SilverMax™

User Manual

Revision 3.22 – September 2001

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INTRODUCTION

SilverMax from QuickSilver Controls, Inc. is a fully integrated motion control system with the motion trajectory controller, motor driver electronics, position encoder and motor all contained in one unit. It requires less space than conventional controllers and simplifies the integration of your system. The incorporated design requires just power and communications to be up and running. The work of integrating a full vector controlled servo system has already been done for you. Smooth, quiet operation with high performance motion control is ready to go.

SilverMax connects to a standard PC using RS-232 or RS-485 and an 8-Bit ASCII or 9-bit Binary protocol. It is designed for master-slave communications and can be connected with other devices such as sensors and data collectors from a single communications port.

SilverMax provides closed-loop servo control using 32-bit calculations. High-resolution position control delivers precise executions every time. It produces smooth motion profiles with minimal noise and vibration. SilverMax can store blocks of motion profiles for execution with a single command.

The available QuickControl software package makes rapid application development easy. And it contains a fully featured command set that provides SilverMax set-up and complex motion control.

Optional C++ and Basic communications examples are available for integration into your source code.

Warnings

SilverMax shall not be used for Life Support applications without explicit written permission from QuickSilver Controls, Inc.

SilverMax is a high performance motion system. As with any motion system, it is capable of producing sufficient mechanical output to cause bodily injury and/or equipment damage if it is improperly operated or if it malfunctions. The user shall not attach SilverMax to any mechanism until its operation is fully understood. Furthermore, the user shall provide sufficient safety means and measures to protect any operator from misuse or malfunction of the motion system. The user assumes all liability for its use.

What is contained in this User Manual

This SilverMax User Manual is a reference manual design to aid the user in the operation and programming of the SilverMax Servomotor family. A companion publication the "**SilverMax Command Reference**" has the detailed description of the SilverMax command set. Many times this manual will discuss or reference the commands detailed in the Command Reference. For this reason both publications are needed for a full understanding of SilverMax operation and programming.

The User Manual is laid out to take the user through a natural progression of product usage.

Getting Started is where to begin since using a "**Startup Kit**" is probably the user's first experience with trying to setup and operate a SilverMax motor.

SilverMax Initialization is next and goes though the Initialization and Initialization programs used to setup SilverMax for a specific application.

SilverMax Overview gives the user some basic knowledge of what is inside of SilverMax from a features point of view.

SilverMax Motion Commands typically are at the top of the list of things to know about, so they are covered right away.

From there, the manual goes through a number of important topics that give the basics of SilverMax operation and programming.

This manual is not exhaustive. It would bore the user and waste everyone's time. Detailed information for specific applications can be found in QuickSilver Controls' application example files found in the QuickControl directory under "QCI Examples" and on QuickSilver Controls' website at www.QuickSilverControls.com or www.qcontrol.com where Application notes are updated periodically.

GETTING STARTED

BEFORE USING A SilverMax Motor:

- Turn Off ALL Power Supplies and Switches
- Read All Set-Up Instructions for Your Specific Motor or Start-Up Kit
- Double-check ALL Intended Connections for Shorts or Unwanted Grounding

These setup instructions are designed to help you configure your SilverMax motor and QuickControl Software. If you carefully follow the setup procedure for your specific SilverMax Start-Up Kit, your motor should be operating within minutes.

Equipment required:

- Personal computer with a 586 (at least 133 MHz) or higher processor running Windows 9x, NT (4.0+), 2000 or Me.
- SilverMax Motor
- Startup Kit (SK1 or SKO) which includes:
  - CD with QuickControl Software version 3.2 and higher
  - SilverMax User Manual (this document)
  - SilverMax Command Reference
  - Cabling

NOTE: The following setup procedures require the usage of a SilverMax Start-Up Kit in order to perform the setup and initialization. If you did not have a Startup Kit, contact your distributor or QuickSilver Controls.

SilverMax Factory Defaults:

When shipped from the factory the SilverMax motor and Quicksilver software are configured with default values that are used to establish initial communications between the motor and your computer. These default values can be changed, "re-initialized", to different settings during the Setup procedure if desired.

SilverMax Unit ID	**16**
SilverMax Supply Voltage	**48VDC**
Serial Communications Protocol	**8 bit ASCII**
Serial Interface	**RS-232**

Start-Up Kits Overview

The QCI-SK1 Start-Up Kits (SilverMax motor, personal computer, and power supply not included) provide a simple and inexpensive means for testing and evaluation of a SilverMax motor. With a standard PC serial COM port and a user supplied power supply, any SilverMax motor can be fully programmed and operated with RS-232 communication protocol.

The SilverMax “Y” evaluation cable is included in each kit to connect your SilverMax motor to a PC, a power supply, and a 9-Pin I/O breakout module. Also included are the QuickControl Software, the SilverMax User Manual, and the SilverMax Command Reference.

The QCI-SKO Start-Up Kits (SilverMax motor, personal computer, and power supply not included) provide a means for testing and evaluation of a SilverMax motor through an Optical I/O board. With a standard PC serial COM port and a user supplied power supply, any SilverMax motor can be fully programmed and operated through an Optical I/O board with RS-232 communication protocol.

The SilverMax Interface cable is included in each kit to connect your SilverMax motor to the Optical I/O board. An additional cable is provided for the connection of the I/O board and a personal computer. Also included are the QuickControl Software, the SilverMax User Manual, and the SilverMax Command Reference.

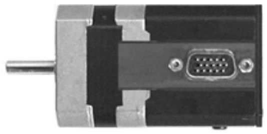
Start-Up Kit Hardware Setup

NOTE: Set-up differs slightly between kits, so read entire set-up section of manual before connecting anything to your motor)

QCI-SK1-FS-1 Start-Up Kit Setup

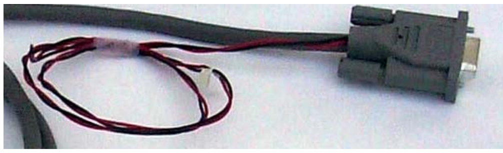
The SilverMax RS-232 “Y” evaluation cable supplied with Kit 1 has three connectors.

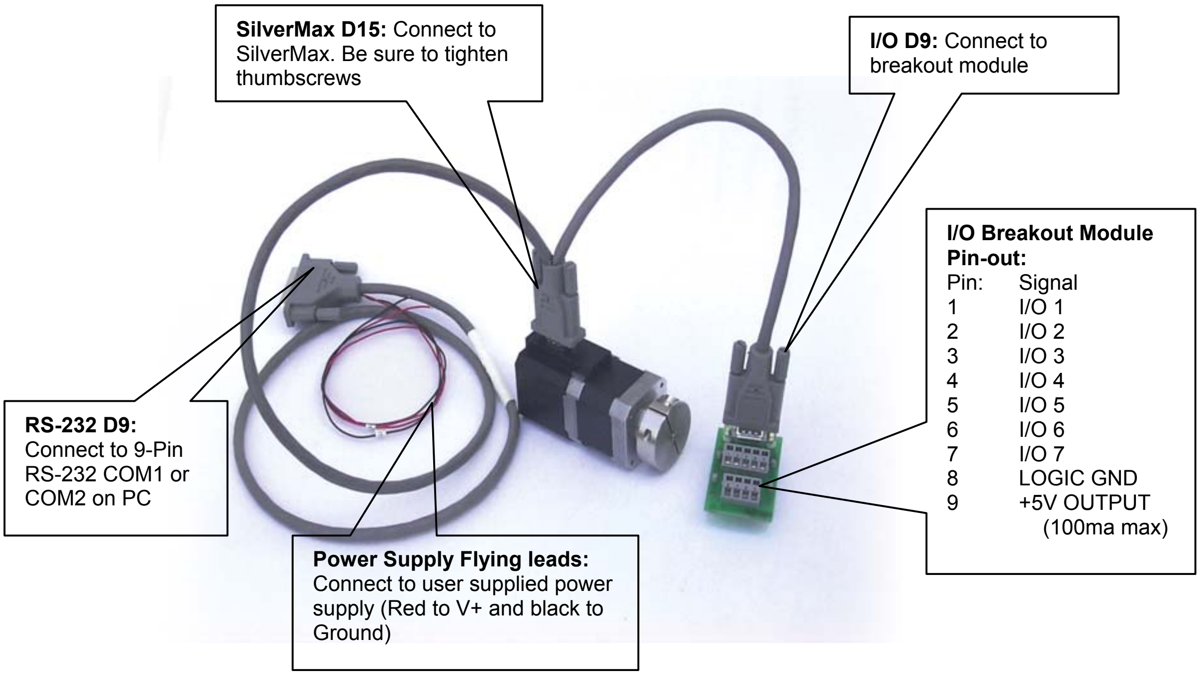
The center 15-pin Female connector (D15 High Density) attaches to the 15-pin male connector on the SilverMax motor.



The 9-pin female I/O connector (Shorter leg with a D9 connector) connects to the supplied breakout module.

The 9-pin female Comm connector (longer leg with a D9 connector) connects to your PC and has flying leads for power supply connection.





SilverMax D15: Connect to SilverMax. Be sure to tighten thumbscrews

I/O D9: Connect to breakout module

I/O Breakout Module Pin-out:

Pin:	Signal
1	I/O 1
2	I/O 2
3	I/O 3
4	I/O 4
5	I/O 5
6	I/O 6
7	I/O 7
8	LOGIC GND
9	+5V OUTPUT (100ma max)

RS-232 D9: Connect to 9-Pin RS-232 COM1 or COM2 on PC

Power Supply Flying leads: Connect to user supplied power supply (Red to V+ and black to Ground)

QCI-SK1-34-1 Start-Up Kit Setup

The Setup for this kit is the same as the setup described above for the QCI-SK1-FS-1 Start-Up Kit, except a SilverMax Line Power Cable is Included.

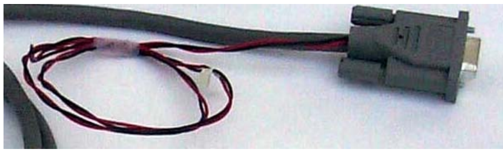
The center 15-pin Female connector (D15 High Density)

attaches to the 15-pin male connector on the SilverMax motor.

The 9-pin female I/O connector of the evaluation Cable

connects to the supplied breakout module.

The 9-pin female Comm connector of the evaluation cable

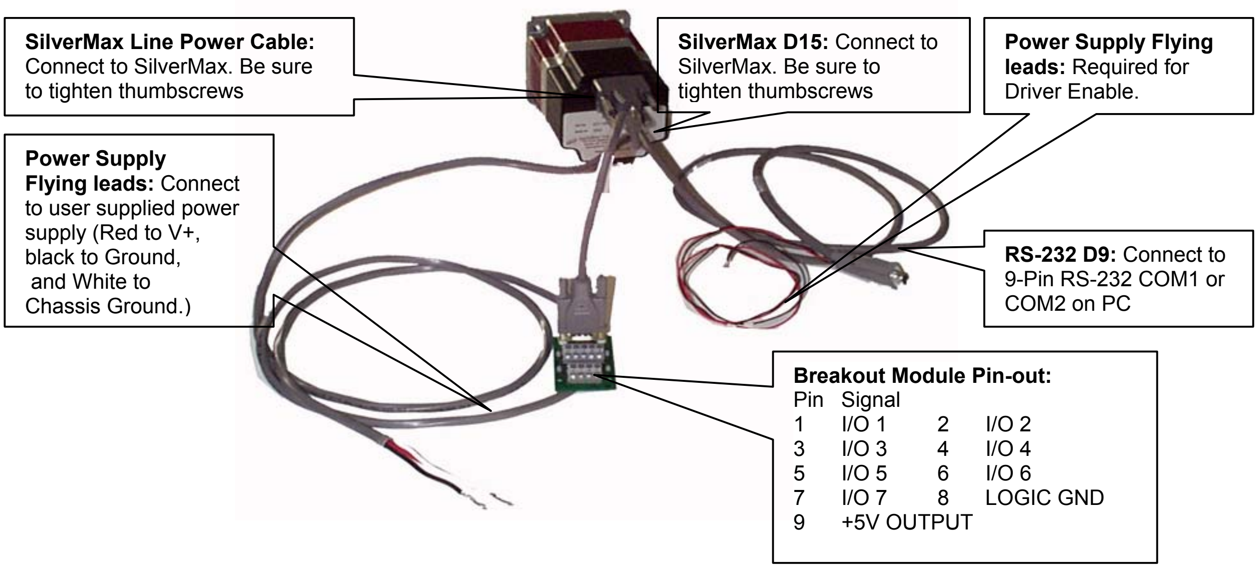


connects to your PC and has flying leads for power supply connection.

The 3-pin female connector on the SilverMax Line Power Cable

connects to the power connector on the 34-frame SilverMax motor.

The red wire at the end of the SilverMax Line Power Cable is connected to V+ of the power supply. The black wire connects to Ground. The white wire connects to chassis ground of the power supply.



SilverMax Line Power Cable: Connect to SilverMax. Be sure to tighten thumbscrews

SilverMax D15: Connect to SilverMax. Be sure to tighten thumbscrews

Power Supply Flying leads: Required for Driver Enable.

Power Supply Flying leads: Connect to user supplied power supply (Red to V+, black to Ground, and White to Chassis Ground.)

RS-232 D9: Connect to 9-Pin RS-232 COM1 or COM2 on PC

Breakout Module Pin-out:

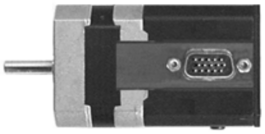
Pin	Signal		
1	I/O 1	2	I/O 2
3	I/O 3	4	I/O 4
5	I/O 5	6	I/O 6
7	I/O 7	8	LOGIC GND
9	+5V OUTPUT		

QCI-SKO-FS-v Start-Up Kit Setup

The SilverMax interface cable is provided to connect the SilverMax motor to the Optical I/O Module (QCI-OPTOC). For more information on the Optical I/O Module, see QCI Technical Document QCI-TD0010 (included).

The female 15-pin connector of the interface cable

attaches to the 15-pin male connector on the SilverMax motor.



The male 15-pin connector of the interface cable

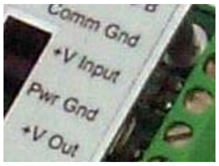
attaches to the 15-pin female connector on the optical I/O board.

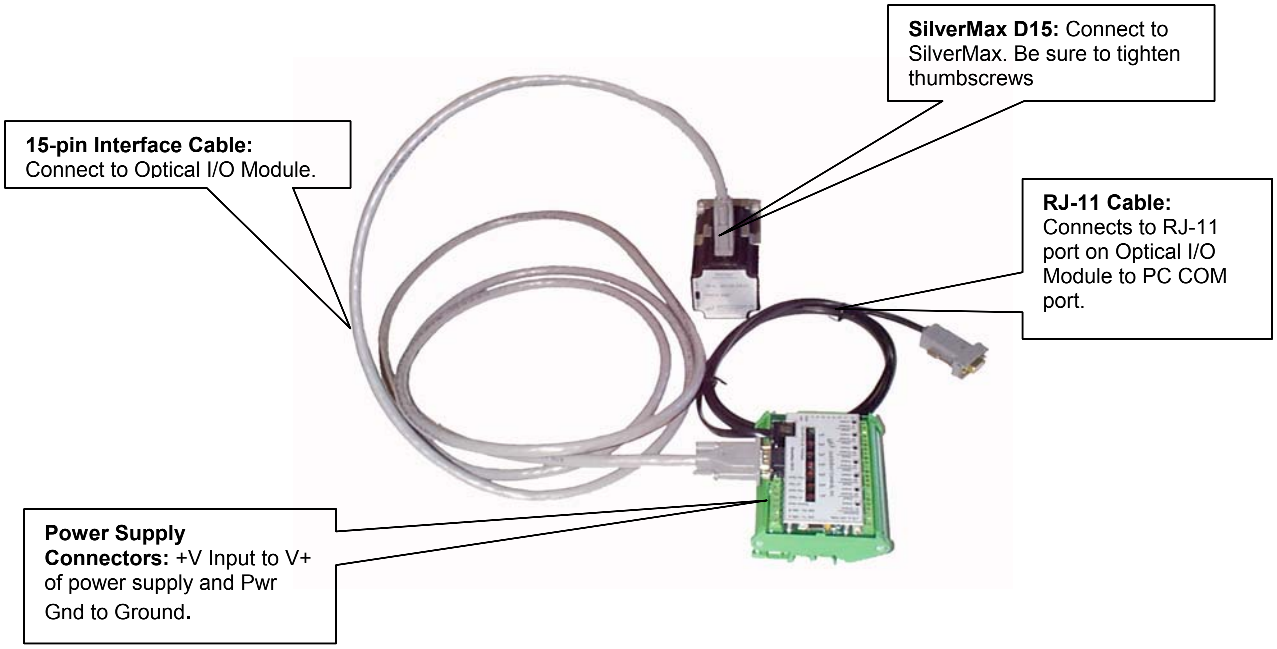
The phone jack-like connector of the RJ-11 serial cable

attaches to the RJ-11 connector on the Optical I/O board.

The 9-pin female Comm connector of the RJ-11 serial cable connects to your PC.

The +V Input connection on the Optical I/O board must be connected to V+ of a power supply and Pwr Gnd connection must be connected to Ground of that power supply.





SilverMax D15: Connect to SilverMax. Be sure to tighten thumbscrews

15-pin Interface Cable: Connect to Optical I/O Module.

RJ-11 Cable: Connects to RJ-11 port on Optical I/O Module to PC COM port.

Power Supply Connectors: +V Input to V+ of power supply and Pwr Gnd to Ground.

QCI-SKO-34-v Start-Up Kit Setup

The Setup for this kit is the same as the setup described above for the QCI-SKO-FS-v Start-Up Kit, except a SilverMax Line Power Cable is Included. For more information on the Optical I/O Module, see QCI Technical Document QCI-TD0010 (included).

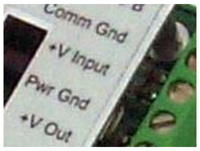
The female 15-pin connector of the interface cable attaches to the 15-pin male connector on the SilverMax motor.

The male 15-pin connector of the interface cable attaches to the 15-pin female connector on the optical I/O board.

The phone jack-like connector of the RJ-11 serial cable attaches to the RJ-11 connector on the Optical I/O board.

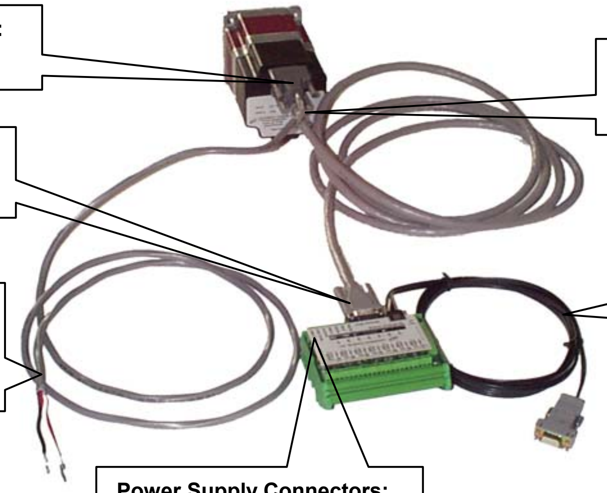
The 9-pin female Comm connector of the RJ-11 serial cable connects to your PC.

The +V Input connection on the Optical I/O board must be connected to V+ of a power supply and Pwr Gnd connection must be connected to Ground of that power supply.



The 3-pin female connector on the SilverMax Line Power Cable connects to the power connector on the 34-frame SilverMax motor.

The red wire at the end of the SilverMax Line Power Cable is connected to V+ of the power supply. The black wire connects to Ground. The white wire connects to chassis ground of the power supply.



SilverMax Line Power Cable: Connect to SilverMax.

SilverMax D15: Connect to SilverMax. Be sure to tighten thumbscrews

15-pin Interface Cable: Connect to Optical I/O Module.

RJ-11 Cable: Connects to RJ-11 port on Optical I/O Module to PC COM port.

Power Supply Connectors: +V Input to V+ of power supply and Pwr Gnd to Ground.

Power Supply Connectors: Required for Driver Enable.

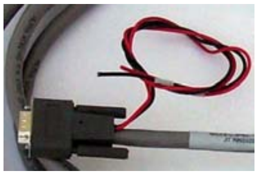
QCI-SKO-34-65-v Start-Up Kit Setup

The Setup for this kit is similar to previously described setups, except the QCI-SK1-34-65 Start-Up Kit contains a SilverMax 34 IP 65 Cable and no Silver Max Line Power Cable. For more information on the Optical I/O Module, see QCI Technical Document QCI-TD0010 (included).

Connect the female round IP-65 connector of the SilverMax

to the male round connector on the 34-frame SilverMax motor.

The 15-pin male connector on the SilverMax 34 IP 65 Cable.



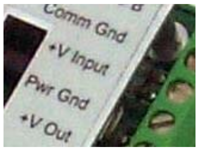
connects to the supplied Optical I/O module.

The phone jack-like connector of the RJ-11 serial cable

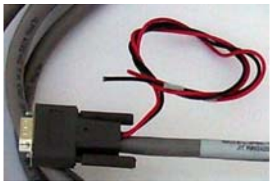
attaches to the RJ-11 connector on the optical I/O board.

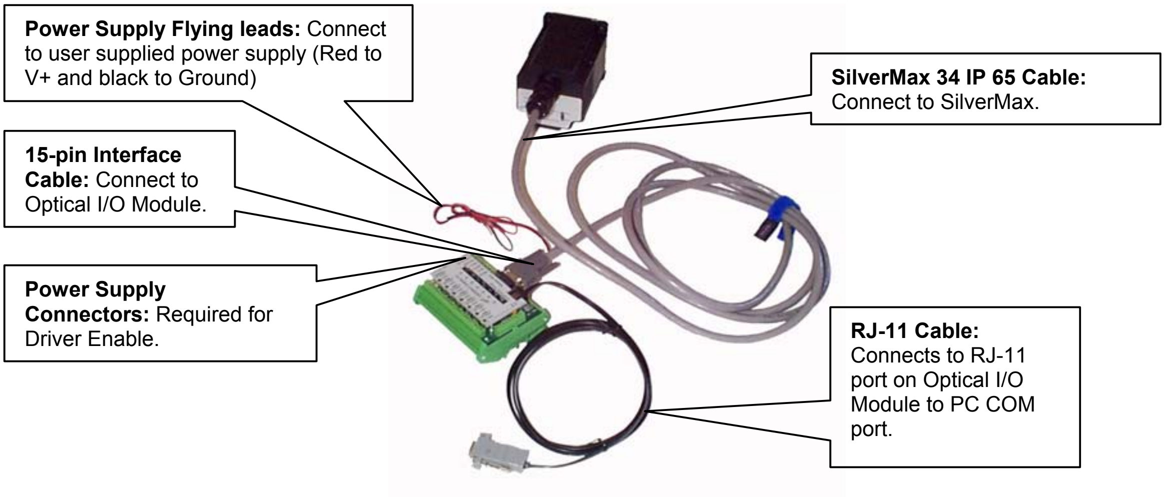
The 9-pin female Comm connector of the RJ-11 serial cable connects to your PC.

The +V Input connection on the optical I/O board must be connected to V+ of a power supply and Pwr Gnd connection must be connected to Ground of that power supply.



The red wire at the end of the SilverMax 34 IP 65 Cable is connected to V+ of the power supply. The black wire connects to Ground. (BOTH these and the power connections on the Optical I/O cable MUST be connected!)





Power Supply Flying leads: Connect to user supplied power supply (Red to V+ and black to Ground)

15-pin Interface Cable: Connect to Optical I/O Module.

Power Supply Connectors: Required for Driver Enable.

SilverMax 34 IP 65 Cable: Connect to SilverMax.

RJ-11 Cable: Connects to RJ-11 port on Optical I/O Module to PC COM port.

Installing QuickControl Software:

NOTE: Do not power up the SilverMax until the setup procedure specifies this action.

NOTE: QuickControl controls the SilverMax in "real-time", it therefore needs full access to your PC's resources. When installing the QuickControl Software it will be necessary to close all shared files and exit open applications. It is also highly recommended that applications requiring large system demands be closed and any screen saver disabled when running QuickControl. Do not power up the SilverMax or Power Interface Box until the setup procedure specifies this action!

1) Upgrading from previous versions.

   Rename the current QuickControl directory to QuickControlOld (or a name of your choice). This will save your old version and allow QuickControl to install correctly. QuickControl is usually installed in:

   C:\Program Files\QuickControl

   Rename to

   C:\Program Files\QuickControlOld

2) Insert QuickControl Setup CD into your CD ROM drive.

3) From the **Start** menu select

   Start ⇒ Run

4) Type in the setup program:

   <CD Drive Letter>: setup

   Follow the instructions on the screen. It is strongly recommended that you select "Typical" installation and accept all the defaults.

5) Reboot PC**:** Remove all diskettes from your floppy drives and re-boot your PC. This can be done by selecting:

   Start ⇒ Shut Down – Restart the Computer?

6) Run QuickControl: From the Start menu select,

   Start ⇒ Programs ⇒ QuickControl

   QuickControl will come up with a blank program.

7) Initialize and Program SilverMax

Go to the QuickControl Help System for a detailed step by step procedure on:

Initializing SilverMax
Programming SilverMax

The QuickControl Help system is accessed through:

Help ⇒ Help Topics ⇒ Getting Started – Tutorials

SilverMax "Status" and "Comm" LEDs:

There are two LEDs on the back of the SilverMax motor that are used for motor status and communications indication.

The **Red LED** indicates in four ways:

1. **A Short Flicker** = Successful communications to the motor.
2. **Bright ON** = Incomplete transmission.
3. **½ Bright ON** = Motor in Idle state.
4. **OFF** = A program is running.

The **Green LED** indicates two ways:

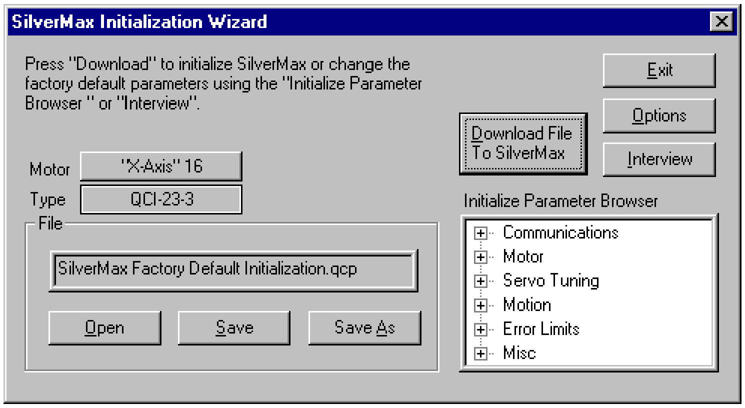
1. **ON** = Power is present and DSP is active on the Motor.
2. **Blinking** = There was a fault at power up.

UPGRADING FROM QUICKCONTROL 3.1 TO 3.2

What is New?

SilverMax Initialization Wizard

Rev 3.1's Initialize SilverMax screen has been replaced with the much simpler SilverMax Initialization Wizard. Initialization files have been upgraded to standard program Files (.QCP). See SilverMax Initialization for details.



SilverMax Initialization Wizard

Press "Download" to initialize SilverMax or change the factory default parameters using the "Initialize Parameter Browser " or "Interview".

Motor: "X-Axis" 16

Type: QCI-23-3

File: SilverMax Factory Default Initialization.qcp

Where Do I Set Motor Voltage?

You no longer have to manually set the motor's supply voltage. QuickControl automatically reads the voltage from the SilverMax and modifies the Initialization file for you The motor voltage can still be set manually by pressing the **Options** button.

How Do I Edit the Initialization Parameters?

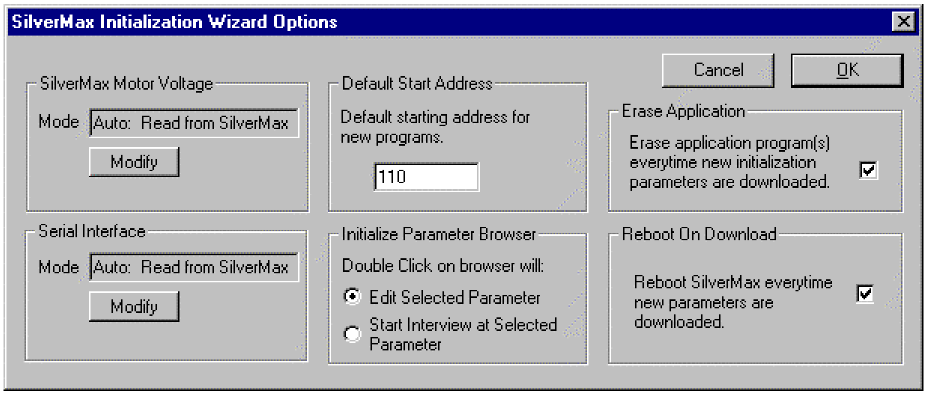
The initialization parameters are accessed through the **Initialization Parameter Browser**.

Can I Still Use My Old Initialization Files?

Although existing initialization files can still be used by way of the "Rev 3.1 Tools" menu item, it is suggested you create new ones with the new wizard. The old files do not have access to any of the new initialization commands that have been developed(compare all the parameters in the browser to what you use to have!).

Default Start Address

The Default Start Address is the place in non-volatile memory where the first program gets stored. In other words, this is the address the initialization program "runs" when it is finished. In Rev 3.1 this was set to 110. In Rev 3.2 this has been increased to 512 do to all the new initialization options we have added. If you upgrade to the SilverMax Initialization Wizard, this will be transparent to you and all your old programs will work just fine. If you choose to continue to use the older initialization files, you will have to set the Default Starting Address to 110. This can be done by pressing the **Options** button and entering 110 into the Default Starting Address field. Exit out of the SilverMax Initialization Wizard and use your old Initialization files from the rev 3.1 Tools menu.



SilverMax Initialization Wizard Options

SilverMax Motor Voltage
Mode: Auto: Read from SilverMax

Serial Interface
Mode: Auto: Read from SilverMax

Default Start Address
Default starting address for new programs.
110

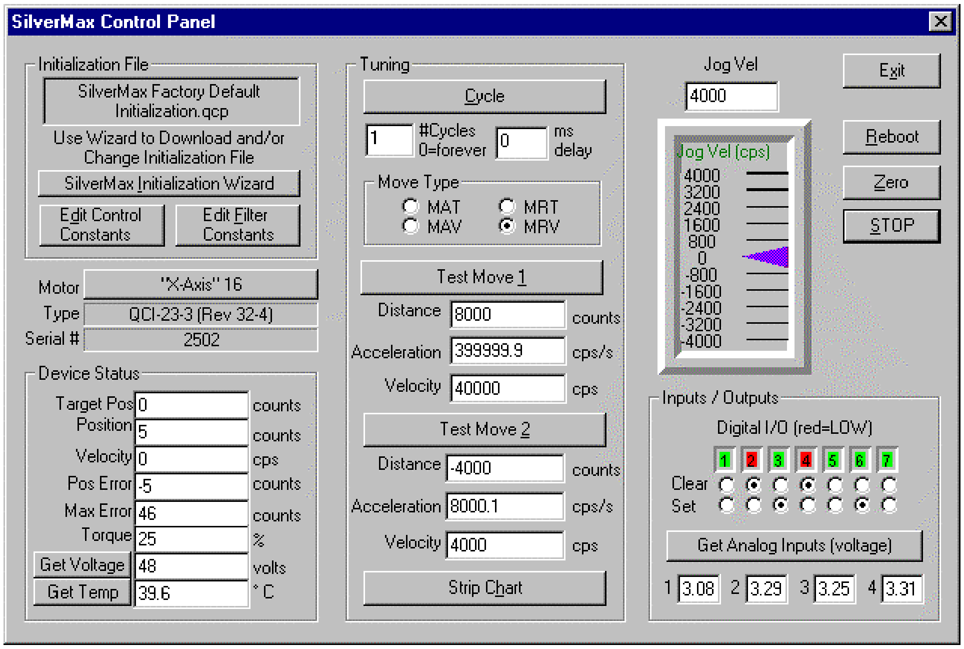
Initialize Parameter Browser
Double Click on browser will:
● Edit Selected Parameter
○ Start Interview at Selected Parameter

Erase Application
Erase application program(s) everytime new initialization parameters are downloaded. ☑

Reboot On Download
Reboot SilverMax everytime new parameters are downloaded. ☑

SilverMax Control Panel

The rev 3.1 **Motion Tuning** and **Jog SilverMax** screens have been replaced with the **SilverMax Control Panel.** See QuickControl Help System for a detailed description of this screen.



SilverMax Control Panel

Initialization File
SilverMax Factory Default Initialization.qcp
Use Wizard to Download and/or Change Initialization File

Motor: "X-Axis" 16
Type: QCI-23-3 (Rev 32-4)
Serial #: 2502

Device Status

Target Pos	0	counts
Position	5	counts
Velocity	0	cps
Pos Error	-5	counts
Max Error	46	counts
Torque	25	%
Get Voltage	48	volts
Get Temp	39.6	°C

Tuning
1 #Cycles 0=forever
0 ms delay

Move Type
○ MAT ○ MRT
○ MAV ● MRV

Test Move 1
Distance: 8000 counts
Acceleration: 399999.9 cps/s
Velocity: 40000 cps

Test Move 2
Distance: -4000 counts
Acceleration: 8000.1 cps/s
Velocity: 4000 cps

Jog Vel: 4000

Inputs / Outputs
Digital I/O (red=LOW)

	1	2	3	4	5	6	7
Clear	○	●	○	●	○	○	○
Set	○	○	●	○	○	●	○

Get Analog Inputs (voltage)
1: 3.08 2: 3.29 3: 3.25 4: 3.31

The major additions include:

Device Status: Voltage (actual voltage measured by SilverMax)
Device Status: Temperature (actual temperature measured by SilverMax)
Inputs/Outputs: Analog Inputs (actual voltage measured by SilverMax)

Single Step/Trace/Breakpoint

Two new buttons have been added to the program Info Toolbar, **Trace** and **Single Step**. Using these buttons you can now single step through your program. A Breakpoint can be set on any line by selecting:

Programs ⇒ Toggle Breakpoint

See the QuickControl Help system for a detailed explanation of these new features.

QuickControl Rev 3.1 Tools

All your old favorites can still be accessed by selecting:

Tools ⇒ Rev 3.1 Tools

SILVERMAX INITIALIZATION

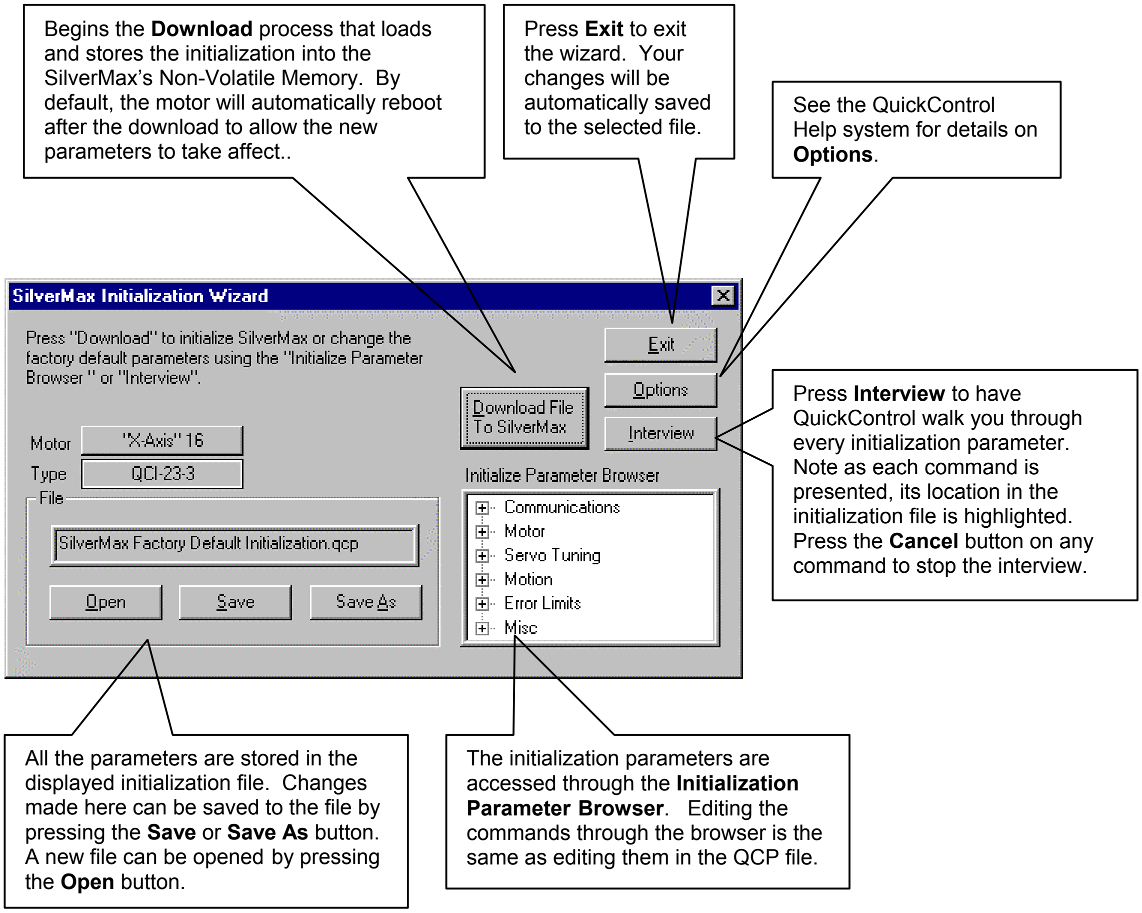
Each SilverMax unit contains internal **Initialization Programs** that set up the operational values and constants for the motor at power up. By default the **Initialization Programs** are downloaded into the non-volatile memory at location "0". User programs start at "512".

SilverMax Factory Default Initialization.qcp

The program "**SilverMax Factory Default Initialization.qcp**" is designed for use with the SilverMax Initialization Wizard tool. This program sets up all motor parameters. The program can also be edited manually to add more commands or modify those that are not shown in the "Initialize" tool. Typically this file should be saved to a different name after it is edited or used for initializing a motor. The wizard can be accessed by selecting:

Tools ⇒ SilverMax Initialization Wizard

SilverMax Initialization Wizard



Press "Download" to initialize SilverMax or change the factory default parameters using the "Initialize Parameter Browser " or "Interview".

Motor: "X-Axis" 16

Type: QCI-23-3

File: SilverMax Factory Default Initialization.qcp

Begins the **Download** process that loads and stores the initialization into the SilverMax's Non-Volatile Memory. By default, the motor will automatically reboot after the download to allow the new parameters to take affect..

Press **Exit** to exit the wizard. Your changes will be automatically saved to the selected file.

See the QuickControl Help system for details on **Options**.

Press **Interview** to have QuickControl walk you through every initialization parameter. Note as each command is presented, its location in the initialization file is highlighted. Press the **Cancel** button on any command to stop the interview.

All the parameters are stored in the displayed initialization file. Changes made here can be saved to the file by pressing the **Save** or **Save As** button. A new file can be opened by pressing the **Open** button.

The initialization parameters are accessed through the **Initialization Parameter Browser**. Editing the commands through the browser is the same as editing them in the QCP file.

The wizard provides a friendly way of editing the initialization program file (i.e. SilverMax Factory Default Initialization.qcp). Note: when the wizard is launched, the initialization file is opened in the background and stays open after the wizard is closed. Editing a SilverMax command in the wizard is the same as editing it in the QCP file.

If the factory defaults are acceptable (described below), turn the SilverMax on and press the **Download…** button to initialize the attached SilverMax. When the "Download Complete" message appears, close the wizard and start using your SilverMax.

Detailed Description of "Download" Steps

When the **Download…** button is pressed the wizard will do the following steps:

1. Check if the selected SilverMax is present by asking it for its firmware revision. If successful, go to step 5.

2. Check if any registered device is present. If successful, go to step 5.

3. Scan network for any SilverMax. If a SilverMax is found, go to step 5.

4. Run Unknown SilverMax Wizard to find a device. If the previous steps could not find a SilverMax, it might be that the SilverMax is running a different Serial Interface (see Serial Interface (SIF) command in SilverMax Command Reference manual) or a different baud rate. The Unknown SilverMax Wizard will walk the user through a procedure to establish communications with a SilverMax of unknown serial interface, baud rate and ID. If no SilverMax is found, the wizard will notify the user that the download has failed.

5. Send Stop (STP) command. This makes it stop moving and end any programs it might be running.

6. Download selected initialization file.

SilverMax Factory Default Initialization File - Detailed

The Initialization program file contains the following programs:

Main Init

The main initialization program which contains all of the initialization commands. This is described in great detail below.

Startup Recovery

Startup Recovery is used during the factory default initialization to indicate an error has occurred. The program will cause the Status LED to pulse.

Kill Motor Recovery

This program gets called whenever a condition in the Kill Motor Recovery (KMR) command is met. The user may modify this program if special processing is required.

For example, if the user wanted the SilverMax to set an error output anytime it detected a “jam”. They would first set the “Moving Error” in the **Kill Motor Conditions (KMC)** command and then add a **Set Output Bit (SOB)** command to the Kill Motor Recovery program.

Power Low Recovery

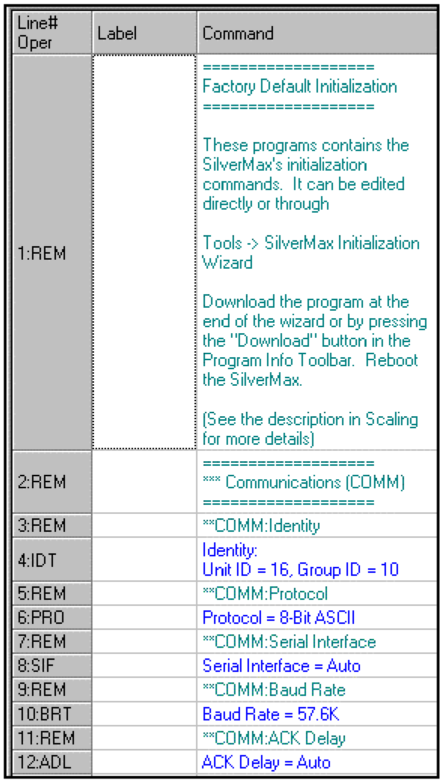
The user may modify this program if special processing is required on a Power Low condition. For example, the user may want to save the SilverMax's current position.

Main Init[0]

The Main Initialization program is broken up into the following sections. Each section editable by the SilverMax Initialization Wizard is a branch on the wizard's Browser. Please refer to the Command Reference for a detailed description of the individual commands.

Communications

At the very beginning of power up the most vital thing to do is establish serial communications with SilverMax. Without this the user may be unable to communicate with SilverMax, which will make diagnosing a problem or configuring the motor difficult. This section is the first to execute.



Line# Oper	Label	Command
1:REM		================== Factory Default Initialization ================== These programs contains the SilverMax's initialization commands. It can be edited directly or through Tools -> SilverMax Initialization Wizard Download the program at the end of the wizard or by pressing the "Download" button in the Program Info Toolbar. Reboot the SilverMax. (See the description in Scaling for more details)
2:REM		================== *** Communications (COMM) ==================
3:REM		**COMM:Identity
4:IDT		Identity: Unit ID = 16, Group ID = 10
5:REM		**COMM:Protocol
6:PRO		Protocol = 8-Bit ASCII
7:REM		**COMM:Serial Interface
8:SIF		Serial Interface = Auto
9:REM		**COMM:Baud Rate
10:BRT		Baud Rate = 57.6K
11:REM		**COMM:ACK Delay
12:ADL		ACK Delay = Auto

IDT: Identity
(default: "16")
The motor Identity command must be the first command in the first program. If it is not present no initialization will take place. This is to prevent an non-initialized motor from attempting to initialize from blank non-volatile memory.

PRO: Protocol:
(default: 8-Bit ASCII)
8-Bit ASCII is the most common protocol used and the easiest to communicate with SilverMax using a standard serial UART.

SIF: Serial Interface
(default: Auto)
SilverMax can operate using either RS-232 or RS-485. In Auto, QuickControl will query SilverMax on its current SIF and set this command to match. This command can also be edited from the Serial Interface field of the SilverMax Initialization Wizard's Option screen.

BRT: Baud Rate
(default: 57.6K)
The serial communications baud rate can be set to lower values such as 9600 or 19200 baud for slower host communications ports or to higher values such as 115200 or 230400 for high speed systems. 57.6K is recommended for RS-232 and RS-485, while 19.2K is recommended for RS-232 multi-drop.

Please note, this command has no affect on the PC's baud rate. If you download an initialization program with a different baud rate than your PC, you will loose communications with the SilverMax as soon as the SilverMax reboots. To re-establish communications, change the PC's baud rate to match the new SilverMax baud rate (Setup⇒Comm Channels).

ADL:ACK Delay
(default: Auto)
Normally SilverMax will immediately acknowledge a received command. It can do this within 120 microseconds after receiving the last character in a command packet. This is sometimes too fast for the host PC or PLC when running on an RS-485 or RS-232 network. SilverMax may be sending its acknowledge packet before the host has switched out of transmit mode. This condition will cause a loss of characters. Setting the ACK Delay will allow SilverMax to delay a

specified period before the acknowledge packet is sent. NOTE: A non-zero ACK Delay puts a SilverMax using RS-232 into RS-232 Multi-Drop mode (See the Command Reference for details).

In Auto, QuickControl will set the ACK Delay to 2.4ms (20 120uSec ticks) if the SilverMax is in RS-485 or RS-232 Multi-Drop mode and to 0ms if it is in straight RS-232 mode.

Startup Error Conditions

At power-up or if the initialization routine is called, SilverMax will verify that the input voltage and the motor temperature are at an acceptable level before proceeding with the motor initialization. If the voltage or temperature is out of range the “Startup Recovery” program will be executed that will aide in the diagnosis of a startup problem.

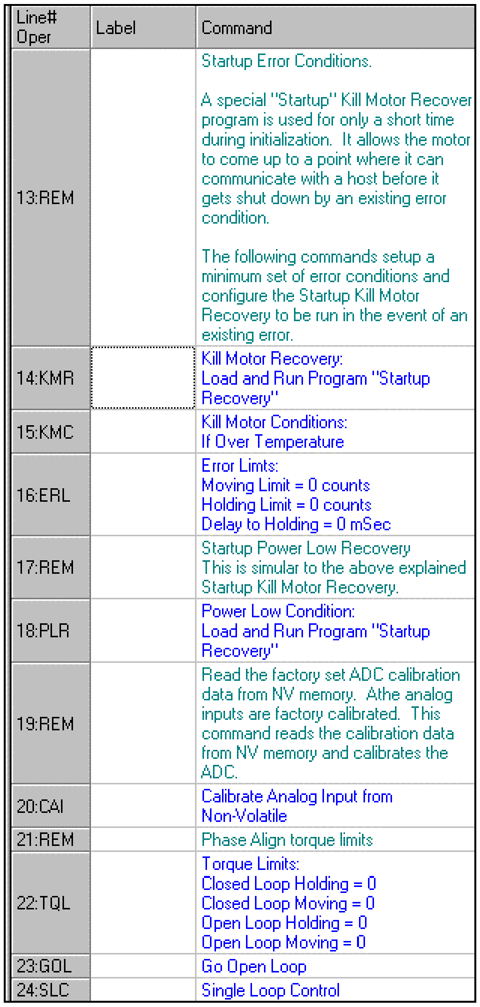
KMR: Kill Motor Recovery
Run “Startup Recovery” program if a Kill Motor Condition occurs.

KMC: Kill Motor Conditions
Set KMC to over temp only (over voltage is always an active KMC). If an over temperature or over voltage condition exist, the SilverMax will now execute the “Startup Recovery” program.

ERL: Error Limits
Disable error limits at startup to suppress nuisance error messages. Until the motor has torque, it will probably have movement errors.

PLR: Power Low Recovery
Run “Startup Recovery” program if a low power condition occurs.

CAI: Calibrate Analog Input
Calibrate analog input channels using factory stored scale factor stored in non-volatile memory.



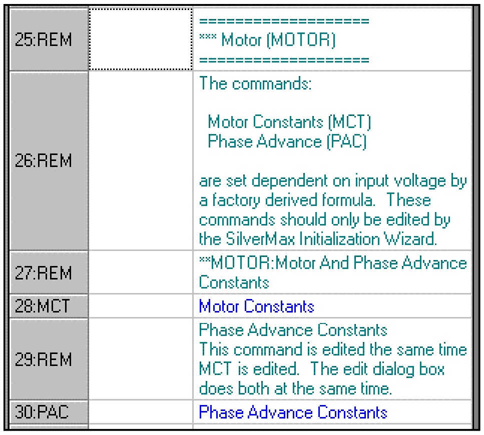
Line# Oper	Label	Command
13:REM		Startup Error Conditions. A special "Startup" Kill Motor Recover program is used for only a short time during initialization. It allows the motor to come up to a point where it can communicate with a host before it gets shut down by an existing error condition. The following commands setup a minimum set of error conditions and configure the Startup Kill Motor Recovery to be run in the event of an existing error.
14:KMR		Kill Motor Recovery: Load and Run Program "Startup Recovery"
15:KMC		Kill Motor Conditions: If Over Temperature
16:ERL		Error Limts: Moving Limit = 0 counts Holding Limit = 0 counts Delay to Holding = 0 mSec
17:REM		Startup Power Low Recovery This is simular to the above explained Startup Kill Motor Recovery.
18:PLR		Power Low Condition: Load and Run Program "Startup Recovery"
19:REM		Read the factory set ADC calibration data from NV memory. Athe analog inputs are factory calibrated. This command reads the calibration data from NV memory and calibrates the ADC.
20:CAI		Calibrate Analog Input from Non-Volatile
21:REM		Phase Align torque limits
22:TQL		Torque Limits: Closed Loop Holding = 0 Closed Loop Moving = 0 Open Loop Holding = 0 Open Loop Moving = 0
23:GOL		Go Open Loop
24:SLC		Single Loop Control

TQL: Torque Limits
GOL: Go Open Loop
SLC: Single Loop Control
Start motor/encoder alignment by setting torque to 0 and entering Open Loop and Single Loop modes (see below for more detail on Motor/Encoder alignment).

Motor

These motor settings are required before the SilverMax can attempt any kind of move including the Motor to Encoder alignment.

MCT: Motor Constants
PAC: Phase Advance Constants
Each SilverMax is set up with unique motor parameters that program it for operation at a set voltage. The most common voltages are 12, 24, 36 and 48. QuickSilver Controls provides parameters for these common voltages in complete initialization files. For other voltages contact QuickSilver Controls' Product Support to obtain parameters for any voltage between 12 and 48. These parameters should not be edited manually.

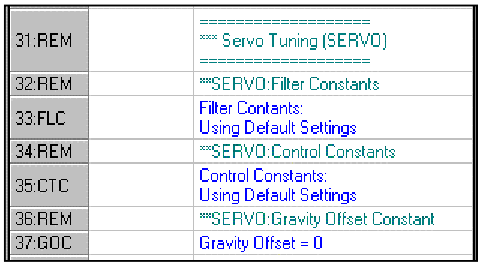


25:REM		=================== *** Motor (MOTOR) ===================
26:REM		The commands: Motor Constants (MCT) Phase Advance (PAC) are set dependent on input voltage by a factory derived formula. These commands should only be edited by the SilverMax Initialization Wizard.
27:REM		**MOTOR:Motor And Phase Advance Constants
28:MCT		Motor Constants
29:REM		Phase Advance Constants This command is edited the same time MCT is edited. The edit dialog box does both at the same time.
30:PAC		Phase Advance Constants

In Auto, QuickControl will query SilverMax for its current voltage and set this command to match. If you are programming SilverMax at a different voltage than will be used in the application, manually set these commands to the application's voltage. These commands can also be edited from the SilverMax Motor Voltage field of the SilverMax Initialization Wizard's Option screen.

Servo Tuning

LC: Filter Constants
CTC: Control Constants
The SilverMax PVIA servo control loop is set up with default parameters which will allow the motor to operate under most conditions. We have found that the factory values work well over 80% of the time. If not, these values can be modified using QuickControl to establish the desired operational control (see Tuning SilverMax for details).



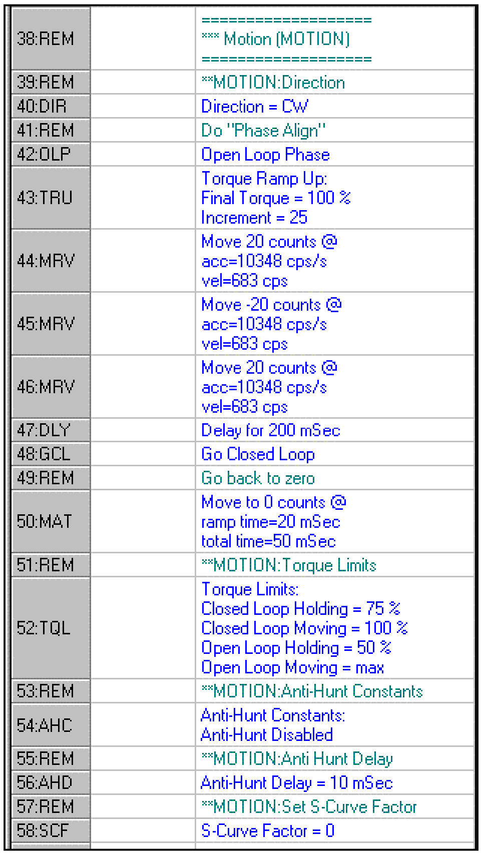
31:REM		=================== *** Servo Tuning (SERVO) ===================
32:REM		**SERVO:Filter Constants
33:FLC		Filter Contants: Using Default Settings
34:REM		**SERVO:Control Constants
35:CTC		Control Constants: Using Default Settings
36:REM		**SERVO:Gravity Offset Constant
37:GOC		Gravity Offset = 0

GOC: Gravity Offset
(default = 0)
Gravity offset is a constant torque injected after the servo loop. A none-zero value will compensate for gravity on vertical loads. See Command Reference for details.

Motion

This section contains parameters affecting general SilverMax motion. They are all editable from both the SilverMax Initialization Wizard or from the program file directly (i.e. double click on the command).

DIR: Direction
TQL: Torque Limits
AHC: Anti-Hunt Constants
AHD: Anti-Hunt Delay
SCF:S-Curve Factor
For details on these commands, see the Command Reference.



38:REM	=================== *** Motion (MOTION) ===================
39:REM	**MOTION:Direction
40:DIR	Direction = CW
41:REM	Do "Phase Align"
42:OLP	Open Loop Phase
43:TRU	Torque Ramp Up: Final Torque = 100 % Increment = 25

44:MRV	Move 20 counts @
	acc=10348 cps/s
	vel=683 cps

45:MRV	Move -20 counts @
	acc=10348 cps/s
	vel=683 cps

46:MRV	Move 20 counts @
	acc=10348 cps/s
	vel=683 cps

47:DLY	Delay for 200 mSec
48:GCL	Go Closed Loop
49:REM	Go back to zero
50:MAT	Move to 0 counts @ ramp time=20 mSec total time=50 mSec
51:REM	**MOTION:Torque Limits
52:TQL	Torque Limits: Closed Loop Holding = 75 % Closed Loop Moving = 100 % Open Loop Holding = 50 % Open Loop Moving = max
53:REM	**MOTION:Anti-Hunt Constants
54:AHC	Anti-Hunt Constants: Anti-Hunt Disabled
55:REM	**MOTION:Anti Hunt Delay
56:AHD	Anti-Hunt Delay = 10 mSec
57:REM	**MOTION:Set S-Curve Factor
58:SCF	S-Curve Factor = 0

Motor/Encoder Alignment Routine

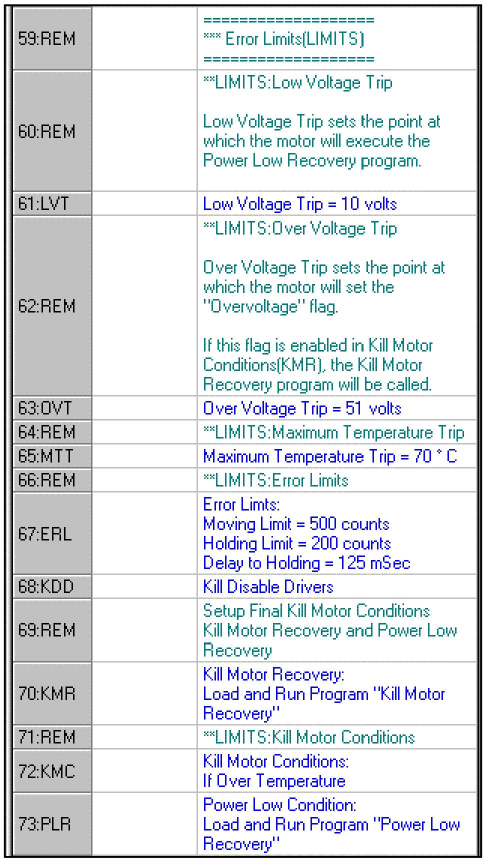
Before the SilverMax can be put into closed loop mode, an alignment between the motor rotor and the Encoder must be established. This is done using one of two different algorithms that will automatically perform this task. Standard alignment is selected when very low residual torque is on the motor at startup and low torque (< 5% of Max) is required to move the load at low speed (< 1 RPM). The Complex alignment is used with high residual torque or when high breakaway torque (stiction) is present during startup.

Standard alignment (Factory Default)
The standard alignment routine simply fixes a known vector (phase value) in the stator windings, clears the encoder count register, then puts the motor into closed loop mode. This is typically done using a high winding current to ensure that the motor rotor aligns itself to the encoder. This routine always takes a pre-determined period of time.

Complex alignment (SilverMax Factory Complex Initialization.qcp)
For loads that have a very high frictional content, the complex alignment routine offers a more accurate system of aligning the encoder to the motor. The complex routine spends more time to make sure that the rotor and encoder are aligned before going into closed loop mode. The timing can vary and therefore the SilverMax should be polled for **Program Complete** before attempting to operate the motor.

Error Limits

Good practice requires that operational limits and error conditions be set up prior to motor operation. Setting up these parameters can provide safer operation or may prevent damage to the motor and system.



59:REM		=================== *** Error Limits(LIMITS) ===================
60:REM		**LIMITS:Low Voltage Trip Low Voltage Trip sets the point at which the motor will execute the Power Low Recovery program.
61:LVT		Low Voltage Trip = 10 volts
62:REM		**LIMITS:Over Voltage Trip Over Voltage Trip sets the point at which the motor will set the "Overvoltage" flag. If this flag is enabled in Kill Motor Conditions(KMR), the Kill Motor Recovery program will be called.
63:OVT		Over Voltage Trip = 51 volts
64:REM		**LIMITS:Maximum Temperature Trip
65:MTT		Maximum Temperature Trip = 70 ° C
66:REM		**LIMITS:Error Limits
67:ERL		Error Limts: Moving Limit = 500 counts Holding Limit = 200 counts Delay to Holding = 125 mSec
68:KDD		Kill Disable Drivers
69:REM		Setup Final Kill Motor Conditions Kill Motor Recovery and Power Low Recovery
70:KMR		Kill Motor Recovery: Load and Run Program "Kill Motor Recovery"
71:REM		**LIMITS:Kill Motor Conditions
72:KMC		Kill Motor Conditions: If Over Temperature
73:PLR		Power Low Condition: Load and Run Program "Power Low Recovery"

LVT: Low Voltage Trip
(default=10V)
Set point at which SilverMax will execute the "Power Low Recovery" program.

OVT: Over Voltage Trip
(default=51V)
MTT: Maximum Temperature Trip
(default=70C)
Set points at which SilverMax will disable its driver and execute the "Kill Motor Recovery" program.

ERL: Error Limits
(default = no limits)
The difference between the "Actual Position" and the "Target Position" can trigger an error flag or "Kill" the motor. The acceptable limits are set here.

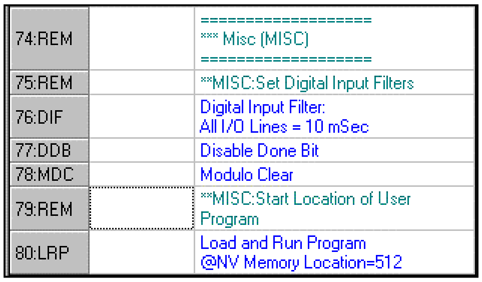
KDD: Kill Disable Drivers
Drivers will be disabled when a Kill Motor Condition occurs.

KMR: Kill Motor Recovery
Run the program "Kill Motor Recovery" any time a Kill Motor Condition occurs.

KMC: Kill Motor Conditions
(default: Kill only on over-temp)
Set KMC to over temp only (over voltage is always an active KMC). If an over temperature or over voltage condition exist, the SilverMax will now execute the "Kill Motor Recovery" program.

PLR: Power Low Recovery
Run the "Power Low Recovery" program if a low power condition occurs.

Misc



74:REM		=================== *** Misc (MISC) ===================
75:REM		**MISC:Set Digital Input Filters
76:DIF		Digital Input Filter: All I/O Lines = 10 mSec
77:DDB		Disable Done Bit
78:MDC		Modulo Clear
79:REM		**MISC:Start Location of User Program
80:LRP		Load and Run Program @NV Memory Location=512

DIF: Digital Input Filter (default=10ms)

DIF is a digital filter on all input lines (de-bounce). This only affects the basic digital inputs and does affect the analog inputs, external encoder signals or step and direction signals.

DDB: Disable Done Bit
MDC: Modulo Clear

Special output modes set to their default states. See the Command Reference for details.

LRP: Load and Run Program (default=512)

After the initialization is complete, SilverMax can begin execution of a user defined program. User programs can be created using QuickControl's program editor (QCP). This command can also be edited from the Default Starting Address of the SilverMax Initialization Wizard's Option screen.

The SilverMax Initialization Wizard requires this line to exist in all init program files. If your application does not require a user program, Check the Erase Application box of the SilverMax Initialization Wizard's Option screen.

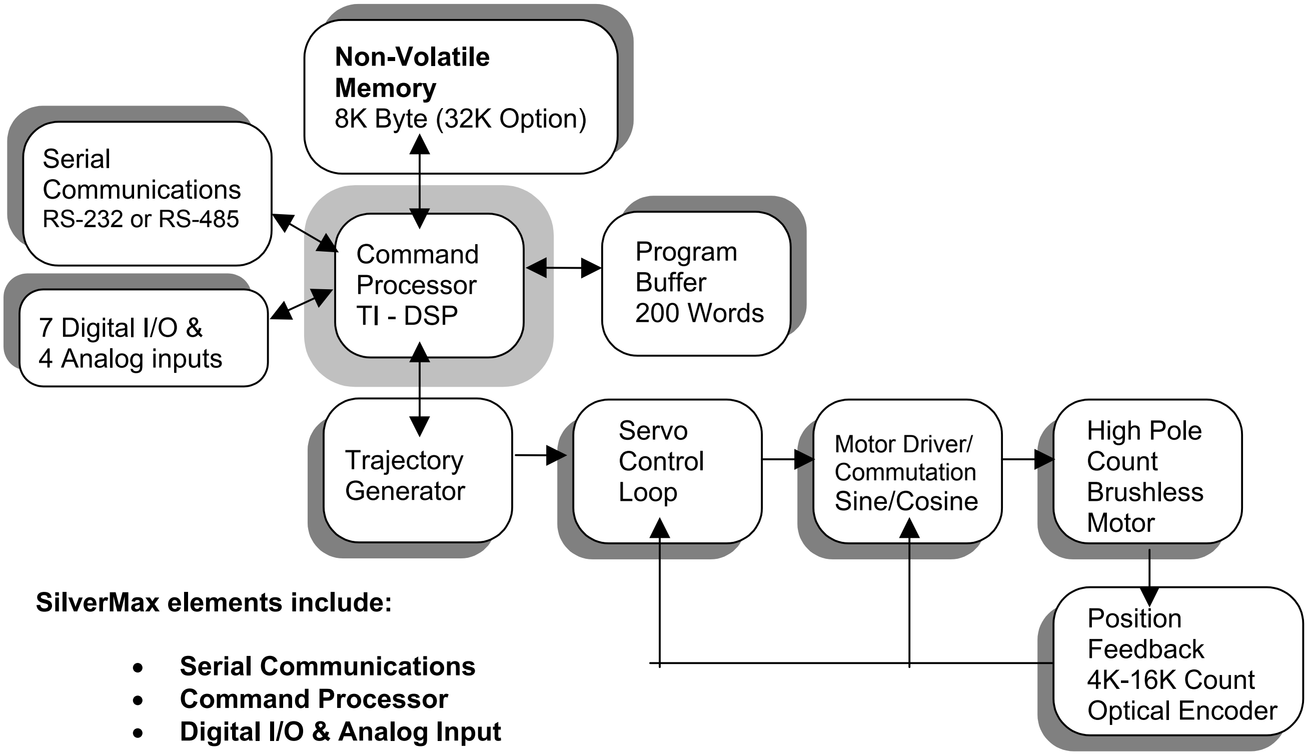
Tools⇒SilverMax Initialization Wizard⇒Options⇒Erase Application.

This will write a single line program at the Default Starting Address (512) consisting of the END: Program End command. When SilverMax reboots, it will execute its initialization program and them load and run the program at 512 which will be an END command. SilverMax will now be in host mode awaiting commands over the serial port.

OVERVIEW

The SilverMax Motion Control System integrates all of the traditional modules for motion control needed to provide rotary position and velocity control in one single mechanical package.

SilverMax Block Diagram



SilverMax elements include:

- **Serial Communications**
- **Command Processor**
- **Digital I/O & Analog Input**
- **Non-Volatile Memory**
- **Trajectory Generator**
- **Servo Control Loop**
- **Motor Driver/Commutation**
- **Brushless Motor**
- **Position Feedback**

All of these elements work together to form an easy-to-use system that requires only DC power for full operation.

Serial Communications

The serial communications furnish SilverMax with an RS-485 multi-drop or RS-232 communications capability at a selectable baud rate (default 57.6K baud). Two different communications protocols are available depending on the system design needs. The serial communications are used to initialize the SilverMax in both network and stand-alone operations. SilverMax's companion product, QuickControl, may be used to quickly prototype motions, initialize and program SilverMax using the serial communications.

Communication Hardware

SilverMax is programmable with two different hardware interfaces for serial communications. RS-485 or RS-232 is selectable by initializing the SilverMax for the desired hardware interface.

RS-485 Multi-Drop

RS-485 is a two-wire serial communications hardware interface. By design, RS-485 can connect up to 32 serial devices in parallel on the same two wires. This provides the ability to network a number of SilverMax units together on a common serial connection. SilverMax is designed to work on a network with its individual addressing and communications protocol. This offers greater simplicity in harnessing and communicating to a number of SilverMax units on a system. If a host controller is used that only supports RS-232, an RS-232 to RS-485 converter can be used that will allow the host to communicate with a SilverMax RS-485 network.

RS-232

RS-232 offers the easiest way to connect SilverMax to a host computer. Through appropriate cabling, a SilverMax can be directly connected to an RS-232 serial communications port. A drawback of RS-232 is that typically only one SilverMax can be connected to the serial port at a time. If a network is required, the RS-485 version with a converter board (RS-232 to RS-485) can be used.

RS-232 Multi-Drop

SilverMax is also able to work on an RS-232 multi-drop network with a limited number of nodes. The number of nodes is limited by the communications drivers and cabling requirements (typically no more than 5). This is a great way of attaching multiple SilverMax to a standard or PLC serial port (i.e. COM1).

Communication Protocols

A simple 9-bit protocol can be used where systems require high data rates, deterministic operation and robust error checking. The 9-bit protocol transmits data in binary form, which minimizes the number of bytes required for a command. An 8-bit ASCII protocol can be used where generic serial communications is required and speed or determinism of transmission is not critical. SilverMax E Series motors are shipped from the factory with both protocols available. The desired protocol is selected when first initializing a SilverMax unit. (For more information see the **9-Bit Binary Communications** and the **8-Bit ASCII Communications** sections below)

Command Processor

The Command Processor interprets each command sent to the SilverMax using the serial communications and then initiates the desired operation. The Command Processor checks each received command to verify that proper syntax is used. If a command is complete, the Command Processor will perform all the necessary functions required to set up and execute the command. If a command is incorrect, the Command Processor will issue an error code through the serial communications. The Command Processor uses a Command Buffer to store and execute commands.

Digital I/O

To give the SilverMax more PLC-like features, there are seven fully programmable digital I/O lines. Each line is software configurable to be a digital input, a digital output or dedicated to a special function. These lines can be configured “on the fly”. Digital outputs can be set into tri-state mode, allowing the lines to be used as both an output and input at the same time.

Using a variety of dedicated modes, these I/O lines can also be used for external encoder input for electronic gearing or camming operations. Inputs can be Step and Direction, A/B quadrature or Step up/down. An external encoder input is provided for dual control loops that enable position control of external mechanisms using a second encoder. The E Series can also output Step and Direction, A/B quadrature or Step up/down from its internal encoder.

To supplement the serial communications, digital inputs can also provide simple control over SilverMax operation. SilverMax programs that use the digital inputs for program flow control can be written and downloaded into the motor. Using the digital inputs, the SilverMax can operate independent of any other controlling device. Home or position sensors can also be connected to the inputs allowing end of travel control.

Analog Inputs

In addition to the digital I/O, SilverMax motors accept analog input. Four analog inputs share four digital I/O lines and will accept 0 to +5 volt analog signals. Analog inputs can be used for control of the motor’s position, velocity, torque or other software programmable operations.

Non-Volatile Memory

SilverMax includes on-board Non-Volatile Memory. The Non-Volatile Memory is used to permanently store SilverMax programs and data. The stored programs can then be used for power-on initialization or for user defined autonomous operation. programs that are stored in Non-Volatile Memory can be recalled by SilverMax for execution even after power has been removed. Stored programs can be recalled and executed using the Serial Communications or Digital Inputs. At power-on, the program stored in the first memory location (“0”) is automatically re-called and executed. This feature allows a SilverMax to operate autonomously or from a Host-controlling device.

Trajectory Generator

The trajectory generator is a significant component of SilverMax. It enables trapezoidal and S-Curve shaped moves that are defined by either the **Relative distance** to move or the **Absolute position**. Motion profiles can be defined either by acceleration and velocity, or by the total motion time plus the ramp time. The generator can also stop motions by using a complex **Stop on digital input** algorithm. The generator monitors both the running position-error value and the holding position-error value, and will automatically set a status bit when an error limit is exceeded. The running and holding error status bits can optionally halt a motion in process by shutting down the motor. The trajectory generator can be fed a step and direction input to permit interfacing a SilverMax with an external indexer.

Servo Control Loop

The Servo Control loop implements a **Patented Control Algorithm** that includes filtering on the Velocity & Acceleration terms. This allows Lead/Lag compensation to be employed for higher performance loops. Also included are a Velocity feed-forward term and an additional Acceleration Feed-Forward term for active damping term. The control algorithm provides gain terms for each of the control parameters and filter time constants for velocity and acceleration feedback filters.

Motor Driver/Commutation

The motor driver is matched to the selected motor and power supply voltage by using motor setup parameters that are pre-set at the factory. This means that there is usually no work required by the user to prepare the motor for operation. The parameters have been optimized to produce maximum performance under a wide range of conditions. Motor commutation is accomplished using the internal encoder for motor phase information. Sine and Cosine signals are used to drive the two phases of the motor thus producing a quiet, low cogging motor output.

Brushless Motor

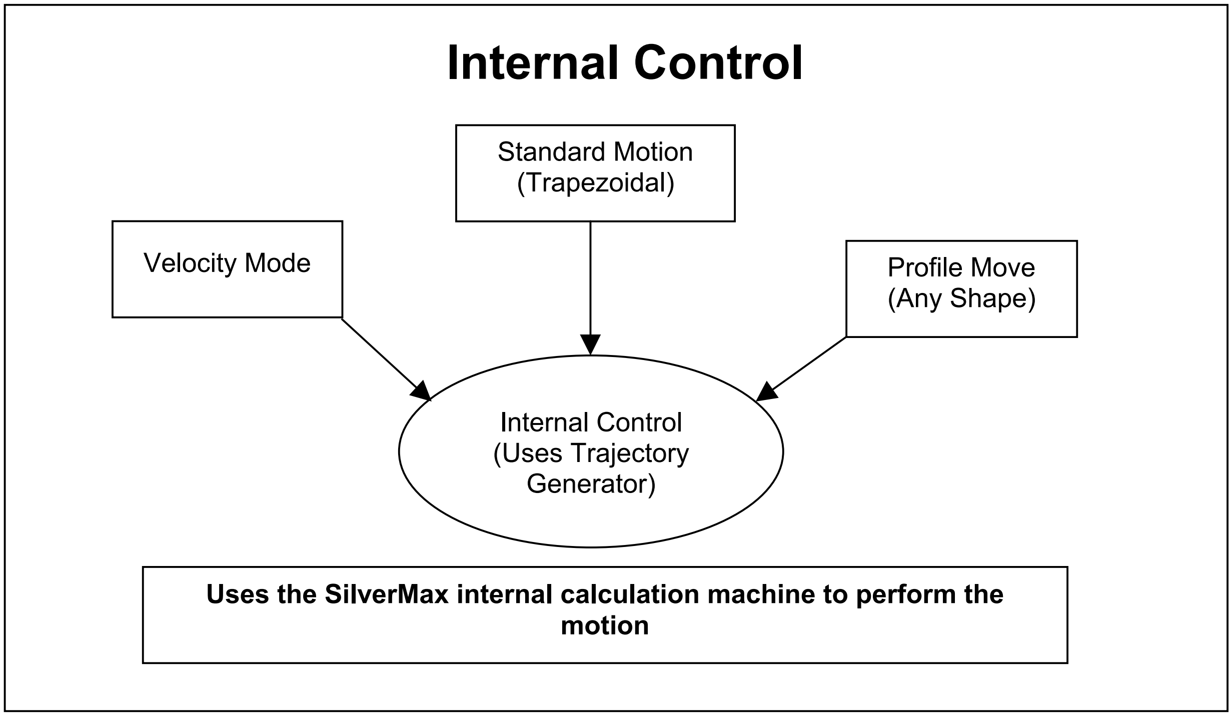
The Brushless Motor is a high pole count Permanent Magnet AC Synchronous Motor. The "magnetic" gearing of a high pole count motor yields high torque in a small package. This type of motor provides for the use of a special "anti-hunting" mode in which the motor windings are driven to hold the motor at the desired position without hunting.

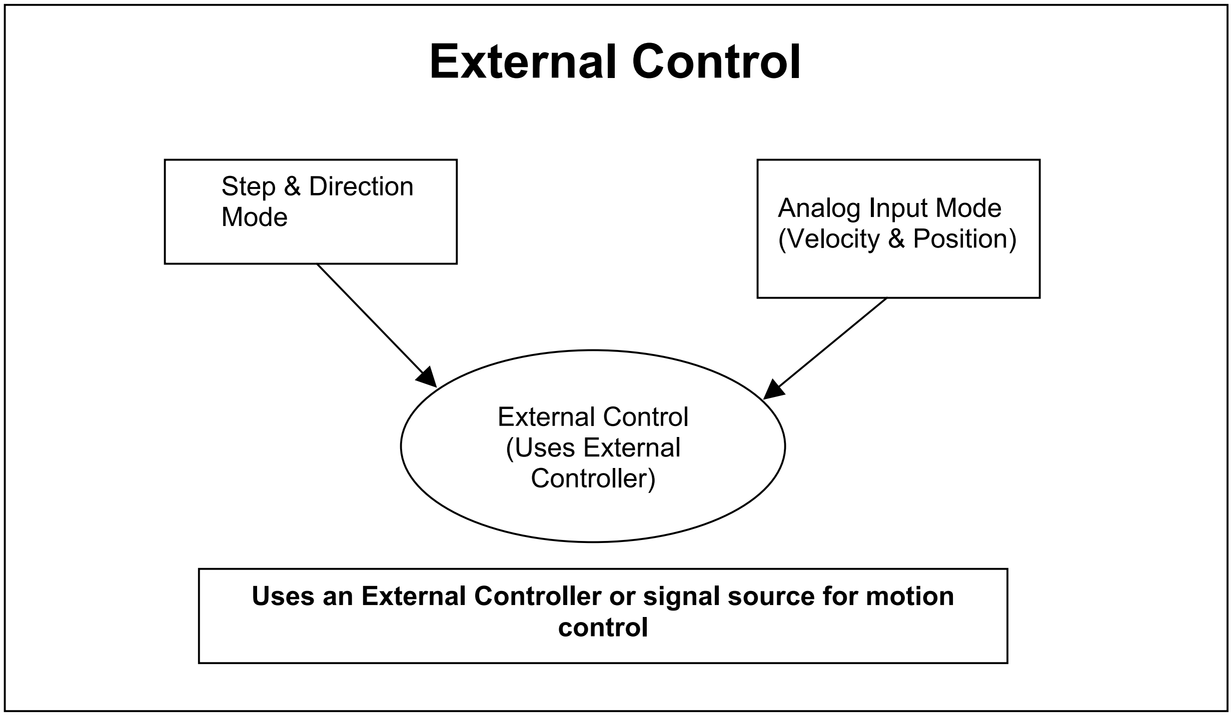
Position Feedback

The Position Feedback furnishes the control system with precise information about the motor position and velocity. The Position Feedback can resolve position information of 4000 (8000 and 16000 on some models) counts per revolution. The position feedback also provides an index pulse for each revolution of the motor.

SilverMax Motion Commands

SilverMax can operate using different motion commands that provide options to meet a variety of motion control needs. SilverMax can be controlled internally or externally depending on the system requirements and can operate in different modes depending on the type of motion needed.


Internal Control
Standard Motion (Trapezoidal)
Velocity Mode
Profile Move (Any Shape)
Internal Control (Uses Trajectory Generator)
Uses the SilverMax internal calculation machine to perform the motion


External Control
Step & Direction Mode
Analog Input Mode (Velocity & Position)
External Control (Uses External Controller)
Uses an External Controller or signal source for motion control

Standard Motion & Profile Move Commands

Internal Trajectory Control

Built into SilverMax is a full-featured trajectory control generator. The generator can algorithmically calculate and create S-Curve and trapezoidal motion profiles. The motion profiles are built from parameters such as distance, acceleration and velocity provided by the user. The following is a discussion on the various command types that provides the user with a number of different techniques for creating a motion profile.

Standard Motion Profiles

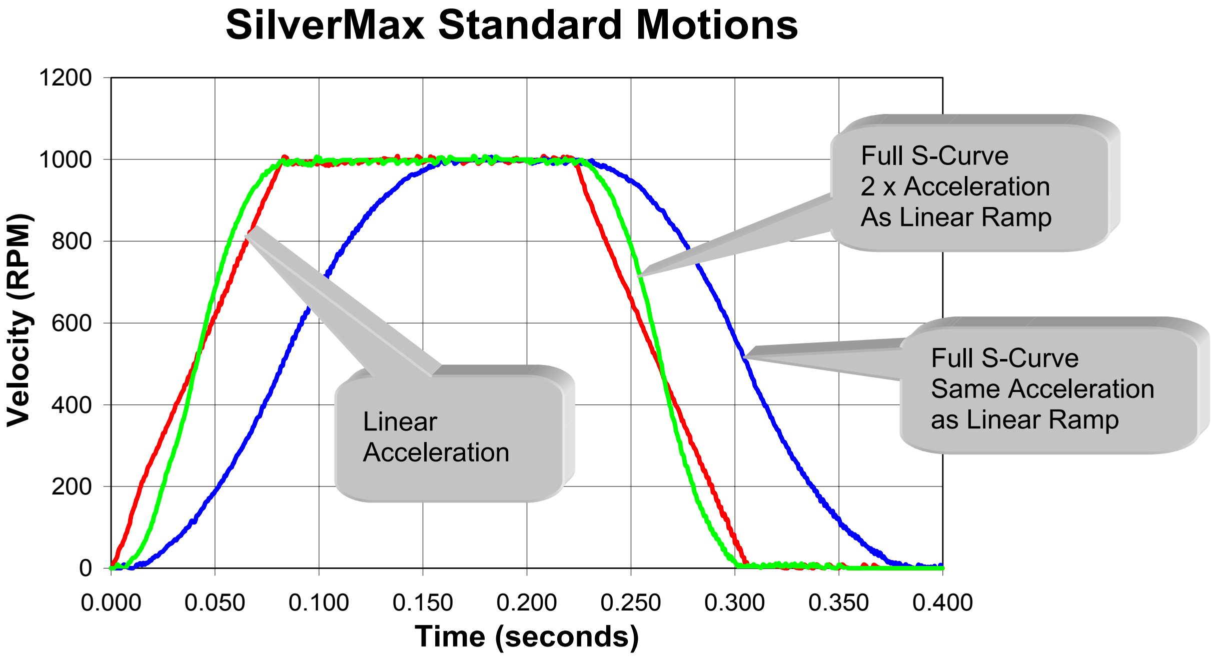
Standard Motion commands provide a basic "Acceleration - Velocity - Deceleration" (Trapezoidal) shaped move that goes a given Relative Distance or to a defined Absolute Position. Standard motions use both **Linear** and **S-Curve** acceleration and deceleration for the excellent control of the load under all conditions. Once initiated these moves cannot be altered dynamically.

Standard Motion commands come in three flavors:

- **Parameterized:** Where all parameters are sent with the command.
- **Registered:** Where the **Distance** or **Position** parameters are located in a **Data Register.**
- **Extended Registered:** Where all of the move parameters except for the **Stop Conditions** are located in **Data Registers**

Each flavor has two different parameter types:

- **Absolute** or **Relative**
  The move runs to a given **Absolute Position** or a **Relative Distance**.
- **Velocity** or **Time**
  The motion profile uses **Acceleration** and **Velocity** or **Acceleration Time** and **Total Time** for the speed parameters.



"Relative" Move Commands

Relative Move commands will cause SilverMax to move a specified distance from its current position. This is a relative position command meaning it will always move the specified distance away from its current position. **Move Relative** commands come in following types.

Move Relative, Velocity Based (MRV)
Three parameters are entered - **Distance, Acceleration & Velocity**. This is the most straightforward command type.

Register Move Relative, Velocity Based (RRV)
Three parameters are entered – **Data Register, Acceleration & Velocity**. The **Distance** parameter is the number of a special internal register called a **Data Register**. The Data Register is used for the distance value. The value entered in the **Data Register** is still in counts. The other parameters are the same as the **MRV** command. This command allows the user to modify the distance value without having to change the command when used as part of a **program**.

Extended Register Move, Velocity Based (XRV)
One parameter is entered – the **Starting Data Register**. Only the **Distance** register location is sent as a parameter, the **Acceleration** & **Velocity** must be stored in two successive **Registers**.

Move Relative, Time Based (MRT)
Three parameters are entered - **Distance, Acceleration Time & Total Time**. This command makes doing time-critical profiles easy. When the desired time to make the move is fixed, using this command will cause SilverMax to make the move, no matter the distance (within limits), in the exact time specified. This is very useful when a number of different axes must be precisely coordinated in time.

Register Move Relative, Time Based (RRT)
Three parameters are entered – **Data Register, Acceleration Time & Total Time**. This combines the **RRV** and **MRT** types parameters together.

Extended Register Move Relative, Time Based (XRT)
One parameter is entered **–** the **Starting Data Register**. Only the **Distance** register location is sent as a parameter, the **Acceleration Time** and **Total Time** must be stored in two successive **Registers**.

“Absolute” Move Commands

Absolute Move commands will cause SilverMax to move to a specified position from its current position. This is different from the “Relative” commands that move a given distance rather than to a specific position. SilverMax keeps track of its current position (as indicated in counts) by continuously monitoring its **Internal Encoder**. When SilverMax moves, the current position is updated by the number of Encoder counts, negative or positive, encountered during the move. When a Move Absolute command is used, SilverMax calculates the number of counts (or distance) required to move to the specified position. If the position given in the command is the same as the current position, SilverMax will not move since it is already at the specified position. Using this command helps prevent over-travel when a command is sent twice by mistake. This command is also useful in setting up Registered positions that can be referenced from the **Dedicated or Data Registers.** Move Absolute commands come in following types.

Move Absolute, Velocity Based (MAV)
Three parameters are entered - **Position**, **Acceleration & Velocity**. This is the basic command type for absolute moves.

Register Move Absolute, Velocity Based (RAV)
Three parameters are entered – **Data Register, Acceleration & Velocity**. The **Data Register** parameter is the **Data Register** that is used to fill in the position value. The value entered in the **Data Register** remains in counts. The other parameters are the same as the **MAV** command. This command allows the user to modify the position value without having to change the command when used as part of a program.

Extended Register Move Absolute, Velocity Based (XAV)
One parameter is entered – the **Starting Data Register**. Only the **Position** register location is sent as a parameter, the **Acceleration** & **Velocity** must be stored in two successive **Data Registers**.

Move Absolute, Time Based (MAT)
Three parameters are entered - **Position, Acceleration Time & Total Time**. This command makes doing time critical profiles easy. When the desired time to make the move is fixed, using this command will cause SilverMax to make the move, no matter the position (within limits), in the exact time specified. This is very useful where a number of different axes must be precisely coordinated in time.

Register Move Absolute, Time Based (RAT)
Three parameters are entered **– Data Register, Acceleration Time & Total Time**. The Data Register specified holds the **Position** parameter. The other two parameters are the same as **MAT**.

Extended Register Move Absolute, Time Based (XAT)
One parameter is entered **–** The **Starting Data Register**. Only the **Position** register location is sent as a parameter, the **Acceleration Time** and **Total Time** must be stored in two successive **Data Registers**.

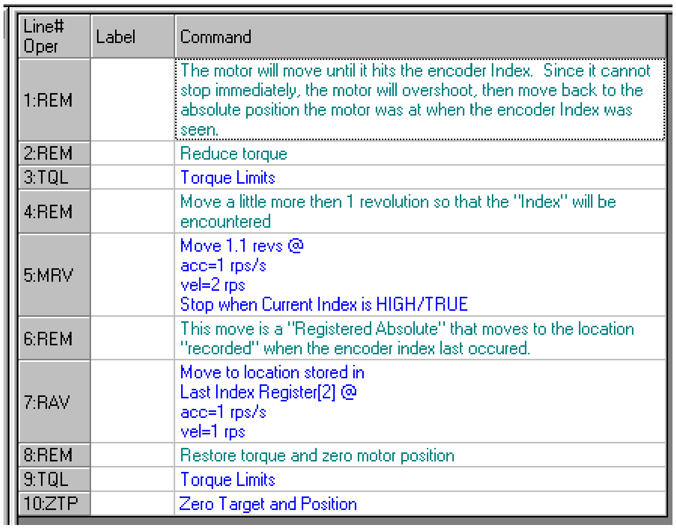
Moves Using Data Registers

A number of the **Standard Motion** commands can use data registers for their parameter information. This allows SilverMax (and the user) more flexibility in programming a Motion. The most common is when Motion commands are used as part of a program and the parameters need to change depending on operating conditions.

The **Example** at the Right shows a homing program that uses the **Internal Index** sensor to stop the motor at a precise once-per-revolution location. In this example line #7 uses a **Registered Move Absolute, Velocity Based (RAV)** command. The Data Register is set to #2 “Last Index”, which is the location of the motor the last time the Index was encountered. The previous move command allowed the motor to find the Index before it stopped.

The **RAV** command will cause the motor to move directly to the “Last Index” position without having to do any extra calculations.

Homing to Encoder Index.qcp



Line# Oper	Label	Command
1:REM		The motor will move until it hits the encoder Index. Since it cannot stop immediately, the motor will overshoot, then move back to the absolute position the motor was at when the encoder Index was seen.
2:REM		Reduce torque
3:TQL		Torque Limits
4:REM		Move a little more then 1 revolution so that the "Index" will be encountered

5:MRV		Move 1.1 revs @
		acc=1 rps/s
		vel=2 rps
		Stop when Current Index is HIGH/TRUE

6:REM		This move is a "Registered Absolute" that moves to the location "recorded" when the encoder index last occured.

7:RAV		Move to location stored in
		Last Index Register[2] @
		acc=1 rps/s
		vel=1 rps

8:REM		Restore torque and zero motor position
9:TQL		Torque Limits
10:ZTP		Zero Target and Position

SilverMax’s **Extended Register** Move commands give the user access to all of the move parameters as **Data Registers**. With this, not only the Position or Distance parameters can be changed outside the command; Acceleration and Velocity can also be modified as **Data Register** values. This gives the ability to modify these parameters based on system needs prior to their use in a program.

See **Profile Move** Commands in the SilverMax Command Reference for more information

Profile Moves

The "**Profile Move**" commands add a new dimension to SilverMax by allowing the move parameters to be changed on-the-fly. This gives the ability to create just about any shape of move that is required. **Profile Move** commands perform very complex profile shapes by allowing the move parameters to be changed dynamically. Move parameters (stored in "**Data Registers**") can be changed by an external **Host** controller or by an internal **program**.

Profile Move commands come in two flavors:

1. **Single Move**; using the **Profile Move** command where the command ends when the Position is reached.
2. **Continuous Move**; using **Profile Move** command where the command doesn't end when the position is reached. The Continuous Move puts SilverMax into a move that, even when at the Target Position, will move again when the **Position** parameter changes – there is no need to issue the move command again. The **Continuous Move** can be terminated with a **"Stop on Input"**, **Halt**, **Stop**, **Velocity Mode** or **Hard Stop Move** command.

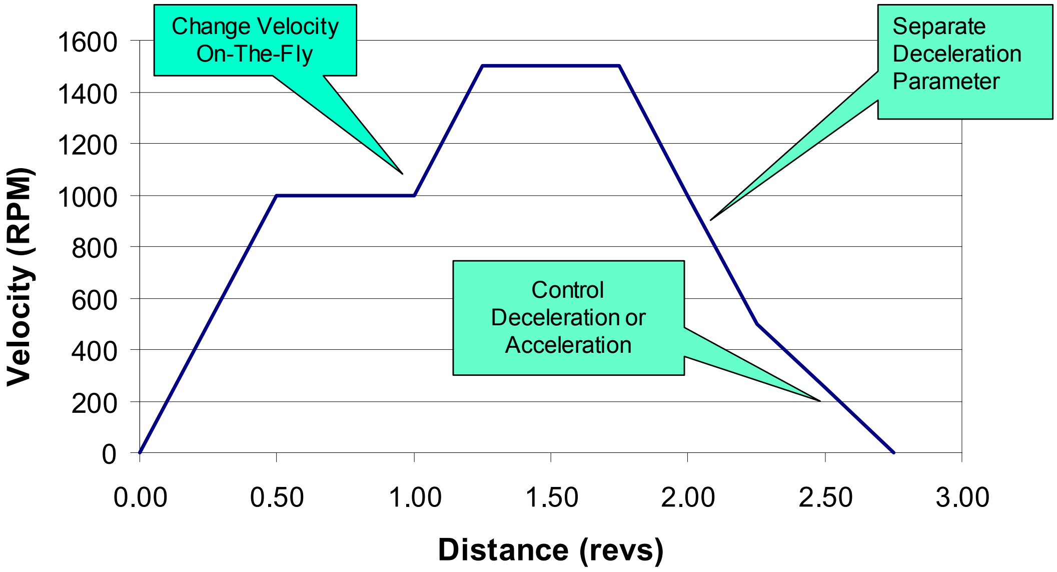
Added with these commands is a separate **Deceleration** parameter for providing different acceleration and deceleration profiles. Also added is an **Offset** parameter, which causes SilverMax to move an "offset" distance after a "Stop on Input" condition is met.

Profile Move commands use **ONLY Linear** acceleration and deceleration.

All **Profile Move** commands use **Data Registers** for parameter storage. The Profile Move commands use five parameters stored in registers #20 to #24 for all moves:

- **Position** (Data Register #20)
- **Acceleration** (Data Register #21)
- **Velocity** (Data Register #22)
- **Deceleration** (Data Register #23)
- **Offset** (Data Register #24)

Advanced Dynamic Motion Control !



Velocity Mode Control

From a **Host Controller** or using an internal **program**, **Velocity** profiles can be created on SilverMax using the **Velocity Mode, Immediate Type** command (Host Controller) or the **Velocity Mode, program Type** (Internal program) that will allow changes in velocity at desired time intervals. This allows the creation of a complex shaped profile where different velocities are required at different times during the move. In this mode distances **cannot** be controlled precisely, therefore other operations such as a final **MOVE ABSOLUTE** command must be used for precise positioning. (Use the **Profile Move** commands for complex position control)

Velocity control can be set so that the SilverMax runs at a constant velocity for an indefinite period of time. The **ERROR LIMITS** command may be used in conjunction with this command to prevent excessive wind-up under conditions where the velocity cannot be maintained. (See **Error Limits** Command for more details; also see **Drag Operation** below)

Torque Control (Using Velocity Mode)

The Torque value can be set for the desired amount under all types of move commands. If a pure torque mode is required, the **Velocity Mode** commands can be set so that the SilverMax will attempt to run at desired maximum speed (Full speed = 4000 RPM). The **ERROR LIMITS** command must be used as mentioned above to prevent excessive wind-up. Torque can then be set using the **Torque Limits** command to a desired value giving a constant torque output on the motor shaft.

External Trajectory Control

If the need arises for external control of a motion profile SilverMax can be placed in optional modes which will accept external control input.

Scaled Step and Direction (Electronic Gearing)

Step and Direction mode allows input of external signals that can be designed to provide the desired motion control profiles. In this mode, two digital input lines are used to input a step pulse and direction state into the SilverMax (A/B Quadrature is also allowed). SilverMax has an internal counter that keeps track of the number of step pulses. If the direction state is a "1", the counter counts up; if the state is a "0", the counter counts down. Every 120us SilverMax checks the counter value and updates its target value with the latest counter value. In this way SilverMax tracks the step count so that its position will match the desired count. A scaling factor allows the user to scale the input pulses by multiplying or dividing the input pulses. The input can be multiplied by up to 32 times or divided by up to 1024.

Position Input Mode

When the **Position Input Mode (PIM)** command is used, SilverMax will take **Target** (desired position) information from a predefined **Data Register** and track the value contained in it. This is done every servo cycle (120 usec.) providing an 8K Hz update rate.

The **Target Register** can be loaded from many sources, including the **Serial Interface** or the **Analog Inputs**. Using the Serial Interface a Host controller can "stream" **Target** information to the SilverMax using the **Write Register, Immediate Type (WRI)** command. The Serial Interface can run at a BAUD rate of up to 230K bits per second which allows sending new data at approximately 500 times per second. (This assumes continuous data feed to the Serial Interface).

Using the **Analog Inputs,** an Analog signal can be used to send the Target information to the predefined Data Register. The Analog Input is converted using an **Analog to Digital Converter (ADC)** to a 10-Bit digital number. The number is filtered to eliminate "noise", then scaled to a 16-Bit value and placed in the Data Register. This is done at the 8K Hz update rate of the servo system. (See **ANALOG CONTINUOUS READ** command for more information)

Both Input sources are put through a data processing algorithm to allow Offsetting, Limiting and Scaling of the data source. (See **Using Input Modes** in the **SilverMax Command Reference** for more information)

Velocity and Torque Input Modes

The **Velocity Input Mode (VIM)** and **Torque Input Mode (TIM)** commands use the same input sources and techniques as the **Position Input Mode (PIM). VIM** and **TIM** will use the **Target Register** for "**Velocity"** and "**Torque**" respectively.

USING INPUTS TO STOP MOTIONS

Commands that use inputs to stop their operation can use a Standard or Advanced process in detecting desired input stop conditions. Eight Digital Inputs are available for evaluation. One of the inputs is a dedicated internal input that is tied to the **Internal Encoder** Index sensor. The index sensor is able to detect a single count position out of the 4000 in one revolution (one count in one revolution). This input is referred to as the "Index". The other seven inputs are user configurable. These inputs can be **Home** sensors, **End of Travel** sensors or even digital inputs from a PLC or Master Controller. Whatever the inputs are, they can be used either alone or together to affect the operation of the motion commands. The following shows the process that is used for sensor detection and utilization.

SilverMax commands can be entered in either their native form or from QuickControl. The native form is required when commanding the SilverMax from a host controller such as a PC or PLC. QuickControl would be used for any stand alone application. Both interfaces are described below.

Standard Usage – Native SilverMax

All eight Digital Inputs plus a few internal conditions are available with Standard usage. Input checking is done on only **ONE** selected input

By using a negative number in the **Stop Enable** parameter, the motion commands can look at a single Digital Input or Internal Status Condition to stop a motion. This is the simplest usage for stopping on Input. The following is a list of possible inputs.

Stop Enable Code	Input Source	Description
0		Do not Check for Input
-1	Hardware	I/O #1
-2	"	I/O #2
-3	"	I/O #3
-4	"	I/O #4
-5	"	I/O #5
-6	"	I/O #6
-7	"	I/O #7
-8	"	Current Index Sensor – (Future implementation, use –9 or –10)
-9	"	Internal Index Sensor
-10	"	External Index Sensor
-11	Internal Status	Moving Error Status
-12	"	Holding Error Status
-13	"	Trajectory Generator Active
-14	"	Delay Counter Active

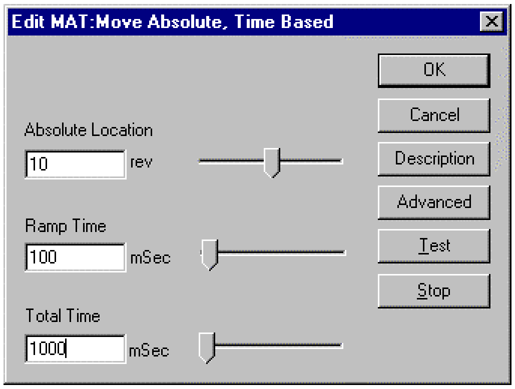
The **Stop State** is set as follows:

Stop State	Description Stop When Stop Enable Condition is
0	FALSE
1	TRUE
2	FALLING (TRUE to FALSE Transition)
3	RISING (FALSE to TRUE Transition)

The value entered is used to evaluate the "TRUE" condition for stopping. If, for example, a motion needs to stop with input #4 in logic high (+5 volts on input) a "1" should be used for the **Stop State**.

Standard Usage – QuickControl

The stop conditions for any move can be edited by pressing the **Advanced** button on the move. For example, to edit the following command, press **Advanced**.



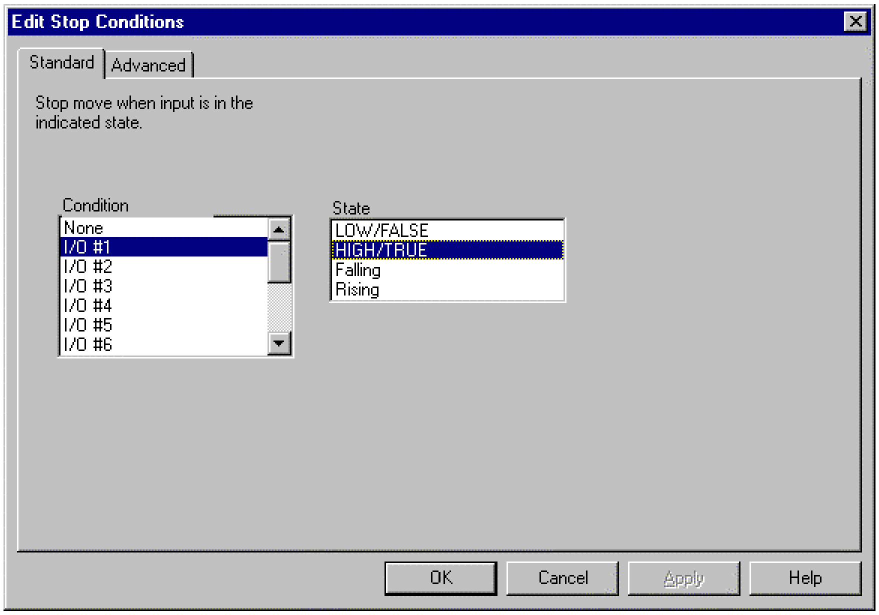
Edit MAT:Move Absolute, Time Based

Absolute Location: 10 rev

Ramp Time: 100 mSec

Total Time: 1000 mSec

The Stop Enable Condition and Stop State are selected from the following screen.



Edit Stop Conditions

Stop move when input is in the indicated state.

Condition: None, I/O #1 (selected), I/O #2, I/O #3, I/O #4, I/O #5, I/O #6

State: LOW/FALSE, HIGH/TRUE (selected), Falling, Rising

Advanced Usage – Native SilverMax

Only four inputs are available with the Advanced usage. The **Index** and **I/O lines #1, #2 and #3**.

Advanced usage is for the times when complex stopping using inputs is required. The advanced method can alter the direction of a move based on an input's starting condition, toggle the "State" values that are being checked and evaluate combinations of input conditions.

A NOTE for **QuickControl** Users: Using the "Programming" interface, the motion Stop conditions can easily be set up using the "Motion Command" setup screens.

Input Checking Process for Motion Commands

First Check (Used to toggle the starting direction of motor)
The upper nibble of the Input Enable Word and Input State Word parameters are used to determine the initial direction of a move based on the selected states of the selected inputs. If any of the selected input conditions are TRUE, the motor will move in the opposite direction indicated in the command. Additionally, if the **Toggle first state** bit is set, the bits representing the desired input that were enabled in the **Input Enable Word** will cause the corresponding bits in the **Input State Word** of the **Preliminary inputs** to be complemented. This allows the motor to look for the opposite edge of a sensor flag if that flag is already activated. A similar operation is performed to the **Input State Word** bits corresponding to the **OR inputs** if the **Toggle Or State** bit is set.

Second Check (Used to do a Two-State input check)
The Second Check does a preliminary test of the inputs. If the **Preliminary** inputs are enabled, the Input conditions must be TRUE for the input checking process to continue. This allows a motion to find a "Two-State" condition of the inputs. This would be useful, for example, in a motor homing routine to first find a sensor covered and then wait for it to be uncovered. If the input conditions are not met at this check, the checking process will not continue and the motion will not be stopped.

Last Check (This may now stop the motor)
The last check can do two different things. The most common is to stop the motor and record the motor position when an input TRUE condition is detected. The second is to just record the motor position. Two different checks are done at this time, the **AND** conditions and the **OR** conditions. These two checks may be used together for stopping a motion while the **AND** condition is used alone for motor position recording.

Stopping a Motion on Input

The **AND** and the **OR** conditions are used together in order to stop the motion. The following are rules for usage.

1. If the **AND** inputs are disabled, only the **OR** inputs are used.

2. If both the **AND** and the **OR** inputs are disabled, motions cannot be stopped using inputs.

3. If the **AND** inputs are used, both the **AND** condition and the **OR** condition must be TRUE to stop the motion.

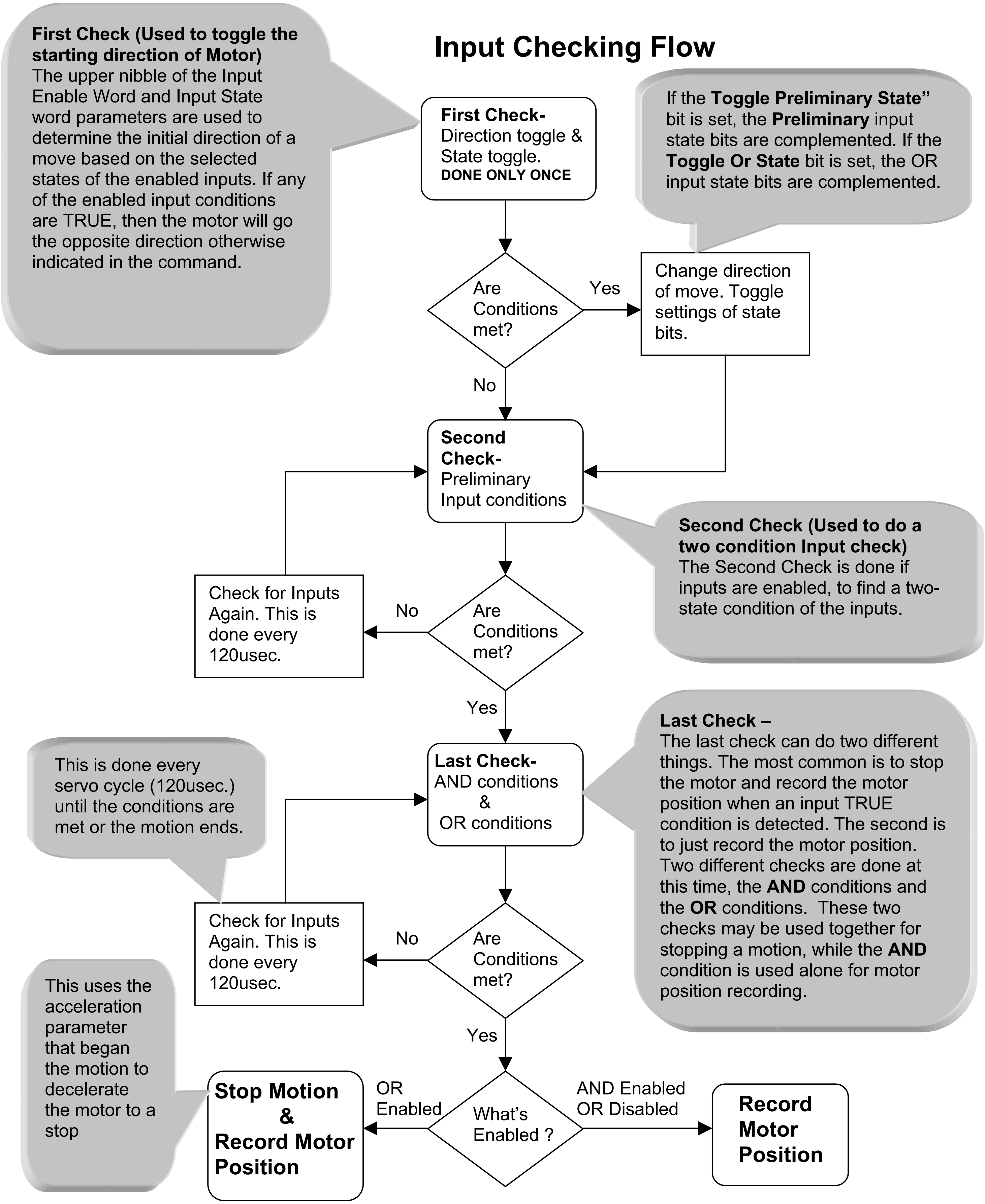
When rule number 3 is used, the inputs are logically “anded” to each other and then tested for TRUE. If the input conditions are met, the motor shaft position when the input condition became TRUE is stored to the **Sensor Found - Data Register** and the **Sensor Found Bit** is set in the **Internal Status Word**. The move underway is set to decelerate to zero using the acceleration parameters that began the motion.

Recording Sensor Found Position

If the **OR** inputs are disabled and the **AND** inputs are enabled, only the motor position will be recorded. When the **AND** input conditions become TRUE, the current motor position is stored to the **Sensor Found - Data Register** and the motion is allowed to continue. T he **Sensor Found** status bit in the **Internal Status Word** is also set.

NOTE: **Stop Enable Word** and the **Stop State Word** processing is the same for all **Motion Profile Commands**.

Input Checking Flow



First Check (Used to toggle the starting direction of Motor)
The upper nibble of the Input Enable Word and Input State word parameters are used to determine the initial direction of a move based on the selected states of the enabled inputs. If any of the enabled input conditions are TRUE, then the motor will go the opposite direction otherwise indicated in the command.

If the **Toggle Preliminary State”** bit is set, the **Preliminary** input state bits are complemented. If the **Toggle Or State** bit is set, the OR input state bits are complemented.

Second Check (Used to do a two condition Input check)
The Second Check is done if inputs are enabled, to find a two-state condition of the inputs.

Last Check –
The last check can do two different things. The most common is to stop the motor and record the motor position when an input TRUE condition is detected. The second is to just record the motor position. Two different checks are done at this time, the **AND** conditions and the **OR** conditions. These two checks may be used together for stopping a motion, while the **AND** condition is used alone for motor position recording.

This is done every servo cycle (120usec.) until the conditions are met or the motion ends.

This uses the acceleration parameter that began the motion to decelerate the motor to a stop

First Check- Direction toggle & State toggle. DONE ONLY ONCE
Are Conditions met?
Yes
Change direction of move. Toggle settings of state bits.
No
Second Check- Preliminary Input conditions
No
Check for Inputs Again. This is done every 120usec.
Are Conditions met?
Yes
Last Check- AND conditions & OR conditions
No
Check for Inputs Again. This is done every 120usec.
Are Conditions met?
Yes
What’s Enabled ?
OR Enabled
Stop Motion & Record Motor Position
AND Enabled OR Disabled
Record Motor Position

Motion Profile Input Options Table

Last Check Process	Bit # in word	Stop Enables Word	Stop States Word
First Check			
State Toggle Bit 15 in both words is used to toggle the states of the Preliminary and OR conditions. This happens if Direction toggle conditions are TRUE	Bit 15	Toggle Preliminary States Set this bit to toggle Preliminary input state bits	Toggle OR States Set this bit to toggle OR input state bits
Direction Toggle Conditions These three bits are used to toggle direction before the motor begins to move. If any condition is TRUE the motor will reverse direction.	Bit 14	Input #3 enabled	Input #3 State
	Bit 13	Input #2 enabled	Input #2 State
	Bit 12	Input #1 enabled	Input #1 State
Second Check			
Preliminary Conditions This is the next condition, it is now checked every cycle. This is used so that a sensor can be checked for Two-State conditions	Bit 11	Index enabled	"1" if index is enabled
	Bit 10	Input #3 enabled	Input #3 State
	Bit 9	Input #2 enabled	Input #2 State
	Bit 8	Input #1 enabled	Input #1 State
If the Preliminary conditions are not met checking stops here			
Last Check – Final conditions:			
AND Conditions This will now allow you to check for sensors that are to be ANDed with the OR conditions. Normally all sensors are ORed with each other	Bit 7	Index enabled	"1" if index is enabled
	Bit 6	Input #3 enabled	Input #3 State
	Bit 5	Input #2 enabled	Input #2 State
	Bit 4	Input #1 enabled	Input #1 State
OR Conditions These conditions are all ORed together for the final check.	Bit 3	Index enabled	"1" if index is enabled
	Bit 2	Input #3 enabled	Input #3 State
	Bit 1	Input #2 enabled	Input #2 State
	Bit 0	Input #1 enabled	Input #1 State
If the Final conditions are met the motor will STOP			

How to Create the Input Values (Native SilverMax only)

The input values that are used as parameters in a motion command take a little work to create. Inside SilverMax, the values are used in Binary form. In this case, both values are used as a 16 bit binary word. Each of the bits is evaluated individually to determine how the inputs will be used to control a motion.

The table above shows the meaning of each bit in the word. The user must first decide which bits need to be set and to what value. Setting a bit to “1” either Enables a function or sets the desired State value to a logic high (+5 volts on the input). Setting a bit to “0” disables a function or sets the desired State value to logic low (0 volts on the input).

The table below shows settings for the State word that will toggle the **OR** states and the move **direction** if Input #1 is logic high (“1”) at the beginning of a motion. It also shows the state value of the OR input #1 (logic high “1”) that would be used to stop the motion.

Toggle OR States	Direction Toggle **State**			Preliminary Inputs **State**				AND Inputs **State**				OR Inputs **State**			
Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
1	0	0	**1**	0	0	0	0	0	0	0	0	0	0	0	**1**

Binary Word = 1001000000000001

After the table is filled out, the next step is to convert the Binary number into a Hexadecimal number. We do this by first grouping the Binary values into sets of 4, this is call a “Nibble”. In Hexadecimal, a Nibble can represent a value of 0 to 15. The letters A, B, C, D, E, F are used in place of 10, 11, 12, 13, 14, 15. This gives a numbering system as shown in the following set:

{0,1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E, F}

Binary Nibbles are converted to a number by adding up the value of each binary digit. The table below shows the value of each bit in a nibble. If a bit is set to “1” its associated value is added into the nibble. Remember to convert the numbers 10 – 15 to A – F for Hexadecimal notation.

Bit Values	**8**	4	2	**1**	8	4	2	1	8	4	2	1	8	4	2	**1**
Binary word	**1**	0	0	**1**	0	0	0	0	0	0	0	0	0	0	0	**1**
Nibbles	**9**				0				0				**1**			

The nibbles are now joined together to form the Hexadecimal word.

Nibbles	9	0	0	1
Hexadecimal Word	9001			

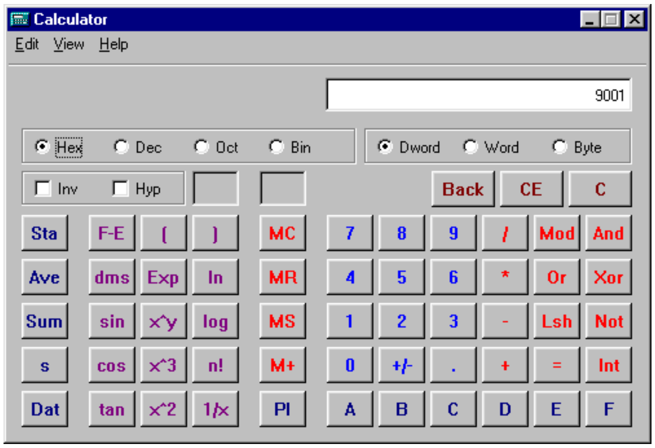
When working in Hexadecimal programmers use a “0x” notation at the beginning of the number to identify it as Hexadecimal. T his avoids any confusion as to the base system of the number.

Hexadecimal Word = 0x9001

Hexadecimal is great for programmers who are writing software in Basic, Visual Basic, C or C++, but for those who are trying to put together ASCII strings on a PLC or other simple controller the number needs to be converted to Decimal. The easiest way to do this is to use the Scientific Calculator application in Windows 95 or Windows NT. The “Calculator” is found in “Programs”/ “Accessories” from the “Start” menu.

If the calculator does not look like the one at the right, go to the “View” menu and change it to “Scientific”.

Put the calculator into “Hex” input mode by clicking the “Hex” button. Now enter the Hexadecimal number into the calculator. (A to F is used in Hex mode)



Calculator

9001

● Hex ○ Dec ○ Oct ○ Bin

● Dword ○ Word ○ Byte

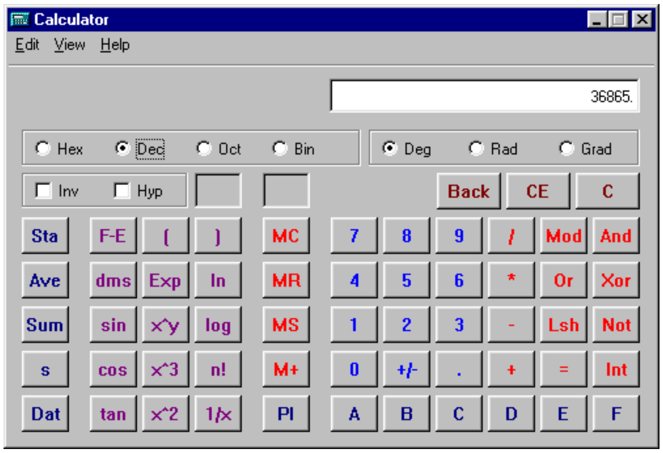
□ Inv □ Hyp

Edit View Help
Back CE C
Sta F-E ( ) MC 7 8 9 / Mod And
Ave dms Exp ln MR 4 5 6 * Or Xor
Sum sin x^y log MS 1 2 3 - Lsh Not
s cos x^3 n! M+ 0 +/- . + = Int
Dat tan x^2 1/x PI A B C D E F

The Hexadecimal number can now be converted to Decimal by simply clicking the “Dec” button.

Decimal Number = 36865

This number can now be used in an ASCII string.



Calculator

36865.

○ Hex ● Dec ○ Oct ○ Bin

● Deg ○ Rad ○ Grad

□ Inv □ Hyp

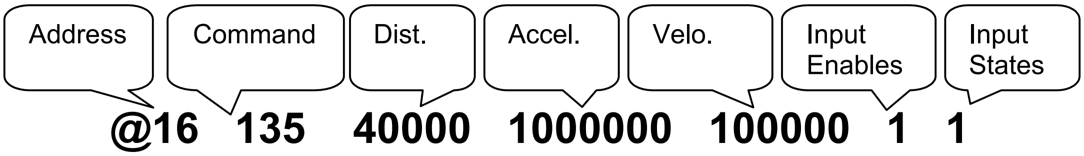
Edit View Help
Back CE C
Sta F-E ( ) MC 7 8 9 / Mod And
Ave dms Exp ln MR 4 5 6 * Or Xor
Sum sin x^y log MS 1 2 3 - Lsh Not
s cos x^3 n! M+ 0 +/- . + = Int
Dat tan x^2 1/x PI A B C D E F

Using Inputs Examples

Basic Stop on Input

This example shows a **MOVE RELATIVE, VELOCITY BASED** move that stops using input #1. In this example the motor will spin at least 10 revolutions looking for an input. If the input occurs before the distance is reached the motion will stop. A point to remember is that when the input condition is met this begins the deceleration of the motor. The position that is actually reached will be the deceleration distance that was required to stop the motion. Slower deceleration rates (set by the Acceleration parameter) will cause greater stopping distances from the edge of detection.

The Command example is shown in the 8-bit ASCII protocol form.



@16 135 40000 1000000 100000 1 1

The table below shows how the value of “1” was derived:

Toggle “Pre” States	Direction Toggle **Enable**			Preliminary Inputs **Enable**				AND Inputs **Enable**				OR Inputs **Enable**			
Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**
0				0				0				**1**			

Input Enable Word = 0x0001 in “Word Hexadecimal” form
Hexadecimal 0x0001 = 1 Decimal
Input Enable Word = “1” in “Decimal” form

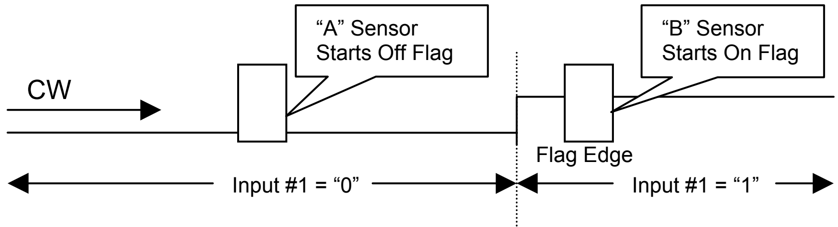
The table below shows how the value of “1” was derived:

Toggle OR States	Direction Toggle **State**			Preliminary Inputs **State**				AND Inputs **State**				OR Inputs **State**			
Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**
0				0				0				**1**			

Input State Word = 0x0001 in “Word Hexadecimal” form
Hexadecimal 0x0001 = 1 Decimal
Input State Word = “1” in “Decimal” form

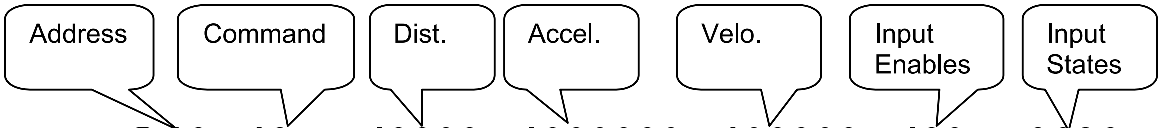
Change Direction and Stop on Input

This example shows a **MOVE RELATIVE, VELOCITY BASED** move that will change the direction of the move based on the beginning condition of input #1, the motion will then be stopped using the same input #1.



The **A** scenario will move the motor clockwise to the "Flag" edge and then stop. In scenario **B** the motor will move counter-clockwise and then stop at the "Flag" edge. The **B** scenario causes the motor to reverse direction before the move and toggles the **State** of the **OR** input #1. Toggling the **State** of input #1 allows the motor to stop when the sensor moves off of the flag.

The Command example is shown in the 8-bit ASCII protocol form.



@16 135 40000 1000000 100000 4097 36865

The table below shows how the value of "4097" was derived:

Toggle "Pre" States	Direction Toggle **Enable**			Preliminary Inputs **Enable**				AND Inputs **Enable**				OR Inputs **Enable**			
Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	0	0	**1**	0	0	0	0	0	0	0	0	0	0	0	**1**
1				0				0				**1**			

Input Enable Word = 0x1001 in "Word Hexadecimal" form
Hexadecimal 0x1001 = 4097 Decimal
Input Enable Word = "4097" in "Decimal" form

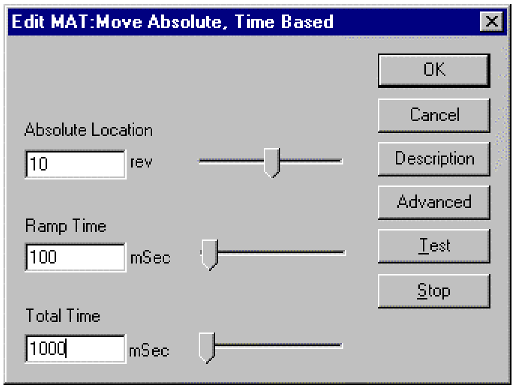
The table below shows how the value of "36865" was derived

Toggle OR States	Direction Toggle **State**			Preliminary Inputs **State**				AND Inputs **State**				OR Inputs **State**			
Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
1	0	0	**1**	0	0	0	0	0	0	0	0	0	0	0	**1**
9				0				0				**1**			

Input State Word = 0x9001 in "Word Hexadecimal" form
Hexadecimal 0x9001 = 36865 Decimal
Input State Word = "36865" in "Decimal" form

Advanced Usage – QuickControl

The stop conditions for any move can be edited by pressing the **Advanced** button on the move. For example, to edit the following command, press **Advanced**.



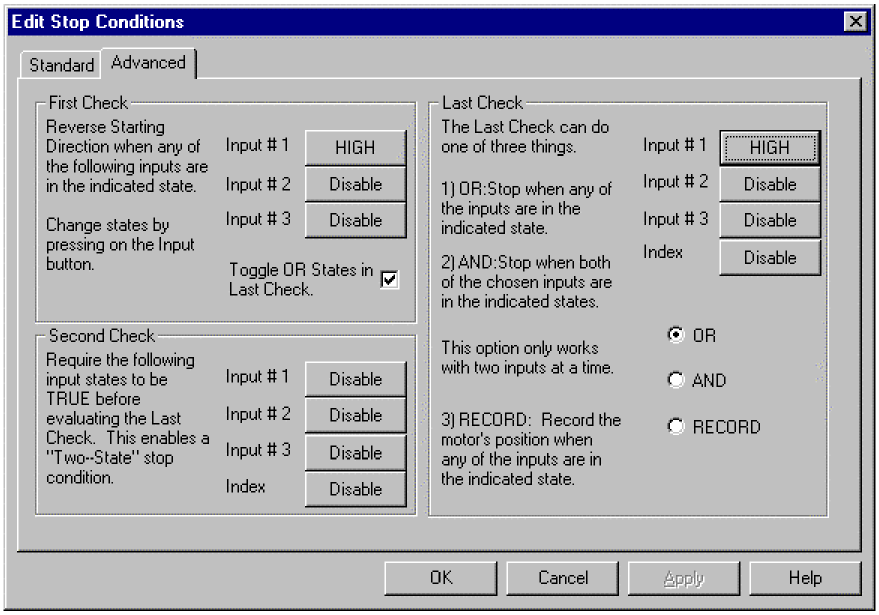
Edit MAT:Move Absolute, Time Based

Absolute Location: 10 rev

Ramp Time: 100 mSec

Total Time: 1000 mSec

Press the **Advanced** tab to edit the Advanced stop conditions. The above **Change Direction and Stop on Input** example above would be as follows.



Edit Stop Conditions

First Check

Reverse Starting Direction when any of the following inputs are in the indicated state.

Change states by pressing on the Input button.

Input # 1: HIGH

Input # 2: Disable

Input # 3: Disable

Toggle OR States in Last Check. ☑

Second Check

Require the following input states to be TRUE before evaluating the Last Check. This enables a "Two-State" stop condition.

Input # 1: Disable

Input # 2: Disable

Input # 3: Disable

Index: Disable

Last Check

The Last Check can do one of three things.

1) OR:Stop when any of the inputs are in the indicated state.

2) AND:Stop when both of the chosen inputs are in the indicated states.

This option only works with two inputs at a time.

3) RECORD: Record the motor's position when any of the inputs are in the indicated state.

Input # 1: HIGH

Input # 2: Disable

Input # 3: Disable

Index: Disable

● OR

○ AND

○ RECORD

USING THE DIGITAL I/O

SilverMax has seven fully programmable digital I/O lines. Each line is software configurable to be a digital input, a digital output, or dedicated to a special function. The configuration can be done “on the fly”. Digital outputs can be configured for tri-state mode, allowing the lines to be used as both an output and an input at the same time.

In addition to the digital I/O, SilverMax accepts four analog inputs. The four analog inputs share four digital I/O lines and will accept a voltage range 0 to +5 volts. Analog inputs can be used for control of the motor’s position, velocity, torque or other software programmable operations.

Using a variety of dedicated modes, the Digital I/O lines can accept external encoder input for electronic gearing or camming operations. Inputs can be Step and Direction, A/B quadrature or Step up/down. An external encoder input is provided for dual control loops that enable position control of external mechanisms using a second encoder. The E series can also output Step and Direction, A/B quadrature or Step up/down from its internal encoder.

Below is a table showing the available Digital Input and Output functions

SilverMax E Series I/O Configuration Table

	Input Functions						Output Functions				
	1	2	3	4	5	6	7	8	9	10	11
I/O Bits	Conditional Motion (Stop On Input)	Program Flow	Kill Motor Inputs	Step & Dir. Input	Analog Input	External Encoder Input	Output Set/ Clear	General Output	Encoder Output	Modulo Output	Done Status
I/O #1	X	X	X				X	X	"A"		X
I/O #2	X	X	X	Step		Index (alt)		X	"B"		
I/O #3	X	X	X	Dir.				X	Index		
I/O #4	X	X			X	"A" ∗		X			
I/O #5	X	X			X	"B" ∗		X			
I/O #6	X	X			X	Index		X		“A”∗	
I/O #7	X	X			X			X		“B”∗	
Encoder Index	X	X	X								

∗ Indicates I/O that can be configured in one of three ways:

1 – A & B Quadrature
2 – Step Up & Step Down
3 – Step & Direction

NOTES: Alternate I/O selections are indicated with “alt”. Alternate I/O is selected using configuration commands.

I/O #4, #5, #6 or #7 must be configured for “input” when using analog signals on the input pins.

Input & Output Functions

Inputs	Description	Associated Commands
Conditional Motion	Used to cause a motion to ramp down and stop. May also be used for changing the move direction. All inputs can be used in "Standard" mode by using a negative number for the I/O line selections	• **"ALL MOTION COMMANDS"** • **VELOCITY MODE, PROGRAM TYPE (VMP)** • **Velocity Mode, Immediate Type (VMI)** • **"ALL INPUT MODE COMMANDS"**
Program Flow	All inputs can be used for conditional branching. The inputs can be decoded such that many conditional branches can be taken using only a few inputs. For example three inputs can be decoded to command SilverMax to run 1 of 7 programs	• **"ALL JUMP COMMANDS"** • **"All PROGRAM CALL AND RETURN COMMANDS"** • **WAIT ON BIT STATE (WBE)** • **WAIT ON BIT EDGE (WBS)**
Kill Motor	Inputs to the Internal Status Word may be enabled in the "Kill Motor" command to cause the motion system to shut down and execute an error routine.	• **KILL MOTOR CONDITIONS (KMC)**
Step & Direction	SilverMax can input Step and Direction signals in a number of different forms. The Step and Direction input is designed to be scalable with a maximum multiplier of 32 and a maximum divisor of 1024.	• **SCALED STEP & DIRECTION (SSD)** • **REGISTERED STEP & DIRECTION (RSD)** • **SELECT EXTERNAL ENCODER (SEE)**
Analog Inputs	Inputs may be used for internal Analog to Digital for conversion. Analog signals can control Velocity, Position or Torque.	• **ANALOG CONTINUOUS READ (ACR)** • **ANALOG READ INPUT (ARI)** • **"ALL INPUT MODE COMMANDS"**
External Encoder	The external encoder input gives the user greater flexibility for inputting digital signals. When using the "Step and Direction" commands the external encoder input gives a variety of input styles.	• **SELECT EXTERNAL ENCODER (SEE)** • **DUAL LOOP CONTROL (DLC)**

Outputs	Description	Associated Commands
Output Set/Clear I/O #1	This is a "left over" from the original SilverMax design and is available for Legacy designs. It should not be used when implementing a new "E" Series design.	• **CONFIGURE I/O (CIO)** • **ENABLE ENCODER MONITOR (EEM)**
General Output	Allows I/O lines to be set high ("1") or low ("0") if enabled.	• **CONFIGURE I/O (CIO)** • **SET OUTPUT BIT (SOB)** • **CLEAR OUTPUT BIT (COB)**
Encoder Output	Outputs the Internal Encoder signals.	• **ENABLE ENCODER MONITOR (EEM)** • **DISABLE ENCODER MONITOR (DEM)**
Modulo Output	Divided down output of the Internal Encoder or External Encoder used for an output to other devices.	• **MODULO SET (MDS)** • **MODULO CLEAR (MDC)** • **MODULO TRIGGER (MDT)**
Done Status	A program or Single command has completed and motion is within the indicated error limits	• **ENABLE DONE BIT (EDB)** • **DISABLE DONE BIT (DDB)**

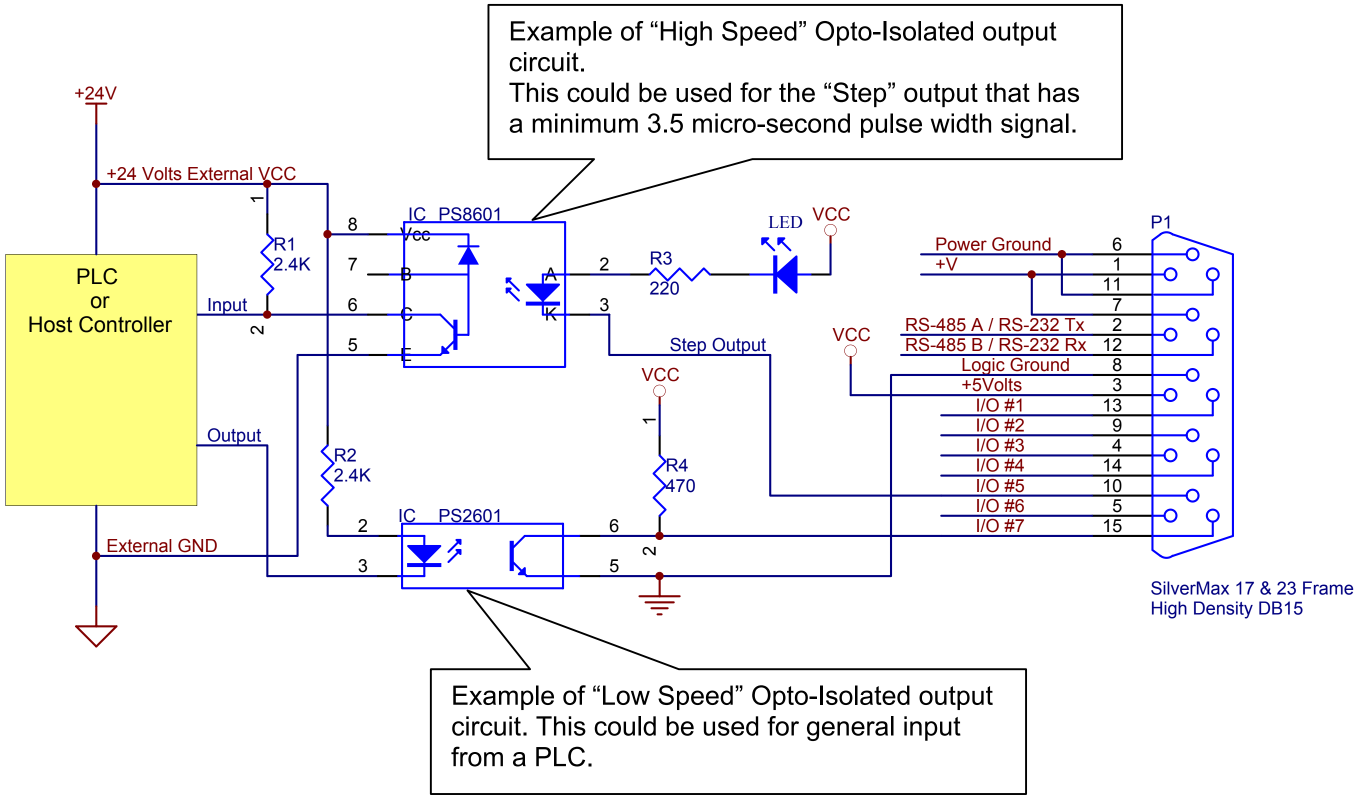
NOTE: Some I/O functions are not compatible. SilverMax will indicate a command error in the **Polling Status Word** when incompatible modes are attempted. (See **I/O Conflicts** below) All I/O is doubly protected with parallel **MOV** clamping followed by series over-voltage limiting to protect the internal circuitry.

See **CONFIGURE I/O (CIO), SET OUTPUT BIT (SOB)** & **CLEAR OUTPUT BIT (COB)** commands

Basic Digital Inputs & Outputs

The digital Inputs and Outputs on SilverMax are “TTL” level with no optical isolation. TTL level signals are 0 to +5 volts with low current drive capability. I/O lines are over-voltage and ESD protected to prevent failure from improper connections.

- All seven I/O lines can be configured for Input or Output.
- When in Output configuration the I/O lines can both “Source” and “Sink” 8 milliamps of current.
- I/O lines #1, #2 & #3 are internally pulled up to +5 volts using a 4.7K ohm resistor.
- I/O lines #4 through #7 are internally pulled up to +5 volts using a 220 K ohm resistor. When used as Input I/O lines #4 through #7 may require lower value resistor pull-ups to reduce possible noise issues.
- All special I/O modes have the same output drive and input constraints.
- Some special purpose outputs such as “Step & Direction” require high speed circuitry.
- A +5 Volt 100ma power supply is available from the motor to power optical, proximity or Hall effect switches.


Example of “High Speed” Opto-Isolated output circuit.
This could be used for the “Step” output that has a minimum 3.5 micro-second pulse width signal.

Example of “Low Speed” Opto-Isolated output circuit. This could be used for general input from a PLC.

`

Use the **CONFIGURE I/O** command to set I/O line to Input or Output mode. Use the **SET OUTPUT BIT** command to set an I/O line High (“1”) , use **CLEAR OUTPUT BIT** command to clear an I/O line to Low (“0”).

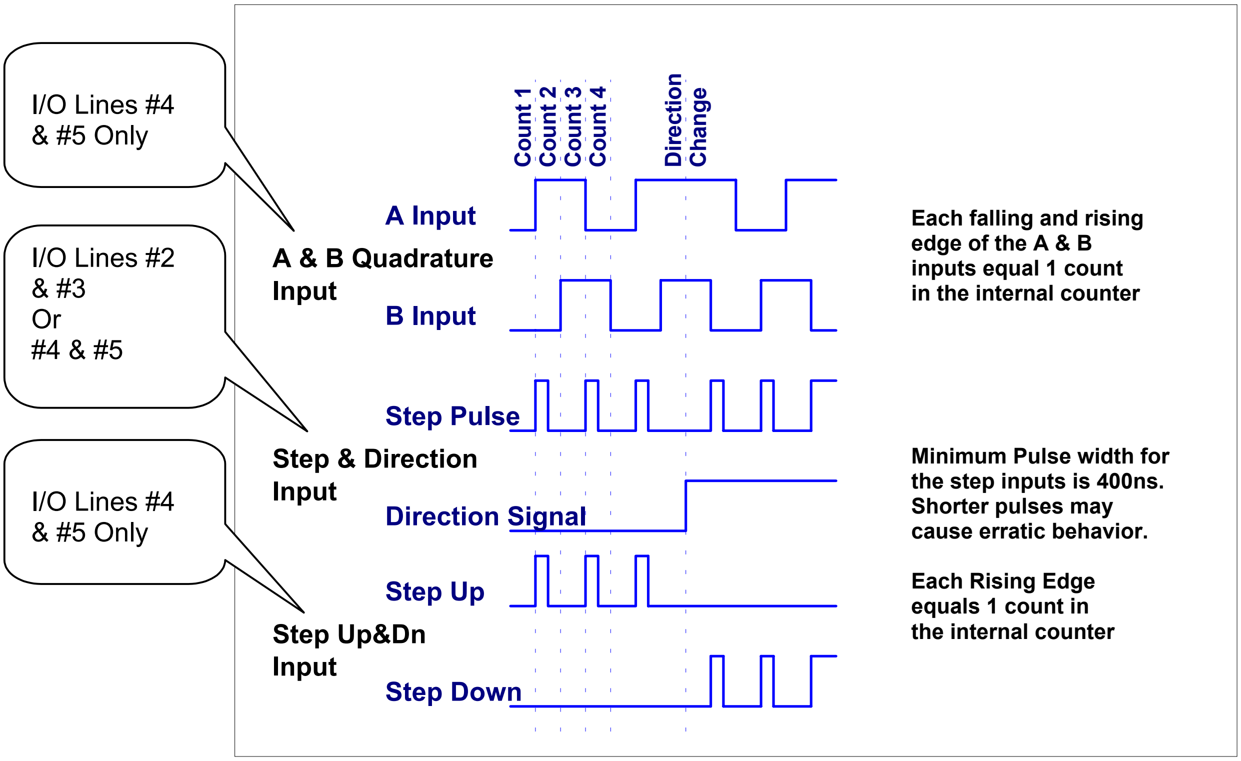
See **SCALED STEP AND DIRECTION** &
SELECT EXTERNAL ENCODER (SEE)

Step & Direction Input (Encoder Input)

SilverMax can input Step and Direction signals in a number of different forms. The Step and Direction input is designed to be a scalable mode with a maximum multiplier of 32 and a maximum divisor of 1024.

The inputs for Step and Direction can be one of three different types: A/B quadrature(Encoder Direct), Step and Direction or Step up/down. I/O lines #2 & #3 or Lines #4 & #5 are used for input.

Examples of the three different Input types



Each falling and rising edge of the A & B inputs equal 1 count in the internal counter

Minimum Pulse width for the step inputs is 400ns. Shorter pulses may cause erratic behavior.

Each Rising Edge equals 1 count in the internal counter

Each step input causes an internal counter in the SilverMax to increment or decrement depending on the "Direction". The internal counter is scaled to provide the "Electronic Gearing" ratios. The **Scaled Step and Direction** command uses the Step and Direction inputs.

See **MODULE SET (MDS)**, **MODULO CLEAR (MDC)**, **MODULO TRIGGER (MDT)** & **SELECT EXTERNAL ENCODER (SEE)**

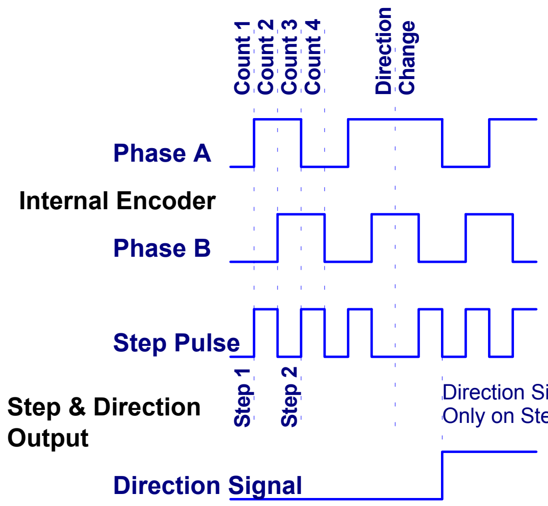
Step & Direction Output (Modulo Output)

Step and Direction output works slightly different than the input. The **Modulo** commands are used to output Step and Direction from the motor. Using the **Modulo** commands the output can be scaled down (1 to 256) from the **Internal Encoder** or from an **External Encoder**. When the output is **Step & Direction** or **Step Up & Step Down** the step pulse rate is always one half the **Encoder Count** rate with a modulo of “1”. The Step and Direction outputs are found on I/O lines #6 & #7.

Step & Direction:
Output provides a 50% duty cycle “Pulse” for the **Step Pulse** output. This gives a minimum pulse width of 3.75 micro seconds at the maximum speed of 4000 RPM.

The SilverMax **Internal Encoder** puts out 4000 counts per revolution. With a modulo of “1” the maximum pulse count is 2000 pulses per revolution.

The **Direction signal** changes state depending on the direction that the Encoder is moving. The Direction signal can change only on the falling edge of the Step pulse.

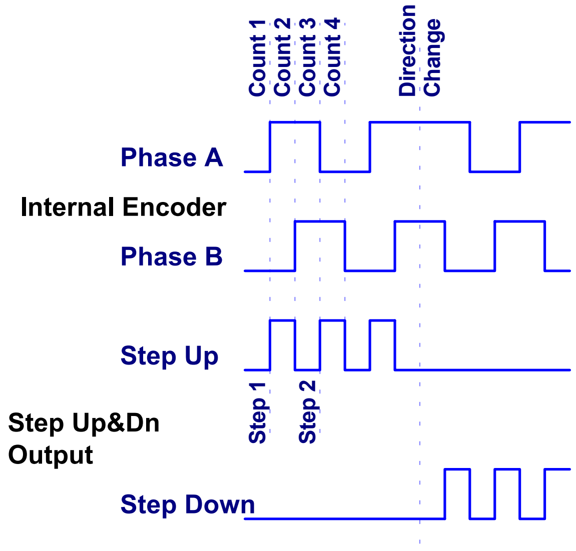


Step & Direction Output mode

Step Pulse changes state with each edge of Phase A or Phase B.

This causes the Step rate to be one half the count rate.

2 Counts = 1 Step



Step Up & Step Down Output mode

Step Pulse changes state with each edge of Phase A or Phase B.

This causes the Step rate to be one half the count rate.

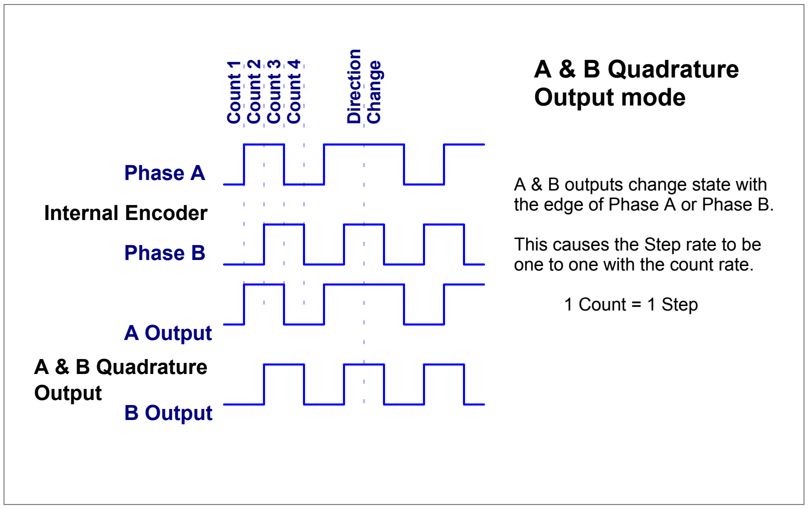
2 Counts = 1 Step

Step Up & Step Down:
Output provides a 50% duty cycle “Pulse” for the **Step Pulse** outputs. This gives a minimum pulse width of 3.75 micro seconds at the maximum speed of 4000 RPM.

The SilverMax **Internal Encoder** puts out 4000 counts per revolution. With a modulo of “1” the maximum pulse count is 2000 pulses per revolution.

The **Step Up** pulses for one direction that the Encoder is moving the **Step Down** pulses for the other direction. Both Step outputs must be “low” before one can be used, this prevents the Step outputs from both being “high” at the same time.

The best type output to use for Step and Direction is the **A & B Quadrature**. When interconnecting two SilverMax units this is the ideal method since SilverMax can both output and input **A & B Quatrature**. **A & B Quatrature** operates with lower "Frequency" signals while maintaining all the needed information. This type is the most noise immune when proper "decoding" circuitry is used. This type does require the inputting device to have decoding circuitry in order to use the full resolution of the output.


Count 1
Count 2
Count 3
Count 4
Direction Change
A & B Quadrature Output mode
Phase A
Internal Encoder
Phase B
A Output
A & B Quadrature Output
B Output
A & B outputs change state with the edge of Phase A or Phase B.
This causes the Step rate to be one to one with the count rate.
1 Count = 1 Step

A & B Quatrature:
Provides a typical "Encoder" style output.
When used with a modulo of "1" it is identical to the **Internal Encoder** signals. The minimum pulse width is 7.5 micro seconds at the maximum speed of 4000 RPM.

The SilverMax **Internal Encoder** puts out 4000 counts per revolution. With a modulo of "1" the maximum pulse count is 1000 pulses per revolution. Using a decoding circuit, the **A & B Quatrature** signals can be converted to 4000 pulses per revolution.

Special I/O

There are a couple of I/O functions that serve special purposes.

Encoder Output

The **Internal Encoder** can be viewed directly by issuing the **ENABLE ENCODER MONITOR** command. In this mode SilverMax simply passes through the **Internal Encoder A**, **B** and **Index** signals.

Done Status

The **Done Status** is a special output function that indicates with an output High ("1") when the motor is executing a motion or has a **Position Error** status. When a motion profile is executing the **Trajectory Generator** calculates the move profile. The calculation is done on a cycle by cycle basis until the entire motion is complete. When a motion is complete and the **Settling Time** is expired, the **Done Status** will output a low ("0") indicating the SilverMax is **Idle** and no position error exists.

The **Done Status** does not indicate whether the motor is Moving or Holding position. It is a status of what it should be doing. **Moving Error** and **Holding Error** Limits must be set using the **ERROR LIMITS** command to use the Done Status to indicate motion complete and in position.

See **ANALOG CONTINOUS READ (ACR)** & **ANALOG READ INPUT (ARI)** commands. Also see **Input Mode** commands.

USING ANALOG INPUTS

Analog inputs are designed for analog signals with a range of 0 to +5 Volts. The internal Analog to Digital Converter (ADC) has 10-Bit resolution that reads 0.00488 volts per count. When an input is used Single Ended the 10-Bit resolution is achieved. When two inputs are used in a Differential fashion an 11-Bit resolution is achieved. Analog inputs #1, #2, #3 and #4 share Digital I/O lines #4, #5, #6 and #7 respectively.

All single channel ADC readings are scaled to a 15-Bit value before being stored in a selected Data Register. Single channel readings range from 0 to 32767 counts with a 0 to 5 volt input. Differential channel readings are converted to 16-Bit values with a range from –32767 to +32767 counts. ADC readings taken using the **Analog Continuous Read** command are filtered with a simple roll-off filter. The filter knee is at 30Hz rolling off at 20db per decade. (60Hz is approximately –6db down)

The ADC is internally referenced to the +5 Volt power supply. When designing analog sources the +5 Volt power supply can be used for power requirements that are less then 100 milliamps. Using the +5 Volt power supply implements a design that minimizes effects from power supply variation.

Analog inputs need to be driven from a low impedance source (10 ohm or less) or with a capacitance across the input. A minimum 0.01ufd. can be used at the input to provide the low impedance source. Typical capacitor values can range from 0.01ufd. to 0.1ufd..

An internal 200K ohm pullup resistor is connected to the +5 Volt power supply and will give a slight bias on the input. The 200K ohm value must be considered in circuit designs that are high impedance or passive.

The **Input Mode** commands can use Analog inputs for **Position**, **Velocity** and **Torque** control. When using these modes Calibration of the input can be done internally without requiring external circuitry. This allows devices such as Joysticks to be directly connected to SilverMax without external interface circuitry. (See **Analog Input Mode** below in this manual)

Selecting Analog Inputs

Single Channel Inputs

Single Channel Input is the simplest way to read an analog signal into SilverMax. For single channel usage the analog signal is referenced to the SilverMax logic ground. Electrical noise can be a problem, therefore an input capacitor may be required. Normally an input capacitor should be used if the source impedance is high.

Analog inputs #1 to #4 share digital I/O lines #4 to #7 respectively. These analog inputs are designed for external analog input readings and can be use for all analog input functions.

Analog input #7 is the non-calibrated V+ input. A calibration factor must be applied to this in order to get a usable result. (See below for details)

Analog input #8 is the non-calibrated internal temperature of the SilverMax. A calibration formula must be use to get a usable result. (See below for details)

Analog input #9 this is not really an analog input, it reads a voltage calibration value out of the **Non-Volatile Memory** that is used to convert the reading from input #7 to a usable value. Only the **Analog Read Input** command can access this value.

Differential Channel Inputs

Differential Channel Input provides an added advantage of giving noise rejection of the analog signals. Also the differential readings will double the resolution of the ADC reading from 10-Bit to 11-Bit. The value read by the Analog inputs will range from -32767 to +32767. To achieve the full range both inputs must be active. If, for example, inputs #1 & #2 are used in differential mode, +32767 will be read when #1 is at +5 volts and #2 is at 0 volts, -32767 will be read when #1 is at 0 volts and #2 is at +5 volts. The inputs used for differential readings are still referenced to the SilverMax logic ground; care should be taken to minimize ground noise and ground loops.

Analog input #5 is the differential reading of inputs #1 & #2. This analog input is designed for external analog input readings and can be used for all analog input functions.

Analog input #6 is the differential reading of inputs #3 & #4. This analog input is designed for external analog input readings and can be used for all analog input functions.

Reading Analog Inputs

There are two methods for reading in analog information:

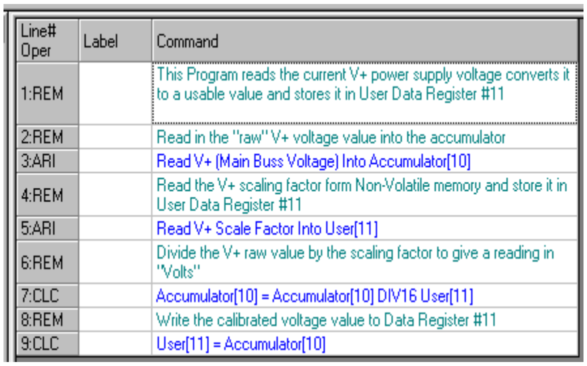
One method is to do a **single read** using the **Analog Read Input** command. This command does a single reading of a selected analog input and places the value in a selected **Data Register**.

The second method is to do **continuous readings** of a selected analog channel using the **Analog Continuous Read** command. This command puts SilverMax into a continuous read cycle that takes an analog reading every servo cycle (120 usec.). Putting SilverMax into **Analog Continuous Read** has no effect on other operations; the readings are done in a “foreground routine” that is designed to work without effecting the controller performance. When in **Analog Continuous Read** the analog value is placed in the selected Data Register after each reading (every 120 usec.). This provides continuous update of the analog signal that allows for better tracking.

Analog Continuous Read can only be set up for 1 channel at a time. The setting can be modified at any time to switch to a different channel or redirect the data to a different **Data Register**.

Reading and Calibrating the V+ Analog Input

The V+ (SilverMax Power Supply) input can be read using the **Single Read** or the **Continuous Read** command. In the example shown, a single reading of the input is taken and placed in the accumulator (Reg. #10). A single reading of the voltage calibration factor is also taken and placed in Data Register #11. The accumulator is divided by Register #11 to achieve a calibrated voltage value. This is stored in Data Register #11 for future use.



Line# Oper	Label	Command
1:REM		This Program reads the current V+ power supply voltage converts it to a usable value and stores it in User Data Register #11
2:REM		Read in the "raw" V+ voltage value into the accumulator
3:ARI		Read V+ (Main Buss Voltage) Into Accumulator[10]
4:REM		Read the V+ scaling factor form Non-Volatile memory and store it in User Data Register #11
5:ARI		Read V+ Scale Factor Into User[11]
6:REM		Divide the V+ raw value by the scaling factor to give a reading in "Volts"
7:CLC		Accumulator[10] = Accumulator[10] DIV16 User[11]
8:REM		Write the calibrated voltage value to Data Register #11
9:CLC		User[11] = Accumulator[10]

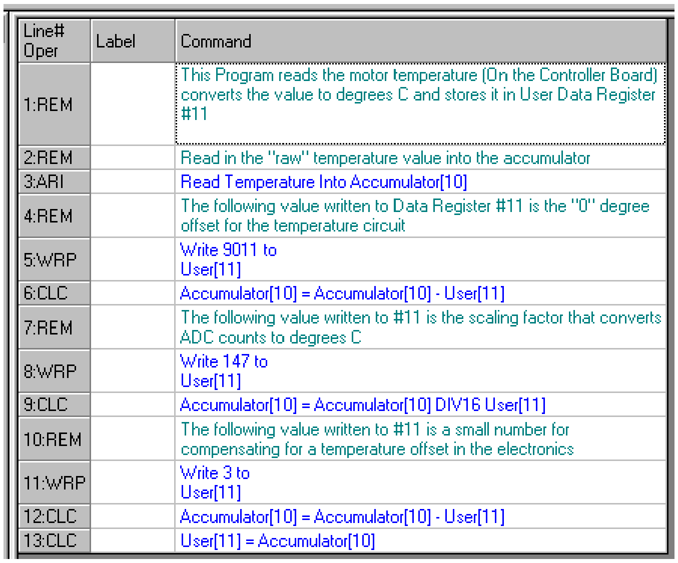
Voltage Calibration equation:

RV = Raw V+ voltage reading
CF = V+ calibration factor

V+ = RV / CF

Reading and Calibrating the Temperature Analog Input

The SilverMax Internal Temperature input can be read using the **Single Read** or the **Continuous Read** command. In the example shown a single reading of the input is taken and placed in the accumulator (Reg. #10). A temperature offset is placed in Data Register #11 and then subtracted from the accumulator. The accumulator is divided by a cal factor placed in Register #11. Finally an offset value is placed in Register #11 and subtracted from the accumulator. The result is stored in Data Register #11 for future use.



Line# Oper	Label	Command
1:REM		This Program reads the motor temperature (On the Controller Board) converts the value to degrees C and stores it in User Data Register #11
2:REM		Read in the "raw" temperature value into the accumulator
3:ARI		Read Temperature Into Accumulator[10]
4:REM		The following value written to Data Register #11 is the "0" degree offset for the temperature circuit
5:WRP		Write 9011 to User[11]
6:CLC		Accumulator[10] = Accumulator[10] - User[11]
7:REM		The following value written to #11 is the scaling factor that converts ADC counts to degrees C
8:WRP		Write 147 to User[11]
9:CLC		Accumulator[10] = Accumulator[10] DIV16 User[11]
10:REM		The following value written to #11 is a small number for compensating for a temperature offset in the electronics
11:WRP		Write 3 to User[11]
12:CLC		Accumulator[10] = Accumulator[10] - User[11]
13:CLC		User[11] = Accumulator[10]

Temperature calibration equation:

RT = Raw Temperature reading
9011 = 0° offset
147 = Counts to Degrees C factor
3 = Temperature offset

Temp in °C = (RT – 9011) / 147 – 3

I/O CONFLICTS

The seven digital I/O lines can be configured to perform a number of different functions. In many cases these functions compete for the I/O resources. Care and thought must be taken when choosing which I/O lines to use for a given function.

The most flexible is the "General" Input and Output. This can be configured on any I/O line and therefore the selected lines should be chosen last. Sometimes no mater how the I/O is used there will be conflicts. The following lists the different functions that will conflict with one another.

NOTE: Before using any **Input Functions** make sure the I/O lines have been configured as "Input" using the **CONFIGURE I/O** command or the appropriate **CLEAR** or **DISABLE** commands.

When using Motion, Conditional or Kill Motor Inputs
Any function that configures an I/O line for "Output" will conflict with these functions. Motion and Conditional commands that use I/O for control do not configure the I/O for input. If an I/O line is configured for Output these commands will read the current "state" of the line, this may cause very unpredictable results.

When using Step and Direction Input or External Encoder Input
Depending on the **SELECT EXTERNAL ENCODER** setup either I/O #2 & #3 or I/O #4 & #5 will be used for Step and Direction input. The **ENABLE ENCODER MONITOR** can conflict with I/O #2 & #3 usage. General Output can conflict with any I/O line used.

When using Analog Input
Analog signals can be used on I/O lines #4, #5, #6 and #7. The **MODULO SET** command uses I/O #6 & #7 for modulo output and will over-write the I/O bit usage even if the Inputs are being used. General Output can conflict with any I/O line used.

NOTE: Before using **Output Functions** make sure the I/O lines have been configured as "Inputs" using the **CONFIGURE I/O** command or the appropriate **CLEAR** or **DISABLE** commands.

When using Modulo Output
General Output is the only function that can conflict with the Modulo function. Configure I/O lines #6 or #7 to input before using the **MODULE SET** command. Use **MODULO CLEAR** to configure I/O back to input before General Output can be used.

When using Encoder Monitor
Before **ENABLE ENCODER MONITOR** can be used, I/O lines #1, #2 and #3 must be configured for "Input". If I/O Line #1 is configured as an "Output" the **ENABLE ENCODER MONITOR** will simply "Set" I/O line #1 High ("1") and not enable Encoder viewing. **DISABLE ENCODER MONITOR** will "Clear" I/O Line #1 to low ("0"). This is a legacy from the original SilverMax design.

When using Done Bit
I/O Line #1 must be configured for "Input" before this function can be used. Attempting an **ENABLE ENCODER MONITOR** or a **CONFIGURE I/O** will cause a command failure. Use the **ENABLE DONE BIT** and **DISABLE DONE BIT** to use this function.

OPERATING IN HOST AND STANDALONE MODE

SilverMax can operate in two distinct modes that each meet different system design needs. Host mode is typically when an external computer based controller is governing each operation of the SilverMax. Standalone mode is when the motor is operating completely independent of any other computer based controller. These modes can be combined in a number of different ways to form a hybrid system design.

Host Mode

Host mode is when SilverMax is connected using the Serial Interface to a “Hosting” computer such a Desktop Computer (PC) or PLC. In this mode the SilverMax waits for each command to be sent, executes the command, and then waits for the next command. In this mode, no internal **program** is running that would allow the unit to perform an operation by itself.

In **Host mode** most of the SilverMax commands are available to execute on an Immediate basis. Some commands such as the **JUMP** or **PROGRAM CALL** are designed to only be used inside **programs** downloaded into the motor. Certain commands, such as the Motion Profile Commands, can only be executed when the motor is Idle. These are called **program Type** because they are intended to be used in SilverMax programs. A few commands, such as **Status Commands,** can be executed at any time, even when a motion is executing.

The primary purpose of Host mode is to allow SilverMax to be a **Passive Follower** to the Host controller waiting for each command before doing any operation. This allows a system designer to achieve many extended operations by having the Host controller and the SilverMax interacting. In cases where many axes of control are required, the Host configuration can achieve very complex or highly coordinated multi-axis control.

When a Host controller is used, a great deal of information can be retrieved from a unit. This can be done using the **Status Commands** or the **Read Register Commands**. The following is a discussion on using the **Poll** command.

Polling SilverMax Using the Poll Command

Polling the SilverMax is a process sending the **Poll** command and receiving back the **Polling Status Word**. Polling is used to check the current status of the SilverMax for item such as errors, command completion and general information. A Host controller can use this information to assist in motion coordination and error checking.

Polling is typically implemented by having the Host controller periodically perform a Polling routine. This routine consists of Polling the Motor using the Poll Command, reading back the status word, checking the word for the desired condition and then clearing the Polling Status Word (see diagram below). If the condition is not TRUE the Polling operation can be repeated using a loop that continues to check the condition until it is TRUE. Repeat loops delays can vary depending on the desired polling rate and the communications baud rates.

Below is an example of a “Polling Routine” that can be used to retrieve status on command execution. This may be used for waiting until a motion completes before sending the next command.

Polling Routine

Example 8-Bit ASCII Code

;Send an initial Poll command
@16 0 (CR) ; Poll

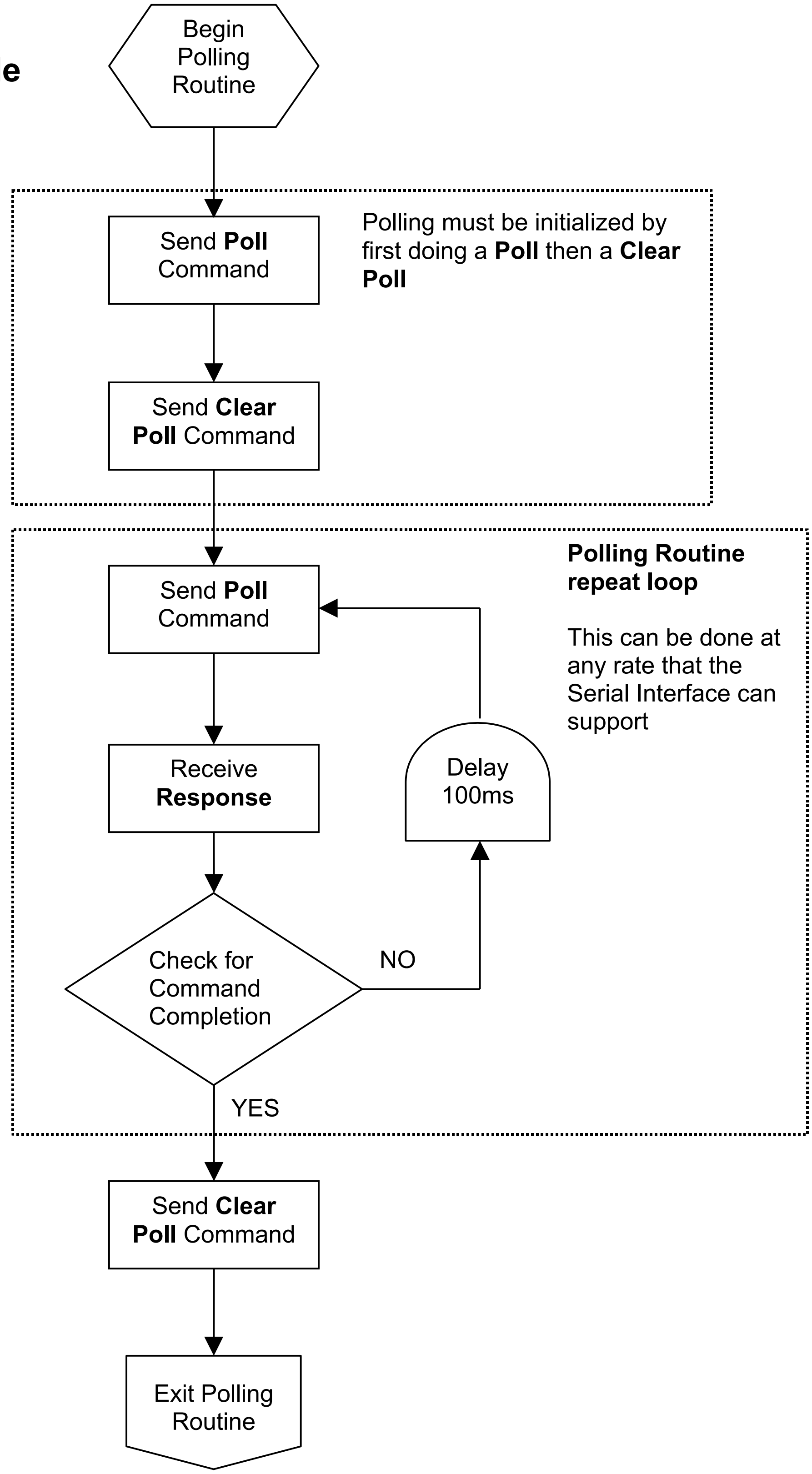
; Clear Entire Status Word
@16 1 65535 (CR) ;Clear Poll

; Actual Poll command
@16 0 (CR) ; Poll

; SilverMax Response
# 10 0000 2000 (CR); Command Complete.

NOTE: 8192 in decimal equals 2000 in hexadecimal

; Clear Only Bit #13
@16 1 8192 (CR) ;Clear Poll


Begin Polling Routine
Send Poll Command
Polling must be initialized by first doing a Poll then a Clear Poll
Send Clear Poll Command
Polling Routine repeat loop
This can be done at any rate that the Serial Interface can support
Send Poll Command
Receive Response
Delay 100ms
Check for Command Completion
NO
YES
Send Clear Poll Command
Exit Polling Routine

Standalone Mode

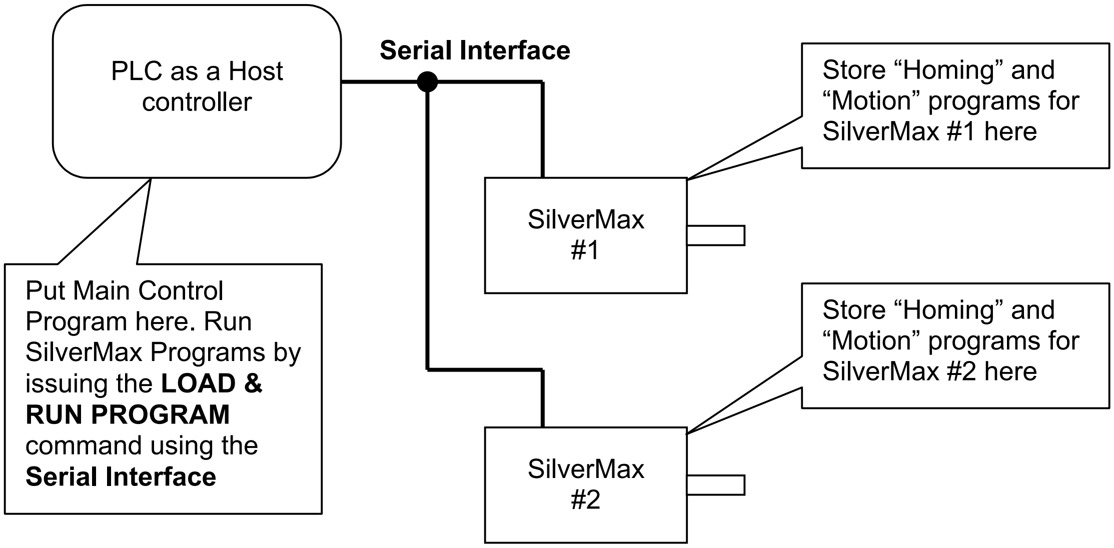
A common mode of SilverMax operation is to download programs in the SilverMax and allow it to run totally independent of any other controller. This is referred to as a “Standalone” mode because the SilverMax can actually stand alone in a system with only a power supply connection. This enables SilverMax to take on PLC-like qualities for operating a small system.

Often in this mode the Digital I/O is used to initiate the required operations by programming the SilverMax to Start programs, End programs or Select programs using different I/O combinations. Special commands have been designed into SilverMax that can use I/O inputs for performing Motion and program flow control.

Host & Standalone Mode Combined

There are times where both modes are required in the system design. This may be when a PLC is used for system control. A PLC typically is not the best at motion control when very critical timing or motion coordination is being implemented. In these cases SilverMax can perform the complex motion programs while the PLC is monitoring the process and initiating the desired programs.

An example of this is having a **homing** program and the **motion** program stored in one or more SilverMax, then using the PLC to initiate these programs at the appropriate time. The PLC can initiate the programs using the I/O or the Serial Interface. Shown below is block diagram of a PLC using the Serial Interface to initiate programs stored in SilverMax. This is a “Multi-drop” serial communications setup that can be accomplished using RS-485 or RS-232 (unique to SilverMax).

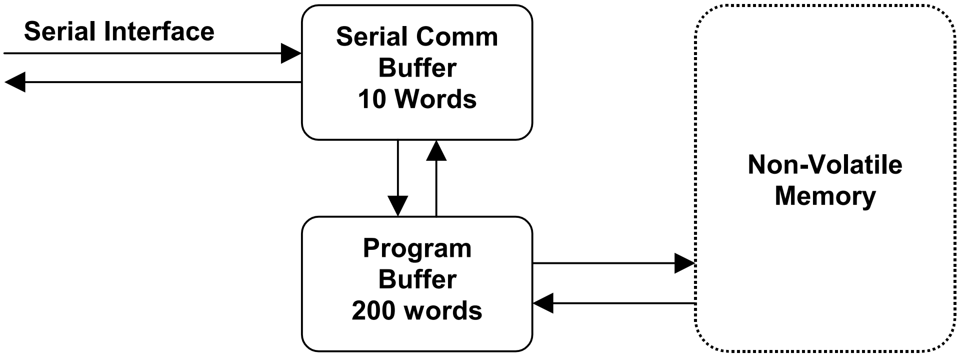

PLC as a Host controller
Serial Interface
Store “Homing” and “Motion” programs for SilverMax #1 here
SilverMax #1
Put Main Control Program here. Run SilverMax Programs by issuing the **LOAD & RUN PROGRAM** command using the **Serial Interface**
Store “Homing” and “Motion” programs for SilverMax #2 here
SilverMax #2

In the above example the PLC can perform the “Polling Routine” to check status and Error conditions on the SilverMax units attached to the serial network. (see above for more information on “Polling”)

PROGRAMMING SILVERMAX

SilverMax Memory Model

Before programming the SilverMax, it is important to understand how the memory for storing and executing programs is set up. There are three types of memory available in the unit: When receiving commands through the **Serial Interface** a **Serial Communications Buffer** is used to temporarily store the Commands, Parameters and Data for the Serial Interface. For executing commands and programs there is a **Program Buffer** for temporary storage of the executing command or program. The **Program Buffer** uses a “Static” type memory cell that can be written any number of times and only maintains information while power is present. For long term storage of programs and data use the **Non-Volatile Memory**. **Non-Volatile Memory** uses a “EEPROM” type memory cell that can be written to a large number of times and retains the data even when power is lost.



Serial Communications Buffer

The Serial Communications Buffer is a 10 Word memory location used to temporarily store in-coming and out-going Commands, Parameters and Data. When sending a Command from a Host system to the SilverMax (using the Serial Interface), SilverMax will temporarily store the information in the buffer as the command is being received. During this time the Command and Parameters are checked for proper syntax and data range. When the entire Command and Parameters have been received, they are either executed directly or transferred to the **Program Buffer** and executed. **Immediate Type** commands are executed directly from the serial Buffer. **Program Type** commands are first transferred to the Program Buffer before execution.

Program Buffer

The Program Buffer provides a 200 Word memory array for program and Command execution. The buffer is used by the SilverMax to hold a single Command or a series of Commands (a program) for eventual execution. Only one program can be held in the buffer at a time. The buffer can be loaded with Commands using the **Serial Interface** or from the **Non-Volatile Memory**. The buffer will hold a Command or series of Commands until over-written or until power is removed.

Programs that are contained in the buffer can also be “written” to the **Non-Volatile Memory** for long term storage. The following is a list of SilverMax Commands that pertain to the Program Buffer.

- **Clear Program (CLP) –** Clears the contents of the Program Buffer
- **Start Download (SDL) –** Puts SilverMax into “Download” mode using Serial Interface
- **Store Program (SPR) –** Stores the currently loaded program into Non-Volatile Memory
- **Run Program (RUN) –** Executes the currently loaded program
- **Load Program (LPR)–** Loads a program from Non-Volatile Memory
- **LOAD AND RUN PROGRAM –** Loads a program from Non-Volatile Memory then executes the program.

Non-Volatile Memory

The Non-Volatile Memory is used for long term storage of SilverMax programs and Data. This type of Memory is used when a program or Data needs to remain in the SilverMax even when power is removed. This is also useful when multiple programs must be stored in the SilverMax. Each program can be stored at a known memory address and loaded when needed.

Non-Volatile Memory is also available for storing Data. When using “Data Registers” for internal data manipulation and usage, there are times when the content of these Data Register needs to be stored. This is often the case when generating “Position offset” or “Calibration” values. The Data Register value can be stored to Non-Volatile memory from a single register or an array of registers.

When storing multiple programs or Data Register values to the Non-Volatile Memory, care must be taken to keep track of the storage addresses. If an improper address is used for loading, the loading process will fail. SilverMax does not keep track of where programs or Data are stored.

When storing programs or Data Registers, SilverMax automatically adds a **Length & Checksum** value at the first memory location. This is used when loading to know the correct number of words to load and to verify the integrity of the data. When storing Data Registers a “0” is stored after the **Length & Checksum** as a “NULL” word. This prevents SilverMax from trying to execute Data as a program.

Program Storage Memory Usage Example (Starting at Address 150)		
# of Words	**Memory Address**	**Stored Elements**
1	150	**Length & Checksum**
9	151	**Command & Parameters** Move Relative, Velocity Based (MRV)
1	160	**Command & Parameters** Zero Target & Position (ZTP)
9	161	**Command & Parameters** Move Absolute, Velocity Based (MAV)
20 Words Total	170 Next available Address	

Data Storage Memory Usage Example (Starting at Address 170)		
# of Words	**Memory Address**	**Stored Elements**
1	170	**Length & Checksum**
1	171	**NULL WORD “0”**
2	173	**Data Register #12**
2	175	**Data Register #13**
2	177	**Data Register #14**
2	179	**Data Register #15**
2	181	**Data Register #16**
2	183	**Data Register #17**
2	185	**Data Register #18**
16 Words Total	187 Next available Address	

Creating Programs Overview

SilverMax programs are constructed from a series of **Program Type** commands. Programs enable SilverMax to execute complex operations independent of any external controller. Programs can consist of **Initialization, Motion, Program Flow, I/O, Data Register** and **Miscellaneous** commands.

Programs can be created and edited using **QuickControl**, a Windows software application designed as support tool for the SilverMax motor line. QuickControl is available from QuickSilver Controls as part of **SilverMax Startup Kits** or can be downloaded from the QuickSilver web site (www.qcontrol.com). For a detailed, step by step explanation on creating a program in QuickControl, see the QuickControl Help system (tutorial).

Creating programs involves combining a series of commands together in the desired order, downloading the series of commands into the SilverMax and optionally storing the series of commands (the program) in the on-board **Non-Volatile Memory**.

Command Types Required

There are two different "Types" of commands that SilverMax accepts, **Immediate Type** and **Program Type**. Immediate type commands can only be issued from a Host controller using the Serial Interface. They CANNOT be used as part of a program or stored in Non-Volatile Memory. The Program Type commands can be used in a program or issued "Real time" using the Serial Interface. (For more information see **Command Types** in the **SilverMax Command Reference**)

How Programs Operate

Programs execute commands sequentially starting at the first line and continuing until the end of the program is reached or until an **Over-ride** command is issued from a Host controller. Programs can perform conditional branching providing the ability to modify their behavior or even start a different program.

Program lines typically perform their command each servo cycle (120 usec.). If a command requires only one servo cycle to execute, the next program line will execute on the next servo cycle. Some commands block program execution while the command is completing its operation. Since commands behave differently the following gives more information on how different commands effect program execution.

*NOTE: The following assumes the SilverMax is not in **Multi-Tasking** mode. **Multi-Tasking** is an advanced topic detailed latter in this document.*

Motion Commands

Motion commands stop program progress when they are executed. When a motion command is issued to SilverMax it transfers all effort into performing the motion profile - during this time Program execution is suspended. This means that no other **Program Type** command can be issued while a motion command is in process. This is true for both programs and issuing commands from the Serial Interface (remember Immediate Types commands can still be used).

Wait Commands

Wait commands such as **WAIT DELAY** and **WAIT ON BIT STATE** operate similar to Motion commands by suspending program execution while waiting for a "Condition" to be met. One exception to this is the **DELAY** command that can be used to set up a delay counter for future use and continue program execution.

Mode Commands

Mode commands such as **VELOCITY MODE** and **SCALED STEP & DIRECTION** completely suspend program execution until an I/O condition is met or an **Over-ride** command is sent from a Host Controller. When using this type of command the intention would be to put SilverMax into the desired mode for continued use.

Data Register Commands
Data Register commands that write data to Non-Volatile Memory will suspend program execution during the storing process. The Non-Volatile Memory takes a certain amount of time to complete a “Write Cycle” due to the physical characteristics of the Non-Volatile Memory storage cells.

All other commands
All other commands execute within a single servo cycle and therefore do not effectively block program execution.

Program Flow Control

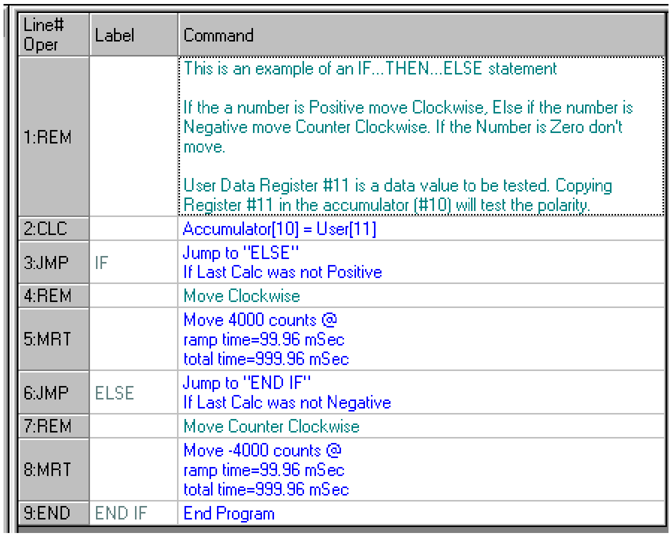
Programs do not just sequence from one line to the next. Branching, both conditional and non-conditional, can be performed at any time. Using the **JUMP**, **PROGRAM CALL**, **PROGRAM RETURN** and **LOAD AND RUN PROGRAM** commands very complex program flow control can be accomplished.

Using the **Program Flow** commands common conditional program flow techniques can be created:

Conditional Program Flow

Conditional program flow control is essential for building complex operations in any kind of a programming environment. SilverMax can use a **JUMP** command in a number of different ways to achieve traditional conditional program flow.

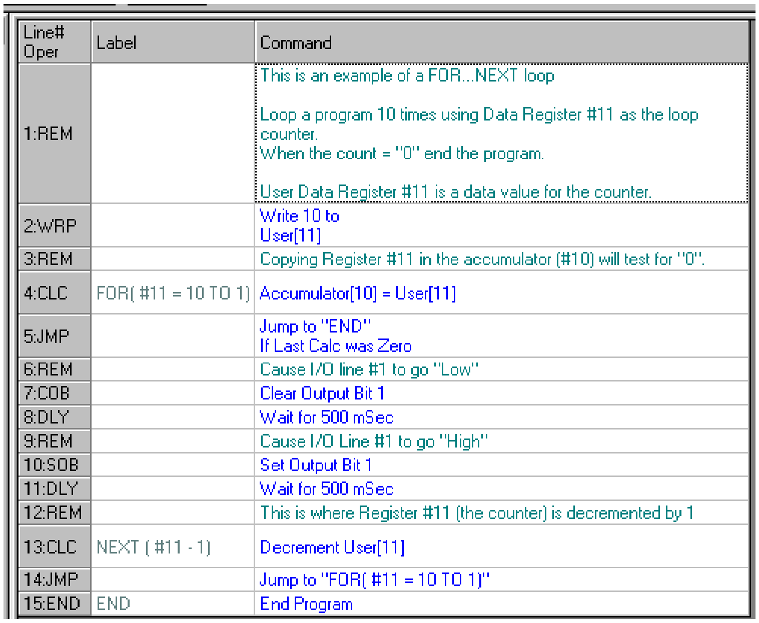
If … Then … Else
The example shown demonstrates using the **JUMP** command to build an IF…THEN…ELSE statement. All programming languages use internal “Conditional Jumps” at a low level to build “IF” commands.



Line# Oper	Label	Command
1:REM		This is an example of an IF...THEN...ELSE statement If the a number is Positive move Clockwise, Else if the number is Negative move Counter Clockwise. If the Number is Zero don't move. User Data Register #11 is a data value to be tested. Copying Register #11 in the accumulator (#10) will test the polarity.
2:CLC		Accumulator[10] = User[11]
3:JMP	IF	Jump to "ELSE" If Last Calc was not Positive
4:REM		Move Clockwise
5:MRT		Move 4000 counts @ ramp time=99.96 mSec total time=999.96 mSec
6:JMP	ELSE	Jump to "END IF" If Last Calc was not Negative
7:REM		Move Counter Clockwise
8:MRT		Move -4000 counts @ ramp time=99.96 mSec total time=999.96 mSec
9:END	END IF	End Program

For … Next

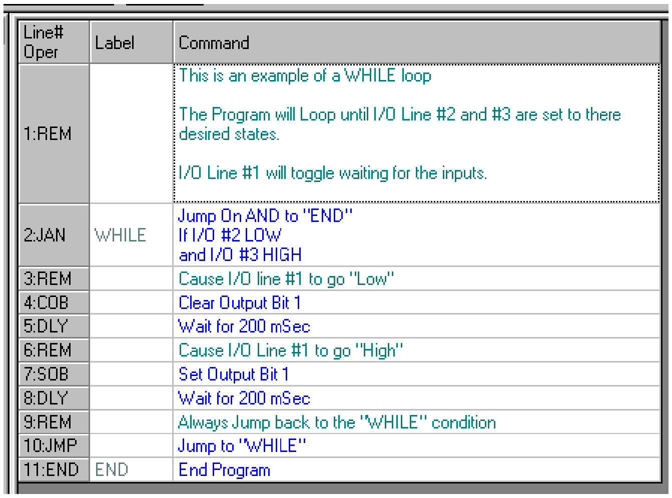
The **For … Next** loop again uses at its core the **JUMP** command to loop through the number of desired iterations. In addition a **Data Register** is used for the loop counter. The **CALCULATION** command has a **Decrement** option that can be used to subtract “1” from any Data Register.



Line# Oper	Label	Command
1:REM		This is an example of a FOR...NEXT loop Loop a program 10 times using Data Register #11 as the loop counter. When the count = "0" end the program. User Data Register #11 is a data value for the counter.
2:WRP		Write 10 to User[11]
3:REM		Copying Register #11 in the accumulator (#10) will test for "0".
4:CLC	FOR(#11 = 10 TO 1)	Accumulator[10] = User[11]
5:JMP		Jump to "END" If Last Calc was Zero
6:REM		Cause I/O line #1 to go "Low"
7:COB		Clear Output Bit 1
8:DLY		Wait for 500 mSec
9:REM		Cause I/O Line #1 to go "High"
10:SOB		Set Output Bit 1
11:DLY		Wait for 500 mSec
12:REM		This is where Register #11 (the counter) is decremented by 1
13:CLC	NEXT (#11 - 1)	Decrement User[11]
14:JMP		Jump to "FOR(#11 = 10 TO 1)"
15:END	END	End Program

While … Loop

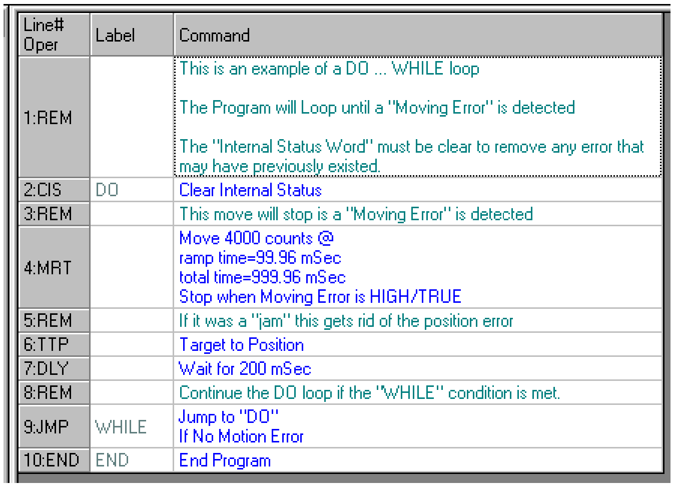
The **While** loop is typically a conditional loop that can exit when entering the loop or at any pass. If the conditions for exiting the loop are TRUE when entering, the While loop will not be executed. In this example two different **Jump** commands are used. The first jump is a special version that looks for the **ANDed** condition of selected digital Inputs. The second jump at the end of the loop acts like a GOTO by doing an unconditional jump back to the beginning.



Line# Oper	Label	Command
1:REM		This is an example of a WHILE loop The Program will Loop until I/O Line #2 and #3 are set to there desired states. I/O Line #1 will toggle waiting for the inputs.
2:JAN	WHILE	Jump On AND to "END" If I/O #2 LOW and I/O #3 HIGH
3:REM		Cause I/O line #1 to go "Low"
4:COB		Clear Output Bit 1
5:DLY		Wait for 200 mSec
6:REM		Cause I/O Line #1 to go "High"
7:SOB		Set Output Bit 1
8:DLY		Wait for 200 mSec
9:REM		Always Jump back to the "WHILE" condition
10:JMP		Jump to "WHILE"
11:END	END	End Program

Do … While

The **Do … While** loop works a little different from the **While** by allowing the loop to execute at least one time before exiting. This loop requires only one **Jump** command at the end. This example shows a repetitive move that exits only if a **Moving Error** is encountered.



Line# Oper	Label	Command
1:REM		This is an example of a DO ... WHILE loop The Program will Loop until a "Moving Error" is detected The "Internal Status Word" must be clear to remove any error that may have previously existed.
2:CIS	DO	Clear Internal Status
3:REM		This move will stop is a "Moving Error" is detected
4:MRT		Move 4000 counts @ ramp time=99.96 mSec total time=999.96 mSec Stop when Moving Error is HIGH/TRUE
5:REM		If it was a "jam" this gets rid of the position error
6:TTP		Target to Position
7:DLY		Wait for 200 mSec
8:REM		Continue the DO loop if the "WHILE" condition is met.
9:JMP	WHILE	Jump to "DO" If No Motion Error
10:END	END	End Program

Using Digital I/O for Flow Control

The **JUMP**, **PROGRAM CALL** and **PROGRAM RETURN** commands are designed to use the **Internal Status Word** and **Digital I/O** for conditional processing. Digital I/O provides an external method for controlling program execution.

Using all seven of the I/O inputs it is possible to set up many different combinations for conditional control. This enables complex system control by simply using "Switches" to setup input conditions.

Downloading Programs Without QuickControl

Downloading a program into a SilverMax allows the execution of complex operations without external input or control. Although using QuickControl to download programs requires simple press a button, the actual process is a little more complicated. The following information is intended to be used by those developers wanting to download programs without using QuickControl (i.e. Use a PC to download a program from a custom C++ program).

Program downloading requires a procedure that loads the series of commands into the **Program Buffer** for execution or for storage into the internal **Non-Volatile Memory**.

Key Notes

- SilverMax can only execute a **program** pre-loaded into its 200 word **Program Buffer**.
- SilverMax has internal **Non-Volatile Memory** that can store 3839 words of information.
- Commands loaded into the **Program Buffer** can be stored into Non-Volatile Memory.
- A **program** can be loaded into the **Program Buffer** in two ways.

  1 - Through the Serial Interface.

  2 - By loading a previously stored program from **Non-Volatile Memory**.
- Only **Program Type** commands can be downloaded into the **Program Buffer**.
- Certain **Program Type** commands should only be executed from within the **Program Buffer**. For Example the **JUMP** and **WAIT DELAY** commands.

Download Process

There are **four steps** to the download process that must be followed in the correct order to complete properly.

Step #1: Clear out the **Program Buffer**.

Use the **Clear Program (CLP)** command to clear the contents of the Program Buffer.

Step #2: Put SilverMax in the download mode.

Use the **Start Download (SDL)** command to set the SilverMax into download mode. In this mode, Program Type commands are stored into the Program Buffer, rather then being executed (most Program Type commands can be executed in an immediate mode). All Program Type commands downloaded after the **Start Download (SDL)** command will be downloaded into the Program Buffer until the download mode is terminated. The download mode is terminated by one of the following, **Run Program (RUN)**, **Store Program (SPR)** or **Clear Program (CLP)** commands.

Step #3: Program Type commands are sent to the SilverMax. When in the download mode a number of commands can be sent to the buffer one at a time. The buffer is limited to 200 words and therefore care must be taken to limit the program size.

Step #4: End the download with the desired operation. Typically one of two things can be done. If the program is to be stored into Non-Volatile Memory the **Store Program (SPR)** command is sent. Doing this will cause the Program Buffer contents to be saved into the on-board Non-Volatile Memory. The **Store Program (SPR)** command designates a memory location to which the program will be stored. When storing the program, SilverMax will calculate the length of words that are to be stored and will place that value at the beginning of the memory location designated. SilverMax later uses the length value to know how many words to load from the Non-Volatile Memory when a **Load Program (LPR)** or a **Load and**

Run Program (LRP) command is sent.

If the program is intended for immediate execution the **Run Program (RUN)** command can be used. This will cause SilverMax to execute the program that is contained in the program Buffer. When the execution is completed the buffer can be over-written with a new Program.

Program Download Example

The following example shows a small 2 line program designed for downloading into the SilverMax Non-Volatile Memory.

NOTE: Example shows command syntax using the 8-Bit ASCII Protocol

The following shows the Download sequence.

1) A **Clear Program (CLP)** command clears any data out of the Program Buffer.

@16 8 (CR)

2) A **Start Download (SDL)** command puts SilverMax into the download mode. Remember, as long as this mode is active, further commands sent to the SilverMax will be downloaded to the Program Buffer. In other words, they will be stored, not executed.

@16 9 (CR)

3) Program Line #1: A **MOVE RELATIVE, VELOCITY BASED (MRV)** command is sent that will be the first command in the program. Remember, because we are in Download Mode, the SilverMax will not move when it gets this command. It will store it at the beginning of the Program Buffer.

@16 135 80000 10000 53687100 0 0(CR)

4) Program Line #2: A **SET OUTPUT BIT (SOB)** command is sent to set output #1 HIGH.

@16 205 1 (CR)

5) A **Store Program (SPR)** command is used to terminate the download process and store the contents of the command buffer into non-volatile memory. The memory address used in this case is “140”. If another program or Data is stored at this address it will be over-written by this command. SilverMax does not check memory for what is previously stored.

@16 13 140 (CR)

Temporary Vs. Long Term Storage

Programs can be stored on the SilverMax in a **Temporary** or **Long Term** manner. Temporary storing can be used when programs are being downloaded by a Host system and their behavior is being constantly modified. Long Term storage is typically used when SilverMax is running in Standalone mode or the programs are changing only on occasion.

Temporary Storage in Program Buffer

Temporary storage is actually the first step toward Long Term storage. The same procedure is used for downloading the program into the SilverMax Program Buffer as described above. The only difference is that the final command **Store Program (SPR)** is not sent. Instead the **Run Program (RUN)** command is used which will immediately execute the program. The program will remain in the Program Buffer until over-written or power to the SilverMax is removed.

Long Term Storage in Non-Volatile Memory

Long Term Storage of programs in Non-Volatile Memory enables SilverMax to “Keep” programs on-board even after power is lost. Storing the program Long Term is simply the final step of the downloading process. Using the **Store Program (SPR)** command the program currently loaded into the Program Buffer can be transferred into the Non-Volatile Memory. This process takes a bit of time to do (approximately 120usec for every 10 words) so typically it is done off-line.

The memory cells used for Long Term storage are a type that “Wear Out” with usage (being written to). The current devices used can be written approximately 100,000 times before the cells become unreliable. For this reason Non-Volatile Memory should not be used for data variable space that requires constant updating. The memory can be “Read” any number of times.

One advantage of using the Non-Volatile Memory for program storage is that more than one program can be stored. Depending on the size as few as 19 programs can be stored or as many as 1900. Temporary storage can only hold one program at a time.

QuickControl downloads programs into Long Term storage.

SPECIAL MODES & OPERATIONS

Anti-Hunt Operation (Eliminates Dithering)

Digital servo systems share a common characteristic of “dithering” when holding at position. Dithering typically occurs when the holding position is near the count transition point of a digital feedback device (i.e. Optical encoder or resolver). This results in a small oscillation of the motor shaft (± 1 count) which in some cases may not be acceptable to the system performance. In more severe cases it can cause a greater oscillation in the total system.

SilverMax has a unique ability to eliminate dithering by transitioning from Closed-Loop mode (Servo Control) to Open-Loop mode when holding position. When the motor’s rotor has been moved to the “Target” position within a pre-defined limit the motor will drop out of Servo control and operate in Anti-Hunt mode. In the Anti-Hunt mode, active control of the motor’s rotor position is suspended until the position error exceeds a different pre-defined limit. If the limit is exceeded SilverMax will move back into Servo Control Mode and again actively control the rotor position.

Two commands can be used to put the SilverMax into Anti-Hunt mode. They are **Anti-Hunt Constants (AHC)** and **Anti-Hunt Mode (AHM)**. See the SilverMax Command Reference for details.

These commands use the following two parameters.

Parameter #1 – Open to Closed Error establishes the point at which SilverMax will **EXIT** anti-hunt operation and return to full Closed-Loop operation (Servo Control).

If, for example, this parameter was set to “10”, when the position error (absolute value of Target position – Actual position) exceeded 10 counts SilverMax would transition from Open-Loop to Closed-Loop operation.

Parameter #2 – Closed to Open Error establishes the point at which the SilverMax will **ENTER** anti-hunt operation and operate in an Open-Loop (Locked Rotor) fashion.

If, for example, this parameter was set to “4”, when the position error (absolute value of Target position – Actual position) was less than 4 counts SilverMax would transition from Closed-Loop to Open-Loop operation. The motor torque required to move to position must be less than the Torque Limit setting before Anti-Hunt will begin.

An additional feature with this parameter is that setting it to a negative value will create a “dead band” area where, no matter what, Anti-Hunt will begin when the position error is less than the parameter #2 setting.

(See **Anti-Hunt Process** below for more detail on **ENTERING** and **EXITING** Anti-Hunt Operation)

Anti-Hunt Torque Settings:

Anti-Hunt operation works using additional torque settings that establish the desired force needed to hold position. The **Torque Limits** command has two extra parameters **Open-Loop Moving** and **Open-Loop Holding** that are used when entering Anti-Hunt operation. Typically these parameters are set to a lower value than the **Closed-Loop Moving** parameter.

PLEASE NOTE: When in Anti-Hunt operation the **Open-Loop Torque Limit** setting reflects the actual current being applied to the motor windings. This may cause significant heating of the motor. For Example: If the **Open-Loop Holding Torque limit** is set to 10,000 which is 50% of the maximum motor torque setting, the motor current will be fixed at 50% of the maximum current. This will cause a greater amount of motor heating. The **Torque Limit** setting should be set just high enough to hold the desired position to prevent over-heating.

Anti-Hunt Delays:

There are two delay settings that effect when Anti-Hunt operation is entered and what Torque Limit value is used. The **Anti-Hunt Delay** command sets when, after the position error has become less then parameter #2, Anti-Hunt operation can begin. This allows SilverMax to move into holding position using Closed-Loop mode before switching to Open-Loop. The **Error Limits** command has a **Delay** parameter that sets when the SilverMax will switch from the **Moving Torque Limit** to the **Holding Torque limit** after a motion has completed. This provides SilverMax with a “Settling Period” after a motion that can keep the Torque Limits at a higher value until all movement has ended.

Anti-Hunt Examples:

Dead Band – This creates a zone where no Torque is applied.
In this example the SilverMax will go into Anti-Hunt operation when the motion is complete and the position error is less than “10”. When in Anti-Hunt **NO** Torque will be applied (Open Loop Torque settings are “0”). This creates an area where the motor can move freely. The **Delay to Holding** only effects Closed Loop operation.

Dead Band Example Command Settings:

Anti-Hunt Constants	Anti-Hunt Delay	Torque Limits	Error Limits
Open to Closed = **10** Closed to Open = **-10**	Delay Count = **0**	Closed Loop Holding = **10000** Closed Loop Moving = **20000** Open Loop Holding = **0** Open Loop Moving = **0**	Moving Error = **100** Holding Error = **20** Delay to Holding = **833** (100 msec)

Live Band – A zone is created when a defined level of holding Torque is applied.
In this example the SilverMax will go into Anti-Hunt operation when the motion is complete and the position error is less then “10”. When in Anti-Hunt a defined amount of Torque will be applied. There may be a brief period where the Open Loop Moving torque is applied helping to pull the position error to zero. The **Delay to Holding** affects both Open Loop and Closed Loop operation.

Live Band Example Command Settings:

Anti-Hunt Constants	Anti-Hunt Delay	Torque Limits	Error Limits
Open to Closed = **10** Closed to Open = **-10**	Delay Count = **0** (0 msec)	Closed Loop Holding = **10000** Closed Loop Moving = **20000** Open Loop Holding = **5000** Open Loop Moving = **20000**	Moving Error = **100** Holding Error = **20** Delay to Holding = **833** (100 msec)

Minimize Position Error – Pulls position error in tight before Anti-Hunt
In this example the SilverMax will go into Anti-Hunt operation when the motion is complete and the position error is less then "4", the required Torque is less than the **Torque Limit** (usually means the position error must be near "0") and after the **Anti-Hunt Delay** has expired. There may be a brief period where the **Open Loop Moving** torque is applied helping to pull the position error to zero. The **Delay to Holding** affects both Open Loop and Closed Loop operation.

Minimize position Error Example Command Settings:

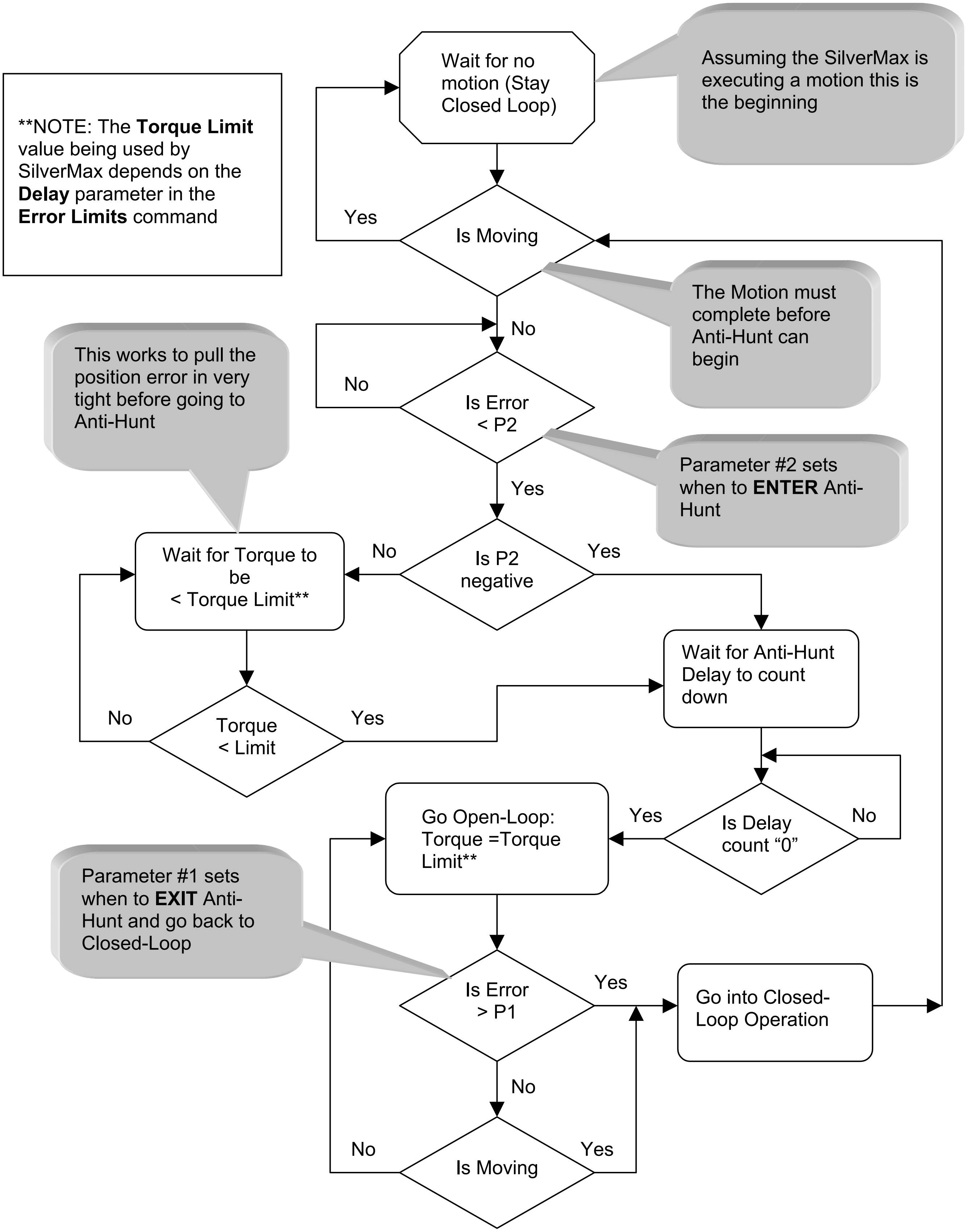
Anti-Hunt Constants	Anti-Hunt Delay	Torque Limits	Error Limits
Open to Closed = **10** Closed to Open = **4**	Delay Count = **416** (0 msec) This gives SilverMax more Closed Loop settling time	Closed Loop Holding = **20000** Closed Loop Moving = **20000** Open Loop Holding = **5000** Open Loop Moving = **5000**	Moving Error = **100** Holding Error = **20** Delay to Holding = **833** (100 msec)

Snap and hold – Pulls position error in tight before Anti-Hunt using high Open Loop Moving Torque.
In this example the SilverMax will go into Anti-Hunt operation when the motion is complete and the position error is less then "4", the required Torque is less than the **Torque Limit** (usually means the position error must be near "0") and after the **Anti-Hunt Delay** has expired. There may be a brief period where the **Open Loop Moving** torque is applied helping to pull the position error to zero. The **Delay to Holding** affects both Open Loop and Closed Loop operation.

Snap and hold Example Command Settings:

Anti-Hunt Constants	Anti-Hunt Delay	Torque Limits	Error Limits
Open to Closed = **10** Closed to Open = **4**	Delay Count = **416** (0 msec)	Closed Loop Holding = **10000** Closed Loop Moving = **20000** Open Loop Holding = **5000** Open Loop Moving = **20000**	Moving Error = **100** Holding Error = **20** Delay to Holding = **833** (100 msec)

Anti-Hunt Process



NOTE: The **Torque Limit value being used by SilverMax depends on the **Delay** parameter in the **Error Limits** command

Wait for no motion (Stay Closed Loop)
Assuming the SilverMax is executing a motion this is the beginning
Is Moving
Yes
No
The Motion must complete before Anti-Hunt can begin
Is Error < P2
No
Yes
Parameter #2 sets when to ENTER Anti-Hunt
This works to pull the position error in very tight before going to Anti-Hunt
Is P2 negative
No
Yes
Wait for Torque to be < Torque Limit**
Torque < Limit
No
Yes
Wait for Anti-Hunt Delay to count down
Is Delay count "0"
Yes
No
Go Open-Loop: Torque =Torque Limit**
Parameter #1 sets when to EXIT Anti-Hunt and go back to Closed-Loop
Is Error > P1
Yes
No
Go into Closed-Loop Operation
Is Moving
No
Yes

"Drag" Mode (Like a Mechanical Clutch)

Most Servo systems can suffer from a problem called "wind-up". This condition occurs when a servomotor cannot keep up with a move or is stalled by a mechanism jam. If the jam is released or whatever is holding back the motor goes away the motor can spin at very high speed to catch up. Commonly the way to prevent this is to simply shutdown the motor. It many cases this is fine, especially if it is due to a jam, but there are case where shutdown is not acceptable.

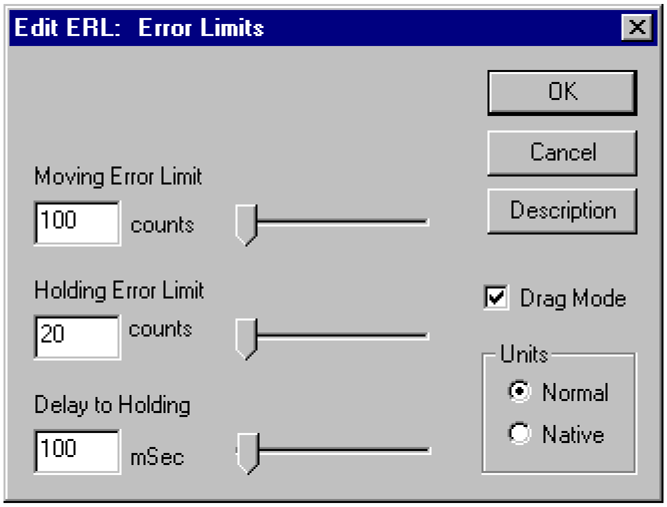
A different method would be to somehow forgive the error like a mechanical clutch does. For a mechanical clutch, when the torque exceeds the clutch limit it will "slip" allowing the motor to continue to move and preventing wind-up. SilverMax has a feature that allows it to do essentially the same thing.

Drag mode is set in the **Error Limits (ERL)** command (see the Command Set Reference for details).

Example: Use QuickControl to set the "drag" so that it will begin when the Moving Error is greater than 100 or when the Holding Error is greater than 20, set the following error limits.

Note the **Drag Mode** box is checked.

The **Delay to Holding** effects when the two different parameters are used. In this case the **Holding Error** will be used 100msec after a motion is complete (**Trajectory Generator** is inactive).



Edit ERL: Error Limits

Moving Error Limit: 100 counts

Holding Error Limit: 20 counts

Delay to Holding: 100 mSec

☑ Drag Mode

Units: ● Normal ○ Native

NOTE: "Drag" mode used in conjunction with the PROFILE MOVE commands will allow SilverMax to "slip" if an over-load or a jam occurs but still complete the move when the over-load or jam is removed. Standard move commands will fall short of the target under the same conditions. This is used to prevent "run-away" when a motor "shutdown" is not the desired method to deal with over-loads or jams.

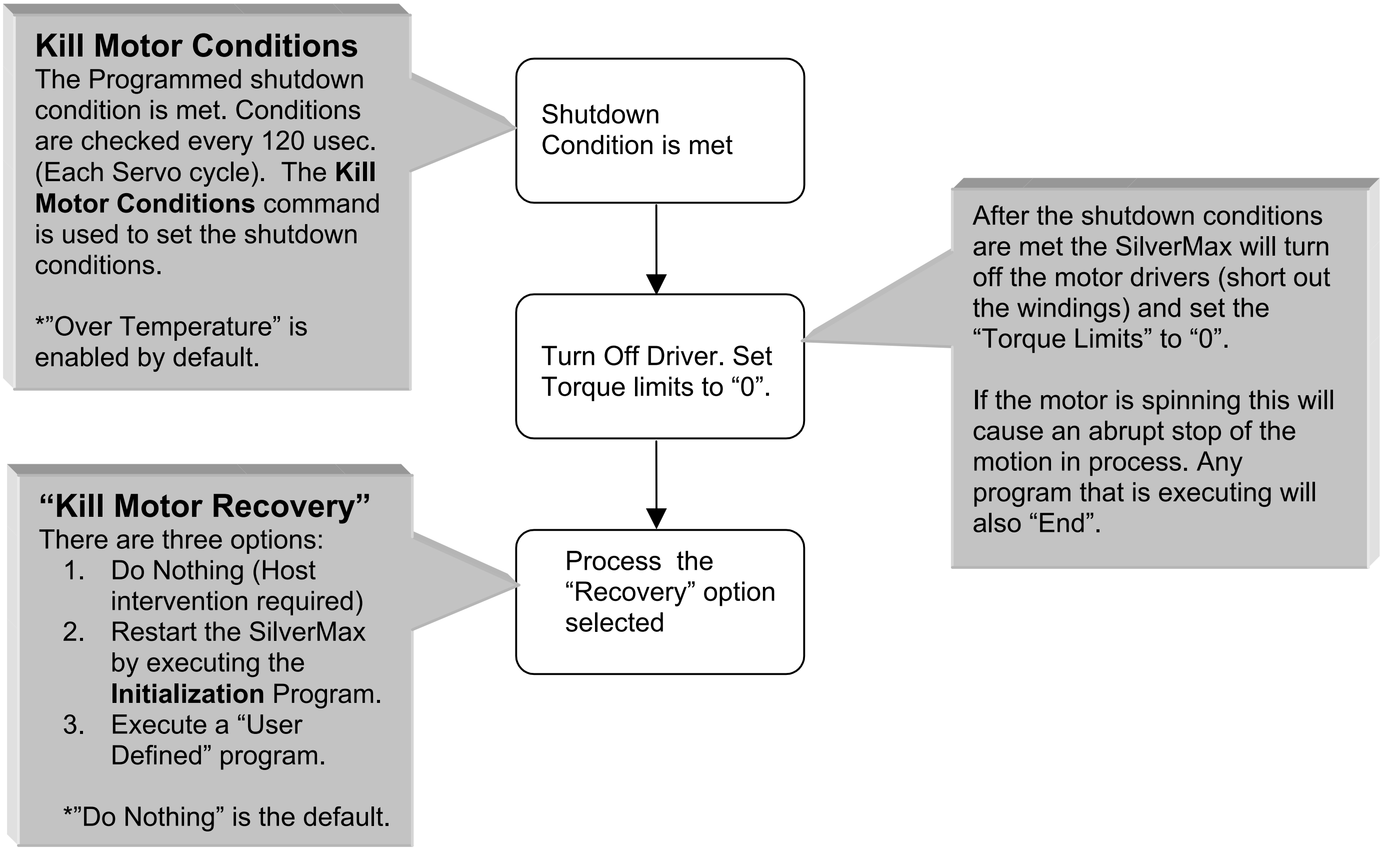
Motor Shutdown (Kill Motor Conditions)

SilverMax is able to detect a number of conditions that can be enabled to “Shutdown” the motor operation. One of the Tasks that is performed every servo tick (every 120 microseconds) is to check a set of **Kill Motor Conditions** that may be used to stop the motor operation. If any one of these conditions are “Enabled” and found to be **TRUE** the SilverMax will execute a process as defined by the **Kill Motor Recovery**. The recovery process can do “Nothing” (Kill the motor and wait), execute a program beginning at address location “0” or execute a program at a specified location.

Motor Shutdown can be done in two different ways depending on the initialization settings. The default shutdown turns off the motor drivers (shorts the windings), which will cause the motor to come to a rapid **uncontrolled shutdown**. The second way will leave the motor operating and “Jump” to the specified recovery program. This allows the motor to do a **controlled shutdown** if required.

Uncontrolled Shutdown:

This is the default that is set in the factory initialization. When a **Kill Motor Condition** is met SilverMax will immediately disable the motor drivers, set the **Torque Limits** to “0” then execute the operation as defined by the **Kill Motor Recovery**. No settings are required other than the **Kill Motor Condition**.


Shutdown Condition is met
Turn Off Driver. Set Torque limits to “0”.
Process the “Recovery” option selected

Kill Motor Conditions
The Programmed shutdown condition is met. Conditions are checked every 120 usec. (Each Servo cycle). The **Kill Motor Conditions** command is used to set the shutdown conditions.

*”Over Temperature” is enabled by default.

After the shutdown conditions are met the SilverMax will turn off the motor drivers (short out the windings) and set the “Torque Limits” to “0”.

If the motor is spinning this will cause an abrupt stop of the motion in process. Any program that is executing will also “End”.

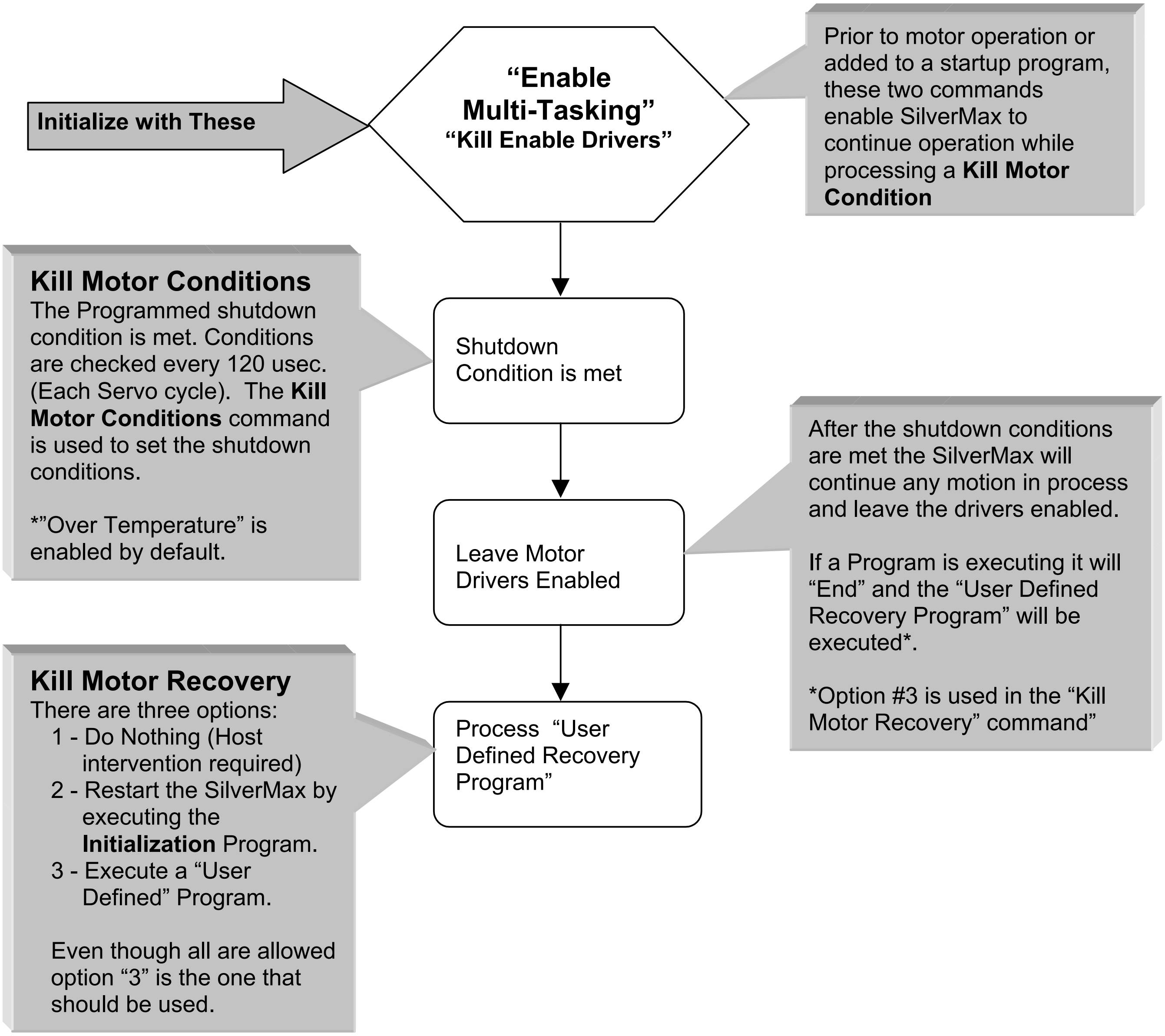
“Kill Motor Recovery”
There are three options:

1. Do Nothing (Host intervention required)
2. Restart the SilverMax by executing the **Initialization** Program.
3. Execute a “User Defined” program.

*”Do Nothing” is the default.

Controlled Shutdown:

This requires a few extra initialization settings to enable the capability. Normally SilverMax cannot process a **Kill Motor Recovery** without shutting down any move and/or program in process. However, when “Multi-Tasking Operation” is enabled a move can continue while the recovery process is taking place. Adding the **Enable Multi-Tasking** command to the initialization process enables “Multi-Tasking Operation”. Even with this the motor driver will still be disabled, a **Kill Enable Driver** command must also be added to over-ride this default. Finally the **Kill Motor Recovery** must be set to process a “User defined Recovery program” that can contain the desired shutdown operations. This Recovery program must be written by the user and stored in the SilverMax Non-Volatile memory at a known address specified in the **Kill Motor Recovery** option parameter.


Initialize with These
“Enable Multi-Tasking”
“Kill Enable Drivers”
Shutdown Condition is met
Leave Motor Drivers Enabled
Process “User Defined Recovery Program”

Prior to motor operation or added to a startup program, these two commands enable SilverMax to continue operation while processing a **Kill Motor Condition**

Kill Motor Conditions

The Programmed shutdown condition is met. Conditions are checked every 120 usec. (Each Servo cycle). The **Kill Motor Conditions** command is used to set the shutdown conditions.

*”Over Temperature” is enabled by default.

After the shutdown conditions are met the SilverMax will continue any motion in process and leave the drivers enabled.

If a Program is executing it will “End” and the “User Defined Recovery Program” will be executed*.

*Option #3 is used in the “Kill Motor Recovery” command”

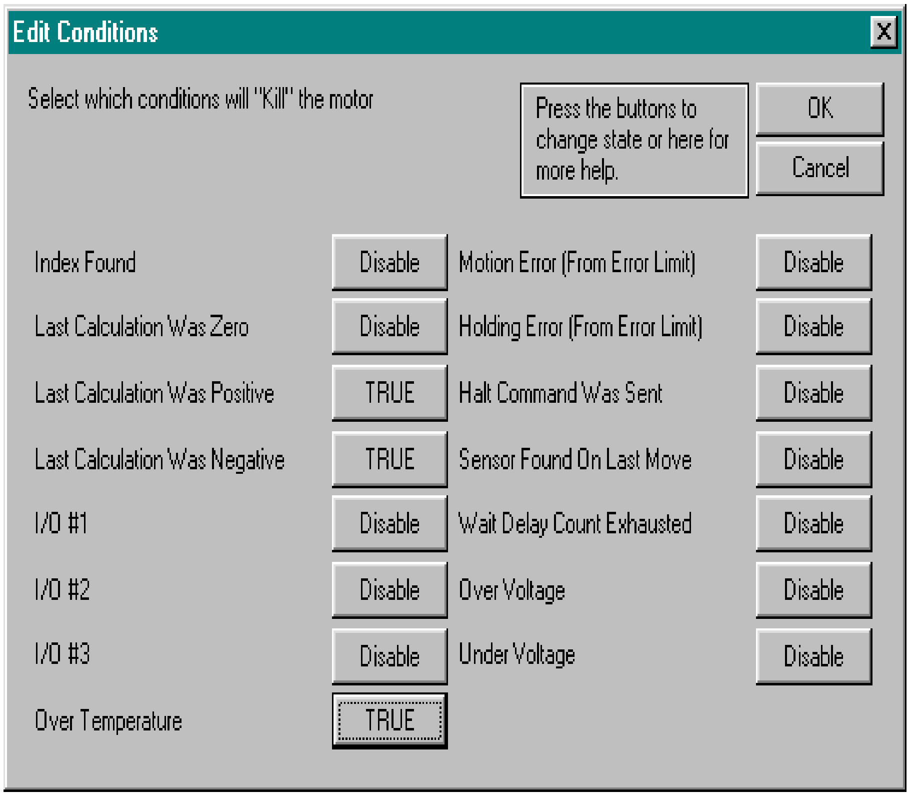
Kill Motor Recovery

There are three options:

1 - Do Nothing (Host intervention required)
2 - Restart the SilverMax by executing the **Initialization** Program.
3 - Execute a “User Defined” Program.

Even though all are allowed option “3” is the one that should be used.

Kill Motor Conditions:



Edit Conditions

Select which conditions will "Kill" the motor

Press the buttons to change state or here for more help.

Index Found	Disable	Motion Error (From Error Limit)	Disable
Last Calculation Was Zero	Disable	Holding Error (From Error Limit)	Disable
Last Calculation Was Positive	TRUE	Halt Command Was Sent	Disable
Last Calculation Was Negative	TRUE	Sensor Found On Last Move	Disable
I/O #1	Disable	Wait Delay Count Exhausted	Disable
I/O #2	Disable	Over Voltage	Disable
I/O #3	Disable	Under Voltage	Disable
Over Temperature	TRUE		

Kill Motor Condition Edit screen from QuickControl
15 Different conditions are available that can be used to “Shutdown” the motor. Each of these conditions can be independently enabled. When enabled the “State” (TRUE or FALSE) that will trigger the “Kill” condition is also set.

The conditions are derived from the **Internal Status Word** that is used by SilverMax in a variety of commands such as the **JUMP** command.

Index Found – (Rarely if ever used)
Since the same status word (**Internal Status Word**) is used by different commands in SilverMax this condition is available but is not necessarily useful as a motor shutdown condition.

Last Calculation Was Zero, Positive or Negative - (These are rarely used)
When a calculation takes place (Using the **CALCULATION** command) the result of the calculation will be one of the above. This allows motor shutdown to occur based on the results of a calculation. If for example a “Position” move parameter should never be “Negative” when calculating a move internally, enabling the **“Last Calculation Was Negative”** to **TRUE** will shutdown the motor.

I/O #1, #2 and #3 - (Used for E-Stop conditions)
Three of the seven digital Inputs are available as shutdown conditions. They are probably most useful when needing an emergency stop (E-Stop) using hardware inputs. When using the “controlled shutdown” method these inputs can be used to redirect motor or program operation.

Over Temperature – (Always Used)
Over-Temperature must always be enabled so that the SilverMax can halt operation if it gets too hot. The over-temperature is actually a combination of the motor driver thermal sensor (not settable) and the internal electronics temperature sensor (Settable using the **Maximum Temperature Trip** command). Either of the two can cause this condition. Internal Temperature can be read back using the **Analog Read Input** command.

Motion and Holding Errors – (Most Commonly used)
In any servo system the most common cause of motor shutdown is when the moving or holding position error exceeds a set limit. Using the **Error Limits** command the amount of acceptable error can be set for both the **Moving Error** and the **Holding Error**. When the error exceeds the limit these flags will be triggered. Typically the **Moving Error** is set to a larger value because of the dynamic conditions encountered during a move. One or both of these conditions can be used for shutdown it just depends on the needs of the system.

Halt Command was sent – (Use to re-initialize the motor after a Halt)
The **Halt** command when sent from a Host system will cause the SilverMax to shutdown. This leaves the SilverMax in a disabled state with no power applied to motor. If this condition is enabled the SilverMax could process an error recovery routine or re-initialize itself without Host intervention.

Sensor Found on Last Move – (Used for "Hard Limit" shutdown)
All motion commands can be stopped using a digital input or other bit state conditions. When a motion command is stopped using inputs this condition is set. If the input was an end-of-travel sensor SilverMax could also shutdown to turn off power to the motor.

Wait Delay Count Exhausted – (Sometimes used for a "Watch Dog" timer)
The Delay counter can be pre-set with a time value that will count down automatically. When the counter reaches "0" this condition is set. Setting the Delay counter and enabling this condition prior to an operation that should complete in a given time allows a "Timeout" function. If the operation does not complete before this condition is disabled (issue another **Kill Motor Condition** command) a shutdown will occur.

Over Voltage – (Can be used for handling a Over-Voltage condition)
Over-Voltage will always cause the motor to shutdown regardless of the **Kill Motor Condition** settings. However, if some type of error recovery is desired setting this condition will allow SilverMax to continue operation after the Over-Voltage. This is useful when the over-voltage is due to heavy deceleration and it is required to regain control of the load.

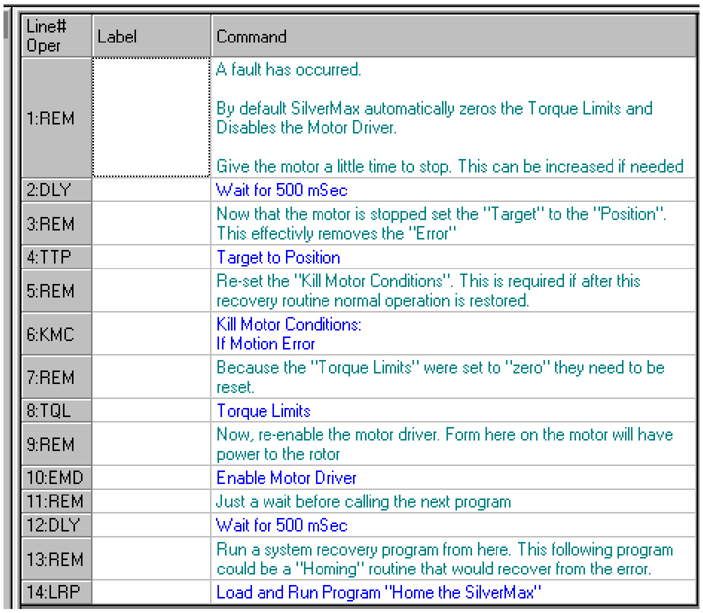
Under Voltage – (Don't use this, use the "Power Low Recovery" instead)
Don't use this unless a motor shutdown is what you really want to do. SilverMax has a unique feature in that a low voltage condition can be used to trigger a special recovery routine that can be use to exit motor operation before power is totally lost. Use the **Power Low Recovery** command to set up this operation. The under-voltage threshold can be set using the **Low Voltage Trip** command.

Kill Motor Recovery Program (Uncontrolled Shutdown):

Handling the Shutdown – The motor shutdown may occur while the motor is in motion. If this is true there may be a period of time required to allow the motor to come to a complete stop. The simplest way to deal with this is to “wait” using a time delay for a period of time required until it is believed that the motor has stopped. This depends on the system implementation therefore the time delay would vary greatly. When the motor has stopped the error processing can begin.

Processing the Error Condition – Depending on the shutdown condition enabled, there may be a number of different things that must be done to clear the error and continue operation or simply alert the “system” or operator of an error. Alerting the “system” or operator may involve toggling a **Digital Output Line**.

Fault Recovery Program



Line# Oper	Label	Command
1:REM		A fault has occurred. By default SilverMax automatically zeros the Torque Limits and Disables the Motor Driver. Give the motor a little time to stop. This can be increased if needed
2:DLY		Wait for 500 mSec
3:REM		Now that the motor is stopped set the "Target" to the "Position". This effectivly removes the "Error"
4:TTP		Target to Position
5:REM		Re-set the "Kill Motor Conditions". This is required if after this recovery routine normal operation is restored.
6:KMC		Kill Motor Conditions: If Motion Error
7:REM		Because the "Torque Limits" were set to "zero" they need to be reset.
8:TQL		Torque Limits
9:REM		Now, re-enable the motor driver. Form here on the motor will have power to the rotor
10:EMD		Enable Motor Driver
11:REM		Just a wait before calling the next program
12:DLY		Wait for 500 mSec
13:REM		Run a system recovery program from here. This following program could be a "Homing" routine that would recover from the error.
14:LRP		Load and Run Program "Home the SilverMax"

The program example shows a “Moving” error recovery that will allow the motor to “Re-Home” and continue on with operation. The first operation is to remove the error this is done using a **Target to Position** command. This removes any “Position” error that may exist. Next, the **Kill Motor Conditions** command is issued again. This is required if normal operation is to resume because the **Kill Motor Recovery** disables the conditions command.

Restoring operation – After a shutdown the system can be restarted automatically by adding a few extra steps to the Recovery program. Since the **Torque Limits** were zeroed out at shutdown they must be re-initialized to the desired values. If a homing routine is to follow, the **Torque Limits** could be set to a lower value required for homing. Next, the motor drivers must be re-enabled using the **Enable Motor Driver** command (Previous versions of SilverMax required issuing the **Motor Constants** command). The SilverMax is now ready for operation. From here a homing or other corrective action program can be executed putting the system back into service.

Kill Motor Recovery Program (Controlled Shutdown):

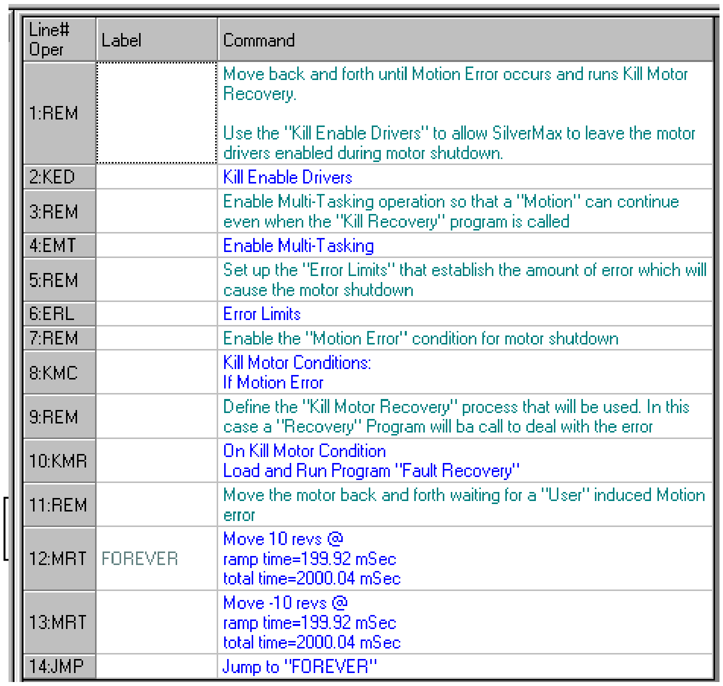
Initializing SilverMax for Controlled Shutdown – Controlled shutdown requires adding a few extra elements to the SilverMax startup. The most important is to add the **Enable Multi-Tasking** command to the startup program. Multi-Tasking will allow SilverMax to continue a motion while processing the shutdown condition. The second is the **Kill Enable Driver** command. This command over-rides the default setting that disables the motor drivers on shutdown.

Handling the Shutdown – In the controlled shutdown scenario the SilverMax does not stop the motion in process, instead the Kill Recovery program is called allowing the motor to stop the motion (or not) in a controlled manner. In the example shown (Fault Recovery program) a Velocity Mode command is issue with a “0” velocity. This will bring the motor to a controlled stop.

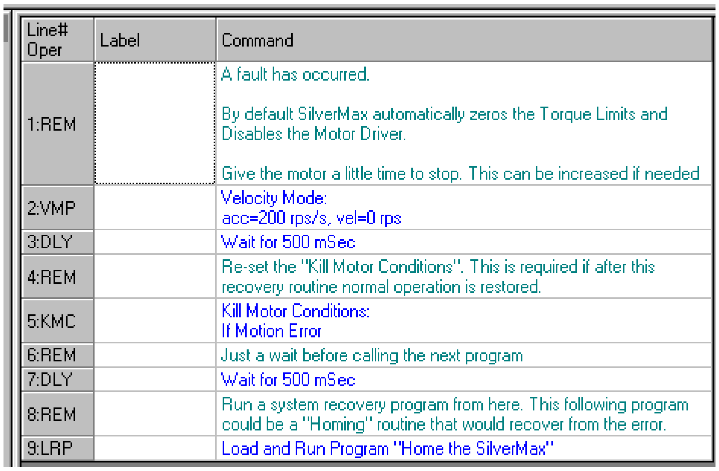
Processing the Error Condition – Depending on the shutdown condition enabled, there may be a number of different things that must be done to clear the error and continue operation or simply alert the “system” or operator of an error. Alerting the “system” or operator may involve toggling a **Digital Output Line**. In this example nothing was required other then re-issuing the **Kill Motor Conditions** command.

Continuing Operation – Continuing on is less complicated in that the motor does not have to be re-initialized. This may be as simple as doing a **Load and Run Program** of the corrective action program.

Startup Program (Begins at power up)



Line# Oper	Label	Command
1:REM		Move back and forth until Motion Error occurs and runs Kill Motor Recovery. Use the "Kill Enable Drivers" to allow SilverMax to leave the motor drivers enabled during motor shutdown.
2:KED		Kill Enable Drivers
3:REM		Enable Multi-Tasking operation so that a "Motion" can continue even when the "Kill Recovery" program is called
4:EMT		Enable Multi-Tasking
5:REM		Set up the "Error Limits" that establish the amount of error which will cause the motor shutdown
6:ERL		Error Limits
7:REM		Enable the "Motion Error" condition for motor shutdown
8:KMC		Kill Motor Conditions: If Motion Error
9:REM		Define the "Kill Motor Recovery" process that will be used. In this case a "Recovery" Program will ba call to deal with the error
10:KMR		On Kill Motor Condition Load and Run Program "Fault Recovery"
11:REM		Move the motor back and forth waiting for a "User" induced Motion error
12:MRT	FOREVER	Move 10 revs @ ramp time=199.92 mSec total time=2000.04 mSec
13:MRT		Move -10 revs @ ramp time=199.92 mSec total time=2000.04 mSec
14:JMP		Jump to "FOREVER"



Line# Oper	Label	Command
1:REM		A fault has occurred. By default SilverMax automatically zeros the Torque Limits and Disables the Motor Driver. Give the motor a little time to stop. This can be increased if needed
2:VMP		Velocity Mode: acc=200 rps/s, vel=0 rps
3:DLY		Wait for 500 mSec
4:REM		Re-set the "Kill Motor Conditions". This is required if after this recovery routine normal operation is restored.
5:KMC		Kill Motor Conditions: If Motion Error
6:REM		Just a wait before calling the next program
7:DLY		Wait for 500 mSec
8:REM		Run a system recovery program from here. This following program could be a "Homing" routine that would recover from the error.
9:LRP		Load and Run Program "Home the SilverMax"

See **Enable Multi-Tasking** and **Disable Multi-Tasking** commands in the SilverMax Command Reference.

Multi-Tasking Operation

"Multi-Tasking" operation allows SilverMax to perform a Motion while executing a program. By default, SilverMax does not continue internal program execution when performing a motion command or while executing in **Velocity Mode, Step and Direction** M**ode** or **Input Mode**. Enabling **Multi-Tasking** causes SilverMax to continue program execution after a motion or mode has been started.

The Primary Benefit of Multi-Tasking:

Is to allow **Programs & Motions** to run at same time. The DSP and internal state machine code permits simultaneous "Task" operation allowing alteration of motion parameters before, after or during actual motion events. The following complex operations are typical:

- **Modify "Profile Moves" On-The-Fly**
- **Create ramps for Electronic Gearing**
- **Set & Clear I/O during Motions**
- **Monitor torque or other parameters**

Other Benefits Include:

Buffer Motion Commands
When executing a **Motion** command, a second **Motion** command, when sent using the serial interface, is "buffered" and will be executed when the previous command is complete.

Intelligent Motor Shutdown
Kill Motor conditions provide programmed "hard shutdown" protection. Specific applications require controlled conditions for shutdown. SilverMax can be preprogrammed to shutdown a motion "gracefully" without destroying vital components.

Execute Immediate Type Commands
During specific motions or Programs, **Immediate** Commands can be executed with no time delay, by sending to the serial communication buffer. The current program will branch and perform the immediate command and then branch back to the next sequential command of its current program.

Multi-Tasking enables SilverMax to perform six(6) different tasks each SilverMax Time Slice (120 microseconds)
The SilverMax **Time Slice** is an interrupt driven time period of 120 microseconds that is used to keep all motor activity on a very consistent time schedule. Each of the six tasks is operated on during this time with the exception of the Serial communications with is operated on 3 times each slice.

Task #1 – Serial Communications
The **Serial Communications** task runs 3 times (every 40 microseconds) each **Time Slice**. During each 40-microsecond period the **Serial Communications** can receive or transmit a serial character. This enables SilverMax to maintain continuous serial communications using **BAUD** rates up to **230,000** bits per second (230K BAUD) even while executing a motion.

Task #2 – Servo Control Loop
Every **Time Slice** the **Servo Control** is updated. This high rate of servo update (8333 times per second) is what gives SilverMax very tight motion and positioning control.

Task #3 – Program Execution

If a program is running, each line of the program will execute on a **Time Slice**. Some commands, like the **Delay**, will cause the program to remain on a line until the command is completed. program execution continues even after a **Motion** command is encountered. This allows other operations such as digital I/O control to be performed while a move is running.

Task #4 – Move

An internal calculation algorithm called the "**Trajectory Generator**" typically accomplishes a move. Each **Time Slice** the **Trajectory Generator** updates its calculation of the on-going move. In the case of a "**Profile Move**" move, parameters can be changed at any time allowing the profile of the move to be dynamically changed.

Task #5 – I/O Status

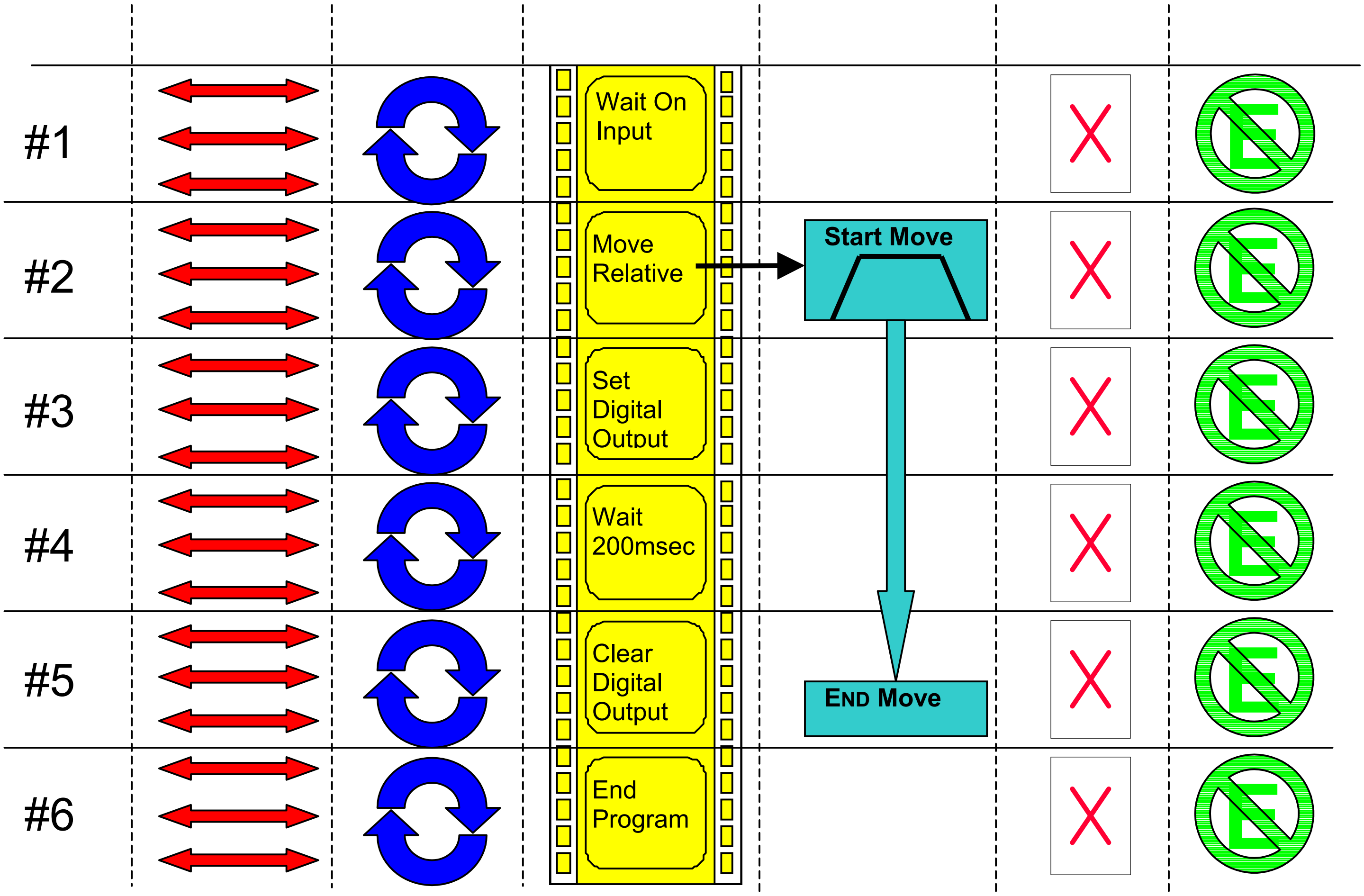
The SilverMax I/O inputs are checked each **Time Slice** so that motions stopping or other program operations can act very rapidly. This gives very accurate position registering when stopping on a digital input.

Task #6 – Error Checking

All internal status checking is done each **Time Slice** to provide the fastest possible response to an error condition. The **Kill Motor Conditions** are part of this checking so that error conditions can immediately shutdown a motor.

SilverMax Multi-Tasking Diagram

	Task #1	Task #2	Task #3	Task #4	Task #5	Task #6
Time Slice (120 usec)	**Serial Comm** (Every 40 usec)	**Servo Loop** (Calculate every 120 usec)	**Program Flow** (1 instruction each 120 usec time slice)	**Move** (Start and End on a 120 usec time slice)	**I/O Status** (Check Input states)	**Error Checking** (Motor Shutdown conditions)



Analog Input Modes (Velocity, Position and Torque)

The Analog input modes provide all the basic motor control that can be achieved using the various move commands using an analog signal for the control input. Be aware that internally SilverMax does all moves using 32-Bit values that give very high resolution for Position or Velocity. Analog inputs cannot come close to this level of resolution because of being limited to 10-Bits. Typically this is OK for Velocity or Torque modes but may not be enough resolution for Position mode.

32-Bit values range from 0 to 4294967295	**(-2,147,483,648 to +2,147,483,647)**
10-Bit values range form 0 to 1023	**(-512 to 511)**

Analog Input Resolution

SilverMax has four analog input channels as part of its input design. These inputs are tied to an internal **Analog to Digital Converter** (**ADC**) that converts the analog signals to numeric values that can be used by the SilverMax DSP controller. The **ADC** is a 10-Bit version which mean that the full range input provides a number from “0” to “1023”. The inputs can accept a voltage range of “0” to “5” volts. Doing a little math, this means that “1” ADC count represents “0.00488” volts (~5 millivolts). Internally the SilverMax scales the number so that a maximum count of “1023” is converted to “32767” (15-Bits).

Analog Read Methods

There are two methods for reading in analog information. One method is to do a **single read** using the **Analog Read Input** command. This command does a single reading of a selected analog input and places the value in a selected **Data Register**.

The second method is to do **continuous readings** of a selected analog channel using the **Analog Continuous Read** command. This command puts SilverMax into a continuous read cycle that takes an analog reading every servo cycle (120 usec.). When in analog continuous read the analog value is place in the selected Data Register after each reading (every 120 usec.). This provides continuous update of the analog signal that allows for better tracking.

Connecting Analog Inputs

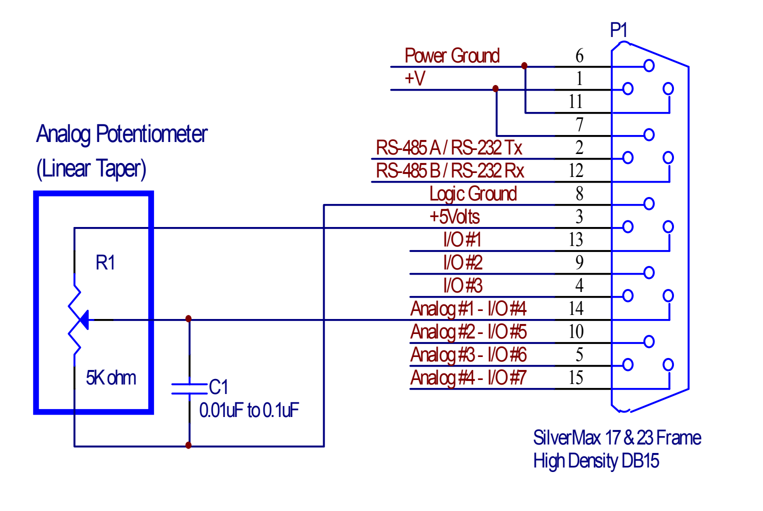
Analog inputs can be use in two different ways, **Single channel** or **Differential Channel**. The method used depends on the system requirements.

Single Channel Input is the simplest way to connect to SilverMax the example below shows a single channel input connection to a potentiometer. In the single channel approach the analog signal is referenced to the SilverMax logic ground. Electrical noise can be problem therefore an input capacitor may be required. Normally an input capacitor should be used if the source impedance is high.

Differential Channel Input has an added advantage of giving noise rejection of low frequency electrical signals. Using differential channel input will also double the resolution of the ADC input from 10-Bit to 11-Bit. The value read by the Analog input commands will range for -32767 to +32767 (0 to 5 volts).

Analog Input Mode Example Using a Potentiometer:

This example shows connecting a 5K ohm potentiometer to input #1. The +5 volt output from the SilverMax is used for the voltage reference. This provides a 0 to 5 volt signal to the Analog Input.



Analog Input Mode (Velocity).qcp

Example Program Description:

Velocity Input Mode
Data is continuously read in from Analog Input #1. The Raw ADC value is placed into **Data Register #12** every 120usec.

Process Example
Assume #12 = **24000**

Step #1: #13 is subtracted from #12
24000 - 16383 = **xxx**

Step #2: Remove deadband value #14
(sign)(ABS(-6000) – 100) = **-5000**

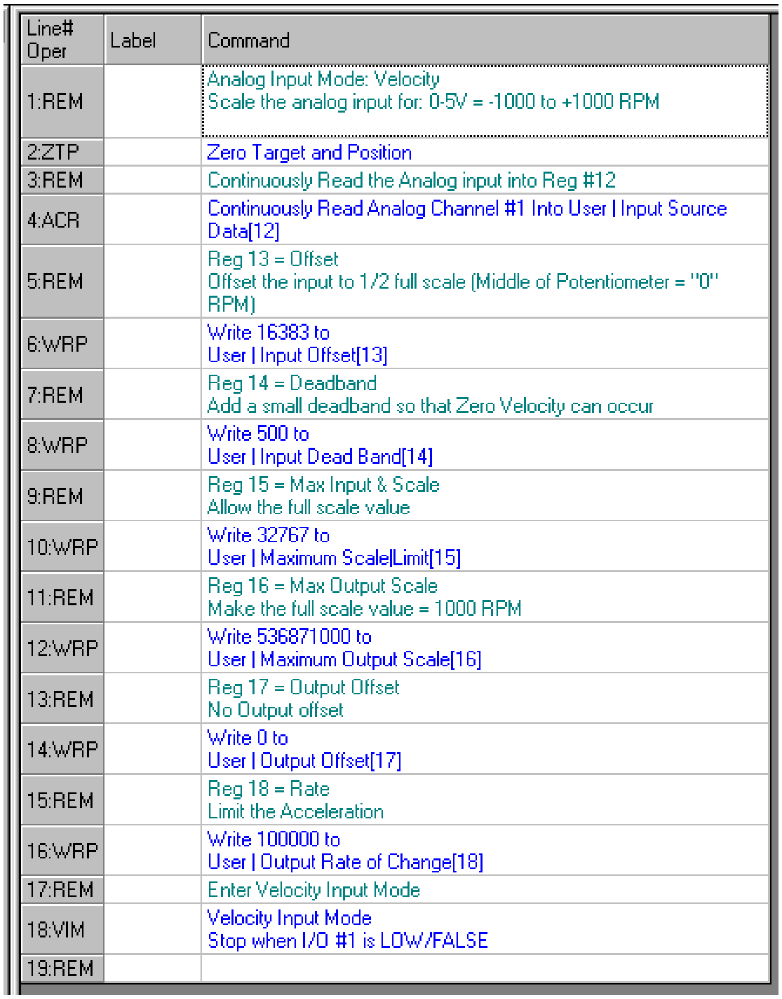
Step #3: Limit and Scale using #15.
Because the result is less than 32767 it won't be limited.
(Limit)(-32767 < -5000 > 32767) **= -5000** (Scale) -6000 / 32767 = **-0.1526**

Step #4: Scale for output by multiplying by #16
-0.1526 x 4000 = **-610**

Step #5: Offset output by subtracting #17
-610 – 0 = **-610**

The Result from Step #5 is used for the motor **Target** position.
Target = -610

Step #6: Limit the **Velocity** of the move using #18. In this case the **Velocity** is limited to 100 RPM.



Line# Oper	Label	Command
1:REM		Analog Input Mode: Velocity Scale the analog input for: 0-5V = -1000 to +1000 RPM
2:ZTP		Zero Target and Position
3:REM		Continuously Read the Analog input into Reg #12
4:ACR		Continuously Read Analog Channel #1 Into User I Input Source Data[12]
5:REM		Reg 13 = Offset Offset the input to 1/2 full scale (Middle of Potentiometer = "0" RPM)
6:WRP		Write 16383 to User I Input Offset[13]
7:REM		Reg 14 = Deadband Add a small deadband so that Zero Velocity can occur
8:WRP		Write 500 to User I Input Dead Band[14]
9:REM		Reg 15 = Max Input & Scale Allow the full scale value
10:WRP		Write 32767 to User I Maximum Scale|Limit[15]
11:REM		Reg 16 = Max Output Scale Make the full scale value = 1000 RPM
12:WRP		Write 536871000 to User I Maximum Output Scale[16]
13:REM		Reg 17 = Output Offset No Output offset
14:WRP		Write 0 to User I Output Offset[17]
15:REM		Reg 18 = Rate Limit the Acceleration
16:WRP		Write 100000 to User I Output Rate of Change[18]
17:REM		Enter Velocity Input Mode
18:VIM		Velocity Input Mode Stop when I/O #1 is LOW/FALSE
19:REM		

Differential Analog Input Example Using a Joystick:

This example uses a Joystick that has an internal voltage divider to provide a voltage reference. This method minimizes effects from power supply variation and electrical noise.

Example Program Description:
Position Input Mode

Data is continuously read in differentially from Analog Inputs #1 & #2. Raw ADC value is placed into **Data Register #12** every 120usec.

A Single differential data read is done from Analog Inputs #1 & #2. This is dynamic offset data from the Joystick that is placed in **Data Register #13**.

Process Example
Assume #12 = **10000**
Assume #13 = **16000**

Step #1: #13 is subtracted from #12
16000 - 10000 = **-6000**

Step #2: Remove deadband value #14
(sign)(ABS(-6000) – 100) = **-**
5000

Step #3: Limit and Scale using #15.
Because the result is less then 32767 it won't be limited.
(Limit)(-32767 < -5000 > 32767)
= -5000
(Scale) -6000 / 32767 = **-0.1526**

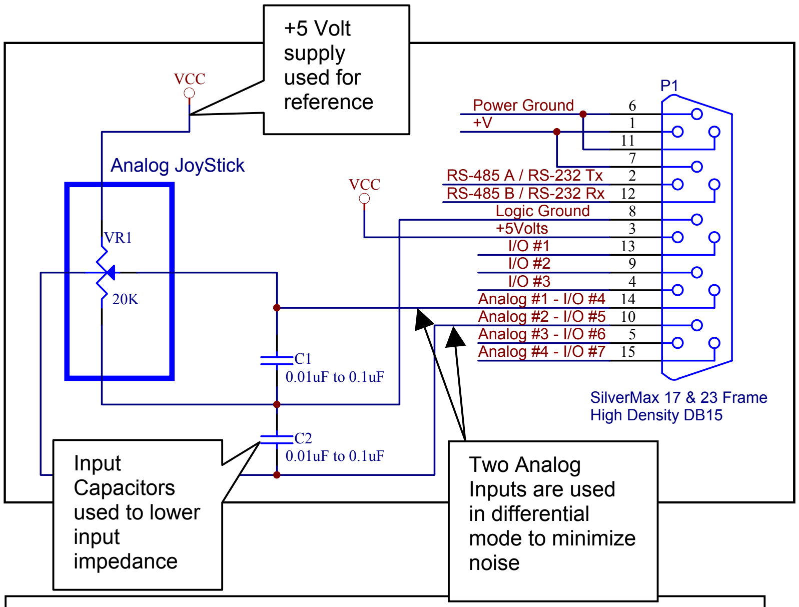
Step #4: Scale for output by multiplying by #16
-0.1526 x 4000 = **-610**

Step #5: Offset output by subtracting #17
-610 – 0 = **-610**

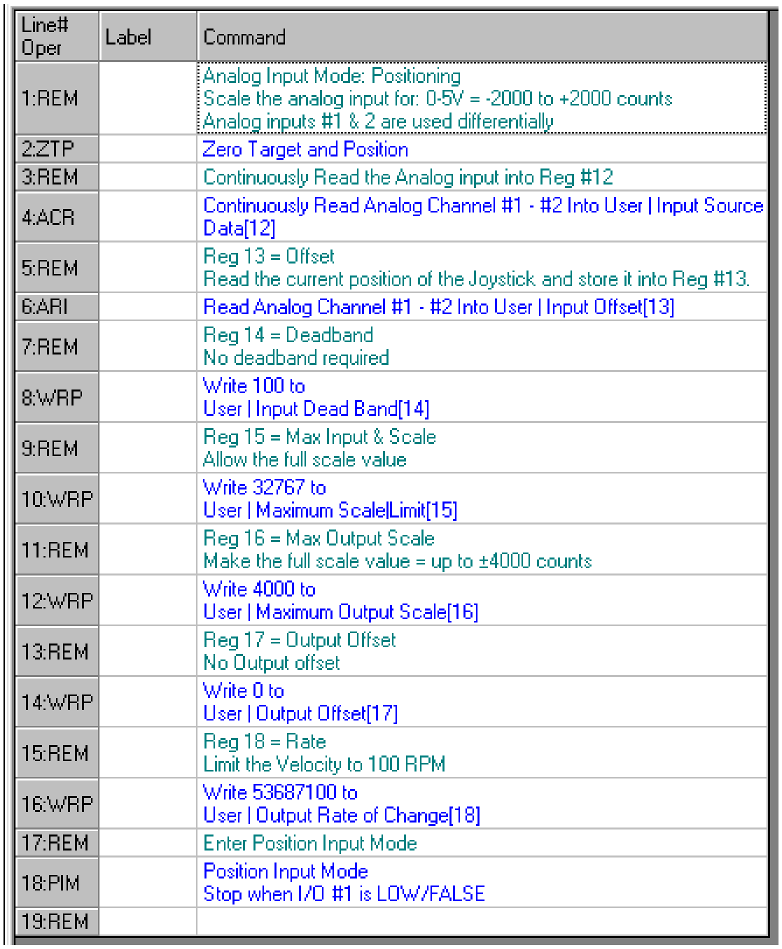
The Result from Step #5 is used for the motor **Target** position.
Target = -610

Step #6: Limit the **Velocity** of the move using #18. In this case the **Velocity** is limited to 100 RPM.

Process is repeated every **Servo Cycle**



Analog Input Mode (Positioning).qcp



Line# Oper	Label	Command
1:REM		Analog Input Mode: Positioning Scale the analog input for: 0-5V = -2000 to +2000 counts Analog inputs #1 & 2 are used differentially
2:ZTP		Zero Target and Position
3:REM		Continuously Read the Analog input into Reg #12
4:ACR		Continuously Read Analog Channel #1 - #2 Into User | Input Source Data[12]
5:REM		Reg 13 = Offset Read the current position of the Joystick and store it into Reg #13.
6:ARI		Read Analog Channel #1 - #2 Into User | Input Offset[13]
7:REM		Reg 14 = Deadband No deadband required
8:WRP		Write 100 to User | Input Dead Band[14]
9:REM		Reg 15 = Max Input & Scale Allow the full scale value
10:WRP		Write 32767 to User | Maximum Scale|Limit[15]
11:REM		Reg 16 = Max Output Scale Make the full scale value = up to ±4000 counts
12:WRP		Write 4000 to User | Maximum Output Scale[16]
13:REM		Reg 17 = Output Offset No Output offset
14:WRP		Write 0 to User | Output Offset[17]
15:REM		Reg 18 = Rate Limit the Velocity to 100 RPM
16:WRP		Write 53687100 to User | Output Rate of Change[18]
17:REM		Enter Position Input Mode
18:PIM		Position Input Mode Stop when I/O #1 is LOW/FALSE
19:REM		

Input Mode Description

Input mode is designed to use **Data Registers** for processing **Position**, **Velocity** or **Torque** information for the given modes. This allows SilverMax to input data from an **Analog Input** or the **Serial Interface** for operating in the selected modes.

The **Data Registers** are used to perform processing on the input data so that the output will give the desired results. If, for example, the input is an analog data source from a Joystick the processing can serve to calibrate the Joystick for the desired motion on the SilverMax. This can be done for almost any kind of data source including data that is sent directly from the **Serial Interface.**

All **Input Mode** commands use the same dedicated **Data Registers** for data storage and manipulation. When SilverMax is placed into one of the input modes (Velocity, Position or Torque) 7 data registers starting at #12 are automatically assigned for use in the data processing.

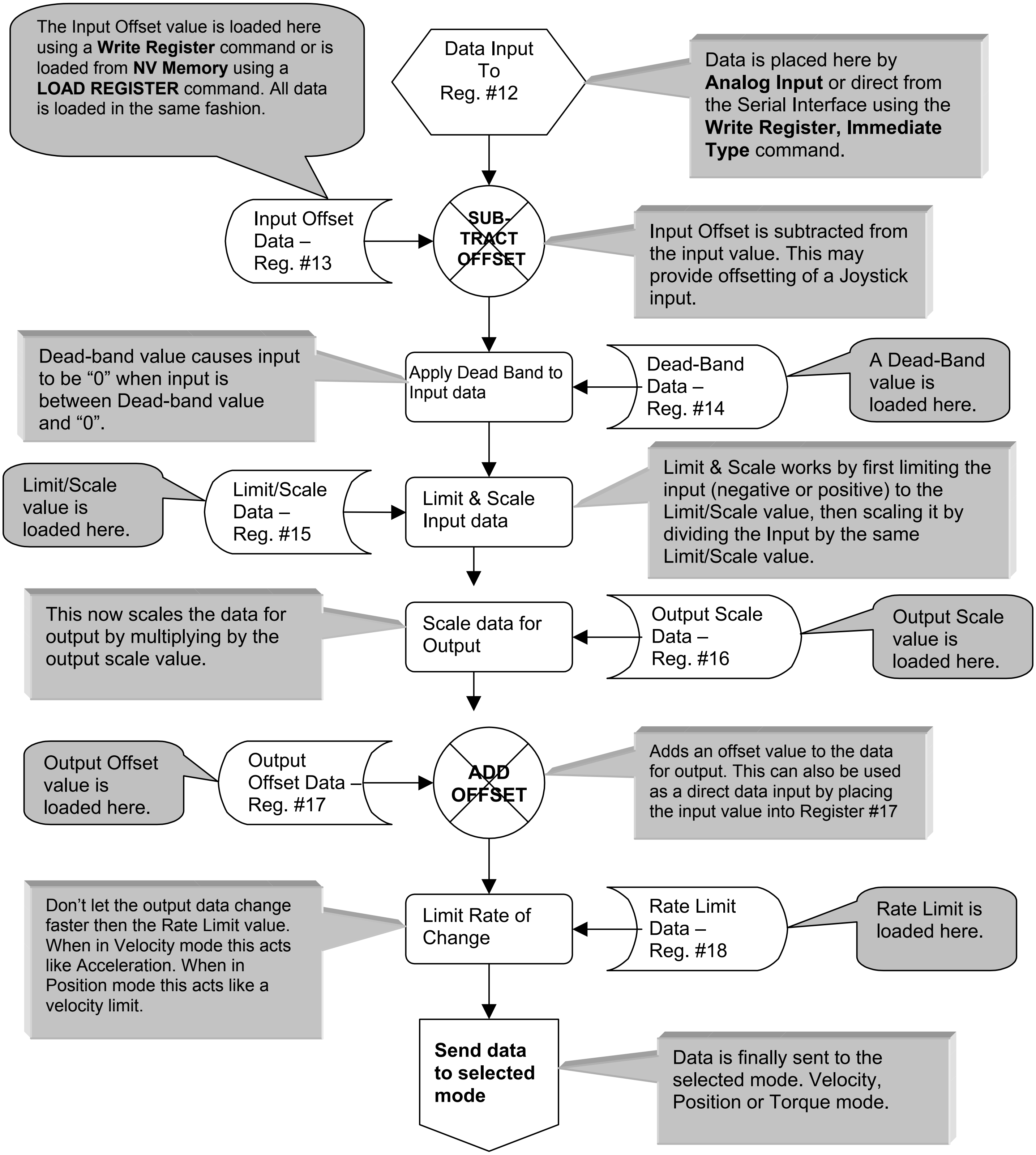
The appropriate **Data Registers** must be initialized before the input modes will work properly. This can be done in two different ways. The **Data Registers** may be initialized using **the Serial Interface** by sending data directly to the registers using the **Write Register, Immediate type** command. This method requires that a Host controller be connected to the **Serial Interface** during initialization. Another method is to use data that has been previously stored in the **Non-volatile memory**. Using the **Register Load Multiple** command all the Data Registers can be initialized at one time. The **Register Load from Non-Volatile** can also be used, but requires each register to be loaded one at a time. If the register load method is used the data must be stored in **Non-Volatile Memory** ahead of time using either the **Register Store Multiple** or the **Register Store to Non-Volatile** commands.

The following is a description of the **Data Registers** used and their functions:

Data Register #	Data Range	Data Source	Data Register Function
#12	-2,147,483,648 to +2,147,483,647	SilverMax or User	Input Source Data – Data can be placed here by Analog or Data Register commands.
#13	-2,147,483,648 to +2,147,483,647	User	Input Offset
#14	0 to 32767	User	Input Deadband
#15	0 to 32767	User	Maximum Scale/Limit
#16	-2,147,483,648 to +2,147,483,647	User	Maximum Output Scale
#17	-2,147,483,648 to +2,147,483,647	User or SilverMax	Output Offset
#18	0 to +2,147,483,647	User	Output Rate of Change Limit

The diagram on the next page shows the data, operations and data flow used for the **Input Modes**.

Input Mode Data Processing Diagram


Data Input To Reg. #12
SUB-TRACT OFFSET
Input Offset Data – Reg. #13
Apply Dead Band to Input data
Dead-Band Data – Reg. #14
Limit & Scale Input data
Limit/Scale Data – Reg. #15
Scale data for Output
Output Scale Data – Reg. #16
ADD OFFSET
Output Offset Data – Reg. #17
Limit Rate of Change
Rate Limit Data – Reg. #18
Send data to selected mode

The Input Offset value is loaded here using a **Write Register** command or is loaded from **NV Memory** using a **LOAD REGISTER** command. All data is loaded in the same fashion.

Data is placed here by **Analog Input** or direct from the Serial Interface using the **Write Register, Immediate Type** command.

Input Offset is subtracted from the input value. This may provide offsetting of a Joystick input.

Dead-band value causes input to be “0” when input is between Dead-band value and “0”.

A Dead-Band value is loaded here.

Limit/Scale value is loaded here.

Limit & Scale works by first limiting the input (negative or positive) to the Limit/Scale value, then scaling it by dividing the Input by the same Limit/Scale value.

This now scales the data for output by multiplying by the output scale value.

Output Scale value is loaded here.

Output Offset value is loaded here.

Adds an offset value to the data for output. This can also be used as a direct data input by placing the input value into Register #17

Don’t let the output data change faster then the Rate Limit value. When in Velocity mode this acts like Acceleration. When in Position mode this acts like a velocity limit.

Rate Limit is loaded here.

Data is finally sent to the selected mode. Velocity, Position or Torque mode.

Calculations

Calculations may be one of the subtlest commands in SilverMax. This command has many different operations that range from integer math to moving data. This command is found in the **Program FLOW** section of the command set because when a Calculation operation takes place **Calculation Flags** are set. **Calculation flags**, **Last Result Was Positive**, **Last Result Was Negative** and **Last Result Was Zero**, can be used by the **JUMP** command to control program flow.

Calculations are done on **Data Registers** which are all designed for 32-Bit storage. **Data Registers** are used as parameters in a number of SilverMax commands.

Some of the following operations are not available on older firmware revisions. Contact your distributor for a firmware upgrade.

Math Operations:

All math operations are Integer**. Data Register #10** acts as an accumulator where results are placed after an operation.

Addition and **Subtraction** can be done on 32-Bit numbers with the result being 32-Bit. SilverMax does not keep track of overflow and therefore data can be lost.

Signed Multiplication is done can be done on **Signed 32-Bit operands** with a **Signed 32-Bit result**. The user is responsible for handling overflow conditions. That is, make sure the two 32 bit numbers product will not be larger than +/- 2147483647 or data will be lost.

Unsigned Multiplication is done using on **32-Bit operands** with a **32-Bit result**.

Signed Division uses a **32-Bit dividend** and a **16-Bit divisor** with a **32-Bit result**.

Incrementing adds a “1” to the a Data Register. This is often used for creating counters. Counters can be used in “FOR … NEXT” loops.

Decrementing subtracts a “1” from the Data Register. This is also used for counters that count down.

Absolute Value finds the “positive” value of the **Data Register**. This is very useful when testing for the magnitude of a number.

Modulo finds the remainder of the **Data Register** after being divided by the **16-Bit operand**. For example 17 modulo 16 = 1.

Bitwise Operations:

These operations perform Bitwise processing on the Data Registers. This is designed for detecting bit patterns in Data Registers.

AND-ing - ANDs each bit of the **Data Register** to each bit of the **Accumulator**. This is done on all 32-Bits. Both bits AND-ed must be a “1” for the result to be “1”.

OR-ing - ORs each bit of the **Data Register** to each bit of the **Accumulator**. This is done on all 32-Bits. Any bit OR-ed that is a “1” will result in a “1”.

XOR-ing - XORs each bit of the **Data Register** to each bit of the **Accumulator**. This is done on all 32-Bits. If both bits XOR-ed are “1” the result will be “0”. If one of the Bits is a “1” and the other is a “0” the result will be a “1”. If both Bits are “0” the result is “0”.

Shift Left/Right – Shift the bits in the **Data Register** left or right one position.

Data Register Operations:

These operations perform data manipulation on the Data Registers usually preparing them for other calculations. (See **Data Register Commands** for other operations such as writing to **NV Memory**)

Loading or Copying, copies the data from a **Data Register** into the Accumulator. Any Data Register can be loaded. The **Load High Word** loads only the “Upper Word” (16-Bits) of the **Data Register** into the Accumulator. **Load Low Word** loads only the “Lower Word” (16-Bits) of the **Data Register** into the Accumulator.

Saving takes the contents of the **Accumulator** (usually after a math operation) and copies it into a **Data Register**. This can only be done to “writable” **Data Registers** (see Data Register Command section).

Clearing clears the contents of the Data Register to “0”.

Word Manipulation - There are several operations for moving the 16-Bit words around in a **Data Register**.

Setting Motor Position:

Subtract from Target and Position is a special purpose operation that subtracts a value from the **Target Data Register** and the **Position Data Register** simultaneously. This is used to explicitly set the SilverMax motor position to a pre-determined value. Subtracting a negative value is the same as adding.

TUNING SILVERMAX

Control System Overview

The SilverMax “factory default” servo loop parameters have been optimized for a nominal load range for each motor. Given a fairly tight coupling, they meet the requirements of most systems. It has been our experience that 9 out of 10 applications can use the factory defaults. Other applications will require servo loop tuning to fit the target system. One of the biggest challenges for servo motors is having stable control with a large mismatch between motor’s rotor inertia and the load inertia of the system. The SilverMax PVIA™ Servo Control algorithm can be tuned to provide stable operation over a very broad range and can be tuned for stable control with large mismatch ratios (i.e. 100:1).

SilverMax PVIA™ Servo Algorithm

SilverMax has a unique servo loop algorithm called Position, Velocity Feedback/Feedforward, Integral and Acceleration Feedback/Feedforward (PVIA). In the PVIA algorithm, position information is used to perform closed loop control of rotor position by detecting and correcting for error in position versus the defined “target position”. Velocity and acceleration are calculated from time history data of the precise rotor position. Current position, velocity and acceleration data are passed on “real time” to the PVIA algorithm with target position, target velocity and target acceleration data. Following the control law, these parameters are used in calculating the motor torque needed to correct any motor position errors.

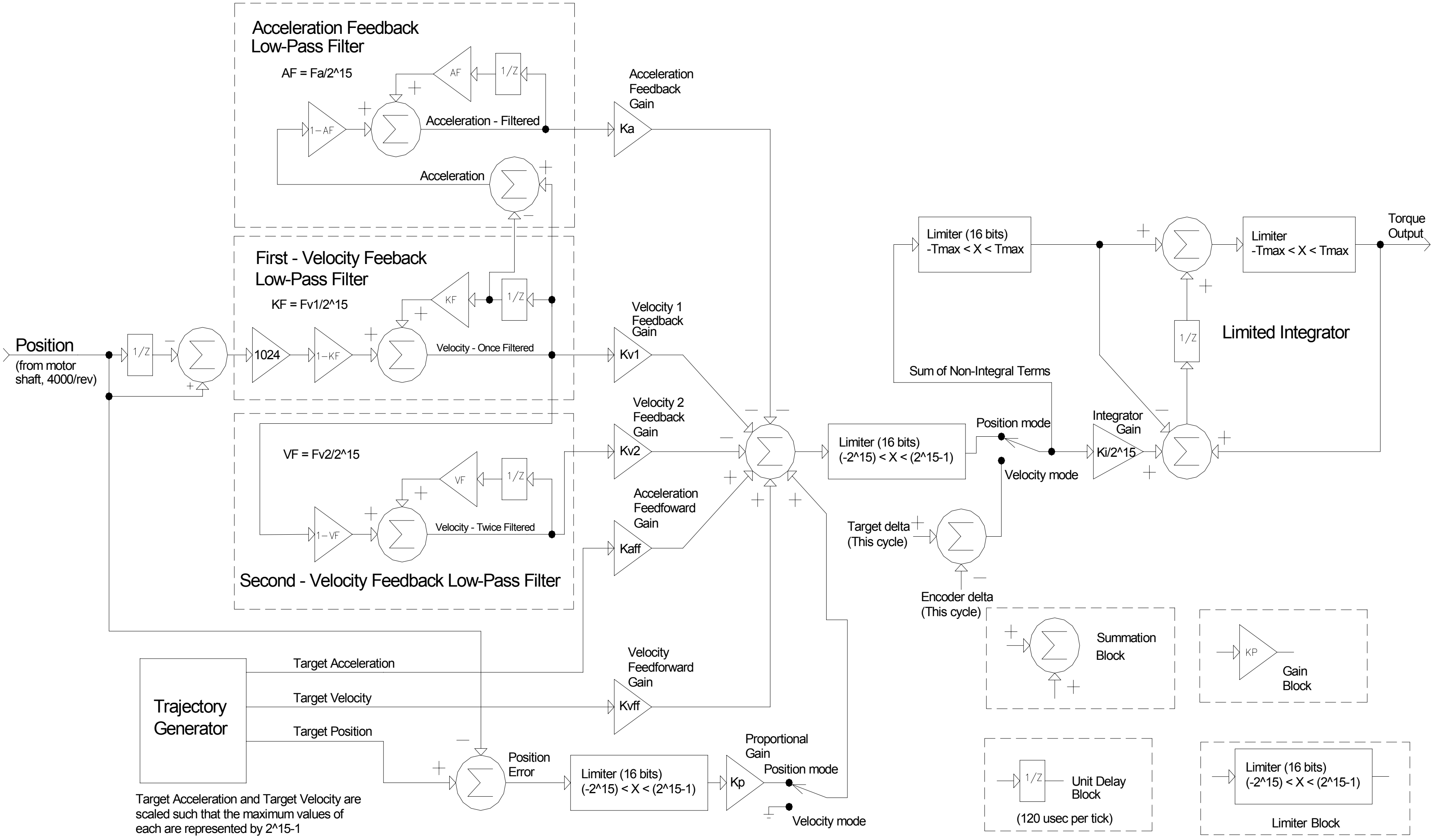
The exact transfer function (when not limiting) is:

C = Actual Position
R = Target Position

$$G(x) = \frac{1 - x/32768}{1 - xz^{-1}/32768}$$

$$\begin{aligned}
\text{Torque} = \quad & \{1 + Ki / [32768\ (1-z^{-1})]\ \}\ * \\
& \{ \\
& \qquad -512\ (1-z^{-1})\ Kv1\ G(Fv1)\ C \\
& \qquad -512\ (1-z^{-1})\ Kv2\ G(Fv1)\ G(Fv2)\ C \\
& \qquad +512\ (1-z^{-1})\ Kvff\ R \\
& \qquad -512\ (1-z^{-1})\ Ka\ G(Fa)\ C \\
& \qquad +512\ (1-z^{-1})\ Kaff\ G(Fv1)\ C \\
& \}
\end{aligned}$$

See below for a description of the terms (i.e. Ki, Kp…).


Acceleration Feedback Low-Pass Filter
AF = Fa/2^15
AF
1/Z
1-AF
Acceleration - Filtered
Acceleration
Acceleration Feedback Gain
Ka
First - Velocity Feeback Low-Pass Filter
KF = Fv1/2^15
KF
1/Z
1024
1-KF
Velocity - Once Filtered
Velocity 1 Feedback Gain
Kv1
Position
(from motor shaft, 4000/rev)
1/Z
VF = Fv2/2^15
VF
1/Z
1-VF
Velocity - Twice Filtered
Second - Velocity Feedback Low-Pass Filter
Velocity 2 Feedback Gain
Kv2
Acceleration Feedfoward Gain
Kaff
Limiter (16 bits) (-2^15) < X < (2^15-1)
Position mode
Velocity mode
Sum of Non-Integral Terms
Limiter (16 bits) -Tmax < X < Tmax
Limiter -Tmax < X < Tmax
Torque Output
1/Z
Limited Integrator
Integrator Gain
Ki/2^15
Target delta (This cycle)
Encoder delta (This cycle)
Trajectory Generator
Target Acceleration
Target Velocity
Target Position
Velocity Feedforward Gain
Kvff
Position Error
Limiter (16 bits) (-2^15) < X < (2^15-1)
Proportional Gain
Kp
Position mode
Velocity mode
Target Acceleration and Target Velocity are scaled such that the maximum values of each are represented by 2^15-1
Summation Block
KP
Gain Block
1/Z
Unit Delay Block
(120 usec per tick)
Limiter (16 bits) (-2^15) < X < (2^15-1)
Limiter Block
Block Diagram Legend

SilverMax PVIA Block Diagram

SilverMax Tuning Commands

Primary Commands

The following two commands set the primary tuning parameters.

Control Constants (CTC)

This command sets the various SilverMax servo loop gain constants. See the SilverMax Command Reference for details.

Proportional (Kp)
Velocity #1 Feedback (Kv1)
Velocity #2 Feedback (Kv2)
Velocity Feedforward (Kff)
Acceleration Feedback (Ka)
Acceleration Feedforward (Kaff)
Integrator (Ki)

Filter Constants (FLC)

Filter Constants selects the cutoff frequency for the velocity and acceleration filters. See the SilverMax Command Reference for details.

Velocity #1 Feedback Filter (Fv1)
Velocity #2 Feedback Filter (Fv2)
Acceleration Feedback Filter (Fa)

Associated Commands

The following commands set parameters associated with tuning.

Anti-Hunt Constants (AHC)

Anti-Hunt Constants set the thresholds used to determine if the position is sufficiently close to the target to allow the motor to go into and to stay in **Anti-hunt mode**. The first parameter is the maximum error (in counts) allowed in the Anti-Hunt mode before the unit will revert to normal closed loop operation. The second parameter is the maximum error allowed to enter the Anti-Hunt mode. See the SilverMax Command Reference for details.

S-Curve Factor (SCF)

Using this command, the shape of motion profile acceleration can be set from Linear to full S-curve. All motion profile commands use the current setting. This command can be set at any time (except for during a motion) allowing each motion profile to be tailored for the best shape. See the SilverMax Command Reference for details.

Torque Limits (TQL)

This command specifies the torque limits for the different operating modes of SilverMax. The two modes are **Open Loop** and **Closed Loop** with each mode having a **Moving** or **Holding** condition being active. The four parameters for the SilverMax torque limits are as follows:
Closed Loop Holding, **Closed Loop Moving**, **Open Loop Holding**, and **Open Loop Moving**.

SilverMax operates in **Moving** mode whenever the trajectory velocity is non-zero. It will continue to use the **Moving** torque limits until the **Delay to Holding** time expires after the last non-zero trajectory velocity is calculated. This allows a higher **Moving** torque limit to persist up to seven seconds after the last motion (or motion step of the **Step and Direction** command).

Following this period (which power up defaults to zero), the **Holding** torque levels are used.

The **Open Loop Holding** value is used by the **Anti-Hunt** mode for the current level that will be used to prevent hunting. This is only used when the **ANTI-HUNT CONSTANTS** are set to a value greater than "0".

Overview of the Control System Parameters

A good understanding of the parameters and settings is useful when figuring what changes should be made to give the desired results. QCI recommends that all users are educated on the parameter descriptions and functions they provide in the control system before tuning the SilverMax. The "typical parameter range" listed in the above table represents values that have been implemented in working applications and are to be utilized as a guide range for user applications. Some applications may have values outside the "typical range".

There are TEN tuning parameters that the user can set in the PVIA algorithm.
The following parameters are calculated in the PVIA algorithm and support the position control of the motor when it is moving and stopped. Velocity and acceleration feedback filters have a "Frequency" setting for rolling off high frequencies that may cause system instabilities. Velocity and acceleration feedforward parameters are used to compensate for the "position lag" effects of the velocity and acceleration feedback gains.

SilverMax Tuning Parameters	**QuickControl Variables**	Typical Parameter Range
Proportional Gain	**Kp**	40 – 400
Velocity #1 Feedback Gain	**Kv1**	0
Velocity #2 Feedback Gain	**Kv2**	5 – 50
Velocity Feedforward Gain	**Kvff**	5 – 50
Acceleration Feedback Gain	**Ka**	0 – 200
Acceleration Feedforward Gain	**Kaff**	0 – 200
Integrator Gain	**Ki**	0 – 2000
Velocity #1 Feedback Filter	**Fv1**	50-200Hz
Velocity #2 Feedback Filter	**Fv2**	70-400Hz
Acceleration Feedback Filter	**Fa**	30-2000Hz

User Accessible SilverMax Tuning Parameters

Proportional Gain (Kp)

Of all parameters this is the most straight forward to understand and use. The position error of the motor provides the most basic information to the algorithm about the state of the motor. It is calculated from the motor's "actual position" and calculated "target position". Torque output is controlled proportionally to the amount of position error detected. By adding in a gain value, the error is amplified providing an appropriate torque output depending on the load and desired stiffness. Higher gain settings increase the motor position holding stiffness and reduce position error.

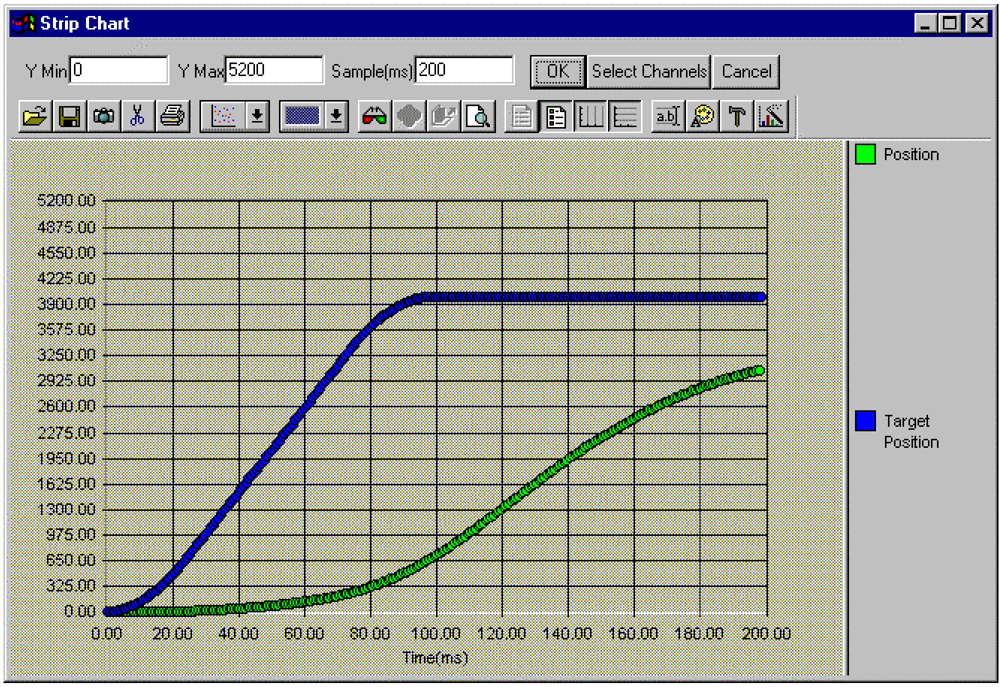
Torque = Kp * (Target Position – Actual Position)
Torque = Kp * Position Error

The best analogy to Kp is a simple spring. If SilverMax were to be replaced by a spring, Kp would be the spring's stiffness. If you were to rotate the shaft you would be either winding or unwinding the spring. The more you rotated the shaft the more the spring would fight you.

To demonstrate the effects of Kp, the following is a Strip Chart (from the QuickControl Control Panel) of a motor with the Filter Constants (FLC) left at their default values and the Control Constants (CTC) set as follows:

Kp=1
Kv1=0
Kv2=0
Kvff=0
Ka=0
Kaff=0
Ki=0

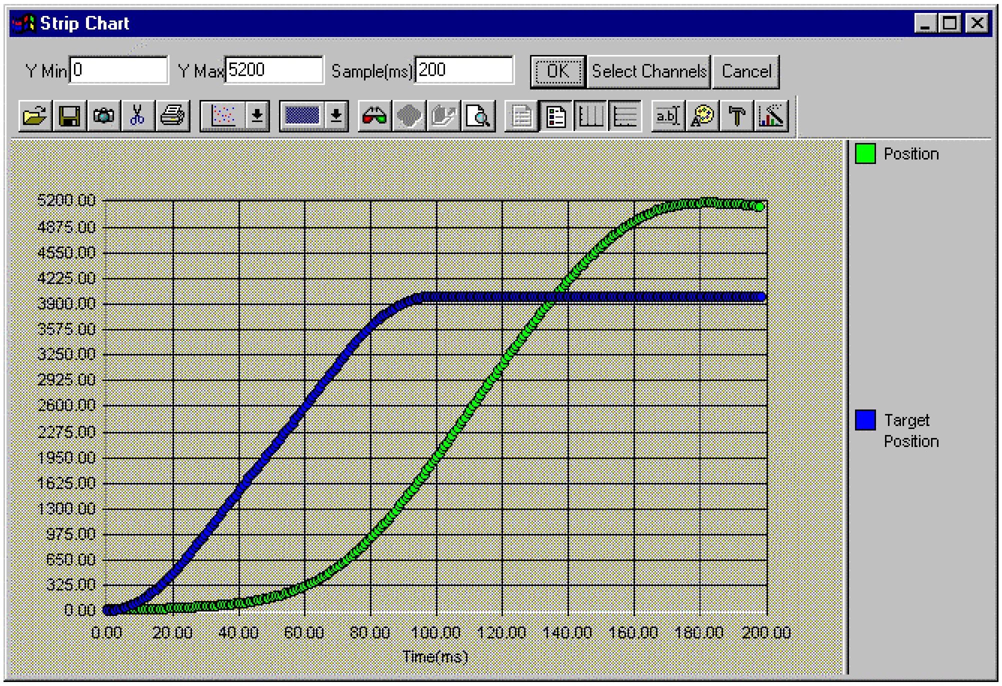
The Strip Chart plots a 4000 count,100ms move with a 25ms ramp time (MAT command). The channels plotted are the "Position" and "Target Position" which represent the actual and target positions of the motor respectively. That is, the Target Position is where the motor is supposed to be. The Position is where the motor actually is.



Kp=1

Notice how much error has to be developed in order to make the motor move.

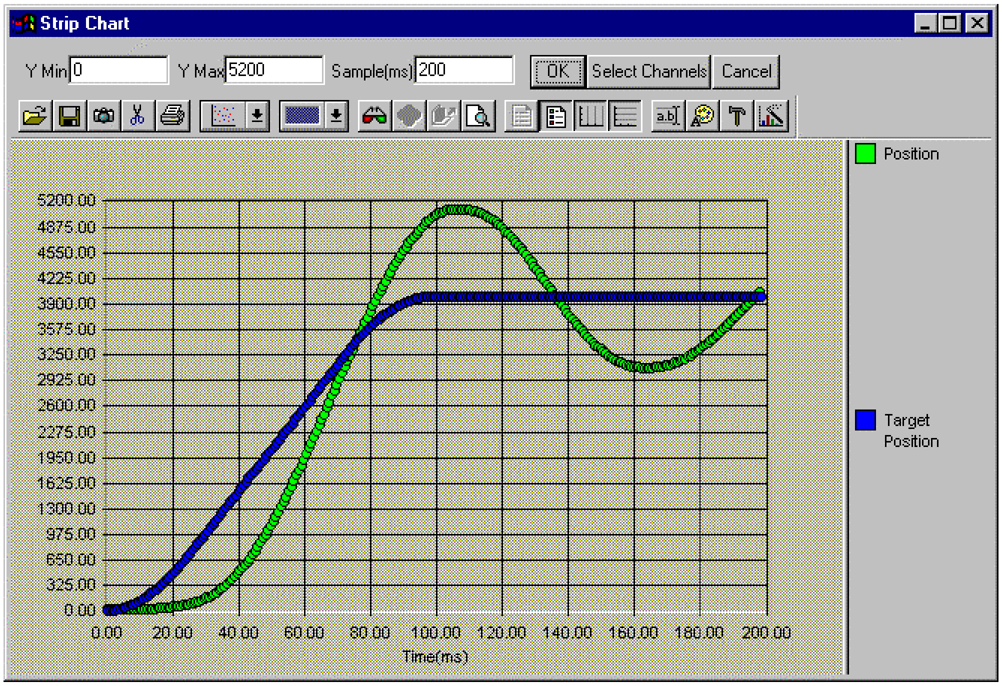
Setting Kp=2 will double the torque and produces the following strip chart.



Y Min 0 Y Max 5200 Sample(ms) 200

Kp=2

Although less error is required to generate sufficient torque, once the motor gets moving it overshoots and does not come back and until enough negative torque is generated. Increasing Kp will continue to have this effect. The overshoot is often called “ringing”. See what increasing Kp to 10 does.



Y Min 0 Y Max 5200 Sample(ms) 200

Kp=10

Going back to our “spring” analogy, by increasing Kp we have created a stiffer spring. Although it is moving to target in a timely manner it is also bouncing around a lot or “ringing”. This is the same thing as a car without shocks. The springs are still working fine, but every time you hit a bump the car bounces a few times. To eliminate the bounce we need some shocks. In PVIA, the Velocity Feedbacks (Kv1 and Kv2) are the "shocks".

Typically Kp is increased to get the desired stiffness and response (reduce Position Error). If Kp gets too high, the SilverMax will start vibrating as it overcompensates for small errors.

Velocity Feedback (Kv1 & Kv2)

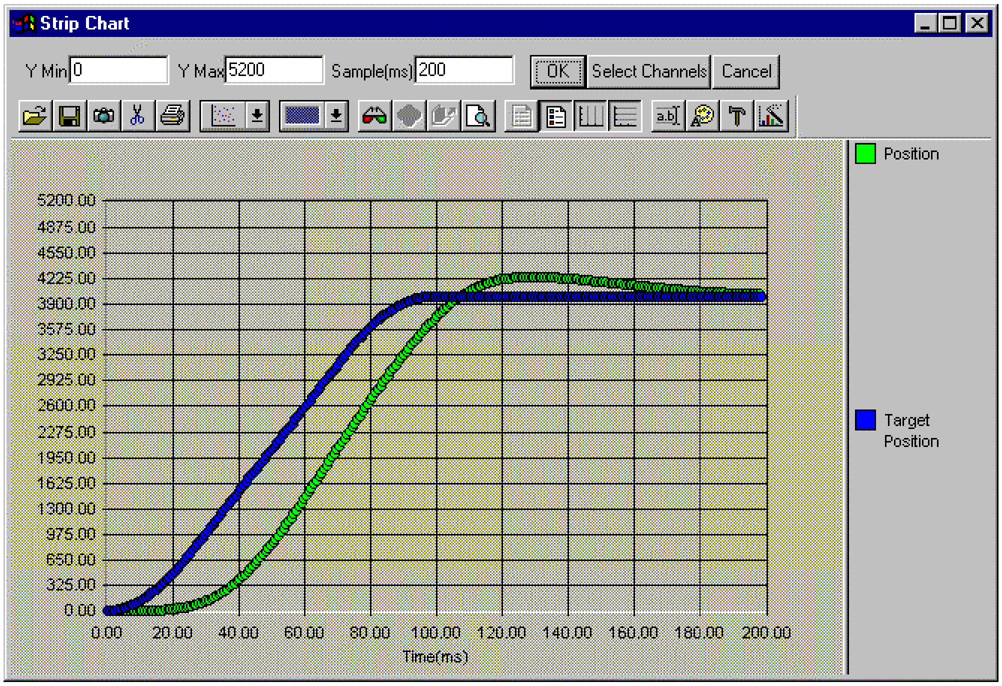
Velocity values are derived from the position information that is read every servo cycle (120 usec). Velocity values are calculated from the change in position that at each servo cycle. The velocity data is filtered by two cascaded low pass filters that provide at their output the filtered Velocity 1 and Velocity 2 values.

Both Velocity values have a gain setting that is used to adjust the amount of velocity feedback that is required. Velocity is a negative feedback value that is used to "Damp" the servo control loop. Setting the gain values at "0" prevents any velocity feedback from being used.

Kv1 is typically set to 0. Kv1 is only needed in rare, high frequency response applications (i.e. 10ms move). In these situations, the extra filtering done to calculate Velocity 2 causes it to not accurately represent the load's velocity.

Kv2 is typically the only Velocity Feedback used. Kv2 is analogous to a shock absorber added to our spring. The larger the Kv2 the more damped the shock. With Kp only, our SilverMax "spring" would oscillate to a stop every time it was moved. Even the smallest amount of Kv2 (i.e. Kv2=1) will add noticeable dampening.

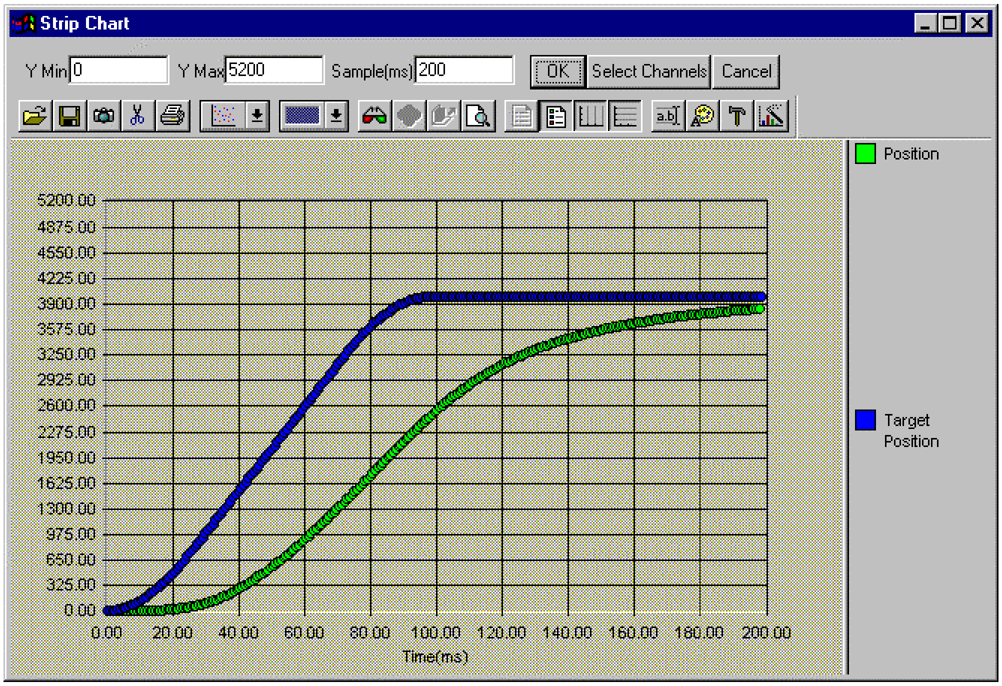
Let us see what a "shock absorber" does to our bouncy system. The following plot is the same as above except Kv2=1



Y Min 0 Y Max 5200 Sample(ms) 200

Kp=10, Kv2=1

Notice what a significant damping effect Kv2 has on the system. Let us make Kv2=3.


Y Min 0 Y Max 5200 Sample(ms) 200

Kp=10,Kv2=3

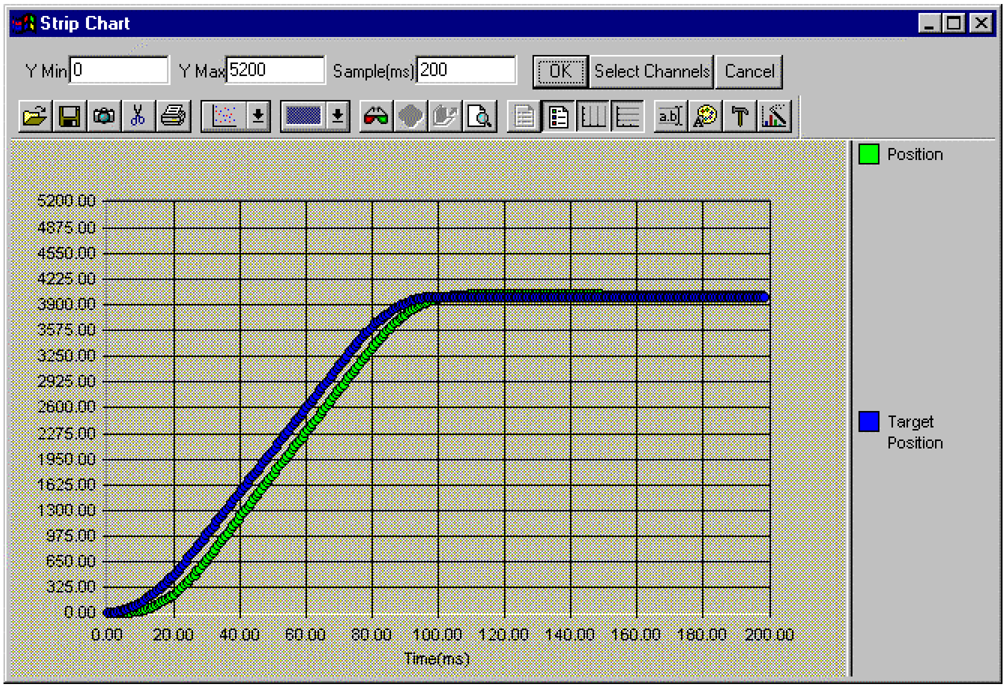
Although the system is more damped, it appears to be having a little trouble matching the velocity of the target. Velocity feedback means substracting some component of the velocity (Kv2 x velocity) from the torque. As Kv2 increases, the velocity feedback will cause a greater velocity error in our system. To compensate for this we need to add some Velocity Feedforward (Kvff).

Velocity Feedforward (Kvff)

SilverMax contains an internal target generator called the “Trajectory Generator”. In real time, SilverMax calculates the motion profile defined by a given command and it’s parameters. On each servo cycle, the “target” value is updated in the servo control loop. Similar to the Velocity Feedback value, a “Target Velocity” value is calculated from the “target” value, instead of the position value. This “target” value is used to compensate a lag in position that is induced by the Velocity Feedback term.

The Velocity Feedforward gain value is set to adjust the required amount of the Velocity Feedforward term. Velocity Feedforward is a positive feedback value used to “anticipate” the velocity needs for the servo control loop. Setting the gain value to zero, prevents the Velocity Feedforward term from being used. Usually, this gain value is set equal to the sum of the Velocity 1 Feedback (Kv1) and Velocity 2 Feedback (Kv2) gain values.

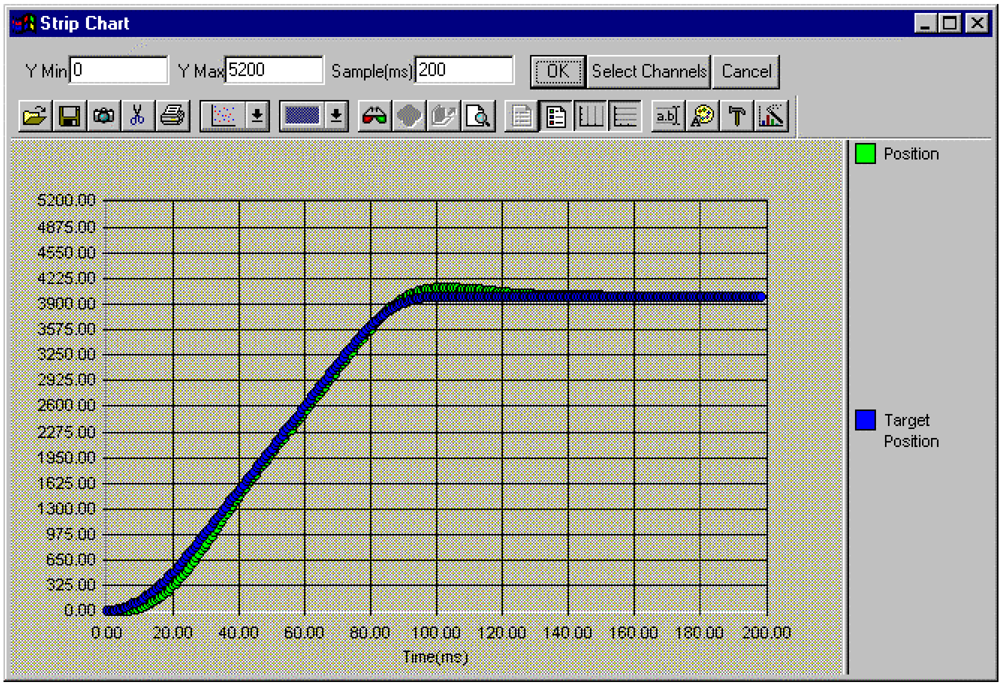
Setting Kvff=3 in our system produces the following chart.



Y Min 0 Y Max 5200 Sample(ms) 200

Kp=10,Kv2=3,Kvff=3

Notice how well the velocity is now tracking. To further improve the system response (reduce Position Error), Kp can be increased. With our dampener in place (Kv2), increasing Kp should not cause the system to ring. Notice how well the system behaves with Kp=40.



Y Min 0 Y Max 5200 Sample(ms) 200

Kp=40,Kv2=3,Kvff=3

Note: For applications that require NO overshoot and fast response, Kvff may be slightly reduced to force a following error such that the response approaches from starting side without overshooting- even in the presence of minimal ringing.

Acceleration Feedback (Ka)

The Acceleration value is derived from the Velocity 1 Post Filter value (See SilverMax PVIA Diagram). The Acceleration Feedback term functions as an "virtual" or "electronic" damper improving the overall system smoothness and decreasing the system settling time. It does this by providing a high frequency phase/gain boost that counters any PVIA changes is shaft velocity.

Ka can be thought of as a large, virtual "flywheel" (a dampener) attached to the back of the motor through a "viscous clutch". Ka would then be the product of the damper viscosity (damping factor) and the damper inertia. Increasing Ka will increase the amount of damping injected into the control loop. The larger the Ka, the larger the "flywheel" and the stiffer the "viscous clutch".

Bring up Ka if additional mid range damping is needed. Excessive Ka will first sound "gritty" as the individual encoder counts are emphasized, or may cause a high frequency squeal.

Ka is most useful when trying to tune out vibrations (resonance modes) induced by system components (i.e. a belt drive). To use this term effectively, motor shaft couplings with very low torsional compliance are normally required. See the section on tuning belt drives at the end of the chapter for an example.

Acceleration Feedforward (Kaff)

The Acceleration Feedforward value is derived from the Velocity Feedforward value. It functions similar to the Velocity Feedforward term by compensating the position lag induced by Acceleration Feedback term.

Normally the Acceleration Feedforward gain term is set to equal the Acceleration Feedback gain term. Although, it may be set slightly higher to assist with the acceleration of high inertial loads.

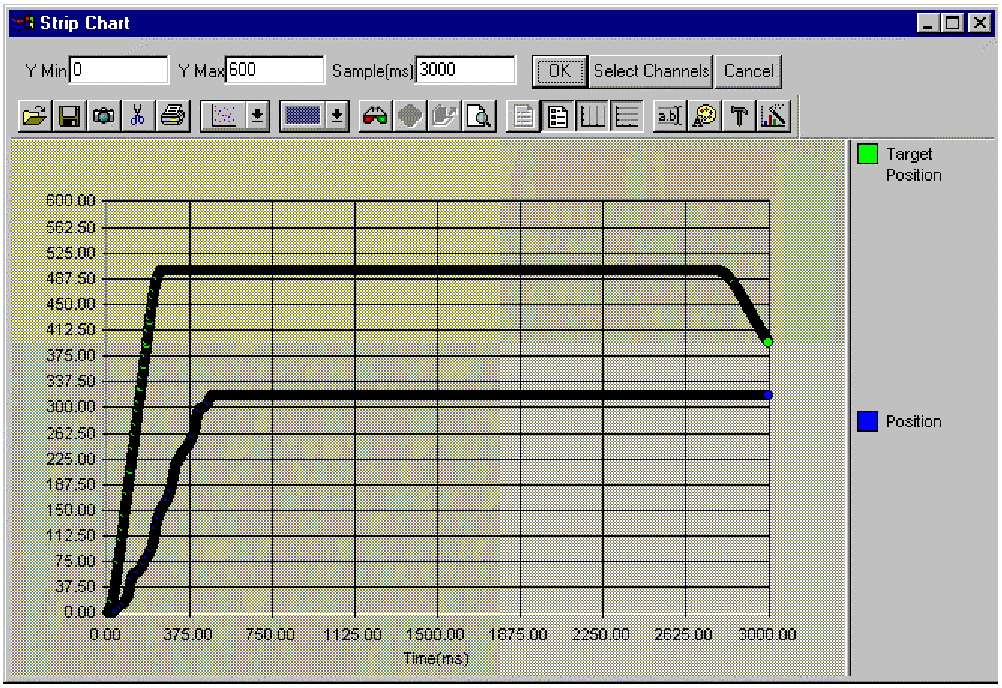
Integrator Gain (Ki)

The integrator parameter is the most important term for controlling steady state position error. The integrator works over time to bring the motor to "zero" error when the "target" position and the "actual" position differ. The longer there is position error, the harder Ki will work to get rid of it. This term is commonly referred to as the "I" term in the traditional PID control loop.

Unlike a PID servo the PVIA integrator term can be set very high without causing "hunting". This is because PVIA automatically clips the accumulated error to reduce the effects of "integrator windup".

Running SilverMax with "0" integrator gain is a valid condition when tuning or where steady state position error is not a critical concern.

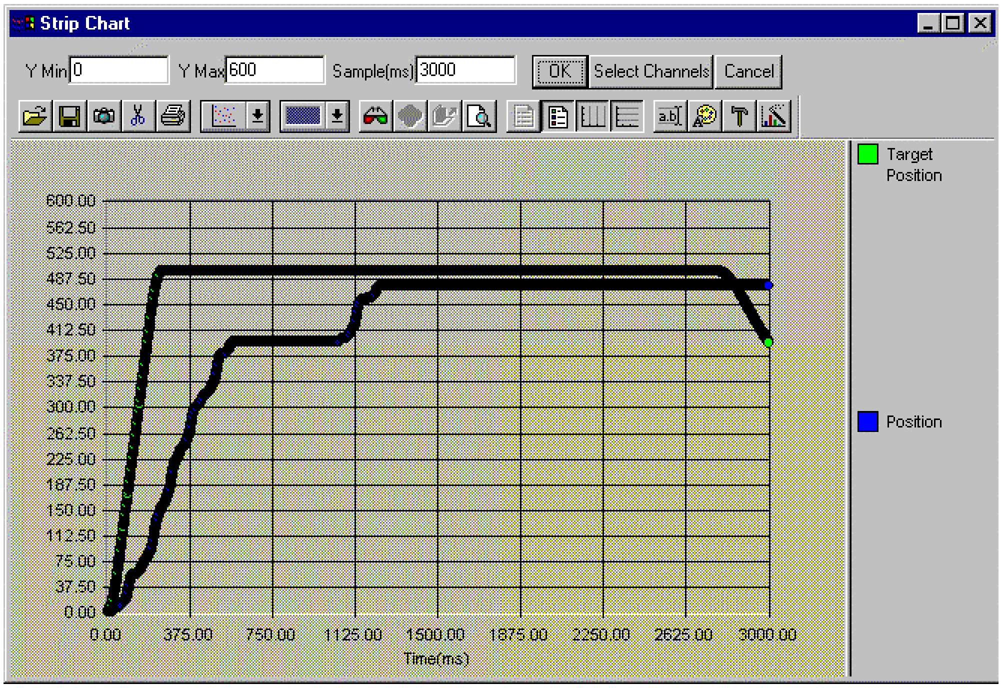
The best way to see the effects of Ki is to start with Kp=7 and plot a short move. The following is a 500 count move.



Y Min 0 Y Max 600 Sample(ms) 3000

Kp=5 all other K's = 0

Notice how the motor never actually gets to the target. There is not enough torque generated by Kp to move the motor into position. By using Ki, more and more torque will be added until the Position Error is zero. The following plot is with Ki=5.



Y Min 0 Y Max 600 Sample(ms) 3000

Kp=7,Ki=5

Increase Ki by a factor of 2 or 3 each time until a low frequency oscillation or excessive overshoot is obvious, then reduce by a factor of 2 or 3.

The product of Ki and Kp generally sets the "stiffness" of a system. In other words, if you double Kp you will have to half Ki to get the same steady state error. A good starting place for Ki can be derived from the default tuning parameters. For example, if your custom tuned system has Kp=200 and the default tuning parameters had Kp=100 and Ki=1000, a good starting place for Ki would be 500.

Velocity Filters (Fv1 & Fv2)

The Velocity Feedback values are filtered by a low-pass filter. Two filters are used, with the first one cascading into the second, for a steeper roll off on the output of the second filter (See the SilverMax PVIA Diagram). Filtering the velocity values allows the velocity gain to be increased for greater damping control of the load. In cases where large inertial mismatches are present, the filters aide in stabilizing the servo control loop to allow greater velocity feedback gain.

Think of a stereo with an equalizer. If you were to zero out the upper half of the frequency slides (reduce the high notes), you would have effectively introduced a low pass into your stereo. The only thing passing through your stereo would be the low (bass) notes.

For a typical system, the first velocity filter (Fv1) is placed at the lowest frequency, the second filter (Fv2) is typically a factor of 2 to 5 times higher, with 3 being typical. This allows Fv1 to roll off gain in the velocity estimator before Fv2 introduces significant phase lag. The two filters, together, help reduce the higher frequency torsional resonance modes of the widely mismatched systems (20:1 to 200:1).

A good rule of thumb is to set these just above your system's reasonable frequency response. For example, if your are trying to move a large flywheel, having these filters up at 1000Hz is unreasonable. There is nothing happening of interest in the 1ms time frame. The flywheel just cannot not move that fast. Putting these filters down under 100Hz is more reasonable.

> *Note: The modes above the roll off frequencies of the velocity estimators are not just ignored, but they are passively damped by the patented drive technique that effectively shorts the windings to signals at frequencies higher than the velocity filters.*

Acceleration Filter (Fa)

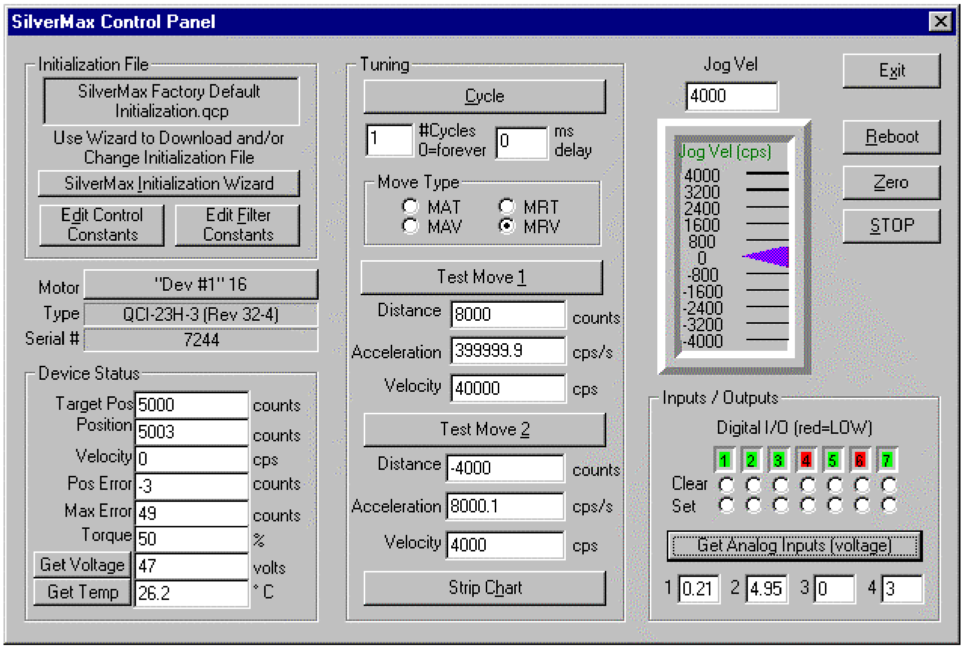
As with the Velocity Feedback term, the Acceleration Feedback term has a low-pass filter used to filter out unwanted high frequency data.

Fa is typically set at about 5x Fv1 - this produces the greatest phase boost while minimizing the high frequency noise amplification. The peak phase boost enhancement is at the geometrical mean of the Fv1 and Fa (square root of the product of these frequencies).

When Ka has been increased to produce a "virtual" dampener (see the section on Ka for details), Fa should be set just above the resonance frequency of the system. See the Belt Driver tuning notes at the end of this chapter for an example.

SilverMax Control Panel

This Control Panel in QuickControl provides the user access to several important features of operation. It allows the user to "JOG" SilverMax at scalable velocities while monitoring the condition of the motor in the Device Status area of the Control Panel. In addition, the Panel provides the means to interactively tune the SilverMax servo loop. Test Moves are available to prototype specific application operations for making the tuning capabilities more realistic. A strip chart can be displayed to show various motion parameters while tuning.



SilverMax Control Panel

Initialization File

SilverMax Factory Default Initialization.qcp

Use Wizard to Download and/or Change Initialization File

Motor: "Dev #1" 16
Type: QCI-23H-3 (Rev 32-4)
Serial #: 7244

Device Status

Target Pos	5000	counts
Position	5003	counts
Velocity	0	cps
Pos Error	-3	counts
Max Error	49	counts
Torque	50	%
Get Voltage	47	volts
Get Temp	26.2	°C

Tuning

#Cycles 0=forever: 1
ms delay: 0

Move Type: ○ MAT ○ MAV ○ MRT ● MRV

Test Move 1

Distance	8000	counts
Acceleration	399999.9	cps/s
Velocity	40000	cps

Test Move 2

Distance	-4000	counts
Acceleration	8000.1	cps/s
Velocity	4000	cps

Jog Vel: 4000

Inputs / Outputs

Digital I/O (red=LOW)

1	2	3	4	5	6	7
🟩	🟩	🟩	🟥	🟩	🟥	🟩

Get Analog Inputs (voltage): 1 0.21 2 4.95 3 0 4 3

Tuning Example – 100x1 Inertial Miss-Match

High resolution, fast following is all about maximizing bandwidth and gain of the system while keeping the damping reasonable to prevent ringing. Below is a simple procedure for tuning SilverMax with a non-frictional 100:1 all inertia load using the tuning tool in QuickControl.

When tuning SilverMax, it is important to keep the Velocity Feedforward (Kvff) term equal the sum of the two velocity feedback terms (Kv1 & Kv2). In addition, the Acceleration Feedforward (Kaff) and feedback terms (Ka) should also be equal.

1. Determine Motion Profile To Be Tuned.

Before beginning to tune SilverMax, determine the motion profile to be tuned using the example moves in the QuickControl Control Panel.

Absolute moves may be used to produce a fast move in one direction and a slow move in the other and will help insure your hard stops are not hit.

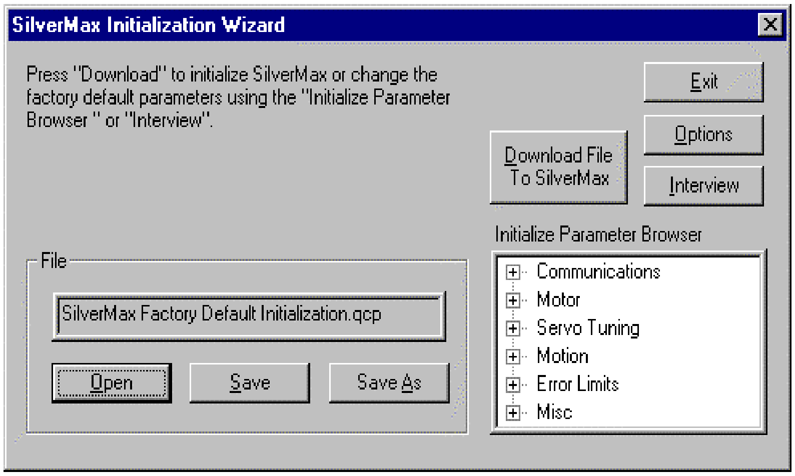
NOTE: Make sure the move is within the SilverMax's torque limits. One of biggest problems with "tuning" a high inertial mismatch system is the "undersized" motor. The SilverMax is trying *to move a very large load (100x times the rotor inertia). Keep an eye on the motor's torque to make sure it does not max out.*

2. Disable Anti-Hunt and Drag Mode

Turn off the Anti-hunt feature and any Error Limit Drag Mode settings. This will allow the user to see the true response of control system (enable them after tuning). This is done in:

Tools ⇒ SilverMax Initialization Wizard

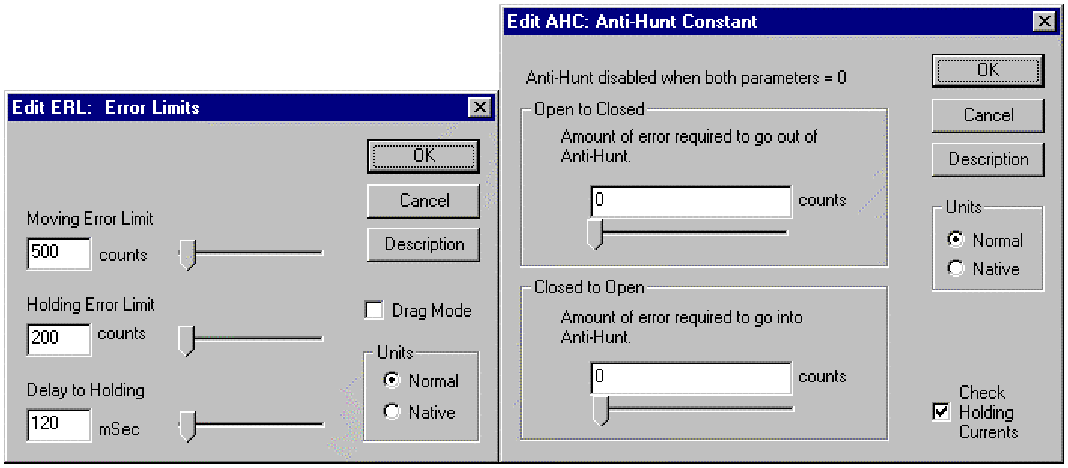
The modes are changed in the Anti-Hunt Constants (AHC) and Error Limits (ERL) commands. AHC can be accessed by way of the Initialization Parameter Browser's "Motion" branch. ERL is accessed by way of the "Error Limits" branch.



SilverMax Initialization Wizard

Press "Download" to initialize SilverMax or change the factory default parameters using the "Initialize Parameter Browser " or "Interview".

File: SilverMax Factory Default Initialization.qcp



Edit ERL: Error Limits

Moving Error Limit: 500 counts

Holding Error Limit: 200 counts

Delay to Holding: 120 mSec

□ Drag Mode

Units: ● Normal ○ Native

Edit AHC: Anti-Hunt Constant

Anti-Hunt disabled when both parameters = 0

Open to Closed: Amount of error required to go out of Anti-Hunt. 0 counts

Closed to Open: Amount of error required to go into Anti-Hunt. 0 counts

Units: ● Normal ○ Native

☑ Check Holding Currents

3. Start With Defaults

Start with the default tuning parameters for your motor.

4. Ki = 0

Start tuning with the integrator term set to zero. (Ki =0)

(Once a stable system with adequate phase margins has been established, then the integrator value can be turned up.)

TEST the move: Note any changes in the operation or sound in motion.

5. Increase Kv2 and Kvff

Increase both velocity terms to 10 times (10X) the default values.

TEST the move. Note any changes in the operation or sound in motion. If a high frequency "screech" occurs in a low inertia system, lower the Kv2 and Kvff until the sounds subside. If excessive overshoot occurs, increase Kv2 and Kvff. Typical adjustments are by a factor of 2 (i.e. either divide by 2 or multiply by 2).

Typically Kv2 and Kvff are adjusted until there is some “screech” during the move, but not at rest.

6. Reduce Fv1 and Fv2

Reduce Fv1 by 3X (1/3) and make Fv2=3xFv1.

Example:

Default:
Fv1 = 209, Fv2 = 209

Change to
Fv1 = 70, Fv2 = 210

This helps reduce the high frequency noise in the system.

TEST the move. Most noise should be gone and the overshoot at minimum. Keep decreasing the velocity filters until the noise goes away. Remember to keep Fv2 = 3xFv1. Typically Fv2 should be well above the system highest velocity. For example, if a 100ms is as fast as the SilverMax can(100ms = 10Hz), then you might set Fv2 at 100Hz.

7. Iterate Kv2 and Kvff, Fv1, Fv2

With noise gone or greatly reduce, try increasing Kv1 and Kvff to increase the damping (decrease the overshoot). When you have minimum noise and overshoot go to the next step.

8. Kv2 and Kvff x 90%

Decrease both velocity terms by 10% to “loosen” up the system.

TEST the move. Bring up the “Strip Chart” and observe the position error incurred from the motion.

9. Kp x2

To decrease the Position Error, increase the Position Gain by 2X.

TEST the move. Some ringing may begin to occur. Bring up the “Strip Chart” and chart the Position Error and Torque. Kp can be increased more if Position Error is too great but watch the torque. If the torque saturates, you are asking too much out of the motor and no amount of tuning will give you more torque.

10. Ki = 100 and Reduce Kp, Kv2, Kvff x75%

Set the Integrator Gain (Ki) to 100 and reduce all gains (K values) by 25% to provide overhead in system operation. Increasing Ki will make the system stiffer when holding a position. Increasing Ki too much will cause oscillation during moves. Keep creeping Ki up until the system feels stiff enough for you.

TEST the move. The move should still be stable. If excess oscillations are occurring, reduce Ki.

11. Save Results

Record and save the results, then download to the motor, reboot and test.

Tuning Notes

Inertial ratios up to 5:1

For a load inertia to motor inertia ratio of 1:1 to 5:1, the default tuning parameters should be sufficient. These have been optimized for each motor for this nominal load range given a fairly tight coupling (servo class coupler, or a stiff belt - Aramid type).

Higher Inertia Ratios

SilverMax can be tuned to handle huge inertial loads with mismatches in 1000:1 or even 3000:1 category. The limiting factor is not the control loop, but the motor's max torque. At some point the SilverMax will just not have enough torque to move the mass in a reasonable time frame.

For higher inertia loads, the load inertia will dominate the response, and therefore the velocity estimator should have a lower bandwidth (low Fv2), for fast variations seen at the motor are not a good estimate of what the load is doing.

Reducing Fv2 reduces the high frequency gain of the system to suppress the high frequency resonance modes, allowing Kv2 to be increased to improve the low frequency damping of the system.

Torque Saturation

Use QuickControl's Control Panel to chart Torque while doing both fast and hard moves as well as very slow moves. If the fast moves are causing the torque to saturate, reduce the acceleration of the move command or your tuning effort may be frustrated! (Trying to stop faster than the torque of the motor allows will cause overshoot - SilverMax cannot stop fast enough and tuning is not going to increase the motor torque!)

Anti-Hunt Settings

Experiment with the anti-hunt values to optimize your operation. The typical 10/4 values are a good start. If normal operation involves overcoming the motor torque by hand or by a load (such as would happen with a gripper or going against a hard stop), then setting the second term to a negative value of the same magnitude (i.e. -4) makes the feeling of the transition into and out of anti-hunt feel more natural. A positive value requires the closed loop torque to be less than the open loop torque as well as the error to be less than the (magnitude of) the limit. This usually requires the load to be settling down on its own, as even a slight error will cause the torque command to go to its limits when the integrator is on. This makes the motor go to zero error before the torque is reduced. This mode cause the anti-hunt to delay until the motor/load has settled down enough for the anti-hunt to hold it. Using a negative value bypasses the torque test, allowing the transition between modes to be only based on position error.

Adjust the closed loop hold torque as well as both open loop torques to reasonable values. Remember that using anti-hunt requires motor current (heat) even if no load is present. The heat generated is to the square of the torque (current), so reducing the holding torque to 25% reduces the heating by a factor of 16!

Special Step and Direction Tuning

For systems using step and direction (camming) inputs the anti-hunt delay (ADH) setting will delay the transition into hold mode to a time that is consistent with your step rate. For example, if the minimum step rate is 100 Hz, then the delay should be at least 10 or 20 ms to keep the system from transitioning between the modes while running.

The Velocity Feedforward term must equal the sum of the two velocity feedback terms. Making it anything else will "squash" your circles by forcing a velocity dependent following (if the feedforward is less) or leading (if the feedforward is greater than the sum of the other two) error. For a clockwise circle with following error, this appears as an ellipse with the major axis at 45 degrees.

Belt Driven Positioning Tables – Direct Drive

SilverMax's high torque coupled with its PVIA servo technology is ideal for direct drive belt applications (i.e. belt driven slides and tables). Direct drive belt applications have two challenges, high inertial mismatch and resonance modes (vibration caused by the belt). We recommend tuning for high inertial mismatch first (described earlier) then knock out the resonance modes. You will find it easier to tune for high inertial mismatches if you pick a move that does not induce a resonance mode in the belt.

Once the high inertial mismatch is taken care of, find the move that is causing the resonance mode and implement PVIA's Viscous Inertial Dampener. This is done by increasing Ka (typically x5 to x10) and increasing Fa to above the belt resonance (typically 1500 to 2000Hz). See the "Acceleration Feedback (Ka)" section for more details.

SilverMax 8-bit and 9-bit Communications Protocols

Choosing Which Protocol to Use

The choice of a protocol depends on several system design issues. Below is a list that will aid you in determining the protocol that will best fit your system design. Use these guidelines or consult the factory for more information

Use 8-Bit ASCII if:

- **Highly coordinated moves are not required**
- **You want an easy to use protocol**
- **You want to do minimal programming**
- **You are using a PLC**

Use 9-Bit Binary if:

- **You need deterministic communications**
- **You require highly coordinated motions**
- **You have strong programming skills**
- **You need reliable communications**

Key Features of 8-bit ASCII

- Uses Standard ASCII characters
- Works with all types of serial communications ports
- Typically no special software driver is required
- Human readable data
- Works with terminal programs

Key Features of 9-Bit Binary

- Consistent Data Length
- Typically higher data transmission rate
- Error Checking (Data length and Checksum)
- Compact Binary data
- Deterministic (Transmission time consistent)
- Works well with highly coordinated multi-axis moves
- Requires ability to Set/Clear Parity Bit on any single byte.

8-BIT ASCII COMMUNICATIONS

An Easy to use 8-Bit ASCII Protocol for SilverMax:

The following section describes the 8-Bit ASCII protocol that is used for communications to the SilverMax. This protocol defines the **Command Packet** that is used to send command messages to the SilverMax, and the **Response Packet** with which the SilverMax responds.

The 8-bit ASCII protocol requires only the **Address**, **Command Code**, and **Parameters** to be sent; it does NOT include a Checksum or character count as the 9-bit protocol does. SilverMax checks each character for proper framing and valid characters, proper syntax and number of parameters.

Command Packets

All communications originate with a **Command Packet** from a Host controller. SilverMax does not initiate communications, it only responds when a Command is sent.

8-Bit ASCII Command Packet data transmission order				
Start Character	**Address**	**Command Code**	**Parameters ….**	**Ending Character**
1 Byte “@”	1 -3 Bytes	1 - 3 Bytes	1 - 10 bytes for each parameter	1 Byte (Carriage Return)

Start Character

The first character of the **Command Packet** is a **Start Character**. For the 8-Bit ASCII Command Packets, this is an **“@”** character. Any characters sent before the @ are ignored, including the responses from other units that are traversing the same communications lines (In the case of RS-485). Following the “@” symbol, one or more spaces characters may be inserted, but are not required.

Address

The destination **Address** character is sent as one to three digits in the range of 1 to 255. The SilverMax checks to see if the address received corresponds to the **Identity**, **Group** or **Global** address. Packets not containing one of these addresses are ignored. Packets addressed to a Group or Global address will be acted upon, but no response will be sent. The Address is delimited with one or more space characters.

The Global address, 255, is a reserved address to which all SilverMax units will respond. It is typically used to stop all motions simultaneously, or to initialize an unknown SilverMax. Group addresses are user-selected addresses that are assigned as a secondary address to a subset of the SilverMax units on a communications network. A Group address would typically be used to initiate a coordinated move of several axes (i.e. a Run Program command) after the wanted motions had been downloaded to each axis individually. The units execute commands sent to a Group address, but they do not reply with a Response Packet.

Command Code

The **Command Code** is the unique number associated with each command. Refer to the SilverMax Command Reference for Command Codes. If the command has no parameters associated with it, the command may be initiated with a **Carriage Return** <CR> which completes the packet (See final character below). The Command is delimited with one or more space characters.

Parameters

If the Command has **Parameters** associated with it, then each Parameter is sent with one or more space <SP> character(s) used to separate the parameters. Typically the number of Parameters can range from one to five. Each Parameter must be delimited with one or more space characters.

Ending Character

The final **Ending Character** is a "**Carriage Return**" <CR> (Hex 0D, Decimal 13). The carriage return signals the end of the Command Packet.

Examples

Example: Send a **Read Register (RRG)** command as follows:

Command = RRG (Command Code = 12)
Address = 16
Data Register# = 1

Fields with data shown in ASCII.

Start Char	Adr	Cmd	Data Register#	End Char
@	16	12	1	<CR> Dec 13

Byte stream with data shown as an ASCII String

"@16 12 1 <CR>"

Example: Send a **MOVE RELATIVE, TIME BASED (MRT)** command to SilverMax as follows:

Command = MRT (Command Code = 177)
Address = 16
Distance = 4000 counts
Ramp Time = 833 ticks (1 tick=120us)
Total Time = 8333 ticks
No stop conditions

Fields with data shown in ASCII:

Start Char	Adr	Cmd	Distance	Ramp Time	Total Time	Stop Enable	Stop State	End Char
@	16	177	4000	833	8333	0	0	<CR>

Byte stream with data shown as an ASCII string:

"@16 177 4000 833 8333 0 0 <CR>"

Poll Command Packet

The Poll Command Packet is a special Command packet that has a shortened form to minimize the communications overhead, as this is probably the most frequently sent packet. The Poll command may be formatted as any other command, as described above, or the “command” portion may be omitted and the SilverMax will interpret the “shortened” form as a Poll command.

Example: if addressing the command to SilverMax #5:

@5<CR> (shortened format)

or

@5 0<CR> (normal command format)

Response Packets

All of the information returned from the SilverMax is in **ASCII Hexadecimal**. The **Address** is returned as a 2 digit Hexadecimal characters, while any **Data** returned is returned as 4 hexadecimal characters for each Data Field. Long Word data (32-bit) is returned as two Data fields (8 total characters)

There are three types of response packets: **Acknowledge (ACK)**, **Returned Data**, and **Negative Acknowledge (NAK)**. Each has a different form to allow them to be easily parsed by the Host system.

Acknowledge (ACK) Response

The ACK response is the positive acknowledge of the receipt of a Command Packet. This response has also been shortened to minimize the load on the Serial Communications Interface, as it is the most common response of the SilverMax.

8-Bit ASCII ACK Response Packet data transmission order		
Start Character	**Address(Hex)**	**Ending Character**
1 Byte “*”	1 - 2 Bytes	1 Byte (Carriage Return)

The Acknowledge response starts with an “*”, followed by a space character, then the SilverMax Address in Hexadecimal, and finally a Carriage Return <CR> to end the packet.

Example: Acknowledge response from SilverMax #16 (which is “10” in Hexadecimal):

*** 10<CR>**

Returned Data Response

The Returned Data packet is sent when a properly formatted request for data is received by a SilverMax. Its format is as follows:

The Returned Data Packet starts with the “#” character to indicate a numeric response, it is followed by a “space” character, then the Command Code in Hexadecimal, followed by the data, again in Hexadecimal. If the response data is larger than a 16-bit response, the response is split into two 16-Bit fields (four hexadecimal characters), with the two fields separated by a space.

The packet is ended with a carriage return.

8-Bit ASCII Returned Data Packet data transmission order				
Start Character	**Address (Hex)**	**Command Code (Hex)**	**Data Fields …. (Hex)**	**Ending Character**
1 Byte "#"	2 Bytes	4 Bytes	4 Bytes each	1 Byte (Carriage Return)

Example: Poll command Returned Data from SilverMax #27 (which is "1B" in Hexadecimal). The actual Returned Data is the **Polling Status Word**.

# 1B 0000 2000<CR>

Example: Read Register command Returned Data from SilverMax #10 (which is "0A" in Hexadecimal); the last 8 digits represent the 32-bits of data. The **Read Registe**r command code is 12 (which is "0C" in Hexadecimal).

# 0A 000C 0005 06A3<CR>

NAK Response

The NAK response packet is sent when the Command issued is not a valid command. When the Command Packet is improperly formatted, or when the Parameters are invalid or a Command is sent at the wrong time such as requesting a motion when the motor is already busy.

The NAK response begins with the "!" character, followed by a space character. Next are the Address, the Command Code, and finally the NAK code, all in hexadecimal and delimited with spaces. The packet is ended with a carriage return.

8-Bit ASCII NAK Response Packet data transmission order				
Start Character	**Address**	**Command Code**	**NAK Code**	**Ending Character**
1 Byte "!"	2 Bytes	4 Bytes	4 Bytes	1 Byte (Carriage Return)

Example: NAK response for a **Read Register (RRG)** (Command Code 0x0C) from SilverMax #10 (0x0A) with an invalid "Data Register" parameter.

! 0A 000C 0007<CR>

Example: NAK response for a **Move Relative, Time Based (MRT)** (Command Code 0xB1) if SilverMax #16 (0x10) is already in motion. The SilverMax will NAK back "Device Busy" as follows:

! 10 00B1 0002 <CR>

(See NAK codes below)

9-BIT BINARY COMMUNICATIONS

Advanced 9-Bit Protocol for SilverMax:

The following section describes the advanced 9-Bit protocol that is used for communications to the SilverMax. This protocol defines the Serial Communications packets that are used to send Commands to the SilverMax, and to receive SilverMax Responses.

The protocol provides both Addressing and error checking of the **Command Packet** to ensure proper delivery. The SilverMax checks each command packet for proper syntax, length and for a correct checksum before responding to the command. The same is used for the **Response Packets** from the SilverMax.

The use of an extra "**9th-bit**" is one of the main differences from the 8-Bit ASCII protocol. The **9th-bit** is actually the "**Parity bit**" of a standard 8-bit serial byte. Using the Parity bit in this way allows the protocol to easily distinguish the "**Address**" byte from all others. When the SilverMax receives a byte with the **9th-bit** set it knows that it is the **Address** and the beginning of the **Command Packet**. Setting parity is called **Mark Parity** and clearing parity is called **Space Parity**.

8-Bit serial byte bit pattern (As sent from a standard UART):

Bit Period	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Desc	**Start Bit**	**Bit #1 LSB**	**Bit #2**	**Bit #3**	**Bit #4**	**Bit #5**	**Bit #6**	**Bit #7**	**Bit #8 MSB**	**Bit #9 Parity**	**Stop Bit**	**Stop Bit**

Command Packets

All communications originate from a Host system using the Serial Communication Interface. SilverMax units do not and cannot initiate communications, they only respond to commands.

9-Bit Binary Command Packet data transmission order				
Address	**Length**	**Command Code**	**Parameters ….**	**Checksum**
1 Byte + 9th bit set	1 Byte	1 Byte	2 or 4 Bytes each	1 Byte

The following gives a description of the **Command Packet**:

Address

The first byte is the **Address** that contains the **Identity**, **Group**, or **Global** address to which the SilverMax the command is being sent. The Parity bit (bit 9) of the serial byte is set to "1" (Mark Parity) to indicate that this byte is an address and is the start of a packet. At this point, the SilverMax processes the Address as explained in the 8 Bit ASCII protocol section.

Length

The second byte is the **Length.** The Length is defined as number of bytes from the Command Code up to but not including the Checksum. This is limited to the range of [0-31], so only the lower 5 bits may be non-zero.

Command Code

The third byte is the **Command Code**. It indicates the desired function. The Command Codes can be obtained from the SilverMax Command Reference.

Parameters

Following the Command Code are any **Parameters** associated with the Command. The SilverMax knows the total count of data from the **Length** character. The number of data characters is also checked with the command type for consistency. 16-Bit words are sent one byte at a time, upper byte first. 32-Bit Long words are sent a byte at a time, upper byte first.

Checksum

The final byte of the packet is the **Checksum**. This is used to verify that the rest of the packet arrived intact. The Checksum is the 2's complement (1's complement + 1) of the sum of the rest of the previous bytes. In other words, add up all bytes from the Address through the final parameter and take the 2's complement.

Example: To calculate the following Read Register (RRG) command
Address = 16 (0x10) – ignore 9th bit
Length = 03 (0x03)
Command = RRG (Command Code = 12, 0x0C)
Data Register# = 1 (0x0001)

Add up all the bytes (all numbers shown in hex)
10 + 03 + 0C + 00 + 01 = 20

1's Complement (invert)
Invert(20) = DF

Add 1
DF + 1 = E0

Checksum = E0

Examples

Example: Send a **Read Register (RRG)** command as follows:

Command = RRG (Command Code = 12)
Address = 16 (Hex 0x10)
Data Register# = 1

Fields with data shown in Hex.

Adr	Len	Cmd	Data Register#	Checksum
10	03	0C	0001	E0

Byte stream with data shown in Hex

10 03 0C 00 01 E0

Example: Send a **MOVE RELATIVE, TIME BASED (MRT)** command to SilverMax as follows:

Command = MRT (Command Code = 177)
Address = 16
Distance = 4000 counts (Hex 0x00000FA0)
Ramp Time = 833 ticks (1 tick=120us) (0x00000341)
Total Time = 8333 ticks (0x0000208D)
No stop conditions

Fields with data shown in Hex:

Adr	Len	Cmd	Distance	Ramp Time	Total Time	Stop Enable	Stop State	Checksum
10	11	B1	00000FA0	00000341	0000208D	0000	0000	8E

Byte stream with data shown in Hex:

10 11 B1 00 00 0F A0 00 00 03 41 00 00 20 8D 00 00 00 00 8E

Poll Command Packet

The Poll Command Packet is a special command packet that has been shortened to minimize the communications overhead, as this is probably the most frequently sent packet.

9-Bit Binary Poll Command Packet data transmission order		
Address	**Length**	**Checksum**
1 Byte + 9th bit set	1 Byte = “00”	1 Byte

- The first character is the **Address** with the 9th bit set.

- The second character - the **Length** - is set to **zero**. This defines the packet as the Poll Command packet. Since the data count is zero, no Command or Parameters are included.

- The third character is the **Checksum**.

Poll Command Example

(Shown with as Binary Data in Hexadecimal format)

Sends **Poll** command to SilverMax #16

10 00 F0

Response Packets

All of the information returned from the SilverMax is in **Binary** Format. The **Address** is returned as a single byte with the 9th-bit set. The **Length** is returned as a single byte. All **Data** is returned as bytes with 2 byte for Words (16-bit) and 4 bytes for Long Words (32-bit). The Checksum is returned as a single byte.

There are three types of response packets: **Acknowledge (ACK)**, **Returned Data**, and **Negative Acknowledge (NAK)**. Each has a different form to allow them to be easily parsed by the Host system.

ACK Response

The ACK response is the positive acknowledge of the receipt of a Command Packet. This response has also been shortened to minimize the load on the Serial Communications Interface, as it is the most common response of the SilverMax.

9-Bit Binary ACK Response Packet data transmission order		
Address	**Length (ACK Code)**	**Checksum**
1 Byte + 9th bit set	1 Byte	1 Byte

- The first byte is the **Address** with the 9th bit set.
- The second byte is the **Length** with a value of zero plus the 8th bit set to indicate an ACK (128 (0x80)).
- The third byte is the **Checksum**.

Example: ACK response from SilverMax #16 (shown in hex):

10 80 70

Returned Data Response

The Returned Data packet is sent when a properly formatted Command for data is received by a SilverMax. Its format is as follows:

9-Bit Binary ACK Response Packet data transmission order				
Address	**Length**	**Command Code**	**Data fields ….**	**Checksum**
1 Byte + 9th bit set	1 Bytes	1 Byte	2 or 4 Bytes each	1 Byte

- The first byte the **Address** with the 9th bit set.
- The second byte is the **Length** which is the number of bytes starting at the Command Code and including all the data fields.
- The third byte is the **Command Code** that is being responded to.
- The requested **Data Fields** are next. 16-Bit words are sent one byte at a time, upper byte first. 32-Bit Long words are sent a byte at a time, upper byte first.
- The Final byte is the **Checksum**.

Example: Send a **Read Register (RRG)** command and receive the following response packet:

Command = RRG (Command Code = 12)
Address = 16
Data Register# = 1

Response Packet with field data shown in Hex:

Adr	Len	Cmd	Value of Register #1	Checksum
10	03	0C	00000FA0	30

Byte stream with data shown in Hex

10 05 0C 00 00 0F A0 30

NAK Response

The NAK response packet is sent when the Command issued is not a valid command. When the Command Packet is improperly formatted, or when the Parameters are invalid or a Command is sent at the wrong time such as requesting a motion when the motor is already busy.

9-Bit Binary NAK Response Packet data transmission order					
Address	**Length**	**NAK Response Code**	**Command Code**	**NAK Error Code**	**Checksum**
1 Byte + 9th bit set	1 Bytes	1 Byte = 255 (0xFF)	1 Byte	2 Bytes	1 Byte

- The first byte is the **Address** with the 9th bit set.
- The second byte is the **Length.** This is defined as the number of bytes starting with the NAK Response Code and including the two bytes for the NAK Error Code.
- The third byte is the **NAK Response Code.** A value of 255 (0xFF) indicates this is a NAK Response Packet.
- The forth byte is the **Command Code** of the command that failed.
- The fifth byte is the **NAK Error Code**. The code is 16-Bit word that indicated the NAK Error.
- The final byte is the **Checksum**.

Example: NAK response for a **Read Register (RRG)** (Command Code 0x0C) from SilverMax #10 (0x0A) with an invalid “Data Register” parameter.

0A 04 FF 0C 00 07 E0

Example: NAK response for a **Move Relative, Time Based (MRT)** (Command Code 0xB1) if SilverMax #16 (0x10) is already in motion. The SilverMax will NAK back “Device Busy” as follows:

10 03 FF 02 B1 3B

(NAK codes defined below)

PROTOCOL DEFINITIONS

SilverMax Negative Acknowledge (NAK) Codes

The following are the strings for the above NAK error codes as they will appear in the NAK Response Packet:

Error Code	Name	Description
1	Bad Command	The device received a command (command number) it did not recognize. If you are sure the command number is correct, check the firmware revision to make sure the command was implemented. A table of commands verses firmware revisions can be found at the end of the Command Reference.
2	Device Busy	The Device is actively executing a previous command. The new command cannot be executed at this time. Some commands cannot be executed while SilverMax is executing a previous command. (See “Commands” for details)
3	Reserved	Reserved for back compatibility from pre E-series units. This response included the expected count, which required a more sophisticated error response parsing code. This error code was replaced with error code 5 which only indicates the error.
4	Reserved	Reserved for back compatibility with pre E-series units.
5	Bad Format	Command number and number of parameters is not consistent.
6	Buffer Full	The device’s Command Buffer is full. Too many bytes were sent to the device for its available Command Buffer space (RAM).
7	Bad Address	An address used in a command was out of range. This includes trying to access a Data Register that does exist, writing to a read-only register, reading or writing a multiple register block into/out of non-volatile memory when the registers are not in the user block (10..40). Also trying to directly read or write to the buffer to an invalid address (negative or larger than the buffer) or trying to read or write zero words of data. Also get one from the Download command if the magic word is incorrect.
8	Bad Response Packet Request	The requested return data was too large for one packet. The serial communications buffer is can transmit only 31 bytes at a time. Break the request into multiple packets

SilverMax Polling Status Codes (Polling Status Word)

(See **Poll** command under **Status Commands** section, Also see **Polling SilverMax Using the Poll Command** above).

Word Bit #	Name	Description
Bit 15	Immediate Command Done	A foreground command that was requested from the immediate mode has completed, such as Non-Volatile Memory Storing operations. Also set if multitasking is enabled, no additional commands are waiting in the buffer, and a motion command completes.
Bit 14	Non-Volatile Memory Checksum Error	A checksum error occurred while trying to read some data or a program from non-volatile memory. Commands such as LRP, RLN and RLM can cause this error.
Bit 13	Program Command Done	The commands in the Command Buffer just completed. Note: If multi-tasking is enabled, this will not be set until all motions have also finished.
Bit 12	Command Error	SilverMax detected an error while executing a program/command. Check parameters for unreasonable values.
Bit 11	Input Found Within Motion Command	The move ended when the selected exit/stop condition was met found. The value in Register 4 has been updated with the sensor found position. (Note: set as soon as the sensor has been found; the motion may take some additional time to come to a stop.)
Bit 10	Low/Over Voltage	A Low Voltage or Over Voltage condition occurred. The voltage must return to normal for this to clear.
Bit 9	Holding Error	Error Limits exceeded while holding(stopped). Set by Error Limits (ERL) command.
Bit 8	Moving Error	Error Limits exceeded while Moving. Set by Error Limits (ERL) command.
Bit 7	Receiver Overflow	SilverMax serial receive (UART) buffer overflowed.
Bit 6	CKS Condition Met	A condition was met while executing the command **CHECK INTERNAL STATUS** (CKS). See SilverMax Command Reference for details. This is a user controlled status bit.
Bit 5	Message Too Long	The received message was greater than 31 bytes
Bit 4	Framing Error	A received byte had an error during reception. This is triggered when no stop bit is detected. It may be caused by noise on the serial channel, or an improperly biased 485 network. Also may be triggered by an incorrect baud rate.
Bit 3	Shut Down	SilverMax shut down due to something set by the KMC command.
Bit 2	Soft Limit	Soft stop limit reached (set by SSL command).
Bit 1	Receive Checksum Error	9 bit checksum did not match with sent checksum. Packet ignored.
Bit 0	Aborted packet	Data errors or new packet received before the last was complete.

SPECIFICATIONS

Serial Communications:

Hardware: RS-232, RS-232 multi-drop or RS-485 multi-drop
Baud Rates: 2400, 4800, 9600, 19.2k , 28.8k, 57.6k, 115.2K or 230.4K
Data Bits: 8
Stop Bits: 1.5 or 2
Parity bit: None
Protocols: "9-Bit Binary" or "8-Bit ASCII"

Digital I/O

Outputs: TTL level (0 to +5 Volts) @ ±5 milliamps (Sinking or Sourcing).

Inputs: TTL level, Inputs #1, #2 and #3 have an internal 4.7K ohm pull-up resistor tied to +5 Volts, Inputs #4, #5, #6 and #7 have an internal 220K ohm pull-up resistor tied to +5 Volts.

Over Voltage Protection: All I/O is doubly protected with parallel **MOV** clamping followed by series over-voltage limiting to protect the internal circuitry.

Analog Inputs

0 to +5 Volt input. Analog Inputs #1 to #4 share Digital Inputs #4, #5, #6 and #7. Each input has an internal 200K ohm pull-up resistor tied to +5 Volts.

Input Power:

12v to 48v - Motor must be initialized for selected voltage
34HC: 15v to 48v

Maximum current – See individual motor specifications in data sheets

There is no over-voltage protection for the supply input. Voltages exceeding 55 volts will permanently damage the motor electronics.

Supply input may require an active voltage clamp for aggressive braking/deceleration or with high inertial loads.

Maximum Operating Temperatures

- 40° C to **70° C** storage

- 10° C to **70° C** operation

100° C on the motor section. The motor can run at a higher temperature if the Electronics section in kept below 70° C.

Serial Communications Buffer Size

10 Words

Program Buffer Size

200 Words

Non-Volatile Memory Size

4K Words (8K Bytes)
Optional: 16K Words (32K Bytes)

Motion Parameters:

Position Resolution:

4000 counts per revolution (.09 degrees)

17/23 Frame Option:
8000 counts per revolution (.045 degrees)

34 Frame Option:
16000 counts per revolution (0.0225 degrees)

Position range:

32 bits: -2,147,483,648 to +2,147,483,647
= ± 536,870 Revolutions
= ± 3370000 radians

Velocity Resolution:

0.000000031 Revolutions/Second or approximately 1 Revolution per year. (195e-9 radians/Sec)

Velocity Range:

31 bits: -1,073,741,824 to +1,073,741,823 (In Velocity Mode)
31 bits: 0 to +2,147,483,647 (In Motion or Profile Move Modes)
= ±4000 RPM
= ±66.6 Revolutions per Second

Maximum velocity:

32 counts/120 microseconds
= 4000 RPM
= 66.6 Revolutions per Second.
= 418.9 radians per Second.

Acceleration Resolution:

0.000000031 counts/120uS/120uS
= 1.03 counts/sec/sec
= 1.62e-3 radians/Sec/Sec

Maximum Acceleration (s/w):

16 counts/120uS/120uS = 0 to full speed in 240 microseconds. (actual acceleration limited by motor torque/(motor + load inertia))

Maximum Acceleration Time when using Time Based Commands:

65,568 * 120 microseconds = 7.86 Seconds

Torque Control Limit:

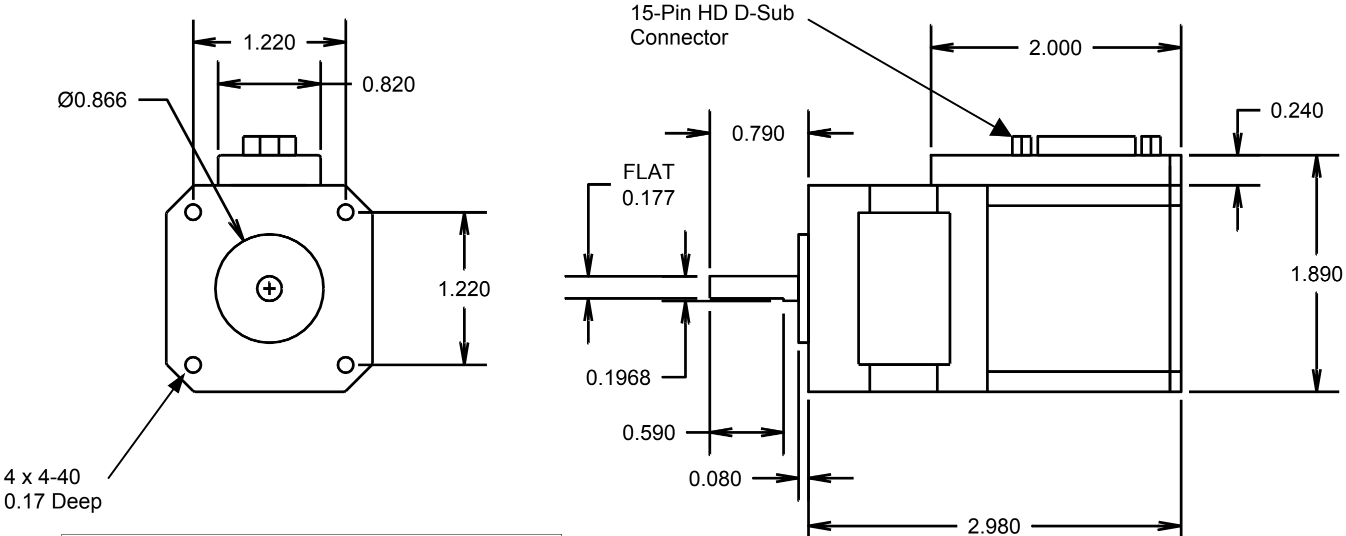
1 part in 32768

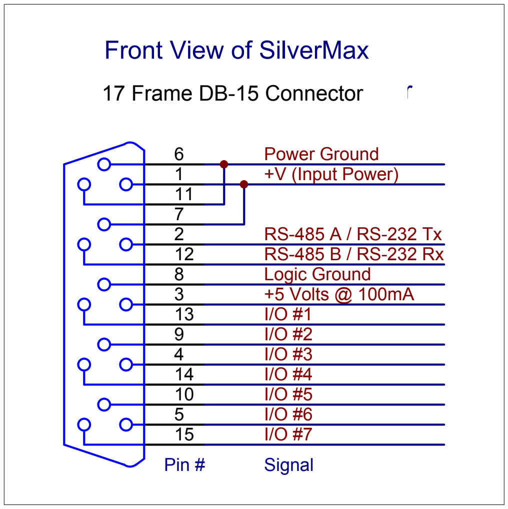
Servo Sample Rate:

120 microseconds = 8.33kHz

Mechanical Specifications

SilverMax 17 Frame



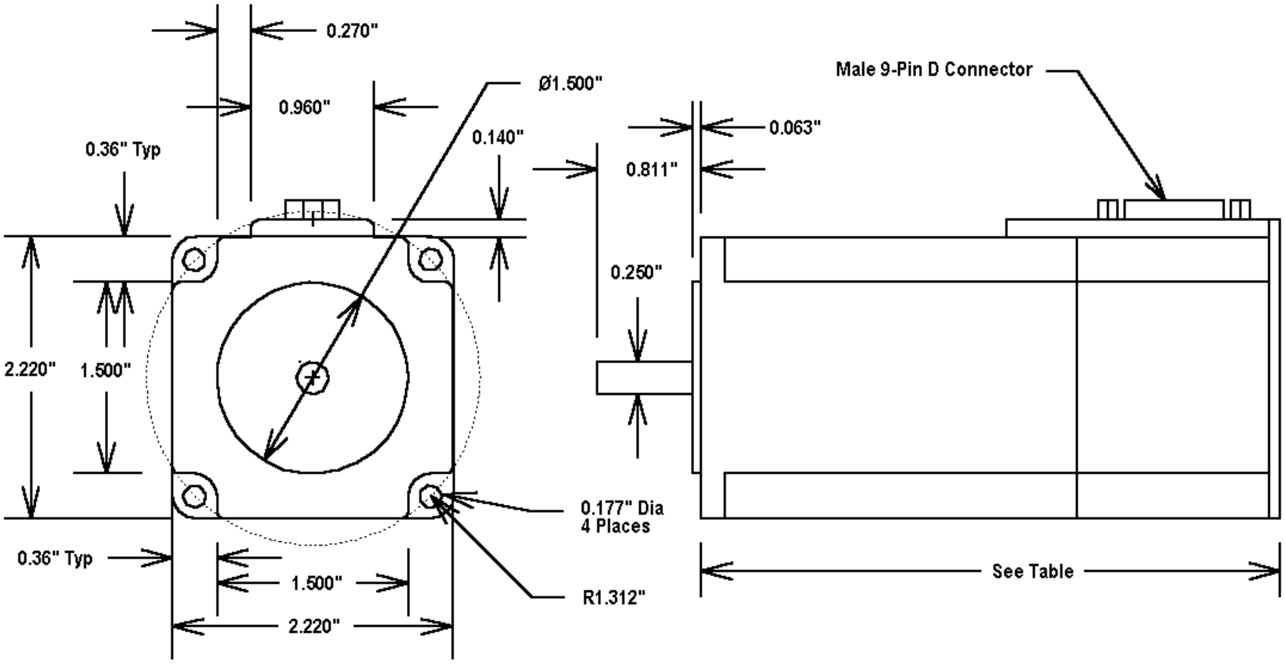


Pin #	Signal
6	Power Ground
1	+V (Input Power)
11	
7	
2	RS-485 A / RS-232 Tx
12	RS-485 B / RS-232 Rx
8	Logic Ground
3	+5 Volts @ 100mA
13	I/O #1
9	I/O #2
4	I/O #3
14	I/O #4
10	I/O #5
5	I/O #6
15	I/O #7

Model Number	Overall Length
17-1 & 17H-1	2.74”
17-3 & 17H-3	3.29”

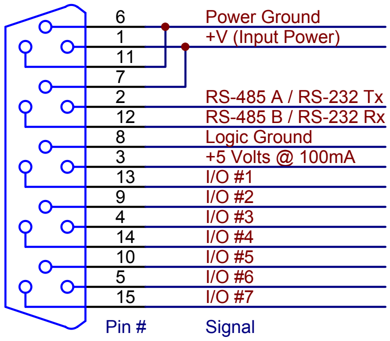
Notes: Inputs #1, #2, and #3 have a 4.7K pull-up to +5 Volts.

SilverMax 23 Frame



Front View of SilverMax

23 Frame DB-15 Connector

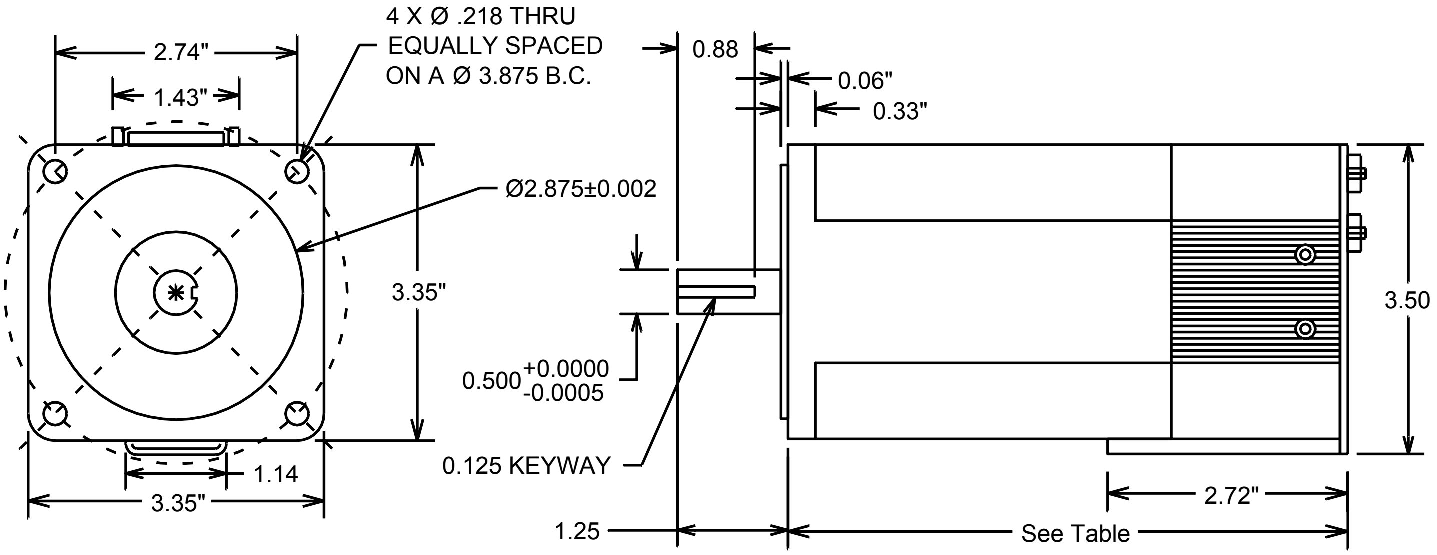


Pin #	Signal
6	Power Ground
1	+V (Input Power)
11	
7	
2	RS-485 A / RS-232 Tx
12	RS-485 B / RS-232 Rx
8	Logic Ground
3	+5 Volts @ 100mA
13	I/O #1
9	I/O #2
4	I/O #3
14	I/O #4
10	I/O #5
5	I/O #6
15	I/O #7

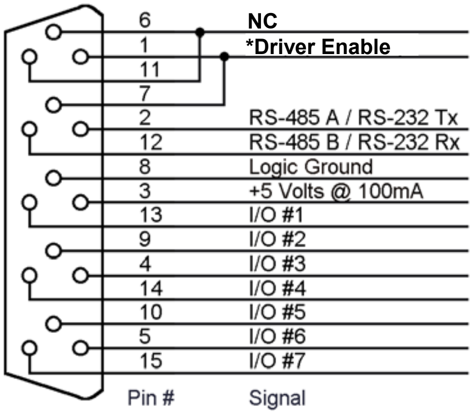
Model Number	Overall Length
23-3	3.69”
23-5	4.55”
23H-1	3.22”
23H-3	3.72”
23H-5	4.65”

Notes: Inputs #1, #2, and #3 have a 4.7K pull-up to +5 Volts.

SilverMax 34N-1, 34H-1 & 34H-2 Frame



High Density DB-15 Connector



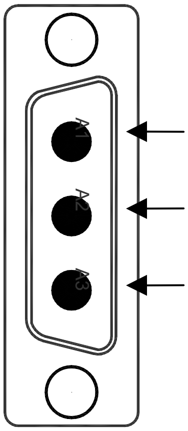
Pin #	Signal
6	NC
1	*Driver Enable
11	
7	
2	RS-485 A / RS-232 Tx
12	RS-485 B / RS-232 Rx
8	Logic Ground
3	+5 Volts @ 100mA
13	I/O #1
9	I/O #2
4	I/O #3
14	I/O #4
10	I/O #5
5	I/O #6
15	I/O #7

Model Number	Overall Length
34N-1	5.13”
34H-1	5.13”
34H-2	6.65”

Notes:

* Driver Enable must be connected to the +V power supply to enable the motor driver circuitry

I/O lines #1, #2, and #3 have an internal 4.7K ohm resistor connected to the internal +5 Volt power supply.



DB-3 Power Connector

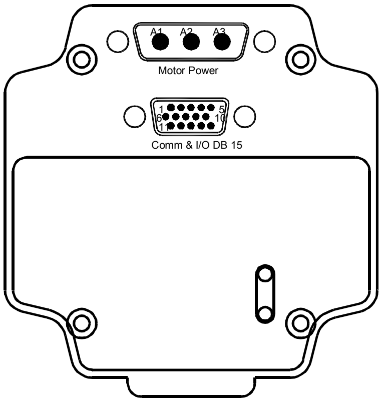
A1 = Chassis Ground*

A2 = +V Power (12 to 48 Volts)

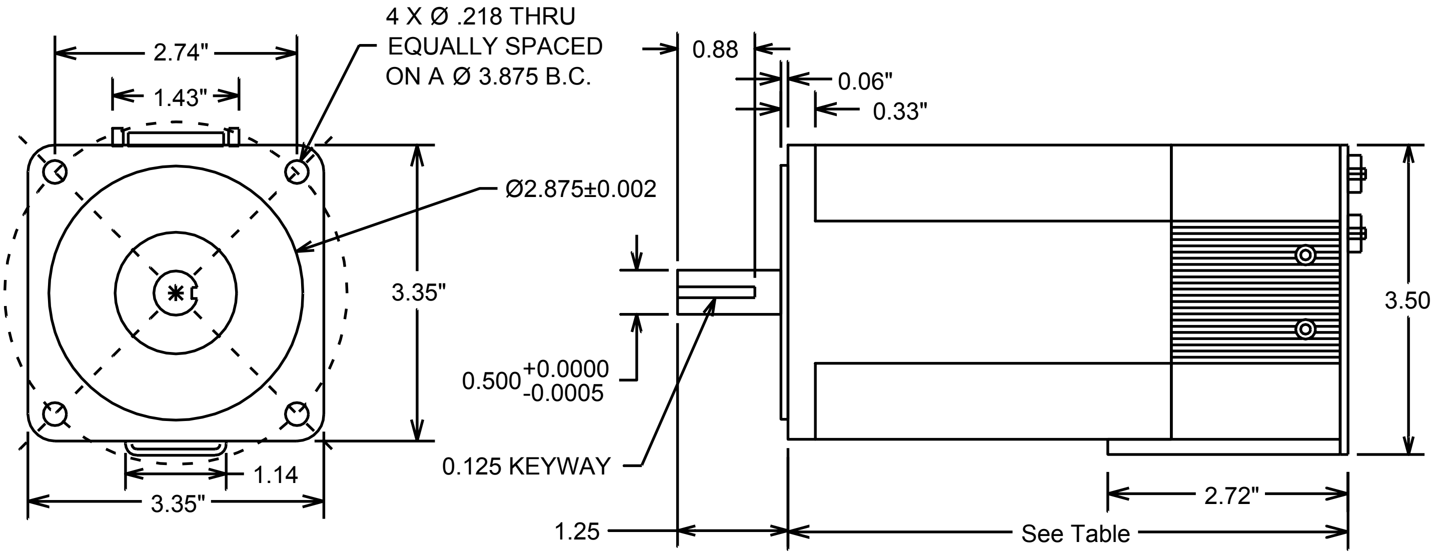
A3 = Power Ground*

***Power & Chassis Ground are internally connected**

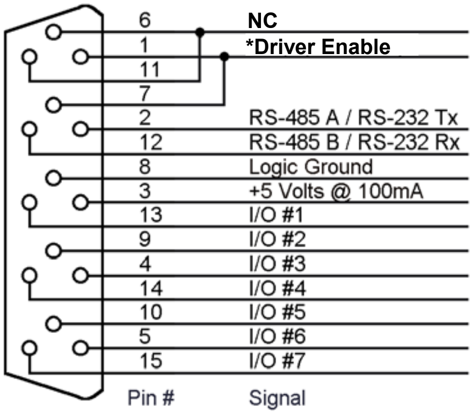
Back View of 34 Frame motors showing connector placement



SilverMax 34H-3 & 34H-4 Frame



Model Number	Overall Length
34N-1	5.13”
34H-1	5.13”
34H-2	6.65”



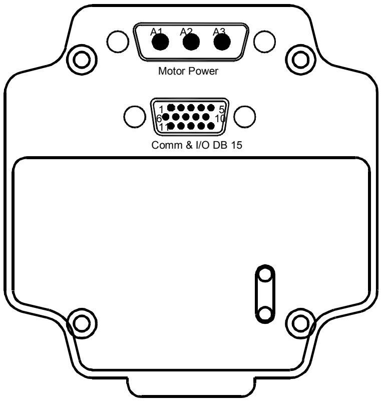
Pin #	Signal
6	**NC**
1	***Driver Enable**
11	
7	
2	RS-485 A / RS-232 Tx
12	RS-485 B / RS-232 Rx
8	Logic Ground
3	+5 Volts @ 100mA
13	I/O #1
9	I/O #2
4	I/O #3
14	I/O #4
10	I/O #5
5	I/O #6
15	I/O #7

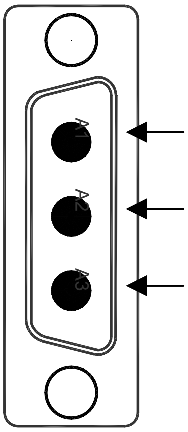
Notes:

* Driver Enable must be connected to the +V power supply to enable the motor driver circuitry

I/O lines #1, #2, and #3 have an internal 4.7K ohm resistor connected to the internal +5 Volt power supply.

Back View of 34 Frame motors showing connector placement





DB-3 Power Connector

A1 = Chassis Ground*

A2 = +V Power (12 to 48 Volts)

A3 = Power Ground*

***Power & Chassis Ground are internally connected**

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