KOFORD
ENGINEERING, LLC

1.1” (28mm) Series

• High performance slotless brushless motors for military, aerospace, power tool, and industrial applications. Housed or frameless, long and ultra short versions.

• Highest power density and efficiency.

• High temperature 240°C rated ML insulation impregnated with 205°C thermally conductive resin for the ultimate in ruggedness.

• Cog free design ideal for precision motion.

• Speeds up 50,000 rpm.

• 4 pole design.

• Available with with hall sensors or sensorless.

• Vacuum versions available.

• Available with encoders and with ball/needle bearing gearboxes with all case hardened alloy steel gears for maximum life.

• Up to 94% efficiency

• Hardened and ground stainless steel shaft

• Long life premium synthetic bearing lube with -73C to 149C temperature range

KOFORD
ENGINEERING, LLC

1.1" (28mm) 4 pole Sensorless Slotless Brushless DC motor.

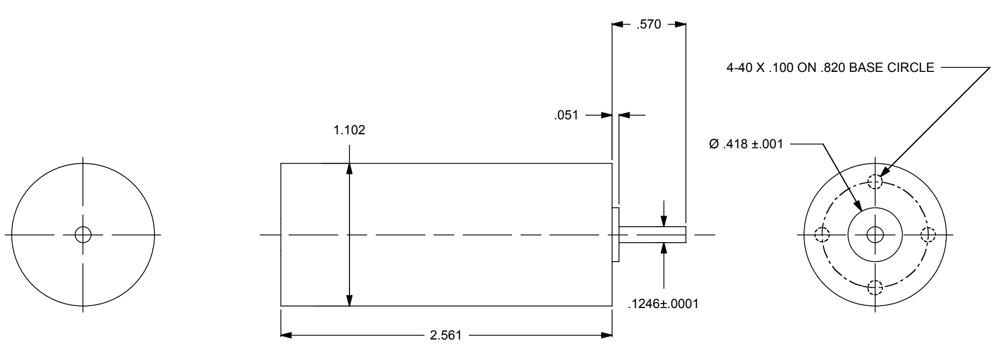
•No Load RPM up to 45,840 rpm **•Rated power 250 watts**

4 pole ultra high performance, rugged, slotless design provides unmatched power density, high continuous and peak torque and is cog free. Available with optical encoders and gearheads. 240°C ML wire and Kapton® ground insulation are used for the ultimate in ruggedness. Leads are Teflon® insulated. Lamination materials are ultra low loss for maximum performance. Available in hall or sensorless configurations. Custom windings available.

Motor Data

Winding		476	952	954	955
Nominal supply voltage	volts	24	24	36	48
No load speed	rpm	11,423	22,848	34,344	45,840
Speed/torque slope	rpm/oz-in	160	297	330	363
Stall torque (theoretical)	oz-in	82	165	246	330
Continuous torque 60°C case/no h.s.	oz-in	24/10	23/10	23/9.4	22/8.3
Continuous current 60°C case/no h.s.	amps	8.5/3.8	16/7.4	16/6.8	16/6.0
Motor constant Km	oz-in/√w	3.1	3.1	3.1	3.1
Winding resistance	ohm±15%	.824	.206	.206	.206
Peak output	watts	126	343	683	956
No load current	amp±50%	.08	.12	.16	.28
Damping factor	oz-in/krpm	.005	.005	.005	.004
Static friction	oz-in	.06	.06	.06	.06
Velocity constant	rpm/volt±12%	476	952	954	955
Torque constant Kt	oz-in/amp	2.83	1.42	1.42	1.42
Stall current	amps	29	116	174	233
Maximum efficiency	%	90	94	94	93
Winding inductance	mH	.20	.05	.05	.05
Mechanical time constant	ms	1.7	1.7	1.7	1.7
Rotor inertia	10^{-4}oz-in-sec^2	1.19	1.19	1.19	1.19
Thermal resistance windings to case	°C/W	1.0	1.0	1.0	1.0
Thermal resistance case to ambient	°C/W	5.7	5.7	5.7	5.7

25 lb. maximum axial force on shaft, maximum winding temperature 150 °C (magnet temperature limited), ambient temperature range -73C to +100C, weight 5.7 oz. Motor performance data is at winding temperature of 20C. Winding resistance does not include .051Ω lead resistance (trim leads as short as possible). Motor performance only. Does not include customer supplied drive.



Leads are 12" minimum Phase leads are 24 gauge, hall leads are 28 gauge, all TFE insulation

Leads	
Blue	Phase A
White	Phase B
Brown	Phase C

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

Example: Part Number 28 S 952 A / A3 / P7

Motor dia. — 28
Type S=sensorless — S
Winding number — 952
Modifications A=none, T=thermistor, V=vacuum, C=Ceramic bearings — A
Encoder A3=360 lines, A1=100 lines — A3
Gearhead P7=6.75:1, P46=45.56:1, P307=307.54:1 — P7

Test Data
Total System Performance
28S952A motor with S24V10A Controller at 24 volts

RPM	Torque oz-in	Watts out	Efficiency %	Amps
21660	0.00	0.00	0.0	0.12
21418	1.27	20.06	78.9	1.04
21108	2.56	39.85	88.8	1.86
20608	3.91	59.42	90.4	2.74
20196	5.04	75.06	91.2	3.43
19737	6.47	94.16	91.7	4.28
19237	7.61	107.95	91.1	4.94
18772	9.07	125.55	89.9	5.82
18501	9.99	136.29	88.9	6.39
18164	11.14	149.21	87.6	7.09
17699	13.08	170.71	85.7	8.29
17381	14.40	184.56	84.5	9.10

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 is a function of motor/gearbox/drive/ and wiring losses

Test Data
Total System Performance
28S952T/P7 gearmotor with S24V10A Controller at 24 volts

RPM	Torque oz-in	Watts out	Efficiency %	Amps
3209	0.00	0.00	0.0	0.18
3173	8.11	19.04	74.8	1.06
3127	16.29	37.72	84.0	1.87
3079	24.89	56.73	85.6	2.76
3035	32.10	72.13	86.4	3.48
2954	41.24	90.17	87.8	4.28
2820	48.48	100.36	85.9	4.87
2765	57.76	118.19	85.1	5.79
2741	63.69	129.18	84.2	6.39
2691	70.96	141.31	82.9	7.10
2622	83.30	161.66	81.2	8.30
2575	91.74	174.83	80.1	9.10

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 is a function of motor/gearbox/drive/ and wiring losses

Test Data
Continuous Duty Total System Performance
28S952T/P7 gearmotor with S24V10A Controller at 24 volts

RPM	Torque oz-in	Watts out	Efficiency %	Amps	ΔT °C	Final Temp °C
3260	0.99	2.40	31.3	0.32	13.8	38.9
3239	3.98	9.53	65.1	0.61	13.7	38.9
3221	8.03	19.15	77.5	1.03	14.7	40.0
3194	12.03	28.44	82.9	1.43	15.6	41.0
3177	16.00	37.60	85.6	1.83	18.5	43.0
3163	20.02	46.89	86.8	2.25	20.6	45.2
3147	24.00	55.85	87.2	2.67	23.0	48.0
3117	27.98	64.43	87.4	3.07	24.1	49.6
3040	31.98	71.97	85.7	3.50	28.6	52.9

Motor was run at load until winding temperature stabilized. Gearbox was attached to a heavy aluminum mounting bracket. Test was run at room ambient 24-25C. Note that there is little change in output power as the motor heats up. Total efficiency is a function of motor/gearbox/drive/ and wiring losses

Test Data
Total System Performance
28S954T/P7 gearmotor with S48V20A Controller at 36 volts

Rpm	Torque Oz-in	Watts Out	Efficiency %	Amps
4852	0.00	0.00	0.00	0.24
4768	8.07	28.47	74.60	1.06
4687	16.26	56.42	82.90	1.89
4630	24.38	83.55	85.30	2.72
4585	32.45	110.13	86.90	3.52
4526	40.64	136.12	86.90	4.35
4481	47.69	158.16	87.50	5.02
4441	56.08	184.32	86.90	5.89
4392	64.22	208.77	86.20	6.72

Dyno test results of a motor and drive combination with voltage held to 36v 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 is a function of motor/gearbox/drive/ and wiring losses

Test Data
Total System Performance
28S955A motor with S48V20A Controller at 48 volts

Rpm	Torque Oz-in	Watts Out	Efficiency %	Amps
43949	0.00	0.0	0.0	0.30
43495	1.26	40.4	72.5	1.16
43045	2.55	80.9	84.3	2.00
42590	3.80	119.3	87.5	2.84
42142	5.09	158.2	89.3	3.69
41692	6.36	195.5	90.9	4.48
41273	7.55	229.8	91.2	5.25
40798	8.80	264.7	91.8	6.01
40153	10.45	309.4	91.7	7.03

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 is a function of motor/gearbox/drive/ and wiring losses

Test Data
Total System Performance
28S955T/P7 gearmotor with S48V20A Controller at 48 volts

Rpm	Torque Oz-in	Watts Out	Efficiency %	Amps
6511	0.00	0.00	0.00	0.30
6423	8.00	37.86	69.50	1.16
6380	16.26	76.88	80.10	2.00
6314	24.22	113.17	83.00	2.84
6258	32.45	150.84	84.70	3.71
6181	40.48	185.19	86.70	4.45
6087	48.10	217.00	86.27	5.24
6010	56.06	249.38	86.15	6.03
5919	66.54	290.47	86.08	7.03

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 is a function of motor/gearbox/drive/ and wiring losses

KOFORD
ENGINEERING, LLC

1.1" (28mm) 4 pole Slotless Brushless DC motor.

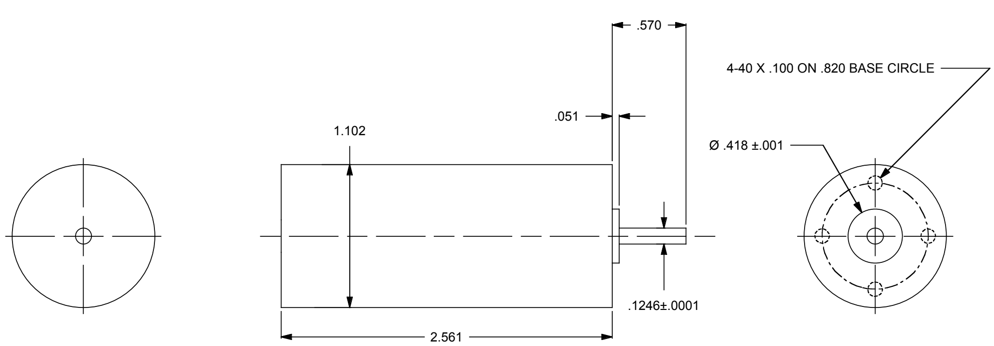
•No Load RPM up to 35,376 rpm **•Rated power 210 watts**

Hall sensor 4 pole ultra high performance, rugged, slotless design provides unmatched power density, high continuous and peak torque and is cog free. 240°C ML wire and Kapton® ground insulation are used for the ultimate in ruggedness. Leads are Teflon® insulated. Lamination materials are ultra low loss for maximum performance. For motion control applications where an encoder is not required and hall sensors will be used for feedback. Available with planetary gearboxes and encoders.

Motor Data

Winding		308	309	310	737
Nominal supply voltage	volts	24	36	48	48
No load speed	rpm	7,392	11,124	14,880	35,376
Speed/torque slope	rpm/oz-in	125	128	152	320
Stall torque (theoretical)	oz-in	68	102	136	391
Continuous torque 60°C case/no h.s.	oz-in	17/12	17/12	17/11	8.5/0
Continuous current 60°C case/no h.s.	amps	4.1/2.8	4.1/2.8	4.0/2.7	5.3/.40
Motor constant Km	oz-in/√w	3.52	3.52	3.52	3.87
Winding resistance	ohm±15%	1.54	1.54	1.54	.224
Peak output	watts	73	145	251	721
No load current	amp±50%	.06	.06	.07	.68
Damping factor	oz-in/krpm	.03	.02	.02	.03
Static friction	oz-in	.06	.06	.06	.06
Velocity constant	rpm/volt±12%	308	309	310	737
Torque constant Kt	oz-in/amp	4.38	4.38	4.38	1.83
Stall current	amps	15.5	23.2	31	214
Maximum efficiency	%	87	90	91	89
Winding inductance	mH	.41	.41	.41	.07
Mechanical time constant	ms	1.5	1.5	1.5	1.2
Rotor inertia	10^{-4}oz-in-sec^2	1.29	1.29	1.29	1.29
Thermal resistance windings to case	°C/W	1.0	1.0	1.0	1.0
Thermal resistance case to ambient	°C/W	5.7	5.7	5.7	5.7

25 lb. maximum axial force on shaft, maximum winding temperature 150 °C (magnet temperature limited), ambient temperature range -73C to +100C, weight 5.8 oz. Motor performance data is at winding temperature of 20C. Winding resistance does not include .051Ω lead resistance (trim leads as short as possible). Motor performance only. Does not include customer supplied drive.



Leads are 12" minimum Phase leads are 24 gauge, hall leads are 28 gauge, all TFE insulation

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

Example: Part Number 28 H 308 A / A3 / P7

Motor dia. — 28
Type H=hall, S=sensorless — H
Winding number — 308
Modifications A=none — A
Encoder A3=360 lines, A1=100 lines — A3
Gearhead P7=6.75:1, P46=45.56:1, P307=307.54:1 — P7

Test Data
Total System Performance
28H308A with H24V10A Controller at 12 volts

RPM	Torque Oz-in	Watts out	Efficiency %	Amps
3479	0.00	0.00	0.0	0.07
3401	0.87	2.19	73.0	0.25
3276	2.10	5.09	83.2	0.51
3224	2.55	6.09	83.2	0.61
3147	3.22	7.50	83.3	0.75
3095	3.66	8.39	82.3	0.85
3027	4.28	9.58	81.5	0.98
2487	9.15	16.85	70.2	2.00
1972	13.95	20.36	56.2	3.02
1481	18.36	20.12	42.4	3.95

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
28H308A with H24V10A Controller at 24 volts

RPM	Torque oz-in	Watts out	Efficiency %	Amps
7030	0.00	0.00	0.0	0.09
6777	1.90	9.53	79.4	0.50
6632	3.09	15.19	84.4	0.75
6488	4.29	20.60	84.9	1.01
6350	5.46	25.67	85.6	1.25
6200	6.66	30.55	84.9	1.50
5917	9.02	39.48	82.7	1.99
5310	14.07	55.29	76.0	3.03
4718	18.91	66.02	68.4	4.02
4109	23.63	71.86	59.6	5.02
3499	28.19	73.01	50.6	6.01
2974	32.88	72.38	43.1	7.00

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
Total System Performance
28H309A with H48V20A Controller at 36 volts

RPM	Torque Oz-in	Watts out	Efficiency %	Amps
10545	0.00	0.00	0.0	0.09
10295	1.98	15.11	82.3	0.51
10119	3.18	23.83	87.1	0.76
9971	4.32	31.91	88.6	1.00
9841	5.49	39.96	88.8	1.25
9340	9.15	63.26	87.9	2.00
8718	14.02	90.46	83.8	3.00
8063	18.87	112.57	78.2	4.00
7328	23.79	129.06	71.8	4.99
6638	28.85	141.73	65.3	6.03
5763	33.58	143.19	56.7	7.01

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
28H310A with H48V20A Controller at 48 volts

RPM	Torque Oz-in	Watts out	Efficiency %	Amps
14080	0.00	0.00	0.0	0.10
13755	1.79	18.17	75.7	0.50
13589	2.99	30.14	83.7	0.75
13422	4.19	41.61	86.7	1.00
13254	5.38	52.78	87.9	1.25
13083	6.56	63.54	88.8	1.49
12746	8.99	84.81	88.3	2.00
12079	13.78	123.15	86.1	2.98
11385	18.84	158.72	82.7	4.00
10612	23.78	186.73	77.6	5.01
9952	28.78	211.98	73.6	6.00
9090	33.25	223.67	66.8	6.98

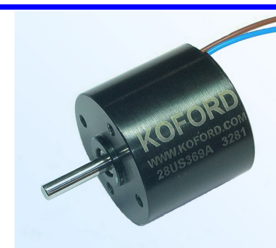
Dyno test results of a motor and drive combination with voltage held to 24v at input of drive using remote voltage sense on the power supply. Winding temperature is held below 40C by running test quickly and/or allowing motor to cool between tests. Test were conducted at room temperature.

KOFORD ENGINEERING, LLC

1.1" (28mm) Ultrashort 4 pole Sensorless Slotless Brushless DC motor.

•No Load RPM up to 11,184 rpm **•Rated power 21 watts**

4 pole ultra high performance, rugged, slotless design provides unmatched power density, high continuous and peak torque and is cog free. Available with optical encoders and gearheads. 240°C ML wire and Kapton® ground insulation are used for the ultimate in ruggedness. Leads are Teflon® insulated. Lamination materials are ultra low loss for maximum performance. Especially suited for pumps, blowers and scanners.

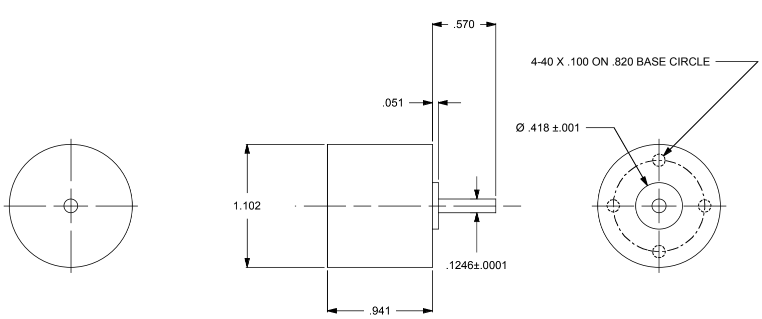


Motor Data

Winding		369	465	1246	466
Nominal supply voltage	volts	12	12	12	24
No load speed	rpm	4,428	5,580	14,952	11,184
Speed/torque slope	rpm/oz-in	1587	1590	1,800	1,700
Stall torque (theoretical)	oz-in	2.9	3.8	9.7	7.5
Continuous torque 60°C case/no h.s.	oz-in	1.9/1.9	3.5/2.2	3.3/2.0	2.9/2.0
Continuous current 60°C case/no h.s.	amps	.53/.53	1.2/.76	3.1/1.9	1.3/.75
Motor constant Km	oz-in/√w	.94	.94	.94	.94
Winding resistance	ohm±15%	15.2	9.3	1.3	9.3
Peak output	watts	2.3	3.6	16	3.6
No load current	amp±50%	.01	.02	.09	.03
Damping factor	oz-in/krpm	.005	.005	.005	.005
Static friction	oz-in	.02	.02	.02	.02
Velocity constant	rpm/volt±12%	369	465	1246	466
Torque constant Kt	oz-in/amp	3.66	2.90	1.08	2.90
Stall current	amps	.8	1.3	9.0	2.6
Maximum efficiency	%	78	79	81	80
Winding inductance	mH	3.0	1.9	.05	1.9
Mechanical time constant	ms	3.2	3.2	3.2	3.2
Rotor inertia	10^{-4}oz-in-sec^2	.20	.20	.20	.20
Thermal resistance windings to case	°C/W	4.4	4.4	4.4	4.4
Thermal resistance case to ambient	°C/W	11.9	11.9	11.9	11.9

25 lb. maximum axial force on shaft, maximum winding temperature 150 °C (magnet temperature limited), ambient temperature range -73C to +100C, weight 1.9 oz. Motor performance data is at winding temperature of 20C. Winding resistance does not include .051Ω lead resistance (trim leads as short as possible). Motor performance only. Does not include customer supplied drive.

Leads are 12" minimum Phase leads are 24 gauge, hall leads are 28 gauge, all TFE insulation



Leads	
Blue	Phase A
White	Phase B
Brown	Phase C

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

Example: Part Number 28 US 465 A / A3 / P7

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

Motor dia.

Type US=ultrashort sensorless

Winding number

Encoder A3=360 lines

Modifications A=none, T=thermistor, V=vacuum

Test Data
Total System Performance
28US1246A with S24V5A Controller at 12 volts

RPM	Torque Oz-in	Watts out	Efficiency %	Amps
15397	0.00	0.0	0.0	0.11
14337	0.54	5.7	79.2	0.60
13372	0.99	9.8	81.7	1.00
12420	1.42	13.0	77.4	1.40
11549	1.84	15.7	72.7	1.80
10550	2.30	17.9	67.8	2.20
9605	2.73	19.3	61.9	2.60
8613	3.18	20.2	56.1	3.00
7668	3.62	20.5	50.2	3.40
6642	4.07	19.9	43.6	3.80
5697	4.52	19.0	37.7	4.20
4691	4.95	17.1	31.0	4.60
3706	5.41	14.8	24.7	5.00

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.

Test Data
Total System Performance
28US1246A/P7 with S24V5A Controller at 12 volts

RPM	Torque Oz-in	Watts out	Efficiency %	Amps
2281	0.0	0.0	0.0	0.18
2124	3.0	4.7	65.3	0.60
1981	6.0	8.8	73.3	1.00
1840	8.9	12.1	72.0	1.40
1711	11.7	14.8	68.5	1.80
1563	14.6	16.8	63.6	2.20
1423	17.3	18.2	58.3	2.60
1276	20.2	19.0	52.8	3.00
1136	23.0	19.3	47.3	3.40
984	25.8	18.9	41.4	3.80
844	28.7	17.9	35.5	4.20
695	31.4	16.1	29.2	4.60
549	34.3	13.9	23.2	5.00

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.

Test Data
Total System Performance
28US466A with S24V5A Controller at 24 volts

RPM	Torque Oz-in	Watts out	Efficiency %	Amps
11529	0	0	0	0.04
10867	0.43	3.45	71.9	0.20
9700	0.99	7.08	73.8	0.40
8606	1.56	9.90	68.8	0.60
7520	2.14	11.87	61.8	0.80
6440	2.74	13.01	54.2	1.00
5400	3.29	13.10	45.5	1.20
4286	3.91	12.36	36.8	1.40
3206	4.46	10.54	27.5	1.60

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.

Test Data
Total System Performance
28US466A/P7 with S24V5A Controller at 24 volts

RPM	Torque Oz-in	Watts out	Efficiency %	Amps
1708	0.00	0.00	0.0	0.08
1610	2.24	2.66	55.4	0.20
1437	6.01	6.39	66.6	0.40
1275	9.84	9.25	64.2	0.60
1114	13.55	11.13	58.0	0.80
954	17.37	12.22	50.9	1.00
800	20.86	12.31	42.7	1.20
635	24.80	11.61	34.6	1.40
475	28.32	9.92	25.8	1.60

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.

Test Data
Total System Performance
28US465A with S24V5A Controller at 12 volts

RPM	Torque Oz-in	Watts out	Efficiency %	Amps
5771	0	0	0	0.03
5529	0.18	0.73	60.8	0.10
5076	0.44	1.65	69.8	0.20
4578	0.73	2.46	68.3	0.30
4084	1.00	3.01	62.7	0.40
3605	1.27	3.32	55.3	0.50
3146	1.54	3.50	48.6	0.60
2633	1.83	3.55	41.3	0.70
2180	2.09	3.33	34.7	0.80
1661	2.39	2.93	27.1	0.90
1235	2.66	2.42	20.2	1.00

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.

Test Data
Total System Performance
28US465A/P7 with S24V5A Controller at 12 volts

RPM	Torque Oz-in	Watts out	Efficiency %	Amps
849	0.00	0.00	0.0	0.07
825	0.53	0.32	26.7	0.10
752	2.31	1.28	53.3	0.20
676	4.22	2.10	58.3	0.30
605	6.10	2.72	56.7	0.40
534	7.93	3.12	52.0	0.50
466	9.58	3.29	45.7	0.60
390	11.58	3.33	39.6	0.70
323	13.25	3.16	32.9	0.80
246	15.19	2.76	25.6	0.90
183	16.89	2.28	19.0	1.00

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.

Test Data
Total System Performance
28US369A with S24V5A Controller at 24 volts

Rpm	Torque Oz-in	Watts Out	Efficiency %	Amps
8867	0	0	0	0.03
7517	0.75	4.15	75.2	0.23
7105	1.02	5.34	74.2	0.3
6618	1.31	6.39	72	0.37
6235	1.55	7.12	68.6	0.43
5791	1.8	7.68	64	0.5
5436	1.99	7.98	60.5	0.55
5043	2.25	8.36	57.1	0.61

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.

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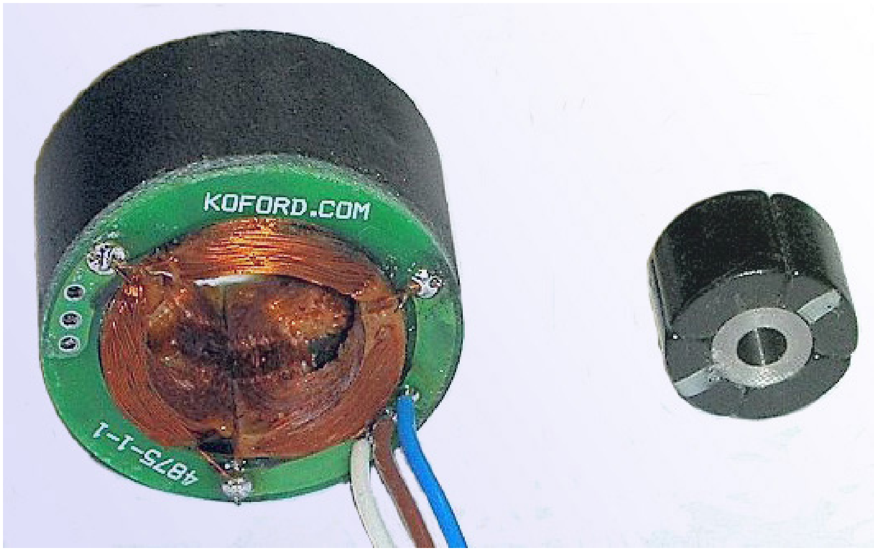
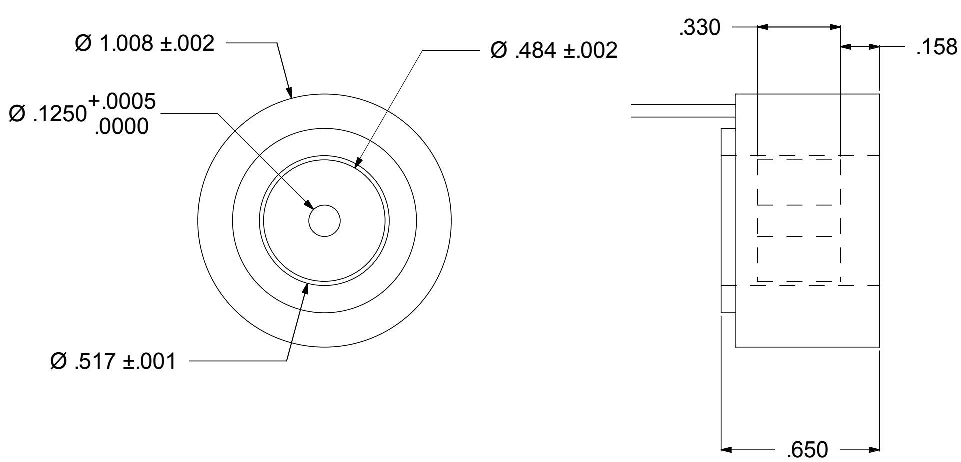
1.008" (25mm) Frameless Slotless Brushless motor.



Frameless version of the 1.1" (28mm) Ultrashort housed motor. This motor is sensorless only and comes with a 4 pole rotor. The same winding number listed on the previous page are used but the part number begains with 25 instead of 28. For example the frameless version of the 28US465A would be 25US465A.

The customer should epoxy the supplied rotor magnet to their magnetic shaft (440C or 416 stainless recomended) and then dynamically balance the assembly to tolerances appropiate to their rpm and bearing system. Low speed windings may not need to be balanced. Suitable heat cure epoxies can be found under the "epoxy" section at Koford.com. The cure temperature should not exceed 150°C. Do not attempt press fitting as this will break the magnet. Room temperature cure epoxies may be used when less durability is required. Close control over the mix ratio is required with these material. "instant" or anerobic adhesives are not recommended.



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

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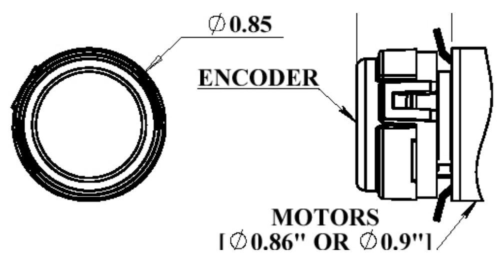
Optical Encoder

A3=360 lines. A and B channels in quadrature. Combined this gives 1440 counts per shaft revolution. Mating connector Molex 51021-400/50079 . Supply voltage 5±.5V. Rpm 16,000 max. Inertia .07 x10^{-4}oz-in-sec^2. -20°C to 100°C.

A1=100 lines. A and B channels in quadrature. Combined this gives 400 counts per shaft revolution. Mating connector Molex 51021-400/50079 . Supply voltage 5±.5V. Rpm 60,000 max. Inertia .07 x10^{-4}oz-in-sec^2. -20°C to 100°C.



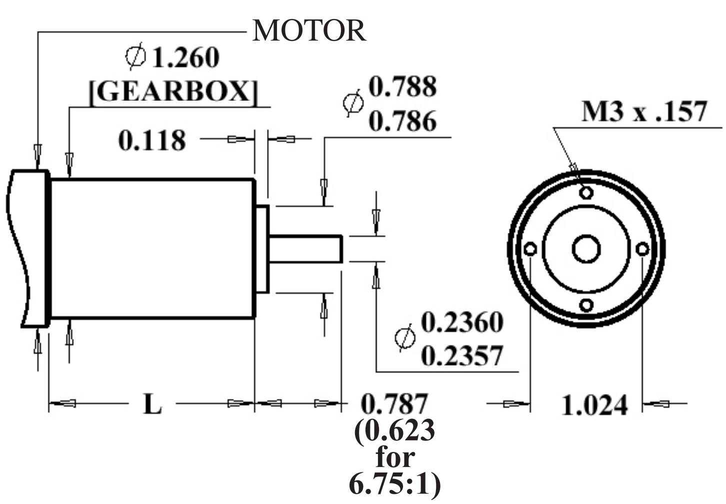
Planetary Gearheads

Construction is planetary with nitrided 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 1.1" (28mm) motors

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

Weight 6.75:1=5.6 oz, 45.56:1=7.4 oz
307.54:1=9.3 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 nitrided alloy steel.
Output is dual sheilded ball bearings.



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

Unit conversions

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

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 28mm 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%.

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 10,000 rpm. 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.

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. The winding resistance at 150°C is 1.51 x the 20°C value.

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).