

# The 500 Manual

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## SUMMARY OF WARRANTY AND DISCLAIMER



POWERTEC Industrial Corporation guarantees the Model 500 brushless DC motor control to be free from defects in materials and workmanship for a period of one year from the date of shipment from the factory. If purchased from an authorized distributor or original equipment manufacturer, this warranty is extended to 18 months from the date of shipment from the factory. Upon written notification to the factory of a suspected defect in materials or workmanship, POWERTEC will, at its sole option, repair or replace at the factory the entire unit or such defective parts as it deems necessary to restore the unit to service. Shipping charges to and from the factory are the responsibility of the user.

There is no other warranty, expressed or implied, including the fitness of purpose for the application. This warranty does not cover accidental or intentional damage, accidental or intentional abuse, defective or incorrect installation, effects on other equipment, or situations over which POWERTEC has no control.

This warranty does not encompass any other claims, including, but not limited to, special, incidental, or consequential damages.

This manual has been written as a guide to the use of POWERTEC products. It represents the best efforts to compile the information contained herein. Such mistakes as may appear in no way affect the above stated warranty. If mistakes of fact are found in this manual, please notify your distributor or POWERTEC at once.

## INTRODUCTION



The brushless DC motor and control are not entirely new. They have been used for years in such things as spacecraft, robots, and computers. They have been found to be efficient, reliable, and precise. They have also, in the past, been found to be expensive.

POWERTEC Industrial Corporation was the pioneer in bringing the brushless DC motor economically into the everyday industrial environment. It is made in standard NEMA frame sizes with standard dimensions. This allowed the brushless DC motor to be used in applications where, previously, it had been too expensive to use when it was compared to its more common AC induction and brush-type DC motor brethren.

POWERTEC's brushless DC motor is designed to operate from standard industry power (230 VAC, 380 VAC and 460 VAC, three phase services) instead of lower voltages and single phase power.

Previously, brushless DC motors were limited in frame size. This meant that larger horsepower needed to run at high speed (up to 6000 to 7000 RPM). POWERTEC builds motors at standard speed ratings (500 through 3600 RPM) in much larger frames (42 frame through 508AT).

The 500 series POWERTEC brushless DC motor control is the result of eight years of experience with brushless motors and controls in industry, finding out what is needed and wanted in a brushless DC motors and controls in the industrial market. This experience has been with brushless DC motors ranging from 1 HP to 600 HP. It has been accomplished in a wide array of applications in many different industries.

The POWERTEC brushless DC Model 500 motor control consists of a basic control unit with options. The price of the basic unit has been kept down by keeping optional items optional, rather than trying to build in everything that might be needed. These options are plug-in options. They are easy to connect and use.

All of the speed regulation characteristics and efficiency of the bigger brothers of the 500 series have been retained. With characteristics close to servo type performance, but not quite servo type performance, the POWERTEC brushless DC motor and control far outperform brush-type DC motors and SCR controls and AC motors and inverters. It takes a lot of peripheral equipment to make an AC induction motor system or a brush-type DC motor system perform as well as the standard POWERTEC brushless DC motor and control combination operates all by itself.

## BRUSHLESS MOTOR BENEFITS



The brushless DC motor combines the best features of the AC induction motor and the brush-type DC motor:

A. The brushless DC motor is as rugged and reliable as the AC motor, with the speed control and the torque/speed characteristics that the brush-type DC motor is supposed to have.

B. The brushless DC motor and control have the speed control and constant torque range in the standard package which are only attained at great expense and complexity with conventional DC packages.

C. The efficiency of the brushless DC motor and control far exceeds that of the other motor/control combinations.

D. The brushless DC motor runs much cooler and has fewer parts to wear out, thereby providing longer life and much reduced maintenance requirements.

POWERTEC Industrial Corporation manufactures a line of brushless DC motors for the industrial environment, supplied by standard 230 VAC, 380 VAC, and 460 VAC three phase power, in environments where traditional industrial motors live. Their operation is highly efficient, their maintenance requirements are small, and the cost is less than comparable AC and DC systems which are equal in capability.



# 1.0 DESCRIPTION OF THE BASIC UNIT

## FEATURES

\* The Model 500 Brushless D.C. motor control is a "wireless" unit. All of the inputs and outputs are connected to one of the two printed circuit boards. There is a ribbon cable between the boards. All customer connections EXCEPT power connections are made with removable plugs and terminal strips.

\* All of the power circuits are isolated from the control circuits, and the control circuit common is connected to the chassis (which must be grounded). This arrangement makes interconnection of units easy.

\* The Model 500 has a standard built-in switching regulator for its power supplies. This means that the control may be operated from AC power lines or from a DC power source. The Model 500 will coast through up to 100 milliseconds of primary plant power loss.

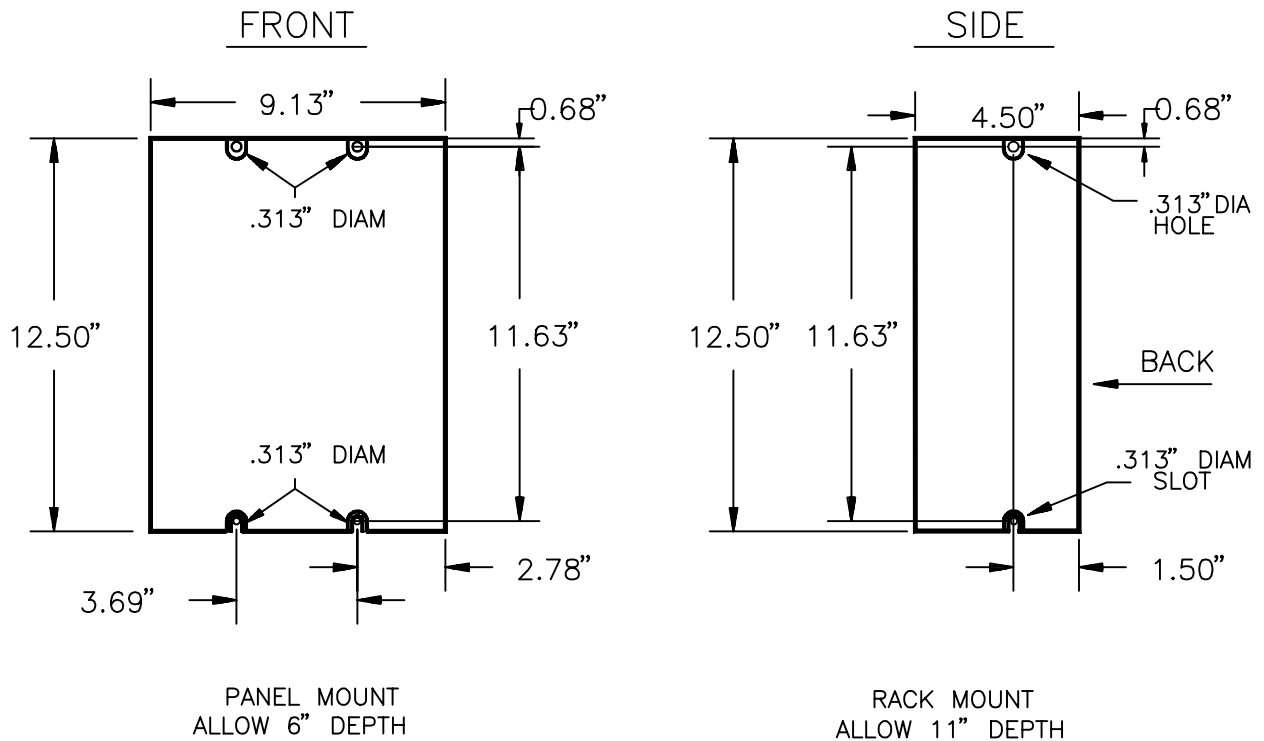
## MOUNTING THE BASIC UNIT

There are two mounting positions for the Model 500:

**PANEL MOUNT** -- The back of the unit mounts flush against a panel or other mounting surface. The plastic cover of the chassis unit opens to the left. Four mounting holes are provided. This method allows the full frontal view of the adjustments and LED's on the board.

**RACK MOUNT** -- The unit mounts with the left side to the mounting surface, with two mounting holes provided. The door opens to the left. This conserves panel space.

CUSTOMER POWER TERMINALS ARE AT TOP OF CHASSIS.



CUSTOMER CONTROL TERMINALS ARE AT BOTTOM OF CHASSIS.

## SERVICE CONDITIONS

*	<b>INPUT VOLTAGE</b>	
	Single phase AC inputs may use any two of the three inputs.	
	DC supplies should be connected to DC bus terminals with appropriate fusing.	
	PJ1 on bottom board installed	
	Up to 1 HP	90 VAC to 140 VAC, 1 phase; or 120VDC to 180VDC
	PJ1 on bottom board removed	
	Up to 2 HP	140 VAC to 250 VAC, 1 phase; or 180VDC to 350VDC
	Up to 3 HP	140 VAC to 250 VAC, 3 phase; or 180VDC to 350VDC
*	<b>INPUT AC FREQUENCY</b>	DC, or 50 to 400 Hertz
*	<b>ALTITUDE</b>	to 3300 feet without derating
*	<b>AMBIENT TEMPERATURE</b>	0°C (32°F) minimum
	(up to 95% humidity)	Chassis -- 55°C (131°F) maximum
	(non-condensing)	Nema1 -- 40°C (104°) maximum

PLEASE NOTE: While the Model 500 will operate with any voltage between 90 VAC and 250 VAC (120 VDC to 320 VDC), the motor must be selected for the available bus voltage.

For voltages less than 230 VAC the maximum speed of a standard motor normally used with a 230 VAC input will be limited. The maximum speed of the motor is the bus voltage divided by the DC voltage of the motor times base speed of the motor. Therefore, if a 190 VAC input is used with a motor rated at 1750 RPM, normally used with a 230 VAC input, the maximum speed will be 265 (the bus voltage available from 190 VAC) divided by 320 VDC (the motor voltage) times 1750 RPM, or 1450 RPM

## APPLICATION DATA

*	<b>ANALOG REFERENCE</b>	
	Linearity (output speed to input reference)	+/- 1.0%
	Speed Regulation (constant reference)	+/- 0.5%
	Speed Drift (referenced to input reference)	+/- 0.5%
*	<b>DIGITAL REFERENCE</b>	
	Linearity (output speed to input frequency)	+/- 0.0%
	Speed Regulation (constant reference)	+/- 0.0%
	Speed Drift (referenced to input frequency)	+/- 0.0%
*	<b>MAXIMUM LOAD</b>	150% for 1 minute
*	<b>SERVICE FACTOR</b>	1.0
*	<b>MAXIMUM MOTOR CURRENT OUTPUT</b>	11 Amperes AC RMS
*	<b>STALL RATING</b>	80% for 1 minute

## STANDARD INPUTS AND OUTPUTS

*	<b>REFERENCE</b>	
	Analog	0 -> +/- 10 VDC, bipolar, with differential input.
	Digital	0 -> 14,000 Hertz maximum
*	<b>PULSE RATE</b>	120 PPR standard with 30 PPR quadrature motor encoder
		60 PPR, 30 PPR, and 12 PPR selectable by DIP switch
*	<b>BUS CONNECTIONS</b>	125VDC to 350VDC (fusing to be supplied by user)
*	<b>DIAGNOSTIC LED's</b>	
	Power	Buss Charged
	Current Limit	Switcher ON
	Regen	Run
		Fault Indicator (7 segment numeric LED)
		Base Drive Indicators (six)

## ADJUSTMENTS

*	ACCEL	0.2 - 60 seconds ramped or 50 milliseconds direct
*	DECEL	0.2 - 60 seconds ramped or 50 milliseconds direct
*	CURRENT LIMIT	
	Motoring	0 -> 150% (adjustment after calibration)
	Regenerative	0 -> 150% (adjustment after calibration)
*	GAIN	30° to 300° full load shaft deflection
*	MAX SPEED	850 -> 14000 RPM (motor dependent)
*	STABILITY	20 to 1 dynamic range

## PLUG-IN OPTIONS

Only ONE option board at a time may be used in each slot

### RIGHT HAND SLOT:

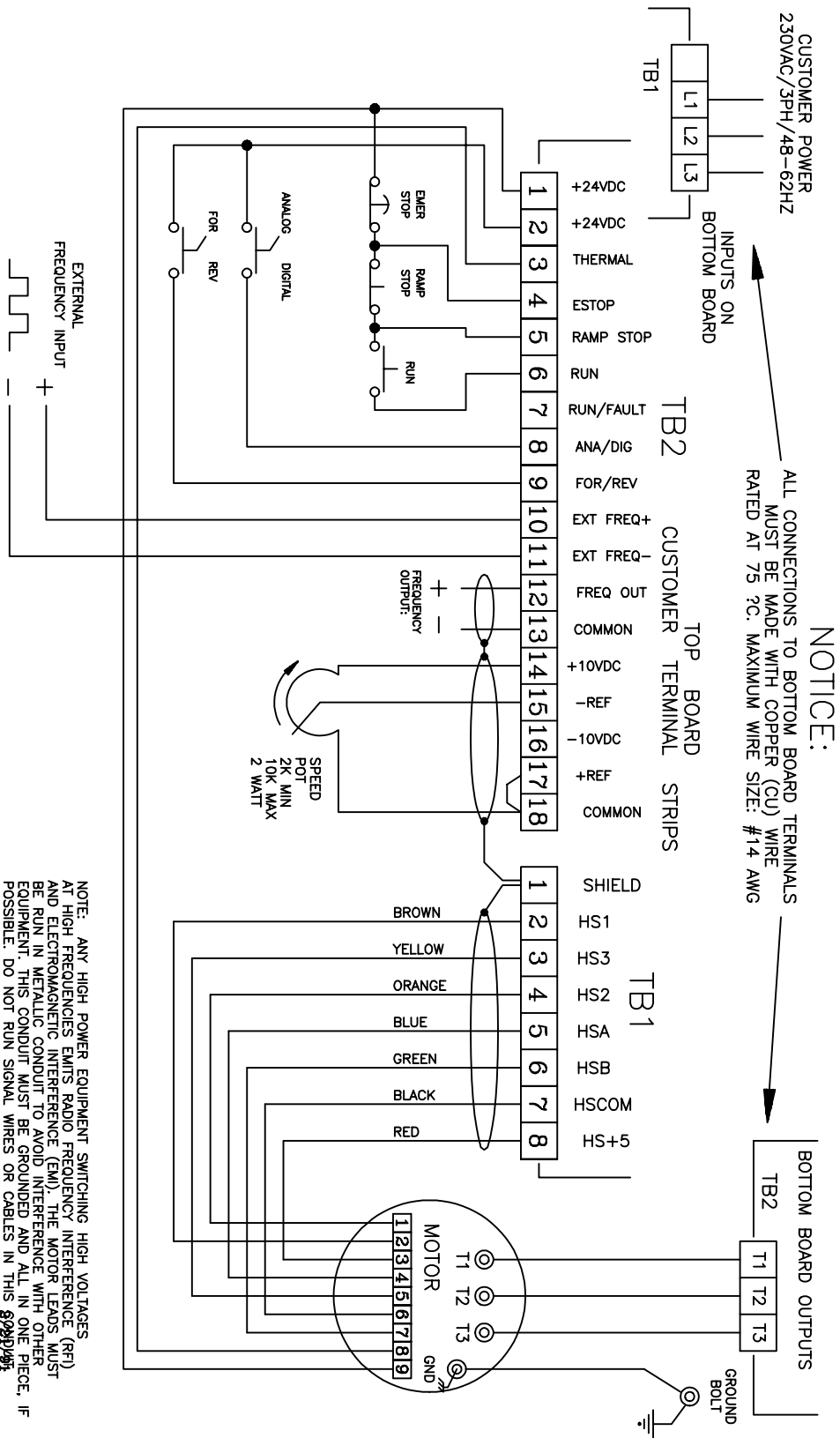
- \* ANALOG INTERFACE 154-007  
Analog speed output (adjustable 0 to 10 VDC, positive, negative, or bi-polar)  
Analog Current output ( 0 to 10 VDC or 0 to 1 milliamp, positive, negative, or bi-polar)
  
- \* SYSTEMS INTERFACE 154-036  
4 to 20 milliamp input  
Analog speed output  
Analog load output  
Torque Limiting or Torque Regulation
  
- \* DANCER INTERFACE 154-060  
Dancer operation with or without PID loop  
Torque Regulation  
Speed control with dancer or load cell trim  
Automatic switching from speed to dancer or load cell control

### LEFT HAND SLOT:

- \* LOGIC EXTENDER 154-008  
Bidirectional Jog function  
Dynamic Braking interlock or Contactor Interlock  
Hold and Ramp to Hold function  
Enable or Zero Speed Output
  
- \* SERVO POWER SUPPLY 154-032  
Supplies power and pulse processing for high count external encoders

### BOTTOM BOARD:

- \* BUS LOADER 154-010  
Plug in bus loader board  
Resistors for separate mounting



NOTE: ANY HIGH POWER EQUIPMENT SWITCHING HIGH VOLTAGES AT HIGH FREQUENCIES EMITS RADIO FREQUENCY INTERFERENCE (RFI) AND ELECTROMAGNETIC INTERFERENCE (EMI). THE MOTOR LEADS MUST BE RUN IN METALLIC CONDUIT TO AVOID INTERFERENCE WITH OTHER EQUIPMENT. THIS CONDUIT MUST BE GROUNDED AND ALL IN ONE PIECE, IF POSSIBLE. DO NOT RUN SIGNAL WIRES OR CABLES IN THIS CONDUIT.

## 2.0 ELECTRICAL INSTALLATION

### POWER SUPPLY OPTIONS

The Model 500 operates on 230 VAC, single phase or three phase, or on 115 VAC single phase. The maximum motor current is 11 amps per phase. The nominal ratings are as follows:

230 VAC three phase input	--	3 HP	maximum with a 320 VDC motor.
230 VAC single phase input	--	2 HP	maximum with a 320 VDC motor.
115 VAC single phase input	--	1 HP	maximum with a 160 VDC motor.
320 VDC DC source input	--	3 HP	maximum with 320 VDC motor.
160 VDC DC source input	--	1.5 HP	maximum with 160 VDC motor.

NOTE: The Model 500 will operate on any voltage from 105 VAC input to 250 VAC, but, for example, if 208 VAC is used for an input, the buss voltage will NOT BE SUFFICIENT to run a 320 VDC motor up to its full speed. Maximum speed (at full load) will be no more than 90%. A 320 VDC motor requires 230 VAC on the input (or 320 VDC input). A 160 VDC motor requires a full 115 VAC input (or a 160 VDC source).

AC input supplies are connected to TB1 on the bottom board. TB1 is a 4 pin heavy duty connector located at the top of the bottom board. There is a ground lug on the chassis located near the input power plug TB1 and the motor power plug TB2 for the power supply ground and motor ground wires.

The left hand pin of TB1 is not used; it is there to identify the plug. Do NOT connect the power supply ground wire ONLY to the left hand pin of the plug TB1. It has no connection on the board.

DC inputs are connected to the 5 pin plug TB3. The center pin is not used, and no connection should be made to it. It is there to separate the voltages of the other pins. There is no connection on the board to the center pin of TB3. Observe the polarity of DC connections to TB3. The positive (+) connections are on the right (as you look at the board), and the negative connections are on the left.

### CONNECTION OF THE MOTOR POWER LEADS AND GROUNDING

The motor power outputs are connected to the bottom board by 3-pin plug TB2. The plug terminals are T1, T2, and T3 from left to right. T1 on TB2 MUST be connected to T1 on the motor, T2 on TB2 MUST be connected to T2 on the motor, and T3 on TB2 MUST be connected to T3 on the motor. If these connections are not made properly, the motor will not run.

In the motor junction box there may be other connections to T1, T2, and T3, depending on how the motor is connected. Do not disconnect any wires connected to T1, T2 and T3 in the motor junction box.

NOTE: THIS IS NOT AN AC MOTOR!  
SWAPPING TWO LEADS OF T1, T2, AND T3 WILL  
NOT REVERSE THE DIRECTION OF THE MOTOR.

To minimize voltage drops in the motor power leads, #14 AWG wire should be used for distances of 100 feet or less, and #12 AWG for longer runs. Using different colors for the motor power leads will help to ensure proper connection (green wire may only be used for the ground connection).

A ground wire must be run from a frame bolt in the motor junction box to the ground bolt on the Model 500 chassis. DO NOT depend on the motor conduit to provide this connection. This ground wire may be #16 AWG for distances of 100 feet or less, and #14 AWG for longer runs. Green insulated wire should be used for this purpose. (NEC and/or local codes may require that the motor be grounded to the frame on which it is mounted. This is in addition to this ground wire to the control.)

## CONNECTION OF THE MOTOR CABLE

The cable to the motor junction box carries the signals from the motor encoder to the Model 500 control. These are low level signals; the cable **MUST BE SHIELDED!** This cable must also be run in a separate conduit from the motor power wires so that the motor power leads do not introduce noise into the cable.

The connections of the cable conductors are given in the table at the right. The colors shown are for Belden Cable Company catalogue #9539 (#24 AWG 9 conductor shielded cable).

As shown in the connection diagram (figure 4), it is not necessary to run the thermal switch connection wires (terminals 8 and 9 in the motor junction box) in the cable. They may be run with regular wire in the same conduit with the motor cable.

If the motor thermal is to be used in a 115 VAC control circuit, the purple and white wires **MUST** be removed from the cable and run outside of the cable (it may be in the same conduit). In that event, a contact must be supplied for TB2 terminals 1 and 3 to indicate when the motor thermal is open, or the drive won't run.

Motor Cable Connections to the Model 500

Control End Connection		Circuit	Color *	Motor End Connection
TB1	1	shield	braided	terminal 10
	2	HS1	brown	terminal 2
	3	HS3	yellow	terminal 5
	4	HS2	orange	terminal 1
	5	HS4	blue	terminal 4
	6	HS5	green	terminal 7
	7	HS COM	black	terminal 6
	8	HS +5VDC	red	terminal 3
TB2	1	thermal	purple	terminal 9
	3	thermal	white	terminal 8

\* standard colors are the colors of Belden Cable Co. cable part number 9539

**DO NOT CONNECT 115 VAC into TB2 terminal 3!**

**DO NOT JUMPER TB2 terminals 1 and 3.** Either connect the motor thermal or a contact controlled by the motor thermal. Bypassing the motor thermal may be hazardous to the motor's health.

The +5 VDC supply on TB1 terminals 8 and 7 is solely for the supply of the encoder. It may not be used to supply any other external devices.

The signals from the encoder on TB1 terminals 2 through 6 are vital to the operation of the control. Attaching anything else to these terminals may load them down or introduce noise which may cause a failure. Therefore attaching anything to terminals 2 through 8 other than the motor cable is prohibited. All shields for the control may be connected to TB1 terminal 1.

## CONTROL CIRCUITS

The Model 500 Brushless DC motor control operates with standard pushbuttons and potentiometers. Control circuit voltages are 48 VDC (+24 VDC to control common and -24 VDC to common). Current in the pushbuttons is less than twenty milliamps.

Control connections are made to TB2 terminals 1 thru 9. All of these connections are less than 30 VDC to ground. Refer to figure 5:

**TERMINALS 1 AND 2: +24 VDC**

There are two +24 VDC connections on TB2 so that too many wires are not required on one terminal. **THE POWER SUPPLIES ON THE MODEL 500 ARE NOT SUFFICIENT TO SUPPORT EXTERNAL DEVICES!** Do NOT connect external relays, peripheral equipment, or other auxiliary devices to the power supplies of the Model 500.

#### TERMINAL 3: MOTOR THERMAL

The motor thermal switch (normally closed), terminals 8 and 9 on the motor terminal strip should be connected to terminals 1 and 3 on TB2. If this connection opens up while running, the control will shut off on a trip function, the motor will coast to a stop, and the thermal fault will show up on the optional fault module.

If not connected, this terminal will measure -24 VDC to common.

This connection must be made for the control to run. DO NOT jumper this connection, or you may run the risk of burning up the motor from overheating.

#### TERMINAL 4: EMERGENCY STOP

This terminal must have +24 VDC (with respect to common) applied for the control to run. If the connection to terminal 4 is opened while running, the control will shut off and the motor will coast to a stop. If there is no connection to terminal 4, it will measure -24 VDC (nominal) to common (or ground).

Normally this connection is made with a momentary normally closed pushbutton (preferably a mechanically maintained open contact) between +24 VDC at terminal 1 (or 2) and terminal 4, as shown in figure 5. A dry relay contact may be used instead. The contact must be closed to run.

#### TERMINAL 5: RAMP STOP

Terminal 5 is the holding contact for the run circuit. It must have +24 VDC applied while running if a momentary contact is used for the START (or RUN) button (terminal 6). If this terminal is opened while running, the control will ramp the motor to zero speed, at the rate set on the ACCEL/DECEL adjustment, then shut off.

If there is no connection to terminal 5, it may measure almost anything while the control is stopped (the terminal is open), or it will measure +24 VDC to common while running.

This connection is normally made with a momentary contact, normally closed pushbutton between terminals 4 and 5. It may be made with a dry relay contact which must remain closed while running if a momentary contact is used for the RUN function. This connection is not necessary if the RUN function is a maintained contact or switch.

#### TERMINAL 6: RUN (or START)

This terminal must be closed to +24 VDC to initiate the run mode. When this contact is made, the control will accelerate to the set speed at the ACCEL/DECEL rate. If terminal 5 is connected to +24 VDC, the control will continue to run after the connection to terminal 6 is opened up. As long as terminal 5 is connected, further closings of terminal 6 will have no effect. If terminal 5 is not connected, the connection to terminal 6 must be maintained while running is desired. When this maintained contact is opened, the control will decelerate to zero speed (at the ACCEL/DECEL rate), and then shut off.

This terminal will measure -24 VDC to common if there is no connection on it and the control is stopped, or it will measure +24 VDC to common while the unit is in operation (whether or not there is a connection on terminal 6). With no connection on terminal 6, a connection on terminal 5 is necessary to maintain run mode.

This connection is usually made with a normally open pushbutton between terminals 5 and 6 (as shown in figure 5). It may be made with a momentary dry relay contact between 5 and 6, or it may be made with a maintained dry relay contact between terminals 4 and 6 if there is no connection on terminal 5 (the so-called "two wire start/stop").

#### TERMINAL 7: RUN or FAULT Output

This terminal is an output for customer usage to indicate a RUN condition (a dry relay contact to common, closed while running), or a FAULT condition (an open-collector transistor to common, transistor on when there is no fault).

Which of these indications is used is determined by the position of the jumper PJ6. If the jumper on PJ6 is on pins 1 and 2, the RUN function is connected to output terminal 7. If jumper PJ6 is on terminals 2 and 3, the transistor collector for the FAULT indication is connected. If there is no jumper PJ6, terminal 7 is open.

DO NOT USE 115 VAC ON TERMINAL 7!

#### TERMINAL 8: ANALOG/DIGITAL

When this terminal is open, it measures -24 VDC to common, and the control speed will be set by the analog speed potentiometer.

When +24 VDC is applied to terminal 8 by a switch, contact or jumper, the control speed is determined by the frequency input at terminals 10 and 11 on TB2.

The control may be switched from analog to digital or from digital to analog at any time, but the switchover is seen as a step function (immediate change) by the control, and the speed change, if any, will take place in current limit.

#### TERMINAL 9: FORWARD/REVERSE

When Jumper PJ4 on the top control board of the Model 500 is in the EXTERNAL position, applying +24 VDC to this previously open terminal causes the control to run in the opposite direction. If the control is running, it will decelerate to zero speed at the ACCEL/DECEL rate, and then accelerate to set speed (analog or digital), at the ACCEL/DECEL rate, in the opposite direction.

When terminal 9 on TB2 is open, and PJ4 is in the EXTERNAL position, it will read zero volts. When it is open and PJ4 is in the INTERNAL position, the terminal is open and it may read anything.

When PJ4 is in the INTERNAL position this terminal has no effect.

## REFERENCE OPTIONS

The speed reference for the Model 500 may be either a digital or an analog signal. If you are going to use a digital speed reference, you must read the MOTOR DIRECTION section to set the motor direction with a pulse train reference.

An analog reference may be derived from one of the built in reference supplies (+10 VDC or -10 VDC), or from an external source capable of supplying 0 to +10 VDC or 0 to -10 VDC for zero speed to full speed operation.

## MOTOR DIRECTION

There is a jumper, PJ4, on the top board which affects the direction of rotation of the motor. It has two positions: EXTERNAL and INTERNAL. The position of this jumper determines the method of selecting motor rotation direction.

When PJ4 is in the EXTERNAL position (left two pins), the direction of rotation is dependent upon the presence or absence of +24 VDC at TB2 terminal 9. This is the better position to use with non-regenerative versions of the Model 500 control.

The connection shown in the diagram on page 8 will give zero speed for 0 volts to full speed for +10 volts. The maximum speed will depend on the set-up of the Model 500. The direction will be determined by the FWD/REV switch if PJ4 is in the EXT position.

When PJ4 is in the INTERNAL position (right two pins), the direction of rotation is dependent upon the polarity of the reference and into which terminal it is introduced. This position is more useful in regenerative versions of the Model 500 control.

As shown in the connection diagram on page 8, the direction of the motor rotation will be clockwise (looking at the shaft end of the motor) if PJ4 on the top board is in the INTERNAL position. In this case, the FWD/REV switch will have no effect.

The table on the next page summarizes some of the combinations possible for directional control with PJ4 in the INTERNAL position. These various combinations allow some flexibility in the case where the Model 500 may need to operate with a reference polarity which cannot be changed. Note that some terminals must be jumpered when they are not used as an input.

## Motor Direction According to Reference Polarity and Input Connections

Speed Pot Connections			PJ4	Motor **	
High End	Wiper	Low End	Position	Direction	Notes
+10 VDC	TB2-15	TB2-18	INT	CCW	jumper TB2 terminals 17 and 18
-10 VDC	TB2-15	TB2-18	INT	CW	jumper TB2 terminals 17 and 18
+10 VDC	TB2-17	TB2-18	INT	CW	jumper TB2 terminals 15 and 18
-10 VDC	TB2-17	TB2-18	INT	CCW	jumper TB2 terminals 15 and 18
-10 VDC	TB2-17	+10 VDC	INT	BOTH	jumper TB2 terminals 15 and 18
+10 VDC	TB2-15	-10 VDC	INT	BOTH	jumper TB2 terminals 17 and 18
external	+ on TB2-15	- on TB2-17	INT	CCW	
external	+ on TB2-17	- on TB2-15	INT	CW	

\*\* Motor direction is based on observation from output shaft end

### MOTOR SPEED -- ANALOG

On the left hand side of the top board, there is a PROGRAMMING switch S1. In normal operation, all of the switches on S1 must be in the OFF position.

In the configuration shown on page 8, the reference is varied from 0 VDC to +10 VDC. Jumper PJ4 should be in the EXTERNAL position so that the FWD/REV switch may be used. The ANALOG/DIGITAL switch should be in the ANALOG POSITION.

Under the above conditions, the MAX SPEED adjustment may be adjusted, for the maximum speed on the nameplate of the motor, from 850 to 3600 RPM. Do not adjust the MAX SPEED for more than the rating on the motor nameplate. Adjusting the motor speed above its rating causes it to lose torque above base speed. NOTE: a cold motor may not reach the speed listed on the motor nameplate under full load. Allow thirty minutes warm up time under load before making the final MAX SPEED adjustment.

Other reference connections are listed in the MOTOR DIRECTION section above.

The output speed at the motor is linear with respect to the input reference voltage. The Model 500 Brushless DC motor control may be started with the speed pot in any position.

When started, the control will accelerate to the speed commanded by the input reference at the rate set on the ACCEL potentiometer if Jumper PJ1 is installed in the RMP position (right two pins) on the top board. When the speed reference is reduced, the motor will decelerate at the DECEL rate. The approximate time adjustment range for the ACCEL and DECEL rates is about 2 to 30 seconds. If PJ1 is installed in the DIR position (the left two pins), the ACCEL and DECEL potentiometers have no effect, and the 500 drive will accelerate and decelerate the motor in current limit.

The analog speed reference may come from an external source which is capable of supplying 1 milliamp at 10 VDC. The external 0 to 10 VDC source may be connected in either positive or negative polarity. This external source must be connected to either the REF+ (terminal 17) and REF- (terminal 15) terminals on TB2. If PJ4 is in the EXTERNAL position, it does not matter which polarity is attached to these terminals. If PJ4 is in the INTERNAL position, the direction of rotation will be determined by the polarity of the external source connection (see Motor Direction section).

THE WIRES CARRYING AN EXTERNAL SPEED REFERENCE SOURCE MUST BE RUN IN SHIELDED, TWISTED PAIR CABLE WITH THE SHIELD CONNECTED TO TB1 TERMINAL 1.

( 4->20 milliamp and other current inputs are available on the optional SYSTEM INTERFACE BOARD.)

The use of external references may introduce problems with ground loops, offsets, and noise. Best results are obtained when the reference source is isolated from power and ground. If the source is grounded on one leg, good results may still be obtained.

A reference source which is NOT ISOLATED FROM ITS AC POWER LINES MAY NOT BE USED. The use of such a supply may result in damage to the Model 500 control because the Model 500 common is connected to ground.

### MOTOR SPEED -- DIGITAL

The motor speed may be commanded by a pulse train injected into the frequency input at terminals 10 and 11 on TB2. To accomplish this, +24 VDC must be applied to terminal 8 on TB2. This may be accomplished with an ANALOG/DIGITAL switch, as shown on page 8, or TB2 terminal 8 may be jumpered to terminal 2 on TB2 if the control is to be run continuously with a digital input.

While terminal 8 is energized, a connected speed pot has no effect. Also, the ACCEL and DECEL adjustments have no effect.

In the standard configuration (all switches of S1 on the top board OFF), the frequency at TB2 must be two times the desired output RPM of the motor, in hertz. The requirements for this input are listed in the table at the right. These are the maximum and minimum requirements only. Optimum operation and reliability may be obtained with a 50% duty cycle, 24VDC square wave.

#### External Pulse Train Requirements

Parameter	Value
Maximum ON state voltage	+30VDC
Minimum ON state voltage	+15 VDC
Maximum OFF state voltage	+1.5 VDC
Minimum OFF state voltage	-30 VDC
Minimum Duty Cycle	10%
Maximum Duty Cycle	90%
Maximum Frequency	8 KHz

The pulse train frequency at terminals 10 and 11 may be continuously maintained, or ramped to or from any speed (including zero).

1. If a frequency is present when the control is started, the motor will accelerate to the commanded speed in current limit.
2. If the control is started with zero frequency present, and the frequency is then injected suddenly, or if the control is started at one frequency and then a new frequency is commanded, the motor will accelerate to the new commanded speed in current limit.

3. If the control is given a ramp stop command or if the frequency is decreased to zero (or if the signal is lost), the motor will decelerate to zero speed.

## OPERATORS STATION PLUG (JP6)

A plug is provided on the top board for connecting an operator's control in the NEMA1 configuration. This plug accommodates connections for Emergency Stop, Ramp Stop, Run, Forward/Reverse, and a Speed Potentiometer. The figure illustrates the connections on this plug. The control voltages and the actions of these connections are the same as for the corresponding connections on the customer connection strip TB2, but there are potential conflicts involved in an attempt to use both the operators terminal plug JP6 and customer connection terminals TB2 at the same time.

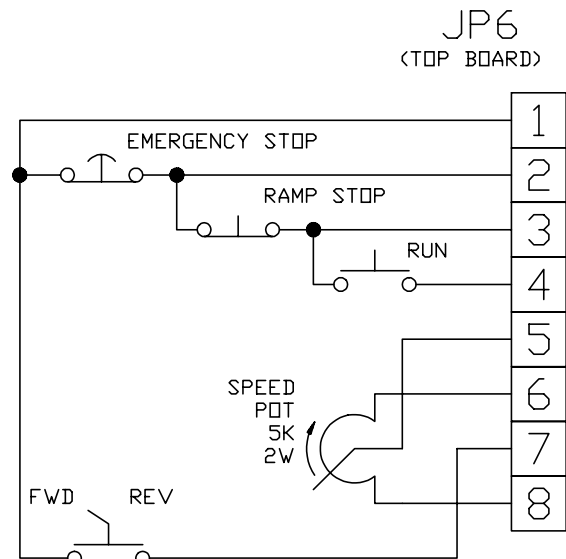
When the JP6 plug is used for an operators station, the connections on the customer connection strip TB2 for the Emergency Stop (terminal 4) and Ramp Stop (terminal 5) pushbuttons **MAY NOT BE USED**. Normally closed pushbuttons on those functions connected to both TB2 and JP6 will be in parallel, and will not have the desired effect.

A Run pushbutton **MAY BE CONNECTED** to TB2 when the operators station is connected to JP6. It will start the control, and will not interfere with the Run button on the operators station.

There is provision on the operator station plug JP6 for a Forward/Reverse switch. If a Forward/Reverse switch is connected to TB2, the switches will conflict with each other if either of them are closed. If both of them are open, then either one will cause the control to reverse direction. If either one is closed, then the other one will have no effect on the motor rotation.

If the speed pot is connected to JP6, a speed pot may not be connected to TB2.

When JP6 is used, auxiliary functions such as the motor thermal switch, Reset, and ANALOG/DIGITAL must still be connected to TB2. The digital frequency must also still be introduced on TB2.

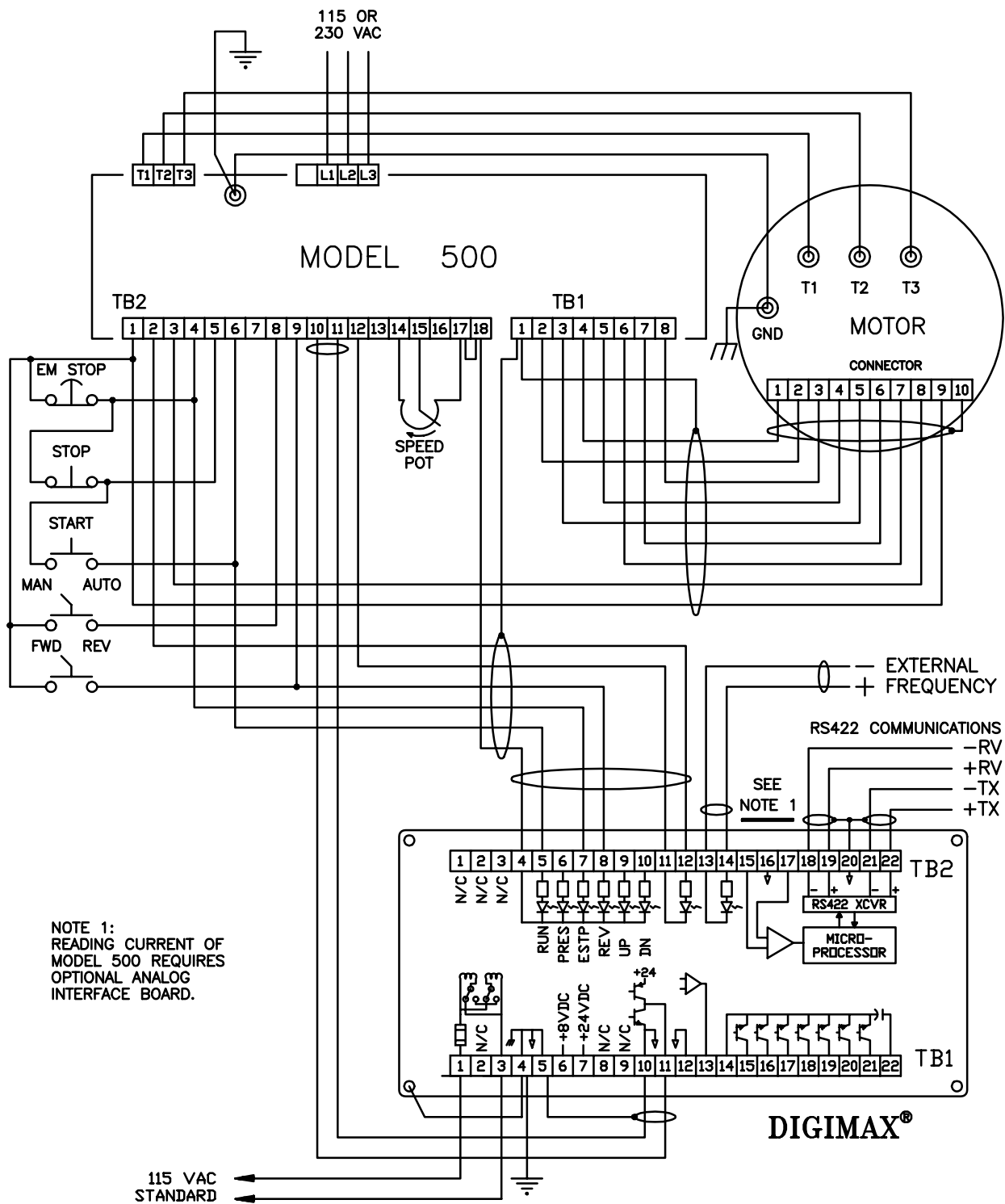


## COMMON BUSS CONSIDERATIONS

Several Model 500's may be operated with their busses in parallel by connecting the positive and negative buss terminals together. This is most commonly done, and it gives the best efficiency, when regenerative controls are tied to other controls which cause the regeneration. Fuses of the KTK type (BUSS Fuse Co. designation for a fast blow fuse) or equivalent fast-blow fuses must be at the input of all but one of these sets of terminals. (Since these fuses are between busses, one unit need not have fuses). The fuses must be rated to interrupt the DC buss voltage. All controls with their busses tied together in this manner must be supplied from the same AC power source.

When the Model 500 is operated from a DC supply, the DC supply **MAY NOT BE** introduced at the input terminals L1, L2, and L3 (the fuses are not sufficient to protect the input when it is DC). The DC supply must be connected to the positive and negative terminals on the bottom board. Fuses (type KTK or equivalent) must be supplied. The fuses must be rated to interrupt the DC supply voltage. Several units may be supplied from the same DC source, but each must have its own fuses. The DC power source must be between 120 VDC and 320 VDC (see the note regarding motor speed in section 2.3).

**NOTE:** When several units are to be operated common buss from an AC source, it is necessary to wire in the L1, L2 and L3 terminals of all of the units so that the front end of one unit is not burdened with the full load of several units.



Connection of the Model 500 to a DIGIMAX

## 3.0 OPERATION OF THE BASIC UNIT

The Model 500 motor control comes in non-regenerative and regenerative models. They are very similar but vary in operational characteristics. In this manual, the basic description which follows generally applies to both units. Where there is a difference in the operation between the non-regenerative and the regenerative models, the differences will appear in bold italic type like this.

### NON-REGENERATIVE VERSUS REGENERATIVE OPERATION

When a motor is running a load in such a way that the motor is drawing current from its power supply, it is said to be **MOTORING**. In the forward direction of motor operation<sup>1</sup>, the motor is operating in the **FORWARD MOTORING** mode. In the reverse direction, when the motor is driving the load (drawing current), it is in the **REVERSE MOTORING** mode. All of the Model 500 motor controls are capable of operating in either of these modes. Electronic reversing by selector switch is built into the control.

If the voltage (CEMF) produced by the rotation of the motor shaft exceeds the available supply voltage, the motor can no longer draw current from the supply. Usually this condition is produced when the motor speed is greater than the speed commanded by the reference, perhaps due to the inertia of the load being greater than the amount of inertia which the can be slowed by the motor in the time allotted.

A moving load will come to a stop by "coasting" in an amount of time determined by the speed, inertia, and friction of the load. The faster a load is moving, the longer it requires to stop. Larger inertias (generally speaking, more mass) take longer to stop, and a higher friction load slows down a load faster. A moving load stops in a coasting situation by dissipating the energy of motion as frictional heat, which acts as a brake. If the amount of inertia is high and the amount of friction is low, the load will take a long time to stop. Mechanical brakes may be used to increase the amount of friction, or the braking force may be supplied by the motor if the control can absorb or dissipate the energy produced.

Non-regenerative motor controls do not have the ability to slow down a load in a time which is less than the motor would normally come to a stop, or slow down to a lower speed, by coasting. It cannot act as a brake, so it shuts off and waits for the speed to drop below the speed commanded by the reference.

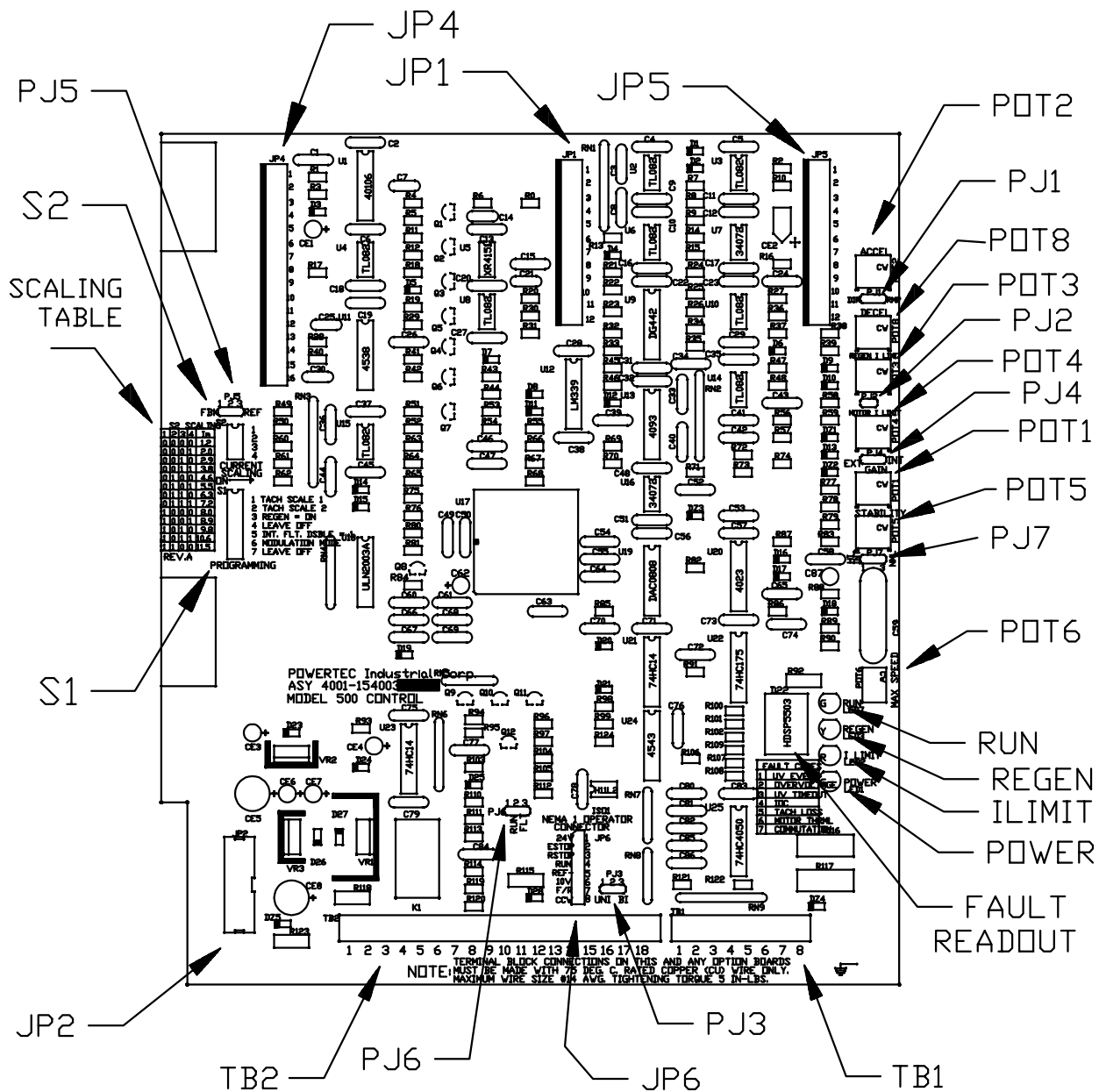
Regenerative motor controls are capable of supplying braking force. A motor which is rotating at a speed which is faster than its controller is commanding becomes a generator. The amount of power generated is proportional to the speed, inertia, and friction of the load and motor, and to the load presented by the controller. These controls will accept current from the motor, and will dissipate the energy recieved.

When this energy is being generated by the motor, and being accepted by the controller, it is said to be **REGENERATING**. In the forward direction, the motor is said to be in the **FORWARD REGENERATING** mode. The same type of operation in the opposite direction is called the **REVERSE REGENERATING** mode.

Regenerative capability gives the motor and control the ability to change from higher speeds to lower speeds (including zero) much more quickly than with other types of controls, resulting in more rapid stops and quick reversals of loads which would otherwise be a lot more sluggish in these actions.

### NOTICE

DO NOT ATTEMPT TO USE A NON-REGENERATIVE MODEL 500 IN ANY REGENERATIVE APPLICATION, AS THE ATTEMPT MAY CAUSE DAMAGE TO THE UNIT. If in doubt as to whether or not your application requires a regenerative motor control, obtain an engineering evaluation.



The Model 500 non-regenerative motor control has an "Application Specific (programmed) Integrated Circuit (ASIC) installed in the L2 socket on the control (top board). Switch S1-3 on the top board should be in the "OFF" position.

The POWERTEC Model 500 Regenerative Brushless DC motor control uses the same ASIC chip to perform the regenerative function. The regenerative option kit is field installable. Switch S1-3 must be in the "ON" position for regenerative operation.

The regenerative control has a BUS LOADER BOARD (part no. 154-010) which plugs into the bottom board, between the top and bottom boards. This board is fastened to the left side wall of the control and has terminals for the connection of the BUS LOADER RESISTOR. The standard buss loader resistor also mounts on the left sidewall of the control.

## JUMPERS

The programming jumpers and switches set up the Model 500 to operate under certain conditions. These changes should be considered according to the necessary operating characteristics of the control in the application. Do not change any jumpers or switches until you have read and understand the effect it will have on the performance of the control. For jumper locations, see the figure on page 18. NOTE: If a jumper is removed, it may be stored by placing the jumper onto one pin without making connection with any other pin.

DO NOT PLACE OR REMOVE JUMPERS WHILE THE CONTROL IS OPERATING!

### BOTTOM BOARD JUMPERS

P1 -- Install for 115 VAC operation. Maximum input voltage with the jumper is 140VAC.  
Remove for 230 VAC operation.

### TOP BOARD JUMPERS

#### PJ1 - DIRECT REFERENCE JUMPER

The ramped reference acceleration and deceleration rates of the Model 500 are normally adjustable from 0.3 to 60 seconds from zero speed to full speed with the ACCEL potentiometer, and from 0.3 to 60 seconds from full speed to zero speed with the DECEL potentiometer. The rate from one set speed to another set speed, or from zero to a speed less than full speed will be a percentage of that time corresponding to the percentage of the change from zero speed to full speed (likewise with a deceleration over less than the full speed range). This requires that the jumper PJ1 be installed in the RMP position (the two right pins on the three-pin PJ1). This will be the most common mode of operation.

Installing the PJ1 jumper in the DIR position (the left two pins) changes the acceleration and deceleration rate of the ramped reference to approximately 50 milliseconds from zero speed to full speed. The motor will then accelerate in current limit, since the control will not be able to supply the necessary power to accelerate at the ramp rate. If an attempt is made to decelerate at that rate, the standard (non-regenerative) control will shut off, allowing the motor to coast to the new, lower speed.

If the jumper on PJ1 is left off entirely, the adjustment range is from 50 millisecond up to about 18 seconds.

The regenerative control will decelerate the motor in REGEN CURRENT LIMIT to the new set speed (to zero, if that is the new set speed). Adequate buss loader power must be provided to dissipate the power of the deceleration.

The purpose of installing PJ1 is to shorten the delay in the acceleration/deceleration circuit to be able to follow an input signal from another source, or to have very quick changes in speed.

#### PJ2 - REGENERATIVE CURRENT DISABLE

Jumper PJ2 should be installed on non-regenerative controls. It has no effect on the operation of the board in the non-regenerative model.

On regenerative controls PJ2 should not be installed, unless it is desired to limit the regenerative current to a very low value.

#### PJ3 - OPERATORS STATION SPEED POT FUNCTION

If an OPERATORS STATION is not connected to JP6, PJ3 has no effect on the operation of the system.

On non-regenerative controls, PJ3 must be in the UNI-directional position (the left two of the three pins as you look at the board). The speed pot connected to plug JP6 will provide a reference of 0 VDC at the counter-clockwise position, +5 VDC at 50% setting, and +10 VDC when the pot is in the clockwise position.

PJ3 gives the regenerative drive a bi-directional speed command on the OPERATORS STATION POT (JP6) only. If the jumper is in the UNI position (the left two of the three pins), the speed pot will operate as in the non-regenerative control. If the jumper PJ3 is moved to the right two pins (BI-directional position), the speed pot will give a -10 VDC reference when it is counterclockwise, 0 when the pot is in the middle (50% of rotation), and +10 VDC when the pot is in the clockwise position. In order for the bi-directional speed pot command, the MOTOR DIRECTION jumper PJ4 must be in the INT position.

If PJ3 is left off completely, a speed pot connected to JP6 will not function as a speed pot, although it may give some speed variation between 80% and 100% in the resulting rheostat configuration.

PJ3 does not affect a speed pot connected to customer terminal board TB2.

#### PJ4 - MOTOR DIRECTION JUMPER

In the non-regenerative control, PJ4 should be in the EXT position so that an external switch may be used to determine the motor direction.

In the regenerative control, PJ4 may be left in the EXT position, and the motor direction will be selected by an external switch. If PJ4 is placed in the INT position, the motor direction will be determined by the polarity of the speed reference. For more detail, see MOTOR DIRECTION section.

If the jumper PJ4 is taken out completely, the motor will run in the forward direction only in either the regenerative or non-regenerative control. The switch will have no effect and neither will the polarity of the reference signal.

#### PJ5 - OUTPUT FREQUENCY SOURCE JUMPER

The pulse train output at TB2 terminals 12 (+) and 13 (-) is representative of the speed of the motor. PJ5 determines the source of the pulse train output - whether it comes from the speed at which the motor is commanded to run, or from the actual speed at which the motor is running.

If the jumper PJ5 is in the FDBK position (the left two pins), the pulse train comes from the motor encoder (after being processed by the ASIC). This position has the advantage that the actual motor speed is being looked at, so that, if the motor should current limit and slow down, the pulse train output will reflect that fact.

If the jumper is in the REF position (the right two pins), the pulse train comes from the pulse train which is commanding the motor speed. This position has the advantage that the pulse train output reflects what the motor should be doing, and will, under all normal circumstances.

If the jumper is left off, there will be no output at TB2 terminals 12 and 13.

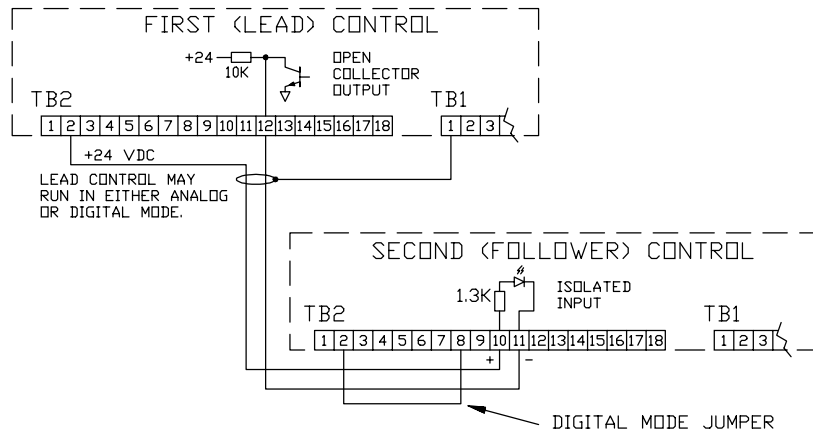
Sometimes, it is desired to have one drive exactly follow the speed of another. This is accomplished in the Model 500 by taking the output frequency of the first drive (see the drawing on page 21), and feeding as a digital speed reference into the second drive. The first drive may operate in analog or digital mode, but the second drive must operate in digital mode.

There may be very slight timing differences in the commanded speed and the actual speed. These differences will most often show up during times of transition, i.e., during acceleration and deceleration, or during load changes. Many of these differences occur due to the storage of pulses in the UP/DOWN counter in the speed loop, necessary to develop the torque in the motor. If the pulse train comes from the actual motor speed, there may be a slight delay in the second motor starting, depending on load and other factors. The motors can be made to start and run more closely together if they both receive the same pulse train.

The output at terminal 12 is the collector of a transistor whose emitter is connected to terminal 13. There is a 10 kilohm pull-up resistor between terminal 12 and the +24 VDC supply.

The output pulse train frequency at TB2 terminals 12 and 13 is the same as the pulse train frequency required at TB2 terminals 10(+) and 11(-) as a speed command in digital mode, which is also the equivalent frequency produced by the VCO in analog mode.

The required frequency is determined by the settings of the switches S1-1 and S1-2. Pulses coming back from the motor encoder channels HS4 and HS5 do so at a rate of 30 pulses per revolution in the two quadrature channels. The settings of SW1-1 and SW1-2 determine whether this 30 PPR pulse rate is multiplied by 4, multiplied by 2, multiplied by 1, or ignored in favor of using the commutation channels for speed feedback.



### PJ6 - RUN OR FAULT OUTPUT SIGNAL JUMPER

Jumper JP6 is used to make a selection of the output at TB2 terminal 7. Connections on TB2 terminal 7 are limited to a maximum of 30 VDC at a maximum of 50 mA.

If the jumper is in the RUN position (the left two pins), TB2 terminal 7 is connected to a RUN relay contact. When the RUN relay is closed (+24 VDC at TB2 terminal 6, or +24 VDC at terminal 5 after terminal 6 has been energized and the RUN hold circuit is active), the relay contact connects TB2 terminal 7 to the drive common. When the RUN relay opens, the contact opens.

If the jumper on PJ6 is in the FLT position (the right two pins), TB2 terminal 7 is connected to the collector of a transistor whose emitter is connected to drive common. This transistor is ON while there is no fault in the drive. When a fault occurs the transistor shuts off. Starting the drive resets the fault.

If the PJ6 jumper is missing, there is no output at TB2 terminal 7.

### PJ7 - NORMAL OR HIGH INERTIA JUMPER

The presence of a high inertial load on the shaft of the motor may require a different dynamic response from the drive. Jumper PJ7 can add additional compensation for inertial loads higher than about 15 times the inertia of the motor.

If PJ7 is in the NML position (right two pins), the normal response circuits are selected.

If PJ7 is in the HI INT position (left two pins), additional lead response is added to the speed loop.

If PJ7 is missing, the circuit acts as if it is in the NML position.

## SWITCHES

There are two groups of switches on the Control Board of the Model 500. These switches alter the parameters of the drive for particular situations.

Switch group S1 has 7 switches which program the ASIC chip.

Switch group S2 calibrates the current feedback.

### SWITCH GROUP S1

Switches 1 and 2 (top 2 switches): PULSE MULTIPLIER

These two switches, marked TACH SCALE 1 and TACH SCALE 2, program the ASIC for the number of motor pulses used for feedback by the chip.

The number of pulses used determines the speed of the motor. The normal pulse feedback from the POWERTEC brushless DC motor comes from the encoder on the back of the motor. The motor speed encoder normally produces 30 pulses per revolution in each of two channels in quadrature (i.e., 90 degrees out of phase with each other). By reading the two pulse trains in different ways, different feedback rates are produced.

The normal mode of operation for 140 frame motors is 4X. This produces pulses at the rate of 120 pulses per revolution. If you set up MAX SPEED to operate a motor at 1750 RPM with the switches S1-1 and S1-2 in the "OFF" position, 120 PPR will be the feedback rate, and 120 PPR will be output at terminal 12 at TB2. If switch S1-2 is then turned "ON" (the motor must be stopped and the drive off when the switch is moved), the motor will then run at 3600 RPM IF IT IS DESIGNED TO DO SO. If it is not, it will not reach the top speed.

A standard 1750 RPM motor in these circumstances will increase in speed to about 1900 to 2500 RPM (depending on the load), and level off due to a condition called "running up against the buss". In this condition, the motor will be going as fast as it can go, and the speed will drift due to voltage, load, and other variations. The CURRENT LIMIT light will be on, but the motor will not be drawing a lot of current (unless there is a heavy load).

If the motor above is running at 3500 under the 2X condition, and the 1X condition is implemented (switch S1-1 is turned "ON" in addition to S1-2), the motor will increase to a top speed of 7200 RPM if it is designed to be able to do so.

The COMM position (switch S1-1 "ON" and S1-2 "OFF") is intended for test purposes and temporary service only. It is a very low gain operation which will reach top speed very rapidly.

#### Switch 3: REGEN MODE

This switch is turned on to implement the REGEN mode. In the non-regen model, it should be off.

In the regenerative model, the switch must be in the "ON" position. If switch S1-3 is off, the regenerative drive will run in a non-regenerative mode of operation.

#### Switch 4: POLES

Switch S1-4 must be in the OFF position unless the motor is specifically labeled telling you to turn it on (2-pole motors). THIS INSTRUCTION WILL COME WITH THE MOTOR! Turning this switch on with a 4-pole will have erratic, and possibly damaging effects.

#### Switch 5: DISABLE INTERNAL FAULTS

This switch is used for troubleshooting. It is shipped in the ON position. Do not turn off unless instructed to do so.

#### Switch 6: MODE SELECT

When this switch is turned on, better low speed performance may be obtained through PWM control on all of the output transistors, rather than three.

When running at low speeds, finer control is required than at high speed. Better control is obtained by PWM modulating all of the output transistors instead of just the three on the negative side, as is normally the case in non-regen and standard regen drives. The cost of this better control at low speed is a slightly reduced efficiency and more motor heating (about 10% more).

#### Switch 7: TEST INTERRUPTS

This switch is used for factory testing. Leave it off at all times.

#### How S1-1 and S1-2 Affect Motor Feedback

S1-1	S1-2	MULT	PPS @ 1750 RPM	MAXIMUM RPM *
OFF	OFF	X 4	3500	4000
OFF	ON	X 2	1750	8000
ON	ON	X 1	875	12000
ON	OFF	COMM	350	***

\* These RPM's require motors designed for these speeds.

\*\*\* Test mode and temporary duty only

## SWITCH GROUP S2

### Switch Settings for 320VDC TENV Motors

HP	Base Speed	Motor Frame	Rated Amps	AC 1ph Amps	AC 3ph Amps	Settings on Switch S2			
1/2	1750	143T	1.9	2.5	1.6	0	0	0	1
1/2	1150	143T	2	2.6	1.7	0	0	0	1
1/2	850	143T	2.2	2.7	1.9	0	0	0	1
3/4	1750	143T	2.9	3.7	2.3	0	0	1	0
3/4	1150	143T	3	3.7	2.4	0	0	1	0
3/4	850	145T	3.3	3.8	2.6	0	0	1	1
1	3600	143T	4.1	5.1	3.1	0	0	1	1
1	2500	143T	3.8	4.9	3	0	0	1	1
1	1750	143T	3.8	4.9	3	0	0	1	1
1	1150	145T	4	5	3	0	0	1	1
1	850	145T	4.4	5.6	3.3	0	1	0	0
1.5	3600	143T	5.6	7	4.2	0	1	0	1
1.5	2500	143T	5.6	7	4.2	0	1	0	1
1.5	1750	145T	5.7	7.1	4.3	0	1	0	1
1.5	1150	145T	6	7.4	4.5	0	1	0	1
1.5	850	L145T	6.5	8.1	4.9	0	1	1	0
2	3600	143T	7.4	9.3	6.4	1	0	0	0
2	2500	145T	7.5	9.3	6.5	1	0	0	0
2	1750	145T	7.5	9.3	6.5	1	0	0	0
2	1150	L145T	7.6	9.4	6.7	1	0	0	0
3	3600	145T	11	13.8	8.3	1	1	0	0
3	2500	145T	11	13.8	8.3	1	1	0	0
3	1750	L145T	11	13.8	8.3	1	1	0	0

NOTE: 1 = ON 0 = OFF

Switch Group S2 is used to calibrate the Model 500 to the motor. The settings of these switches are very important to the proper functioning of the motor and control.

**NOTE: MAKE CHANGES ON S2 ONLY WHILE THE MODEL 500 IS NOT IN THE RUN MODE!**

Setting the switches too low may result in unnecessary trips and/or current limiting of the motor control, resulting in poor performance.

Setting the switches too high may result in damage to the motor!

The table on the left is a list of the more common motors used with the Model 500 and the switch settings used for those motors. If you have a motor which is not on the list, or a 160 VDC motor, set the switches according to the rated current of the motor. (Pick a motor with the same rated current.)

Note that some low RPM ratings of 1 1/2, 2 and 3 horsepower motors may not be used on the Model 500. The maximum current rating of the Model 500 is 11 amps RMS. If a larger motor is used, it will be limited to that amount of current, even if all the switches on S2 are turned on.

## ADJUSTMENTS

There are no adjustments on the bottom board of the Model 500.

The adjustments on the Model 500 control are customer adjustments which allow some of the characteristics to be modified for individual situations. These adjustments are limited in their effect so that they cannot BY THEMSELVES cause a serious problem with the control, but there is a possibility that a combination of adjustments and conditions existing in the application may cause problems with tripping or a failure to operate as expected.

### ACCEL RATE -- POT 2

The ACCEL potentiometer on the Model 500 sets the acceleration rate. The accel rate is linear and does not interact with the decel rate.

The ACCEL rate is adjustable from about 0.3 to 60 seconds from zero speed to full speed. If jumper PJ1 is installed in the left hand (DIR) position, the ACCEL pot will have no effect. Acceleration time is then about 50 milliseconds to full speed.

The ACCEL pot has no effect in DIGITAL MODE.

### DECEL RATE -- POT 8

The DECEL potentiometer on the Model 500 sets the deceleration rate. The decel rate is linear and does not interact with the accel rate.

The DECEL rate is adjustable from about 0.3 to 60 seconds from full speed to zero speed. If jumper PJ1 is installed in the left hand (DIR) position, the DECEL pot will have no effect. Deceleration time is then about 50 milliseconds from full speed to zero speed.

The DECEL pot has no effect in DIGITAL MODE.

The ACCEL rate sets the amount of time it takes to go from one speed to another. The normal specification in terms of time is from zero speed to full speed. This specification is the time it takes the controller to go from one extreme to the other. The motor and load may impose other action which is quite different.

The actual acceleration rate may be limited by current limit if the combination of the load and acceleration rate need more power than is available.

The actual deceleration rate is dependent upon the coast time of the motor. If you shut off the control while the motor is running, it will take a certain amount of time for the motor and load to come to rest. As a rule, that amount of time cannot be made shorter with a non-regenerative motor control. Setting a shorter decel time will only allow the control to shut off and the motor will then coast to a stop anyway. To be effective, the time set on the DECEL pot of a non-regenerative control must be longer than the coast time.

A regenerative control will accelerate in the same way that a non-regenerative control will. The regenerative control's acceleration rate may also be limited by current limit.

The deceleration rate, however, may be shorter than the coast time. If the decel time is shorter than the coast time, the motor will regenerate power to the drive, which will dissipate it in the regen resistors to force the motor, and thus the load, down in speed. The amount of braking available will be limited by REGEN current limit.

### REGEN I LIMIT -- POT 3

The REGEN I LIMIT pot on a non-regenerative Model 500 will have no effect on the operation of the unit.

The REGEN I LIMIT pot on the regenerative control sets the amount of current limit in the regenerative mode of operation. This may vary from 0% current of the control to 150% of motor current when properly calibrated to the motor being operated. This adjustment works in conjunction with switch S2 and the jumper PJ2.

#### MOTOR I LIMIT -- POT 4

The MOTOR I LIMIT pot on the Model 500 limits the amount of current which may be supplied to the motor. It is adjustable from 0% to 150% of the amount of current set up by the calibration switch S2.

#### STABILITY -- POT 5

Adjust the STABILITY pot to stabilize the speed of the motor when operating on light loads or high inertia loads, or loads which have varying load cycles. Turning the STABILITY pot CCW makes the drive more responsive, while turning the pot clockwise makes the drive more sluggish.

#### GAIN -- POT 1

The GAIN pot will affect the number of pulses it takes to reach current limit. If it is set low (CCW), it takes about 90 accumulated pulses (about 300° of motor shaft rotation) to build up to 150% output current with the current limit potentiometer set to maximum. It therefore takes a larger number of reference pulses to produce a given amount of current in the motor. This may show up as a hesitation in starting or upon speed changes, when compared to another brushless DC motor.

For single motor applications, this pot may be set fully CCW. Overall speed regulation will not be affected. Once the necessary number of pulses have been accumulated for the current level required, the motor must match the speed reference pulse for pulse. No further pulses may accumulate. There is very little to "gain" in most single motor applications by setting the GAIN pot to a higher level. The effect of setting the GAIN too high in single motor is a very stiff shaft, which may appear to be jittery, or stepping at low speed with a varying load. This effect will be most noticeable at GAIN settings higher than 50% of the pot rotation.

In multi-motor applications (especially with a frequency input), a high gain will give excellent tracking between motors. When the GAIN is set to 100% CW, no more than 20 pulses will accumulate (about 60° of motor shaft rotation). It is only in the most critical tracking applications that the maximum GAIN setting will be required. The STABILITY pot setting becomes more critical as the GAIN setting is increased.

#### MAX SPEED -- POT 6

This 10-turn pot adjusts the output pulse rate from the Voltage Controlled Oscillator (VCO) used in the analog section of the Model 500. This max speed adjustment is a calibration to the input reference level; it is not an absolute speed limit.

The Model 500 is a digital drive, but most people use drives of its size with potentiometers or external voltages for speed reference. In order to interface the drive with the motor, we must generate a pulse train which is compatible with the pulse train coming back from the motor. The pulse train coming from the motor's encoder is 30 PPR in two channels, in quadrature.

The Model 500 can be programmed to read the feedback as 4 times the base rate of 30 PPR, as 2 times the base rate, at the base rate, or to temporarily, at least, look at the commutation channels at 0.4 times the base 30 PPR rate. The major difference is accuracy and low speed performance. The standard Model 500 is set up to read the feedback as 4 times the base rate, or 120 Pulses per Revolution of the motor. This means that the pulse train frequency used for feedback on a 1750 RPM motor will be 1750 RPM times 120 PPR divided by 60 seconds per minute, or 3500 hertz. To make the motor run at 1750 RPM, the VCO must generate a 3.5 kilohertz pulse train. (the external frequency, when used, must do the same, but that is not affected by the MAX SPEED adjustment).

The VCO is adjustable from about 1700 hertz to about 8000 hertz when a 10 VDC reference signal is applied. This means that the motor speed can be adjusted for about 850 RPM to about 3500 RPM when S1-1 and S1-2 are programmed for the 4X position (both switches off).

If this pot is turned up too high (CW), the Model 500 will be generating a frequency higher than the motor can return at its own highest speed, which is limited by CEMF. This condition is known as "being up against the bus". A MOTOR I LIMIT indication will be seen because the reference pulses will saturate the pulse counter.

If this condition is suspected, check S1-1 and S1-2 for the proper settings, and then turn the MAX SPEED pot CCW until the current limit LED goes out. If it does not go out, check the motor connections on TB1 on the control logic (top) board.

## L.E.D. INDICATORS

The LED indicator lights on the Model 500 indicate when a particular condition exists. They help to keep track of the operation of the unit. There are three colors used: red, green, and yellow. In general, a green light SHOULD be ON during normal operation. A yellow light is neutral -- whether or not it is on is not vital, but is informative. A red light is usually undesirable -- BUT red LED's are used as base driver indicators because red is the most visible color. Due to the PWM operation of the LED's (low average voltage), red shows up better than the other colors.

### BOTTOM BOARD INDICATORS

#### SWITCHER -- LED8

The first light to come on when power is applied will be the SWITCHER LED. This LED is connected to the switcher output and cannot work unless the switcher is actually on. The LED will begin to come on between 60 and 70 VDC on the buss capacitors. If the SWITCHER LED is off, check the POWER light on the top board (see below). If the POWER light is on, the SWITCHER LED itself may be defective.

#### CAUTION!!

AFTER THE POWER TO THE MODEL 500 IS TURNED OFF, THE SWITCHER WILL CONTINUE TO OPERATE UNTIL THE CAPACITOR BANK IS DRAINED DOWN TO LESS THAN 50 VDC.  
DO NOT ATTEMPT TO WORK ON THE CONTROL UNTIL ALL OF THE LED'S ARE OFF!

#### RELAY ON -- LED7

The RELAY ON LED comes on when the bus voltage on the main capacitor reaches a level sufficient for operation. Relay CR bypasses the charging circuit and allows normal operation. The Model 500 will not run until RELAY CR is energized.

#### BASE DRIVERS -- LED1 through LED6

These LED's indicate the presence of base drive to the respective output power transistors. All six of the output transistors are contained in the OUTPUT TRANSISTOR BLOCK. Transistors 1, 2, and 3 are normally "block fired" (i.e., no PWM), so these lights are easy to see. Transistors 4, 5, and 6 are normally PWM controlled. Under light loads and/or at very slow speeds they may be difficult to see. If the MODE select switch (S1-6, page 22), is on at slow speed, it may be difficult to see any of the lights. At higher speeds it will appear that all of the LED's are on because the sequence is switching so rapidly.

In the regenerative Model 500, the top three transistors (1, 2, and 3) are block fired during motoring operation. During regenerative operation, all transistors are PWM controlled. Under light regenerative loads, it may be hard to see the base driver LED's. If the MODE select switch is on, all transistors are PWM controlled at all times, but the efficiency of the motor is less.

### TOP BOARD INDICATORS

#### POWER -- LED1

The POWER LED operates from the raw positive and negative 24 VDC supplies. In order for the POWER light to be on, the switcher must be operating, and the cable to the bottom board must be in place.

#### RUN -- LED 7

The RUN LED is on when the RUN relay is on. The RUN relay will be on when 24VDC is being supplied to TB2 terminal 6 or when +24VDC is being supplied to TB2 terminal 5 AFTER +24VDC has been supplied to TB2 terminal 6 and been removed if the RUN circuit has sealed in. In that case, the +24 VDC must be removed from TB2 terminal 5 to drop the RUN relay.

### REGEN -- LED3

The REGEN LED does not operate in the non-regenerative Model 500.

The REGEN LED on the regenerative unit indicates that the net current flow is from the motor to the control. If the REGEN LED is continuously lit, it is a good idea to check the voltage across the buss loader resistor(s). A standard VOM will give an average DC value, and a true RMS DVM will give an AC value. The resistor(s) should be checked for both values to determine that the resistors are adequate.

### CURRENT LIMIT -- LED2

When a CURRENT LIMIT indicator is given, it is especially important to note the circumstances under which it occurs, since the CURRENT LIMIT indicator may be given under several different circumstances, not all of which are actually due to excessive current:

\*\* EXCESS MOTORING CURRENT - This current limit condition means that the load is too great for the current setup of the control. The control is actively limiting the current to the motor. This involves the Current calibrate setting (S2, page 23) and the CURRENT LIMIT adjustment (MOTOR I LIMIT, page 25). DO NOT INCREASE THE CURRENT LIMIT UNTIL THE AMOUNT OF CURRENT ACTUALLY GOING TO THE MOTOR IS VERIFIED! This may be done with a clamp-on ammeter on the motor leads.

\*\* EXCESS REGENERATIVE CURRENT - This current limit condition means that the control is trying to limit the current coming back from the motor to the level set by the REGEN I LIMIT (page 24). This condition may be identified by the fact that the REGEN LED will be on at the same time.

\*\* INSUFFICIENT MOTOR FEEDBACK - This current limit indication is not a current limit condition at all. Due to the nature of the speed loop, the excess (or lack) of reference pulses is converted into a current command. If the motor does not return enough pulses to satisfy the speed loop, for whatever reason, the current command keeps increasing until the control indicates CURRENT LIMIT, even if very little current is being drawn. At this point, the motor will probably be going as fast as it can go. There are several possible reasons for this:

1. LOST COMMUTATION CHANNEL (HS1, HS2, or HS3)
2. LOST FEEDBACK CHANNEL (HS4, HS5, HS+, or HS-)
3. MOTOR UNABLE TO REACH SPEED -- the motor cannot reach the commanded speed due to temperature, excess command, or some other condition (other than too much current) preventing it from going fast enough (also see "up against the buss" under MAX SPEED, page 25).

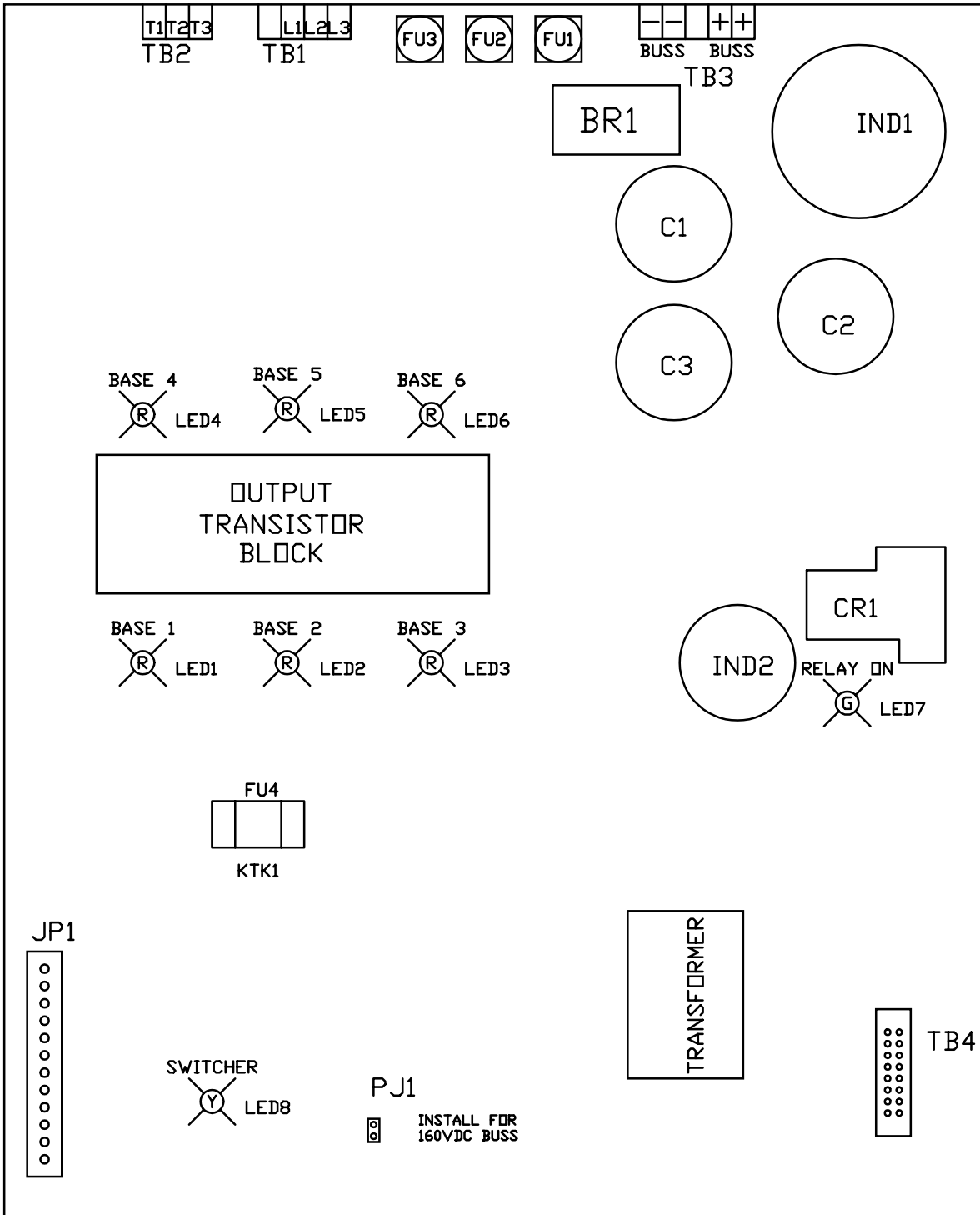
NOTE: A COLD BRUSHLESS DC MOTOR PRODUCES MORE CEMF THAN A WARM ONE. FOR THIS REASON, THE MOTOR MAY NOT BE ABLE TO REACH FULL SPEED NEAR FULL LOAD UNTIL IT HAS REACHED OPERATING TEMPERATURE. THIS IS TRUE OF ALL DC MOTORS AND IS ACCOUNTED FOR IN NEMA SPECIFICATIONS. THE GOOD NEWS IS THAT A COLD MOTOR ALSO PRODUCES MORE TORQUE PER AMP.

### FAULT INDICATOR -- 7 SEGMENT READOUT

The seven segment LED readout replaces the three indicators LED4, LED5, and LED6 used for fault indications in earlier Model 500's.

When the Model 500 control stops running unexpectedly, the readout should be checked for a number to determine the reason. The readout will give a basic indication, but further troubleshooting may be required to find the problem.

0	Normal Stop	The control circuit was opened.
1	Undervoltage	The input voltage is too low.
2	Overvoltage	The Bus voltage exceeded the limit.
3	UV Timeout	The Model 500 will tolerate a low voltage condition for 100 ms.
4	I Overcurrent	The current to the transistors exceeded the limit.
5	Tach Loss	Feedback from the motor was lost.
6	Motor Thermal	The motor thermal circuit opened.
7	Commutation	One of the position encoder channels was erroneous.



NOTE: NOT TO SCALE! SOME PARTS MAY BE SHOWN OUT OF POSITION.

The bottom board of the Model 500

## 4.0 OPTIONS

### REGENERATIVE OPTION KIT

The Model 500 may be converted in the field from a non-regenerative to a regenerative motor control without replacing the entire drive. It must be used only after it has been determined that regenerative operation is necessary and how much regeneration is necessary. The amount of regeneration required depends upon such factors as speed, gearing, inertias, and degree to which the motor will be overhauled (made to go faster than the commanded speed). An engineering evaluation of the system is strongly advised to ensure that adequate resistance and power capacity is used. If a proper amount of dissipative capacity is not used, the Regen kit will not give any benefit. It could result in damage to the resistor(s) and/or the Bus Loader board.

The standard Regen option kit (order # 154-RGN) consists of two parts:

1. The Buss Loader Board (Part # 154-010)
2. A Regen Resistor (Part # 154-019)

### PROCEDURE:

The Buss Loader module is installed behind the top board in plug terminal TB5. The top board may be removed to facilitate the installation (disconnect the cable, do not let the top board hang down by the cable). All connections to the bottom board are made by PJ1. The only other connections that need to be made are the two wires to the Regen resistors to TB2 on the Buss Loader Board. These connections are made to the OUTSIDE terminals on the three terminal strip (the middle terminal is not connected to anything).

The Regen resistor supplied with the kit is a 50 ohm, 40 watt metal case resistor which mounts on the left sidewall of the chassis above the Buss Loader Board. This resistor will supply up to 10% regen capability for up to 1 horsepower. This takes care of most cases which involve deceleration times of 5 seconds or less.

If more regeneration is necessary, resistors will have to be mounted externally. They may be connected to the terminals on TB2 on the Bus Loader board. Disconnect, or do not install the standard kit resistor. **DO NOT CONNECT THE EXTERNAL RESISTORS IN PARALLEL WITH THE STANDARD RESISTOR !!**

The standard regenerative kit, as stated previously, comes with one 50 ohm 40 watt resistor. This will supply the amounts of regeneration in the table on the right under the STD KIT RGN PCT column. Up to 1 HP, 10 % regeneration or more is supplied. Beyond the standard kit, external resistors must be supplied.

REGENERATIVE RESISTORS TABLE

Resistor value is 50 OHMS in all cases.

**NOTICE: USING LESS THAN 50 OHMS RESISTANCE WITH THE REGENERATIVE MODULE MAY DAMAGE THE MODULE!**

The values for 10%, 25%, 50%, and 100% in the table are the watts necessary to accomplish those levels of regeneration. A 25% duty cycle means 25 % regeneration for 100% of the time (continuously), or 100% regeneration 25% of the time (fifteen seconds per minute, then cooling to ambient). The duty cycle of power resistors varies widely from manufacturer to manufacturer, and the individual characteristics of the resistors used

Horsepower	Standard Kit Regen %	10% Regen wattage	25% Regen wattage	50% Regen wattage	100% Regen wattage
1/2	20%	40	100	200	400
3/4	12%	40	150	300	600
1	10%	40	200	400	800
1.5	7%	100	300	600	1200
2	5%	150	400	750	1500
3	3%	225	600	1200	2300

**DO NOT USE LESS THAN 50 OHMS AT ANY TIME !!**  
100 OHMS MAY BE USED UP TO 1.5 HP AT 230VAC.

## OPTIONS

### ANALOG INTERFACE BOARD

The ANALOG INTERFACE BOARD is a convenient output device for normalized signals representing current and speed. It installs directly on the Model 500 via two built in plugs, JP1 and JP5.

The POWERTEC Model 500 brushless DC motor control has a standard speed output of frequency. The ANALOG INTERFACE BOARD option makes current and speed signals available in a 0 to -10 VDC format.

The ANALOG INTERFACE BOARD gives normalized output signals for speed and current. The speed signal [terminals 3(+) and 2(-)] is available in a unipolar 0 -> -10 VDC form (see note below), but it may be varied over a wide range. The current signal [terminals 1(+) and 2(-)] is available in both unipolar and bipolar forms, and may be output as a voltage or current, but it is dependent upon the host drive's calibration.

See the Analog Interface board manual for further information.

### LOGIC EXTENDER BOARD

The POWERTEC Logic Extender Board (Part No. 154-008) is a plug-on option board. It is used to add optional functions to the Model 500 which are not included in the main Logic Board.

The additional functions are [+24VDC is available at terminals 1 and 2]:

- A. JOG CLOCKWISE (adjustable speed) [+24VDC to terminal 3]
- B. JOG COUNTERCLOCKWISE (adjustable speed) [+24VDC to terminal 4]
- C. RAMP TO HOLD (ramp to zero speed from any speed) [+24VDC to terminal 5]
- D. HOLD (stop in current limit) [+24VDC to terminal 6]
- E. FAULT OUTPUT (NO dry contact, 1A 125VAC) [terminals 7 and 8] Contact is closed while there is no fault in the drive. Opens on fault, does not open on stop.
- F. MULTI-FUNCTION CONTACT (NO dry contact, 1A 125 VAC) [terminals 9 and 10] May be used for Dynamic Braking, Output contactor, Brake control, enable output, or zero speed.

The Multifunction output is programmable on the board by jumpers. Two timers may be used with it.

There are indicating LED's on the board to show the various functions as they are used.

See the Logic Extender board manual for further information.

### SYSTEMS INTERFACE BOARD

The SYSTEMS INTERFACE BOARD contains all of the functions of the Analog Interface board (option E3.0) plus 4-20 milliamp input and torque limiting operation or torque regulation operation.

The Motor Speed output (terminals 3[+] and 6[-]) gives a 0 to +10VDC signal for 0 -> maximum motor speed. The maximum output (+10 VDC) may be adjusted with the SPEED potentiometer.

The Motor Load output (terminals 4[+] and 6[-]) gives a -10 VDC to +10 VDC signal for motor current. Regenerative current limit (-150%) gives a -10 VDC signal and motoring current limit (+150%) gives +10 VDC.

A 4 to 20 mA converter has an input at terminals 1[-] and 2[+]. Jumper JP2 controls the effect of the output to the drive (a jumper must be connected from terminal 5 to the Model 500 speed input at TB2 terminal 15 or 17. This connection is not made internally, although the common connection is internal).

There are two TORQUE modes - Torque Limiting and Torque Regulation.

In TORQUE LIMITING mode (PJ1 out and PJ4 and PJ5 in the N position), the Systems Interface will remain in speed control until enough load develops to reach the preset torque level(s). One pot may be used (input at terminal 10[+]) or individual pots may be used for motoring (input at terminal 10[+]) and regenerative (input at terminal 9[-]) torque levels. Jumper PJ3 makes this selection.

In TORQUE REGULATING mode (PJ1 installed), the Systems Interface board changes the Model 500 into a Torque regulated drive. The motor will increase speed until the load required by the input at terminal 10[+] (0 to 150%) is satisfied or the maximum speed of the motor is attained. There is no speed control in this mode.

Reference supplies are available at terminals 11 (+10 VDC) and 12 (-10 VDC). Commons for the pots are available at terminals 7 and 8.

See the Systems Interface board manual for further information.

## SERVO POWER SUPPLY BOARD

When more accuracy is desired or lower speeds are required, a higher count encoder may be attached to the motor. This encoder will require a power supply and processing of the signals. Because of the relatively weak nature of the signals, noise protection and shielding are considered vital.

The Servo Power Supply board (part no. 154-032) installs directly on the Model 500 via plug JP4. The Servo Power Supply board occupies the left hand option board position on the top board, and thus cannot be used at the same time as the Logic Extender board.

The Servo Power Supply board supplies either +5 VDC @ 100 milliamps or +15 VDC @ 50 mA to power the optical encoder. The voltage selection is made with PJ1. When the jumper is on pins 1 and 2 (the left two pins), there is +15 VDC present at terminal 1 (terminal 6 is common) on TB3 for encoder power. When the jumper is on the right two pins (2 and 3), there is +5 VDC at terminal 1. If the jumper is left off, there will be +5 VDC at terminal 1.

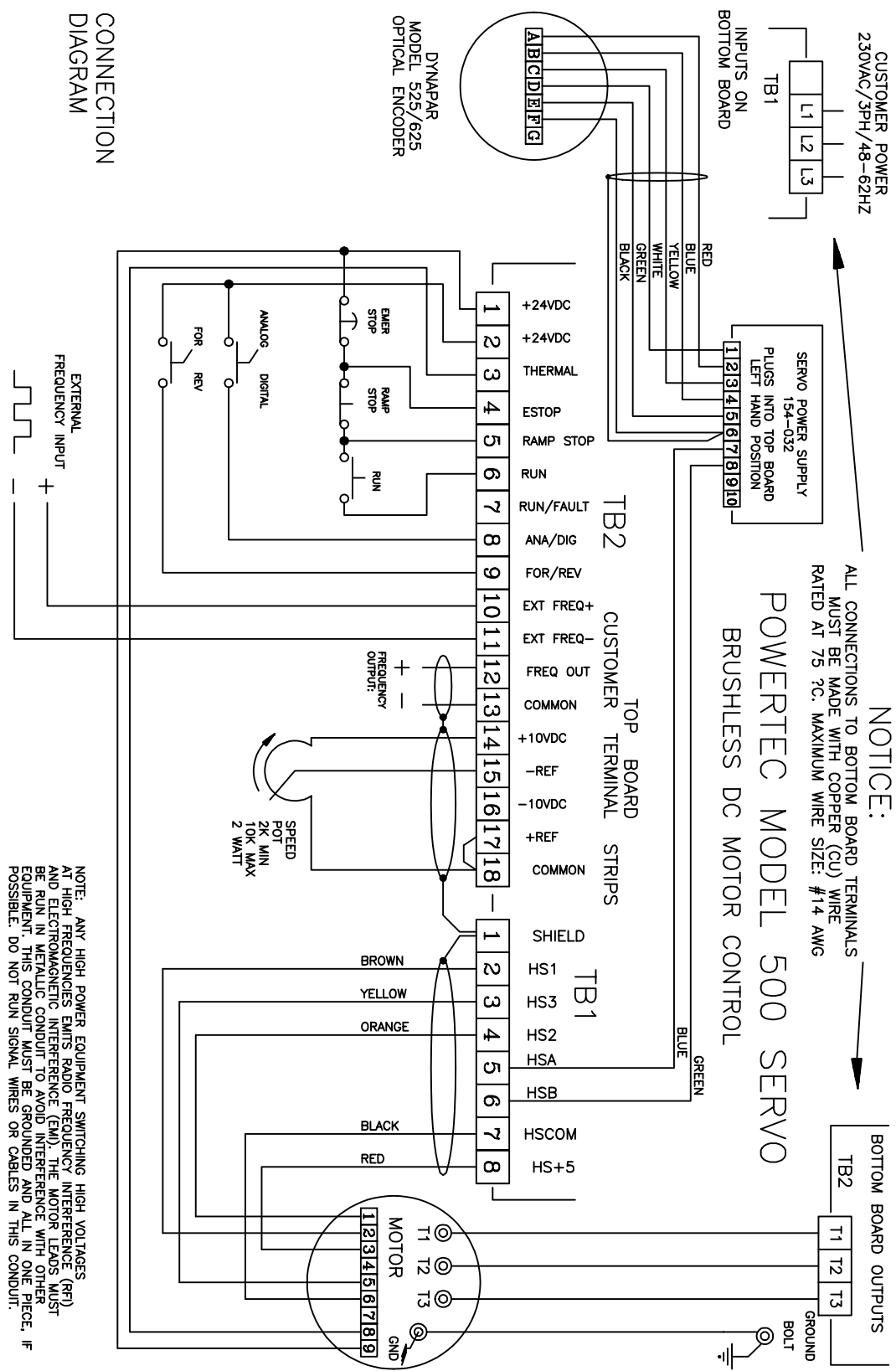
The differential line inputs, A and /A, and B and /B, are input on terminals 2, 3, 4, and 5, respectively. There is no provision for a Z channel. There are indicator LED's on channels A and B to visually demonstrate the operation of the channels.

The channel A output is at terminal 7, and this should be connected to TB1 terminal 5 of the Model 500. The channel B output is at TB2 terminal 8. This should be connected to TB1 terminal 6 of the Model 500. These outputs are the pulse feedback. If, after starting, the motor increases speed without control, these two terminals may have to be swapped.

Terminals 9 (+) and 10 (-) are a NOT FAULT output. When the drive is not faulted, the LED indicator D7 (NOFLT) will be lit and the transistor output of an optical coupler connected to terminals 9 and 10 is turned on. This may be used to operate a relay or a PLC input.

There are also troubleshooting LED's on the Servo Power Supply board:

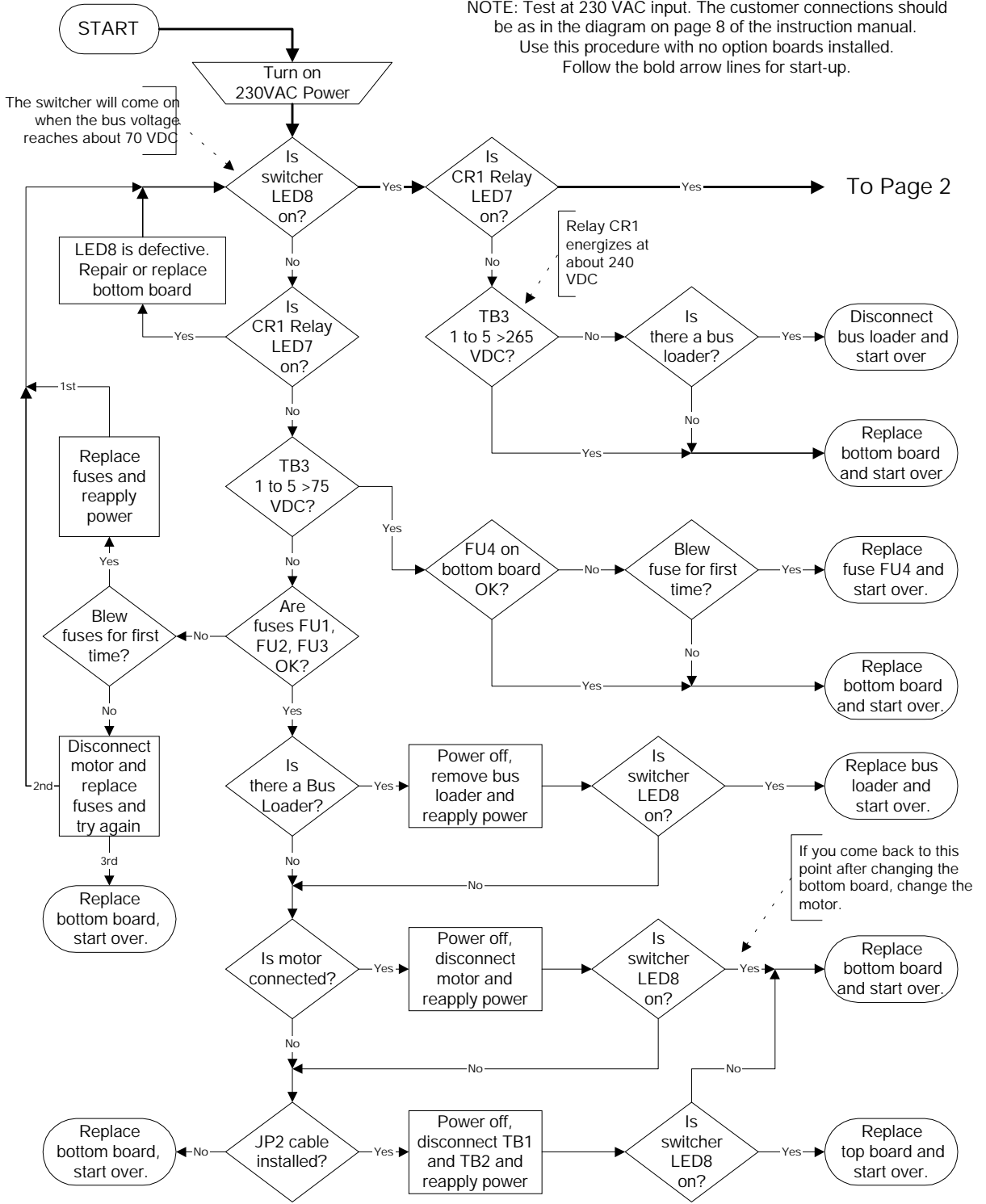
1. ZSPD -- D1 (Yellow) -- The Zero Speed LED is ON when the drive is at zero speed, turns OFF when the motor begins to turn, and stays OFF until the motor stops turning. The Zero Speed LED will remain lit until the motor stops in the event of a fault.
2. VCLMP -- D2 (Red) -- The Velocity Amplifier Clamp LED is ON when the drive is in the stop or EMERGENCY STOP mode. It turns OFF while the drive is in the RUN mode, including the RAMP STOP Time. In the event of a fault, the VCLMP LED will turn ON.
3. REFCLP -- D3 (Red) -- The Reference Clamp LED is ON while the drive is in the STOP or Emergency STOP mode, and turns ON while the drive is in the RUN mode. The Reference Clamp LED turns ON during RAMP STOP. If a fault occurs, the REFCLMP will turn ON.
4. NOTEN -- D4 (Yellow) -- The Not Enabled LED is ON when the drive is in the STOP mode, the EMERGENCY STOP mode, or when the drive is faulted. The Not Enabled LED turns OFF while the drive is running, including the RAMP STOP time.
5. NOESTP -- D5 (Green) -- The Not Emergency Stop is ON while +24 VDC is present at TB2 terminal 4. The NOESTP LED will turn OFF if TB2 terminal 4 is not energized.
6. RUN -- D6 (Green) -- The RUN LED is ON while the drive RUN relay is energized. The RUN LED does not shut OFF if there is a fault.
7. NOFLT -- D7 (Red) -- See the description of the fault output above.
- 8,9 CHA, CHB -- D8, D9 (Red) -- Indicate operation of the encoder.



CONNECTION  
DIAGRAM

# POWERTEC Model 500 Drive Start up and Troubleshooting Chart

NOTE: Test at 230 VAC input. The customer connections should be as in the diagram on page 8 of the instruction manual.  
Use this procedure with no option boards installed.  
Follow the bold arrow lines for start-up.

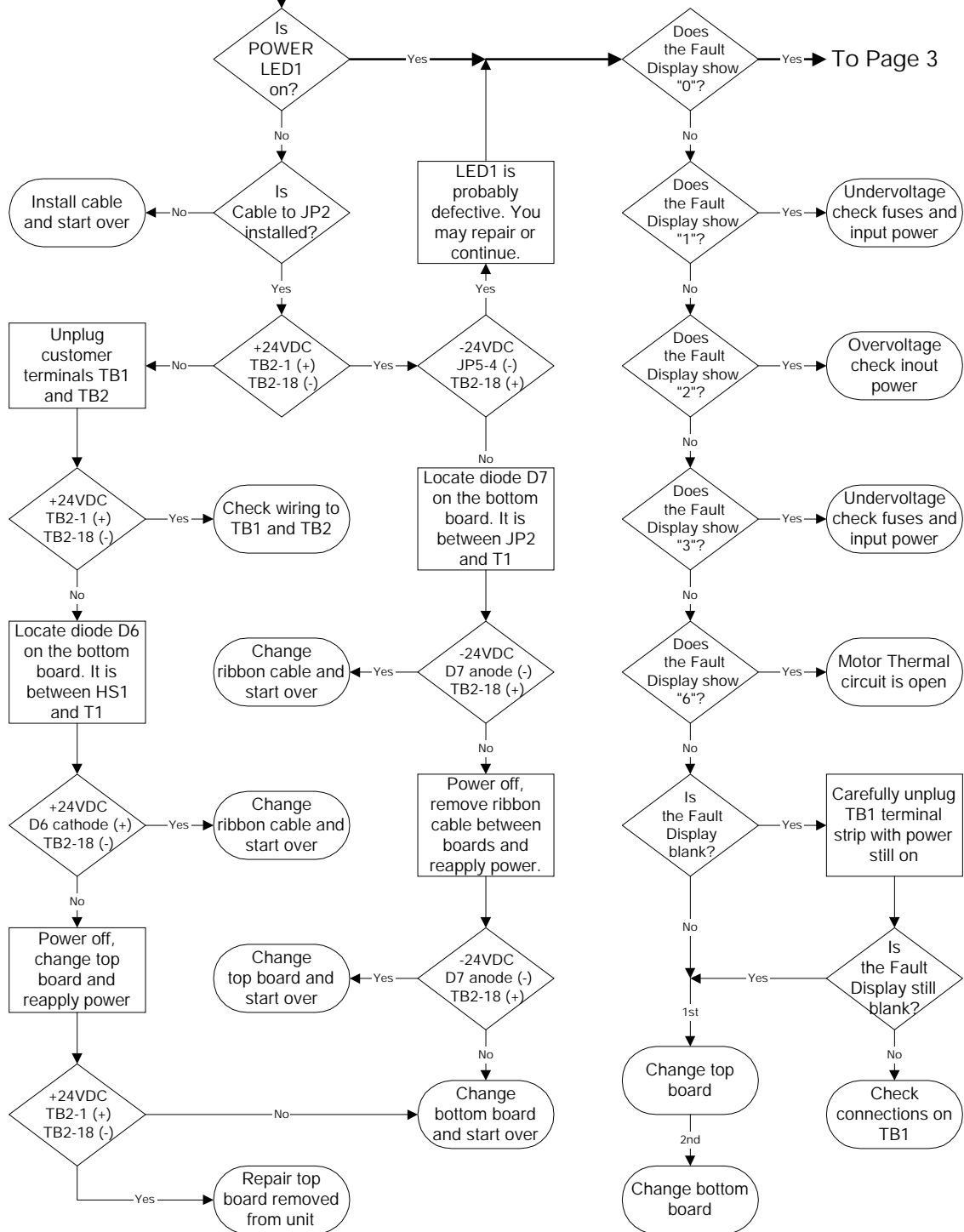


Following this procedure requires spare parts.

Page 1

# POWERTEC Model 500 Drive Start up and Troubleshooting Chart

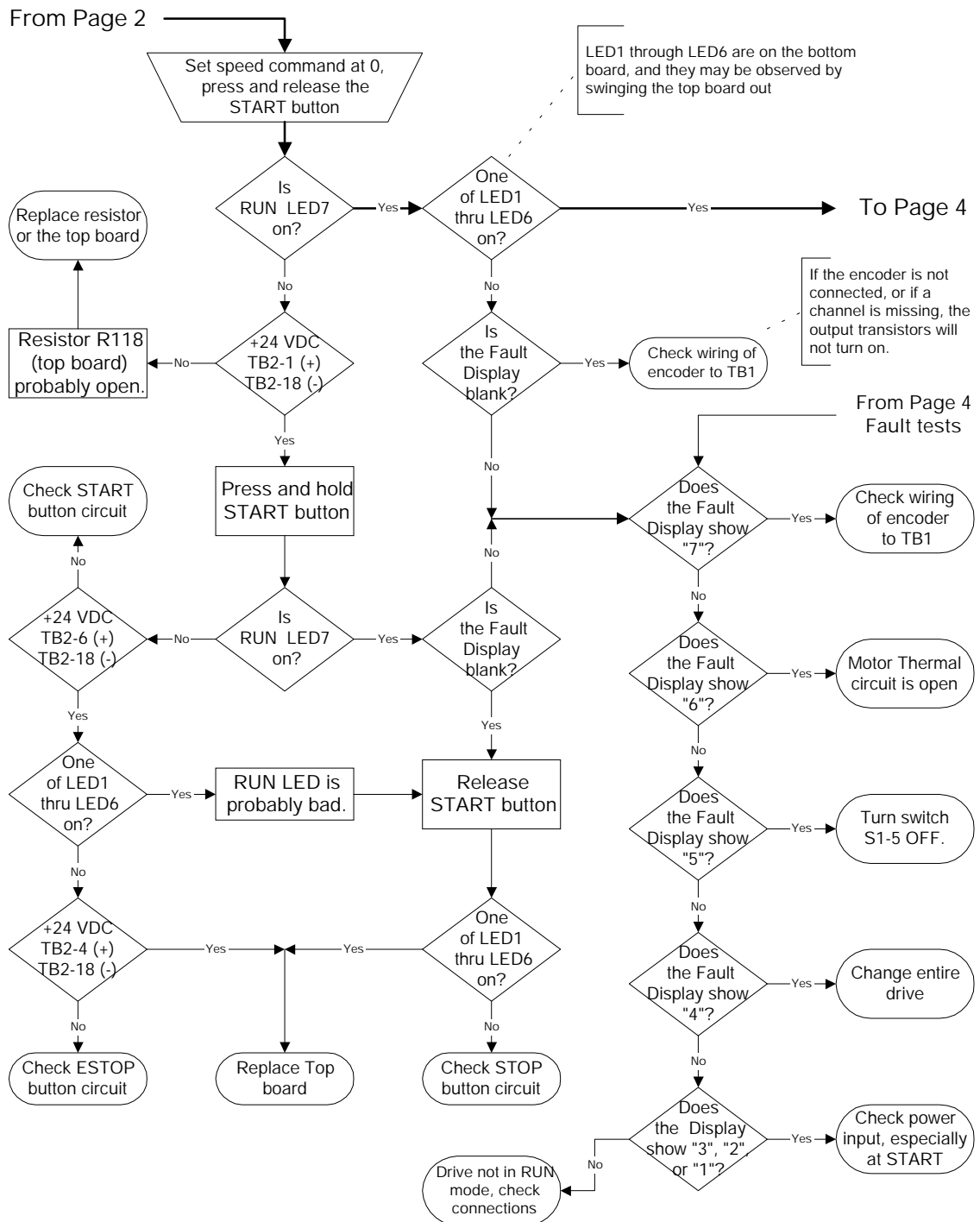
From Page 1



Following this procedure requires spare parts.

Page 2

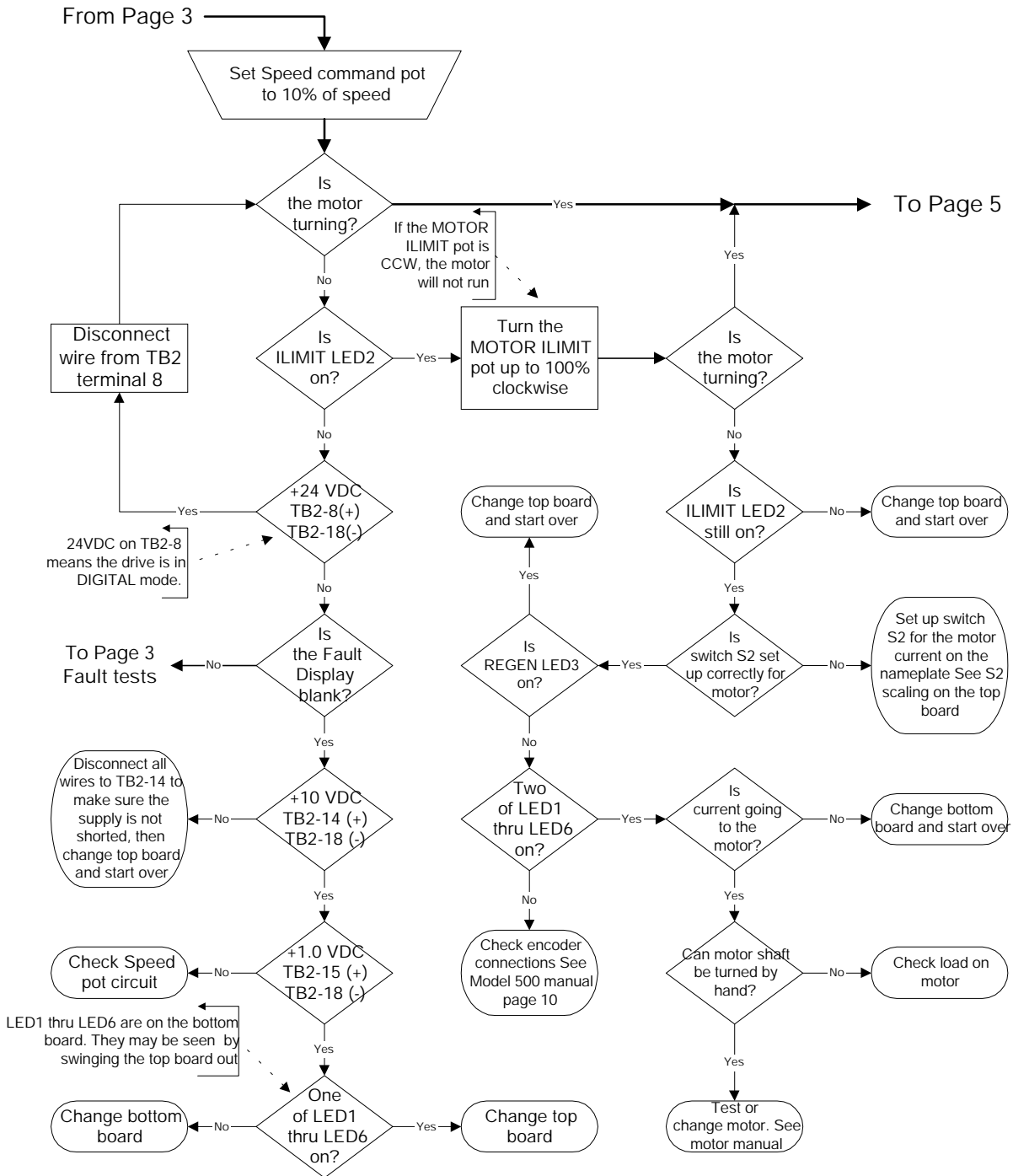
# POWERTEC Model 500 Drive Start up and Troubleshooting Chart



Following this procedure requires spare parts.

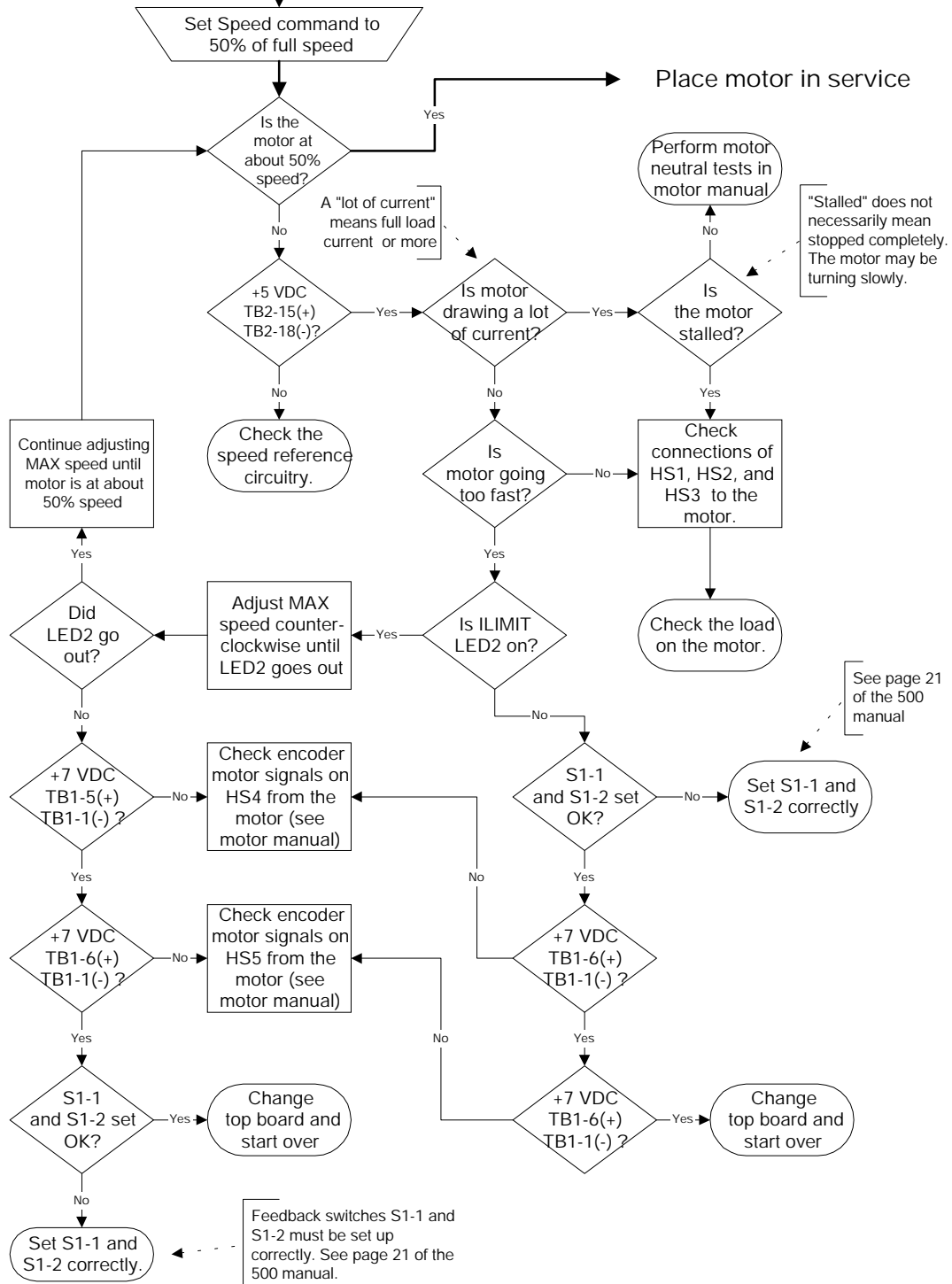
Page 3

# POWERTEC Model 500 Drive Start up and Troubleshooting Chart



# POWERTEC Model 500 Drive Start up and Troubleshooting Chart

From Page 4

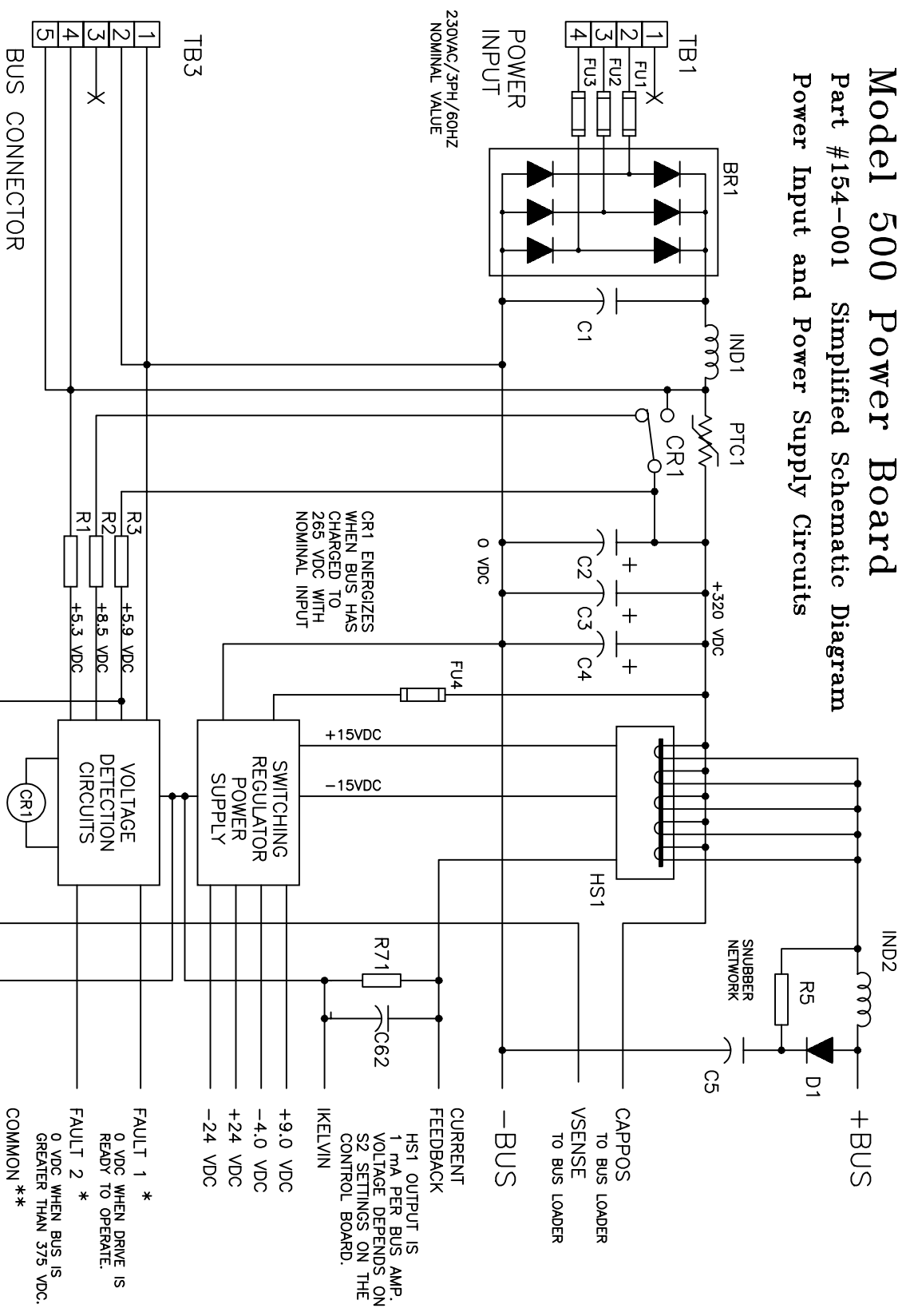


Following this procedure requires spare parts.

# Model 500 Power Board

## Part #154-001 Simplified Schematic Diagram

### Power Input and Power Supply Circuits



CR1 ENERGIZES WHEN BUS HAS CHARGED TO 265 VDC WITH NOMINAL INPUT

HS1 OUTPUT IS 1 mA PER BUS AMP. VOLTAGE DEPENDS ON S2 SETTINGS ON THE CONTROL BOARD.

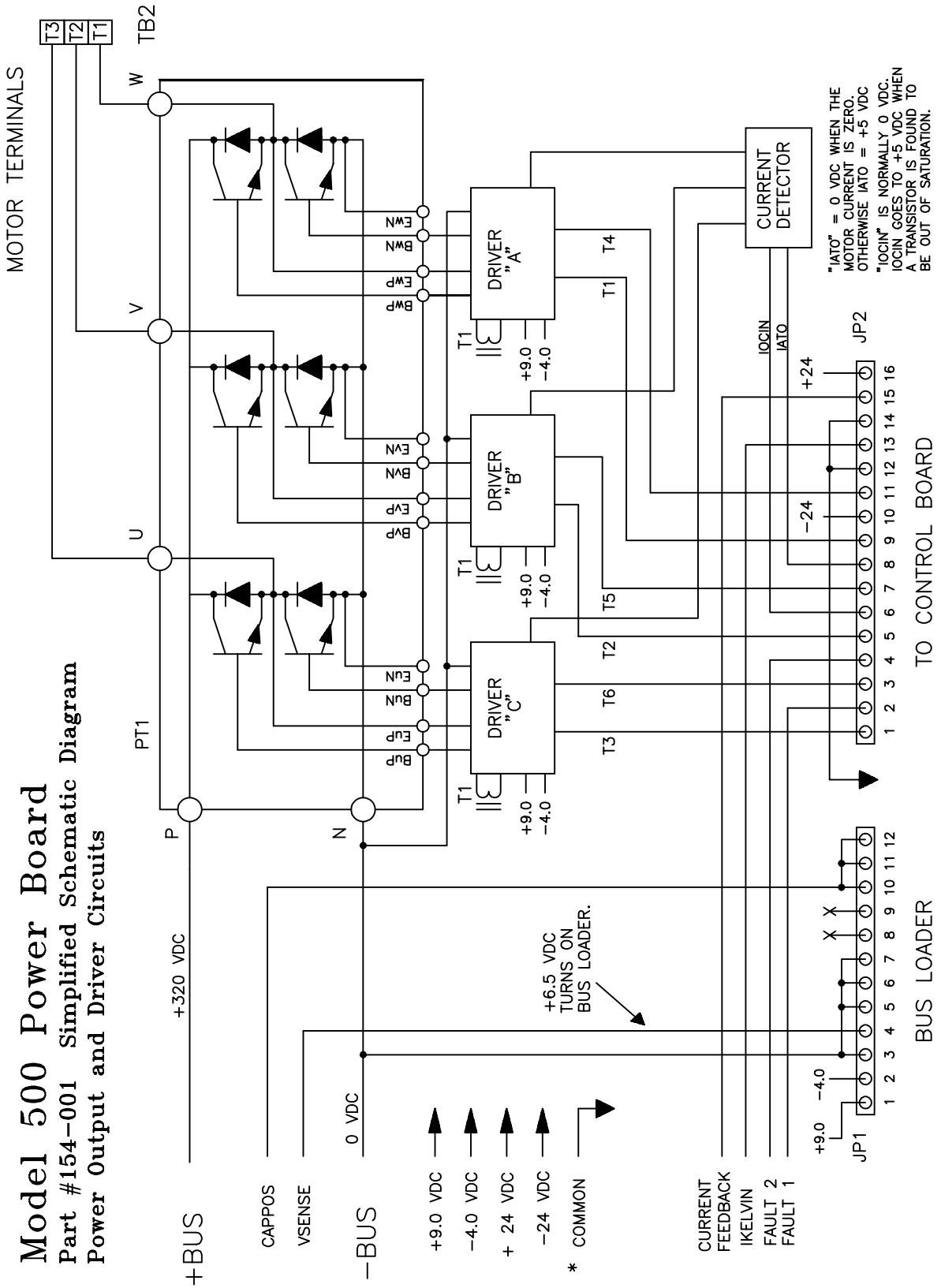
FAULT 1 \*  
0 VDC WHEN DRIVE IS READY TO OPERATE.  
FAULT 2 \*  
0 VDC WHEN BUS IS GREATER THAN 375 VDC.  
COMMON \*\*

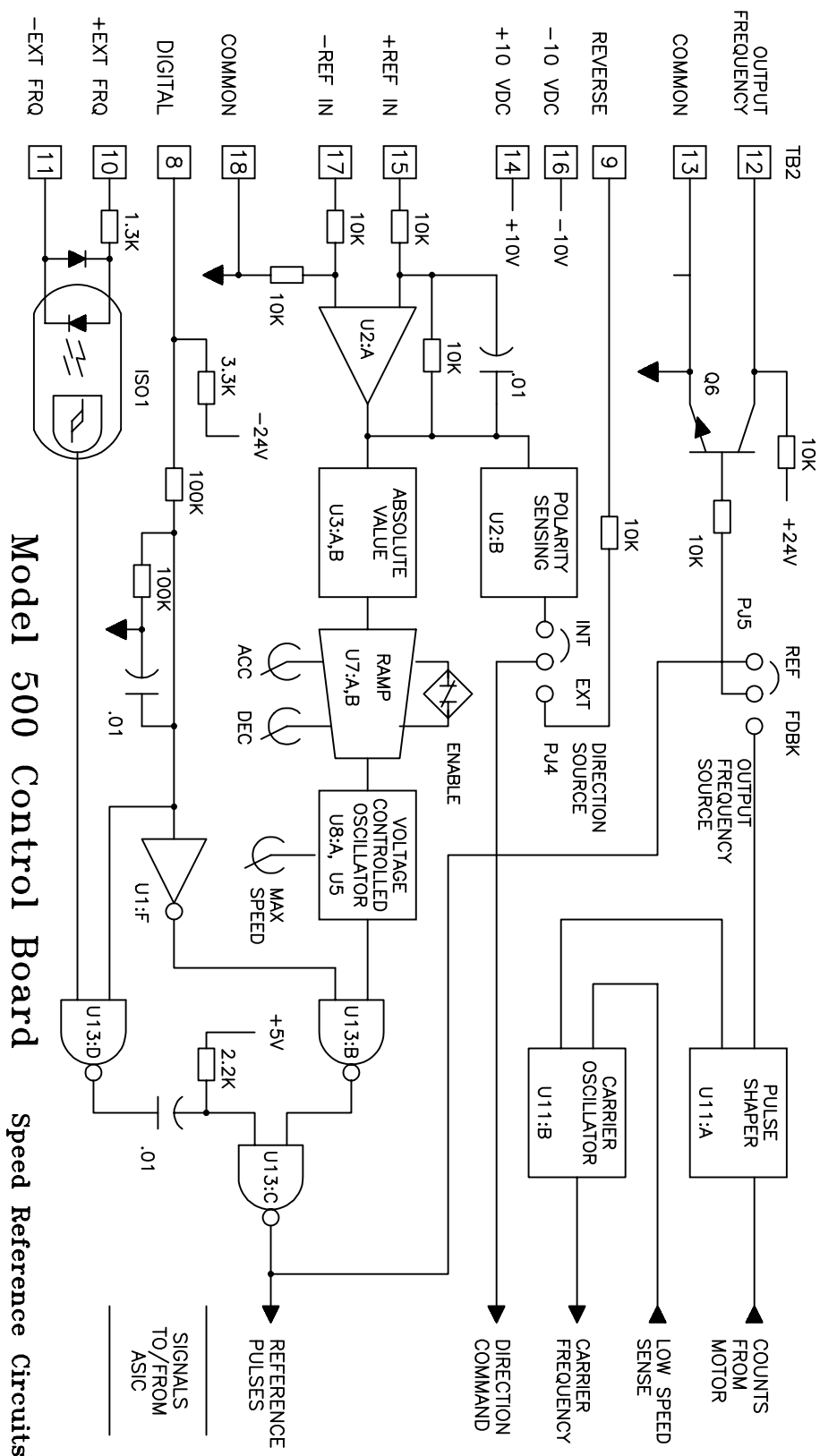
\* NOTE: FAULT LINES HAVE +5 VDC PULL-UP ON CONTROL BOARD.  
\*\* NOTE: COMMON IS NOT THE SAME AS - BUS

# Model 500 Power Board

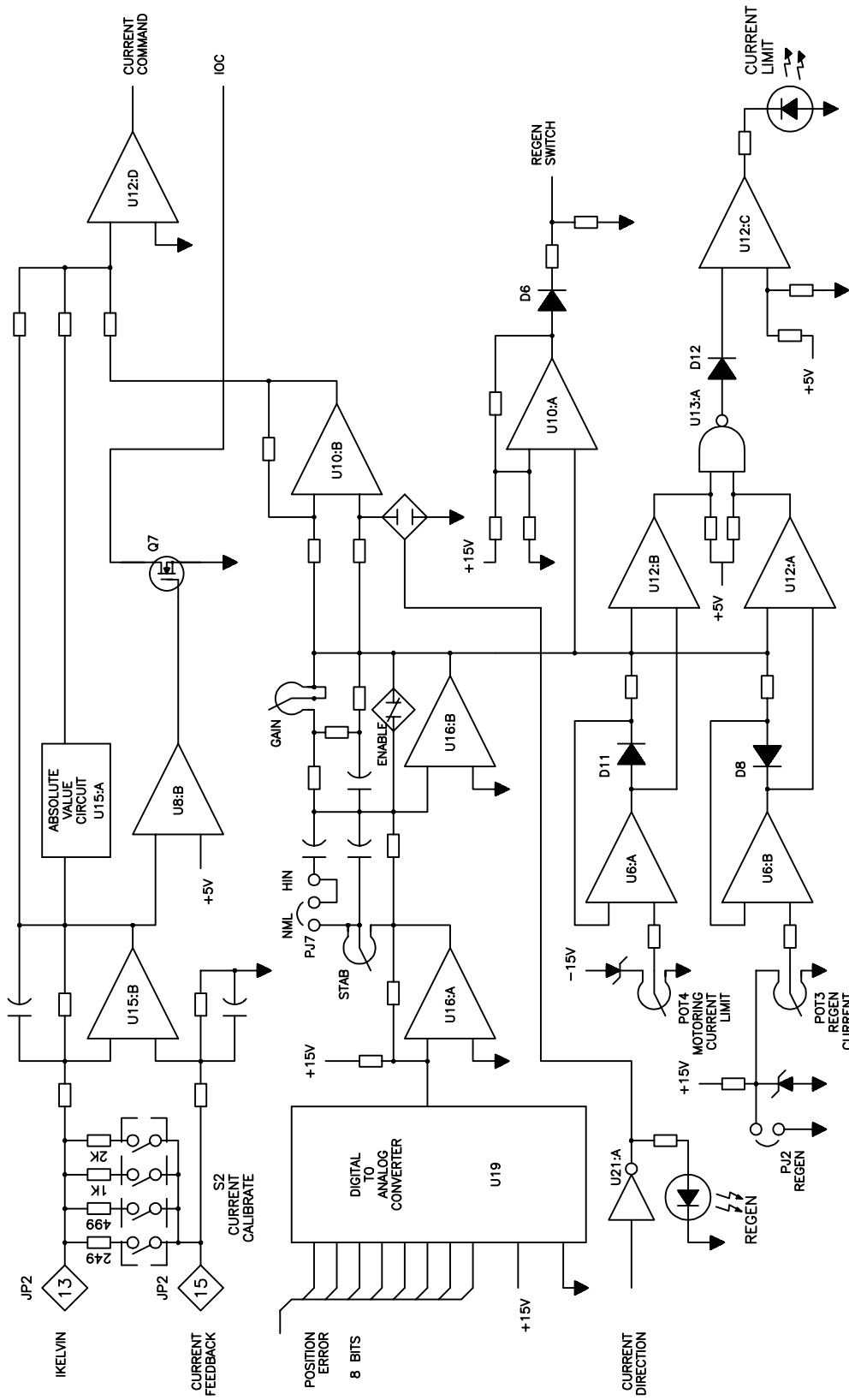
## Part #154-001 Simplified Schematic Diagram

### Power Output and Driver Circuits

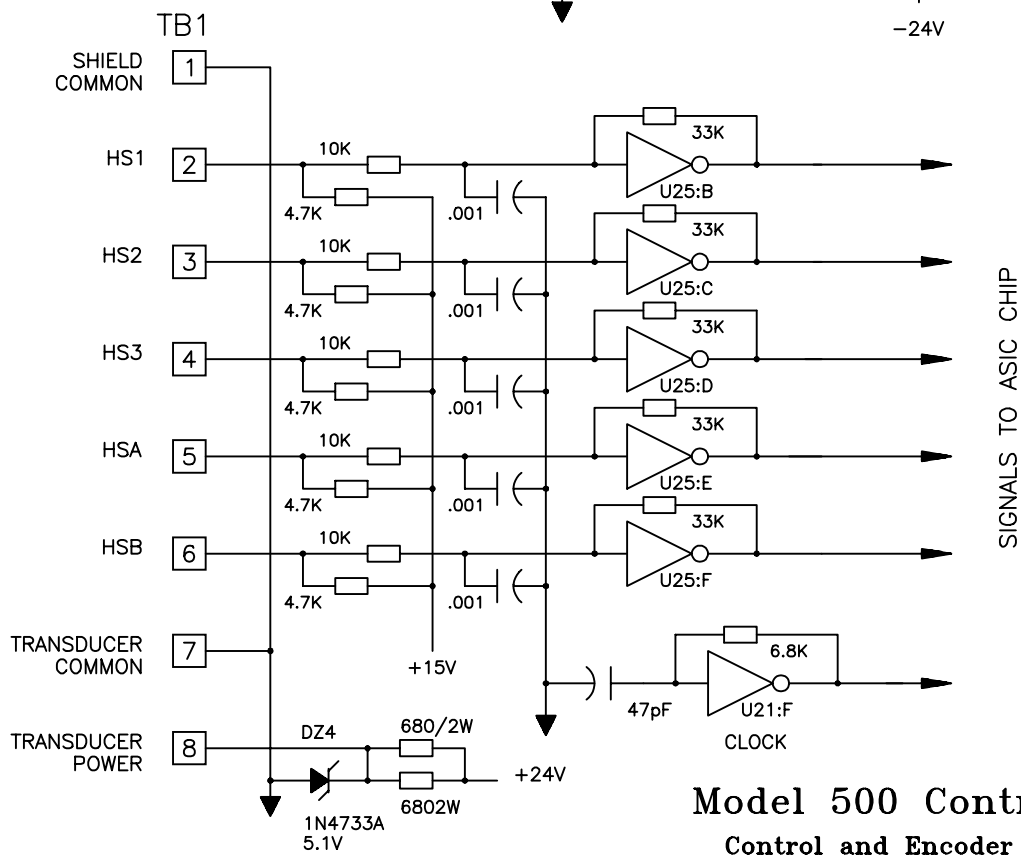
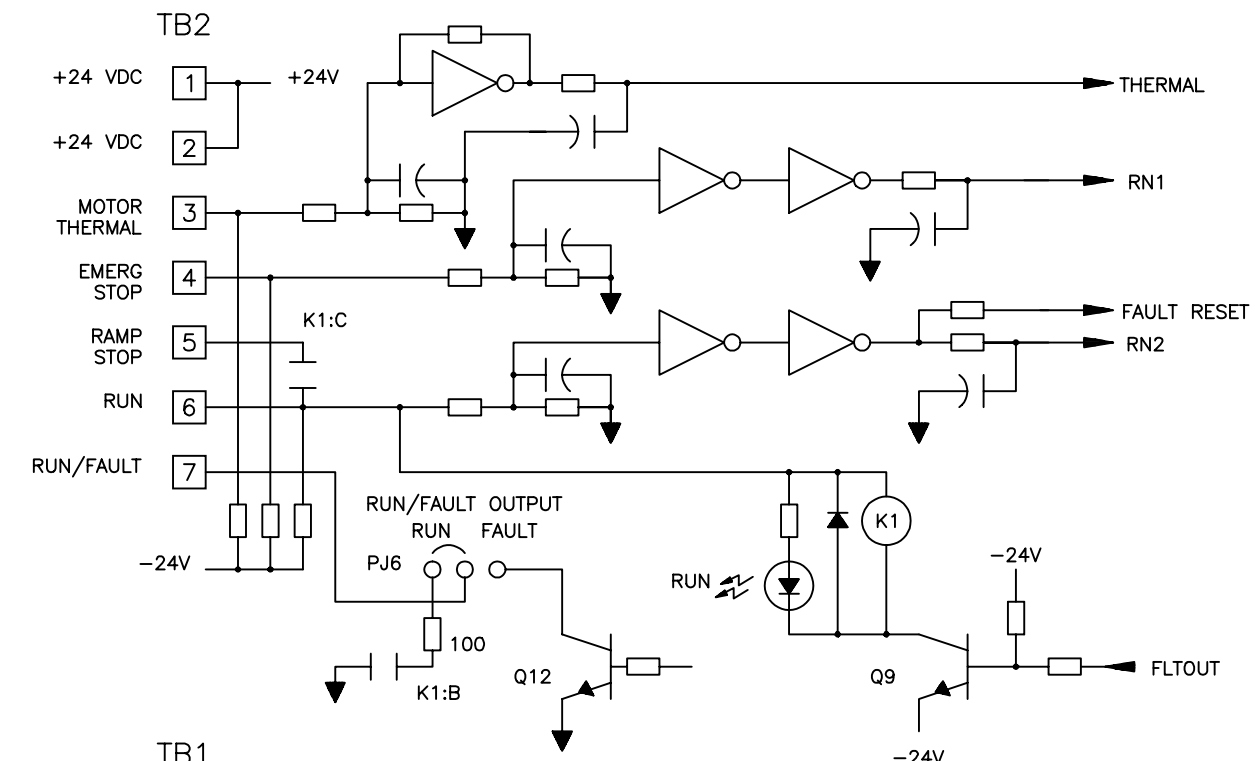




Model 500 Control Board Speed Reference Circuits.



Model 500 Control Board Current Control Circuits



**Model 500 Control Board**  
Control and Encoder circuits



