versions with custom preprogramed speed which will be constant with varying load and input voltage are available, as well as 3 and 5 wire versions allowing a 0-5v control voltage or a speed pot to control the speed.

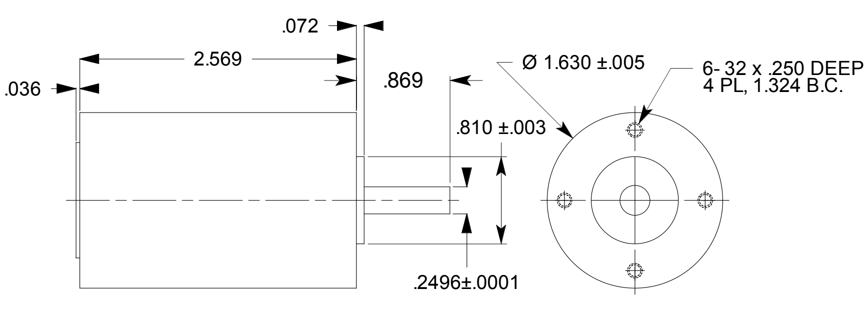
Motor Data

Winding		130	298	952	596	299
Nominal supply voltage	volts	24	24	24	24	48
No load speed	rpm±12%	3,120	7,200	22,848	14,304	14,400
Speed/torque slope	rpm/oz-in	62	63	97	73	86
Maximum efficiency	%	75	85	89	87	87
Continuous torque heat sink/no h.s.	oz-in*	25/20	50/24	47/18	50/24	50/24
Motor constant Km	oz-in/√w	5.2	5.2	5.2	5.2	5.2
Winding resistance#	ohm±15%	4.20	.75	.074	.19	.75
Peak output	watts	28	154	960	520	527
No load current	amp±50%	.10	.20	1.06	.54	.27
Damping factor	oz-in/krpm	.14	.06	.04	.04	.04
Static friction	oz-in	.60	.60	.60	.60	.60
Velocity constant	rpm/volt±12%	130	298	952	596	299
Torque constant Kt	oz-in/amp	10.4	4.50	1.42	2.25	4.50
Stall current	amps	5.7	32	324	128	64
Stall torque (theoretical)	oz-in	59	144	460	288	288
Winding inductance	mH	3.2	.52	.052	.10	.52
Mechanical time constant	ms	4.4	4.4	4.4	4.4	4.4
Rotor inertia	10^{-4}oz-in-sec^2	7.1	7.1	7.1	7.1	7.1
Thermal res. winding to housing	°C/W	.73	.73	.73	.73	.73
Thermal res. housing to ambient	°C/W	2.8	2.8	2.8	2.8	2.8

Ambient temperature range -73C to 149C. The thermal time constant is 11 minutes.

Weight 15oz, 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.
#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

Ordering Information: contact us at mail@koford.com

Example: Part Number 42B H 298 A - A5 - P10 — Gearbox P10=10.875:1

- Motor type — 42B
- Type S=sensorless H=120°halls — H
- Winding number — 298
- Modifications A=none, T=thermistor, V=vacuum compatible H=hollow shaft (.180 bore) — A
- Encoder w index A5=500 line(2000 count) — A5

Test Data
Total System Performance
42BH298T with H24V20A Controller at 24 Volts

Rpm	Torque Oz-in	Watts Out	Efficiency %	Amps
7380	0.00	0.00	0.0	0.20
7103	4.11	21.60	78.1	1.10
6896	8.07	41.09	84.6	2.00
6637	11.79	57.92	85.2	2.80
6369	16.11	75.93	84.5	3.70
6119	20.11	91.09	82.5	4.60
5832	24.45	105.52	79.9	5.50
5578	28.29	116.78	76.0	6.40
5279	32.31	126.23	72.0	7.30
5009	35.69	132.29	67.2	8.20
4697	39.82	138.44	63.4	9.10

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. Test were conducted at room temperature. Full length motor leads were used. Increased performance would result from shortening motor leads to the minimum length possible.

Test Data
Total System Performance
42BH299T with H48V20A Controller at 36 Volts

Rpm	Torque Oz-in	Watts Out	Efficiency %	Amps
11110	0.00	0.00	0.0	0.22
10778	3.97	31.65	73.3	1.20
10503	8.02	62.31	83.4	2.10
10226	12.10	91.56	85.8	3.00
9929	16.46	120.96	85.0	4.00
9683	19.96	143.00	83.2	4.80
9343	24.86	171.90	82.5	5.80
9088	28.33	190.51	80.2	6.60
8780	32.05	208.25	78.2	7.40
8445	36.07	225.40	75.4	8.30
8060	40.34	240.59	71.9	9.30
7474	46.49	257.14	67.4	10.60
6854	51.45	260.94	60.9	11.90

Dyno test results of a motor and drive combination with voltage held to 32v 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. Increased performance would result from shortening motor leads to the minimum length possible.

Test Data
Total System Performance
42BH299T with H48V20A Controller at 48 Volts

Rpm	Torque Oz-in	Watts Out	Efficiency %	Amps
14830	0.00	0.00	0.0	0.24
14481	4.06	43.54	69.8	1.30
14179	8.35	87.57	82.9	2.20
13921	12.49	128.69	86.4	3.10
13627	16.41	165.44	86.2	4.00
13311	20.51	202.02	84.6	5.00
13033	24.11	232.54	83.5	5.80
12709	28.02	263.56	82.0	6.70
12256	33.69	305.49	80.0	7.90
11943	36.76	324.92	78.4	8.60
11429	41.77	353.28	74.8	9.90
11045	45.27	370.07	72.7	10.60
10232	53.31	403.72	67.8	12.40

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. Test were conducted at room temperature. Increased performance would result from shortening motor leads to the minimum length possible.

Total System Performance
42BS952A with S28V40A Controller at 24 Volts

Rpm	Torque oz-in	Watts Out	Efficiency %	Amps
22848	0.00	0.00	0.0	0.90
22370	4.00	65.98	74.3	3.70
21892	8.00	129.15	82.8	6.50
21414	12.00	189.49	84.9	9.30
20936	16.00	247.01	85.1	12.10
20458	20.00	301.71	84.4	14.90
19980	24.00	353.60	83.2	17.70
19502	28.00	402.66	81.8	20.50
19024	32.00	448.91	80.3	23.30
18546	36.00	492.33	78.6	26.10
18068	40.00	532.93	76.8	28.90
17590	44.00	570.72	75.0	31.70
17112	48.00	605.68	73.1	34.50

Results of a motor and drive combination with voltage held to 24v with winding temperature held below 40C. Data is for full length motor leads, shortening motor leads to the minimum length possible would increase efficiency. Efficiency values includes motor, drive and wiring (motor lead) losses.

Test Data
Total System Performance
42BH298A-P10 with H24V20A Controller at 24 Volts

Rpm	Torque oz-in	Watts Out	Efficiency %	Amps
648	0	0	0	0.2
627	39	18.1	75.4	1
602	88	39.1	81.6	2
577	137	58.4	81.1	3
552	186	75.8	78.9	4
527	234	91.4	76.1	5
502	283	105.2	73.0	6
477	332	117.1	69.7	7
452	381	127.3	66.3	8
427	430	135.6	62.8	9
402	479	142.1	59.2	10
376	528	146.9	55.6	11
352	577	149.8	52.0	12
326	626	150.8	48.3	13
301	675	150.1	44.7	14
276	724	147.6	41.0	15
251	773	143.2	37.3	16

Results of a motor and drive combination with voltage held to 24v with winding temperature held below 40C. Data is for full length motor leads, shortening motor leads to the minimum length possible would increase efficiency. Efficiency values includes motor, drive and wiring (motor lead) losses.

Test Data
Total System Performance
42BH299A-P10 with H48V20A Controller at 48 Volts

Rpm	Torque oz-in	Watts Out	Efficiency %	Amps
1301	0	0	0.0	0.2
1277	38	36	75.1	1.0
1246	88	81	84.3	2.0
1216	138	124	85.8	3.0
1186	188	164	85.4	4.0
1155	237	202	84.2	5.0
1125	287	238	82.7	6.0
1095	337	272	80.9	7.0
1065	387	304	79.0	8.0
1034	436	333	77.0	9.0
1004	486	360	75.0	10.0
974	536	385	72.9	11.0
944	585	407	70.7	12.0
914	635	428	68.6	13.0
883	685	446	66.4	14.0
853	735	462	64.2	15.0
823	784	476	62.0	16.0
792	834	487	59.7	17.0

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. Test were conducted at room temperature. Increased performance would result from shortening motor leads to the minimum length possible.

KOFORD ENGINEERING, LLC

1.6" (42mm) Slotless Brushless motor. High Speed 2 pole windings

• 55,548 rpm no load **•Rated power up to 1,000 watts**

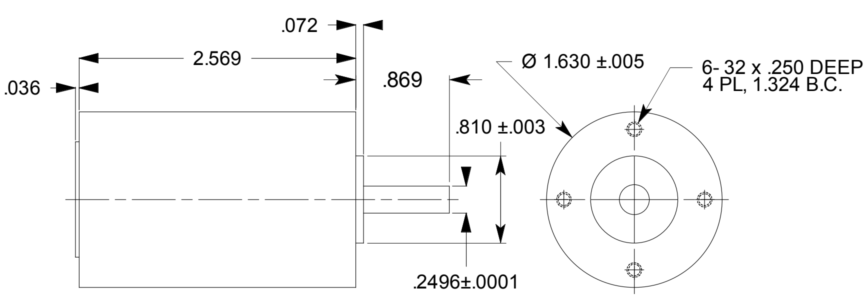
Ultra low loss Nickel Iron laminations, high power density slotless design. 240°C ML wire and Kapton® ground insulation are used for the ultimate in ruggedness. The magnets are 200°C Neo, Ceramic hybrid ball bearings with custom machined nonmetallic retainers, TFE lead wires, and hardened and ground 440C stainless shaft are used for the ultimate in performance. Unit are supplied either with 120° halls rated at 150°C, or for high speed blowers sensorless units may be used. Slotless design eliminates cog and reduces bearing loads due to air gap asymmetries compared to conventional slotted motors. Encoders and temperature sensors are optional, and custom windings can be provided. Vacuum compatible units can be supplied. Encoders and gearboxes are available.

Motor Data

Winding		1156	580	1501	1502	1158
Nominal supply voltage	volts	24	48	24	28	48
No load speed	rpm±12%	27,744	27,840	36,024	42,056	55,584
Speed/torque slope	rpm/oz-in	114	114	135	144	171
Maximum efficiency	%	93	93	94	94	94
Continuous torque heat sink/no h.s.	oz-in*	45/22	45/22	43/17	42/13	38/0
Motor constant Km	oz-in/√w	5.2	5.2	5.2	5.2	5.2
Winding resistance#	ohm±15%	.05	.19	.03	.03	.05
Peak output	watts	1300	1252	2000	2700	3320
No load current	amp±50%	.66	.33	.84	.95	.90
Damping factor	oz-in/krpm	.020	.020	.015	.015	.015
Static friction	oz-in	.20	.20	.20	.20	.20
Velocity constant	rpm/volt±12%	1156	580	1501	1502	1158
Torque constant Kt	oz-in/amp	1.16	2.33	.90	.90	1.16
Stall current	amps	492	250	808	942	985
Stall torque (theoretical)	oz-in	571	582	727	848	1142
Winding inductance	mH	.022	.101	.009	.009	.022
Mechanical time constant	ms	4.5	4.5	4.5	4.5	4.5
Rotor inertia	10^{-4}oz-in-sec^2	7.1	7.1	7.1	7.1	7.1
Thermal res. winding to housing	°C/W	.73	.73	.73	.73	.73
Thermal res. housing to ambient	°C/W	2.8	2.8	2.8	2.8	2.8

Ambient temperature range -73C to 150C A heat sink and/or blower cooling is required except for very low on time and low duty cycle applications. Weight 15oz, maximum winding temp. 200C, maximum case temp. 150C. Data is for winding and magnet temperature of 20°C. The thermal time constant is 11 minutes.

*Case held to 60°C with customer supplied fan, heat sink or cooling jacket/still air and no heat sink.
#Not including 11.8mΩ untrimmed lead wire resistance. 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: contact us at mail@koford.com

Example: Part Number 42B H 1156 A / A5 / P10 – Gearbox P10=10.875:1

Motor type — 42B
Type S=sensorless H=120°halls — H
Winding number — 1156
Modifications A=none, T=thermistor, V=vacuum compatible — A
Encoder w index A5=500 line(2000 count) — A5

Test Data
Total System Performance
42BS1158A with S48V20A Controller at 48 Volts

RPM	Torque Oz-in	Watts out	Efficiency %	Amps
55386	0	0	0	0.9
55201	1.10	44.78	49.1	1.9
55016	2.21	89.42	64.2	2.9
54853	3.31	133.73	73.3	3.8
54658	4.42	177.67	78.7	4.7
54473	5.52	221.34	82.3	5.6
54288	6.63	264.71	83.9	6.6
54081	7.73	307.65	85.5	7.5
53886	8.84	350.33	86.7	8.5
53690	9.94	392.68	87.4	9.4
53526	11.05	434.99	88.0	10.3
53342	12.15	476.84	88.5	11.3
53146	13.25	518.28	88.6	12.2
52939	14.36	559.28	88.7	13.2
52776	15.46	600.45	88.7	14.1
52580	16.57	640.96	88.6	15.1
52395	17.67	681.28	88.5	16.1
52189	18.78	721.00	88.4	17.0
52015	19.88	760.87	88.3	17.9
51808	20.99	803.01	88.1	18.9
51612	22.09	838.88	87.8	19.9

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. Test were conducted at room temperature. Total efficiency reflect losses in drive, wiring and motor

Test Data
Total System Performance
42BS1158A/P10 with S48V20A Controller at 48 Volts

RPM	Torque Oz-in	Watts out	Efficiency %	Amps
5093	0	0	0	1.0
5076	11.75	43.98	48.2	1.9
5059	23.50	87.67	62.9	2.9
5044	35.25	131.11	71.9	3.8
5026	47.00	174.19	77.2	4.7
5009	58.75	217.00	80.7	5.6
4992	70.50	259.52	82.3	6.6
4973	82.25	301.62	83.8	7.5
4955	94.00	343.46	85.0	8.5
4937	105.75	384.98	85.7	9.4
4922	117.50	426.46	86.3	10.3
4905	129.25	467.49	86.8	11.3
4887	141.00	508.12	86.9	12.2
4868	152.75	548.32	87.0	13.2
4853	164.50	588.68	87.0	14.1
4835	176.25	628.39	86.9	15.1
4818	188.00	667.92	86.8	16.1
4799	199.75	706.87	86.7	17.0
4783	211.50	745.96	86.6	17.9
4764	223.25	784.27	86.4	18.9
4746	235.00	822.43	86.1	19.9

continuous duty limit without cooling (at 5059 RPM row)

continuous duty limit with cooling, limited by gearbox (at 4764 RPM row)

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. Test were conducted at room temperature. Total efficiency reflect losses in drive, wiring and motor

Test Data
Total System Performance
42BS1156A with S28V40A Controller at 24 Volts

RPM	Torque Oz-in	Watts out	Efficiency %	Amps
27513	0.0	0	0	0.5
27448	0.5	11	41.0	1.1
27329	1.6	34	70.2	2.0
27057	3.9	78	82.4	4.0
26752	6.2	123	85.0	6.0
26491	8.3	164	85.8	8.0
26111	10.6	207	86.3	10.0
25774	12.8	247	86.3	12.0
25469	15.1	290	86.3	14.0
25208	17.5	332	85.9	16.0
24936	19.4	365	85.3	18.0
24577	21.9	406	84.5	20.0
24371	24.0	440	83.6	22.0
23925	26.6	479	82.8	24.0
23642	28.7	511	81.9	26.0
23381	31.2	549	80.9	28.0
23109	33.1	576	80.1	30.0
22805	35.3	607	79.1	32.0
22370	37.9	640	78.1	34.0
22098	40.3	669	77.2	36.0
21783	42.3	693	76.3	38.0
21369	45.3	728	75.07	40.4

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. Total efficiency reflect losses in drive, wiring and motor

Test Data
Total System Performance
42BS1156A/P10 with S28V40A Controller at 24 Volts

RPM	Torque Oz-in	Watts out	Efficiency %	Amps
2530	0.0	0	0	0.6
2524	5.7	11	40.2	1.1
2513	17.8	33	68.8	2.0
2488	42.3	78	80.8	4.0
2460	66.9	121	83.3	6.0
2436	89.7	161	84.1	8.0
2401	114.9	203	84.6	10.0
2370	139.3	243	84.6	12.0
2342	164.6	284	84.6	14.0
2318	190.1	325	84.2	16.0
2293	211.5	358	83.6	18.0
2260	238.6	398	82.8	20.0
2241	261.4	432	82.0	22.0
2200	289.4	470	81.2	24.0
2174	312.6	501	80.3	26.0
2150	339.2	538	79.4	28.0
2125	360.3	565	78.5	30.0
2097	384.4	595	77.5	32.0
2057	413.2	627	76.6	34.0
2032	438.1	656	75.7	36.0
2003	459.8	679	74.8	38.0
1965	492.8	714	73.6	40.4

continuous duty limit without cooling — (at 2342 RPM row)

continuous duty limit of gearbox — (at 2260 RPM row)

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. Total efficiency reflect losses in drive, wiring and motor

KOFORD ENGINEERING, LLC

1.6" (42mm) Slotless Brushless motor. Ultra High Speed 2 pole windings

• up to 73,040 rpm no load **•Rated power up to 485 watts**

Magnetic design provides cool operation at high speed. Ultra low loss nickel iron laminations, and low drag ceramic hybrid ball bearings with machined self lubricating non metallic retainers are used in conjuction with a high power density slotless design to provide high efficiency (up to 94%) and high power density. 240°C ML wire and Kapton® ground insulation are used for the ultimate in ruggedness, along with 200°C Neo magnet, TFE lead wires, and hardened and ground 440C stainless shaft for the ultimate in performance. Slotless design eliminates cog and reduces bearing loads due to air gap asymmetries compared to conventional slotted motors. Custom windings can be provided. Vacuum compatible units can be supplied. May also be used as a high speed generator when used with a three phase bridge.

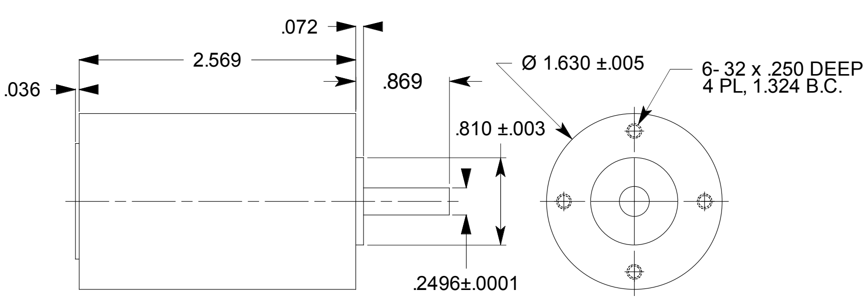
Motor Data

Winding		3042	2535	1268	1521	2172
Nominal supply voltage	volts	24	28	48	48	48
No load speed	rpm±12%	73,008	70,980	60,864	73,008	104,297
Speed/torque slope	rpm/oz-in	875	863	805	875	1055
Maximum efficiency	%	94	94	94	94	94
Continuous torque heat sink/no h.s.	oz-in*	16/7.6	16/7.6	16/7.6	16/7.6	15/7.0
Motor constant Km	oz-in/√w	1.88	1.88	1.88	1.88	1.88
Winding resistance#	ohm±15%	.056	.080	.320	.223	.110
Peak output	watts	969	963	771	969	980
No load current	amp±50%	.46	.35	.17	.23	.33
Damping factor	oz-in/krpm	.001	.001	.001	.001	.001
Static friction	oz-in	.10	.10	.10	.10	.10
Velocity constant	rpm/volt±12%	3042	2535	1268	1521	2172
Torque constant Kt	oz-in/amp	.45	.53	1.07	.89	.62
Stall current (theoretical)	amps	428	348	150	215	436
Stall torque (theoretical)	oz-in	192	184	160	215	270
Winding inductance	mH	.023	.036	.134	.093	.046
Mechanical time constant	ms	4	4	4	4	4
Rotor inertia	10^{-4}oz-in-sec^2	7	7	7	7	7
Thermal res. winding to housing	°C/W	.73	.73	.73	.73	.73
Thermal res. housing to ambient	°C/W	2.8	2.8	2.8	2.8	2.8

Ambient temperature range -73C to 150C Weight 15 oz, maximum winding temp. 200C, maximum case temp. 150C. Data is for winding and magnet temperature of 20°C. The thermal time constant is 11 minutes.

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

#Not including 11.8mΩ untrimmed lead wire resistance. 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: contact us at mail@koford.com

Example: Part Number 42B S 1521 A

Motor type — 42B

Type S=sensorless — S

Winding number — 1521

Modifications A=none, T=thermistor, V=vacuum compatible, H=.180 bore hollow shaft — A

Test Data
Total System Performance
42BH2172T with H48V20A Controller at 48 Volts

RPM	Torque Oz-in	Watts out	Efficiency %	Amps
104,297	0.00	0.00	0.0	0.36
100,074	2.25	166.18	86.6	4.00
99,019	2.95	215.39	89.7	5.00
97,964	3.66	264.39	91.8	6.00
96,909	4.36	311.56	92.7	7.00
95,854	5.06	357.65	93.1	8.00
94,799	5.77	403.35	93.4	9.00
93,744	6.47	447.25	93.2	10.00
92,689	7.17	490.06	92.8	11.00
91,634	7.88	532.46	92.4	12.00
90,579	8.58	573.08	91.8	13.00
89,524	9.28	612.62	91.2	14.00
88,469	9.98	651.06	90.4	15.00
87,414	10.69	689.06	89.7	16.00
86,359	11.39	725.33	88.9	17.00
85,304	12.09	760.49	88.0	18.00
84,249	12.80	795.20	87.2	19.00
83,194	13.50	828.19	86.3	20.00

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. Test were conducted at room temperature.

KOFORD ENGINEERING, LLC 1.6" (42mm) Slotless Brushless motor. Corrosion Resistant/Autoclavable 2 pole windings

• up to 28,800 rpm no load **•Rated power up to 185 watts**

Corrosion resistant and autoclavable design featuring Samarium Cobalt magnet, 440C stainless shaft, TFE leads, autoclavable resistant polyimide insulation system, ceramic hybrid ball bearings, and anodized housing. Suitable for autoclaving and for wet hydrogen or any similar corrosive environment. High power density cog free slotless design. Unit are supplied either with 120° halls rated at 150°C, or in sensorless configuration. Slotless design eliminates cog and reduces bearing loads due to air gap asymmetries compared to conventional slotted motors. In addition the slotless design provides easy start up and maximum performance with sensorless drives. Available with temperature sensors. Custom windings can be provided.

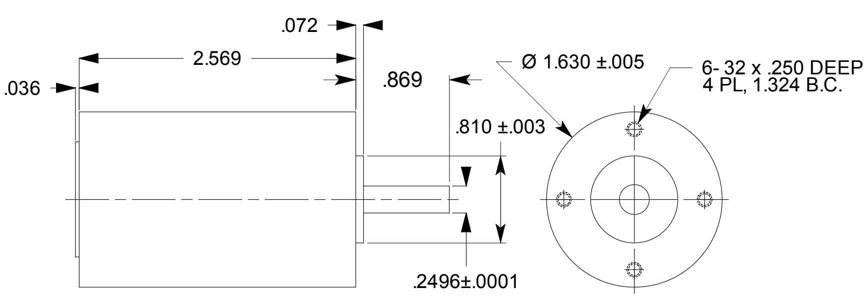
Motor Data

Winding		599	1200	600
Nominal supply voltage	volts	24	24	48
No load speed	rpm±12%	14,376	28,800	28,800
Speed/torque slope	rpm/oz-in	91	149	149
Maximum efficiency	%	88	88	88
Continuous torque heat sink/no h.s.	oz-in*	46/20	46/4	46/4
Motor constant Km	oz-in/√w	5.2	5.2	5.2
Winding resistance#	ohm±15%	.19	.05	.19
Peak output	watts	350	1300	1300
No load current	amp±50%	.47	1.63	.82
Damping factor	oz-in/krpm	.06	.06	.06
Static friction	oz-in	.20	.20	.20
Velocity constant	rpm/volt±12%	599	1200	600
Torque constant Kt	oz-in/amp	2.25	1.13	2.25
Stall current	amps	126	480	240
Stall torque (theoretical)	oz-in	283	542	540
Winding inductance	mH	.101	.022	.101
Mechanical time constant	ms	4.5	4.5	4.5
Rotor inertia	10^{-4}oz-in-sec^2	8.1	8.1	8.1
Thermal res. winding to housing	°C/W	.73	.73	.73
Thermal res. housing to ambient	°C/W	2.8	2.8	2.8

Ambient temperature range -73C to 150C A heat sink and/or blower cooling is required except for very low on time and low duty cycle applications. Weight 15oz, maximum winding temp. 200C, maximum case temp. 150C. Data is for winding and magnet temperature of 20°C

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

#Not including 11.8mΩ untrimmed lead wire resistance. 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: contact us at mail@koford.com

Example: Part Number 42B H 599 C / P10 — Gearbox P10=10.875:1

Motor type — 42B
Type S=sensorless H=120°halls — H
Winding number — 599
Options: C=none, CT=thermistor, CH=hollow shaft(.180 bore) — C

KOFORD ENGINEERING, LLC

1.6" (42mm) Slotless Brushless motor. 4 pole 24V windings

• 3,708 to 9,312 rpm no load **•up to 473 watts continuous**

4 pole design with ultra high energy 80°C Neo magnets results in increased power density over 2 pole designs. The 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. The output shaft is hardened and ground 440C stainless, and high temp TFE insulated lead wires are used. The slotless design reduces bearing loads due to air gap asymmetries compared to conventional slotted motors. Unit are supplied either with 120° halls, or for pumps, blowers and beam choppers, sensorless versions are available. Custom windings can be supplied upon request. Encoders, vacuum compatible versions, hollow shaft motors, and motor with thermistor temperature sensors are offered as options. Gearboxes are available.

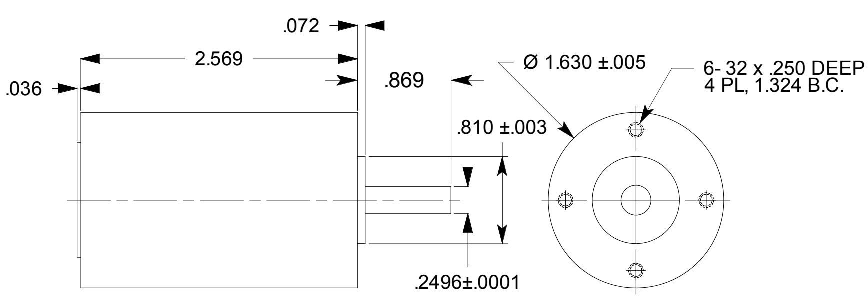
Motor Data

Winding		203	388
Rated supply voltage	volts	24	24
No load speed	rpm±12%	4,872	9,312
Speed/torque slope	rpm/oz-in	12	15
Maximum efficiency	%	88	89
Continuous torque-heat sink/no h.s.	oz-in*	79/28	79/8.5
Rated power-heatsink/no h.s.	watts*	228/93	473/57
Rated speed	rpm	3,924/4,536	8,127/9,184
Rated current	amps	13/4.7	23/3.1
Motor constant Km	oz-in/√w	10.9	11.1
Winding resistance#	ohm±15%	.337	.098
No load current	amp±50%	.28	.81
Damping factor	oz-in/krpm	.24	.24
Static friction	oz-in	.60	.60
Velocity constant	rpm/volt±12%	203	388
Torque constant Kt	oz-in/amp	6.33	3.49
Winding inductance	mH	.238	.065
Mechanical time constant	ms	.8	.8
Rotor inertia	10^{-4}oz-in-sec^2	7.1	7.1
Thermal res. winding to housing	°C/W	.73	.73
Thermal res. housing to ambient	°C/W	2.8	2.8

Ambient temperature range -73C to 70C

Weight 15oz, maximum winding temp. 80C (magnet limited) Data is for winding and magnet temperature of 20°C

*Case held to 20°C with customer supplied heat sinking or cooling jacket /still air and no heat sink.
#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: contact us at mail@koford.com

Example: Part Number 42B H 203 A - A5 - P10 —Gearbox P10=10.875:1

Motor type — 42B
Type S=sensorless H=120°halls — H
Winding number — 203
Modifications A=none, T=thermistor, V=vacuum compatible, H=hollow shaft (.180 bore) — A
Encoder w index A5=500 line(2000 count) — A5

KOFORD ENGINEERING, LLC

1.6" (42mm) Slotless Brushless motor. 4 pole 24V windings

• 7944 rpm no load **•up to 366 watts continuous**

4 pole design with ultra high energy 200°C Neo magnets results in increased power density over 2 pole designs. The 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. The output shaft is hardened and ground 440C stainless, and high temp TFE insulated lead wires are used. The slotless design reduces bearing loads due to air gap asymmetries compared to conventional slotted motors. Unit are supplied either with 120° halls, or for pumps, blowers and beam choppers, sensorless versions are available. Custom windings can be supplied upon request. Encoders, vacuum compatible versions , hollow shaft motors, and motor with thermisor temperature sensors are offered as options. Gearboxes are available.

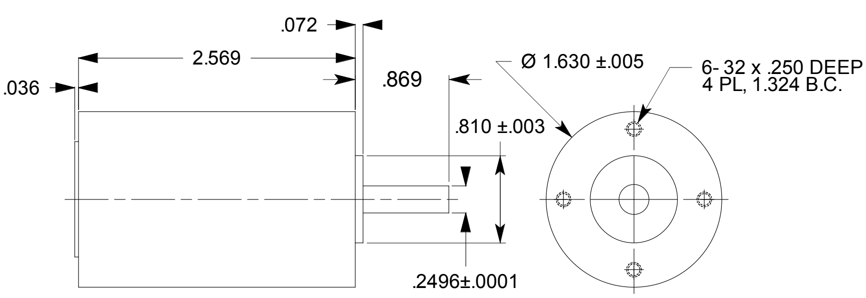
Motor Data

Winding		331
Rated supply voltage	volts	24
No load speed	rpm±12%	7,944
Speed/torque slope	rpm/oz-in	21
Maximum efficiency	%	85
Continuous torque heat sink/no h.s.	oz-in*	79/35
Rated power heat sink/no h.s.	watts*	366/186
Rated speed	rpm	6,285/7,209
Rated current	amps	20/9.2
Motor constant Km	oz-in/√w	8.8
Winding resistance#	ohm±15%	.215
Peak output	watts	553
No load current	amp±50%	.65
Damping factor	oz-in/krpm	.26
Static friction	oz-in	.60
Velocity constant	rpm/volt±12%	331
Torque constant Kt	oz-in/amp	4.08
Stall current	amps	111
Winding inductance	mH	.141
Mechanical time constant	ms	1.3
Rotor inertia	10^{-4}oz-in-sec^2	7.1
Thermal res. winding to housing	°C/W	.73
Thermal res. housing to ambient	°C/W	2.8

Ambient temperature range -73C to 150C

Weight 15oz, maximum winding temp. 150C (hall sensor limited) Data is for winding and magnet temperature of 20°C

*Case held to 20°C with customer supplied heat sinking or cooling jacket /still air and no heat sink.
#Lead wires resistance 11.8mΩ if used at full length
Leads are 12" minimum
Phase leads are 18



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 42B H 331 A - A5 - P10—Gearbox P10=10.875:1

- Motor type — 42B
- Type S=sensorless H=120°halls — H
- Winding number — 331
- Modifications A=none, T=thermistor, V=vacuum compatible, H=hollow shaft (.180 bore) — A
- Encoder w index A5=500 line(2000 count) — A5

KOFORD ENGINEERING, LLC

1.6" (42mm) Slotless Brushless motor. 2 pole 12V windings

• 1,548 to 15,000 rpm no load **•Rated power 200 watts**

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 and beam choppers, sensorless versions are available. Custom windings can be supplied upon request. Encoders, vacuum compatible versions, hollow shaft motors, and motor with thermistor temperature sensors are offered as options. Custom gearboxes can be supplied.

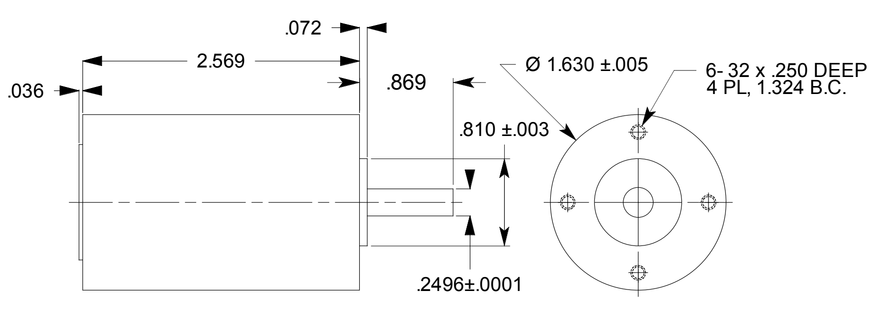
Motor Data

Winding		129	297	951	1199
Nominal supply voltage	volts	12	12	12	12
No load speed	rpm±12%	1,548	3,564	11,412	14,388
Speed/torque slope	rpm/oz-in	58	64	100	115
Maximum efficiency	%	66	77	84	87
Continuous torque heat sink/no h.s.	oz-in*	20/20	56/20	57/26	54/24
Motor constant Km	oz-in/√w	5.2	5.2	5.2	5.3
Winding resistance#	ohm±15%	4.1	.75	.074	.045
Peak output	watts	17	43	385	586
No load current	amp±50%	.10	.26	1.06	1.16
Damping factor	oz-in/krpm	.28	.16	.04	.04
Static friction	oz-in	.60	.60	.60	.60
Velocity constant	rpm/volt±12%	129	297	951	1,199
Torque constant Kt	oz-in/amp	10.4	4.50	1.42	1.13
Stall current	amps	2.9	17	162	266
Stall torque (theoretical)	oz-in	30	69	230	300
Winding inductance	mH	3.2	.519	.052	.030
Mechanical time constant	ms	4.4	4.4	4.4	4.4
Rotor inertia	10^{-4}oz-in-sec^2	7.1	7.1	7.1	7.1
Thermal res. winding to housing	°C/W	.73	.73	.73	.73
Thermal res. housing to ambient	°C/W	2.8	2.8	2.8	2.8

Ambient temperature range -73C to 149C

Weight 15oz, maximum winding temp. 200C Data is for winding and magnet temperature of 20°C

*Case held to 20°C with customer supplied heat sinking or cooling jacket /still air and no heat sink.
#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: contact us at mail@koford.com

Example: Part Number 42B H 297 A - A5 - P10 — Gearbox P10=10.875:1

- Motor type — 42B
- Type S=sensorless H=120°halls — H
- Winding number — 297
- Modifications A=none, T=thermistor, V=vacuum compatible, H=hollow shaft (.180 bore) — A
- Encoder w index A5=500 line(2000 count) — A5

Test Data
Total System Performance
42BH297A with H24V10A Controller at 12 Volts

Rpm	Torque Oz-in	Watts Out	Efficiency %	Amps
3819	0.00	0.00	0.00	0.50
3733	2.00	5.53	57.60	0.80
3603	4.02	10.71	68.65	1.30
3501	6.02	15.60	76.50	1.70
3373	8.04	20.07	76.02	2.20
3231	10.03	23.99	74.04	2.70
3100	12.07	27.71	72.16	3.20
2970	14.06	30.92	71.57	3.60
2837	16.09	33.80	68.70	4.10
2703	18.04	36.10	65.40	4.60
2565	19.99	37.95	63.25	5.00
2414	22.02	39.35	59.62	5.50
2316	24.07	41.28	57.33	6.00
2251	25.90	43.25	56.32	6.40
2099	28.06	43.62	52.68	6.90
1950	30.00	43.30	48.76	7.40
1733	32.05	41.12	43.38	7.90
1566	34.04	39.47	39.63	8.30
1517	36.06	40.49	38.34	8.80

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.

Test Data
Total System Performance
42BH951A with H24V20A Controller at 12 Volts

Rpm	Torque Oz-in	Watts Out	Efficiency %	Amps
12038	0.00	0.00	0.00	1.70
11945	2.00	17.72	61.53	2.40
11748	4.00	34.78	74.32	3.90
11551	5.99	51.27	80.61	5.30
11352	8.00	67.24	82.40	6.80
11148	10.00	82.52	82.85	8.30
10936	12.04	97.50	82.91	9.80
10732	14.01	111.30	82.10	11.30
10519	16.03	124.79	81.24	12.80
10301	18.00	137.24	80.54	14.20
10076	20.02	149.33	79.26	15.70
9844	22.02	160.41	77.72	17.20

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.

KOFORD
ENGINEERING, LLC

1.6" (42mm) Slotless Brushless motor. 4 pole 12V windings

• 3,564 rpm no load **•Rated power 50 watts**

4 pole design with ultra high energy 80°C Neo magnets results in increased power density over 2 pole designs. The 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.The output shaft is hardened and ground 440C stainless, and high temp TFE insulated lead wires are used. The slotless design reduces bearing loads due to air gap asymmetries compared to conventional slotted motors. Unit are supplied either with 120° halls, or for pumps, blowers and beam choppers, sensorless versions are available. Custom windings can be supplied upon request. Encoders, vacuum compatible versions , hollow shaft motors, and motor with thermistor temperature sensors are offered as options. Custom gearboxes can be supplied.

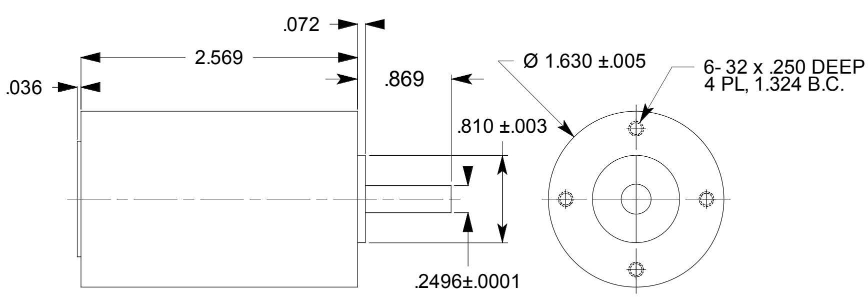
Motor Data

Winding		202	387	763
Nominal supply voltage	volts	12	12	12
No load speed	rpm±12%	2,424	4,644	9,156
Speed/torque slope	rpm/oz-in	12	13	21
Maximum efficiency	%	84	86	89
Continuous torque heat sink/no h.s.	oz-in*	81/37	82/37	82/36
Motor constant Km	oz-in/√w	10.9	11.7	11.2
Winding resistance#	ohm±15%	.337	.089	.024
Peak output	watts	76	265	726
No load current	amp±50%	.23	.62	1.6
Damping factor	oz-in/krpm	.24	.34	.24
Static friction	oz-in	.60	.60	.60
Velocity constant	rpm/volt±12%	202	387	763
Torque constant Kt	oz-in/amp	6.33	3.49	1.74
Stall current	amps	35.6	125	500
Stall torque (theoretical)	oz-in	225	470	870
Winding inductance	mH	.238	.065	.016
Mechanical time constant	ms	.8	.8	.8
Rotor inertia	10^{-4}oz-in-sec^2	7.1	7.1	7.1
Thermal res. winding to housing	°C/W	.73	.73	.73
Thermal res. housing to ambient	°C/W	2.8	2.8	2.8

Ambient temperature range -73C to 70C

Weight 15oz, maximum winding temp. 80C (magnet limited) Data is for winding and magnet temperature of 20°C

*Case held to 20°C with customer supplied heat sinking or cooling jacket /still air and no heat sink.
#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: contact us at mail@koford.com

Example: Part Number 42B S 202 A - A5 - P10 — Gearbox P10=10.875:1

- 42B — Motor type
- S — Type S=sensorless H=120°halls
- 202 — Winding number
- A — Modifications A=none, T=thermistor, V=vacuum compatible, H=hollow shaft (.180 bore)
- A5 — Encoder w index A5=500 line(2000 count)

Test Data
Total System Performance
42BS202A with S18V15A Controller at 12 Volts

Rpm	Torque Oz-in	Watts Out	Efficiency %	Amps
2393	5.41	9.57	78.99	1.01
2295	12.27	20.83	85.94	2.02
2249	15.53	25.86	85.85	2.51
2190	19.47	31.55	85.08	3.09
2103	25.92	40.35	83.43	4.03
2013	32.65	48.64	80.89	5.01
1917	39.50	56.03	77.68	6.01
1821	46.63	62.84	74.27	7.05
1719	53.94	68.61	69.73	8.20
1660	60.15	73.89	67.66	9.10
1585	63.57	74.56	64.73	9.60

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.

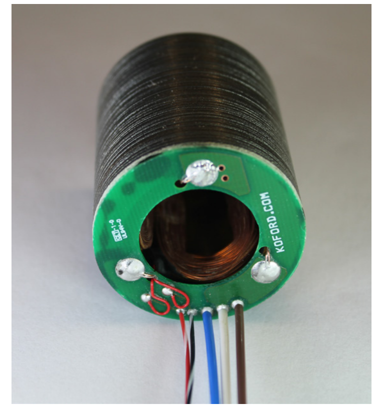
Test Data
Total System Performance
42BS202A with S24V10A Controller at 12 Volts

Rpm	Torque Oz-in	Watts Out	Efficiency %	Amps
2495	4.55	8.41	70.04	1.00
2403	11.22	19.95	82.72	2.01
2362	14.39	25.16	83.53	2.51
2311	17.62	30.13	83.70	3.00
2269	20.94	35.17	83.50	3.51
2226	24.01	39.56	82.63	3.99
2128	30.65	48.27	80.13	5.02
2037	36.87	55.59	77.08	6.01
1925	43.72	62.30	73.64	7.05
1833	50.85	68.99	70.98	8.10
1743	57.09	73.62	67.41	9.10
1595	61.97	73.17	63.51	9.60

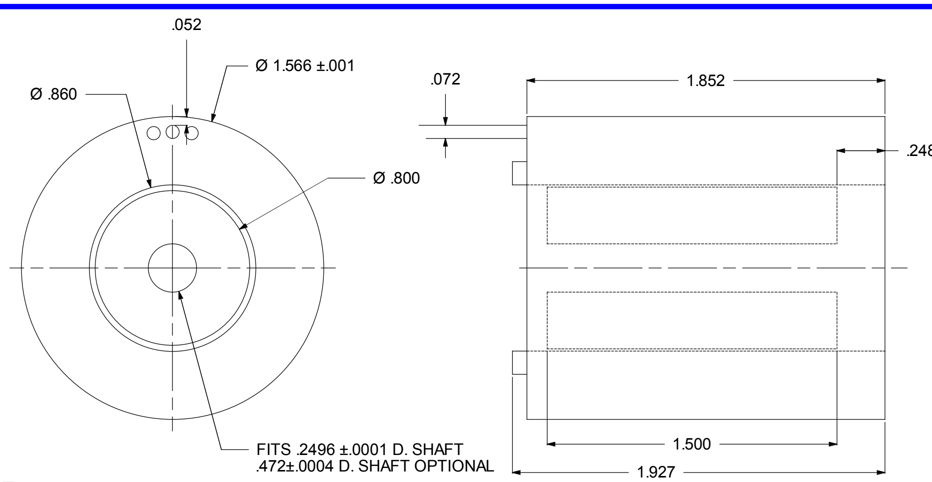
Dyno test results of a motor and drive combination with voltage held to 12v at input of drive using remote voltage sense on the power supply. Winding temperature is held below 40C by running test quickly and/or allowing motor to cool between tests. Test were conducted at room temperature.

KOFORD ENGINEERING, LLC

1.6" (42mm) 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. For designs that require a large shaft diameter such as pumps with ceramic shafts, 12mm bore and a .375 bore 2 pole magnet is available. The 12mm bore reduces Kt by 16% with a magnetic shaft, the Kt of the .375 bore is unchanged. 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 at our factory to a customer supplied shaft. Do not use Anaerobic or acrylic adhesives for bonding the 2 pole magnets. 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 an axial clamp with heat transfer grease between the motor stator and housing is recommended. 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 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 drag. If a hall sensor mounted to the stator is required the standard configuration covers the lead wire end of the magnet and prevents insertion of the rotor from that direction. Halls can be provided with a through bore configuration, however efficiency will be several percentage points less then the standard configuration. .375 and 12mm bores require the through bore hall board, consult factory for part numbers. Custom winds and rotors for other shaft sizes can be provided.



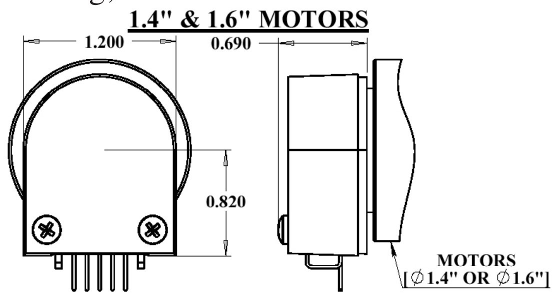
weight 12 oz.

For the frameless version of a motor use F in the winding number. Example 42FBS298A

KOFORD
ENGINEERING, LLC

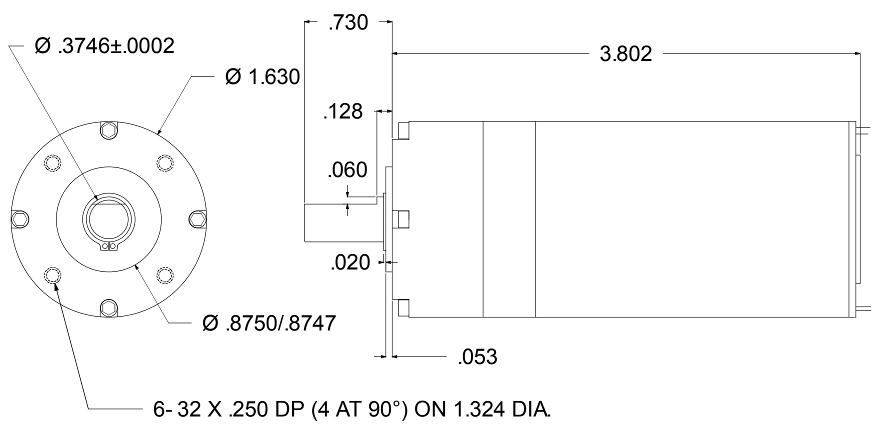
Optical Encoders

Mating connector AMP103977-4. Supply voltage 5±.5V.
Rpm 50,000 max. Weight .5 oz, inertia .08 x 10^{-4} oz-in-sec^2.
temperature rating, -40°C to 100°C



Planetary Gearheads

P10 10.875:1 planetary gearbox with needle bearing planets and a maximum input speed of 60,000 rpm. Continous torque 231 oz-in (40,000 rpm input), peak torque 800 oz-in. Weight 6.4 oz., temperature rating -70°C to 150°C. Gearhead increases overall length by 1.333" Motor cooling must be directly applied to the motor housing by use of a fan or a cooling coil on the motor OD. It is not possible to cool the motor through the gearbox mounting.



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

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 42mm 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 (200,000+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%.

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 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. 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. For example at 150°C the winding resistance is 1.51 times the resistance at 20°C, so this higer 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 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. Keep the hall wires away from the phase leads or shield them. 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. For futher reduction consider enclosing the drive or motor and drive or motor/drive/power supply in a metal enclosure and place a EMI filter at the input of the power supply or if the drive is not in the enclosure place it at the input to the drive. Off the shelf EMI filters are offered by various vendors and generally consist of inductors and caps.

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 includes 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 drive output at maximum. As the speed is turned down the 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).