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# OC950 Installation and Hardware Reference Manual

**Document Part # MA950**
**Rev G**

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**Revision History**

| Issue | Date | Brief Description |
|---|---|---|
| G | 06/04 | Update corporate identity and contact information |

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**WARNING**

***Alerts you to potential physical danger or harm. Failure to follow warning notices could result in personal injury or death.***



**CAUTION**

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**NOTE**

***Highlights information critical to your understanding or use of the product.***

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# 1. OVERVIEW

This section introduces the OC950 Programmable Option Card. Topics covered are:

- OC950 Overview
- How to Use this Manual
- Warranty Information

Installation and Setup is a step-by-step guide allowing you to configure an SC950 and run your motor within a few minutes. It is strongly recommended that you go through Installation and Setup first. This will give you a feel for using the SC950 and lay the framework for reading the other chapters. Thoroughly read OC950 Interfaces and Connections, Servo Loop Parameters, and Troubleshooting to gain the most from the OC950.

## *1. 1 OC950 PROGRAMMABLE OPTION CARD DEFINITION*

The OC950 is an option card that is installed in the option card slot of Danaher Motion's Pacific Scientific SC900 servo drive. Combined, the SC900 and OC950 create the SC950. It provides stand-alone, single-axis programmable positioning capability to a high performance, digital servo drive.

The SC950 inherits all the advanced, high-performance functionality as well as the small package size of the SC900 platform. The SC950 also inherits all the hardware resources of that platform, including 6 points of bi-directional discrete I/O, two analog outputs, one analog input, one encoder input port and one encoder output port. The SC900 platform also provides two high-speed registration inputs.

Resources provided on all varieties the OC950 include twenty-one points of bi-directional discrete I/O and an RS-232/RS-485 serial communications port.

The OC950 provides for direct connection to Opto22 Industrial I/O mounting racks and industrial I/O modules with the use of the CA950-IO adapter module.

### 1.1.1. OC950 HARDWARE VARIETIES

Two optional memory (NVRAM: nonvolatile random access memory) configurations are available, 32kx8 or 128kx8. NVRAM is battery backed, with a ten year life, and unlimited amount of write cycles. The memory provides storage for the user programs.

A PacLAN™ network interface is offered as an OC950 option. PacLAN supports 2.5 MB/sec communications among a cluster of SC950 drives. The port is compatible with standard ArcNET products using 93 W coax cable in a bus configuration.



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### 1.1.1.1. Standard Version

Combinations of the two memory offerings and the PacLAN option results in four standard versions of the OC950:

| | |
|---|---|
| OC950-501-01 | Base 950 Option Card 32kx8 NVRAM |
| OC950-502-01 | Base 950 Option Card 128kx8 NVRAM |
| OC950-503-01 | Base 950 Option Card 32kx8 NVRAM + PacLAN |
| OC950-504-01 | Base 950 Option Card 128kx8 NVRAM + PacLAN |

### 1.1.1.2. Enhanced Version

In addition, there is an Enhanced version of the OC950 which supports additional features, including MODBUS and camming.

| | |
|---|---|
| OC950-601-01 | Enhanced 950 Option Card 32kx8 NVRAM |
| OC950-602-01 | Enhanced 950 Option Card 128kx8 NVRAM |
| OC950-603-01 | Enhanced 950 Option Card 32kx8 NVRAM + PacLAN |
| OC950-604-01 | Enhanced 950 Option Card 128kx8 NVRAM + PacLAN |



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# 2. INSTALLATION AND SETUP

This section provides a step-by-step introduction to setting a system up to run the OC950 and the 950IDE PC interface software. This procedure uses the minimum possible equipment to run an unloaded motor and sets motor speed from a PC's serial port. It is strongly recommended that all first time users go through this procedure to become familiar with the OC950 and the 950IDE PC interface software before installing the servo system in a machine.

## 2. 1 HARDWARE SETUP

To go through this product introduction procedure you will need the following items:

- SC900 Base Servo Drive
- OC950 Programmable Option Card
- Appropriate Brushless Motor with nothing attached to the shaft
- PC Running Windows 3.1 or Windows95/NT
- 950IDE Floppy Disk
- Motor Power and Feedback Cables (J2, J3)
- RS-232 Communications Cable (J51)
- DB-25 Connector Mate (J4)
- AC Power Line (J1)

If your OC950 is not already installed in your SC900, then use the following instructions to install it.



**CAUTION**

***NEVER insert or remove an Option Card with the Control AC Power (J1-5, 6) active. Damage to the base SC900 or the Option Card could occur.***

1. Remove Control AC Power from the SC900. The system status LED should be blank.
2. Loosen the two locking screws counterclockwise on the existing faceplate or existing Option Card and remove.
3. Position the new Option Card so that the silk screen reads the same as the base SC900.
4. Insert the Option Card by sliding it in all the way until it is flush with the base SC900.
5. Tighten the two locking screws by turning clockwise.

## 2. 2 CONNECTIONS

Connect the motor, feedback, and AC Power cables as shown in the Connection Diagram but **do not apply the AC power at this time**. It is recommended that Danaher Motion motor and feedback cables be used during setup since improper cabling is the primary cause of start up problems.

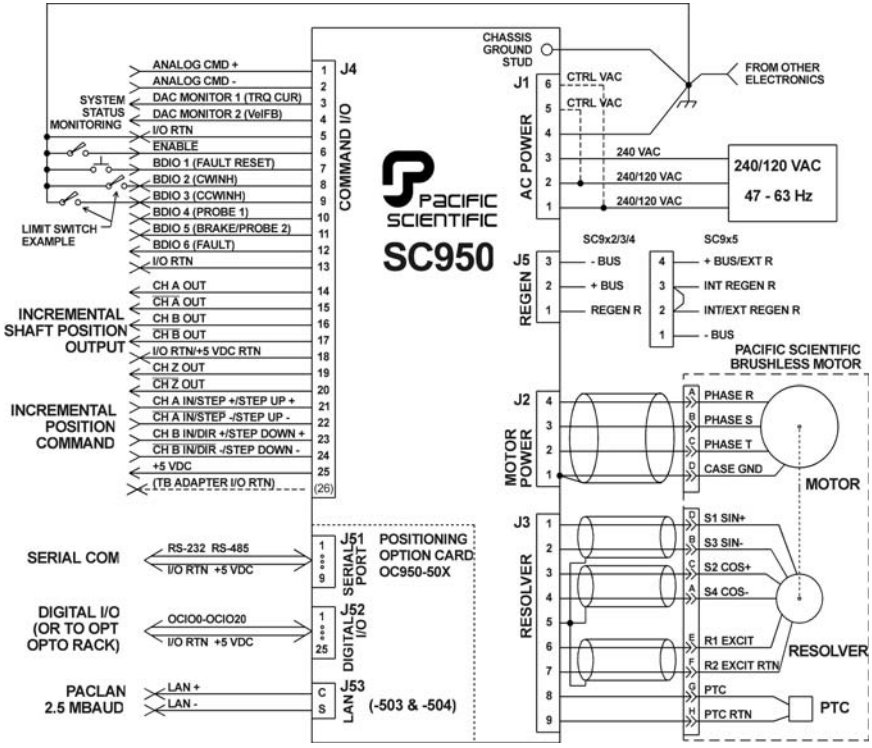


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Danaher Motion's RS-232 cable (part # CS-232-750) connects the 9-pin serial port socket on the OC950 to the PC. If this cable is unavailable, a simple 3-wire cable can be made using the wiring diagram shown on page 15.

The last connection needed provides the hardware enable to the SC900 via J4-6 and I/O RTN on J4-5. Preferably, connect a toggle switch between J4-6 and J4-5. If a toggle switch is not available, use a clip lead that connects and disconnects J4-6 to J4-5.

## 2.2.1. CONNECTION DIAGRAM




## 2. 3 SOFTWARE INSTALLATION

1. Insert the 950IDE diskette in your disk drive (A: or B:). Start Windows® and choose **Run** from the **File** menu of the Program Manager.
2. At the Command Line, type `A:\setup950` or `B:\setup950.`
3. Either press the <**Enter**> key ***or*** click **OK.**



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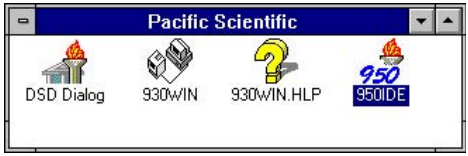
4. Select the drive (default is C) and directory (default is \950Win) in which you want 950IDE installed.
5. Select a **Program Manager Group** (default is Pacific Scientific) in which to place the icons.

NOTE

***When finished, remove the 950IDE disk from the drive and store it in a safe place.***

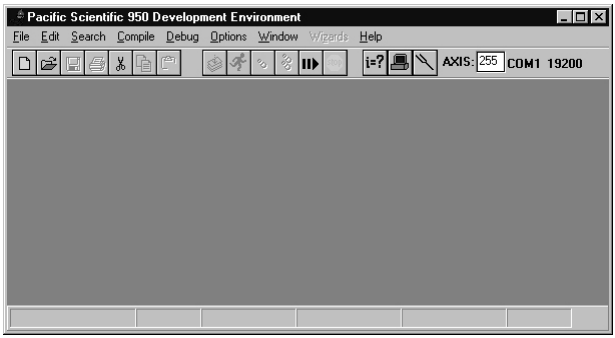
## 2. 4 USING 950IDE

To begin using 950IDE, if not already open, open the **Pacific Scientific Group** from the Program Manager. Double-click the 950 icon.




### 2.4.1. 950IDE MAIN MENU

Once you double-click on the 950 icon, the Main Menu appears:




### 2.4.2. MOVEMENT KEYS

950IDE is a standard Windows application and the normal cursor movement keys operate the same way as in all windows applications.

<**F1**> gives context sensitive on-line help



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# 2. 5 SYSTEM CONFIGURATION

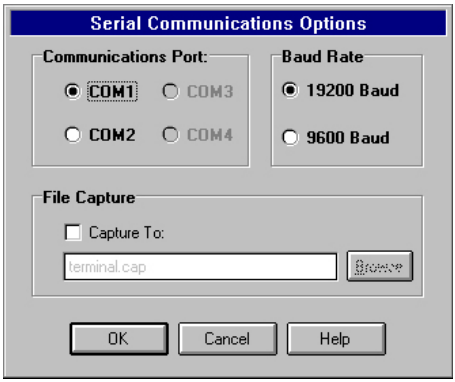
## 2.5.1. APPLYING AC POWER

Carefully check all wiring connections and ensure that J4-6 is not connected to J4-5. Apply AC power to your controller. The drive status display LED should be alternately flashing U C (unconfigured) after the power up message.

## 2.5.2. SERIAL PORT

To specify the PC serial port that is connected to the OC950:

1. Select **Communications** from the **Options** menu and the following dialogue box appears:



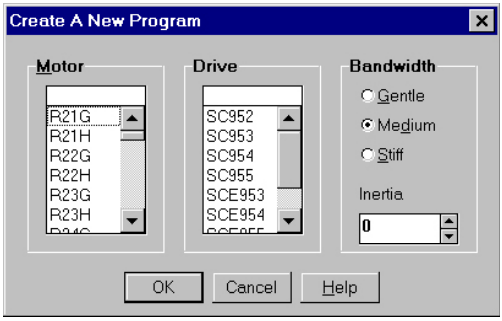

2. Specify the serial port you want to use.
3. Specify the baud rate and click **OK**.
4. Select **Variables** from the **Compile** menu.
5. Type **BaudRate** in the Variable/expression box and press <**Enter**>.
6. If the current value is incorrect, <**Tab**> to **New Value** and enter the correct baud rate.



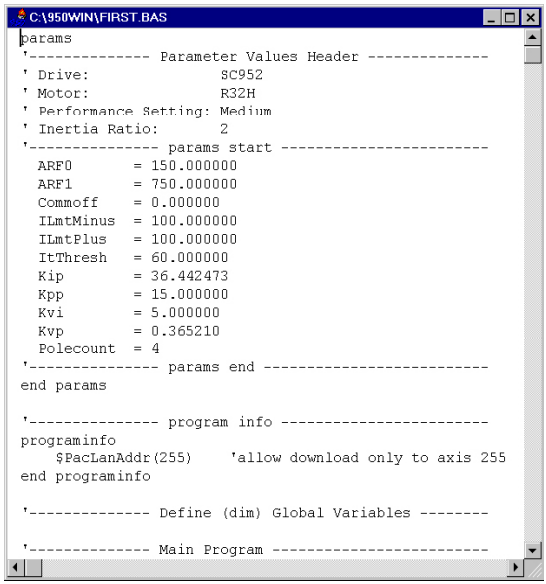
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## 2.5.3. CREATE A NEW PROGRAM

Select **New** from the **File** menu and the following dialog box appears:



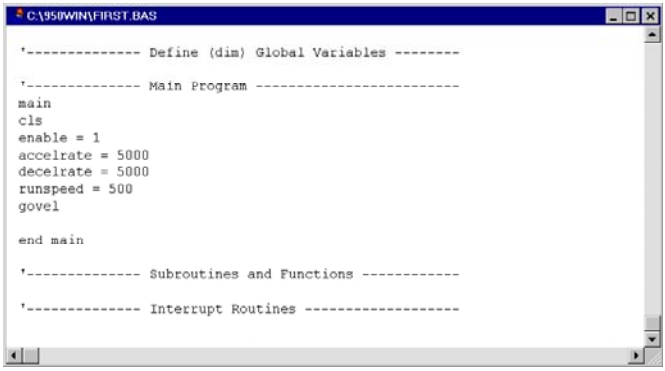

- Select the appropriate **Motor Part Number** from the dropdown menu.
- Select the **Drive** you're using (Example: SC953).
- Select **Medium**.
- Select an **inertia ratio**.
- Click **OK**.
- Select a **filename** (***.BAS** extension) for your new program.
- Click **OK**, and the following window appears:






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You can begin typing your program. To create a simple **JOG** move, type the following:




**NOTE**

***The drive status display should show a steady 0 for configured and not enabled.***

The current loop has been properly compensated for the selected motor, and the servo parameters have been set to a medium response (approximately 75 Hz velocity loop bandwidth) for the unloaded motor. Additional default settings have also been implemented.

**NOTE**

***For additional tuning, click on the on-line tuning button in the toolbar and follow the on-line help.***



Tuning Button

## 2.5.4. WIZARDS

The following wizards in the 950IDE facilitate program creation:

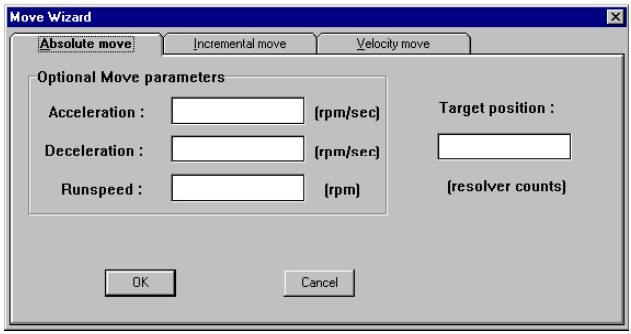
- Select Case
- Modbus and A-B DF1 Map
- Interrupt Handler
- Move Command
- Cam Setup



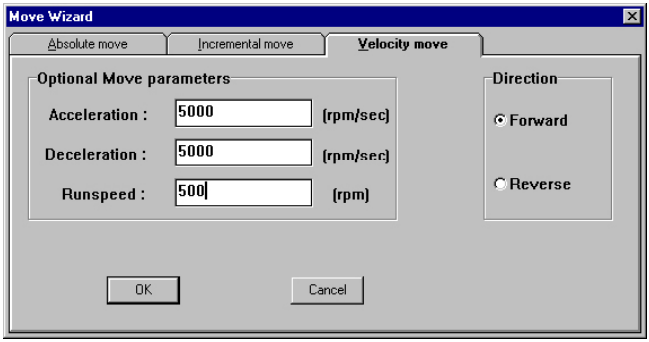
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To use a template to create a **JOG** move:

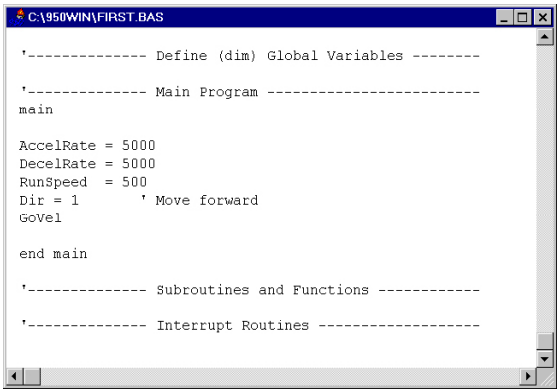
1. Select **Move Command** from the **Wizards** menu and the following window appears:




2. Select the **Velocity Move** tab and enter the appropriate parameters.




3. Click **OK.** The text is inserted in the main program, below the cursor.






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## 2.5.5. ENABLING DRIVE

Enable the controller by closing the switch between the Enable input (J4-6) and I/O RTN (J4-5). The commanded motor speed is the power-up default (set to 0 during configuration).

**WARNING**

***Before proceeding, the motor may need to be temporarily clamped down to prevent inertial forces from displacing the motor.***

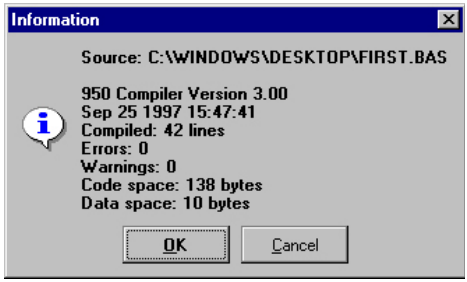
## 2.5.6. COMPILING A PROGRAM

The SC950 requires a compiled program to be downloaded via serial communications. To compile a program:

1. Select **Compile** from the **Compile** menu.
2. Press <**Ctrl**> <**F5**> or click the **Run** icon.

   Any error detected during compilation aborts further compilation (after the error is encountered), display the compilation status, and returns to the program, highlighting the program line containing the error.

3. Make necessary corrections until the program is successfully compiled and the Compiler Status indicates zero errors.




## 2.5.7. RUN PROGRAM

Select **Run** from the **Compile** menu, press <**F5**> ***or*** click the Compile icon.

## 2.5.8. WORKING WITH BREAKPOINTS

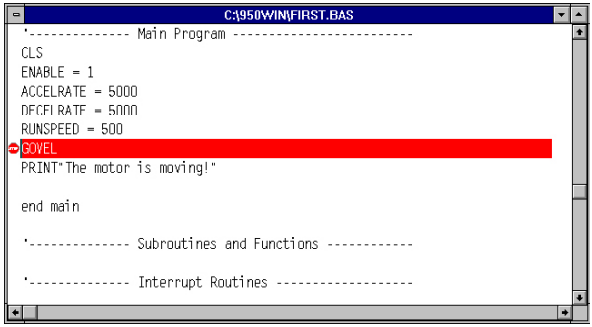
Breakpoints halt program execution at a specific location. 950IDE can set up to nine breakpoints within a program. Set breakpoints prior to running the program.



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## 2.5.9. SETTING BREAKPOINTS

1. Place the cursor on the line of code in which you want to set a breakpoint.
2. Select **Set Breakpoint** from the **Debug** menu or press <**F9**>.




## 2.5.10. REMOVING BREAKPOINTS

1. Place the cursor on the line of code which contains a breakpoint that you want to clear.
2. Select **Clear Breakpoint** from the **Debug** menu or press <**F9**>.
3. To remove all breakpoints in a program, select **Clear All Breakpoints** from the **Debug menu**.

## 2.5.11. CONTINUING PROGRAM EXECUTION

When a breakpoint is encountered during program execution, the SC950 suspends program execution and awaits further instruction. After a breakpoint is encountered, program execution can be continued by:

Selecting **Continue** from the **Compile** menu to continue program execution until the next breakpoint.

***OR***

Selecting **Single Step** from the **Debug** menu.

***OR***

Pressing <**F8**> to single step through the program line by line

***OR***

Clicking on the **Single Step** icon.



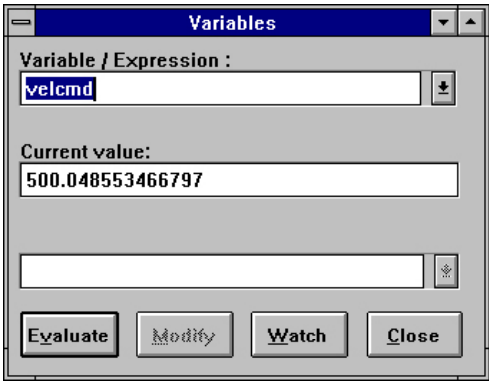
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# 2.5.12. VARIABLES WINDOW

## *2.5.12.1. Motor Velocity*

Select **Variables** in the **Compile** menu. The *Variables* window allows all parameters, variables, and commands to be examined, changed, or actuated as appropriate.

Type the variable name in the **Variable/Expression** box. To examine the shaft velocity, type **velcmd** in the **Variable/Expression** box and press <**Enter**>. The present value of the motor velocity command in the drive is displayed under **Current Value.**

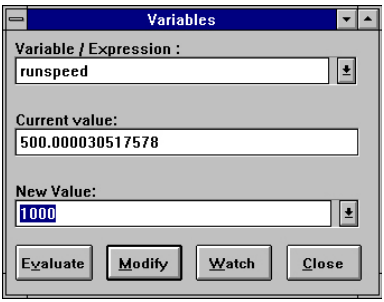



To continuously read and update the measured velocity, press **Evaluate**.

## *2.5.12.2. Modifying Variables*

To modify the value of the **RUNSPEED**, type RUNSPEED in the **Variable/expression** box and press <**Enter**>.The current value of **RUNSPEED** is displayed.

To change the value, enter **1000** in the **New Value** box and click **Modify**.






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Type GOVEL in the **Variable/Expression** box and press <**Enter**>. The motor should run at the new speed.

## 2.5.13. VIEWING VARIABLES

Use a Watch window to monitor multiple variables. Variables displayed in the Watch window are updated as breakpoints are encountered or after each single step.

To open a Watch Window, select **Watch Window** from the **Debug** menu.

### *2.5.13.1. Add Variables to a Watch Window:*

You can add variables to the watch window while a program is not executing.

1. Select **Variables** from the **Compile** menu.
2. Type the name of the variable you which to watch in the **Variable/Expression** box and click the **Watch** button. The Variable is added to the Watch window.




### *2.5.13.2. Remove Variables from a Watch Window*

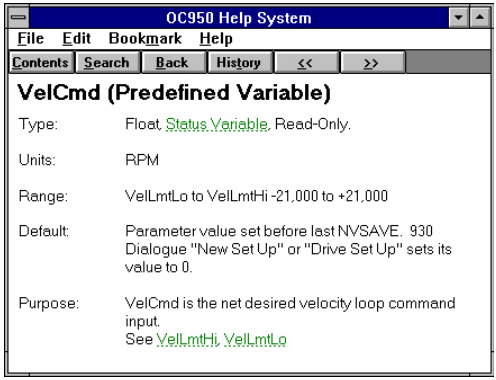
You can remove any variable that has been added to the Watch window at any time. Select the variable in the Watch window and press <**Delete**>.

To get help information on a particular key word, press <**F1**> while the cursor is located somewhere on that word in the **Variable/Expression** box.



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With **VelCmd** in the **Variable/Expression** box, <**F1**> should bring up the following help window:




## 2.5.14. SAVING A PROGRAM

Select **Save As** from the **File** menu. Type the file name, `FIRST.BAS` and click <**OK**>. The program is saved on disk in a file named FIRST.BAS.

## 2.5.15. OPENING A PROGRAM

Select **Open** from the **File** menu. Select **FIRST.BAS** from the list of file names and click <**OK**>. The program **FIRST.BAS** (saved to disk) is read from the disk and displayed.

## 2.5.16. EXITING 950IDE

To exit 950IDE, select **Exit** from the **File** menu.

You should now know how to start and exit 950IDE, create a program, monitor and change variable values.



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# 3. OC950 INTERFACES AND CONNECTIONS

This section describes the OC950 interfaces and required connection information. The OC950 plugs into an SC900 servo controller.

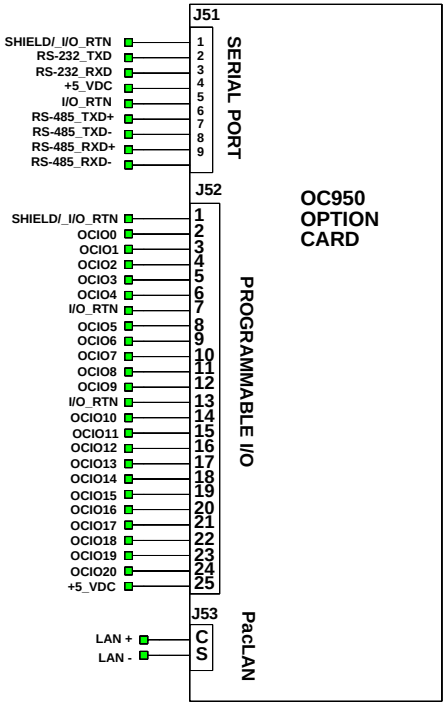
**WARNING**

***Install the OC950 with the servo controller's power off!***

Turn the two lock screws (on the front panel of the OC950) until resistance is met to properly seat the OC950 into the base unit. A communications address selection switch resides on the OC950 printed circuit board and is accessible only when removed from the SC900 servo base unit. The OC950 external connections include:

- Serial communications port (J51)
- Bi-directional I/O connections, OCIO0-OCIO20 (J52)
- Optional PacLAN™ communications port (J53)

## *3. 1 CONNECTION DIAGRAM*



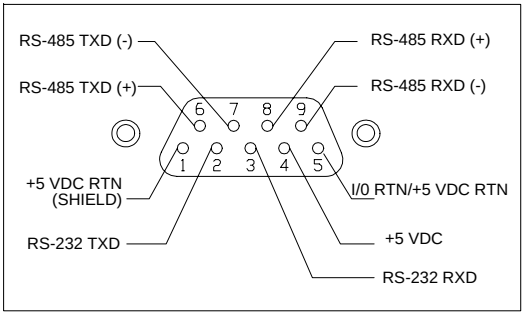



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## 3. 2 SERIAL PORT J51

The serial port (J51), utilizes the 9 contact female D subminiature style connector shown below. A brief description of each signal is included in the table below. For additional information, please refer to the OC950 Serial Communications Transceiver Schematic.

| Input/Output | Pin | Explanation |
|---|---|---|
| +5 VDC RTN / Shield | J51-1 | Common / Shield |
| RS-232 TXD | J51-2 | RS-232 transmitter output (from OC950) |
| RS-232 RXD | J51-3 | RS-232 transmitter input (to OC950) |
| +5 VDC | J51-4 | +5 VDC output (200 mA maximum between J51-4, J52-25 & J4-25) |
| I / O RTN / +5 VDC RTN | J51-5 | Common |
| RS-485 TXD (+) | J51-6 | RS-485 transmitter output (from OC950) |
| RS-485 TXD (-) | J51-7 | |
| RS-485 TXD (+ | J51-8 | RS-485 transmitter input (to OC950) |
| RS-485 TXD (- | J51-9 | |




Use the information provided in this section to connect the SC950 to your computer for use with the 950 Integrated Development Environment (950IDE) (due to the intelligent communications protocol utilized, it is not possible to configure or program the OC950 with a dumb terminal). Two communication links are available, RS-232 and RS-485. RS-485 allows a single computer to communicate with up to 32 SC950's in multi-axis configurations. A DIPswitch on the OC950 selects the communications address for RS-485 communication. The 950IDE defaults to communicate with axis 255 upon start up.



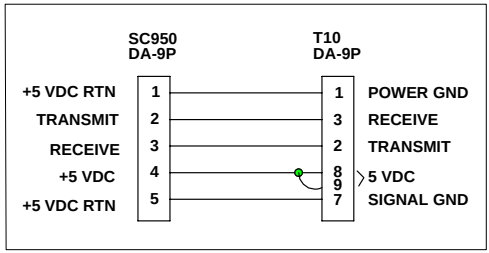
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## 3.2.1. J51 SERIAL PORT T10 CONNECTIONS (RS-232)

The T10 terminal requires a DC-9P 9-pin plug-in male D connector.

**NOTE**

***The T10 terminal is a Burr-Brown TM2500.***




1. Solder the cable leads to the SC950 mating connector and the T10 connector as shown.
2. Assemble the connector housings.
3. Plug the connectors into the SC950 and T10 and affix the connectors to the units.

## 3.2.2. PARAMETER SETUP

Set up the T10 terminal as follows:

1. Enter the setup mode by pressing period ( . ) while power is applied to the T10 (wait until the two letter prompt appears). *Refer to the terminal manual for more information*.
2. Enter the following values:

| | | | |
|---|---|---|---|
| **VW = 4** | Default | **LE = 0** | Local Echo OFF |
| **TM = 0** | Character Mode | **EN = 1** | Line Terminator (CR) |
| **TD = 0** | Turnaround Delay | **KC = 2** | Key Click |
| **BR = 2** | Baud Rate (9600) | **KR = 1** | Key Repeat |
| **DF = 4** | 8 Bits, No Parity | **CU = 2** | Cursor |
| **HS = 0** | Default (DTR asserted) | | |

**NOTE**

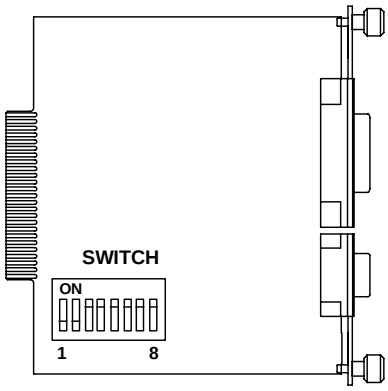
***The SC950 must be configured for 9600 baud (BaudRate = 9600), 8 bit, no parity data formats. Refer to the MA950-LR Reference Manual for additional information on configuring baud rate.***



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## 3. 3 S1 SWITCH

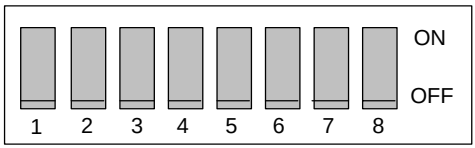
The S1 switch sets the communication address for each OC950. RS-485 requires the ability to select different addresses for multi-drop communications. Looking down at the top of the OC950, the diagram below shows the location of switch S1.




**NOTE**

***Each SC950 subsystem connected to an RS-485 multi-drop installation or PacLAN must have a unique serial address.***

The diagram below shows the S1 default switch settings. The OC950 factory default address is 255 (All switches off).




The switches are:

**On** in the up position (away from number)

**Off** in the down position (toward number)

**NOTE**

***When using RS-232 communications, leave the address set at 255.***



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## 3.3.1. S1 ADDRESS TABLE

| Address | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| 0 | On | On | On | On | On | On | On | On |
| 1 | Off | On | On | On | On | On | On | On |
| 2 | On | Off | On | On | On | On | On | On |
| 3 | Off | Off | On | On | On | On | On | On |
| 4 | On | On | Off | On | On | On | On | On |
| 5 | Off | On | Off | On | On | On | On | On |
| 6 | On | Off | Off | On | On | On | On | On |
| 7 | Off | Off | Off | On | On | On | On | On |
| 8 | On | On | On | Off | On | On | On | On |
| 9 | Off | On | On | Off | On | On | On | On |
| 10 | On | Off | On | Off | On | On | On | On |
| 11 | Off | Off | On | Off | On | On | On | On |
| 12 | On | On | Off | Off | On | On | On | On |
| 13 | Off | On | Off | Off | On | On | On | On |
| 14 | On | Off | Off | Off | On | On | On | On |
| 15 | Off | Off | Off | Off | On | On | On | On |
| 16 | On | On | On | On | Off | On | On | On |
| 17 | Off | On | On | On | Off | On | On | On |
| 18 | On | Off | On | On | Off | On | On | On |
| 19 | Off | Off | On | On | Off | On | On | On |
| 20 | On | On | Off | On | Off | On | On | On |
| 21 | Off | On | Off | On | Off | On | On | On |
| 22 | On | Off | Off | On | Off | On | On | On |
| 23 | Off | Off | Off | On | Off | On | On | On |
| 24 | On | On | On | Off | Off | On | On | On |
| 25 | Off | On | On | Off | Off | On | On | On |
| 26 | On | Off | On | Off | Off | On | On | On |
| 27 | Off | Off | On | Off | Off | On | On | On |
| 28 | On | On | Off | Off | Off | On | On | On |
| 29 | Off | On | Off | Off | Off | On | On | On |
| 30 | On | Off | Off | Off | Off | On | On | On |
| 31 | Off | Off | Off | Off | Off | On | On | On |
| 32 | On | On | On | On | On | Off | On | On |
| 33 | Off | On | On | On | On | Off | On | On |
| 34 | On | Off | On | On | On | Off | On | On |
| 35 | Off | Off | On | On | On | Off | On | On |
| 36 | On | On | Off | On | On | Off | On | On |
| 37 | Off | On | Off | On | On | Off | On | On |
| 38 | On | Off | Off | On | On | Off | On | On |
| 39 | Off | Off | Off | On | On | Off | On | On |
| 40 | On | On | On | Off | On | Off | On | On |
| 240 | On | On | On | On | Off | Off | Off | Off |
| 241 | Off | On | On | On | Off | Off | Off | Off |
| 242 | On | Off | On | On | Off | Off | Off | Off |
| 243 | Off | Off | On | On | Off | Off | Off | Off |



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| Address | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| 244 | On | On | Off | On | Off | Off | Off | Off |
| 245 | Off | On | Off | On | Off | Off | Off | Off |
| 246 | On | Off | Off | On | Off | Off | Off | Off |
| 247 | Off | Off | Off | On | Off | Off | Off | Off |
| 248 | On | On | On | Off | Off | Off | Off | Off |
| 249 | Off | On | On | Off | Off | Off | Off | Off |
| 250 | On | Off | On | Off | Off | Off | Off | Off |
| 251 | Off | Off | On | Off | Off | Off | Off | Off |
| 252 | On | On | Off | Off | Off | Off | Off | Off |
| 253 | Off | On | Off | Off | Off | Off | Off | Off |
| 254 | On | Off | Off | Off | Off | Off | Off | Off |
| 255* | Off | Off | Off | Off | Off | Off | Off | Off |

** For RS-232 operation (factory default)*

1. Remove power from the SC950 servocontroller.
2. Refer to the table for the appropriate address.
3. Reconnect power to the SC950 servocontroller.
4. Repeat steps 1 through 3 for other SC950 units on the bus. Be sure to give the other units unique addresses.

## 3.3.2. OCIO + 5 VDC

A + 5 VDC supply resides on the SC900. This supply is connected to J51-4, J52-25 (OCIO port), and J4-25 (command port on base unit). The **total** current draw from **all** connections must ***not*** exceed 200 mA.

## 3.3.3. RS-232 CONNECTIONS

RS-232 connections on J51 are shown below. Cable wiring required for connecting to either 9- or 25-pin serial ports of most computers are also shown.



**NOTE**

***Pinouts vary among computer manufacturers. Check the hardware reference manual for your machine before wiring.***

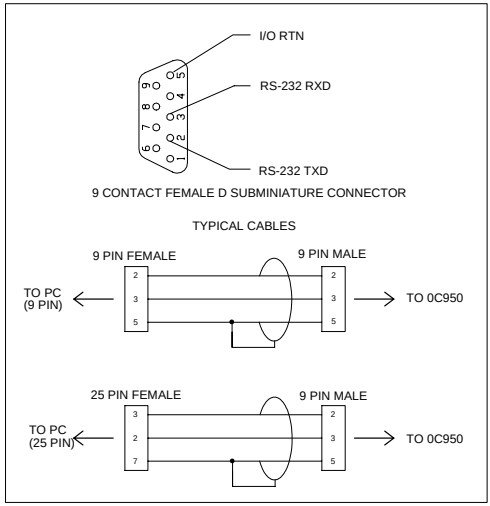


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### *3.3.3.1. Cabling Diagram*

**NOTE**

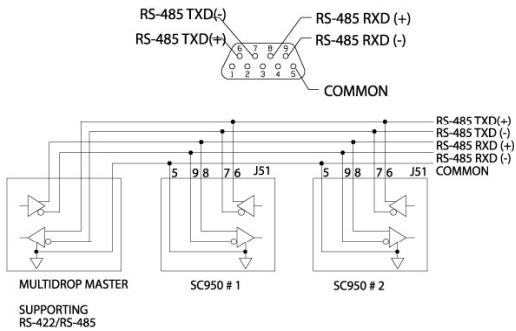
***Shielded wiring is recommended for the serial communications cable to minimize potential errors from electrical noise.***




## 3.3.4. RS-485/RS-422 CONNECTIONS

Up to 31 SC950s can be connected in parallel to a multi-drop master. The SC950s must each have a unique address, set using DIPswitch S1 (See S1 Switch). RS-485/RS-422 connections to J51 are shown below. A multi-drop interconnection diagram, showing multiple axes connected to a single host is also included.

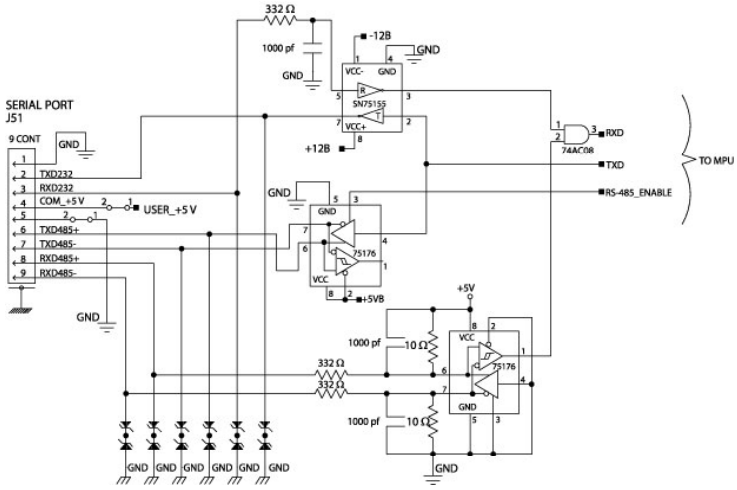
### *3.3.4.1. RS-485/RS-422 Diagram*






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## *3.3.4.2. OC950 Serial Communications Transceiver Schematic*






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# 4. SERVO LOOP PARAMETERS

This chapter describes setting parameters associated with the velocity and position loops. In some cases the user must adjust control loop parameters due to large mismatches between motor and load inertia, mechanical resonance, backlash, etc. This chapter provides guidance for handling these situations.

Refer to Appendix A Selecting Motor Control Functionality for a description of the control loop architecture and control loop block diagrams.



**NOTE**

***The two anti-resonant zeroes (ARZ0 and ARZ1) are assumed to both be off (set to zero) for this discussion.***

## *4. 1 VELOCITY LOOP*

The velocity loop block diagram is shown in Figure 2 in Appendix A. Velocity loop bandwidth is the key indicator of system performance. Systems with fast settling time must have high velocity loop bandwidth. Conversely, if the velocity loop bandwidth is low, attempting to achieve fast settling time by increasing the position loop bandwidth, **KPP**, leads to overshoot and ringing.

### 4.1.1. VELOCITY LOOP BANDWIDTH

The velocity loop bandwidth (fvc) is given by the equation:

$$f_{vc}(Hz) = \frac{KVP * K_T\sqrt{3}/2}{2\pi * J_{TOT}} \approx 0.138 * KVP * \frac{K_T}{J_{TOT}}$$

where:

**KVP** is the velocity loop proportional gain in amps/(rad/sec)

$\mathbf{K_T}$ is the 0-peak line-line motor torque constant in lb-in/amp

$\mathbf{J_{TOT}}$ is the total inertia (motor total + load total) in lb-in-sec2. (Any consistent set of units for $\mathbf{K_T}$, $\mathbf{J_{TOT}}$ (i.e., **MKS)**, that yields $\mathbf{K_T/J_{TOT}}$ in rad/sec2/amp will work)

The motor torque constant is the value of $\mathbf{K_T}$ peak published in the Motion Control Solutions catalog.



**NOTE**

***$f_{vc}$ is the unity gain open-loop crossover frequency of the idealized rigid single mass system.***



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## 4.1.1.1. Default Bandwidths

When creating a new program, the selections set **KVP** to achieve the velocity loop bandwidths shown below, assuming there is no load on the motor shaft and the motor has no mechanical brake or other secondary devices installed



**NOTE**

***The bandwidth depends on the desired system response.***

| | Gentle | Medium | Stiff |
|---|---|---|---|
| **$f_{vc}$ Velocity Loop Bandwidth (Hz)** | 25 | 75 | 200 |

**Load Inertia**

Bandwidth changes inversely with total inertia. If the load inertia equals the motor plus resolver inertia, the velocity loop bandwidth is half the values shown. If the load inertia is ten times the motor plus resolver inertia, the bandwidths are one eleventh these values. Clearly, **KVP** must be increased to compensate for increased load inertia if bandwidth is to be maintained. Typically, load inertia up to 3(motor + resolver) gives acceptable performance without further optimization.

The most common servo setup problem is adding large load inertia without a corresponding increase in **KVP**. The value of **KVP** to achieve a desired bandwidth can easily be calculated as:

$$KVP = \frac{2\pi * f_{vc} * J_{TOT}}{K_T \sqrt{3}/2} \approx 7.26 * f_{vc} * \frac{J_{TOT}}{K_T}$$

**Example**

To achieve 75 Hz bandwidth with an R32G motor having 20 to 1 load inertia = 0.011 lb-in-sec$^2$:

$J_{TOT}$[1] = 0.00055 + 0.011 = 0.01155 lb-in-sec$^2$

$K_T$[2] = 4.4 lb-in/amp

$$KVP = 7.26 * 75 * \frac{0.01155}{4.4} = 1.43$$

[1] Motor plus resolver inertia (0.00055 lb-in-sec$^2$) for the R32G motor is found in the catalog.

[2] $K_T$ can be found in the catalog as $K_T$ peak (4.4 lb-in/amp)



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950IDE can also be used to make the calculation. Simply enter the inertia ratio and 950IDE calculates the appropriate value for **KVP** to achieve 25, 75 or 180 Hz bandwidth, depending on the choice made for system response.

There is no specific answer to the general question, "What should the bandwidth be?" In general, the higher the velocity loop bandwidth, the faster the settling time and the better the rejection of torque disturbances (increased stiffness). Typically, velocity loop bandwidths range from 30 to 100 Hz. However, too high a bandwidth can lower the damping of resonance in mechanical linkages, causing excessive ringing and/or wear in coupled mechanics. Remember, it is the resulting motion at the end of any mechanical linkages that typically matters — not the response at the motor shaft.

**High Load Inertia**

It would seem that setting **KVP** is simply a matter of increasing its value to compensate for load inertia. Unfortunately, the following problems often interfere, particularly when the load inertia is large compared with the motor's inertia:

1. **Mechanical resonance** between motor and load cause high frequency oscillation.
2. **Backlash** between motor and load effectively unload the motor over a small angle. Within this small angle the increased bandwidth results in oscillations.
3. **Ripple** in the velocity feedback signal results in large motor ripple current if **KVP** is large.

As a general rule, any system with **KVP** set higher than 5 times the medium bandwidth setting requires adjustments to the default **ARF0** and **ARF1** settings.

**Resonance**

Mechanical resonance is caused by springiness between motor inertia and load inertia. This may result from belts, flexible couplings, or the torsion stiffness of shafts. In general, the stiffer the couplings, the higher the resonance frequency and the easier it is to tune the system for good performance.

If the velocity loop breaks into an oscillation at a frequency well above the calculated velocity loop bandwidth, a resonance problem may exist. A second symptom is that the frequency of oscillation is relatively constant in the presence of changes to **ARF0** and **ARF1**.



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### ARF0 and ARF1

Two digital anti-resonant low-pass filters, **ARF0** and **ARF1**, are included in the velocity loop. Their purpose is to lower the gain above $\mathbf{f_{vc}}$, especially at any resonant frequency greater than $\mathbf{f_{vc}}$ so oscillations do not occur. Default values, also a function of the selected system response, are shown below:

| | Gentle | Medium | Stiff |
|---|---|---|---|
| **ARF0 (Hz)** | 100 | 150 | 1500 |
| **ARF1 (Hz)** | 200 | 750 | 1x105 |

If the velocity loop bandwidth cannot be raised to an acceptable value without encountering a resonant oscillation:

1. Set both **ARF0** and **ARF1** to 400 Hz and set **KVP** low enough to prevent oscillation.
2. Increase **KVP** slowly until oscillation at the resonant frequency just begins.
3. Reduce **KVP** slightly until the oscillation just stops. Compute the velocity loop bandwidth using the formula given at the beginning of this section. If the velocity loop bandwidth is less than .25 times the value of **ARF0** and **ARF1**, then proceed to Step 4. Otherwise, go to Step 5.
4. Decrease both **ARF0** and **ARF1** by 20% and go back to Step 2.
5. The velocity loop bandwidth should now be approximately one quarter the value of **ARF0** and **ARF1**. For margin, reduce **KVP**, **ARF0**, and **ARF1** by 20%.

### Backlash

Some backlash may be unavoidable, especially when gear reduction is used. If backlash is present, the inertia match must be good (load inertia should be roughly equal to motor inertia) for good servo performance. Gearing reduces the inertia reflected to the motor by the square of the gear reduction from motor to load. Select a gear ratio to give the required match.

### Current Ripple

The velocity feedback signal in standard SC900 drives operating with the standard 20 arc-min resolver can have up to 3% p-p ripple. The resulting motor torque current ripple, with no **ARF0**/**ARF1** filtering, can be calculated using:

$$\text{Current ripple (amps p - p)} = \frac{3}{100} * Speed(rpm) * \frac{2\pi}{60} * KVP$$

$$\approx 0.003 * Speed(rpm) * KVP$$



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There is cause for concern when this p-p number exceeds 40% of the drive's or motor's current rating. Monitor the motor current using Dac Monitors on J4-3 to ensure actual ripple current, with **ARF0**/**ARF1** filtering, is not excessive.

Motor current ripple is reduced by lowering **ARF0**'s and **ARF1**'s low-pass filter break frequencies. This benefit is limited by velocity loop bandwidth and stability constraints. Velocity feedback ripple and motor current ripple are also reduced by specifying a higher accuracy resolver.

**KVI**

**KVI** sets the "lag-break" frequency of the velocity loop. **KVI** is equal to the frequency in Hz where the velocity loop compensation transitions from predominantly integral characteristics to predominantly proportional characteristics. Drive rejection of torque disturbances increase as **KVI** increases. Default values for **KVI** are:

| | Gentle | Medium | Stiff |
|---|---|---|---|
| **KVI (Velocity Loop Lag-Break Freq. (Hz))** | 1.7 | 5.0 | 13.3 |

If the drive is to be used within a position loop (either with **BlkType**=2 or when using an external position drive and **BlkType**=1), **KVI** should be equal to or less than 0.1 times the velocity loop bandwidth. If no position loop is used, set **KVI** to 0.25 times the velocity loop bandwidth (or higher if some ringing can be tolerated). In general, the response to a velocity command step (or truncated ramp) has velocity overshoot for non-zero values of **KVI**.

## 4. 2 *POSITION LOOP*

When **BlkType** = 2, a position loop is configured outside the velocity loop. Figure 3 in Appendix A illustrates the structure of the position loop. The velocity loop must be set up and evaluated in terms of bandwidth before attempting to setup the position loop.

**KPP**

The position loop proportional gain, **KPP**, determines the settling time of the position loop. **KPP** is the bandwidth of the position loop, in Hz, assuming an ideal velocity loop. Default values for **KPP** are:

| | Gentle | Medium | Stiff |
|---|---|---|---|
| **KPP (Position Loop Bandwidth (Hz))** | 5 | 15 | 50 |



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In general, the higher the value of **KPP**, the faster the settling time. However, trying to set **KPP** to a high value with inadequate velocity loop bandwidth results in overshoot and ringing. A good trade off is to set **KPP** 0.2 times the velocity loop bandwidth. Slightly higher values can be used if overshoot can be tolerated.

### KVFF

**KVFF** is the velocity feed forward gain. In the absence of velocity feed forward (**KVFF** = 0), the commanded velocity is proportional to the position (following) error. This means that the actual position lags the commanded position by a value proportional to the speed. The error is smaller for larger values of **KPP**.

The following table gives a feel for the following error magnitude.

| Speed (rpm) | KPP (Hz) | Following Error (revolutions) |
|---|---|---|
| 1000 | 10 | 0.27 |
| 2000 | 10 | 0.53 |
| 5000 | 10 | 1.33 |
| 1000 | 20 | 0.13 |
| 2000 | 20 | 0.27 |
| 5000 | 20 | 0.66 |



**NOTE**

***Following error can easily exceed one complete motor revolution. In many electronic gearing applications, such following errors are not acceptable (real gears don't have following errors!) Also, stepper systems don't have such errors.***

Feed forward takes advantage of the fact that the SC900 DSP knows the frequency of the encoder or step inputs and knows how fast the motor should be going at any given instant. All or part of this velocity can be added to the velocity command to reduce following error. If **KVFF** is set to 100 (%), the steady state following error reduces to zero.

### Overshoot

Setting **KVFF** equal to 100% can result in position overshoot. Somewhat lower values may be required, if this is a problem. **KVFF** set to 70%-80% typically achieves the fastest step response with no overshoot. However, setting **KVFF** to less than 100% gives steady state following error when running at constant speed.



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## 4. 3 ADVANCED VELOCITY LOOP TUNING

### Continuous Time Transfer Function Approximation

The transfer function for the velocity loop compensation block is given below

$$\frac{FVelErr}{VelErr}(s) = \frac{\left(\frac{s}{\omega_z}\right)^2 + \frac{1}{Q_z}\frac{s}{\omega_z} + 1}{\left(\frac{s}{\omega_f}\right)^2 + \frac{1}{Q_f}\frac{s}{\omega_f} + 1}$$

$$\frac{ICmd}{VelErr}(s) = \frac{\left(\frac{s}{\omega_z}\right)^2 + \frac{1}{Q_z}\frac{s}{\omega_z} + 1}{\left(\frac{s}{\omega_f}\right)^2 + \frac{1}{Q_f}\frac{s}{\omega_f} + 1}(KVP)\left(1 + \frac{2\pi(KVI)}{s}\right)$$

For **ARx0** > 0 both roots are real and:

$$\omega_x = 2\pi\sqrt{(ARx0)(ARx1)}$$

$$Q_x = \frac{(ARx0)(ARx1)}{ARx0 + ARx1}$$

For **ARx0** < 0 roots are a complex pair and:

$$\omega_x = 2\pi(ARx0)$$

$$Q_x = ARx1$$



**NOTE**

***The numerator of*** $\frac{FvelErr}{VelErr}$ ***(s) reduces to 1 when ARZ0 and ARZ1 both=0.***

***If ARZ0 or ARZ1=0 the numerator reduces to*** $\frac{s}{2\pi ARZx} + 1$



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**Discrete Time Transfer Function**

The velocity loop compensation is actually implemented as a digital discrete time system function on the DSP. The continuous time transfer function is converted to the discrete time domain by a backward Euler mapping:

$$s \rightarrow \frac{1}{T_s}\left(1 - z^{-1}\right)$$

*where $T_s$ = 250 µs*



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# 5. TROUBLESHOOTING

This section covers maintenance and troubleshooting of the SC950 servo controller.

The SC950 series servo controllers are designed for minimum maintenance. Remove superficial dust and dirt from the unit using clean, dry, low-pressure air. Performed as needed, this procedure minimizes problems due to dust and dirt buildup.

## *5. 1 TROUBLESHOOTING*

The system status display located on the front panel indicates unit status and is useful for troubleshooting. **0** means the drive is neither faulted nor enabled, while **8** means the drive is not faulted and enabled. **0.** means the drive is disabled and a program is running, **8.** means the drive is enabled and a program is running. Alternating **8** ┐ means actively inhibiting CW motion and alternating **8** ┌ means actively inhibiting CCW motion.

### 5.1.1. SYSTEM STATUS

| Status LED | Value | Fault Meaning |
|---|---|---|
| (Blinking) 1 | 1 | Velocity feedback (**VelFB**) over speed |
| (Blinking) 2 | 2 | Motor Over-Temp |
| (Blinking) 3 | 3 | Drive Over-Temp |
| (Blinking) 4 | 4 | Drive I*t |
| (Blinking) 5 | 5 | I-n Fault (9x3) |
| (Blinking) 6 | 6 | Control ±12 V supply under voltage |
| (Blinking) 7 | 7 | Output over current or bus over voltage |
| (Blinking) 9 | 9 | Shunt regulator overload |
| (Blinking) A | 10 | Bus OV detected by DSP |
| (Blinking) *b* | 11 | Auxiliary +5 V Low |
| (Blinking) C | 12 | Not assigned |
| (Blinking) *d* | 13 | Not assigned |
| (Solid) E* | 14 | Processor throughput fault |
| (Blinking) E* | 14 | Power Up Self Test Failure |
| (Alternating) E1 | 225 | Bus UV, Bus Voltage **VBusThresh** |
| (Alternating) E2 | 226 | Ambient Temp Too Low |
| (Alternating) E3 | 227 | Encoder commutation align failed (Only **CommSrc**=1) |
| (Alternating) E4 | 228 | Drive software incompatible with NV memory version |



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| Status LED | Value | Fault Meaning |
|---|---|---|
| (Alternating) E5* | 229 | Control Card hardware not compatible with drive software version |
| (Alternating) E6 | 230 | Drive transition from unconfigured to configured while enabled |
| (Alternating) E7 | 231 | Two **AInNull** events too close together |
| (Alternating) F1 | 241 | Excessive Position Following Error |
| (Alternating) F2* | 242 | Program Checksum Error (Memory Error) |
| (Alternating) F3* | 243 | Parameter Checksum Error (Memory Error) |
| (Alternating) F4 | 244 | Run Time Error (Err) |

***FaultReset** cannot reset these faults. See Extended Faultcodes for further information on Blinking E, Blinking 1 and Alternating F2 and F3.

## 5.1.2. EXTENDED FAULTCODES

| LED Display | Value of ExtFault | Description |
|---|---|---|
| 1 | 1 | **VelFB** < 21038 |
| 1 | 2 | **VelFB** < 1.5*max(**VelLmtxx**) |
| E | 0 | No **ExtFault** information |
| E | 1 | Resolver calibration data corrupted |
| E | 2 | Excessive DC offset in current feedback sensor |
| E | 3 | DSP incompletely reset by line power dip |
| E | 6 | Excessive DC offset in Analog Command A/D |
| E | 7 | Unable to determine option card type |
| E | 8 | DSP stack overflow |
| E | 10 | Firmware and control card ASIC incompatible |
| E | 11 | Actual Model does not match value in nonvolatile memory |
| E | 12 | Unable to determine power stage |
| E | 15 | RAM failure |
| E | 16 | Calibration RAM failure |
| F2 | 13 | Control card nonvolatile parameters corrupt |
| F3 | 14 | Option card nonvolatile parameters corrupt |



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## 5.1.3. TROUBLESHOOTING TABLE

| Problem (and system status numbers) | Possible cause | Action |
|---|---|---|
| System status display not lit. | No control power. | Check that SC955 has AC switch set to INT or SC952, SC953 and SC954, have 115 VAC or 230 VAC applied to J3 pins 5,6. |
| | Blown control power fuse. | Replacement of fuses within the drive is rarely useful and not recommended. A blown fuse is a strong indication that the drive is defective and should be returned to the factory for repair. |
| Controller unconfigured (U/C). | New controller. | Perform controller setup. |
| Resolver conversion overspeed (1). | Incorrect resolver phasing. | Verify proper phasing. |
| | Open or intermittent resolver connector. | Check connector and cable. |
| Motor over-temperature (2). | Motor PTC pins open. | Connect PTC pins (J3-8 and J3-9). |
| | Temperature overload due to high motor ambient temperature or excessive RMS torque. | Lower ambient temperature. Operate within continuous torque rating. |
| | Motor PTC damaged. | Check motor PTC for resistance $\leq$ 310 Ω. |
| Controller over-temperature (3). | Temperature overload due to: | |
| | High ambient temperature. | Lower ambient temperature to below 50° C (60° C, if derated). |
| | Restriction of cooling air due to insufficient space around unit. | Provide sufficient cooling space. |
| | Operation above continuous power rating. | Operate within continuous power rating. Add fan option to controller to boost continuous rating. |
| | Fan inoperative. | Return to factory for fan replacement. |
| IT Fault (4). | Excessive time at peak current. | Check time spent at peak current. If excessive, change profile or load. (Use larger motor/drive.) |
| Line-neutral fault (5). | Motor cable short to ground.<br>Motor winding short. | Check motor cable. |
| | Internal failure. | Contact distributor. |



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| Problem (and system status numbers) | Possible cause | Action |
|---|---|---|
| Servocontroller logic supply under-voltage (6). | External short on signal connectors. | Remove connectors and reapply power. |
| | Insufficient voltage on J1-5 and J1-6. | Check voltage with meter ( ≥ 90 V). |
| | Internal failure. | Contact distributor. |
| Output over-current, or bus over-voltage (7). | Excessive ac input voltage. | Reduce AC input voltage to below 264 VAC. |
| | Output short circuit. | Check for short. |
| | Motor cabling wires shorted together. | Check for short. |
| | Motor cabling shorted to ground. | Check for short. |
| | Open or missing regen resistor. | Check regen wiring. |
| | Internal motor winding short circuit. | Check for short. |
| | Insufficient motor inductance.<br>SC952 > 4 mH<br>SC953 > 2 mH<br>SC954 > 1 mH<br>SC955 > 0.5 mH | Check current loop compensation parameters in software. Replace motor with motor of correct inductance. |
| Drive enabled (8) | Normal Operation | None. |
| Drive enabled, no faults (8.) | Program running. | None. |
| Enabled, inhibits active.<br>(8 ⌐) CCW Inhibit active<br>(8 ¬) CW Inhibit active<br>(8 ∩) CCW&CW Inhibit active | Drive Inhibits are active. | Deactivate inhibit inputs. |
| Unit will not enable (does not display 8 when enable applied). | External enable not applied. | Apply enable input to pin J4-6. |
| | Internal fault. | Contact distributor. |
| | Software enable not on. | Set Enable variable to 1. |
| | No bus power. (9x4, 9x5 only) | Apply Bus power. |
| Problem (and system status numbers) | Possible cause | Action |
| Shunt regulator overload (9) | Excessive regen in application | Increase cycle time.<br>Reduce the inertia.<br>Add external regen with higher wattage. |
| | Improper external regen wiring or components on J5. | Check connections on J5. |
| | Internal failure. | Return to factory for repair. |
| Bus overvoltage (A) | Bus AC input overvoltage. | Check AC voltage < 264. |
| | Internal failure. | Return to factory for repair. |



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| Problem (and system status numbers) | Possible cause | Action |
|---|---|---|
| +5 V low ( *b* ) | Short on pin J52-25. | Remove J52 connector. Reapply AC power. |
| | Short on pin J51-4. | Remove J51 connector. Reapply AC power. |
| | Short on pin J4-25. | Remove J4 connector. Reapply AC power. |
| | Internal failure. | Return to factory for repair. |
| Microprocessor throughput fault. (E) | Intermittent failure from environment noise. | Unconfigure drive and cycle AC power.<br>Check ground connections.<br>Check for excessive ground noise and loose AC connections. |
| | Internal failure or firmware version conflict. | Return to factory for repair. |
| Bus Under-voltage (E1) | VBus < **VBusThresh** | **VBusThresh** is set too high. |
| | | VBus is low because bus AC power is low. Check J1-1, J1-2, and J1-3. |
| Ambient temperature too low (E2) | Ambient temperature <0° C | Measure temperature in control cabinet. Condition if necessary. |
| | Internal failure. | Return to factory for repair. |
| Encoder commutation alignment failure (E3) | Not enough current to lock the motor shaft to proper position within 1 second. | Check **IlmtPlus** and **IlmtMinus**.<br>If vertical load, reduce load or increase motor/drive.<br>Verify motor brake releases properly. |
| | Internal failure. | Return to factory for repair. |
| Incompatible 950IDE (E4) | 950IDE version is incompatible with drive's NV memory version. | Verify that **FWV** and 950IDE version are the same. If **FWV** = 200, then 950IDE should be version 2.0 or higher. |
| Control card hardware not compatible with drive software version (E5) | Resolver wiring error. | Remove J2 and J3 connectors. Cycle power. If fault is now a "2", then correct resolver excitation wiring. |
| | Internal failure. | Return to factory for repair. |
| Drive transition from UnConfigured to Configure while enabled (E6) | Hardware Enable input active. | Disable hardware Enable input. Re-configure drive then cycle power. |
| | Enable inactive during several configurations, drive still faults. | Return for repair. |
| Two **AInNull** events too close together. (E7) | Connection to **AInNull** input has switch bounces. | Use **BDOutX** to trigger the **AInNull** input. Replace switch if no fault occurs. |



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| Problem (and system status numbers) | Possible cause | Action |
|---|---|---|
| Following error overflow (F1) | **CwInh** and/or **CcwInh** held low while commanding motion. | Check **CwInh** and **CcwInh** inputs and variables. |
| | Loss of feedback information. | Disable drive and spin motor shaft by hand. Verify Position variable is changing. If not, swap out motor/cables or drive with know good spare to isolate defective part. |
| | Open motor phase. | Check wiring and motor winding for open circuit. |
| | Loss of motor power. | Bus voltage is low. |
| | Tuning Wizard incomplete. | No motor selected, therefore cannot respond. |
| User Program Checksum Fault (F2) | Checksum fault while reading user program memory during power up. | Cycle AC power. Download the program. |
| | Memory allocation error. Program is writing to a variable address location that has not been dimensioned. | Check Dim section of program for string variables and arrays. |
| Parameter checksum error (F3) | Checksum fault reading NV memory. Typically during power cycle or after program download. | Check for AC momentary glitch. Do not interrupt program or waveshape download with keystroke or power cycle. |
| | | Download a new parameter set. Download a program with a valid parameters section. |
| | Internal failure. | Return to factory for repair. |
| Run time error (F4) | Programming error. | Read error number in Output Window or check value of Err in the variables window. Look up values in run-time error table and make necessary corrections to your program. |
| Processor failure ( *h* ) | Excessive noise in application or internal failure. | Cycle AC power.<br>Return to factory for repair. |



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| Problem (and system status numbers) | Possible cause | Action |
|---|---|---|
| Unit is enabled, no system status faults (status code 8), but motor does not respond. | Seized load or excessive load friction. | Reduce load. |
| | Reset command on J4-7. | Remove reset from J4-7. |
| | No bus power. | Apply bus power. |
| | Open motor connections. | Connect motor. |
| Motor oscillates or runs erratically. | Improper shielding and grounding. | Shield cabling correctly. |
| | Improper drive set up. | Review set up procedure. |

## 5.1.4. COMMUNICATIONS TROUBLESHOOTING TABLE

| Symptom | Corrective Action |
|---|---|
| SC950 will not respond to commands over the serial link | Verify that SC950 is NOT running a program (8. or 0. on status display). |
| | Verify that axis address is set to 255 using switch S1. |
| | Verify that baud rate and COM port are set correctly in the 950 IDE. |
| | Check terminal transmit and receive lines from computer to receive and transmit lines on J51. (See Section 3.2) |
| | Verify that the serial cable is functioning properly.<br>1. Disconnect serial cable from J51.<br>2. Short pins 2 & 3<br>3. Type a character on the keyboard.<br>4. Verify that character entered echoes back to output window. |
| | Verify that three wire serial cable is connected to J51. |
| | Internal failure. Return to factory for service. |
| SC950 will not respond during RS-422/RS-485 operation | Verify that each unit has a unique serial address using switch S1. |

If problems continue to exist, contact your local distributor for further assistance.



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## 5.1.5. Contact Information

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Danaher Motion Customer Support

**Phone:** (815) 226-2222

**Email:** customer.support@DanaherMotion.com

**Web:** www.DanaherMotion.com



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# APPENDIX A SELECTING MOTOR CONTROL FUNCTIONALITY

The SC900 family has three distinct modes of controlling the motor shaft and two distinct sources for the shaft command:

**Modes**

- Torque Control
- Velocity Control
- Position Control

**Commands**

- Analog Command
- Program Control

## *A.1 TORQUE BLOCK MODES*

### A.1.1 ANALOG COMMAND TORQUE BLOCK (**BLKTYPE** = 0)

This mode allows the differential analog voltage between terminals J4-1 and J4-2 to set the motor's terminal torque current amplitude. Since the actual motor current amplitude (**IFB**) times the motor's 0-peak line-line torque constant $\mathbf{K_T}$ times is the shaft torque, then the analog input directly controls motor shaft torque. The overall gain of this block, i.e. the output current amplitude in amps per input volt, is set by the **CmdGain** parameter directly in A/V and should be set by the user to the desired value.

Figure 1 shows the analog torque block mode has the same signal processing as a velocity loop except that the velocity error signal (**VelErr**) is set to **VelCmd** not to (**VelCmd** - **VelFB**) and that the **VelCmd** clamp is bypassed. Thus, the analog input goes through a number of signal processing steps before becoming the motor torque current command **ICmd**.

1. Analog differential amplifier with 1200 Hz low pass filter.
2. High resolution A/D sampled at the velocity loop update rate and added to **ADOffset**.
3. **ADF0** adjustable low pass filter to become **AnalogIn**.
4. Bypass the **VelLmtHi**, **VelLmtLo** clamp.
5. Velocity error variable **VelErr** is set equal to **VelCmdA**.
6. The anti-resonance second order velocity loop compensation block controlled by **ARF0**, **ARF1**, **ARZ0**, and **ARZ1** to become **FVelErr**.
7. The proportional and integral velocity loop compensation block controlled by **KVP** and **KVI**, respectively.



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8. Through **IlmtPlus** and **IlmtMinus** current clamp to become **ICmd** (motor torque current).

Although this looks like a large amount of processing, the options allow tailoring the response to fit a particular application.

Typically, most signal blocks are set to directly pass the signal so **ICmd** = **CMDGain***(**AnalogIn**) as directly as possible. The set of parameters below accomplish this:

**ADF0** = 100,000 Hz to bypass, 1000 Hz by auto set up

**ARF0** = 100,000 Hz

**ARF1** = 100,000 Hz

**ARZ0** = 0 (not active)

**ARZ1** = 0 (not active)

**KVP** = 1 A/rad/sec

**KVI** = 0 Hz



**WARNING**

***KVP must be set to 1 A/rad/sec for the units on CmdGain to be correct. If CmdGain is set to 1 Amp/V and KVP to 2 A/rad/sec, an analog input of 1 volt incorrectly gives 2 amps of output torque current amplitude.***

When changing **BlkType** to 0 to get an analog torque block, set **KVP** to 1, **KVI** to 0, and the other items in the above list to appropriate values to get the system working as desired.



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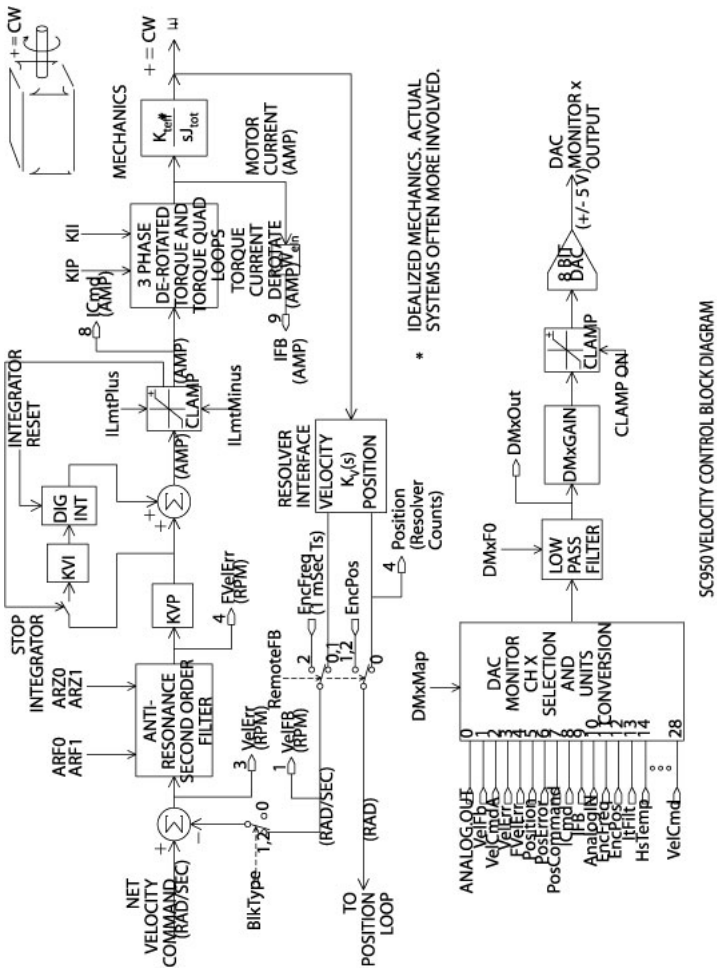



*Figure 1*

## A.2.1 ANALOG COMMAND VELOCITY BLOCK (**BLKTYPE** = 1)

This mode allows the differential analog voltage between terminals J4-1 and J4-2 to set the motor's shaft velocity (shaft speed). The overall gain of this block (output shaft velocity per input volt) is set by **CmdGain** in krpm/V and should be set by the user to the desired value.

The analog input goes through a number of signal processing steps before becoming the actual motor velocity command **VelCmd** as shown in Figure 2.



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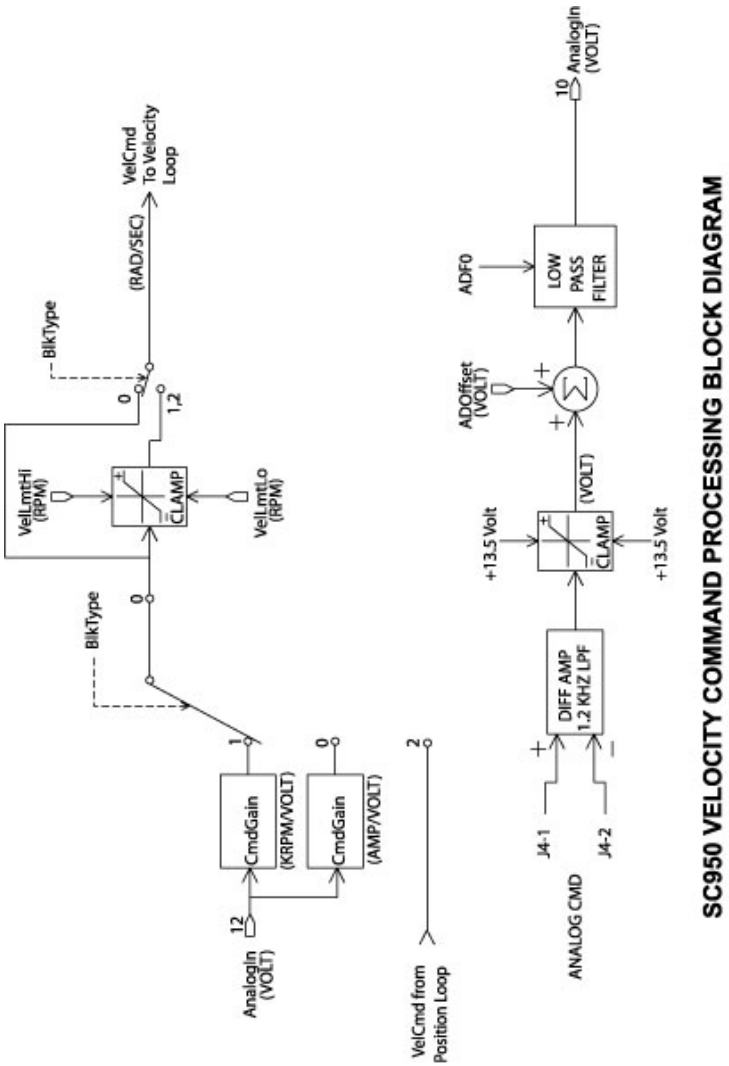



*Figure 2*

1. Analog input differential amplifier with 1200 Hz low pass filter.
2. High resolution A/D sampled at the velocity loop update rate and added to **ADOffset**.
3. **ADF0** adjustable low pass filter to become **AnalogIn**.
4. Range clamped by **VelLmtHi** and **VelLmtLo**.



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The actual velocity command (**VelCmd**) is then combined with the measured shaft velocity (**VelFB**) and processed by the velocity loop compensation to create the motor torque current command (**ICmd**). The detailed signal processing steps to create **ICmd** are listed below and shown in Figure 1.

1. **VelErr** set equal to (**VelCmdA** - **VelFB**)
2. The anti-resonance second order velocity loop compensation block controlled by **ARF0**, **ARF1**, **ARZ0**, and **ARZ1** to become **FVelErr**.
3. The proportional and integral velocity loop compensation block controlled by **KVP** and **KVI,** respectively.
4. Through **IlmtPlus** and **IlmtMinus** current commands clamp to become **ICmd** (motor torque current command).

For more information on tuning the velocity loop see Servo Loop Parameters.

## *A.3 Position Block Modes*

### A.3.1 Digital Command Position Block (**BlkType** = 2)

This mode is just a velocity block mode with the **VelCmd** coming from the position loop. See Figure 3. In particular, **PosError** = **PosCommand** - **Position Feedback**.

$$VelCmd = 2\pi * KPP * PosErr + \frac{KVFF}{100} * \left[ \frac{d}{dt}(PosCommand) \right]$$

where:
**PosCommand** is the position command in counts
**KPP** is the proportional position loop gain
**KVFF** is the velocity feed forward gain percentage.

When the SC900 is disabled and **BlkType** = 2, **PosCommand** is set to the position feedback value. This insures that when the drive is enabled, it picks up motion from its present position.



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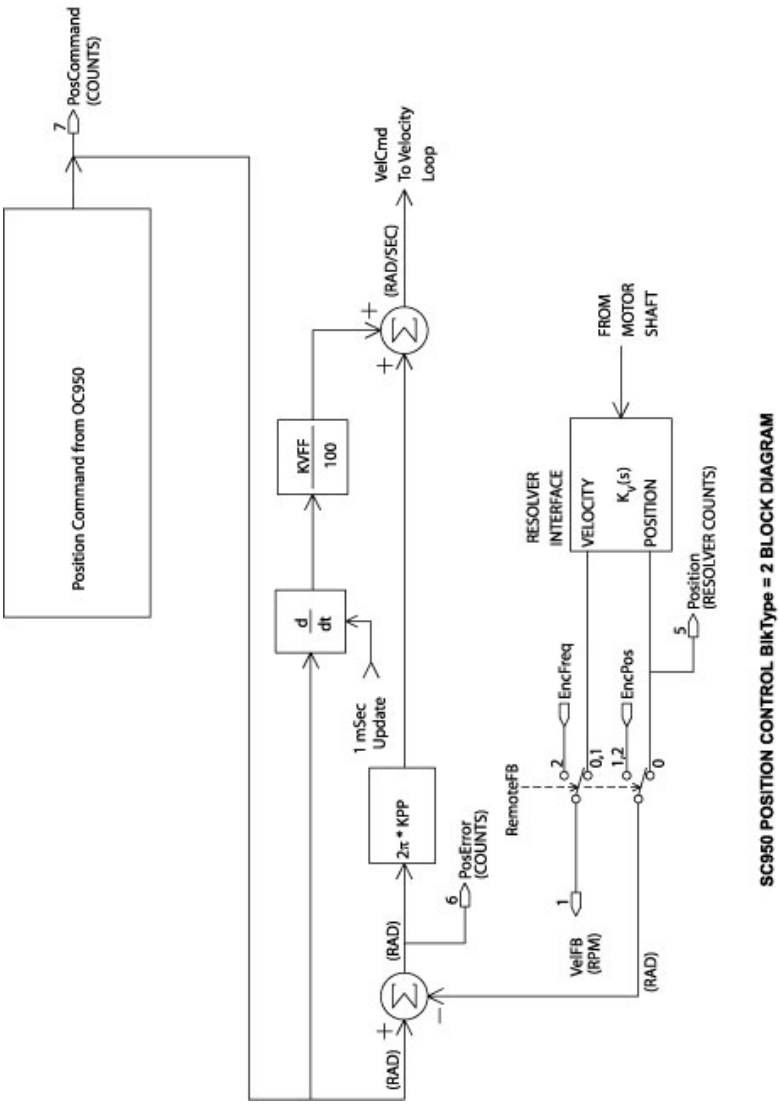



*Figure 3*



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# APPENDIX B OC950 SPECIFICATIONS

## B.1 OC950 J51 SERIAL INTERFACE

| | |
|---|---|
| **Type** | RS-232/RS485 (address selectable) |
| **Baud Rate** | 19200 or 9600 (software selectable) |
| **Parity** | No parity |
| **Data Word** | 10 bits: 1 start, 8 Data, 1 stop |
| **Connector** | 9 Contact Female D-subminiature |

## B.2 OC950 J52 PROGRAMMABLE INPUTS / OUTPUTS

| | |
|---|---|
| **Input/Output Type & Quantity** | 21 Bi-Directional Channels |
| **Logic Voltage** | 5 to 24 volt, 40 V Absolute Maximum |
| **Input Channel** | |
| Pull-up resistor | 10 k Ω to + 12 VDC |
| Low-to-High Logic Threshold | 3.5 volts maximum |
| High-to-Low Logic Threshold | 1.0 volts minimum |
| Hysteresis | 0.5 volts minimum, 1.5 volts maximum |
| Filter RC Time constant | 100 microseconds |

## B.3 OUTPUT CHANNEL

| | |
|---|---|
| **Device** | Open Drain DMOS Transistor |
| **Sink Capability** | 100 mA |
| **Drain-to-Source - Impedance** | 5 Ω typical, 9.5 Ω maximum at 125° C |
| **Connector** | 25 Contact Female D-subminiature |

## B.4 USER +5 V POWER

**(OC950 J51-4, J52-25 and SC900 J4-25)**

| | |
|---|---|
| Output Voltage | 5 volts ± 5% |
| Output Current | 200 mA, Maximum |



**NOTE**

***Output current is the combined current of all three connection points.***



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## B.5 OC950 J53 (OPTIONAL) PACLAN

| | |
|---|---|
| **Data Rate** | 2.5 MBaud |
| **Termination Impedance** | 93 Ω |
| **Cable Type** | coaxial, RG62U |
| **Maximum Bus Segment Length** | 305 meters |
| **Maximum Stations/Segment** | 8 |
| **Connector** | Standard BNC |

## B.6 NVRAM - PROGRAM MEMORY

**Data Retention** 10 Years



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