IMEC 105-040300-01
Main Board

400 Series
Brushless Servo Controller

Instruction Manual

October 1987

IMEC Corporation
A Subsidiary of Pacific Scientific

TABLE OF CONTENTS

LIST OF FIGURES

SECTION 1

INTRODUCTION

WARNING - DANGEROUS VOLTAGES

Voltage levels within this controller can exceed 400 VDC and/or 230 VAC. These voltage levels can cause serious injury or be fatal, therefore follow good electrical practices, applicable electrical codes and the contents of this manual.

1.1 General

This manual outlines Installation/Set-up, Troubleshooting, and Maintenance procedures for IMEC Corporation's 400 Series of Brushless Servo Controllers. It also contains controller specifications.

IMPORTANT NOTE

THIS MANUAL DESCRIBES THE STANDARD CONTROLLER CONFIGURATION WHICH IS IDENTIFIED BY A -001- CUSTOMIZATION CODE IN THE PRODUCT MODEL NUMBER (SEE SECTION 6). MODELS HAVING A DIFFERENT CUSTOMIZATION CODE WILL HAVE DIFFERENCES FROM THE STANDARD PRODUCT. THESE DIFFERENCES WILL BE DESCRIBED BY A CUSTOMIZATION SHEET WHICH WILL BE INCLUDED WITH THE PRODUCT OR IS AVAILABLE FROM IMEC CORPORATION. USUALLY THESE MODIFICATIONS WILL BE MINOR SUCH AS CURRENT LOOP COMPENSATION COMPONENT CHANGES TO OPTIMIZE PERFORMANCE FOR THE MOTOR BEING DRIVEN.

These controllers are designed to operate Pacific Scientific Brushless Servo Motors or other 3-phase, Permanent Magnetic (PM) Brushless Servo motors. Each controller is an independent, stand-alone unit capable of four quadrant control of a single PM Brushless Servo motor. The controller can be configured with a Brushless Servo motor as either a torque block or, if the motor is equipped with a Tachsyn®, as a velocity block. The controller employs high-frequency PWM current control to achieve high quality servo performance. Multiple protection circuits and careful design insure trouble-free operation.

1.2 Features

- Transformerless, direct 115/230VAC line operation
- Magnetically/optically isolated output stage to improve reliability and reduce crosstalk and ground loop disturbances
- MOV protected input circuitry
- Integral fusing
- Wide velocity loop dynamic range adjustment
- Peak current limit adjustment
- Multiple Protection Circuits
  - Output Fault
    - Protects against line-line and line-ground shorts.
  - Controller OT
    - Protects controller against thermal overload.
  - DC Bus Fault
    - Protects against bus overvoltage
  - Control Voltage OK
    - Protects against out of tolerance control voltages.
  - Motor OT
    - Input which allows connection to a motor mounted thermal overload sensor.

1.3 Options

Shunt regulator

Custom compensation

Noise reducing output toroid

Safety cover

SECTION 2

CONTROLLER SPECIFICATION

2.1 Electrical

Model	401	402
Input Voltage	115/230 VAC (+10,-15%) 1 or 3 phase, 47-63 Hz	
Bus Voltage (nominal)		
230 VAC Input	320 VDC	
115 VAC Input	160 VDC	
Output Current		
Peak	3.50 A	7.0 A
Continuous (stall)		
230 VAC Input	1.75 A	3.5 A
115 VAC Input	2.1 A	4.2 A
Output Power		
Peak		
230 VAC Input	1000 W	2000 W
115 VAC Input	500 W	1000 W
Continuous (stall)		
230 VAC, 3 Phase Input	500 W	1000 W
230 VAC, 1 Phase Input	350 W	700 W
115 VAC, 1 Phase Input	175 W	350 W
Shunt Regulator (Optional)		
Peak Power (0.3 seconds)	1500 W	
Continuous Power	20 W	
Efficiency (@ rated continuous power)	>90%	
Form Factor	<1.01	
Current Loop Bandwidth	3 kHz max.	
Velocity Offset	Adjustable to zero	
Velocity Offset Drift (referred to input)	50 uV/°C typ.	
Velocity Input Command	± 10 V	
Output Ripple Frequency	20 kHz	
Fault Output	Open collector, 30 VDC, 25 mA sink	

2.2 Environmental

This unit is of "open frame" design and is intended to be placed within a cabinet. The cabinet should be ventilated by filtered or conditioned air to prevent the accumulation of dust and dirt on the controller's electronic components. The air should also be free of corrosive or electrically conductive contaminants.

The controller is cooled by natural convection. To insure proper cooling, maintain the spacing recommendations outlined in Section 3.2. Also sufficient air flow must be maintained to keep the cabinet's internal ambient within the controller's rating given the power dissipation estimates listed in Section 2.4.

The following specifications apply to all controllers:

OPERATING TEMPERATURE	
FULL RATINGS	0°C to 50°C
DERATED (SEE NOTE 1)	50°C to 60°C
HUMIDITY	10% to 90%, non-condensing
ALTITUDE	1500 Meters (5000 Ft)
STORAGE TEMPERATURE	-55°C to 70°C

NOTE 1: Linearly derate the continuous current and power ratings to 70% at 60°C.

2.3 Mechanical

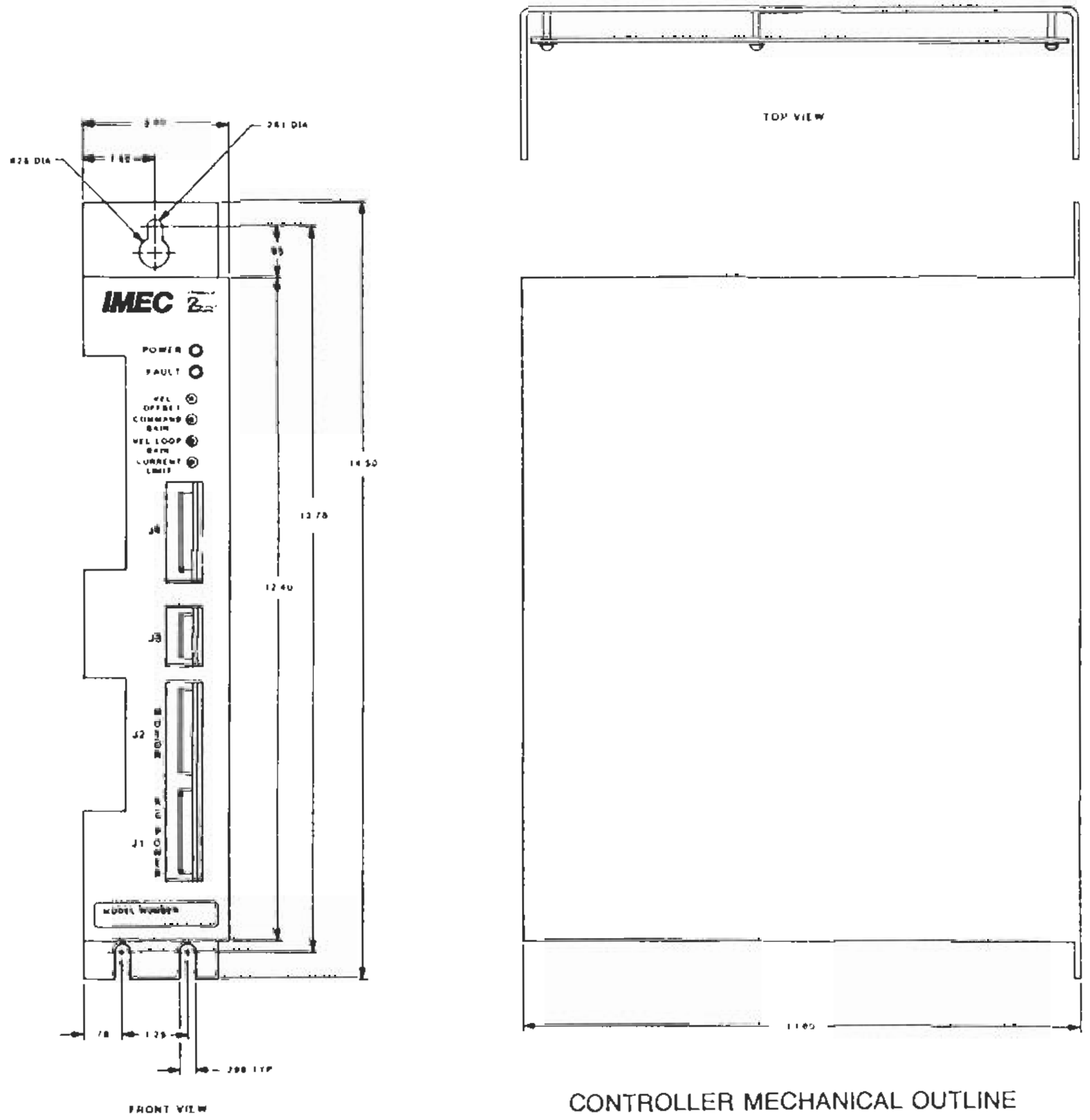
Figure 2.1 gives a mechanical outline of the controller. Three slots are provided for mounting the unit on a cabinet wall or other vertical surface. The controller must be mounted vertically. The unit weighs approximately 5 lbs. and should be mounted accordingly.

All interface signals to the controller are made via plug-in connectors on the front panel. Feedback and Command signals are interfaced using 15 contact and 8 contact plug-in connectors respectively with 0.1" contact centers. Power connections for the motor and input power source are made on two 10 contact plug-in connectors with 0.156" contact centers. Access to input fuses and the control voltage supply fuse is from the side of the unit.

2.4 Power Dissipation

The table below lists the power dissipation (losses) of each controller model at various percentages of rated continuous output power. These numbers are approximate and do not include shunt regulator power (i.e. regenerated power).

% of Rated Continous Output Power	Power Dissipation Watts	
	401	402
0%	10	10
25%	15	20
50%	20	35
75%	27	54
100%	35	77



CONTROLLER MECHANICAL OUTLINE
FIGURE 2.1

INSTALLATION/SET-UP

Due to the wide variety of uses for this controller, it is the responsibility of the user or those applying the controller to determine the suitability of this product for any intended application. In no event will IMEC Corporation be responsible or liable for indirect or consequential damages resulting from the use of this controller. The figures, tables and examples shown in this manual are intended solely to supplement the text. Because of the varied requirements of any particular application, IMEC Corporation cannot assume responsibility or liability for actual use based upon the illustrative uses and applications included in this manual.

WARNING

DANGEROUS VOLTAGES, CURRENTS, TEMPERATURES, TORQUES, FORCES, AND ENERGY LEVELS EXIST IN THIS CONTROLLER AND ITS ASSOCIATED MOTOR. EXTREME CAUTION AND CARE SHOULD BE EXERCISED IN THE APPLICATION OF THIS EQUIPMENT. ONLY QUALIFIED INDIVIDUALS SHOULD WORK ON THIS CONTROLLER AND ITS APPLICATION.

3.1 Unpacking and Inspection

Remove the controller from its shipping carton and check the items against the packing list. A nameplate located on the side of the controller identifies the unit by model number and serial number. Section 6.1 describes the model numbering system.

Inspect the controller for any physical damage that may have been sustained during shipment. All claims for damage whether concealed or obvious must be made to the shipper by the buyer as soon as possible after receipt of the unit. Remove all packing materials from the unit. If the unit is to be stored, it should be stored in a clean, dry place. The storage temperature should be between -55°C and 70°C. To prevent damage during storage, it is recommended that the unit be stored in its original shipping carton after completing inspection for damage.

3.2 Mounting

Figure 2.1 illustrates the mechanical outline of the controller. Mounting is by three slots located on the controller. The controller should be mounted vertically on a flat, solid surface taking into consideration the approximate 5 lb. weight of the unit.

The controller should not be subjected to excessive vibration or shock. The environment should be free of corrosives, moisture and dust. Refer to Section 2.2 for the controller's environmental specifications. To insure proper cooling, there must be a minimum unobstructed space of 4 inches above and below the controller and 1 inch on each side.

Since this controller is of "open frame" construction, it should be located within an enclosure to protect it from physical or environmental damage. The unit will fit in a standard 12" deep NEMA enclosure. An optional Safety Cover is available to provide added protection for the controller.

3.3 I/O Definitions (Refer to Figure 3.1)

POWER Connector

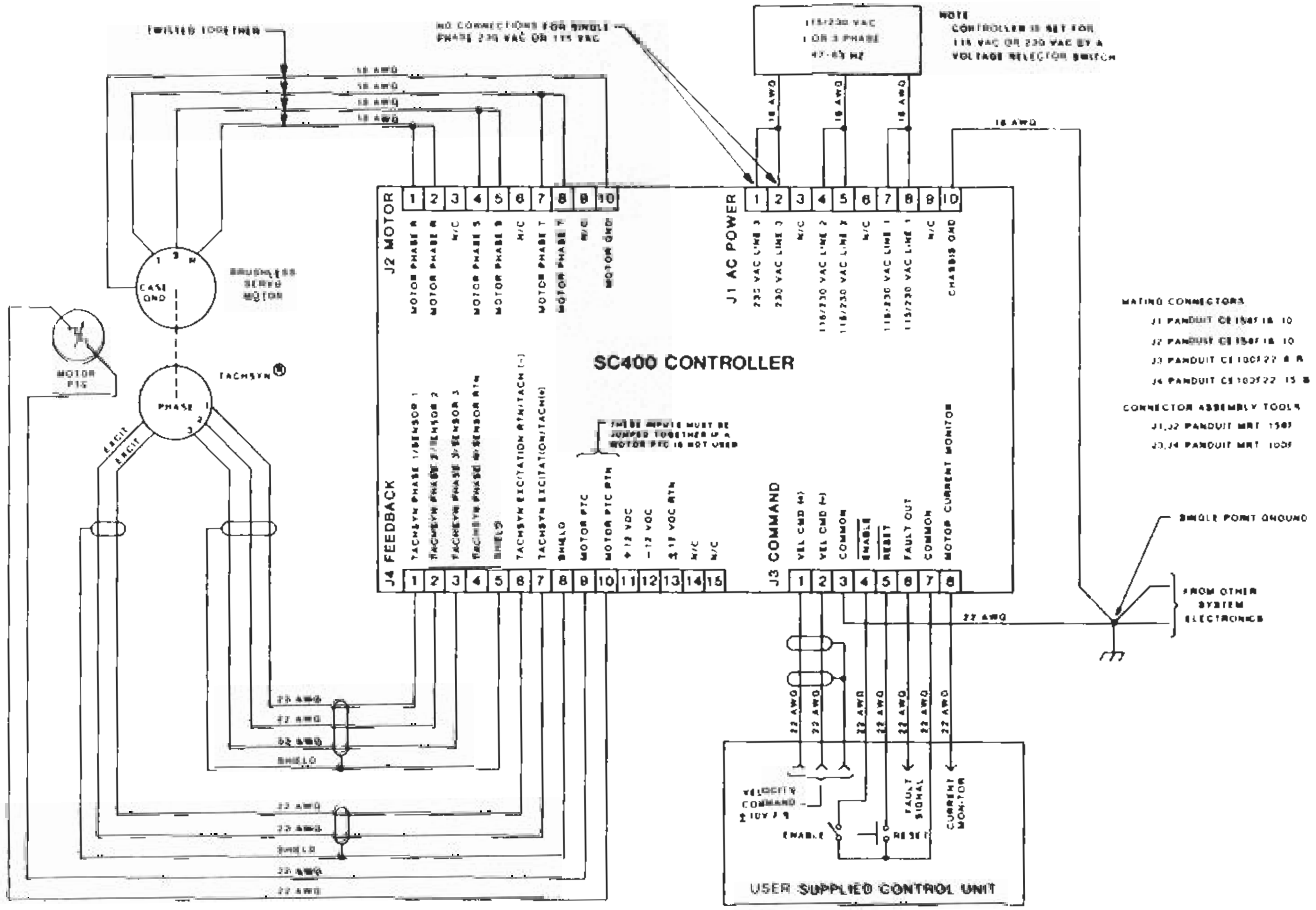
J1-1,2 [230 VAC LINE 3]
-4,5 [115/230 VAC LINE 2]
-7,8 [115/230 VAC LINE 1]
These terminals are the 115/230VAC, 1 or 3 phase inputs. No special phasing of the input is necessary. For single phase 115 VAC or 230 VAC operation, the LINE 1 and LINE 2 inputs must be used. For three phase 230 VAC operation, use all three input lines.

WARNING

THIS UNIT WILL OPERATE OFF A 115 VAC OR 230 VAC LINE. THE VOLTAGE SELECTOR SWITCH MUST BE IN THE CORRECT POSITION OR SEVERE DAMAGE MAY OCCUR TO THE UNIT. DAMAGE CAUSED BY THE INCORRECT SETTING OF THIS SWITCH IS NOT COVERED BY THE WARRANTY.

J1-3,6,9 [N/C]
These terminals are not used. They are provided for voltage isolation between the AC input lines.

J1-10 [CHASSIS GROUND]
This terminal is provided as the safety grounding point for the controller. This terminal MUST be tied to earth ground to prevent shock hazard.



CONTROLLER INTERCONNECTION DIAGRAM

FIGURE 3.1

MOTOR Connector

J2-1,2 [MOTOR PHASE R]
-4,5 [MOTOR PHASE S]
-7,8 [MOTOR PHASE T]
These terminals are the controller output phases R, S, and T. Proper phasing of these outputs relative to the motor terminals is important, double check these connections when wiring motor.

J2-3,6,9 [N/C].
These terminals are not used. They are provided for voltage isolation between the motor output phases.

J2-10 [MOTOR GROUND]
This terminal is provided as the grounding point for the motor case. The motor case MUST be properly grounded to ensure proper operation of the controller and motor.

COMMAND Connector

J3-1 [VEL CMD(+)]
-2 [VEL CMD(−)]
These two terminals are the Velocity Command inputs. The Velocity Command input is a ±10 V analog signal. The input impedance is 50Kohm minimum.

J3-3,7 [COMMON]
This is the controller common point and is at the same potential as 12VDC RTN. These terminals provide a reference point for the ENABLE and RESET input signals, the FAULT OUT output signal, and the MOTOR CURRENT MONITOR output.

J3-4 [ENABLE]
The controller is enabled by closing a contact between this terminal and the COMMON terminal. An open collector transistor can also be used to enable the controller by connecting the collector to terminal 4 and the emitter to terminal 7. Terminal 4 input load is a 3.32Kohm pull-up to +12 VDC while terminal 7 is 12 VDC RTN. The contact or transistor should have a rating exceeding 12 V with a Vce(sat) < 1 VDC at 5 mA. See Figure 3.3.

J3-5 [RESET]
Controller faults are reset by closing a contact between this terminal and the COMMON terminal. Reset can be activated in any controller condition and will immediately disable the controller. An open collector transistor can also be used to reset the controller by connecting the collector to terminal 5 and the emitter to terminal 7. Terminal 5 input load is a 3.32Kohm pull-up to +12 VDC while terminal 7 is 12 VDC RTN. As such, the contact or transistor should have a rating exceeding 12 V with a Vee(sat) < 1 VDC at 5 mA. See Figure 3.3.

J3-6 [FAULT OUT]
This terminal is an open collector output. The output is pulled low if there is power applied to the controller and no faults are present. The output is rated at 25 mA sink and 30 VDC. See Figure 3.3.

J3-8 [MOTOR CURRENT MONITOR]
This terminal outputs a +4.4 V Full Scale DC signal which is proportional to the amplitude of the constant portion of the controller's six-step output current. The scale factor of this output is 1.26 V/A for the SC401 and 0.63 V/A for the SC402. This output has a 1Kohm output impedance and should have a load impedance of 20Kohm or greater.

FEEDBACK Connector

J4-1 [TACHSYN® PHASE 1/SENSOR 1]
-2 [TACHSYN® PHASE 2/SENSOR 2]
-3 [TACHSYN® PHASE 3/SENSOR 3]
-4 [TACHSYN® PHASE N]
-5 [SHIELD]
These five terminals are the inputs for the three Tachsyn® output signals and their shield or for three digital commutation signals and their shield. The Phase N input is not used. A seven position DIP switch selects whether the inputs are to be used for Tachsyn® interface or digital commutation signals. Set DIP switch S1-2,3,4 to OFF for use with the plug-in Tachsyn® Processor card. When S1-2,3,4 are ON, these inputs are each pulled-up to +12 VDC via a 22.1Kohm resistor and will accept +12 VDC CMOS compatible commutation signals.

J4-6 [TACHSYN® EXCITATION RTN/TACH(-)]
-7 [TACHSYN® EXCITATION/TACH(+)]
-8 [SHIELD]
These three terminals are outputs for the Tachsyn® excitation signals or inputs for a brushless tachometer signal. A seven position DIP switch is used to select the desired function of these terminals. Set DIP switch S1-6,7 to OFF for use with the plug-in Tachsyn® Processor card. When S1-6,7 are ON, the terminals are a differential input for a brushless tachometer. The input will accept a ±9V Full Scale tachometer signal and has an input impedance of 20Kohm minimum. SHIELD is provided for connection of a cable shield.

J4-9 [MOTOR PTC]
-10 [MOTOR PTC RTN]
These two terminals provide an interface for a motor mounted positive temperature coefficient thermistor (PTC). The PTC acts as thermal overload protection for the motor. This input can also be interfaced to a thermostat (normally closed contact). This is a high impedance circuit and as such will require a thermostat intended for dry contact operation. See Section 3.7.1 for contact current rating. **These inputs must be jumpered together if a PTC is not used.**

J4-11 [+12 VDC]
-12 [-12 VDC]
-13 [12 VDC RTN]
These three terminals provide +12 VDC, -12 VDC and 12 VDC Return. The maximum allowable load on these supplies is 10 mA. These supplies are intended to power motor commutation transducers and/or an electronic brushless tachometer if present.

J4-14 [COMMON]
This terminal is the common reference for input and output signals. It is at the same potential as 12 VDC RTN.

J4-15 [N/C]
This terminal is not used.

3.4 Controller Wiring

Figure 3.1 schematically illustrates the interconnection of the controller. Wire sizes, wiring practices, and grounding/shielding techniques described in this manual are intended as a guideline only. Due to the variety of applications served by this controller, no single method of controller interconnection is universally applicable. The information included in this manual represents common servo controller wiring practices and should prove satisfactory in the majority of applications. However, local electrical codes, special operating conditions or system configurations should take precedence over the information provided herein.

Due to the switching nature of this or any other PWM controller, care should be exercised in routing power and signal wiring in the system. Noise radiated from nearby electrical or electronic equipment may cause undesired servo motor movement due to pickup by the controller's signal inputs. Likewise, the controller's power outputs can generate noise which could be picked up by the controller's signal inputs or by other electronic equipment where lines run near the controller's output wiring.

To reduce the possibility of noise pickup, power and signal lines should be twisted, shielded and routed separately. Ideally the power and signal lines should be run in separate conduits or spaced at least 12" apart. Details of shielding are given later in this section.

To minimize shock hazards to personnel and damage to equipment, all components of the servo system should have their chassis connected to a common earth ground point. Local electrical codes will usually outline the requirements regarding grounding of electronic equipment. The following suggestions and recommendations should be satisfactory in most applications.

An 18 AWG wire should be connected between an earth ground point and each of the following points:

- Controller chassis ground terminal [J1-10]
- Input transformer ground stud, if applicable

The motor wiring and AC input wiring should be 18 AWG as shown in the interconnection diagram. The J1 and J2 plug-in connectors are designed for use with 18 AWG wire. Use Panduit hand insertion tool MRT-156F or Panduit automatic tool MCT with CTD-156F head.

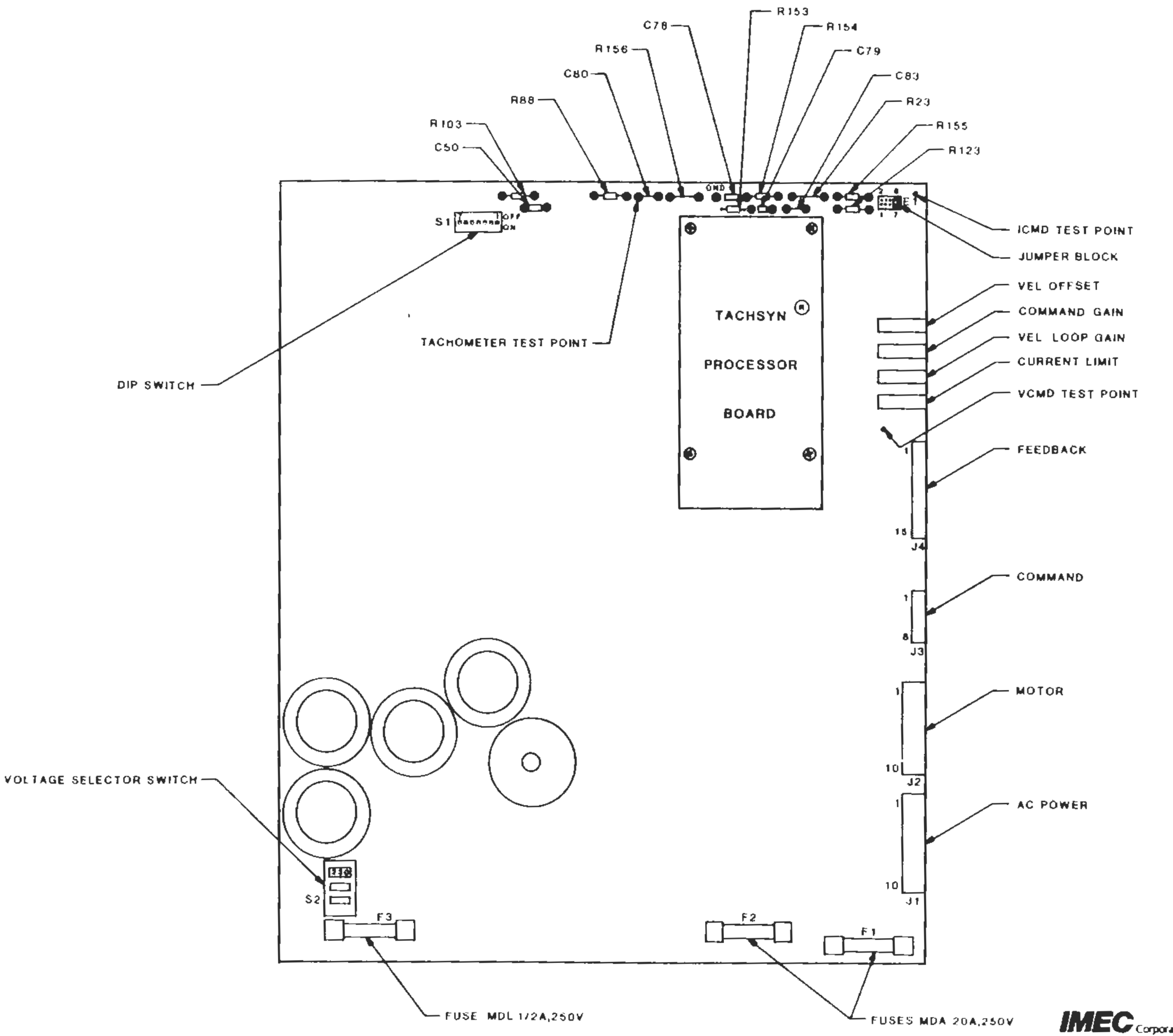
To reduce radiated noise, the 3 motor leads should be twisted together. Additionally, the motor's ground wire should be twisted together with the 3 motor leads. To further reduce radiated noise, IMEC can supply a toroid through which the 3 motor leads are wrapped several times. This technique typically eliminates any noise problems.

Controller signal connections are all made to plug-in connectors J3 and J4. These connectors are designed for use with 22 AWG wire. Use Panduit hand insertion tool MRT-100F or Panduit automatic tool MCT with CTD-100F head.

An important aspect of the controller wiring is the proper connection of the 3 motor terminals and the commutation signals. The controller will not properly drive the motor if these signals are not phased correctly.

The standard 400 Series Servo Controller is designed for use with a Tachsyn® feedback transducer. This transducer provides all necessary commutation and velocity information for the controller. The Tachsyn® signals are interfaced via J4 and processed by a plug-on Tachsyn® Processor card. Figure 3.1 shows the interconnection of the 400 Series Servo Controller to a Pacific Scientific motor equipped with a Tachsyn®.

The 400 Series can be used with Hall-effect sensors or other types of commutation transducers which produce +12VDC CMOS compatible commutation signals. The 400 Series can also accept velocity feedback information from a brushless tachometer or any other type of device which will produce an analog velocity signal.



LOCATION OF ADJUSTMENTS

FIGURE 3.2

IMEC Corporation
A Subsidiary of Pacific Scientific
The Schraft Center, 529 Main Street, Charlestown, MA 02129
Tel (617) 242-4800

3.5 Plug Jumper/Switch Set-up

The controller has one plug jumper, one seven position DIP switch, and a voltage selector switch which allow the user to select various controller modes. Location of the jumper and switches are shown in Figure 3.2.

Jumper Block E1

This jumper block is located in the upper right corner of the controller PC board. There are four jumper positions available which correspond to the following:

Jumper Position	Function
1 – 2	Current (Torque) Control ±10V command produces ± rated peak output current
3-4	Custom Velocity Loop Compensation Factory installed special velocity loop compensation
5-6	Standard Vel. Loop Compensation #2 Velocity loop compensation for high gain systems
7-8	Standard Vel. Loop Compensation #1 Velocity loop compensation for low gain systems

DIP Switch S1

A seven position DIP switch is located in the upper left corner of the controller PC board. This DIP switch is used to set the controller for the desired commutation and velocity feedback devices. It also can be used to force a given commutation state. The forced state, which is equivalent to a high input on the Sensor 1 and 2 inputs and a low input on the Sensor 3 input, is obtained by turning switch S1-1 to the ON position. This state causes the Phase S and Phase T outputs to be active while the Phase R output is disabled. This forced state switch can be used to aid in Tachsyn® or Hall-effect alignment or to use the controller as a DC brush servo motor controller.

For use as a brush servo motor controller, all S1 switches are set to ON. The two motor leads are connected to the Phase S and T outputs and the tachometer leads are connected to the Tach(+) and Tach(-) inputs. The Tachsyn® processor board is not required. For further information on using this controller with a DC brush servo motor, contact the factory.

In the standard configuration, a Tachsyn® Processor card is plugged into the J5/J6 connectors on the controller PC board. All seven positions of DIP switch S1 must be set to OFF when using the Tachsyn® Processor. If the controller is to be used with Hall-effect devices and/or a brushless tachometer, all S1 positions must be set to ON except S1-1 which should be set to OFF and the Tachsyn® Processor card must be removed. The following table summarizes the operation of each S1 switch.

		DIP Switch S1 Setting	
Switch	Input Affected	OFF	ON
S1-1	None	Normal operation	Forces commutation state 110.
S1-2	J4-1	Tachsyn® Phase 1	Commutation Sensor 1
S1-3	J4-2	Tachsyn® Phase 2	Commutation Sensor 2
S1-4	J4-3	Tachsyn® Phase 3	Commutation Sensor 3
S1-5	J4-5	Tachsyn® Neutral	Sensor Rtn
S1-6	J4-6	Tachsyn® Excit. Rtn	Tach(−)
S1-7	J4-7	Tachsyn® Excitation	Tach(+)

Voltage Selector Switch

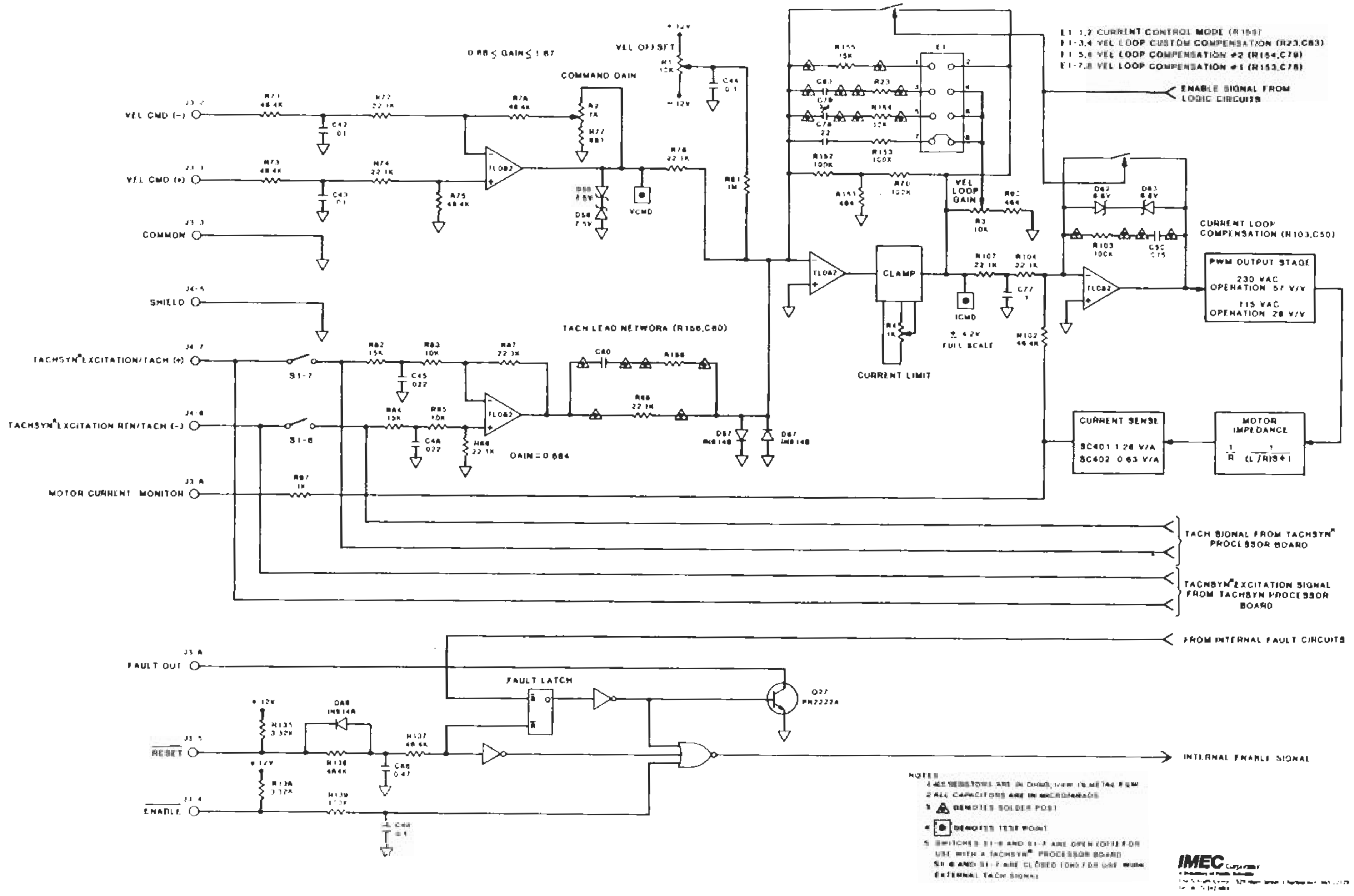
This two position switch sets the controller for 115VAC or 230VAC operation. THIS SWITCH MUST BE SET TO THE PROPER POSITION. IMPROPER SETTING OF THIS SWITCH CAN CAUSE SEVERE DAMAGE TO THE CONTROLLER.

3.6 Potentiometer Set-up

The controller has four user adjustments located on the front panel. Figure 3.2 shows the location of these potentiometers and Figure 3.3 shows their function in the circuitry.

VEL OFFSET

This 15 turn potentiometer is used to adjust the Velocity Loop offset to zero. With a Velocity Command of zero applied to the controller's VEL CMD input, adjust this potentiometer until the motor stops turning.



VELOCITY LOOP SCHEMATIC
FIGURE 3.3

COMMAND GAIN

This 15 turn potentiometer is used to set the velocity command gain. This adjustment allows the user to vary the "RPM/Volt" scale factor of the command input. Clockwise rotation increases the "RPM/Volt" input scale factor.

CURRENT LIMIT

This 15 turn potentiometer adjusts the peak output current limit. Clockwise rotation increases the current limit. Full clockwise is 100% of peak rated output current and full counterclockwise is 0% of peak rated output current.

VEL LOOP GAIN

This 15 turn potentiometer is used to vary the AC loop gain of the Velocity Loop over a 20 to 1 range. Velocity loop dynamics which are affected by the motor and load can be adjusted using this potentiometer. Information on its adjustment is contained in Section 3.8. Clockwise rotation increases the AC loop gain.

3.7 Special Adjustments

Figures 3.2 and 3.3 show several resistors and capacitors mounted on solder posts. These components control the velocity loop dynamics, the current loop dynamics, and the Motor PTC input (J4-9 and 10). The controller comes from the factory with standard component values installed in these solder posts. The remainder of this section describes how to change these values if necessary. If solder post mounted components are changed, the replacement components should be specified as below:

Resistors — 1%, 1/4 watt, metal film
Capacitors — 10%, 50 volt, X7R or BX monolithic ceramic.

If the user wants special values installed to tailor the controller to a specific application, custom value components can be installed by the factory. Consult the factory or the local IMEC representative regarding the Custom Compensation Option.

3.7.1 Motor PTC Input Adjustment (R123)

Figure 3.4 shows the Motor PTC input structure and resistor R123 which is the input pull-up. Comparator U23 has 3 VDC applied to its non-inverting input as a reference. With R123 at the factory installed 100Kohm value, the Motor PTC should be selected to have an approximate 33Kohm resistance at the desired motor trip-out temperature. This value corresponds to the standard PTC used in Pacific Scientific Brushless Servo Motors. By changing R123, the user can tailor the Motor PTC input to match the PTC provided with the motor if it differs from the standard. The value of R123 is calculated by the formula:

$R123 = (3)(R_{PTC} + 0.1)$

where $R123$ = value of resistor R123 in Kohms,
R_{PTC} = value in Kohms of motor mounted PTC at the desired trip-out temperature.

(Note: R123 has to be 1Kohm or larger.)

A contact-type, normally closed thermostat can be used in place of a PTC. However, the contact must be rated for low current operation since the largest current available is 12mA (R123=1Kohm).

3.7.2 Current Loop Dynamics Adjustment (R103, C50)

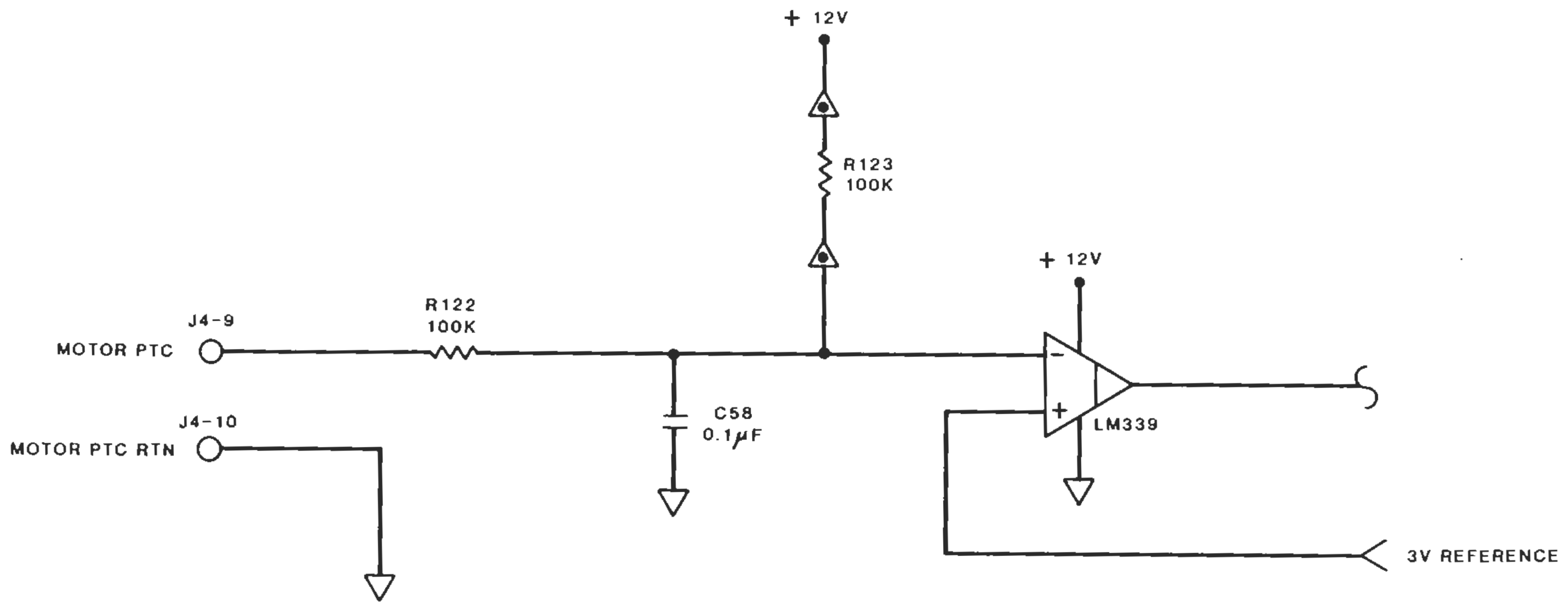
Resistor R103 and capacitor C50 control the proportional plus integral compensation of the controller current loops. These components are shown in Figure 3.2 and Figure 3.3. They are used to adjust the current loop dynamics in situations where the motor inductance is out of the range of the nominal compensation installed at the factory. Custom current loop compensation to match the Pacific Scientific motor being used is available, consult the factory or the local IMEC representative. Since misadjustment of these components can cause possible damage to the controller's power section, extreme care should be exercised if changing these components. Consult the factory if in doubt.

For the 401, use the following formula to determine the value of resistor R103:

230VAC Operation:

$12\ mH < L_{LL} < 36\ mH$, R103 = 100Kohm [standard value]

$9\ mH < L_{LL} < 12\ mH$, R103 = 100Kohm X (L_{LL}/24mH)
$L_{LL} > 36\ mH$, R103 = 100Kohm X (L_{LL}/24mH)
$L_{LL} < 9\ mH$, Consult Factory.



DENOTES SOLDER POST

MOTOR PTC INPUT CIRCUIT
FIGURE 3.4

IMEC Corporation
Subsidiary of Pacific Scientific
The Schraffi Center, 529 Main Street, Charlestown MA 02129
Tel (617) 242-4800

115VAC Operation:

6 mH < L_{LL} < 18 mH, R103 = 100Kohm [standard value]

4 mH < L_{LL} < 6 mH, R103 = 100Kohm X (L_{LL}/12mH)
L_{LL} > 18 mH, R103 = 100Kohm X (L_{LL}/12mH)
L_{LL} < 4 mH, Consult Factory.

where R103 is in Kohms and L_{LL} is the line-to-line motor inductance in milliHenries.

For the 402, use the following formula to determine the value of resistor R103:

230VAC Operation:

6 mH < L_{LL} < 18 mH, R103 = 100Kohm [standard value]

4 mH < L_{LL} < 6 mH, R103 = 100Kohm X (L_{LL}/12mH)
L_{LL} > 18 mH, R103 = 100Kohm X (L_{LL}/12mH)
L_{LL} < 4 mH, Consult Factory.

115VAC Operation:

3 mH < L_{LL} < 9 mH, R103 = 100Kohm [standard value]

2 mH < L_{LL} < 3 mH, R103 = 100Kohm X (L_{LL}/6mH)
L_{LL} > 9 mH, R103 = 100Kohm X (L_{LL}/6mH)
L_{LL} < 2 mH, Consult Factory.

where R103 is in Kohms and L_{LL} is the line-to-line motor inductance in milliHenries.

If resistor R103 is changed, capacitor C50 must be changed per the following formula:

C50 = 1.5/R103

where R103 is in Kohms and C50 is in uF.

The factory installed, standard value for C50 is 0.015 uF.

3.7.3 Tachometer Lead Network Adjustment (R156, C80)

Resistor R156 and capacitor C80 provide a tachometer lead network. Since such a network is only used in certain applications, the controller is shipped from the factory without components installed in these locations. Component selection for these locations should be determined by the user according to the specific application.

3.7.4 Tachometer Gain Adjustment (R88)

Resistor R88 is the tachometer gain setting resistor. This resistor along with the COMMAND GAIN potentiometer determines the gain of the VEL CMD input. The formula below defines the VEL CMD gain:

$$\frac{(0.77)(R88)}{(R78)(K_{TACH})} < K_{CMD} < \frac{(1.9)(R88)}{(R78)(K_{TACH})}$$

where K_{CMD} = VEL CMD input gain in Krpm/Volt,
K_{TACH} = Tachometer gain in Volt/Krpm.

Using the standard factory value of 22.1Kohm for R78 and R88 gives the following range of VEL CMD gains:

$$\frac{0.77}{K_{TACH}} < K_{CMD} < \frac{1.9}{K_{TACH}}$$

or for other values of R88

$$\frac{R88}{(28.7)(K_{TACH})} < K_{CMD} < \frac{R88}{(11.6)(K_{TACH})}$$

where R88 is in Kohms

Exercise caution if changing the value of resistor R88. If a brushless tachometer is used in the system, note that it has an output saturation point at approximately ±9V due to its internal op amp. If R88 is made too large, the tachometer output can be saturated. At saturation, increases in tachometer speed will not be reflected in its output since it is voltage limited. This would lead to a runaway condition until the speed was brought back within the linear output range of the tach.

3.7.5 Velocity Loop DC Gain Adjustment (R152)

R152 sets the DC gain of the velocity loop. In many positioning control applications, a well-defined, finite DC gain is desired to insure proper operation of the position loop. If desired, the DC gain limit can be eliminated by removing R152. This may be desirable in a speed control application. The DC gain is defined as the velocity error needed to produce full motor torque (current). From Figure 3.3 note that full current is produced by a ±4.2 V current command. The formula below defines the velocity error voltage, VE, necessary to produce full motor torque:

$$V_E = \frac{R88}{(52)(R152)}$$

where R88 and R152 are resistance in Kohms.

For the standard values of R88 = 22.1Kohm and R152 = 100Kohm, VE = 4.3 mV. Hence a 4.3 mV velocity error voltage will produce full motor torque. Note that this DC gain is not affected by the VEL LOOP GAIN adjustment.

3.7.6 Velocity Loop Dynamics Adjustment

Jumper block E1 and the VEL LOOP GAIN potentiometer are used to set the velocity loop dynamics. The E1-7,8 position provides PI compensation for systems with lower torque/inertia ratios. The E1-5,6 position reduces the loop gain by a factor of 10 for systems with high torque/inertia ratios. In either position, the VEL LOOP GAIN potentiometer allows the gain to be adjusted over a 20 to 1 range.

In addition the E1-3,4 position, allows R23 and C83 to set the velocity loop PI compensation. The user can install their own compensation components in these locations. If the custom compensation option is ordered, the factory will install the specific custom compensation components in these locations.

If the controller is to be used in a "torque block" (current control) mode, i.e. without a tachometer or equivalent velocity feedback transducer, the E1 jumper should be placed in the E1-1,2 position and the COMMAND GAIN potentiometer should be turned full counterclockwise. In this configuration, a ±9 V input on the VEL CMD inputs will result in ± peak rated output current. The VEL LOOP GAIN potentiometer has no effect when the jumper is set in this position.

3.8 Initial Power Up

Every controller is burned-in and fully tested before leaving the factory. However, it is possible that damage has been sustained by the controller during shipping. This procedure should be followed to insure that the controller has not sustained shipping damage and has been installed properly. If problems are encountered during this procedure refer to Section 4 or the appropriate section of this manual. Procedure A assumes that the controller is configured as a velocity block using a Tachsyn® and has a Tachsyn® Processor card installed. If the unit is configured as a torque block without velocity feedback refer to Procedure B. Procedure B assumes that Hall-Effect devices are used for commutation signals and there is no Tachsyn® Processor installed.

3.8.1 Procedure A (Velocity Block)

(1) Check that the unit has been wired and mounted per instructions in Sections 3.2 and 3.4 of this manual. Be especially careful in checking the 115/230VAC input and motor connections.

WARNING

INSURE THAT THE VOLTAGE SELECTOR SWITCH IS SET TO THE CORRECT LINE VOLTAGE. INCORRECT SETTING OF THIS SWITCH CAN CAUSE SEVERE DAMAGE TO THE CONTROLLER.

(2) Set the adjustments and jumpers as follows:

Plug Jumpers	
E1	Set to appropriate position. E1-3,4; E1-5,6; or E1-7,8

Potentiometers	
VEL LOOP GAIN	Full CCW.
CURRENT LIMIT	Full CCW.
COMMAND GAIN	Full CCW.
VEL OFFSET	Factory Set

DIP Switch	
S1-1	OFF
S1-2	OFF
S1-3	OFF
S1-4	OFF
S1-5	OFF
S1-6	OFF
S1-7	OFF

(3) Insure that the ENABLE input is inactive.

(4) Apply 115/230VAC power to the controller.

(5) Verify that only the POWER LED is lit.

(6) ENABLE the controller.
The motor may rotate at this point. Be prepared to disable the controller or remove 115/230VAC power if excessive motion occurs.

(7) Command a small velocity. Rotate the CURRENT LIMIT adjustment CW approximately 3 turns.

(8) The motor should be stable or rotate slowly in one direction.

(9) Slowly rotate the CURRENT LIMIT adjustment CW. The motor should rotate slowly in a smooth, controlled manner. If operation appears normal, set the CURRENT LIMIT to the desired value. If the motor rotates normally, but in the direction opposite of that desired for the given VEL CMD input polarity, do the following: Remove 115/230VAC power, reverse the Tachsyn® excitation leads J4-6 and J4-7. Restart this procedure.

(10) If the motor is rotating smoothly, slowly turn the VEL LOOP GAIN adjustment CW until it is full CW or until the motor begins to oscillate. Turn the adjustment CCW approximately 1 turn to achieve final setting. This is a simple, empirical way of setting the velocity loop dynamics. If a more exact response is desired, attach an oscilloscope to the tachometer output. See Figure 3.2 for tachometer output location. Input small velocity steps and monitor the tach output. Adjust VEL LOOP GAIN to obtain the desired step response.

(11) If the motor oscillates at all settings of the VEL LOOP GAIN adjustment, the other compensation network should be tried. If neither standard compensation network prevents oscillation, custom compensation components may be required. Remove 115/230VAC power. Place a resistor decade box set at 100Kohms (or a 100Kohm resistor) across the R23 solder posts. Place a capacitor decade box set at 1 uF across the C83 solder posts. Set the E1 jumper to the E1-3,4 position. Restart this procedure at step (3). Insure that the VEL LOOP GAIN adjustment is set at full CCW. If the motor still oscillates, contact the factory. Slowly rotate VEL LOOP GAIN CW until the motor oscillates. Turn the adjustment 1 turn CCW to achieve the final setting. As before if a more exact response is desired, monitor the velocity loop's step response. Decrease the value of C83 until overshoot occurs or increase it until the overshoot disappears. Next adjust R23 to further shape the step response. Install the required components.

(12) After the response has been set, set the VEL CMD input to zero. Adjust VEL OFFSET until motor rotation is zero.

(13) Apply a known voltage to the VEL CMD input. Monitor the motor speed using a handheld tach. Adjust COMMAND GAIN to obtain the desired VEL CMD gain.

3.8.2 Procedure B (Torque Block)

(1) Check that the unit has been wired and mounted per instructions in this manual. Be especially careful in checking the 115/230VAC input and motor connections.

WARNING

INSURE THAT THE VOLTAGE SELECTOR SWITCH IS SET TO THE CORRECT LINE VOLTAGE. INCORRECT SETTING OF THIS SWITCH CAN CAUSE SEVERE DAMAGE TO THE CONTROLLER.

(2) Set the adjustments and jumpers as follows:

Plug Jumpers	
E1	Set to position E1-1,2.

Potentiometers	
VEL LOOP GAIN	Set at any position.
CURRENT LIMIT	Set full CCW.
COMMAND GAIN	Set full CCW.
VEL OFFSET	Factory Set

DIP Switch	
S1-1	OFF
S1-2	ON
S1-3	ON
S1-4	ON
S1-5	ON
S1-6	ON
S1-7	ON

(3) Insure that the ENABLE input is inactive.

(4) Apply 115/230VAC power to the controller.

(5) Verify that only the POWER LED is lit.

(6) ENABLE the controller.
Insure that the VEL CMD input is zero. The motor may rotate at this point. Be prepared to disable the controller or remove 115/230VAC power if excessive motion occurs.

(7) Command a small current(torque).

(8) The motor should rotate in a smooth manner. If it rotates in the opposite direction of that desired for the given VEL CMD input polarity, do the following: Remove 115/230VAC power, and reverse the VEL CMD input wires. Restart this procedure.

(9) CURRENT LIMIT, COMMAND GAIN and VEL OFFSET adjust torque limit, torque command gain, and offset torque respectively when the controller is in this configuration. These adjustments are best made by using the Motor Current Monitor output. Attach a voltmeter between J3-8 and J3-7 and set it to read 10V full scale. Set the VEL CMD input to zero. Adjust VEL OFFSET until the voltmeter reads approximately zero. Lock the motor shaft in place. Turn the CURRENT LIMIT adjustment to full CW. Apply a 1 VDC signal to the VEL CMD input. Adjust COMMAND GAIN to get the desired output current for a 1 volt command. The monitor output signal gain is 1.26 V/A for the 401 and 0.63 V/A for the 402. Finally set CURRENT LIMIT by applying a signal to the VEL CMD input to obtain full output current and then adjusting CURRENT LIMIT until the voltmeter indicates the desired current limit point.

3.9 Velocity Loop / Current Loop Circuits

The velocity loop and current loop circuits are illustrated in schematic Figure 3.3.

The velocity command input is a differential amplifier stage with a 1000 Hz low pass filter. The amplifier has a gain adjustment range of 0.68 to 1.67 which is controllable by potentiometer R2, COMMAND GAIN. Test point V CMD allows monitoring of the velocity command signal.

The velocity feedback or tachometer input is also a differential amplifier stage. This amplifier has a fixed gain of 0.884 and a low pass filter break frequency of 1200 Hz. The tachometer signal can be monitored on the solder post of capacitor C80 (See Figure 3.2).

The outputs of the command input differential amplifier and feedback input differential amplifier are summed via resistors R78 and R88 of the velocity error amplifier. A velocity offset adjustment term is also summed at this node via potentiometer R1, VEL OFFSET, and resistor R81. The resulting velocity error signal is processed by the velocity loop compensation network selected by the setting of jumper block E1.

All three velocity compensation networks are PI (proportional + integral). Compensation network #1 has a PI break frequency of 7.2 Hz and compensation network #2 has a PI break frequency of 16 Hz. The custom compensation setting allows the user to set the PI compensation to the desired value. The fourth jumper block E1 setting gives strictly proportional gain and is intended for use in a torque block mode rather than in a velocity block mode.

Solder posts are provided to allow the addition of a tachometer lead network (R156, C80) for the user desiring this type of velocity loop compensation.

The DC gain of the velocity error amplifier is limited and set by resistors R152, R70, and R151. The proportional AC gain is set by the compensation network selected (resistor R153, R154, or R23) and the setting of potentiometer R3, VEL LOOP GAIN. This potentiometer setting affects only the AC proportional gain, it does not affect the DC gain and it does not affect the proportional gain if jumper block E1 is set to E1-1,2.

The output of the velocity error amplifier is the current command which can be monitored on the I CMD test point. This signal has a full scale range of ±4.2 V which corresponds to ± peak rated output current (3.5 A for 401 and 7.0 A for 402). The current limit clamp circuit in the velocity error amplifier allows the current limit to be reduced below this peak value by adjusting potentiometer R4, CURRENT LIMIT.

It is important to note that the current command is processed by a 144 Hz low pass filter consisting of resistors R107, R104 and capacitor C77. This filter is included to eliminate or reduce the effects of low frequency mechanical resonances often found in the mechanical system being driven by the servo motor. For applications requiring high bandwidth velocity control (> 125 Hz), this filter may have to be removed or changed. This can most easily be accomplished by removing or changing C77. Also note that in torque block applications this filter will reduce the apparent current loop bandwidth to 144 Hz even though the actual current loop bandwidth is typically between 1000 and 2000 Hz. Once again, removing or changing C77 can eliminate or move the 144 Hz filter.

If a mechanical resonance problem is still present even with the standard 144 Hz filter in place, adding a second low pass filter with a frequency of about 150 Hz may solve the resonance problem. This filter is easily implemented by placing the appropriate capacitor across the velocity loop proportional gain setting resistor (R23, R153, or R154) being used. If the E1-7,8 setting is being used, place a 0.01 uF capacitor across R153. If the E1-5,6 setting is being used, place a 0.1 uF capacitor across R154. If the E1-3,4 setting is being used, select the capacitor such that:

$$C = 1/R23 \text{ where } R23 = \text{kohms}, C = \text{uF}.$$

Note that this adds a second low pass filter at 150 Hz. This will only be acceptable on systems requiring a velocity loop bandwidth of 80 Hz or less.

The current loop employs PI compensation which is set by the current error amplifier feedback network consisting of resistor R103 and capacitor C50. See Section 3.7.2 for selection of these components. The PI break frequency is set at 106 Hz. The current error signal is generated by summing the current command signal and current feedback signal via resistors R107, R104 and resistor R102. The current feedback signal is available as a monitor point on connector pin J3-8.

The output of the current error amplifier is the motor voltage command which drives the PWM output stage. Note that the gain of the output stage depends upon the line voltage being used.

Current loop bandwidth is inversely proportional to motor inductance. Hence higher inductance motors require higher proportional gain to obtain the same bandwidth as lower inductance motors. The PI compensation components are selected to obtain a current loop bandwidth of between 700 and 2100 Hz over a specified 3 to 1 inductance range. This can be seen in Section 3.7.2 where a given value of resistor R103 covers a 3 to 1 range of motor inductances. Note that the inductance ranges covered by a specific value of R103 are different for 115 VAC operation versus 230 VAC operation. This is due to the fact that the PWM output stage gain depends upon the line voltage being used.

The voltage applied to the motor, divided by the motor impedance, gives the motor current. The motor current is measured by the current sensor circuits and fed back to the current error amplifier via resistor R102.

TROUBLESHOOTING

Controller faults are indicated by the red and green diagnostic LEDs located at the top of the front panel. Faults will also be indicated by the FAULT OUT output (J3-6) ceasing to sink current. Before proceeding through the troubleshooting sequence verify that the input fuses and control voltage supply fuse are intact and that 115/230VAC is present at the controller's input terminals. Also insure that the voltage selector switch is set to the proper position.

WARNING

DANGEROUS VOLTAGES, CURRENTS, TEMPERATURES, TORQUES, FORCES, AND ENERGY LEVELS EXIST IN THIS CONTROLLER AND ITS ASSOCIATED MOTOR. EXTREME CAUTION AND CARE SHOULD BE EXERCISED IN THE APPLICATION OF THIS EQUIPMENT. ONLY QUALIFIED INDIVIDUALS SHOULD WORK ON THIS CONTROLLER AND ITS APPLICATION.

There are no field serviceable components in the controller. It is recommended that in the event of a controller failure the entire unit be replaced and the defective unit returned to the factory for repair. Verify that the controller is defective before replacing or returning for repair.

During troubleshooting, the highest priority LED is the green POWER LED. If this LED is not lit, a fault has occurred on the ±12V supplies or AC power is not being applied. In this case, ignore the red FAULT LED since a false indication could be given due to the loss or interruption of the ±12V power.

An intermittent short on the ±12V supply may trip-out the controller but not indicate the fault. This would occur due to the ±12V being shorted long enough to clear the power-up reset circuit. Upon removal of the ±12V short circuit, a power-up reset would be generated which would clear all fault indicators.

TROUBLESHOOTING GUIDE

SYMPTOM	POSSIBLE CAUSE
POWER LED not lit.	* 115/230 VAC power not applied. * Voltage selector switch improperly set. * 115/230 VAC power out of tolerance (+10%, −15%). * Blown control voltage fuse [F3] or input fuse [F1,F2]. * Short circuit on ±12 VDC outputs (J4-11,12,13).
FAULT LED lit.	* Controller overtemperature Excessive ambient temperature. Restriction of cooling air due to insufficient spacing around the unit. Unit is being operated above its continuous power rating. * Motor overtemperature Motor PTC connection(s) open. If a motor PTC is not being used, place a jumper between J4-9 and J4-10. Motor thermal overload due to excessive ambient temperature or excessive RMS torque output. * Output short circuit Motor power wires are shorted together. Motor power wire(s) is shorted to ground. Internal motor winding short circuit. Internal motor winding short to the motor case. Insufficient motor inductance.

SYMPTOM	POSSIBLE CAUSE
FAULT LED lit (cont.).	* Bus overvoltage Excessive AC input voltage (> 253 VAC). Shunt Regulator option required. If shunt regulator is installed, there could be excessive regenerated energy.
Controller is enabled, POWER LED is lit, FAULT LED is off, but the motor does not respond.	* Open motor connection(s). * Seized load or excessive load friction. * Velocity command not reaching J3-1,2. * ENABLE command is not reaching J3-4. * The unit is receiving a RESET command on J4-5. * There is an open or misconnection of the Tachsyn® . * The CURRENT LIMIT potentiometer is turned full CCW.
System is unstable (oscillates).	* Velocity loop compensation or VEL LOOP GAIN adjustment is incorrect (See Section 3.6 and 3.7). * Improper shielding and grounding. Wire per the diagrams in this manual. The motor case must be grounded and the Tachsyn® wiring must be shielded as shown in the Interconnection Diagram. * User supplied position loop is improperly compensated.
System runs away.	* Tachsyn® and/or motor are wired incorrectly. * User supplied position loop has failed.
Motor operates erratically.	* Improper motor and/or Tachsyn® wiring. * Improper shielding and grounding. Wire per the diagrams in this manual. The motor case must be grounded and the Tachsyn® wiring must be shielded as shown in the Interconnection Diagram.

MAINTENANCE

5.1 Routine Maintenance

The SC400 Series of Brushless Servo Controllers are designed for minimum maintenance. The following limited procedures performed on a regular basis should result in trouble-free controller operation if the unit has been installed and set-up in accordance with this manual.

* Examine the controller for dust and dirt build-up. Remove any build-up using clean, dry, low pressure air.
* If the controller has a significant build-up of dust, dirt or grease, or if it has been exposed to corrosive or electrically conductive contaminants, it should be removed from service and cleaned using agents suitable for use on printed wiring boards and electronic components.

There are no field serviceable components except the fuses. Return defective units to the factory for repair.

Controllers returned for repair should be packed in the shipping carton from the replacement controller and returned to IMEC Corporation for repair. A Returned Materials Authorization number (RMA #) must be obtained from IMEC Corporation prior to returning products for repair.

The buyer is responsible for proper packing and shipment of controllers returned for repairs. In no event will IMEC Corporation be responsible or liable for damage resulting from shipment.

WARNING

DANGEROUS VOLTAGES, CURRENTS, TEMPERATURES, TORQUES, FORCES, AND ENERGY LEVELS EXIST IN THIS CONTROLLER AND ITS ASSOCIATED MOTOR. EXTREME CAUTION AND CARE SHOULD BE EXERCISED IN THE APPLICATION OF THIS EQUIPMENT. ONLY QUALIFIED INDIVIDUALS SHOULD WORK ON THIS CONTROLLER AND ITS APPLICATION.

5.2 Fuse Replacement

The controller is fused for protection by three 230VAC fuses which are located at the bottom of the controller PC board. See Figure 3.2.

WARNING

DISCONNECT INPUT VOLTAGE AND ALLOW AT LEAST 2 MINUTES OR MORE FOR INTERNAL VOLTAGES TO DECAY BEFORE SERVICING THE UNIT OR REPLACING FUSES.

The Control Voltage Supply fuse [F3] is a 1/4" X 1-1/4" Dual Element, 1/2 A, 250V unit. Replace only with a Bussman MDL 1/2 or equivalent.

The main input fuses [F1,F2] are 1/4" X 1-1/4" 20A, 250V units. Replace only with Bussman MDA 20 fuses or equivalent.

SECTION 6

PRODUCT NUMBERING

6.1 Product Numbers

The 400 Series Brushless Servo Controllers are designated by the model numbering system shown below. The first field designates the Series member by power level. The second field is for a Customization Code. The standard product has a Customization Code of 001. For special orders, IMEC will assign a unique Customization Code to identify the special requirements. The final field is for Option Code. If this field is left blank, the controller will be set-up for use with digital commutation devices such as Hall-Effect tranducers and a brushless tachometer (Tachsyn® Processor card is not installed).

The standard controller would have one of the four Tachsyn® Processor cards installed for use with the Tachsyn® transducer. The four processor cards are distinguished by different tachometer gradients.

SC4 X X - X X X - X X

Option Code
- Blank = Hall sensor/Brushless tachometer Interface
- T1 = Tachsyn® Processor, 0.5 V/Krpm tach gradient
- T2 = Tachsyn® Processor, 1.0 V/Krpm tach gradient
- T3 = Tachsyn® Processor, 2.0 V/Krpm tach gradient
- T4 = Tachsyn® Processor, 4.0 V/Krpm tach gradient

Customization Code
- Factory assigned
- 001 = standard controller

Power Level
- 01 = 1.75A cont., 3.5A pk.
- 02 = 3.50A cont., 7.0A pk.

400 SERIES
BRUSHLESS SERVO CONTROLLER
INSTRUCTION MANUAL ADDENDUM
FEBRUARY 1988

The SC400 Series of controllers has been expanded in power level with the addition of the SC403 model. The SC403 is functionally equivalent to the SC401 and SC402 models with an increase in output power level and some other minor changes. This addendum to the 400 Series Instruction Manual outlines the changes.

DIMENSIONS

The SC403 is identical in dimension with the SC401 and SC402 with the exception of the width. Referring to Figure 2.1 in the instruction manual, the width dimension of the SC403 is 4.5" rather than the 2.8" of the SC401/SC402.

I/O WIRING

The SC403 I/O is identical to the SC401/SC402 with the exception that the motor connector J2 and the power connector J1 are different. On the SC403 J1 and J2 are plug-in, screw terminal connectors. Pin-outs for the connectors are screened on the front of the SC403 but are repeated below:

Power Connector, J1		Motor Connector, J2	
J1-1	230 VAC LINE	J2-1	MOTOR PHASE R
J1-2	115/230 VAC LINE	J2-2	MOTOR PHASE S
J1-3	115/230 VAC LINE	J2-3	MOTOR PHASE T
J1-4	CHASSIS GROUND	J2-4	MOTOR GROUND

Figure 3.1 in the instruction manual is the interconnection diagram for the 400 Series and applies to the SC403 with the above exceptions for J1 and J2.

LOCATION OF ADJUSTMENTS

The PC board layout for the SC403 is slightly different than that of the SC401/SC402. Figure 3.2 in the instruction manual shows the location of various adjustments for the SC401/SC402. The SC403 layout is the same with the exception of the Voltage Selector Switch S2 and the input fuses. The Voltage Selector Switch is easily identifiable on the SC403. A third input fuse F3, is built into the SC403 and located with the other two input fuses F1 and F2 at the bottom of the PC board. The control voltage supply fuse is still used, it is F4 on the SC403 and F3 on the SC401/SC402.

SC403 ELECTRICAL SPECIFICATIONS

The SC403 has more than twice the ouput power capability of the SC402. The table below summarizes the electrical specifications of the SC403. These specifications are an extension of the SC401/SC402 Electrical Specifications shown in Section 2.1 of the Instruction Manual.

	SC403
Input Voltage	115/230 VAC (+10,-15%) 1 or 3 phase, 47-63 Hz
Bus Voltage (nominal)	
230 VAC Input	320 VDC
115 VAC Input	160 VDC
Output Current	
Peak	15 A
Continuous (stall)	
230 VAC Input	7.5 A
115 VAC Input	7.5 A
Output Power	
Peak	
230 VAC Input	4500 W
115 VAC Input	2250 W
Continuous (stall)	
230 VAC, 3 Phase Input	2250 W
230 VAC, 1 Phase Input	1575 W
115 VAC, 1 Phase Input	800 W
Shunt Regulator (Optional)	
Peak Power (0.3 seconds)	6000 W
Continuous Power	40 W
Efficiency (@ rated continuous power)	> 90%
Form Factor	< 1.01
Current Loop Bandwidth	3 kHz max.
Velocity Offset	Adjustable to zero
Velocity Offset Drift (referred to input)	50 uV/°C typ.
Velocity Input Command	± 10 V
Output Ripple Frequency	15 kHz
Fault Output	Open collector, 30 VDC, 25 mA sink
Operating Temperature	
Full Ratings	0°C to 50°C
Derated(See Note 1)	50°C to 60°C

Specifications subject to change without notice.

Notes: 1. Linearly derate the continuous current and power ratings to 70% at 60°C.

PACIFIC SCIENTIFIC®

BRUSHLESS MOTION CONTROL APPLICATION NOTES

WIRING, GROUNDING, AND SHIELDING TECHNIQUES

Proper wiring, grounding, and shielding techniques are important in obtaining proper servo operation and performance. Incorrect wiring, grounding, or shielding can cause erratic servo performance or even a complete lack of operation. This note summarizes the proper techniques and is intended as a supplement to the information contained in the controller instruction manuals.

Motor Power Wiring (See Figure 1)

Pacific Scientific motors are three phase and hence have three terminals. These three motor terminals are labelled R, S, and T. It is imperative that the R, S, and T motor terminals be connected to the respective R, S, and T outputs of the controller. Improper phasing of these terminals will result in erratic motor operation including "deadspots", runaway, or stall.

Another important aspect of motor wiring is grounding of the motor. Motor wiring should be viewed as a four wire connection rather than a three wire connection with the fourth wire being motor ground. The motor must be properly grounded to insure proper operation and to prevent shock hazard.

There is capacitive coupling between the motor's three phase winding and the motor's case. When PWM voltages are applied to the motor terminals, the motor case tends to follow these voltages because of the coupling capacitance. If the motor is not grounded, a shock hazard is present because of capacitively coupled voltage on the motor case. Hence the motor must be grounded to prevent shock hazard.

When the motor is grounded, pulses of current flow in the ground wire due to the motor's winding-case capacitance. These pulses are short in duration and occur at the PWM frequency. Electrical noise due to these pulses can be radiated if proper techniques are not used. To prevent radiated noise, the motor ground wire should be tightly bundled or twisted with the three wires connected to the motor terminals. This will typically reduce radiated noise to an acceptable level.

If desired or required, two other techniques can be applied to attenuate noise further. The first is shielding the four motor wires. The shield should be connected at the controller end only. As a general rule a shield should only be connected at one end to prevent ground loops.

The second technique is the insertion of a common mode choke in the three wires connecting the motor terminals to the controller. This common mode choke is simply 10 turns of each motor terminal wire on a Ferroxcube 500T600-3C8 ferrite toroidal core. This choke acts to reduce the amplitude of the current pulses flowing in the motor ground wire. Figure 1(d) illustrates using these two techniques.

Pacific Scientific's 600 Series of brushless servo amplifiers have the common mode choke built-in and do not require the use of this external choke.

As a general rule, the motor wiring should be kept as far away as possible from the feedback transducer wiring and any other signal level wiring. In addition, all signal level wiring should be done using shielded cable to reduce the risk of noise problems.

Feedback Transducer Wiring

Pacific Scientific brushless servo systems use three standard feedback devices. For a torque only control system, Hall-effect devices are used. These devices provide motor commutation information to the brushless servo controller. For analog velocity control systems, a Tachsyn® is used. This device provides motor commutation information and motor velocity information. Finally, for position control systems and some velocity control systems a resolver is used. This device provides, motor commutation information, motor velocity information, and motor position information. For more information on any of these feedback devices, refer to Pacific Scientific Application Note 102.

Each of the feedback devices described above must be properly wired to insure proper operation of the servo system. The wiring practices for each device are described below.

Hall-effect Devices (See Figure 2)

Three Hall-effect devices are required to provide commutation information for Pacific Scientific three-phase brushless servo motors. The Hall-effect outputs are open collector transistors. These outputs drive the brushless servo controller sensor inputs which have resistor pull-ups.

Wiring for the Hall-effect devices consists of one wire for each of the three sensor signals and two wires which provide power to the Hall-effect devices. The three sensor signal wires should be twisted together and the two power wires should be twisted together.

For improved noise immunity, the five wires can be placed in a shield which is connected to the 12V RTN at the controller. This is especially important if the motor wiring is run near (within 12 inches) of the sensor wiring. The shield should only be connected at the controller end.

Tachsyn® Wiring (See Figure 3)

The Tachsyn® is a five wire device that operates similar to a resolver. Two of the Tachsyn® wires are a high frequency excitation signal. The remaining three wires are outputs which supply commutation and velocity information to the controller. **Both sets of wires must be shielded and the two excitation wires must be in a separate shield from the output wires. If they are not placed in separate shields, the motor will not operate or will operate erratically.**

The Tachsyn® must always be wired as shown in Figure 3. Any other wiring scheme will result in improper motor operation.

Resolver Wiring (See Figure 4)

The resolver is a six wire device. As with the Tachsyn®, two of the wires are a high frequency excitation signal. The remaining four wires are outputs which supply commutation, velocity, and position information to the controller. These four wires are separated into two distinct pairs; sine (S1 and S3) and cosine (S2 and S4). Hence the six wires are segregated into three pairs. Each pair must be run in a separate shield to insure proper motor operation.

The resolver must always be wired as shown in Figure 4. Any other wiring scheme may result in improper motor operation.

Grounding

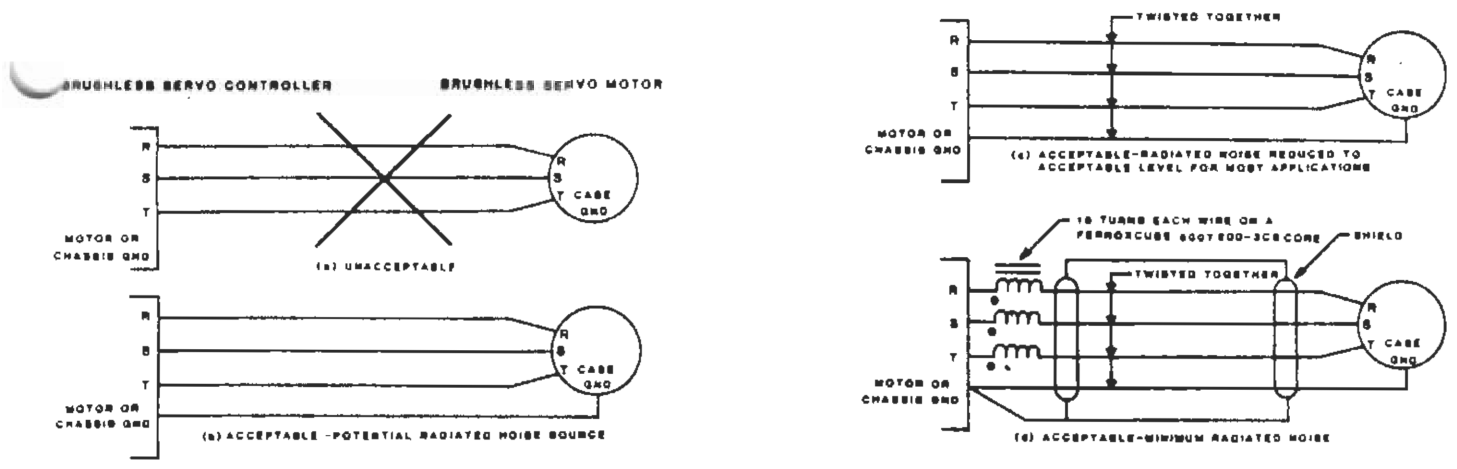
The grounding procedures listed in the controller instruction should be followed. In general, the following rules should be observed.

All component chassis ground points and signal ground or common points should be tied together at a single point (star connection). This point should then be tied with a single conductor to an earth ground point. This form of grounding prevents ground loops and insures that all components are properly grounded against shock hazard.

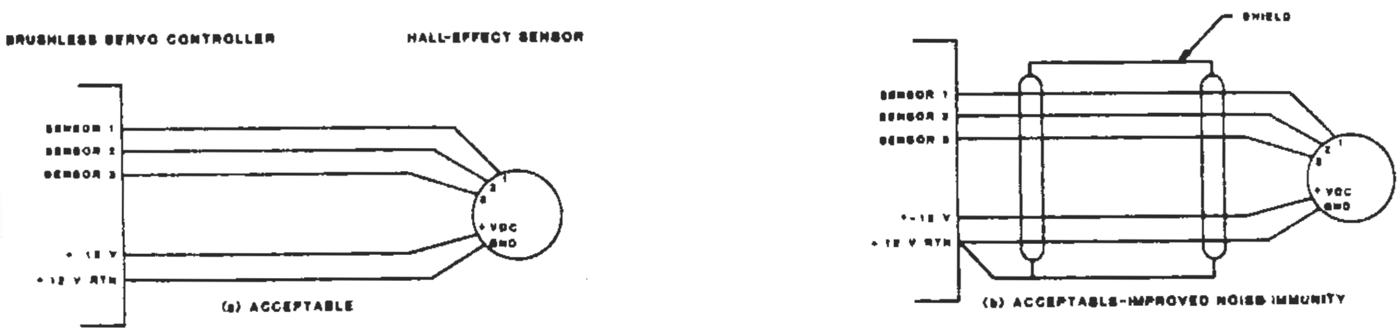
Shielding

In general, it is good practice to shield all wires carrying low level signals. This is especially important if the signal level wires are run near power level wiring such as motor wires or relay wires.

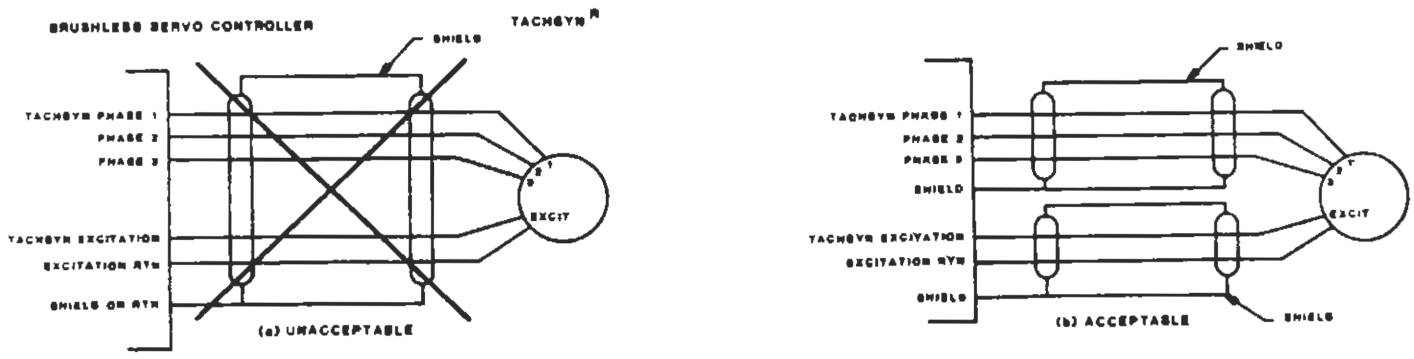
When shielding wires, connect only one end of the shield, preferably the source end. Connecting both ends of a shield will result in ground loops. It is recommended that the unconnected end of the shield be insulated to prevent accidental connection



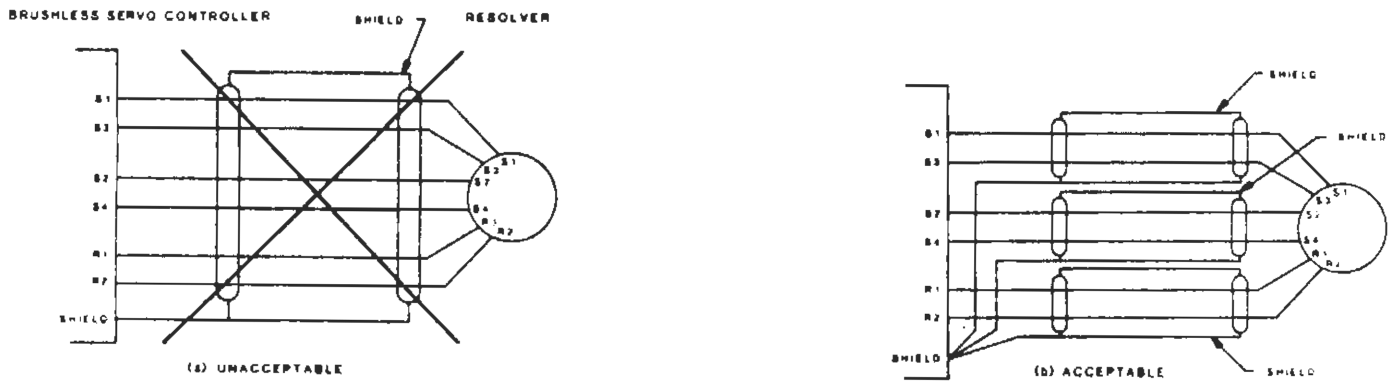
MOTOR WIRING
FIGURE 1



HALL EFFECT SENSOR WIRING
FIGURE 2



TACHSYN R WIRING
FIGURE 3



RESOLVER WIRING
FIGURE 4

NOTES

IMEC
A Subsidiary of
Pacific Scientific

IMEC Corporation
The Schrafft Center
Charlestown, MA 02129
Tel (617) 242-4800