GSI Lumonics Scan Controller User Manual

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GSI Lumonics Scan Controller User Manual

Contents:

System Overview

The Scan Controller is a small intelligent system intended to control one or two axes of the GSI Lumonics SAX family of scanner servo amplifiers, and associated peripherals. It will work in either a stand-alone configuration or in conjunction with a host computer. The basic components of a complete system consist of the following:

1. One or two axes of SAX/Galvo micropositioning
2. One SC2000 Scan Controller
3. Cabling
4. Power Supply
5. A host computer (for setup and optionally for operation), including software
6. Other system components interfaced to the Scan Controller

The Scan Controller is programmed through its communications interface (J1) using either the GSI Lumonics supplied LabVIEW™[1] interface, or customer-designed host-side software. For stand-alone operation, this programming will result in a sequence of user programs stored in the Scan Controller's local nonvolatile (FLASH) memory. These programs will run automatically at system power-up. For operation in conjunction with a host computer, the system designer can choose a mode of operation between the controller and the host anywhere on the continuum between totally autonomous and tightly coupled.

The Scan Controller interfaces directly to the position command, position feedback, and binary communications of one or two SAX single axis servos. This allows not only full position control of the system, enable and status interlock and but also allows position feedback, galvo temperature status and calibration information to be read digitally by the host computer.

In addition to controlling two SAX single axis servos, the Scan Controller has hooks to aid in the interface and control of other peripherals typically associated with these systems. These include sync inputs and outputs, a pixel clock system, a calibration/data capture system, and other functionality available to volume OEM system designers. Figure 1 and Figure 2 show block diagrams of typical systems.

[1] LabVIEW is a trademark of National Instruments Corporation

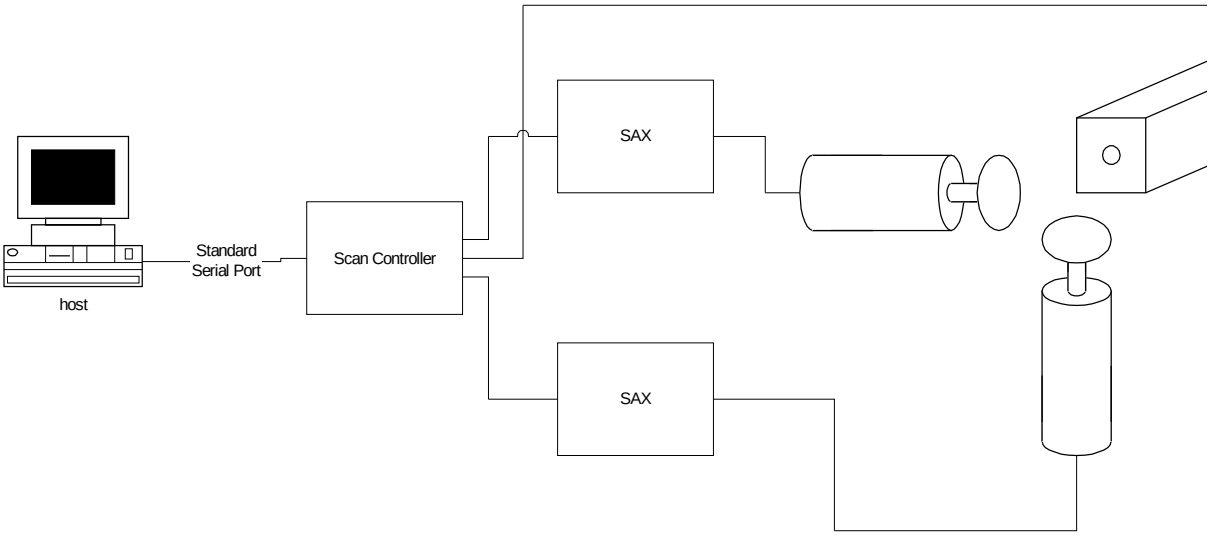

Figure 1 Scan Controller with host computer

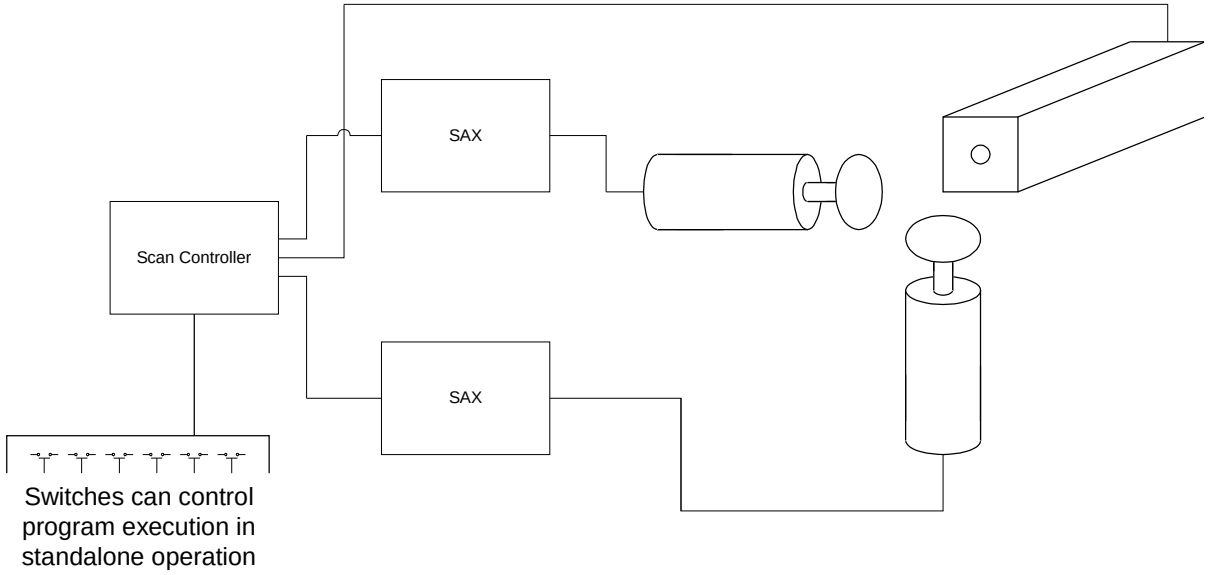

Figure 2 Typical standalone system

System Interconnection

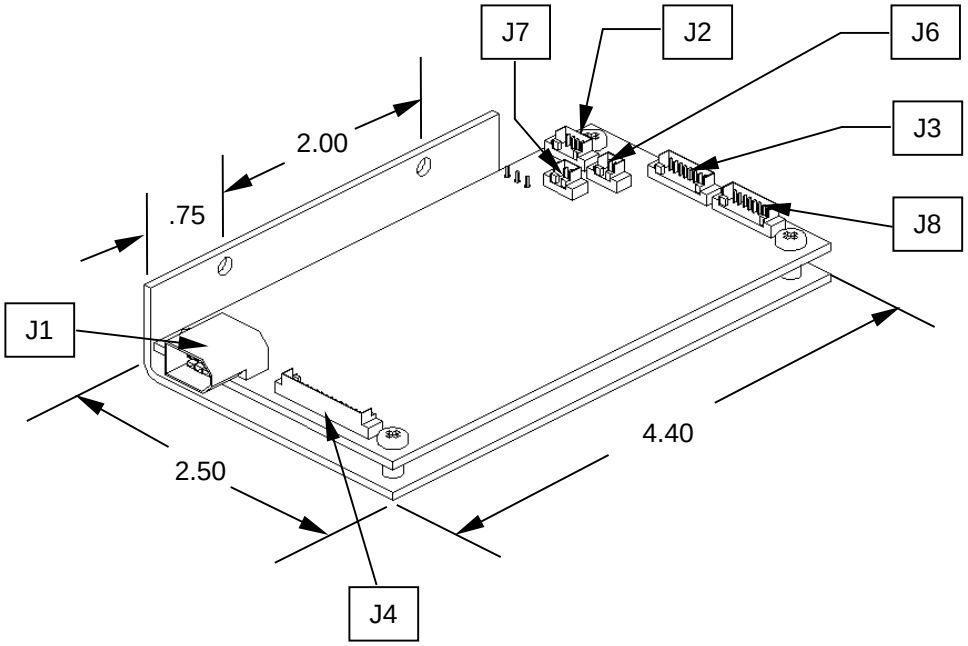

Figure 3: Bracket Assembly

The bracket assembly is shown in Figure 3 (units are inches). The Scan Controller bracket consists of an aluminum L-bracket with two #8 clearance holes located on the riser. The circuit board standoff nearest J4 also serves as the heatsink mounting point for the 5-volt regulator.

A sketch of the top view of the Scan Controller is shown in Figure 4, with its pinout shown in Figure 5, and a system interconnection diagram in Figure 6.

SAX Interface

Figure 7 shows the specific interconnection of the SAX interface when the Scan Controller is attached to two SAX servo amplifiers. Figure 8 shows the interconnection between Scan Controller and a single SAX amplifier. Note that the **~Temp_OK** and **~Servo_Rdy** inputs have been grounded out for the unused axis.

The operation of the SAX interlock circuitry bears some discussion. There are three signals interconnecting each SAX and the Scan Controller:

~Servo_Rdy	SAX output	indicates functioning servo
~Temp_OK	SAX thermal controller output	indicates temperature in regulation
~Servo_Enb	SAX input	required for servo operation (typically, ~Servo_Enb is asserted, and within a second or so ~Servo_Rdy goes true if the servo is functional)

The interlock system is as follows:

On system powerup, **~Servo_Enb** and **~Servo_Rdy** are unasserted. When the user desires to operate one or both axes, the `Enable` command is given, causing **~Servo_Enb** to go low for the enabled axes. After a wait period of about 2 seconds, the Scan Controller expects **~Servo_Rdy** to be asserted, and to stay asserted until the `Disable` command is given. Any activity on the **~Servo_Rdy** signal until then is cause for an error condition to be generated, halting program execution, and causing **~Servo_Enb** to be unasserted.

Use of this interlock system is optional – users can simply tie the **~Servo_Enb** signal to the SAX low (disconnecting it from the Scan Controller **~Servo_Enb** signal), and similarity tie the **~Servo_Rdy** input to the Scan Controller low. This is shown with the unused axis in Figure 8, and with both axes in Figure 9.

The ~Temp_OK signal is not used in the software interlock, but can be used to qualify conditionals in programs, and can be read by the host computer (program operation can be delayed at powerup until the system temperature is stable.

Power Supply

Figure 11 shows the interconnection between the SAX, Scan Controller, and a +/- 15v system power supply. If the system requires rails higher than +/- 15v, the Scan Controller may need heat sinking in addition to its simple L bracket to keep its regulator adequately cool. Finding the best system chassis grounding point is a major issue. A single ground point usually gives best performance. It can be at the Scan Controller, the SAX, the galvo, or the host computer.

The +5V in/out pin provides additional flexibility. As shown in Figure 10, this can be utilized to drive small auxiliary loads, like pull-ups on logic lines, or small laser diodes. The available current is a function of the end-user's packaging and rail voltage (the major constraint is heating of the 5v regulator on the Scan Controller). Under some circumstances, OEM design-ins may choose to utilize an external 5v supply, to minimize dissipation at the Scan Controller. This may be advisable if very high rails are used for the SAX (+/- 24v).

Sync / Cal

The Sync/Cal connector provides access to the synchronization/calibration I/O as well as the pixel clock output of the Scan Controller. These signals are broken down as follows:

Sync[1..4]	Connector pins 1-4	These are open-drain outputs. They can sink up to 100mA continuous, and withstand peaks of 40v	Written through the `SetSync` and `UnSetSync` commands. Read through the `WaitSync` and `If` commands (this allows a mechanism for inter-program control)
Sync[5..8]	Pins 6-9	These are CMOS inputs with 10K Ohm pull-down resistors.	Read through the `WaitSync` and `If` commands
Sync/Cal[9..12]	Pins 10-13	These are CMOS inputs with 10K Ohm pull-down resistors.	Read through the `WaitSync` and `If` commands. Also load the relevant `Cal` registers on a low to high transition. These are visible to the host upon issuing an `?OpticalCal` command.
Sync[13]	NA	Controls operation of the position-based Pixel clock (opens the PLL tracking loop)	Written through the `SetSync` and `UnSetSync` commands.
Sync[14]	NA	Gates the output of the Pixel clock	Written through the `SetSync` and `UnSetSync` commands.

Figure 10 shows a system using one of the (open drain) sync outputs and the auxiliary 5v output to power and control a diode laser module. The sync output is used to modulate the lasers light output, and coordinate it with beam motion.

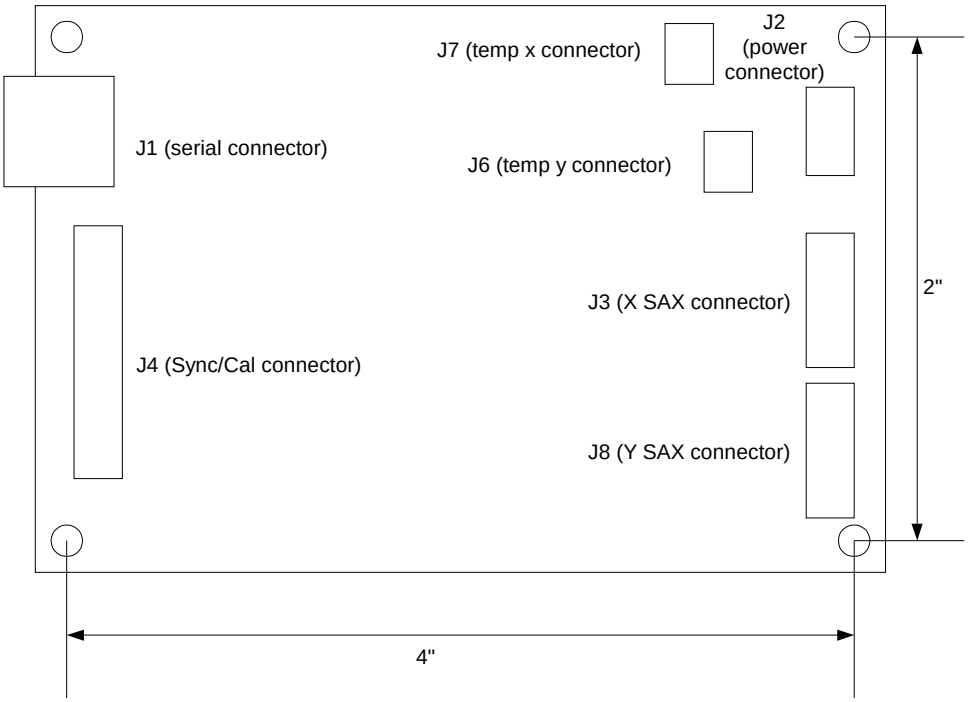

Figure 4 Top view of Scan Controller

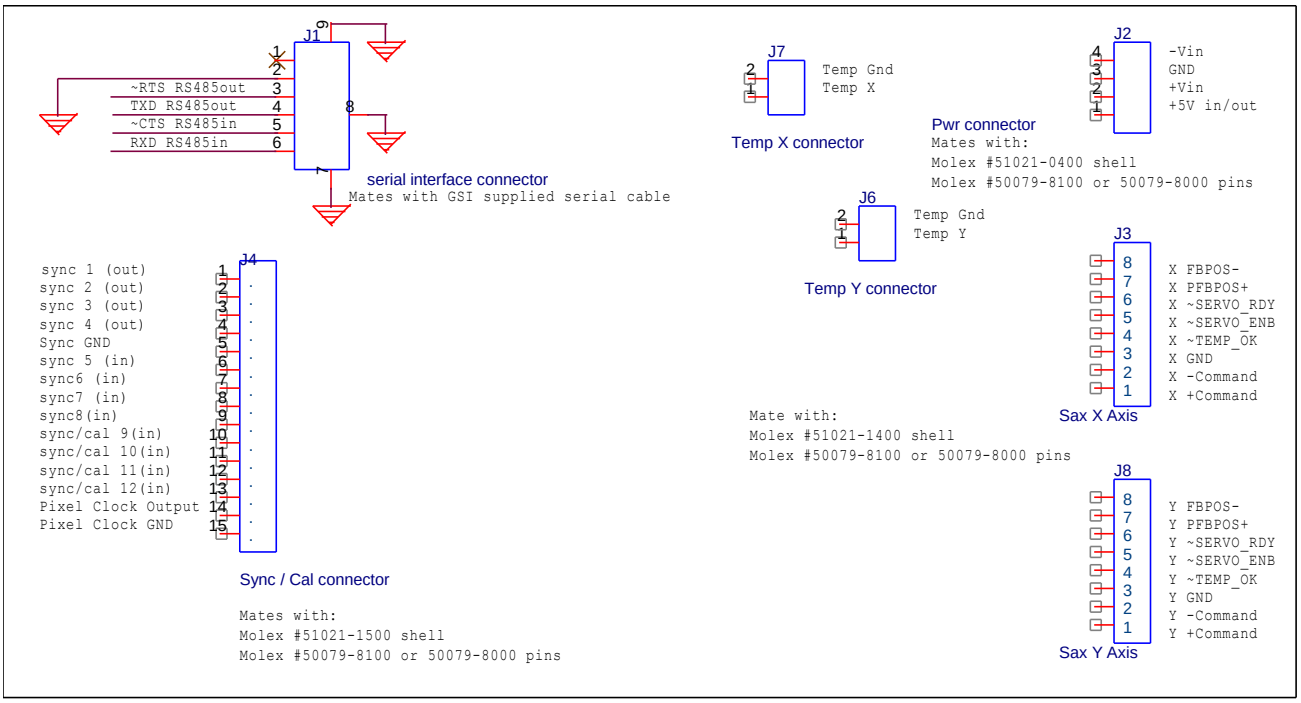

Figure 5 Pinout of Scan Controller

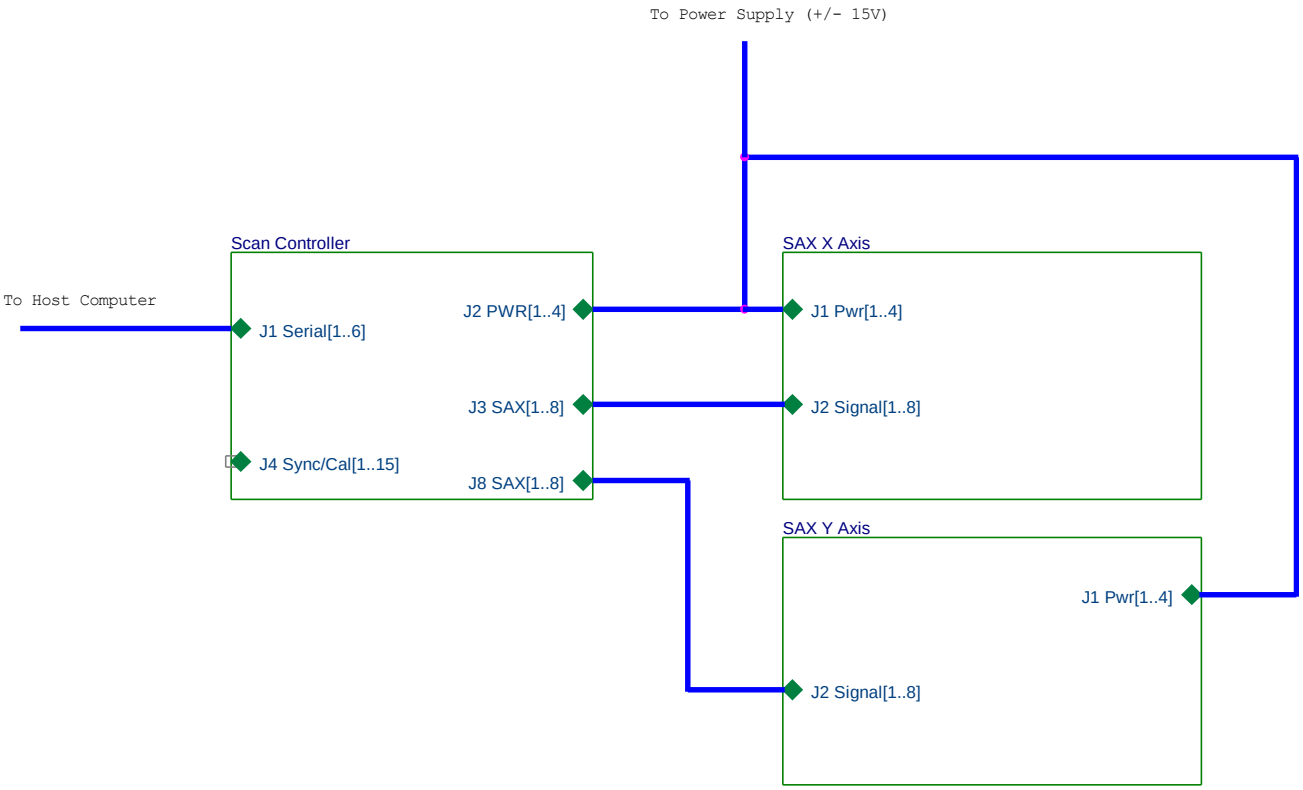

Figure 6 SAX connected to Scan Controller

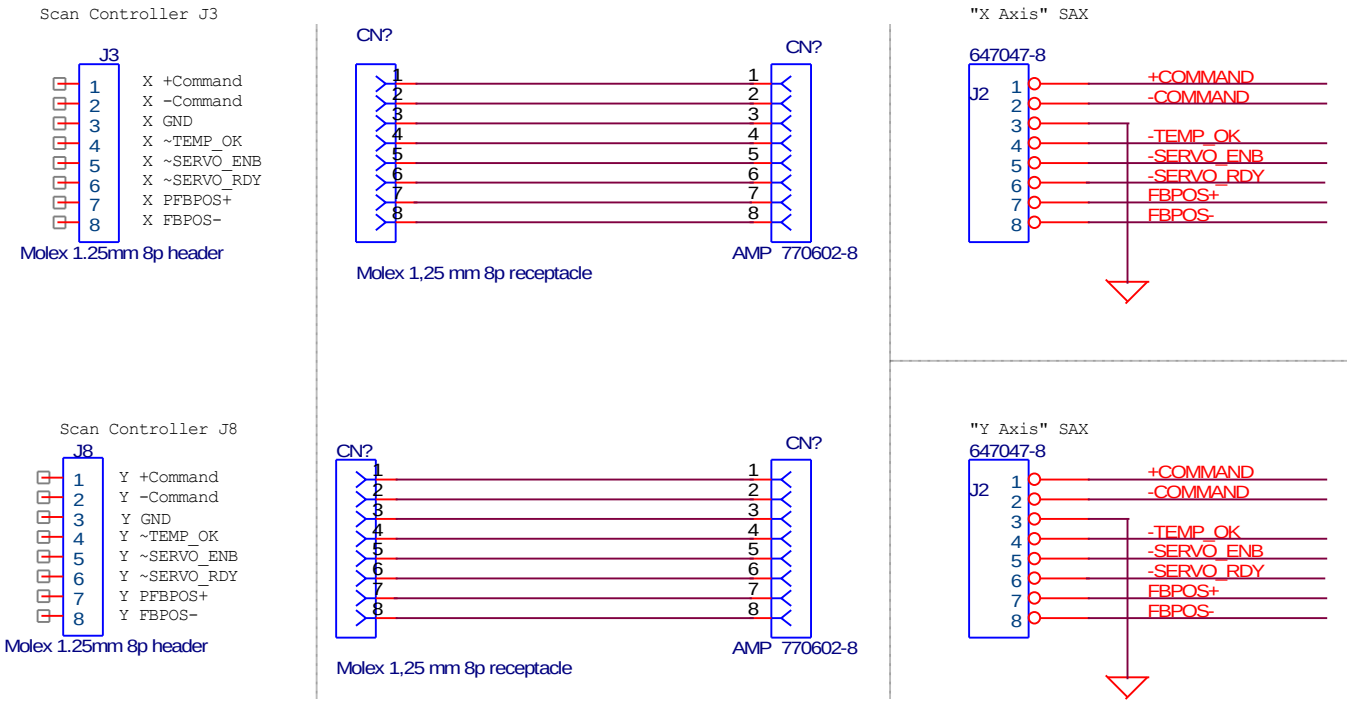

Figure 7 Scan Controller to 2X SAX interconnection diagram

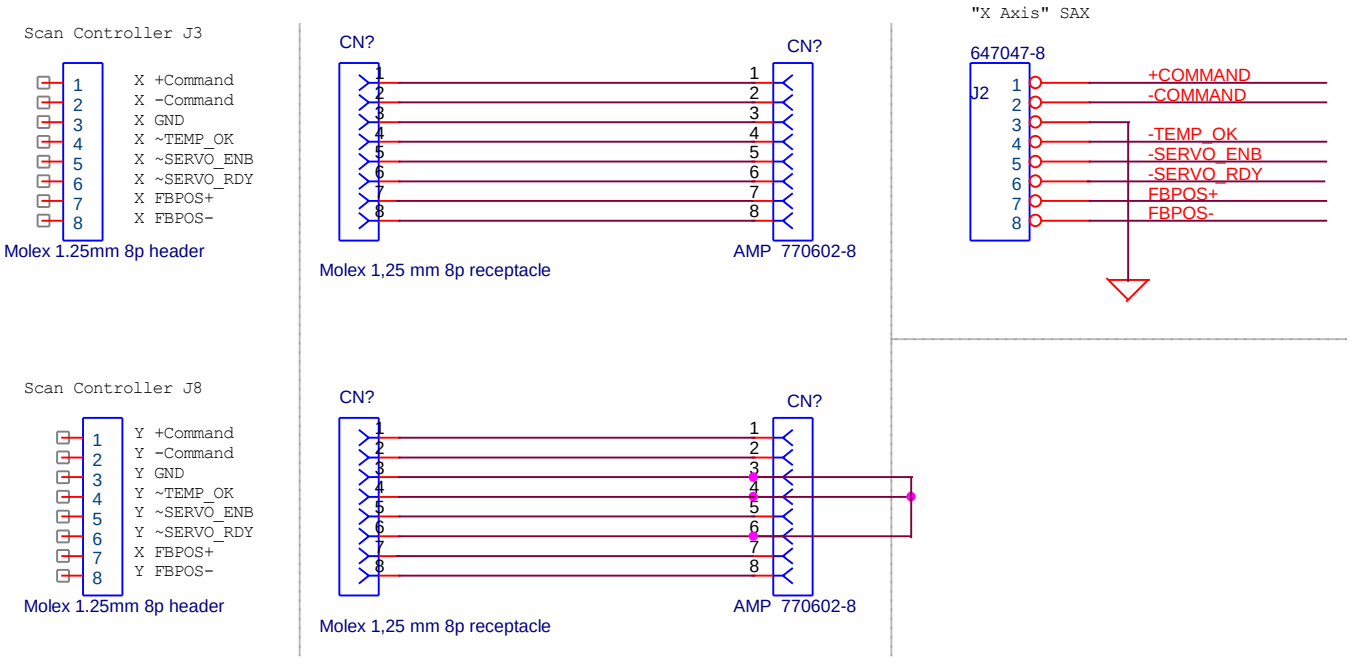

Figure 8 Scan Controller to 1X SAX interconnection diagram

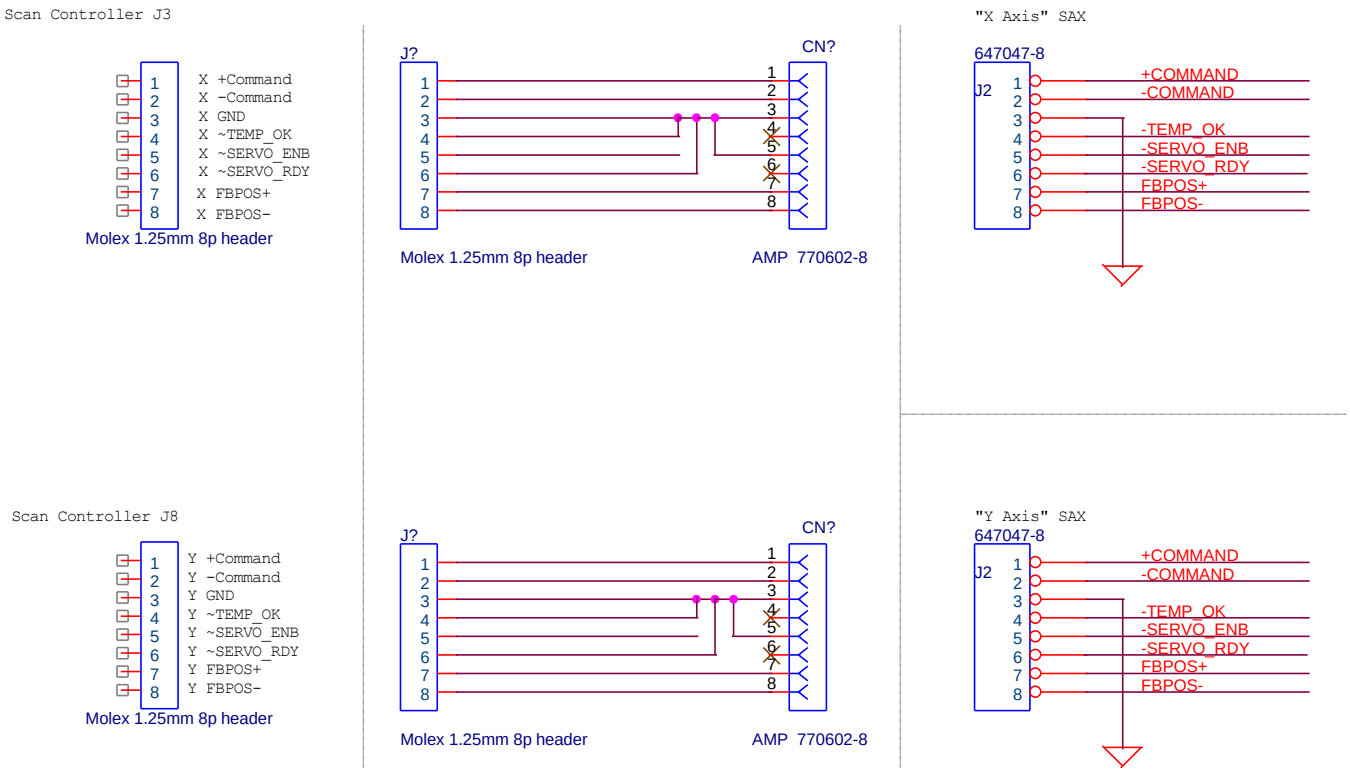

Figure 9 2X SAX without Enable interlock

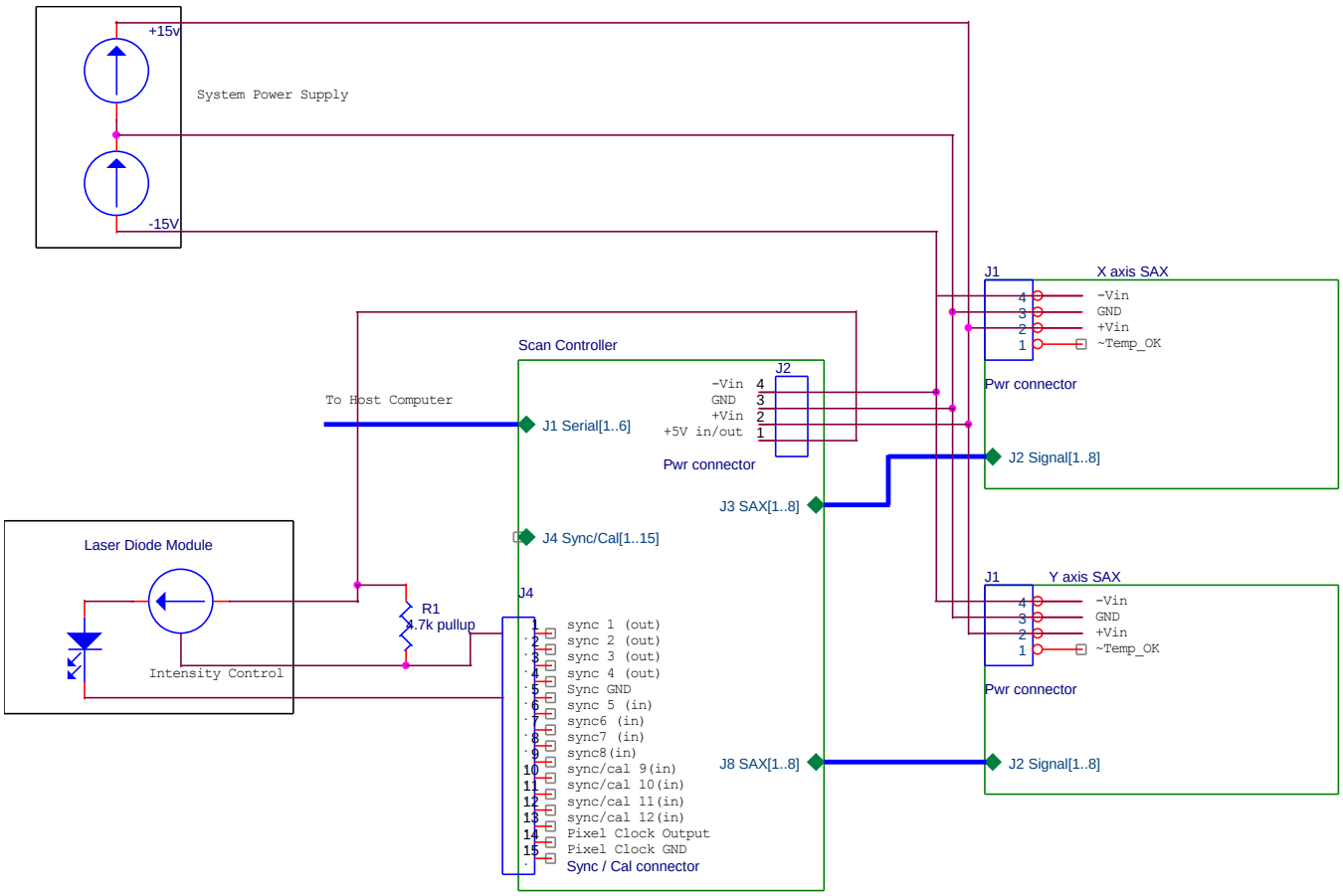

Figure 10 Two-axis system with laser diode control

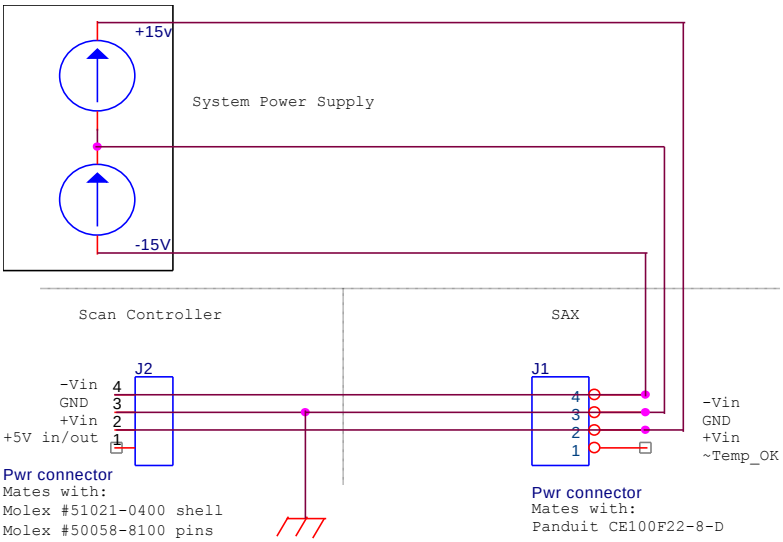

Figure 11 Typical Power Supply configuration

Software Overview

The LabVIEW™ software furnished with the Scan Controller allows users to easily and quickly communicate with the system. It is intended primarily as an environment for designing and programming stand-alone applications, and for system evaluation. Pieces of the code can be utilized in host-based real-time systems, but that is not its primary intent. Other LabVIEW™ code intended for real-time use, as well as Visual Basic support code may become available as the need arises.

The code is available in a number of forms:

As LabVIEW™ 4.1 or 5.0 VIs	Requires that the user own a LabVIEW™ programming environment	Cost structure yet undetermined – distribution with or without block diagrams, etc. TBD
As LabVIEW™ 4.1 compiled standalone code	Distributed with the system	For Win-95 or Win-NT 4.0 systems only

Software Installation

The LabVIEW™ application is presently furnished on CDROM. Alternately, 4 floppy disks can be generated from the CDROM; read the ReadMe.txt file for the latest information and changes. The software is installed by running '<CDROM>:\install\setup.exe'. The setup program will create a default installation directory (typically C:\GSI), install the application and support files, create a program group and add an item in the Windows start menu.

Preparation

Connect the Scan Controller serial cable to an available port on the host computer, connect the SAX modules and turn the Scan Controller power ON.

Program Startup

The Command Line Interface program is invoked either from the Windows Start menu or by a double-mouse-click on its icon (located in the default folder.) The main program window will rise as shown in Figure 12 and the program will begin executing by running the initialization step. During initialization, the **Ready** light will remain red indicating that user operations cannot be serviced. Please do not press any buttons until the **Ready** light turns green.

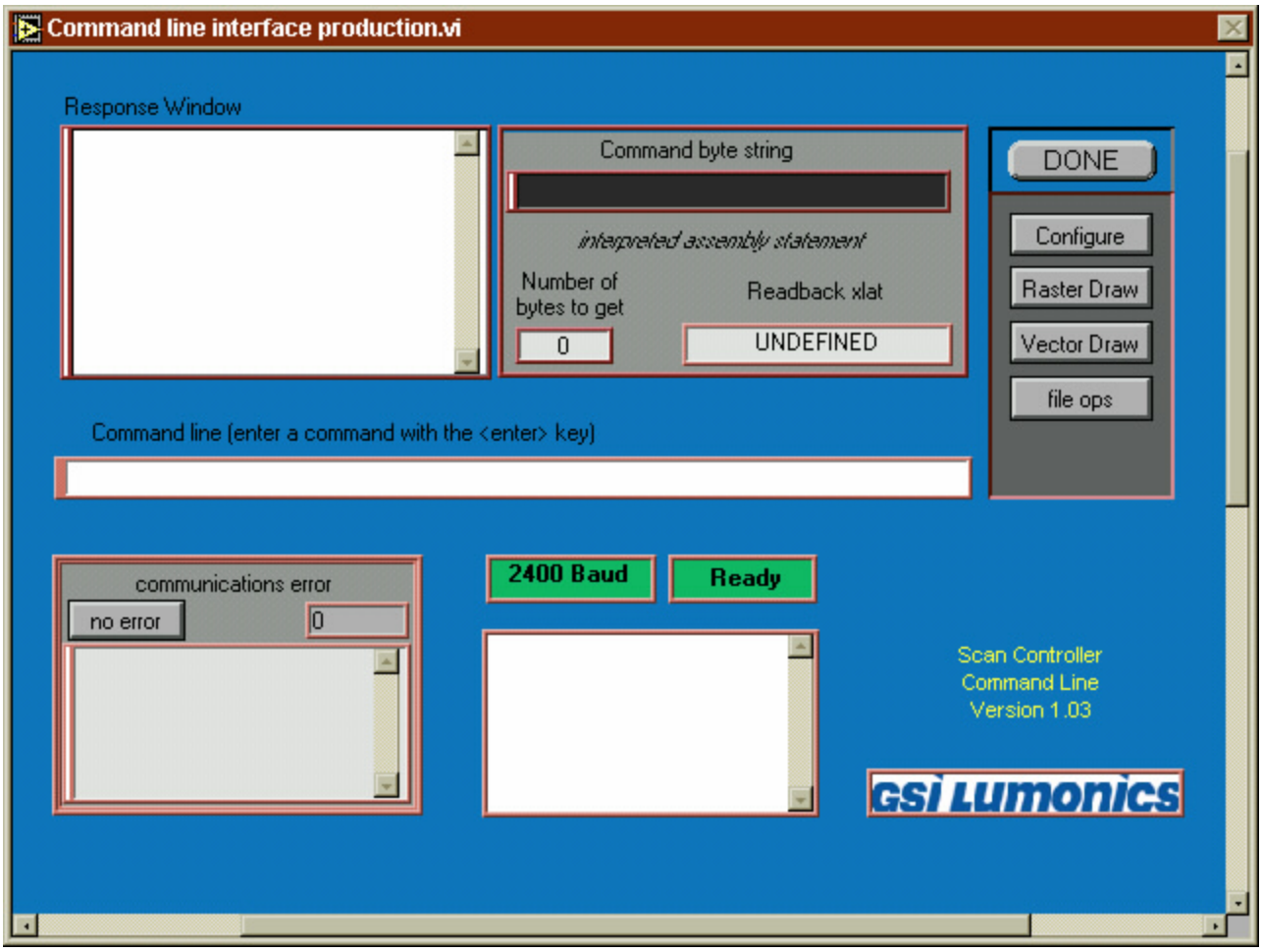

Figure 12 CommandLine Interface Main Window

Window Descriptions

The initialization step will automatically raise the Serial Port selector sub-window asking you to set the serial port device for Scan Controller communications (see Figure 13). The port names used in the program are similar to the Windows designations, COM1, COM2, COM3 and COM4. Select a port designation either by a left-mouse-click in the body of the control to view all ports available or by flipping through the list of available ports by left-mouse-clicking on the up/down triangles. Press **Done** to enter your selection of serial port.

Expert → The Command Line Interface program 'remembers' the Serial Port selection while loaded in RAM and the next time the program is started, it will use the previous Serial Port selection without popping up the Serial Port selector sub-window. This behavior can cause problems during initial trials on a new computer because an incorrect serial port may be automatically selected, and the only way to clear the selection is to close the Command Line Interface program and reopen from disk. A backdoor for this situation is provided by pressing **Almost Done** after selecting the serial port. **Almost Done** will enter your Serial Port selection but will not enable the automatic selection mechanism. If the Comm Port selection is incorrect, simply 1) stop the program with the **Done** button, located in the upper right corner of the Main Window and 2) restart the Command Line; you will be prompted to select a Serial Port once again.

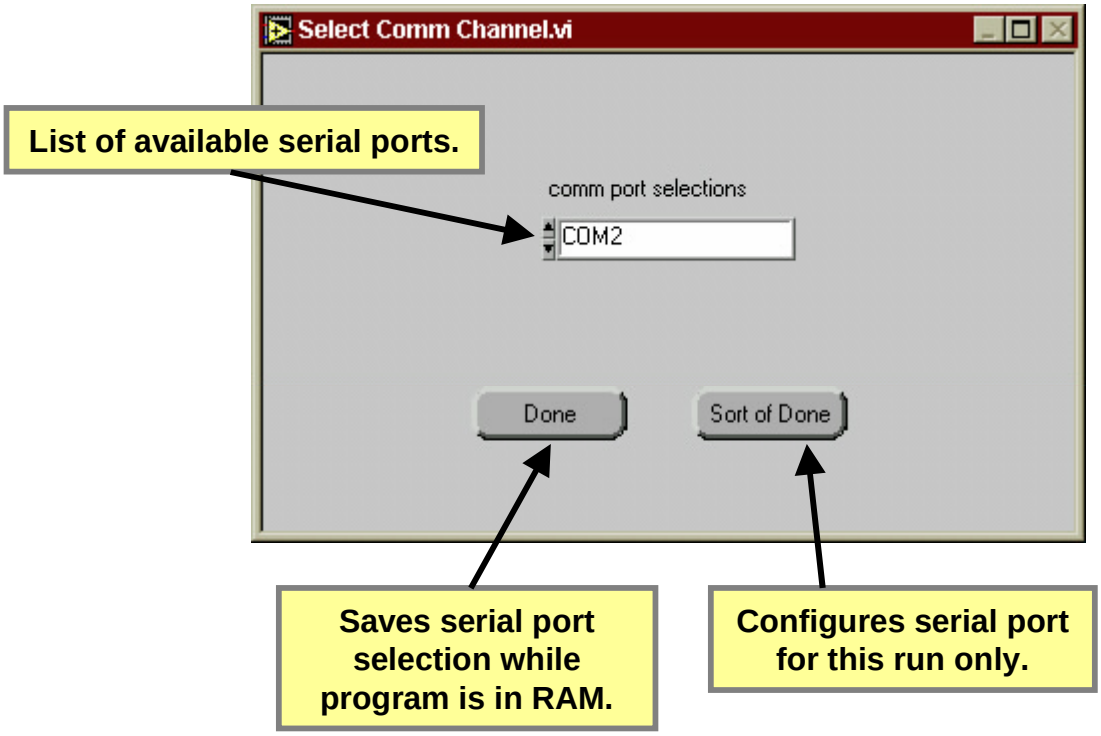

Figure 13 Serial Port Declaration

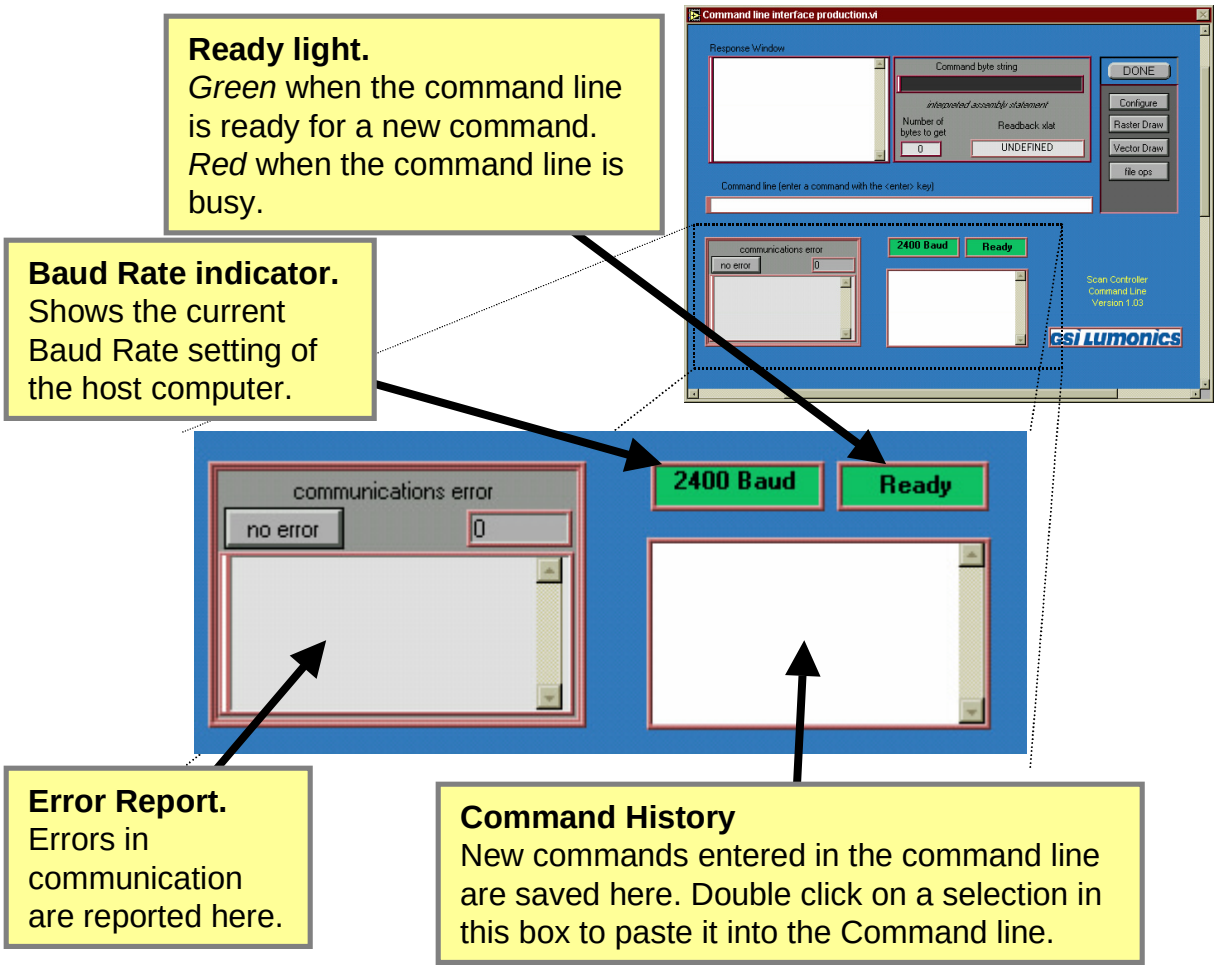

Figure 14 Status Displays

Status Displays

The Status Displays (shown in expanded view in Figure 14) report back information about the operation of the Command Line interface with the Scan Controller. Errors can be checked here, the current communications baud rate is shown, as well as a 'busy' signal when the program is involved with a time consuming operation. Finally, the command history (20 deep) of Scan Controller commands entered in from the command line is available for re-execution with a simple double-mouse-click.

Error Report

Error messages are reported to the operator through the Communications Error window. If there is a problem talking to the Scan Controller or if there is some internal error or assembler error, a message will be displayed describing the problem. In addition, the indicator "no error" will turn from gray to red clearly indicating that there was an error during the last command. The error display can be cleared by pressing the <enter> key with no command entered in the command line, key focus on the command line.

Command History

A list box in the bottom center of the main screen shows the last 20 commands entered from the command line, where the most recent command enters the history list at the top. If the newest command is the same as the previous command it is not added to the command history. Use the mouse to operate the scroll bar of the command history list box to find a command that needs to be entered again. Double click on the line, the command is pasted into the command line, press <enter> to send the command to the Scan Controller.

Baud Rate Indicator and Ready signal

The Baud Rate Indicator and Ready signal show the state of communication across the serial port from the computer to the Scan Controller. The Baud Rate indicator shows the current baud rate setting for the host computer. The baud rate defaults to 2400 baud when the Command Line Interface program is first started. Expert→ The default startup baud rate can be adjusted by operating the CLI.EXE front panel control 'Startup baud rate' accessable through the CLI.EXE front panel vertical scroll bar. Stop the CLI.EXE program by pressing the 'Done' button and adjust the baud rate. Then resart the program by pressing the run arrow located in the upper left corner of the main screen. The Ready signal turns from Green to Red when the Command Line interface program is busy performing an operation. Do not press buttons or terminate the program while the Ready signal is busy (Red).

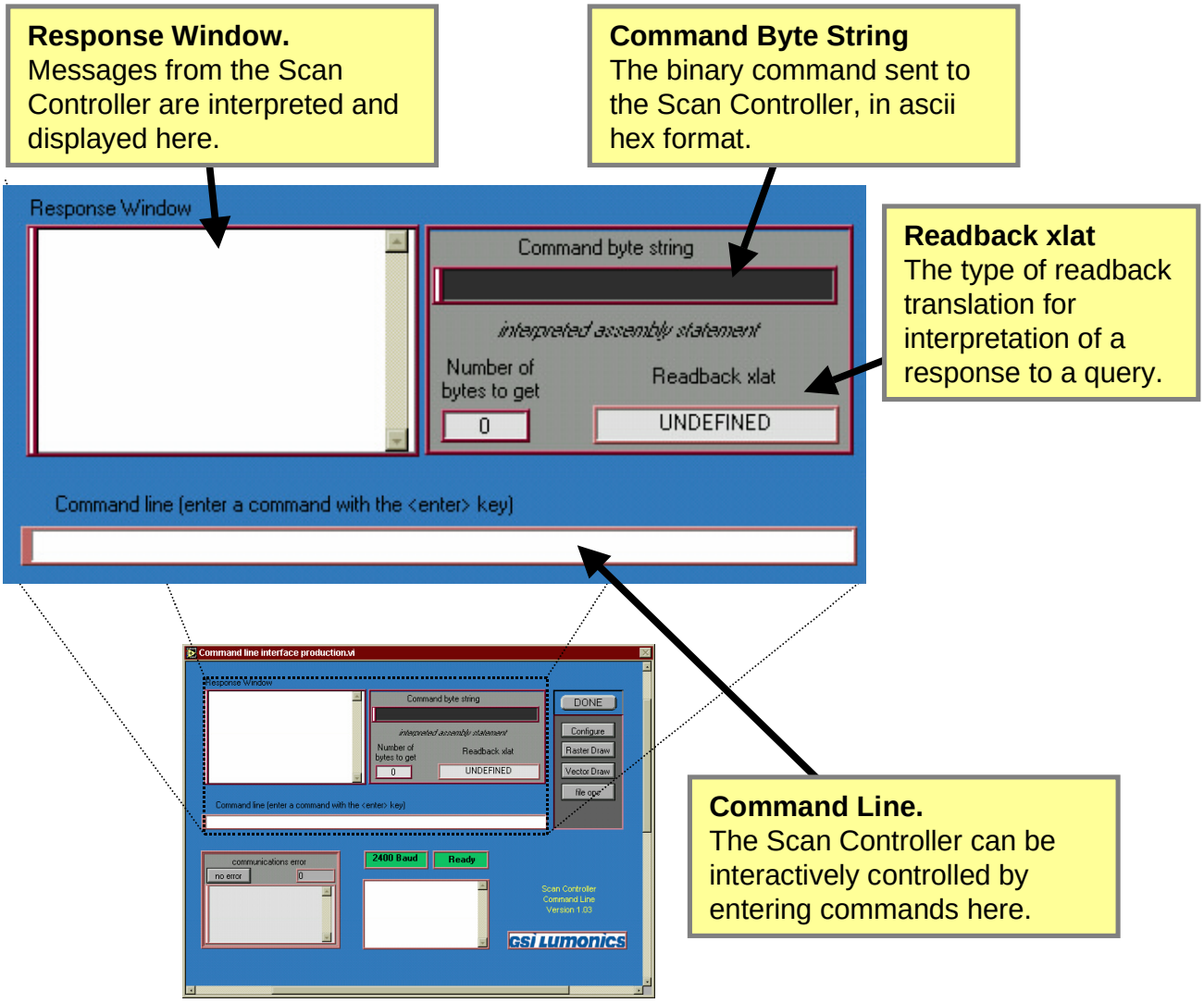

Figure 15 Command Line

Command Line Interface Controls and Displays

The Scan Controller can be controlled interactively by entering SC2000 assembly language commands at the command line prompt, shown in expanded view in Figure 15. There are also facilities that reveal the binary commands sent to the Scan Controller as the result of Command Line input and certain button activated functions; this allows the Command Line to be used as a source of binary commands that can be copied and included in other types of programs that communicate with the Scan Controller.

Command Line

The Command Line is a single line text input box that provides a means of interactive control of the Scan Controller through SC2000 assembly language commands. With the exception of program creation commands, every SC2000 assembly language command can be entered from the Command Line where the command is checked, assembled and transmitted via the serial port to the Scan Controller. Query commands, commands that start with '?', can be issued and the Scan Controller response is reported in the Response Window in ASCII hex and decoded form. Each command is entered by pressing the <enter> key. A history of commands entered from the command line displayed in the Command History list box located just beneath the command line.

Response Window

The Response Window is where to look for information sent back from the Scan Controller or from the command line interface program. This information can include the result of query commands, data translations and operational

messages. The Response Window is cleared when you enter a new command from the command line or when you invoke a high level operation from the button pad.

Machine Code Display

A display of assembled binary command data (machine code) is provided as a convenience for developers wishing to communicate with the Scan Controller in binary format. The Machine Code Display shows the translation of the SC2000 assembly language statement entered from the command line after assembly. The Command Byte string is the binary data sent to the Scan Controller, the Machine Code. This is displayed in hexadecimal format with the bytes sent to the Scan Controller in left-to-right order. If the statement entered on the Command Line was a query command, information is provided on the number of bytes to read back and the type of translation to apply to the readback data.

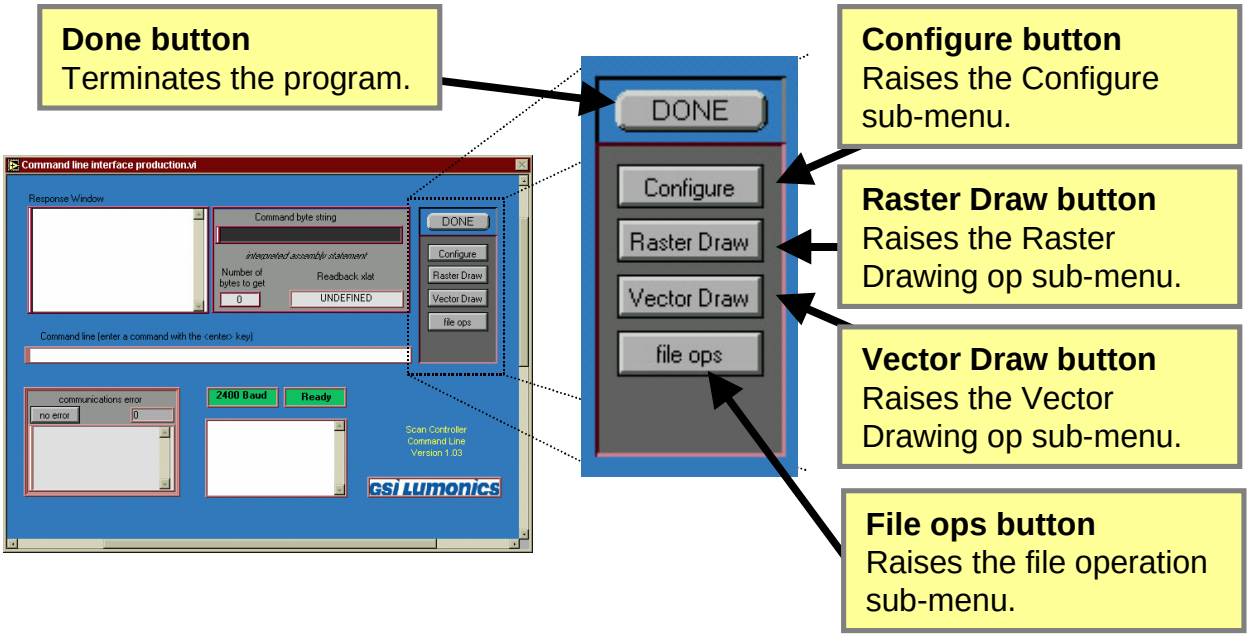

Figure 16 Button Pad

Main Window Button Pad

The majority of the high level functions of the Command Line Interface program are invoked by button presses on the Button pad (see Figure 16), with the logical structure shown in Table 1.

Done Button

Press the Done button to end the Command Line interface program on the host computer. The Done button does not affect the operation of the Scan Controller.

Configure Button

Press the Configure button to call up the Configure sub-menu. Options in the Configure sub-menu are:

1. Configure Communications.
2. Host Computer.
3. Configure Pixel clock.
4. Position readback calibration.
5. Adjust and save global parameters.

Raster Draw button

Press the Raster Draw button to call up the Raster Draw operation sub-menu. From here you can invoke one of several drawing tools that generate programs designed to run in raster mode or dual single axis mode.

Vector Draw button

Press the Vector Draw button to call the Vector Draw operation sub-menu. From here you can invoke one of several drawing tools that generate Scan Controller programs designed to run in vector mode. Available options are:

1. Draw Circle
2. Draw Free-form line

Table 1 Function Button locator tree

Main Window				
Configure	**Raster Draw**	**Vector Draw**	**File ops**	**Done**
Sub-menu	**Sub-menu**	**Sub-menu**	**Sub-menu**	
Serial Port	**Load wave**	**Load circle**	**Done**	
Host	**HF Sine**	**Load line**	**Cancel**	
Pixel Clock	**Cancel**	**Cancel**		
Readback Cal				
Global Params				
Cancel				

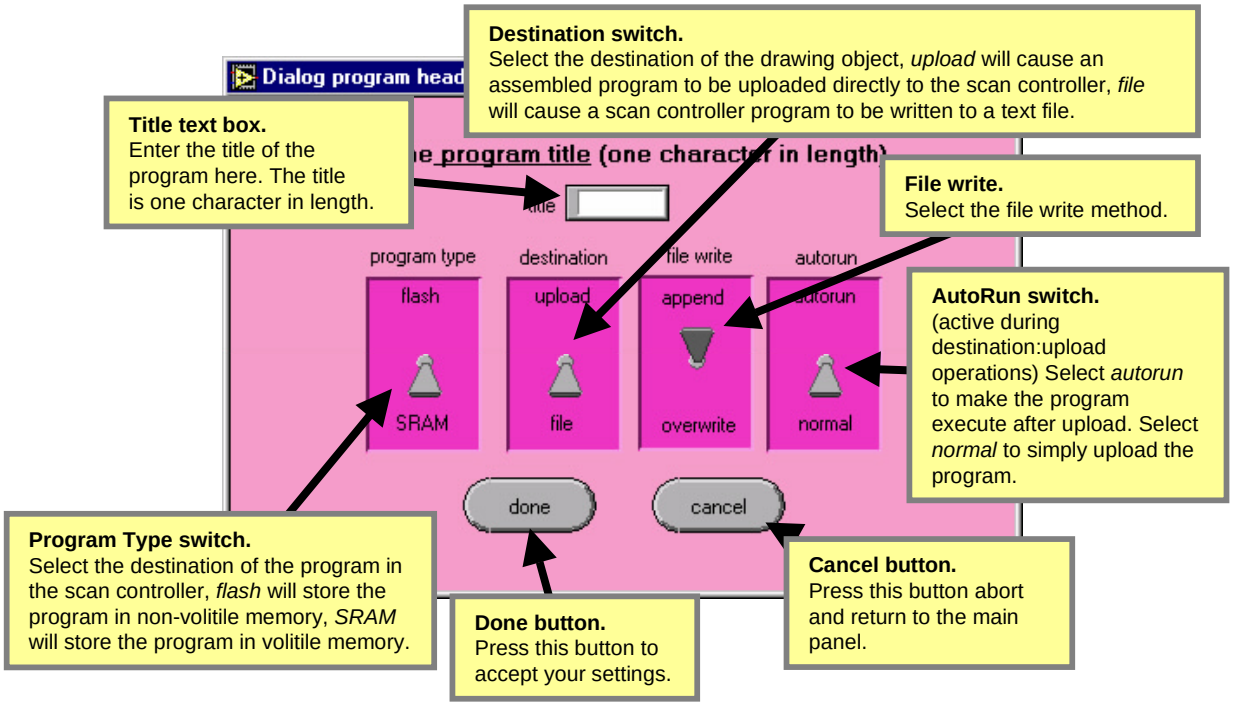

Figure 17 Program Destination sub-window

Program Destination Sub-window

The Program Destination Sub-window (see Figure 17) is used to direct the assembled version of a program to a destination. You can unpload a program directly to the Scan Controller or you can save the program to an assembly language source file. The Program Destination sub-window will appear after each high level drawing operation. In addition to the destination of the program, you can also specify various program attributes such as the program name and the type of program, flash or volatile.

Title Text Box

Enter a one character title for the program in the text box. Expert →do not enclose the character in single quotes. When you wish to execute the program by typing ExecutePGM from the command line, you must enter a character program name by surrounding the character with single quotes. You can also call a program by the ASCII character value as a decimal, hex or octal number. Valid program names are 0-9, a-Z and A-Z as well as other characters.

AutoRun Switch

When AutoRun is set to the up position, interpreted commands will be appended to the compiled program to commence program execution after it is saved in the Scan Controller memory.

Append/Overwrite Switch

When set to Append, new Scan Controller programs saved to an existing file will be appended to the end of the file. When set to Overwrite, new Scan Controller programs saved to an existing file will overwrite the contents of the file.

Destination Switch

Use the destination Switch to select where the program will finally reside. In the up position the program will be uploaded directly to the Scan Controller via the serial port. In the down position, the program will be saved to a file disk. Expert → When a program is saved to disk it retains the Scan Controller storage specification (Flash or SRAM as set with the Program Type Switch).

Program Type Switch

Use the program Type Switch to select the storage location inside the Scan Controller. The switch is operated by placing the mouse cursor on the switch graphic and left-mouse clicking. In the up position, the switch will cause the program to be saved to non-volatile Scan Controller memory by appending the prefix CreateFlashPGM to the program. Expert → Note that flash programs cannot be download to the Scan Controller while a motion program is running. In the down

position the switch will cause the program to be saved to volatile memory on the Scan Controller by appending the CreatePGM prefix to the motion program.

Done Button

When all the options have been configured, press the Done Button to enter the settings and start the program save operation. Done will return control to the Main window.

Cancel Button

You can press the Cancel button at any time. The program will be lost. Cancel will return control to the Main window.

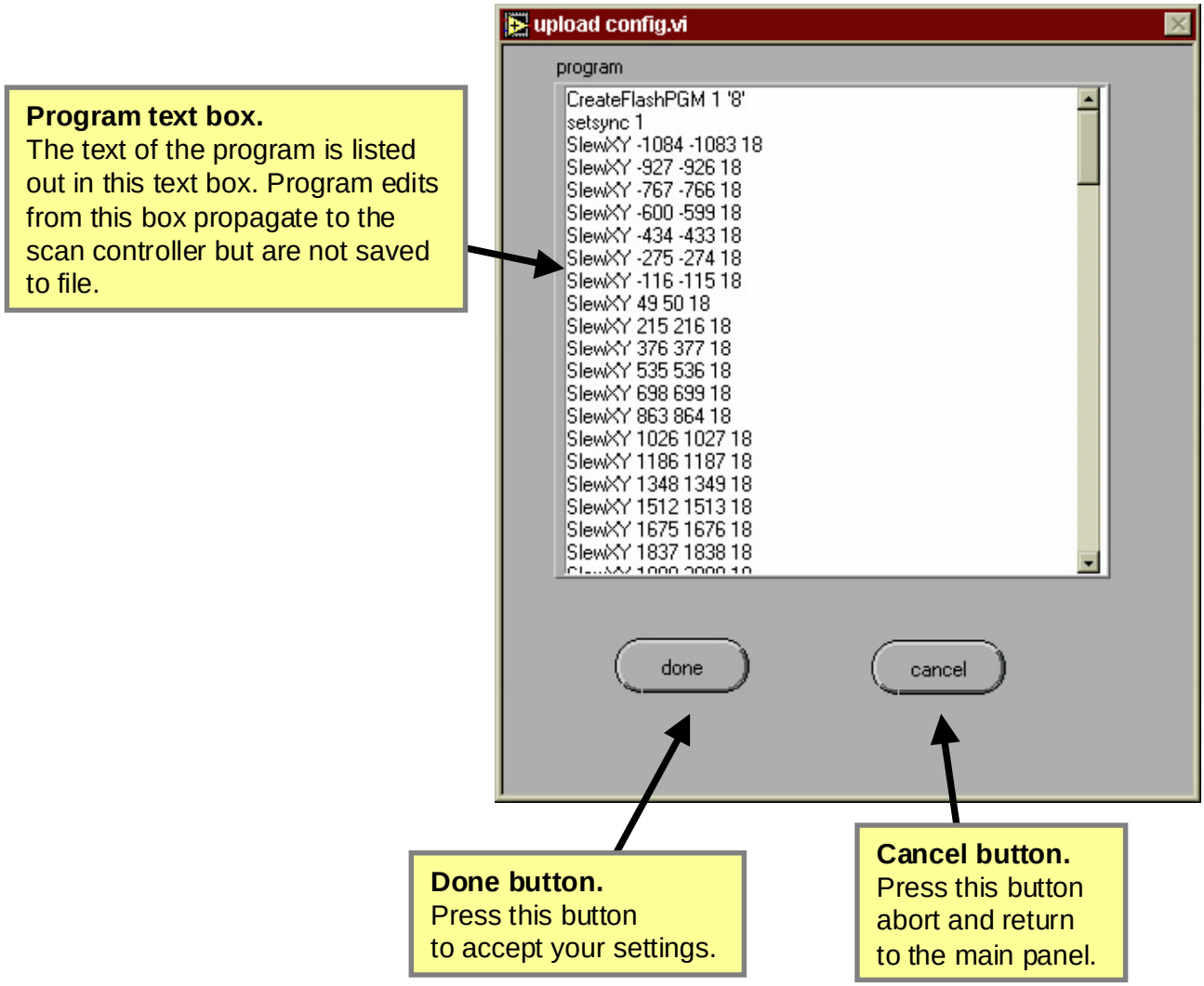

Figure 18 Upload Configuration sub-window

Upload Configuration Sub-window

The Upload Configuration Sub-window, shown in Figure 18, is raised just before a source-code or ASCII-hex program is submitted to the assembler and uploaded to the Scan Controller. The window provides a type of stream editor where it is possible to change commands, add or remove lines or the name of a program without changing the original source file.

Program Text Box

The program text box displays a listing of the program either as Scan Controller assembly language or ASCII-hex depending upon the type of file read. The scroll-bar on the left allows vertical panning through long programs. Use the keyboard to make changes to the text, use the mouse to highlight portions of text. Highlighted regions can be copied to the paste buffer using ctrl-c. Selected text is cut with ctrl-x and text is pasted with ctrl-v.

Done Button

Press the Done button to assemble and upload the program text. If you have not made any changes to the text, the uploaded program will be exactly the same as the source file. Done will return control to the Main Window.

Cancel Button

Press the Cancel button to quit before uploading to the Scan Controller. Cancel will return control to the Main Window.

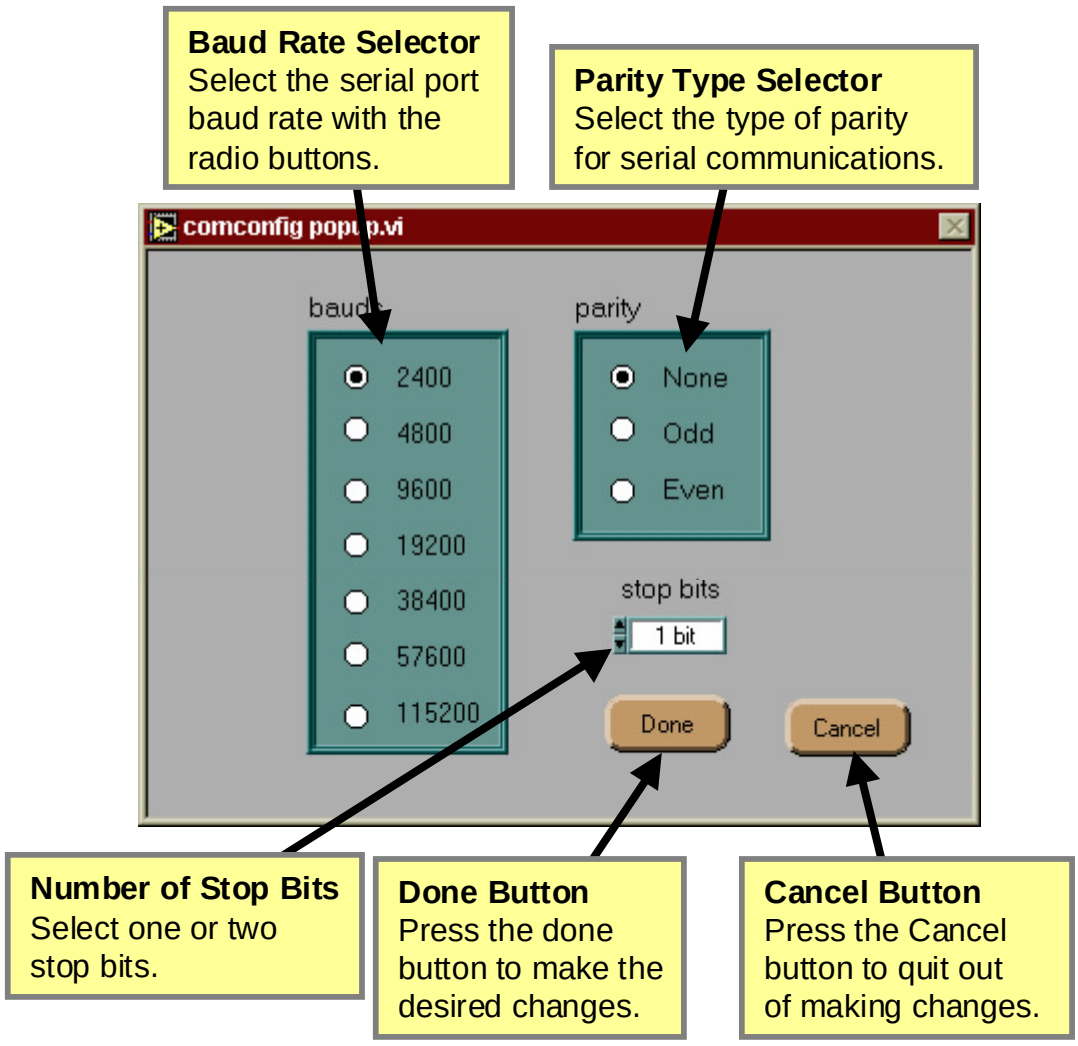

Figure 19 Serial Port Configuration sub-window

Serial Port Configuration sub-window

Use this window (see Figure 19) to configure the baud rate, parity and stop bits settings of the RS-232 connection between the host computer and the Scan Controller. Changes made from this interface will be reflected in both the Scan Controller and the host computer.

Baud Rate Selector

Click the mouse on one of the radio buttons to select the baud rate for subsequent Scan Controller – Command Line communications. Expert→ The power on default baud rate for the Scan Controller is always 2400 baud.

Parity Type Selector

Click the mouse on one of the radio buttons to select the type of parity for subsequent Scan Controller – Command Line communications. Expert→ The power on default parity for the Scan Controller is always None.

Number of Stop Bits

Select either one stop bit or two stop bits by clicking the mouse over the embedded pull-down menu.
Expert→ The power-on default number of stop bits is always one.

Done Button

Press the done button to effect the serial port configuration changes and return to the Main Window.

Cancel button

Press the Cancel button to return to the Main window without making any changes to the serial port settings.

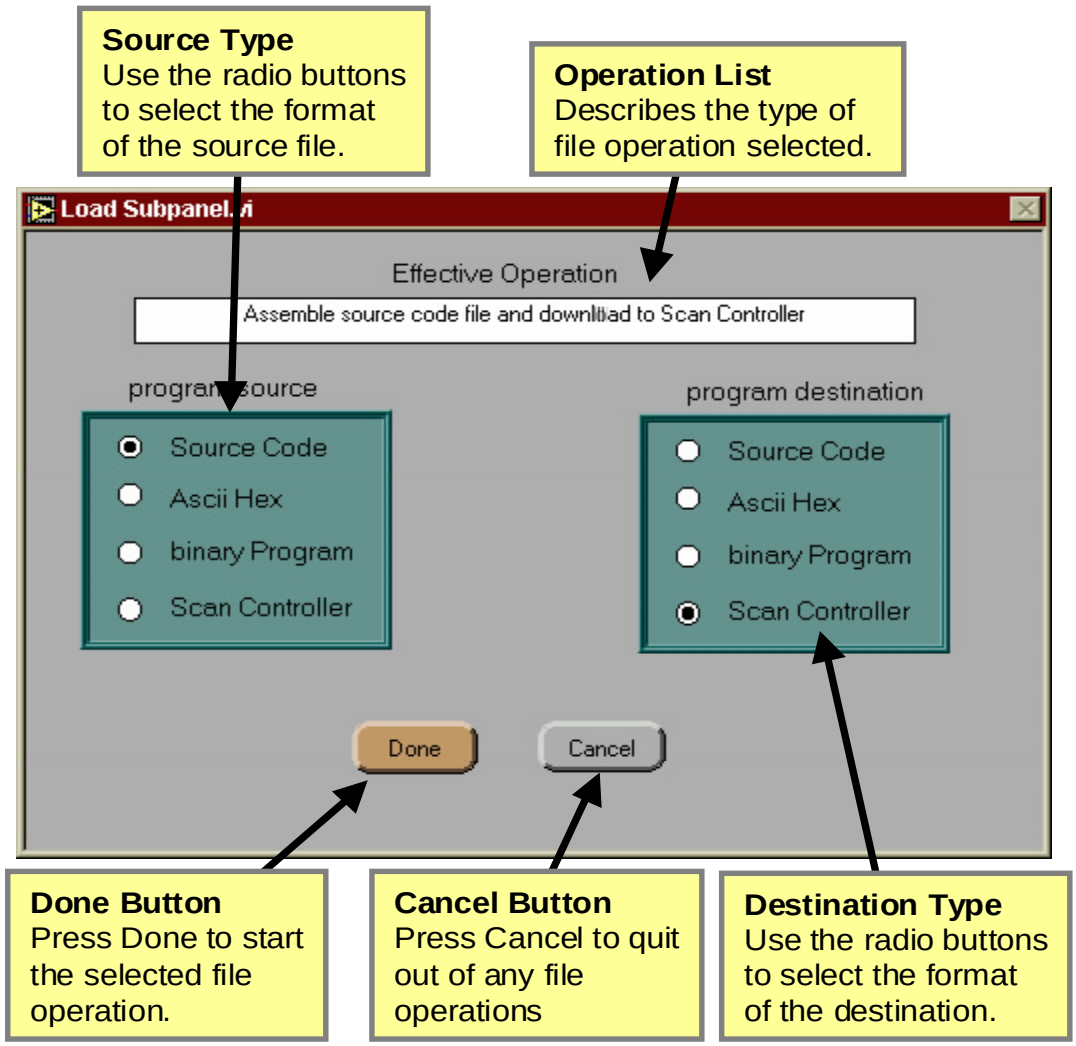

Figure 20 File Operation sub-window

File Operations sub-window

This window (see Figure 20) provides an interface between the Scan Controller and files on the host computer and also operates as a translation utility for file formats and downloads of binary program listings from the Scan Controller.

Operation List
The text written here describes, in plain talk, the type of operation that will be performed.

Source Type Selector
Use the mouse to declare the format of the source file (the file to be read). Expert→ Scan Controller source not currently supported.

Destination Type Selector
Use the mouse to declare the format of the destination file (the file to be written). Select 'Scan Controller' to download a program file from the computer to the Scan Controller.

Done Button
Press the Done button to begin the desired operation. If the source and/or destination involve files on the host computer, you will be prompted for file names from pop-up file dialog boxes.

Cancel Button
Press the Cancel Button to quit out of any file operations and return to the Main Window.

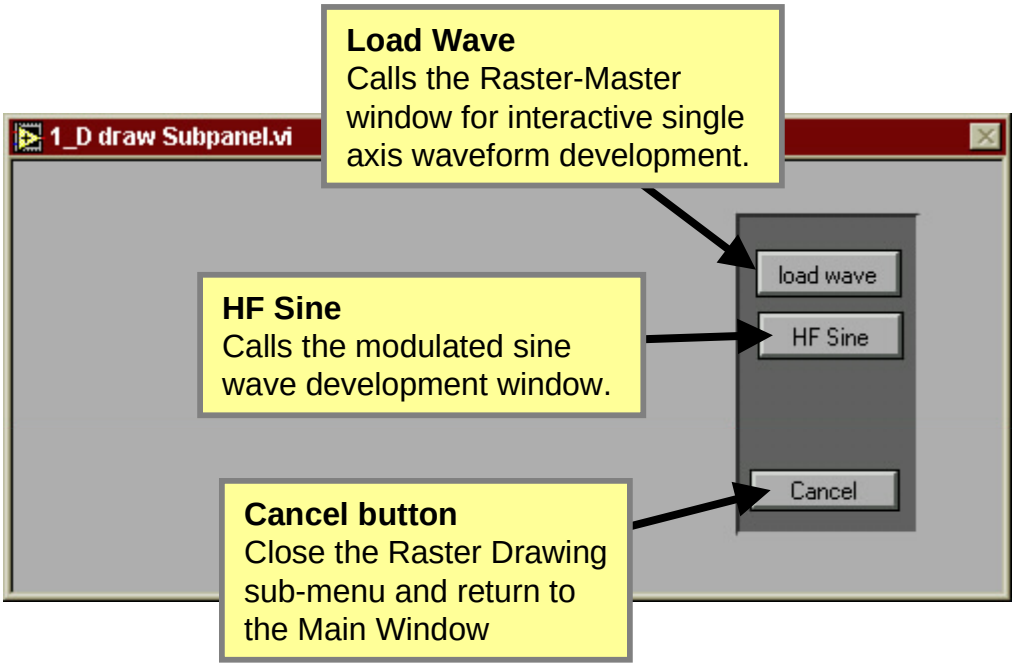

Figure 21 Raster operation sub-menu

Raster Operations sub-menu

Interactive tools from this sub-menu (see Figure 21) generate raster programs such as periodic sine, triangle, square, and sawtooth waveforms for single axis control and also modulated high-frequency sine wave programs for pixel clock control.

Load Wave
This button invokes the period waveform generator utility. Use this utility create a raster scanning waveform as a Scan Controller program file.

HF Sine
This button calls the modulated sine wave development window which takes a periodic raster scan wave as input and uses it to modulate a high frequency sine wave. The result is stored as a Scan Controller program file.

Cancel button
Press this button to close the sub-menu and return to the Main Window.

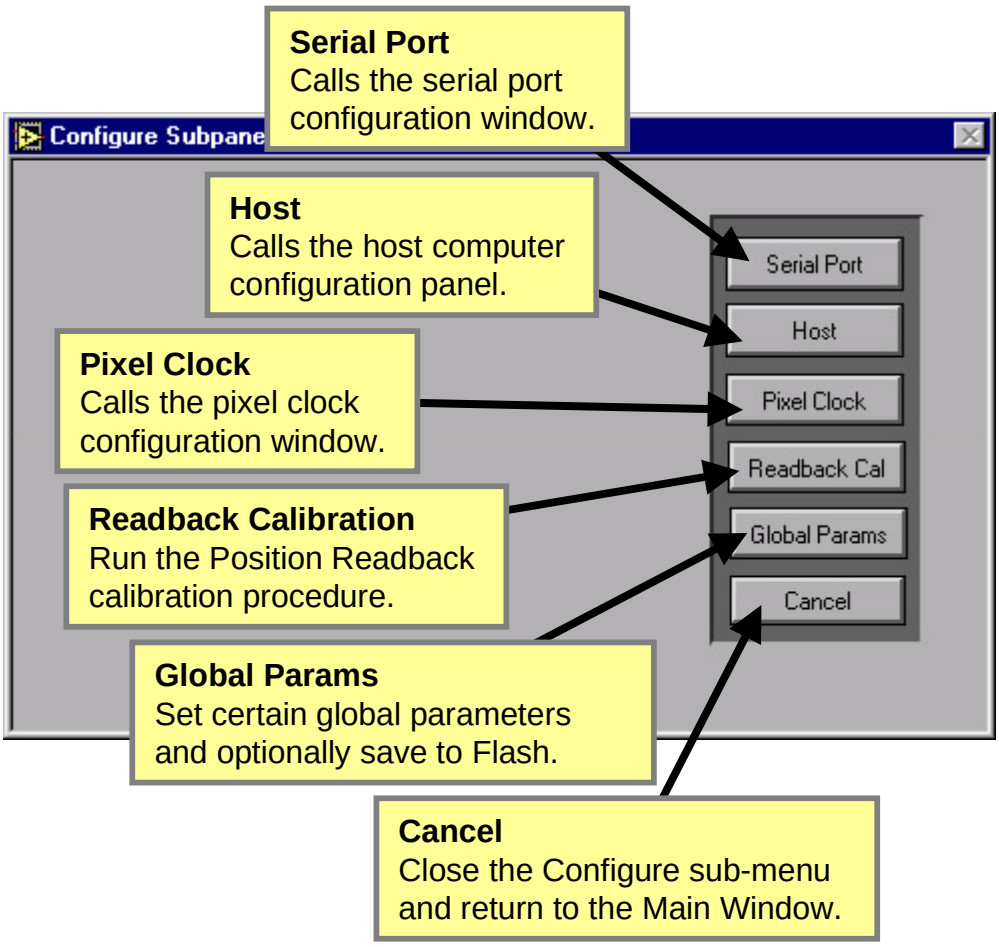

Figure 22 Configuration sub-menu

Configuration sub-menu

The configuration sub-menu (see Figure 22) is used as a jump point to various configuration tools that adjust various system parameters such as serial port baud rate and pixel clock settings.

Serial Port button

Press the Serial Port button to invoke the RS-232 setup window. From this window you can configure the baud rate (up to 115.2K baud) , parity and stop bits of both the Scan Controller and the host computer.

Host button

Press the Host button to call the host configuration panel. Current support for one option, configure Command Line Interface Program to operate on computers with limited RAM with a speed tradeoff.

Pixel Clock button

The on-board Scan Controller pixel clock can be configured through a user interface screen.

Readback Cal button

The CLI will interactively control the Scan Controller and the X and Y SAXes via the serial interface to produce a linear calibration of the position readback signal. This calibration will be uploaded to the Scan Controller and saved to non-volatile memory. The procedure requires a working X-Y galvo head with SAXes either manually enabled from the command line or through the use of the hard wired enable SAX interface cables.

Global Params

This button will invoke a screen that allows editing of certain global configuration parameters for the Scan Controller. The value of the parameter can be set by entering a number in the provided numeric control. Check the check box to alter

the parameter. Parameters are altered once the ‘Done’ button is pressed and only those parameters ‘checked’ will be changed. The current value of all parameters can be save to non-volitile RAM by checking the ‘Save to Flash’ check box.

Cancel button

Press the Cancel button to close the configuration sub-menu and return to the Main Widow.

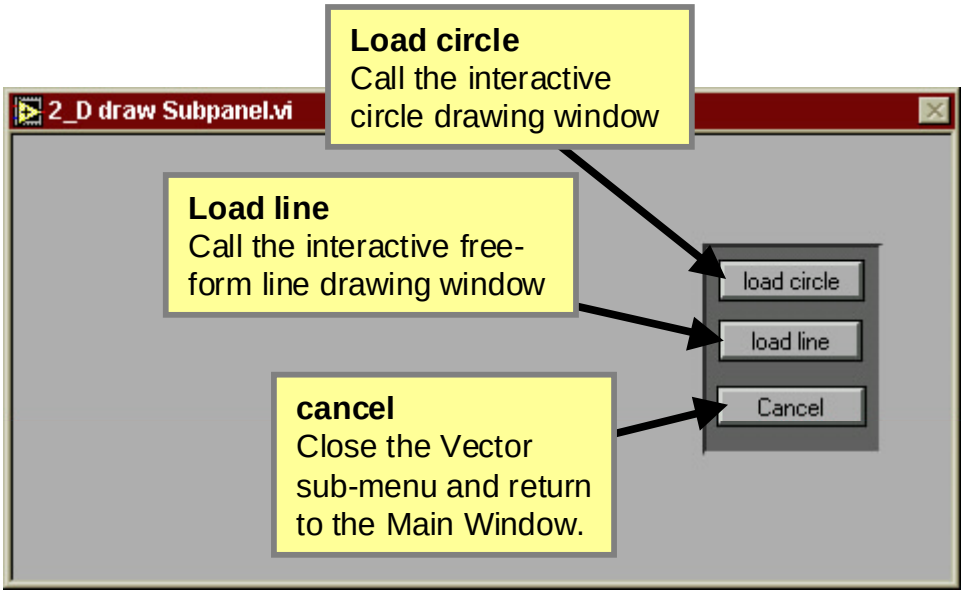

Figure 23 Vector Drawing Sub-menu

Vector Drawing sub-menu

The Vector Drawing sub-menu (see Figure 23) allows you to select one of a number of high level vector drawing tools used to develop Scan Controller programs for X-Y systems.

Load Circle

Press the Load Circle button to call the circle drawing program where you can draw absolutely positioned circles or relative circles. Circle programs are stored as Scan Controller assembly language files.

Load Line

Press the Load Line button to call the freeform line drawing program. Use the mouse to draw a freeform, two dimensional line on the canvas. The line is represented as a continuous spline curve with adjustable knot point distance. A line drawing program is stored as a Scan Controller assembly language file.

Cancel

Press Cancel to return to the Main Window.

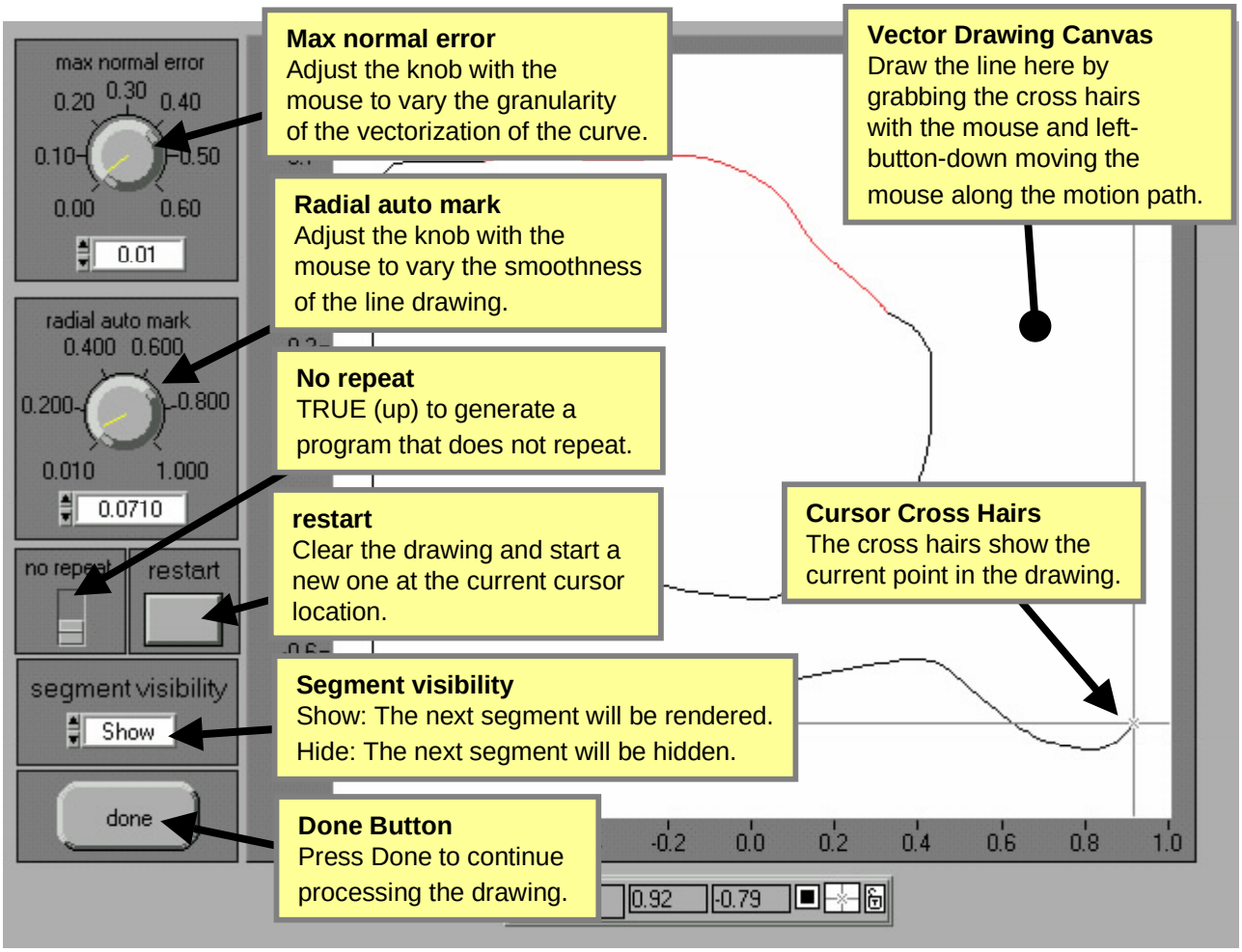

Figure 24 Free-form line drawing sub-window

Line Drawing sub-window

Use the Line Drawing window (see Figure 24) to create freeform motion paths. A line is drawn by grabbing the cross-hair cursor with the mouse and then tracing out the motion path desired.

Max normal error

This knob controls the maximum normal error between the approximation vector and an arc of the curve the endpoints of which lie on the head and tail of the approximation vector. For a given setting of this 'max normal error' control, a head to tail sequence of vectors will be generated along the curve such that the length of a line normal from a given vector to the curve arc that it approximates will never exceed the control setting. This is the manner of converting curved trajectories to Scan Controller programs. The vectorization sub-panel is not available for line drawings as it is in circle drawing but the effect is the same. See the section "Circle vectorization sub-window" and try the circle drawing tool for a visual example of the vectorizing effect of the 'max normal error' control.

Radial Auto-Mark

This knob controls the spacing of knot points along the spline interpolated line. Larger settings of radial auto-mark result in smoother lines, but also lines which do not always travel the exact path traced by the mouse. Settings of 0.01 to 0.4 have the greatest effect in drawing detail and overall smoothness. Radial auto-mark can be changed during the course of a line drawing to get a combination of smooth lines and fine detail.

No repeat

The action of this switch when in the up position (TRUE) is to generate a Scan Controller program that does not have a repeat statement. The effect is such that when the program is run, the path traced is one traverse of the drawn path and then the end of the program.

Restart

Press this button to clear the current drawing and reset the start point to the current cursor location. This allows you to start the drawing were you want.

Segment visibility

There are two types of lines drawn, ‘shown’ and ‘hidden’. The segment visibility is set before the line is drawn. ‘Shown’ lines are displayed on the computer screen in black and ‘hidden’ lines are shown in red. Please note also that when the ‘segment visibility’ control is changed the spline for that segment is closed. This closure generates a corner at the endpoint of the previous spline and the start of the next spline. The end and start points are coincident but the first derivatives from the left and from the right may be different. Traversal of this corner may cause inertial mirror effects not present during the traversal of the spline interpolated curve. The mechanism of turning the laser on and off is to insert ‘setsync 1’ and ‘unsetsync 1’ commands at the corners. If other sync channels are to be used for laser control, the program can be saved as a file and edited with a text editor.

Done button

Press the Done button to convert the drawing into a Scan Controller program, after which you will be prompted to save the line drawing as a file in the Scan Controller assembly language format.

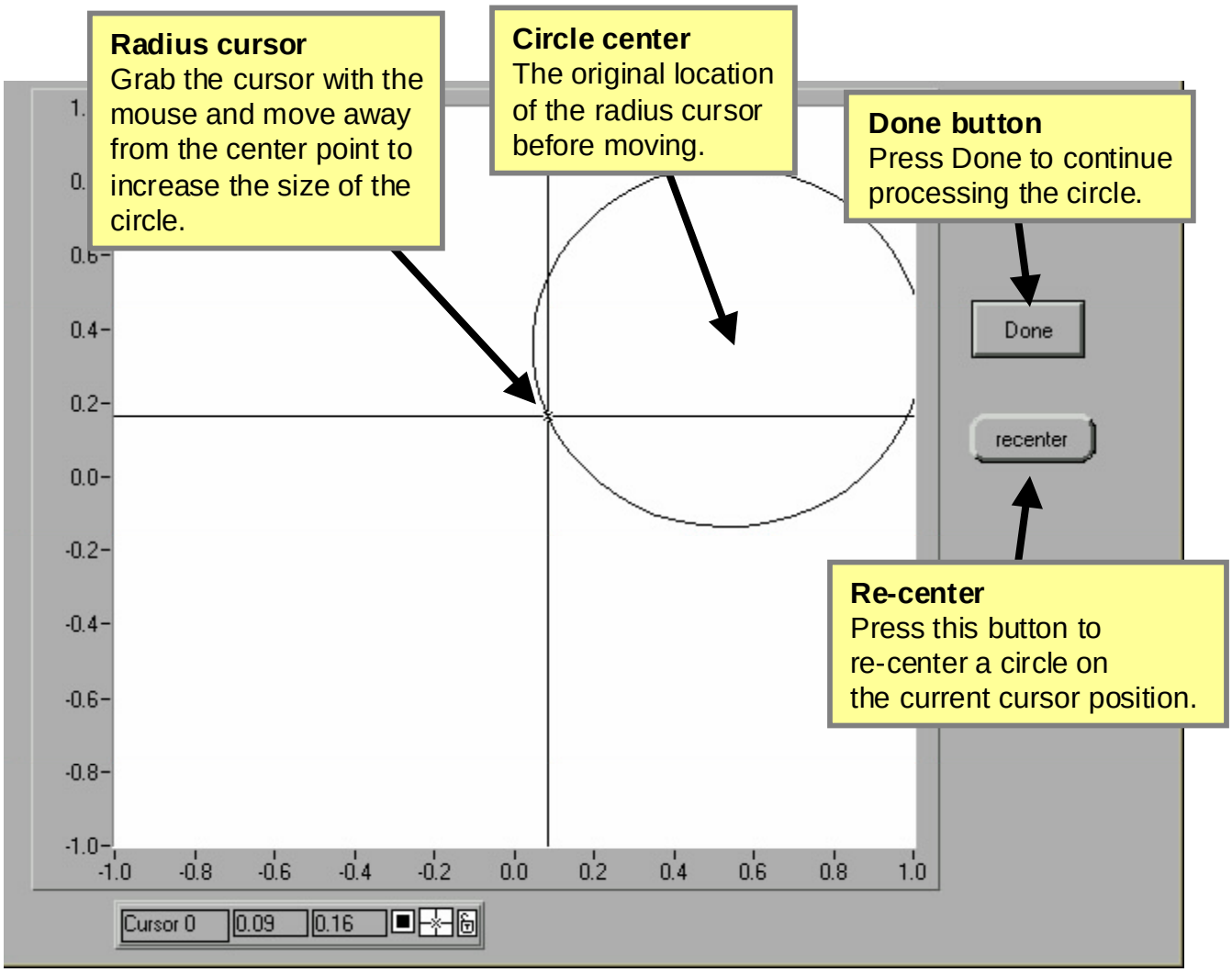

Figure 25 Circle drawing sub-window

Circle Drawing sub-window

Use the Circle Drawing window (see Figure 25) to generate circles of various sizes. A circle is drawn by grabbing the cross-hair cursor and moving away from the center point; a circle is rendered with its center at the initial cursor point.

Recenter

Press the recenter button to begin a new circle with a center at the current cursor location.

Done

Press the done button to convert the rendered circle into a Scan Controller program. You will be prompted to vectorize the circle and then save the circle program as a file in the Scan Controller assembly language format.

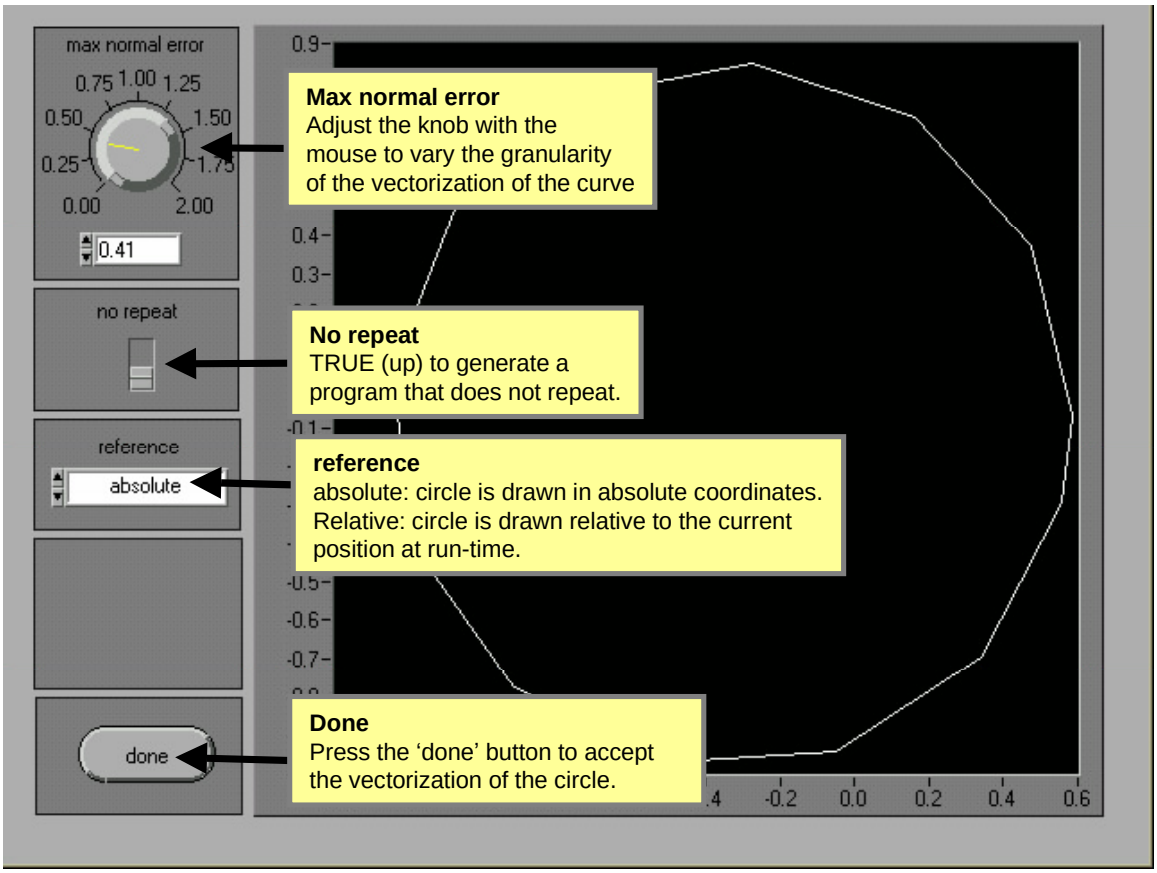

Figure 26: Circle vectorization sub-window

Circle vectorization sub-window

Use the Circle vectorization sub-window to convert the smooth curve circle into a group of vectors that approximate the path of the circle. This tool allows curve generation in the Scan Controller by providing a tradeoff between program size and smoothness of the curve.

Max normal error

This knob controls the maximum normal error between the approximation vector and an arc of the curve the endpoints of which lie on the head and tail of the approximation vector. For a given setting of this 'max normal error' control, a head to tail sequence of vectors will be generated along the curve such that the length of a line normal from a given vector to the curve arc that it approximates will never exceed the control setting. This is the manner of converting curved trajectories to Scan Controller programs.

No repeat

The action of this switch when in the up position (TRUE) is to generate a Scan Controller program that does not have a repeat statement. The effect is such that when the program is run, the path traced is one revolution about the circle.

Reference

Circle programs may be generated using either absolute positioning commands or relative positioning commands. 'Absolute' will cause a circle program to be generated which contains slewxy commands. Positioning in the field of view is directly tied to the origin of the drawing screen. 'Relative' will cause a circle program to be generated which contains deltaslewxy commands. Positioning in the field of view is relative to the current mirror position before the program is run.

Done

Press the 'Done' button to accept the vectorization of the circle.

Operating the Scan Controller

Once the CLI program is initialized, the **Ready** light on the CLI main panel should turn green, indicating that the Command Line Interface program is in the idle state. Single line SC2000 assembly language commands can be sent to the Scan Controller by typing in the *Command Line* box. Press <enter> to assemble the command and send the binary to the Scan Controller over the serial line. High-level interface tools are started by raising a sub-menu of operations with one of the buttons located on the right side of the main window. The Command Line Interface assembler will perform error checking on programs submitted from files and immediate commands entered from the *Command Line* and error reports will be generated in the case of out of range arguments, illegal or improper commands, etc.. SC2000 assembly language commands are documented in the Reference section at the end of this document.

An example of typical operation is as follows::

1. **Raster Draw / Load Wave**: This brings up the window shown in Figure 27. **Signal Source** provides the means to select the basic wave-shape. **Frequency** and **Amplitude** (in peak volts, of the commanded wave-form) can be entered in the appropriate places. **Offset** will adjust a DC offset term which is added to the wave-form, and the **phase** variable sets the location the 'repeat' statement. **Ticks per sample** controls how finely the waveform is broken up into straight-line segments. The Scan Controller codec operates at a constant update rate of 43.411 kHz (it outputs command voltages to the galvo at this constant rate). One way of generating wave-forms is to store one point for each point output to the galvo. For many applications this is unnecessary – the program can be made of many fewer points, and the Scan Controller will generate straight lines between them using the **slewxy** or **slew** commands. **The Ticks per sample** control controls this granularity. When it is set to 1 a command is generated for each point to the galvo – if it is set to 10 then a command is generated for every ten points, and straight lines are drawn between them. For 'Ticks per Sample' of one, this control re-names itself **Periods** and allows multiple periods of a waveform to be generated. This is useful for generating higher frequency waveforms. The waveform plot shows the effects of varying these controls, in real-time. Finally, the **derivitator** control allows the display and generation of the time derivative of the wave-form. This can be useful where velocity, rather than position is the variable of interest. When the desired wave-form is present in the plot, pressing the **Done** button brings up the Program Destination Window, shown in Figure 17. This allows you to direct the program to the Scan Controller or store to a file on the host. The title is any single character, which will be converted to a number by the program (the program describing this sine wave is called 'a').
2. **File Ops source code ⇒ Scan Controller**: This allows you to take an already created program stored on the host and load it to the user interface. The sine wave program created above has the listing shown below, and can be assembled and sent to the Scan Controller using the file ops window, shown in Figure 20.

```
CreatePGM 0 'a'
Slew 1897 13
Slew 3898 13
Slew 5759 13
Slew 7411 13
Slew 8795 13
Slew 9862 13
Slew 10572 13
Slew 10900 13
Slew 10834 13
Slew 10377 13
Slew 9544 13
Slew 8367 13
Slew 6887 13
Slew 5158 13
Slew 3243 13
Slew 1211 13
Slew -866 13
Slew -2911 13
Slew -4850 13
Slew -6615 13
Slew -8140 13
Slew -9371 13
Slew -10264 13
Slew -10785 13
Slew -10917 13
```

```
Slew -10654 13
Slew -10006 13
Slew -8996 13
Slew -7662 13
Slew -6050 13
Slew -4220 13
Slew -2237 13
Slew -173 13
repeat
end
```

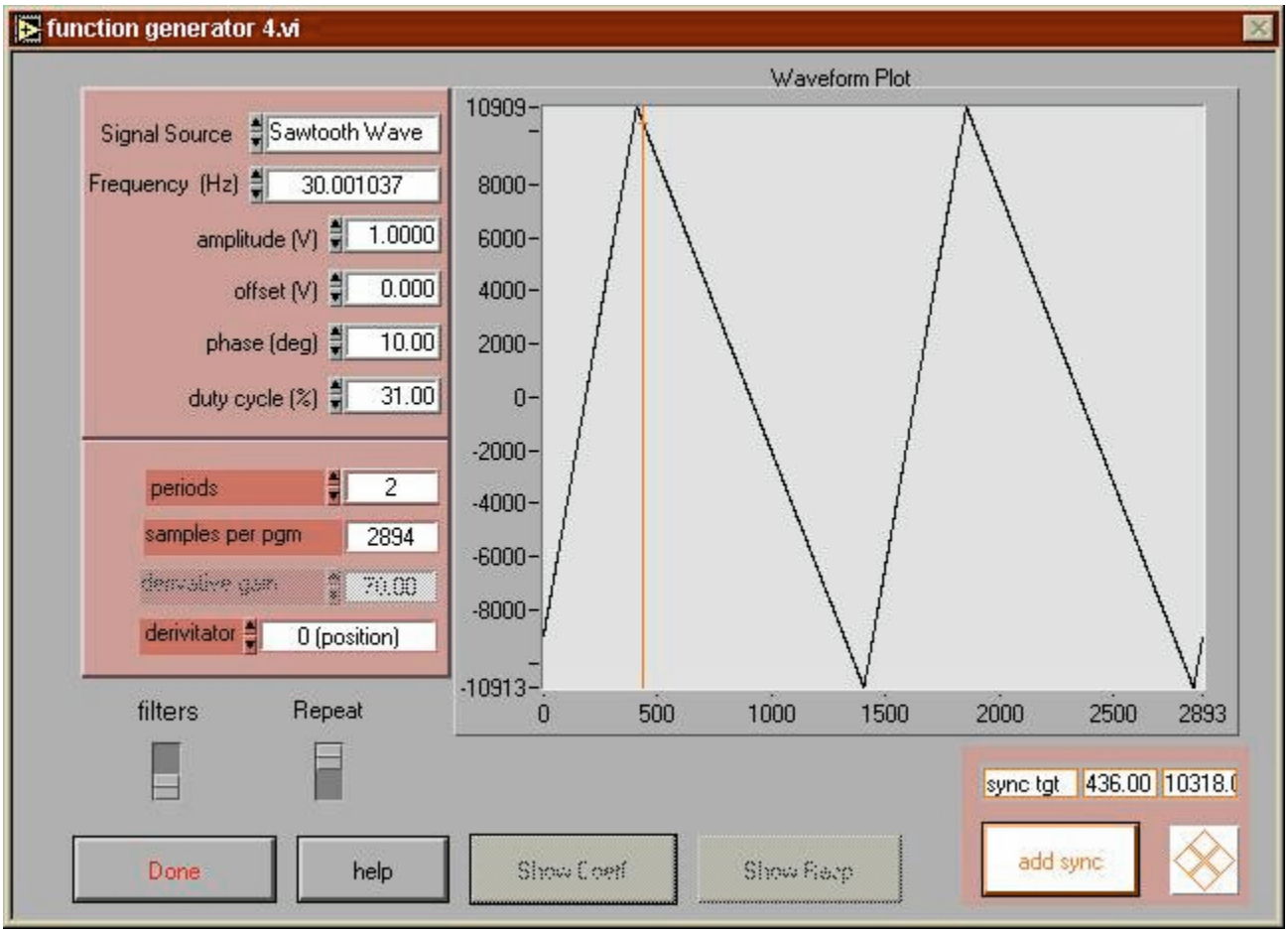

Figure 27 Load wave window

Tutorial: Writing Scan Controller programs

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Date: 06-02-99

Introduction.

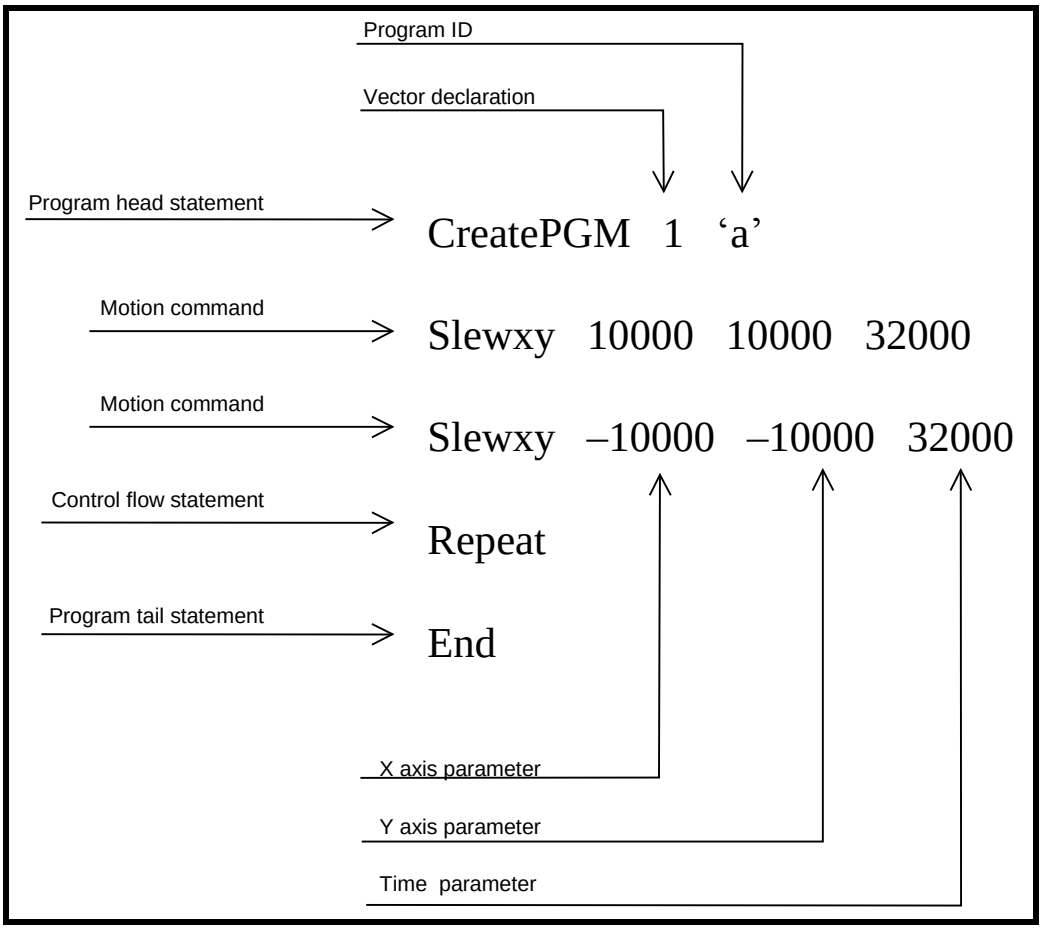
The GSI Lumonics Scan Controller accepts a motion program language that consists of a binary machine language. Scan Controller assemblers and assembler components are provided by GSI Lumonics to allow the motion application developer to use English language commands for controlling single axis, dual single axis and dual axis motions as well as interactive control of the Scan Controller. The full range of motion control expression native to the binary machine language is available through the use of the SC2000 assembly language. This document is a tutorial and application note to help the motion application developer understand and use the SC2000 assembly language in conjunction with a Scan Controller assembler.

Quick Start.

Scan Controller programs are typed into a text file with a text editor such as Wordpad (save with text only option).
Expert → It is not possible to enter a Scan Controller program from the Command Line prompt, you must use a file.
There are two basic operating modes in the Scan Controller. Vector mode is used to simultaneously control X and Y axis galvos to produce vector drawing. Raster mode is used to control a select single axis. Vector commands can be distinguished from raster commands by the presence of an 'xy' suffix. For example, 'Slewxy' is a vector command and 'Slew' is a raster command.

The following is a simple vector program that generates a slowly traced 45 degree line:

```
CreatePGM 1 'a'
Slewxy 10000 10000 32000
Slewxy -10000 -10000 32000
Repeat
End
```

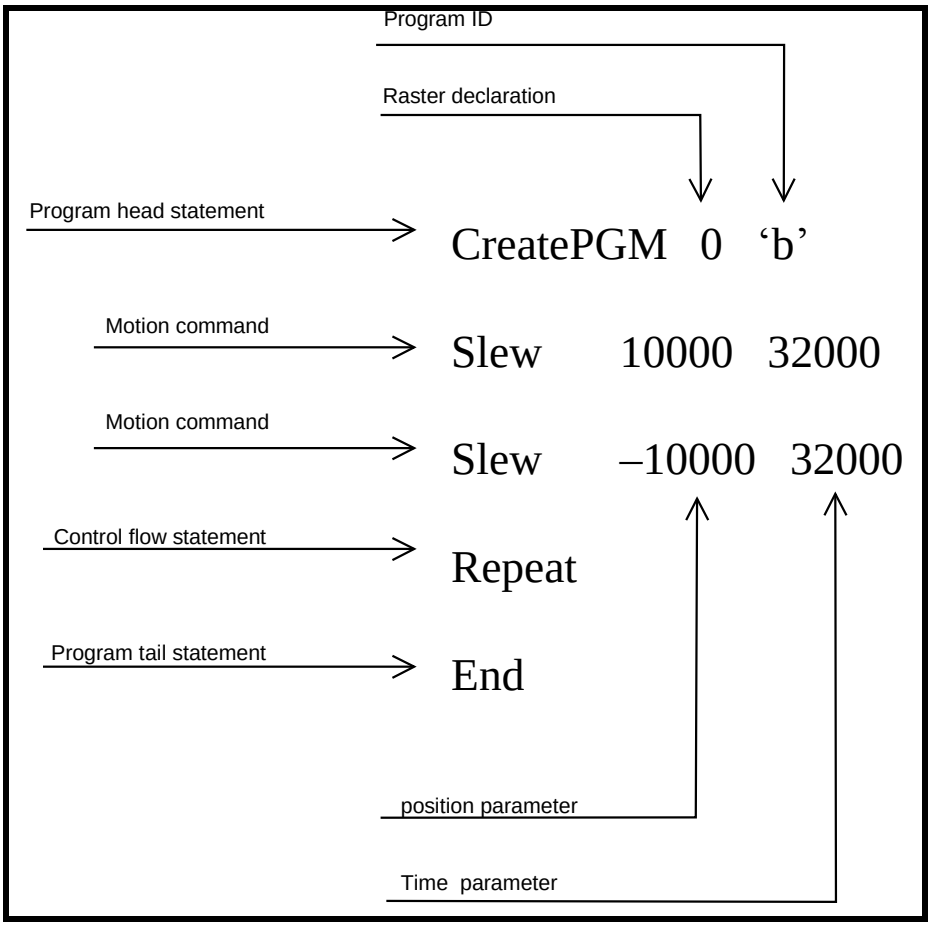


This program can be executed by uploading the program and then entering the following command at the command line:

```
vector
ExecutePGM 'a'
```

The following is a simple raster program that generates a slowly traced horizontal or vertical line:

```
CreatePGM 0 'b'
Slew 10000 32000
Slew –10000 32000
Repeat
End
```



This program can be executed by uploading the program and then entering the following commands at the command line for horizontal motion:

```
Raster 1
ExecutePGM 'b'
```

or for vertical motion:

```
Raster 2
ExecutePGM 'b'
```

Scan Controller language overview.

Keywords fall into six groups:
1. Semantic directives
2. Flow control statements
3. Motion statements
4. Side effect statements
5. Immediate directives
6. Assembler directives

Of the six groups, immediate commands cannot appear in programs and semantic statements cannot be nested.

Vector & Raster
CreatePGM CreateFlashPGM End

Table 2 Semantic directives

Vector & Raster	Vector	Raster
Repeat NRepeat ExecutePGM Wait Waitsync If <sync> ExecutePGM If TempOK <device> ExecutePGM ExitPgm AbortPgm	ExecuteRasterPGM If <sync> ExecuteRasterPGM If TempOK <device> ExecuteRasterPGM WaitPositionXY	WaitPosition

Table 3 Flow Control statements

Vector	Raster
PositionXY SlewXY DeltaPositionXY DeltaSlewXY	Position Slew DeltaPosition DeltaSlew

Table 4 Motion Command statements

(Motion commands are divided into raster and vector commands)

Vector & Raster	Vector	Raster
Setsync Unsetsync DelayedSetSync DelayedUnsetSync Enable Disable ConfigPixelClock ComConfig	DeltaTweakAxisXY TweakAxisXY	DeltaTweakAxis TweakAxis

Table 5 Side effect statements

Directives	Queries
Raster Vector PackMemory ReleasePgm SetConfigVar SetGSS SetXPROffset SetXPRGain SetYPROffset SetYPRGain SetSetSyncDelay SetUnsetSyncDelay SaveConfigInFlash	?FreeFlashSpace ?FreeRAMSpace ?ID ?Position ?Temp ?TempOK ?OpticalCal ?Status ?Sync

Table 6 Immediate directives

(Immediate directives are either commands or queries and cannot be included in programs. They are listed here for completeness.)

Directives
#

Table 7 Assembler Directives

(Assembler directives control the operation of the assembler and do not have any direct translation to the Scan Controller binary language.)

Program Definition.

Semantic statements are directives that cannot be nested in programs. Programs begin with a head statement, either the 'CreatePGM' statement or the 'CreateFlashPGM' statement. The header statement of a program is required. All programs have a tail statement, the 'end' statement. The tail statement of a program is required. In between the head and tail statements a program can contain synchronization and flow control statements and raster or vector motion statements. Note that raster and vector motion commands cannot be mixed in one program. Thusly, a program is declared to be either as raster or vector by the first parameter of the head statement.

```
CreatePGM 0 'r'
statement
.
.
.

statement
end
```

'CreatePGM' and 'CreateFlashPGM' take the same parameters. Parameter-1 is the program type: '0' for raster programs and '1' for vector programs. Parameter-2 is the name or program-ID written in any number format valued from 1 to 255.

The 'end' statement signifies the end of the program identified by program-ID. 'CreatePGM – end' pairs cannot be nested; if the assembler parses a 'CreatePGM' directive before an 'end' directive after encountering an initial 'CreatePGM' directive it will flag an error.

The text that follows the 'end' statement can be either directives or statements; the Scan Controller assembler will assemble commands inside and outside of the 'CreatePGM' mode context and it is up to the communications application to manage coordination of directive, query and program operation of the Scan Controller. Therefore, assembler is capable of assembling single statements from a command line, multiple Scan Controller programs written in a single file or a mixture of Scan Controller programs and immediate directives. For example, the following file, when assembled and uploaded, will define a program and then execute it.

```
# render a box shape
CreatePGM 1 'a'
Slewxy 1000 1000 500
Slewxy -1000 1000 500
Slewxy -1000 -1000 500
Slewxy 1000 -1000 500
Repeat
End

#run the program
ExecutePGM 'a'
```

Program Flow Control

Scan Controller programs run in the standard sequential statement execute style; the statements are executed in order from the first statement to the second, etc. Program flow control statements modify the basic sequential execution of a program thereby providing a richer environment for motion control.

Perhaps the simplest program flow control command is the 'Wait' statement. It takes one parameter, the number of 23µS counts to wait. The 'Wait' statement basically generates a pause in the program at the current position, in either vector or raster mode. When in dual single axis vector mode, a 'Wait' in the program of one axis will not affect the other axis program. Note that the time paused is unconditional, the program will not continue until the wait timer expires. While the 'Wait' command is unconditional, the 'Waitsync' command allows a variable length program pause by stopping the program at the current position until a signal is received on a sync pin. 'Waitsync' takes one parameter, the sync channel number. A read only sync channel (5 - 12) can be wired to an external sensor or button, or a read/write sync channel (1 - 4) can be shared between two programs running dual single axis mode. 'Waitsync' is valid in both vector and raster modes. 'WaitPosition' and 'WaitPositionXY' are used to pause program execution until the galvo reaches the target position. These commands operate in the same manner as Waitsync except that the RMS value of the position readback buffer is used rather than the value of the sync channel. Tolerance of this command to position error can be tuned with the WaitPosition parameter and by adjusting the size of the sample buffer (see SetGSS) .

When an executing program encounters the 'Repeat' command or the 'NRepeat' command, the point of execution returns to the first statement of the program and execution proceeds from there. In the case of 'NRepeat' the program will only repeat as many times as specified by the NRepeat parameter (N times), then it will fall through to subsequent instructions in the program or, if it is the last statement in the program, execution will return to the calling program or the idle mode. Expert → A given program may contain only one 'NRepeat' statement.

Repeating programs can be stopped (actually all programs are stopped) by issuing the 'AbortPGM' or 'ExitPGM' commands from the command line. Programs can also be stopped by creating a 'stopper program' that contains just the 'ExitPGM' or 'AbortPGM' statement. Arrange to have this program run as the result of a conditional test of a sync pin or a temperature signal. When the condition asserts and the point of execution arrives at the conditional statement, all running programs will stop and the Scan Controller will return to immediate command mode. In terms of stopping programs, 'ExitPGM' provides a graceful exit from the program by cancelling the action of all 'repeat' and 'if <sync channel 1,2,3 or 4>' statements. There may be some delay between the time that the ExitPGM command is issued and when the program stops. Issue the ?status command and wait for a response that identifies Exitpgm success (0x000000250000). Expert →sync inputs (channels 5-12), WaitPositionand WaitPositionXY statements are not affected by ExitPgm. 'AbortPGM' terminates the program as soon as possible also disabling the servos. Expert →AbortPgm will disable both SAXes. The choice of these two modes of stopping along with other commands in the 'stopper program' provide a flexible means of stopping programs under various conditions. For example the 'stopper program' can also perform other cleanup operations such as disabling lasers or extinguishing machine vision lighting by controlling these devices from the sync channel pins. Expert → Issuing the 'ExitPGM' command on non-repeating programs has no effect except for 'if <sync channel 1,2,3 or 4>' , so given a program that you wish to stop that contains particularly long slews, the appropriate command for immediate halting is 'AbortPGM' .

The 'ExecutePGM' statement is used to spawn a new program from inside a parent program and could be classified as an unconditional branch statement. 'ExecutePGM' is sensitive to the current operating mode of the Scan Controller. If the controller is operating in Vector mode, only vector programs can be started by the 'ExecutePGM' program statement. Similarly in Raster mode, only new raster programs can be executed, with the additional constraint that execution always occurs on the same axis as that of the parent. Please note also that the Scan Controller has a finite call depth for 'ExecutePGM' .

Somewhat more formalized conditional statements in the SC2000 assembly language are 'If <sync channel> ExecutePGM' and the 'If TempOK <device> ExecutePGM' statements. These are simple 'if' clauses; 'else' clauses are not supported. Expert → The entire program statement must be written on one line. The two flavors of 'if' statements support program spawning from an external signal (sync channels 5 - 12) or internal flag (sync channels 1 - 4)

and program spawning under the control of the axis servo temperature with the TempOK <device> form. Both are available in vector and raster modes.

Forms of previously discussed flow control statements are available (when in vector mode) to begin yet another execution mode called the dual single axis mode. Dual single axis mode will execute two raster programs concurrently, one on the X-axis and one on the Y-axis. The standard program invocation `'ExecuteRasterPGM'` will commence the dual single axis mode from vector mode. The command takes two arguments, Arg-1 is the X-axis program and Arg-2 is the Y-axis program. Similarly, the conditional statements that start the dual single axis mode take X-axis and Y-axis arguments. These commands are `'If <sync channel> ExecuteRasterPGM'` and `'If TempOK <device> ExecuteRasterPGM'`.

Motion Commands

Motion commands exhibit the most thorough symmetry between vector and raster modes of all the command groups. For each vector motion command there is a corresponding raster motion command. The coordinate values of all the absolute motion and positioning commands range from –32768 to +32767 and correspond to voltages on the SAX drive pins, where –32768 ≅ 3.1 Volts, 32767 ≅ -3.1 Volts and 0 ≅ 0.0 Volts. Command values outside of this range will be flagged as errors by the assembler.

In the SC2000 assembly language the fundamental positioning command is the absolute position statement 'PositionXY' for vector and 'Position' for raster. The vector form takes two parameters, the X-coordinate and the Y-coordinate while the raster form takes just one parameter, the coordinate. The position commands will cause the servo control voltage to change very rapidly, in effect "setting" the position of the galvo. This change in position command can happen faster than the servo driver can keep up, so thought must be given towards total system response to large step changes.

Large steps can be programmed in a smoother manner with the slew commands. The absolute positioning slew statement for vector mode is 'SlewXY' and for raster mode it is 'Slew'. The vector slew command takes three parameters, the X-coordinate, the Y-coordinate and the count. X and Y coordinates have the same range as above in the position commands. The count parameter has a value for 1 to 32767 and represents the number of 23 μS ticks that pass while the line is drawn to the new coordinate. The path control voltage during a slew is a linear ramp from the current position to the new absolute position over the course of <count> ticks. In raster mode this is just a simple smooth ramp. In vector mode, two concurrent ramps are generated, possibly different in slope, start point and end point, the only common factor being the time it takes to complete each ramp.

Tick counts	Time (seconds)
433	0.0100163725
4323	0.1000017975
21615	0.500017975
43230	1.000017975
65535	1.515988
[2]155625203	3600.0000084
[1]4294967296	99353.33097

Table 8: Tick count vs. time

The positioning commands described above operate in the absolute coordinate system of –32768 to +32767 for X and Y axis. Another set of SC2000 commands operate using relative coordinates. In vector mode these statements are 'DeltaPositionXY' and 'DeltaSlewXY' and in raster mode they are 'DeltaPosition' and 'DeltaSlew'. Again, the vector deltaposition command takes two parameters, the X-axis parameter and the Y-axis parameter but instead of indicating the target coordinates absolutely, the parameters indicate an offset relative to the current position (here current position is the last commanded position value, not the reading of the position detector.) Limits for the offset value are the same as for the position commands, -32768 to +32767. The count parameter specifies the number of ticks to pass for the motion to complete.

[1,2] 32 bit count for 'wait' statement

Side Effect Statements

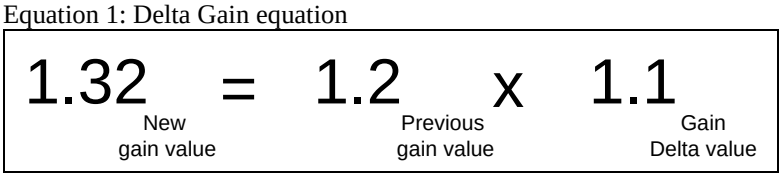
Side effect statements are used to control devices or channels in ways that do not involve motion control of the galvo. Certain commands operate with zero cycle overhead, making it possible after fully specifying a motion program with slew and position statements, to insert side effect statements for the purpose of control and synchronization without affecting the validity of the independently developed motion program.

The most fundamental side effect statements are 'enable' and 'disable', which are used to enable and disable the SAX servo boards. 'enable' and 'disable' each take a single parameter, the device specification. 1 is the X-axis, 2 is the Y axis and 3 specifies both axis for simultaneous enable or disable both SAXes at the same time. It is important to note that SAX modules must be enabled before they can servo command voltages. Enable and disable can be issued from inside a program making it possible to operate SAX boards according to conditions detected at the temperature or sync pin inputs as well as at the beginning and end of a program.

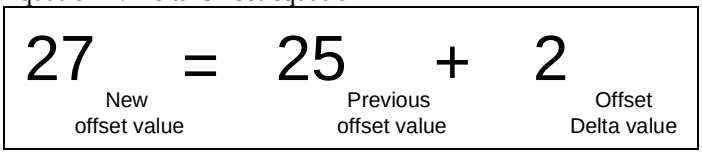
'SetSync' and 'UnsetSync' operate on the first four sync channels. These four are different from the other eight sync channels in that they can be both written to and read out. Each command takes one argument, the sync channel specification, valued from 1 to 4. The hardware pins corresponding to the sync channel are located in J4. Channel 1 operates pin 1, channel 2 operates pin 2, etc. The 'SetSync' command turns on an open drain MOSFET causing the J4 pin to sink current through to J4 pin 5. 'UnsetSync' turns the open drain MOSFET off leaving the pin in a high impedance state with respect to pin 5. The read operation for these sync channels references the 'internal output port mirror register', not the logic level present on the pin. 'SetSync' and 'UnsetSync' can also be used internally by programs providing a simple flag mechanism that two programs can use for communication when running in dual single axis mode. In this manner of operation, no external connection is required. Two related commands are 'DelayedSetSync' and 'DelayedUnsetSync' and their action is exactly the same as 'SetSync' and 'UnsetSync' except that the transistor action occurs some number of ticks after the command is executed in the program. The delay is specified in a global configuration variable, typically set to compensate for Codec and servo delays.

'DeltaTweakAxisXY', 'DeltaTweakAxis', 'TweakAxisXY' and 'TweakAxis' are used to adjust the gain and offset correction factors on the fly. 'DeltaTweakAxis' and 'TweakAxis' are used in raster mode and 'DeltaTweakAxisXY' and 'TweakAxisXY' are used in vector mode. The 'DeltaTweakAxis' commands take two kinds of parameters, gain and offset, which are processed as deltas or incrementals of the current correction values. The gain parameter is a floating-point value ranging between 0.5 and 1.5. This gain delta is multiplied by the current gain value to produce the new gain value (the power-on default gain value is 1.0, see Equation 1.) The offset incremental, a positive or negative integer, is added to the current offset value, the result being stored as the offset correction, effectively relocating the origin by the incremental value (see Equation 2).

Equation 1: Delta Gain equation



Equation 2: Delta Offset equation



The 'TweakAxis' and 'TweakAxisXY' commands take the same kinds of parameters as those above but instead of being deltas they are the actual gain or offset value and the action of the command is just to set the gain and offset to the given values. These commands can be either program statements or immediate directives and care should be taken to

understand the operational context in which these commands are executed. Typically, 'TweakAxis' and 'DeltaTweakAxis' can only be instructions in a raster program or can only be entered when a raster program is running. Similarly, 'TweakAxisXY' and 'DeltaTweakAxisXY' can only run in the vector context. Of special interest is the Dual Single Axis mode initiated by the 'ExecuteRasterPGM' command. From the outside, this mode is the same as vector mode, and you should enter 'TweakAxisXY' or 'DeltaTweakAxisXY' as a concurrent immediate directive. From the inside (in the context of the running programs) the Scan Controller is in raster mode and the statements 'TweakAxis' or 'DeltaTweakAxis' should be used in programs.

The '?Position' command will readback the current position of the galvo as reported by the galvo's position sensor. This reading has a two point calibration associated with it making it possible to calibrate the readback value of the galvo to the commanded position. Calibration values are entered with the commands 'SetXPROffset', 'SetXPRGain', 'SetYPROffset', and 'SetYPRGain' and the values relate the readback value to the raw position sensor reading with the following formula: $PRead_{axis} = PRGain_{axis} \times PRaw_{axis} + PROffset_{axis}$. Calibration values as entered with these commands are in volatile memory. Calibration values can be stored in non-volatile memory by using the command 'SaveConfigInFlash' and when the Scan Controller is power-cycled, the saved configuration values will be automatically loaded. Subsequent execution of the commands 'SetXPROffset', 'SetXPRGain', 'SetYPROffset' and 'SetYPRGain' will adjust the current calibration values, but unless the 'SaveConfigInFlash' command is executed, the updated calibration values will be lost when the Scan Controller is power cycled, and the values restored upon power-cycle will be the values stored in flash.

The command 'SetGSS' adjusts size of the 'WaitPosition' sample buffer for both the X and Y axis. This size can be any value from 1 to 100. It is saved to flash at the same time as the above parameters by using the 'SaveConfigInFlash' command and modification of the run-time value is the same as above. The Global Sample Size determines the number of position values used in the RMS computation of error from target. In the time domain the Global Sample Size determines the size of a sliding window that holds a finite position readback history.

Two additional configuration variables stored into Flash memory by the 'SaveConfigInFlash' command are the tick delay values stored by the 'SetSetSyncDelay' and 'SetUnsetSyncDelay' commands. These delay values are used by the commands 'DelayedSetSync' and 'DelayedUnsetSync'. There are separate global delays for the Set and Unset versions; each 'DelayedSetSync' command in a program has the same delay, but this can be different from the 'DelayedUnsetSync' delay. Expert → If the delay time is longer than the total tick count of a short, repeating program, a stack overflow error will result. Expert → The delayed signal will continue to operate after a program has completed.

Immediate Directives

Immediate directives are commands and queries that cannot be executed from within a program and will not be covered as a group in this section. Certain commands are of special interest, however. `'Raster'` and `'Vector'` are the statments used to set the operating mode. `'Vector'` is used to set the operating mode for vector programs and dual single axis programs. `'Raster'` takes one parameter, the axis specifier, and causes all programs declared as raster and all raster commands to be executed on the specified axis. Note that the operating mode of the Scan Controller is checked by the firmware before executing a command or program. If the operating mode, raster or vector, does not match the command type, an error will be raised and all further commands will be ignored. This error must be cleared by the ?status command. Finally, `'ReleasePGM'` is used to remove a program from memory and takes one parameter, the program name. The Scan Controller needs to be power cycled before memory can be reclaimed from the non-volatile memory. Programs that have been released but that reside in SRAM memory can be removed and space reclaimed by using the `'PackMemory'` statement.

Assembler Directives

The only assembler directive is the comment character `'#'`. Lines can begin with a comment or a comment can appear on the right side of a program statement. For example, both lines below contain comments.

```
# this is a comment line
slewxy 3000 3000 5000  # move across the diagonal
```

Comments are stripped out of the source code before assembly.

Glossary

Absolute Position: A location definition offset from the origin (0,0).

Character Number: ASCII characters are byte-sized numbers in the range of 30 – 127. They are written as a single printable character inside single quotes. For example, a program named '5' is equivalent to a program-ID of 53.

Comment: The comment character, '#' causes everything from the '#' to the end of the line to be ignored by the assembler. Comments can appear on their own line or on the same line as a program statement.

Command: The Scan Controller accepts a binary command language. Commands have variable length and typically consist of a 1 byte command prefix and zero or more 2 byte parameter values. The Scan Controller binary command interface is fully documented in the section 'Command Reference'.

Decimal Number: Decimal numbers are written as normal numbers and can be positive or negative. For example, 30000, -250 and +4500 are all decimal numbers. Note that decimal numbers cannot contain commas or decimal points and if there is a sign, there can be no space between the sign and the number.

Device: The axis of voltage control are called devices. Numbers are used to identify the axis where 1 is the X-axis, 2 is the Y-axis and 3 is both axis as a group.

Directive: A statement that changes the operational mode of the Scan Controller.

Floating point number: Floating point numbers are written in decimal notation. They can have an optional leading sign. If the number is less than +/- 1, the number must have a leading zero. For example, the value '.5' must be written '0.5'. Windows users who have enabled European local may use the ',' character as the ones separator.

Hexadecimal number: A number written in the 'c' syntax 0xFFFF. In the example 0x1234, '4' is the least significant digit (ones), '3' is next least significant (16s), '1' is the most significant (65536s). Hexadecimal numbers are typically used for program names and for representation of raw binary data.

Number Format: Numbers are written as character, decimal, floating point, hexadecimal or octal.

Octal Number: Octal numbers are written using the '\0' prefix. For example, \0177 is equivalent to 127.

Parameter: An argument for a function. Parameters appear after the keyword and are separated by spaces.

Raster: A mode of Scan Controller operation where a motion command operates on a single axis.

Relative Position: A location definition offset from the current location.

Statement: Part of a program written in the SC2000 assembly language, a statement consists of a keyword and any required parameters. There can be zero or one statements per line in a program file.

Tick Count: The heartbeat of the Scan Controller motion command system. There are 23.1325 μS between each tick count or about 43,475 ticks per second.

Vector: A mode of Scan Controller operation where a motion command operates on both axis.

Special System Topics

Contact Information

The SC2000 Scan Controller, a product of GSI Lumonics Component Group

- *Address……*.500 Arsenal St, Watertown, MA 02472-2806
- *Phone……*.(617) 924-1010 Ext.182 (Applications HotLine)
- *World Wide Web……*...http://www.gsilumonics.com

Flash upgrade procedure for Scan Controller firmware.

The GSI Scan Controller firmware is field upgradable. Distributions of new firmware are made with a file in one of two formats:

1. hex file format, denoted as a filename with a .hex extension.
2. binary file format, denoted as a filename with a .bin extension.

The firmware field upgrade procedure is as follows:

1. Connect the Scan Controller to a computer which is running the CLI.EXE General Scanning command line interface program.
2. Transfer the firmware upgrade file to the local hard drive.
3. Power up the Scan Controller and verify communications, optionally set baud rate to maximum.
4. Insure that no programs are running on the Scan Controller (especially the default power-on program).
5. Invoke Scan Controller file transfer by pressing the 'file ops' button.
6. Set file transfer destination to 'Scan Controller', set file transfer source to either 'ASCII Hex' or 'binary program' depending upon the file extension of your firmware upgrade file.
7. Press 'Done', a file dialog appears. Navigate to the upgrade file, select it and press OK.
8. For ASCII Hex, press ‘DONE’ at the stream editor (please make no changes)
9. The upgrade process now proceeds, transfer progress is reported in the Response Window.
10. The upgrade is complete when the 'Ready' signal turns from Red to Green.
11. Power cycle the Scan Controller, if the baud rate was set to a value other than 2400 baud, please reset to 2400 baud, and establish communications. Verify that firmware was correctly upgraded by issuing the **?id** command. The **?id** should report back the expected firmware version if the upgrade was a success. If the firmware version is 0.0 then the boot code is responding and the download will have to be attempted again, now only at 2400 Baud.

Command Timing / System Latency Issues

The Scan Controller is intended to provide low jitter delivery of an output waveform, with predictable timing. Delays of the same order as the fixed delay through the galvo are encountered in the Scan Controller, and must be taken into account during system design.

The most significant delays occur between the time when an instruction is evaluated, and when an actual voltage value emerges from the output of the DAC. This delay is due to a number of factors, dominated by the anti-imaging filters in the DAC. Compared with this, other delays, for instance between when an instruction is evaluated and when a Sync pin changes state, are negligible. Figure 28 shows this delay as 315µs, in response to PGM ‘a’, whose listing follows the figure. Note that the `setsync 13` instruction and the `PositionXY -320 -320` instruction are evaluated simultaneously by the DSP – the sync command shows up at the output pin virtually instantaneously, but the position command takes 315µs before it appears at the command input to the SAX. Note that there will be further delays, of this same order of magnitude, between when the command is seen by the SAX and when the mirror has actually moved into position – each system will need to be evaluated and the appropriate delays taken into account. Figure 29 shows the

system behavior in response to PGM ‘c’, whose listing also follows the figure. By inserting a `'Wait 12'` command delaying the ‘`Setsync`’ relative to the ‘`PositionXY`’ command the two are synchronized.

Another significant delay exists in the AtoD chain, which allows the Scan Controller to read the position detector of the galvo. This delay is somewhat longer than the DAC delay – about 400µs – and has to be taken into account especially in deriving system calibration numbers, discussed below in the section Calibration Registers.

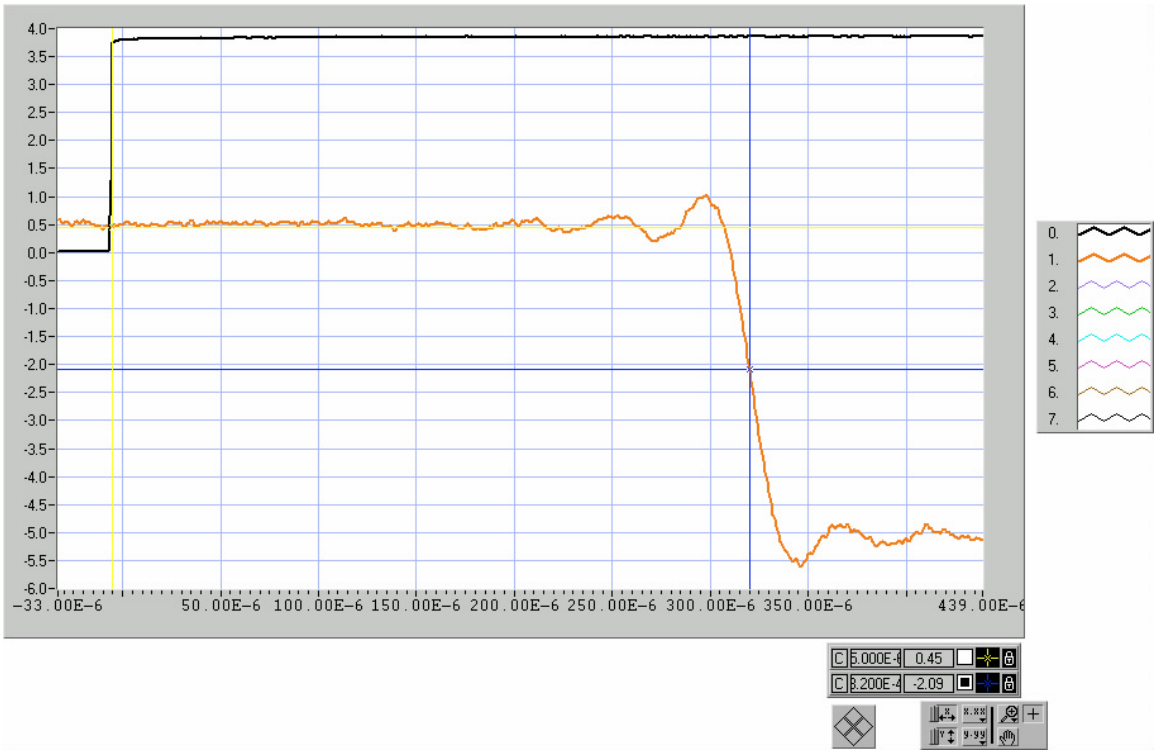


Figure 28 Example of D to A vs Sync delay

```
CreatePGM 1 'a'
setsync 13
PositionXY -320 -320
Wait 2000
UnSetSync 13
PositionXY 320 320
Wait 2000
repeat
end
```

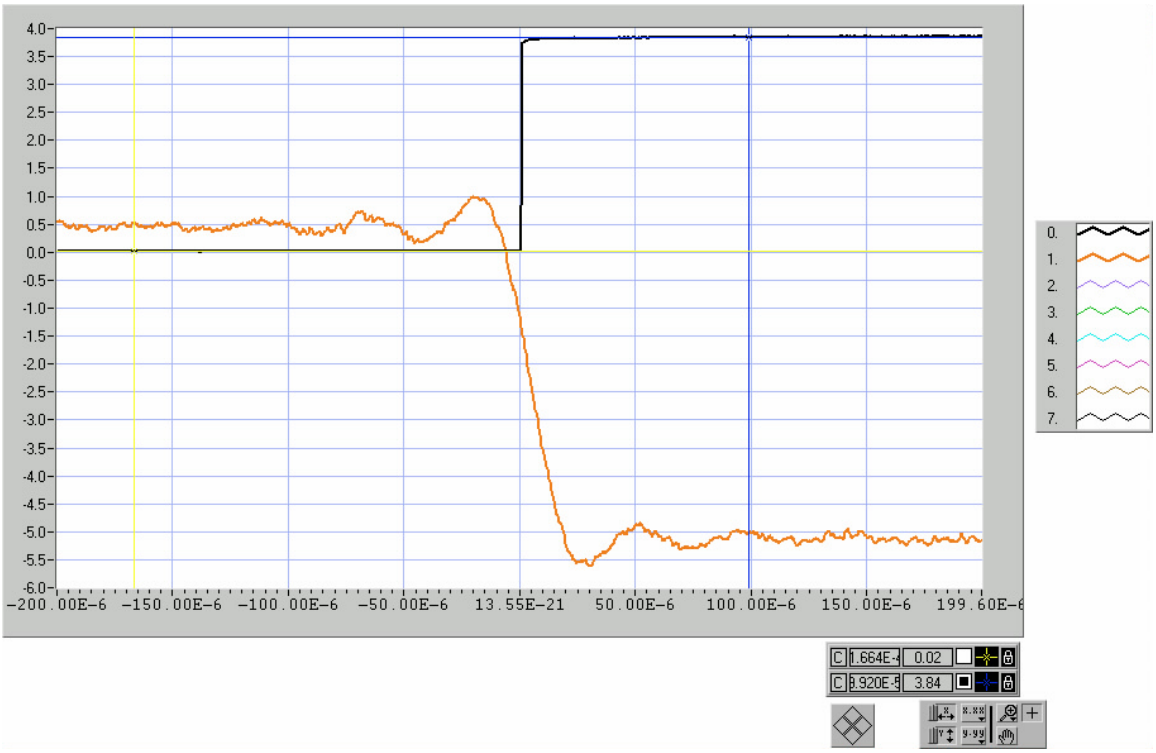


Figure 29 Example of compensated D to A vs Sync delay

CreatePGM 1 'c'

```
PositionXY -320 -320
Wait 12
setsync 13
Wait 2000
PositionXY 320 320
Wait 12
UnSetSync 13
Wait 2000
repeat
end
```

The SC2000 command set includes commands tailored to handle the latency inherent in the Codec and in the servo and positioning galvos. These commands fall under the category of side effect commands are named DelayedSetSync and DelayedUnsetSync. The action of these commands in similar to SetSync and UnsetSync in that they control the state of the sync output channels 1-4, 13 and 14; except that the electrical output action of the command is postponed some number of tick counts from time of execution in the motion control program. The commands provide the abstraction of writing a program based soley upon the ideal control voltage timeline; sync signals for laser control can be inserted where appropriate based upon program specified mirror position while adjustable delays take care of the real-world latencies of the positioning system at run-time.

Pixel Clock

The pixel clock system in the Scan Controller allows users to easily generate a wide variety of periodic timing signals synchronized with the galvo scan signal. The pixel clock can operate in one of two modes – 'time based' and 'position based'. Time-based operation is much simpler, and will be explained first. Both of these modes use a National Semiconductor programmable clock generator – the CGS410 – to generate the clock signal. The resulting signal is then gated in the Scan Controller with the '`Setsync 14`' and '`Unsetsync 14`' commands, and output to J4 pin 14 for external use. Note that all of the Sync vs DAC delay issues discussed in the Command Timing / System Latency Issues section apply here.

The time-based pixel clock simply uses the Scan Controller's 33.33MHz main system clock as the reference input to the CGS410. The CGS410 is then programmed to output the appropriate output frequency. Programming of the device is done through the Scan Controller command '`ConfigPixelClock`'. This is discussed below. A block diagram of the CGS410 is shown in Figure 30. In this way, any output frequency which is a rational multiple of the clock frequency can be realized. Note that the system 'tick' frequency is equal to $33.34MHz/768$ - these numbers become important when trying to configure pixel clocks whose frequency is an exact multiple of the scan frequency (a necessary constraint if the pixels are to remain fixed with respect to the scan waveform).

$$F_{out} = 33.34MHz \frac{N}{R * P * L}$$

Equation 3

The local oscillator of the CGS410 should be run in the region between 65 and 135MHz. Its frequency is given by Equation 4:

$$F_{Lo} = 33.34MHz \frac{N}{R}$$

Equation 4

$$F_{tick} = 100e6 / (384 \times 2 \times 3)$$

Equation 5: Formula for 23 uS tick count frequency

$$M / (384 \times 2) = N / (R \times P \times L)$$

Equation 6:Let pixel clock be a multiple M of the tick count

$$M = (N \times 384 \times 2) / (R \times P \times L)$$

Equation 7: Rational relationship of pixel clock to tick frequency

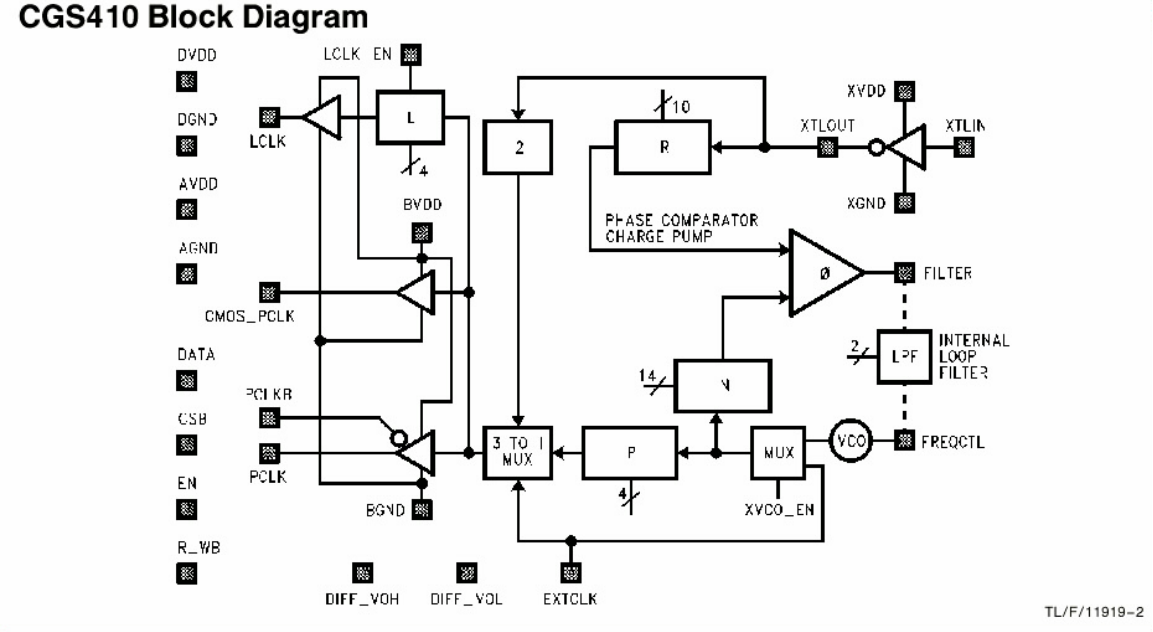


Figure 30 CGS410 block diagram

Invoking the command '`ConfigPixelClock`' at the command line interface brings up the window shown in Figure 31. For a detailed explanation of all these functions please review the CGS410 documentation, available from National Semiconductor's website. This screen shows the proper switch settings for a typical time-based pixel clock application (resulting in a 260.47 kHz pixel clock frequency). The settings are sent to the Scan Controller, and the clock is programmed when the **Done** button is pressed.

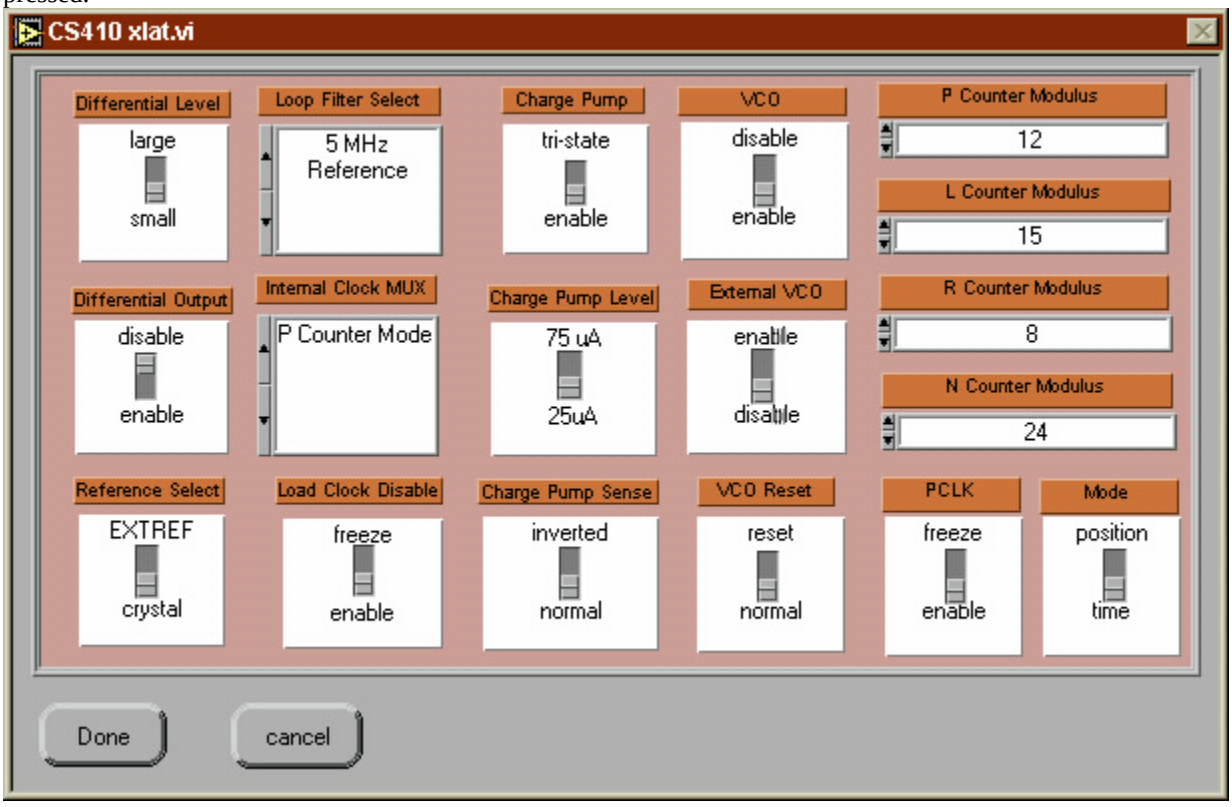


Figure 31 ConfigPixelClock configuration screen

The ‘position based’ pixel clock is considerably more versatile, and more complicated. Instead of using the fixed system clock as the time reference to the CGS410, this allows the user to synthesize a clock by comparing the command voltage from the ‘Y’ axis to the voltage coming into the ‘X’ axis position feedback port. *These features are generally available only to single axis systems – the second axis is use to encode information for the pixel clock operation*. This allows the pixel clock to perform a number of additional functions:

1. It allows the pixels to maintain a constant position in spite of small errors in scanner response
2. It can also, by encoding the proper information in the Y channel program, allow pixel clock operation with sinusoidal velocity profiles (useful for resonant scanner operation).

ConfigPixelClock commands can be used in programs to change the pixel clock parameters on the fly or to initialize the pixel clock from the default power-on program. Parameters for the ConfigPixelClock command consist of 6 numbers, typically in hexadecimal format. It is possible to use the GSI Lumonics Command Line Interface to generate the six parameters as hexadecimal numbers by invoking the Pixel Clock command window from the config menu. After the appropriate settings are mad, press ‘done’. At this point, a binary command is sent to the Scan Controller that configures the pixel clock to the required settings, and these settings can be immediately verified. Once the command binary has been sent, a hexadecimal version of the command will appear in the ‘Command Byte String’ window (see Figure 15). This hex string and be copied and pasted into the program file, after which it is modified by removing the first two hex characters and then preceding the remaining hex character pairs with ‘0x’, in order to write the parameters as 6 hexadecimal bytes in a form acceptable to the assembler.

More details on the operation of the position based pixel clock will show up in this space soon…

Calibration Registers

As described in the Command Reference section for the command '?OpticalCal' rising edges input to the Sync 9 – 12 inputs (J4 pins 10-13) will cause the instantaneous values of a number of system variables to be latched to the calibration registers. These can then be downloaded to the host upon issuing the '?OpticalCal' command, and processed to yield new values of system calibration parameters. The stored system variables are as follows:

X-Axis Output Pos	Y-Axis Output Pos	X-Axis Read Pos	Y-Axis Read Pos	X-Axis System Gain	X-Axis System Offset	Y-Axis System Gain	Y-Axis System Offset

The system latency issues discussed in the Command Timing / System Latency Issues section apply here as well. Figure 32 shows the issues associated with this latency (for one axis). Assuming the system is commanded to a constant angular velocity by the Command Stream, the DAC output will follow with its characteristic delay (315µs), the galvo/servo system will exhibit an additional delay (of the same order, a function of load and tuning). Finally, the AtoD follows with its delay (roughly 400µs). At time t_o, a cal pulse is received resulting in the instantaneous system state (command and position, represented by ● in Figure 32, and the instantaneous values of the system gain and offset parameters) being captured. This data, together with a knowledge of the commanded velocity and delay times will enable the user to establish the precise position of the calibration sensor in the field of view, and derive appropriate correction factors.

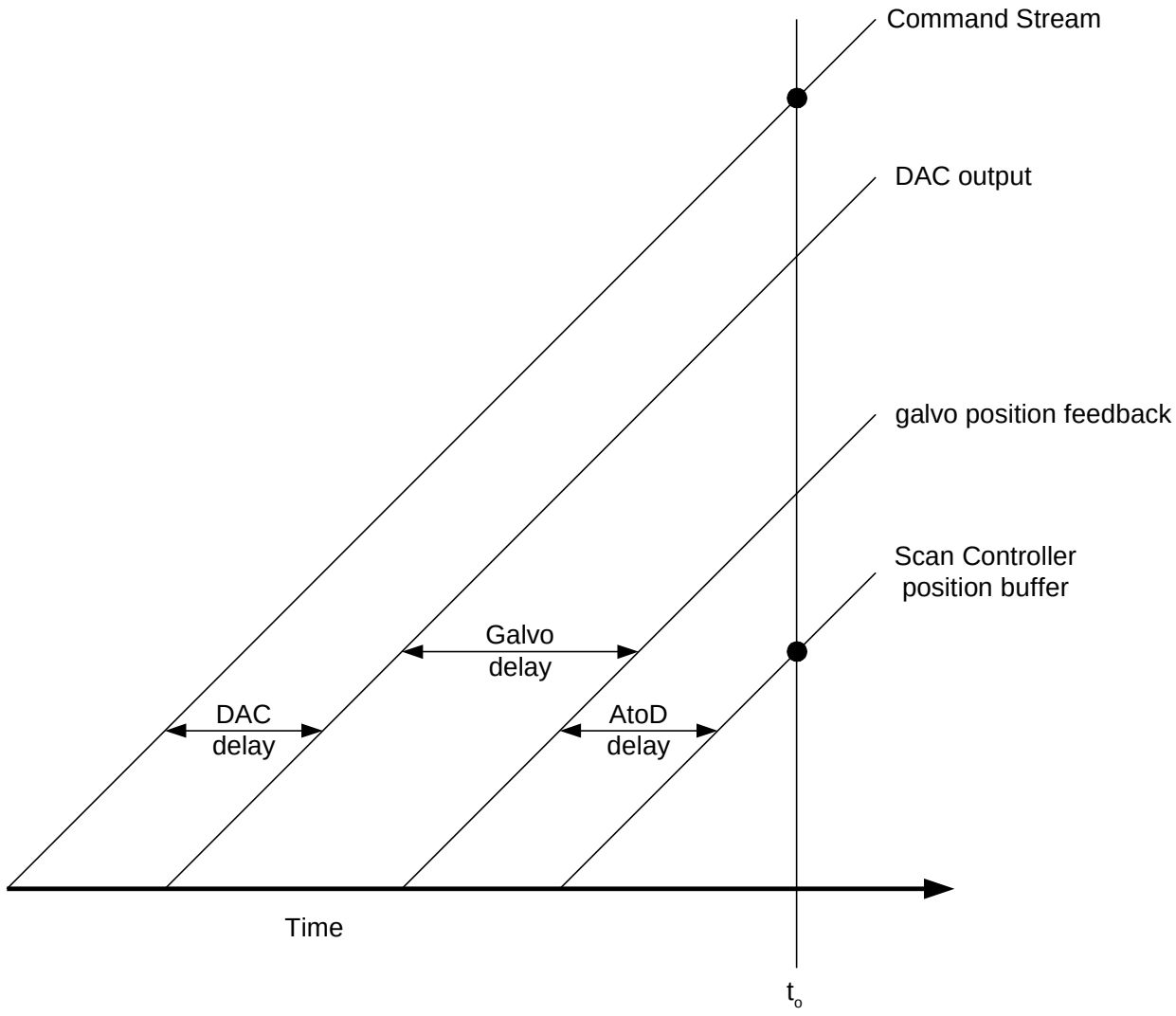


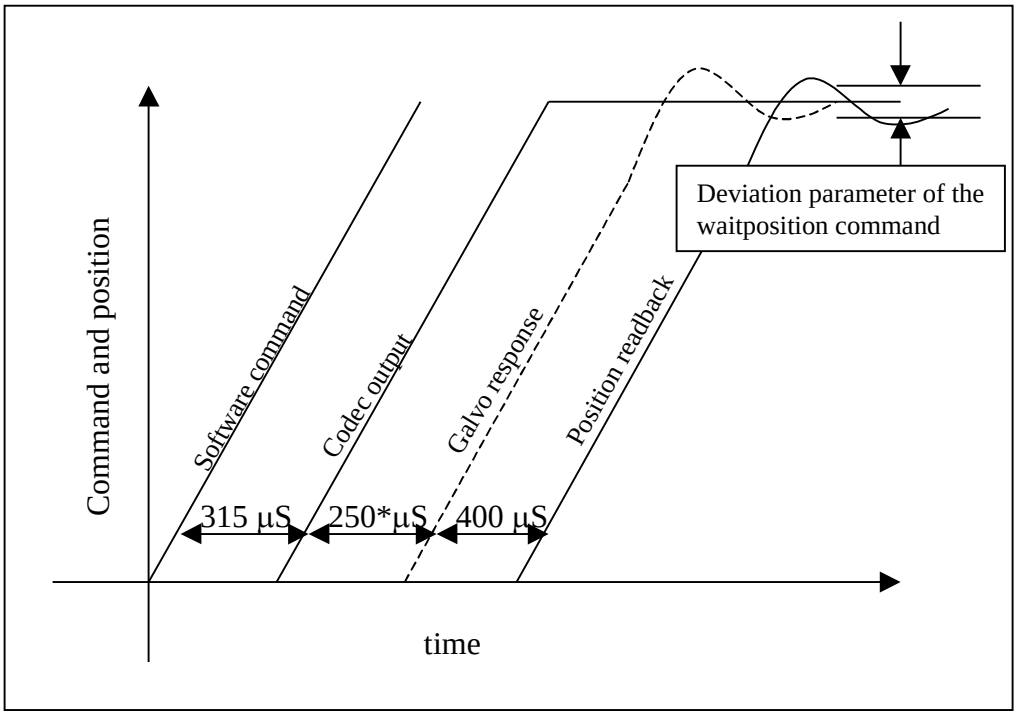
Figure 32 Timing of sync pulse

D to A and A to D Issues

The latency of the Codec and the total response of the galvo positioning system and tune come into play when using the `waitposition` and `waitpositionxy` commands. `Waitposition` will typically take one parameter, deviation, the allowable RMS deviation of the the position signal over an interval. The exact formula used to computer deviation is

$$dev_{RMS} = \sqrt{\sum_{1}^{n}\left(Pos_{T\arg et} - Pos_{n}\right)^{2}/n}$$

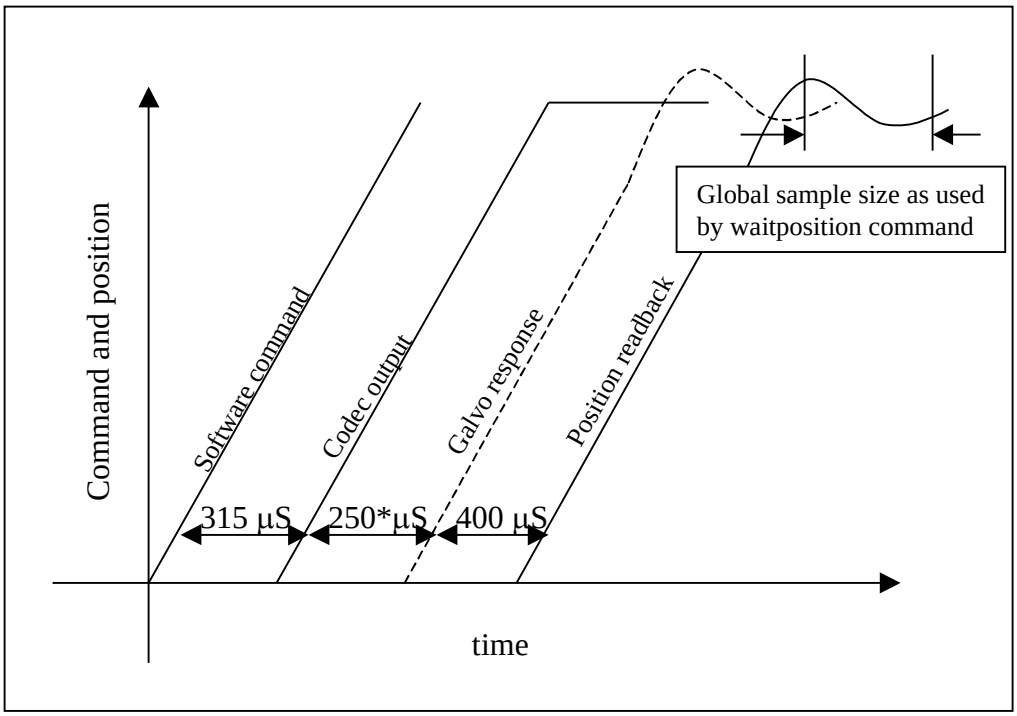
where dev_{RMS} is a parameter of `waitposition` and `waitpositionxy` and 'n' is the global sample size.



*dependent on servo characteristics

Figure 33

As shown in Figure 33 the deviation defines an interval about the final position of the galvo.



*dependent on servo characteristics

Figure 34

As shown in Figure 34 the Global Sample Size defines the number of ticks over which the RMS value of the deviate is computed.

RasterMaster explained

Raster Draw / Load Wave is explained in the section 'Operating the Scan Controller' on page 35. When the signal source is set to **rastermaster** a set of utilities is invoked which is useful in designing structured ramp waveforms, often used in scanning applications. A ramp waveform is used as the basis for this, and passed through a set of filters before being displayed. These filters are controlled from the filter window which pops up, as shown in Figure 35. There are five Bessel filters in series, with types low-pass, high-pass, band-pass and band-reject. Note that these are recursive digital filters, and can be unstable with some combinations of input parameters. Also note that the cutoff frequencies are constrained to be below the Nyquist limit, which is set not just by the 43.4 kHz tick rate, but by the real sample rate (i.e. if ticks per sample is 2, the effective sample rate is 21.7 kHz). Figure 37 shows the function generator window with a typical raster waveform, and Figure 38 shows the corresponding velocity waveform.

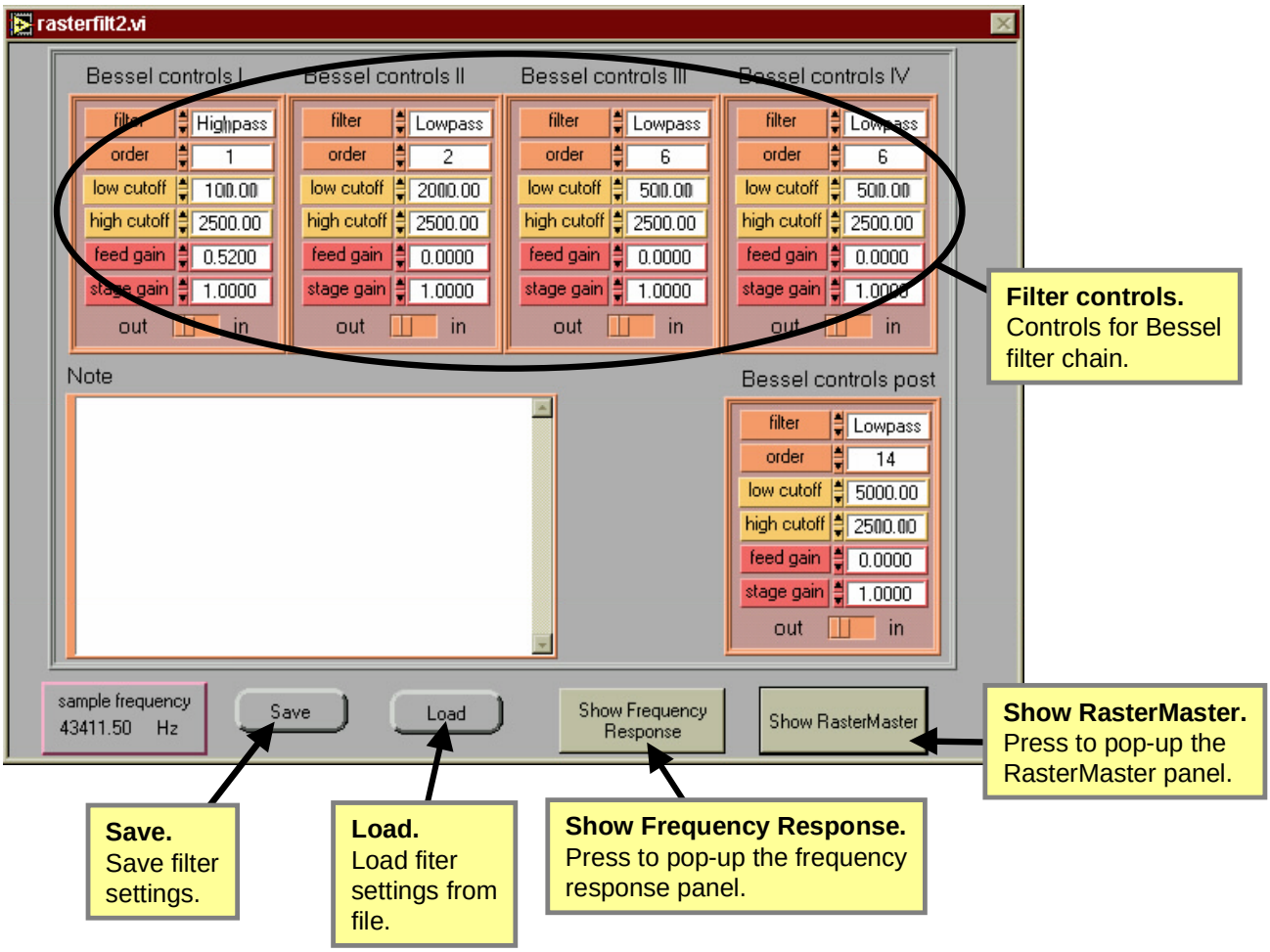


Figure 35 Raster filter window

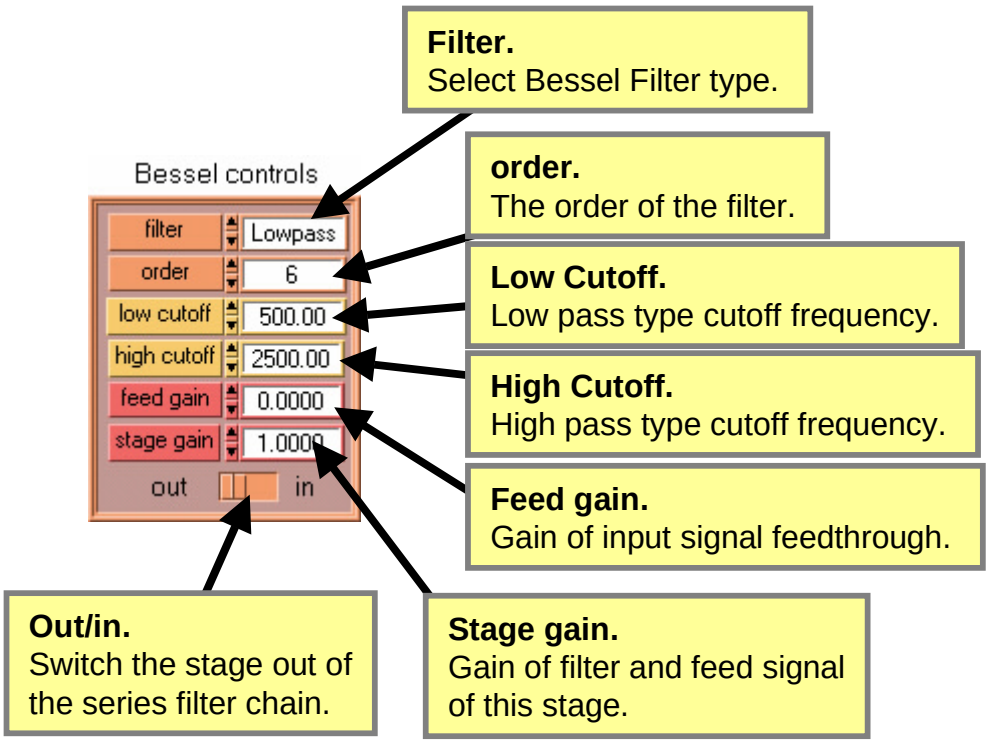


Figure 36 Closeup of filter stage controls

As shown in Figure 36, a filter block control section consists of seven controls. **Out/in** simply switches the filter block in or out of the series path. **Filter** provides a way to select the type of filter: one of low-pass, high-pass, band-pass or band-reject. **Low cutoff** is used to adjust the cutoff frequency of the low-pass filter and the low cutoff frequency of the band-pass and band-reject filters. **High cutoff** is used to adjust the cutoff frequency of the high-pass filter and the high cutoff frequency of the band-pass and band-reject filters. **Order** sets the order of the filter, typically 1 through 50. **Feed gain** is used to add unfiltered input signal to the output of the stage. **Stage gain** is used to adjust the overall output level of the stage.

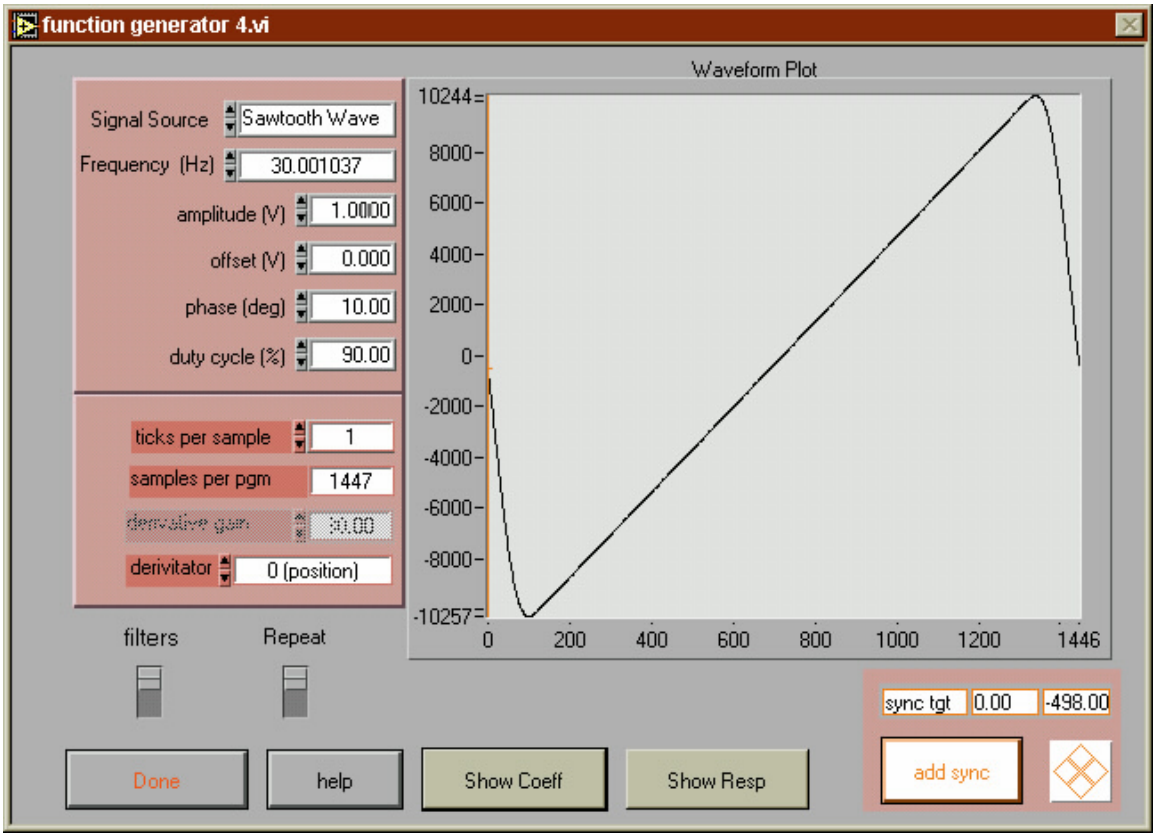


Figure 37 Typical rastermaster wave-form

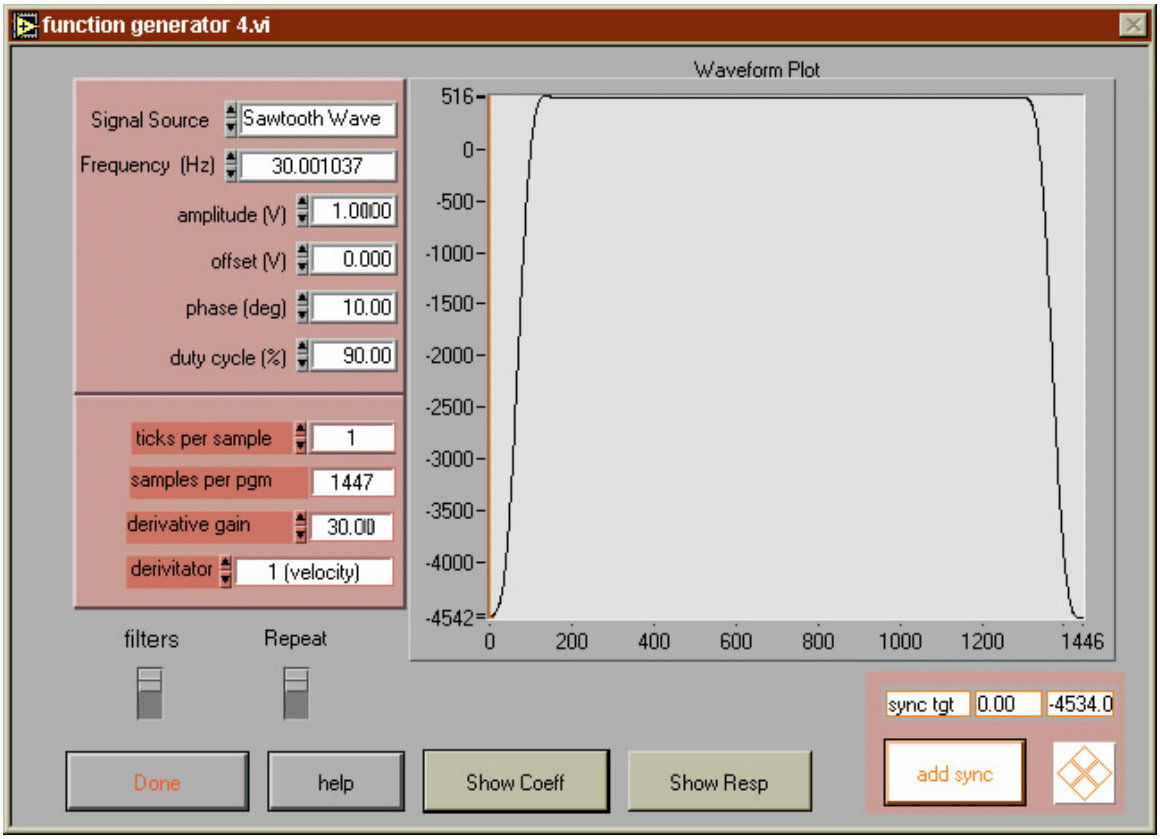


Figure 38 rastermaster displaying velocity waveform

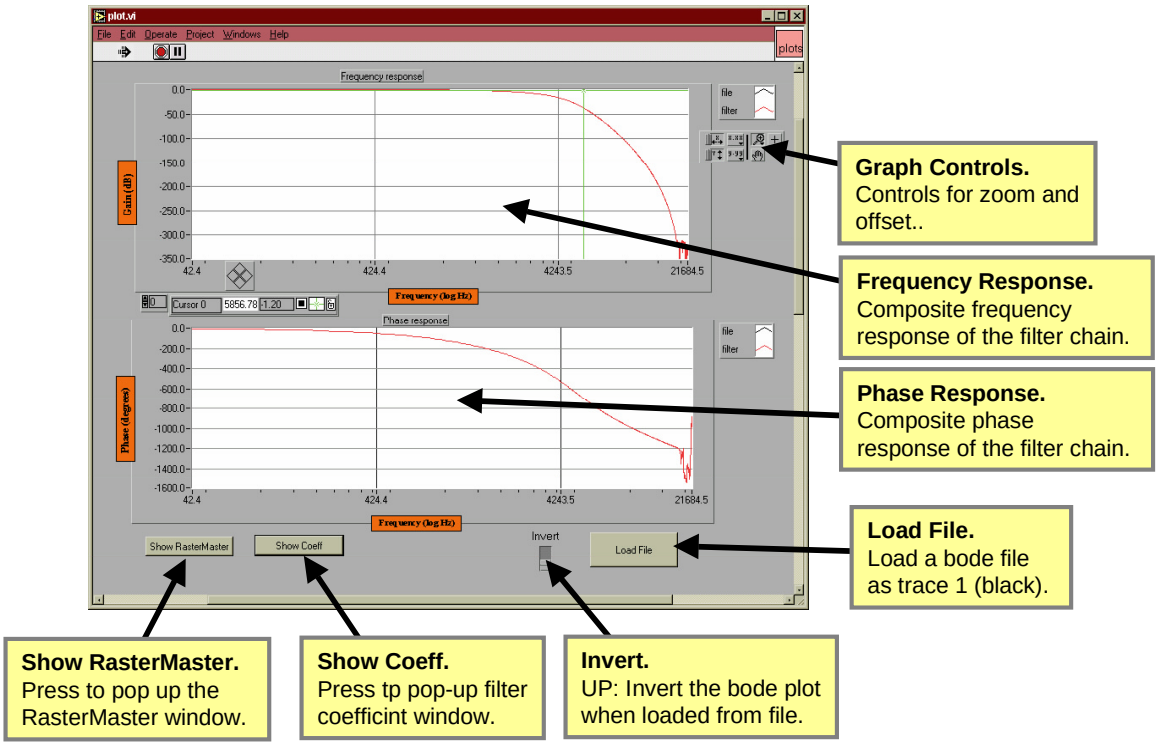


Figure 39 Filter Response Window

Command Reference

Scope

This command reference refers to:

SC2000 firmware Version 1.2
CLI.EXE Version 1.2
GSI Lumonics SC2000 LabVIEW Driver Library Version 1.2
Active X Motion Assembler Component Version 0.07.0011

Statements

Statements are composed of one command and a variable number of parameters. There are no optional parameters for Scan Controller commands. Conditional statements actually have two commands per statement and they are an exception.

Parameter Format

Parameters are either integers or floating point numbers. Parameters are typically transmitted to the Scan Controller as 16 bit value although there are some exceptions. All parameters are literal values in a statement and they are separated from each other and from the command text by whitespace.

Floating point numbers are always written in the standard fixed point format with the decimal point located after the ones position, one or more leading digits and one or more trailing digits. For example, `'1.3'` `'0.6'` and `'4.55'` and `'6,7'` are all acceptable floating point numbers. Examples of unacceptable floating point number format `are '4.9e1' '.5' '5.'`. Certain computer systems may be configured for European local, in which case the acceptable decimal point is the comma character.

Integers can be written as decimal, character, octal or hexadecimal numbers. Decimal numbers may have a leading '+' or '-' sign and 1 or more digits. For example, -45 +23 200 56000 are all acceptable decimal integers. Examples of unacceptable decimal integers include 56,000 and 56.000. Character integers are written as a single printable ASCII character surrounded by single quotes. Examples of acceptable character integers are '4' 'A' and '!'. Examples of unacceptable character integers are ''' and '\045'. Octal numbers are written with a leading '\0' followed by the number in base 8. Examples of acceptable octal numbers are \050 \0233 \0456. Hexadecimal numbers are written using the c language style. They have a leading '0x' followed by the hex digits. Examples of acceptable hex integers are 0x50 0xFFFF.

DIGIT	=>	[0-9]
OCTAL_DIGIT	=>	[0-7]
HEX_DIGIT	=>	[0-9a-fA_F]

DECIMAL_INTEGER	=>	[+-]*[0-9]+
OCTAL_INTEGER	=>	[\][0][0-7]+
HEX_INTEGER	=>	[0][xX][0-9afAF]+
CHAR_INTEGER	=>	['][0-9a-zA-Z][']

FLOAT	=>	[0-9]+[\.\,][0-9]+

Explanation of Operational Modes

Overview:	There are various modes of operation that overlap or are mutually exclusive depending upon those compared.
Raster Mode:	A fundamental operating mode for either programs or immediate instructions in which all motion commands are directed to a specified axis.
Vector Mode:	A fundamental operating mode for either programs or immediate instructions where motion commands are simultaniously directed to both the X and Y axises.
Program Instruction Mode:	When a program is running the operational context of the instructions of the program will be Program Instruction Mode. In contrast, query commands and the system configuration commands cannot be executed from a program, i.e. they are not valid in Program Instruction Mode.
Immediate Instruction mode:	This is the idle mode of the Scan Controller, when a program is not running. Typically, every command can be executed from this mode except those that deal exclusively with the operation of programs, i.e. Repeat, Nrepeat, and End.
Dual Single Axis:	This mode is only available when the ExecuteRasterPgm command is executed. This mode is characterized by two raster programs running concurrently, one on each axis.
Concurrent Instruction mode:	This mode comes about when a program is running and you try to enter a command over the communications interface. Typically, commands valid for this mode are the query commands.

Assembly	Binary
?FreeFlashSpace	?FreeFlashSpace
?FreeRAMSpace	?FreeRAMSpace
?ID	?ID
?OpticalCal	?OpticalCal
?Position	?Position
?Status	?Status
?Sync	?Sync
?Temp	?Temp
?TempOK	?TempOK
AbortPgm	AbortPgm
ComConfig	ComConfig
ConfigPixelClock	ConfigPixelClock
CreateFlashPgm	CreateFlashPgm
CreatePgm	CreatePgm
DelayedSetSync	DelayedSetSync
DelayedUnSetSync	DelayedUnSetSync
DeltaPosition	DeltaPosition
DeltaPositionXY	DeltaPositionXY
DeltaSlew	DeltaSlew
DeltaSlewXY	DeltaSlewXY
DeltaTweakAxis	DeltaTweakAxis
DeltaTweakAxisXY	DeltaTweakAxisXY
Disable	Disable
Enable	Enable
End	End
ExecutePgm	ExecutePgm
ExecuteRasterPgm	ExecuteRasterPgm
ExitPgm	ExitPgm
Ifexecutepgm	Ifexecutepgm
Ifexecuterasterpgm	Ifexecuterasterpgm
Iftempokexecutepgm	Iftempokexecutepgm
Iftempokexecuterasterpgm	Iftempokexecuterasterpgm
Nrepeat	Nrepeat
PackMemory	PackMemory
Position	Position
PositionXY	PositionXY
Raster	Raster
ReleasePgm	ReleasePgm
Repeat	Repeat
SaveConfigInFlash	SaveConfigInFlash
SetConfigVar	SetConfigVar
SetGSS	SetGSS
SetSetSyncDelay	SetSetSyncDelay
SetSync	SetSync
SetUnsetSyncDelay	SetUnsetSyncDelay
SetXPRGain	SetXPRGain
SetXPROffset	SetXPROffset
SetYPRGain	SetYPRGain
SetYPROffset	SetYPROffset
Slew	Slew
SlewXY	SlewXY
TweakAxis	TweakAxis
TweakAxisXY	TweakAxisXY
UnSetSync	UnSetSync
Vector	Vector
Wait	Wait
WaitPosition	WaitPosition

WaitPositionXY WaitSync	WaitPositionXY WaitSync

?FreeFlashSpace

Command Description: Returns byte count of available flash memory.

Valid Run-time Modes					
Raster Mode	*Vector Mode*	*Dual Single Axis Mode*	*Program Instruction*	*Immediate Instruction*	*Concurrent Instruction*
YES	YES	YES	NO	YES	YES

Parameters

(none)

Syntax: `?FreeFlashSpace`

Note: The **?FreeFlashSpace** command returns the amount of space available (in bytes) in the non-volatile (flash) area of Scan Controller memory.

?FreeFlashSpace

Binary Interface:

Command Byte: 0x26

Parameters: None

Tick count: <timing dependent upon Baud rate>

Return Count: 4 bytes as (1) big endian doubleword

Notes:

Example:

```
'?FreeFlashSpace' -> "26"
(Readback) "00060000" -> '393216'
```

393216 byte free

```
Given 0x 00  01  FF  FE
          1 | 2 | 3 | 4
get the bytes in the order 1 2 3 4
```

?FreeRAMSpace

Command Description: Returns byte count of available SRAM.

Valid Run-time Modes					
Raster Mode	*Vector Mode*	*Dual Single Axis Mode*	*Program Instruction*	*Immediate Instruction*	*Concurrent Instruction*
YES	YES	YES	NO	YES	YES

Parameters

(none)

Syntax: `?FreeRAMSpace`

Note: **?FreeRAMSpace** returns the amount of available space, in bytes, for loading programs into SRAM (volatile) area of the Scan Controller memory.

?FreeRAMSpace

Binary Interface:

Command Byte: 0x27

Parameters: None

Tick count: <timing dependent upon Baud rate>

Return Count: 4 bytes as (1) big endian doubleword

Notes:

Example:

```
'?FreeRAMSpace' -> "27"
(readback) "0001F000" -> '126976'
```
126976 bytes free

```
Given 0x 00  01  FF  FE
          1 | 2 | 3 | 4
get the bytes in the order 1 2 3 4
```

?ID

Command Description: Return system revision information.

Valid Run-time Modes					
Raster Mode	*Vector Mode*	*Dual Single Axis Mode*	*Program Instruction*	*Immediate Instruction*	*Concurrent Instruction*
YES	YES	YES	NO	YES	YES

Parameters

(none)

Syntax: `?Id`

Note: **?Id** returns the Boot Loader Firmware Version number, the Main Firmware Version number, the Hardware number and the Device ID number. If the firmware version number is 0.0 then the Boot Loader has responded to the **?Id** command instead of the main firmware. The Hardware number is typically 2 and the Device ID number is typically 3.

?ID

Binary Interface:

Command Byte: 0x29

Parameters: None

Tick count: <timing dependent upon Baud rate>

Return Count: 6 bytes as 6 bytes

Boot Segment Revision	<byte 1> . <byte 2>
Firmware Revision (default 1.0)	<byte 3> . <byte 4>
Hardware (default 0)	<byte 5>
Device ID (default 0)	<byte 6>

Notes:

Example:

```
'?Id' -> "29"
(readback) "010001F10200" -> 1,0,1,241,2,0
```

Boot Segment Revision 1.0
Firmware Revision: 1.241
Hardware: 2
Device ID: 0

?OpticalCal

Command Description: Return the contents of the path compensation registers.

Valid Run-time Modes					
Raster Mode	*Vector Mode*	*Dual Single Axis Mode*	*Program Instruction*	*Immediate Instruction*	*Concurrent Instruction*
YES	YES	YES	NO	YES	YES

Parameters

(none)

Syntax: `?OpticalCal`

Note: Returns the most recently latched readings from the path compensation registers.

?OpticalCal

Binary Interface:

Command Byte: 0x2D

Parameters: None

Tick count: <timing dependent upon Baud rate>

Return Count: 64 bytes as (32) big endian words

Channel	X-Axis Output Pos	Y-Axis Output Pos	X-Axis Read Pos	Y-Axis Read Pos	X-Axis System Gain	X-Axis System Offset	Y-Axis System Gain	Y-Axis System Offset
9	Word 1	Word 2	Word 3	Word 4	Word 5	Word 6	Word 7	Word 8
10	Word 9	Word 10	Word 11	Word 12	Word 13	Word 14	Word 15	Word 16
11	Word 17	Word 18	Word 19	Word 20	Word 21	Word 22	Word 23	Word 24
12	Word 25	Word 26	Word 27	Word 28	Word 29	Word 30	Word 31	Word 32

where *Output Position* is the most recent value of the position command register at the time of trigger, *Read Position* is the corrected position readback value at the time of trigger, *System Gain* is the overall position command gain coefficient at the time of trigger, and *System Offset* is the overall position command offset constant at the time of trigger. The values are latched into the Scan Controller optical calibration registers by a positive edge trigger on any of sync channels 9 – 12. Optical calibration values can be read by issuing the **?OpticalCal** command. Capture and readback can occur in the idle mode or while a program is running, thereby providing a mechanism to know the position, accuracy and correction factor at any given time.

Notes:

The gain value read back is the integer representation of gain. Use the following formula to convert the integer to floating point gain: $fgain = igain/32768$.

Notes:

The position readback value is derived from the following formula:

$$PRead_{axis} = PRGain_{axis} \times PRaw_{axis} + PROffset_{axis}$$

Where $PRead$ is the position sensor reading reported by ?OpticalCal and ?Position, *PRaw* is the uncorrected position sensor reading and *axis* specifies either the X or Y axis. See `SetXPROffset`, `SetXPRGain`, `SetYPROffset`, `SetYPRGain` or `SetConfigVar`.

Example: `'?OpticalCal' -> "2D"`

?Position

Command Description: Return the current position on the given axis.

Valid Run-time Modes					
Raster Mode	*Vector Mode*	*Dual Single Axis Mode*	*Program Instruction*	*Immediate Instruction*	*Concurrent Instruction*
YES	YES	YES	NO	YES	YES

Parameters

axis *axis* specifies which axis' position will be returned.

axis	*Meaning*
1	X-axis position
2	Y-axis position

Syntax: `?Position` *`axis`*

Note: The **?position** command is used to read back the current position of the given axis. The value returned is the corrected value of the measured signal of the Galvo position detector.

?Position

Binary Interface:

Command Byte: 0x2A

Parameters: 2 bytes as (1) big endian word

Tick count: <timing dependent upon Baud rate>

Return Count: 2 bytes as 1 big endian word

Notes:

The position readback value is derived from the following formula:

$$PRead_{axis} = PRGain_{axis} \times PRaw_{axis} + PROffset_{axis}$$

Where $PRead$ is the position sensor reading reported by ?OpticalCal and ?Position, $PRaw$ is the uncorrected position sensor reading and *axis* specifies either the X or Y axis. See `SetXPROffset`, `SetXPRGain`, `SetYPROffset`, `SetYPRGain` or `SetConfigVar`.

Example:

```
'?Position 1' -> "2A0001"
(Readback) "1388" -> '5000'
```

X-axis position detector reads 5000.

?Status

Command Description: Returns error information and clears error state.

Valid Run-time Modes					
Raster Mode	*Vector Mode*	*Dual Single Axis Mode*	*Program Instruction*	*Immediate Instruction*	*Concurrent Instruction*
YES	YES	YES	NO	YES	YES

Parameters

(none)

Syntax: `?Status`

Note: The **?Status** command returns the error information described in the Error Processing section of this document. When an error is discovered while a stored program is executing or while commands are being received over the communication link, all subsequent commands are ignored until a **?Status** command is issued or the controller is power cycled. If the error occurs while a program is running, the program will continue to run until the **?status** command is issued. If the SC2000 is in the error state (LED ON) **?status** will return the error code of the command in error, halt any running programs, set the LED to OFF and unlock command processing. If there is no error, **?status** returns the success code of the last command executed.

?Status

Binary Interface:

Command Byte: 0xFF

Parameters: 8 bytes as the fixed value 0xFFFFFFFFFFFFFFFF

Tick count: <timing dependent upon Baud rate>

Return Count: 6 bytes as (3) big endian words

First word, Error Source	
value	*Meaning*
0	Error in interpreted command
1-255	Error in program command, PGM-ID
9999	System Error

Second word, Command in error Same as Command Byte definition.

Third word, Error code See Appendix for Error code definitions.

Note:

See Appendix for error codes.

Example:

```
'?Status' -> "FFFFFFFFFFFFFFFF"
(readback) "000000FF0000" -> 0, 255, 0

0   -> report from interpreted mode
255 -> '?status' reporting (last command executed)
0   -> ?status returned success
```

?Sync

Command Description: Returns the logic state of the sync and SAX pins as bits in a word.

Valid Run-time Modes					
Raster Mode	*Vector Mode*	*Dual Single Axis Mode*	*Program Instruction*	*Immediate Instruction*	*Concurrent Instruction*
YES	YES	YES	NO	YES	YES

Parameters

(none)

Syntax: ***?***Sync

?Sync

Binary Interface:

Command Byte: 0x39

Parameters: None

Tick count: <timing dependent upon Baud rate>

Return Count: 2 bytes as 1 big endian word

Note: X Servo Ready, Y Servo Ready, and Syncs 1-4 are inverted logic.

Note: See the following table for return value bit designations.

Bit position															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Sax		Sync #													
Xrd	Yrd	14	13	12	11	10	9	8	7	6	5	4	3	2	1

Example:

```
'?Sync' -> "39"
(readback) "6F" -> sync 6 and sync 7
asserted, X servo ready and Y servo ready
asserted.
```

?Temp

Command Description: Read servo temperature.

Valid Run-time Modes					
Raster Mode	*Vector Mode*	*Dual Single Axis Mode*	*Program Instruction*	*Immediate Instruction*	*Concurrent Instruction*
YES	YES	NO	NO	YES	NO

Parameters

(none)

Syntax: `?Temp`

?Temp

Binary Interface:

Command Byte: 0x2B

Parameters: None

Tick count: <timing dependent upon Baud rate>

Return Count: 8 bytes as (4) big endian words

word 1	X-axis servo temperature (J7)
word 2	X-axis alternate servo temperature
word 3	Y-axis servo temperature (J6)
word 4	Y-axis alternate servo temperature

Notes:

Readings are in counts of 4096, 0 – 5V.

Example: `'?Temp' -> "2B"`

?TempOK

Command Description: Check temperature of the given device.

Valid Run-time Modes					
Raster Mode	*Vector Mode*	*Dual Single Axis Mode*	*Program Instruction*	*Immediate Instruction*	*Concurrent Instruction*
YES	YES	YES	NO	YES	YES

Parameters

device_id The *device_id* specifies from which SAX device to read the temperature.

device_id	*Meaning*
1	X-axis temperature flag
2	Y-axis temperature flag
3	The logical AND of X and Y temperature flags

Syntax: `?TempOK` *`device_id`*

?TempOK

Binary Interface:

Command Byte: 0x2C

Parameter : 2 bytes as (1) big endian word

Tick count: <timing dependent upon Baud rate>

Return Count: 2 bytes as (1) big endian word

0 = FALSE (device temperature not OK)
1 = TRUE (device temperature OK)

Notes:

When device = 3, the result is the Boolean AND of device 1 and device 2.

Example: `'?TempOK 1' -> "2C0001"`

AbortPgm

Command Description: Halts the currently running program and disables servos.

Valid Run-time Modes					
Raster Mode	*Vector Mode*	*Dual Single Axis Mode*	*Program Instruction*	*Immediate Instruction*	*Concurrent Instruction*
YES	YES	YES	YES	YES	YES

Parameters

(none)

Syntax: `AbortPgm`

Note: **AbortPgm** will stop all running programs immediately and disable both servos.

AbortPgm

Binary Interface:

Command Byte: 0x20

Parameters: None

Tick count: 0

Return Count: 0

Notes:

Example: `'AbortPgm' -> "20"`

ComConfig

Command Description: Configure RS-232 serial port parameters for communication.

Valid Run-time Modes					
Raster Mode	*Vector Mode*	*Dual Single Axis Mode*	*Program Instruction*	*Immediate Instruction*	*Concurrent Instruction*
YES	YES	YES	YES	YES	YES

Parameters

baud_rate *baud_rate* specifies the speed at which serial communications takes place. See the following table for the *baud_rate* specifier and the associated baud rate.

Parameter Value	*Baud Rate Setting*
1	2400
2	4800
3	9600
4	19,200
5	38,400
6	57,600
7	115,200

data_bits *data_bits* specifies the number of data bits to use when communicating over the serial interface.

This value is always 8.

stop_bits *stop_bits* specifies the number of stop bits to use for an RS-232 byte transmission.

Parameter Value	*Stop Bit Setting*
1	One stop bit
2	Two stop bits

parity *parity* specifies the type of parity to use for RS-232 communications.

Parameter Value	*Parity Setting*
0	No parity
1	Odd parity
2	Even parity

interface *Interface* specifies the type of serial communications interface to use when communicating with the Scan Controller.

This value is always 232, use RS 232 interface

Syntax: `ComConfig` *`baud_rate data_bits stop_bits parity interface`*

Note: The Scan Controller RS-232 UART is initialized at power-on for 2400 baud, 8 data bits, 1 stop bit, and no parity. Use ComConfig to change those settings. Hardware CTS/RTS handshaking is used exclusively.

ComConfig

Binary Interface:

Command Byte: 0x23

Parameters: 10 bytes as (5) big endian words

Tick count: 0

Return Count: 0

Notes:

Example: `'ComConfig 4 8 1 0 232' -> "2300040008000100000E8"`

ConfigPixelClock

Command Description: Configure the Scan Controller on-board time based pixel clock.

Valid Run-time Modes					
Raster Mode	*Vector Mode*	*Dual Single Axis Mode*	*Program Instruction*	*Immediate Instruction*	*Concurrent Instruction*
YES	YES	YES	YES	YES	NO

Parameters

Syntax: `ConfigPixelClock` *p1 p2 p3 p4 p5 p6*

Note:

Sends 48 bits to command pixel clock.

Bit 0 – 1 for Position based pixel clock
– 0 for Time based pixel clock
Bit 1- 47 – pixel clock command.

ConfigPixelClock

Binary Interface:

Command Byte: 0x1D

Parameters: 6 bytes as a 48 bit binary command.

Tick count: 1

Return Count: 0

Notes: See the National Semiconductor CGS410 User Manual for bit definitions.

The CLI pixel clock tool provides a graphical user interface to the pixel clock chip. The binary result sent to the Scan Controller from the tool is displayed in the *Interpreted Assmbly Statement* window see Figure 15 .

Example: `'ConfigPixelClock 0x33 0x34 0x35 0x36 0x37 0x38' -> "1D33343536373`

CreateFlashPgm

Command Description: The action of Create Flash Program is to initiate the storage mechanism in the Scan Controller so that a program may be saved to non-volatile memory on-board the Scan Controller.

Valid Run-time Modes					
Raster Mode	*Vector Mode*	*Dual Single Axis Mode*	*Program Instruction*	*Immediate Instruction*	*Concurrent Instruction*
YES	YES	NO	NO	YES	NO

Parameters

program_type *program_type* identifies the type of program to be saved.

program_type	*Meaning*
0	This is a Raster program
1	This is a Vector program

program_id *program_id* is the identification code or program name for the new flash program. The *program_id* is a number in the range 1–255.

Syntax: `CreateFlashPgm` *`program_type program_id`*

Example: `CreateFlashPgm 1 'a'`

Note: Place **CreateFlashPgm** with a program type and a program id that you choose as the first statement in a group of commands that you wish to permanently store on the Scan Controller. All commands sent down to the Scan Controller will be saved in flash memory until the **End** command is encountered. The point of execution will pass to these commands when called with **ExecutePGM** or **ExecuteRasterPgm**.

Note: Programs placed in flash memory will remain available even after the Scan Controller is power cycled. Program Id 1 has a special purpose; commands saved with program id 1 will automatically execute when the Scan Controller is powered up.

Note: If Error Code not equal to zero, commands will not be saved. Please reclaim Flash space by power cycling the Scan Controller.

CreateFlashPgm

Binary Interface:

Command Byte: 0x1E

Parameters: 4 bytes as (2) big endian words

Tick count: <timing dependent upon Baud rate>

Return Count: 0

Note: Flash programs cannot be uploaded while a program is running.

Note: If **CreateFlashPgm** is executed with a program Id that already identifies a Flash program, the previous program will be marked for reclamation. Reclamation marking can also be forced by executing the ReleasePGM command. Space marked for reclamation will become available for new programs when the Scan Controller is power cycled.

Example: `'CreateFlashPgm 1 100' -> "1E00010065"`

CreatePgm

Command Description: Store a Scan Controller program in volatile memory on-board the Scan Controller.

Valid Run-time Modes					
Raster Mode	*Vector Mode*	*Dual Single Axis Mode*	*Program Instruction*	*Immediate Instruction*	*Concurrent Instruction*
YES	YES	YES	NO	YES	YES

Parameters

program_type *program_type* identifies the type of program to be saved.

program_type	*Meaning*
0	This is a Raster program
1	This is a Vector program

program_id *program_id* is the identification code or program name for the new SRAM program. The Program ID is a number in the range 1–255.

Syntax: `CreatePgm` *`program_type Program_id`*

Note: **CreatePgm** is the first statement in a program that you wish to store in the SRAM portion of the Scan Controller memory. Programs stored in this area will be lost after a power cycle. **CreatePgm** initiates a special 'transfer' mode where commands sent after the **CreatPgm** statement are stored in SRAM rather the executing immediately. The special 'transfer' mode is terminated by the `end` statement.

Note: Programs stored in the SRAM area of the Scan Controller can be transferred from the host to the Scan Controller while another program is executing motion commands. This operation is undefined if you transfer a new program with the same name as the one being transferred.

Note: If Error Code is not equal to zero, commands will not be saved.

CreatePgm

Binary Interface:

Command Byte: 0x21

Parameters: 4 bytes as (2) big endian words

Tick count: <timing dependent upon Baud rate>

Return Count: 0

Notes:

Note: If **CreatePgm** is called with a program Id that already identifies a SRAM program, the previous SRAM program will be marked for reclamation. Reclamation marking can also be forced by executing the ReleasePGM command. Space marked for reclamation will become available for new programs by executing the **PackMemory** command or power cycling the Scan Controller.

Note: If a new program is uploaded with the same program ID as an existing Flash program, the program ID will reference the SRAM program until the Scan Controller is power cycled, after which the program ID will reference the Flash program once again.

Example: `'CreatePgm 1 0xDE' -> "21000100DE"`

DelayedSetSync

Command Description: Sets the sync bit for the specified channel after the configured delay (see SetConfigVar).

Valid Run-time Modes					
Raster Mode	*Vector Mode*	*Dual Single Axis Mode*	*Program Instruction*	*Immediate Instruction*	*Concurrent Instruction*
YES	YES	YES	YES	YES	NO

Parameters

channel_mask *channel_mask* specifies which one of the writable sync channels is to be set.

channel_mask	*Meaning*
1	Sync Channel 1 (J4, pin 1 pulls low)
2	Sync Channel 2 (J4, pin 2 pulls low)
3	Sync Channel 3 (J4, pin 3 pulls low)
4	Sync Channel 4 (J4, pin 4 pulls low)
13	turns INTCNTL on
14	drives PCLKOUT output with the clock on CMOS_PCLK input pin

Note: The number of tick counts that **DelayedSetSync** waits before setting the named channel is a global variable set by the **SetConfigVar** command or the **SetSetSyncDelay** comamand.

Syntax: Delayed`SetSync` *`channel_mask`*

DelayedSetSync

Binary Interface:

Command Byte: 0x36

Parameters: 2 bytes as (1) big endian signed word.

Tick count: 0

Return Count: 0

Notes:

Example: `'DelayedSetSync 4' -> "360004"`

DelayedUnSetSync

Command Description: Resets the sync bit for the specified channel after the configured delay (see SetConfigVar).

Valid Run-time Modes					
Raster Mode	*Vector Mode*	*Dual Single Axis Mode*	*Program Instruction*	*Immediate Instruction*	*Concurrent Instruction*
YES	YES	YES	YES	YES	NO

Parameters

channel_mask *channel_mask* specifies which one of the writable sync channels is to be reset. Valid numbers for *channel_mask* are 1, 2, 3, 4, 13, and 14.

channel_mask	*Meaning*
1	Sync Channel 1 (J4, pin 1 high impedance)
2	Sync Channel 2 (J4, pin 2 high impedance)
3	Sync Channel 3 (J4, pin 3 high impedance)
4	Sync Channel 4 (J4, pin 4 high impedance)
13	turns INTCNTL of
14	Disconnects PCLKOUT output from the clock on CMOS_PCLK input pin

Note: The number of tick counts that **DelayedUnsetSync** waits before setting the named channel is a global variable set by the **SetConfigVar** command or the **SetSetSyncDelay** comamand.

Syntax: Delayed`UnsetSync` *`channel_mask`*

DelayedUnsetSync

Binary Interface:

Command Byte: 0x37

Parameters: 2 bytes as (1) big endian signed word.

Tick count: 0

Return Count: 0

Notes:

Example: `'DelayedUnsetSync 4' -> "370004"`

DeltaPosition

Command Description: Set the position of the current axis relative to the current position.

Valid Run-time Modes					
Raster Mode	*Vector Mode*	*Dual Single Axis Mode*	*Program Instruction*	*Immediate Instruction*	*Concurrent Instruction*
YES	NO	YES	YES	YES	NO

Parameters

offset *offset* specifies a new position relative to the current value of the position command register. The current run-time axis is referenced for position command register value. *offset* has units of DAC counts.

$-32768 \leq offset \leq 32767$

Syntax: `DeltaPosition` *`device_id`*

DeltaPosition

Binary Interface:

Command Byte: 0x03

Parameter : 2 bytes as (1) big endian signed word

Tick count: 1

Return Count: 0

Notes:

Example: `‘DeltaPosition 550’ -> ‘030226”`

DeltaPositionXY

Command Description: Set the vector position relative to the current position.

Valid Run-time Modes					
Raster Mode	*Vector Mode*	*Dual Single Axis Mode*	*Program Instruction*	*Immediate Instruction*	*Concurrent Instruction*
NO	YES	NO	YES	YES	NO

Parameters

x-offset *x-offset* specifies a position relative to the current value of the X-axis position command register. *x-offset* has units of DAC counts.

$-32768 \leq x\text{-}offset \leq 32767$

y-offset *y-offset* specifies a position relative to the current value of the Y-axis position command register. *y-offset* has units of DAC counts.

$-32768 \leq y\text{-}offset \leq 32767$

Syntax: `DeltaPositionXY` *`x-offset y-offset`*

DeltaPositionXY

Binary Interface:

Command Byte: 0x04

Parameters: 4 bytes as (2) big endian signed words.

Tick count: 1

Return Count: 0

Notes:

Example: `'DeltaPositionXY 500 -600' -> "0401F4FDA8"`

DeltaSlew

Command Description: Move smoothly on the current axis relative to the current position.

Valid Run-time Modes					
Raster Mode	*Vector Mode*	*Dual Single Axis Mode*	*Program Instruction*	*Immediate Instruction*	*Concurrent Instruction*
YES	NO	YES	YES	YES	NO

Parameters

offset *offset* specifies the distance along the current axis to smoothly move from the current value of the position command register of the specified axis over *count* ticks. *offset* has units of DAC counts.

$-32768 \leq offset \leq 32767$

count *count* specifies the number of 23 μS ticks in which to smoothly move in a straight line.

$1 \leq count \leq 32767$

Syntax: `DeltaSlew` *`offset count`*

DeltaSlew

Binary Interface:

Command Byte: 0x07

Parameters: 4 bytes as (1) big endian signed word and (1) big endian unsigned word.

Tick count: Value of *count*

Return Count: 0

Notes:

Example: `'DeltaSlew 4000 31000' -> "070FA07918"`

DeltaSlewXY

Command Description: Move smoothly relative to the current vector position.

Valid Run-time Modes					
Raster Mode	*Vector Mode*	*Dual Single Axis Mode*	*Program Instruction*	*Immediate Instruction*	*Concurrent Instruction*
NO	YES	NO	YES	YES	NO

Parameters

x-offset *x-offset* specifies the distance along the X-axis to smoothly move from the current value of the X-axis position command register over *count* ticks. *x-offset* has units of DAC counts.

$-32768 \leq x\text{-}offset \leq 32767$

y-offset *y-offset* specifies the distance along the Y-axis to smoothly move from the current value of the Y-axis position command register over the *count* ticks. *y-offset* has units of DAC counts.

$-32768 \leq y\text{-}offset \leq 32767$

count Count specifies the number of 23 μS ticks in which to smoothly move in a straight line.

$1 \leq count \leq 32767$

Syntax: `DeltaSlewXY` *`x-offset y-offset count`*

DeltaSlewXY

Binary Interface:

Command Byte: 0x08

Parameters: 6 bytes as (2) big endian signed words and (1) big endian unsigned word.

Tick count: Value of *count*

Return Count: 0

Notes:

Example: `'DeltaSlewXY 230 -450 600' -> "0800E6FE3E0258"`

DeltaTweakAxis

Command Description: Apply gain and offset deltas to subsequent raster operations.

Valid Run-time Modes					
Raster Mode	*Vector Mode*	*Dual Single Axis Mode*	*Program Instruction*	*Immediate Instruction*	*Concurrent Instruction*
YES	NO	YES	YES	YES	YES

Parameters

gain_factor The *gain_factor* is multiplied by the current axis current composite gain factor to produce a new composite gain factor.

$0.5 \leq gain\_factor \leq 1.5$

offset-delta The *offset-delta* is added to the current axis current composite offset to produce the new current axis composite offset. *offset-delta* has units of DAC counts.

$-32768 \leq offset\_delta \leq 32767$

Syntax: `DeltaTweakAxis` *`gain_factor offset-delta`*

DeltaTweakAxis

Binary Interface:

Command Byte: 0x17

Parameters: 4 bytes as (1) big endian unsigned word and (1) big endian signed word.

Tick count: 1

Return Count: 0

Notes:

gain is converted from a float to an integer by the following formula:

$$igain = \text{truncate}\,(32768 \times fgain)$$

Example: `'DeltaTweakAxis 1.0 10000' -> "1780002710"`

DeltaTweakAxisXY

Command Description: Apply gain and offset deltas to subsequent vector operations.

Valid Run-time Modes					
Raster Mode	*Vector Mode*	*Dual Single Axis Mode*	*Program Instruction*	*Immediate Instruction*	*Concurrent Instruction*
NO	YES	NO	YES	YES	YES

Parameters

x-gain_factor The *x-gain_factor* is multiplied by the current composite X-axis gain factor to produce a new composite X-axis gain factor.

$$0.5 \le x\_gain\_factor \le 1.5$$

x-offset-delta The *x-offset_delta* is added to the current X-axis offset to produce the new X-axis offset. *x-offset-delta* has units of DAC counts.

$$-32768 \le x\_offset\_delta \le 32767$$

y-gain_factor The *y-gain_factor* is multiplied by the current composite Y-axis gain factor to produce a new composite Y-axis gain factor.

$$0.5 \le y\_gain\_factor \le 1.5$$

y-offset -delta The *y-offset _delta* is added to the current Y-axis offset to produce the new Y-axis offset. *y-offset-delta* has units of DAC counts.

$$-32768 \le y\_offset\_delta \le 32767$$

Syntax: `DeltaTweakAxisXY` *`x-gain_f x-offset-d y-gain_f y-offset-d`*

DeltaTweakAxisXY

Binary Interface:

Command Byte: 0x18

Parameters: 8 bytes as (1) big endian unsigned word, (1) big endian signed word, (1) big endian unsigned word, and (1) big endian signed word.

Tick count: 1

Return Count: 0

Notes:

gain is converted from a float to an integer by the following formula:

$$igain = \text{truncate}\,(32768 \times fgain)$$

Example: `'DeltaTweakAxisXY 0.8 -200 1.02 10' -> "186666FF38828F000A"`

Disable

Command Description: The disable command will disable the specified SAXes connected to the Scan Controller.

Valid Run-time Modes					
Raster Mode	*Vector Mode*	*Dual Single Axis Mode*	*Program Instruction*	*Immediate Instruction*	*Concurrent Instruction*
YES	YES	YES	YES	YES	NO

Parameters

device_id *device_id* specifies that either or both of the SAX servos are to be disabled.

Device_id	*Meaning*
1	X-axis servo
2	Y-axis servo
3	Both servos

Syntax: `Disable` *`device_id`*

Disable

Binary Interface:

Command Byte: 0x15

Parameter: 2 bytes as (1) big endian signed word.

Tick count: 1

Return Count: 0

Notes:

Example: `'Disable 1' -> "150001"`

Enable

Command Description: The Enable command will enable the specified SAXes connected to the Scan Controller.

Valid Run-time Modes					
Raster Mode	*Vector Mode*	*Dual Single Axis Mode*	*Program Instruction*	*Immediate Instruction*	*Concurrent Instruction*
YES	YES	YES	YES	YES	NO

Parameters

device_id The *device_id* specifies that either or both of the SAX servos are to be enabled.

device_id	*Meaning*
1	X-axis servo
2	Y-axis servo
3	Both servos

Syntax: `Enable` *`device_id`*

Enable

Binary Interface:

Command Byte: 0x14

Parameter: 2 bytes as (1) big endian signed word

Tick count: 1

Return Count: 0

Notes:

Example: `'Enable 1' -> "140001"`

End

Command Description: Marks the end of a Scan Controller program.

Valid Run-time Modes					
Raster Mode	*Vector Mode*	*Dual Single Axis Mode*	*Program Instruction*	*Immediate Instruction*	*Concurrent Instruction*
YES	YES	YES	YES	NO	YES

Parameters

(none)

Syntax: `End`

Note: The **End** command marks the end of a program that is to be stored in a memory area of the Scan Controller. The **End** command takes the Scan Controller out of 'transfer' mode such that motion commands are executed immediately if the Scan Controller is in idle mode.

End

Binary Interface:

Command Byte: 0x16

Parameters: 4 bytes as (1) unsigned little endian long word

Tick count: <timing dependent upon Baud rate>

Return Count: 0

Notes: CRC values are computed using the CRC32 algorithm. A sample C language program that computes the CRC checksum of a ASCII hex program is shown in the appendix (see Program to generate CRC at the end of the document). A default CRC value of 0xFFFFFFFF can be used to upload a program without the benefit of CRC checking. If CRC checking is required, please note that the '**createpgm**' statement and the '**end**' statement (first and last lines) are not included in the CRC checksum computation.

Example: `'End' -> "16FFFFFFFF"`

ExecutePgm

Command Description: Commence the execution of the named program.

Valid Run-time Modes					
Raster Mode	*Vector Mode*	*Dual Single Axis Mode*	*Program Instruction*	*Immediate Instruction*	*Concurrent Instruction*
YES*	YES*	YES*	YES*	YES*	NO

Parameters

program_id *program_id* is the identification code or program name of the program that is to be deleted. The *program_id* is a number in the range 1–255.

Syntax: `ExecutePgm` *`program_id`*

Note: *`program_id`* must identify a vector command file if:

- **ExecutePgm** is issued by the user following a VECTOR command.
- **ExecutePgm** is called from a vector command file.

`program_id` must identify a raster command file if:

- **ExecutePgm** is issued by the user following a RASTER <axis> command.
- **ExecutePgm** is called from a raster command file.

ExecutePgm starts executing a function/program stored on the embedded controller.

The user provides a program id when the code is stored on the embedded controller using **CreateFlashPgm** or **CreatePgm** to identify Functions/programs. This id is then used with **ExecutePgm** to invoke the stored code.

Program Ids assigned to programs stored in either flash or RAM range from 1 to 255. If **ExecutePgm** is called with a program id that is out of range or that has no code previously stored, then an error will be generated and nothing gets executed. If another program is currently running an error will be returned. Also an error is generated if **ExecutePgm** is called with a pgm id that doesn't obey the rules for pgm id stated above.

ExecutePgm

Binary Interface:

Command Byte: 0x0E

Parameters: 2 bytes as (1) big endian signed word.

Tick count: less than 3

Return Count: 0

Notes:

Example: `'ExecutePgm 0x45' -> "0E0045"`

ExecuteRasterPgm

Command Description: Enter Dual Single Axis mode and commence the execution of the named raster programs.

Valid Run-time Modes					
Raster Mode	*Vector Mode*	*Dual Single Axis Mode*	*Program Instruction*	*Immediate Instruction*	*Concurrent Instruction*
NO	YES	NO	YES	YES	NO

Parameters

x_pgm_id *x_pgm_id* is the identification code or program name for the raster program that will run on the X-axis. *x_pgm_id* is a number in the range 1–255.

y_pgm_id *y_pgm_id* is the identification code or program name for the raster program that will run on the Y-axis. *y_pgm_id* is a number in the range 1–255.

Syntax: `ExecuteRasterPgm` *`x_pgm_id y_pgm_id`*

Note: To start two independent operations for raster operation, call **ExecuteRasterPgm** with two arguments, a program id for the x-axis and a program id for the y-axis.

Program IDs range from 1 to 255. If **ExecuteRasterPgm** is called with a program id that is out of the acceptable range or if the given program ID has no code associated with it, an error will be generated and nothing gets executed. If another program is currently running an error will be returned.

ExecuteRasterPgm

Binary Interface:

Command Byte: 0x0F

Parameters: 4 bytes as (2) big endian signed words.

Tick count: less than 3

Return Count: 0

Notes:

Example: `'ExecuteRasterPgm 234 235' -> "0F00EA00EB"`

ExitPgm

Command Description: Use ExitPgm to terminate programs by having them fall through repeat and waitsync [1-4] statements.

Valid Run-time Modes					
Raster Mode	*Vector Mode*	*Dual Single Axis Mode*	*Program Instruction*	*Immediate Instruction*	*Concurrent Instruction*
YES	YES	YES	YES	YES	YES

Parameters

(none)

Syntax: `ExitPgm`

Note: When **ExitPgm** is used to terminate a program there may be a delay before the program finally stops. Termination of the program can be determined over the communications link by issuing the **?Status** command. **?Status** will report back ExitPgm Success (000000250000) when the program finally terminates.

Note: When **ExitPgm** is issued while a program is not running and then **?Status** is entered next, the command field in the status report will not be set to **ExitPgm** but rather the last command executed befoe the **ExitPgm** command.

Note: **ExitPGM** works by suppressing the iteration property of the **Repeat** statement and the pause for synchronization property of the **WaitSync**[1-4] statement. Note that only sync channels 1-4 are suppressed; if **ExitPGM** is applied to a program that is waiting on a sync channel in the range 5-12, the external stimulus will have to be applied to the channel or the **AbortPGM** command will have to be used.

ExitPgm

Binary Interface:

Command Byte: 0x25

Parameters: None

Tick count: dependent upon the program call depth and program structure

Return Count: 0

Notes:

Example: `'ExitPgm' -> "25"`

If

Command Description: Execute an instruction if a sync Channel is set.

Valid Run-time Modes					
Raster Mode	*Vector Mode*	*Dual Single Axis Mode*	*Program Instruction*	*Immediate Instruction*	*Concurrent Instruction*
YES*	YES	YES*	YES	YES	NO

Parameters

sync_channel *sync_channel* specifies which one of the readable sync channels shall be used in the **If** command. Valid numbers for *sync_channel* are 1 – 12.

Syntax 1: `If` *`sync_channel`* `ExecuteRasterPgm` *`x_pgm_id y_pgm_id`*

Syntax 2: `If` *`sync_channel`* `ExecutePgm` *`program_id`*

Example:
```
If 5 ExecutePgm 'a'
```

Example:
```
If 12 ExecuteRasterPgm 5 45
```

Note: The **If** statement is a special idiom of the Scan Controller language in that two commands are written in one statement. The command to be executed as the consequent of the if statement is constrained to be either **ExecutePgm** or **ExecuteRasterPgm**.

Note: The **If <channel> ExecuteRasterPgm** statement can only be issued from a vector program or from the command line.

If

Binary Interface:

Command Byte: 0x0A for If <chan> ExecutePGM, 0x0B for If <chan> ExecuteRasterPgm

Parameters:

- 2 bytes as 1 big endian signed word for ExecutePgm.
- 4 bytes as 2 big endian signed words for ExecuteRasterPgm.

Tick count: less than 3

Return Count: 0

Notes:

Example: `'If 7 ExecutePgm 0x45' -> "0A00070045"`

Example: `'If 7 ExecuteRasterPgm 7 7' -> "0B000700070007"`

If TempOK

Command Description: Execute an instruction if a device temperature is acceptable.

Valid Run-time Modes					
Raster Mode	*Vector Mode*	*Dual Single Axis Mode*	*Program Instruction*	*Immediate Instruction*	*Concurrent Instruction*
YES*	YES	YES*	YES	YES	NO

Parameters

device_id The *device_id* specifies from which SAX device to read the temperature.

device_id	*Meaning*
1	X-axis temperature flag
2	Y-axis temperature flag
3	The logical AND of X and Y temperature flags

Syntax 1: `If TempOK` *`device_id`* `ExecuteRasterPgm x`*`_pgm_id y_pgm_id`*

Syntax 2: `If TempOK` *`device_id`* `ExecutePgm` *`program_id`*

Example:
```
If TempOK 3 ExecuteRasterPgm 'a' 'd'
```

Example:
```
If TempOK 1 ExecutePgm 45
```

Note: The **If TempOK** statement is a special idiom of the Scan Controller language in that two commands are written in one statement. The command to be executed as the consequent of the if statement is constrained to be either **ExecutePgm** or **ExecuteRasterPgm**.

Note: The **If TempOK <device> ExecuteRasterPgm** statement can only be issued from a vector program or from the command line.

If TempOK

Binary Interface:

Command Byte: 0x0C for If TempOK <device> ExecutePGM, 0x0D for If TempOK <device> ExecuteRasterPgm

Parameters:

- 2 bytes as (1) big endian signed word for ExecutePGM.
- 4 bytes as (2) big endian signed words for ExecuteRasterPgm.

Tick count: less than 3

Return Count: 0

Notes:

Example: `'If TempOK 2 ExecutePgm 5' -> "0C00020005"`

Example: `'If TempOK 2 ExecuteRasterPgm 56 57' -> "0D000200380039"`

NRepeat

Command Description: The NRepeat command will cause the Scan Controller program flow to return to the first instruction in the program where execution is repeated a given number of times.

Valid Run-time Modes					
Raster Mode	*Vector Mode*	*Dual Single Axis Mode*	*Program Instruction*	*Immediate Instruction*	*Concurrent Instruction*
YES	YES	YES	YES	NO	NO

Parameters

Repeat_count *repeat_count* specifies the number of times NRepeat will return to the first instruction before fall through to the next instruction.

$$0 \leq REpeat\ \_\ count < 32768$$

Syntax: N`repeat` *`repeat_count`*

Note: A repeat_count of zero will cause the command to act in the same manner as the repeat instruction.

Note: A given program can contain only one NRepeat command but a program that uses NRepeat may call other programs that use NRepeat.

Note: NRepeat differs from the Repeat instruction in that additional commands may follow the NRepeat statement.

NRepeat

Binary Interface:

Command Byte: 0x38

Parameters: 2 bytes as (1) big endian signed word.

Tick count: 0

Return Count: 0

Notes:

Example: `'Nrepeat 12' -> "38000C"`

PackMemory

Command Description: Reclaim memory from deleted programs and previous program versions and then compact available memory.

Valid Run-time Modes					
Raster Mode	*Vector Mode*	*Dual Single Axis Mode*	*Program Instruction*	*Immediate Instruction*	*Concurrent Instruction*
YES	YES	NO	NO	YES	NO

Parameters

(none)

Syntax: `PackMemory`

Note: **PackMemory** will reclaim fragmented space in SRAM memory. This operation is automatically performed each time the system powers up as the SRAM is volatile memory. Memory fragmentation will occur when 1) a new program is uploaded with the same name as an existing program or 2) the **ReleasePGM** command is run on a given program ID.

Note: Flash memory is packed by issuing the **ReleasePGM** on the given program and then power-cycling the Scan Controller.

PackMemory

Binary Interface:

Command Byte: 0x1F

Parameters: None

Tick count: <dependent upon memory fragmentation>

Return Count: 0

Notes:

Example: `'PackMemory' -> "1F"`

Position

Command Description: Set the absolute position of the current axis.

Valid Run-time Modes					
Raster Mode	*Vector Mode*	*Dual Single Axis Mode*	*Program Instruction*	*Immediate Instruction*	*Concurrent Instruction*
YES	NO	YES	YES	YES	NO

Parameters

coord Set the absolute position on the current axis to *coord*. *coord* has units of DAC counts.

$-32768 \leq coord \leq 32767$

Syntax: `Position` *`coord`*

Note: The **position** command can generate large servo motions faster than the mechanical system response. Please use **position** commands with care.

Position

Binary Interface:

Command Byte: 0x01

Parameters: 2 bytes as (1) big endian signed word.

Tick count: 1

Return Count: 0

Notes:

Example: `'Position 300' -> "01012C"`

PositionXY

Command Description: Set the absolute vector position.

Valid Run-time Modes					
Raster Mode	*Vector Mode*	*Dual Single Axis Mode*	*Program Instruction*	*Immediate Instruction*	*Concurrent Instruction*
NO	YES	NO	YES	YES	NO

Parameters

x-coord Set the absolute position of the X-axis to *x-coord*. *x-coord* has units of DAC counts.

$-32768 \leq x\_coord \leq 32767$

y-coord Set the absolute position of the Y-axis to *y-coord*. *y-coord* has units of DAC counts.

$-32768 \leq y\_coord \leq 32767$

Syntax: `PositionXY` *`x-coord y-coord`*

PositionXY

Binary Interface:

Command Byte: 0x02

Parameters: 4 bytes as (2) big endian signed words.

Tick count: 1

Return Count: 0

Notes:

Example: `'PositionXY 5000 4000' -> "0213880FA0"`

Raster

Command Description: Declare the target axis for subsequent single axis (raster) commands and place the Scan Controller in raster mode.

Valid Run-time Modes					
Raster Mode	*Vector Mode*	*Dual Single Axis Mode*	*Program Instruction*	*Immediate Instruction*	*Concurrent Instruction*
YES	YES	NO	NO	YES	NO

Parameters

axis Specifies the axis on which subsequent motion command will operate. *axis* is a number defined as follows:

axis	*Meaning*
1	X-axis
2	Y-axis

Syntax: `Raster` *`axis`*

Raster

Binary Interface:

Command Byte: 0x19

Parameters: 2 bytes as (1) big endian signed word

Tick count: 1

Return Count: 0

Notes:

Example: `'Raster 1' -> "190001"`

ReleasePgm

Command Description: Mark the named program as deleted.

Valid Run-time Modes					
Raster Mode	*Vector Mode*	*Dual Single Axis Mode*	*Program Instruction*	*Immediate Instruction*	*Concurrent Instruction*
YES	YES	YES	NO	YES	YES

Parameters

program_id — *program_id* is the identification code or program name of the program that is to be deleted. The *program_id* is a number in the range 1–255.

Syntax: `ReleasePgm` *`program_id`*

Note: The action of **ReleasePgm** is to mark a program as available for reclamation inorder to recover memory for other programs. In the case of SRAM memory the **PackMemory** command may be issued for memory compaction. In the case of Flash Memory, the Scan Controller must be power cycled for Flash Memory compaction.

ReleasePgm

Binary Interface:

Command Byte: 0x22

Parameters: 2 bytes as (1) big endian signed word.

Tick count: 1

Return Count: 0

Notes:

Example: `'ReleasePgm 'a'' -> "220061"`

Repeat

Command Description: The Repeat command will cause the Scan Controller program flow to return to the first instruction in the program where execution is repeated.

Valid Run-time Modes					
Raster Mode	*Vector Mode*	*Dual Single Axis Mode*	*Program Instruction*	*Immediate Instruction*	*Concurrent Instruction*
YES	YES	YES	YES	NO	NO

Parameters

(none)

Syntax: `Repeat`

Repeat

Binary Interface:

Command Byte: 0x09

Parameters: None

Tick count: 0

Return Count: 0

Notes:

Example: `'Repeat' -> "09"`

SaveConfigInFlash

Command Description: Save the values of configuration variables into non-volatile memory.

Valid Run-time Modes					
Raster Mode	*Vector Mode*	*Dual Single Axis Mode*	*Program Instruction*	*Immediate Instruction*	*Concurrent Instruction*
YES	YES	NO	NO	YES	NO

Parameters

(none)

Syntax: `SaveConfigInFlash`

Note: The following variables will be save to flash when this command is invoked:

- X-Position-Readback-Offset
- Y-Position-Readback-Offset
- X-Position-Readback-Gain
- Y-Position-Readback-Gain
- Global-Sample-Size
- DelayedSetSync delay
- DelayedUnsetSync delay

Note: This command show only be invoked when the Scan Controller is in idle mode.

SaveConfigInFlash

Binary Interface:

Command Byte: 0x35

Parameters: None

Tick count: 1

Return Count: 0

Notes:

Example: `'SaveConfigInFlash' -> "35"`

SetConfigVar

Command Description: Sets the value of a configuration variable.

Valid Run-time Modes					
Raster Mode	*Vector Mode*	*Dual Single Axis Mode*	*Program Instruction*	*Immediate Instruction*	*Concurrent Instruction*
YES	YES	NO	NO	YES	NO

Parameters

Id *Id* identifies the job to perform.

Value *Value* is the value that the variable will take.

Syntax: `SetConfigVar` *`Id Value`*

Note:

Configuration Variables			
Id	**Variable**	**Values(default)**	**See Command**
1	Global Sample Size	1 to 100 (10)	WaitPositionXY, WaitPosition
2	X readback gain correction	0.5 to 1.5	WaitPositonXY, WaitPositon, ?Position
3	X readback offset correction	-32,768 to 32,767	
4	Y readback gain correction	0.5 to 1.5	
5	Y readback offset correction	-32,768 to 32,767	
6	SetSync delay	0 to 32,767	DelayedSetSync
7	UnSetSync delay	0 to 32,767	DelayedUnSetSync

Note: The Global Sample size is the number of position readings that will be used in by the WaitPosition calculations (see WaitPositionXY and WaitPosition).

Note: The gain and offset variables are the correction factors to be applied to the position readings so it will agree with the axis position register values that are sent to the SAX.

SetConfigVar

Binary Interface:

Command Byte: 0x30

Parameters: 4 bytes as (2) big endian unsigned words

Tick count: 1

Return Count: 0

Notes:

- Parameter value checking is not performed on this command.
- Gain values must be translated manually.
  gain is converted from a float to an integer by the following formula:

$$igain = \text{truncate}\,(32768 \times fgain)$$

Example: `'SetConfigVar 1 25' -> "3000010019"`

SetGSS

Command Description: Set the sample size of the position readback buffer.

Valid Run-time Modes					
Raster Mode	*Vector Mode*	*Dual Single Axis Mode*	*Program Instruction*	*Immediate Instruction*	*Concurrent Instruction*
YES	YES	NO	NO	YES	NO

Parameters

Buffer_Size Set the size of the position readback buffer to *Buffer_Size*.

$1 \leq Buffer\_Size \leq 100$

Syntax: `SetGSS` *`Buffer_Size`*

Note: The mnemonic used is **SetG**lobal**S**ample**S**ize

Note: Power on default value is the value saved in Flash.

SetGSS

Binary Interface:

Command Byte: 0x30

Parameters: 4 bytes as the constant 0x0001 and (1) unsigned word.

Tick count: 1

Return Count: 0

Notes:

Example: `'SetGSS 50' -> "3000010032"`

SetSetSyncDelay

Command Description: Set the global value of the tick delay for the DelayedSetSync command.

Valid Run-time Modes					
Raster Mode	*Vector Mode*	*Dual Single Axis Mode*	*Program Instruction*	*Immediate Instruction*	*Concurrent Instruction*
YES	YES	NO	NO	YES	NO

Parameters

delay Set the tick delay for the DelayedSetSync command to the value *delay*.

$0 \leq delay < 32767$

Syntax: `SetSetSyncDelay` *`delay`*

Note: Power on default value is the value saved in Flash.

SetSetSyncDelay

Binary Interface:

Command Byte: 0x30

Parameters: 4 bytes as the constant 0x0006 and (1) big endian unsigned word.

Tick count: 1

Return Count: 0

Notes:

Example: `'SetSetSyncDelay 31' -> "300006001F"`

SetUnsetSyncDelay

Command Description: Set global value of the tick delay for the DelayedUnsetSync command.

Valid Run-time Modes					
Raster Mode	*Vector Mode*	*Dual Single Axis Mode*	*Program Instruction*	*Immediate Instruction*	*Concurrent Instruction*
YES	YES	NO	NO	YES	NO

Parameters

delay Set the tick delay for the DelayedUnsetSync command to the value *delay*.

$0 \leq delay < 32767$

Syntax: `SetUnsetSyncDelay` *`delay`*

Note: Power on default value is the value saved in Flash.

SetUnsetSyncDelay

Binary Interface:

Command Byte: 0x30

Parameters: 4 bytes as the constant 0x0007 and (1) big endian unsigned word.

Tick count: 1

Return Count: 0

Notes:

Example: `'SetUnsetSyncDelay 31' -> "300007001F"`

SetXPRGain

Command Description: Set the value of the X-axis position readback correction coefficient.

Valid Run-time Modes					
Raster Mode	*Vector Mode*	*Dual Single Axis Mode*	*Program Instruction*	*Immediate Instruction*	*Concurrent Instruction*
YES	YES	NO	NO	YES	NO

Parameters

gain Set the X-axis position readback gain coefficient to the value *gain*.

$0.5 \leq gain \leq 1.5$

Syntax: `SetXPRGain` *`gain`*

Note: The mnemonic used is **SetXP**osition**R**eadback**Gain**

Note: Power on default value is the value saved n Flash.

SetXPRGain

Binary Interface:

Command Byte: 0x30

Parameters: 4 bytes as the constant 0x0002 and (1) big endian unsigned word.

Tick count: 1

Return Count: 0

Notes:

gain is converted from a float to an integer by the following formula:

$$igain = \text{truncate}\,(32768 \times fgain)$$

Example: `'SetXPRGain 1.1' -> "3000020000"`

SetXPROffset

Command Description: Set the value of the X-axis position readback correction constant.

Valid Run-time Modes					
Raster Mode	*Vector Mode*	*Dual Single Axis Mode*	*Program Instruction*	*Immediate Instruction*	*Concurrent Instruction*
YES	YES	NO	NO	YES	NO

Parameters

offset Set the value of the X-axis position readback offset correction to *offset*.

$-32768 \leq offset \leq 32767$

Syntax: `SetXPROffset` *`offset`*

Note: The mnemonic used is **SetXP**osition**R**eadback**Offset**

Note: Power on default value is the value saved in Flash.

SetXPROffset

Binary Interface:

Command Byte: 0x30

Parameters: 4 bytes as the constant 0x0003 and (1) big endian signed word.

Tick count: 1

Return Count: 0

Notes:

Example: `'SetXPROffset 102' -> "0900030066"`

SetYPRGain

Command Description: Set the value of the Y-axis position readback correction coefficient.

Valid Run-time Modes					
Raster Mode	*Vector Mode*	*Dual Single Axis Mode*	*Program Instruction*	*Immediate Instruction*	*Concurrent Instruction*
YES	YES	NO	NO	YES	NO

Parameters

gain Set the value of the Y-axis position readback correction coefficient to the value *gain*.

$0.5 \leq gain \leq 1.5$

Syntax: `SetYPRGain` *gain*

Note: The mnemonic used is **SetYP**osition**R**eadback**Gain**

Note: Power on default value is the value saved in Flash.

SetYPRGain

Binary Interface:

Command Byte: 0x30

Parameters: 4 bytes as the constant 0x0004 and (1) big endian unsigned word.

Tick count: 1

Return Count: 0

Notes:

gain is converted from a float to an integer by the following formula:

$$igain = \text{truncate}\,(32768 \times fgain)$$

Example: `'SetYPRGain 0.9' -> "300004"`

SetYPROffset

Command Description: Set the value of the Y-axis position readback offset correction.

Valid Run-time Modes					
Raster Mode	*Vector Mode*	*Dual Single Axis Mode*	*Program Instruction*	*Immediate Instruction*	*Concurrent Instruction*
YES	YES	NO	NO	YES	NO

Parameters

offset Set the value of the Y-axis position readback offset correction constant to *offset*.

$-32768 \leq offset \leq 32767$

Syntax: `SetYPROffset` *`offset`*

Note: The mnemonic used is **SetYP**osition**R**eadback**Offset**

Note: Power on default value is the value saved in Flash.

SetYPROffset

Binary Interface:

Command Byte: 0x30

Parameters: 4 bytes as the constant 0x0005 and (1) big endian signed word.

Tick count: 1

Return Count: 0

Notes:

Example: `'SetYPROffset -1740' -> "300005F92F"`

SetSync

Command Description: Sets the sync bit for the specified channel.

Valid Run-time Modes					
Raster Mode	*Vector Mode*	*Dual Single Axis Mode*	*Program Instruction*	*Immediate Instruction*	*Concurrent Instruction*
YES	YES	YES	YES	YES	NO

Parameters

channel_mask *channel_mask* specifies which one of the writable sync channels is to be set.

Syntax: `SetSync` *`channel_mask`*

channel_mask	*Meaning*
1	Sync Channel 1 (J4, pin 1 pulls low)
2	Sync Channel 2 (J4, pin 2 pulls low)
3	Sync Channel 3 (J4, pin 3 pulls low)
4	Sync Channel 4 (J4, pin 4 pulls low)
13	turns INTCNTL on
14	drives PCLKOUT output with the clock on CMOS_PCLK input pin

SetSync

Binary Interface:

Command Byte: 0x12

Parameters: 2 bytes as (1) big endian signed word.

Tick count: 0

Return Count: 0

Notes:

Example: `'SetSync 4' -> "120004"`

Slew

Command Description: Move smoothly to the given absolute position on the current axis in the specified number of tick counts.

Valid Run-time Modes					
Raster Mode	*Vector Mode*	*Dual Single Axis Mode*	*Program Instruction*	*Immediate Instruction*	*Concurrent Instruction*
YES	NO	YES	YES	YES	NO

Parameters

coord The absolute position on the current axis to slew to *coord*.

$-32768 \leq coord \leq 32767$

count The number of 23 μS ticks that it will take to complete the slew motion.

$1 \leq count \leq 32767$

Syntax: `Slew coord count`

Note: Gradually moves to the given x and y positions over *count* number of 23 μS ticks.

Slew

Binary Interface:

Command Byte: 0x05

Parameters: 4 bytes as (1) big endian signed word and (1) big endian unsigned word.

Tick count: value of *count*

Return Count: 0

Notes:

Example: `'Slew 5000 350' -> "051388015E"`

SlewXY

Command Description: Move smoothly to the given absolute vector position in the specified number of tick counts.

Valid Run-time Modes					
Raster Mode	*Vector Mode*	*Dual Single Axis Mode*	*Program Instruction*	*Immediate Instruction*	*Concurrent Instruction*
NO	YES	NO	YES	YES	NO

Parameters

x-coord The absolute position of the X-axis destination.

$-32768 \leq x\_coord \leq 32767$

y-coord The absolute position of the Y-axis destination.

$-32768 \leq y\_coord \leq 32767$

count *count* specifies the number of 23 μS ticks in which to smoothly move in a straight line.

$1 \leq count \leq 32767$

Syntax: `SlewXY` *`x-coord y-coord count`*

Note: Gradually moves to the given x and y positions over *count* number of 23 μS ticks.

SlewXY

Binary Interface:

Command Byte: 0x06

Parameters: 6 bytes as (2) big endian signed words and (1) big endian unsigned word.

Tick count: Value of *count*

Return Count: 0

Notes:

Example: `'SlewXY 5000 5000 450' -> "061388138801C2"`

TweakAxis

Command Description: Apply gain and offset to subsequent axis operations.

Valid Run-time Modes					
Raster Mode	*Vector Mode*	*Dual Single Axis Mode*	*Program Instruction*	*Immediate Instruction*	*Concurrent Instruction*
YES	NO	YES[1]	YES	YES	YES

Parameters

gain The gain factor is applied to the motion command coordinates of the current axis where a *gain* of 1.0 corresponds to the identity transformation.

$0.5 \leq gain \leq 1.5$

offset *offset* describes the offset of the origin of the current axis for motion commands.

$-32768 \leq offset \leq 32767$

Syntax: `TweakAxis` *`gain offset`*

Note: *TweakAxis* a raster mode command used to set the absolute gain and offset values of the current axis.

Note 1: *TweakAxis* may not be issued concurrent with Dual Single Axis mode but it may be a program instruction in either or both of the Dual Single axis programs.

TweakAxis

Binary Interface:

Command Byte: 0x1B

Parameters: 4 bytes as (1) big endian unsigned word and (1) big endian signed word.

Tick count: 1

Return Count: 0

Notes:

gain is converted from a float to an integer by the following formula:

$$igain = \text{truncate}\,(32768 \times fgain)$$

Example: `'TweakAxis 1.0 0' -> "1B80000000"`

TweakAxisXY

Command Description: Apply gain and offset to subsequent vector operations.

Valid Run-time Modes					
Raster Mode	*Vector Mode*	*Dual Single Axis Mode*	*Program Instruction*	*Immediate Instruction*	*Concurrent Instruction*
NO	YES	YES[1]	YES	YES	YES

Parameters

x-gain The gain factor is applied to the motion command coordinates of the X-axis where an *x-gain* of 1.0 corresponds to the identity transformation.

$0.5 \le x\_gain \le 1.5$

x-offset *x-offset* describes the offset of the origin of the X-axis for motion commands.

$-32768 \le x\_offset \le 32767$

y-gain The gain factor is applied to the motion command coordinates of the Y-axis where a *y-gain* of 1.0 corresponds to the identity transformation.

$0.5 \le y\_gain \le 1.5$

y-offset *y-offset* describes the offset of the origin of the Y-axis for motion commands.

$-32768 \le y\_offset \le 32767$

Syntax: `TweakAxisXY x-gain x-offset y-gain y-offset`

Note 1: *TweakAxisXY* may be issued concurrent with Dual Single Axis mode but may not be a program instruction contained in one of the Dual Single Axis mode programs.

Note: *TweakAxisXY* is a vector mode command used to set the gain and offset values for both the X and Y axis.

TweakAxisXY

Binary Interface:

Command Byte: 0x1C

Parameters: 8 bytes as (1) big endian unsigned word, (1) big endian signed word, (1) big endian unsigned word and (1) big endian signed word.

Tick count: 1

Return Count: 0

Notes:

gain is converted from a float to an integer by the following formula:

$$igain = \text{truncate}\,(32768 \times fgain)$$

Example: `'TweakAxisXY 1.0 0 1.0 0' -> "1C8000000080000000"`

UnSetSync

Command Description: Resets the Sync bit for the specified channel.

Valid Run-time Modes					
Raster Mode	*Vector Mode*	*Dual Single Axis Mode*	*Program Instruction*	*Immediate Instruction*	*Concurrent Instruction*
YES	YES	YES	YES	YES	NO

Parameters

channel_mask *channel_mask* specifies which one of the writable sync channels is to be reset. Valid numbers for *channel_mask* are 1, 2, 3, 4, 13, and 14.

channel_mask	*Meaning*
1	Sync Channel 1 (J4, pin 1 high impedance)
2	Sync Channel 2 (J4, pin 2 high impedance)
3	Sync Channel 3 (J4, pin 3 high impedance)
4	Sync Channel 4 (J4, pin 4 high impedance)
13	turns INTCNTL of
14	Disconnects PCLKOUT output from the clock on CMOS_PCLK input pin

Syntax: `UnsetSync` *`channel_mask`*

UnsetSync

Binary Interface:

Command Byte: 0x13

Parameters: 2 bytes as (1) big endian signed word.

Tick count: 1

Return Count: 0

Notes:

Example: `'UnsetSync 4' -> "130004"`

Vector

Command Description: Place the Scan Controller in vector mode.

Valid Run-time Modes					
Raster Mode	*Vector Mode*	*Dual Single Axis Mode*	*Program Instruction*	*Immediate Instruction*	*Concurrent Instruction*
YES	YES	NO	NO	YES	NO

Parameters

(none)

Syntax: `Vector`

Note: The **Vector** command is used to change the operational mode of the Scan Controller to Vector operations. In the **Vector** mode, the Scan Controller will only accept motion commands of type vector, commands that have the XY suffix. Also, only programs of type 1 can be executed with the **ExecutePgm** command. Raster programs can be executed from vector mode with the **ExecuteRaterPgm** command.

Vector

Binary Interface:

Command Byte: 0x1A

Parameters: None

Tick count: 1

Return Count: 0

Notes:

Example: `'Vector' -> "1A"`

Wait

Command Description: Pause execution for the given number of tick counts.

Valid Run-time Modes					
Raster Mode	*Vector Mode*	*Dual Single Axis Mode*	*Program Instruction*	*Immediate Instruction*	*Concurrent Instruction*
YES	YES	YES	YES	YES	NO

Parameters

wait_count Pause execution of commands, either immediate or in a program, for count number of 23 µS tick. Count is a number between 0 and 4294967296.

Syntax: `Wait` *`wait_count`*

Wait

Binary Interface:

Command Byte: 0x10

Parameters: 4 bytes as (1) middle endian double word.

Tick count: Value of *count*

Return Count: 0

Notes:

Example: 'Wait 56000' -> "10DAC00000"

```
                    Given 0x 00  00  DA  C0
                              1 | 2 | 3 | 4
          send the bytes in the order  3 4 1 2
```

WaitPosition

Command Description: Pause Scan Controller program execution until the commanded position for the current axis is reached.

Valid Run-time Modes					
Raster Mode	*Vector Mode*	*Dual Single Axis Mode*	*Program Instruction*	*Immediate Instruction*	*Concurrent Instruction*
YES	NO	YES	YES	YES	NO

Parameters

dev *dev* is the deviation limit, in DAC counts, about the target X-axis position.

Syntax: `WaitPosition dev`

Note: The computed deviation is the size of the *window* around the commanded position it takes the form of

$$dev_{RMS} = \sqrt{\sum_{1}^{n}\left(Pos_{Target} - Pos_{n}\right)^{2} / n}$$

with n being the value of the global sample size parameter (see configuration settings). The larger the value of n the better rejection of overshoot of the galvo's position but the slower the response. If the user wants to act on the current position reading n can be set to 1. Program execution stops at the WaitPosition command until $dev < dev_{RMS}$.

Note: When using WaitPosition in dual single axis mode, remember each axis program will move on when the position for it's axis meets the specified requirement. This will not keep the axis program in sync. In fact it may very well cause them to lose sync if there has been an effort to synchronize them.

Example: If the user wants a ±10 count window averaged over five 23µS readings, set the deviation to 10 and the sample size to 5.

WaitPosition

Binary Interface:

Command Byte: 0x32

Parameters: 2 bytes as (1) big endian word.

Tick count: dependent on servo

Return Count: 0

Notes:

Example: `'WaitPosition 1500' -> "3205DC"`

WaitPositionXY

Command Description: Pause Scan Controller program execution until the commanded position is reached.

Valid Run-time Modes					
Raster Mode	*Vector Mode*	*Dual Single Axis Mode*	*Program Instruction*	*Immediate Instruction*	*Concurrent Instruction*
NO	YES	NO	YES	YES	NO

Parameters

X-dev *X-dev* is the deviation value about the target X-axis position.

Y-dev *Y-dev* is the deviation value about the target Y-axis position.

Syntax: `WaitPositionXY X-dev Y-dev`

Note: The computed deviation is the size of the *window* around the commanded position it takes the form of

$$dev_{RMS} = \sqrt{\sum_{1}^{n}\left(Pos_{T\arg et} - Pos_{n}\right)^{2} / n}$$

with n being the value of the global sample size parameter (see configuration settings). The larger the value of n the better rejection of overshoot of the galvo's position but the slower the response. If the user wants to act on the current position reading n can be set to 1. Program execution stops at the WaitPosition command until $dev < dev_{RMS}$ for both axis'.

Note: When using WaitPosition in dual single axis mode, remember each axis program will move on when the position for its axis meets the specified requirement. This will not keep the axis program in sync. In fact it may very well cause them to lose sync if there has been an effort to synchronize them.

Example: If the user wants a ±10 count window averaged over 5 23µSec readings, set the deviation to 10 and the sample size to 5.

WaitPositionXY

Binary Interface:

Command Byte: 0x31

Parameters: 4 bytes as (2) big endian words.

Tick count: dependent on servo

Return Count: 0

Notes:

Example: `'WaitPositionXY 2000 -4000' -> "3107D0F060"`

WaitSync

Command Description: Pause Scan Controller program execution until the specified sync channel is set.

Valid Run-time Modes					
Raster Mode	*Vector Mode*	*Dual Single Axis Mode*	*Program Instruction*	*Immediate Instruction*	*Concurrent Instruction*
YES	YES	YES	YES	YES	NO

Parameters

sync_channel *sync_channel* specifies which one of the readable sync channels shall be used to operate the **WaitSync** command.

sync_channel	*Meaning*
1	Pause execution until a setsync 1 command is executed.
2	Pause execution until a setsync 2 command is executed.
3	Pause execution until a setsync 3 command is executed.
4	Pause execution until a setsync 4 command is executed.
5	Pause execution until J4, pin 6 goes high
6	Pause execution until J4, pin 7 goes high
7	Pause execution until J4, pin 8 goes high
8	Pause execution until J4, pin 9 goes high
9	Pause execution until J4, pin 10 goes high
10	Pause execution until J4, pin 11 goes high
11	Pause execution until J4, pin 12 goes high
12	Pause execution until J4, pin 13 goes high

Syntax: `WaitSync` *`sync_channel`*

WaitSync

Binary Interface:

Command Byte: 0x11

Parameters: 2 bytes as (1) big endian signed word.

Tick count: if sync channel is true tick count = 0, if sync channel is false count = real time.

Return Count: 0

Notes:

Example: `'WaitSync 5' -> "110005"`

Binary Command Format:

Operating Command Syntax	8 Bit ID [3]		16 Bit Value	16 Bit Value	16 Bit Value	16 Bit Value
	Dec	hex				
Position <pos>	1	1	position			
PositionXY <x pos> <y pos>	2	2	X position	Y position		
DeltaPosition <rel pos>	3	3	rel position			
DeltaPositionXY <x rel pos> <y rel pos>	4	4	X rel pos	Y rel pos		
Slew <position> <count>	5	5	position	Count		
SlewXY <x pos> <y pos> <count>	6	6	X position	Y position	count	
DeltaSlew <rel pos> <count>	7	7	rel position	count		
DeltaSlewXY <x rel pos> <y rel pos> <count>	8	8	X rel pos	Y rel pos	count	
Repeat	9	9				
If <channel> ExecutePgm <pgm-id>	10	A	channel	pgm id		
If <channel> ExecuteRasterPgm <pgm-id> <pgm-id>	11	B	channel	X pgm-id	Y pgm id	
If TempOK<device> ExecutePgm <pgm-id>	12	C	device	pgm id		
If TempOK<device> ExecuteRasterPgm <X-id><Y-id>	13	D	device	X pgm-id	Y pgm id	
ExecutePgm <pgm-id>	14	E	pgm id			
ExecuteRasterPgm <x-axis pgm-id> <y-axis pgm-id>	15	F	X pgm-id	Y pgm id		
Wait <count>	16	10	lo-count	hi-count		
WaitSync <channel>	17	11	channel			
SetSync <channel>	18	12	channel			
UnSetSync <channel>	19	13	channel			
Enable <device number>	20	14	device			
Disable <device number>	21	15	device			
DeltaTweakAxis	23	17	Inc gain	Inc offset		
DeltaTweakAxisXY	24	18	Inc x-gain	Inc x-offset	Inc y-gain	Inc y-offset
TweakAxis <gain> <offset>	27	1B	<gain>	<offset>		
TweakAxisXY <xgain> <xoffset> <ygain><yoffset>	28	1C	<xgain>	<xoffset>	<ygain>	<yoffset>
ConfigPixelClock	29	1D	<bytes 1,2>	<bytes 3,4>	<bytes 5,6>	
AbortPgm	32	20				
ComConfig <1><2><3><4><5><6>	35	23	<baud>	<data bits>	<stop bits>	<parity><*>
ExitPgm	37	25				
WaitPositionXY <X-deviation> <Y-deviation>	49	31	<x-devia>	<y-devia>		
WaitPosition <deviation>	50	32	<deviatio>			
DelayedSetSync <channel>	54	36	channel			
DelayedUnsetSync <channel>	55	37	channel			
Nrepeat <r-count>	56	38	r-count			

[3] Command ID is 8 bits when received over the communication link. When fetched from byte memory it is 16 bits.

User Command Syntax	8 Bit ID [2]		16 Bit Value	16 Bit Value	16 Bit Value	16 Bit Value
	dec	Hex				
End	22	16	CRC lo	CRC hi		
Raster <axis>	25	19	1- x 2 - y			
Vector	26	1A				
CreateFlashPgm <type><pgm id>	30	1E	<pgm type>	<pgm id>		
PackMemory	31	1F				
CreatePgm <type><pgm id>	33	21	<pgm type>	<pgm id>		
ReleasePgm	34	22	<pgm id>			
?FreeFlashSpace	38	26				
?FreeRAMSpace	39	27				
?ID	41	29				
?Position <axis>	42	2A	1- x 2 - y			
?Temp	43	2B				
?TempOK <device number>	44	2C	<device>			
?OpticalCal	45	2D				
SetConfigVar <Id> <value>	48	30	<Id>	<value>		
SetGSS <length>	48	30	1	<length>		
SetXPROffset <offset>	48	30	2	<offset>		
SetXPRGain <gain>	48	30	3	<gain>		
SetYPROffset <offset>	48	30	4	<offset>		
SetYPRGain <gain>	48	30	5	<gain>		
SetSetSyncDelay	48	30	6	<t-delay>		
SetUnsetSyncDelay	48	30	7	<t-delay>		
SaveConfigInFlash	53	35				
?Sync	57	39				
?Status	255	FF	0xFFFF	0xFFFF	0xFFFF	0xFFFF

When a program is running, only the highlighted commands may be issued by the user.
Any other command will cause an error.

<*> - more bytes to follow

[2] See footnote prev page

Scan Controller error codes

0	"Success."
1	"Type argument not 0 or 1."
2	"Not in raster mode."
3	"X-Axis Program is not of type Raster"
4	"Y-Axis Program is not of type Raster."
5	"Program is not of type Raster"
6	"Not in vector mode."
7	"Program is not of type Vector"
8	"Invalid channel number"
9	"Invalid channel number"
10	"Axis argument not 1 or 2."
12	"Invalid device number."
13	"X-Axis Program ID not in the range 1 - 255."
14	"Y-Axis Program ID not in the range 1 - 255."
15	"Program ID not in the range 1 - 255."
16	"Y-Axis Program ID is marked as inactive."
17	"Program ID is marked as inactive."
18	"Program ID is unassigned."
19	"X-Axis Program ID is marked as inactive."
20	"Another program is already running."
21	" Illegal command while a program is running.”
22	"Illegal data bits."
23	"Unsupported baud rate."
24	"Illegal media type."
26	"Illegal stop bits."
27	"Illegal parity."
28	"Unknown command number encountered."
29	"PIR UART Line Status Error."

30 "BDMA Read Queue Overflow."

31 "Stack Overflow - caused when program nesting too deep."

32 "Stack Underflow."

33 "Repeat command not issued from a command file."

34 "Dispatch Queue Overflow."

35 "Out Of Flash Memory."

36 "Out Of SRAM Memory."

37 "Out of Flash Memory Allocation Table Space."

38 "Out of SRAM Memory Allocation Table Space."

39 "Computed CRC did not match received CRC."

40 "Startup encountered an unknown command."

41 "Cannot write to memory, memory locked."

42 "Invalid Id."

43 "Parameter out of range."

44 " X Axis SAX not ready"

45 " Y Axis SAX not ready"

46 " Sync Queue Overflow"

47 " Command is not legal in a program"

48 " Command is not an immediate command"

49 " RS-485 not yet supported"

Binary Interface Definition

This section defines the relationship between the Scan Controller Assembly language and the binary machine language transmitted to the SC2000 Scan Controller.

```
#%%DI assembler syntax file%%
#Author: Fred Stewart
#Date 9-16-99

####  Format of command description record ###

# field 1: command text
# field 2: number of input parameters
# field 3: binary ID
# field 4: input parameter and implicit parameter format strings
# field 5: command execution context
# field 6: number of bytes to read back
# field 7: readback interpretation
# field 8: binary format string

#######################################

######### Field descriptions ############

# Field 1: command text
# Abstract: The text of the command as a collection index. Note that
#           multi-word statements are mangled down to one word my removing
#           all intervening parameters and whitespace. The 'command text'
#           is downcased when the syntax file is read into the assembler.
#          Note, all commands are sent as BYTE

# Field 2: number of input parameters
# Abstract: The number of parameters that the command takes. Note that
#           all parameters are required. The end statement has an implicit
#           parameter (CRC value) that does not appear in the source line.

# Field 3: binary ID
# Abstract: The byte representation of the machine code. This is a decimal number.

# Field 4: parameter format string
# Abstract: This is a quoted string with tokens separated by whitespace. The number
#           of token is equal to the number of parameters that the command accepts.
#           The token format for each parameter consists of enumerated type tokens
#          separated by a '%' token separator. Each parameter token is composed of
#          three enumerated type tokens that specify the following attributes in the
#           following order: 'Type of parameter' , 'binary format' , 'addressing mode'.

#### Type of parameter
# Abstract: Describes what the parameter is, used for bounds check of input variables.

# type explainations
#-> UNDEFINED  This will generate an assembler error.
#-> STRING     This is byte data, not accepted by the scan controller at this time
#-> LENGTH     This is an asciiz string preamble, not accepted by the scan controller at this time
#-> CRC        This is a CRC checksum of a Scan Controller program. It can have two values:
#->             1. A value of 0xFFFFFF is the default checksum and is ignored.
#->             2. A computed CRC checksum. The computation of the CRC checksum is illustrated
#->                in the source code crctable.c and the corresponding program crc-gen.exe .
#-> COUNT      This is a 1 byte tick count value for slew commands. 0 - 32767
#-> SN         This is a serial number, not accepted by the scan controller at this time
#-> COMTYPE    Communications interface. This value is always 232.
#-> PARITY     Number of parity bits. 0 - none, 1 - odd, 2 - even
#-> STOPBITS   Number of stop bits 1 or 2
#-> DATABITS   Number of data bits. This value is always 8.
#-> SYNCDELAY   Latency, in ticks, for operation of delayedsetsync and delayedunsetsync.  0 - 32767

#-> BAUD              baud rate
# baud rate specifier
```

```
# val  baud
# 1 - 2400
# 2 - 4800
# 3 - 9600
# 4 - 19200
# 5 - 38400
# 6 - 57600
# 7 - 115200

#-> AXIS       Axis specifier 1 - X axis, 2 - Y axis
#-> PGMTYPE    Program type, 0 - raster program , 1 - vector program.
#-> DEVICEID   Device ID. 1 - X axis, 2 - Y axis, 3 - both axis.
#-> RASTERVAL  Raster mode target axis, 1 - x axis, 2 - y axis
#-> PGMID      Program name, 1-255
#-> RELPOS     Relative position -32768 - 32767
#-> ABSPOS     Absolute position -32768 - 32767
#-> RELOFFSET  Relative offset -32768 - 32767

#-> GAIN       Gain value 0.5 - 1.5 in an assembly language statement.
# To convert the floating point gain value to an integer, multiply the gain by 32768
# and retain the integer part of the result. Use the integer in the binary comand to the
# scan controller.

#-> GSS        global sample size  1 - 100

#-> CHANMASK   Channel mask 1 - 4, 13, 14
#-> CHANID     Channel id 1 - 12, 13, 14
#-> DBLWORD    double word data, 4 bytes
#-> WORD       word data, 2 bytes
#-> BYTE       byte data
#-> CONST      constant value, not used

#### binary format
# Abstract: Describes how to format a multi-byte number for serial transmission. Note,
#           this section has some notation problems, the descriptions match the formatting
#           for the machine but the description labels do not make sense outside of my
#           context, for example LEWORD is formatted as a big endian word, but the label
#           really means little endian.

#type explainations
#-> BYTE               not used
#-> LEWORD     big endian, two byte value, send MSB first, LSB last.
#-> BEWORD     not used
#-> LEDBLWORD  middle endian, 4 byte value
#              Given 0x 00  01  FF  FE
#                       1 | 2 | 3 | 4
#              Send the bytes in the order 3 4 1 2

#-> BEDBLWORD  not used


##### addressing mode
# Abstract: the only addressing mode for parameters is immediate.

#type explainations
#-> IMM: immeadiate addressing mode. The actual value of the parameter is sent.


# Field 5: command execution context
# Abstract: The context a assembler operation for this command. Some commands
#           cannot be executed from within a program. For these commands, the
#           assembler will generate an error. The token is a list of enumerated
#           tokens separated by '|' the or connector. The or connector signifies
#           that the command may be assembled in multiple contexts.

#type explainations
#-> ASMR: program context, commands in a raster program.
#-> ASMV: program context, commands in a vector program.
#-> INT: interpreter context, allows all commands for the Scan Controller.
#-> TST: a command designed to test the assembler, not sent to the Scan Controller.
#-> DIS: disallowed command, command is never translated, assembler generates an error.


# Field 6: number of bytes to read back
# Abstract: The number of bytes to read back from the Scan Controller. This is used
```

```
#           to in conjunction with query commands that collect and interpret
#           data from the Scan Controller. This is a decimal number.


# Field 7: readback interpretation
# Abstract: Method of interpreting the data read back from the Scan Controller. Consists
#           of a single enumerated type token.

# type explainations
###-> MEMINSPECT              Program listing, currently undefined.

###-> MEMSPACE         Available memory space value.
# Big endian double word, 4 byte value
#              Given 0x 00  01  FF  FE
#                        1 | 2 | 3 | 4
#              get the bytes in the order 1 2 3 4

###-> IDVAL            ID value.
#  2 bytes     Boot Segment Revision           <byte 1> . <byte 2>
#  2 bytes     Firmware Revision (default 1.0) <byte 3> . <byte 4>
#  1 byte      Hardware (default 0)            <byte 5>
#  1 byte      Device ID (default 0)           <byte 6>

###-> OCALVAL          Optical Calibration value.
#              X-Axis Output Pos      Y-Axis Output Pos      X-Axis Read Pos        Y-Axis Read Pos
       X-Axis System Gain     X-Axis System Offset   Y-Axis System Gain     Y-Axis System Offset
#Channel 9     Word 1                 Word 2                 Word 3         Word 4          Word 5
               Word 6                 Word 7                 Word 8
#Channel 10    Word 9                 Word 10                Word 11        Word 12         Word 13
               Word 14                Word 15                Word 16
#Channel 11    Word 17                Word 18                Word 19        Word 20         Word 21
               Word 22                Word 23                Word 24
#Channel 12    Word 25                Word 26                Word 27        Word 28         Word 29
               Word 30                Word 31                Word 32


###-> POSVAL           Position value. 1 word, each word is two bytes, MSB first, LSB last


###-> SYNCVAL           Sync readback value. 1 word, each word is two bytes, MSB first, LSB last
#   bit  0: sync 1
#   bit  1: sync 2
#   bit  2: sync 3
#   bit  3: sync 4
#   bit  4: sync 5
#   bit  5: sync 6
#   bit  6: sync 7
#   bit  7: sync 8
#   bit  8: sync 9
#   bit  9: sync 10
#   bit 10: sync 11
#   bit 11: sync 12
#   bit 12: sync 13 (inverted sense)
#   bit 13: sync 14
#   bit 14: Y axis servo ready
#   bit 15: X axis servo ready


###-> ERRORVAL         Error report from ?status command.
## 3 words, each word is two bytes, MSB first, LSB last
# word 1: Function/Program ID
#     0        error in PIR (communications)
#     1 - 255  error from program (pgm ID)
#     9999     system error

# word 2: Command Number (the command value as a word instead of a byte)
# word 3: Error Number (See Const.h for error code definitions.)


###-> SYSDATA          System data, this is currently undefined.

###-> TEMPVAL          Temperature value
# 4 words, each word is two bytes, MSB first, LSB last.
#  word 1: x-axis servo temperature
#  word 2: x-axis alternate servo temperature
```

```
#  word 3: y-axis servo temperature
#  word 4: y-axis alternate servo temp


###-> BOOLEAN          Boolean value, 2 bytes, MSB first, LSB last, value 0 or 1
###-> NONE             No readback context, bytes are thrown away.
###-> UNDEFINED               Generates an assembler error.


# Field 8: binary format string
# Abstract: This is included as a pathetic hack for the end statement. The data is
#           a quoted CSV string.

#operational commands
Position:1:1:"ABSPOS%LEWORD%IMM":INT|ASMR:0:NONE:"1"
PositionXY:2:2:"ABSPOS%LEWORD%IMM ABSPOS%LEWORD%IMM":INT|ASMV:0:NONE:"2"
DeltaPosition:1:3:"RELOFFSET%LEWORD%IMM":INT|ASMR:0:NONE:"3"
DeltaPositionXY:2:4:"RELOFFSET%LEWORD%IMM RELOFFSET%LEWORD%IMM":INT|ASMV:0:NONE:"4"
Slew:2:5:"ABSPOS%LEWORD%IMM COUNT%LEWORD%IMM":INT|ASMR:0:NONE:"5"
SlewXY:3:6:"ABSPOS%LEWORD%IMM ABSPOS%LEWORD%IMM COUNT%LEWORD%IMM":INT|ASMV:0:NONE:"6"
DeltaSlew:2:7:"RELOFFSET%LEWORD%IMM COUNT%LEWORD%IMM":INT|ASMR:0:NONE:"7"
DeltaSlewXY:3:8:"RELOFFSET%LEWORD%IMM RELOFFSET%LEWORD%IMM COUNT%LEWORD%IMM":INT|ASMV:0:NONE:"8"
Repeat:0:9:"":ASMR|ASMV:0:NONE:"9"
Ifexecutepgm:2:10:"CHANID%LEWORD%IMM PGMID%LEWORD%IMM":INT|ASMR|ASMV:0:NONE:"10"
Ifexecuterasterpgm:3:11:"CHANID%LEWORD%IMM PGMID%LEWORD%IMM PGMID%LEWORD%IMM":INT|ASMV:0:NONE:"11"
Iftempokexecutepgm:2:12:"DEVICEID%LEWORD%IMM PGMID%LEWORD%IMM":INT|ASMR|ASMV:0:NONE:"12"
Iftempokexecuterasterpgm:3:13:"DEVICEID%LEWORD%IMM PGMID%LEWORD%IMM
PGMID%LEWORD%IMM":INT|ASMV:0:NONE:"13"
ExecutePgm:1:14:"PGMID%LEWORD%IMM":INT|ASMR|ASMV:0:NONE:"14"
ExecuteRasterPgm:2:15:"PGMID%LEWORD%IMM PGMID%LEWORD%IMM":INT|ASMV:0:NONE:"15"
Wait:1:16:"DBLWORD%LEDBLWORD%IMM":INT|ASMR|ASMV:0:NONE:"16"
WaitSync:1:17:"CHANID%LEWORD%IMM":INT|ASMR|ASMV:0:NONE:"17"
SetSync:1:18:"CHANMASK%LEWORD%IMM":INT|ASMR|ASMV:0:NONE:"18"
UnSetSync:1:19:"CHANMASK%LEWORD%IMM":INT|ASMR|ASMV:0:NONE:"19"
Enable:1:20:"DEVICEID%LEWORD%IMM":INT|ASMR|ASMV:0:NONE:"20"
Disable:1:21:"DEVICEID%LEWORD%IMM":INT|ASMR|ASMV:0:NONE:"21"
End:0:22:"CRC%BEDBLWORD%IMM":ASMR|ASMV:0:NONE:"22"
DeltaTweakAxis:2:23:"GAIN%LEWORD%IMM RELOFFSET%LEWORD%IMM":INT|ASMR:0:NONE:"23"
DeltaTweakAxisXY:4:24:"GAIN%LEWORD%IMM RELOFFSET%LEWORD%IMM GAIN%LEWORD%IMM
RELOFFSET%LEWORD%IMM":INT|ASMV:0:NONE:"24"
Raster:1:25:"RASTERVAL%LEWORD%IMM":INT:0:NONE:"25"
Vector:0:26:"":INT:0:NONE:"26"
TweakAxis:2:27:"GAIN%LEWORD%IMM RELOFFSET%LEWORD%IMM":INT|ASMR:0:NONE:"27"
TweakAxisXY:4:28:"GAIN%LEWORD%IMM RELOFFSET%LEWORD%IMM GAIN%LEWORD%IMM
RELOFFSET%LEWORD%IMM":INT|ASMV:0:NONE:"28"
ConfigPixelClock:6:29:"BYTE%BYTE%IMM BYTE%BYTE%IMM BYTE%BYTE%IMM BYTE%BYTE%IMM BYTE%BYTE%IMM
BYTE%BYTE%IMM":INT|ASMV|ASMR:0:NONE:"29"
CreateFlashPgm:2:30:"PGMTYPE%LEWORD%IMM PGMID%LEWORD%IMM":INT:0:NONE:"30"
PackMemory:0:31:"":INT:0:NONE:"31"
AbortPgm:0:32:"":INT|ASMV|ASMR:0:NONE:"32"
CreatePgm:2:33:"PGMTYPE%LEWORD%IMM PGMID%LEWORD%IMM":INT:0:NONE:"33"
ReleasePgm:1:34:"PGMID%LEWORD%IMM":INT:0:NONE:"34"
ComConfig:5:35:"BAUD%LEWORD%IMM DATABITS%LEWORD%IMM STOPBITS%LEWORD%IMM PARITY%LEWORD%IMM
COMTYPE%LEWORD%IMM":INT|ASMV|ASMR:0:NONE:"35"
ExitPgm:0:37:"":INT|ASMV|ASMR:0:NONE:"37"
?FreeFlashSpace:0:38:"":INT:4:MEMSPACE:"38"
?FreeRAMSpace:0:39:"":INT:4:MEMSPACE:"39"
?ID:0:41:"":INT:6:IDVAL:"41"
?Position:1:42:"AXIS%LEWORD%IMM":INT:2:POSVAL:"42"
?Temp:0:43:"":INT:8:TEMPVAL:"43"
?TempOK:1:44:"DEVICEID%LEWORD%IMM":INT:2:BOOLEAN:"44"
?OpticalCal:0:45:"":INT:64:OCALVAL:"45"
SetConfigVar:2:48:"WORD%LEWORD%IMM WORD%LEWORD%IMM":INT:0:NONE:"48"
SetGSS:1:48:"GSS%LEWORD%IMM":INT:0:NONE:"48,0,1"
SetXPRGain:1:48:"GAIN%LEWORD%IMM":INT:0:NONE:"48,0,2"
SetXPROffset:1:48:"RELOFFSET%LEWORD%IMM":INT:0:NONE:"48,0,3"
SetYPRGain:1:48:"GAIN%LEWORD%IMM":INT:0:NONE:"48,0,4"
SetYPROffset:1:48:"RELOFFSET%LEWORD%IMM":INT:0:NONE:"48,0,5"
SetSetSyncDelay:1:48:"SYNCDELAY%LEWORD%IMM":INT:0:NONE:"48,0,6"
SetUnsetSyncDelay:1:48:"SYNCDELAY%LEWORD%IMM":INT:0:NONE:"48,0,7"
WaitPositionXY:2:49:"WORD%LEWORD%IMM WORD%LEWORD%IMM":INT|ASMV:0:NONE:"49"
WaitPosition:1:50:"WORD%LEWORD%IMM":INT|ASMR:0:NONE:"50"
SaveConfigInFlash:0:53:"":INT:0:NONE:"53"
?Status:0:255:"":INT:6:ERRORVAL:"255,255,255,255,255,255,255,255,255"
```

```
DelayedSetSync:1:54:"CHANMASK%LEWORD%IMM":INT|ASMR|ASMV:0:NONE:"54"
DelayedUnsetSync:1:55:"CHANMASK%LEWORD%IMM":INT|ASMR|ASMV:0:NONE:"55"
NRepeat:1:56:"WORD%LEWORD%IMM":ASMR|ASMV:0:NONE:"56"
?Sync:0:57:"":INT:2:SYNCVAL:"57"
```

Program to generate CRC

```
/* CreatePGM statement and End statement are not included in the CRC checksum.*/

#include <ctype.h>
#include <stdio.h>
#include <stdlib.h>

unsigned int CRCtable[] = {
    0x00000000, 0x77073096, 0xEE0E612C, 0x990951BA, 0x076DC419, 0x706AF48F,
    0xE963A535, 0x9E6495A3, 0x0EDB8832, 0x79DCB8A4, 0xE0D5E91E, 0x97D2D988,
    0x09B64C2B, 0x7EB17CBD, 0xE7B82D07, 0x90BF1D91, 0x1DB71064, 0x6AB020F2,
    0xF3B97148, 0x84BE41DE, 0x1ADAD47D, 0x6DDDE4EB, 0xF4D4B551, 0x83D385C7,
    0x136C9856, 0x646BA8C0, 0xFD62F97A, 0x8A65C9EC, 0x14015C4F, 0x63066CD9,
    0xFA0F3D63, 0x8D080DF5, 0x3B6E20C8, 0x4C69105E, 0xD56041E4, 0xA2677172,
    0x3C03E4D1, 0x4B04D447, 0xD20D85FD, 0xA50AB56B, 0x35B5A8FA, 0x42B2986C,
    0xDBBBC9D6, 0xACBCF940, 0x32D86CE3, 0x45DF5C75, 0xDCD60DCF, 0xABD13D59,
    0x26D930AC, 0x51DE003A, 0xC8D75180, 0xBFD06116, 0x21B4F4B5, 0x56B3C423,
    0xCFBA9599, 0xB8BDA50F, 0x2802B89E, 0x5F058808, 0xC60CD9B2, 0xB10BE924,
    0x2F6F7C87, 0x58684C11, 0xC1611DAB, 0xB6662D3D, 0x76DC4190, 0x01DB7106,
    0x98D220BC, 0xEFD5102A, 0x71B18589, 0x06B6B51F, 0x9FBFE4A5, 0xE8B8D433,
    0x7807C9A2, 0x0F00F934, 0x9609A88E, 0xE10E9818, 0x7F6A0DBB, 0x086D3D2D,
    0x91646C97, 0xE6635C01, 0x6B6B51F4, 0x1C6C6162, 0x856530D8, 0xF262004E,
    0x6C0695ED, 0x1B01A57B, 0x8208F4C1, 0xF50FC457, 0x65B0D9C6, 0x12B7E950,
    0x8BBEB8EA, 0xFCB9887C, 0x62DD1DDF, 0x15DA2D49, 0x8CD37CF3, 0xFBD44C65,
    0x4DB26158, 0x3AB551CE, 0xA3BC0074, 0xD4BB30E2, 0x4ADFA541, 0x3DD895D7,
    0xA4D1C46D, 0xD3D6F4FB, 0x4369E96A, 0x346ED9FC, 0xAD678846, 0xDA60B8D0,
    0x44042D73, 0x33031DE5, 0xAA0A4C5F, 0xDD0D7CC9, 0x5005713C, 0x270241AA,
    0xBE0B1010, 0xC90C2086, 0x5768B525, 0x206F85B3, 0xB966D409, 0xCE61E49F,
    0x5EDEF90E, 0x29D9C998, 0xB0D09822, 0xC7D7A8B4, 0x59B33D17, 0x2EB40D81,
    0xB7BD5C3B, 0xC0BA6CAD, 0xEDB88320, 0x9ABFB3B6, 0x03B6E20C, 0x74B1D29A,
    0xEAD54739, 0x9DD277AF, 0x04DB2615, 0x73DC1683, 0xE3630B12, 0x94643B84,
    0x0D6D6A3E, 0x7A6A5AA8, 0xE40ECF0B, 0x9309FF9D, 0x0A00AE27, 0x7D079EB1,
    0xF00F9344, 0x8708A3D2, 0x1E01F268, 0x6906C2FE, 0xF762575D, 0x806567CB,
    0x196C3671, 0x6E6B06E7, 0xFED41B76, 0x89D32BE0, 0x10DA7A5A, 0x67DD4ACC,
    0xF9B9DF6F, 0x8EBEEFF9, 0x17B7BE43, 0x60B08ED5, 0xD6D6A3E8, 0xA1D1937E,
    0x38D8C2C4, 0x4FDFF252, 0xD1BB67F1, 0xA6BC5767, 0x3FB506DD, 0x48B2364B,
    0xD80D2BDA, 0xAF0A1B4C, 0x36034AF6, 0x41047A60, 0xDF60EFC3, 0xA867DF55,
    0x316E8EEF, 0x4669BE79, 0xCB61B38C, 0xBC66831A, 0x256FD2A0, 0x5268E236,
    0xCC0C7795, 0xBB0B4703, 0x220216B9, 0x5505262F, 0xC5BA3BBE, 0xB2BD0B28,
    0x2BB45A92, 0x5CB36A04, 0xC2D7FFA7, 0xB5D0CF31, 0x2CD99E8B, 0x5BDEAE1D,
    0x9B64C2B0, 0xEC63F226, 0x756AA39C, 0x026D930A, 0x9C0906A9, 0xEB0E363F,
    0x72076785, 0x05005713, 0x95BF4A82, 0xE2B87A14, 0x7BB12BAE, 0x0CB61B38,
    0x92D28E9B, 0xE5D5BE0D, 0x7CDCEFB7, 0x0BDBDF21, 0x86D3D2D4, 0xF1D4E242,
    0x68DDB3F8, 0x1FDA836E, 0x81BE16CD, 0xF6B9265B, 0x6FB077E1, 0x18B74777,
    0x88085AE6, 0xFF0F6A70, 0x66063BCA, 0x11010B5C, 0x8F659EFF, 0xF862AE69,
    0x616BFFD3, 0x166CCF45, 0xA00AE278, 0xD70DD2EE, 0x4E048354, 0x3903B3C2,
    0xA7672661, 0xD06016F7, 0x4969474D, 0x3E6E77DB, 0xAED16A4A, 0xD9D65ADC,
    0x40DF0B66, 0x37D83BF0, 0xA9BCAE53, 0xDEBB9EC5, 0x47B2CF7F, 0x30B5FFE9,
    0xBDBDF21C, 0xCABAC28A, 0x53B39330, 0x24B4A3A6, 0xBAD03605, 0xCDD70693,
    0x54DE5729, 0x23D967BF, 0xB3667A2E, 0xC4614AB8, 0x5D681B02, 0x2A6F2B94,
    0xB40BBE37, 0xC30C8EA1, 0x5A05DF1B, 0x2D02EF8D };


int main(int argc,char *argv[]) {

      FILE *infile = NULL;
```

```
	unsigned int nCrc = 0xFFFFFFFF;
	unsigned int Count = 0;
	unsigned char OneByte;

	if(argc != 3) {
		printf("Usage: crc-gen [-h|-b] <input file>\n\
			-h signifies ascii hex file.\n\
			-b signifies binary file.\n");
		exit (0);
	}
	if(!strcmp(argv[1], "-b")) {

		if((infile = fopen (argv[2], "rb")) == NULL) {
			printf ("Unable to open %s as the input file\n", argv[2]);
			exit(1);
		}
		while (!feof(infile)) {
			if(fread(&OneByte, 1 , 1, infile)){
				Count++;
				nCrc = ( nCrc >> 8 ) ^ \
				CRCtable[(unsigned char)\
				 ((unsigned char) nCrc ^ OneByte ) ];
			}
		}
		fclose(infile);
	}
	else if (!strcmp(argv[1],"-h")) {

		char StringHold[4];

		StringHold[2] = '\0';
		if((infile = fopen (argv[2], "rt")) == NULL) {
			printf ("Unable to open %s as the input file\n", argv[2]);
			exit(1);
		}
		while (!feof(infile)) {
			if(isxdigit(StringHold[0] = fgetc(infile))) {
				if(isxdigit(StringHold[1] = fgetc(infile))) {
					sscanf(StringHold,"%X",&OneByte);
					Count++;
					nCrc = ( nCrc >> 8 )\
					 ^ CRCtable[(unsigned char)\
					 ((unsigned char) nCrc ^ OneByte ) ];
				} else {printf ("Odd hex string\n");exit (1);}
			}
		}
		fclose(infile);

	}
	else {printf("Unknown file type switch\n"); exit (1);}
	printf("Num Bytes = %d\nCRC = %08X\n", Count, nCrc ^ 0xFFFFFFFF );
	return 0;
}
```