

- 24V windings
- Sensorless
- Up to 200,000 rpm
- Maximum continuous power to 60 watts

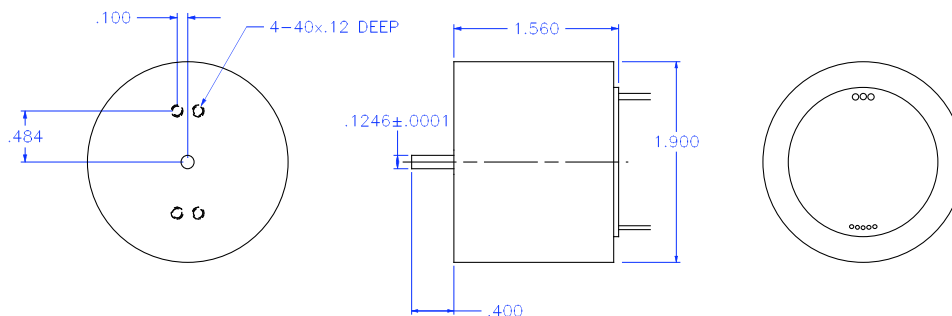
Slotless design is cog free, and provides high efficiency, with cool and quiet operation at high speed. High speed ceramic hybrid bearings for longest life. Continuous operation up to 200,000 rpm when motor is mounted to a thick aluminum mounting bracket or fan or water cooled. The V (vacuum compatible option) is constructed using all non outgassing materials suitable for vacuum use. Water or refrigerant cooling is required for continuous vacuum operation since there is no cooling by ambient air. A winding temperature sensor is available. The motor features a hardened stainless shaft, Teflon insulated lead wires, 240°C magnet wire, precision balance, anodized machined aluminum housing. Special modifications are possible such as hollow shafts, custom shaft lengths, and custom windings. For 8333 and 6785 use S24V5A-4G drive, for 3392 use S24V5A-4F drive.



### Motor Data

| Winding                                |   | 8333    | 6785    | 3392    | 5284    |
|--|---|---------|---------|---------|---------|
| Nominal supply voltage                 | volts                                   | 24      | 24      | 24      | 24      |
| no load speed                          | rpm ±12%                                | 200,000 | 162,841 | 81,408  | 126,818 |
| speed/torque slope                     | rpm/oz-in                               | 26,650  | 22,600  | 13,723  | 18,162  |
| Continuous torque case 20°C/no h.s.*   | oz-in                                   | .5/0    | .94/.54 | 1.2/.75 | 1.2/.43 |
| Continuous current case 20°C/no h.s.*  | amps                                    | 3.5/0   | 5.0/3.0 | 3.1/2.0 | 4.9/2.8 |
| Maximum cont. power case 20°C/no h.s.* | watts                                   | 68/0    | 98/60   | 57/39   | 93/37   |
| Motor constant Km                      | oz-in/√w                                | .30     | .32     | .33     | .33     |
| Winding resistance not including leads | ohm±15%                                 | .30     | .37     | 1.5     | .62     |
| Torque at 5 amps                       | oz-in                                   | .7      | .9      | 2.0     | 1.2     |
| No load current                        | amp±50%                                 | .40     | .29     | .10     | .21     |
| Damping factor                         | oz-in/krpm                              | .00026  | .00028  | .00032  | .00032  |
| Static friction                        | oz-in                                   | .012    | .012    | .012    | .012    |
| Velocity constant                      | rpm/volt                                | 8,333   | 6,785   | 3,392   | 5284    |
| Torque constant Kt                     | oz-in/amp                               | .162    | .199    | .398    | .255    |
| Maximum efficiency                     | %                                       | 86      | 87      | 85      | 86      |
| Winding inductance                     | mH                                      | .011    | .017    | .068    | .027    |
| Rotor inertia                          | 10 <sup>-4</sup> oz-in-sec <sup>2</sup> | .111    | .111    | .111    | .111    |
| Thermal res. winding to case           | °C/W                                    | 5.2     | 5.2     | 5.2     | 5.2     |
| Thermal case to ambient                | °C/W                                    | 4.3     | 4.3     | 4.3     | 4.3     |

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



| Leads |         |
|-------|---------|
| Blue  | Phase A |
| White | Phase B |
| Brown | Phase C |

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

**Example:** Part Number 48 S 8333 T

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

**24V winding**

**• 40,332 rpm**

**•Maximum continuous power 31 watts**

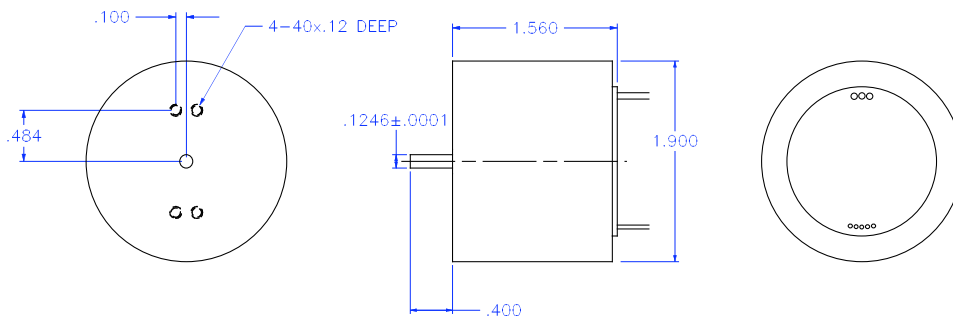
Slotless design is cog free, provides high efficiency, and cool quiet operation at high speed. Stainless ball bearings with high performance lube are standard. Available with 120° hall sensors or sensorless. Hall sensors recommended for positioning or where a large inertial load is attached to the shaft.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



### Motor Data

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

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



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

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**Example:** Part Number 48 H 1680 A / A5

Motor dia. \_\_\_\_\_  
 Type S=sensorless H=120°halls \_\_\_\_\_  
 Winding number \_\_\_\_\_

Encoder A5=500lines(2,000 count)  
 Modifications A=none, V=Vacuum compatible,  
 T=Thermistor (sensorless only), H=.040" bore hollow shaft

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

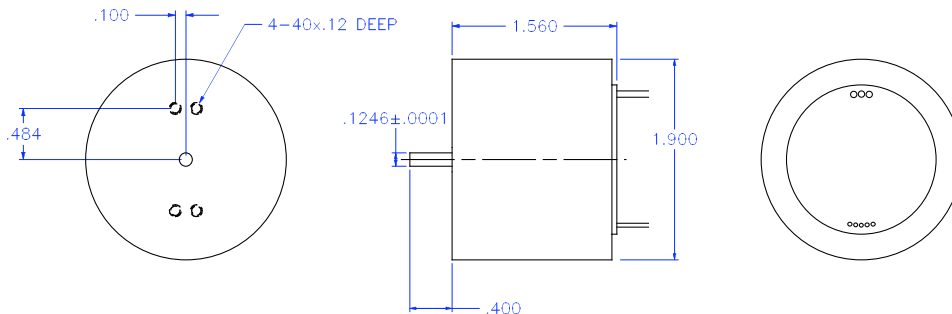
Slotless design is cog free, and provides high efficiency, with cool and quiet operation at high speed. High speed ceramic hybrid bearings for longest life. Continuous operation up to 151,200 rpm when motor is mounted to a thick aluminum mounting bracket or fan or water cooled. The V (vacuum compatible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



### Motor Data

| Winding                                |   | 12600   | 7566    |
|--|---|---------|---------|
| Nominal supply voltage                 | volts                                   | 12      | 12      |
| no load speed                          | rpm ±12%                                | 151,200 | 90,792  |
| speed/torque slope                     | rpm/oz-in                               | 21,372  | 14,746  |
| Continuous torque case 20°C/no h.s.*   | oz-in                                   | 1.0/.53 | 1.1/.74 |
| Continuous current case 20°C/no h.s.*  | amps                                    | 10/5.5  | 6.6/4.3 |
| Maximum cont. power case 20°C/no h.s.* | watts                                   | 95/54   | 60/43   |
| Motor constant Km                      | oz-in/√w                                | .30     | .31     |
| Winding resistance not including leads | ohm±15%                                 | .13     | .32     |
| Torque at 5 amps                       | oz-in                                   | .48     | .85     |
| No load current                        | amp±50%                                 | .51     | .23     |
| Damping factor                         | oz-in/krpm                              | .00028  | .00032  |
| Static friction                        | oz-in                                   | .012    | .012    |
| Velocity constant                      | rpm/volt                                | 12,600  | 7,566   |
| Torque constant Kt                     | oz-in/amp                               | .107    | .178    |
| Maximum efficiency                     | %                                       | 86      | 85      |
| Winding inductance                     | mH                                      | .005    | .014    |
| Rotor inertia                          | 10 <sup>-4</sup> oz-in-sec <sup>2</sup> | .111    | .111    |
| Thermal res. winding to case           | °C/W                                    | 5.2     | 5.2     |
| Thermal case to ambient                | °C/W                                    | 4.3     | 4.3     |

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



| Leads |         |
|-------|---------|
| Blue  | Phase A |
| White | Phase B |
| Brown | Phase C |

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**Example:** Part Number 48 S 2575 T

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

**12V winding**

**• 40,692 rpm**

**• Maximum continuous power 31 watts**

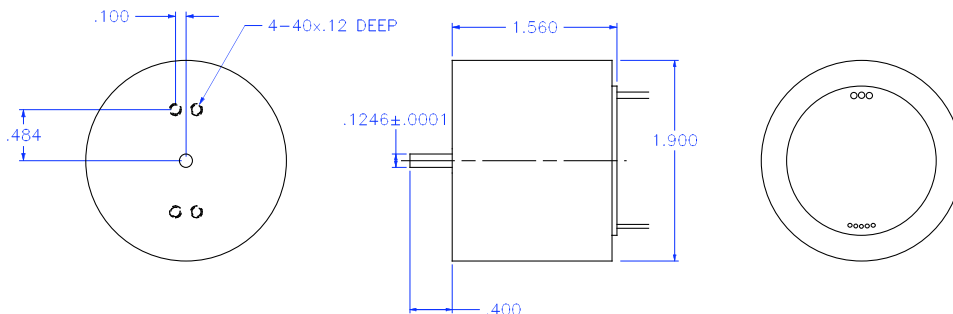
Slotless design is cog free, provides high efficiency, and cool quiet operation at high speed. Stainless ball bearings with high performance lube are standard. Available with 120° hall sensors or sensorless. Hall sensors recommended for positioning or where a large inertial load is attached to the shaft.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



### Motor Data

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

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



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

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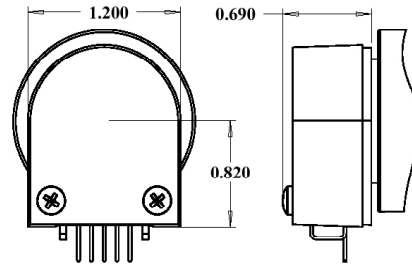
**Example:** Part Number 48 H 3391 A / A5

Motor dia. \_\_\_\_\_  
 Type S=sensorless H=120°halls \_\_\_\_\_  
 Winding number \_\_\_\_\_

Encoder A5=500lines(2,000 count)  
 Modifications A=none, V=Vacuum compatible  
 T=Thermistor (sensorless only)

# Optical Encoders

Mating connector AMP103977-4. Supply voltage  $5 \pm .5V$ .  
Rpm 50,000 max. Weight .5 oz, inertia  $.08 \times 10^{-4}$ oz-in-  
sec<sup>2</sup>



### Unit conversions

$^{\circ}\text{F} - 32 \div 1.8 = ^{\circ}\text{C}$  example:  $212^{\circ}\text{F} = 100^{\circ}\text{C}$ ,  $^{\circ}\text{C} \times 1.8 + 32 = ^{\circ}\text{F}$  example:  $100^{\circ}\text{C} = 212^{\circ}\text{F}$ ,  $\text{in} \times 25.40 = \text{mm}$ ,  
 $\text{mm} \times 0.03937 = \text{in.}$ ,  $\text{oz} \times 28.3495 = \text{g}$ ,  $\text{oz-in} \times 7.06 = \text{mNm}$ ,  $\text{mNm} \times .142 = \text{oz-in}$ ,  $\text{Nm} \times .142 = \text{oz-in}$ ,  
 $\text{Ncm} \times 1.42 = \text{oz-in}$ ,  $\text{rpm} \times .1047 = \text{rad s}^{-1}$ ,  $\text{V/R/S} \times .1047 = \text{volts/rpm}$ ,  $746 \text{ watts} = 1\text{hp}$ ,  $\text{lb-in}^2 \times$   
 $.04144 = \text{oz-in-sec}^2$

### Understanding Data Sheets

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

### Hall Sensors

The parameters shown are for sensorless commutation. For operation up to around 60,000 rpm the performance of the hall sensor motor will match that of the sensorless motor (except for increased drive power consumption due to the halls). Above 60,000 rpm the current consumption of hall motors rapidly increases, and hall motors should be avoided if possible. Hall sensors are necessary if very fast start up (less then 1-2 seconds to full speed) a speed range wider then 2 or 3 to one, or operation at speeds near zero or holding position at zero rpm are required. Like other semiconductor components hall sensors are electrostatic sensitive. Hall motors are supplied in electrostatic safe packaging and should be kept in the packaging until use. When trimming wire length, adding connectors, and hooking up motors, workers should be grounded to prevent electrostatic damage to the sensors.

### Balancing

Components attached to the motor shaft should be dynamically balanced to G6.3 or better and located as close to the motor body as possible. G6.3 is equal to  $0.64 \times \text{weight (oz.)}/\text{rpm} = \text{unbalance in milli oz-in}$ . If the components have appreciable length they must be balance in 2 planes. Parts mounted to the motor shaft should not extend past the end of the motor shaft.

### Motor technology

The Koford 48HS brushless series of motors are high speed slotless sintered rare earth permanent magnet motors with unique technology. Compared to other brushless motors they have higher speed capabilities, better efficiency, lighter weight and more durable construction (ML Class 220C wire insulation bonded with 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 voltage lower then the specified voltage. Motors must not be operated over the maximum speed listed. To obtain speeds over 100,000 rpm the S18V15A drive must be used. Hall drives are not recommended for speeds over 60,000 rpm.

### Motor selection

Hall sensor motor can start large inertial loads. For this reason they are most suitable for applications such as beam choppers providing that a speed above 60,000 rpm is not required. If higher speeds are required then a sensorless motor must be used with the S18V15A drive. This drive requires operation from a variable voltage power supply with a current limit of 15 amps or less. For most applications a 3 to 5 amps supply will be suitable. These power supplies are readily available for electronics distributors.

### 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  $14,000 - (5 \times 800) = 10,000$  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. The 20°C continuous torque values listed are based on the motor housing being held to 20°C by such means as a refrigerated cooling jacket clamped to the OD of the motor. If the ambient temperature is above 20°C then the continuous duty torque is reduced.

### **Vacuum Applications**

Standard motors are suitable for low vacuum applications. For high vacuum applications use (option V). Vacuum grade motors are made with low outgassing material and baked before shipping. A vacuum bake by the customer immediately prior to use may be desirable to reduce initial pump down time. An important consideration is that in a vacuum there is no heat removal by air contacting the motor housing. Therefore 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. A liquid cooling jacket with a heat exchanger can also be used for the ultimate performance.

### **Motor hook up**

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

### **EMI**

Koford drives and motors have low levels of emi relative to other motors but in sensitive applications the following steps are suggested. First keep the phase wires as short as physically possible and twist or braid them together and if necessary add a shield jacket terminated at one end. An off the shelf EMI filter rated for the drive current (5 amps) connected between the power source and the drive will reduce conducted emissions. Mounting the drive inside of a metal enclosure and using shielded cable and connectors will reduce radiated emissions.

### **PWM basics**

Variable speed drives operate using PWM where the voltage to the motor is rapidly turned on and off. This is the same as a switching power supply where the motor is the filter. A PWM drive operates like a transformer, for example if the motor pulls 20 amps at 12 volts and the input to the drive is 36 volts then the input current to the drive will be  $12/36 \times 20$  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). The S18V15A drive does not use PWM so this is not applicable. With this drive the motor current will be the same as the power supply current.



## Thermistor resistance for Koford motors

| Temp<br>[degree<br>C] | Temp<br>[degree F] | Rt/R25 | Temp Coef<br>[%/C] | Resistance<br>[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                  |