MODEL LC4/5 "PLUS"

USER'S MANUAL

This manual covers the use and maintenance of the model LC4/5 "PLUS" series Brushless DC Motor Control product family. Included in this manual are the following model numbers:

LC4A-(P) LC5A-(P)
LC4B-(P) LC5B-(P)
LC4C-(P) LC5C-(P)
LC4D-(P) .....

This document applies to serial numbers beginning after XXXXX0894.

If you require further assistance, please call or write:

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READ ENTIRE MANUAL FIRST. DO NOT RETURN PRODUCTS WITHOUT PRIOR AUTHORIZATION DIRECT FROM AUTOMOTION.

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SAFETY PRECAUTIONS

Read this page and section 1.0 before using the LC4/5 Drive

To operate your control successfully, these minimum safety precautions MUST be followed to insure proper performance without injury to the operator and damage to motor or control. **FAILURE TO OBSERVE THESE SAFETY PRECAUTIONS COULD RESULT IN SERIOUS BODILY INJURY, INCLUDING DEATH IN EXTREME CASES.**

1. DO NOT touch any of the terminals numbered 16, 17, 18, 19 or 20 when power is applied. All of these terminals are located on connector P2. WARNING! The voltages at these connector pins are dangerous and can produce an electric shock. Bare wires from adjacent connector pins must never be allowed to touch one another. P2 pin 15 must be connected to an external earth ground.
2. Always operate the control within the prescribed input voltage limits.
3. Each model has dangerous voltages present on the circuit boards and stores a high voltage charge after being disconnected from the AC power source. DO NOT REMOVE THE COVER IF ONE IS IN PLACE. DO NOT ATTEMPT TO SERVICE THIS PRODUCT IF A PROBLEM OCCURS.
4. Be cautious when using the control in a 4 Quadrant mode. Instant direction changes can damage the amplifier. Read manual carefully for 4 quadrant limitations.
5. Do not parallel multiple motors off of the same control.
6. Under no circumstances must a phase output from the control be connected to anything other than a passive inductive load, such as a motor. See manual for minimum inductance requirements.
7. The packaged control is designed for use in a NEMA type 1 service. Direct contact with liquids or corrosive chemicals should be avoided. Use in a dust free environment.
8. Excessive speed can destroy some DC brushless motors and damage user equipment. Check the motor manufacturer's specifications to ensure the maximum current and voltage output for your control model does not exceed the motor limitations.
9. Do not remove the connectors P1 or P2 from the control while the motor is operating. DO NOT plug connector P2 into the control when wired to live AC power.
10. Read Automotion's Life support Policy, Section 22 for application limitations.
11. Never mount this product in the vicinity of combustible materials. Never use this product in an atmosphere of potentially explosive or highly combustible gases or particles.
12. Models with an external shunt resistor require special installation procedures. An external shunt can become either a shock or fire hazard if not properly mounted and used. Consult Automotion for details.

1.0 Safety Precautions:

READ THIS ENTIRE SECTION BEFORE ATTEMPTING TO USE THE LC4/5!

To operate the LC4/5 successfully, these minimum safety precautions MUST be followed to insure proper performance with minimal risk of injury to the operator and damage to motor or LC4/5 control.

Failure to observe these safety precautions could result in serious bodily injury, including death in extreme cases, and will void the warranty.

Automotion's products are not authorized for use as critical components in life support devices or systems without the express written approval of the President of Automotion Incorporated.

1. Do not touch any of the output terminals numbered 16,17, 18, 19, or 20 when power is applied. The voltages at these terminals are dangerous and can produce an electrical shock and cause lethal personal injury. The wires connected there should never have too much insulation removed allowing bare wire to be exposed beyond the terminal block. Bare wires from adjacent terminals must never be allowed to touch one another when power is applied to the LC4/5 control. Ground terminal number 15 MUST always be connected to an appropriate external EARTH power ground during use of the LC4/5 control.

2. Always operate the LC4/5 control within the prescribed voltage limits. To attempt to operate outside these bounds may result in damage to the LC4/5 control. See section 3.3

3. All LC4/5 models have dangerous voltages present on the internal circuit boards and use large electrolytic capacitors which store a high voltage charge after the unit is disconnected from the power supply. Do not attempt to service these units if a problem occurs or remove the cover! First consult section 18.0, ``In Case of Trouble.'' If this fails to solve the problem, call AUTOMOTION.

4. Care must be exercised when using the LC4/5 control in a 4 Quadrant mode. Instant direction changes under these conditions can cause electrical damage to the amplifier. Before using the LC4/5 in this mode, read section 14.0, ``Reversing the Motor, 4 Quadrant Operation.''

5. The LC4/5 will control only one brushless DC motor at a time. Do not parallel additional motors off of the same LC4/5 control.

6. Under no circumstances must a phase output from the LC4/5 control be connected to anything other than a passive inductive motor load. Other loads could cause immediate damage to the LC4/5 control.

7. The LC4/5 packaged control is designed for use in a NEMA type 1 service. The LC4/5 open frame control requires additional protection. Proper ventilation and mounting is required for reliable performance. Direct contact with liquids, corrosive chemicals, or corrosive gases must be avoided. The operating environment must be clean, dry and free from dust. Special packaging will be needed for the LC4/5 if these conditions are violated. See Section 10.0 "Installation: Mechanical," for more details.

8. Check the motor's peak RPM rating. Excessive speed can destroy some DC brushless motors and damage user equipment. In addition, check the motor manufacturer's specifications to make certain the maximum current limited output for your LC4/5 model will not risk permanent demagnetization of the motor. If the current is too high, see Section 17.0, ``Setting the Maximum Current Limited Output,'' for details on how the upper limit on the LC4/5

may be reduced to a safe level to match the motor's limits.

9. Do not remove the connectors P1 or P2 from the LC4/5 while the motor is operating. This can cause electrical arcing which can damage the connector pins. DO NOT plug connector P2 into the LC4/5 frame when live AC power is wired into the mating connector body.

10. Application limitations for the LC4/5 product are presented in Section 22.0 "Life Support Policy."

11. Never mount this product in the vicinity of combustible materials. Never use this product in an atmosphere of potentially explosive or highly combustible gas and/or dust. The LC4/5 should always be located inside an enclosure which is both intrinsically fire safe and shock safe. This may necessitate the need for safety interlocks on the outside enclosure to disconnect all power whenever service is performed.

12. If the LC4/5 is equipped with provisions for an optional external shunt resistor, then special precautions will need to be followed. An external shunt resistor must be mounted within its own enclosure which must be designed to prevent any fire hazard should the resistor overheat for any reason. User access to this resistor must be restricted to prevent any possibility of a shock or burn hazard.

13. When applications permit conditions in which excessive motor speed will cause unsafe operation, external provisions may be required for user protection. This product should not be depended upon to prevent excess motor speed in which user safety may be compromised.

2.0 Unpacking and Repacking:

When your package arrives, inspect the shipping box carefully, and save ALL packing materials. Contact the carrier promptly if damage is discovered. Your LC4/5 has arrived carefully packaged from AUTOMOTION in a static proof bag. As you unseal this bag inspect the contents carefully. There should not be any loose or damaged parts in this bag. While unpacking, if you discover any loose or damaged parts, notify AUTOMOTION within two working days.

Compare the packing slip against all items included in the box. Any shortages or other inspection problems should be reported immediately. Never attempt to operate or power-up the LC4/5 if there is any visible external damage or if it sounds as though there are loose materials inside the chassis.

AUTOMOTION recommends that all packing materials be saved in case the LC4/5 ever needs to be shipped again. Always place the LC4/5 in the same static proof bag used in the original shipment. Abundant filler material should always be placed around the LC4/5 bag so that it cannot shift inside the box.

Always insure your shipment for the proper replacement value of its contents. AUTOMOTION will not assume responsibility for any returned goods which have been damaged outside of our factory because of improper packaging or handling. All goods shipped to AUTOMOTION must have prior return authorization and be shipped FREIGHT PREPAID.

3.0 LC4/5 Product Family Specifications:

3.1 Drive type:

2 Quadrant, six step, 3 Phase, Full Wave PWM controlled output.

3.2 Maximum Current Limited Output:

LC4A	3.25	Amps RMS continuous.
	4.5	Amps RMS peak* limited.
LC4B	5.7	Amps RMS continuous.
	8.0	Amps peak* limited.
LC4C	10.7	Amps RMS continuous.
	15.0	Amps peak* limited.
LC4D	14.2	Amps RMS continuous.
	20.0	Amps RMS peak* limited.
LC5A	3.25	Amps RMS continuous.
	4.5	Amps peak* limited.
LC5B	7.1	Amps RMS continuous.
	10.0	Amps peak* limited.
LC5C	10.7	Amps RMS continuous.
	15.0	Amps peak* limited.

* Defined as the peak of a six step waveform.

See ``Reversing the Motor, 4 Quadrant Operation'' for precautionary details.

3.3 Operational Voltage Supply Range:

LC4- 95 to 132 volts AC-RMS, single phase, 50/60 Hz. 145 VAC peak for 1 sec. Automatic over/under voltage shutdown employed. AC line inputs are MOV protected.

LC5- 190 to 245 volts AC-RMS, single phase, 50/60 Hz. 260 VAC peak for 1 sec. Automatic over/under voltage shutdown employed. AC line inputs are MOV protected.

3.4 PWM Operating Frequency:

Approximately 18 KHz.

3.5 Operating Temperature Range:

0 to +50 degrees Celsius. Automatic over temperature shutdown employed at +50 degrees Celsius on heat sink. Consult Automotion if a larger range is required.

3.6 Storage Temperature Range:

-20 to +85 degrees Celsius.

3.7 Operating Humidity Range:

5 to 95% RH non-condensing.

3.8 Output Voltage to Motor:

LC4- Nominally +160 volts chopped DC, phase-to-phase. This is based upon a supply voltage of 115 volts AC-RMS, at full-rated continuous output amps.

LC5- Nominally +320 volts chopped DC, phase-to-phase. This is based upon a supply voltage of 230 volts AC-RMS, at full-rated continuous output amps.

3.9 Product Size:

Packaged Unit:

Height	9.25	inches (23.5 cm)
Width	5.4	inches (13.7 cm)
Depth	8.5	inches (21.6 cm)
Weight	6.25	lb. max (2.81 Kg)

Open Frame Unit:

Height	10.5	inches (26.7 cm)
Width	3.5	inches (8.9 cm)
Depth	6.25	inches (15.9 cm)
Weight	3.2	lb. max (1.45 Kg)

3.10 Heat Sink Cooling:

External forced air cooling may be necessary when prolonged high amperage duty cycles are used and/or high ambient air temperature exists. The LC4/5 will automatically shutdown whenever the heat sink temperature reaches approximately 50 degrees Celsius. To restart the motor, toggle the Start/Stop input after the heat sink has cooled.

3.11 Speed Control:

Stock model is equipped for both external 4 quadrant speed control or Closed Loop, 2 quadrant internal speed regulation. The external speed control may be provided by means of either an analog signal for 0 to +10 volts, or an external PWM source. See the appropriate sections in this manual for further details on each of these capabilities. An optional +/- 10 volt analog signal input card is available. See Section 19.0, "Optional Equipment."

3 .12 Commutation Control:

Normally provided by three rotor positional sensors located within the brushless DC motor. These sensors may be either of the Hall variety or optical in nature. See section 7.0, ``Motor Requirements.''

3.13 Commutation Code:

User selectable for either 60 or 120 electrical degrees of signal phase displacement. See section 7.0, ``Motor Requirements.''

3.14 Additional Controls:

Start/stop, forward/reverse, dynamic brake, external current limit trip input, external signal input for closed loop speed control. An optional current signal output is available, but must be configured at the factory. See the Table of Contents for further information.

3.15 Motor Compatibility:

Any three phase WYE or DELTA wound brushless DC motor designed to operate with 160 volts DC power and possessing a minimum winding inductance of 150 micro Henries or greater and a minimum winding electrical time constant of 0.5 msec. See Section 7.0, ``Motor Requirements'' for more information.

3.16 Logic Control:

All logic I/O terminals numbered 1 through 14 are electrically isolated from the AC power. External logic interfacing should be implemented using TTL outputs. Simple toggle switches may also be used. The maximum input voltage should not exceed +24 volts DC. See appendix for suggested wiring hook-ups.

3.17 Dynamic Braking Limitations:

Some limitations exist in the use of the dynamic brake. Dynamic Brake Limitations: Maximum 2% Duty Cycle. 10 watts continuous/ 650 Watts intermittent. Please read Section 15.0, ``Dynamic Braking the Motor,'' if you intend to use this feature.

3.18 Full Short Circuit Protection:

The LC4/5 is protected from damage due to a momentary direct short circuit to ground, a short to the AC power supply rails, or a phase-to-phase short. Inadvertent shorts in the motor or motor phase lines may result in the drive tripping off line

and the annunciation of the fault. The fault may be cleared and the drive restarted without damage (once the short has been removed), by resetting the enable/disable line. Frequent short circuits may eventually damage the drive.

3.19 1500 VAC HiPot Tested:

The LC4/5 is tested at the factory for dielectric strength between incoming AC power and user SELV interface circuits. It is also tested for dielectric strength between incoming AC power and chassis frame ground. The HiPot test level used is 1500 VAC between SELV circuits on connector P1 and incoming AC power on connector P2. A HiPot test level of 1500 VAC is used between the chassis frame ground and incoming AC power on connector P2.

3.20 Packaging:

Models with the subscript ``P'' are packaged in a NEMA 1 type ventilated enclosure. All others are open frame. DO NOT PLACE ANY LC4/5 IN CONTACT WITH LIQUIDS, ELECTRICALLY CONDUCTIVE MATERIALS, OR CORROSIVE CHEMICALS OR ALLOW FOREIGN MATERIALS TO FALL INTO THE LC4/5.If the LC4/5 must be used in an environment which violates these conditions, contact AUTOMOTION for special packaging recommendations.

3.21 Fuse Sizes:

When replacing a fuse, always use properly rated devices. For the LC4A, use only a LITTELFUSE #314007 or equivalent. For the LC4B, use only a LITTELFUSE #314010 or equivalent. For the LC4C, use only a LITTELFUSE #314020 or equivalent. For the LC4D, use only a LITTELFUSE #314025 or equivalent.

For the LC5A, use only a LITTELFUSE #314010 or equivalent. For the LC5B, use only a LITTELFUSE #314015 or equivalent . For the LC5C, use only a LITTELFUSE #314020 or equivalent.

If the LC4/5 is subject to frequent power-up conditions, a different fuse may need to be specified.

4.0 Quick-Start Set up:

The following steps should be followed in the order shown to complete the proper electrical installation. Always cut and strip only enough insulation off of connecting wires to mate with the LC4/5 terminals. Do not leave bare wires exposed beyond the edge of the terminal block. This would create a potential hazard to the operator and the system from short circuits between adjacent terminals. **NEVER MAKE ELECTRICAL CONNECTIONS OR WIRING ADJUSTMENTS WITH LIVE POWER APPLIED TO THE LC4/5 CONTROL.** Please refer to FIGURE 1 for information when performing the following installation steps.

4.1 Step One:

Wire motor phases to proper terminals on the LC4/5 control. Use the wire sizes recommended in Section 6.0, ``Power Supply Requirements.'' The three phase wires should be twisted together with approximately six twists per foot (0.3 meters).

4.2 Step Two:

Wire the rotor positional sensors into the control. In a typical installation, there will be 5 wires serving the sensor assembly. They are: S1, S2, S3, + low voltage DC power (i.e., Terminal #4, +12 volt DC), and LOGIC GROUND (i.e., Terminal #5).

Light gauge wire may be used, such as 24 AWG. When the distance between the motor and the control exceeds 6 feet (1.8 meters), AUTOMOTION recommends using a shielded cable for the sensor wires. A single shield covering the entire bundle should be sufficient with the shield terminated ONLY at Terminal #5 of the LC4/5 control. The motor end of the shield should be left open. If unshielded wire is used, twist these five wires together with approximately six twists per foot (0.3 meters).

LC4/5 BASIC WIRING DETAILS

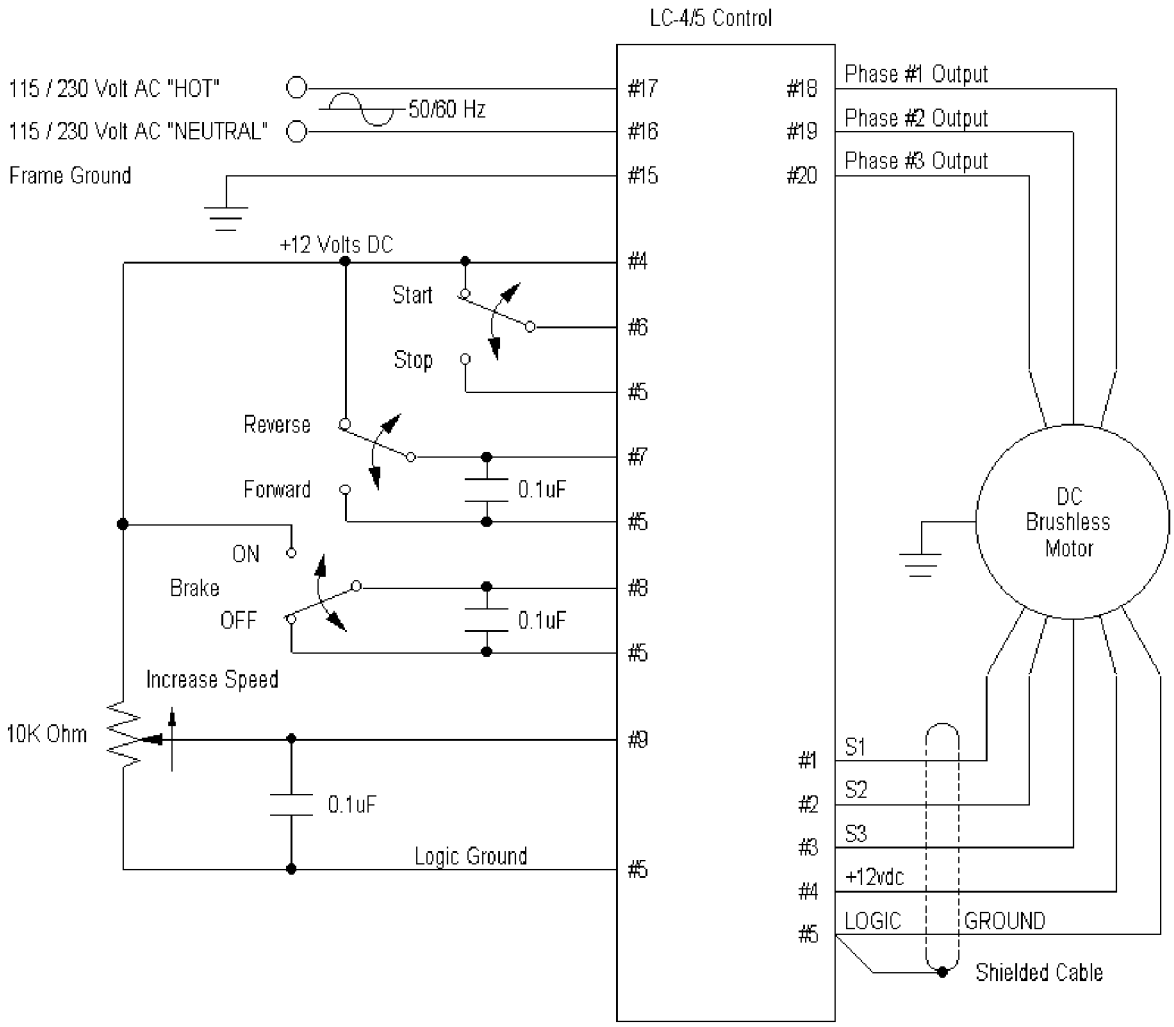

FIGURE 1

NOTES! **LOGIC GROUND** and chassis ground are **NOT** common with each other and normally are kept separate from each other externally. Also, be aware of restrictions involving the use of the Forward/Reverse at high RPM's. **SEE THE MANUAL FOR ADDITIONAL DETAILS**!!

Shown above is a simple open loop speed control installation.

4.3 Step Three:

Determine the proper commutation signal phase shift required for your motor (i.e., 60 or 120 electrical degrees) and place the jumper in JUMPER GROUP 2 located on the bottom of the LC4/5 in the proper position as described below. See FIGURE 4 or FIGURE 5 for placement details. Units are normally shipped in the 120 degree mode, unless otherwise indicated. Reference Section 7.0, ``Motor Requirements'' for more information.

4.4 Step Four:

Decide whether you will be using either open or closed loop speed control. If open loop is required, use Terminal #9 as the input for this 0 to + 10 volt analog signal, which is referenced to LOGIC GROUND (i.e., Terminal #5). A +10 volt DC signal at Terminal #9 will run the motor at maximum current limited RPMs. Please note that for open loop speed control a simple external potentiometer with a minimum resistance of 10K ohms may be used to control your motor RPM's. See section 12.0, "Running the Motor With the LC4/5 Control: CLOSED LOOP" for details.

Your LC4/5 is designed to operate in several different speed control modes. These include: Open loop, 1, 2, or 4 quadrant speed control using a 0 to +10 volt analog signal; optional +/- 10 volt input; internal single quadrant closed loop speed control with the tach signal provided by the commutation sensors; internal single quadrant closed loop speed control with the tach signal provided by an external encoder input; external PWM control.

4.5 Step Five:

If you use Forward/Reverse or Dynamic Brake controls, these ports may be toggled by either a simple SPDT switch, or by TTL signal outputs from an external electronic based control. If external TTL signals are used, the common return path must be connected to terminal #5 (LOGIC GROUND).

4.6 Step Six:

With the external AC 50/60 Hz, feed power temporarily DISCONNECTED, wire the feeder block or the power cord into the LC4/5 control at connector J2. Use the wire sizes recommended in Section 6.0, ``Power Supply Requirements.'' NEVER MAKE POWER CONNECTIONS TO THE LC4/5 WITH LIVE AC POWER.

4.7 Step Seven:

Before operating the LC4/5 control for the first time, make sure that all logic control inputs are wired correctly and that the current drain out of Terminal #4 will be no more than 50 mA. Whenever AC power is first applied after a brownout or after a momentary power interruption, the LC4/5 will require a power-up reset. This is done by toggling the Start/Stop input port (i.e., Terminal #6) from OFF to ON. Please note that it is normal for the ``Power/OT Fault'' and LED to be lit at power-up or after a power interruption. Always check the setting of the front panel trim pots. Improper adjustment can cause needless delays and trouble. Review Section 5.0, ``Last Minute Check List'' before operating the LC4/5 for the first time.

5.0 Last Minute Check List:

(*read before operating the LC4/5 for the first time*)

Have you connected your AC power cables correctly?

_____ yes_____ no

Are all connectors snapped into place?

_____ yes_____ no

Have you checked your motor phase output connections and all other wiring to make certain there are no shorts?

_____ yes_____ no

Will your power source supply the correct AC voltage?

_____ yes_____ no

(Remember to bring the motor speed up gradually the first time you operate the LC4/5).

Have you adjusted the user accessible trim pots correctly?

_____ yes_____ no

If you are NOT using input Terminals #10 and/or #11, have you connected them to Terminal #5 (LOGIC GROUND)?

_____ yes_____ no

Have you read through this manual entirely including the SAFETY PRECAUTIONS?

_____ yes_____ no

If you answer ``NO'' to any of the preceding questions, make the necessary corrections before proceeding.

Please note, upon power up, the drive default condition for Terminal #6 start/stop is ``Stop''. Start/stop input must be toggled OFF and ON to start the motor.

6.0 Power Supply Requirements:

6.1 Power Source:

The power source used with the LC4/5 product family must be a nominal 115 volts for the LC4 or a nominal 208/220 volts for the LC5 models. This source must be single phase AC service with a nominal line frequency of 50/60 Hz, +/- 3%, and the amperage capacity for the supply circuit must be rated at least 10 amperes above the continuous output rating for your particular LC4/5 model.

For the LC4 models, the voltage range must be between 95 and 132 VAC-RMS or an automatic shutdown of the control may occur. Any continuous supplied voltage over 132 VAC-RMS may cause damage to the LC4 control. The AC line inputs for the LC4 are MOV protected for very short ``soft'' line transients above 145 VAC.

For the LC5 models,the voltage range must be between 200 and 245 VAC-RMS or an automatic shutdown of the control may occur. Any continuous supplied voltage over 245 VAC-RMS may cause damage to the LC5 control. The AC line inputs for the LC5 are MOV protected for very short ``soft'' line transients above 260 VAC.

Consult AUTOMOTION for limitations.

6.2 AC Voltage Fluctuation:

Voltage fluctuations on the AC supply line may adversely affect the maximum RPM level attainable by your motor and speed stability, especially when operating in an open loop mode.

6.3 Wire Size:

AUTOMOTION recommends that a minimum wire size of 16 AWG be used for connecting the LC4/5 to both the AC power source and to the three phases of the motor. Use 14 AWG wire for the motor phase connections and the AC power connections if the individual wire lengths exceed 6 feet (1.8 meters).

6.4 Cable Requirements

The phase output cable should have a maximum distributed capacitance of 100 pF/ft (328 pF/meter) up to a total of 1000 pF.

Total capacitance being the sum of phase to phase and phase to ground (shield) capacitance. If cable losses are higher, compensating line inductors may be required. Contact Automotion for application assistance.

6.5 Fuses:

The LC4/5 product line is internally fused. Should the fuse blow, always determine why this occurred before attempting to operate the LC4/5 again. See Section 3.21 for fuse sizes.

6.6 Line Filter:

In some noise sensitive or noisy systems, it may be desirable to place a line filter between the LC4/5 AC power input terminals and AC power source. Such devices are commercially available. Ask AUTOMOTION for recommendations.

7.0 Motor Requirements:

7.1 Commutation Feedback:

The LC4/5 control is designed to operate with a three phase brushless DC motor. This motor must employ either three Hall or optical sensors for rotor positional feedback. These sensors must be capable of operation off of the +12 VDC supply provided by the LC4/5. The signal outputs of these sensors may use either passive or active pull-ups. The LC4/5 DOES provide internal pull-ups. So, if the sensors used by your motor do not provide active pull-ups, then passive external pull-ups of three 10K Ohm, 1/4 Watt resistors are optional, though recommended. See FIGURE 2 for details.

For distances less than six feet (1.8 meters), twist the sensor wires and sensor power wires together with approximately six twists per foot (0.3 Meter). If the distance between the motor and control exceeds six feet (1.8 meters), use shielded wire for the commutation sensor signal lines and the commutation sensor power lines. DO NOT co-mingle commutation sensor signal lines with motor phase lines.

7.2 Electrical Characteristics:

The brushless DC motor should be three phase with either a WYE or DELTA wound stator. The motor inductance should not be less than 150 micro Henries phase-to-phase at full amperage. The total number of poles on the rotor assembly does not affect the performance of the LC4/5 control except at very high RPM's.

For the LC4 model, the motor should operate with a DC voltage power source at a minimum of +200 volts. For the LC5 model, the motor should operate with a DC voltage power source at a minimum of +400 volts. Motors should also pass a HiPot test of 1500VAC or higher between all phase lines and frame ground, and also between all phase lines and the commutation sensors.

7.3 Phase Shift Selection:

Before operating, configure the LC4/5 control to match the phase shift between the signals supplied by the three rotor positional sensors. You can use the LC4/5 with either 60 or 120 electrical degree phase shift. See FIGURE 3.

To program the LC4/5, see FIGURE 4 or FIGURE 5 for an illustration of where to locate the proper jumper pins on the bottom of the chassis. All units are shipped from the factory set for 120 electrical degrees unless otherwise noted.

* **To use the LC4/5 control with 60 electrical degree signal phase shift, place the Group 2 jumper in position ``B''.**

* **To use the LC4/5 control with 120 electrical degree signal phase shift, place the Group 2 jumper in position ``A''.**

Please note that the three rotor positional sensor signals coming into the LC4/5 from your motor must be square waves. When the motor is running at a constant velocity, these signals should exhibit a 50% duty cycle.

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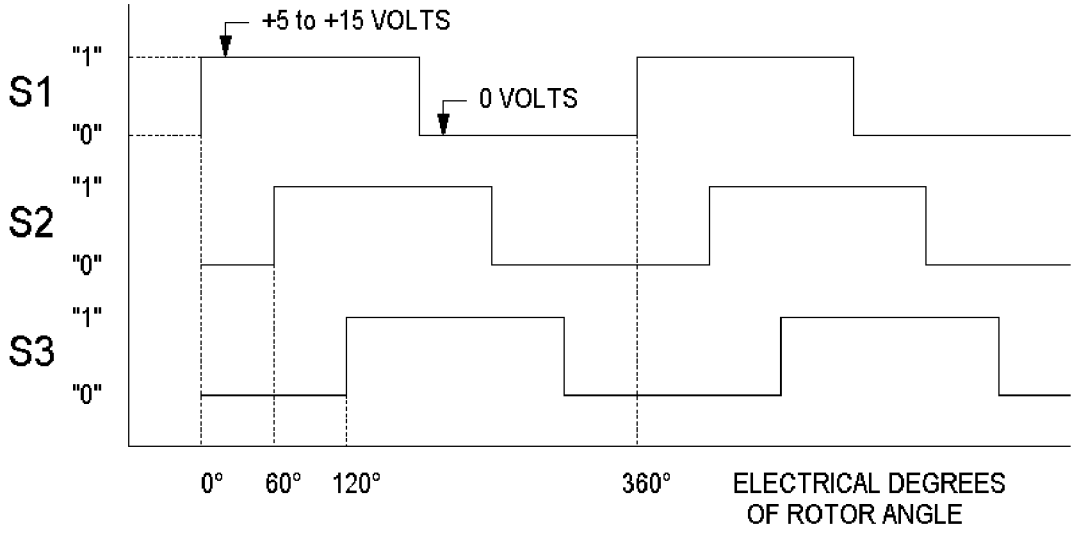
Typical Hall Sensor Interface

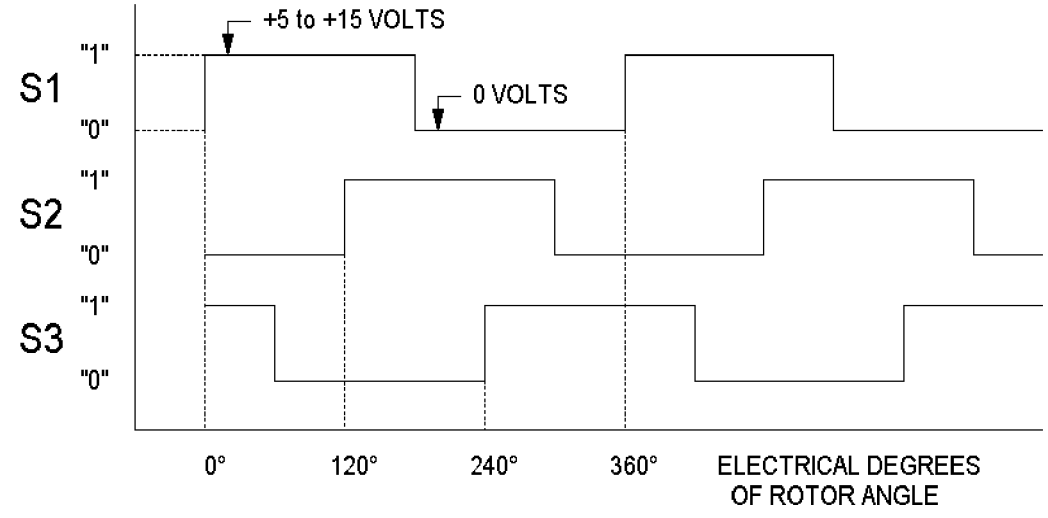
(Must be duplicated for each of the three signal inputs).

FIGURE 2

OPTIONS FOR COMMUTATION SIGNAL PHASE RELATIONSHIPS



60 DEGREE COMMUTATION
SIGNAL FORMAT



120 DEGREE COMMUTATION
SIGNAL FORMAT

NOTE: Each commutation signal has a balanced 50% duty cycle when the motor is running at a constant velocity.

FIGURE 3

FIGURE 4

PACKAGED LC4/5

FIGURE 5

OPEN FRAME LC4/5

8.0 External Shunt Resistor:

8.1 Shunt Requirement For Regenerative Braking:

During rapid deceleration of the motor, power regeneration occurs. This causes kinetic energy to be returned to the LC4/5 control. For small inertial loads this may not be a problem, but for larger loads this returned energy must be dissipated by the control. The amount of energy return will depend upon both the rate of motor deceleration plus the size of the motor load.

The LC4/5 control may be purchased with the option to use an external shunt resistor. This is usually a user supplied part. It is absolutely essential that this shunt resistor be properly sized and protected. AUTOMOTION will assist the user in the selection of this part when requested.

The user is also burdened with the responsibility to make the installation of this external shunt resistor both fire safe and shock safe. Should any failure cause this resistor to overheat or cause its electrical cable to fail, the user must provide an intrinsically safe environment for this part so that no fire hazard can occur. A well designed heat shield is a user requirement for this part. This shield must also serve the purpose of preventing any possibility for a shock or burn hazard.

AUTOMOTION does not recommend that this resistor be placed in the vicinity of either combustible or explosive materials and/or gases.

If no external shunt resistor is installed the user must understand that excess regeneration may cause nuisance trips. While this occurrence will not damage the control, it will disrupt the normal operation of the motor. Consequently, it is necessary for the external shunt resistor to be properly sized. See Section 8.3 for advice.

8.2 Shunt Safety Precautions:

AUTOMOTION recommends that certain safety precautions be followed in keeping with good engineering practice when using an external shunt resistor. In particular the following considerations are of importance:

- Selection of a properly sized resistor.
- Correct location and mounting for this external resistor.
- Correct wiring for this resistor to the Automotion brushless drive.

8.3 Selection of an External Shunt Resistor Value:

The duty cycle for an external shunt resistor is application dependent. As such it helps to estimate just how much kinetic energy is stored in the motor and its load when deceleration begins. It is this kinetic energy which transfers back to the drive whenever a deceleration cycle begins.

AUTOMOTION recommends using the AUTOMOTION Field Application Bulletin No. 101-0195 for more selection details.

AUTOMOTION DOES NOT recommend the use of a shunt resistor with less than a 50 Watt rating for any application. Consult AUTOMOTION if you wish to violate this guideline.

8.4 Location and Mounting of the External Shunt Resistor:

The shunt resistor is a heat producing element powered from high voltage electricity. Consequently the user must follow several common sense safety guidelines to avoid possible problems later. The following is a list of suggested methods for mounting the external shunt resistor:

· DO NOT mount the shunt in the proximity of flammable materials. It is suggested that it be mounted only upon a metal surface, such as steel. It is also suggested that if it is to be installed in an enclosure, then this enclosure be made out of nonflammable metal materials with flow through air ventilation.

· DO NOT use the shunt in an explosive atmosphere.

·DO NOT use the shunt in a location where it may be exposed to humidity condensation or other liquids.

· Always locate the shunt in a location where it will remain clean and dry.

· The shunt is activated by potentially lethal voltages. Mount the shunt someplace where it will not expose the user or service personnel to a shock hazard. A 115 VAC sourced drive can deliver voltages between 200 and 250 peak volts to the shunt. A 208/230 VAC sourced drive can deliver voltages between 400 and 450 peak volts to the shunt.

· Always locate the shunt resistor in a location where it has space for ventilation. DO NOT locate in a closed space without free air movement.

The following formulas are an indication of the maximum continuous wattage developed across the shunt when whenever it is ON. We suggest you design your installation to be fire and shock safe with this information in mind.

For a 115 VAC sourced drive:

Maximum wattage = (34150) / (Shunt resistance in Ohms)

For a 208/230 VAC sourced drive:

Maximum wattage = (132500) / (Shunt resistance in Ohms)

Temperature limiting devices are available to aid in the removal of the power source from the shunt resistor in the event it begins to overheat for any reason. However, they are not a substitute for making the basic installation fire proof.

The simplest way to limit the heat concentration at the shunt resistor is to use the highest ohmic value resistor(s)possible plus higher wattage capacity in every application. This will help to keep shunt resistor surface temperature as low as possible under all circumstances. Worst case testing is always required to insure safe performance at all times.

8.5 Suggested Wiring Methods for the External Shunt Resistor :

At the user's option, a temperature sensitive fuse or switch can be used in conjunction with the external shunt resistor. The function of this device is to limit the temperature rise of the shunt resistor should it ever overheat. The following devices have been tried by Automotion and show merit in this purpose.

1. **Elmwood part #JD090-V231.**

2. **Therm-O-Disc part #G5A01077C.**

3. **RCD Components fusible resistor #TF04D/.25 Ohm/±5% Tol.**

4. **Bussman heat limiter fuse part #TGC.**

Devices 1 and 2 are suitable for application as shown in FIGURE 6 ONLY! All of these listed devices are suitable for application as shown in FIGURE 7. Each part has a slightly different threshold temperature for opening. Check the manufacturers data sheet carefully before use. Any temperature sensing device should be a non-resettable type. The use of any temperature limiting device is not intended to substitute for any safety precautions previously stated.

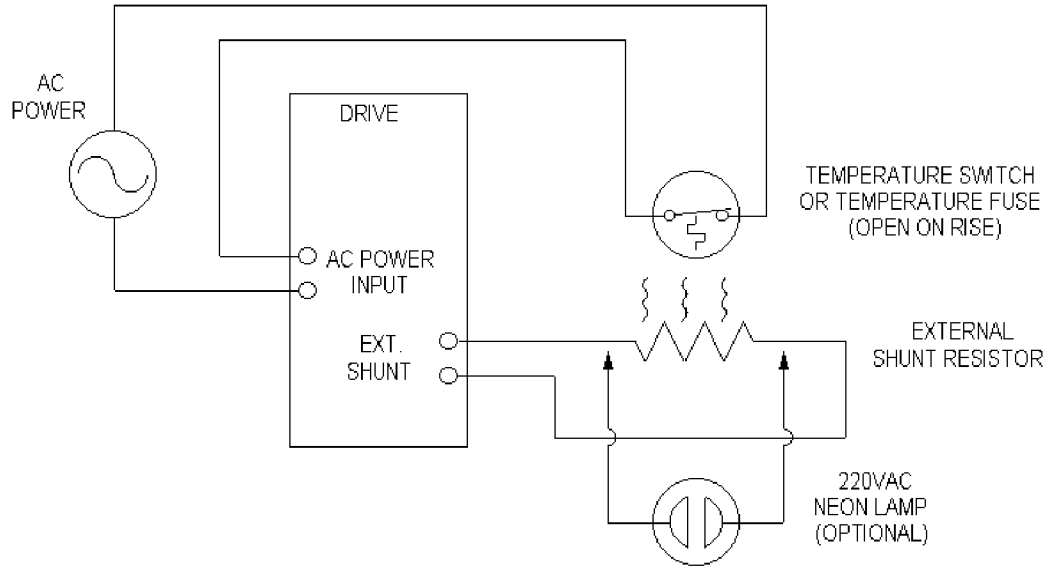


FIGURE 6

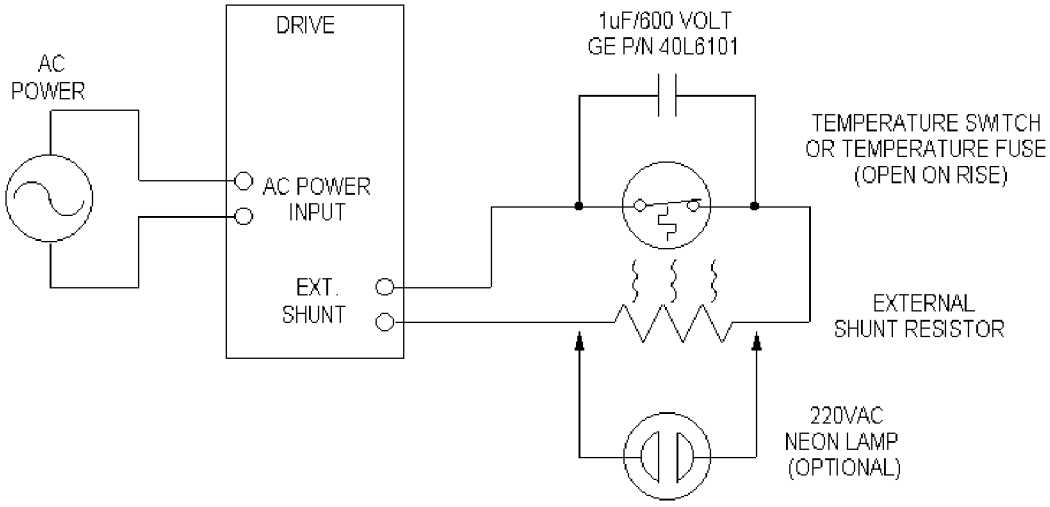


FIGURE 7

The optional neon lamp is intended to show the user just how heavy a duty cycle is applied to the shunt resistor. It will blink every time the shunt resistor is toggled. If it blinks with a very short duty cycle under worst case decel conditions, the chances are that a higher ohmic resistor value could be used. If it DOES NOT blink at all an external shunt resistor may not be needed.

If the user decides to use a temperature sensitive fuse or switch, it is very important that this device be located in close proximity to the shunt resistor. It is obvious that if the surface temperature of the shunt resistor becomes excessively hot the components listed on the previous page must respond effectively. Generally the temperature sensitive device should be mounted in contact with the surface of the shunt resistor or very close to it.

Automotion favors the use of the installation shown in FIGURE 6 whenever possible. This is because it requires fewer components. If the installation in FIGURE 7 is used, the 1 µf capacitor should be located away from the path of heat if the shunt resistor should overheat.

The capacitor shown in FIGURE 7 is made by General Electric under their part #40L6101. It may be possible to find an equivalent substitute. It is non-polarized and rated for 600 Volt DC service. If the installation shown in FIGURE 7 is used then this capacitor is required. Any installation without it is likely to render the temperature fuse or temperature switch as ineffective.

Whichever method is chosen to locate the external shunt resistor, it should be wired to the Automotion drive using at least 16 AWG wire rated for 600 VAC service. We recommend that the wire have a Teflon jacket with a minimum 105° C temperature rating. Wiring guidelines are given in Section 8.1, "Shunt Requirement For Regenerative Braking". It is important that the wire to the shunt resistor be dressed using good installation practice to prevent any short circuits from happening. Short circuits will damage the Automotion drive.

The final method of installation should be tested to confirm that it functions correctly and safely. Also apply heat to the temperature sensing device chosen to confirm that it works consistently in your operating environment. Multiple tests are recommended.

Any questions regarding the external shunt resistor should be directed to AUTOMOTION. These recommendations are intended to provide some help in your installation of an external shunt resistor. They are not a substitute for using good judgment and following recognized standards in your industry for making your installation safe and reliable under all possible conditions.

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9.0 Input/Output Terminal Identification:

Terminal Number	Function Description
1	COMMUTATION SIGNAL S1, INPUT PORT. Digital signal required from motor. A 10K ohm pull-up resistor is provided internally.
2	COMMUTATION SIGNAL S2, INPUT PORT. Digital signal required from motor. A 10K ohm pull-up resistor is provided internally.
3	COMMUTATION SIGNAL S3, INPUT PORT. Digital signal required from motor. A 10K ohm pull-up resistor is provided internally.
4	+12 VOLT DC REGULATEDOUTPUT PORT. 25 mA maximum load. This may be the power source for the commutation sensors in motor and some external logic.
5	LOGIC GROUND. All external logic should be referenced here. This port is isolated from chassis frame ground and from the AC power lines.
6	START/STOP CONTROL INPUT PORT. Approximately 4.7K ohm input Z. This port is TTL compatible. The maximum applied voltage here must not exceed +24 VDC. 0 volts stops the control. The default condition is STOP.
7	FORWARD/REVERSE DIRECTION CONTROL, INPUT PORT. This port is TTL compatible. The maximum applied voltage here must not exceed +24 VDC. O volts enables ``forward'' motor rotation. Default condition is FORWARD.
8	DYNAMIC BRAKE CONTROL, INPUT PORT. This port is TTL compatible. 0 volts turns off the brake. The default condition is brake ``OFF''.
9	OPEN LOOP SPEED CONTROL INPUT PORT. Requires a 0 to +10 volt signal to set the open loop motor speed. +10 volts produces maximum motor RPM's and 100% PWM amplifier output. 0 volts produces zero motor speed and 0% PWM amplifier output. The input Z is approximately 22K ohm. The default condition is zero speed. (+/- volt input optional.)
10	DUAL SPEED SELECT CONTROL, INPUT PORT. A TTL compatible port for selecting one of two Closed Loop speed settings. This uses the internal single quadrant Closed Loop speed control. Both speed settings are controlled through built-in pots. The default condition selects Velocity Setpoint #1.
11	EXTERNAL CLOSED LOOP SPEED CONTROL, INPUT PORT. This port allows for an external signal source to control the internal single quadrant Closed Loop speed. The input Z is approximately 10K ohm.
12	EXTERNAL ENCODER/ EXTERNAL PWM INPUT PORT. This port is TTL compatible. The maximum applied voltage here must not exceed +24 VDC. See Sections 12, 13, and Appendix A & B for configuration details.
13	CURRENT SIGNAL OUTPUT PORT. (Optional). Approximately +.05 volts/Ampere. See Section 19.1 for details.
14	EXT. CURRENT LIMIT TRIP, INPUT PORT. Whenever a digital signal is applied here of +12 volts in amplitude, the LC4/5 stops sourcing current to the motor. Input Z is approximately 22K ohms. See Section 17.0 for details.
15	CHASSIS FRAME GROUND (i.e., heat sink)

16 AC NEUTRAL POWER INPUT PORT.
LC4- 115 VOLTS AC,50/60 Hz.
LC5- 208/220 VOLTS AC, 50/60 Hz, (Not Fused.).

17 AC HOT POWER INPUT PORT.
LC4- 115 VOLTS AC, 50/60Hz.
LC5- 208/220 VOLTS AC, 50/60 Hz, (Fused).

18 MOTOR PHASE #1 OUTPUT.

19 MOTOR PHASE #2 OUTPUT.

20 MOTOR PHASE #3 OUTPUT.

10.0 Installation: Mechanical:

10.1 General Information for all Installations:

Never mount this product in the vicinity of combustible materials. Never use this product in an atmosphere of potentially explosive or highly combustible gas and/or dust. Direct contact with liquids, corrosive chemicals, or corrosive gases must be avoided. The LC4/5 must be used in environments which have a supply of clean and dry air. High humidity is to be avoided where there is a risk of condensation.

The LC4/5 must always be located inside an enclosure which is both intrinsically fire safe and electric shock safe. This may necessitate the need for safety interlocks on the outside enclosure to disconnect all power whenever service is performed.

Mount the LC4/5 vertically on a clean and flat surface. This will provide natural convection air cooling. The need for forced air cooling may be required in environments with high ambient air temperatures and/or heavy duty cycles.

Whenever the heat sink temperature reaches approximately 50 degrees Celsius (122 degrees Fahrenheit), the LC4/5 will automatically shut down. If the surface temperature of the mounting base of heat sink is around or above 50 degrees Celsius, additional forced air cooling will be required.

Do not place the LC4/5 in an environment subject to high vibrational stress. If this is necessary, contact AUTOMOTION.

This product contains capacitors which store a high voltage electric charge for several minutes after all outside power is removed. Beware that at least **12** minutes must pass after all external power is disconnected before this product may be physically handled.

10.2 Packaged Models:

The LC4/5 model "P" unit is a packaged device designed to conform to NEMA type 1 standards. The control is designed to mount vertically so that convection air flows naturally through the heat sink fins. If the control is mounted in any other manner, forced air cooling may be required. Notches in the side brackets are provided for mounting the unit. Never drill holes into or mount brackets upon the case.

10.3 Open Frame Models:

The LC4/5 model "O" unit is an open frame device. It has no cover wrapped around it which is designed to provide complete mechanical or electrical protection. This requires the user to provide adequate protection as needed. In particular the user must mount and use the LC4/5 open frame control inside of a protective enclosure which is both fire safe and electric shock safe.

The open frame device is designed to be mounted upon a cold plate surface. This means it must be placed upon a surface which has sufficient thermal mass to draw the heat away from the rear mounting surface of the control.

11.0 Running the Motor With the LC4/5 Control - OPEN LOOP:

11.1 Set up:

To operate the LC4/5 control in an open loop mode means that there is not any built-in means of speed regulation. Rather, the speed will be governed based upon the analog signal supplied on Terminal #9. Other factors influencing speed stability in an open loop mode are the load applied to the motor, the AC line voltage stability, and the maximum current delivery of the LC4/5 model being used.

To set up the control for open loop operation, examine FIGURE 4 or FIGURE 5. Locate and adjust the Velocity Set #1 and the Tach Gain pots fully counter-clockwise. Locate and adjust the Velocity Set #2 pot fully clockwise. These three pots are approximately 17 turn devices and to adjust them will usually produce a noticeable "click" when they are at the fully CCW or CW extremes. Also decide how much, if any, "Soft Start" time is needed, and how much current limited output is required. Refer to Section 17.0, "Setting the Maximum Current Limited Output" and Section 16.0, "Using Soft Start."

11.2 Speed Control

To control the speed a 0 to +10 volt signal must be applied to Terminal #9. This variable analog voltage should be referenced to Terminal #5 (LOGIC GROUND). The amplitude of the analog voltage applied to Terminal #9 linearly modulates the duty cycle of the PWM controlled output voltage to the motor windings.

At 100% duty cycle modulation the motor will rotate at maximum speed. If the motor is unloaded, the speed will only be limited by the peak-to-peak voltage applied to the motor, which is a nominal +160 volts for the LC4 and +320 volts for the LC5. If the load upon the motor increases enough to cause excessive current to be drawn, the PWM duty cycle will automatically be reduced to limit the peak current level, causing the speed to fall off.

The Appendix shows several examples of how an external speed control may be provided in the open loop mode.

Before running the motor, pre-select the commutation phase code, set the motor drive direction by using Terminal #7, and disable the Dynamic Brake by applying 0 volts to Terminal #8. Limitations apply for rapid direction changes at rotational speeds above 1000 RPM. See Section 14.0, "Reversing the Motor, 4 Quadrant Operation."

Remember, upon initial power up or after a momentary power loss, the LC4/5 default condition is stop. The start/stop input must be toggled once to start the motor.

To start the control, Terminal #6 must be activated by a +5 volt TTL signal. Now the analog voltage may be increased on Terminal #9. If the motor is wired correctly, it should begin to turn slowly, but smoothly, as the analog voltage increases at Terminal #9. Also wire Terminals #10 and #11 to Terminal #5 (LOGIC GROUND) if the internal closed loop speed control is not to be used. When running in the open loop mode, the signal applied to Terminal #9 proportionally controls the amount of modulation applied to the motor. However, the speed of the motor in the open loop mode will NOT necessarily vary in direct proportion to the voltage applied to Terminal #9.

12.0 Running the Motor With the LC4/5 Control - CLOSED LOOP:

12.1 Set up:

To operate in a closed loop mode the speed is regulated through a means of feedback control. This feedback system will automatically try to compensate for fluctuations in either the motor load or the supply voltage, which would otherwise change the speed.

The built-in closed loop speed control system on the LC4/5 is 2 quadrant only. If the motor speed should overshoot the setpoint or if there is an overriding load, the control will not produce a negative torque on the motor to slow it down. Rather, the LC4/5 will simply stop

sourcing power to the motor until the speed drops. More elaborate 4 quadrant performance may be achieved with the Forward/ Reverse and/or Dynamic Brake functions, however, certain limitations apply. AUTOMOTION does not recommend toggling the Forward/Reverse line while under closed loop control unless the Current Limit pot setting is set midway. (i.e., 8 turns off fully CCW). The built-in closed loop speed control system on the LC4/5 is designed for 2 quadrant velocity loop control only.

The built-in closed loop speed control system on the LC4/5 allows two options for creating a tachometer signal necessary for speed regulation. They are:

1. Hall Signal feedback
2. External encoder feedback

The Hall signal feedback is provided by the motor. It is not as effective as a high resolution encoder at low speeds or where tight speed regulation is required (< +/- 1%). In general, the Hall signal approach is suitable for speeds above 350 RPM.
To select the Hall signal feedback mode, place the jumper in Group 1 in position "A". Place it in position "B" to select the external encoder feedback mode. Speed stability with either approach is influenced by the setting of the Tach Gain pot, the Slew pot, the load, and the total dynamic speed range of the motor.
To control the closed loop speed, the LC4/5 allows two options. They are:

1. Internal speed pots
2. Externally supplied voltage reference

12.2 Use of Internal Speed Pots:

To use the internal speed pots, note the front panel layout in FIGURE 4 or FIGURE 5. There are two on-board pots used for setting the closed loop speed. They are designated "Vel. Set #1" and "Vel. Set #2." With a TTL logic level "0" input on Terminal #10, pot #1 is automatically selected as the primary speed control pot. "Vel. Set #2" is your secondary speed control pot selected by TTL logic level "1" input on Terminal #10. Both pots are 17 turn devices with full CW producing maximum speed. The maximum allowable voltage input on Terminal #10 is +24 volts DC and the minimum voltage input is -0.3 volts DC.

The maximum speed level using pot #2 can never exceed the speed setting for pot #1. These two pots can be used for dual RPM level shifting while under closed loop speed control. Just remember to select the desired pot using Terminal #10 as described above.

12.3 Use of an External Voltage Reference:

To supply an external reference voltage to set the closed loop speed, adjust both pot #1 and pot #2 to their fully CCW positions. These pots are 17 turn types. Use Terminal #11 as the input port for this externally supplied signal. The signal amplitude applied to Terminal #11 should range from 0 to +10 volts for full range control. The maximum voltage should not exceed +12 volts or be less than -0.3 volts. When Terminal #11 is not in use it should be left disconnected or strapped to Terminal #5 (LOGIC GROUND). After the Tach Gain Pot is adjusted, the voltage span to attain full speed may become very narrow. External scaling may be effected through the use of a series resistor with terminal #11.

12.4 Tach Gain and Slew Adjustments:

When using closed loop control, the proper adjustment of the tach gain pot will impact the performance of the motor under changing load conditions. Automotion recommends that, initially, the tach gain pot, which is a 17 turn device, be set approximately halfway. This establishes a moderate tach gain. Higher or lower gain may be needed later, depending upon the desired system response and stiffness. In general, a higher tach gain setting will provide for a lower speed drop as the motor load increases.

If the motor vibrates, or the speed is erratic, the LC4/5 could be in a current limit mode or there could be too much system gain, or poor loop compensation. One possible solution is to adjust the slew pot to reduce the loop response {i.e.,CCW}. If the LC4/5 is in a

current limit mode the "Current Limit" red LED will glow.

The slew pot helps produce a lag in overall loop response when operating under closed loop conditions. This pot should be left in the fully CW position for the fastest loop response. Before operating the LC4/5 under internal closed loop control disconnect any input connection to Terminal #9. It could prevent proper performance of the internal closed loop system. Please refer to Appendices for additional information and suggested wiring connections.

13.0 External PWM Speed Control:

An external digital PWM signal can be used to control the output modulation to the motor. If one is used, AUTOMOTION recommends that the base frequency be no higher than 20 KHz.

To set-up external PWM, place the LC4/5 in the Stop mode. Next, strap Terminal #9 to Terminal #4. Examine FIGURE 4 or FIGURE 5 to locate and place the Group 1 jumper in position "C". The external PWM signal source must be fed into the LC4/5 via Terminal #12. This signal source should be TTL compatible.

The logic inside the LC4/5 is positive true. A logic high level for the PWM signal translates into an ON condition in the output amplifier. The external PWM source will have complete speed control over the motor.
except when the output is in a current limited state. Whenever the motor goes into current limit the output modulation and override the external PWM source.

If the motor goes into a current limit mode, the Current Limit LED on the front panel will glow. The brighter the glow, the higher the peak current draw. Precise speed may be difficult to maintain when operating in a current limit mode.

14.0 Reversing the Motor, 4 Quadrant Operation:

The LC4/5 control permits the reversal of the motor while in motion. However, some discretion is required when under closed loop or operating above the 1000 RPM level. Please refer to Appendix for additional information and suggested wiring connections.

A 4 quadrant drive means the motor and control can produce a negative torque which opposes the direction of shaft rotation. This negative torque is limited by the maximum output current and the torque constant of the motor. This operation is different than dynamic braking since the effects of negative torque by dynamic braking decrease with lower shaft speeds.

Under closed loop control, if the motor is to be subject to direction reversals AUTOMOTION requires that the Current Limit setpoint be reduced. Looking at the front panel find the Current Limit pot. This pot should be adjusted for a halfway position (approximately 8 turns off the fully CCW position).

15.0 Dynamic Braking the Motor:

When it is desirable to dynamically brake the motor, Terminal #8 should be toggled to a TTL logic ``1'' level. The maximum signal amplitude allowed here is +24 volts.

To release the dynamic brake pull Terminal #8 down to LOGIC GROUND potential as found on Terminal #5 or apply a TTL logic ``0'' level signal. Do not take the voltage on Terminal #8 below LOGIC GROUND potential, which is 0 volts.

In order for the dynamic brake to be fully effective, the voltage on Terminal #9 during the braking cycle must be +10 volts DC. Any voltage less than +10 volts DC will begin to diminish the effectiveness of the dynamic brake. This has the benefit in allowing the deceleration rate to be controlled. However, the effect of the brake drops off rapidly with

voltage levels much below +9 volts DC on Terminal #9 during a dynamic brake cycle.

The standard dynamic brake feature can absorb energy at a rate of 10 Watts continuously and 650 Watts intermittently. This translates into a maximum duty cycle rate 2% ON and 98% OFF, or 3 Seconds ON and 150 Seconds (or longer) OFF. If higher rates are required, consult AUTOMOTION.

16.0 Using Soft Start:

The LC4/5 control has a built-in Soft Start feature. This permits the acceleration rate for the motor to be controlled. To locate the Soft Start pot, refer to FIGURE 4 or FIGURE 5. When adjusted to the maximum setting clockwise, the motor will accelerate at the slowest rate. Acceleration at this rate may take 60 seconds or more to reach setpoint speed. When the Soft Start pot is set for the minimum setting (i.e., maximum acceleration) it must be in the fully counter-clockwise position. This pot is a 12 turn device.

The Soft Start feature is useful in accelerating delicate loads up to running speeds. The Soft Start feature is only in effect after the Start/Stop input signal on Terminal #6 is toggled. Once the Soft Start cycle times out, it cannot be repeated until the Start/Stop input is again toggled OFF and back ON.

17.0 Setting the Maximum Current Limited Output:

The Current Limit pot located on the front panel of the LC4/5 (See FIGURE 1) is used to set the maximum current limited delivery from the LC4/5 control. The peak current output will reach a maximum level after approximately 17 full CW turns on the Current Limit pot. The relationship between the actual current limit and the pot setting is linear. When the LC4/5 is in a current limit mode, the ``Current Limit'' red LED will glow. Should the rotor of the motor ever become firmly locked during a run condition, the LC4/5 will automatically shut down after a few seconds and the ``Current Limit'' red LED will glow brightly. To restart the LC4/5, the Start/Stop input must be toggled from OFF to ON.

You can remotely control the trip level of current limit by feeding a digital pulse signal, between 2 and 10 uSec. in duration, into Terminal #14. This signal must be +12 volts in amplitude as referenced to Terminal #5 (LOGIC GROUND). When a +12 volt digital pulse with a fast leading edge is applied to Terminal #14, the LC4/5 will turn off output amperage to the motor until the next cycle begins on the internal 18 KHz PWM oscillator.

This is useful when used in conjunction with the Current Signal Output Option which can be ordered with the LC4/5. The combination of this option and a simple comparator circuit will allow the user to remotely control the current limit setpoint.

18.0 In Case of Trouble:

Should your motor and LC4/5 control not perform properly after following the installation and operation procedures, read through this list of symptoms.

18.1 Symptom 1:

Running the motor in the open loop mode nothing happens (i.e., the rotor does not move at all once power is applied).

* SOLUTION *

Check that only the Green LEDs are lit. If all LEDs are off, check that the AC power supply connections are correct and that 115 volt AC power is applied. Check the fuse.

If the fuse is blown check each output connection for shorts or otherwise improper wiring. If the fuse blows a second time contact AUTOMOTION immediately.

Should any red LEDs be lit, see the LED diagnostics chart for advice. The motor will not run in the open loop speed control mode without a voltage above LOGIC GROUND up to +10 volts being applied to Terminal #9. Try toggling the Start/Stop input port, Terminal #6,

first to 0 volts DC and then to +5 volts DC. Remember that a 0 volt DC signal is required at the Dynamic Brake input port, Terminal #8. Both closed loop speed control pots, Vel. Set #1 and #2, must be set FULLY CCW and the Tach Gain pot must be set FULLY CCW in order to attain full open loop rotor speed. Note that all external logic control signals applied to the LC4/5 must be referenced to Terminal #5 (LOGIC GROUND).

Are the three motor phase output connections connected?

Are all of the LC4/5 wiring connections placed into their respective terminals securely?

Are the front panel connectors snapped into place securely?

Check your three rotor positional sensors for proper electrical connections and check that you have properly selected your sensor signal phase angle. Are the three rotor position sensor signals, designated S1, S2 and S3, of proper amplitude? (i.e., +12 volts DC for a ``1'' state and 0 volts for a ``0'' state. See FIGURE 3). The Appendix contains suggested wiring connections for several popular brushless motor manufacturers.

18.2 Symptom 2:

When running the motor without a load, the operating current seems to be excessive, or the motor vibrates at low RPM. Alternatively, the motor must be hand-turned to start rotation.

* SOLUTION *

Check the position of your commutation sensors located within or upon the motor frame. They must be adjusted for optimum commutation efficiency. Rotate the sensor assembly a few degrees both CW and CCW relative to the stator and again try running the motor. If the current begins to increase or decrease, the sensor assembly may be misaligned. Adjust it accordingly to reduce the unloaded current drawn and improve commutation efficiency.

When the commutation is properly ``NEUTRALIZED,'' the motor will run at the same RPM in both directions while unloaded using a constant speed control signal into Terminal #9.

Has jumper Group 2 (See FIGURE 4 or FIGURE 5) been properly programmed to select either 120 or 60 degree phase shift for the commutation signals?

18.3 Symptom 3:

The rotor jerks erratically back and forth, or the motor vibrates while in motion.

* SOLUTION *

Are motor output phase connections connected and in the correct order? Also perform the same check upon the three rotor positional sensor connections.

Has jumper Group 2 (See FIGURE 4 or FIGURE 5) been properly programmed to select either 120 or 60 degree phase shift for the commutation signals?

Check the dynamic balance of your motor and load.

If you are using internal closed loop speed control, try reducing the slew pot setting or reducing the tach gain setting. See Section 12.4 for details.

18.4 Symptom 4:

When running the motor, the rotor hums and moves very little or not at all.

* SOLUTION *

Check status of all LEDs. If they are all OFF, read symptom #1 carefully or compare status with the LED Diagnostics Chart in FIGURE 8.

Disconnect all power from the LC4/5 control and try to free spin the rotor. Does it bind or

LED Diagnostics Chart

For use in conjunction with Figures 4 and 5.

FIGURE 8

NOTE! See the manual for additional details on each individual condition listed in the chart above.

feel excessively stiff? Investigate for possible motor bearing misalignment or damage.

Is the load which is coupled to the rotor shaft excessive or binding? Check this carefully. Try running the motor without the load.

Are there any commutation dead spots? Monitor the signals from the three rotor positional sensors, designated S1, S2 and S3 one at a time. Use a voltmeter with power applied to the drive then slowly rotate the motor shaft by hand through one complete revolution. Each transition to a ``1'' state should produce a +12 volt DC signal into the appropriate LC4/5 input terminal. Each transition to a ``0'' state should produce a near 0 volt signal into the appropriate LC4/5 input terminal. Contact AUTOMOTION for details. Check solution for Symptom 3.

18.5 Symptom 5:

When the motor begins to accelerate the control shuts down and the motor coasts to a stop. The ``Power/OT Fault'' red LED comes on.

* SOLUTION *

The AC line voltage may be low. Check this carefully.

18.6 Symptom 6:

When attempting to run the motor, the ``Power/OT Fault'' red LED comes on and/or the motor shuts down.

* SOLUTION *

Check your supply line voltage. If it is below 95 volts AC for a LC4; or if it is below 190 VAC for a LC5; the control will shutdown automatically. Check the temperature of the LC4/5 chassis. If it is near or above 50 degrees Celsius (122 degrees Fahrenheit) the control is too hot and will shutdown automatically.

Check for shorts in the motor phase lines - either phase-to-phase or phase-to-ground.

Check your 115 VAC (for a LC4) or 220 VAC (for a LC5) supply line for severe line transients or surges with high peak voltages. It may be necessary to add an external line filter. Contact AUTOMOTION for suggestions.

18.7 Symptom 7:

When dynamically braking the motor, the ``Power/OT Fault'' red LED comes on and the motor shuts down.

* SOLUTION *

The duty cycle of the dynamic brake may be excessive. Reduce the frequency of braking if possible. Otherwise an auxiliary braking resistor may need to be installed. Contact AUTOMOTION for assistance.

18.8 Symptom 8:

The dynamic brake has little effect in slowing the motor.

* SOLUTION *

When the dynamic brake is applied, check the voltage at Terminal #9. This voltage needs to be +10 volts DC. See Section 15.0 for details.

18.9 Symptom 9:

When running motor under closed loop control, the speed is not stable.

* SOLUTION *

Check the ``Current Limit'' red LED. If it is glowing then the motor is drawing enough current while spinning to force the drive into a current limit mode. This can adversely affect speed stability because the motor is being starved for sufficient current to operate. Set the Current Limit pot at its maximum CW limit.

Check the load upon the motor. Is it excessive

or binding? Does the motor shaft spin freely when the external load is removed? The load upon the motor shaft may be excessive and more power may be required than either the LC4/5 or the motor can deliver. Check the solutions for Symptoms 2 and 4.

If the above steps fail to correct the problem, contact AUTOMOTION. **DO NOT** attempt to service the LC4/5 control. To do so will immediately void the warranty and expose the user to hazardous voltages.

19.0 Optional Equipment:

19.1 Current Signal Output Option:

The optional current signal output feature must be configured at the time of purchase and cannot be added in the field. This option produces an analog signal output which is proportional to the delivered amperage through the motor.

The calibration factor for this analog signal is approximately +.05 volts per Amp. There is a built-in offset voltage of approximately +6 volts DC. The amperage signal will ride on top of this offset voltage. Some low pass filtration may be needed for this signal because the drive's 18 KHz chopping rate will cause this signal to have some high frequency ringing upon it. The appropriate time constant for this filter will vary depending upon the application. AUTOMOTION will be pleased to provide application support if needed.

The maximum load impedance on Terminal #13 should be no less than 10K ohm.

Refer to Section 9.0, ``Input/Output Terminal Identification,'' and FIGURE 9 for additional information.

19.2 +/- 10 Volt Analog Control Option:

The LC4/5 may be purchased with an option to permit the user to use an external +/- 10 Volt signal to control the motor velocity. If your drive is equipped with this option, your +/- 10 Volt control signal must be coupled into Terminal #9 on the LC4/5. Please note that Terminal #9 is the open loop input port for the LC4/5. The speed may then be throttled and the direction of rotation controlled by using a singular bipolar analog signal into Terminal #9 when using this option. However, the LC4/5 will NOT regulate speed under varying load conditions when using this option. The user must provide for the closed loop speed regulation in their external system hardware. When the LC4/5 is equipped with this option the following pots are disabled permanently:

VEL. SET #1
VEL SET #2
TACH GAIN
SLEW

This means that the LC4/5's on board 2 quadrant speed control system is non-functional.

To use the LC4/5 when equipped with this option, the absolute amplitude of the applied signal on Terminal #9 controls in direct proportion the amount of applied voltage modulation to the motor. This means 0 Volts translates into approximately 0% PWM output and +/-10 Volts translates into approximately 100% PWM output to the motor.

The level of applied modulation may or may not vary the speed of the motor in a linear fashion. Linearity is a function of a number of factors, such as motor design and motor load. This is why if precise speed control is needed, an external speed regulator system is required.

The input impedance looking into Terminal #9 on the LC4/5 equipped with this option is approximately 5K Ohm. The polarity of the applied signal into Terminal #9 controls the direction of shaft rotation. The relative direction of shaft rotation for positive or negative signal polarity may be programmed into the LC4/5 by the user if a jumper wire is connected between Terminal #7 and either Terminal #4 or Terminal #5. Do NOT ever short Terminals #4 and #5 together.

19.3 External Variable DC Bus Input Option:

The LC4/5 product may be purchased with an option to permit the user to supply a variable DC rail input to the drive. This substitutes for the fixed voltage AC power source normally used as a power supply for the motor rail. This option must be configured at the factory.

It allows the user to supply an external rail of either 15 to 200 volts DC for a LC4 model, or 15 to 400 volts DC for a LC5 model. This is done through a separate 2 pin power connector that is installed when this option is specified. See APPENDIX for details.

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Use of the optional current signal output feature.

FIGURE 9

Suggested method for current loop feedback.

20.0 Custom Features Section:

If your unit included any non-standard, custom features; they would be listed here.

21.0 Warranty:

AUTOMOTION INCORPORATED hereinafter referred to as the ``Company,'' warrants its products for a period of 2 years from date of shipment to be free of defects caused by faulty material or inferior workmanship. The liability of the Company under this warranty extends to the replacement, repair, or issuance of credit, at the Company's option, for any of its products which are returned by the initial Purchaser during such period, provided:

The Company is promptly notified in writing upon discovery of such defects by Purchaser.

The defective product(s) is returned to the Company after the Company has issued a Return Authorization Number, with all return transportation charges prepaid by Purchaser.

The Company's examination of such product(s) shall disclose to its satisfaction that such defects exist and have not been caused by improper installation, neglect, repair, alteration, misapplication, or accident caused by the Purchaser.

Under no circumstances shall the Company be liable for collateral or consequential damages of any nature incurred through the use of our products.

22.0 Life Support Policy:

AUTOMOTION'S PRODUCTS ARE NOT AUTHORIZED FOR USE AS CRITICAL COMPONENTS IN LIFE SUPPORT DEVICES OR SYSTEMS WITHOUT THE EXPRESS WRITTEN APPROVAL OF THE PRESIDENT OF AUTOMOTION INCORPORATED.

As described herein:

Life support devices or systems are devices or systems which, (a) are intended for surgical implant into the body, or (b) support or sustain life, and whose failure to perform, when properly used in when properly used in accordance with instructions for use provided in the User's Manual and in the labeling, can be reasonable expected to result in a significant injury to the user.

A critical component is any component of a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system, or to affect its safety or effectiveness.

23.0 Appendices:

Appendix A:

Suggested method for external logic control interfacing.

NOTES: **Use of the PWM signal input for speed control is optional. If this input is to be used Terminal #9 should be connected to Terminal #4. See the manual for additional details.**

All logic input/output signals on the LC4/5 are electrically isolated from the motor drive output power.

Appendix B:

Use of an external input signal with an external closed loop speed reference signal input.

NOTES: **The input impedance of Terminal #11 is 10K ohm. Therefore, both the low pass filter time constant required to smooth the incoming PWM signal and the peak signal required. A buffer amplifier between the RC filter and Terminal #11 may be needed. The signal source coming into Terminal #11 need not be just from a PWM generator. An analog source may be used directly.**

Check the Group 1 jumper setting if an external encoder signal is to be used. See Section 12.0 for details.

Appendix C:

Motor Phase Commutation Sequence and Input/Output State Tables:

The following tables may be used to understand how the feedback signals from the three rotor positional sensors are decoded and subsequently energize the output phases of the LC4/5 control.

In each table a ``1'' designates a + or ``high'' logic signal level. Conversely, a ``0'' designates a ``low'' logic signal level. For correct signal transition recognition, all + or ``high'' logic signal levels must match, but not exceed, the amplitude of the voltage available on Terminal #4 of the LC4/5 control. AUTOMOTION recommends that the output voltage source available at Terminal #4 be used to power your external rotor positional sensors.

I/O State Table; 60 Electrical Degree Communication Signal Phase Shift:

			Forward Motion		Reverse Motion	
			Current Source	-Current Sink	+Current Source	-Current Sink
S1	S2	S3	Output Enabled	Output Enabled	Output Enabled	Output Enabled
0	0	0	Phase 2	Phase 1	Phase 1	Phase 2
1	0	0	Phase 2	Phase 3	Phase 3	Phase 2
1	1	0	Phase 1	Phase 3	Phase 3	Phase 1
1	1	1	Phase 1	Phase 2	Phase 2	Phase 1
0	1	1	Phase 3	Phase 2	Phase 2	Phase 3
0	0	1	Phase 3	Phase 1	Phase 1	Phase 3

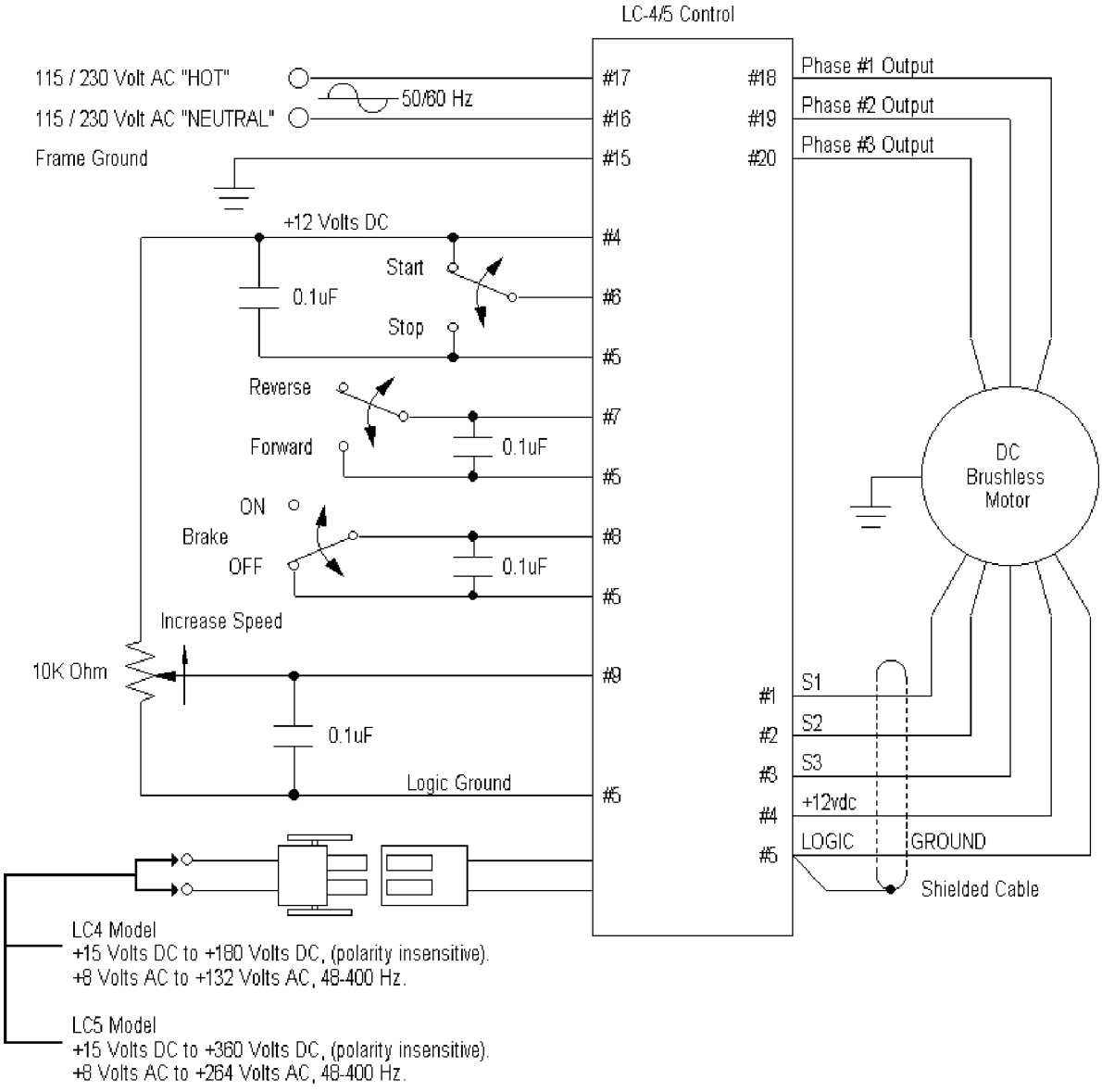
I/O State Table; 120 Electrical Degree Communication Signal Phase Shift Mode:

			Forward Motion		Reverse Motion	
			Current Source	-Current Sink	+Current Source	-Current Sink
S1	S2	S3	Output Enabled	Output Enabled	Output Enabled	Output Enabled
0	0	1	Phase 2	Phase 1	Phase 1	Phase 2
1	0	1	Phase 2	Phase 3	Phase 3	Phase 2
1	0	0	Phase 1	Phase 3	Phase 3	Phase 1
1	1	0	Phase 1	Phase 2	Phase 2	Phase 1
0	1	0	Phase 3	Phase 2	Phase 2	Phase 3
0	1	1	Phase 3	Phase 1	Phase 1	Phase 3

Please Note: The Dynamic Brake input port, when enabled, will activate current sink outputs and disable all current source outputs. By applying a 0 to +10 volt DC analog signal to Terminal #9, the rate of braking may be throttled. See Section 15.0, ``Dynamic Braking the Motor,'' for additional details.

Appendix D:

Basic wiring installation details of LC4/5 with optional DC bus input.



NOTES! **LOGIC GROUND** and chassis ground are **NOT** common with each other and normally are kept separate from each other externally. Also, be aware of restrictions involving the use of the Forward/Reverse at high RPM's. **SEE THE MANUAL FOR ADDITIONAL DETAILS**!!

Shown above is a simple open loop speed control installation.

24.0 Addendum:

TABLE OF CONTENTS

PLEASE NOTE!

Read this manual entirely. Particularly "SAFETY PRECAUTIONS"
BEFORE attempting to use the
LC4/5 Brushless Motor Control.

List of Illustrations

PLEASE NOTE!

Read this manual entirely. Particularly "SAFETY PRECAUTIONS"
BEFORE attempting to use the
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