AMETEK, Inc.

Rotron Technical Products Division

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User's Guide

NUMBER 4930740

Low Voltage Brushless DC Motor/Blower Controllers

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Rev. D

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1.0 Introduction

This User's Guide will provide general information on the use and operation of AMETEK's Brushless DC controllers and their interfaces. Actual motor performance will depend upon the specific controller model, motor characteristics, and the user's application.

AMETEK's Low Voltage Brushless DC Motor/Blower Controller modules are a series of commutation, current limit, and speed control electronics that may be used to power a variety of brushless DC motors and blowers. These controllers are available with a wide range of options and most user-specific applications can be accommodated.

The electronics module utilizes a uni-directional, single quadrant "Speed Control" circuit. Speed control is achieved by converting the frequency of the on pulses from the motor Rotor Position Sensors to an analog DC voltage. This voltage is compared to the User's Input Command (AN/IN) voltage, or the voltage from an internal reference. The compensated error between the actual speed and the AN/IN or reference voltage is used to control the voltage applied to the motor windings in a manner to minimize the speed error. The User's Input Command (AN/IN) or the internal reference voltage directly controls the duty cycle of the pulse-width modulated voltage applied to the motor phases. Protection features include over-temperature sensing and cycle by cycle current limiting.

WARNING: THIS PRODUCT IS NOT NORMALLY OPERATED AT VOLTAGES THAT ARE CONSIDERED TO BE POTENTIALLY DANGEROUS! HOWEVER, AS IN ANY DEVICE USING ELECTRICAL POWER, FAILURE TO OBSERVE APPROPRIATE SAFETY PRECAUTIONS COULD RESULT IN SERIOUS BODILY INJURY, INCLUDING DEATH IN EXTREME CASES.

We recommend that adequate instructions and warnings by the Original Equipment Manufacturer (OEM) include labels clearly stating the precautions necessary for this type of equipment in the application.

WARNING: THESE CONTROLLERS OPERATE ONLY WITH DC VOLTAGE APPLIED AT THE INPUT TERMINALS. AT NO TIME IS AC VOLTAGE TO BE APPLIED TO THE INPUT TERMINALS. DAMAGE TO THE CONTROLLER IS ALMOST GUARANTEED IF THIS IS DONE.

NOTE: Please refer to AMETEK Safety Bulletin number 4930700.

2.0 Electrical Performance Characteristics

DC Power Input:

Models are available for DC inputs of:

12 VDC (-1V +3V), 36 VDC (±4V)
with a maximum current limit of 5 Amperes or 10 Amperes (model dependant).
24 VDC (-3V +4V) for 5 Amp models and
24 VDC (±4) for 10 amp models.

Note: Care should be taken to observe proper supply polarity when connecting power to the unit. Reverse voltage will damage the controller module.

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Speed Adjustment:

User's Analog Input Command Voltage Range: 0 to +5 VDC, maximum.

Internal Speed Set: Internal potentiometer allows manual control of voltage applied to motor.

Analog or Internal: Typical $\pm$ 2% from nominal speed at +25^{O}C.

Connectors:

Motors:

5 and 10 Ampere:

Rotor Position Sensors and User I/O (J4):

Molex P/N 15-42-7012 or equivalent. Molex P/N 22-56-6127 and P/N 16-02-0103, or equivalent, may be used for mating connector housing and terminal.

Phases and Input Power (J1):

Screw terminals EBY Electro Mini-Block P/N EB805/5WG or equivalent.

Blowers:

5 Ampere:

Blower Rotor Position Sensors and Phases (J4):

Molex P/N 70553-0007 or equivalent. Molex P/N 50-57-9408 and P/N 16-02-0103, or equivalent, may be used for mating housing and contact respectively.

Controller Power and Analog Speed Input (J1):

Molex P/N 26-61-5030 or equivalent. Molex P/N 09-50-8033 and P/N 08-52-0113, or equivalent, may be used for mating housing and contact respectively.

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10 Ampere

Blower Rotor Position Sensors and Phases (J4):

Molex P/N 26-61-5080 or equivalent. Molex P/N 09-50-8083 and P/N 08-52-0113, or equivalent, may be used for mating housing and contact respectively.

Controller Power and Analog Speed Input (J1):

Molex P/N 26-61-5030 or equivalent. Molex P/N 09-50-8033 and P/N 08-52-0113, or equivalent, may be used for mating housing and contact respectively.

Ambient Temperature:

Operational: 0^{o}C to $+50^{o}$C Storage: -40^{o}C to $+85^{o}$C

PWM Frequency:

25 kHz

3.0 Installation

Interface:

Please refer to the Controller Hook-up Diagrams in Section 9. The commutation electronics allows for 60^{o} or 120^{o} commutation. See the Commutation Diagram in Section 10 for proper alignment of motor rotor position sensors and motor phases.

Use care when making initial power connections. Application of improper input power polarity or improper connection to the motor phase outputs may result in destruction of the module. Make sure that motor Rotor Position Sensor (Hall Effect) power and signals are properly connected.

Power Input and Output:

EBY Screw Terminal Connector, J1: (5 Ampere and 10 Ampere Motor Controllers)

Pin 1	+V Power Input
Pin 2	Motor Phase B Output
Pin 3	Motor Phase A Output
Pin 4	Motor Phase C Output
Pin 5	Power Ground Input

Molex 3-Pin Header, J1: (5 Ampere and 10 Ampere Blower Controllers)

Pin 1	+V Power
Pin 2	Power Ground Input
Pin 3	Analog Speed Input

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Rotor Position Sensor and User I/O, J4:

Molex Dual Row Connector, J4: (5 Ampere and 10 Ampere Motor Controllers.)

Motor

Pin 1 No connection

Pin 2 +Vreg Output, used to power Rotor Position Sensors (Hall Effect devices), maximum current available is 20 mA.

Pin 3 Rotor Position Sensor H3 Input

Pin 4 Rotor Position Sensor H2 Input

Pin 5 Rotor Position Sensor H1 Input

Pin 6 Ground return for Rotor Position Sensors

User

Pin 7 AN/IN, User's Analog Command Input for external speed or voltage control, 0-5 VDC, input protected against over voltage, input resistance is greater than 100K Ohms

Pin 8 FOUT, digital pulse output corresponding to motor speed, frequency is dependent on the number of motor poles:

FOUT (Hz) = (Motor RPM/20)(Motor Poles)

Pin 9 F/R, forward/reverse, Clockwise/Counter-clockwise input. **Do not change the state of this input while power is applied to the module!** This input may be left open or grounded to pin 12 to determine the direction of rotation of the motor. User interface must be capable of sinking approximately 0.3 mA.

Pin 10 O/E, Output Enable input. Leaving this pin open enables motor rotation; grounding this pin to pin 12 will disable the motor. User interface must be capable of sinking approximately 0.06 mA.

Pin 11 +Vref output, approximately 6.25 VDC for use with user supplied external control potentiometer, see the Controller Block Diagram. Maximum output current available is 10 mA.

Pin 12 Ground return for User I/O signals

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Rotor Position Sensor and Phase Connections, J4: (10 Ampere Blower Controller)

Pin 1	Phase A Connection.
Pin 2	Phase B Connection.
Pin 3	Phase C Connection.
Pin 4	Rotor Position Sensor ground return.
Pin 5	+Vreg Output, used to power Rotor Position Sensors (Hall Effect devices), maximum current available is 20 mA.
Pin 6	Rotor Position Sensor H1 Input.
Pin 7	Rotor Position Sensor H2 Input
Pin 8	Rotor Position Sensor H3 Input

Rotor Position Sensor and Phase Connections, J4: (5 Ampere Blower Controller)

Pin 1	Phase B Connection.
Pin 2	Phase A Connection.
Pin 3	Rotor Position Sensor ground return.
Pin 4	Rotor Position Sensor H1 Input.
Pin 5	Rotor Position Sensor H2 Input
Pin 6	Rotor Position Sensor H3 Input
Pin 7	+Vreg Output, used to power Rotor Position Sensors (Hall Effect devices), maximum current available is 20 mA.
Pin 8	Phase C Connection.

4.0 Operation

Prior to initial application of power, re-check all connections.

Speed Adjustment:

Depending upon the model number ordered and option jumpers set at the factory, various speed adjustment modes are available. The range of control will depend on the motor winding and power supply voltage. The frequency to voltage conversion ratio may be altered as required for specific applications. In general, the module has been designed to operate with specific standard motors offered by AMETEK. The control electronics has a built-in potentiometer that may be used to directly control speed or the user may input an analog voltage to adjust motor speed.

Internal Control:

In this mode, no voltage is required at the Analog Speed-Input pin. The internal potentiometer is connected to the drive electronics and may be used to directly control motor speed over the desired range.

Potentiometer Fully Counter-Clockwise:	Maximum Motor RPM
Potentiometer Fully Clockwise:	Motor Off

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Analog Control:

In this mode, an analog signal between 0 to 5 VDC applied to the Analog Speed-Input pin and is used to control motor speed.

Analog Speed-Input Pin 5 Volts:	Maximum Motor RPM
Analog Speed-Input Pin 0 Volts:	Motor Off

User Commands:

Refer to section 3.0 for available options and function for each controller family.

Initial Power Up

With the Speed Command Input voltage set to minimum, or with the internal potentiometer set fully clockwise, or with the O/E input line tied to Ground (pin 12), apply DC power to the unit. Enable the unit by opening the O/E input, increase the Speed Command Input voltage, or adjust the potentiometer to obtain the desired speed.

Do not change the state of the F/R pin with power applied to the unit. This may cause damage to the module or the motor.

The FOUT pin, model dependent, may be monitored with an oscilloscope to ensure motor rotation. The pulse width of this output will vary from model to model, depending upon the motor and speed range selected.

NOTE: For initial testing, the user may wish to apply power with the O/E input grounded on motor controllers. With the unit disabled, use an oscilloscope to monitor the Rotor Position Sensor inputs while rotating the motor manually to ensure that proper switching of these inputs occurs.

5.0 Detailed Operation

Input DC power is applied to the Power Output Stage and the internal, Low Voltage Supply. The low voltage power source supplies the analog and digital circuits with approximately 15 VDC. The Commutation and Control chip further regulates the 15 VDC to provide a stable reference (Vref) of approximately 6.25 VDC.

The electronics module implements six-step commutation of the brushless DC motor using Hall Effect devices to detect motor rotor position. The Hall Effect information is used to select which MOSFET transistors in the Power Output Stage are turned ON to enable rotation in the desired direction. The Hall Effect signals are also used by a Frequency to Voltage converter to provide motor speed feedback. Motor speed scaling is determined by the controller model number, the motor winding, and the power supply.

The Analog Command Input (AN/IN) may be used to adjust the motor speed. Jumper J6 (10 amp) or Jumper J5 (5 amp) determines whether the Controller uses the AN/IN signal or the internal potentiometer. The speed is set by comparing the error between AN/IN or the internal potentiometer speed command and the actual motor speed. The error between the two is amplified

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and compensated by the Commutation and Control Error Amplifier. The output of this amplifier controls the duty cycle of an internal PWM Modulator which operates at approximately 25 kHz. This frequency ensures good bandwidth and minimum current ripple in the stator. In Voltage Control Mode, the velocity loop is opened and the gain of the compensation amplifier adjusted to allow the AN/IN or internal potentiometer voltage to directly control the PWM duty cycle, thus controlling the average voltage applied to the motor.

A sensing resistor in the lower bus supply line is used to measure current. In Current Limit, the duty cycle of the PWM Modulator is shortened in proportion to the over-current condition and limits the peak current in the motor windings. With proper heat sinking, the controller is capable of operating in Current Limit indefinitely; however, care should be taken that the motor temperature does not exceed its design limits. A Negative Temperature Coefficient (NTC) resistor is mounted on the Power Output Stage heat sink. This device will shut down the Commutation and Control logic if the heat sink temperature exceeds approximately +100°C. The Controller will remain disabled until the heat sink temperature is less than +80°C, then it will automatically restart.

6.0 Application

Controller models that are ordered with AMETEK motors have been compensated to operate with those motors. In selecting the proper amplifier for any motor, several parameters are particularly important.

6.1 Maximum motor phase voltage- There are several Controller Models available for different voltage ranges, see section 1.0 for the voltage ranges. Under no-load conditions, this voltage may be used to determine motor no-load speed.

6.2 PWM Frequency- The Controller has a nominal PWM frequency of 25 kHz. This value, combined with the motor inductance and maximum motor phase voltage, allows the user to calculate the ripple current in the motor.

6.3 Current Limiting- The Controller limits motor peak current to either 5 Amperes or 10 Amperes, depending on the model selected. This limiting feature, combined with the inductance of the motor, the maximum motor voltage, and the PWM frequency, determines the average current (torque) available. The stall or acceleration torque of a given motor is not simply 5 or 10 Amperes multiplied by the motor Kt.

6.4 Speed Control- The Controller implements a very simple PI loop. In applications with AMETEK motors, the loop is set to minimize overshoot based on the motor characteristics. If the user's application involves the addition of high inertial or frictional loads, a custom optimization may be necessary to reduce speed error or response time.

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7.0 Troubleshooting

1) Unit Will Not Start

   a) DC Power not applied;

   b) Connector is mis-wired;

   c) Polarity of User Command Input is reversed;

   d) Motor is stalled, over-current condition exists;

   e) Power Output Stage heat sink temperature still exceeds +100°C due to operating point, ambient temperature, or both.

2) Unit Runs, but Will Not Reach Required Speed

   a) Motor or Controller is undersized for the application;

   b) Internal pot is improperly adjusted;

   d) Excessive friction on motor shaft;

   e) Insufficient voltage at Speed Command Input;

   f) Rotor Position Sensors or Motor Phases not properly connected.

3) Unit Starts, Runs Briefly, then Stops

   Power Output Stage heat sink temperature still exceeds +100°C due to operating point, ambient temperature, or both.

8.0 Model Information

Please contact AMETEK Rotron Technical Products Division for Controller Model information.

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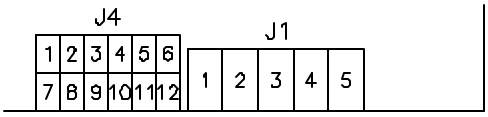
9.0 Hook-up Diagrams

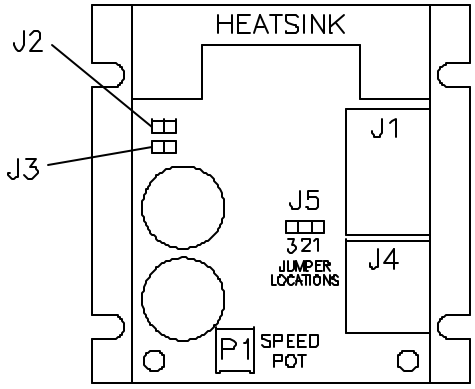
9.1 5 Amp Motor Controller Connection Diagram:



J4−1 NC
J4−2 HALL + (+12V)
J4−3 HALL 3
J4−4 HALL 2
J4−5 HALL 1
J4−6 HALL − (GND)
J4−7 ANALOG SPEED IN
J4−8 FREQ. OUT
J4−9 FORWARD/REVERSE
J4−10 OUT/ENABLE
J4−11 VREF. (6.25V @ 10mA)
J4−12 GND

J1−1 VIN
J1−2 PHASE B
J1−3 PHASE A
J1−4 PHASE C
J1−5 VIN RTN

JUMPER SETTINGS:
J2 ELECTRICAL SPACING
J3 DIRECTION
J5 SPEED COMMAND
1−2 ENABLES SPEED POT.
2−3 ENABLES SPEED INPUT (J4−7)



HOOKUP:

J4-1	NO CONNECTION	J4-7	BLACK	J1-1	RED, +VDC
J4-2	YELLOW	J4-8	VIOLET	J1-2	PHASE B
J4-3	ORANGE	J4-9	WHITE	J1-3	PHASE A
J4-4	RED	J4-10	WHITE/GREEN	J1-4	PHASE C
J4-5	BROWN	J4-11	WHITE/RED	J1-5	BLACK, VIN RETURN
J4-6	GREEN	J4-12	WHITE/BLACK		

JUMPER SETTINGS:

J2 DISABLED FOR 60 DEGREE ELECTRICAL SPACING. ENABLED FOR 120 DEGREE ELECTRICAL SPACING.
J3 DISABLE OR ENABLE TO DETERMINE FORWARD/REVERSE ROTATION.
J5 SET TO POSITION 1-2 FOR INTERNAL SPEED POTENTIOMETER.
SET TO POSITION 2-3 FOR ANALOG SPEED INPUT.

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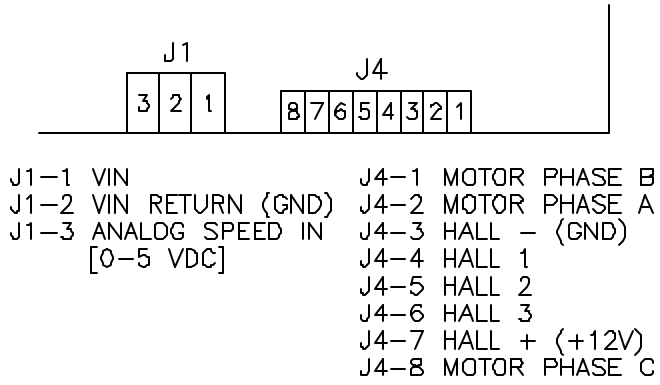
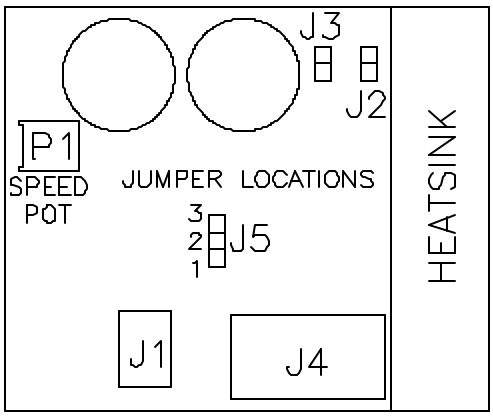
9.2 5 Amp Blower Controller Connection Diagram





Hookup:

J1-1	RED +V	J4-1	Brown
J1-2	BLACK V RTN	J4-2	Red
J1-3	WHITE (Analog in 0-5V)	J4-3	Orange
		J4-4	Yellow
		J4-5	Green
		J4-6	Blue
		J4-7	Violet
		J4-8	Gray

Jumper Settings:

J2 DISABLED FOR 60 DEGREE ELECTRICAL SPACING. ENABLED FOR 120 DEGREE ELECTRICAL SPACING.
J3 DISABLE OR ENABLE TO DETERMINE FORWARD/REVERSE ROTATION.
J5 SET TO POSITION 1-2 FOR INTERNAL SPEED POTENTIOMETER.
SET TO POSITION 2-3 FOR ANALOG SPEED INPUT.

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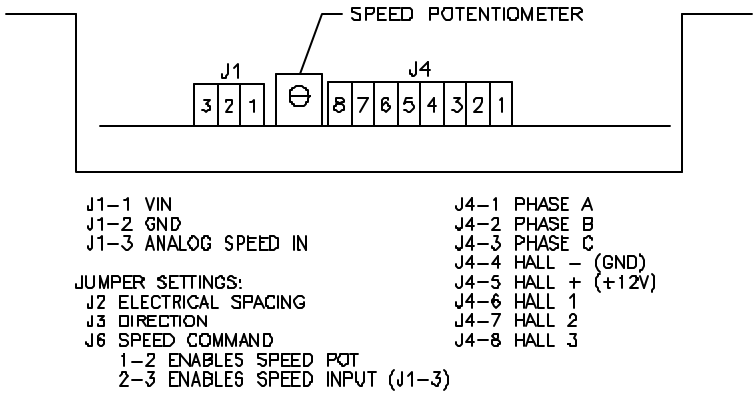
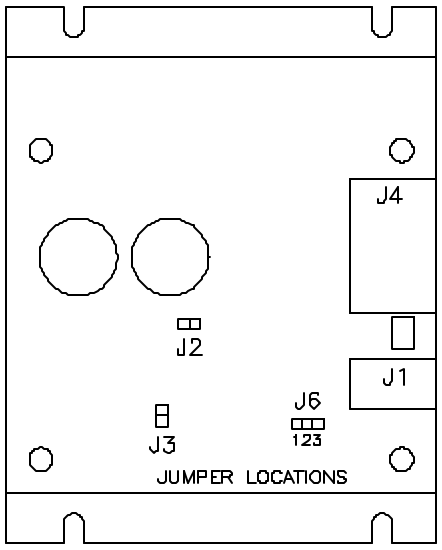
9.3 10 Amp Blower Controller Connection Diagram:





HOOKUP:

J1-1	RED (+V)	J4-1	BROWN
J1-2	BLACK (GND)	J4-2	RED
J1-3	WHITE (ANALOG SPEED IN) [0-5 VDC]	J4-3	ORANGE
		J4-4	YELLOW
		J4-5	GREEN
		J4-6	BLUE
		J4-7	VIOLET
		J4-8	GRAY

JUMPER SETTINGS:

J2 DISABLED FOR 60 DEGREE ELECTRICAL SPACING. ENABLED FOR 120 DEGREE ELECTRICAL SPACING.
J3 DISABLE OR ENABLE TO DETERMINE FORWARD/REVERSE ROTATION.
J6 SET TO POSITION 1-2 FOR INTERNAL SPEED POTENTIOMETER.
SET TO POSITION 2-3 FOR ANALOG SPEED INPUT.

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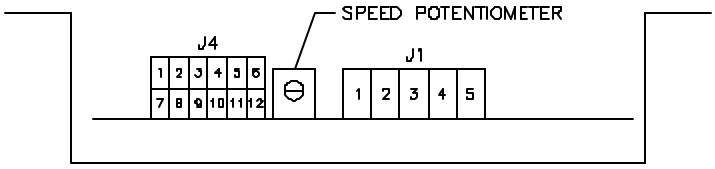
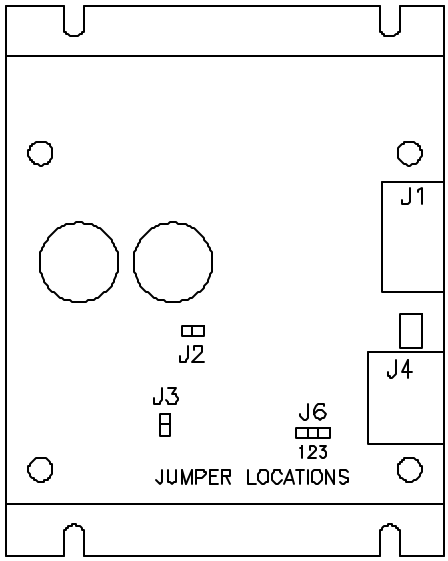
9.4 10 Amp Motor Controller Connection Diagram:



J4–1 NC
J4–2 HALL + (+12V)
J4–3 HALL 3
J4–4 HALL 2
J4–5 HALL 1
J4–6 HALL – (GND)
J4–7 ANALOG SPEED IN
J4–8 FREQ. OUT
J4–9 FORWARD/REVERSE
J4–10 OUT/ENABLE
J4–11 VREF (6.25V @ 10mA)
J4–12 GND

J1–1 VIN
J1–2 PHASE B
J1–3 PHASE A
J1–4 PHASE C
J1–5 VIN RTN (GND)

JUMPER SETTINGS:
J2 ELECTRICAL SPACING
J3 DIRECTION
J6 SPEED COMMAND
1–2 ENABLES SPEED POT.
2–3 ENABLES SPEED INPUT (J4–7)



HOOKUP:

J4-2	VIOLET	J1-1	RED +VDC
J4-3	BLUE	J1-2	PHASE B
J4-4	GREEN	J1-3	PHASE A
J4-5	YELLOW	J1-4	PHASE C
J4-6	ORANGE	J1-5	BLACK VRTN

JUMPER SETTINGS:

J2 DISABLED FOR 60 DEGREE ELECTRICAL SPACING. ENABLED FOR 120 DEGREE ELECTRICAL SPACING.
J3 DISABLE OR ENABLE TO DETERMINE FORWARD/REVERSE ROTATION.
J6 SET TO POSITION 1-2 FOR INTERNAL SPEED POTENTIOMETER.
SET TO POSITION 2-3 FOR ANALOG SPEED INPUT.

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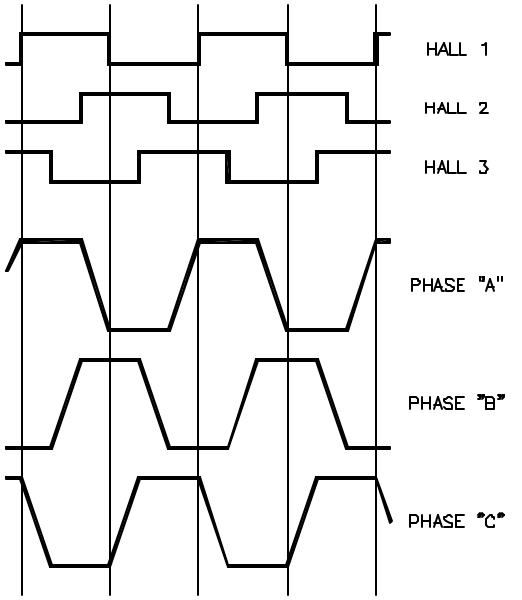
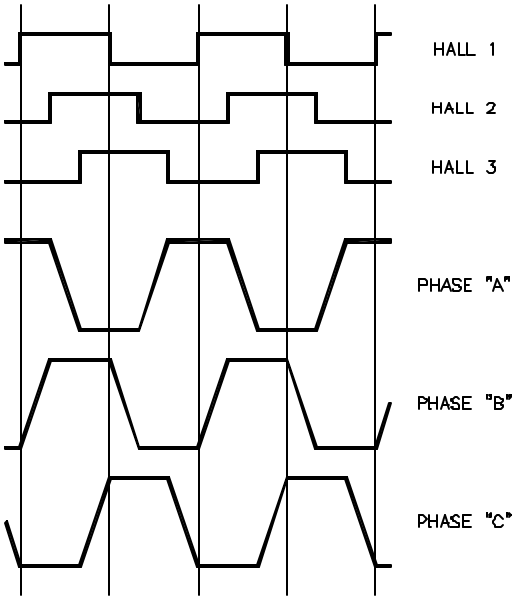
10. Commutation Diagram:



120 DEGREE ELECTRICAL SPACING
6–STEP TRAPEZOIDAL WAVE DRIVE
(WAVEFORMS WITH RESPECT TO GROUND)



60 DEGREE ELECTRICAL SPACING
6–STEP TRAPEZOIDAL WAVE DRIVE
(WAVEFORMS WITH RESPECT TO GROUND)

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