INSTRUCTION MANUAL

NO. 7038

FOR

AC BRUSHLESS SERVO DRIVE

MODEL 712-510-110

CONTROLLER PART NO. 0712603

MOTOR PART NO. 9012504

MODEL G26T-120

MARCH, 1988

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SWEODRIVE AC BRUSHLESS SERVOCONTROLLER

WARRANTY

Seller warrants that the products sold will be free from defects in material and workmanship and perform to Seller's applicable published specifications for a period of two (2) year from date of shipment from Sweo Controls, Inc. The liability of Seller hereunder shall be limited to replacing or repairing, at its option, any defective units or parts thereof which are returned F.O.B. Seller's plant, Bellevue, Washington. In no event shall Seller be liable for any consequential or incidental damages.

Equipment or parts which have been subject to abuse, misuse, accident, alteration, neglect, unauthorized repair or installation are not covered by warranty. Seller shall make the final determination as to the existance and cause of any alleged defect. No liability is assumed for expendable items such as fuses. No warranty is made with respect to custom equipment or products produced to Buyer's specifications except as specifically stated in writing by Seller in the contract for such custom equipment.

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Except as hereinabove provided, SELLER MAKES NO WARRANTIES, EXPRESS OR IMPLIED, INCLUDING ANY WARRANTY OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE.

SERVICES

The following services shall be provided:

A. Telephone technical assistance by experienced engineers.
B. Replacement PC boards and power units stocked at the factory for replacement.
C. An exchange plan for damaged or failed power units and printed circuit boards.

1.0 GENERAL INFORMATION

1.1 INTRODUCTION

The purpose of this manual is to provide installation, startup, operating and maintenance instructions for the Sweo A.C. Brushless Servo Controller. The 712 series drives, available in the range from 3 to 20 HP, are especially adapted for high performance servo control systems. Each controller is factory tested and set up to operate a specified brushless AC motor per cover sheet. A setup sheet showing proper control settings for this drive is included at the end of this manual.

Sections 1-4 are in standard format while the cover sheet, Fuse List Drawing list (section 5 with attached drawings), and the attached setup sheet are tailored to each drive.

1.2 SAFETY NOTICE

WARNING

This equipment contains voltages which may be as high as 400 volts and rotating parts on motors and driven machines. High voltage and moving parts can cause serious or fatal injury. Only qualified personnel familiar with this manual and any driven machinery should attempt to startup or troubleshoot this equipment. Observe these precautions:

1. USE EXTREME CAUTION, DO NOT TOUCH any circuit board, power device or motor electrical connection without insuring unit is properly grounded and no high voltage is present. DO NOT apply AC power before grounding per instructions herein. DO NOT open cover for 2 minutes after removing AC power to allow capacitors to discharge.

2. BE CERTAIN that possible violent motion of motor shaft and driven machinery due to improper control operation will not cause personel injury or damage. Peak torques of several times rated motor torque can occur during a control failure.

3. Motor circuit may have high voltage present whenever AC power is applied, even when motor is not rotating.

1.3 DRIVE DESCRIPTION (Figure 1; Drawings 7123 & 7153)

The 712 series controller is a complete brushless drive controller which operates from three phase 208 or 240 VAC

power to control a permanent magnet synchronous AC motor in an industrial drive system. This controller may also be operated on a single phase power source with reduced performance. Outline and mounting of the controller enclosure is specified on drawing 7153.

The controller consists of the following major elements in a compact enclosed assembly:

1. Mounting base with grounded heat sink, on which are mounted up to 3 bus capacitors C1, C2 and C3, the 3 main power transistors Q1, Q2, and Q3, output current sensing resistors R2 and R3, the three phase diode bridge BR1, the input filter inductor L1, the soft starting resistor R1, soft start bypass SCR, (part of Q5 module) regenerated energy regulator transistor Q4 and the power terminal block. Units rated over 20 amps rms also have a fan for circulation of cooling air.

2. Base drivers A5, A6 and A7 mounted over the 3 main power transistors.

3. Swing-out circuit mounting plate with mod-demod assembly A4 and power supply assembly A3 mounted on the inside surface.

4. Control board A1 and personality board A2 mounted on the outside surface of the swing-out plate.

The functional block diagram of Figure 1 and drawing 7123 shows the internal connection of the elements listed above.

1.3.1 INTERCONNECTIONS

Drawing 7226 shows the interconnection of the controller, AC power, brushless motor, and typical customer I/O's. All power connections are made to the terminal block on the top of the controller. All signal connections are made to plug-in terminal strips J1 & J2 on control board A1.

1.3.2 INDICATORS, ADJUSTMENTS AND TEST POINTS

Controller status and fault lights are located on control board, A1. All adjustments and setup selections are made with the pots and jumpers located on personality board A2. Test connector J9 provides setup, adjustment and monitoring points as identified in drawing 7226.

1.4 CONTROLLER CIRCUIT FUNCTIONAL DESCRIPTION (Figure 1)

Figure 1 shows the functional arrangement of the controller and A.C. motor. Motor voltage and frequency is created by the three main power transistor pairs Q1, Q2 and Q3 which operate in a PWM (pulse width modulation) mode from the DC

Bus. This bus voltage is provided by the three phase diode bridge BR1, inductor L1, and capacitors C1, thru C6. Input AC three phase power is supplied directly to the bridge through controller terminals L1, L2 and L3. Power Supply A3 assembly is powered directly from the DC bus.

The A3 power supply furnishes several functions:

1. Controls charging current to the bus capacitors through the soft start circuit, thus preventing an inrush current upon AC power application.

2. Controls the shunt regulator transistor Q4 to prevent overvoltage on the bus supply by discharging the bus through an external regeneration resistor.

3. Develops regulated control power to operate the other circuit boards in the system.

4. Enables drive operation if power conditions are proper.

5. Connects a safety bleed resistor across the capacitor bank when AC line power is removed.

Each main power transistor pair is controlled and monitored by its associated Base Driver Assembly A5, A6 or A7. These base drivers amplify the PWM control signals and monitor the operation of the power transistors to insure reliable output stage operation with output short circuit and ground fault protection.

The output currents through terminals T2 and T3 are sensed with resistors and converted to common-referenced signals by the Mod-Demod A4. This board isolates the power circuit sensing resistors from the control circuits and provides gain and offset trimming of the feedback signal.

Each of the three main power transistor pairs is controlled by its individual current loop, operating from the isolated current feedback and the input current command from the commutation logic. The resulting current error is amplified by the current error amplifier and applied to the PWM modulation comparators with the 2.5 KHz triangle wave oscillator signal to develop the PWM modulation applied to the base driver. The fault disable logic removes base drive output in the event an output circuit or control fault is detected.

The commutation and tach feedback from the motor are developed from the Tachsyn brushless transducer output by the signal conditioning circuitry. Both digital and analog tach signals are developed; the analog tach is used for speed control and the digital tach is used for overspeed protection.

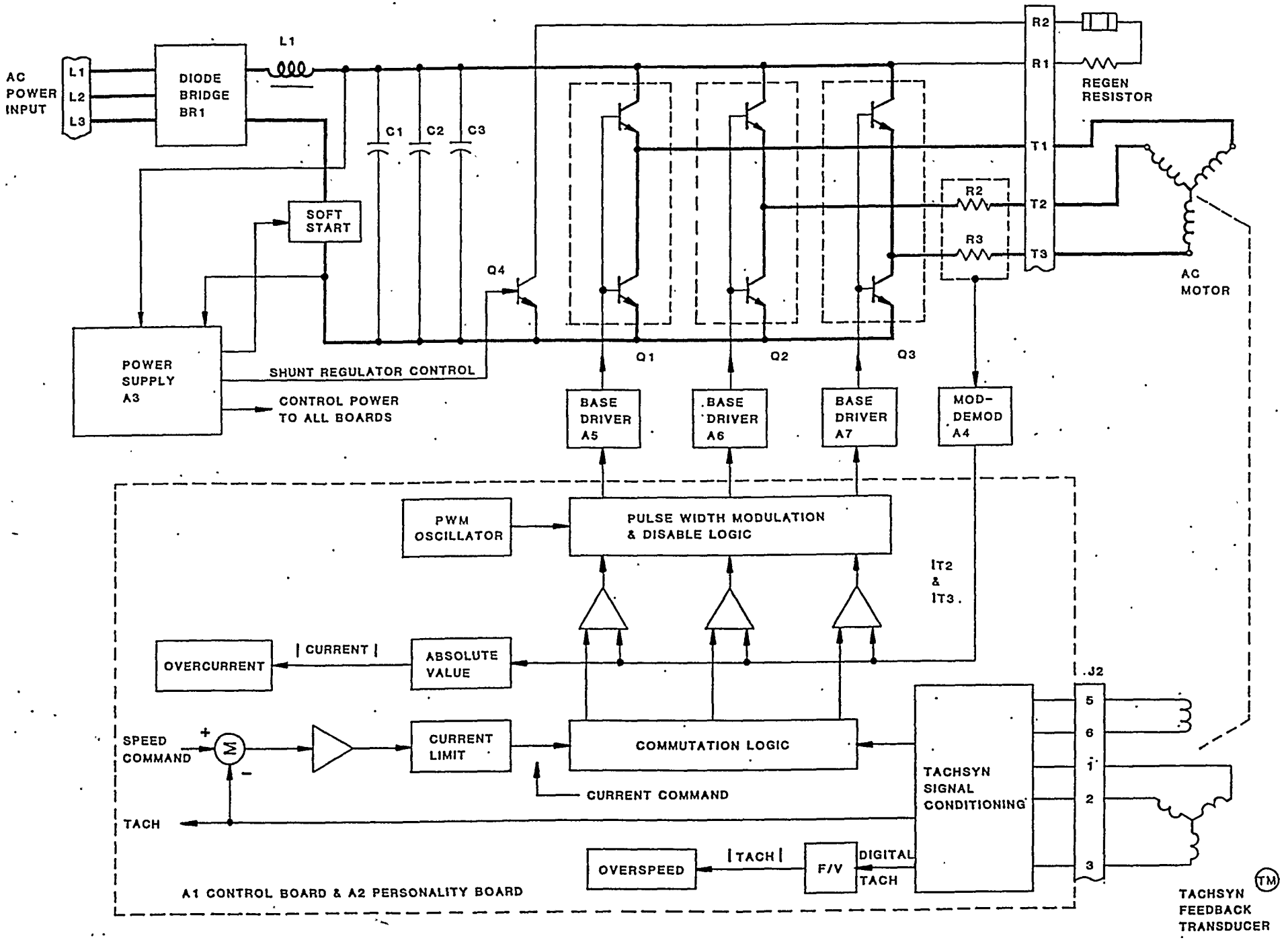


FIGURE 1 FUNCTIONAL BLOCK DIAGRAM

1.5 PROTECTIVE FEATURES

This controller includes extensive fault monitoring circuits to insure safe reliable operation and to aid in troubleshooting. The following latching red LED fault indicators are supplied:

PWR	(DS2-1)	Lights when a dc bus overvoltage or undervoltage condition occures. If the AC power fails this and all LEDs are turned off.
BD1	(DS2-2)	Fault at output T1 latches and lights this indicator. Fault may be loss of adequate transistor base drive, output short or ground fault.
BD2	(DS2-3)	Fault at output T2 latches and lights this indicator. Fault may be loss of adequate transistor base drive, output short or ground fault.
BD3	(DS2-4)	Fault at output T3 latches and lights this indicator. Fault may be loss of adequate transistor base drive, output short or ground fault.
OS	(DS3-1)	Latches and lights upon motor over-speed, independent of tachometer voltage. Overspeed setting is user adjustable.
OT	(DS3-2)	Latches and lights two seconds after motor or controller thermostat opens.
IOC	(DS3-3)	Latches and lights when output current exceeds internally preset level.
±15	(DS3-4)	Latches and lights upon low or missing +15V or -15V control power.

All faults indicated by these indicators may be reset either by removing and reapplying AC power (power-up reset) or by applying a reset input to J1-9.

The following open collector outputs provide fault status information at J1:

READY (J1-15) (NO FAULT)	Open collector which indicates either drive ready or drive fault. Logic high or low output on READY is internal switch SW1-3 selectable.

OVERTEMP WARNING (J1-16) — Open collector which operates when motor or controller thermostat opens to provide two second warning before controller trips off with overtemp fault as discussed above. Logic high or low output on O'TEMP is internal switch SW1-6 selectable.

1.6 STATUS INDICATORS AND OUTPUTS

The following green LED indicators show controller status:

AT SPD (DS1-1) — Lights when motor speed is within ±1% of maximum speed of commanded speed.

CW (DS1-2) — Lights when ENABLE 1 (J1-13 & 14) input is present.

CCW (DS1-3) — Lights when ENABLE 2 (J1-11 & 12) input is present.

RDY (NO FAULT) (DS1-4) — Lights when power is applied, no fault conditions exist and reset is not applied. Normally lights 2 seconds after AC power is applied or reset is removed.

The following open collector status outputs are provided for interface with other control equipment:

LOW SPEED J1-17 — Open collector output which operates at speeds below typically ±1% max speed. Logical high or low output at LOW SPEED is internal switch SW1-2 selectable.

AT SPEED J1-18 — Jumper JP3 selectable open collector output which operates at speeds within typically ±1% max speed of commanded speed. Logic high or low output AT-SPEED is internal switch SW1-1 selectable.

SET SPEED J1-19 — Jumper JP4 selectable open collector output which operates at speeds above or below a set speed as selected with internal switch SW1-5. SET SPEED is adjustable with potentiometer R53.

1.7 ADJUSTMENTS

1.7.1 PERSONALITY BOARD A2 (See Figure 2)

All normal user adjustments are located on the personality board A2. Adjust per setup instructions in Section 2.

R22	RATE GAIN	Adjusts rate servo loop gain, CW to increase gain.
R23	ACCEL-DECEL	Adjusts acceleration and deceleration, CW to increase (decreases accel-decel times).
R24	MAX SPEED	Adjusts max motor speed for a given speed command input, CW to increase motor speed.
R38	ZERO TRIM	Adjusts zero offset of speed loop input.
R39	TACH SCALE	Adjusts scale factor of controller tach feedback, CW to increase tach signal.
R52	CURRENT LIMIT	Adjusts maximum current the controller will supply to the motor, CW to increase limit.
R53	SET SPEED	Adjusts trip point of set speed logic output, CW to increase set speed.
R66	OVERSPEED	Adjusts overspeed setting, CW to increase overspeed setting.
R67	EXTERNAL	(Optional). Adjusts maximum current of the controller CURRENT LIMIT (see R52). Active only when the external current limit input is connected to common, CW to increase limit.

1.7.2 MOD-DEMOD A4

These adjustments are factory preset and normally require no field adjustment.

R14	T3 OFFSET	Adjusts offset of T3 current signal
R15	T3 SCALE	Adjusts scale factor of T3 current signal
R30	T2 OFFSET	Adjusts offset of T2 current signal
R29	T2 SCALE	Adjusts scale factor of T2 current signal

1.7.3 TACHSYN PHASING

This motor adjustment is factory preset and normally requires no field adjustment. The controller includes an alignment mode to check and adjust phasing between the tachsyn and motor. The adjustment proceedure is givien in section 2.4 of this manual.

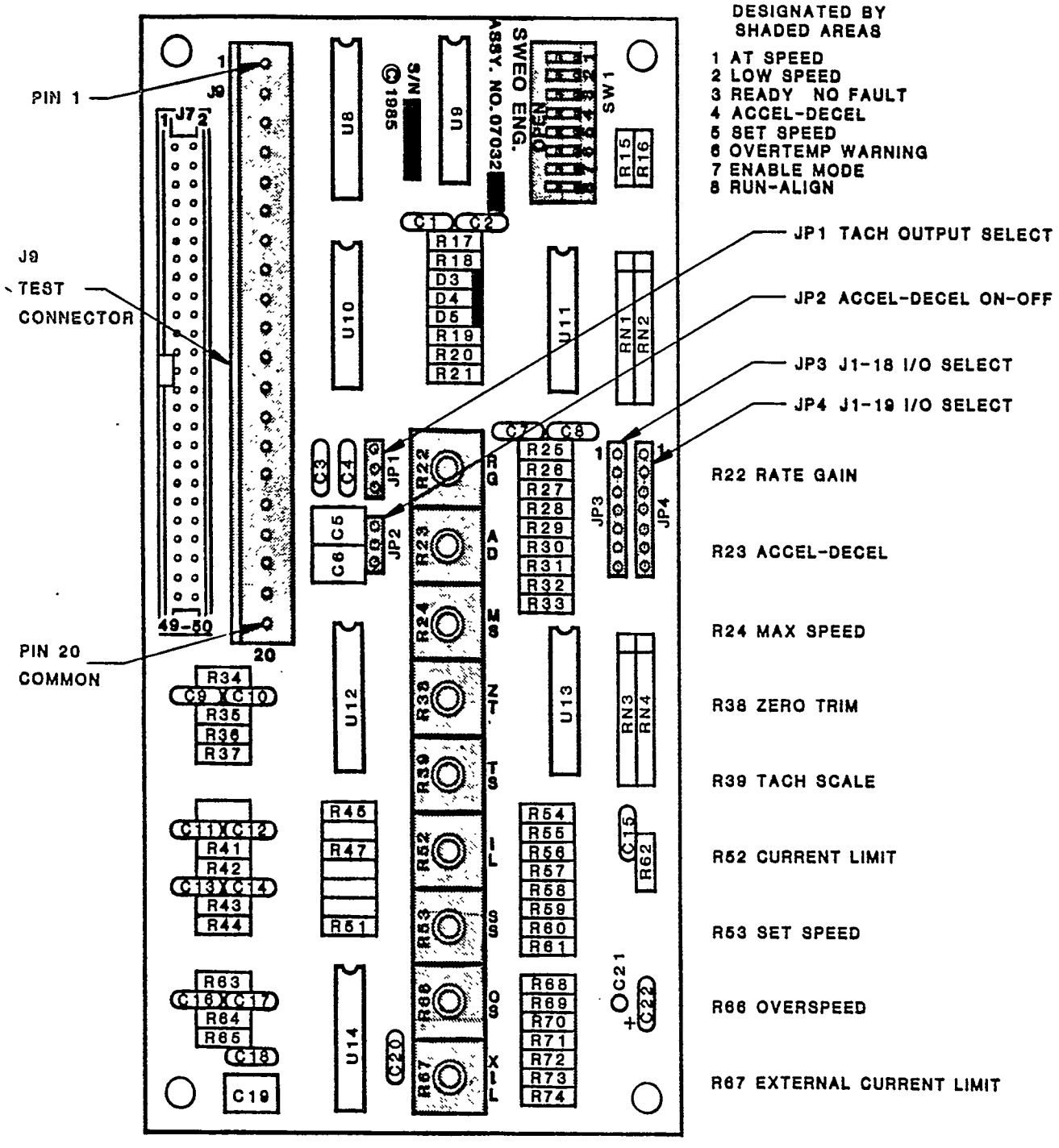


FIGURE 2

PERSONALITY BOARD SET UP AND ADJUSTMENT LOCATIONS

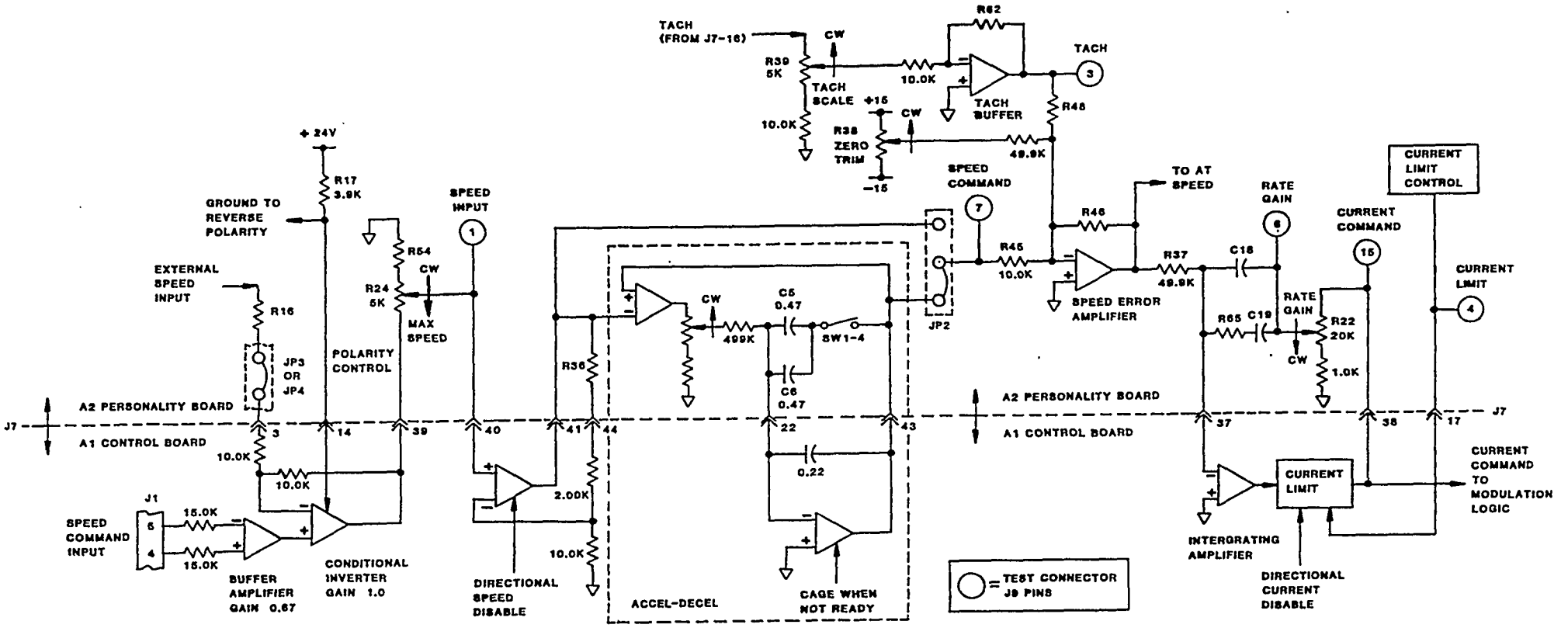


FIGURE 3

SIMPLIFIED SCHEMATIC DIAGRAM SPEED CONTROL CIRCUITS

2.0 INSTALLATION AND STARTUP

Check motor nameplate and power source voltage to insure they match the controller nameplate and information contained in this manual. DO NOT USE THIS CONTROLLER ON ANY OTHER VOLTAGES OR MOTORS without factory approval.

2.1 MOUNTING (Drawing 7153)

This controller is designed for panel mounting. Mount in a clean dry enclosure with an internal ambient temperature of not greater than +50 degrees C. DO NOT mount controller above transformer or other heat source. DO provide 2" minimum clear area above and below the controller to allow free flow of air over heat sink on the back of the enclosure.

Mounting dimensions are shown in drawing 7153. Note that both power and plug-in signal connections are made to the top of the control. Provide access to the front of the module to adjust potentiometers and to observe indicators. Allow room for swinging the hinged circuit board panel out to gain access to the power components.

2.2 WIRING (Drawing 7226)

All wiring shall be in accordance with the National Electric Code and applicable local codes.

2.2.1 POWER WIRING

Connect 208 or 230 VAC line-line three phase AC power to controller input terminals L1, L2 and L3. Use suitable fault protection per table below:

Circuit Breaker -	Three phase, 240VAC, 60A, thermal magnetic. G.E. THQ or TEB series are typical.
Fuses	250VAC, 60A slow-blow type Buss FRN 60 and LPN 60 are typical

Use AWG #8 wire minimum.

If single phase input power is to be used, connect power to controller terminals L1 and L2. Note that controller capacity is restricted to 60% of normal when operated on single phase power.

Wire the three phase motor stator to the controller using approporately sized wire. Connect controller terminals T1, T2 and T3 directly to motor or through a DC rated contactor to provide positive disconnection for the motor. A motor circuit contactor is recommended whenever motor motion due

to a controller fault must be prevented for personnel or equipment safety.

Ground the chassis ground lug and motor frame to machine or plant ground using AWG #6 wire minimum.

High inertia and overhauling loads require an external regeneration resistor with suitable fuse or breaker protection. Minimum resistance of the regeneration resistor is 6 ohms. The resistor dissipation capability must be selected to suit the average regenerating or overhauling load. The protective fuse or breaker must be rated at 400VDC minimum with a low enough rating to interrupt upon a control failure causing continuous connection of the resistor across the DC bus (280 to 350VDC). Sweo Controls supplies three kits for this purpose:

R3 300 watts continuous, one 6 ohm, 300 Watt resistor with Buss KLM 30 fuse and holder.

R6 600 watts continuous, two 12 ohm 300 watt resistors to be used in parallel, with Buss KLM 30 fuse and holder.

R9 900 watts continuous, three 20 ohm, 300 watt resistors to be used in parallel, with Buss KLM 30 fuse and holder.

2.2.2 SIGNAL WIRING

All motor signal and control wires are terminated on plug-in terminal strip J2. Use twisted shielded pairs and triplets as shown in Drawing 7226, with shields terminated on controller end only. Maximum cable length between J2 and the AC motor is 150' using shielded cable with 22 AWG minimum wire size and maximum wire-wire capacity of 60 pf/foot.

All customer control and signal wiring is terminated on plug-in terminal strip J1. Common on this terminal strip is isolated from the power circuits and grounded to the chassis. All signal and control inputs are relative to common except the Buffered Speed Command Input and the opto-isolated Enable 1 & 2 inputs.

Standard J1-4 & 5 signal input scaling is 10V $\pm$2 V = Max Speed. This input is buffered to provide 40 db minimum common mode isolation up to $\pm$15 volts common mode input relative to common. Either input may be grounded at the signal source so long as the common mode range isn't exceeded.

The J1-6 Tach Output is available for speed monitoring or metering. Jumper selectable absolute value of tach voltage or bipolar tach voltage is available as discussed in

Section 2.3.1.

The J1-9 reset input may be operated with an open collector or switch input to common to reset any fault indication except power supply loss. This input must be open to operate the drive.

The J1-11 to 14 Enable inputs are factory connected to operate as either CW-CCW or Speed-Torque enable. The configuration used in this controller is specified in the setup sheet. See Drawing 7226 for typical connections and operating notes.

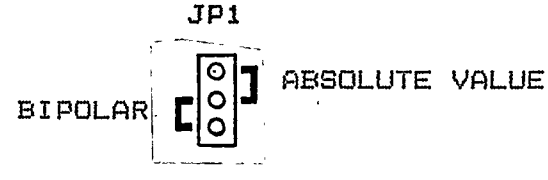
The open collector and multipurpose terminals J1-15 to 19 provide many possible I/O combinations. See Theory of Operation Section for details on use of these connections. Current and voltage limitations of the open collector outputs are specified in Section 3.7.9.

2.3 PERSONALITY BOARD JUMPER AND SWITCH SELECTIONS

Select the jumper and switch settings on the personality board to suit the application requirements. See Figure 2 for jumper and switch locations and functions.

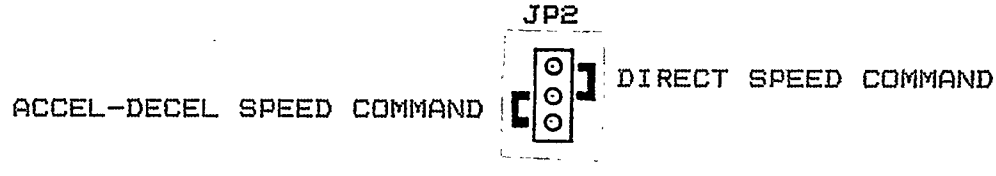
2.3.1 JP1 TACH OUTPUT SELECTION

This jumper selects J1-6 Tach Output. Set push-on jumper in upper position for positive analog voltage proportional to speed. Set push-on jumper in lower position for bipolar speed output.



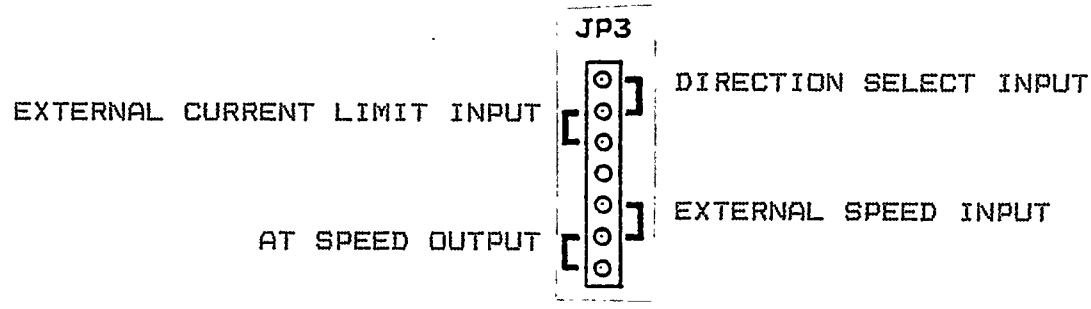
2.3.2 JP2 ACCEL-DECEL ON-OFF SELECTION

Set push-on jumper in upper position for direct Speed Command Input with no Accel-Decel limiting. Set push-on jumper in lower position for Accel-Decel limiting of the Speed Command Input.



2.3.3 JP3 I/O SELECTION FOR J1-18

This jumper strip provides four J1-18 I/O selections for jumper positions as shown below:

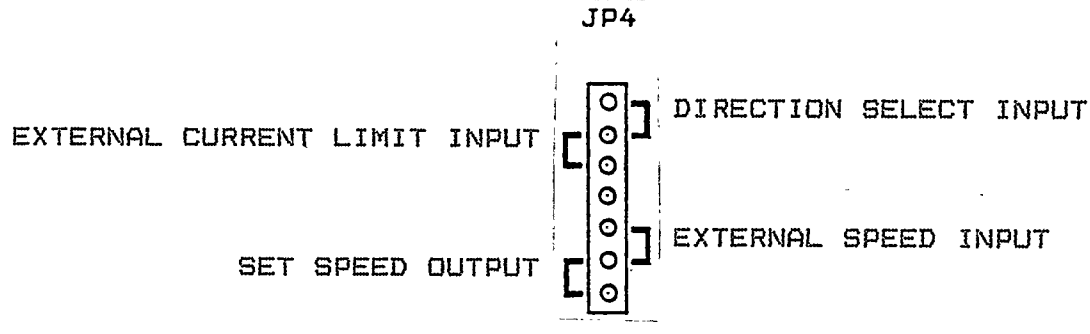


CAUTION:

ONLY ONE JUMPER MAY BE INSTALLED ON JP3

2.3.4 JP4 I/O SELECTION FOR J1-19

This jumper strip provides four J1-19 I/O selections for jumper positions as shown below:



CAUTION:

ONLY ONE JUMPER MAY BE INSTALLED ON JP4

2.3.5 SW1 SELECTIONS

See Figure 2 for location of these selections:

		SWITCH	FUNCTION
1.	AT SPEED	OFF	J1-18 open collector ON when drive AT SPEED
		ON	J1-18 open collector ON when drive not AT SPEED
2.	LOW SPEED	OFF	J1-17 open collector ON below LOW SPEED
		ON	J1-17 open collector ON above LOW SPEED
3.	READY = NO-FAULT	OFF	J1-15 open collector ON with drive not READY
		ON	J1-15 open collector ON with drive READY
4.	ACCEL-DECEL	OFF	Low ACCEL-DECEL time range
		ON	High ACCEL-DECEL time range
5.	SET SPEED	OFF	J1-19 open collector ON above Set Speed
		ON	J1-19 open collector ON below Set Speed
6.	OVERTEMP WARNING	OFF	J1-16 open collector ON at normal temperature
		ON	J1-16 open collector ON at Over-temperature
7.	ENABLE MODE	OFF	Speed-Torque Enable Mode
		ON	CW-CCW Enable Mode
8.	RUN-ALIGN	OFF	Drive Run Mode = Normal Setting
		ON	Drive Transducer Align Mode

CAUTION:

DO NOT OPERATE SW1-7 OR 8 during normal operation. Select SW1-7 Enable mode before operating controller. See Section 2.4 for use of Run-Align switch.

2.4 TACHSYN PHASING ADJUSTMENT

With motor electrically connected to controller and shaft disconnected from load, connect AC power to controller WITH ENABLE INPUTS OPEN OR DISCONNECTED. Switch SW1-8 (RUN-ALIGN) to ON to place controller in Align mode, this will cause current to flow through motor windings T2 and T3. Motor shaft will rotate to position of minimum torque; rotate shaft slightly about this position by hand to confirm that motion is unrestricted by friction.

Properly phased Tachsyn output at test connector J9 is then:

SIN A, J9-9 to J9-20	+2.5 to +3.5 VDC
SIN B, J9-10 to J9-20	Less than ±0.05VDC
SIN C, J9-11 to J9-20	-2.5 to -3.5 VDC

Check phasing at J9 using DVM, with DVM common connected to J9-20. If phasing requires adjustment, loosen 3 clamps holding Tachsyn stator to motor end bell and rotate stator to achieve above specified voltages. Retighten clamps and recheck SIN B null voltage to confirm proper alignment.

Switch SW1-8 to OFF to place controller in Run mode.

2.5 PERSONALITY BOARD POTENTIOMETER ADJUSTMENTS (Figure 2)

Make all measurements described below with DVM common on J9-20 except as otherwise noted. See Setup Sheet in Drawings section for factory recommended settings.

2.5.1 R52 CURRENT LIMIT - TEST OUTPUT J9-4

Make this adjustment with AC power applied, RDY on, both enable inputs open or disconnected (CW & CCW off), and External Current Limit input open (if used). Set potentiometer R52 for desired Current Limit up to the maximum per attached set up sheet.

2.5.2 R67 EXTERNAL CURRENT LIMIT-TEST OUTPUT J9-4

If this option is supplied, follow 2.5.1 above except connect External Current Limit Input (J1-18 or -19, depending on JP3 and JP4 selection) to common to activate external limit. Set potentiometer R67 for desired External Current Limit up to the maximum allowed by the setting of R52.

2.5.3 R66 OVERSPEED - TEST OUTPUT J9-8

Use setup per 2.5.1; set potentiometer R66 for desired overspeed setting up to the maximum overspeed allowed per the attached set up sheet.

CAUTION:

MECHANICAL DAMAGE MAY OCCUR AT MOTOR SPEEDS ABOVE THE MAXIMUM OVER SPEED ALLOWED

2.5.4 R53 SET SPEED - TEST OUTPUT J9-16

Use setup per 2.5.1; set potentiometer R53 for desired set speed setting. Increasing speed setting will be up to 20% higher than decreasing speed setting due to hysteresis in the set speed comparator.

2.5.5 R22 RATE GAIN - TEST INPUT J9-15, OUTPUT J9-6

Gain setting defined in the setup sheet may be made using setup of 2.5.1, connecting 1 Kohm resistor from J9-15 to J9-18, first measuring DC voltage at J9-15 and then adjusting R22 to cause DC voltage at J9-6 to be (0.XX)(J9-15 voltage). Use 0.XX = Gain Ratio from setup sheet, item 5.

To adjust Rate Gain for a load other than that indicated in the setup sheet, complete other adjustments below, then enable drive and apply step speed commands with jumper JP2 set for no Accel-Decel limiting. Observe the motor tach output at J9-3 with oscilloscope and set R22 for desired response, adjusting CW to increase gain setting. Too CW a gain setting will cause overshoot and may cause oscillations in the drive; too CCW a setting will cause sluggish response. If load is variable in the application (e.g., switchable ratio between motor and load), check gain setting with both extremes of load and select best compromise between ideal settings for each load. Measure resulting gain setting using procedure described above, record on setup sheet for future reference.

2.5.6 R38 ZERO TRIM - MONITOR MOTOR SHAFT ROTATION

With AC power applied and RDY on, apply zero speed command and activate both Enable inputs to cause CW and CCW to be on; then adjust R38 for zero motor shaft rotation.

2.5.7 R39 TACH SCALE-TEST OUTPUTS J9-3 & 14

With setup per 2.5.6, increase speed command to cause tach output measured with DVM at J9-3 to agree with requirement on set up sheet in the input column to within ± 0.1 volt. Then connect DVM from J9-3 to J9-14 and adjust R39 for DVM reading less than ± 0.020 volt (thus trimming Tachsyn speed output to equal absolute tach output derived from digital tach). Make R24 adjustment per 2.5.8 after this adjustment.

2.5.8 R24 MAX SPEED - TEST OUTPUT J9-1

With setup per 2.5.7, after Tach Scale adjustment is complete, raise speed input to desired maximum voltage, then adjust R24 to attain desired maximum speed measured with DVM at J9-14.

2.5.9 R23 ACCEL-DECEL - TEST OUTPUT J9-14

With setup per 2.5.7 and Accel-Decel limited input selected with JP2, apply rapid speed command change from zero to max speed and monitor J9-14 output using oscilloscope. Select high or low range with SW1-4 and adjust R23 for desired accel-decel time.

3.0 THEORY OF OPERATION

3.1 MOTOR ASSEMBLY

The AC permanent magnet synchronous motor has a 3 phase Y connected stator as illustrated in Figure 1. The motor rotor position and speed are sensed by a Tachsyn TM mounted in line on the rear of the motor. This frameless brushless electromagnetic transducers rotor is mounted directly on the motor shaft and its stator is mounted with 3 synchro clamps to the motor rear end bell. Phasing of the Tachsyn to the motor is accomplished by loosening the synchro clamps, rotating the Tachsyn stator and reclamping.

3.2 CONTROLLER BUS POWER SUPPLY (Figure 1 and Drawing 7123)

Drawing 7123 shows the interconnection of the power components. Incoming AC power to L1 thru L3 is rectified to DC by the diode bridge BR1 and filtered by inductor L1. The inductor reduces current ripple from the AC line on the capacitors C1-C3 to minimize line KVA and interference which might otherwise be conducted from the controller to the AC lines. The capacitors store DC bus eneregy providing a safe nominal voltage for the power transistors by supplying peak currents and absorbing a limited amount of regenerated power. Normal bus power supply voltages range from 275 VDC under heavy load at low line voltage to 348 VDC with no load at high line voltage. Motor regeneration will raise the DC bus voltage causing operation of the shunt regulator which maintains the DC bus voltage below 378 VDC.

Excessive current inrush upon power application is prevented by the soft start circuitry composed of R1, A8 fuses F1-F2 and the SCR in Q5. This SCR is turned on by the power supply A3 to bypass the charging resistors R1 only after R1 has a voltage drop of less than 30 VDC and the DC bus is over 225 VDC. The power supply A3 is interlocked with the control board A1 to prevent operation of the main output transistors until the capacitors are bypassed by the SCR in Q5.

The DC bus voltage is continuously monitored by the power supply A3 which turns on the shunt regulator transistor Q4 when the voltage approaches 375 VDC to draw current through the external regen resistor connected to terminals R1 and R2 dissipating the regenerated energy. The peak energy that can be absorbed is limited by the maximum resistor current that can be controlled by Q4. The controller will limit the capacitor voltage to 375 volts; for example a 20 OHM regen resistor connected to the controller will absorb 7.0 KW peak.

3.3 CONTROLLER POWER SUPPLY A3 (Drawing 7123)

The power supply assembly operates directly from the raw DC bus of 200 to 375 VDC derived from a 208 or 230 VAC line and accomplishes the following:

1) Supplies a 27 kHz, 100 VAC RMS p-p regulated square-wave, nominally rated 100 watts for base drive and auxiliary loads.

2) Supplies a precision regulated plus and minus 15.0 VDC supply at 400 ma each.

3) Supplies a regulated plus and minus 24 VDC for auxiliary relay and DC fan use, nominally rated at 25 watts total.

4) Delays power supply operation upon power application to ensure the external DC bus capacitors have charged sufficiently to start the power supply.

5) Limits the internally regulated intermediate 180 VDC bus voltage and current levels on a pulse-by-pulse basis. Overvoltage shutdown backs up the voltage limit in the event of a regulator transistor short thus preventing excessive output voltages.

6) Provides the gate signal to an external soft start bypass SCR which is coordinated with AC line voltage presence, bus to line differential voltage, and bus undervoltage.

7) Generates the base drive current to an external power transistor to shunt regulate the DC bus voltage during motor controller regeneration.

8) Provide independent opto-isolated status signals for bus under voltage, but overvoltage, and shunt regulator transistor drive.

9) Turns on the safety bleed transistor during absence of all AC linepower to connect the DC bus capactiors to an external discharge resistor.

The power supply assembly monitors the soft start resistor voltage and DC bus voltage to control the following functions:

1. Soft Start Resistor Voltage over 30 VDC, which inhibits turn on of the soft start circuit and the power output circuit.

2. DC Bus Voltage under 225 VDC, which inhibits turn-on of the soft start circuit and the power output circuit.

3. DC Bus Voltage over 375 VDC, which turns on the shunt regulator transistor Q4.

4. DC Bus Voltage over 386 VDC, which inhibits operation of the power output circuit.

Components and board spacings on the power supply provide a voltage isolation exceeding 1000 volts between the power circuit and the chassis ground referenced control circuits which operate from the supply.

3.4 CONTROLLER POWER OUTPUT CIRCUIT

The power output circuit consists of the three dual Darlington power transistors Q1, Q2 and Q3 with the two current sensing resistors R2 and R3. These power transistors are the isolated mounting type with internal clamping diodes on each transistor to limit maximum voltage to the bus voltage. The current sensors are 0.01 ohm on controllers rated up to 75 amps peak and 0.005 ohm on controllers rated 76-150 amps peak.

The output transistors are pulse width modulation (PWM) controlled and monitored by the base drivers (A5, A6, A7) in response to control board A1 logic that determines which transistors are to be turned on. One transistor in each pair is always off at any given time to avoid short circuiting the bus supply and damaging the output transistors.

3.5 CONTROLLER MOD-DEMOD A4

The mod-demod circuit operates from ± 15 VDC supplied by the power supply and contains two independent modulator-demodulator channels. Each modulator-demodulator channel operates at a carrier frequency of about 500 KHz to modulate the DC current signal from one of the output sensing resistors, transformer couple the signal, demodulate it relative to signal common and amplify with a gain of approximately 10 volts/volt. The resulting buffered output is zero trimmed with R14 for the T3 channel and R30 for the T2 channel. Gain is adjusted to compensate for sensing resistor and mod-demod circuit tolerances using R15 for the T3 channel and R29 for the T2 channel. These adjustments are made at the factory to result in an output applied to the A1 control board of 0.1 volt/amp on controllers rated up to 75 amps peak and 0.05 volt/amp on controllers rated 76 to 150 amps peak.

Components and board spacings on the mod-demod provide a voltage isolation exceeding 1000 volts between the current sensing resistors and the chassis ground referenced control circuits.

3.6 CONTROLLER BASE DRIVERS A5, A6 & A7.

Each base driver contains two independent base driver channels, one for each half of the dual Darlington power transistor controlled by the driver. Each channel has a transformer isolated ± 8 VDC power supply which operates from the 27 KHz 50 volt input from A3, an opto-isolated current limited base driver circuit for the Darlington transistor it controls and an excess collector-emitter voltage shutdown circuit for the controlled transistor.

The supply on each channel furnishes the necessary current for the isolated base driver circuit. The base driver circuit is an opto-coupled input type which provides a current limited forward base drive output of a current rating matched to the power transistor it drives. It also provides a high current reverse base drive for fast turnoff of the Darlington power transistor it drives. The excess collector-emitter voltage circuit monitors the driven power transistor and automatically shuts off the power transistor if excessive collector-emitter voltage (which indicates an output fault current) is detected. This shutdown creates an opto-coupled output fault signal which is sent to the control board for shutdown of the controller and latching fault indication.

3.7 CONTROL BOARD A1 (Ref. Figures 1 & 3)

The control board operates with the personality board A2 to:

1) Provide Tachsyn sensor excitation and signal conditioning.

2) Provide 2.5 KHz pulse width modulated outputs to the base drivers in response to current loop error signals, with those current loops operating from commutator current command inputs with current feedback from the A4 mod-demod.

3) Commutate the current command input using the conditioned Tachsyn outputs for the motor rotor position feedback.

4) Provide a speed control loop to develop the current command from the speed command and the Tachsyn tach feedback.

5) Provide current command limiter.

6) Provide speed command conditioning.

7) Provide latching supply voltage, overtemperature, over current, overspeed and output fault protection and indication.

8) Provide opto-coupled Enable circuits.

All A1 control boards with the same part number are identical. All adjustments and components which are selected to suit a particular motor are located on the A2 personality board.

3.7.1 TACHSYN SIGNAL CONDITIONING (FOR STANDARD 4 POLE MOTOR)

The Tachsyn is excited through A1J2-5 and 6 at 10 KHz by an oscillator on the control board. The Y connected Tachsyn output at J2 contains both speed (low frequency) and position (10 KHz modulated) information which is processed by the signal conditioner to yield:

1) Two cycle per motor revolution sine wave position output for each phase, approximately 4 volts peak amplitude. These outputs are phased at 120 electrical degrees to each other (60 degrees of shaft rotation) and may be monitored at A2J9-9, 10 and 11.

2) Six cycle per motor revolution digital tach square wave output available on A2J9-5.

3) Bipolar DC tach output, supplied through connector J7-16 to the Tach scale pot, A2R39. The scaled and buffered tach signal is available on A2J9-3 with the scale factor specified on the setup sheet.

4) Logic outputs to the commutation circuit.

3.7.2 OUTPUTS TO BASE DRIVERS

The base driver outputs are 2.5 KHz modulated square waves, one for each half of the three dual power output transistors. These signals are developed by three independent current loops, one per power output transistor. The current command for each loop is supplied by the speed loop through the current limit and the current feedback is supplied from the A4 mod-demod. Each current loop sums the command and feedback signals, amplifies the resulting signal and compares it with the 2.5 KHz oscillator triangle wave output to develop the PWM output supplied to the base drivers.

The current loop compensation components (R34,35,40-43,C9-14) are located on the A2 personality board to allow them to be selected to suit the motor being controlled. All other base driver control circuitry is located on the control board.

3.7.3 COMMUTATION LOGIC

The current command is supplied from the current limited speed loop integrating amplifier as shown on Figure 3. It may be monitored at A2J9-15. The commutation logic applies the current command signal to two of the three current loops, with polarity selected to cause current flow through the two motor windings.

3.7.4 SPEED CONTROL LOOP

The speed control loop, shown in Figure 3, accepts a speed command from the source selected by personality board jumper JP2 (monitored at A2J9-7), a tach feedback signal from the tach buffer (monitored at A2J9-3) and a zero trim input from personality board zero trim pot R38. The sum of these signals is amplified by the speed error amplifier to develop the At Speed output. This error signal is amplified by the integrating amplifier with a rate gain set by pot R22 and limited by the current limit circuit described in the next section to develop the current command output.

Note on Figure 3 that all selectable compensation components and adjustments are located on the A2 personality board.

3.7.5 CURRENT LIMITER

Peak current is limited by limiting the current command voltage applied to the modulator logic. The A1 control board current limit circuitry responds to the current limit voltage from the A2 personality board, which can be monitored at A2J9-4. See description of current limit voltage circuits in the personality board section.

3.7.6 SPEED COMMAND CONDITIONING

Figure 3 illustrates the speed command conditioning circuits. The speed command signal applied at terminals J1-4 & 5 of the control board is buffered with a differential amplifier. The common mode isolation provided by this amplifier is a minimum of 40 db for common mode voltages less than ±15 VDC.

The conditional inverter has a gain of -1.0 or +1.0 as determined by the Direction Select Input option jumper, JP3 or JP4. The normally non-inverting amplifier becomes an inverting amplifier when JP3-1 or JP4-1 is connected to common.

Tach feedback voltage is derived by a frequency to voltage conversion of the Tachsyn commutation signals. The scale factor of the resulting tach signal for this controller is specified under "tach scaling" on the set up sheet.

The speed command input is scaled with the Max Speed pot R24, adjustable for 8 to 12 volts = Max speed. This point is monitored at A2J9-1. Gain of the directional speed disable amplifier is set with A2 personality board R36.

The accel-decel circuit has a 40:1 adjustment range with R23 in each of two ranges selected with SW1-4. In the low time range, SW1-4 off, the rate of change of output is adjustable from approximately 3 to 130 volts/second, corresponding to about 0.08 to 3 seconds for zero to maximum speed. In the high time range, SW1-4 on, the rate of change of output is adjustable from approximately 0.5 to 20 volts/second corresponding to about 0.5 to 20 seconds for zero to maximum speed.

The speed command to be applied to the rate loop is selected with JP2 for either direct or accel-decel limited speed command. The selected speed command is monitored at test point A2J9-7.

3.7.7 LATCHING FAULT PROTECTION AND INDICATION

Fault conditions are detected, latched and indicated by red LEDs on control board, A1. The following indicators and their associated detectors are provided:

1) PWR: Monitors fault outputs of power supply assembly, A3, for overvoltage or undervoltage fault indications. Either of these conditions shuts down the controller and turns on the PWR LED.

2) BD1, BD2 or BD3: Each transistor base driver fault output is monitored. The controller shuts down whenever an excessive voltage drop occurs (indicating an output overload) or driver supply failure occurs. See section 3.6. The fault is latched and indicated on the appropriate LED indicating which output connection, transistor pair or base driver caused the tripout.

3) OS: An overspeed detector compares absolute value of tach voltage to A2R66 overspeed pot setting. Controller shuts down, latches and indicates whenever speed voltage exceeds the Overspeed setting. Setting of pot A2R66 can be measured on test point A2J9-8.

4) OT: Overtemperature is indicated by the opening of controller heat sink thermostat TS1 (set at 80 degrees C) or motor winding thermostat. Shut down, latch and indication occurs after 2 second time delay. During the delay period, the open collector Overtemperature Warning output at controller J1-16 terminal is activated.

5) IOC: Overcurrent conditions are detected by comparing

controller current to a level set by resistor A2R72. The value of A2R72 is factory preset.

6) ±15: A power supply failure detector monitors the ±15 volt power supplies. The controller is shut down whenever either 15 volt supply drops below 12 volts. A complete loss of +15 volt power will not cause an indication since the logic operates on +15 volts, this condition will turn off all red and green LED indicators.

3.7.8 ENABLE LOGIC

The control board includes two LED indicated opto-coupled enable inputs, both of which must be applied for normal bidirectional motor operation. These inputs are factory configured to operate in either of the following modes:

1) SPEED-TORQUE ENABLE MODE

ENABLE 1 input to J1-13 & -14 enables drive current (and hence torque) in both directions with zero speed command. ENABLE 2 input to J1-11 & -12 enables both directions of speed input.

2) CW-CCW ENABLE MODE

ENABLE 1 input to J1-13 & -14 enables drive current and speed in the CW direction only. ENABLE 2 input to J1-11 & -12 enables drive current and speed in the CCW direction only.

3.7.9 OPEN COLLECTOR LOGIC OUTPUTS

Open collector logic outputs rated 75 ma, 30 VDC maximum are supplied at J1-15, 16, and 17 for external indication of READY, OVERTEMP WARNING and LOW SPEED logic conditions. Logic output of each (normally on or off) is switch selectable on the A2 personality board. Two additional logic outputs are available at J1-18 & -19 as selected with A2 personality board jumpers JP3 and JP4.

3.8 CONTROLLER PERSONALITY BOARD A2 (Ref Figures 1, 2 & 3, Drawing 7031.)

This board includes provisions for modifying controller servo parameters and selecting logic and control I/O fuctions. Specific component loading for this controller is shown in the personality board parts list and setup instructions for this controller are listed in the Setup Sheet, Section 6. All A2 boards with the same part number and setup are interchangeable without field adjustment.

3.8.1 LOOP COMPENSATION

The current loop amplifier feedback compensation components C9-C14 and R34,35, 40-43 are selected to match the motor R and L parameters. The speed loop compensation and gain have been selected to suit the motor and load. The tach is scaled with pot R39.

3.8.2 F/V CONVERTER

The U14 F/V converter converts the commutation frequency input from the A1 control board to a positive absolute value tachometer signal, which operates the overspeed circuit and is available for external speed indication.

3.8.3 CURRENT LIMIT

The current limit voltage supplied to the A1 control board through J7-17 is developed at U9-4 as the lowest of four limits:

1) Current limit pot R52 output.

2) Average current limit from U9-13 input supplied from U13-1 output which switches low to reduce the limit whenever absolute value of average current at C21 exceeds voltage divider setting.

3) Speed variable current limit set by R51 and R60. This limit reduces the current limit at high speeds to maintain peak power within the controller rating.

4) Optional external current limit through pot R67 at U9-9 input.

3.8.4 SPEED COMPARATORS

Comparators for low (near-zero) speed, set speed (level is pot adjustable with R53) and at-speed (speed within 2% of command input) are provided. These outputs are provided through the control board.

4.0 TROUBLESHOOTING

WARNING

This equipment contains voltages which may be as high as 400 volts and rotating parts on motors and driven machines. High voltage and moving parts can cause serious or fatal injury. Only qualified personnel familiar with this manual and any driven machinery should attempt to startup or troubleshoot this equipment. Observe these precautions:

1. USE EXTREME CAUTION, DO NOT TOUCH any circuit board, power device or motor electrical connection without insuring unit is properly grounded and no high voltage is present. DO NOT apply AC power before grounding per instructions herein. DO NOT open cover for 2 minutes after removing AC power to allow capacitors to discharge. ALWAYS check DC voltage between two bus bars on large capacitors when opening enclosure and bleed down to 10 volts maximum with resistor before servicing.

2. BE CERTAIN that possible violent motion of motor shaft and driven machinery due to improper control operation will not cause personel injury or damage. Peak torques of several times rated motor torque can occur during a control failure.

3. Motor circuit may have high voltage present whenever AC power is applied, even when motor is not rotating.

4.1 INSTRUMENTS

Most troubleshooting can be performed with only a digital voltmeter (DVM) with an input impedance exceeding 1 megohm. Setup of speed loop response and evaluation of output current waveforms require a 1 MHz minimum bandwidth two channel oscilloscope.

4.2 TROUBLESHOOTING GUIDE

4.2.1 NO READY (RDY) LIGHT AND NO RED FAULT INDICATIONS

1. Check AC power connections and line fuses or breaker. AC voltage must be in the range of 190 to 253 VAC at terminals L1-L2, L2-L3, L3-L1 to operate the controller. If incoming power breaker or fuses are blown, remove AC power and check resistance between L1, L2 and L3 terminals with ohmmeter. Low resistance may indicate either a failed diode bridge or SCR. Observe WARNING precautions and replace BR1 or Q5 (SCR module).

2. Check supply voltages at test connector J9-17 (-15 VDC) and J9-18 (+15 VDC) relative to common, J9-20. Both must be within ± 1 volt of nominal for proper operation.

   If ±15 VDC power supplies are failed, remove AC power, wait 2 minutes, open cover and swing out hinged plate with control and personality boards to expose fuses A8F1, A8F2 and A3F1. Check fuses with ohmmeter and replace if necessary.

   WARNING

   High voltage on electrolytic capacitors C1 thru C3 decays slowly. DO NOT TOUCH. CHECK DC VOLTAGE BETWEEN THE TWO BUS BARS ON THE LARGE CAPACITORS WITH VOLTMETER and bleed with resistor to 10 volts DC maximum for safe servicing. DO NOT REMOVE PLUG A3P2 FROM POWER SUPPLY ASSEMBLY, A3. This will disconnect the safety bleed resistor, R5 from the DC bus.

   Verify that fuses A8F1 and A8F2 are good, then re-apply input power while observing POWER SUPPLY ON light, located on power supply board, A3. If this LED does not turn on, check fuse A3F1. If A3F1 is blown, turn off power wait 2 minutes and replace it. If POWER SUPPLY ON light does not turn on or if A3F1 fails a second time, replace power supply board, A3.

3. Check Reset Inputs J1-9 and J9-19 to be sure neither is grounded. Voltage below +10 volts, relative to common, at either input will prevent Ready.

4. If AC power and resets are OK, switch power OFF for 10 seconds then ON to reset power supply protection circuitry. Ready should light within 3 seconds.

5. If Ready doesn't occur with above steps, replace power supply A3 after observing precautions of (2) above. DO NOT remove any connectors or boards without removing power and ensuring main bus supply voltage is less than 10 volts DC.

4.2.2 "PWR" FAULT INDICATION

This latching fault indication occurs when main bus supply voltage has been too high or too low, even momentarily.

1. Apply Reset Input (Momentary closure between J1-8 & 9 or J9-19 & 20) to reset latch. Ready will occur within 3 seconds after Reset Input is removed if a momentary high or low bus caused the tripoff. Momentary low bus

voltage is usually caused by one AC line opening; high bus voltage is usually caused by regeneration of the motor with inadequate or open regeneration resistor circuit.

2. If Reset doesn't clear fault, check AC voltage, which must be in range 190 to 253 VAC line-line.

4.2.3 "BD1", "BD2" OR "BD3" FAULT INDICATION

1. Current limit may be set too high, see setup sheet. Try reducing current limit 20% below normal to determine if limit is slightly over maximum allowable with motor being used.

2. If only one indicator is on, a ground fault on that output line is likely. If two or three indicators are on, the fault is most likely line-line. Remove AC power, disconnect output lines from control and check wiring and motor resistance line-line and line to ground.

3. If no external faults exist, remove AC power, wait 2 minutes, open enclosure observing WARNING precautions, bleed capacitor DC voltage to 10 volts maximum with resistor and then shunt the two capacitor bus bars. Remove shunt between bus bars, then measure resistance from each bus bar to output terminals T1, T2 and T3 using ohmmeter polarity to back bias power transistor diodes shown in Figure 1. Any resistance less than 500K ohms indicates fault in transistor or internal wiring. Replace power transistor and its associated base driver for any outputs showing less than 500K resistance (power transistor failure usually damages its base driver). Check base drivers visually for burned components and be sure all connections to base drivers are properly installed.

4. If no power circuit faults are found, replace base driver or interchange with another output base driver to determine if fault follows base driver. If so, base driver should be replaced.

5. If base driver replacement doesn't eliminate faults, replace control board.

4.2.4 "OS" FAULT INDICATION

1. Overspeed setting may be too low, see setup sheet for proper setting and readjust if necessary.

2. Excessive speed command may have been applied to cause overspeed.

4.2.5 "OT" FAULT INDICATION

1. Check continuity of normally closed motor temp switch input, J2-7 to 8.

2. Controller heat sink may overheat due to excessive load, failed fan or clogged cooling fins. If indication persists with cool heatsink check the continuity of normally close switch TS1 and its wiring.

4.2.6 "IOC" FAULT INDICATION

1. Current limit may be set too high, see setup sheet. Try reducing current limit 20% below normal to determine if limit is slightly over maximum allowable with motor being used.

2. Current loop compensation may be mismatched with motor being used. Individual phase currents can be monitored with oscilloscope at J9-12 & 13 relative to J9-20, maximum current on any output can be monitored at J9-2. Contact factory for assistance in optimizing compensation.

3. Replace control and personality boards if they are properly matched to the motor but cause overcurrent tripouts.

4.2.7 "±15" FAULT INDICATION

1. This latched fault indication will occur upon momentary reduction of ±15 volts below allowable levels, possibly due to external load on these supplies. Apply Reset Input (momentary closure between J1-8 & 9 or J9-19 & 20) to reset latch.

2. Check ± 15 volt outputs at J1-1 & 3 to common J1-2, either voltage 20% below normal will cause the indication. Check control and personality board IC chips and resistors for possible overheating indicating fault overloading the power supply. Replace power supply observing WARNING precautions if either 15 volt supply is low and no apparent fault exists on control or personality board.

4.2.8 "CW" OR "CCW" INDICATORS OFF WITH ENABLE(S) APPLIED

1. Check voltages J1-13 to -14 for CW and J1-11 to -12 for CCW; these voltages must be 12 volts DC minimum with positive polarity at J1-11 and -13 to operate Enable circuits.

2. Replace control board first, then personality board.

4.2.9 NO TORQUE WITH READY (RDY) AND BOTH CW & CCW INDICATORS ON

1. Current Limit may be near zero. Check limit setting with DVM at J9-4 relative to J9-20.

2. Commutation signals may be missing. Check Tachsyn phasing per Section 2.4.

3. Replace control board first, then personality board.

4.2.10 NO MOTOR SHAFT ROTATION

1. Ready (RDY) and both enable (CW & CCW) indicators must be ON, see 4.2.1 or 4.2.8 if not.

2. Control may be in Align mode, switch S1-8 must be OFF to run the motor.

3. If no shaft torque resisting shaft rotation occurs, see 4.2.9.

4. Speed command may be zero, conditioned command may be monitored at J9-7.

5. See 4.2.11 if erratic or jittery motion of shaft occurs in response to speed command.

4.2.11 ERRATIC OR JITTERY SHAFT ROTATION

1. Commutation signals may be misaligned or partially missing. Check alignment per Section 2.4.

2. Motor may be connected with opposite phase rotation to that of Tachsyn. Remove AC power and reverse motor connections by interchanging controller terminals T1 and T2. Then re-align transducer per Section 2.4 and retry.

3. Tachsyn signals may be noisy. Check wiring to be sure wires from Tachsyn are properly shielded with shields terminated at controller per connection diagram.

4. Rate loop gain may be too high, set lower by turning personality board pot R22 CCW.

5. Personality or control board may not be matched to motor. Check setup sheet for proper motor, personality board and control board part numbers.

4.2.12 WRONG RESPONSE TO SPEED COMMANDS

1. Input common mode voltage may be exceeded. Maximum common mode at J1-4 & 5 is $\pm$15 volts relative to

chassis common. Connect control input source common to the controller common to minimize common mode voltage.

2. Direction select input may be noisy or connected erroneously. See Sections 2.3.3 and 2.3.4.

3. Tach polarity may be reversed.

5.0 FUSE LIST

QTY	RATING	SWEO PN	COMMERCIAL EQUIV	REF. DES.
2	2A, 250VAC	4392000	Buss FNM 2	A8F1, A8F2
1	1A, 600VAC	4331000	Buss KTK 1 Littlefuse KLK 1	A3F1

6.0 DRAWINGS (7038)

SU7035	Personality Board Setup Sheet
7226	Interconnect Diagram
7123	Wiring Diagram - AC Brushless Servo Drive
7153	Outline and Mounting - AC Brushless Drive
7031D	Schematic - Personality Board
0700	Installation Drawing - Regen Resistor Kit
PL0712603	Parts List - System
PL1722500	Parts List - Controller
PL0700214	Parts List - Control Board
PL0073026	Parts List - Personality Board