

DYNETIC SYSTEMS COMPANY

DYNETIC BE12-6 SERIES & DYNETIC BE15-8 SERIES

BRUSHLESS PWM SERVO AMPLIFIER

OPERATING MANUAL

DYNETIC SYSTEMS

NEW CONCEPTS IN MOTION

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TABLE OF CONTENTS

		Page
1.0	DESCRIPTION	
	1.1 Functional Block Diagram	1
	1.2 Power Stage Specifications.....	1
	1.3 Mounting Dimensions.....	2
	1.4 Mechanical Specifications	2
	1.5 Pin Identification	3
	1.6 Switch Identification	4
	1.7 Potentiometer Identification	4
2.0	MODE SELECTION	
	2.1 Current (Torque) Mode	5
	2.2 Encoder Velocity Mode	5
	2.3 Open-Loop Mode	5
3.0	WIRING INSTRUCTIONS	
	3.1 Schematic	6
	3.2 Noise Considerations & System Grounding	6
	3.3 DC Power Supply Wiring	8
	3.4 Motor Wiring	9
	3.5 CE-EMC Wiring Requirements	9
4.0	SET-UP INSTRUCTIONS	11
5.0	AMPLIFIER ADJUSTMENT (TUNING) PROCEDURE	
	5.1 Command Signal	12
	5.2 Feedback Elements	12
	5.3 Potentiometer Adjustments	12
	5.4 Compensation Adjustments (Voltage-to-Speed Mode)	13
	5.5 Test Points for Potentiometers.....	15
6.0	TROUBLESHOOTING	15
7.0	CAUTIONARY NOTES	17
8.0	WARRANTY	17

Dynetic Systems
Dynetic BE12-6 & BE15-8 Series Brushless PWM Amplifiers
Operating Manual

1.0 DESCRIPTION

1.1 Functional Block Diagram

1.2 Power Stage Specifications

SPECIFICATION	BE12-6	BE15-8
DC SUPPLY VOLTAGE	20 - 60 V	20 - 80 V
PEAK CURRENT (2 sec. Maximum)	± 12 A	± 15 A
MAXIMUM CONTINUOUS CURRENT	± 6 A	± 7.5 A
MINIMUM LOAD INDUCTANCE	200 µH	200 µH
SWITCHING FREQUENCY	33 KHz ± 15%	33 KHz ± 15%
HEATSINK (BASE) TEMPERATURE RANGE	-25° to +65°C, disables if > 65°C	-25° to +65°C, disables if > 65°C
POWER DISSIPATION AT CONTINUOUS CURRENT	10 W	15 W
OVER-VOLTAGE SHUT-DOWN (self reset)	62 V	86 V

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Dynetic BE12-6 & BE15-8 Series Brushless PWM Amplifiers
Operating Manual

BANDWIDTH	2.5 KHz	2.5 KHz
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1

1.3 Mounting Dimensions

1.4 Mechanical Specifications

MECHANICAL SPECIFICATIONS	
POWER CONNECTOR	Screw terminals
SIGNAL CONNECTOR	Molex connector
SIZE	5.09 x 2.98 x 0.99 inches 129.3 x 75.8 x 25.1 mm
WEIGHT	10 oz. 0.28 kg

2

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 Operating Manual

1.5. Pin Identification

CONNECTOR	PIN	NAME	DESCRIPTION/NOTES	I/O
P2	1	MOTOR A	Motor phase A connection	O
	2	MOTOR B	Motor phase B connection	O
	3	MOTOR C	Motor phase C connection	O
	4	POWER GND	Power ground	GND
	5	HIGH VOLTAGE	DC power input	I
P1	1	BE Series +5V @ 5mA	For customer use	O
	2	SIGNAL GND	Reference ground	GND
	3	BE Series -5V @ 5mA	For customer use	O
	4	+REF IN	Differential reference input, Maximum $\pm 15V$, 50K input resistance	I
	5	-REF IN		
	6	BE-ENCODER-B IN	Quadrature encoder input, 5V CMOS level	I
	7	BE-ENCODER-A IN	Quadrature encoder input, 5V CMOS level	I
	8	CURRENT MONITOR OUT	Current monitor, $1 V = 2 A \pm 10\%$	O
	9	$\overline{\text{INHIBIT IN}}$	Pull to ground to inhibit. For inverted inhibit inputs, see section "G".	I
	10	+V ENCODER 30 mA OUT	Power for encoder, Short circuit protected, +6 V @ +30 mA	O
	11	--- GND ---		GND
	12	HALL 1	HALL sensor inputs, logic levels, Internal 2 K Ω pull-up. Maximum low level input is 1.5 V, Minimum high level input is 3.5 V.	I
	13	HALL 2		
	14	HALL 3		
	15	VELOCITY MONITOR OUT	Velocity monitor output BE Series 1V-22KHz Encoder frequency	O
	16	FAULT OUT (red LED)	TTL level output. Becomes high during Output short circuit, over-voltage, over Temperature, inhibit, and during power-up Reset. Fault condition indicated by red LED.	O

1.6 Switch Identification

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 Operating Manual

SWITCH	FUNCTION DESCRIPTION	SETTING	
		ON	OFF
1	Duty-cycle feedback	Open loop	No effect
2	60 / 120 degree commutation phasing setting	120 degree	60 degree
3	Loop integrator. This capacitor normally ensures "error-free" operation in velocity mode by reducing the error-signal (output of summing amplifier) to zero.	Shorts out the velocity loop integrator capacitor	Off
4	Test / Offset. Sensitivity of the "offset" pot. Used as an on-board reference signal in test mode.	Test	Offset

1.7 Potentiometer Identification

POTENTIOMETER	DESCRIPTION	TURNING CW
Pot 1	Loop gain adjustment in open loop & velocity modes. Voltage-to-current scaling factor adjustment in current mode.	Increases loop gain
Pot 2	Current limit. It adjusts both continuous and peak current Limit by maintaining their ratio (50%).	Increases current limit
Pot 3	Reference gain. It adjusts the ratio between input signal And output variables (voltage, current, velocity).	Increases reference input gain
Pot 4	Test / Offset. Used to adjust any imbalance in the input signal or in the amplifier. When SW4 (DIP switch) is ON, the sensitivity of this pot is greatly increased thus it can be used as an on-board signal source for testing purposes.	N/A

2.0 MODE SELECTION

The BE12-6 & BE15-8 amplifiers operate in the following modes:

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 Operating Manual

Amplifier Mode	Controlled Variable	Feedback to Amplifier
Current (Torque) Mode	motor current	current, internal
Encoder Velocity Mode	motor speed	encoder, external
Open-Loop Mode	motor voltage	none

Mode	SW1	SW2	SW3	SW4	Encoder
Current	Off	X	On	X	Not Connected
Encoder	Off	X	Off	X	Connected
Open Loop	On	X	Off	X	Not Connected

X - Does not affect mode.

2.1 Current (Torque) Mode

The current mode produces a torque output from the motor proportional to the reference voltage input. DC motor output torque is proportional to the motor current. Torque mode is especially important if the servo amplifier is used with a digital position controller (under this condition, a movement of the motor shaft from the desired position causes a large correction torque, or "stiffness"). Therefore, this mode may produce a "run away" condition if operated without a controller.

2.2 Velocity Control Using Encoder (Encoder Velocity Mode)

The frequency of the encoder signal is proportional to the motor speed. Internal circuitry decodes velocity information from encoder feedback. This analog signal is available for closed loop velocity control. Since the resolution of an encoder is much higher than of Hall Effect sensors, much better low speed control can be obtained.

2.3 Open-Loop Mode

In this mode the reference input voltage commands a proportional motor voltage (by changing the duty cycle of the output switching). This mode is not a closed loop configuration (unlike the other modes described), therefore the average output voltage is also a function of the power-supply voltage.

3.0 WIRING INSTRUCTIONS

3.1 Schematic

The following schematic shows typical amplifier wiring configurations:

3.2 Noise Considerations and System Grounding

"Noise" in the form of interfering signals can be coupled:

-capacitively (electrostatic coupling) onto signal wires in the circuit (the effect is more serious for high impedance points).

-magnetically to closed loops in the signal circuit (independent of impedance levels).

-electromagnetically to signal wires acting as small antennas for electromagnetic radiation.

-from one part of the circuit to other parts through voltage drops on ground lines.

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Dynetic BE12-6 & BE15-8 Series Brushless PWM Amplifiers
Operating Manual

The proceeding wiring diagrams show a typical servo system using a Dynetic Systems servo amplifier.

Experience shows that the main source of noise is the high DV/DT (typically about 1V/nanosecond) of the amplifier's output power MOSFETS. This PWM output can couple back to the signal lines through straight capacitance "C1" between output and input wires. The best methods are to reduce capacitance between the offending points (move signal and motor leads apart), add shielding and use differential inputs at the amplifier. For extreme cases use of a filter card is recommended (contact our engineering department).

Unfortunately low-frequency magnetic fields are not significantly reduced by metal enclosures. Typical sources are 50 or 60 Hz power transformers and low frequency current changes in the motor leads. The best therapy here is to avoid large loop areas in signal, power-supply and motor wires. Twisted pairs of wires are quite effective in reducing magnetic pick up because the enclosed area is small, and the signals induced in successive twist cancel.

Aside from overall shielding the best way to reduce radio-frequency coupling is to keep leads short.

The voltage source shown between the amplifier and controller grounds typically consists of some 60 Hz voltage, harmonics of the line frequency, some radio-frequency signals, IR drops and other "ground noise". The differential inputs of the servo amp will ignore the small amount of "ground signal".

Long signal wires (10-15 feet and up) can also be a source of noise when driven from a typical OP AMP output. Due to the inductance and capacitance of the wire the OP AMP output can oscillate. It is always recommended to set a fixed voltage at the controller and then check the signal at the amplifier with an oscilloscope to make sure that the signal is "clean".

Servo system wiring typically involves wiring a controller (digital or analog), servo amp(s) a power supply and motor(s). Wiring these servo system components is fairly easy when a few simple rules are observed.

7

The signal gnd(return) of the controller(CTRL SGNL GND) must be connected to the signal gnd of the servo amp(AMP SGNL GND) either directly or through chassis gnd, to avoid noise pick up due to the "floating" differential servo amp input.

It is recommended that the signal and power wires are routed in a separate cable harness.

In most servo systems all the grounds are connected to a single chassis ground (normally the same as Earth ground). In the power section there are two grounds "DC GND" and "AC GND" (see wiring diagram). Either of these grounds can be connected to "CHASSIS GND". If the system design requires that "AC GND" is connected to "CHASSIS GND" then the servo amp must have internal optical isolation in order to connect "CONTL SGNL GND" or "AMP SGNL GND" to "CHASSIS GND". This opto isolation is required to avoid a dead short across "DB1" diode bridge, through "DC GND".

For servo amps without optical isolation if "DC GND" and "AMP SGNL GND" are connected to "CHASSIS GND" then it is not necessary to connect the signal wire shield to "AMP SGNL GND" because these grounds are then connected through the chassis.

The grounding design is ultimately the responsibility of the user.

3.3 Power Supply Wiring

All of Dynetic Systems servo amplifiers operate from a single polarity unregulated DC power supply. Reservoir capacitance of 2,000 μF /ampere of maximum output current will reduce ripple to 4V p-p at 120 Hz (single phase AC input).

The PWM current spikes generated by the power output are supplied by the internal power supply capacitors. In order to keep the ripple current on these capacitors to an acceptable level it is necessary to use heavy power supply leads and keep them short (less than 3 feet). If the power supply leads exceed 3 feet then the amplifier must be "by passed" by a capacitor of at least 1,000 μF within 3 feet of the servo amp. Reduce the inductance of the power leads by twisting them.

When multiple amplifiers are installed in a single application, precaution regarding ground loops must be taken. Whenever there are two or more possible current paths to a ground connection, damage can occur or noise can be introduced in the system. The following rules apply to all multiple axis installations, regardless of the number of power supplies used:

- A. Run separate power supply leads to each amplifier directly from the power supply filter capacitor.
- B. Use the differential input to the amplifier to avoid common mode noise.
- C. Never "daisy-chain" any power or DC common connections. Use "star" connection instead.

3.4 Motor Wiring

Use of a twisted, shielded pair for the motor power cables is recommended. Ground the shields to the amplifier's chassis ground and to the motor's frame. The motor power input leads are connected to amplifier's output.

CAUTION: DO NOT use wire shield to carry motor current or power!

3.5 CE-EMC Wiring Requirements

Additional Installation Instructions Necessary For Meeting EMC Requirements

General

1. Shielded cables must be used for all interconnect cables to the amplifier and the shield of the cable must be grounded at the closest ground point with the least amount of resistance.

2. The amplifier's metal enclosure must be grounded to the closest ground point with the least amount of resistance.
3. The amplifier must be mounted in such a manner that the connectors and exposed printed circuit board are not accessible to be touched by personnel when the product is in operation. If this is unavoidable there must be clear instructions that the amplifier is not to be touched during operation. This is to avoid possible malfunction due to electrostatic discharge from personnel.

Analog Input Amplifiers

4. A Fair Rite model 0443167251 round suppression core must be fitted to the low level signal interconnect cables to prevent pickup from external RF fields.

PWM Input Amplifiers

5. A Fair Rite model 0443167251 round suppression core must be fitted to the PWM input cable to reduce electromagnetic emissions.

MOSFET Switching Amplifiers

6. A Fair Rite model 0443167251 round suppression core must be fitted to the motor cable connector to reduce electromagnetic emissions.
7. An appropriately rated Schaffner 2080 series AC power filter in combination with a Fair Rite model 5977002701 torroid (placed on the supply end of the filter) must be fitted to the AC supply to any MOSFET amplifier system in order to reduce conducted emissions fed back into the supply network.

9

IGBT Switching Amplifiers

8. An appropriately rated Schaffner 2070 series AC power filter in combination with a Fair Rite model 0443167251 round suppression core (placed on the supply end of the filter) must be fitted to the AC supply to any IGBT amplifier system in order to reduce conducted emissions fed back into the supply network.
9. A Fair Rite model 0443164151 round suppression core and model 5977003801 torroid must be fitted at the motor cable connector to reduce electromagnetic emissions.

Fitting of AC Power Filters

10. The above mentioned AC power filters should be mounted flat against the enclosure of the product using the two mounting lugs provided on the filter. Paint should be removed from the enclosure where the filter is fitted to ensure good metal to metal contact. The filter should be mounted as close to the point where the AC power enters the enclosure as possible. Also the AC power cable on the load end of the filter should be routed as far from the AC power cable on the supply end of the filter and all other cables and circuitry to minimize RF coupling.

Dynetic Systems
Dynetic BE12-6 & BE15-8 Series Brushless PWM Amplifiers
Operating Manual

For reference purposes, the Technical Construction File Number is TCF No. J97001250.007 (Rev 1).

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Please contact factory regarding low voltage directive (LVD) information.

4.0 SET-UP INSTRUCTIONS

Precautions

Do not install the amplifier without first determining that all chassis power has been removed for at least 10 seconds. Never remove an amplifier from installation with power applied.

To ensure reliable operation, the wiring and cautionary notes must be reviewed prior to set up.

Brushless amplifier with brush type motor.

To drive a brush-type motor disconnect all Hall sensor inputs, set phase setting switch to 60 degrees and use Motor-A, Motor-B. See brush-type set up instructions. For step number four configure amplifier for open loop mode instead of voltage mode.

Brush Type Setup instructions

Dynetic Systems' amplifiers are designed to operate in a self-test mode, using the "offset" potentiometer to control an on-board signal source.

This test can be used to confirm that the amplifier is functionally operational. Read the setup instruction before applying power:

Dynetic Systems
Dynetic BE12-6 & BE15-8 Series Brushless PWM Amplifiers
Operating Manual

1. **Review cautionary notes and wiring section before proceeding.**
2. Connect power. Do *not* connect the motor yet!
3. Check that LED indicates normal operation.
4. Set test mode according to data sheet for voltage mode.
5. Set offset/test switch ON. Measure the voltage across motor output with a DC voltmeter, turn the "test" potentiometer. Voltage should vary between \pm bus voltage. Set the output voltage with the "test" potentiometer to a low value before connecting the motor leads.
6. **Set current limit according to motor specifications. Protecting the motor from excessive levels of current is the responsibility of the user.**
7. Verify that the load circuit meets minimum inductance requirements and that the power supply voltage does not exceed amplifier rated voltage or 150% of the nominal motor voltage.
8. Turn the power off. Connect the motor. Turn the power back on. "Tweak" the "test" potentiometer to change motor speed in both directions. Set the offset/test switch OFF.
9. Ground both reference inputs and then using the offset pot, set motor for zero speed.
10. Set mode suitable for your application.

11

5.0 AMPLIFIER ADJUSTMENT (TUNING) PROCEDURE

5.1 Command Signal

The command signal is a reference voltage which is applied to the amplifier to control the motor direction and speed.

5.2 Feedback Elements

The feedback element can be any device capable of generating a voltage signal proportional to velocity, position or any parameter of interest. Such signals can be provided directly by a tachometer or potentiometer or indirectly by other feedback devices such as resolvers and encoders. These devices must have their outputs converted to a DC voltage before being connected to the amplifier.

The feedback element must be connected for negative feedback. This negative feedback will cause a difference between the command signal and the feedback signal. This difference is called the error signal. The amplifier compares the feedback signal to the command signal to produce the required output to the load by continually reducing the error signal to zero.

CAUTION: These initial adjustments should be performed with the motor shaft decoupled from the application.

With a zero (0) speed command applied, momentarily apply power to the amplifier. If upon application of power the motor rapidly accelerates, a run-away condition exists due most likely to the reversal of either motor or feedback element wiring. If the motor and feedback elements are properly connected and the amplifier is functioning normally, the motor shaft will remain stationary or drift slightly in either direction with power

applied. Trim the "offset" potentiometer for minimum amplifier output current by observing motor drift with REF inputs grounded.

If the motor does not run-away but emits a high pitched squeal, turn the loop gain potentiometer counterclockwise until motor squeal stops.

5.3 Potentiometer Adjustments

Offset Adjustment

Before offset adjustment is made, reference inputs must be grounded or commanded to 0 volts. Put the test offset switch in the on position, and trim the "offset" potentiometer for minimum amplifier output current by observing motor drift. Turn test offset switch off. Offset adjustment is complete.

Loop Gain Adjustment

This potentiometer adjusts the gain in the forward portion of the closed loop (velocity mode). Starting from the CCW position, turn CW until motor shaft oscillates. Then back off one turn.

Note: This potentiometer should be set completely CCW in current mode. Use the reference gain potentiometer for scaling.

12

Reference Gain Adjustment

This potentiometer adjusts the ratio between input signal and output variables (voltage, current, velocity). Turn this potentiometer clockwise until the required output is obtained for a given input signal.

Current Limit Adjustments

WARNING: It is critical to set the current limit so that the instantaneous motor current does not exceed the specified motor peak current rating. Should this occur, the motor permanent magnets may be demagnetized. This would reduce both torque constant and torque rating of the motor and may seriously affect system performance.

Most Dynetic Systems servo amplifiers feature peak and continuous current limit adjustments. The maximum peak current is needed for fast acceleration and deceleration. Most amplifiers are capable of supplying the maximum peak current for 2 sec. and then the current limit is reduced gradually to the continuous value. The purpose of this is to protect the motor in stalled condition by reducing the current limit to the maximum continuous value. Current limiting is implemented in the amplifier by reducing the output voltage.

The current limit adjustment potentiometer has 12 active turns plus 1 inactive turn at each end and is approximately linear. Thus, to adjust the current limit, turn the potentiometer counter-clockwise to zero (using ohmmeter), then turn clockwise to the appropriate value. If the peak current reference does not reach the set peak current limit, the time for peak current will be longer than 2 sec. The actual time will be a function of RMS current. One CW turn of the P2 potentiometer approximately equals one Amp of peak current.

A selection of amplifiers feature separate peak and continuous current limit adjustments. This can be done by connecting an external resistor between the continuous current limiting pin and the signal ground. In addition, many amplifiers have the option of current limiting using the DIP switches. If this is an option, it will be indicated in the switch function section for the particular amplifier.

5.4 Compensation Adjustments (Voltage-to-Speed Mode)

Servo system performance can be judged by the following three characteristics:

- Stability
- Accuracy
- Responsiveness without overshoot

It is a short and straightforward process to meet all three of these criteria. The process involves obtaining a stable servo using the compensation adjustment while optimizing the response of the system.

For this purpose, it is necessary to be able to feed in a small step at the reference input and observe the feedback signal on oscilloscope. Set the compensation adjustment to obtain a properly compensated response. This will be the fastest response without overshoot. If the system is undercompensated (slow response without overshoot) turn the compensation potentiometer clockwise. If it is overcompensated (overshoot and oscillation), turn the compensation potentiometer counterclockwise.

13

Practical Hints About Loop Compensation:

WARNING: Do not allow a motor to run for long periods of time if it is oscillating or squealing. Overheating can occur.

NOTE: In most applications, the compensation can be adjusted by rotating potentiometer Pot 1 (loop gain) clockwise until the motor oscillates audibly and then backing off until it stops. This simple procedure also applies to voltage mode.

Dynetic Systems' amplifiers feature optional user installed through hole components for custom compensation. These components can be used to implement custom compensation. For most applications the standard built-in compensation is satisfactory. The amplifier block diagrams show the built-in SMT component values for every user installed through hole component. These built-in SMT components can be removed easily by a regular fine tip soldering iron by heating up both sides of the component alternatively, then gently lifting component.

Contact factory for custom compensation application help.

Current loop:

The current loop response is determined by the current loop gain resistor. The greater the resistor value the faster the response. Typically the 10K setting is recommended for load inductors less than 3 mH and the 100K setting is recommended for more than 3 mH. This may be accomplished by either switching in the extra resistor with the DIP switch or installing a through hole resistor. For load inductor values higher than 5 mH a 200K or higher through hole resistor can be installed for faster response. If the resistor value is too high for the inductance then overshoot or oscillation occurs in the current loop. A through hole capacitor can be added to the current loop to increase the capacitance if the system is oscillatory. This should not be done to counter the effects of choosing a resistance value in the current loop that is too high for the inductance.

Voltage loop:

Compensating the voltage loop requires the least amount of effort. Turn Pot 1 CW and back off if oscillation occurs.

Velocity loop:

The velocity loop response is determined by the loop gain potentiometer P1. The larger the resistor value (CW) the faster the response. The velocity integrator capacitor can be used to compensate for large load inertia. Large load inertias require higher capacitor values. This may be accomplished by either switching in the extra capacitor with the DIP switch or installing a through hole capacitor. The need for an extra capacitor can be verified by shorting out the velocity integrator capacitor with the DIP switch. If the velocity loop is stable with the capacitor shorted out and unstable with the capacitor in the circuit then a larger capacitor is needed.

14

IR feedback:

Start with a very high (or open) IR feedback resistor with an unloaded motor shaft. Command a low motor speed (about 20-200 RPM). Without the IR feedback the motor shaft can be stalled easily. Decreasing the IR feedback resistor will make the motor shaft more difficult to stop. Too much IR feedback, i.e. too low resistor value, will cause motor run-away when torque is applied to the motor shaft.

Analog position loop:

Use of a tachometer is recommended to obtain a responsive position loop because the position loop is closed around the velocity loop. First the velocity loop must be stabilized (or voltage loop for undemanding applications). The position loop gain is determined by the fixed gain of the input differential amplifier of the servo amplifier. For best results the servo amplifier can be ordered with a higher differential amplifier gain. Please consult the factory.

5.5 Test Points For Potentiometers

After the potentiometer adjustments in the compensation section are complete, the resistance values can be measured for future adjustments or duplication on other amplifiers. Test points for the potentiometer wipers are provided and are located under all four potentiometers. **Make sure the power is off**, then measure the resistance between the test point and the outer leg of the potentiometer or between the test point and an appropriate ground. See the amplifier's functional block diagram to determine which ground should be used for each potentiometer. The potentiometers are all approximately 50K.

6.0 TROUBLESHOOTING

Overload Fault:

1. Verify that the motor shaft freely rotates with no power applied. The load on the motor must be

free of jams.

2. Verify that the minimum inductance requirement is met.

Heatsink Temperature:

1. Verify that the heatsink temperature is less than 65°C.

Over-Voltage Shutdown:

1. Check the power input voltage for a value in excess of those listed in the Specifications. If larger than listed, check the AC power line connected to the power supply for proper value.
2. Check the regenerative energy absorbed during deceleration. This is done with a voltmeter or scope monitor of the power supply voltage. If the supply voltage increased above specified value then additional power supply capacitance is necessary. Additional capacitors must be electrolytic type and located as close to the amplifier as possible.

Under-Voltage Shutdown:

1. Verify power supply voltages for minimum conditions per Specifications.

Short Circuit Fault:

1. Check each motor lead with respect to motor housing and power ground for shorts.
2. Measure motor armature resistance with the amplifier disconnected between motor leads.

Status:

1. Check positive inhibit, negative inhibit and inhibit inputs for proper input.

Causes of Erratic Operation:

1. Improper grounding.
2. Noisy command signal. Check for system ground loops.
3. Mechanical backlash, deadband, slippage, etc.
4. Excessive tachometer noise.
5. Noisy inhibit lines.
6. Excessive voltage spikes on bus.

7.0 CAUTIONARY NOTES

DO NOT reverse the power supply leads.

DO NOT spin the motor without power. The motor acts as a generator and will charge up the power supply capacitors through the amplifiers. Excessive speed may cause over-voltage breakdown in the power transistors. Note that an amplifier having an internal power converter that operates from the high voltage supply will become operative.

DO NOT short the motor at a high speed. When the motor is shorted its own voltage may produce a current flow as high as ten (10) times the amplifier peak current. The short itself should not damage the amplifier but may be bad for the motor. If the connection arcs or opens while the motor is spinning rapidly, this high current flows back into the amplifier due to stored energy in the motor's inductance and may damage the amplifier.

8.0 WARRANTY

Dynetic Systems Company warrants its product to be free from defects under normal use and is limited to replacing or repairing at its factory any of its products which are returned to the factory of origin within one (1) year after shipment, transportation charges prepaid, which are disclosed to Dynetic Systems Company's satisfaction to be defective. This warranty supersedes all other warranties, express or implied, including any implied warranty or fitness for a particular purpose, and all other obligations or liabilities on the part of Dynetic Systems Company and it neither assumes nor authorizes any other person to assume for the seller any other liabilities in connection with the sale of the said articles.

The original warranty period is not extended by the above mentioned provisions for any replaced or repaired articles. This warranty shall not apply to any products that have been subjected to misuse, negligence or accident.

