

GreenDrive™ Manual



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Emerson Motor Technologies GreenDrive™ Manual

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SAFETY INFORMATION

Safety Precautions

This product is intended for professional incorporation into a complete system by qualified persons. If you install the product incorrectly, it may present a safety hazard. The product and system may use high voltages and currents, carry a high level of stored electrical energy, or are used to control mechanical equipment that can cause injury. You must give close attention to the electrical installation and system design to avoid hazards either in normal operation or in the event of equipment malfunction. System design, installation, commissioning, and maintenance must be carried out by personnel who have the necessary training and experience. Read and follow this safety information and this instruction manual carefully.

Qualified Person

For the purpose of this manual and product, a "qualified person" is one who is familiar with the installation, construction and operation of the equipment and the hazards involved. In addition, this individual has the following qualifications:

- Is trained and authorized to energize, de-energize, clear and ground and tag circuits and equipment in accordance with established safety practices.
- Is trained in the proper care and use of protective equipment in accordance with established safety practices.
- Is trained in rendering first aid.

Setup, Commissioning and Maintenance

It is essential that you give careful consideration to changes to control settings. Depending on the application, a change could have an impact on safety. You must take appropriate precautions against inadvertent changes or tampering. Restoring default parameters in certain applications may cause unpredictable or hazardous operation.

Safety of Machinery

All machinery in which this product is used must comply with all federal, state, and local safety standards. The level of integrity offered by the product's control function - for example stop/start, forward/reverse and maximum speed is not sufficient for use in safety-critical

applications without additional independent channels of protection. All applications where malfunction could cause injury or loss of life must be subject to a risk assessment, and further protection provided where needed.

Identification of Safety Information

Safety related information throughout this manual is identified with the following markings:

⚠ WARNING

"Warning" indicates a potentially hazardous situation that, if not avoided, could result in death or serious injury.

⚠ CAUTION

"Caution" indicates a potentially hazardous situation that, if not avoided, may result in minor or moderate injury.

CAUTION

"Caution" used without the safety alert symbol indicates a potentially hazardous situation that, if not avoided, may result in property damage.

NOTE

For the purpose of this manual and product, "Note" indicates essential information about the product or the respective part of the manual.

⚠ WARNING

Failure to follow safe installation guidelines can cause death or serious injury. The voltages used in motion control systems can cause severe electric shock and/or burns, and could be lethal. Extreme care is necessary at all times when working with or adjacent to this equipment. The installation must comply with all relevant safety legislation in the country of use.

NOTE

Fuses

Fuses or over-current protection must be provided in accordance with the National Electrical Code and any additional local codes.

NOTE

Users must determine the suitability of the control for their application, including the level of reliability required, and are solely responsible for the function of the end-use product. These controls contain exposed electrical components and are not intended to withstand exposure to water or other environmental contaminants which can compromise insulating components. Such exposure may result in insulation breakdown and accompanying localized electrical heating. A control may remain permanently closed or open as a result of exposure to excessive mechanical, electrical, thermal or environmental conditions or at normal end-of-life. If failure of the control to operate could result in personal injury or property damage, the user should incorporate supplemental system control features to achieve the desired level of reliability and safety. For example, backup controls have been incorporated in a number of applications for this reason.

INTRODUCTION

Thank you for selecting the GreenDrive™ control. This manual contains all basic and necessary information concerning the GreenDrive™ control.

If you require any additional information, please contact Emerson Motor Technologies/Hurst Division at 812-385-2564 or hurst@emerson.com.

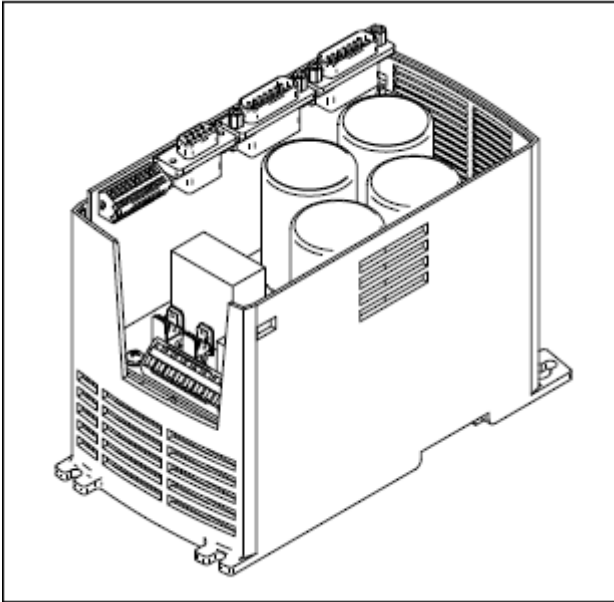
Features

- Wide range of input voltage
- BLDC or Induction motor types
- 6 communications options
- Manual operation as standard on all drives
- Small footprint
- All members of family in same small footprint*
- Easily Configurable
- Multiple encoder options
- Dedicated connections
- Onboard expansion port for future proofing.
- PC based Software Interface Tool for parameter changing

* An additional fan may be required for the larger version of this drive.

Product Description

The Greendrive is designed to be a out of the box solution which gets you up and running in minimal time. Greendrive is not just one drive but is to be a family of three drives, ranging in power from 700Watts to 2.5KW. With a wide variety of communications packages, there is bound to be one that suits most requirements, no matter how demanding.



Greendrive with cover removed.

Getting Started

Connecting Your Greendrive

There are a number of connections that are required in order for you to be able to operate your new Greendrive.

The number of these required will depend upon the requirements you specified when you ordered your drive. Please refer to the required sections for your drive.

All Drives

Mains input

The 700 watt and 1100 watt drives are capable of being powered from either 110volts a.c or 230volts a.c. The voltage setting link is usually fitted in the factory.

The 2500 watt drive is only capable of being operated from a 230volts a.c.supply.

All supplies are rated for 50 or 60 hertz.

*****PLEASE ENSURE MAINS SUPPLY IS DISCONNECTED BEFORE CONTINUING*****

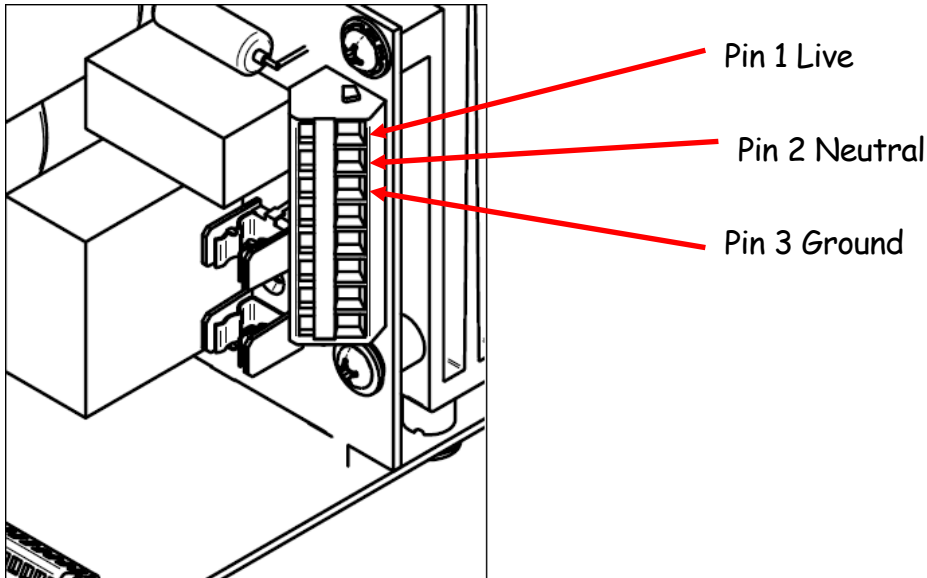


Figure 1

Using a small screwdriver (if the correct tool is not available) depress the tab in the slot above the terminal required. This opens the terminal. Insert the wire and remove the screwdriver, the wire should be held secure by the clamping force of the connector.



Depress the tab by inserting a small screwdriver

Figure 2

Motor Connections

Using the same method as above to connect the four motor power cables.
(3 phases and Ground)

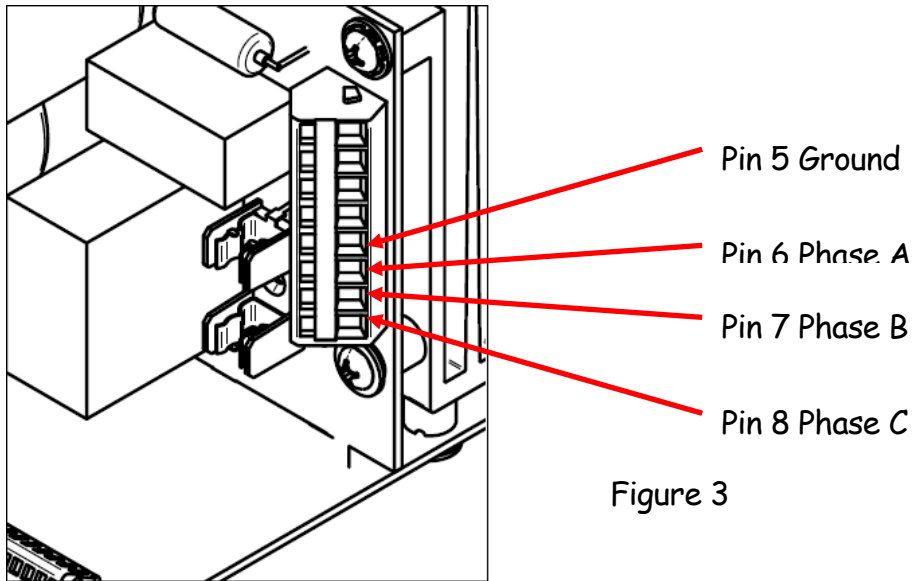


Figure 3

Control Options (Dependant on Options ordered)

1, Basic Control

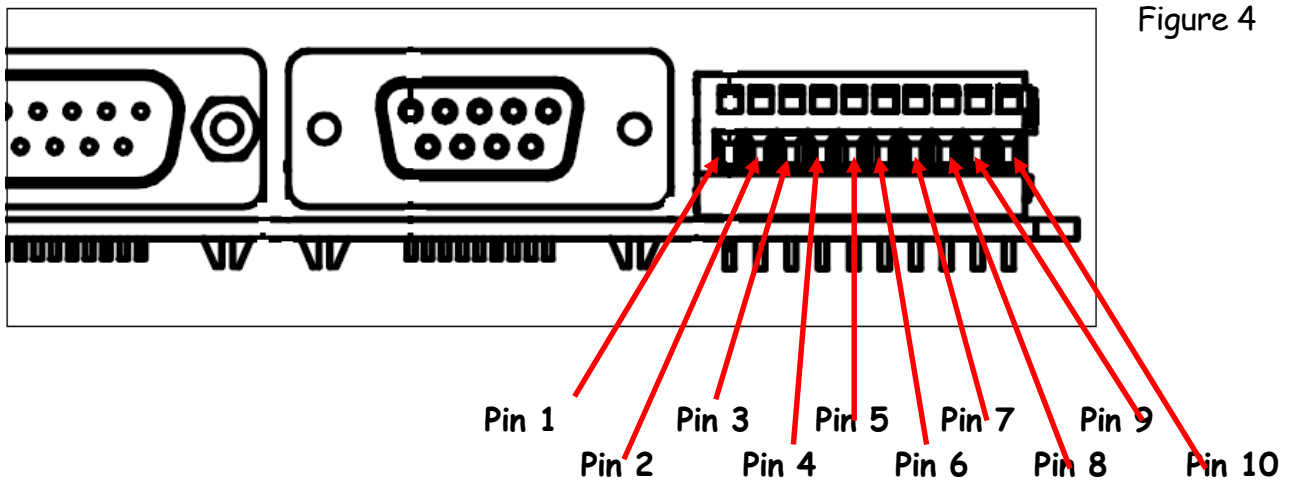


Figure 4

Use a small screwdriver (or the correct tool if provided) depress the tab and insert the wire into the hole. Remove the tool and check the clamp is holding the wire securely.

Pin 1 Chassis Ground

Connect any cable screen or ground wire for the controller box.

Pin 2 Analog Input

The drive will accept a 0 to +5Vdc command, or a + or- 10Vdc command or a 0 to +10Vdc command. The method will have been pre configured prior to buying the unit. (Configuration is by changing values of internal components)

The supply of the dc voltage (+5, +10 or +/-10) for the control is the responsibility of the customer.

It may be derived by regulating down the +15V supplied from the drive on Pin X.

Connect a potentiometer. The larger the Ohmic value the better across the supply volts and 0 Volts. Connect the wiper to Pin 2.

As the potentiometer is wound up the motor speed will increase, from stop to full speed.

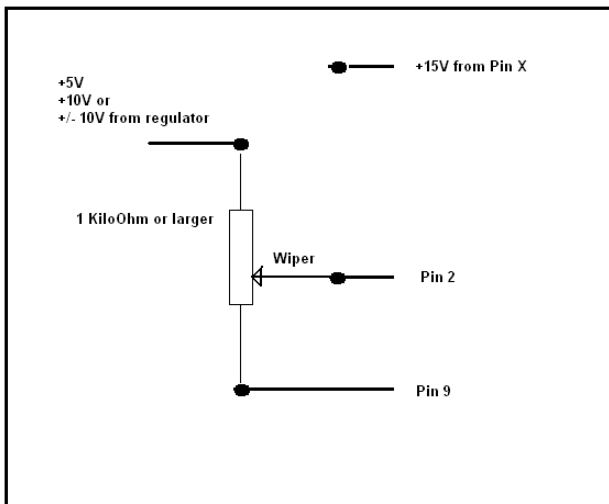


Figure 5

Pin 3 Stop/Go

The stop go control is just a simple switch which connects the OV_An to Pin 3.

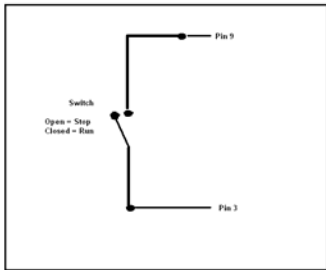


Figure 6

Pin 4 Direction

The stop go control is just a simple switch which connects the OV_An to Pin 4.

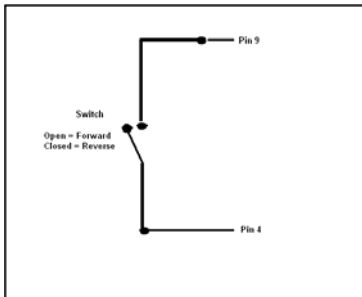


Figure 7

Pin 5 PWM Demand

The PWM (Pulse Width Modulation) can be used instead of the analog potentiometer and direction switch method. The input is set for an open collector type output from the PWM source.

The duty cycle of 0 to 100% is set so that from 45% to 0% the speed increases in a reverse direction.

From 45% to 55% the motor drive is at stop. (No demand)

From 55% to 100% the motor speed increases in a forward direction.

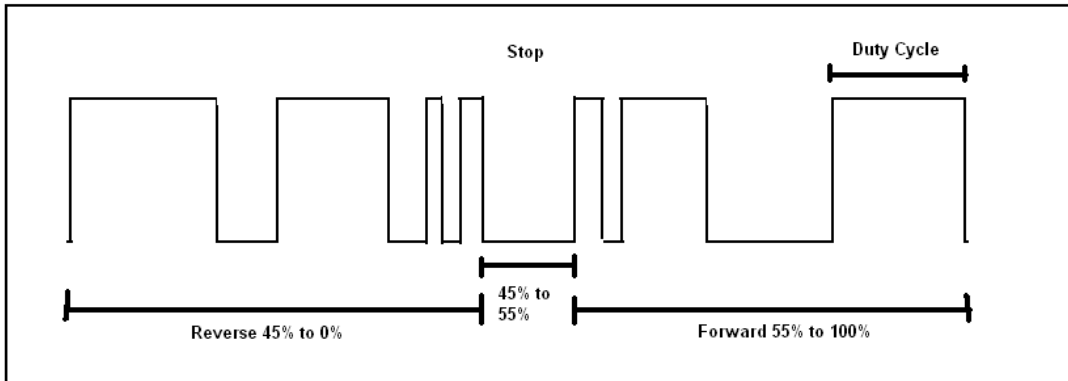


Figure 8

Pin 6 Fault LED

The Fault LED is for a customer visual indicator. This is a user fitted option.

The current for this indicator must not exceed 20mA. Excessive current will damage the circuitry in the drive.

Connect the indicator between the +15V supply (Pin X) and Pin 6 observing polarity.

When the drive is at stop the indicator will be solid, and go out when running.

In the event of a fault the indicator will flash in a sequence.

These fault codes are referenced in the troubleshooting table at the end of this guide.

Pin 7 Ready LED

The Ready LED is for a customer visual indicator. This is a user fitted option.

The current for this indicator must not exceed 20mA. Excessive current will damage the circuitry in the drive.

Connect the indicator between the +15V supply (Pin X) and Pin 7 observing polarity.

This indicates that the drive is receiving mains power.

Pin 8 Tachometer (For Customer Use)

The Tachometer output is a pulse train derived from the Phase A hall sensor. (If Fitted) The speed is equal to the number of electrical revolutions per mechanical revolution of the motor.

If a different population has been requested then the pulse train will be from the onboard micro controller.

The amplitude of the pulse train is 0 to +5V dc.

If the hall sensors are not fitted then provision will be made for the drive to output a tacho signal created by the processor.

Pin 9 0Volts Analog

The return point for analog voltages

Pin 10 0 Volts

The return point for digital voltages

Motor Feedback Signals

Hall Sensors and Thermistors

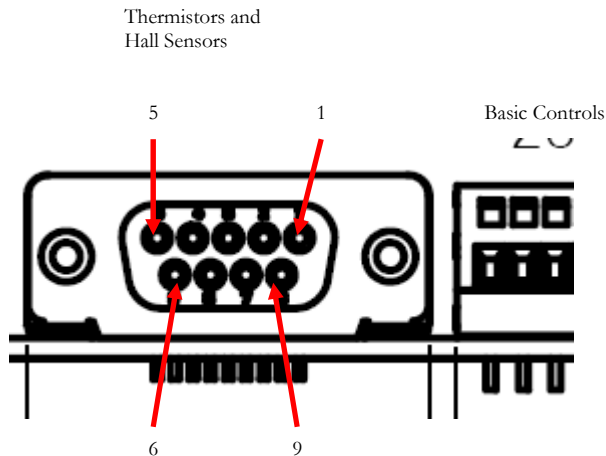


Figure 9

Pin 1

Chassis ground for screen cable connection

Pin 2

Hall sensor A input to drive

Pin 3

Hall sensor B input to drive

Pin 4

Hall sensor C input to drive

Pin 5

Analog Ground

Pin 6

Hall sensor supply +5 or +10 Vdc

Pin 7

Thermistor input 1 connection for NTC thermistor.
Ensure LK2 is not fitted if NTC is to be used

Pin 8

Thermistor input 2 common point for either NTC or PTC

Pin 9

Thermistor input 3 connection for PTC thermistor
Ensure LK3 is not fitted if PTC is to be used

Encoder and Thermistors

Encoder and Thermistors

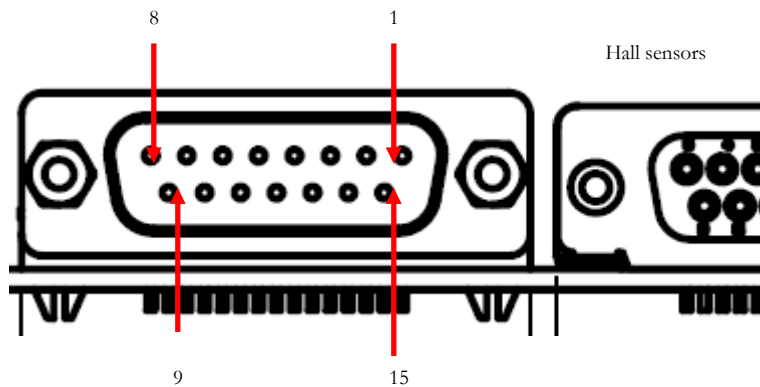


Figure 10

Pin 1

Chassis ground for screen cable connection

Pin 2

Thermistor input 1 connection for NTC thermistor.
Ensure LK2 is not fitted if NTC is to be used

Pin 3

Thermistor input 2 common point for either NTC or PTC

Pin 4

Thermistor input 3 connection for PTC thermistor
Ensure LK3 is not fitted if PTC is to be used

Pin 5
Encoder Index 1 input

Pin 6
Encoder Index 2 input

Pin 7
Encoder Strobe 1 input

Pin 8
Encoder Strobe 2 input

Pin 9
Encoder sensor supply +5 or +10 Vdc

Pin 10
Not Connected

Pin 11
Analog Ground

Pin 12
Encoder A1

Pin 13
Encoder A2

Pin 14
Encoder B1

Pin 15
Encoder B2

Communications Options

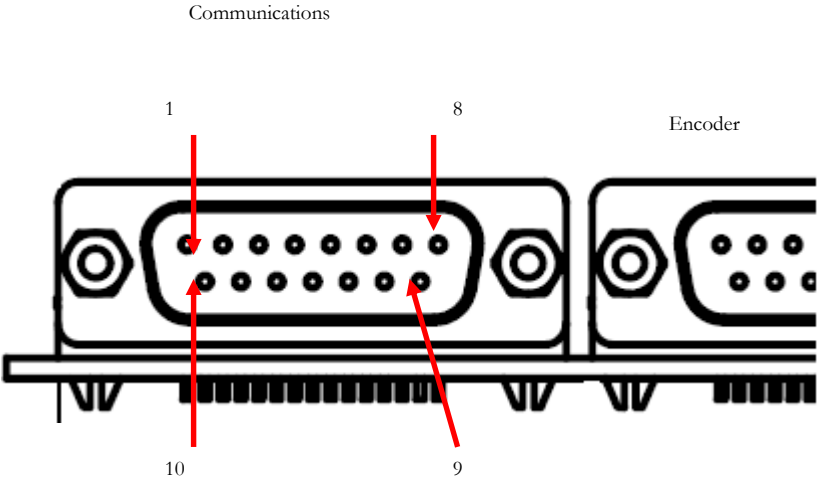


Figure 11

Pin 1
Not Connected

Pin 2
RS232 Transmit

Pin 3
RS 232 Receive

Pin 4
RS 485 Hi

Pin 5
RS485 Lo

Pin 6
CAN Hi

Pin 7
CAN Lo

Pin 8
Not Connected

Pin 9
I²C SCLA

Pin 10
I²C SDAA

Pin 11
SPISIMO

Pin 12
SPISTE

Pin 13
SPISOMI

Pin 14
SPICLK

Pin 15
User Ground or digital ground for referencing digital signals

Driving Instructions

Manual Operation with a potentiometer.

- 1, Ensure the correct supply for your drive is connected but not turned on.
- 2, Check the motor is connected
- 3, Check that the NTC and PTC connections are made to either the Encoder or Hall sensor connector. Ensure the unused sensor is linked out (see above)
- 4, Check potentiometer is connected and set to zero
- 5, Set direction switch to required direction.
- 6, Check Run/Stop switch is connected and at stop
- 7, Ensure it is safe to spin the motor.
- 8, Switch on the mains supply.
- 9, Observe the Green LED Ready light is illuminated.
- 10, Observe the fault LED is flashing.
- 11, Move the Stop/Go switch to the Go position
- 12, Adjust the potentiometer and observe the motor spins, and its speed increases as the potentiometer is wound up.
Likewise if you wind it down speed decreases. (note this may be a slower action than wind up due to inertia in the rotor and load)
- 13, Observe the Fault LED does not illuminate.
- 14, To stop the motor simply move the Stop/Go switch to stop.

Note:

- (a) It is not necessary to wind the speed pot back to zero before stopping. However if the load cannot accept a fast start it would be better to do so.
- (b) Direction as set by the direction switch should not be changed unless the motor is stationary.

Operation with PWM Demands

- 1, Follow steps 1 to 3 above
- 2, Check PWM input is connected
- 3, Check Run/Stop switch is connected and at stop
- 4, Follow steps 7 to 10 above
- 5, Send a PWM signal to the drive. Note that the speed and direction are set by the duty cycle.

45% to 0% duty cycle = Reverse stop to full speed.
45% to 55% duty cycle = Stop
55% to 100% duty cycle = Forward stop to full speed.

6, To stop the motor send a duty cycle of 50%.

Serial Communications Operations

Operation from CAN

It would be possible to have customer chosen identifiers for specific operations programmed into the software. The drive is usually shipped with a pre defined configuration of CAN messages and identifiers to enable quick start operation

Operation from SPI

On this SPI bus the drive is a Slave.

The drive is usually shipped with a pre defined configuration of SPI messages and identifiers to enable quick start operation.

It would be possible to have customised identifiers and messages

Operation from I²C

The drive is usually shipped with a pre defined configuration of I²C messages and identifiers to enable quick start operation.

It would be possible to have customised identifiers and messages

Operation from RS232

The drive is usually shipped with a pre defined configuration of RS232 messages and identifiers to enable quick start operation.

It would be possible to have customised identifiers and messages

Operation from RS485

The drive is usually shipped with a pre defined configuration of RS485 messages and identifiers to enable quick start operation.

It would be possible to have customised identifiers and messages

Replacing Factory installed software

It is possible for the software installed at time of manufacture to be replaced in the field, by an engineer or by the customer using a supplied software interface tool.

The Software interface tool, would allow the customer to change or set certain parameters in the operating software, and then upload them into the EEPROM within the drive.

The Software Interface Tool is a option and is currently still being developed.(Aug 08)

To install the updated software

The drive can be boot loaded from the Software interface tool by using the Texas Instruments Boot Loader.

With the drive in a safe state and power removed, remove the plastic lid of the drive.

Place Jumper LK4 in place.

Connect the RS232 serial communications leads and have the software interface tool ready to transmit information to the drive.

Power up the drive, and observe that the green light is on.

Operation of the Red LED is not meaningful.

The drive is now in a state where it is waiting for instructions from the Software interface tool.

Transmit the new data to the drive.

When transmit is complete Verify the data.

Power down the drive

Remove the RS232 cable from the Software Interface Tools, and refit correct cables as required.

Remove LK4 jumper

Replace the drive plastic lid.

Power up the drive and verify new operating parameters.

THERMAL PROTECTION

CHOOSING A POWER SUPPLY

There are two important parameters to consider when choosing a power supply in your application, voltage and current.

Motor Power Supply

- **Voltage Input Range: 12 to 45 Vdc**

Refer to your motor label for rated voltage. The integrated motor control is intended to be operated from a low voltage DC power supply rated between **12 to 45 Vdc**. The maximum voltage of the GreenDrive™ is 45 Vdc, therefore do not exceed this voltage. Filter capacitors are supplied internal to the GreenDrive™ control for increased reliability under typical power conditions. It is recommended that the power supply meet the latest editions of UL60950 and CSA 60950 specifications.

- **Current Input Range: 3x Rated Motor Current**

The maximum or rated power supply current needed should be at least three times the rated motor current to ensure adequate overhead for intermittent motor overloading.

Connecting inputs and outputs

Motor Power Supply Connections

⚠ CAUTION

Never connect or disconnect the power supply to a motor or control while the power is turned on.

NOTE

All wire gauge sizes must be in accordance with all federal, state, and local codes.

Inputs

Speed/Torque

The Speed/Torque input can be used in Open Loop Speed, Closed Loop Speed, or Torque Operating Modes. The Speed/Torque input operates in Analog Control Method where the voltage applied relates to a current level in the motor. The Speed/Torque input can have a 0-5 Vdc input or a potentiometer in conjunction with optional integrated power supply. The 0-5 Vdc input consists of a variable command input and a GND input. The potentiometer consists of three pins, a 5-volt input, a GND input and a variable command output. The user can adjust the command output by adjusting the potentiometer with the wiper connected to the command input and the other two potentiometer connections attached to the +5 Vdc and GND pins of the connector pins. The impedance of the 0-5V input is 20K Ω .

NOTE

Care must be taken by the user not to exceed the 0-5 volt range of the variable command input. Voltages outside this range could cause permanent damage to the control.

PWM

The PWM input can be used in Open Loop Speed and Closed Loop Speed Operating Modes. The PWM input operates in PWM Control method, where the PWM command is from 0 to 100%; 0% being no current applied to the windings and 100% full current applied to the windings. The frequency of the PWM signal in the PWM control method operates between 15 kHz and 25 kHz.

Direction/PWM & Direction

The Direction input can be used in Open Loop Speed, Closed Loop Speed, Preset Speed, or Torque Operating Modes. The Direction input operates in Analog and PWM Control Methods where the input level determines the direction of the motor. The input will be used in conjunction with PWM (Pin 3) and Speed/Torque (Pin 2). A high level (5 Vdc) causes a clockwise direction (viewed from the lead end). A low level (0 Vdc) causes a counter-clockwise direction (viewed from the lead end). This line has an internal 1.5k Ω pull up resistor. The 1.5k Ω pull up resistor requires the pin to be driven by a circuit capable of sinking at least 3.5 mA.

The PWM & Direction input can be used in Open Loop Speed and Closed Loop Speed Operating Modes. The PWM & Direction input operates in PWM & Direction Control Method where 0% duty cycle maximum command in the counterclockwise direction (viewed from the lead end),

50% duty cycle minimum command (0 input), 100% duty cycle maximum command in the clockwise direction (viewed from the lead end). The frequency of the PWM signal in the PWM & Direction control method operates at 2.5kHz.

Enable

The Enable input is used in all control methods and operating modes. A low level (0 Vdc) on the Enable pin enables the control to start the selected Control Type. A high level (+5 Vdc) on the Enable input causes the GreenDrive® to stop controlling the motor, thus allowing the motor to coast. This line has an internal 1.8kΩ pull up resistor. The 1.8kΩ pull up resistor requires the pin to be driven by a circuit capable of sourcing at least 3.5 mA.

+5 Vdc

NOTE

In this section, pin 10 is described as an externally supplied input.

- **Voltage Input Range: 4.75 to 5.25 Vdc**
- **Current Input Range: minimum of 56 mA**

The +5 Vdc input provides power for internal electronics. The user supplied +5 Vdc input is critical to the performance of the motor control. Care and attention must be taken not to deviate away from voltage specifications to prevent potential harm to the motor control system.

Outputs

Tachometer

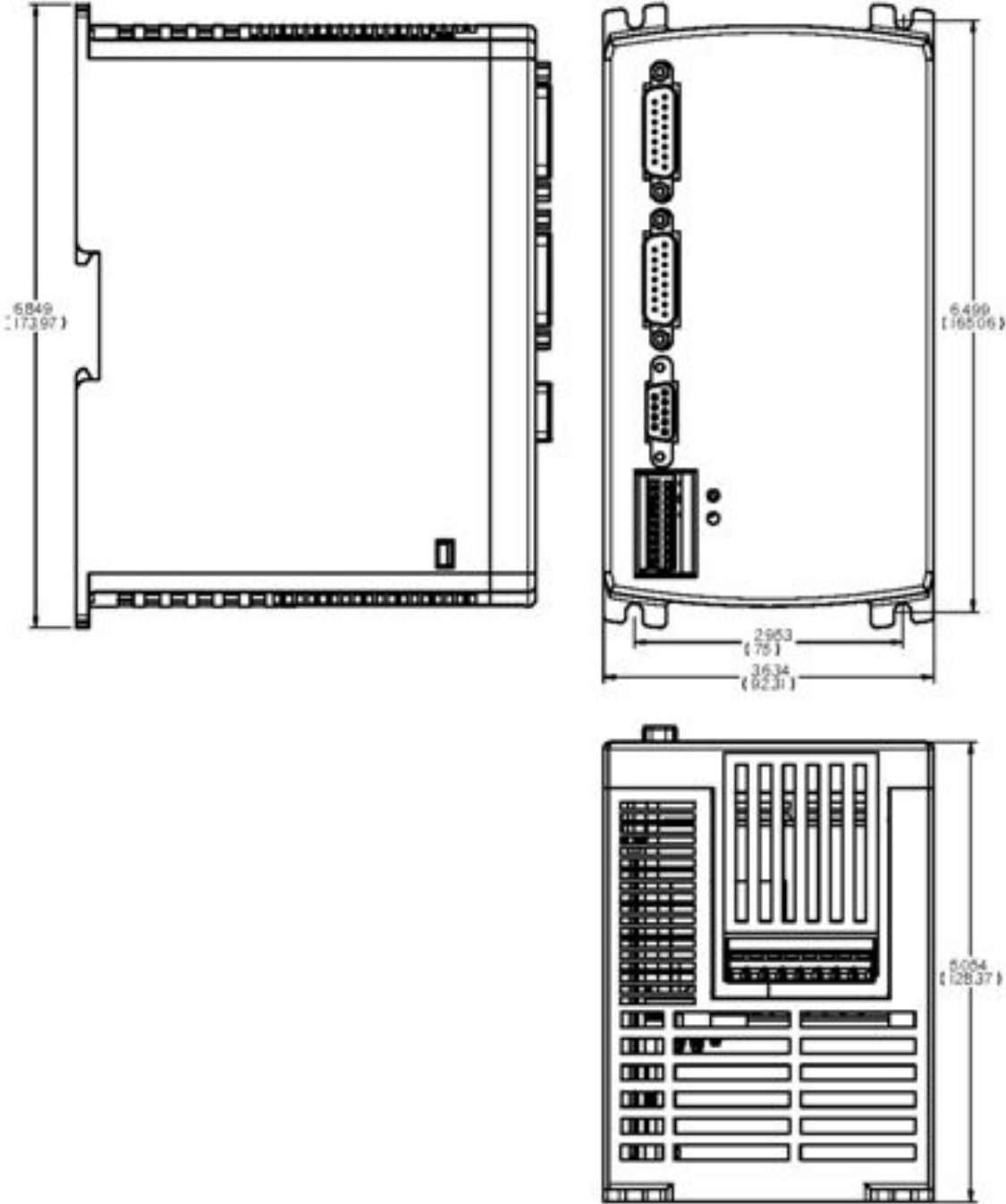
Tachometer outputs are generated from an internal controller by the three hall effect sensors.

CONTROL TYPES

The GreenDrive® can operate in one of four operating modes: Open Loop Speed, Closed Loop Speed, Pre-Set Speed, or Torque. The control method can come from three possible sources on the user control connector (Analog, PWM, or PWM & Direction). All control methods provide four-quadrant control for the brushless DC motor. The following describes each operating mode and possible control method:

MECHANICAL SPECIFICATIONS

Dimensional Outline Drawings



ENVIRONMENTAL SPECIFICATIONS

Pollution degree:	2 environment
Enclosure classification:	IP50
Operating Temperature Range:	0°C to +40°C (32°F to +104°F)
Storage Temperature Range	-40°C to +85°C (-40°F to 185°F)
Operating Humidity Range:	20% to 90%
Humidity:	10% to 95% - non-condensing
Vibration:	2g, 10 Hz to 2000 Hz

TYPICAL APPLICATIONS

- Adhesive Tester
- Antenna Positioning and Tuning Devices
- Automated Inspection Equipment
- Automatic Carton Marking & Dating Machines
- Automatic Food Processing Equipment
- Automatic I.V. Dispensing Equipment
- Baseball Pitching Machine
- Blood Agitators
- Blood Cell Analyzer
- Blood Cell Separators
- CD/DVD Buffing Machine
- Chart Recorders
- Coil Winding Machines Controls
- Commercial Feeding Systems
- Consumer Water Vending Machines
- Conveyor Systems
- Credit Card Manufacturing
- Dental Light (Remote Control)
- Diaphragm Pumps
- Digital Press Printer
- Digital Time and Temperature Displays
- Earthquake Detection Equipment
- EKG Chart Drives
- Elevator Door Opener
- Enteral Feeding Pumps
- Floor Surface Friction Coefficient Tester
- Fountain Lighting and Valve Controls
- Frozen Carbonated Beverage Machine
- Gas Blood Analyzers
- High Speed Computer Printers
- Indoor/ Outdoor Advertising Display & Signs
- Industrial Glue Dispensing Machines
- Industrial Grinding Equipment
- Label Printing
- Laboratory Pumps
- Laboratory Stirrers
- Mail Postage and Inserting Machine
- Massage Equipment
- Material Handling Cranes
- Mobile Watt-Hour Meter Reading for Residential Areas
- Motor Driven Laboratory Slide Trays
- Motor Driven Syringe
- Offset Printing Equipment
- Oil Skimmers
- Pellet Stove
- Planetarium Simulated Star and Planet Drives
- Radio & TV Tower Warning Light Flashers
- Railroad Signal Equipment
- Remote Focusing Microscopes
- Silicone Wafer Production Equipment
- Steel Mill Process Scanners
- Tape Cleaning Equipment
- Telescope Drives
- Tension Testing Machines
- Turntable Drives
- Ultrasonic Medical Diagnostic Equipment
- Vending Machines
- Water and Sewage Treatment Controls
- X-Ray Equipment
- XY Plotters

WARRANTY

EMERSON MOTOR COMPANY
DIVISION OF EMERSON ELECTRIC CO.
TERMS AND CONDITIONS OF SALE



Emerson Motor Company, division of Emerson Electric Co. is herein referred to as the "Seller" and the customer or person or entity purchasing goods ("Goods") from Seller is referred to as the "Buyer." These Terms and Conditions, any price list or schedule, quotation, acknowledgment or invoice from Seller relevant to the sale of the Goods and all documents incorporated by specific reference herein or therein, constitute the complete and exclusive statement of the terms of the agreement governing the sale of Goods by Seller to Buyer. Seller's acceptance of Buyer's purchase order is expressly conditional on Buyer's assent to all of Seller's terms and conditions of sale, including terms and conditions that are different from or additional to the terms and conditions of Buyer's purchase order. Buyer's acceptance of or payment for the Goods will manifest Buyer's assent to these Terms and Conditions. Seller reserves the right in its sole discretion to refuse orders.

1. PRICES: Unless otherwise specified in writing by Seller, the price quoted or specified by Seller for the Goods shall remain in effect for thirty (30) days after the date of Seller's quotation or acknowledgment of Buyer's order for the Goods, whichever occurs first, provided an unconditional authorization from Buyer for the shipment of the Goods is received and accepted by Seller within such time period. If such authorization is not received by Seller within such thirty (30) day period, Seller shall have the right to change the price for the Goods to Seller's price for the Goods at the time of shipment. All prices are exclusive of taxes, transportation and insurance, which are to be borne by Buyer.

2. TAXES: Any current or future tax or governmental charge (or increase in same) affecting Seller's costs of production, sale, or delivery or shipment, or which Seller is otherwise required to pay or collect in connection with the sale, purchase, delivery, storage, processing, use or consumption of Goods, shall be for Buyer's account and shall be added to the price or billed to Buyer separately, at Seller's election.

3. TERMS OF PAYMENT: Unless otherwise specified by Seller, terms are net thirty (30) days from date of Seller's invoice in U.S. currency. Seller shall have the right, among other remedies, either to terminate this agreement or to suspend further performance under this and/or other agreements with Buyer in the event Buyer fails to make any payment when due, which other agreements Buyer and Seller hereby amend accordingly. Buyer shall be liable for all expenses, including attorneys' fees, relating to the collection of past due amounts. If any payment owed to Seller is not paid when due, it shall bear interest, at a rate to be determined by Seller, which shall not exceed the maximum rate permitted by law, from the date on which it is due until it is paid. Should Buyer's financial responsibility become unsatisfactory to Seller, cash payments or security satisfactory to Seller may be required by Seller for future deliveries and for the Goods theretofore delivered. If such cash payment or security is not provided, in addition to Seller's other rights and remedies, Seller may discontinue deliveries.

4. SHIPMENT AND DELIVERY: While Seller will use all reasonable commercial efforts to maintain the delivery date(s) acknowledged or quoted by Seller, all shipping dates are approximate and not guaranteed. Seller reserves the right to make partial shipments. Seller, at its option, shall not be bound to tender delivery of any Goods for which Buyer has not provided shipping instructions and other required information. If the shipment of the Goods is postponed or delayed by Buyer for any reason, Buyer agrees to reimburse Seller for any and all storage costs and other additional expenses resulting therefrom. Risk of loss and legal title to the Goods shall transfer to Buyer for sales in which the end destination of the Goods is outside of the United States immediately after the Goods have passed beyond the territorial limits of the United States. For all other shipments, risk of loss for damage and responsibility shall pass from Seller to Buyer upon delivery to and receipt by carrier at Seller's shipping point. All shipments are F.O.B. Seller's shipping point. Any claims for shortages or damages suffered in transit are the responsibility of Buyer and shall be submitted by Buyer directly to the carrier. Shortages or damages must be identified and signed for at the time of delivery.

5. LIMITED WARRANTY: Subject to the limitations of Section 6, Seller warrants that the Goods manufactured by Seller will be free from defects in material and workmanship and meet Seller's published specifications at the time of shipment under normal use and regular service and maintenance for a period of one year from the date of shipment of the Goods by Seller, unless otherwise specified by Seller in writing. Products purchased by Seller from a third party for resale to Buyer ("Resale Products") shall carry only the warranty extended by the original manufacturer. THE WARRANTY SET FORTH IN THIS SECTION 5 AND THE WARRANTY SET FORTH IN SECTION 7, ARE THE SOLE AND EXCLUSIVE WARRANTIES GIVEN BY SELLER WITH RESPECT TO THE GOODS AND ARE IN LIEU OF AND EXCLUDE ALL OTHER WARRANTIES, EXPRESS OR IMPLIED, ARISING BY

OPERATION OF LAW OR OTHERWISE, INCLUDING WITHOUT LIMITATION, MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE WHETHER OR NOT THE PURPOSE OR USE HAS BEEN DISCLOSED TO SELLER IN SPECIFICATIONS, DRAWINGS OR OTHERWISE, AND WHETHER OR NOT SELLER'S PRODUCTS ARE SPECIFICALLY DESIGNED AND/OR MANUFACTURED BY SELLER FOR BUYER'S USE OR PURPOSE.

This warranty does not extend to any losses or damages due to misuse, accident, abuse, neglect, normal wear and tear, negligence (other than Seller's), unauthorized modification or alteration, use beyond rated capacity, unsuitable power sources or environmental conditions, improper installation, repair, handling, maintenance or application or any other cause not the fault of Seller. To the extent that Buyer or its agents has supplied specifications, information, representation of operating conditions or other data to Seller in the selection or design of the Goods and the preparation of Seller's quotation, and in the event that actual operating conditions or other conditions differ from those represented by Buyer, any warranties or other provisions contained herein which are affected by such conditions shall be null and void. If within thirty (30) days after Buyer's discovery of any warranty defects within the warranty period, Buyer notifies Seller thereof in writing, Seller shall, at its option and as Buyer's exclusive remedy, repair, correct or replace F.O.B. point of manufacture, or refund the purchase price for, that portion of the Goods found by Seller to be defective. Failure by Buyer to give such written notice within the applicable time period shall be deemed an absolute and unconditional waiver of Buyer's claim for such defects. Goods repaired or replaced during the warranty period shall be covered by the foregoing warranty for the remainder of the original warranty period or ninety (90) days from the date of shipment, whichever is longer. Buyer assumes all other responsibility for any loss, damage, or injury to persons or property arising out of, connected with, or resulting from the use of Goods, either alone or in combination with other products/components. Section 5 applies to any entity or person who may buy, acquire or use the Goods, including any entity or person who obtains the Goods from Buyer, and shall be bound by the limitations therein, including Section 6. Buyer agrees to provide such subsequent transferee conspicuous, written notice of the provisions of Sections 5 and 6.

6. LIMITATION OF REMEDY AND LIABILITY: THE SOLE AND EXCLUSIVE REMEDY FOR BREACH OF ANY WARRANTY HEREUNDER (OTHER THAN THE WARRANTY PROVIDED UNDER SECTION 7) SHALL BE LIMITED TO REPAIR, CORRECTION OR REPLACEMENT, OR REFUND OF THE PURCHASE PRICE UNDER SECTION 5. SELLER SHALL NOT BE LIABLE FOR DAMAGES CAUSED BY DELAY IN PERFORMANCE AND THE REMEDIES OF BUYER SET FORTH IN THIS AGREEMENT ARE EXCLUSIVE. IN NO EVENT, REGARDLESS OF THE FORM OF THE CLAIM OR CAUSE OF ACTION (WHETHER BASED IN CONTRACT, INFRINGEMENT, NEGLIGENCE, STRICT LIABILITY, OTHER TORT OR OTHERWISE), SHALL SELLER'S LIABILITY TO BUYER AND/OR ITS CUSTOMERS EXCEED THE PRICE PAID BY BUYER FOR THE SPECIFIC GOODS PROVIDED BY SELLER GIVING RISE TO THE CLAIM OR CAUSE OF ACTION. BUYER AGREES THAT IN NO EVENT SHALL SELLER'S LIABILITY TO BUYER AND/OR ITS CUSTOMERS EXTEND TO INCLUDE INCIDENTAL, CONSEQUENTIAL OR PUNITIVE DAMAGES. The term "consequential damages" shall include, but not be limited to, loss of anticipated profits, business interruption, loss of use, revenue, reputation and data, costs incurred, including without limitation, for capital, fuel, power and loss or damage to property or equipment. It is expressly understood that any technical advice furnished by Seller with respect to the use of the Goods is given without charge, and Seller assumes no obligation or liability for the advice given, or results obtained, all such advice being given and accepted at Buyer's risk. To the extent that Seller has been provided by or on behalf of Buyer

any specifications, description of operating conditions or other data and information in connection with the selection or design of the Goods and/or the provision of Services, and the actual operating conditions or other circumstances differ from those provided by Buyer and relied upon by Seller, any warranties or other provisions contained herein which are affected by such conditions shall be null and void.

7. **PATENTS AND COPYRIGHTS:** Subject to the limitations of the second paragraph of Section 6, Seller warrants that the Goods sold, except as are made specifically for Buyer according to Buyer's specifications, do not infringe any valid U.S. patent or copyright in existence as of the date of shipment. This warranty is given upon the condition that Buyer promptly notify Seller of any claim or suit involving Buyer in which such infringement is alleged and cooperate fully with Seller and permit Seller to control completely the defense, settlement or compromise of any such allegation of infringement. Seller's warranty as to use patents only applies to infringement arising solely out of the inherent operation according to Seller's specifications and instructions (i) of such Goods, or (ii) of any combination of Goods acquired from Seller in a system designed by Seller. In the event such Goods are held to infringe such a U.S. patent or copyright in such suit, and the use of such Goods is enjoined, or in the case of a compromise or settlement by Seller, Seller shall have the right, at its option and expense, to procure for Buyer the right to continue using such Goods, or replace them with non-infringing Goods, or modify same to become non-infringing, or grant Buyer a credit for the depreciated value of such Goods and accept return of them. In the event of the foregoing, Seller may also, at its option, cancel the agreement as to future deliveries of such Goods, without liability.

8. **EXCUSE OF PERFORMANCE:** Seller shall not be liable for delays in performance or for non-performance due to acts of God; acts of Buyer; war; fire; flood; weather; sabotage; strikes or labor disputes; civil disturbances or riots; governmental requests, restrictions, allocations, laws, regulations, orders or actions; unavailability of or delays in transportation; default of suppliers; or unforeseen circumstances or any events or causes beyond Seller's reasonable control. Deliveries or other performance may be suspended for an appropriate period of time or canceled by Seller upon notice to Buyer in the event of any of the foregoing, but the balance of the agreement shall otherwise remain unaffected as a result of the foregoing. If Seller determines that its ability to supply the total demand for the Goods, or to obtain material used directly or indirectly in the manufacture of the Goods, is hindered, limited or made impracticable due to causes set forth in the preceding paragraph, Seller may allocate its available supply of the Goods or such material (without obligation to acquire other supplies of any such Goods or material) among itself and its purchasers on such basis as Seller determines to be equitable without liability for any failure of performance which may result therefrom.

9. **CANCELLATION:** Buyer may cancel orders only upon reasonable advance written notice and upon payment to Seller of Seller's cancellation charges which include, among other things, all costs and expenses incurred, and, to cover commitments made, by the Seller and a reasonable profit thereon. Seller's determination of such termination charges shall be conclusive.

10. **CHANGES:** Buyer may request changes or additions to the Goods consistent with Seller's specifications and criteria. In the event such changes or additions are accepted by Seller, Seller may revise the price and dates of delivery. Seller reserves the right to change designs and specifications for the Goods without prior notice to Buyer, except with respect to Goods being made-to-order for Buyer.

11. **NUCLEAR/MEDICAL: GOODS AND SERVICES SOLD HEREUNDER ARE NOT FOR USE IN CONNECTION WITH ANY NUCLEAR, MEDICAL, LIFE-SUPPORT AND RELATED APPLICATIONS.** Buyer accepts goods and services with the foregoing understanding, agrees to communicate the same in writing to any subsequent purchasers or users and to defend, indemnify and hold harmless Seller from any claims, losses, suits, judgments and damages, including incidental and consequential damages, arising from such use, whether the cause of action be based

in tort, contract or otherwise, including allegations that the Seller's liability is based on negligence or strict liability.

12. **ASSIGNMENT:** Buyer shall not assign its rights or delegate its duties hereunder or any interest herein without the prior written consent of Seller, and any such assignment, without such consent, shall be void.

13. **QUANTITY:** Buyer agrees to accept overruns of up to ten percent (10%) of the order on "made-to-order" goods, including parts. Any such additional items shall be priced at the price per item charged for the specific quantity ordered.

14. **TOOLING:** Tool, die, and pattern charges, if any, are in addition to the price of the Goods and are due and payable upon completion of the tooling. All such tools, dies and patterns shall be and remain the property of Seller. Charges for tools, dies, and patterns do not convey to Buyer, title, ownership interest in, or rights to possession or removal, or prevent their use by Seller for other purchasers, except as otherwise expressly provided by Seller and Buyer in writing with reference to this provision.

15. **INSPECTION/TESTING:** Buyer, at its option and expense, may inspect and approve the testing by Seller of the Goods for compliance with Seller's standard test procedures prior to shipment, which inspection and testing shall be conducted at Seller's plant at such reasonable time as is specified by Seller. Any rejection of the Goods must be made promptly by Buyer before shipment. Tests shall be deemed to be satisfactorily completed and the test fully met when the Goods meet Seller's criteria for such procedures.

16. **DRAWINGS:** Seller's prints and drawings (including without limitation, the underlying technology) furnished by Seller to Buyer in connection with this agreement are the property of Seller and Seller retains all rights, including without limitation, exclusive rights of use, licensing and sale. Possession of such prints or drawings does not convey to Buyer any rights or license, and Buyer shall return all copies (in whatever medium) of such prints or drawings to Seller immediately upon request therefore.

17. **GENERAL PROVISIONS:** These terms and conditions supersede all other communications, negotiations and prior oral or written statements regarding the subject matter of these terms and conditions. No change, modification, rescission, discharge, abandonment, or waiver of these terms and conditions shall be binding upon the Seller unless made in writing and signed on its behalf by a duly authorized representative of Seller. No conditions, usage of trade, course of dealing or performance, understanding or agreement purporting to modify, vary, explain, or supplement these terms and conditions shall be binding unless hereafter made in writing and signed by the party to be bound, and no modification or additional terms shall be applicable to this agreement by Seller's receipt, acknowledgment, or acceptance of purchase orders, shipping instruction forms, or other documentation containing terms at variance with or in addition to those set forth herein. Any such modifications or additional terms are specifically rejected and deemed a material alteration hereof. If this document shall be deemed an acceptance of a prior offer by Buyer, such acceptance is expressly conditional upon Buyer's assent to any additional or different terms set forth herein. No waiver by either party with respect to any breach or default or of any right or remedy, and no course of dealing, shall be deemed to constitute a continuing waiver of any other breach or default or of any other right or remedy, unless such waiver be expressed in writing and signed by the party to be bound. All typographical or clerical errors made by Seller in any quotation, acknowledgment or publication are subject to correction. The validity, performance, and all other matters relating to the interpretation and effect of this agreement shall be governed by the law of the state of Missouri without regard to its conflicts of laws principles. Buyer and Seller agree that the proper venue for all actions arising in connection herewith shall be only in Missouri and the parties agree to submit to such jurisdiction. No action, regardless of form, arising out of transactions relating to this contract, may be brought by either party more than two (2) years after the cause of action has accrued. The U.N. Convention on Contracts for the International Sales of Goods shall not apply to this agreement.

MC-TC-1000 Revised 9/06

GLOSSARY OF TERMS

Ambient Temperature - The temperature of the surrounding environment.

BLDC (Brushless DC) Motor - A synchronous electric motor which is powered by direct current (DC) electricity and which has an electronically controlled commutation system, instead of a mechanical commutation system based on brushes. In such motors, current and torque, and voltage and rpm are linearly related.

Commutation - The action of applying currents or voltages to the proper electrical motor phases so as to produce optimum motor torque at a motor's shaft.

Current - The flow (movement) of electric charge. The SI unit of electric current is the ampere.

Efficiency - *See Energy Efficiency.*

ELV (Extra-Low Voltage) circuit - One in which the electrical potential of any conductor against earth (ground) is not more than either 50 volts RMS (70 volts peak) for alternating current (AC), or 120 volts for direct current (DC).

Encoder - An electro-mechanical device used to convert the angular position of a shaft or axle to an analog or digital code. *See also Resolver.*

Energy Efficiency - A dimensionless number, with a value between 0 and 1; when multiplied by 100, a percentage is given.

Equipotential Bonding - Process of bringing metallic objects to the same potential, reducing the shock hazard.

International Protection (IP) Ratings - Defined in International Standard IEC 60529. This system classifies the degrees of protection provided against the intrusion of solid objects (including body parts like hands and fingers), dust, accidental contact, and water in electrical enclosures. It uses a two digit code to specify the degree of particle and water resistance of an enclosed object. The first digit indicates the degree of protection of the interior from the ingress of solid foreign objects. The second digit indicates the degree of protection of the interior from the ingress of water. The table below describes the two digits that describe the level of protection of the enclosure.

TABLE 20 - DESCRIPTION OF IP STANDARD

First Digit	Description	Second Digit	Description
X	Not tested (no protection specified)	X	Not tested (no protection specified)
0	No protection provided	0	No protection provided
1	Protection against entry of objects larger than 50 square mm	1	Protection against drops of water falling vertically
2	Protection against entry of objects larger than 12 square mm	2	Protection against drops of water falling vertically when the object is tilted up to 15 degrees from its normal position
3	Protection against entry of objects larger than 2.5 square mm	3	Protection from entry of water spray from angle of up to 60 degrees from vertical
4	Protection against entry of objects larger than 1.0 square mm	4	Protection from entry of water splashes or spray from any direction
5	Protection against entry of dust in sufficient quantity to prevent satisfactory operation	5	Protection from a low pressure jet of water in any direction
6	Complete protection against entry of dust	6	Protection against heavy seas or a strong jet of water in any direction
		7	Protection against immersion up to 1 meter
		8	Protection against submersion over 1 meter

IP50 - Subset of the IP Rating; The "5" in the description indicates complete protection, (limited ingress permitted) dust protected; dust deposits are permitted, but their volume must not affect the function of the unit. The "0" indicates no special protection against water or liquids. *See also International Protection (IP) Ratings.*

NEMA (National Electrical Manufacturers Association) - Sets many common standards used in electrical products.

PELV (Protected Extra-Low Voltage) circuit - An electrical system in which the voltage cannot exceed ELV under normal conditions, and under single-fault conditions, *except* earth faults in other circuits.

PPR - Pulses per Revolution

PWM (Pulse Width Modulation) - A type of signal that varies the duty cycle, to either convey information over a communications channel or control the amount of power sent to a load; uses a square wave where the width of its pulse is varied periodically, resulting in the variation of the average value of the waveform.

Resolver - A type of rotary electrical transformer used for measuring degrees of rotation. It is considered an analog device, and has a digital counterpart, the encoder.

Tachometer - An instrument or circuit that measures the rotation speed of a shaft or disk.

Torque - A vector that measures the tendency of a force to rotate an object about some axis; the force applied to a lever multiplied by its distance from the length of the lever arm.

TTL (Transistor-Transistor Logic) - a class of digital circuits built from bipolar junction transistors (BJT), and resistors. It is called *transistor-transistor logic* because both the logic gating function (e.g., AND, NOR) and the amplifying function are performed by transistors.

Voltage - The difference of electric potential between two points of an electrical or electronic circuit, expressed in volts. It measures the potential energy of an electric field to cause an electric current in an electrical conductor.

APPENDIX

Reference and Agency Documents

The following reference/agency documents apply in part or entirely as indicated in the body of this document.

Reference Documents

UL 60950, CSA 60950, UL 60730, and National Electric Code (NFPA 70)

Safety Agency Approvals

The Motor control is designed to meet the relevant requirements of UL60730. To be determined if Agency certification is completed.

RoHS Regulation

Construction and parts conform to European Union (EU) compliance of RoHS Directive 2002/95/EC.



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Revision: A

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