Motion Engineering, Inc.

33 South La Patera Lane
Santa Barbara, CA 93117
ph (805) 681-3300
fax (805) 681-3311
info@motioneng.com

For the following MEI motion controllers:

CPCI Bus	*ISA Bus*	*PC-104 Bus*	*STD Bus*	*DSPpro Series*
CPCI/DSP	PCX/DSP	104/DSP	SERCOS/STD	DSPpro-Serial
PCI Bus	LC/DSP	104X/DSP	STD/DSP	DSPpro-VME
PCI/DSP	SERCOS/DSP	SERCOS/104	*VME Bus*	
	PC/DSP		V6U/DSP	

DSP & DSPpro Series C Programming Reference

Mar 2002

DSP & DSPpro Series
C Programming Reference

Mar 2002
Part # M001-0002 rev A

Motion Engineering, Inc.
33 South La Patera Lane
Santa Barbara, CA 93117-3214
ph 805-681-3300
fax 805-681-3311
e-mail: technical@motioneng.com

Motion Engineering, Inc.

1 INTRODUCTION

2 CONFIGURATION FUNCTIONS

CONTENTS

1 INTRODUCTION

2 CONFIGURATION FUNCTIONS

3 OPERATION FUNCTIONS

A ABOUT THE DSP CONTROLLER

B ABOUT SERCOS

FIGURES

1 INTRODUCTION

2 CONFIGURATION FUNCTIONS

3 OPERATION FUNCTIONS

A ABOUT THE DSP CONTROLLER

B ABOUT SERCOS

CHAPTER 1 INTRODUCTION

The Function Library

C programming skill is required!

The function library is written for C programmers, and will enable you to integrate your data acquisition, user interfaces, vision systems, and similar systems with motion and I/O control. You must be proficient with the C language and whichever operating system and compiler you use. We are happy to help you with the function libraries and *motion programming* issues, but we are not the best party to ask about how to run your compiler. If you have any questions about your specific compiler, contact the compiler manufacturer directly.

Supported Languages & Operating Systems

Motion Engineering supports the C and C++ programming languages. The DSP function library is written in standard ANSI-compatible C. After the software is installed, the sources and make-files for the function library will be located in the *sources* directory. Motion Engineering also supports Visual Basic programming under Windows, Windows95/98, and Windows NT. Note that Motion Engineering *does not support* Visual Basic under DOS.

The standard software distribution is available for DOS, Windows 3.x, Windows 95/98 and Windows NT. In addition to the standard software distribution, optional software is available for various real-time operating systems:

For information about optional software, or if you desire the library to be ported to other operating systems, please contact the *Sales Department* at Motion Engineering.

Software Distribution

The software distribution contains several utility programs. For more information, refer to the release note which accompanies your software distribution.

Which MEI software distribution you receive depends upon which operating system you are using. Software distributions, on CD-ROM, contain release notes, compiled libraries, DLLs, sources, makefiles, utility programs, sample code, and device drivers (when applicable).

To Load the Software

Insert CD-ROM, auto-run will start the installation process.

To Update Existing Software

If you are updating an older version of the firmware and library, **you must delete or archive all old versions of that software.** If you have several different versions of the same software on your computer, you may get unpredictable and undesirable results.

To download new firmware, switch to the directory where all the new .ABS and the CONFIG.EXE files are stored, and then run the CONFIG.EXE program.

Safety Tip

BEFORE running CONFIG.EXE,
ALWAYS DISCONNECT all cables from the DSP Series controller
and TURN OFF the power to any external devices, such as amplifiers and drivers, etc.

The CONFIG.EXE program downloads new firmware and configures the DAC offsets, and **throws away all previous configurations** (stored in the controller's boot memory).

If your controller is located at an address other than the default (**300 hex**) then set an environment variable called '*DSP*' to the appropriate address. For example, if '*set DSP=base:0x280*' is executed at the DOS prompt, SETUP.EXE, CONFIG.EXE and any other programs which call *do_dsp(...)* will automatically read the 'DSP' variable and access the controller at address **280 hex**. Also, read the RELXX.PDF, which describe the latest updates to the software library.

To Compile Your Program

For information about compiling your program, please see the specific release note for the operating system that you are using.

Library Organization

The library is organized into 2 major sub-libraries: low-level and medium-level. The low-level sub-library deals with all positions, velocities, accelerations, and jerk values in a **fixed point numeric format**. Floating point math is not performed at this level. The low-level sub-library knows the internal organization of the DSP controller.

The medium-level sub-library contains the **floating point** calculations necessary for trapezoidal profile motion, constant velocity motion, parabolic, S-curve motion or coordinated motion. The *unit-of-measurement* code converts the *floating point* numbers of the medium-level sub-library to the *fixed point* numbers required at the low-level sub-library.

After the software is installed, the function library sources will be located in the *sources* directory.

Table 1-1 Library Source Files in sources Directory

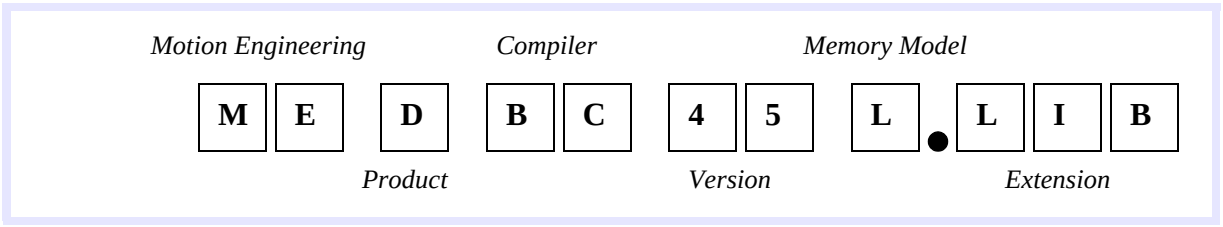
Filename	*Contains*
PCDSP.H	contains *#defines* and prototypes for medium-level functions
IDSP.H	contains *#defines* and prototypes for low-level functions
SERCOS.H	contains *#defines* and prototypes for SERCOS-specific functions

Most applications will use only the medium-level functions, all of which are documented in this manual. You are welcome to examine the library sources. Some of the low-level functions may be helpful in creating your own special purpose motion control functions. However, due to their complexity and infrequent use in most applications, the low-level functions are not documented. If you need a special function or feature, please contact *Technical Support.*

We recommend that you **do not modify the original sources**. If you use the standard function library, debugging and upgrading software will be much easier to do in the future.

Compiled Library Naming Convention

Figure 1-1 Naming Convention for Compiled Libraries



Motion Engineering uses a naming convention for its compiled libraries. The characters represent Motion Engineering, the product, the compiler, version, and memory model that was used to create the library, and also whether the library is statically or dynamically linked.

For example, the DSP Series controller static library MEDBC45L.LIB was compiled with Borland Version 4.5, under the large memory model.

Table 1-2 Library Product, Compiler and Versions

Code	*Version*	*Description*
D	-	DSP Series Motion Control Function Library
BC	45	Borland C/C++ v4.5 compiler
BC	50	Borland C/C++ v5.0 compiler
BC	31	Borland C/C++ v3.1 compiler
CL	80	Microsoft Visual C/C++ v8.0 compiler
CL	60	Microsoft C/C++ v6.00a compiler
VC	60	Microsoft Visual C/C++ 6.0 compiler
VC	50	Microsoft Visual C/C++ 5.0 compiler
VC	40	Microsoft Visual C/C++ 4.x compiler
VC	22	Microsoft Visual C/C++ 2.x compiler
VC	15	Microsoft Visual C/C++ 1.5x compiler

Table 1-3 Library Memory Models

Code	*Memory Model*
S	small
M	medium
L	large
H	huge
F	flat (32-bit library)
other	depends on compiler

Table 1-4 Library Extensions

Extension	*Description*
LIB	Static library
DLL	Dynamic link library

Library/Firmware Version Control

There are several *#defines* to identify software versions and to protect against software/firmware incompatibilities:

Table 1-5 Library Product, Compiler and Versions

#define	*Version*	*Description*
PCDSP_VERSION	240	Software Version number used to verify compatibility with firmware
PCDSP_ASCII_VERSION	2.5.000	Software Version as a string

The motion function library and firmware have *independent* version numbers. To determine compatibility between the function library and the firmware, compare the first 2 digits of the firmware and motion library version numbers.

In your application, use the initialization functions *dsp_init(…)*, *do_dsp(…)*, and *m_setup(…)* to check for software/firmware compatibility. If they are not compatible, these functions return *error 11* (PC software/DSP firmware version incompatible). Always have your application check the error return codes after initialization.

The firmware version can be determined with the utility program VERSION.EXE or the function *dsp_version(…)*. The motion library version can be determined by the identifier "PCDSP_ASCII_VERSION," which is defined in the source file *pcdsp.h*.

Library Compilation

To Recompile the Function Library

Please consult the *operating system/compiler-specific Release Note* for information about re-compiling the function library.

To Compile under Unsupported Operating Systems

There are commonly 2 areas of difficulty in porting the function library to other operating systems typically appear: **hardware access** and **different integer sizes**.

1. **Hardware access**
   Under some operating systems the C compilers don't provide *in-port* or *out-port* instructions, requiring some assembly support. In this case, modifying the functions DSP_IN and DSP_OUT would be necessary. In other cases, systems can further deny I/O access through hardware, forcing the system designer to either provide special privilege to that program or write a device driver.

2. **Different integer sizes**
   Our library relies on certain numbers to be 16 or 32 bits. It is very important that *int16*, *unsigned16*, *int32*, and *unsigned32* are defined with the appropriate sizes. The error DSP_STRUCTURE_SIZE, returned only by *dsp_init(...)* exposes problems. In the file IDSP.H there are typedefs for some new size-specified types:

Table 1-6 Library Typedefs

Typedef	***Size (bits)***	***Signed?***	***Comments***
int8	8	Yes	
unsigned8	8	No	
int16	16	Yes	
unsigned16	16	No	
int24	24 (32)	Yes	Must be at least 24 bits, we use 32 bit numbers.
unsigned24	24 (32)	No	
int32	32	Yes	
unsigned32	32	No	

Application Development Tips

Before Writing Any Code

Do not start writing your application until you have:

1. Installed the DSP Series controller
2. Commanded two-point motion with either *Motion Console or* the SETUP.EXE program
3. Successfully compiled and executed the HELLODSP.C program

Writing the application requires a basic understanding of the controller's design, the hardware (both the controller and external devices), the firmware, and the software. Most of the information you will need to create your application is available in this manual and on the *Applications* distribution CD-ROM. Start by taking a careful look at chapters 2 and 3. Both chapters are logically organized into sections of functions that support specific features. Also, look over the sample programs on the *Applications* distribution diskette.

Before programming, configure and thoroughly test the hardware with *Motion Console* (for Windows-based systems) or the SETUP.EXE program (for DOS-based systems). **Be sure that you can perform *two-point motion* with all of your motors before you write any code**.

Tip: If you do not have motors connected to the DSP controller, you can simulate motors by configuring the axes as open-loop steppers. The programming is the same for servo and step motors. Refer to the controller's installation manual for more details.

Coding Recommendations

We recommend several techniques that can help you write and debug your applications quickly and easily.

1. **Write small programs** to test individual features,
   And then combine the small code modules into the larger application.
   If a feature doesn't work properly in the application code, you can always go back to the small programs to figure out what to do next.

2. **Build debugging tools** into your code.
   Most functions return error codes, so write code to check the error codes.
   Also, the library contains many functions that examine the current condition of the controller, such as *get_command(...)*, *get_position(...)*, *get_error(...)*, *get_dac_output(...)*, *axis_status(...)*, *axis_state(...)* and *axis_source(...)*.

3. **Make the application as simple as possible**.
   Most applications do not require interrupts, so don't use interrupts unless you really, *really* need them. Writing code that uses interrupts can become very difficult very quickly.

Homing Routines Can Be Complicated

Almost every application requires a homing routine, because immediately after a system is turned on, the controller does not know the physical locations of the motors. You use a homing routine to calibrate the physical location of the motors with the absolute coordinates tracked by the DSP controller. You use different algorithms for a homing routine *depending upon the mechanical system* that you are using. Note that when planning a homing routine, the most important thing is the **repeatability** of the home location.

Quite often, the homing routine is one of the most complicated portions of a motion application, so be methodical. Refer to the *Sample Applications Distribution* on the CD-ROM and the *Applications* distribution on the CD-ROM for example homing programs.

Use the Error Codes

If any function doesn't work as expected, have your application check the function's return code, because most functions in the library return an integer error code. An error code of **0** (defined as DSP_OK in *pcdsp.h*) indicates success of the last operation; any other nonzero code indicates a problem.

It is very important to check the error code returned by the initial call to *dsp_init(...)*, *do_dsp(...)*, or *serc_reset(…)*. If *dsp_init(...)*, *do_dsp(...)*, or *serc_reset(…)* fails, it usually indicates a hardware or configuration problem which will likely prevent any motion to be performed correctly after *dsp_init(...)* or *do_dsp(...)* fails.

Look for Exception Events

DSP Series controllers have several built-in safety features, which include hardware limit inputs, home inputs, amp faults inputs, software position limits, position error limits, and encoder broken wire detection. All of these safety features can be examined and configured using the SETUP.EXE program or *Motion Console*. The firmware stores default configurations for the safety features.

Always check the configurations for the limit inputs, home inputs, amp faults inputs, software position limits, and position error limits. If these inputs are not connected, they may float and trigger unexpected exception events in the controller. Configure all unused limit inputs, home inputs, amp faults inputs, software position limits, or position error limits for *No Event*.

Save & Maintain Your Firmware

The DSP Series controller has nonvolatile memory which contains the firmware, which contains executable code and configuration information. The controller's behavior and software compatibility are determined by the firmware configuration, because at start-up, the firmware is loaded into the DSP. You can easily download firmware to your controller, or upload the firmware contents to a disk file.

Note that it is **your responsibility** to maintain the appropriate firmware file(s) for your machine's configuration. Also note that MEI *always* ships the DSP Series controllers with the latest software and firmware.

When building several machines, it is important to save the current firmware configuration to a disk file. Future DSP Series controllers can be configured using one of the following methods:

Method 1: Download a configured firmware file

Configure the controller's firmware with SETUP.EXE, *Motion Console*, or your application program. Next upload the configured firmware to a disk file. When you build machines in the future, simply download the configured firmware file from the disk to the controller.

Method 2: Download a default firmware file and then configure it

Save a copy of the default firmware files from the distribution CD-ROM. When you build machines in the future, simply download the default firmware file from the diskette to the controller. Next configure the controller's firmware with SETUP.EXE, Motion Console, or your application program.

Method 3: Have your application download a firmware file and configure it

Every time that the machine is turned on, download firmware from your application to the controller. This method makes it easy to upgrade software and firmware on machines in the field. The only restriction is that the firmware can only be reconfigured 10,000 times.

To upload or download firmware, use the SETUP.EXE program or *Motion Console*.
To download firmware and to zero the DAC offsets, use the CONFIG.EXE program.

CONFIG.EXE Utility

You use the CONFIG.EXE program to download firmware to the controller, configure the DAC offsets, and perform some basic tests of the axes. Normally you don't need to use the CONFIG.EXE program, because the controller is configured at our factory.

Safety Tip

Before running CONFIG.EXE,
Always disconnect all cables from the DSP Series controller
and **turn OFF the power** to any external devices, such as amplifiers and drivers, etc.

To run CONFIG.EXE, switch into the directory where all the .ABS files and CONFIG.EXE are stored, and then type *CONFIG*. CONFIG will download 8AXIS.ABS file (or 8AXISSER.ABS for SERCOS controllers) and then perform a series of tests. The tests verify proper communication between the controller and the host CPU, verify on-board memory, configure the DAC offsets, and determine the number of hardware axes. The configured DAC offsets are saved into the controller's firmware, **and are not saved to the firmware files on disk**. If there are any problems, the CONFIG program will display error messages onscreen.

Table 1-7 CONFIG.EXE Command Options

Option	***Description***
-f [*filename*]	Configure the controller with a particular firmware file
-d [*filename*]	Download a firmware file
-u [*filename*]	Upload a firmware file
-b [*base*]	Set the base address
-a [*axes*]	Configure *axes* number of axes
-v	Verbose mode- display all messages
-w	Display no warning messages

To download a specific firmware file (.ABS) and configure the DAC offsets, type '*CONFIG -F MYFIRM.ABS*' at the DOS prompt. The CONFIG.EXE program will download MYFIRM.ABS and configure the DAC offsets appropriately. This method is very useful for configuring multiple controller boards.

To download a specific firmware file (.ABS) and not configure the DAC offsets, type '*CONFIG -D MYFIRM.ABS*'.

To upload firmware to a disk file, type *'CONFIG-U MYFIRM.ABS'*.

To configure a controller located at an address other than the default (300 hex), use the ***-b*** command line switch. For example, to configure a controller located at address **0x280**, type *'CONFIG -B 0x280'*.

Troubleshooting Tips

Finding the cause of the problem is often more difficult than the solution.

Isolate the Problem:

1. If the problem occurs during the execution of your application, then try to create the smallest piece of code that reproduces the problem.

2. Run the SETUP.EXE program or Motion Console for a second opinion. (The position status and axis status screens are the most helpful.) Note that the SETUP.EXE program *and* Motion Console use the *same function library* as your application does.

Determine if it is a hardware or software problem:

1. If the problem is in the hardware, find which signals are at fault. Is it the user I/O, dedicated I/O, the +/-10 V control signal, the step/direction signals, the encoder inputs, or the analog inputs?

   Does the problem occur when the DSP Series controller is connected or disconnected from the external devices?

   Can the problem be reproduced on another computer?

   Can the problem be reproduced using another DSP Series controller?

2. Is the problem consistent or random?

   Use an oscilloscope to look at the integrity of the signals. Are the signals clean or noisy?

   Do the signals look the same when connected or disconnected from the external devices?

   Are the signals noisy when the motor is moving or standing still. Or when the amplifier is powered on or off?

If the problem is in software, try to reproduce the problem with the smallest piece of code possible. Next fax this small piece of code along with a description of the problem to MEI. Be specific about the problem and any other information that is pertinent. Don't forget to include your name, phone and fax number, and date.

Motion Developer's Support Program

Motion Engineering takes technical support seriously. We want your system to work! To continue to provide the best possible applications support, we have created the Motion Developer's Support Program. Participation in the Motion Developer's Support Program is required in order to receive application support. Contact MEI for more information.

MEI's Motion Developer's Support Program ensures that your critical project will receive the utmost applications support for timely problem resolution and faster development.

The Motion Developer's Support Program includes:

One year of 24 hour/day, 7 day/week application technical support by telephone, e-mail, and/or fax (weekends and holidays included)

Priority access to application engineers with response in the same business day

Updated Motion Developer's Kit (MDK) - provided on CD-ROM. This includes MEI's DSP Series development tools, libraries, and sample code for Windows NT, Windows 95/98, and Windows 3.x with the current MEI features, functions, and bug fixes.

One year of software maintenance and updates for MDK software, tools, libraries, and sample applications code.

Table 1-8 Contacting MEI Technical Support

24-hour support	(805) 681-3300
Fax	(805) 681-3311
e-mail	*technical@motioneng.com*

To Get Software Updates

MEI periodically releases new software/firmware versions. New features are implemented, performance enhanced, and new applications developed. The latest firmware/software releases are available on our FTP site at **ftp://ftp.motioneng.com**.

The DSP Series controller has non-volatile memory space to store the firmware and configuration parameters. All of the DSP Series controllers are compatible with the latest firmware and software versions. Firmware can be easily downloaded to the controller with CONFIG.EXE.

Future Controller Purchases

MEI ships the DSP Series controllers with the latest software, firmware, and on-board programmable logic. When building multiple machines, we recommend that you save a configured version of your firmware to a diskette. The next time you build a machine, simply load that firmware (from diskette) to the DSP Series controller using the CONFIG.EXE program. This method is easiest.

We are constantly adding new features and improving the capability of our controllers, by revising the hardware and programmable logic to meet increased application demands. All future hardware/programmable logic revisions are *backwards-compatible* with older software and firmware revisions, and new features can be enabled if you start using the latest versions of software and firmware.

VERSION.EXE Utility

The VERSION program reads the hardware identity, PROM version (on-board logic), and the firmware version from the controller and displays them to the screen. The firmware version and option numbers can be read directly from your application code with the functions *dsp_version(...)* and *dsp_option(...)*.

Firmware Versions

MEI always ships the DSP controllers with the latest software and firmware. The firmware, software and Motion Console all have a version check built into the code. If the library version is incompatible with the firmware version, controller status will be listed as "bad" in Motion Console's *Controller List* and the controller will be inaccessible.

If you wish to use an earlier version of the firmware on a newly purchased controller, or if you have an older controller and want to use a new firmware version, run the CONFIG program as described in the section in *CONFIG.EXE Board Configuration Program,* or use the Motion Console application.

Note that current firmware versions are available 24 hours a day on Motion Engineering's FTP site (*ftp.motioneng.com*). Files for downloading are located in the */pub* directory.

CHAPTER 2 CONFIGURATION FUNCTIONS

This chapter describes the medium-level functions used for configuration, logically organized into topics that support specific features. The function prototypes are in PCDSP.H.

Quick List

Configuration Functions

Type	*Functions*	*Description*
Firmware		
page 2-13	set_axis(*axis*, *enable*)	Enables/disables an axis
	set_boot_axis(*axis*, *enable*)	Enable/disable an axis' *boot* configuration status
	get_axis(*axis*, * *enable*)	Read an axis' enabled/disabled configuration status
	get_boot_axis(*axis*, * *enable*)	Read an axis' enabled/disabled *boot* configuration status
	dsp_axes(void)	Returns the number of enabled axes
	dsp_version(void)	Returns the firmware version number
	dsp_option(void)	Returns the firmware option number
Sample Rate		
page 2-14	dsp_sample_rate(void)	Returns the DSP sample rate
	dsp_boot_sample_rate(void)	Returns the boot value sample rate
	set_sample_rate(*rate*)	Set the DSP sample rate
	set_boot_sample_rate(*rate*)	Set the boot value sample rate
Boot Memory		
page 2-15	download_firmware_file(* *file*)	Copy a firmware file from the host CPU to the DSP's boot memory
	upload_firmware_file(* *file*)	Copy the firmware file from the DSP's boot memory to the host CPU.
	mei_checksum(void)	Update DSP boot memory checksum
Closed Loop Config		
page 2-17	dsp_closed_loop(*axis*, * *closed*)	Read if an axis is configured for open or closed loop
	dsp_boot_closed_loop(*axis*, * *closed*)	Read if an axis is configured for open or closed loop *at boot*
	dsp_set_closed_loop(*axis*, *closed*)	Configure an axis for open or closed-loop (groups of 2)
	dsp_set_boot_closed_loop(*axis*, *closed*)	Configure an axis for open or closed-loop *at boot*
Feedback Config		
page 2-18	set_feedback(*axis*, *device*)	Set or get the feedback device
	get_feedback(*axis*, * *device*)	
	set_boot_feedback(*axis*, *device*)	Set or get the *boot* feedback device
	get_boot_feedback(*axis*, * *device*)	
	set_dual_loop(axis, velocity_axis, dual)	Set the dual loop position and velocity axes
Dual Loop Config		
page 2-20	set_dual_loop(*axis*, *velocity_axis*, *dual*)	Set/get the dual loop position and velocity axes
	get_dual_loop(*axis*, *velocity_axis*, * *dual*)	
	set_boot_dual_loop(*axis*, *velocity_axis*, *dual*)	Set/get the *boot* dual loop position and velocity axes
	get_boot_dual_loop(*axis*, *velocity_axis*, * *dual*)	

Type	Functions	Description
Encoder Integrity Checking		
page 2-22	set_feedback_check(*axis*, *state*)	Enable/disable encoder feedback fault detection
	get_feedback_check(*axis*, * *state*)	Read feedback fault detection configuration
Step Output Config		
page 2-24	dsp_stepper(*axis*)	Returns TRUE if an axis' step output is enabled
	dsp_boot_stepper(*axis*)	Returns TRUE if an axis' step output is enabled *at boot*
	dsp_set_stepper(*axis*, *stepper*)	Enable/disable an axis' step output (groups of 2)
	dsp_set_boot_stepper(*axis*, *stepper*)	Enable/disable an axis' *boot* step output (groups of 2)
	dsp_step_config(*axis*, *mode)	Reads step mode configuration
	dsp_boot_step_config(*axis*)	Returns *boot* step mode configuration
	dsp_set_step_config(*axis*, *mode*)	Sets the step mode configuration
	dsp_set_boot_step_config(*axis*, *mode*)	Sets the *boot* step mode configuration
Step Output Speed Range		
page 2-26	dsp_step_speed(*axis*, * *speed*)	Read an axis' step output speed range
	dsp_boot_step_speed(*axis*, * *speed*)	Read an axis' *boot* step output speed range
	dsp_set_step_speed(*axis*, *speed*)	Configure an axis' step output speed range
	dsp_set_boot_step_speed(*axis*, *speed*)	Configure an axis' *boot* step output speed range
Analog Output Voltage Config		
page 2-28	is_unipolar(*axis*)	Returns TRUE if an axis' analog output is unipolar
	is_boot_unipolar(*axis*)	Returns TRUE if an axis' analog output is unipolar *at boot*
	set_unipolar(*axis*, *state*)	Configure an axis' analog output
	set_boot_unipolar(*axis*, *state*)	Configure an axis' *boot* analog output
PID Filter Parameters		
page 2-29	set/get_filter(*axis*, * *coefficients*)	Set or get PID filter coefficients
	set/get_boot_filter(*axis*, * *coefficients*)	Set or get *boot* PID filter coefficients
	set/get_integration(*axis*, *mode*)	Set or get the *integration mode*
	set/get_boot_integration(*axis*, *mode*)	Set or get *boot integration mode*
Auxiliary Filter Parameters		
page 2-31	set/get_aux_filter(*axis*, * *coefficients*)	Set or get *auxiliary* digital filter coefficients
	set/get_boot_aux_filter(*axis*, * *coefficients*)	Set or get *boot auxiliary* digital filter coefficients
Home Action Config		
page 2-32	set/get_home(*axis*, *action*)	Set or get the *home/index* logic action
	set/get_boot_home(*axis*, *action*)	Set or get the *boot home/index* logic action
Home Logic Config		
page 2-34	set/get_home_index_config(*axis*, *config*)	Set or get the *home/index* logic configuration
	set/get_boot_home_index_config(*axis*, *config*)	Set or get the *boot home/index* logic configuration
	set/get_home_level(*axis*, *level*)	Set or get the *active state* of the home/index logic
	set/get_boot_home_level(*axis*, *level*)	Set or get the *boot active state* of the home/index logic

Type	*Functions*	*Description*
Limit Inputs Action Config		
page 2-37	set/get_positive_limit(*axis*, *action*)	Set or get the *positive* limit input action
	set/get_boot_positive_limit(*axis*, *action*)	Set or get the *boot positive* limit input action
	set/get_negative_limit(*axis*, *action*)	Set or get the *negative* limit input action
	set/get_boot_negative_limit(*axis*, *action*)	Set or get the *boot negative* limit input action
Limit Inputs Level Config		
page 2-39	set/get_positive_level(*axis*, *level*)	Set or get the *active state* of the positive limit input
	set/get_boot_positive_level(*axis*, *level*)	Set or get the *boot active state* of the positive limit input
	set/get_negative_level(*axis*, *level*)	Set or get the *active state* of the negative limit input
	set/get_boot_negative_level(*axis*, *level*)	Set or get the *boot active state* of the negative limit input
Amp Fault Inputs		
page 2-41	set/get_amp_fault (*axis*, *action*)	Set or get the *amp fault* input action
	set/get_boot_amp_fault (*axis*, *action*)	Set or get the *boot amp fault* input action
	set/get_amp_fault_level (*axis*, *level*)	Set or get *active state* of amp fault input
	set/get_boot_amp_fault_level(*axis*, *level*)	Set or get *boot active state* of amp fault input
Amp Enable Outputs		
page 2-43	set/get_amp_enable(*axis*, *state*)	Set or get the *state* of the amp enable output
	set/get_boot_amp_enable(*axis*, *state*)	Set or get the *boot state* of the amp enable output
	set/get_amp_enable_level(*axis*, *level*)	Set or get the *run state* of the amp enable output
	set/get_boot_amp_enable_level(*axis*, *level*)	Set or get *boot run state* of the amp enable output
Software Limit		
page 2-45	set/get_positive_sw_limit(*axis*, *pos*, *action*)	Set or get the *positive* software position limit
	set/get_boot_positive_sw_limit(*axis*, *pos*, *action*)	Set or get the *boot positive* software position limit
	set/get_negative_sw_limit(*axis*, *pos*, *action*)	Set or get the *negative* software position limit
	set/get_boot_negative_sw_limit(*axis*, *pos*, *action*)	Set or get the *boot negative* software position limit
In Position		
page 2-47	set/get_in_position(*axis*, *limit*)	Set or get the *width* of the in-position window
	set/get_boot_in_position(*axis*, *limit*)	Set or get the *boot width* of the in-position window
Error Limit		
page 2-48	set/get_error_limit(*axis*, *limit*, *action*)	Set or get the *maximum position error* limit
	set/get_boot_error_limit(*axis*, *limit*, *action*)	Set or get the *maximum boot position error* limit
Interrupt Configuration		
page 2-50	dsp_interrupt_enable(*state*)	Enable interrupts via User I/O bit 23
	interrupt_on_event(*axis*, *state*)	Generate CPU interrupt on an exception event

SERCOS Functions

Type	*Functions*	*Descriptions*
Initialization		
page 2-53	serc_reset(*baud*, *ndrives*, * *dinfo*)	Resets controller & initializes SERCOS
	get_sercos_phase(* *phase*)	Reads the SERCOS ring initialization phase
Configure Phase 2/3 IDNs		
page 2-56	configure_phase2_idns(*nidns*, * *didns*)	Specifies IDNs to be set during phase 2 init
	configure_phase3_idns(*nidns*, * *didns*)	Specifies IDNs to be set during phase 3 init
Cyclic Data Configuration		
page 2-58	configure_at_data(*natdata*, * *at_data*)	Specifies IDNs to be placed in the AT
	configure_mdt_data(*nmdtdata*, * *mdt_data*)	Specifies IDNs to be placed in the MDT
Drive Addresses		
page 2-60	get_drive_addresses(*baud*, * *ndrives*, * *dr_addrs*)	Determines the addresses for SERCOS nodes
Changing Op Modes		
page 2-61	change_operation_mode(*axis*, *mode*)	Changes the drive's operation mode
Read/Write IDN		
page 2-62	set_idn(*axis*, *idn*, *value*)	Writes an IDN value to a SERCOS node
	get_idn(*axis*, *idn*, * *value*)	Reads an IDN value from a SERCOS node
	get_idn_size(*axis*, *idn*, * *size*)	Reads element 7's size from the specified IDN
	get_idn_string(*axis*, *dr_addr*, *idn*, * *str*)	Reads a string from an IDN
	get_idn_attributes(*axis*, *idn*, * *attr*)	Reads an IDN's attributes
Read/Write Multiple IDNs		
page 2-64	set_idns(*axis*, *dr_addr*, *idns*, * *idns*)	Writes an array of IDN values to a SERCOS node
	get_idns(*axis*, *dr_addr*, *firstidn*, *idns*, * *idns*)	Reads an array of IDN values from a SERCOS node
Procedures		
page 2-66	start_exec_procedure(*axis*, *procedure*)	Starts a SERCOS drive procedure
	cancel_exec_procedure(*axis*, *procedure*)	Cancels a SERCOS drive procedure
	exec_procedure_done(*axis*, *procedure*, * *done*)	Determines a drive procedure's completion
Read/Write Cyclic Data		
page 2-68	read_cyclic_at_data(*axis*, *offset*)	Reads cyclic data from an Amplifier Telegram
	read_cyclic_mdt_data(*axis*, *offset*)	Reads cyclic data from the Master Data Telegram
	write_cyclic_mdt_data(*axis*, *offset*, *data*)	Writes cyclic data to the Master Data Telegram
Enable/Disable LED		
page 2-70	turn_on_sercos_led(void)	Enables the LED from the output module
	turn_off_sercos_led(void)	Disables the LED from the output module
Drive Status/Reset		
page 2-71	get_drive_status(*axis*, * *status*)	Read the SERCOS node's status word
	reset_sercos_drive(*axis*)	Resets a SERCOS node
Diagnostics		
page 2-73	get_class_1_diag(*axis*, * *code*, * *msg*)	Read class 1 diagnostic message from drive
	get_class_2_diag(*axis*, * *code*, * *msg*)	Read class 2 diagnostic message from drive

typedefs and #defines

Here is a list of the most important *typedefs* used in the code:

P_INT	a (usually far) pointer to an integer
P_CHAR	a (usually far) pointer to a null terminated string
P_DOUBLE	a (usually far) pointer to a double
VECT	a (usually far) pointer to an array of doubles

Here is a list of the most important *#defines* used in the code:

Table 2-1 True & False Values

#define	***Value***	***Explanation***
TRUE	1	For assignment purposes only
FALSE	0	For assignment purposes only

Table 2-2 High & Low Values

#define	***Value***	***Explanation***
HIGH	1	For assignment purposes only
LOW	0	For assignment purposes only

Table 2-3 DSP Configuration'

DSP	***Value***	***Explanation***
PCDSP_BASE	0x300	Default base I/O address in hex
PCDSP_MAX_AXES	8	Maximum possible number of axes

Table 2-4 DSP Software Version

Version	***Value***	***Explanation***
PCDSP_VERSION	240	Software Version number used to verify compatibility with firmware
PCDSP_ASCII_VERSION	"2.5.09"	Software Version as a string

Table 2-5 I/O Port

I/O	***Value***	***Explanation***
IO_INPUT	0	Configure I/O port as input
IO_OUTPUT	1	Configure I/O port as output

Also see **init_io(...)**, page 3-58.

Table 2-6 Events

Exception Events	*Value*	*Explanation*
NO_EVENT	0	Ignore a condition
NEW_FRAME	2	Begin execution of the next sequenced frame
CHECK_FRAMES	6	Used internally to generate e-stops when the list is empty
STOP_EVENT	8	Generate a Stop Event
E_STOP_EVENT	10	Generate an E-Stop Event
ABORT_EVENT	14	Disable PID control, and disable the amp enable output

Also see **axis_state(...)**, page 3-45.

Table 2-7 Axis Status

Status	*Value*	*Explanation*
IN_SEQUENCE	0x0010	Frame(s) left to be triggered
IN_POSITION	0x0020	Within allowable position error window
IN_MOTION	0x0040	Command velocity is non-zero
DIRECTION	0x0080	Sign of command velocity (true == negative)
FRAMES_LEFT	0x0100	Frames to be executed for an axis

Also see **axis_status(...)**, page 3-44.

Table 2-8 Axis Source

Source	*Value*	*Explanation*
ID_NONE	0	No event has occurred
ID_HOME_SWITCH	1	Home logic was activated
ID_POS_LIMIT	2	Positive limit input was activated
ID_NEG_LIMIT	3	Negative limit input was activated
ID_AMP_FAULT	4	Amplifier fault input was activated
ID_X_NEG_LIMIT	7	Software negative travel limit was exceeded
ID_X_POS_LIMIT	8	Software positive travel limit was exceeded
ID_ERROR_LIMIT	9	Software position error was exceeded
ID_PC_COMMAND	10	CPU has commanded a Stop, E-Stop, Abort, or Clear Status
ID_OUT_OF_FRAMES	11	Attempted the next frame with no frame present
ID_FEEDBACK_FAULT	12	Broken wire was detected
ID_FEEDBACK_ILLEGAL_STATE	13	Improper feedback logic state was detected
ID_AXIS_COMMAND	14	Event was triggered by another axis

Also see **axis_source(...)**, page 3-46.

Table 2-9 PID Filter Parameters

PID Filter Parameters	*Value*	*Explanation*
COEFFICIENTS	10	Number of elements expected by *set/get_filter(...)*
DF_P	0	Proportional gain
DF_I	1	Integral gain
DF_D	2	Derivative gain - damping term
DF_ACCEL_FF	3	Acceleration feed forward
DF_VEL_FF	4	Velocity feed forward
DF_I_LIMIT	5	Integration summing limit
DF_OFFSET	6	To change analog output
DF_DAC_LIMIT	7	0..32767->0-10v; max DAC output possible
DF_SHIFT	8	2^(n) divisor to change scale factor
DF_FRICT_FF	9	Friction feed forward

Also see **set/get_filter(...)**, page 2-29.

Table 2-10 Aux Filter Parameters

Auxiliary Filter Parameters	*Value*	*Explanation*
AUX_FILTER_COEFFS	10	number of elements expected by *set/get_aux_filter(...)*

Also see **set/get_aux_filter(...)**, page 2-31.

Error #defines

Table 2-11 Error #defines

Error defines	*Value*	*Explanation*
MAX_ERROR_LEN	150	Max length for error message string
DSP_OK	0	No error
DSP_NOT_INITIALIZED	1	Did you call *dsp_init(...)?*
DSP_NOT_FOUND	2	DSP not found at the given I/O address
DSP_INVALID_AXIS	3	Illegal axis specified
DSP_ILLEGAL_ANALOG	4	Illegal analog channel specified
DSP_ILLEGAL_IO	5	Illegal I/O port/bit specified
DSP_OUT_OF_MEMORY	6	Out of internal DSP memory
DSP_FRAME_UNALLOCATED	7	Downloaded an unallocated frame
DSP_ILLEGAL_PARAMETER	8	Illegal Accel, Velocity or Jerk
DSP_ILLEGAL_CONVERSION	9	Zero CountsPerDistance or SecondsPerPeriod
DSP_FRAME_NOT_CONNECTED	10	Unloaded an unconnected frame
DSP_FIRMWARE_VERSION	11	PC software v PCDSP_ASCII_VERSION/ DSP firmware version incompatible
DSP_ILLEGAL_TIMER	12	Invalid 8254 timer was selected
DSP_STRUCTURE_SIZE	13	FRAME Structure size is incorrect; a porting problem is suspected
DSP_TIMEOUT_ERROR	14	The wait for a transfer block exceeded the allowable time
DSP_RESOURCE_IN_USE	15	Libraries' Global Resource is in use
DSP_CHECKSUM	16	Boot memory checksum error
DSP_CLEAR_STATUS	17	Can't clear status
DSP_NO_MAP	18	Coordinated motion not inititalized
DSP_NO_ROOM	19	Out of DSP FIFO buffer space
DSP_BAD_FIRMWARE_FILE	20	Specified firmware file is corrupt or nonexistent
DSP_ILLEGAL_ENCODER_CHANNEL	21	Illegal encoder channel specified
DSP_FUNCTION_NOT_AVAILABLE	22	Function is no longer available
DSP_NO_EXTERNAL_BUFFER	23	External buffer is full or does not exist
DSP_NT_DRIVER	24	Windows NT DSPIO Driver not found
DSP_FUNCTION_NOT_APPLICABLE	25	Function is not applicable
DSP_NO_DISTANCE	26	Zero distance move
DSP_FIRMWARE_CHECKSUM	27	Firmware buffer checksum error
DSP_FEATURE_NOT_SUPPORTED	28	Requested feature not supported by current software/firmware
DSP_ENVIRONMENT_NOT_SUPPORTED	29	Requested function not supported by current compiler or Operating System
DSP_SERCOS_SLAVE_ERROR	100	General error in slave's service container
DSP_SERCOS_INVALID_PARAM	101	Invalid parameter passed to *serc_reset()*
DSP_SERCOS_DISTORTED	102	Data is distorted
DSP_SERCOS_LOOP_OPEN	103	SERCOS loop is open
DSP_SERCOS_EARLY	104	Master Sync Telegram was sent too early
DSP_SERCOS_LATE	105	Master Sync Telegram was sent too late

Table 2-11 Error #defines

Error defines	*Value*	*Explanation*
DSP_SERCOS_MST_MISSING	106	Master Sync Telegram is missing
DSP_SERCOS_DRIVE_INIT	107	Drive(s) not found
DSP_SERCOS_INVALID_DRIVE_TYPE	108	Invalid drive mode
DSP_SERCOS_INVALID_DRIVE_NUMBER	109	Invalid number of drives
DSP_SERCOS_INVALID_DRIVE_ADDR	110	Invalid drive address
DSP_SERCOS_DUPLICATE_DRIVE_ADDR	111	Duplicate drive address
DSP_SERCOS_PROC_FAILURE	112	Procedure has failed
DSP_SERCOS_AXIS_ASSIGNMENT	113	Axis is not assigned to a valid drive
DSP_SERCOS_RESET	114	Use *serc_reset(...)* instead of *dsp_reset(...)* with SERCOS controllers
DSP_SERCOS_VARIABLE_READ	115	Use *get_idn_string(...)* to read variable length strings
DSP_SERCOS_INVALID_IDN_AT	116	Invalid IDN in the AT cyclic data
DSP_SERCOS_INVALID_IDN_MDT	117	Invalid IDN in the MDT cyclic data
DSP_SERCOS_127_FAILURE	118	Drive is not able to enter phase 3
DSP_SERCOS_128_FAILURE	119	Drive is not able to enter phase 4
DSP_SERCOS_IDN_NOT_AVAILABLE	120	IDN is not supported in the drive
DSP_SERCOS_NO_CHANNEL	121	Could not open a service channel
DSP_SERCOS_ELEMENT_MISSING	122	IDN element not supported by drive
DSP_SERCOS_SHORT_TRANS	123	Service channel transmission is too short
DSP_SERCOS_LONG_TRANS	124	Service channel transmission is too long
DSP_SERCOS_STATIC_VAL	125	IDN element is static
DSP_SERCOS_WRITE_PROTECT	126	IDN element is write protected
DSP_SERCOS_MIN	127	Value is less than allowable range
DSP_SERCOS_MAX	128	Value is greater than allowable range
DSP_SERCOS_INVALID_DATA	129	Data is not valid
DSP_SERCOS_PROTOCOL	130	Protocol error in slave
DSP_SERCOS_HS_TIMEOUT	131	Service channel handshake timeout
DSP_SERCOS_BUSY	132	Slave's BUSY_AT bit is on
DSP_SERCOS_CMD	133	Drive set the command modification bit
DSP_SERCOS_M_NOT_READY	134	Master's M_BUSY bit is off
DSP_SERCOS_SC_TIMEOUT	135	Service container timeout error
DSP_SERCOS_REC_ERR	136	Invalid service container transmission
DSP_SERCOS_INVALID_CYCLE_TIME	137	Cycle time is too short
DSP_SERCOS_USER_AT	138	Max cyclic user AT data was exceeded
DSP_SERCOS_USER_MDT	139	Max cyclic user MDT data was exceeded
DSP_SINCOM_TABLE_CREATION	200	SinCom table creation error
DSP_SINCOM_HEADER_CREATION	201	SinCom header creation error
DSP_SINCOM_NOT_POSSIBLE	202	Commutation not able to fit within SINCOM table
DSP_SINCOM_NO_MOTION	203	SinCom initialization created no motion
DSP_SINCOM_CURRENT_ERR	204	SinCom drive high-current warning

Also see **dsp_error(...)**, page 3-13.

More #defines

Table 2-12 Master Slave Control

Link	*Value*	*Explanation*
LINK_ACTUAL	1	Actual position master slave control
LINK_COMMAND	2	Command position master slave control

Also see **mei_link(...)**, page 3-73.

Table 2-13 Integration Modes

Integration Modes	*Value*	*Explanation*
IM_STANDING	0	Integration active only when command velocity is zero
IM_ALWAYS	1	Integration is always active

Also see **set/get_integration(...)**, page 2-29.

Table 2-14 Feedback Devices

Feedback Devices	*Value*	*Explanation*
FB_ENCODER	0	Incremental encoder is used for actual position
FB_ANALOG	1	Analog input is used for actual position
FB_PARALLEL	2	User I/O (32 bits) is used for actual position

Also see **set/get_feedback(...)**, page 2-18.

Table 2-15 Home/Index Configurations

Home/Index Configurations	*Value*	*Explanation*
HOME_ONLY	0	Home sensor only (active high or active low)
LOW_HOME_AND_INDEX	1	Home sensor ANDed with index (active low home, active high index)
INDEX_ONLY	2	Index only (active high or active low)
HIGH_HOME_AND_INDEX	3	Home sensor ANDed with index (active high home, active high index)

Also see **set/get_home_index_config(...)**, page 2-34.

Table 2-16 Step Output Pulse Speeds

Step Pulse Output Speed Range	***Value***	***Explanation***
DISABLE_STEP_OUTPUT	0	Disable step pulse output
R17KHZ_STEP_OUTPUT	3	Fast step pulse output rate range
R70KHZ_STEP_OUTPUT	2	Middle step pulse output rate range
R275KHZ_STEP_OUTPUT	1	Min step pulse output rate range
R550KHZ_STEP_OUTPUT	4	Max step pulse output rate range

Also see **dsp_set_step_speed(...)**, page 2-26.

Table 2-17 Step Mode Types

Stepper Mode	***Value***	***Explanation***
STEPDIR	0	For step and direction operation
CWCCW	1	For clockwise and counter clockwise operation

Also see **dsp_step_config(...)**, page 2-24.

Table 2-18 Trigger Sense

Trigger Sense	***Value***	***Explanation***
POSITIVE_SENSE	1	Greater than or equal to (>=)
NEGATIVE_SENSE	0	Less than (<)

Also see **dsp_position_trigger(...)**, page 3-88.

Firmware

set_axis	enables/disables an axis
set_boot_axis	enable/disable an axis' boot configuration status
get_axis	read an axis' enabled/disabled configuration status
get_boot_axis	read an axis' enabled/disabled boot configuration status
dsp_axes	returns the number of enabled axes
dsp_version	returns the firmware's version number
dsp_option	returns the firmware's option number

SYNTAX

set_axis(int16 *axis*, int16 *enable*)
set_boot_axis(int16 *axis*, int16 *enable*)
get_axis(int16 *axis*, int16 * *enable*)
get_boot_axis(int16 *axis*, int16 * *enable*)

int16 **dsp_axes**(void)
int16 **dsp_version**(void)
int16 **dsp_option**(void)

PROTOTYPE IN

pcdsp.h

DESCRIPTION

In firmware version 2.4F4 or higher, there is only one firmware file: 8AXIS.ABS (or for SERCOS, 8AXISSER.ABS). This file contains the code necessary to control up to 8 axes. An axis can be enabled (*enable* = TRUE) or disabled (*enable* = FALSE) with **set_axis(…)**. An axis' enabled/disabled status can be read with **get_axis(…)**. The boot axis configuration status can be set with **set_boot_axis(…)** and can be read with **get_boot_axis(…)**.

dsp_axes(...) simply returns the number of enabled axes. However, the number of axes returned by **dsp_axes(…)** may not be sequential.

The firmware has a 16-bit version and 16-bit option number for identification purposes. **dsp_version(void)** returns the integer version number and **dsp_option(void)** returns the integer option number.

Table 2-19 Firmware Version & Option Numbers

Function	*Label*	*Bits*	*Description*
dsp_version(...)	Version	4-15	Calculated by (dsp_version( ) / 1600.0)
	Revision	0-3	design changes represented as a character
dsp_option(...)	Dev	15	1 for development, 0 for release
	Sub-Revision	12-14	minor changes represented as a number
	Option	0-11	optional firmware

RETURN VALUES

	Returns
set_axis(...) **set_boot_axis**(...) **get_axis**(...) **get_boot_axis**(...)	Error return codes (see *Error Handling* on page 3-13)
dsp_axes(...) **dsp_version**(...) **dsp_option**(...)	Values

Sample Rate

dsp_sample_rate	returns the number of samples per second
dsp_boot_sample_rate	returns the boot value for the number of samples per second
set_sample_rate	sets the number of samples per second
set_boot_sample_rate	sets the number of samples per second in boot memory

SYNTAX

int16 **dsp_sample_rate**(void)
int16 **dsp_boot_sample_rate**(void)
int16 **set_sample_rate**(unsigned16 *rate*)
int16 **set_boot_sample_rate**(unsigned16 *rate*)

PROTOTYPE IN

pcdsp.h

DESCRIPTION

dsp_sample_rate(...) and **dsp_boot_sample_rate(..)** return the sample timer clock rate in samples per second. The default sample rate for all controllers is 1250 samples/second. This is a conservative sample rate but is more than adequate for most applications.

set_sample_rate(...) and **set_boot_sample_rate(..)** alter the DSP's sample timer. Changing the sample rate will have a direct effect on the response of the system and may require the digital filter parameters to be adjusted. Generally, at higher sample rates the digital filter parameters will need to be lowered.

Also, a change in the sample rate will affect the calculation of the velocities and accelerations. However, the library will adjust the conversion factors according to changes in the sample rate. This guarantees that the units used by your program will be calculated correctly.

The firmware's execution time determines the maximum possible sample rate. If the sample rate is set too high (above 1500 Hz on 8 axis firmware) the firmware will run as fast as possible. In this case the sample rate set by **set_sample_rate(...)** and the actual sample rate of the DSP are different, and the velocities and accelerations will be executed incorrectly.

Table 1-20 Max Sample Rate

Axis	*Sample Rate (Hz)*
1	7100
2	4700
3	3500
4	2700
5	2300
6	2000
7	1700
8	1500

EXECUTION

dsp_sample_rate(...)/ dsp_boot_sample_rate(..) performone transfer block read.
set_sample_rate(...)/ set_boot_sample_rate(..) perform one transfer block write.

RETURN VALUES

	Returns
dsp_sample_rate(...) **dsp_boot_sample_rate**(..)	Values
set_sample_rate(...) **set_boot_sample_rate**(..)	Error return codes (see *Error Handling* on page 3-13)

Boot Memory

download_firmware_file	copy a firmware file from the host CPU to the DSP's boot memory
upload_firmware_file	copy the firmware file from the DSP's boot memory to the host CPU
mei_checksum	update the DSP's boot memory checksum

SYNTAX

int16 **download_firmware_file**(char * *file*)

int16 **upload_firmware_file**(char * *file*)

unsigned16 **mei_checksum**(void)

PROTOTYPE IN

pcdsp.h

DESCRIPTION

download_firmware_file(...) copies a firmware file (.ABS) from the host CPU to the DSP's boot memory and resets the controller, loading the firmware from boot memory to dynamic memory. After the file is downloaded, be sure to call **mei_checksum(...)**.

To copy a firmware file from the DSP's boot memory to the host CPU, use **upload_firmware_file(…)**.

mei_checksum(...) calculates the size of the data stored in boot memory, writes the calculated checksum into boot memory and returns the checksum (not an error code). **mei_checksum(...)** also performs a non-volatile storage into the flash boot memory (surface mount controllers only).

When **dsp_init(...)** or **dsp_reset(...)** are called, the checksum is recalculated and compared with the checksum stored in boot memory. If the checksums do not match, then *error 16* (DSP_CHECKSUM) will be returned. If any of the 'boot' functions are called or the boot memory has been modified then **mei_checksum(...)** must be called, otherwise the next **dsp_init(...)** or **dsp_reset(...)** will fail.

All of the *surface mount* DSP Series controllers have flash RAM that stores the firmware and boot configuration. The flash RAM can be written to with **mei_checksum(...)** up to 10,000 times. The PC/DSP Series controllers have battery-backed RAM that stores the firmware and boot configuration, with no limitation on the number of times it can be written to.

RETURN VALUES

	Returns
download_firmware_file(...) **upload_firmware_file**(...) **mei_checksum**(...)	Error return codes (see *Error Handling* on page 3-13)

SEE ALSO

dsp_init(...), **dsp_reset(...)**

SAMPLE CODE

This code sets the boot configuration of the home sensor of axis 0 to trigger NO_EVENT and then calls checksum. The configuration does not take effect until the controller is reset.

```
# include <stdio.h>
# include "pcdsp.h"

int main()
{
     if (dsp_init(PCDSP_BASE))/* any problems initializing? */
             return dsp_error;/* just terminate the program. */

     set_boot_home(0, NO_EVENT);
     mei_checksum();

     return dsp_error ;     /* global variable provided by the library */
}
```

NOTES

The checksum is a required setup for the health check that **dsp_init(...)** performs. When the boot memory checksum doesn't agree with the saved checksum then there could be problems communicating with the controller, or the controller itself may not have been reset properly. See the *Installation Manual* for instructions about how to download firmware.

Closed Loop Configuration

dsp_closed_loop	read if an axis is configured for open or closed-loop operation
dsp_boot_closed_loop	read if an axis is configured for open or closed-loop operation at boot
dsp_set_closed_loop	configure an axis for open or closed-loop operation
dsp_set_boot_closed_loop	configure an axis for open or closed-loop operation at boot

SYNTAX

int16 **dsp_closed_loop**(int16 *axis*, int16 * *closed*)

int16 **dsp_boot_closed_loop**(int16 *axis*, int16 * *closed*)

int16 **dsp_set_closed_loop**(int16 *axis*, int16 *closed*)

int16 **dsp_set_boot_closed_loop**(int16 *axis*, int16 *closed*)

PROTOTYPE IN

pcdsp.h

DESCRIPTION

dsp_set_closed_loop(...) configures an axis for either closed-loop (*closed* = TRUE) or open loop operation (*closed* = FALSE). The axes must be configured in pairs (0 and 1, 2 and 3, etc.). In open-loop mode, the step-pulse and direction outputs are redirected back into the encoder inputs.

In closed-loop mode the actual position is read in from one of several possible feedback devices. The feedback device can be configured with the **set_feedback(...)** function. The encoder is the default position feedback device.

dsp_closed_loop(...) is used to determine if an axis has been configured as closed-loop or open-loop.

The boot functions store/read the feedback configuration for each axis in boot memory. These are loaded on power-up or **dsp_reset(...)**. Be sure to call **mei_checksum(...)** after the boot memory is modified.

SEE ALSO

set_feedback(...)

RETURN VALUES

	Returns
dsp_closed_loop(...) **dsp_boot_closed_loop**(...) **dsp_set_closed_loop**(...) **dsp_set_boot_closed_loop**(...)	Error return codes (see *Error Handling* on page 3-13)

SAMPLE CODE

This sample code checks if axis 0 is configured for closed loop operation.

```
# include <stdio.h>
# include "pcdsp.h"

int main()
{
     int16 closed;

     if (dsp_init(PCDSP_BASE))   /* any problems initializing? */
             return dsp_error;    /* just terminate the program. */

     dsp_closed_loop(0, &closed);
     if (closed)
             printf("Axis 0 is configured for closed loop operation\n");

     return dsp_error ;        /* global variable provided by the library */
}
```

Feedback Configuration

set_feedback	configure the feedback device for an axis
set_boot_feedback	configure the boot feedback device for an axis
get_feedback	read the feedback device configuration for an axis
get_boot_feedback	read the feedback device boot configuration for an axis

SYNTAX

int16 **set_feedback**(int16 *axis*, int16 *device*)
int16 **set_boot_feedback**(int16 *axis*, int16 *device*)
int16 **get_feedback**(int16 *axis*, int16 * *device*)
int16 **get_boot_feedback**(int16 *axis*, int16 * *device*)

PROTOTYPE IN

pcdsp.h

DESCRIPTION

set_feedback(...) configures the feedback device for a closed-loop axis. The possible feedback devices are:

Table 2-21 Possible Feedback Devices

#define	*Value*	*Feedback selected*
FB_ENCODER	0	Encoder is used for feedback (default)
FB_ANALOG	1	Analog input is used for feedback
FB_PARALLEL	2	Header P1 is used for 32-bit position feedback

The PC, PCX, STD, CPCI, V3U, V6U DSP Series controllers have 8 undedicated 12-bit analog input channels which are numbered 0 to 7. The DSPpro-Serial, DSPpro-PC, and DSPpro-VME also have 8 12-bit analog input channels. The 104, LC, and EXM DSP Series controllers and the SERCOS controllers do NOT have analog-to-digital converters. These functions are not applicable to the 104, LC, EXM, and SERCOS DSP Series.

The analog-to-digital conversion operates by writing a control word to the A/D component, waiting at least 15 microseconds, and then reading the digital value. The analog inputs can be read by the DSP or directly from the Host CPU. To guarantee proper analog-to-digital conversions, the DSP and the PC cannot read the analog inputs at the same time. If any axis is configured for servo on analog, axis analog, or on board jogging, then the Host CPU must not call the functions **start_analog(...)**, **read_analog(...)** or **get_analog(...)**.

FB_ANALOG uses the 12 bit analog-to-digital converter for position feedback. FB_PARALLEL uses headers P1 and P3 on the PC, PCX, STD, V3U, V6U DSP Series controllers for 32 bit position feedback. See the *Installation Manual* for more information. **get_feedback(...)** is used to determine the feedback device for a closed-loop axis. Note that the 104/DSP, LC/DSP, and EXM/DSP only support encoder feedback.

The analog input channel, and its configuration are set by **set_analog_channel(...)**. The default configuration is *axis* = *channel*, *differential* = FALSE, and *bipolar* = FALSE. Be sure to configure only one analog input *channel* per *axis*. **set_analog_channel(...)** is very useful in systems that need to switch between several analog input channels.

The boot functions store/read the feedback configuration for each axis in boot memory. These are loaded on power-up or **dsp_reset(...)**. Be sure to call **mei_checksum(...)** after the boot memory is modified.

RETURN VALUES

	Returns
set_feedback(...) **set_boot_feedback**(...) **get_feedback**(...) **get_boot_feedback**(...)	Error return codes (see *Error Handling* on page 3-13)

SEE ALSO **set_analog_channel(...)**, **get_axis_analog(...)**

SAMPLE CODE This sample code checks if axis 0 has an encoder for its feedback device.

```
# include <stdio.h>
# include "pcdsp.h"

int main()
{
     int16 device;

     if (dsp_init(PCDSP_BASE))    /* any problems initializing? */
             return dsp_error;    /* just terminate the program. */

     get_feedback(0, &device);
     if (device == FB_ENCODER)
             printf("Axis 0 uses an encoder for position feedback\n");

     return dsp_error ;          /* global variable provided by the library */
}
```

Dual Loop Configuration

set_dual_loop	configure an axis for dual loop operation
set_boot_dual_loop	configure an axis for dual loop operation at boot
get_dual_loop	read if an axis is configured for dual loop operation
get_boot_dual_loop	read if an axis is configured for boot dual loop operation

SYNTAX

int16 **set_dual_loop**(int16 *axis*, int16 *velocity_axis*, int16 *dual)*
int16 **set_boot_dual_loop**(int16 *axis*, int16 *velocity_axis*, int16 *dual*)
int16 **get_dual_loop**(int16 *axis*, int16 * *velocity_axis*, int16 * *dual*)
int16 **get_boot_dual_loop**(int16 *axis*, int16 * *velocity_axis*, int16 * *dual*)

PROTOTYPE IN

pcdsp.h

DESCRIPTION

set_dual_loop(...) configures an axis for either dual loop feedback control (*dual* = TRUE) or single loop feedback control (*dual* = FALSE). When a motor is configured for dual loop, the position information is taken from the *position_axis* encoder (usually connected to the load) and the velocity information is taken from the *velocity_axis* encoder (usually mounted to the motor). The dual loop PID algorithm uses the *position_axis* encoder for the proportional and integral terms, and the *velocity_axis* encoder (motor) for the derivative term.

After an axis is configured for dual loop feedback, all motion and PID filter parameters should be commanded to the position axis. The position axis' control output (+/-10 volts or STEP and DIR) should be connected to the motor. The velocity axis' control output (+/-10 volts or STEP and DIR) is not used by the DSP.

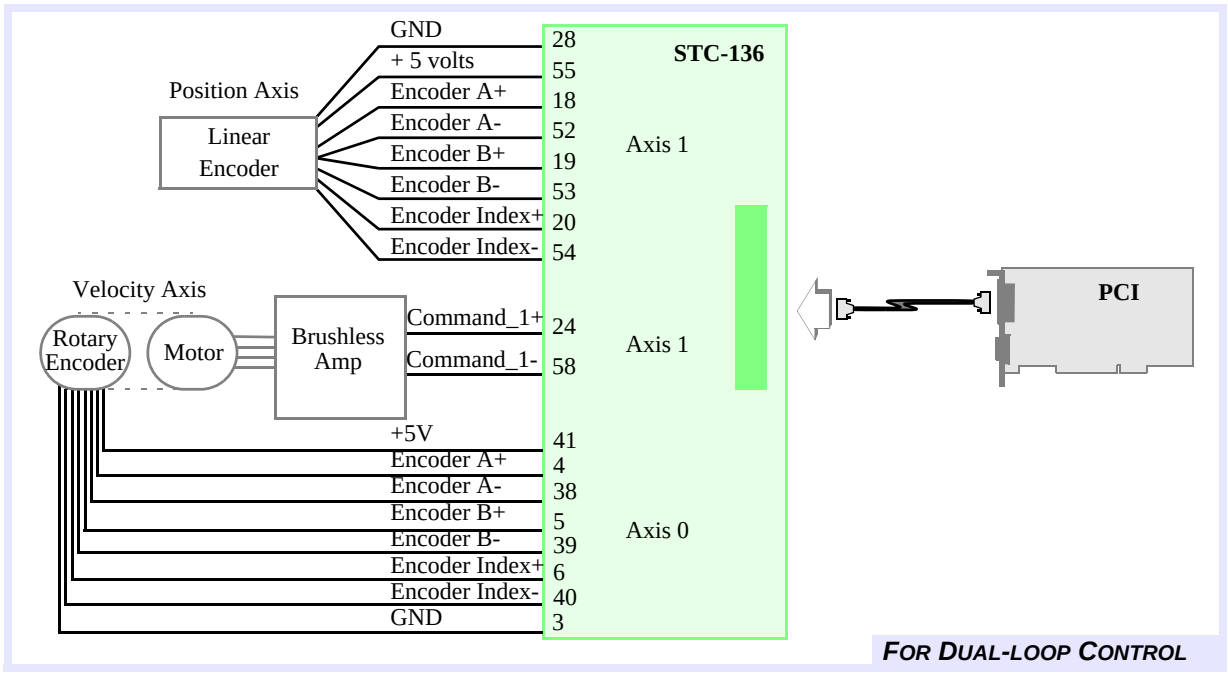
get_dual_loop(...) reads the dual loop configuration.
When configuring the *velocity_axis* for dual-loop control we are really just creating a velocity based encoder. Be sure not to mix a dual-loop *velocity_axis* with a cammed *master_axis*.

The boot functions store/read the feedback configuration for each axis in boot memory. These are loaded on power-up or **dsp_reset(...)**. Be sure to call **mei_checksum(...)** after the boot memory is modified.

RETURN VALUES

	Returns
set_dual_loop(...*)* **set_boot_dual_loop**(...) **get_dual_loop**(...) **get_boot_dual_loop**(...)	Error return codes (see *Error Handling* on page 3-13)

Figure 2-1 Dual-Loop Control: PCI/DSP



SAMPLE CODE This sample code configures an axis for dual-loop operation and is commanded.

```
# include <stdio.h>
# include "pcdsp.h"

# define POSITION_AXIS      0
# define VELOCITY_AXIS      1

int main()
{
     double actual;

     if (dsp_init(PCDSP_BASE))     /* any problems initializing? */
             return dsp_error;     /* just terminate the program. */

     set_dual_loop(POSITION_AXIS, VELOCITY_AXIS, TRUE);

     start_move(POSITION_AXIS, 10000.0, 1000.0, 10000.0);
     while (!motion_done())
     {       get_position(0, &actual);
             printf("Actual Position: %12.0lf\r", actual);
     }

     return dsp_error ;          /* global variable provided by the library */
}
```

Encoder Integrity Checking

set_feedback_check	enable/disable encoder feedback fault detection
get_feedback_check	read feedback fault detection configuration

SYNTAX

int16 **set_feedback_check**(int16 *axis*, int16 *state*)
int16 **get_feedback_check**(int16 *axis*, int16 * *state*)

PROTOTYPE IN

pcdsp.h

ENCODER SAFETY

The latest DSP-Series hardware, firmware, and software revisions support the following encoder safety features:

- Broken Wire Detection (requires differential encoder)
- Illegal State Detection (requires differential encoder)
- Encoder Input State Filtering.

The following hardware revisions (or higher) are required to support these:

Controller	***Rev***
PCX/DSP	3
STD/DSP	8
104/DSP	6
104X/DSP	1
LC/DSP	8
V6U/DSP	3
PCI/DSP	1
CPCI/DSP	1

Older hardware revisions cannot be upgraded to support the new encoder safety features.

DESCRIPTION

Use **set_feedback_check(…)** to control broken encoder wire and illegal state detection: enabled (***state*** = TRUE) or disabled (***state*** = FALSE) . Use **get_feedback_check(…)** to read the current axis' feedback checking configuration. When feedback checking is enabled, the DSP will examine the broken wire and illegal state registers every sample. If the DSP detects an encoder failure, an Abort Event will be generated on the appropriate axis.

The encoder inputs (channel A+, A-, B+, B-) are monitored by the FPGA (an on-board logic component). The encoder inputs are sampled at 10 MHz. A 4-state digital filter has been added to each of the encoder inputs position counters in the FPGA. This filter requires that an encoder input (channel A+, A-, B+, B-) be stable for 4 clock cycles (400 nanoseconds) before a transition is recognized.

A broken encoder wire condition occurs when either A+ or A- channels or B+ and B- channels are in the same logic state for 3 consecutive sample periods (300 nsec). When a broken encoder wire is detected, broken wire generates an ABORT_EVENT and returns a source of ID_FEEDBACK_FAULT. Broken wire detection is not applicable to single ended encoders.

An Illegal State condition occurs when the A and B encoders both change state between two consecutive samples. When an error condition is detected, Illegal State Detection generates an ABORT_EVENT and returns a source of ID_FEEDBACK_ILLEGAL_STATE.

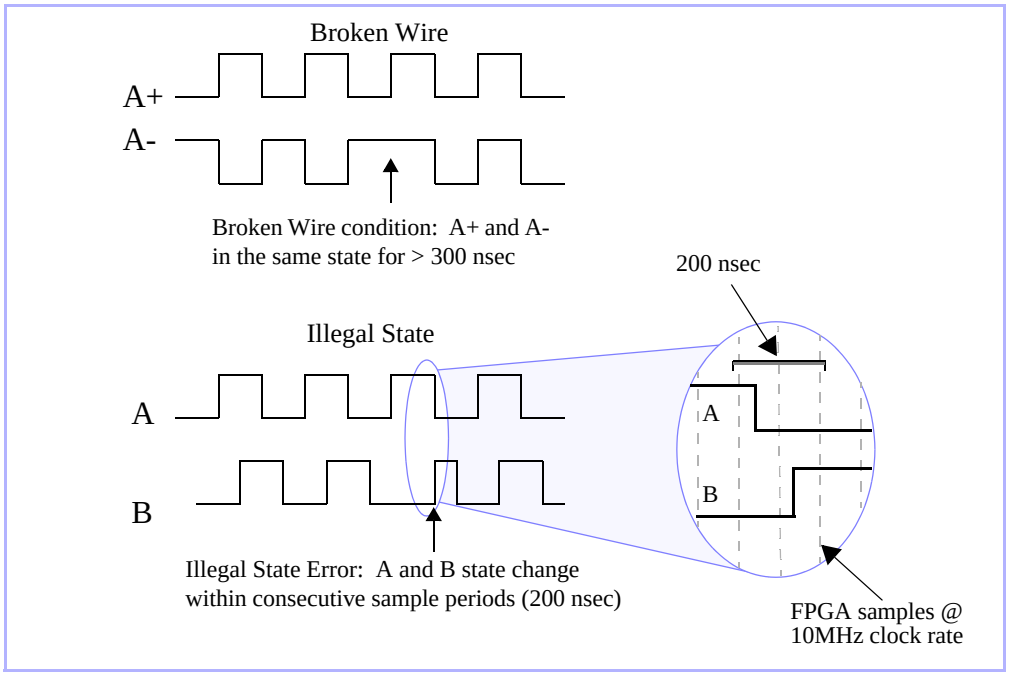
axis_source(...) can be used to determine the cause of the Exception Event. Two new identi-

fiers have been added to support Events caused by broken encoder wires and illegal states:

#define	*Explanation*
ID_FEEDBACK_FAULT	Broken encoder wire
ID_FEEDBACK_ILLEGAL_STATE	Illegal encoder state logic

To clear a broken encoder wire or illegal state condition, be sure and clear the source of the error then call **controller_run(...)**. This function will clear the broken wire, illegal state registers, and the Abort Event.

DIAGRAM



RETURN VALUES

	Returns
set_feedback_check(...) **get_feedback_check**(...)	Error return codes (see *Error Handling* on page 3-13)

SEE ALSO **axis_state(…)**, **axis_source(…)**, **controller_run(…)**

Step Output Configuration

dsp_stepper	returns TRUE if an axis' step output is enabled
dsp_boot_stepper	returns TRUE if an axis' step output is enabled at boot
dsp_set_stepper	enable/disable an axis' step output
dsp_set_boot_stepper	enable/disable an axis' boot step output
dsp_step_config	reads step mode configuration
dsp_boot_step_config	returns boot step mode configuration
dsp_set_step_config	sets the step mode configuration
dsp_set_boot_step_config	sets the boot step mode configuration

SYNTAX

int16 **dsp_stepper**(int16 *axis*)
int16 **dsp_boot_stepper**(int16 *axis*)
int16 **dsp_set_stepper**(int16 *axis*, int16 *stepper*)
int16 **dsp_set_boot_stepper**(int16 *axis*, int16 *stepper*)
int16 **dsp_step_config**(int16 *axis*, int16 **mode*)
int16 **dsp_boot_step_config**(int16 *axis*)
int16 **dsp_set_step_config**(int16 *axis*, int 16 *mode*)
int16 **dsp_set_boot_step_config**(int16 *axis*, int16 *mode*)

PROTOTYPE IN

pcdsp.h

DESCRIPTION

dsp_set_stepper(...) configures an *axis* for use with a step motor. The STEP and DIR output are enabled when *stepper* = TRUE and disabled when *stepper* = FALSE. This affects pairs of axes (0 and 1, 2 and 3 etc.). Don't forget to change the digital filter tuning parameters when switching from servo to step motors. **dsp_stepper(...)** returns TRUE if an axis is configured for stepper operation.

The function **dsp_step_config(...)** reads the current step mode configuration from the DSP controller. The function **dsp_set_step_config(...)** sets the step mode configuration . The boot mode configuration can be written with **dsp_set_boot_step_config(..)** and read with the function **dsp_boot_step_config(..)**. These functions require that the 1.33/2.33 PROM chipset be installed on the DSP Series controller with 2.4G2 firmware or greater. The supported values for *mode* are:

#	define	STEPDIR	0	*for step and direction*
#	define	CWCCW	1	*for clockwise/ counter clockwise*

The boot functions store/read the stepper configuration for each axis in boot memory. These are loaded on power-up or **dsp_reset(...)**. Be sure to call **mei_checksum(...)** after the boot memory is modified.

RETURN VALUES

	Returns
dsp_stepper(...) **dsp_boot_stepper**(...) **dsp_boot_step_config**(...)	Values
dsp_set_stepper(...) **dsp_set_boot_stepper**(...) **dsp_step_config**(...) **dsp_set_step_config**(...) **dsp_set_boot_step_config**(...)	Error return codes (see *Error Handling* on page 3-13)

SAMPLE CODE This sample code checks if the step output is enabled for axis 0.

```
# include <stdio.h>
# include "pcdsp.h"

int main()
{
     if (dsp_init(PCDSP_BASE))   /* any problems initializing? */
            return dsp_error;    /* just terminate the program. */

     if (dsp_stepper(0))
            printf("Axis 0's step ouptut is enabled\n");
     else
            printf("Axis 0's step output is disabled\n");

     return dsp_error ;       /* global variable provided by the library */
}
```

Step Output Speed Range

dsp_step_speed	Read an axis' step output speed range
dsp_boot_step_speed	Read an axis' boot step output speed range
dsp_set_step_speed	Configure an axis' step output speed range
dsp_set_boot_step_speed	Configure an axis' boot step output speed range

SYNTAX

int16 **dsp_step_speed**(int16 *axis*, int16 * *speed*)
int16 **dsp_boot_step_speed**(int16 *axis*, int16 * *speed*)
int16 **dsp_set_step_speed**(int16 *axis*, int16 *speed*)
int16 **dsp_set_boot_step_speed**(int16 *axis*, int16 *speed*)

PROTOTYPE IN

pcdsp.h

DESCRIPTION

Use **dsp_set_step_speed(...)** to configure the *step speed* range of an axis.

Table 2-22 Step Pulse Output

#define	*Value*	*Old #defines*
DISABLE_STEP_OUTPUT	0	DISABLE_STEP_OUTPUT
R17KHZ_STEP_OUTPUT	3	SLOW_STEP_OUTPUT
R70KHZ_STEP_OUTPUT	2	MEDIUM_STEP_OUTPUT
R275KHZ_STEP_OUTPUT	1	FAST_STEP_OUTPUT
R550KHZ_STEP_OUTPUT	4	Not Applicable

The speed range sets the maximum pulse rate output. The lower the speed range, the higher the resolution, and the better the step motor will perform. Slow is most frequently used. The only limitation of the Slow setting is the maximum velocity. Using the Slow setting has no effect on the maximum acceleration or the maximum jerk.

A new step output speed, R550KHZ_STEP_OUTPUT, has been added to accomodate applications that require higher step rates. This feature requires that the 1.33/2.33 PROM chipset be installed on the DSP Series controller and firmware version 2.4G2 or greater.

The step output speeds have also been renamed to reflect the actual tested limits for each range. For version compatibility, the old #defines will work with the new libraries.

Table 2-23 Step Speed Ranges

Controller	*Slow*	*Medium*	*Fast*	*Superfast*
PC/DSP	0 to 125 kHz	0 to 500 kHz	0 to 2.0 MHz	N/A
PCX/DSP	0 to 17 kHz	0 to 70 kHz	0 to 275 kHz	0 to 550 kHz
STD/DSP	0 to 17 kHz	0 to 70 kHz	0 to 275 kHz	0 to 550 kHz
104/DSP	0 to 17 kHz	0 to 70 kHz	0 to 275 kHz	0 to 550 kHz
LC/DSP	0 to 17 kHz	0 to 70 kHz	0 to 275 kHz	0 to 550 kHz
V6U/DSP	0 to 17 kHz	0 to 70 kHz	0 to 275 kHz	0 to 550 kHz
104X/DSP	0 to 17 kHz	0 to 70 kHz	0 to 275 kHz	0 to 550 kHz
CPCI/DSP	0 to 17 kHz	0 to 70 kHz	0 to 275 kHz	0 to 550 kHz
PCI/DSP	0 to 17 kHz	0 to 70 kHz	0 to 275 kHz	0 to 550 kHz
DSPpro-Serial	0 to 17 kHz	0 to 70 kHz	0 to 275 kHz	0 to 550 kHz
DSPpro-VME	0 to 17 kHz	0 to 70 kHz	0 to 275 kHz	0 to 550 kHz

dsp_step_speed(...) reads an *axis*' *speed* range configuration.

The boot functions store/read the step speed configuration for each axis in boot memory. These are loaded on power-up or **dsp_reset(...)**. Be sure to call **mei_checksum(...)** after the boot memory is modified.

RETURN VALUES

	Returns
dsp_step_speed(...) **dsp_boot_step_speed**(...) **dsp_set_step_speed**(...) **dsp_set_boot_step_speed**(...)	Error return codes (see *Error Handling* on page 3-13)

SAMPLE CODE

This sample code enables the STEP and DIR outputs for axis 0 using the *slow speed* range.

```
# include <stdio.h>
# include "pcdsp.h"

int main()
{
     if (dsp_init(PCDSP_BASE))   /* any problems initializing? */
             return dsp_error;    /* just terminate the program. */

     set_unipolar(0, TRUE);             /* enable direction output bit */
     dsp_set_stepper(0, TRUE);            /* enable step-pulse output */
     dsp_set_step_speed(0, R17KHZ_STEP_OUTPUT);    /* slow speed range */

     return dsp_error ;       /* global variable provided by the library */
}
```

Analog Output Voltage Configuration

is_unipolar	returns TRUE if an axis' analog output is unipolar
is_boot_unipolar	returns TRUE if an axis' analog output is unipolar at boot
set_unipolar	configure an axis' analog output
set_boot_unipolar	configure an axis' boot analog output

SYNTAX

int16 **is_unipolar**(int16 *axis*)
int16 **is_boot_unipolar**(int16 *axis*)
int16 **set_unipolar**(int16 *axis*, int16 *state*)
int16 **set_boot_unipolar**(int16 *axis*, int16 *state*)

PROTOTYPE IN

pcdsp.h

DESCRIPTION

set_unipolar(...) configures an *axis*' analog output voltage for either unipolar (*state* = TRUE) or bipolar (*state* = FALSE) operation.

If an axis is configured for bipolar operation, the analog output voltage range will be from -10 volts to +10 volts. The sign of the voltage indicates either the positive or negative direction.

If an axis is configured for unipolar operation, the analog output voltage range will be from 0 volts to +10 volts. The direction output bit will indicate positive or negative direction. Unipolar is the correct configuration for step motors. If a step motor axis is configured for bipolar operation, it will only go in one direction.

The boot functions store/read the unipolar configuration for each axis in boot memory. These are loaded on power-up or **dsp_reset(...)**. Be sure to call **mei_checksum(...)** after the boot memory is modified.

RETURN VALUES

	Returns
is_unipolar(...) **is_boot_unipolar**(...)	Values
set_unipolar(...) **set_boot_unipolar**(...)	Error return codes (see *Error Handling* on page 3-13)

SAMPLE CODE

This sample code checks if axis 0 is configured for unipolar operation.

```
# include <stdio.h>
# include "pcdsp.h"

int main()
{
     if (dsp_init(PCDSP_BASE))   /* any problems initializing? */
             return dsp_error;    /* just terminate the program. */

     if (is_unipolar(0))
             printf("Analog output is configured for 0 to 10 volts\n");
     else
             printf("Analog output is configured for +/- 10 volts\n");

     return dsp_error ;       /* global variable provided by the library */
}
```

PID Filter Parameters

set_filter	set the PID filter coefficients
set_boot_filter	set the boot PID filter coefficients
get_filter	get the PID filter coefficients
get_boot_filter	get the boot PID filter coefficients
set_integration	set the integration mode
set_boot_integration	set the boot integration mode
get_integration	get the integration mode
get_boot_integration	get the boot integration mode

SYNTAX

int16 **set_filter**(int16 *axis*, int16 * *coeffs)*
int16 **set_boot_filter**(int16 *axis*, int16 * *coeffs*)
int16 **get_filter**(int16 *axis*, int16 * *coeffs*)
int16 **get_boot_filter**(int16 *axis*, int16 * *coeffs*)

int16 **set_integration**(int16 *axis*, int16 *mode*)
int16 **set_boot_integration**(int16 *axis*, int16 *mode*)
int16 **get_integration**(int16 *axis*, int16 * *mode*)
int16 **get_boot_integration**(int16 *axis*, int16 * *mode*)

PROTOTYPE IN

pcdsp.h

DESCRIPTION

set_filter(...) configures an *axis*' filter coefficients. **get_filter(...)** reads the current filter coefficients used by the DSP controller. Both functions expect a pointer to an array of integers, mapped as follows:

Table 2-24 PID Filter Parameters

#define	*Value*	*Explanation*
DF_P	0	Proportional gain
DF_I	1	Integral gain
DF_D	2	Derivative gain - damping term
DF_ACCEL_FF	3	Acceleration feed forward
DF_VEL_FF	4	Velocity feed-forward
DF_I_LIMIT	5	Integration summing limit
DF_OFFSET	6	Voltage output offset
DF_DAC_LIMIT	7	Voltage output limit
DF_SHIFT	8	2^(n) divisor
DF_FRICT_FF	9	Friction Feed Forward
COEFFICIENTS	10	Number of elements

The integration mode for an axis is set by calling **set_integration(...)** with *mode*:

Table 2-25 Integration Active/Not Active

#define	*Value*	*Explanation*
IM_STANDING	0	Integration active only when command velocity is zero
IM_ALWAYS	1	Integration is always active

The boot functions store/read the digital filter coefficients for each axis in boot memory. These are loaded on power-up or **dsp_reset(...)**. Make sure to call **mei_checksum(...)** after the boot memory is modified.

RETURN VALUES

	Returns
set_filter(...) **set_boot_filter**(...) **get_filter**(...) **get_boot_filter**(...) **set_integration**(...) **set_boot_integration**(...) **get_integration**(...) **get_boot_integration**(...)	Error return codes (see *Error Handling* on page 3-13)

SEE ALSO **dsp_set_filter(...)**

SAMPLE CODE The following code decreases the gain before a first move, and increases it before a second move:

```
# include <stdio.h>
# include "pcdsp.h"

int main()
{
     int16 Coefficients[COEFFICIENTS];

     if (dsp_init(PCDSP_BASE))   /* any problems initializing? */
             return dsp_error;    /* just terminate the program. */

     get_filter(0, Coefficients);
     Coefficients[DF_P] = 512;          /* low proportional gain */
     set_filter(0, Coefficients);       /* set the filter parameters */
     move(0, 100000., 8000., 16000.);

     Coefficients[DF_P] = 1024;         /* high proportional gain */
     set_filter(0, Coefficients);       /* set the filter parameters */
     move(0, 0., 8000., 16000.);

     return dsp_error ;        /* global variable provided by the library */
}
```

NOTES Sometimes it is difficult to find a set of tuning parameters that will produce accurate motion without oscillation (usually due to poor mechanical systems with servo motors). Thus, it may be necessary to have 2 sets of tuning parameters.

One set of parameters with a low gain might be used when the motor is not in motion and another set of tuning parameters with a higher gain could be used during motion. See the *Installation Manual* for helpful hints on finding correct filter parameters.

Auxiliary Filter Parameters

set_aux_filter	set the auxiliary digital filter coefficients
set_boot_aux_filter	set the boot auxiliary digital filter coefficients
get_aux_filter	get the auxiliary digital filter coefficients
get_boot_aux_filter	get the boot auxiliary digital filter coefficients

SYNTAX

int16 **set_aux_filter**(int16 *axis*, int16 * *coeffs*)
int16 **set_boot_aux_filter**(int16 *axis*, int16 * *coeffs*)
int16 **get_aux_filter**(int16 *axis*, int16 * *coeffs*)
int16 **get_boot_aux_filter**(int16 *axis*, int16 * *coeffs*)

PROTOTYPE IN

pcdsp.h

DESCRIPTION

set_aux_filter(...) configures an *axis*' auxiliary filter coefficients. **get_aux_filter(...)** reads the current auxiliary filter coefficients used by the DSP controller. Both functions expect a pointer to an array of integers.

Table 2-26 First Auxiliary Coefficient

#define	*Value*	*Explanation*
AUX_FILTER_COEFFS	10	Number of elements

Currently, only the first auxiliary digital filter coefficient is supported. The derivative term of the PID algorithm can be calculated at slower sample rates than the other terms. The lower 8 bits of the first auxiliary filter coefficient (B0) control the derivative sample rate:

Table 2-27 Derivative Sample Rate

B0	*Derivative Sample Rate*
0	DSP Sample Rate
1	DSP Sample Rate / 2
3	DSP Sample Rate / 4
7	DSP Sample Rate / 8
15	DSP Sample Rate / 16
31	DSP Sample Rate / 32

The first auxiliary coefficient (B0) should be equal to (2^n) -1 where 2^n is the DSP sample rate divisor. Using (2^n)-1 will guarantee a uniform derivative sample rate. Systems with very high rotational inertia will benefit from a derivative term with a lower sample rate. As the derivative sample rate is decreased, its effectiveness increases.

The boot functions store/read the auxiliary digital filter coefficients for each axis in boot memory. These are loaded on power-up or **dsp_reset(...)**. Be sure to call **mei_checksum(...)** after the boot memory is modified.

RETURN VALUES

	Returns
set_aux_filter(...), **set_boot_aux_filter**(...) **get_aux_filter**(...), **get_boot_aux_filter**(...)	Error return codes (see *Error Handling* on page 3-13)

SEE ALSO

set_filter(...), **get_filter(...)**, **dsp_sample_rate(...)**, **get_sample_rate(...)**

Home Action Configuration

set_home	set the home/index logic action
set_boot_home	set the boot home/index logic action
get_home	read the home/index logic action
get_boot_home	read the boot home/index logic action

SYNTAX

int16 **set_home**(int16 *axis*, int16 *action*)
int16 **set_boot_home**(int16 *axis*, int16 *action*)
int16 **get_home**(int16 *axis*, int16 * *action*)
int16 **get_boot_home**(int16 *axis*, int16 * *action*)

PROTOTYPE IN

pcdsp.h

DESCRIPTION

set_home(...) configures the DSP to generate an *action* when an *axis*' home logic is activated. The home logic may be some combination of the home and index inputs. The home and index inputs are logically combined or individually ignored based on the configuration set by s**et_home_index_config(...)**.

The *action* can be one of the following values:

Table 2-28 Possible Homing Actions

#define	*Value*	*Explanation*
NO_EVENT	0	Ignore a condition
NEW_FRAME	2	Begin execution of the next sequenced frame
STOP_EVENT	8	Decelerate to a stop (at specified stop rate)
E_STOP_EVENT	10	Decelerate to a stop (at specified E-stop rate)
ABORT_EVENT	14	Disable PID control and the amplifier for this axis

get_home(...) reads an *axis*' home/index logic *action* configuration.

The home/index logic is level triggered and is not latched.

The boot functions store/read the home/index logic action in boot memory. These are loaded on power-up or **dsp_reset(...)**. Be sure to call **mei_checksum(...)** after the boot memory is modified.

RETURN VALUES

	Returns
set_home(...) **set_boot_home**(...) **get_home**(...) **get_boot_home**(...)	Error return codes (see *Error Handling* on page 3-13)

SERCOS

The function **set_home(…)** is applicable to a SERCOS/DSP-controller if the SERCOS drive's Status bits are mapped into the dedicated I/O registers. Also see page 2-53, *SERCOS Initialization*. If the drive's status bits are NOT mapped into the dedicated I/O registers, then disable the dedicated I/O by setting the action to NO_EVENT.

SEE ALSO

set_home_index_config(...), **set_home_level(...)**, **dsp_home_action(...)**

SAMPLE CODE This code configures the DSP to generate a STOP_EVENT when the home signal goes low.

```
# include <stdio.h>
# include "pcdsp.h"

int main()
{
     if (dsp_init(PCDSP_BASE))   /* any problems initializing? */
             return dsp_error;    /* just terminate the program. */

/* configure the home logic for home input only */
     set_home_index_config(0, HOME_ONLY);
     set_home_level(0, FALSE);   /* configure for active low logic */
     set_home(0, STOP_EVENT);    /* configure for a Stop Event */

     return dsp_error ;        /* global variable provided by the library */
}
```

Home Logic Configuration

set_home_index_config	configure the home/index logic
set_boot_home_index_config	configure the boot home/index logic
get_home_index_config	read the home/index logic configuration
get_boot_home_index_config	read the boot home/index logic configuration
set_home_level	configure the active state of the home/index logic
set_boot_home_level	configure the boot active state of the home/index logic
get_home_level	read the active state of the home/index logic configuration
get_boot_home_level	read the boot active home state of the home/index logic configuration

SYNTAX

int16 **set_home_index_config**(int16 *axis*, int16 *config*)
int16 **set_boot_home_index_config**(int16 *axis*, int16 *config*)
int16 **get_home_index_config**(int16 *axis*, int16 * *config*)
int16 **get_boot_home_index_config**(int16 *axis*, int16 * *config*)

int16 **set_home_level**(int16 *axis*, int16 *level*)
int16 **set_boot_home_level**(int16 *axis*, int16 *level*)
int16 **get_home_level**(int16 *axis*, int16 * *level*)
int16 **get_boot_home_level**(int16 *axis*, int16 * *level*)

PROTOTYPE IN

pcdsp.h

DESCRIPTION

set_home_index_config(...) configures the home/index logic

Each axis has a dedicated home and index input. The home and index inputs are logically combined or individually ignored based on the configuration. The home/index configuration affects axes in groups of four (0 to 3, or 4 to 7).

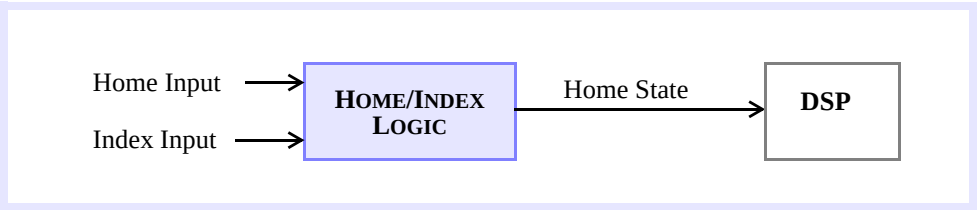
Table 2-29 Home Index Configurations

#define	*Value*	*Explanation*
HOME_ONLY	0	home input only (active high or active low)
LOW_HOME_AND_INDEX	1	home input ANDed with index (active low home and active high index)
INDEX_ONLY	2	index only (active high or active low)
HIGH_HOME_AND_INDEX	3	home input ANDed with index (active high home and active high index)

These configurations require version 1.21, 2.21 (or later) EPROMs for the surface mount controllers or Home 1D and Home 2D (or later) GALs for the PC/DSP.

Each sample the DSP examines the home logic to decide if an exception event should be generated. To guarantee that the DSP does not miss the home logic the home input and/or index pulse must be longer than one DSP sample. The default sample rate is 1250 samples/sec.
set_home_level(...) configures an axis' home logic for either active low (*level* = FALSE) or active high (*level* = TRUE) operation.

Figure 2-2 Motion Status During Trapezoidal Profile Move



The following table shows all of the possible home logic configurations. An Event is generated when the home logic reaches the active state. A value of 0 indicates a low signal (0 volts) and a value of 1 indicates a high signal (+5 volts). True indicates an exception event is generated and False means no exception event is generated.

Table 2-30 Possible Home Logic Configurations

Config	*Home*	*Index*	*Event Active Low*	*Event Active High*
0	0	0	**True**	False
0	0	1	**True**	False
0	1	0	False	**True**
0	1	1	False	**True**
1	0	0	False	**True**
1	0	1	**True**	False
1	1	0	False	**True**
1	1	1	False	**True**
2	0	0	**True**	False
2	0	1	False	**True**
2	1	0	**True**	False
2	1	1	False	**True**
3	0	0	False	**True**
3	0	1	False	**True**
3	1	0	False	**True**
3	1	1	**True**	False

Home/index logic configurations 1 and 3 invert the combined logic of the home and index signals (for backwards compatibility). In most applications, when home/index configuration 1 or 3 is used the home/index level should be set to active low (FALSE).

get_home_index_config(...) reads the home/index logic configuration. **get_home_level(...)** reads the active state configuration of the home/index logic.

The boot functions store/read the home/index configurations in boot memory. These are loaded on power-up or **dsp_reset(...)**. Be sure to call **mei_checksum(...)** after the boot memory is modified.

RETURN VALUES

	Returns
set_home_index_config(...) **set_boot_home_index_config**(...) **get_home_index_config**(...) **get_boot_home_index_config**(...) **set_home_level**(...) **set_boot_home_level**(...) **get_home_level**(...) **get_boot_home_level**(...)	Error return codes (see *Error Handling* on page 3-13)

SERCOS

The functions **set_home_level(…)**, **get_home_level(…)**, **set_boot_home_level(…)**, and **get_boot_home_level(…)** are applicable to a SERCOS/DSP Series controller if the SERCOS drive's Status bits are mapped into the dedicated I/O registers. Also see page 2-53, *SERCOS Initialization*. If the drive's Status bits are NOT mapped into the dedicated I/O registers, then disable the dedicated I/O by setting the action to NO_EVENT.

SEE ALSO

set_home(...), **dsp_home_action(...)**, **home_switch(...)**

SAMPLE CODE

This code configures the DSP to generate a STOP_EVENT when the home signal is low and the index is high.

```
# include <stdio.h>
# include "pcdsp.h"

int main()
{
     if (dsp_init(PCDSP_BASE))    /* any problems initializing? */
             return dsp_error;     /* just terminate the program. */

/* configure the home logic for home & index */
     set_home_index_config(0, LOW_HOME_AND_INDEX);
     set_home_level(0, FALSE);   /* configure for active low logic*/
     set_home(0, STOP_EVENT);    /* configure for a Stop Event */

     return dsp_error ;       /* global variable provided by the library */
}
```

NOTES

Almost every application requires a homing routine. The programmer needs to decide how to home the axes based on the mechanics of the system. Very often, the homing routine is the most complicated task in an application. Be sure to examine the Applications distribution disk. It contains several sample homing routines.

Limit Input Action Configuration

set_positive_limit	set an axis' positive limit input action
set_boot_positive_limit	set an axis' boot positive limit input action
get_positive_limit	read an axis' positive limit input action
get_boot_positive_limit	read an axis' boot positive limit input action
set_negative_limit	set an axis' negative limit input action
set_boot_negative_limit	set an axis' boot negative limit input action
get_negative_limit	read an axis' negative limit input action
get_boot_negative_limit	read an axis' boot negative limit input action

SYNTAX

set_positive_limit(int16 *axis*, int16 *action*)
set_boot_positive_limit(int16 *axis*, int16 *action*)
get_positive_limit(int16 *axis*, int16 * *action*)
get_boot_positive_limit(int16 *axis*, int16 * *action*)

set_negative_limit(int16 *axis*, int16 *action*)
set_boot_negative_limit(int16 *axis*, int16 *action*)
get_negative_limit(int16 *axis*, int16 * *action*)
get_boot_negative_limit(int16 *axis*, int16 * *action*)

PROTOTYPE IN

pcdsp.h

DESCRIPTION

set_positive_limit(...), **set_negative_limit(...)** configure the DSP to generate an *action* when an *axis*' positive, negative limit input is activated. The *action* can be one of the following:

Table 2-31 Possible DSP-Generated Actions

#define	*Value*	*Explanation*
NO_EVENT	0	Ignore a condition
NEW_FRAME	2	Begin execution of the next sequenced frame
STOP_EVENT	8	Decelerate to a stop (at specified stop rate)
E_STOP_EVENT	10	Decelerate to a stop (at specified E-stop rate)
ABORT_EVENT	14	Disable PID control and the amplifier for this axis

get_positive_limit(...), **get_negative_limit(...)** read an axis' limit input action configuration.

The boot functions store/read the limit configurations for each axis in boot memory. These are loaded on power-up or **dsp_reset(...)**. Be sure to call **mei_checksum(...)** after the boot memory is modified.

RETURN VALUES

	Returns
set_positive_limit(...) **set_boot_positive_limit**(...) **get_positive_limit**(...) **get_boot_positive_limit**(...) **set_negative_limit**(...) **set_boot_negative_limit**(...) **get_negative_limit**(...) **get_boot_negative_limit**(...)	Error return codes (see *Error Handling* on page 3-13)

SERCOS

The functions **set_positive_limit(…)** and **set_negative_limit(…)** are applicable to a SERCOS/DSP Series controller if the SERCOS drive's status bits are mapped into the dedicated I/O registers. Also see page 2-53, *SERCOS Initialization*. If the drive's Status bits are NOT mapped into the dedicated I/O registers, then disable the dedicated I/O by setting the action to NO_EVENT.

SEE ALSO

set_positive_level(...), **set_negative_level(...)**, **pos_switch(...)**, **neg_switch(...)**

SAMPLE CODE

This code configures the positive limit input (active low) to trigger an E_STOP_EVENT.

```
# include "pcdsp.h"

int main()
{
     if (dsp_init(PCDSP_BASE))   /* any problems initializing? */
             return dsp_error;    /* just terminate the program. */

     set_positive_limit(0, E_STOP_EVENT);
     set_positive_level(0, FALSE);

     return dsp_error ;        /* global variable provided by the library */
}
```

Limit Input Level Configuration

set_positive_level	configure the active state of an axis' positive limit input
set_boot_positive_level	configure the boot active state of an axis' positive limit input
get_positive_level	read the active state of an axis' positive limit input
get_boot_positive_level	read the boot active state of an axis' positive limit input
set_negative_level	configure the active state of an axis' negative limit input
set_boot_negative_level	configure the boot active state of an axis' negative limit input
get_negative_level	read the active state of an axis' negative limit input
get_boot_negative_level	read the boot active state of an axis' negative limit input

SYNTAX

set_positive_level(int16 *axis*, int16 *level*)
set_boot_positive_level(int16 *axis*, int16 *level*)
get_positive_level(int16 *axis*, int16 * *level*)
get_boot_positive_level(int16 *axis*, int16 * *level*)

set_negative_level(int16 *axis*, int16 *level*)
set_boot_negative_level(int16 *axis*, int16 *level*)
get_negative_level(int16 *axis*, int16 * *level*)
get_boot_negative_level(int16 *axis*, int16 * *level*)

PROTOTYPE IN

pcdsp.h

DESCRIPTION

set_positive_level(...), **set_negative_level(...)** configure an axis' limit input for either active low (*level* = FALSE) or active high (*level* = TRUE) operation.

Each sample the DSP examines an axis' limit inputs and command velocity to decide if an exception event should be generated. When the command velocity is positive, the negative limit input is ignored. When the command velocity is negative, the positive limit input is ignored.

When the command velocity is zero, both limit inputs are ignored. To guarantee that the DSP does not miss a limit, the limit input pulse must be longer than one DSP sample. The default sample rate is 1250 samples/sec.

get_positive_level(...), **get_negative_level(...)** read an axis' active state configuration of the positive, negative limit input.

The boot functions store/read the limit level configurations for each axis in boot memory. These are loaded on power-up or **dsp_reset(...)**. Be sure to call **mei_checksum(...)** after the boot memory is modified.

RETURN VALUES

	Returns
set_positive_level(...) **set_boot_positive_level**(...) **get_positive_level**(...) **get_boot_positive_level**(...) **set_negative_level**(...) **set_boot_negative_level**(...) **get_negative_level**(...) **get_boot_negative_level**(...)	Error return codes (see *Error Handling* on page 3-13)

SERCOS

The functions s**et_positive_level(…)**, **set_negative_level(…)**, **set_boot_positive_level(…)**, **set_boot_negative_level(…)**, **get_positive_level(…)**, **get_negative_level(…)**, **get_boot_positive_level(…)**, and **get_boot_negative_level(…)** are applicable to a SERCOS/DSP Series controller if the SERCOS drive's Status bits are mapped into the dedicated I/O registers. Also see page 2-53, *SERCOS Initialization*. If the drive's Status bits are NOT mapped into the dedicated I/O registers, then disable the dedicated I/O by setting the action to NO_EVENT.

SEE ALSO

set_positive_limit(...), **set_negative_limit(...)**, **pos_switch(...)**, **neg_switch(...)**

SAMPLE CODE

This code configures the positive limit input (active low) to trigger an E_STOP_EVENT.

```
# include "pcdsp.h"

int main()
{
     if (dsp_init(PCDSP_BASE))   /* any problems initializing? */
             return dsp_error;    /* just terminate the program. */

     set_positive_limit(0, E_STOP_EVENT);
     set_positive_level(0, FALSE);

     return dsp_error ;       /* global variable provided by the library */
}
```

Amp Fault Input Configuration

set_amp_fault	set an axis' amp fault input action
set_boot_amp_fault	set an axis' boot amp fault input action
get_amp_fault	read an axis' amp fault input action
get_boot_amp_fault	read an axis' boot amp fault input action
set_amp_fault_level	configure the active state of an axis' amp fault input
set_boot_amp_fault_level	configure the boot active state of an axis' amp fault input
get_amp_fault_level	read the active state of an axis' amp fault input
get_boot_amp_fault_level	read the boot active state of an axis' amp fault input

SYNTAX

set_amp_fault(int16 *axis*, int16 *action*)
set_boot_amp_fault(int16 *axis*, int16 *action*)
get_amp_fault(int16 *axis*, int16 * *action*)
get_boot_amp_fault(int16 *axis*, int16 * *action*)

set_amp_fault_level(int16 *axis*, int16 *level*)
set_boot_amp_fault_level(int16 *axis*, int16 *level*)
get_amp_fault_level(int16 *axis*, int16 * *level*)
get_boot_amp_fault_level(int16 *axis*, int16 * *level*)

PROTOTYPE IN

pcdsp.h

DESCRIPTION

set_amp_fault(...) configure the DSP to generate an *action* when an *axis*' amp fault input is activated. The *action* can be one of the following:

Table 2-32 Possible Axis Actions

#define	*Value*	*Explanation*
NO_EVENT	0	Ignore a condition
NEW_FRAME	2	Begin execution of the next sequenced frame
STOP_EVENT	8	Decelerate to a stop (at specified stop rate)
E_STOP_EVENT	10	Decelerate to a stop (at specified E-stop rate)
ABORT_EVENT	14	Disable PID control and the amplifier for this axis

set_amp_fault_level(...) configures an axis' amp fault input for either active low (*level* = FALSE) or active high (*level* = TRUE) operation.

Each sample the DSP examines an axis' amp fault input to decide if an exception event should be generated. To guarantee that the DSP does not miss an amp fault, the amp fault input pulse must be longer than one DSP sample. The default sample rate is 1250 samples/sec.

get_amp_fault(...) reads an axis' amp fault action configuration. **get_amp_fault_level(...)** reads an axis' active state configuration of the amp fault input.

The boot functions store/read the amp fault configurations for each axis in boot memory. These are loaded on power-up or **dsp_reset(...)**. Be sure to call **mei_checksum(...)** after the boot memory is modified.

RETURN VALUES

	Returns
set_amp_fault(...) **set_boot_amp_fault**(...) **get_amp_fault**(...) **get_boot_amp_fault**(...) **set_amp_fault_level**(...) **set_boot_amp_fault_level**(...) **get_amp_fault_level**(...) **get_boot_amp_fault_level**(...)	Error return codes (see *Error Handling* on page 3-13)

SERCOS

The functions **set_amp_fault_level(…)**, **get_amp_fault_level(…)**, **set_boot_amp_fault_level(…)**, and **get_boot_amp_fault_level(…)** are applicable to a SERCOS/DSP Series controller if the SERCOS drive's status bits are mapped into the dedicated I/O registers. Also see page 2-53, *SERCOS Initialization*. If the drive's Status bits are NOT mapped into the dedicated I/O registers, then disable the dedicated I/O by setting the action to NO_EVENT.

SEE ALSO

amp_fault_switch(...)

SAMPLE CODE

This code configures the amp fault input (axis 0) to trigger an ABORT_EVENT when the amp fault signal is low.

```
# include <stdio.h>
# include "pcdsp.h"

int main()
{
     if (dsp_init(PCDSP_BASE))   /* any problems initializing? */
             return dsp_error;    /* just terminate the program. */

     set_amp_fault(0, ABORT_EVENT);
     set_amp_fault_level(0, FALSE);

     return dsp_error ;        /* global variable provided by the library */
}
```

Amp Enable Output Configuration

set_amp_enable	set the state of an axis' amp enable output
set_boot_amp_enable	set the boot state of an axis' amp enable output
get_amp_enable	read the state of an axis' amp enable output
get_boot_amp_enable	read the boot state of an axis' amp enable output
set_amp_enable_level	configure the Run state of an axis' amp enable output
set_boot_amp_enable_level	configure the boot Run state of an axis' amp enable output
get_amp_enable_level	read the Run state of an axis' amp enable output
get_boot_amp_enable_level	read the boot Run state of an axis' amp enable output

USAGE:

SYNTAX

int16 **set_amp_enable**(int16 *axis*, int16 *state*)
int16 **set_boot_amp_enable**(int16 *axis*, int16 *state*)
int16 **get_amp_enable**(int16 *axis*, int16 * *state*)
int16 **get_boot_amp_enable**(int16 axis, int16 * *state*)

int16 **set_amp_enable_level**(int16 *axis*, int16 *level*)
int16 **set_boot_amp_enable_level**(int16 *axis*, int16 *level*)
int16 **get_amp_enable_level**(int16 *axis*, int16 * *level*)
int16 **get_boot_amp_enable_level**(int16 *axis*, int16 * *level*)

PROTOTYPE IN

pcdsp.h

DESCRIPTION

set_amp_enable(...) tells the DSP to set an axis' amp enable output to a high or low *state*. The *state* of the output can be TRUE (+5V) or FALSE (0V).

set_amp_enable_level(...) configures an axis' amp enable output for either active low (*level* = FALSE) or active high (*level* = TRUE) operation. The amp enable level configuration is used by the DSP and the functions **enable_amplifier(...)** and **disable_amplifier(...)**.

During an Abort Event the DSP automatically disables the amp enable output. The polarity of a disabled amp enable output is determined by **set_amp_enable_level(...)**. To re-enable the amp enable output, the Abort Event must be first be cleared with **controller_run(...)**. Then the amp enable output can be re-enabled with **set_amp_enable(...)** or **enable_amplifer(...)**.

Notice that the DSP does NOT automatically re-enable the amp enable output during a **controller_run(...)**. This is a safety feature. The Abort Event is the DSP's highest priority. It is the programmer's responsibility to examine the cause of the Abort Event with **axis_source(...)** and determine if the problem is serious.

During normal operation, (no Abort Event) the amp enable output can be enabled or disabled with **set_amp_enable(...)**, **enable_amplifier(...)** or **disable_amplifer(...)**. The polarity of the amp enable output must be configured with **set_amp_enable_level(...)** before **enable_amplifier(...)** or **disable_amplifier(...)**.

get_amp_enable(...) reads the *state* of an axis' amp enable output. **get_amp_enable_level(...)** reads an axis' active state configuration of the amp enable output.

The default boot configuration for the amp enable output is disabled.

The boot functions store/read the amp enable configurations for each axis in boot memory. These are loaded on power-up or **dsp_reset(...)**. Be sure to call **mei_checksum(...)** after the boot memory is modified.

SERCOS

The functions **set_amp_enable_level(…)**, **get_amp_enable_level(…)**, **set_boot_amp_enable_level(…)**, **get_boot_amp_enable_level(…)**, **set_boot_amp_enable(…)**, and **get_boot_amp_enable(…)** are not applicable to a SERCOS/ DSP Series controller.

SEE ALSO

axis_state(...), **axis_source(...)**, **controller_run(...)**, **controller_idle(...)**, **enable_amplifier(...)**, **disable_amplifier(...)**

RETURN VALUES

	Returns
set_amp_enable(...) **set_boot_amp_enable**(...) **get_amp_enable**(...) **get_boot_amp_enable**(...) **set_amp_enable_level**(...) **set_boot_amp_enable_level**(...) **get_amp_enable_level**(...) **get_boot_amp_enable_level**(...)	Error return codes (see *Error Handling* on page 3-13)

SAMPLE CODE

This code demonstrates how to toggle the amp enable output.

```
#include<stdio.h>
#include<dos.h>
#include "pcdsp.h"

int main()
{
     int16 value;

     if (dsp_init(PCDSP_BASE))   /* any problems initializing? */
            return dsp_error;    /* just terminate the program. */

     controller_run(0);
     set_amp_enable(0, TRUE);    /* enable amplifier */
     get_amp_enable(0, &value);
     printf("\nAmp enable state: %d", value);

     controller_idle(0);           /* automatically disables the amp */
     get_amp_enable(cnt, &value);
     printf("\nAmp enable state: %d", value);

     return dsp_error ;        /* global variable provided by the library */
}
```

Software Position Limits

set_positive_sw_limit	configure the positive software position limit and action
set_boot_positive_sw_limit	configure the boot positive software position limit and action
get_positive_sw_limit	read the positive software position limit and action
get_boot_positive_sw_limit	read the boot positive software position limit and action
set_negative_sw_limit	configure the negative software position limit and action
set_boot_negative_sw_limit	configure the boot negative software position limit and action
get_negative_sw_limit	read the negative software position limit and action
get_boot_negative_sw_limit	read the boot negative software position limit and action

SYNTAX

set_positive_sw_limit(int16 *axis*, double *pos*, int16 *action*)
set_boot_positive_sw_limit(int16 *axis*, double *pos*, int16 *action*)
get_positive_sw_limit(int16 *axis*, double * *pos*, int16 * *action*)
get_boot_positive_sw_limit(int16 *axis*, double * *pos*, int16 * *action*)

set_negative_sw_limit(int16 *axis*, double *pos*, int16 *action*)
set_boot_negative_sw_limit(int16 *axis*, double *pos*, int16 *action*)
get_negative_sw_limit(int16 *axis*, double * *pos*, int16 * *action*)
get_boot_negative_sw_limit(int16 *axis*, double * *pos*, int16 * *action*)

PROTOTYPE IN

pcdsp.h

DESCRIPTION

set_positive_sw_limit(...), **set_negative_sw_limit(...)** configure the DSP to generate an *action* when an *axis*' positive, negative software command position limit is exceeded. The *action* can be one of the following:

Table 2-33 Possible Axis Actions

#define	*Value*	*Explanation*
NO_EVENT	0	Ignore a condition
NEW_FRAME	2	Begin execution of the next sequenced frame
STOP_EVENT	8	Decelerate to a stop (at specified stop rate)
E_STOP_EVENT	10	Decelerate to a stop (at specified E-stop rate)
ABORT_EVENT	14	Disable PID control and the amplifier for this axis

The command position resolution is 32 bits whole and 32 bits fractional. The software limits range is +/-2,147,483,647 counts.

get_positive_sw_limit(...), **get_negative_sw_limit(...)** read an axis' positive, negative software command position limit.

The boot functions store/read software limits in boot memory. These are loaded on power-up or **dsp_reset(...)**. Be sure to call **mei_checksum(...)** after the boot memory is modified.

RETURN VALUES

	Returns
set_positive_sw_limit(...) **set_boot_positive_sw_limit**(...) **get_positive_sw_limit**(...) **get_boot_positive_sw_limit**(...) **set_negative_sw_limit**(...) **set_boot_negative_sw_limit**(...) **get_negative_sw_limit**(...) **get_boot_negative_sw_limit**(...)	Error return codes (see *Error Handling* on page 3-13)

SAMPLE CODE

This code configures the software position limits for all of the axes. If an axis exceeds 100000 counts/pulses in the positive direction or -100000 counts/pulses in the negative direction a STOP_EVENT will be generated.

```
# include <stdio.h>
# include "pcdsp.h"

int main()
{
     int16 axis;

     if (dsp_init(PCDSP_BASE))   /* any problems initializing? */
             return dsp_error;    /* just terminate the program. */

     for (axis = 0; axis < dsp_axes(); axis++)
     {       set_positive_sw_limit(axis, 100000, STOP_EVENT);
             set_negative_sw_limit(axis, -100000, STOP_EVENT);
     }

     return dsp_error ;       /* global variable provided by the library */
}
```

In Position

set_in_position	configure the width of an axis' in-position window
set_boot_in_position	configure the width of an axis' in-position window
get_in_position	read the width of an axis' in-position window
get_boot_in_position	read the boot width of an axis' in-position window

SYNTAX

set_in_position(int16 *axis*, double *limit*)
set_boot_in_position(int16 *axis*, double *limit*)
get_in_position(int16 *axis*, double * *limit*)
get_boot_in_position(int16 *axis*, double * *limit*)

PROTOTYPE IN

pcdsp.h

DESCRIPTION

set_in_position(...) configures an axis' in-position *limit* window. Each axis has a software and hardware in-position status bit. Each sample the DSP compares the absolute value of the position error to the in-position *limit* and updates the software and hardware in-position status bits. If the position error > *limit* then in-position is FALSE. If the position error <= *limit* then in-position is TRUE.

The position error is the difference between an axis' command and actual positions. The position error and in-position window resolution is 16 bits whole. The position error does not roll-over, it saturates at +/-32,767 counts.

get_in_position(...) reads an axis' configured in-position window.

The boot functions store/read the in-position window in boot memory. These are loaded on power-up or **dsp_reset(...)**. Be sure to call **mei_checksum(...)** after the boot memory is modified.

RETURN VALUES

	Returns
set_in_position(...) **set_boot_in_position**(...) **get_in_position**(...) **get_boot_in_position**(...)	Error return codes (see *Error Handling* on page 3-13)

SEE ALSO

in_position(...), **get_error(...)**

SAMPLE CODE

This code sets axis 0's in position window and prints the state of the in position during a trapezoidal profile motion.

```
# include <stdio.h>
# include "pcdsp.h"

int main()
{
     if (dsp_init(PCDSP_BASE))   /* any problems initializing? */
             return dsp_error;    /* just terminate the program. */

     set_in_position(0, 5);       /* in position window = +/- 5 counts */

     start_move(0, 10000, 1000, 8000);
     while (! motion_done(0))    /* wait for command motion competion */
             printf("In Position: %d\r", in_position(0));

     return dsp_error ;       /* global variable provided by the library */
}
```

Error Limit

set_error_limit	configure an axis' maximum position error limit and action
set_boot_error_limit	configure an axis' boot maximum position error limit and action
get_error_limit	read an axis' maximum position error limit and action configuration
get_boot_error_limit	read an axis' boot maximum position error limit and action configuration

SYNTAX

set_error_limit(int16 *axis*, double *limit*, int16 *action*)

set_boot_error_limit(int16 *axis*, double *limit*, int16 *action*)

get_error_limit(int16 *axis*, double * *limit*, int16 * *action*)

get_boot_error_limit(int16 *axis*, double * *limit*, int16 * *action*)

PROTOTYPE IN

pcdsp.h

DESCRIPTION

set_error_limit(...) configures the DSP to generate an *action* when the absolute value of an *axis*' position error exceeds the error limit. The valid range for the error limit is 0-32,767. Each sample the DSP compares the absolute value of the position error to the error *limit*. If the position error > *limit* then the configured *action* is generated. The *action* can be one of the following:

Table 2-34 Possible Axis Actions

#define	*Value*	*Explanation*
NO_EVENT	0	Ignore a condition
NEW_FRAME	2	Begin execution of the next sequenced frame
STOP_EVENT	8	Decelerate to a stop (at specified stop rate)
E_STOP_EVENT	10	Decelerate to a stop (at specified E-stop rate)
ABORT_EVENT	14	Disable PID control and the amplifier for this axis

The position error is the difference between an axis' command and actual positions. The position error resolution is 16 bits whole. The position error does not rollover, it saturates at +/-32,767 counts.

get_error_limit(...) reads an axis' configured error *limit* and *action*.

The boot functions store/read the error limit in boot memory. These are loaded on power-up or **dsp_reset(...)**. Be sure to call **mei_checksum(...)** after the boot memory is modified.

RETURN VALUES

	Returns
set_error_limit(...) **set_boot_error_limit**(...) **get_error_limit**(...) **get_boot_error_limit**(...)	Error return codes (see *Error Handling* on page 3-13)

SEE ALSO

get_error(...), **set_in_position(...)**, **in_position(...)**

SAMPLE CODE

This code configures axis 0's error limit for an ABORT_EVENT. After the motion is completed **axis_source(...)** checks if the error limit triggered an Abort Event.

```
# include "pcdsp.h"

int main()
{
     if (dsp_init(PCDSP_BASE))   /* any problems initializing? */
             return dsp_error;    /* just terminate the program. */

     set_error_limit(0, 20, ABORT_EVENT);  /* error limit = +/- 20 cts */
     move(0, 10000, 1000, 8000);

     if (axis_source(0) == ID_ERROR_LIMIT)
             printf("\nERROR limit exceeded");

     return dsp_error ;        /* global variable provided by the library */
}
```

NOTES

We strongly recommend configuring the error limit for an ABORT_EVENT. The DSP will disable PID control and the amp enable output if the amplifier, motor, or encoder fails.

Interrupt Configuration

dsp_interrupt_enable	configures User I/O bit 23 or the DSP to generate interrupts
interrupt_on_event	configures an axis to interrupt the CPU after an event completes

SYNTAX

int16 **dsp_interrupt_enable**(int16 *state*)

int16 **interrupt_on_event**(int16 *axis*, int16 *state*)

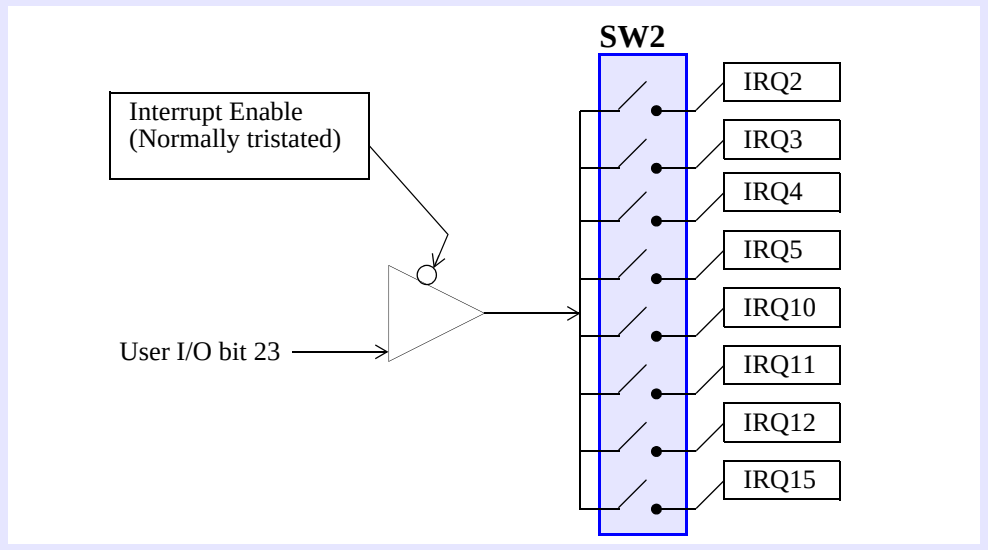
PROTOTYPE IN

pcdsp.h

DESCRIPTION

The switch "SW2" connects the interrupt circuitry to a host CPU's IRQ line (only on ISA, 104, STD and VME bus controllers):

Figure 2-3 DSP Interrupt Circuits



IRQ lines are automatically assigned to PCI and CPCI bus controllers by the BIOS at boot up. Please use *Motion Console* or see the section, *PCI Inititalization* page 3-10, for obtaining the IRQ values assigned to your PCI controller.

The DSP Series controllers can generate interrupts to the host CPU with two different configurations. There are two signals, "Interrupt Enable" and "User I/O bit 23" that create the interrupt circuitry. The "Interrupt Enable" is controlled by the DSP. "User I/O bit 23" is located in the controller's external memory. It is controlled by the host software (when configured as an output) or by an external signal (when configured as an input).

Interrupts can be generated by the "Interrupt Enable" signal or "User I/O bit 23."

EXTERNAL INTERRUPT GENERATION (I/O BIT #23):

If **dsp_interrupt_enable(…)** is **enabled** (state = TRUE) then interrupts are generated when User I/O bit 23 transitions from a low (0 volts) to a high (+5 volts). Depending on the controller model, User I/O bit 23 can be configured as an input or an output.

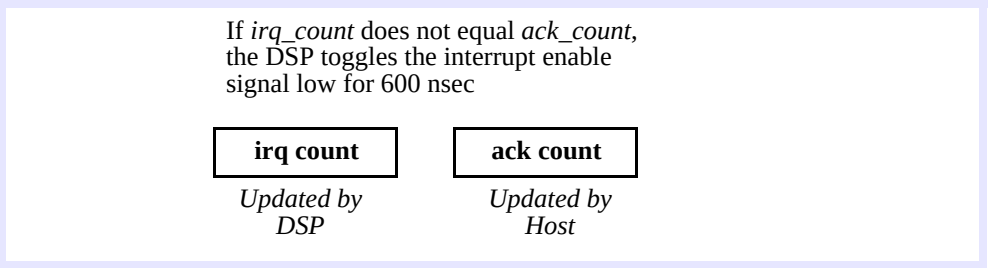
INTERNAL INTERRUPT GENERATION (FRAME GENERATED IRQS AND I/O MONITORING IRQS):

If **dsp_interrupt_enable(…)** is **disabled** (state = FALSE) and User I/O bit 23 is low (0 volts), then interrupts can be generated by the DSP. In this configuration, the DSP generates interrupts based on two internal registers (per axis) called the *irq_count* and the *ack_count*.

The *irq_count* register is updated by the DSP and the *ack_count* register is updated by the host processor. Every sample the DSP examines *irq_count* and *ack_count*. If they are different, the DSP toggles the IRQ line low for 600 nanoseconds. The DSP will continue to generate interrupts until the host CPU responds. The host must acknowledge the interrupt by setting *ack_count* equal to *irq_count*.

Source	*Interrupt Enable Logic*	*Bit 23*	*IRQ?*
Bit 23	True	Low to high	Yes
Events, frames, I/O monitoring	False	High	No
Events, frames, I/O monitoring	False	Low	Yes

Figure 2-4 DSP's Internal Memory Registers



interrupt_on_event(...) enables (state = TRUE) or disables (state = FALSE) an axis from generating interrupts to the host CPU after a Stop, E-Stop, or Abort Event occurs. When enabled, an axis' internal *stopped* frame increments the *irq_count* register. The stopped frame is executed after the command velocity reaches zero. The host must acknowledge the interrupt by setting *ack_count* equal to *irq_count*.

If the interrupt source is the DSP's I/O monitoring, then the DSP generates interrupts based on a single internal register. The *io_changed* register is updated based on a comparison of the user I/O with a *mask* and *value* set by **set_io_mon_mask(...)**. Each sample the DSP monitors the I/O and updates *io_changed*. If *io_changed* is non-zero, the DSP toggles the IRQ line low for 600 nanoseconds. The DSP will continue to generate interrupts until the host CPU responds. The host must acknowledge the interrupt by clearing the *io_changed* flag.

The file INTHND.C (available in the apps directory) contains sample code for these interrupt generation methods. The interrupt routine is intended to be small. Its purpose is to catch the interrupt and report it to the software. This sample code is written for the Borland and Microsoft "C" compilers.

Several cards in a PC system can share the same IRQ line. Sharing interrupts requires an external pull-up resistor on the IRQ line. The latest revisions of the surface mount DSP Series controllers already have this resistor. The PC/DSP does not have this resistor. The file *MINTHND.C* (available in the apps directory) contains sample code for multiple controller interrupt sharing. This sample code is written for the Borland and Microsoft "C" compilers.

Interrupt programming is very difficult and should be left to experienced programmers. There are several programming restrictions inside interrupt routines. Most compilers don't support floating point math, variable declarations, print statements etc. inside interrupt routines. Because of these restrictions, MEI's standard function library is NOT supported inside interrupt routines.

Warning! Interrupts on the STD, VME, PCI and CPCI busses are handled differently than the PC. Please contact MEI for more information.

SEE ALSO **init_io(...)**, **set_io(...)**, **set_bit(...)**, **set_io_mon_mask(...)**, **io_changed(...)**

PINOUTS See the appropriate *Install Guide*.

RETURN VALUES

	Returns
dsp_interrupt_enable(...) **interrupt_on_event**(...)	Error return codes (see *Error Handling* on page 3-13)

NOTES

Don't forget to set the IRQ jumper or switch on the controller.

SERCOS Initialization

serc_reset	resets the controller and initializes SERCOS communication
get_sercos_phase	reads the SERCOS ring initialization phase

SYNTAX

int16 **serc_reset**(int16 *baud*, int16 *ndrives*, DRIVE_INFO * *dinfo)*
int16 **get_sercos_phase**(int16 * *phase*)

PROTOTYPE IN

sercos.h, sercrset.h

DESCRIPTION

serc_reset(...) is required to initialize a SERCOS ring. Be sure to initialize the controller first with **do_dsp(...)** or **dsp_init(...)**. Then, a call to **serc_reset(...)** will reset the controller and initialize the SERCOS ring in the following phases:

Table 2-35 SERCOS Phases

Phase	*Description*
0	Start synchronized real-time communication
1	Find the drives and I/O modules
2	Configure the communication data structure
3	Start communication, verify proper operation
4	Operational mode

baud specifies the ring communication rate in bits per second. *baud* can be specified with one of the following *#defines*:

Table 2-36 Baud Rates

#define	*Value*	*Explanation*
BIT_RATE2	2	2 Mbits/sec
BIT_RATE4	4	4 Mbits/sec

ndrives specifies the number of SERCOS nodes to be initialized. The valid range for *ndrives* is between 1 and 8. Nodes can be any SERCOS compatible slave device. These include servo drives, digital I/O modules, A/D modules, D/A modules, position feedback modules, etc.

* *dinfo* is a pointer to an array of DRIVE_INFO structures. The configuration for each SERCOS node is specified by a DRIVE_INFO structure:

```
typedef struct {
    int16 drive_axis;          /* controller's axis number */
    unsigned16 drive_addr;     /* node address */
    unsigned16 drive_mode;     /* operational mode */
    unsigned16 drive_mfg;      /* node manufacturer */
    } DRIVE_INFO;
typedef DRIVE_INFO *DriveInfo;
```

drive_axis is the controller's axis number assigned to a SERCOS node. The valid range for *drive_axis* is between 0 and 7.

drive_addr is the SERCOS node's address. Each SERCOS node must have its own unique address. The valid range for *drive_addr* is between 1 and 254 (*drive_addr* = 0 is reserved for broadcast messages).

drive_mode is the operational mode. It can be specified with one of the following *#defines*:

Table 2-37 SERCOS Drive Modes

#define	*Value*	*Explanation*
TORQMODE	1	Torque mode (telegram type 7)
VELMODE	2	Velocity mode (telegram type 7)
POSMODE	3	Position mode (telegram type 7)
VELOCITY_STD	5	Standard telegram type 3 (no user specified cyclic data)
POSITION_STD	6	Standard telegram type 4 (no user specified cyclic data)
POS_VEL_STD	7	Standard telegram type 5 (no user specified cyclic data)
EXT_VELMODE	9	Indramat drive, Velocity mode, 2nd position encoder (telegram type 7)
DUAL_LOOP_VELMODE	10	Velocity control, dual encoder feedback (telegram type 7)
ANALOG_VELMODE	11	Velocity control, analog feedback (telegram type 7)
ANALOG_TORQUEMODE	12	Torque control, analog feedback (telegram type 7)
USERMAP	13	user specified cyclic data (telegram type 7)

Note: Any drive mode with _STD appended will not support user-specified cyclic data. **serc_reset(...)** will ignore user specified cyclic data configurations for a drive mode appended with _STD.

serc_reset(...) will automatically map the following bits from the drive's status word into the DSP's dedicated I/O registers (for all *drive_modes* except USERMAP):

Table 2-38 Mapping of Drive Status Word to Dedicated I/O Registers

Bit	*Explanation*	*DSP's Dedicated I/O*
13	Drive Shutdown - Error in Class 1 Diagnostic (see IDN 11)	Amp Fault
7	Real-time status bit 2 (IDN 306)	Pos and Neg Limit
6	Real-time status bit 1 (IDN 304)	Home

Every sample, the DSP examines the Dedicated I/O registers to determine if a controller exception event should be triggered. For more information, also see

- Dedicated I/O (*Inputs* page 3-56)
- Exception Events (*Axis State* page 3-45, *Axis Source* page 3-46)
- *Event Recovery* (page 3-54)
- Home Config (*Action* page 2-32, *Logic* page 2-34)
- Limit Config (*Input Action* page 2-37, *Input Level* page 2-39)
- Amp Fault Config (*Input* page 2-41, *Enable Output* page 2-43)
- Events (*Stop* page 3-48, *Emergency Stop* page 3-50, *Abort* page 3-52)

For more about the *Drive Status Word*, see *SERCOS Drive Status/Reset* on page 2-71.

drive_mfg is the SERCOS node manufacturer. It can be specified with one of the following #defines:

Table 2-39 SERCOS Manufacturer defines

#define	*Value*	*Manufacturer*
LUTZE	0	Lutze
PACSCI	1	Pacific Scientific
MODICON	2	AEG/Modicon
INDRAMAT	3	Indramat
KOLLMORGEN	4	Kollmorgen
MEI	5	Motion Engineering, Inc.
SANYO_DENKI	6	Sanyo Denki
OTHER	32	Not manufacturer-specific

If a *#define* does not match a particular SERCOS node's manufacturer, then use OTHER. Also, please contact Motion Engineering with any information concerning SERCOS node manufacturers not specified with a *#define*.

Use **get_sercos_phase(...)** to read the SERCOS ring's current initialization phase.

SEE ALSO

dsp_init(...), **do_dsp(...)**, **configure_phase2_idns(...)**, **configure_phase3_idns(...)**, **configure_mdt_data(...)**, **configure_at_data(...)**, **enable_amplifier(...)**, **disable_amplifier(...)**, **get_drive_status(...)**

RETURN VALUES

	Returns
serc_reset(...) **get_sercos_phase**(...)	Error return codes (see *Error Handling* on page 3-13)

SAMPLE CODE

This code initializes SERCOS communication with an Indramat servo drive:

```
#include "pcdsp.h"
#include "sercos.h"
#include "sercrset.h"

#define NODES               1      /* Number of nodes on SERCOS ring */
#define AXIS                0
#define NODE_ADDR           1

DRIVE_INFO drive_info[NODES] = {
/*    {Axis, Drive address, Operation mode, Manufacturer} */
      {AXIS, NODE_ADDR, POSMODE, INDRAMAT}
};

int main(void)
{
      if (dsp_init(PCDSP_BASE))   /* any problems initializing? */
            return dsp_error;

      if (serc_reset(BIT_RATE2, NODES, drive_info))
            return dsp_error;

      enable_amplifier(AXIS);    /* enable servo drive */

      return dsp_error;
}
```

NOTES

The SINIT*xx*.C sample programs demonstrate SERCOS communication initialization for several different drives, I/O modules, and configurations.

SERCOS Phase 2 & 3 IDNs Configuration

configure_phase2_idns	specifies IDNs to be set during Phase 2 initialization
configure_phase3_idns	specifies IDNs to be set during Phase 3 initialization

SYNTAX

int16 **configure_phase2_idns**(unsigned16 *nidns*, DRIVE_IDNS * *didns*)
int16 **configure_phase3_idns**(unsigned16 *nidns*, DRIVE_IDNS * *didns*)

PROTOTYPE IN

sercos.h, sercrset.h

DESCRIPTION

Several IDNs can only be accessed during the SERCOS ring initialization Phases 2 and 3. Typically, these IDNs contain operational data that is used during Phase 4 (normal operation).

configure_phase2_idns(...) specifies the IDNs to be set by **serc_reset(…)** during SERCOS ring initialization Phase 2.

configure_phase3_idns(...) specifies the IDNs that will be set by **serc_reset(…)** during SERCOS ring initialization Phase 3.

Be sure to always invoke **configure_phase2_idns(…)** and/or **configure_phase3_idns(…)** before **serc_reset(…)**.

nidns specifies the number of IDNs to be set.

* *didns* is a pointer to an array of DRIVE_IDNS structures. The configuration for each IDN is specified by a DRIVE_IDNS structure:

```
typedef struct {
    unsigned16 idn;
    long value;
    unsigned16 drive_addr;
    } DRIVE_IDNS;
typedef DRIVE_IDNS *DriveIdns;
```

idn is the Identification Number (IDN). The valid range for *idn* is between 1 and 65535. *idn*'s 1 to 32767 are defined in the SERCOS specification. IDNs 32768 to 65535 are defined by the node (drive) manufacturer. For more information, please consult the node (drive) manufacturer's documentation.

value is the 32 bit operating data for the specified *idn.*

drive_addr is the SERCOS node's address. Each SERCOS node must have it's own unique address. The valid range for *drive_addr* is between 1 and 254 (*drive_addr* = 0 is reserved for broadcast messages).

SEE ALSO

serc_reset(…)

RETURN VALUES

	Returns
configure_phase2_idns(...) **configure_phase3_idns**(...)	Error return codes (see *Error Handling* on page 3-13)

SAMPLE CODE

This code initializes SERCOS communication with an Indramat servo-drive:

```
#include “pcdsp.h”
#include “sercos.h”
#include “sercrset.h”

#define NODES               1   /* Number of nodes on Sercos ring */
#define      AXIS           0
#define NODE_ADDR           1

#define PHASE2_IDNS         2   /* Number of Phase 2 IDNs */
#define PHASE3_IDNS         1   /* Number of Phase 3 IDNs */

DRIVE_INFO drive_info[NODES] = {
/*   {Axis, Drive address, Operation mode, Manufacturer} */
     {AXIS, NODE_ADDR, POSMODE, INDRAMAT}
};

DRIVE_IDNS phase_2_idns[PHASE2_IDNS] = {
/* {IDN, Value, Drive Address} */
     {79, 36000, NODE_ADDR},    /* Rotational Position Resolution */
     {55, 0x0, NODE_ADDR}          /* Position Polarity */
};

DRIVE_IDNS phase_3_idns[PHASE2_IDNS] = {
/* {IDN, Value, Drive Address} */
     {104, 2000, NODE_ADDR}      /* Position Loop Gain */
};

int main(void)
{
     if (dsp_init(PCDSP_BASE))  /* any problems initializing? */
             return dsp_error;

     if (configure_phase2_idns(PHASE2_IDNS, phase_2_idns))
             return dsp_error;
     if(configure_phase3_idns(PHASE3_IDNS, phase_3_idns))
             return dsp_error;
     if (serc_reset(BIT_RATE2, NODES, drive_info))
             return dsp_error;

     enable_amplifier(AXIS);    /* enable servo drive */

     return dsp_error;
}
```

NOTES

The SINIT*xx*.C sample programs demonstrate SERCOS communication initialization for several different drives, I/O modules, and configurations.

SERCOS Cyclic Data Configuration

configure_at_data	specifies IDNs to be placed in the Amplifier Telegram.
configure_mdt_data	specifies IDNs to be placed in the Master Data Telegram.

SYNTAX

int16 **configure_at_data**(unsigned16 *natdata*, CYCLIC_DATA * *at_data*)

int16 **configure_mdt_data**(unsigned16 *nmdtdata*, CYCLIC_DATA * *mdt_data*)

PROTOTYPE IN

sercrset.h

DESCRIPTION

Some IDNs can be accessed through cyclic data. Every SERCOS loop update, the cyclic data is updated by the master controller and the nodes. The cyclic data contains the Amplifier Telegram(s) (one per SERCOS node) and the Master Data Telegram (sent by the controller).

configure_at_data(…) specifies the IDNs to be placed in the cyclic data by **serc_reset(…)** during SERCOS ring initialization.

configure_mdt_data(...) specifies the IDNs to be placed in the cyclic data by **serc_reset(…)** during SERCOS ring initialization.

Be sure to always invoke **configure_at_data(…)** and/or **configure_mdt_data(…)** before **serc_reset(…)**.

natdata specifies the number of IDNs to be placed in the Amplifier Telegram. *nmdtdata* specifies the number of IDNs to be placed in the Master Data Telegram. The valid range for *natdata* and *nmdtdata* is between 1 and 30. A maximum of 30 words (16 bits) can be placed in an axis' AT or MDT.

* *at_data* and * *mdt_data* are pointers to arrays of CYCLIC_DATA structures. The user specified cyclic data is defined by a CYCLIC_DATA structure:

```
typedef struct {
unsigned16 idn;
unsigned16 drive_addr;
} CYCLIC_DATA;
typedef CYCLIC_DATA * CyclicData;
```

The specific IDNs that can be placed into the AT or MDT is defined by the SERCOS node manufacturer. The list of configurable data for the AT can be found in IDN 187. The list of configurable data for the MDT can be found in IDN 188.

After the ring has been successfully initialized with **serc_reset(…)**, the AT and MDT cyclic data can be accessed with **read_cyclic_at_data(…)**, **read_cyclic_mdt_data(…)**, and **write_cyclic_mdt_data(…)**.

SEE ALSO

serc_reset(…), **read_cyclic_at_data(…)**, **read_cyclic_mdt_data(…)**, **write_cyclic_mdt_data(…)**

RETURN VALUES

	Returns
configure_at_data(...) **configure_mdt_data**(...)	Error return codes (see *Error Handling* on page 3-13)

SAMPLE CODE

This code initializes SERCOS communication with an Indramat servo-drive:

```
#include “pcdsp.h”
#include “sercos.h”
#include “sercrset.h”

#define NODES               1    /* Number of nodes on SERCOS ring */
#define AXIS                0
#define NODE_ADDR           1

#define AT_IDNS             1    /* Number of IDNS for the AT */
#define MDT_IDNS            1    /* Number of IDNS for the MDT */

DRIVE_INFO drive_info[NODES] = {
/*   {Axis, Drive address, Operation mode, Manufacturer} */
     {AXIS, NODE_ADDR, POSMODE, INDRAMAT}
};

CYCLIC_DATA at_idns[AT_IDNS] = {
/* {IDN, Drive Address} */
     {130, NODE_ADDR}           /* Probe 1, Positive Edge Position Value */
};

CYCLIC_DATA mdt_idns[MDT_IDNS] = {
/* {IDN, Drive Address} */
     {91, NODE_ADDR}            /* Bipolar Velocity Limit */
};

int main(void)
{
     if (dsp_init(PCDSP_BASE));   /* any problems initializing? */
             return dsp_error;

     if (configure_at_data(AT_IDNS, at_idns))
             return dsp_error;
     if (configure_mdt_data(MDT_IDNS, mdt_idns))
             return dsp_error;
     if (serc_reset(BIT_RATE2, NODES, drive_info))
             return dsp_error;

     enable_amplifier(AXIS);      /* enable servo drive */

     return dsp_error;
}
```

NOTES

The SINIT*xx*.C sample programs demonstrate SERCOS communication initialization for several different drives, I/O modules, and configurations.

SERCOS Drive Addresses

get_drive_addresses — determines the addresses for SERCOS nodes

SYNTAX

get_drive_addresses(int16 *baud*, int16 * *ndrives*, unsigned16 * *dr_addrs*)

PROTOTYPE IN

sercos.h, sercrset.h

DESCRIPTION

get_drive_addresses(…) determines the addresses of all the found nodes on a SERCOS ring. Each address (1 to 255) is tested sequentially until eight nodes are found or until all addresses have been tested.

baud specifies the ring communication rate in bits per second. *baud* can be specified with one of the following *#defines*:

Table 2-40 SERCOS Baud Rates

#define	*Value*	*Explanation*
BIT_RATE2	2	2 Mbits/sec
BIT_RATE4	4	4 Mbits/sec

* *ndrives* is a pointer to the number of SERCOS nodes found. The valid range for * *ndrives* is between 0 and 8. Nodes can be any SERCOS compatible slave device. These include servo drives, digital I/O modules, A/D modules, D/A modules, position feedback modules, etc.

* *dr_addrs* is a pointer to an array of SERCOS node addresses. Each SERCOS node must have it's own unique address. The valid range for * *dr_addrs* is between 1 and 254 (* *dr_addrs* = 0 is reserved for broadcast messages).

SEE ALSO

dsp_init(...), **do_dsp(...)**, **serc_reset(…)**

RETURN VALUES

	Returns
get_drive_addresses(...)	Error return codes (see *Error Handling* on page 3-13)

SAMPLE CODE

This code demonstrates how to find the SERCOS node addresses connected to the ring:

```
#include “pcdsp.h”
#include “sercos.h”
#include “sercrset.h”

int main(void)
{    int16 nodes, i;
     unsigned16 addrs[PCDSP_MAX_AXES];

     if (dsp_init(PCDSP_BASE))   /* any problems initializing? */
            return dsp_error;

     get_drive_addresses(BIT_RATE2, &nodes, addrs);
     for (i = 0; i < PCDSP_MAX_AXES; i++)
            printf(“\nAddress:%u”, addr[i]);

     return dsp_error;
}
```

NOTES

get_drive_addresses(…) should only be called before the SERCOS ring is brought up. This function will not work if the SERCOS ring is already in Phase 3 or Phase 4.

SERCOS Change Operation Mode

change_operation_mode switches the operation mode for a SERCOS drive

SYNTAX int16 **change_operation_mode**(int16 *axis*, unsigned16 *mode*)

PROTOTYPE IN sercos.h

DESCRIPTION During **serc_reset(…)** the primary and optional secondary operation mode(s) for a SERCOS drive can be configured. The operation mode defines the control loops for the controller and drive. SERCOS supports Torque, Velocity and Position digital control loops between the controller and the drive.

change_operation_mode(...) switches the SERCOS drive operational mode between the primary and secondary modes. Switching operation modes can be performed without disabling the drive or re-initializing the SERCOS ring. The primary and secondary operation modes are defined by IDNs 32, 33, 34, and 35. The following operation modes are available:

Table 2-41 SERCOS Operating Modes

Mode	*Explanation*
0	Primary operation mode (defined by IDN 32)
1	Secondary operation mode 1 (defined by IDN 33)
2	Secondary operation mode 2 (defined by IDN 34)
3	Secondary operation mode 3 (defined by IDN 35)

The range for *mode* is between 0 and 3. Please consult the drive manufacturer's documentation for more information concerning operation modes and operation mode switching.

SEE ALSO **configure_phase2_idns(...)**, **serc_reset(…)**, **set_idn(…)**, **get_idn(…)**

RETURN VALUES

	Returns
change_operation_mode(...)	Error return codes (see *Error Handling* on page 3-13)

SERCOS Read/Write IDN

set_idn	writes an IDN value to a SERCOS node
get_idn	reads an IDN value from a SERCOS node
get_idn_size	reads Element 7's size from the specified IDN
get_idn_string	reads a string from an IDN
get_idn_attributes	reads the attributes from the specified IDN

SYNTAX

int16 **set_idn**(int16 *axis*, unsigned16 *idn*, int32 *value*)
int16 **get_idn**(int16 *axis*, unsigned16 *idn*, int32 * *value*)
int16 **get_idn_size**(int16 *axis*, unsigned16 *idn*, int16 * *size*)
int16 **get_idn_string**(int16 *axis*, unsigned16 *dr_addr*, unsigned16 *idn*, char * *str*)
int16 **get_idn_attributes**(int16 *axis*, unsigned16 *idn*, IDN_ATTRIBUTES * *attr*)

PROTOTYPE IN

pcdsp.h, sercos.h

DESCRIPTION

set_idn(...) writes a *value* to the SERCOS node's specified *idn*. Nodes can be any SERCOS compatible slave device. These include servo drives, digital I/O modules, A/D modules, D/A modules, position feedback modules, etc. **get_idn(…)** reads a *value* from the SERCOS node's specified *idn*.

set_idn(…) and **get_idn(…)** write/read the *idn* values through the Service Channel. The Service Channel provides a mechanism to send/receive non-time critical data. The data values are buffered and sent/received in 16 bit blocks.

get_idn_size(…) reads an IDN's operation data length from the IDN's element 3 (bits 16-17). *size* is the number of 16 bit words allocated for the fixed length operation data. The valid range for *size* is between 0 and 2. *size* = 0 indicates the operation data is variable length.

get_idn_string(...) reads a variable length string from the SERCOS node's specified *idn*. **str* is a pointer to a string. The string length is MAX_ERROR_LEN characters in length.

get_idn_attributes(…) reads the attributes from the SERCOS node's specified idn. **attr* is a pointer to a IDN_ATTRIBUTE structure. The attributes are defined by an IDN_ATTRIBUTES structure:

```
typedef struct {
unsigned16 elem_1;
unsigned16 elem_2[MAX_E2_INTS];
unsigned long elem_3;
unsigned16 elem_4[MAX_E4_INTS];
long elem_5;
long elem_6;
} IDN_ATTRIBUTES;
typedef IDN_ATTRIBUTES *IdnAttributes;
```

axis is the controller's axis number assigned to a particular SERCOS node. The controller axis numbers are defined during SERCOS ring initialization with **serc_reset(…)**. The valid range for *axis* is between 0 and 7.

dr_addr is a SERCOS node addresses. Each SERCOS node must have its own unique address. The valid range for *dr_addr* is between 1 and 254 (*dr_addr* = 0 is reserved for broadcast messages).

idn is the Identification Number. The valid range for *idn* is between 1 and 65535. IDNs 1 to 32767 are defined in the SERCOS specification. IDNs 32768 to 65535 are defined by the node (drive) manufacturer. For more information, please consult the node (drive) manufacturer's documentation.

value is the 32 bit operating data for the specified *idn*. IDNs support either 32 bit or 16 bit data values. **set_idn(…)** and **get_idn(…)** automatically mask the upper bits for 16 bit data value sizes.

SEE ALSO **configure_phase2_idns(...)**, **configure_phase3_idns(…)**, **serc_reset(…)**

RETURN VALUES

	Returns
set_idn(...) **get_idn**(...) **get_idn_size**(...) **get_idn_string**(...) **get_idn_attributes**(...)	Error return codes (see *Error Handling* on page 3-13)

SAMPLE CODE This code demonstrates how to read an IDN value. Be sure to always initialize SERCOS communication with **serc_reset(…)** before reading/writing IDNs:

```
#include “pcdsp.h”
#include “sercos.h”

#define AXIS                0
#define ADDR                1    /* Node Address */
#define IDN                 30   /* Manufacturer Version */

int main(void)
{    int16 size;
     int32 value;
     char string[MAX_ERROR_LEN];

     if (dsp_init(PCDSP_BASE))   /* any problems initializing? */
            return dsp_error;

     get_idn_size(AXIS, IDN, &size);

     if (size)
     {      get_idn(AXIS, IDN, &value);
            printf("\nData length(words) is: %d\n", size);
            printf("\nValue: %ld", value);
     }
     else
     {      get_idn_string(AXIS, 1, IDN, string);
            printf("\nData length is variable\n");
            printf("\n%s", string);
     }

     return dsp_error;
}
```

SERCOS Read/Write Multiple IDNs

set_idns	writes an array of IDN values to a SERCOS node
get_idns	reads an array of IDN values from a SERCOS node

SYNTAX

int16 **set_idns**(int16 *axis*, unsigned16 *dr_addr*, unsigned16 *idns*, IDNS * *idns*)

int16 **get_idns**(int16 *axis*, unsigned16 *dr_addr*, unsigned16 *firstidn*, unsigned16 *idns*, IDNS * *idns*)

PROTOTYPE IN

sercos.h

DESCRIPTION

set_idns(...) writes an array of sequential IDN values to a SERCOS node.

get_idns(…) reads an array of sequential IDN values from a SERCOS node. Nodes can be any SERCOS compatible slave device. These include servo drives, digital I/O modules, A/D modules, D/A modules, position feedback modules, etc.

axis is the controller's axis number assigned to a particular SERCOS node. The controller axis numbers are defined during SERCOS ring initialization with **serc_reset(…)**. The valid range for *axis* is between 0 and 7.

dr_addr is a SERCOS node addresses. Each SERCOS node must have it's own unique address. The valid range for *dr_addr* is between 1 and 254 (*dr_addr* = 0 is reserved for broadcast messages).

If the SERCOS communication ring is in phase 3 or 4, then the node is specified by *axis*. If the ring is in phase 1 or 2, then the drive is specified by *dr_addr*.

**idns* is a pointer to an array of IDNS structures:

```
typedef struct {
unsigned16 idn;
long value;
int16 error;           /* error code from set/get_idn(...) */
} IDNS;
typedef IDNS *Idns;
```

idn is the Identification Number. The valid range for *idn* is between 1 and 65535. IDNs 1 to 32767 are defined in the SERCOS specification. IDNs 32768 to 65535 are defined by the node (drive) manufacturer. For more information, please consult the node (drive) manufacturer's documentation.

value is the 32 bit operating data for the specified *idn*. IDNs support either 32 bit or 16 bit data values. **set_idns(…)** and **get_idns(…)** automatically mask the upper bits for 16 bit data value sizes.

error is the error code returned by the internal call to **set/get_idn(…)**. **set_idns(…)** will not write values to IDNs that have a non-zero number in the *error* field. Any failure to read/write an IDN value will be stored in *error*.

Generally, do not write to IDNs 1 through 30 with **set_idns(…)**. IDNs 1 through 30 contain SERCOS ring operation data and are initialized during **serc_reset(…)**.

set_idns(…) and **get_idns(…)** write/read the idn values through the Service Channel. The Service Channel provides a mechanism to send/receive non-time critical data. The data values are buffered and sent/received in 16 bit blocks.

SEE ALSO

serc_reset(…), **set_idn(…)**, **get_idn(…)**

RETURN VALUES

	Returns
set_idns(...) **get_idns**(...)	Error return codes (see *Error Handling* on page 3-13)

SAMPLE CODE

This code demonstrates how to read an array of IDN values. Be sure to always initialize SERCOS communication with **serc_reset(…)** before reading/writing IDNs:

```
#include “pcdsp.h”
#include “sercos.h”

#define AXIS                0
#define ADDR                1    /* Node Address */
#define FIRST_IDN           30

#define TOTAL               400  /* Number of IDNs */
IDNS buffer[TOTAL];

int main(void)
{    int16 i;

     if (dsp_init(PCDSP_BASE))    /* any problems initializing? */
            return dsp_error;

     get_idns(AXIS, ADDR, FIRST_IDN, TOTAL, buffer);
     for(i = 0; i < TOTAL; i++)
            if (!buffer[i].error)
                   printf("S-0-%4d:\t%ld\n", buffer[i].idn, buffer[i].value);

     get_idns(axis, srcaddr, 0x8000, 100, buffer);
     for(i = 0; i < 100; i++)
            if (!buffer[i].error)
                   printf("P-0-%4d:\t%ld\n", (buffer[i].idn - 0x8000),
                          buffer[i].value);

     return dsp_error;
}
```

SERCOS Procedures

start_exec_procedure	starts a SERCOS drive procedure
cancel_exec_procedure	cancels a SERCOS drive procedure
exec_procedure_done	determines a SERCOS drive procedure's completion

SYNTAX

int16 **start_exec_procedure**(int16 *axis*, unsigned16 *procedure*)
int16 **cancel_exec_procedure**(int16 *axis*, unsigned16 *procedure*)
int16 **exec_procedure_done**(int16 *axis*, unsigned16 *procedure*, int16 * *done*)

PROTOTYPE IN

sercos.h

DESCRIPTION

Procedures are internal processes that occur in a SERCOS drive or I/O module. The drive procedures execute independently of the controller. Typically, drive procedures are lengthy and complex processes.

start_exec_procedure(...) initiates a drive procedure assigned to the specified controller axis. **cancel_exec_procedure(...)** cancels a drive procedure assigned to the specified controller axis. **exec_procedure_done(...)** determines if a drive procedure assigned to the specified controller axis has completed.

axis is the controller's axis number assigned to a particular SERCOS node. The controller axis numbers are defined during SERCOS ring initialization with **serc_reset(…)**. The valid range for *axis* is between 0 and 7.

procedure is defined by an Identification Number (IDN). The valid range for *procedure* is between 1 and 65535. IDNs 1 to 32767 are defined in the SERCOS specification. IDNs 32768 to 65535 are defined by the node (drive) manufacturer. For more information, please consult the node (drive) manufacturer's documentation.

Procedures and IDNs share the same data block structure. The data block's attribute element 3 defines if the IDN should be handled as a Procedure.

The start or end of a procedure is handled through the Service Channel (non-cyclic data block). After the drive or I/O module receives a procedure command, it responds with a procedure command acknowledgment and turns on the "busy" bit in its drive status word. After the Procedure completes, the drive or I/O module will clear the "busy" bit.

Generally, the time required to complete a drive procedure is unknown. Some procedures are completed by the drive. Other procedures must be completed by the controller with **cancel_exec_procedure(...)**. Please consult the SERCOS node manufacturer's documentation for more detailed information.

SEE ALSO

set_idn(…), **get_idn(…)**, **serc_reset(…)**, **get_drive_status(...)**

RETURN VALUES

	Returns
start_exec_procedure(...) **cancel_exec_procedure**(...) **exec_procedure_done**(...)	Error return codes (see *Error Handling* on page 3-13)

SAMPLE CODE

This code demonstrates a homing procedure. Be sure to always initialize SERCOS communication with **serc_reset(…)** before commanding procedures:

```
#include <stdio.h>
#include <conio.h>
#include “pcdsp.h”
#include “sercos.h”

#define AXIS                0

int main()
{    long done = 0, pos;

     if (dsp_init(PCDSP_BASE))   /* any problems initializing? */
            return dsp_error;    /* just terminate the program. */

     set_error_limit(AXIS, 0.0, NO_EVENT);
     enable_amplifier(AXIS);
     set_idn(AXIS, 52, 0L);              /* set home position value */
     start_exec_procedure(AXIS, 148);  /* start home procedure */
     get_idn(AXIS, 403, &done);

     while((!done) && (!kbhit()))   /* wait for procedure completion */
            get_idn(axis, 403, &done);
     getch();

     get_idn(AXIS, 47, &pos);
     set_position(AXIS, (double)pos);
     cancel_exec_procedure(AXIS, 148);
     set_error_limit(AXIS, 32767.0, ABORT_EVENT);

     return dsp_error ;       /* global variable provided by the library */
}
```

SERCOS Read/Write Cyclic Data

read_cyclic_at_data	reads cyclic data from an Amplifier Telegram
read_cyclic_mdt_data	reads cyclic data from the Master Data Telegram
write_cyclic_mdt_data	writes cyclic data to the Master Data Telegram

SYNTAX

int16 **read_cyclic_at_data**(int16 *axis*, unsigned16 *offset*)
int16 **read_cyclic_mdt_data**(int16 *axis*, unsigned16 *offset*)
int16 **write_cyclic_mdt_data**(int16 *axis*, unsigned16 *offset*, int16 *data*)

PROTOTYPE IN

sercos.h

DESCRIPTION

Some IDNs can be accessed through cyclic data Every SERCOS loop update, the cyclic data is updated by the master controller and the nodes. The cyclic data contains the Amplifier Telegram(s) (one per SERCOS node) and the Master Data Telegram (sent by the controller).

read_cyclic_at_data(...) reads a 16-bit value from the Amplifier Telegram's user-configured cyclic data.

read_cyclic_mdt_data(…) reads a 16-bit value from the Master Data Telegram's user-configured cyclic data.

write_cyclic_mdt_data(...) writes a 16-bit value to the Master Data Telegram's user-configured cyclic data.

axis is the controller's axis number assigned to a particular SERCOS node. The controller axis numbers are defined during SERCOS ring initialization with **serc_reset(…)**. The valid range for *axis* is between 0 and 7.

offset specifies the location in the AT or MDT to read/write the 16-bit data word. The data and offset configurations are based on the CYCLIC_DATA structures passed to **configure_at_data(…)** and **configure_mdt_data(…)**.

SEE ALSO

configure_at_data(…), **configure_mdt_data(…)**, **serc_reset(…)**

RETURN VALUES

	Returns
read_cyclic_at_data(...) **read_cyclic_mdt_data**(...) **write_cyclic_mdt_data**(...)	Error return codes (see *Error Handling* on page 3-13)

SAMPLE CODE This code initializes SERCOS communication with an Indramat servo drive:

```
#include “pcdsp.h”
#include “sercos.h”
#include “sercrset.h”

#define NODES               1    /* Number of nodes on SERCOS ring */
#define AXIS                0
#define NODE_ADDR           1

#define AT_IDNS             1    /* Number of IDNS for the AT */

DRIVE_INFO drive_info[NODES] = {
/*    {Axis, Drive address, Operation mode, Manufacturer} */
      {AXIS, NODE_ADDR, POSMODE, INDRAMAT}
};

CYCLIC_DATA at_idns[AT_IDNS] = {
/* {IDN, Drive Address} */
      {40, NODE_ADDR}            /* Velocity Feedback Value */
};

int main(void)
{
      if (dsp_init(PCDSP_BASE));      /* any problems initializing? */
            return dsp_error;

      if (configure_at_data(AT_IDNS, at_idns))
            return dsp_error;
      if (serc_reset(BIT_RATE2, NODES, drive_info))
            return dsp_error;

      enable_amplifier(AXIS);/* enable servo drive */
      v_move(AXIS, 5000.0, 50000.0);  /* accel to constant velocity */

      while (!kbhit())
      {       act_vel = ((unsigned16)read_cyclic_at_data(0, 0) |
                        (((int32)read_cyclic_at_data(0, 1)) << 16));
            printf("ActVel: %10ld\r", act_vel);
      }
      getch();
      v_move(AXIS, 0.0, 50000.0);     /* decel to a stop */

      return dsp_error;
}
```

SERCOS Enable/Disable LED

turn_on_sercos_led	enables the LED from the Tx module
turn_off_sercos_led	disables the LED from the Tx module

SYNTAX

int16 **turn_on_sercos_led**(void)

int16 **turn_off_sercos_led**(void)

PROTOTYPE IN

sercos.h

DESCRIPTION

The SERCOS controller has an optical receiver (Rx) and optical transmitter (Tx) to interface to the fiber optic ring. The light emitting from the Tx module can be enabled with **turn_on_sercos_led(…)** and disabled with **turn_off_sercos_led(…)**. These functions are very useful for visually testing the LED module or a fiber optic cable.

Warning, do not call **turn_on_sercos_led(...)** or **turn_off_sercos_led(...)** after the SERCOS ring has been initialized. These functions will disrupt communication. **serc_reset(...)** must be called to re-initialize the SERCOS ring.

SEE ALSO

serc_reset(…)

RETURN VALUES

	Returns
turn_on_sercos_led(...) **turn_off_sercos_led**(...)	Error return codes (see *Error Handling* on page 3-13)

SAMPLE CODE

This code simply toggles the LED on and off several times.

```
#include <stdio.h>
#include “pcdsp.h”
#include “sercos.h”

int main()
{    int i;

     if (dsp_init(PCDSP_BASE))   /* any problems initializing? */
            return dsp_error;    /* just terminate the program. */

     for (i = 0; i < 20; i++)
     {      turn_on_sercos_led();
            sleep(1);              /* wait one second */
            turn_off_sercos_led();
     }

     return dsp_error ;       /* global variable provided by the library */
}
```

SERCOS Drive Status/Reset

get_drive_status	read the SERCOS node's status word
reset_sercos_drive	resets a SERCOS node

SYNTAX

get_drive_status(int16 *axis*, int16 * *status*)
reset_sercos_drive(int16 *axis*)

PROTOTYPE IN

sercos.h

DESCRIPTION

get_drive_status(…) reads an axis' *Drive Status Word* directly from the controller. The controller axis' *status word* is updated by the real-time cyclic data from IDN 135. The *Drive Status Word* contains the operation status bits (SERCOS specification):

Table 2-42 SERCOS Drive Status Word

Bit(s)	*Explanation*
14, 15	Ready to Operate
13	Drive Shutdown - Error in Class 1 Diagnostic (see IDN 11)
12	Change bit for Class 2 Diagnostic (see IDN 12)
11	Change bit for Class 3 Diagnostic (see IDN 13)
10	Reserved
9, 8	Actual Operation Mode (IDNs 32, 33, 34, 35)
7	Real-time status bit 2 (IDN 306)
6	Real-time status bit 1 (IDN 304)
5	Procedure command change bit
4, 3	Reserved
2	Service Container Error (non-cyclic data)
1	Busy (non-cyclic data)
0	Amplifier Handshake (non-cyclic data)

serc_reset(...) will automatically map the following bits from the drive's *status word* into the DSP's dedicated I/O registers (for all *drive_modes* except USERMAP):

Table 2-43 Drive Status Word Mapping to DSP Dedicated I/O Register

Bit	*Description*	*DSP's Dedicated I/O Register*
13	Drive Shutdown - Error in Class 1 Diagnostic (see IDN 11)	Amp Fault
7	Real-time status bit 2 (IDN 306)	Home
6	Real-time status bit 1 (IDN 304)	Pos and Neg Limit

Every sample, the DSP examines the Dedicated I/O registers to determine if a controller exception event should be triggered. For more information, also see

- Dedicated I/O (*Inputs*, page 3-56)
- Exception Events (*Axis State* page 3-45, *Axis Source* page 3-46)
- Event Recovery (page 3-54)
- Home Config (*Action* page 2-32, *Logic* page 2-34)
- Limit Config (*Input Action* page 2-37, *Input Level* page 2-39)
- Amp Fault Config (*Input* page 2-41, *Enable Output* page 2-43)
- Events (*Stop* page 3-48, *Emergency Stop* page 3-50, *Abort* page 3-52)

reset_sercos_drive(…) initiates drive procedure 99 and waits for completion. Procedure 99

clears the *Class 1 Diagnostic* (IDN 11), the *Interface Status* (IDN 14) and the *Manufacturer Class 1 Diagnostic* (IDN 129).

axis is the controller's axis number assigned to a particular SERCOS node. The controller axis numbers are defined during SERCOS ring initialization with **serc_reset(…)**. The valid range for *axis* is between 0 and 7.

SEE ALSO **axis_state(...)**, **axis_source(...)**, **serc_reset(…)**, **get_idn(...)**

RETURN VALUES

	Returns
get_drive_status(...) **reset_sercos_drive**(...)	Error return codes (see *Error Handling* on page 3-13)

SAMPLE CODE This code demonstrates how to read the *Drive Status Word* and reset a *Class 1* error. Be sure to always initialize SERCOS communication with **serc_reset(…)** before invoking **get_drive_status(…)** or **reset_sercos_drive(…)**:

```
#include <stdio.h>
#include “pcdsp.h”
#include “sercos.h”

#define CLASS_1_ERROR       0x2000    /* bit 13 */
#define CLASS_2_ERROR       0x1000    /* bit 12 */
#define AXIS                0

int main()
{    int status;
     int code;
     char string;

     if (dsp_init(PCDSP_BASE))   /* any problems initializing? */
            return dsp_error;    /* just terminate the program. */

     get_drive_status(AXIS, &status);
     printf("\nDrive Status:0x%x", status);

     if (status & CLASS_1_ERROR)
     {      get_class_1_diag(AXIS, &code, string);
            printf("\nClass 1:(0x%x) %s", code, string);

            disable_amplifier(AXIS);
            reset_sercos_drive(AXIS);
            controller_run(AXIS);
            enable_amplifier(AXIS);
     }

     if (status & CLASS_2_ERROR)
     {      get_class_2_diag(AXIS, &code, string);
            printf("\nClass 2:(0x%x) %s", code, string);
     }

     return dsp_error ;       /* global variable provided by the library */
}
```

SERCOS Diagnostics

get_class_1_diag	read the Class 1 Diagnostic information
get_class_2_diag	read the Class 2 Diagnostic information

SYNTAX **get_class_1_diag**(int16 *axis*, int16 * *code*, char * *msg*)
get_class_2_diag(int16 *axis*, int16 * *code*, char * *msg*)

PROTOTYPE IN sercos.h

DESCRIPTION **get_class_1_diag(...)** reads the Class 1 Diagnostic information from a SERCOS node. The Class 1 Diagnostic *code* contains details concerning a drive shutdown error (reported by the drive status word, bit 13):

Table 2-44 Class 1 Diagnostic Word

Bit(s)	*Explanation*
0	Overload shutdown (IDN 114)
1	Amplifier over temperature shutdown (IDN 203)
2	Motor over temperature shutdown (IDN 204)
3	Cooling error shutdown (IDN 205)
4	Control voltage error
5	Feedback error
6	Error in the “commutation” system
7	Over current error
8	Over voltage error
9	Under voltage error
10	Power supply phase error
11	Excessive position deviation (IDN 159)
12	Communication error (IDN 14)
13	Over travel limit is exceeded (IDNs 49, 50)
14	Reserved
15	Drive Manufacturer specific error (IDN 129)

get_class_2_diag(...) reads the Class 2 Diagnostic information from a SERCOS node. The Class 2 Diagnostic *code* contains details concerning a *drive shutdown warning* (reported by the drive status word, bit 12):

Table 2-45 Class 2 Diagnostic Word

Bit(s)	*Explanation*
0	Overload warning (IDN 310)
1	Amplifier over temperature warning (IDN 311)
2	Motor over temperature warning (IDN 312)
3	Cooling error warning (IDN 313)
4-14	Reserved
15	Drive Manufacturer specific warning (IDN 181)

axis is the controller’s axis number assigned to a particular SERCOS node. The controller axis numbers are defined during SERCOS ring initialization with **serc_reset(…)**. The valid range for *axis* is between 0 and 7.

**msg* is a pointer to a string that describes the shutdown or warning conditions. The string length is MAX_ERROR_LEN characters.

SEE ALSO **get_drive_status(...)**, **reset_sercos_drive(...)**, **get_idn(...)**, **get_idn_string(...)**, **get_idn_attributes(...)**

RETURN VALUES

	Returns
get_class_1_diag(...) **get_class_2_diag**(...)	Error return codes (see *Error Handling* on page 3-13)

SAMPLE CODE This code demonstrates how to read the Class 1 and Class 2 diagnostic information. Be sure to always initialize SERCOS communication with **serc_reset(…)** before invoking **get_class_1_diag(…)** or **get_class_2_diag(…)**:

```
#include <stdio.h>
#include “pcdsp.h”
#include “sercos.h”
#define AXIS                0

int main()
{    int code;
     char string;

     if (dsp_init(PCDSP_BASE))   /* any problems initializing? */
            return dsp_error;    /* just terminate the program. */
     get_class_1_diag(AXIS, &code, string);
     printf("\nClass 1:(0x%x) %s", code, string);
     get_class_2_diag(AXIS, &code, string);
     printf("\nClass 2:(0x%x) %s", code, string);
     return dsp_error ;        /* global variable provided by the library */

}
```

CHAPTER 3 OPERATION FUNCTIONS

This chapter describes the medium-level functions used for motion operations, logically organized into topics that support specific features. The function prototypes are in PCDSP.H. “Sample Code” sections are code fragments; they do not contain everything needed to compile and run.

Quick List

Type	Function	Description
Initialization		
page 3-8	dsp_init(*controller_address*)	Software initialization
	dsp_reset(void)	Hardware reset
Initialization with Environmental Variables		
page 3-9	do_dsp(void)	Initialize controller from shell environment variables
	understand_dsp(* *var*)	Reads DSP environment variable
	dsp_base	DSP base address
PCI and Compact PCI Initialization		
page 3-10	find_pci_dsp(**boards_found*, **pci_addresses*, **pci_interrupt*)	Finds the address and IRQs of PCI/CPCI controllers on the bus
PCI and Compact PCI Board Identification		
page 3-11	dsp_get_id(*board_addr*, *id_addr*, **data*)	Reads the identification register
	dsp_set_id(*board_addr*, *id_addr*, *data*)	Configures the identification register
Error Handling		
page 3-13	dsp_error	Returns last error code variable
	error_msg(*code*, * *dst*)	Copies error message to buffer
Single Axis Point to Point Motion		
page 3-17	start_move(*axis*, *position*, *vel*, *accel*)	Begin a trapezoidal profile move
	move(*axis*, *position*, *vel*, *accel*)	Perform a trapezoidal profile move
	start_r_move(*axis*, *distance*, *vel*, *accel*)	Begin a relative trapezoidal profile move
	r_move(*axis*, *distance*, *vel*, *accel*)	Perform a relative trapezoidal profile move
	start_t_move(*axis*, *position*, *vel*, *accel*, *decel*)	Begin a non-symmetrical trapezoidal profile move
	t_move(*axis*, *position*, *vel*, *accel*, *decel*)	Perform a non-symmetrical trapezoidal profile move
	wait_for_done(*axis*)	Wait for an axis to finish
Single-Axis S-Curve Profile Motion		
page 3-19	start_s_move(*axis*, *position*, *vel*, *accel*, *jerk*)	Begin an S-curve move
	s_move(*axis*, *position*, *vel*, *accel*, *jerk*)	Perform an S-curve profile move
	start_rs_move(*axis*, *distance*, *vel*, *accel*, *jerk*)	Begin a relative S-curve move
	rs_move(*axis*, *distance*, *vel*, *accel*, *jerk*)	Perform a relative S-curve profile move
	start_sprof_move(*axis*, *position*, *vel*, *accel*, *jerk*)	Begin an S-curve move
	sprof_move(*axis*, *position*, *vel*, *accel*, *jerk*)	Perform an S-curve profile move
Single Axis Parabolic Profile Motion		
page 3-21	start_p_move(*axis*, *final*, *vel*, *accel*, *jerk*)	Begin a parabolic profile move
	p_move(*axis*, *final*, *vel*, *accel*, *jerk*)	Perform a parabolic profile move
Multi-Axis Point-to-Point Motion		

Type	*Function*	*Description*
page 3-22	start_move_all(*length, * axes, * position, * vel, * accel*)	Begin a multi-axis trapezoidal profile move
	move_all(*length, * axes, * position, * vel, * accel*)	Perform a multi-axis trapezoidal profile move
	wait_for_all(*length, * axes*)	Wait for all axes to finish
Velocity Move		
page 3-23	v_move(*axis, vel, accel*)	Accelerate an axis to a constant velocity
Coordinated Axis Map		
page 3-24	map_axes(*n_axes, * map_array*)	Maps coordinated motion axes x, y, z.....
Start/End Coordinated Point List		
page 3-25	start_point_list(void)	Start an interpolated point list
	end_point_list(void)	End an interpolated point list
	get_last_point(* *x*)	Get last commanded point
Coordinated Motion Parameters		
page 3-26	set_move_speed(*speed*)	Set the vector velocity
	set_move_accel(*accel*)	Set the vector acceleration
	set_arc_division(*degrees*)	Set the interpolation arc segment length
	arc_optimization(*opt*)	Enable/Disable optimum acceleration calculations for arcs
	set_move_ratio(* *ratio*)	Set the axis resolution ratios
Start/Stop Coordinated Motion		
page 3-28	start_motion(void)	Start coordinated motion
	stop_motion(void)	Stop coordinated motion
	set_points(*points*)	Set the number of points before motion starts
	all_done(void)	Returns TRUE if motion is complete
Linear Coordinated Motion		
page 3-29	move_2(*x, y*)	2-axis linear interpolated move
	move_3(*x, y, z*)	3-axis linear interpolated move
	move_4(*x, y, z, w*)	4-axis linear interpolated move
	move_n(* *x*)	n-axis linear interpolated move
	add_point(* *x*)	Add a point to point list
Circular Coordinated Motion		
page 3-29	arc_2(*x_center, y_center, angle*)	2-axis circular interpolated move
	add_arc(* *center, angle, division*)	Add an arc to point list
User I/O During Coordinated Motion		
page 3-31	set/reset_move_bit(*bitNo*)	Turn on/off an output bit at the next point
	change_move_bit(*bitNo, state*)	Update an output bit at the next point
	set_move_output(*value*)	Update 16 bits of user I/O (ports 0 & 1) at the next point
Cubic Spline Coordinated Motion		
page 3-33	load_spline_motion(*n_axes, * axis_map, n_points, * (* points_list), * g, * end_flag*)	Download frames for an n-axis cubic spline motion
	start_spline_motion(*n_axes, * axis_map*)	Start a cubic spline coordinated motion

Type	Function	Description
Frame Buffer Mgmt		
page 3-36	fifo_space(void)	Returns the number of free frames left in the buffer
	frames_to_execute(*axis*)	Returns the number of frames left to execute for an axis
Position Control		
page 3-38	set/get_position(*axis*, *position*)	Set or get current actual position
	dsp_encoder(*axis*)	Read 16 bit position directly from the encoder
	set/get_command(*axis*, *position*)	Set or get current command position
	set/get_last_command(*axis*, *position*)	Set or get last command position value
	get_error(*axis*, * *error*)	Get current position error
Trajectory Control		
page 3-40	set/get_velocity(*axis*, *vel*)	Set or get current command velocity
	set/get_accel(*axis*, *accel*)	Set or get current command acceleration
	set/get_jerk(*axis*, *jerk*)	Set or get current command jerk
Motion Status		
page 3-42	in_sequence(*axis*)	Returns TRUE during loading or execution of frames
	in_motion(*axis*)	Returns TRUE if command velocity is non-zero
	in_position(*axis*)	Returns TRUE if axis is in-position
	negative_direction(*axis*)	Returns TRUE if command velocity is negative
	frames_left(*axis*)	Returns TRUE if frames left for an axis
	motion_done(*axis*)	Returns TRUE if !in_sequence, !in_motion, !frames_left
	axis_done(*axis*)	Returns TRUE if motion_done && in_position
Axis Status/State/Source		
page 3-44	axis_status(*axis*)	Read the axis status word & return it
page 3-45	axis_state(*axis*)	Read if an exception event has occurred & return status word
page 3-46	axis_source(*axis*)	Read the cause of an exception event & return status word
Stop Event		
page 3-48	set_stop(*axis*)	Generate a Stop Event on an axis
	set/get_stop_rate(*axis*, *rate*)	Set or get deceleration rate for a Stop Event
	set/get_boot_stop_rate(*axis*, *rate*)	Set or get boot deceleration rate for a Stop Event
Emergency Stop Event		
page 3-50	set_e_stop(*axis*)	Generate an E-Stop Event on an axis
	set/get_e_stop_rate(*axis*, *rate*)	Set or get deceleration rate for an E-Stop Event
	set/get_boot_e_stop_rate(*axis*, *rate*)	Set or get boot deceleration rate for an E-Stop Event
Abort Event		
page 3-52	controller_idle(*axis*)	Generate an Abort Event on an axis
	disable_amplifier(*axis*)	Set the state of the amp enable output
Event Recovery		

Type	*Function*	*Description*
page 3-54	clear_status(*axis*)	Clear a Stop Event or an E-Stop Event on an axis
	controller_run(*axis*)	Clear an Abort Event on an axis
	enable_amplifier(*axis*)	Set the state of the amp enable output
Dedicated Inputs		
page 3-56	home_switch(*axis*)	Returns the state of home logic
	pos_switch(*axis*)	Returns the state of positive limit sensor
	neg_switch(*axis*)	Returns the state of negative limit sensor
	amp_fault_switch(*axis*)	Returns the state of amp fault sensor
User I/O Port Control		
page 3-58	init_io(*port, direction*)	Configure an I/O port as input or output
	init_boot_io(*port, direction*)	Configure an I/O port as input or output at boot
	set/get_io(*port, value*)	Set or get the state of an 8-bit I/O port
	set/get_boot_io(*port, value*)	Set or get the boot state of an 8-bit I/O port
User I/O Bit Control		
page 3-61	bit_on(*bitNo*)	Get the state of an individual I/O bit
	boot_bit_on(*bitNo*)	Get the boot state of individual I/O bit
	set/reset_bit(*bitNo*)	Set the state of an individual I/O bit
	change_bit(*bitNo, state*)	Update the state of an individual I/O bit
	change_boot_bit(*bitNo, state*)	Update the boot state of individual I/O bit
User I/O Monitoring		
page 3-63	set_io_mon_mask(*port, mask, value*)	Configure the DSP to monitor User I/O
	io_changed(void)	Returns the state of DSP's I/O monitoring flag
	io_mon(*port, * status*)	Read the status of an I/O port
	clear_io_mon(void)	Reset the DSP's I/O monitoring flag
Analog Inputs		
page 3-65	init_analog(*channel, differential*, bipolar)	Initialize analog inputs
	get_analog(*channel, * value*)	Read an analog input
	start_analog(*channel*)	Write a control word to A/D circuitry
	read_analog(**value*)	Read an analog input (after start_analog)
Axis Analog Inputs		
page 3-67	set/get_axis_analog(*axis, state*)	Set or get the DSP's analog input read configuration
	read_axis_analog(*axis, *value*)	Read an axis' analog input channel (via the DSP)
	set/get_analog_channel(*axis, channel, differential, bipolar*)	Set or get an analog input channel for an axis
	set/get_boot_analog_channel(*axis, channel, differential, bipolar*)	Set or get a boot analog input channel for an axis
Axis Analog Outputs		
page 3-69	set/get_dac_channel(*axis, channel*)	Set or get an analog output channel for an axis
	set/get_boot_dac_channel(*axis, channel*)	Set or get a boot analog output channel for an axis
	set/get_dac_output(*axis, voltage*)	Set or get the 16 bit DAC value
Counter/Timer		
page 3-71	init_timer(*channel, mode*)	Initialize an 8254 counter/timer

Type	Function	Description
	set/get_timer(*channel*, *t*)	Set or get a counter/timer value
Master/Slave Operation		
page 3-73	mei_link(*master*, *slave*, *ratio*, *source*)	Configure two axes for master/slave operation
	endlink(*slave*)	Discontinue master/slave operation
Master/Cam Operation		
page 3-75	set_cam(*master_axis*, *cam_axis*, *cam*, *source*)	Configure two axes for master/cam operation
	set_boot_cam(*master_axis*, *cam_axis*, *cam*, *source*)	Configure two axes for boot master/cam operation
Feed Speed Override		
page 3-77	dsp_feed_rate(*feed_rate*)	Change all axes running speed from 0% to 200%
	axis_feed_rate(*axis*, *feed_rate*)	Change an axis' running speed from 0% to 200%
Position Latching		
page 3-79	arm_latch(*enable*)	Enables the DSP interrupt and resets a ready flag
	latch_status(void)	Returns FALSE until positions latch is complete
	get_latched_position(*axis*, * *position*)	Returns the latched position of an axis
	latch(void)	Generate a position latch from software
On-Board Jogging		
page 3-81	jog_axis(*axis*, *jog_channel*, *c*, *d*, *m1*, *m2*, *enable*)	Configure on board analog input jogging for one axis
Multiple Controllers		
page 3-83	m_setup(*boards*, * *controller_addresses*)	Initialize pointers to access multiple controllers
	m_board(*board_number*)	Switch pointers to access a particular board
	m_axis(*actual_axis*)	Switch pointers to access a particular axis
Trajectory Frames		
page 3-85	dsp_dwell(*axis*, *duration*)	Delay execution of next frame
	dsp_position(*axis*, *position*, *duration*)	Update command position and delay next frame
	dsp_velocity(*axis*, *vel*, *duration*)	Update velocity and delay next frame
	dsp_accel(*axis*, *accel*, *duration*)	Update accel and delay next frame
	dsp_jerk(*axis*, *jerk*, *duration*)	Update jerk and delay next frame
	dsp_end_sequence(*axis*)	Clear the in_sequence status bit
I/O Frames		
page 3-87	dsp_io_frame(*axis*, *port*, *ormask*, *andmask*)	Set the state of an 8-bit I/O port
	dsp_io_trigger(*axis*, *bit*, *state*)	Delay next frame until bit level changes to state
	dsp_io_trigger_mask(*axis*, *port*, *mask*, *state*)	Delay next frame until bit level(s) change to state

Type	*Function*	*Description*
Position Triggered Frames		
page 3-88	dsp_position_trigger(*axis*, *triggeraxis*, *triggerpos*, *sense*, *actual*, *action*)	Generate an action when a position is exceeded
	dsp_actual_position_trigger(*axis*, *position*, *sense*)	Delay next frame until actual position is exceeded
	dsp_command_position_trigger(*axis*, *position*, *sense*)	Delay next frame until command position is exceeded
Looping Sequence Frames		
page 3-90	dsp_marker(*axis*, * *marker*)	Download a marker frame
	dsp_goto(*axis*, *marker*)	Download a frame that points to another frame
Action Frames		
page 3-92	dsp_axis_command(*axis*, *destaxis*, *action*)	Send an action to another axis
	dsp_home_action(*axis*, *action*)	Download a frame to set the home logic action
	dsp_positive_limit_action(*axis*, *action*)	Download a frame to set the positive limit action
	dsp_negative_limit_action(*axis*, *action*)	Download a frame to set the negative limit action
	dsp_error_action(*axis*, *action*)	Download a frame to set the error limit action
Filter Frame		
page 3-94	dsp_set_filter(*axis*, * *coeffs*)	Download a frame to set the PID filter parameters
Frame Control		
page 3-95	dsp_control(*axis*, *bit*, *state*)	Enable/disable frame control bits
	set/reset_gate(*axis*)	Set or reset the gate flag for one axis
	set/reset_gates(*length*, * *axes*)	Set or reset the gate flag for several axes
Time		
page 3-97	get_dsp_time(void)	Returns the DSP's sample timer value
	get_frame_time(*axis*)	Returns an axis' frame sample timer value
Direct Memory Access		
page 3-98	dsp_read_dm(*addr*)	Read from DSP's external data memory
	dsp_write_dm(*addr*, *dm*)	Write to DSP's external data memory

Initialization

dsp_init	set controller's I/O base address for all other software calls
dsp_reset	reset the controller to its power-up state

SYNTAX

int16 **dsp_init**(int16 *controller_address*)
int16 **dsp_reset**(void)

PROTOTYPE IN

pcdsp.h

DESCRIPTION

dsp_init(...) sets the controller base address and reads other configuration data from the DSP controller. Every program must call **dsp_init(...)** before any other function can be used. Make sure to check the error code. The *controller_address* specifies the I/O base address of the controller. The value of *controller_address* must match the switch settings on the controller (see the *Installation Manual*). The identifier PCDSP_BASE is defined in PCDSP.H as **0x300**; the factory default base address.

dsp_reset(...) causes a power-up reset of the DSP controller. The software and hardware configurations are re-read from boot memory, the command and actual positions are reset, the amp enable output is disabled, user I/O is reconfigured, etc., **dsp_reset(...)** also calls **dsp_init(...)** so make sure to check the error code. A hardware reset causes the DSP to release control of the axes and I/O for a few milliseconds which may cause motors to jump.

SERCOS

If the SERCOS communication ring has been initialized with **serc_reset(…)**, then **dsp_reset(…)** will simply return error code 114 (DSP_SERCOS_RESET).

SEE ALSO

do_dsp(...), **m_setup(…)**, **map_axes(...)**

RETURN VALUES

	Returns
dsp_init(...) **dsp_reset**(...)	Error return codes (see *Error Handling* on page 3-13)

SAMPLE CODE

This sample code simply initializes the DSP controller and prints the error message. All programs must call **dsp_init(...)** to initialize communication with the controller:

```
# include "pcdsp.h"

int main()
{
     int16 error;
     char buffer[MAX_ERROR_LEN];

     error = dsp_init(PCDSP_BASE);   /* initialize the controller */
     error_msg(error, buffer);
     printf("\nValue: %d Message: %s", error, buffer);

     return dsp_error;       /* global variable provided by the library */
}
```

NOTES

Often times we have seen code that calls **dsp_reset(...)** before **dsp_init(...)**.
Don't do this! Make sure you always call **dsp_init(..)** first. **dsp_init(...)** only initializes the software and has no effect on the current state of the controller. Most applications do not need to call **dsp_reset(...)**.

Initialization with Environment Variables

do_dsp	initialize controller with shell environment variables
understand_dsp	reads DSP environment variable
dsp_base	global variable representing the controller I/O address

SYNTAX

int16 **do_dsp**(*void*)

int16 **understand_dsp**(char * *var*)

int16 **dsp_base**

PROTOTYPE IN

pcdsp.h

DESCRIPTION

These functions know how to understand an environment variable called *DSP*, and are provided to allow easy access to external parameters in your program.

understand_dsp(...) interprets the environment variable *DSP*. Currently, *DSP* supports a single parameter called *BASE*, which is used to specify the base I/O address of the controller. If *BASE* is specified, then *dsp_base* is set to the value specified.

For example, if *set DSP=base:0x280'* is executed at the DOS prompt, and later **understand_dsp(...)** is called, then it will assign *dsp_base* with an address of **0x280**. By default, *dsp_base* is assigned PCDSP_BASE.

do_dsp(...) executes **understand_dsp(...)**. It then calls **dsp_init(...)** with *dsp_base* as the address. **do_dsp(...)** returns the error code given by **dsp_init(...)**.

RETURN VALUES

	Returns
do_dsp(...) **understand_dsp**(...)	Error return codes (see *Error Handling* on page 3-13)

SAMPLE CODE

This sample code simply initializes the DSP controller and prints the error message. The function **do_dsp(...)** initializes the controller with the address set by the environment variable *dsp_base*. If the environment variable has not been set then the controller will be initialized using the default address PCDSP_BASE:

```
# include "pcdsp.h"

int main()
{
     int16 error;
     char buffer[MAX_ERROR_LEN];

     error = do_dsp();
     error_msg(error, buffer);
     printf("\nValue: %d Message: %s", error, buffer);
     return dsp_error;         /* global variable provided by the library*/
}
```

NOTES

The environment variable is very useful when programs need to access DSP controllers at different I/O addresses. SETUP.EXE and CONFIG.EXE use **do_dsp(...)** to initialize the DSP controller.

PCI and CompactPCI Initialization

find_pci_dsp

finds the address and IRQs of all MEI PCI/CPCI controllers on the bus

SYNTAX

int16 **find_pci_dsp**(int16 * *boards_found*, int16 * *pci_addresses*, int16 * *pci_interrupt*)

PROTOTYPE IN

pcdsp.h

DESCRIPTION

Since the BIOS dynamically assigns PCI and CPCI devices their addresses and IRQ resources at boot up, the function **find_pci_dsp(...)** provides the user with the number of PCI and CPCI controllers found in the system, *boards_found*, as well as their IO address, *pci_address*, and IRQ, *pci_interrupt*. This function is valid under DOS, Windows 95/98, Windows NT and VxWorks 5.3.1.

find_pci_dsp(...) should be used in conjunction with **dsp_init(...)** to properly locate and initialize communication with a PCI bus motion controller.

The define **MAX_PCI_BOARDS** has been added to the library to allocate the maximum number of PCI devices in a system to be 20.

RETURN VALUES

dsp_init(...), do_dsp(...), m_setup(...), map_axes(...)

RETURN VALUES

See *Error Handling* on page 3-13 for the error return codes

SAMPLE CODE

This sample code calls the **find_pci_dsp(...)** function to return the resources of any PCI controllers found on the bus.

```
# include <stdio.h>
# include <stdlib.h>
# include "pcdsp.h"

int main()
{
     int16 count, boardsfound, addrs[MAX_PCI_BOARDS],
     irqs[MAX_PCI_BOARDS];

     printf("Searching for PCI bus DSP boards...\n");
     find_pci_dsp(&boardsfound, addrs, irqs);
     if(boardsfound)
     {
            printf(" %d MEI Controller%s found:\n, boardsfound, boardsfound >
            1?"s" :"");
            for(count = 0; count < boardsfound ; count++)
            {
                   printf(" Board%d at I/O address: 0x%X using IRQ: %d\n", count,
                   addrs[count] & 0xFFFF, irqs[count]);
            }
     }
     else
            printf(" No PCI motion controllers found in system.\n");

     printf("\n");
     return 0 ;
}
```

NOTES

The **find_pci_dsp(...)** function only returns the address and IRQs of all PCI controllers found on the bus. **dsp_init(...)** will still need to be used to initialize communication with the controller. Please see the *Initialization* section in this manual for further usage instructions.

PCI and CompactPCI Board Identification

dsp_get_id	reads the identification register on the MEI controller
dsp_set_id	configures the indentification register on the MEI controller

SYNTAX

int16 **dsp_get_id**(int16 *board_addr, unsigned16 id_addr, unsigned32 * data*)
int16 **dsp_set_id**(int16 *board_addr, unsigned16 id_addr, unsigned 32 data*)

PROTOTYPE IN

pcdsp.h

DESCRIPTION

Two functions are used to support the Board Identification feature implemented on PCI and CPCI DSP controllers under a 32-bit Microsoft environment only. MEI has provided the user with two 32-bit DWORD registers to store board identification information or general user information. The functions **dsp_get_id(...)** and **dsp_set_id(...)** allow the user to read and write to the DSP_BOARD_ID and DSP_USER_ID 32-bit registers, where *board_addr* is the base address of the controller, *id_addr* is the desired identification address and *data* is the desired identification value. MEI also provides READ ONLY data registers for reading other board information:

Identification Address	*Value*	*Register Definition*	*User Read or Write*
DSP_BOARD_ID	0x7C	Board Identification Number	User Read/Write
DSP_USER_ID	0x78	User Identification Number	User Read/Write
DSP_SERIAL_ID	0x74	Controller Serial Number*	User Read Only
DSP_PART_ID	0x70	Controller Part Number*	User Read Only
DSP_REV_ID	0x6C	Controller Revision Identification*	User Read Only
DSP_FEATURE_ID	0x68	Special Feature Identification*	User Read Only
**Identification information not yet implemented on the controllers at time of release - Nov 1999.*			

RETURN VALUES

dsp_init(...), do_dsp(...), m_setup(...), map_axes(...)

RETURN VALUES

See *Error Handling* on page 3-13 for the error return codes

SAMPLE CODE

This sample code simply retrieves the address of a PCI/DSP or CPCI/DSP controller and sets a specific Board and User ID to identify the controller by.

```
# include <stdio.h>
# include <stdlib.h>
# include "pcdsp.h"

int main()
{
     int16 count, boardsfound, addrs[MAX_PCI_BOARDS],
     irqs[MAX_PCI_BOARDS];
     unsigned32 val;

     printf("Searching for PCI bus DSP boards...\n");
     find_pci_dsp(&boardsfound, addrs, irqs);
     if(boardsfound)
     {
            printf(" %d MEI Controller%s found:\n, boardsfound, boardsfound >
            1?"s":"");
            for(count = 0; count < boardsfound ; count++)
            {
                   printf(" \tBoard%d at I/O address: 0x%X using IRQ: %d\n",
                   count, addrs[count] & 0xFFFF, irqs[count]);
                   dsp_set_id(addrs[count], DSP_BOARD_ID, 0xBEEFCAFE);
                   dsp_set_id(addrs[count], DSP_USER_ID, 0xCAFEBEEF);
```

```
                dsp_get_id(addrs[count], DSP_BOARD_ID, &val);
                printf("Board ID read: 0x%8X\n", val);

                dsp_get_id(addrs[count], DSP_USER_ID, &val);
                printf("User ID read: 0x%8X\n", val);
        }
}
else
        printf(" No PCI motion controllers found in system.\n");

printf("\n");
return 0 ;
}
```

Error Handling

dsp_error	last error code global variable
error_msg	get error message

SYNTAX

extern int16 **dsp_error**

int16 **error_msg**(int16 *code*, char * *dst*)

PROTOTYPE IN

pcdsp.h

DESCRIPTION

Most functions return an integer error code. The error code indicates the successful or unsuccessful execution of a function. Non-zero return values are errors. The global variable *dsp_error* is used to hold the most recent error code. The function **error_msg(...)** copies an ASCII description of the error corresponding to *code* into the character array pointed to by *dst*. This character array must be able to hold at least MAX_ERROR_LEN characters.

PCDSP.H defines these identifiers for each error code. See the next table.

SAMPLE CODE

This code prints an error message if **dsp_init(...)** fails. This is recommended as a motion program's typical initialization:

```
# include "pcdsp.h"

int main()
{
     int16 error;
     char buffer[MAX_ERROR_LEN];

     error = dsp_init(PCDSP_BASE);
     if (error)
     {       error_msg(error, buffer);
             printf("\nValue: %d Message: %s", error, buffer);
     }
     return dsp_error;        /* global variable provided by the library */
}
```

RETURN VALUES

	Returns
dsp_error	Value (Last error code variable)
error_msg(...)	Error return codes (see *Error Handling* on page 3-13)

NOTES

Make sure that you always check the error message when **dsp_init(...)** is called. This function is the most likely to fail. It is a good idea to check the error codes returned by all of functions. The error codes were created to help programmers catch programming mistakes and hardware failures.

Table 3-1 Error Codes

#define	***Value***	***Description***
DSP_OK	0	This error code indicates successful completion of the last function.
DSP_NOT_INITIALIZED	1	**dsp_init(...)** must be called to initialize library static data. This error is returned if this static initialization hasn't been performed.
DSP_NOT_FOUND	2	**dsp_init(...)** wasn't able to find the DSP controller at the given I/O base address.

Table 3-1 Error Codes

#define	*Value*	*Description*
DSP_INVALID_AXIS	3	Any function taking an *axis* parameter can return this error code, indicating reference to a non-existent axis.
DSP_ILLEGAL_ANALOG	4	Some of the DSP Series controllers have eight analog inputs, numbered 0 to 7. This error indicates a reference to a non-existent *channel*.
DSP_ILLEGAL_IO	5	The DSP Series controllers have up to 6 User I/O ports. Any function taking a *port* parameter can return this code, indicating reference to a non-existent User I/O *port*.
DSP_OUT_OF_MEMORY	6	
DSP_FRAME_UNALLOCATED	7	These are internal library error messages, and should never be seen at higher levels. If you receive one of these messages, please contact us. They indicate problems passing information to the DSP controller.
DSP_ILLEGAL_PARAMETER	8	A move with zero *acceleration*, *velocity*, or *jerk* is considered illegal.
DSP_ILLEGAL_CONVERSION	9	When either the Counts per Distance or Seconds per Period conversion factors are zero, any function using positions, velocities, or accelerations can return this error.
DSP_FRAME_ NOT_CONNECTED	10	This is an internal library error message for debugging purposes and should never be seen at higher levels.
DSP_FIRMWARE_VERSION	11	The firmware loaded from the boot memory (into the DSP) and the C function libraries have version numbers. This error message occurs when the firmware and library versions do not match or other fundamental configuration problems exist.
DSP_ILLEGAL_TIMER	12	The 8254 timer is configured using the function **init_timer(...)**. This error message occurs when an invalid timer number is chosen with **init_timer(...)**, **set_timer(...)** or **get_timer(...)**.
DSP_STRUCTURE_SIZE	13	Indicates problems after porting the library to another operating system or compiler with different integer sizes. Also see *Compiling under Unsupported Operating Systems*, page 1-5.
DSP_TIMEOUT_ERROR	14	Indicates that the DSP controller is not responding.
DSP_RESOURCE_IN_USE	15	The function libraries have a few global resources. This error message occurs when a resource is already in use. Those functions that are not re-entrant will return this code if re-entered.
DSP_CHECKSUM	16	The **dsp_init(...)** function checks the boot memory of the DSP controller. This error message indicates the boot memory has been corrupted or there are bus communication problems.
DSP_CLEAR_STATUS	17	**clear_status(...)** can't be performed while **in_sequence(...)** is TRUE. This message indicates that the event was not cleared.
DSP_NO_MAP	18	**map_axes(...)** was not called before using coordinated motion.
DSP_NO_ROOM	19	This error indicates that the frame buffer is full. The frame buffer has a capacity of 600 frames.
DSP_BAD_FIRMWARE_FILE	20	This error indicates that the firmware file cannot be opened or is corrupt.
DSP_ILLEGAL_ ENCODER_CHANNEL	21	Encoder channel number is out of range.
DSP_FUNCTION_ NOT_AVAILABLE	22	This function is not supported in this library version.

Table 3-1 Error Codes

#define	*Value*	*Description*
DSP_NO_EXTERNAL_BUFFER	23	Optional host CPU FIFO frame buffer is full or not available.
DSP_NT_DRIVER	24	The DSPIO device driver for Windows NT support has not been installed properly.
DSP_FUNCTION_ NOT_APPLICABLE	25	This function is not applicable to the current controller configuration.
DSP_NO_DISTANCE	26	A move with zero distance was commanded.
DSP_FIRMWARE_CHECKSUM	27	The firmware buffer checksum value is not valid.
DSP_FEATURE_NOT_SUPPORTED	28	The requested firmware is not supported by the current software/hardware.
DSP_ENVIRONMENT_ NOT_SUPPORTED	29	The requested function is not supported by current compiler or operating system.
DSP_SERCOS_SLAVE_ERROR	100	General failure of a SERCOS slave device. This error occurs when the slave is not responding.
DSP_SERCOS_ INVALID_PARAM	101	SERCOS parameter out of range.
DSP_SERCOS_DISTORTED	102	Data transmitted/received on the SERCOS loop is distorted.
DSP_SERCOS_LOOP_OPEN	103	SERCOS fiber optic ring is not closed.
DSP_SERCOS_EARLY	104	Master Sync Telegram was sent too early
DSP_SERCOS_LATE	105	Master Sync Telegram was sent too late.
DSP_SERCOS_MST_MISSING	106	Master Sync Telegram was not sent.
DSP_SERCOS_DRIVE_INIT	107	SERCOS drive(s) were not found.
DSP_SERCOS_ INVALID_DRIVE_TYPE	108	SERCOS drive mode is not supported by the drive.
DSP_SERCOS_ INVALID_DRIVE_NUMBER	109	Number of SERCOS drives is out of range.
DSP_SERCOS_ INVALID_DRIVE_ADDR	110	SERCOS drive address is out of range.
DSP_SERCOS_ DUPLICATE_DRIVE_ADDR	111	SERCOS drive address is already in use by another drive.
DSP_SERCOS_PROC_FAILURE	112	SERCOS drive failed to execute a procedure.
DSP_SERCOS_ AXIS_ASSIGNMENT	113	Axis number has not been assigned to a SERCOS drive.
DSP_SERCOS_RESET	114	Returned by **dsp_reset(...)** when used with a SERCOS controller. Use **serc_reset(...)** instead.
DSP_SERCOS_ VARIABLE_READ	115	SERCOS IDN value is a variable length string. Use the function **get_idn_string(...)** instead.
DSP_SERCOS_ INVALID_IDN_AT	116	SERCOS IDN cannot be placed in the user configurable portion of the Amplifier Telegram.
DSP_SERCOS_ INVALID_IDN_MDT	117	SERCOS IDN cannot be placed in the user configurable portion of the Master Data Telegram.
DSP_SERCOS_127_FAILURE	118	SERCOS drive failed to execute procedure 127. Loop cannot advance to phase 3.
DSP_SERCOS_128_FAILURE	119	SERCOS drive failed to execute procedure 128. Loop cannot advance to phase 4.
DSP_SERCOS_ IDN_NOT_AVAILABLE	120	SERCOS drive does not support the specified IDN.
DSP_SERCOS_NO_CHANNEL	121	SERCOS Service channel is not available.

Table 3-1 Error Codes

#define	Value	Description
DSP_SERCOS_ ELEMENT_MISSING	122	SERCOS drive does not support the specified IDN element.
DSP_SERCOS_SHORT_TRANS	123	SERCOS data transmission is too short.
DSP_SERCOS_LONG_TRANS	124	SERCOS data transmission is too long.
DSP_SERCOS_STATIC_VAL	125	SERCOS data value cannot be changed.
DSP_SERCOS_ WRITE_PROTECT	126	SERCOS data value is write protected (read only).
DSP_SERCOS_MIN	127	SERCOS data value is less than the allowable range.
DSP_SERCOS_MAX	128	SERCOS data value is greater than the allowable range.
DSP_SERCOS_ INVALID_DATA	129	SERCOS data value is not valid.
DSP_SERCOS_PROTOCOL	130	SERCOS protocol error in drive.
DSP_SERCOS_HS_TIMEOUT	131	SERCOS service channel handshake timeout error.
DSP_SERCOS_BUSY	132	SERCOS drive's BUSY_AT bit is on.
DSP_SERCOS_CMD	133	SERCOS drive's command modification bit is on.
DSP_SERCOS_ M_NOT_READY	134	SERCOS M_BUSY bit is off.
DSP_SERCOS_SC_TIMEOUT	135	SERCOS service channel timeout error.
DSP_SERCOS_REC_ERR	136	SERCOS service container invalid transmission error.
DSP_SERCOS_ INVALID_CYCLE_TIME	137	SERCOS cycle time is too short.
DSP_SERCOS_USER_AT	138	The maximum data length for the user specified cyclic data in the Amplifier Data Telegram has been exceeded.
DSP_SERCOS_USER_MDT	139	The maximum data length for the user specified cyclic data in the Master Data Telegram has been exceeded.
DSP_SINCOM_TABLE_CREATION	200	Indicates error in SinCom table creation.
DSP_SINCOM_HEADER_ CREATION	201	Indicates error in SinCom header creation.
DSP_SINCOM_NOT_POSSIBLE	202	Commutation is not able to fit within the SINCOM table.
DSP_SINCOM_NO_MOTION	203	No motion was created during SinCom initialization.
DSP_SINCOM_CURRENT_ERR	204	High current warning from SinCom drive.

Single Axis Point-to-Point Motion

start_move	begin a trapezoidal profile motion sequence
move	begin a trapezoidal motion sequence and wait for completion
start_r_move	begin a relative trapezoidal profile motion sequence
r_move	begin a relative trapezoidal profile motion sequence and wait for completion
start_t_move	begin a non-symmetrical trapezoidal profile motion sequence
t_move	begin a non-symmetrical trapezoidal motion sequence and wait for completion
wait_for_done	wait for the current sequence to complete

SYNTAX

int16 **start_move**(int16 *axis*, double *position*, double *velocity*, double *acceleration*)
int16 **move**(int16 *axis*, double *position*, double *velocity*, double *acceleration*)
int16 **start_r_move**(int16 *axis*, double *distance*, double *velocity*, double *acceleration*)
int16 **r_move**(int16 *axis*, double *distance*, double *velocity*, double *acceleration*)

int16 **start_t_move**(int16 *axis*, double *position*, double *velocity*, double *acceleration*, double *decel*)
int16 **t_move**(int16 *axis*, double *position*, double *velocity*, double *acceleration*, double *decel*)
int16 **wait_for_done**(int16 *axis*)

PROTOTYPE IN

pcdsp.h

DESCRIPTION

start_move(...) causes the axis to accelerate, slew at constant velocity, and decelerate to a stop at the specified absolute *position*, immediately returning control to the program. The acceleration rate is equal to the deceleration rate. **move(...)** starts an absolute coordinate move and waits for completion.

start_r_move(...) causes the axis to accelerate, slew at constant velocity, and decelerate to a stop at the relative *distance*, immediately returning control to the program. The acceleration rate is equal to the deceleration rate. **r_move(...)** starts a relative move and waits for completion.

start_t_move(...) causes the axis to accelerate, slew at constant velocity, and decelerate to a stop at the absolute *position*, immediately returning control to the program. **t_move(...)** starts an absolute coordinate move and waits for completion.

If the move distance is too short to reach the specified velocity the controller will accelerate for the first half of the distance and decelerate for the second half (triangular profile).
wait_for_done(...) waits for the motion to complete.

EXECUTION

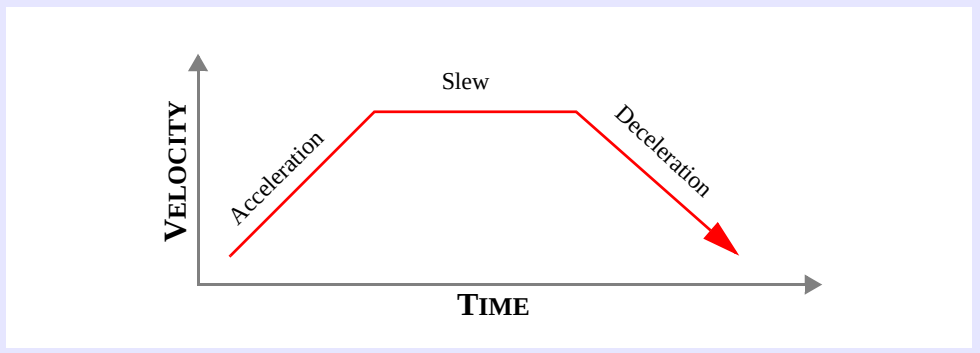
These functions download 5 frames to the controller: acceleration, velocity, deceleration, command position, and dwell. The **start_move(...)**, **move(...)**, **start_t_move(...)** and **t_move(...)** functions may also require one sample before the frames are downloaded to read the command position.

RETURN VALUES

	Returns
start_move(...) **move**(...) **start_r_move**(...) **r_move**(...) **start_t_move**(...) **t_move**(...) **wait_for_done**(...)	Error return codes (see *Error Handling* on page 3-13)

SEE ALSO **motion_done(...)**, **axis_done(...)**

Figure 3-1 Trapezoidal Profile Motion



SAMPLE CODE This program continuously moves axis 0 between two points.

```
# include "pcdsp.h"

# define P1                 1000000.0
# define P2                 0.0

int main()
{
     int16 e, f = 0;

     e = dsp_init(PCDSP_BASE),

     while (!e)
     {       if(f)
                   e = move(0, P1, 8000, 32000);  /* trapezoidal profile motion */
             else
                   e = move(0, P2, 8000, 32000);
             f = !f;
     }
     return e;
}
```

NOTES The relative move functions **start_r_move(...)** and **r_move(...)** take about one sample period (default = 0.8 milliseconds) less time to execute than **start_move(...)** and **move(...)**. Since, the relative move functions calculate the motion profile in terms of velocity, acceleration, and time, they don't need to get the current command position. The single axis trapezoidal profile motion functions guarantee that the final command position is equal to the position parameter specified.

If the move is a trapezoidal profile, then the acceleration time = Velocity/Acceleration.
If the move is a triangular profile, then the acceleration time = SQUARE ROOT (Distance/Acceleration).

Single-Axis S-Curve Profile Motion

start_s_move	begin a S-curve profile motion sequence
s_move	begin a S-curve profile motion sequence and wait for it to complete
start_rs_move	begin a relative S-curve profile motion sequence
rs_move	begin a relative S-curve profile motion sequence and wait for it to complete
start_sprof_move	begin a S-curve profile motion sequence
sprof_move	begin a S-curve profile motion sequence and wait for it to complete

SYNTAX

int16 **start_s_move**(int16 *axis*, double *position*, double *velocity*, double *acceleration*, double *jerk*)

int16 **s_move**(int16 *axis*, double *position*, double *velocity*, double *acceleration*, double *jerk*)

int16 **start_rs_move**(int16 *axis*, double *dist*, double *velocity*, double *acceleration*, double *jerk*)

int16 **rs_move**(int16 *axis*, double *dist*, double *velocity*, double *acceleration*, double *jerk*)

int16 **start_sprof_move**(int16 *axis*, double *position*, double *velocity*, double *acceleration*, double *jerk*)

int16 **sprof_move**(int16 *axis*, double *position*, double *velocity*, double *acceleration*, double *jerk*)

PROTOTYPE IN

pcdsp.h

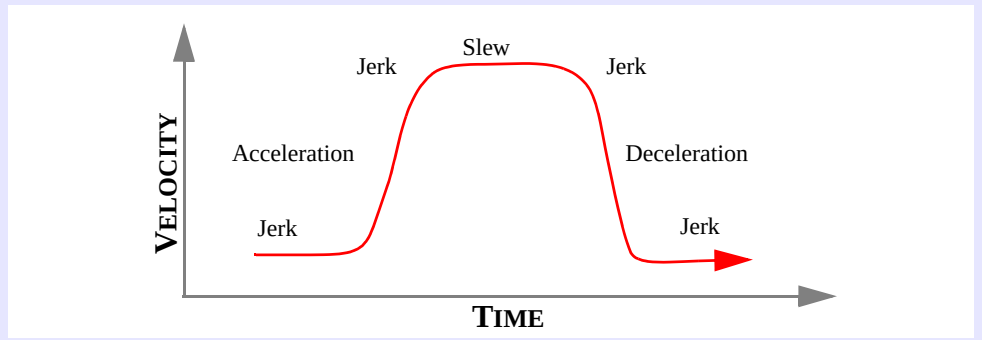
DESCRIPTION

start_s_move(...) causes the axis to accelerate with S-curve acceleration, slew at constant velocity, and decelerate to a stop at the specified absolute position, immediately returning control to the program. The acceleration profile is equal to the deceleration profile. **s_move(...)** starts an absolute S-curve profile motion and waits for completion.

start_rs_move(...) causes the axis to accelerate with S-curve acceleration, slew at constant velocity, and decelerate to a stop at the specified relative distance, immediately returning control to the program. The acceleration profile is equal to the deceleration profile. **rs_move(...)** starts a relative S-curve profile motion and waits for completion.

S-curve acceleration profiles are useful for both stepper and servo motors. The smooth transitions between the start of the acceleration ramp and the transition to the constant velocity produce less wear and tear than a trapezoidal profile motion. The smoother performance increases the life of the motors and mechanics of a system.

Figure 3-2 S-Curve Profile Motion



The S-curve profile motion functions were designed to always produce smooth motion. Certain combinations of parameters however, may not reach the command velocity, may cause longer than expected move times or may cause a slight bump at the end of the motion.

If the acceleration and jerk parameters combined with the final position don't allow an axis to reach the maximum velocity, then the acceleration is decreased. This means that with moves that don't reach maximum velocity, actually decreasing the maximum velocity may allow the axis to run faster.

If the following **guidelines** are followed, then the motion will be accurate, smooth, and the motion time will be as expected:

X = move distance, Vel = velocity, Acc = acceleration, J = jerk

1) Vel/Acc > Acc/J
   if (Vel/Acc < Acc/J) then (Vel/Acc = Acc/J)

2) X/Vel > Vel/Acc + Acc/J
   if (X/Vel < (Vel/Acc + Acc/J)) then (X/Vel = Acc/J + Vel/Acc)

Each individual time component can be calculated by:

Acc/J	=	time for each jerk portion
Vel/Acc - Acc/J	=	time for each acceleration portion
X/Vel - Vel/Acc - Acc/J	=	time for the constant velocity

The total time to complete the move can be calculated by:

Time = Acc/J + Vel/Acc + X/Vel

start_sprof_move(…) and **sprof_move(…)** use a different algorithm to generate the S-curve motion profiles than **start_s_move(…)** and **s_move(…)**. The “sprof” algorithm explicitly calculates the jerk, acceleration, and velocity times. Based on the move parameters, the algorithm reduces the velocity time first and then reduces the acceleration time. The algorithm guarantees a continuous profile ending at the final position specified.

The guidelines listed above are not required for **start_sprof_move(…)** or **sprof_move(…)**.

EXECUTION

These functions require 1 sample to read the command position and then download 9 frames to the controller: positive jerk, acceleration, negative jerk, velocity, negative jerk, deceleration, positive jerk, command position and dwell.

RETURN VALUES

	Returns
start_s_move(...) **s_move**(...) **start_rs_move**(...) **rs_move**(...) **start_sprof_move**(...) **sprof_move**(...)	Error return codes (see *Error Handling* on page 3-13)

SEE ALSO

motion_done(...), **axis_done(...)**

NOTES

Consider using S-curve motion when moving liquids, high inertial loads, or other such systems that are usually under-powered.

Single-Axis Parabolic Profile Motion

start_p_move	begin a parabolic profile motion
p_move	begin a parabolic profile motion and wait for it to complete

SYNTAX

start_p_move(int16 *axis*, double *final*, double *vel*, double *accel*, double *jerk*)
p_move(int16 *axis*, double *final*, double *vel*, double *accel*, double *jerk*)

PROTOTYPE IN

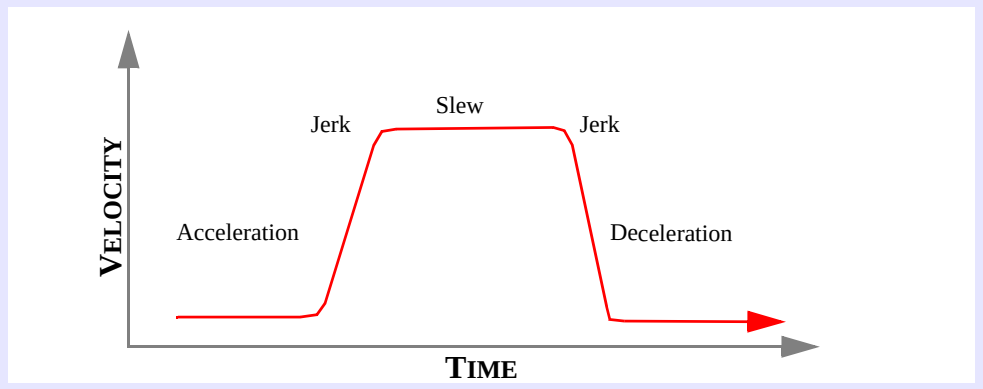
pcdsp.h

DESCRIPTION

start_p_move(...) causes the axis to accelerate with a parabolic profile, slew at constant velocity, and decelerate to a stop at the specified absolute position, immediately returning control to the program. The acceleration profile is equal to the deceleration profile. **p_move(...)** starts the motion and waits for completion.

The parabolic profile motion is very useful for stepper motor control. Since a stepper motor's torque curve is inversely related to its speed, it is more susceptible to stalling at high speeds. Thus, using a parabolic profile can increase the top speed of a stepper motor.

Figure 3-3 Parabolic Profile Motion



EXECUTION

These functions require one sample to read the command position and then download 7 frames to the controller: acceleration, negative jerk, velocity, positive jerk, deceleration, command position, and dwell.

RETURN VALUES

	Returns
start_p_move(...) **p_move**(...)	Error return codes (see *Error Handling* on page 3-13)

SEE ALSO

motion_done(...), **axis_done(...)**

Multi-Axis Point-to-Point Motion

start_move_all	begin a trapezoidal profile motion sequences on multiple axes
move_all	begin the motion sequences and wait for completion
wait_for_all	wait for all of the motion sequences to complete

SYNTAX

int16 **start_move_all**(int16 *len*, int16 * *axes*, double * *position*, double * *velocity*, double * *accel*)

int16 **move_all**(int16 *len*, int16 * *axes*, double * *position*, double * *velocity*, double * *accel*)

int16 **wait_for_all**(int16 *len*, int16 * *axes*)

PROTOTYPE IN

pcdsp.h

DESCRIPTION

start_move_all(...) causes the specified axes to accelerate, slew at constant velocity, and decelerate to a stop at the specified absolute position. The move axes are specified by axes and the number of axes is defined by len. The function **move_all(...)** starts the motion and waits for completion. Both functions guarantee that motion begins on all axes at the same sample time.

If the move distance is too short to reach the specified velocity the controller will accelerate for the first half of the distance and decelerate for the second half (triangular profile).
wait_for_all(...) waits for the motion to complete for all of the specified axes.

EXECUTION

These functions download 5 frames to each axis: acceleration, velocity, deceleration, command position, and dwell.

RETURN VALUES

	Returns
start_move_all(...) **move_all**(...) **wait_for_all**(...)	Error return codes (see *Error Handling* on page 3-13)

SEE ALSO

motion_done(...), **axis_done(...)**

SAMPLE CODE

This code moves axis 0 and axis 1 to positions 1000 and 2000 respectively. If we choose velocities and accelerations that are proportional to the ratio of the distances, then the axes will arrive at their endpoints at the same time (simultaneous motion).

```
# include <stdio.h>
# include "pcdsp.h"

int main()
{
     int16 axes [2] = {0, 1};
     double
            positions[2] = {1000.0, 2000.0},
            velocities[2] = {4000.0, 8000.0},
            accels[2] = {50000.0, 100000.0};

     if (dsp_init(PCDSP_BASE))   /* any problems initializing? */
            return dsp_error;    /* just terminate the program. */

     move_all(2, axes, positions, velocities, accels);

     return dsp_error ;        /* global variable provided by the library */
}
```

Velocity Move

v_move — accelerate to a constant velocity

SYNTAX — int16 **v_move**(int16 *axis*, double *velocity*, double *acceleration*)

PROTOTYPE IN — pcdsp.h

DESCRIPTION — **v_move(...)** *accelerates* an *axis* to the specified constant *velocity*. The axis will continue to travel at a constant velocity until the velocity is changed or the axis is commanded to stop. The direction is determined by the sign of the velocity parameter.

RETURN VALUES

	Returns
v_move(...)	Error return codes (see *Error Handling* on page 3-13)

SEE ALSO — **set_velocity(...)**

EXECUTION — This function downloads 3 frames to the controller: acceleration, velocity, and dwell.

SAMPLE CODE — This code moves axis 0 in *velocity mode* until a key is pressed.

```
# include "pcdsp.h"

int main()
{
     double position;

     if (dsp_init(PCDSP_BASE))   /* any problems initializing? */
            return dsp_error;    /* just terminate the program. */

     v_move(0, 1000, 8000);     /* accelerate axis 0 to 1000 counts/sec */

     while (!kbhit())           /* wait for a key press */
     {      get_position(0, &position)
            printf("Position: %8.0lf", position);
     }
     getch();                   /* get the key */
     v_move(0, 0, 1000);        /* decelerate axis 0 to a stop */

     return dsp_error ;        /* global variable provided by the library */
}
```

NOTES — The most common use for velocity control is homing sequences (see the sample programs on the *Applications* diskette). If you use this function in a loop make sure to wait for **frames_left(...)** to return FALSE before executing **v_move(...)** so that you do not fill the buffer.

Coordinated Axis Map

map_axes — configure the axis map for coordinated motion

SYNTAX

int16 **map_axes**(int16 *n_axes*, int16 * *map_array*)

PROTOTYPE IN

pcdsp.h

DESCRIPTION

map_axes(...) initializes a group of axes for coordinated motion. **map_axes(...)** must be called before any coordinated motion function is used. The axes are specified by the *map_array* and the number of axes is defined by *n_axes*. For example if the x, y, and z coordinates correspond to axes 2, 4, and 5, the following code could be used to define the coordinate system:

```
int16 ax[3] = {2, 4, 5};
map_axes(3, ax);
```

n_axes also configures the User I/O ports available to **set_move_bit(...)**, **reset_move_bit(...)**, and **change_move_bit(...)**. For example, in the code above *n_axes* = 3, which sets user I/O ports 0,1, and 2 to be available during coordinated motion. Also, *after* **map_axes(...)** is called, be sure to initialize the ports as outputs or inputs.

EXECUTION

This function configures the coordinated axes in software. It does not access the controller.

RETURN VALUES

	Returns
map_axes(...)	Error return codes (see *Error Handling* on page 3-13)

SEE ALSO

init_io(...), **set_move_bit(...)**, **reset_move_bit(...)**, **change_move_bit(...)**

SAMPLE CODE

This code performs some circular coordinated moves. Axes 0 and 1 are used to produce an arc and then the axis map is changed. This is followed by an arc on axes 1 and 2.

```
# include <stdio.h>
# include "pcdsp.h"

int main()
{
     int16 axes[] = {0, 1, 2};

     if (dsp_init(PCDSP_BASE))   /* any problems initializing? */
            return dsp_error;    /* just terminate the program. */

     map_axes(3, axes);          /* map axes to be coordinated */
     set_move_speed(800.0);    /* initialize the vector speed */
     set_move_accel(2000.0);  /* initialize the vector acceleration */

     start_point_list();
     move_3(0.0, 0.0, 0.0);    /* move axes to 0.0 */
     arc_2(100, 100, 180);      /* move axes 0 and 1 in an arc */
     axes[0] = 2;
     axes[2] = 0;
     map_axes(3, axes);          /* re-map the axes */
     set_move_speed(800.0);    /*initialize the vector speed */
     set_move_accel(2000.0);  /*initialize the vector acceleration */
     arc_2(100, 100, 180);      /* move axes 2 and 1 in an arc */
     end_point_list();
     start_motion();           /* begin motion */

     return dsp_error;        /* global variable provided by the library */
}
```

NOTES

We recommend calling **map_axes(...)** at the beginning of your program, after **dsp_init(...)**. Be sure to always call **set_move_speed(…)** and **set_move_accel(…)** after **map_axes(…)**.

Start/End Coordinated Point List

start_point_list	initialize a list of points
end_point_list	terminate a point list
get_last_point	read the last point that was added to the list

SYNTAX

int16 **start_point_list**(void)
int16 **end_point_list**(void)
void **get_last_point**(double * *x*)

PROTOTYPE IN

pcdsp.h

DESCRIPTION

start_point_list(...) begins a list of points describing a continuous coordinated motion path. **end_point_list(...)** terminates the point list. The motion will stop at the last point entered in the path. **start_point_list(…)** automatically checks if a previous point list has been completed. If the previous point list has not been completed, then **end_point_list(…)** will be called automatically.

After **start_point_list(...)**, each subsequent call to a coordinated motion function creates and downloads point(s) to the frame buffer. The path between each point is interpolated by blending accelerations. This produces a sequence of blended moves which approximates a path described by the straight lines joining the points.

The DSP controller begins executing the list of points when **start_motion(...)** is called. **start_motion(...)** can be called at any time after the first two points have been downloaded to the controller. If the coordinated path is larger than the DSP's buffer then the host processor must keep adding points before the DSP needs them. If the DSP runs out of points then an E-Stop Event will be triggered on all of the mapped axes and an axis source of ID_OUT_OF_FRAMES will be returned.

Make sure when creating the point list to call **start_motion(...)** before completely filling the buffer. Once the buffer is full, no points will be downloaded until space becomes available.

get_last_point(...) reads the last point generated in the point list. It is very useful for finding the endpoint absolute coordinates of an arc.

RETURN VALUES

	Returns
start_point_list(...) **end_point_list**(...) **get_last_point**(...)	Error return codes (see *Error Handling* on page 3-13)

SEE ALSO

map_axes(...), **move_n(...)**, **arc_2(...)**, **add_point(...)**, **add_arc(...)**, **start_motion(...)**, **stop_motion(...)**, **fifo_space(...)**, **frames_to_execute(...)**

Coordinated Motion Parameters

set_move_speed	set vector velocity
set_move_accel	set vector acceleration
set_arc_division	set interpolation arc segment length
arc_optimization	enable/disable optimum acceleration calculations for arcs
set_move_ratio	set the mapped axes resolution ratios

SYNTAX

int16 **set_move_speed**(double *speed*)
int16 **set_move_accel**(double *accel*)
int16 **set_arc_division**(double *degrees*)
int16 **arc_optimization**(int16 *opt*)
int16 **set_move_ratio**(double * *ratio*)

PROTOTYPE IN

pcdsp.h

DESCRIPTION

The vector velocity and vector acceleration can be specified for coordinated motion by **set_move_speed(...)** and **set_move_accel(...)**. **set_move_speed(...)** and **set_move_accel(...)** can also be used inside a point list to change the vector acceleration and vector velocity at specific points.

set_arc_division(...) specifies the maximum angle (in degrees) between successive points along the arc. The default is 5 degrees.

a**rc_optimization(...)** enables (*opt* = TRUE) or disables (*opt* = FALSE) the automatic calculation of the optimum acceleration for an arc. The default state for arc optimization is enabled. When **arc_optimization(...)** is enabled, circular interpolation is greatly improved by choosing the best acceleration for the motion. The optimum acceleration is given by the following formulas:

$\mathbf{A_{opt}} = \mathbf{V^2/d}$ or $\mathbf{A_{opt}} = \mathbf{V^2/r\theta}$

where $\mathbf{A_{opt}}$ is the best acceleration, V is the **set_move_speed(...)** velocity, **d** is the segment length, **r** is the radius, and θ is the arc division (in radians).

If the acceleration is higher than $\mathbf{A_{opt}}$, the linear portions may be noticeable.
If the acceleration is lower than $\mathbf{A_{opt}}$, the motion will be slowed during the arc and it will lose its roundness.

Both **arc_2(...)** and **add_arc(...)** automatically change the acceleration to $\mathbf{A_{opt}}$ during the circular interpolated move. After the circular interpolated move is finished, the acceleration is set to the original **set_move_accel(...)** acceleration.

set_move_ratio(double * ratio**)** configures scale factors for coordinated axes, often required when the mechanical resolutions of the axes are different. The size of the *ratio* array and its elements are based on the axes mapped in **map_axes(...)**. For example, to draw a circle in a 2-axis system with the y-axis having twice the resolution as the x-axis, first call **map_axes(...)**, and then call **set_move_ratio(**ratio**)**, where ratio[0] = 1.0 and ratio[1] = 2.0.

RETURN VALUES

	Returns
set_move_speed(...) **set_move_accel**(...) **set_arc_division**(...) **arc_optimization**(...) **set_move_ratio**(...)	Error return codes (see *Error Handling* on page 3-13)

SEE ALSO **arc_2(...)**, **add_arc(...)**

SAMPLE CODE This code performs some linear coordinated moves. The vector velocity is increased at the second point.

```
# include "pcdsp.h"

int main()
{
     int16 axes[] = {0, 1, 2};

     if (dsp_init(PCDSP_BASE))    /* any problems initializing? */
             return dsp_error;     /* just terminate the program. */

     map_axes(3, axes);            /* map axes to be coordinated */
     set_move_speed(800.0);       /* initialize the vector speed */
     set_move_accel(4000.0);     /* initialize the vector acceleration */

     start_point_list();
     move_3(100.0, 0.0, 100.0);  /* move axes to x, y, z*/
     set_move_speed(1200);       /* new speed at next point */
     move_3(800.0, 100.0, 400.0);
     move_3(0.0, 0.0, 0.0);
     end_point_list();
     start_motion();         /* begin motion */

     return dsp_error;       /* global variable provided by the library */
}
```

NOTES We strongly recommend that you DO NOT DISABLE **arc_optimization(...)**.

Start/Stop Coordinated Motion

start_motion	start the execution of a coordinated motion profile
stop_motion	stop the execution of a coordinated motion profile
set_points	set the number of points before motion is automatically started
all_done	reads if the coordinated motion is complete

SYNTAX

int16 **start_motion**(void)
int16 **stop_motion**(void)
int16 **set_points**(int16 *points*)
int16 **all_done**(void)

PROTOTYPE IN

pcdsp.h

DESCRIPTION

start_motion(...) starts motion along a pre-defined path. There must be at least 2 points in the points list before **start_motion(...)**. Once **start_motion(...)** has been called the host processor must keep adding points to the list or call **end_point_list(...)**. If a point is reached and no new point is defined, an E-Stop event will be triggered on all of the mapped axes.
stop_motion(...) causes a Stop event to occur on all of the mapped axes, causing the motion to decelerate to a stop. The deceleration rate is determined by the **set_stop_rate(...)** function.
set_points(...) specifies the number of points to be downloaded before motion starts. The function library automatically calls **start_motion(...)** when the number of downloaded points exceeds the *points* parameter.
all_done(...) returns TRUE when all of the mapped axes have completed the coordinated motion sequence.

RETURN VALUES

	Returns
start_motion(...) **stop_motion**(...) **set_points**(...)	Error return codes (see *Error Handling* on page 3-13)
all_done(...)	Value

SAMPLE CODE

This code performs some linear coordinated moves.

```
# include "pcdsp.h"

int main()
{
     int16 axes[] = {0, 1, 2, 3};

     if (dsp_init(PCDSP_BASE))   /* any problems initializing? */
             return dsp_error;    /* just terminate the program. */

     map_axes(3, axes);            /* map axes to be coordinated */
     set_move_speed(800.0);       /* initialize the vector speed */
     set_move_accel(2000.0);     /* initialize the vector acceleration */

     start_point_list();
     move_3(100.0, 100.0, 0.0);    /* move axes to x, y, z */
     move_3(200.0, 200.0, 200.0);
     end_point_list();

     getch();                /* wait for a key */
     start_motion();         /* begin motion */

     return dsp_error;       /* global variable provided by the library */
}
```

Linear Coordinated Motion

move_2	add a 2-axis point to the path
move_3	add a 3-axis point to the path
move_4	add a 4-axis point to the path
move_n	add an *arbitrary-number-of-axes* point to the path
add_point	add a point to the list

SYNTAX

int16 **move_2**(double *x*, double *y*)
int16 **move_3**(double *x*, double *y*, double *z*)
int16 **move_4**(double *x*, double *y*, double *z*, double *w*)
int16 **move_n**(double * *x*)
int16 **add_point**(double * *x*)

PROTOTYPE IN

pcdsp.h

DESCRIPTION

These functions add a point to the list of points defining the path. **add_point(...)** is provided for compatibility with earlier software releases. It is identical to **move_n(...)**.

Typically, each linear interpolated point requires 2 frames per axis.

These functions can also be called outside of a point list which results in immediate execution. When used outside of a point list successive linear coordinated moves are not blended together.

These functions check if there is enough room in the frame buffer before downloading frames. If there is not enough room then the function will return the error code DSP_NO_ROOM.

RETURN VALUES

	Returns
move_2(...) **move_3**(...) **move_4**(...) **move_n**(...) **add_point**(...)	Error return codes (see *Error Handling* on page 3-13)

SAMPLE CODE

This code performs some individual linear coordinated moves.

```
# include "pcdsp.h"

int main()
{
     int16 axes[] = {0, 1, 2};

     if (dsp_init(PCDSP_BASE))  /* any problems initializing? */
             return dsp_error;   /* just terminate the program. */

     map_axes(3, axes);            /* map axes to be coordinated */
     set_move_speed(800.0);
     set_move_accel(2000.0);

     move_3(100.0, 0.0, 0.0);   /* move axes to x, y, z  */
     move_2(1000.0, 1000.0);    /* move to position x, y */

     return dsp_error;         /* global variable provided by the library */
}
```

NOTES

move_2(...), **move_3(...)**, etc., are added for convenience and should be used with corresponding systems. For example if you have a 4-axis system but only want to move 2 axes then use **move_2(...)**. **map_axes(...)** can be used to switch the system of axes.

Circular Coordinated Motion

arc_2	add a 2-axis circular arc to the point list
add_arc	add a 2-axis circular arc to the point list

SYNTAX

int16 **arc_2**(double *x_center*, double *y_center*, double *angle*)
int16 **add_arc**(double * *center*, double *angle*, double *division*)

PROTOTYPE IN

pcdsp.h

DESCRIPTION

arc_2(...) creates a sequence of points following a circular arc and adds them to the point list. The arc starts at the last point in the point buffer and continues through the specified angle. A positive value for *angle* produces clockwise arcs and a negative value produces counter-clockwise arcs. The center of the arc is specified by the parameters *x_center* and *y_center*. division specifies the maximum angle (in degrees) between successive points along the arc.
add_arc(...) is identical to **arc_2(...)** except that the parameter center is a pointer to an array of doubles.

Typically, each circular interpolated point (one point per *division*) requires 2 frames per axis.

These functions can also be called outside of a point list which results in immediate execution. When used outside of a point list successive circular coordinated moves are not blended together.

These functions check if there is enough room in the frame buffer before downloading frames. If there is not enough room then the function will return the error code DSP_NO_ROOM.

Circular interpolation is greatly improved by choosing the best acceleration for the motion. The optimum acceleration is given by the following formulas:

$\mathbf{A_{opt}} = \mathbf{V^2/d}$ or $\mathbf{A_{opt}} = \mathbf{V^2/r\theta}$

where $\mathbf{A_{opt}}$ is the best acceleration, **V** is the **set_move_speed(...)** velocity, **d** is the segment length, **r** is the radius, and θ is the arc division (in radians).

If the acceleration is higher than $\mathbf{A_{opt}}$, the linear portions may be noticeable.
If the acceleration is lower than $\mathbf{A_{opt}}$, the motion will be slowed during the arc and it will lose its roundness.

Both **arc_2(...)** and **add_arc(...)** automatically change the acceleration to $\mathbf{A_{opt}}$ during the circular interpolated move. After the circular interpolated move is finished, the acceleration is set to the original **set_move_accel(...)** acceleration. The automatic optimum acceleration calculation can be disabled with **arc_optimization(...)**.

SEE ALSO

arc_optimization(...), **set_arc_division(...)**, **fifo_space(...)**, **frames_left(...)**

RETURN VALUES

	Returns
arc_2(...) **add_arc**(...)	Error return codes (see *Error Handling* on page 3-13)

NOTES

When **arc_optimization(...)** is enabled, about 1/2 as many frames are used when **arc_optimization(...)** is disabled.

User I/O During Coordinated Motion

set_move_bit	turn on output bit at next point
reset_move_bit	turn off output bit at next point
change_move_bit	change state of output bit at next point
set_move_output	set output state (16-bit) at next point

SYNTAX

int16 **set_move_bit**(int16 *bitNo*)
int16 **reset_move_bit**(int16 *bitNo*)
int16 **change_move_bit**(int16 *bitNo*, int16 *state*)
int16 **set_move_output**(unsigned int16 *value*)

PROTOTYPE IN

pcdsp.h

DESCRIPTION

During coordinated motion, these functions change the state of the output bits at the beginning of the acceleration into the next point. The *number of ports* that can be accessed with the coordinated I/O functions is equal to the *number of axes* configured with **map_axes(...)**.

Use **set_move_bit(...)**, **reset_move_bit(...)**, and **change_move_bit(...)** to set or clear an individual output bit during coordinated motion. Use **set_move_output(...)** to set the first 16 bits of User I/O (ports 0, 1). Before using any of the User I/O functions, call **init_io(...)** to initialize the User I/O.

PINOUTS

See the appropriate *Install Guide*.

SEE ALSO

init_io(...), **set_io(...)**

RETURN VALUES

	Returns
set_move_bit(...) **reset_move_bit**(...) **change_move_bit**(...) **set_move_output**(...)	Error return codes (see *Error Handling* on page 3-13)

SAMPLE CODE

This code performs some linear coordinated moves, toggling user I/O bits at each point.

```
# include <stdio.h>
# include "pcdsp.h"

int main()
{
     int16 axes[] = {0, 1};

     if (dsp_init(PCDSP_BASE))  /* any problems initializing? */
            return dsp_error;   /* just terminate the program. */

     init_io(0, IO_OUTPUT);    /* initialize port 0 as outputs */
     set_io(0, 0);               /* turn off all bits on port 0 */
     map_axes(2, axes);          /* map axes to be coordinated */
     set_move_speed(800.0);
     set_move_accel(2000.0);

     start_point_list();
     set_move_bit(0);           /* turn on bit 0 at next point */
     move_2(1000.0, 1000.0); /* move axes to x,y (bit 0 will turn on) */
     set_move_output(0);        /* turn off bits on port 0 at next point */
     move_2(3000.0, 100.0);  /* move axes to x,y */
     end_point_list();
     start_motion();
```

```
    return dsp_error;        /* global variable provided by the library */
}
```

NOTES

set_move_bit(...), **reset_move_bit(...)**, **change_move_bit(...)**, and **set_move_output(...)** are only valid when used between a **start_point_list(...)** and **end_point_list(...)**. All of the standard I/O functions: **set/get_io(...)**, **set/reset_bit(...)**, **change_bit(...)**, and **bit_on(...)** can be used for immediate access to the user I/O.

Cubic Spline Coordinated Motion

load_spline_motion	download frames for an *n*-axis cubic spline coordinated motion
start_spline_motion	start the execution of a cubic spline coordinated motion

SYNTAX

int16 **load_spline_motion**(int16 *n_axes*, int16 * *axis_map*, int16 *n_points*, long * (* *point_list*), double * *g*, int16 * *end_flag*)

int16 **start_spline_motion**(int16 *n_axes*, int16 * *axis_map*)

PROTOTYPE IN

pcdsp.h

DESCRIPTION

load_spline_motion(...) calculates a coordinated cubic spline motion and downloads a sequence of frames to the DSP's frame buffer. The number of axes is specified by *n_axes* and the particular axes are specified by *axis_map*.

The interpolated cubic spline is calculated based on the *point_list* which contains positions (in units of encoder counts) and times (in units of DSP samples). The number of points is specified by *n_points*. The jerk profiles between each point are based on the distances and times between the points. Each interpolated point requires one frame per axis. The DSP frame buffer can hold a maximum of 600 frames.

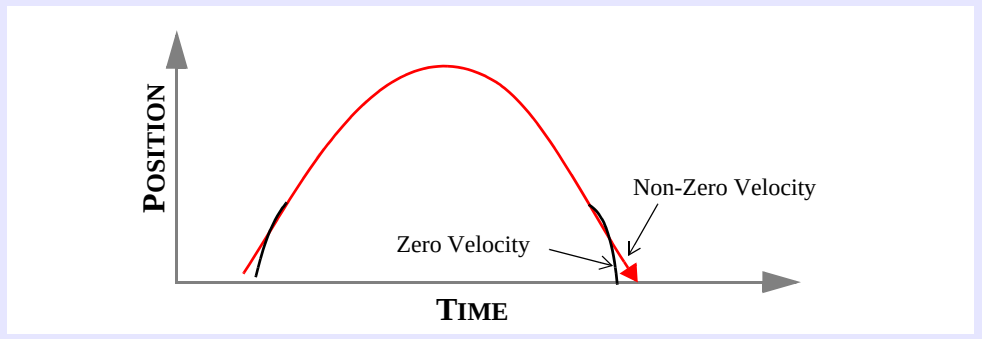
The *g* factor determines the degree of smoothness (curvature) of the interpolated cubic spline. The valid range for *g* is between 0.0 (straight line sections between points) and 1.0 (smoothest curve between points).

The cubic spline algorithm guarantees that the motion path will hit each point in the *point_list* exactly. The accuracy of the path between the points depends on the distance between the points and the *g* factor. Shorter distances and smaller values of *g* produce the most accurate paths.

The *end_flag* specifies the path at the start and end points. The motion at the end points can be configured for a non-zero velocity path (*end_flag* = FALSE) or zero velocity path (*end_flag* = TRUE).

A non-zero velocity path creates a profile that interpolates the motion beyond the end points. This creates the most direct profile to the end points. This works best with points lists that account for acceleration and deceleration (points closer together) at the end points.
A zero velocity path creates the smoothest (usually not direct) profile to the end points.

Figure 3-4 End Point Handling



start_spline_motion(...) executes the motion profile for *n_axes* specified by the *axis_map*.

RETURN VALUES

	Returns
load_spline_motion(...) **start_spline_motion**(...)	Error return codes (see *Error Handling* on page 3-13)

LIMITATIONS

Cubic Spline Coordinated motion functions not supported under Visual Basic.

SAMPLE CODE

This code creates a simple cubic spline coordinated motion path for 2 axes. The command positions are displayed during the motion execution.

```
# include <stdio.h>
# include <stdlib.h>
# include <conio.h>
# include <dos.h>
# include "pcdsp.h"

# define POINTS            10
# define AXES              2

static long time_data[POINTS];   /* time units are in DSP samples */
static long pos_data_0[POINTS];
static long pos_data_1[POINTS];

void display(int16 n_axes, int16 * axis_map)
{
     int16 i;
     double cmd, vel;

     while (!kbhit())
     {       for (i = 0; i < n_axes; i++)
             {       get_command(axis_map[i], &cmd);
                     get_velocity(axis_map[i], &vel);
                     printf("Ax:%1d C:%6.0lf V:%6.0lf  ", axis_map[i], cmd, vel);
             }
             printf("\n");
     }
     getch();
}

int main()
{
     int16 i, sample_rate, end_flag[AXES], axis_map[AXES] = {0, 1};
     double g [AXES];
     long * point[AXES+1];

     if (dsp_init(PCDSP_BASE))    /* any problems initializing? */
             return dsp_error;     /* just terminate the program. */

     for(i = 1; i < POINTS; i++)  /* create a simple point list */
     {       time_data[i] = time_data[i-1] + dsp_sample_rate();
             pos_data_0[i] = pos_data_0[i-1] + 2000;
             pos_data_1[i] = pos_data_1[i-1] + 1500;
     }
     point[0] = time_data;
     point[1] = pos_data_0;
     point[2] = pos_data_1;
     g[0] = 1.0;
     g[1] = 1.0;
     end_flag[0] = TRUE;             /* zero velocity path end points */
     end_flag[1] = TRUE;

     load_spline_motion(AXES, axis_map, POINTS, point, g, end_flag);
     printf("Frames loaded. Fifo space: %d\n\n", fifo_space());
     start_spline_motion(AXES, axis_map);
     display(AXES, axis_map);
```

```
    return dsp_error;         /* global variable provided by the library */
}
```

Frame Buffer Management

fifo_space	returns the number of available frames in the DSP's buffer
frames_to_execute	returns the number of frames left to execute for an axis

SYNTAX

int **fifo_space**(void)

int **frames_to_execute**(int *axis*)

PROTOTYPE IN

pcdsp.h

DESCRIPTION

The DSP has frame counters to keep track of the used and free frames. **fifo_space(void)** returns the number of available frames left in the buffer. **frames_to_execute(...)** returns the number of frames left to execute for an axis. The frame buffer has a fixed size of 600 frames.

At boot time or after a **dsp_reset(...)**, **fifo_space(...)** will return 600. After frames are downloaded, the number of free frames will be reduced. The last frame for each axis will not be released to the free list, it acts as a place holder. Therefore, **fifo_space(...)** may return less than 600 (one less per axis).

SEE ALSO

start_point_list(...), **end_point_list**, **move_2(...)**, **arc_2(...)**

RETURN VALUES

	Returns
fifo_space(...) **frames_to_execute**(...)	Values

SAMPLE CODE

This code demonstrates how to manage the DSP frame buffer for continuous contouring. This sample is programmed as a state machine.

```
# include <stdio.h>
# include <conio.h>
# include <stdlib.h>
# include "pcdsp.h"

int state;                  /* one state variable for axes 0 and 1 */
int seq_flag;               /* flag to enable/disable sequence repeat */

# define READY              0    /* State Values */
# define BEGIN_SEQUENCE     1
# define REPEAT_SEQUENCE    2
# define END_SEQUENCE       3

# define SPACE              300  /* free frames before next sequence */

void initialize(void)
{
     int16 map[2] = {0, 1};
     if (dsp_init(PCDSP_BASE))/* any problems initializing? */
            exit(1);          /* just terminate the program. */
     map_axes(2, map);        /* setup coordinated axes */
     seq_flag = 0;            /* initialize sequence repeat flag */
     set_move_speed(4000.0);
     set_move_accel(80000.0);
}

void sequence(void)
{
     move_2(100.0, 200.0);
     arc_2(200.0, 200.0, -360);
     arc_2(300.0, 300.0, 180);
     move_2(0.0, 0.0);
```

```
}

void CheckState(void)
{
     switch (state)
     {       case BEGIN_SEQUENCE:
                     start_point_list();
                     sequence();
                     start_motion();
                     seq_flag = TRUE;
                     state = READY;
                     break;

             case REPEAT_SEQUENCE:
                     sequence();
                     state = READY;
                     break;

             case END_SEQUENCE:
                     end_point_list();
                     seq_flag = FALSE;
                     state = READY;
                     break;

             case READY:
                     break;
     }
}

int main()
{
     int16 axis, done, key;

     initialize();
     printf("\nb=begin, e=end, esc=quit\n");
     for (done = 0; !done; )
     {       CheckState();
             if ((fifo_space() > SPACE) && seq_flag)
                     state = REPEAT_SEQUENCE;

             if (kbhit())   /* key pressed? */
             {       key = getch();
                     switch (key)
                     {       case 'b':
                             state = BEGIN_SEQUENCE;
                             break;

                             case 'e':
                             state = END_SEQUENCE;
                             break;

                             case 0x1B:             /* <ESC> */
                             done = TRUE;
                             break;
                     }
             }
     }
     return 0;
}
```

Position Control

set_position	set the actual position and command position
get_position	get the current actual position
dsp_encoder	read the 16-bit value directly from the encoder circuitry
set_command	set the current command position register
get_command	get the current command position
set_last_command	sets the last command position value
get_last_command	get the last command position
get_error	get the current position error

SYNTAX

int16 **set_position**(int16 *axis*, double *position*)
int16 **get_position**(int16 *axis*, double * *position*)
int16 **dsp_encoder**(int16 *axis*)
int16 **set_command**(int16 *axis*, double *position*)
int16 **get_command**(int16 *axis*, double * *position*)

int16 **set_last_command**(int16 *axis*, double *position*)
int16 **get_last_command**(int16 *axis*, double * *position*)
int16 **get_error**(int16 *axis*, double * *error*)

PROTOTYPE IN

pcdsp.h

DESCRIPTION

set_position(...) updates the command and actual position registers. **set_position(...)** loads a frame into the DSP's frame buffer which sets the axis' command and actual position in the same sample period. **get_position(...)** reads the axis' actual position. The command position resolution is 32 bits whole and 32 bits fractional. The actual position resolution is 32 bits whole. Both the command and actual positions are updated by the DSP every sample.

dsp_encoder(...) reads the 16-bit actual position directly from the encoder circuitry which is mapped in the external memory of the DSP.

set_command(...) updates an axis' command position register. Be careful, changes in the command position will cause the motor to jump immediately to the new position.
get_command(...) reads an axis' command position.

set_last_command(…) sets the last command position variable. **get_last_command(...)** reads a library internal global variable. The last command position is used in the calculation of absolute position moves. These functions are very helpful when mixing function calls that generate point-to-point and coordinated and user-defined frame motion profiles.

get_error(...) returns the difference between an axis' command and actual positions. The position error resolution is 16 bits whole. The position error does not rollover, it saturates at +/-32,767 counts.

SERCOS

set_position(…) will work properly with drives configured for Velocity or Torque mode. If a SERCOS drive is configured for Position mode, **set_position(…)** will return DSP_FUNCTION_NOT_APPLICABLE unless the drive is executing the drive controlled homing procedure (IDN 148).

WARNING!

If a drive is configured for Position mode, calling **set_position(...)** at inappropriate times will cause the motor to jump.

Under normal operating conditions, setting the position is not advised. Note, however that some functions (like drive homing procedures) will call **set_position(...)**, and in those cases, it's OK.

RETURN VALUES

	Returns
set_position(...) **get_position**(...) **dsp_encoder**(...) **set_command**(...) **get_command**(...) **set_last_command**(...) **get_last_command**(...) **get_error**(...)	Error return codes (see *Error Handling* on page 3-13)

EXECUTION

set_position(...) downloads a frame to update the command and actual positions. **dsp_encoder(...)** performs a 16-bit read directly from the encoder chip. The other functions perform reads/writes to the DSP's external data memory. **get_last_command(...)** reads the last command software global variable.

SAMPLE CODE

This function resets the command and actual position register for axis 0, and displays its position through a move to 100,000 counts. Then it displays the axis' 32 bit actual position (from the DSP) and the 16 bit encoder value (from the encoder circuitry).

```
# include <stdio.h>
# include "pcdsp.h"

int main()
{
     double actual;

     if (dsp_init(PCDSP_BASE))    /* any problems initializing? */
            return dsp_error ;    /* just terminate the program. */

     set_position(0, 0.);        /* reset command and actual positions */
     while (!motion_done(0))  /* wait for position reset completion */
            ;
     start_move(0, 100000.0, 5000., 10000.);  /* move to 100,000. */

     while (!motion_done(0))
     {       get_position(0, &actual);         /* 32bit actual position */
            printf("Current Position: %12.0lf\r",  actual);
     }
     printf("\nEnc: %d\n", dsp_encoder(0));  /* 16bit encoder counter */

     return dsp_error ;        /* global variable provided by the library */
}
```

NOTES

Often we have seen customer code that calls a **set_position(...)** followed by a **get_position(...)**. Since **set_position(...)** creates a frame that is buffered by the DSP, it is possible for the CPU to read the actual position register before the **set_position(...)** is executed.

The value read from **dsp_encoder(...)** may not be equal to the actual position. The encoder circuitry is reset at power-up or when **dsp_reset(...)** is called.

Trajectory Control

set_velocity	set the command velocity
get_velocity	get the command velocity
set_accel	set the command acceleration
get_accel	get the command acceleration
set_jerk	set the command jerk
get_jerk	get the command jerk

SYNTAX

int16 **set_velocity**(int16 *axis*, double *velocity*)
int16 **get_velocity**(int16 *axis*, double * *velocity*)
int16 **set_accel**(int16 *axis*, double *acceleration*)
int16 **get_accel**(int16 *axis*, double * *acceleration*)
int16 **set_jerk**(int16 *axis*, double *jerk*)
int16 **get_jerk**(int16 *axis*, double * *jerk*)

PROTOTYPE IN

pcdsp.h

DESCRIPTION

set_velocity(...) updates an axis' command velocity register. The direction is determined by the sign of the velocity. **get_velocity(...)** reads the axis' current command velocity.

set_accel(...) updates an axis' command acceleration register. The direction is determined by the sign of the acceleration. **get_accel(...)** reads the axis' current command acceleration.

set_jerk(...) updates an axis' command jerk register. The direction is determined by the sign of the jerk. **get_jerk(...)** reads the axis' current command jerk.

The command velocity, acceleration, and jerk all have a resolution of 16 bits whole and 32 bits fractional. Every sample the DSP updates the trajectory:

$T_n = T_{n-1} + FdSpd$ — T_n is the time at sample n
$A_n = A_{n-1} + FdSpd * J$ — J is the jerk
$V_n = V_{n-1} + FdSpd * A_n$ — A_n is the acceleration at sample n
$X_n = X_{n-1} + FdSpd * V_n$ — V_n is the velocity at sample n

X_n is the command position at sample n
FdSpd is the feed speed

RETURN VALUES

	Returns
set_velocity(...) **get_velocity**(...) **set_accel**(...) **get_accel**(...) **set_jerk**(...) **get_jerk**(...)	Error return codes (see *Error Handling* on page 3-13)

SAMPLE CODE

This code instantaneously sets the command velocity on axis 0 to 1000 counts/sec. The axis remains in motion at constant velocity until a key is pressed.

```
# include "pcdsp.h"

int main()
{
     if (dsp_init(PCDSP_BASE))   /* any problems initializing? */
            return dsp_error;    /* just terminate the program. */

     set_velocity(0, 1000);   /* travel indefinitely at 1000 counts/sec */
     getch();                   /* wait for a key press */
     set_velocity(0, 0.0);     /* stop axis 0 */

     return dsp_error ;        /* global variable provided by the library */
}
```

NOTES

set_accel(...) and **set_jerk(...)** are rarely used. A non-zero **set_accel(...)** or **set_jerk(...)** will cause an axis to increase in velocity until the command jerk or acceleration is set to zero. These functions can cause an axis to continuously accelerate if not used properly.

Motion Status

in_sequence	returns TRUE during the loading or execution of frames
in_motion	returns TRUE if command velocity is non-zero
in_position	returns TRUE if within an allowable window
negative_direction	returns TRUE if command velocity is negative
frames_left	returns TRUE if frames are left for an axis
motion_done	returns TRUE if !in_sequence, !in_motion, && !frames_left
axis_done	returns TRUE if motion_done && in_position

SYNTAX

int16 **in_sequence**(int16 *axis*)
int16 **in_motion**(int16 *axis*)
int16 **in_position**(int16 *axis*)
int16 **negative_direction**(int16 *axis*)

int16 **frames_left**(int16 *axis*)
int16 **motion_done**(int16 *axis*)
int16 **axis_done**(int16 *axis*)

PROTOTYPE IN

pcdsp.h

DESCRIPTION

in_sequence(...) returns TRUE during the loading or execution of frames for an axis.

in_motion(...) returns TRUE if an axis' command velocity is non-zero.

in_position(...) returns TRUE if an axis' actual position is within the window specified by **set_in_position(...)**.

negative_direction(...) returns TRUE if an axis' command velocity is negative.

frames_left(...) returns TRUE if an axis has any frames left to be executed. These functions are partially derived from **axis_status(...)**.

motion_done(...) returns TRUE if **in_sequence**, **in_motion**, and **frames_left** are FALSE.

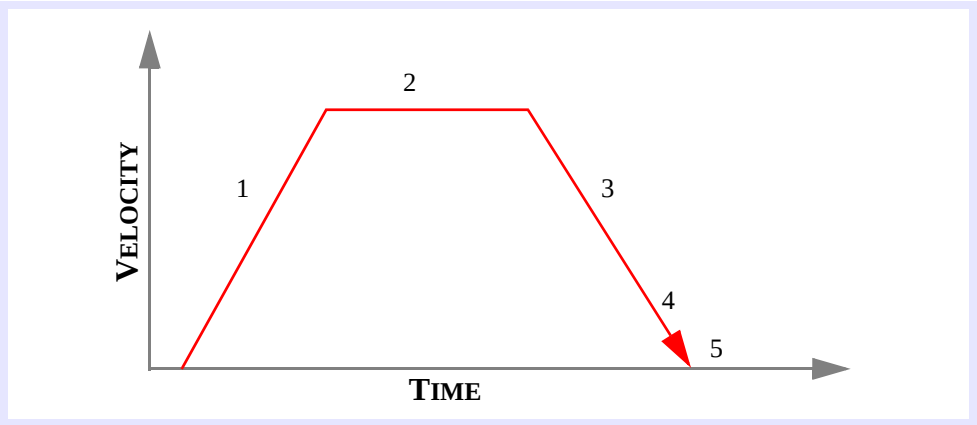
axis_done(...) returns TRUE if **motion_done(...)** is TRUE and **in_position** is TRUE.

The following table and diagram shows the return values of the functions **in_sequence(...)**, **in_motion(...)**, and **frames_left(...)** during a typical trapezoidal profile move.

Table 3-2 Return Values for in_sequence, in_motion, frames_left

Frame	*in_sequence*	*in_motion*	*frames_left*	*Profile*
1	1	1	1	acceleration
2	1	1	1	slew
3	1	1	1	deceleration
4	1	0	1	update
5	0	0	0	dwell

Figure 3-5 Motion Status During Trapezoidal Profile Move



RETURN VALUES

	Returns
in_sequence(...) **in_motion**(...) **in_position**(...) **negative_direction**(...) **frames_left**(...) **motion_done**(...) **axis_done**(...)	Values

Axis Status

axis_status — returns the current running condition of an axis

SYNTAX

int16 **axis_status**(int16 *axis*)

PROTOTYPE IN

pcdsp.h

DESCRIPTION

axis_status(...)returns an integer value whose bits correspond to an axis' current condition.

Table 3-3 axis__status Conditions for an Axis

#define	*Value (hex)*	*Description*
IN_SEQUENCE	0x10	frames left in list for an axis
IN_POSITION	0x20	within allowable position window
IN_MOTION	0x40	command velocity is non-zero
DIRECTION	0x80	sign of command velocity
FRAMES_LEFT	0x100	frames to be executed for an axis

RETURN VALUE

	Returns
axis_status(...)	Value (integer that represents the status)

SEE ALSO

in_sequence(...), **in_motion(...)**, **in_position(...)**, **negative_direction(...)**, **frames_left(...)**

SAMPLE CODE

This code commands a trapezoidal profile move to an absolute location. After the move is complete, the status of the IN_POSITION bit is displayed.

```
# include <stdio.h>
# include <conio.h>
# include "pcdsp.h"

int main()
{
     if (dsp_init(PCDSP_BASE))  /* any problems initializing? */
            return dsp_error;   /* just terminate the program. */

     start_move(0, 1000, 2000, 8000);
     while (!motion_done(0)) /* wait for the command profile completion */
            ;

     while (!kbhit())
            printf("In Position %d\r", axis_status(0) & IN_POSITION);
     getch();

     return dsp_error ;       /* global variable provided by the library */
}
```

NOTES

The motion status functions **in_sequence(...)**, **in_motion(...)**, **in_position(...)**, n**egative_direction(...)**, and **frames_left(...)** are partially derived from **axis_status(...)**. The functions may return different values than the status word. We strongly recommend using the individual functions.

Axis State

axis_state — returns the current running event on an axis

SYNTAX

int16 **axis_state**(int16 *axis*)

PROTOTYPE IN

pcdsp.h

DESCRIPTION

axis_state(...) returns an integer value that corresponds to an *axis'* current event. If the value is less than or equal to 2 then the state is normal. If the value is greater than 2 then an exception event has occurred.

Table 3-4 axis_state Conditions for an Axis

#define	***Value***	***Description***
NO_EVENT	0	Ignore a condition
NEW_FRAME	2	Begin execution of the next sequenced frame
STOP_EVENT	8	Decelerate to a stop (at specified stop rate)
E_STOP_EVENT	10	Decelerate to a stop (at specified E-stop rate)
ABORT_EVENT	14	Disable PID control and the amplifier for this axis

RETURN VALUE

	Returns
axis_state(...)	Value (integer that represents the *axis'* current event)

SAMPLE CODE

This sample code moves axis 0 (velocity control), executes an STOP_EVENT, and waits for the motion to complete. Then the code reads the state of the axis 0.

```
# include <stdio.h>
# include <dos.h>
# include "pcdsp.h"

int main()
{
     if (dsp_init(PCDSP_BASE))    /* any problems initializing? */
            return dsp_error;     /* just terminate the program. */

     v_move(0, 1000, 8000);     /* accelerate to constant velocity */
     delay(1000);
     set_stop(0);                /* trigger a STOP_EVENT */
     while(! motion_done(0))   /* wait for event completion */
            ;
     if (axis_state(0) == STOP_EVENT)/* STOP_EVENT? */
     {       printf("\nA STOP_EVENT occurred on axis 0");
            clear_status(0);   /* clear the STOP_EVENT */
     }

     return dsp_error ;         /* global variable provided by the library */
}
```

NOTES

We recommend using **axis_state(...)** to check if an axis is working properly. If **axis_state(...)** returns an value greater than 2 then call **axis_source(...)** to find the cause of the event.

Axis Source

axis_source — returns the cause of an exception event

SYNTAX

int16 **axis_source**(int16 *axis*)

PROTOTYPE IN

pcdsp.h

DESCRIPTION

axis_source(...) returns an integer value that corresponds to the cause of an exception event on an axis. The integer return value describes the source of the event:

Table 3-5 Possible Sources of Exception Events (Returned by axis_source)

#define	*Value*	*Description*
ID_NONE	0	No event has occurred
ID_HOME_SWITCH	1	Home logic was activated
ID_POS_LIMIT	2	Positive limit input was activated
ID_NEG_LIMIT	3	Negative limit input was activated
ID_AMP_FAULT	4	Amplifier fault input was activated
ID_X_NEG_LIMIT	7	Software negative travel limit exceeded
ID_X_POS_LIMIT	8	Software positive travel limit exceeded
ID_ERROR_LIMIT	9	Software position error exceeded
ID_PC_COMMAND	10	CPU generated a stop, e-stop, abort, clear status
ID_OUT_OF_FRAMES	11	Attempted next frame with no frame present
ID_FEEDBACK_FAULT	12	Feedback fault detected
ID_FEEDBACK_ILLEGAL_STATE	13	Improper feedback logic state detected
ID_AXIS_COMMAND	14	Event triggered by another axis

RETURN VALUE

	Returns
axis_source(...)	Value (integer that corresponds to the cause of an exception event)

SAMPLE CODE

This code moves axis 0 using a call to **v_move(...)**, executes an E_STOP_EVENT, and waits for the motion to complete. Then it reads the source of the event (generated from the host processor) on axis 0.

```
# include <stdio.h>
# include <dos.h>
# include "pcdsp.h"

int main()
{
     if (dsp_init(PCDSP_BASE)) /* any problems initializing? */
            return dsp_error;  /* just terminate the program. */

     v_move(0, 1000, 8000);     /* accelerate to constant velocity */
     delay(1000);
     set_e_stop(0);              /* trigger an E_STOP_EVENT */
     while(! motion_done(0))  /* wait for event completion */
            ;
     /* did the host trigger an event? */
     if (axis_source(0) == ID_PC_COMMAND)
     {      printf("\nThe host triggered the Event");
            clear_status(0);  /* clear the E_STOP_EVENT */
     }

     return dsp_error ;        /* global variable provided by the library */
```

```
}
```

NOTES

Use **axis_state(...)** to read an axis' current event. If **axis_state(...)** returns an value greater than 2, then call **axis_source(...)** to find the cause of the event.

Stop Event

set_stop	generate a Stop Event on an axis
set_stop_rate	set the Stop Event deceleration rate
set_boot_stop_rate	set the boot Stop Event deceleration rate
get_stop_rate	read the Stop Event deceleration rate
get_boot_stop_rate	read the boot Stop Event deceleration rate

SYNTAX

int16 **set_stop**(int16 *axis*)
int16 **set_stop_rate**(int16 *axis*, double *rate*)
int16 **set_boot_stop_rate**(int16 *axis*, double *rate*)
int16 **get_stop_rate**(int16 *axis*, double * *rate*)
int16 **get_boot_stop_rate**(int16 *axis*, double * *rate*)

PROTOTYPE IN

pcdsp.h

DESCRIPTION

set_stop(...) generates a Stop Event on an *axis*. A Stop Event causes the DSP to:

1) prevent the Host from downloading frames
2) set the **axis_state(…)** to STOP_EVENT
3) set the **axis_source(…)** to ID_PC_COMMAND
4) decelerate the axis to a stop
5) clear the frames from the buffer for the axis

set_stop_rate(...) configures the Stop Event deceleration rate. **clear_status(...)** clears the Stop Event from the DSP's memory. **get_stop_rate(...)** reads the configured Stop Event deceleration rate from the DSP.

The boot functions store/read the Stop deceleration rates in boot memory. These are loaded on power-up or **dsp_reset(...)**. Be sure to call **mei_checksum(...)** after the boot memory is modified.

SEE ALSO

clear_status(...), **axis_state(...)**, **axis_source(...)**, *Event Recovery* page 3-54

RETURN VALUES

	Returns
set_stop(...) **set_stop_rate**(...) **set_boot_stop_rate**(...) **get_stop_rate**(...) **get_boot_stop_rate**(...)	Error return codes (see *Error Handling* on page 3-13)

SAMPLE CODE

This code sets the Stop deceleration rate for axis 0. It then moves axis 0 (velocity control), executes a Stop Event, waits for the event to complete, and then clears the event.

```
# include <stdio.h>
# include "pcdsp.h"

int main()
{
     if (dsp_init(PCDSP_BASE)) /* any problems initializing? */
            return dsp_error;  /* just terminate the program. */

     set_stop_rate(0, 10000);  /* deceleration rate = 10000 cts/sec */
     v_move(0, 1000, 8000);     /* accelerate to constant velocity */
     getch();                     /* wait for a key */
```

```
    set_stop(0);                /* trigger a STOP_EVENT */
    while(! motion_done(0))   /* wait for event completion */
        ;
    clear_status(0);          /* clear the STOP_EVENT */

    return dsp_error ;        /* global variable provided by the library */
}
```

NOTES

If the Stop rate is too small, then the axis may travel father than you expect.

Emergency Stop Event

set_e_stop	generate an Emergency Stop Event on an axis
set_e_stop_rate	set the Emergency Stop Event deceleration rate
set_boot_e_stop_rate	set the boot Emergency Stop Event deceleration rate
get_e_stop_rate	read the Emergency Stop Event deceleration rate
get_boot_e_stop_rate	read the boot Emergency Stop Event deceleration rate

SYNTAX

int16 **set_e_stop**(int16 *axis*)
int16 **set_e_stop_rate**(int16 *axis*, double *rate*)
int16 **set_boot_e_stop_rate**(int16 *axis*, double *rate*)
int16 **get_e_stop_rate**(int16 *axis*, double * *rate*)
int16 **get_boot_e_stop_rate**(int16 *axis*, double * *rate*)

PROTOTYPE IN

pcdsp.h

DESCRIPTION

set_e_stop(...) generates an E-Stop event on an *axis*. An E-Stop event causes the DSP to:

1) prevent the Host from downloading frames
2) set the **axis_state(...)** to E_STOP_EVENT
3) set the **axis_source(...)** to ID_PC_COMMAND
4) decelerate the axis to a stop
5) clear the frames from the buffer for the axis

Use **set_e_stop_rate(...)** to configure the E-Stop event deceleration rate.
Use **clear_status(...)** to clear the E-Stop event from the DSP's memory.
Use **get_e_stop_rate(...)** to read the configured E-Stop event deceleration rate from the DSP.
The boot functions store/read the E-Stop deceleration rates in boot memory, which are loaded on power-up or **dsp_reset(...)**. Be sure to call **mei_checksum(...)** after the boot memory is modified.

SEE ALSO

clear_status(...), **axis_state(...)**, **axis_source(...)**, *Event Recovery* page 3-54

RETURN VALUES

	Returns
set_e_stop(...) **set_e_stop_rate**(...) **set_boot_e_stop_rate**(...) **get_e_stop_rate**(...) **get_boot_e_stop_rate**(...)	Error return codes (see *Error Handling* on page 3-13)

SAMPLE CODE

This code sets the E-Stop deceleration rate for axis 0. It then moves axis 0 (velocity control), executes an E-Stop event, waits for the event to complete, and then clears the event.

```
# include <stdio.h>
# include "pcdsp.h"
int main()
{
     if (dsp_init(PCDSP_BASE))   /* any problems initializing? */
            return dsp_error;    /* just terminate the program. */

     set_e_stop_rate(0, 10000); /* deceleration rate = 10000 cts/sec */
     v_move(0, 1000, 8000);      /* accelerate to constant velocity */
     getch();                     /* wait for a key */
     set_e_stop(0);               /* trigger an E_STOP_EVENT */
     while(! motion_done(0))   /* wait for event completion */
            ;
     clear_status(0);          /* clear the E_STOP_EVENT */
```

```
    return dsp_error ;        /* global variable provided by the library */
}
```

NOTES

If the E-Stop rate is too small, the axis may travel farther than you expect. This is critical for limit inputs configured for E-Stop events. If the E-Stop rate is too small and the motor hits the limit switch at a high velocity, the motor *might not stop* before the end of travel. The E-Stop event has a higher priority than the Stop event.

Abort Event

controller_idle	set the controller into idle mode by generating an Abort event
disable_amplifier	set the state of the amp enable output to the disabled state

SYNTAX

int16 **controller_idle**(int16 *axis*)

int16 **disable_amplifier**(int16 *axis*)

PROTOTYPE IN

pcdsp.h

DESCRIPTION

controller_idle(...) generates an Abort event on an axis. An Abort event causes the DSP to:

1) set the **axis_state(...)** to ABORT_EVENT
2) set the **axis_source(...)** to ID_PC_COMMAND
3) disable the axis' PID control
4) set the analog output voltage to the filter DF_OFFSET parameter
5) disable the axis' amp enable output
6) clear the frames from the buffer for the axis
7) prevent the Host from downloading frames

Notice that the DSP automatically disables the amp enable output during an Abort event. The DSP does NOT automatically re-enable the amplifier when an Abort event is cleared.

disable_amplifier(...) sets an axis' amp enable output to the disabled state. The polarity of the amp enable output logic must be configured with **set_amp_enable_level(...)** before **disable_amplifier(...)** is used.

controller_run(...) clears the Abort event from the DSP's memory. The Abort Event has the highest priority in the DSP.

SEE ALSO

controller_run(...), **enable_amplifier(...)**, **set_amp_enable(...)**, **set_amp_enable_level(...)**, **set_filter(...)**, **set_dac_output(...)**, *Event Recovery* page 3-54

RETURN VALUES

	Returns
controller_idle(...) **disable_amplifier**(...)	Error return codes (see *Error Handling* on page 3-13)

SAMPLE CODE

The following program executes an Abort Event, waits for the event to complete, clears the event, and re-enables the amplifier:

```
# include <stdio.h>
# include "pcdsp.h"

int main()
{
     if (dsp_init(PCDSP_BASE))    /* any problems initializing? */
             return dsp_error;     /* just terminate the program. */

     set_amp_enable_level(0, TRUE);   /* active high amp enable logic */
     controller_idle(0);                 /* trigger an ABORT_EVENT */
     while(! motion_done(0))          /* wait for event completion */
             ;
     controller_run(0);       /* clear the event and re-enable PID control */
     enable_amplifier(0);     /* re-enable the amplifier */

     return dsp_error ;       /* global variable provided by the library */
}
```

NOTES

To control the analog output directly, call **controller_idle(...)** or **set_filter(...)** with the PID values equal to zero, and then adjust the DAC offset with **set_filter(...)** or **set_dac_output(...)**.

Event Recovery

clear_status	clear a Stop Event or an E-Stop Event on an axis
controller_run	clear an Abort Event on an axis
enable_amplifier	set the state of the amp enable output to the enabled state

SYNTAX

int16 **clear_status**(int16 *axis*)
int16 **controller_run**(int16 *axis*)
int16 **enable_amplifier**(int16 *axis*)

PROTOTYPE IN

pcdsp.h

DESCRIPTION

clear_status(...) clears the Stop Event or E-Stop Event on an axis:

1) set the **axis_state(...)** to NO_EVENT
2) set the **axis_source(...)** to ID_PC_COMMAND

The status of an axis cannot be cleared during the execution of an exception event. For example, after a Stop Event is generated you must wait until the axis has completed the event (wait for **motion_done(...)** to return TRUE) before calling **clear_status(...)**. If the event has not completed **clear_status(...)** won't do anything and will return error code 17.

controller_run(...) clears an Abort Event on an axis:

1) set the command position equal to the actual position
2) reset the integrator
3) enable the axis' PID control
4) set the **axis_state(...)** to NO_EVENT
5) set the **axis_source(...)** to ID_PC_COMMAND

The status of an axis cannot be cleared during the DSP's execution of an exception event. For example, after an Abort Event is generated you must wait until the axis has completed the event (wait for **motion_done(...)** to return TRUE) before calling **controller_run(...)**. If the event has not completed **controller_run(...)** won't do anything and will return error code 17.

Notice that the DSP does not automatically re-enable the amp enable output during a **controller_run(...)**. Once the Abort Event has been cleared, the amp enable output can be enabled with **enable_amplifer(...)**. The polarity of the amp enable output logic must be configured with **set_amp_enable_level(...)** before **enable_amplifier(...)** is used.

SERCOS

enable_amplifier(…) enables a SERCOS drive if the communication loop is in phase 4. **disable_amplifier(…)** disables a SERCOS drive.

SEE ALSO

controller_idle(...), **disable_amplifier(...)**, **set_amp_enable(...)**, **set_amp_enable_level(...)**, **set_filter(...)**

RETURN VALUES

	Returns
clear_status(...) **controller_run**(...) **enable_amplifier**(...)	Error return codes (see *Error Handling* on page 3-13)

SAMPLE CODE

This code executes an Abort Event, waits for the event to complete, disables the amp fault input, clears the event, re-enables the amplifier, and re-enables the amp fault inputs. It then moves axis 0 (velocity control), executes a Stop Event, waits for the event to complete, and then clears the event:

```
# include <stdio.h>
# include "pcdsp.h"

int main()
{
     if (dsp_init(PCDSP_BASE))    /* any problems initializing? */
            return dsp_error;     /* just terminate the program. */

     set_amp_enable_level(0, TRUE);   /* active high amp enable logic*/
     set_amp_fault_level(0, FALSE);   /* active low amp fault logic */
     controller_idle(0);                 /* trigger an ABORT_EVENT */

     while(! motion_done(0))          /* wait for event completion */
            ;
     set_amp_fault(0, NO_EVENT);    /* disable amp fault input */
     controller_run(0);        /* clear the event and re-enable PID control */
     enable_amplifier(0);              /* re-enable the amplifier */
     set_amp_fault(0, ABORT_EVENT); /* re-enable the amp fault input */

     set_stop_rate(0, 10000);   /* deceleration rate = 10000 cts/sec */
     v_move(0, 1000, 8000);      /* accelerate to constant velocity */
     getch();                      /* wait for a key */
     set_stop(0);                  /* trigger a STOP_EVENT */
     while(! motion_done(0))    /* wait for event completion */
            ;
     clear_status(0);         /* clear the STOP_EVENT */

     return dsp_error ;       /* global variable provided by the library */
}
```

NOTES

Always make sure that **motion_done(...)** returns TRUE before calling **clear_status(...)** and **controller_run(...)**. Internally, **controller_run(...)** calls **clear_status(...)**.

Also, always call **controller_run(...)** first, then **enable_amplifier(...)**.

Dedicated Inputs

home_switch	returns the state of the home logic
pos_switch	returns the state of the positive limit input
neg_switch	returns the state of the negative limit input
amp_fault_switch	returns the state of the amplifier fault input

SYNTAX

int16 **home_switch**(int16 *axis*)
int16 **pos_switch**(int16 *axis*)
int16 **neg_switch**(int16 *axis*)
int16 **amp_fault_switch**(int16 *axis*)

PROTOTYPE IN

pcdsp.h

DESCRIPTION

home_switch(...) returns the current state of an axis' home logic. The home logic may be some combination of the home and index inputs. The home and index inputs are logically combined or individually ignored based on the configuration set by **set_home_index_config(...)**.

pos_switch(...) returns the current state of the positive limit input. **neg_switch(...)** returns the current state of the negative limit input. **amp_fault_switch(...)** returns the current state of the amp fault input.

These functions return TRUE if the input is high (+5 volts) and FALSE if the input is low (0 volts). They read the state directly from the I/O circuitry and therefore, may not reflect the state of the controller. For example, suppose an axis' positive limit input is configured as active low to generate a STOP_EVENT. When the command velocity is zero, and the limit input is low, **pos_switch(...)** will return FALSE even though the DSP did not generate a STOP_EVENT. The dedicated inputs are level-triggered and are not latched.

RETURN VALUES

	Returns
home_switch(...) **pos_switch**(...) **neg_switch**(...) **amp_fault_switch**(...)	Values [zero (FALSE) or non-zero (TRUE)]

SERCOS

The functions **home_switch(…)**, **pos_switch(…)**, **neg_switch(…)**, and **amp_fault_switch(…)** are applicable to a SERCOS/DSP Series controller if the SERCOS drive's status bits are mapped into the dedicated I/O registers. Also see page 2-53, *SERCOS Initialization*.

If the drive's status bits are NOT mapped into the dedicated I/O registers, then disable the dedicated I/O by setting the action to NO_EVENT.

SEE ALSO

set_home_index_config(...), **set_positive_limit(...)**, **set_positive_level(...)**

SAMPLE CODE

This code continuously reads the state of the home input for axis 0, until a key is pressed.

```
# include <stdio.h>
# include <conio.h>
# include "pcdsp.h"

int main()
{
     if (dsp_init(PCDSP_BASE))    /* any problems initializing? */
            return dsp_error;     /* just terminate the program. */

/* configure the home logic for home input only */
```

```
    set_home_index_config(0, HOME_ONLY);
    while(! kbhit())
            printf("Home: %d\r", home_switch(0));
    getch();

    return dsp_error ;         /* global variable provided by the library */
}
```

NOTES

Sometimes high frequency noise will be picked up by the I/O lines which might inexplicably trigger exception events. These functions are very useful for checking the state of a sensor to see if it was really triggered or if there is noise on the line.

User I/O Port Control

init_io	initialize an I/O port as input or output
init_boot_io	set the boot configuration of an I/O port as input or output
set_io	set an 8-bit byte port value
set_boot_io	set the boot 8-bit byte port value
get_io	get an 8-bit byte port value
get_boot_io	get the boot 8-bit byte port value

SYNTAX

int16 **init_io**(int16 *port*, int16 *direction*)
int16 **init_boot_io**(int16 *port*, int16 *direction*)
int16 **set_io**(int16 *port*, int16 *value*)
int16 **set_boot_io**(int16 *port*, int16 *value*)

int16 **get_io**(int16 *port*, int16 * *value*)
int16 **get_boot_io**(int16 *port*, int16 * *value*)

PROTOTYPE IN

pcdsp.h

DESCRIPTION

init_io(...) configures an 8-bit port as either input or output. Use the identifier IO_INPUT or IO_OUTPUT to specify the direction of a port. Make sure to configure all of the user I/O ports before using them. **get_io(...)** returns the current state of both input and output ports. **set_io(...)** changes the state of an output port to the value specified. **set_io(...)** has no effect on an input port.

I/O bits 26, 30, 34, and 38 cannot be configured as outputs for PC/DSP (100-400)'s. These bits were converted from the Home inputs (5 to 8 axis controller) to user I/O bits and due to the hardware, cannot be used as outputs. This doesn't prevent you from using the other bits as outputs. I/O bits 26, 30, 34, and 38 are not available on the PCX, STD, V3U, V6U, 104X, and CPCI DSP Series (100-400) controllers, as well as the DSPpro-PC and DSPpro-VME controllers.

The I/O ports are configured by default to be inputs at boot. The **init_boot_io(...)** and **set_boot_io(...)** can be used to change the boot state of the I/O ports. This may be useful when the DSP is used with opto-isolation modules which invert the logic of the I/O signals.

The boot functions store/read the I/O configuration for each port in boot memory. These are loaded on power-up or **dsp_reset(...)**. Be sure to call **mei_checksum(...)** after the boot memory is modified.

PINOUTS

For more pinouts, see the appropriate *Installation or User Guide*.
(50 pin headers, Opto-22, Grayhill and Gordos-compatible.
Even-numbered pins are grounds and pin 49 is +5 volts.)

SEE ALSO

To modify an individual I/O bit: **bit_on(...)**, **set_bit(...)**, **reset_bit(...)**, **change_bit(...)**

RETURN VALUES

	Returns
init_io(...) **init_boot_io**(...) **set_io**(...) **set_boot_io**(...) **get_io**(...) **get_boot_io**(...)	Error return codes (see *Error Handling* on page 3-13)

Table 3-6 User I/O Connector (Any board)
PC/PCX, STD, V6U, 104X & CPCI DSP Series

Bit	Port	Header	Pin	Bit	Port	Header	Pin	Bit	Port	Header	Pin
0	0	P1	47	8	1	P1	31	16	2	P1	15
1	0	P1	45	9	1	P1	29	17	2	P1	13
2	0	P1	43	10	1	P1	27	18	2	P1	11
3	0	P1	41	11	1	P1	25	19	2	P1	9
4	0	P1	39	12	1	P1	23	20	2	P1	7
5	0	P1	37	13	1	P1	21	21	2	P1	5
6	0	P1	35	14	1	P1	19	22	2	P1	3
7	0	P1	33	15	1	P1	17	23	2	P1	1

Table 3-7 User I/O Connector (Boards with 4 axes or less)
PC/PCX, STD, V6U, 104X & CPCI DSP Series

Bit	Port	Header	Pin	Bit	Port	Header	Pin	Bit	Port	Header	Pin
24	3	P3	47	32	4	P3	31	40	5	P3	15
25	3	P3	45	33	4	P3	29	41	5	P3	13
26	3	P3	43*	34	4	P3	27*	42	5	P3	11
27	3	P3	41	35	4	P3	25	43	5	P3	9
28	3	P3	39	36	4	P3	23	44	5	P3	7
29	3	P3	37	37	4	P3	21	45	5	P3	5
30	3	P3	35*	38	4	P3	19*	46	5	P3	3
31	3	P3	33	39	4	P3	17	47	5	P3	1

* bits 26, 30, 34, and 38 can be configured as inputs on the PC/DSP and are not available on the PCX, STD, and V6U
**bit 22 can also be used as “DSP Interrupt”
***bit 23 can also be used as “PC Interrupt”

Table 3-8 User I/O Connector:
104 & LC DSP Series (100 pins)

Bit	Port	Module	Pin	Bit	Port	Module	Pin	Bit	Port	Module	Pin
0	0	1	39	8	1	2	89	16	2	1	45
1	0	1	41	9	1	2	91	17	2	1	47
2	0	1	43	10	1	2	93	18	2	1	46
3	0	1	40	11	1	2	90	19	2	1	48
4	0	1	42	12	1	2	92	20	2	2	95
5	0	1	44	13	1	2	94	21	2	2	97
6*	0	-	-	14*	-	-	-	22	2	2	96
7*	0	-	-	15*	-	-	-	23	2	2	98

* bits 6, 7, and 14 are not available on the 104 and LC.
** bit 22 can also be used as “DSP Interrupt”
***bit 23 can also be used as “PC Interrupt”

SAMPLE CODE

This code configures port 0 as inputs and port 1 as outputs. Axis 0 is accelerated to a constant velocity until port 0 bit 0 goes high. Then port 1 bit 2 is turned on, and the axis is decelerated to a stop.

```
# include <stdio.h>
# include "pcdsp.h"

int main()
{
     int val;

     if (dsp_init(PCDSP_BASE))   /* any problems initializing? */
            return dsp_error;    /* just terminate the program. */

     init_io(0, IO_INPUT);    /* configure port 0 as inputs */
     init_io(1, IO_OUTPUT);    /* configure port 1 as outputs */
     set_io(1, 0);               /* turn off all bits on port 1 */

     v_move(0, 1000, 5000);     /* accelerate to constant velocity */
     while (!get_io(0,&val))   /* get_io returns an error if not OK */
     {       if(val & 1)
            break;               /* wait for bit 0. */
     }
     v_move(0, 0, 5000);          /* decelerate to a stop */

     get_io(1, &val);
     set_io(1, 0x4 | val);    /* turn on bit 2 of port 1 */

     return dsp_error ;        /* global variable provided by the library */
}
```


The following conversion table shows values for different base units.

Table 3-9 Conversion of Base Units for User I/O Port

Bit	*Decimal*	*Hex*	*Binary*	*Complement (Hex)*
0	1	0x01	00000001	0xFE
1	2	0x02	00000010	0xFD
2	4	0x04	00000100	0xFB
3	8	0x08	00001000	0xF7
4	16	0x10	00010000	0xEF
5	32	0x20	00100000	0xDF
6	64	0x40	01000000	0xBF
7	128	0x80	10000000	0x7F

User I/O Bit Control

bit_on	returns the current state of an I/O bit
boot_bit_on	returns the boot state of an I/O bit
set_bit	sets the state of an I/O bit to TRUE
reset_bit	sets the state of an I/O bit to FALSE
change_bit	changes the state of an I/O bit
change_boot_bit	changes the boot state of an I/O bit

SYNTAX

int16 **bit_on**(int16 *bitNo*)
int16 **boot_bit_on**(int16 *bitNo*)
int16 **set_bit**(int16 *bitNo*)
int16 **reset_bit**(int16 *bitNo*)

int16 **change_bit**(int16 *bitNo*, int16 *state*)
int16 **change_boot_bit**(int16 *bitNo*, int16 *state*)

PROTOTYPE IN

pcdsp.h

DESCRIPTION

The *User I/O* bits are accessible by the **bit_on(...)**, **set_bit(...)**, **reset_bit(...)**, and **change_bit(...)** functions. The bits are numbered 0 to 47 (6 ports). **bit_on(...)** returns the current state of both input and output bits. **set_bit(...)** sets the state of an output bit to TRUE and **reset_bit(...)** sets the state of an output bit to FALSE. **change_bit(...)** changes the state of a bit to either TRUE or FALSE.

I/O bits 26, 30, 34, and 38 cannot be configured as outputs for PC/DSP (100-400)'s. These bits were converted from the *Home* inputs (5 to 8 axis controller) to *User I/O* bits and due to the hardware, cannot be used as outputs. This doesn't prevent you from using the other bits as outputs. Note that I/O bits 26, 30, 34, and 38 are not available on the PCX, STD, V3U, and V6U DSP Series (100-400) controllers.

The I/O ports are configured (default) to be inputs at boot. The **change_boot_bit(...)** function can be used to change the boot state of an output bit. The **boot_bit_on(...)** function can be used to read the boot state of an I/O bit. This may be useful when the DSP is used with opto-isolation modules which invert the logic of the I/O signals.

The boot functions store/read the I/O configuration for each port in boot memory. These are loaded on power-up or **dsp_reset(...)**. Be sure to call **mei_checksum(...)** after the boot memory is modified.

PINOUTS

For more pinouts, refer to page 3-58 or see the appropriate *Install Guide*.

RETURN VALUES

	Returns
bit_on(...) **boot_bit_on**(...)	Values (the bit state)
set_bit(...) **reset_bit**(...) **change_bit**(...) **change_boot_bit**(...)	Error return codes (see *Error Handling* on page 3-13)

SAMPLE CODE

This code checks the state of *User I/O* bit 0 and if bit 0 is on (high), turns on *User I/O* bit 8. If bit 0 is off (low) then *User I/O* bit 9 is turned on (high) for 1 sec and then turned off.

```
# include <stdio.h>
# include <dos.h>
# include "pcdsp.h"

int main()
{
     int16 val;

     if (dsp_init(PCDSP_BASE))    /* any problems initializing? */
            return dsp_error;     /* just terminate the program. */

     init_io(0, IO_INPUT);       /* configure port 0 as inputs */
     init_io(1, IO_OUTPUT);     /* configure port 1 as outputs */
     set_io(1, 0);                /* turn off all bits on Port 1 */

     if (bit_on(0))                  /* check state of input bit 0 */
            set_bit(8);              /* turn on output bit 8 */
     else
     {      change_bit(9, TRUE);  /* turn on output bit 8 */
            delay(1000);
            reset_bit(9);           /* turn off output bit 9 */
     }

     return dsp_error ;       /* global variable provided by the library */
}
```

NOTES

All the "bit" functions are just a simplified interface to **set_io(...)** and **get_io(...)**. The functions make calls to **set_io(...)**, **set_boot_io(...)**, **get_io(...)**, and **get_boot_io(...)** and do the bitwise manipulation of the 8-bit port value for you.

User I/O Monitoring

set_io_mon_mask	configure the DSP to monitor User I/O
io_changed	returns the state of the DSP's monitoring flag
io_mon	read the status of a monitored I/O port
clear_io_mon	reset the DSP's I/O monitoring flag

SYNTAX

int16 **set_io_mon_mask**(int16 *port*, int16 *mask*, int16 *value*)
int16 **io_changed**(void)
int16 **io_mon**(int16 *port*, int16 * *status*)
int16 **clear_io_mon**(void)

PROTOTYPE IN

pcdsp.h

DESCRIPTION

The DSP can monitor up to 6 user I/O ports. If any of the specified bits change state the DSP continuously stores the changed bits into a status register and sets a flag. If interrupts are enabled and an IRQ is configured then an interrupt will be generated to the PC.

set_io_mon_mask(...) configures the DSP to monitor specific user I/O bits. The valid *port* range is from 0 to 5. The *mask* specifies to the DSP which bits to monitor. The *value* is compared by the DSP to the masked bits. If the masked bits are different from the specified *value* then the **io_changed(...)** flag is set.

io_changed(...) returns the state of the DSP's I/O monitoring flag. If none of the specified bits have changed (all ports), then **io_changed(...)** returns FALSE. If any of the specified bits have changed (all ports) then **io_changed(...)** returns TRUE until **clear_io_mon(...)** is called.

io_mon(...) examines which bits have changed. The bits in *status* reflect which bit or bits have changed since the time the DSP set the **io_changed(...)** flag. *Status* keeps a continuous account of the specified bits that have changed by ORing the previous *status* with the latest I/O changes. The *status* may not be the same as the current state of the user I/O bits. **get_io(...)** should be used to read the current state of the User I/O bits for a specific port.

clear_io_mon(void) resets the monitor status for all ports and clears the **io_changed(...)** flag. This does not clear the mask or the value set by **set_io_mon_mask(...)**. If the masked bits do not match the specified value, then the DSP will set the **io_changed(...)** flag TRUE within two samples.

I/O bits 26, 30, 34, and 38 cannot be configured as outputs for PC/DSP (100-400)'s. These bits were converted from the Home inputs (5 to 8 axis controller) to user I/O bits and due to the hardware, cannot be used as outputs. This doesn't prevent you from using the other bits as outputs. I/O bits 26, 30, 34, and 38 are not available on the PCX, STD, V3U, V6U, 104X, and CPCI DSP Series (100-400) controllers, as well as the DSPpro-PC and DSPpro-VME controllers.

PINOUTS

For more pinouts, refer to page 3-58 or see the appropriate *Install Guide*.

RETURN VALUES

	Returns
set_io_mon_mask(...)	Error return codes (see *Error Handling* on page 3-13)
io_changed(void)	Values (the state of I/O monitoring flag)
io_mon(...) **clear_io_mon**(...)	Error return codes (see *Error Handling* on page 3-13)

SEE ALSO

Interrupt Configuration, page 2-50.

SAMPLE CODE

This code configures the DSP to monitor user I/O bit 0. When the bit goes high, the DSP will set **io_changed(...)** to TRUE. Then the DSP I/O monitoring is disabled and **io_changed(...)** is cleared.

```
# include <stdio.h>
# include <dos.h>
# include "pcdsp.h"

# define PORT              0
# define MASK              0x1

int main()
{
     int16 status;

     if (dsp_init(PCDSP_BASE))   /* any problems initializing? */
            return dsp_error;    /* just terminate the program. */
     init_io(PORT, IO_INPUT);    /* set port 0 to INPUT */

/* configure the DSP to watch bit 0 (active high) */
     set_io_mon_mask(PORT, MASK, 0x0);

     while (!io_changed())         /* wait for bit 0 to go high */
          ;
     io_mon(PORT, &status);     /* read the status of port 0's I/O bits */
     printf("\nStatus: %d", status);
     set_io_mon_mask(PORT, 0x0, 0x0); /* disable the DSP I/O monitoring */
     clear_io_mon();                  /* clear the io_changed flag */

     return dsp_error ;     /* global variable provided by the library */
}
```

Analog Inputs

init_analog	initialize analog inputs
get_analog	get an analog input value
start_analog	write control word to A/D circuitry
read_analog	read analog input (15 usec after control word)

SYNTAX

int16 **init_analog**(int16 *channel*, int16 *differential*, int16 *bipolar*)
int16 **get_analog**(int16 *channel*, int16 * *value*)
int16 **start_analog**(int16 *channel*)
int16 **read_analog**(int16 * *value*)

PROTOTYPE IN

pcdsp.h

DESCRIPTION

The PC, PCX, STD, CPCI, V3U, V6U DSP Series controllers have 8 undedicated 12-bit analog input channels which are numbered 0 to 7. The DSPpro-Serial, DSPpro-PC, and DSPpro-VME also have 8 12-bit analog input channels. The 104, LC, and EXM DSP Series controllers and the SERCOS controllers do NOT have analog-to-digital converters. These functions are not applicable to the 104, LC, and EXM DSP Series.

The analog-to-digital conversion operates by writing a control word to the A/D component, waiting at least 15 microseconds, and then reading the digital value. The analog inputs can be read by the DSP or directly from the Host CPU. To guarantee proper analog-to-digital conversions, the DSP and the PC cannot read the analog inputs at the same time.

If any axis is configured for servo on analog, axis analog, or on board jogging, then the Host CPU must NOT call the functions **start_analog(...)**, **read_analog(...)** or **get_analog(...)**.

start_analog(...) writes a control word to the A/D to begin the analog-to-digital conversion. After the conversion is complete, the digital value can be read with **read_analog(...)**.

get_analog(...) calls **start_analog(...)**, waits for a small period of time and then calls **read_analog(...)**. **get_analog(...)** works well with most host processors, except for high speed CPUs (486, Pentiums etc.). If you see any inconsistencies with the **get_analog(...)** function then call **start_analog(...)**, wait at least 15 microseconds, and then call **read_analog(...)**. The analog signal is converted to a 12 bit digital value.

The default configuration for the analog inputs is 0 to +5 volts (0 to 4095), with single-ended inputs (8 channels). **init_analog(...)** configures an analog input channel for unipolar or bipolar and single-ended or differential operation.

When configured for bipolar operation, the input voltage range is -2.5 volts to +2.5 volts (-2048 to 2048). When configured for differential inputs (up to 4 channels), the analog circuitry reads difference between each pair of channels (0 and 1, 2 and 3, etc.) to filter out noise.

The even numbered channels (0, 2, 4, 6) are the (+) signals and the odd numbered channels (1, 3, 5, 7) are the (-) signals. The differential analog input value should be configured and read from the (+) channel (0, 2, 4, or 6).

The analog inputs are not buffered, so do not exceed +5 volts or -2.5 volts.

PINOUTS

See next page. For more pinouts, see the appropriate *Installation or User Guide*.

RETURN VALUES

	Returns
init_analog(...) **get_analog**(...) **start_analog**(...) **read_analog**(...)	Error return codes (see *Error Handling* on page 3-13)

Table 3-10 Analog Input Connections

Signal	*Header*	*Pin*
GND	P8	1
Analog GND	P8	2
-12 volts	P8	5
+12 volts	P8	7
+5 volts	P8	9
GND	P8	19
Analog GND	P8	20

Signal	*Header*	*Pin*
Analog in 0	P8	4
Analog in 1	P8	6
Analog in 2	P8	8
Analog in 3	P8	10
Analog in 4	P8	12
Analog in 5	P8	14
Analog in 6	P8	16
Analog in 7	P8	18

SAMPLE CODE This code monitors the analog input (channel 0), printing the value to the screen.

```
# include <stdio.h>
# include <conio.h>
# include "pcdsp.h"

int main()
{
     int16 val;

     if (dsp_init(PCDSP_BASE))    /* any problems initializing? */
            return dsp_error;     /* just terminate the program. */

     while (!kbhit())
     {      get_analog(0, &val);  /* read the A/D, channel 0 */
            printf("Analog input channel 0: %d\r", val);
     }
     getch();

     return dsp_error ;        /* global variable provided by the library */
}
```

Axis Analog Inputs

set_axis_analog	configure the DSP to read an analog input for an axis
get_axis_analog	read the axis analog configuration
read_axis_analog	read the axis analog input with the DSP
set_analog_channel	set an analog channel for an axis
set_boot_analog_channel	set a boot analog channel for an axis
get_analog_channel	read the configured analog channel for an axis
get_boot_analog_channel	read the boot configured analog channel for an axis

SYNTAX

int16 **set_axis_analog**(int16 *axis*, int16 *state*)
int16 **get_axis_analog**(int16 *axis*, int16 * *state*)
int16 **read_axis_analog**(int16 *axis*, int16 * *value*)
int16 **set_analog_channel**(int16 *axis*, int16 *channel*, int16 *differential*, int16 *bipolar*)

int16 **set_boot_analog_channel**(int16 *axis*, int16 *channel*, int16 *differential*, int16 *bipolar*)
int16 **get_analog_channel**(int16 *axis*, int16 * *channel*, int16 * *differential*, int16 * *bipolar*)
int16 **get_boot_analog_channel**(int16 *axis*, int16 * *channel*, int16 * *differential*, int16 * *bipolar*)

PROTOTYPE IN

pcdsp.h

DESCRIPTION

The PC, PCX, STD, CPCI, V3U, V6U DSP Series controllers have 8 undedicated 12-bit analog input channels which are numbered 0 to 7. The DSPpro-Serial, DSPpro-PC, and DSPpro-VME also have 8 twelve-bit analog input channels. The 104, LC, and EXM DSP Series controllers and the SERCOS controllers do NOT have analog-to-digital converters. These functions are not applicable to the 104, LC, and EXM DSP Series.

The analog-to-digital conversion operates by writing a control word to the A/D component, waiting at least 15 microseconds, and then reading the digital value. The analog inputs can be read by the DSP or directly from the Host CPU. To guarantee proper analog-to-digital conversions, the DSP and the PC cannot read the analog inputs at the same time. If any axis is configured for servo-on-analog, axis analog, or on-board jogging, then the Host CPU must NOT call the functions **start_analog(...)**, **read_analog(...)** or **get_analog(...)**.

set_axis_analog(...) configures the DSP to read an axis' analog input each sample. The automatic axis analog reading is enabled when *state* = TRUE and disabled when *state* = FALSE. One channel is read per axis. **get_axis_analog(...)** reads an axis' analog configuration.

read_axis_analog(...) reads the axis analog input from the DSP. The analog input channel, and its configuration are set by **set_analog_channel(...)**. The default configuration is *axis* = channel, *differential* = FALSE, and *bipolar* = FALSE. Be sure to configure only one analog input channel per axis.

Using the axis analog configuration it is possible for the PC to read an analog channel with **read_axis_analog(...)** when an axis is configured for servo on analog or **jog_axis(...)**.

If *bipolar* = TRUE, the input voltage range is -2.5 volts to +2.5 volts (-2048 to 2047).
If *differential* = TRUE, the analog circuitry reads difference between each pair of channels (0 and 1, 2 and 3, etc.) to filter out noise. When configured for differential, the analog input value should be configured and read from the (+) channels (0, 2, 4, 6). The odd numbered channels (1, 3, 5, 7) are the (-) signals.

set_analog_channel(...) also configures the analog input channel when an axis is configured for servo on analog or jogging. This is very useful in systems that need to switch between several analog input channels. **get_analog_channel(...)** reads the current A/D configuration.

The analog inputs are not buffered, so the controller will be damaged if input voltages exceed+5 volts or -2.5 volts. Also, do not apply any voltage to the inputs with the controller powered off.

SEE ALSO **init_analog(...)**, **get_analog(...)**, **start_analog(...)**, **read_analog(...)**, **jog_axis(...)**, **set_feedback(...)**

PINOUTS See the appropriate *Install Guide*.

RETURN VALUES

	Returns
set_axis_analog(...) **get_axis_analog**(...) **read_axis_analog**(...) **set_analog_channel**(...) **set_boot_analog_channel**(...) **get_analog_channel**(...) **get_boot_analog_channel**(...)	Error return codes (see *Error Handling* on page 3-13)

SAMPLE CODE This code configures the DSP to read analog input channel 0 and prints the value to the screen.

```
# include <stdio.h>
# include <conio.h>
# include "pcdsp.h"

int main()
{
     int16 val;

     if (dsp_init(PCDSP_BASE))    /* any problems initializing? */
            return dsp_error;     /* just terminate the program. */

/* configure the DSP to read axis 0's analog input every sample */
     set_axis_analog(0, TRUE);

     while (!kbhit())
     {       read_axis_analog(0, &val);   /* read axis 0's analog input */
             printf("Analog input channel 0: %d\r", val);
     }
     return dsp_error ;       /* global variable provided by the library */
}
```

Axis Analog Outputs

set_dac_channel	configure the DAC channel for an axis
set_boot_dac_channel	configure the boot DAC channel for an axis
get_dac_channel	read the configured DAC channel for an axis
get_boot_dac_channel	read the configured boot DAC channel for an axis
set_dac_output	set the value of the 16-bit analog output
get_dac_output	get the 16-bit value of the analog output

SYNTAX

int16 **set_dac_channel**(int16 *axis*, int16 *channel*)
int16 **set_boot_dac_channel**(int16 *axis*, int16 *channel*)
int16 **get_dac_channel**(int16 *axis*, int16 * *channel*)
int16 **get_boot_dac_channel**(int16 *axis*, int16 * *channel*)

int16 **set_dac_output**(int16 *axis*, int16 *voltage*)
int16 **get_dac_output**(int16 *axis*, int16 * *voltage*)

PROTOTYPE IN

pcdsp.h

DESCRIPTION

The DSP controller has one 16-bit digital-to-analog converter per axis.

set_dac_channel(...) configures the DAC channel for an axis. The default configuration is *axis = channel*. This is very useful in systems that need to switch between several feedback devices or several PID algorithms.

get_dac_channel(...) reads the current DAC configuration. Be sure to configure only one axis per DAC output channel.

Normally the analog outputs are controlled by the DSP with the PID algorithm. The analog outputs can also be controlled directly from the CPU with **set_dac_output(...)**. To control the analog outputs directly from the CPU, disable PID control by setting the PID filter parameters to zero with **set_filter(...)** or by calling **controller_idle(...)**.

Valid ranges for voltage are: +32767 (10V) to -32768 (-10V). **get_dac_output(...)** can be used to read the value of the output voltage during run mode or idle mode.

SEE ALSO

controller_idle(...), **set_filter(...)**

RETURN VALUES

	Returns
set_dac_channel(...) **set_boot_dac_channel**(...) **get_dac_channel**(...) **get_boot_dac_channel**(...) **set_dac_output**(...) **get_dac_output**(...)	Error return codes (see *Error Handling* on page 3-13)

SAMPLE CODE

This code disables PID control and sets an analog output of 1V for axis 0 until a key is pressed. The analog output voltage is then set to zero volts and PID control is re-enabled.

```
# include "pcdsp.h"

int main()
{
     if (dsp_init(PCDSP_BASE))    /* any problems initializing? */
             return dsp_error;     /* just terminate the program. */

     controller_idle(0);             /* trigger an ABORT_EVENT */
     set_dac_output(0, 3276);     /* set analog output to 1 volt */
     getch()                         /* wait for a key press */

     set_dac_output(0, 0);          /* set analog output to 0 volts */
     controller_run(0);              /* re-enable PID control */

     return dsp_error ;       /* global variable provided by the library */
}
```

NOTES

set_dac_output(...) can be used with open-loop velocity control, force control, or other analog operated devices. When used with voltage (velocity) controlled amplifiers or step motors the analog output corresponds to the motor velocity. When used with current controlled amplifiers, the analog output corresponds to the torque applied to the motor.

The **set_dac_output(...)** function modifies the offset filter parameter, so make sure to set the analog output back to zero before the PID is re-enabled.

Counter/Timer

init_timer	initialize the undedicated 8254 counter/timer
set_timer	set a timer value
get_timer	get a timer value

SYNTAX

int16 **init_timer**(int16 *channel*, int16 *mode*)
int16 **set_timer**(int16 *channel*, unsigned16 *t*)
int16 **get_timer**(int16 *channel*, unsigned16 * *t*)

PROTOTYPE IN

pcdsp.h

DESCRIPTION

The PC, PCX, STD, V3U, V6U, CPCI, 104X DSP Series controllers and the DSPpro-Serial, DSPpro-PC, and DSPpro-VME have an undedicated 82C54 counter/timer. The 104, LC, and EXM DSP Series do NOT have an undedicated 82C54 counter/timer. These functions are not applicable to the 104, LC, and EXM DSP Series.

The 82C54 supports several counter modes, which are configured with the **init_timer(...)** function. The modes are defined:

MODE 0: INTERRUPT ON TERMINAL COUNT

Mode 0 is typically used for event counting. After the Control Word is written, OUT is initially low, and will remain low until the Counter reaches zero. OUT then goes high and remains high until a new count or a new Mode 0 Control Word is written into the Counter.

GATE = 1 enables counting
GATE = 0 disables counting

GATE has no effect on OUT.

MODE 1: HARDWARE RETRIGGERABLE ONE-SHOT

OUT will be initially high. OUT will go low on the CLK pulse following a trigger to begin the one-shot pulse, and will remain low until the Counter reaches zero. OUT will then go high and remain high until the CLK pulse after the next trigger.

MODE 2: RATE GENERATOR

This Mode functions like a *divide-by-N* counter. It is typically used to generate a real-time Clock interrupt. OUT will initially be high. When the initial count decrements to 1, OUT goes low for one CLK pulse. OUT then goes high again, the Counter reloads the initial count and the process is repeated. Mode 2 is periodic; the same sequence is repeated indefinitely. For an initial count of *N*, the sequence repeats every *N* CLK cycles.

GATE = 1 enables counting
GATE = 0 disables counting

If GATE goes low during an output pulse, OUT is set high immediately. A trigger reloads the Counter with the initial count on the next CLK pulse; OUT goes low *N* CLK pulses after the trigger. Thus the GATE input can be used to synchronize the Counter.

MODE 3: SQUARE WAVE MODE

Mode 3 is typically used for Baud rate generation. Mode 3 is similar to Mode 2 except for the duty cycle of OUT. OUT will initially be high. When half the initial count has expired, OUT goes low for the remainder of the count. Mode 3 is periodic; the sequence above is repeated indefinitely. An initial count of *N* results in a square wave with a period of *N* CLK cycles.

GATE = 1 enables counting
GATE = 0 disables counting

If GATE goes low while OUT is low, OUT is set high immediately; no CLK pulse is required. A trigger reloads the Counter with the initial count on the next CLK pulse. Thus the GATE input can be used to synchronize the Counter.

MODE 4: SOFTWARE TRIGGERED STROBE

OUT will be initially high. When the initial count expires, OUT will go low for one CLK pulse and then go high again. The counting sequence is "triggered" by writing the initial count.

GATE = 1 enables counting
GATE = 0 disables counting

GATE has no effect on OUT.

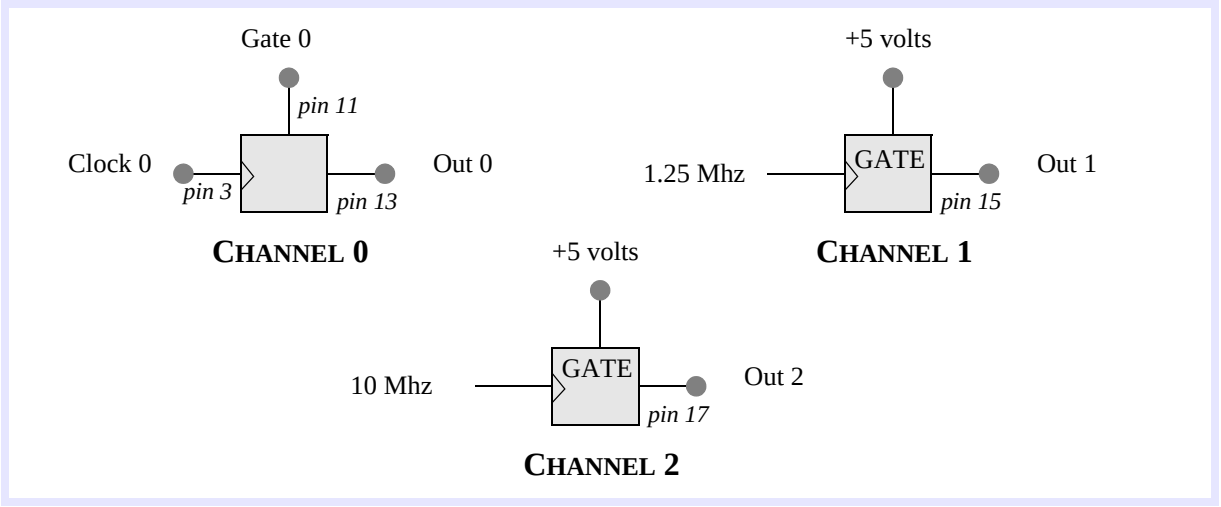
MODE 5: HARDWARE TRIGGERED STROBE (RETRIGGERABLE)

OUT will initially be high. Counting is triggered by a rising edge of GATE. When the initial count has expired, OUT will go low for one CLK pulse and then go high again.

set_timer(...) changes the initial count value for the associated counter. The value in t is copied to the counter register. **get_timer(...)** is used to read the current value in a timer.

There are 3 channels available, each with a separate output (OUT 0, OUT 1, and OUT 2). Channel 0 has a CLOCK input (Clock 0) and a GATE input (Gate 0). These can be connected to an external source. The Clock inputs for channels 1 and 2 are internally connected to 1.25 MHz and 10.0 MHz respectively. The Gate inputs (channels 1 and 2) are tied to +5volts (enabled).

Figure 3-6 Undedicated Counter/Timer



PINOUTS See next page or the appropriate *Installation* or *User Guide*.

RETURN VALUES

	Returns
init_timer(...) **set_timer**(...) **get_timer**(...)	Error return codes (see *Error Handling* on page 3-13)

LIMITATIONS Counter/Timer functions not available on the PCI/DSP.

Master/Slave

mei_link	connect 2 axes together with a ratio
endlink	disconnect 2 axes

SYNTAX

int16 **mei_link**(int16 *master*, int16 *slave*, double *ratio*, int16 *source*)
int16 **endlink**(int16 *slave*)

PROTOTYPE IN

pcdsp.h

DESCRIPTION

mei_link(...) configures 2 axes for master/slave operation. When axes are linked, the DSP calculates the slave's control position from the master's change in position (either command or actual) multiplied by some ratio every sample. The DSP handles the slaving, so the host processor is then able to proceed with no additional overhead. The parameters are:

Table 3-11 Master/Slave Parameters

Parameter	***Description***
master	controlling axis
slave	axis to follow the master
ratio	ratio of the slave/master operation
source	LINK_ACTUAL or LINK_COMMAND

Use the *#defines* LINK_ACTUAL and LINK_COMMAND to specify whether the link is based on the actual or command position of the master axis. When the axes are linked, the slave axis begins its link from its current position (keeping the difference in positions between the master and the slave as an offset).

mei_link(...) can be called when the master is at any position, when the master is moving, or when the slave is moving. The ratio can be changed on the fly by calling **mei_link(...)** with a new ratio.

To end a link when the master or slave is not moving, simply call **endlink(...)**. To end a link when the master or slave is moving call **mei_link(...)** with *ratio* = 0.0, then after the slave has stopped moving, call **endlink(...)**.

Be careful when linking moving axes or changing the ratio, the motors may not be able to keep up with abrupt changes. When axes are linked do not call **set_position(...)** on the linked axes. Watch out for large link ratios. A large ratio will cause any perturbations on the master axis to be magnified by the ratio and applied to the slave. Also, watch out for round-off errors when using fractional ratios. The resolution of the DSP's ratio is 16 bit whole and 16 bit fractional.

When axes are linked together, motion can still be commanded on both axes. This feature is very useful for blending motion profiles.

RETURN VALUES

	Returns
mei_link(...) **endlink**(...)	Error return codes (see *Error Handling* on page 3-13)

SAMPLE CODE

This code links the command position of axis 1 to axis 0. The DSP handles the slaving, so the host processor is then able to proceed with no overhead.

```
# include "pcdsp.h"

int main()
{
     if (dsp_init(PCDSP_BASE))    /* any problems initializing? */
             return dsp_error;     /* just terminate the program. */

/* positionally link master axis 0 to axis 1 with a 2:1 ratio */
     mei_link(0, 1, 2.0, LINK_COMMAND);

/* move a relative distance and wait for completion */
     r_move(0, 1000.0, 2000.0, 20000.0);

     endlink(1);              /* disable master slave control */

     return dsp_error ;       /* global variable provided by the library */
}
```

Master/Cam

set_cam	configure 2 axes for master/cam operation
set_boot_cam	configure 2 axes for master/cam operation at boot

SYNTAX

int16 **set_cam**(int16 *master_axis*, int16 *cam_axis*, int16 *cam*, int16 *source*)
int16 **set_boot_cam**(int16 *master_axis*, int16 *cam_axis*, int16 *cam*, int16 *source*)

PROTOTYPE IN

pcdsp.h

DESCRIPTION

Use **set_cam(...)** to configure 2 axes for master/cam operation. Camming is enabled when *cam* = TRUE, and disabled when *cam* = FALSE. When *source* = CAM_ACTUAL, the *cam_axis'* motion profile will be executed based on the rate of change of the *master_axis'* actual encoder input. When *source* = CAM_COMMAND, the *cam_axis'* motion profile will be executed based on the rate of change of the *master_axis'* command position.

$T_n = T_{n-1} + FdSpd$ — T_n is the time at sample *n*
$A_n = A_{n-1} + FdSpd * J$ — *J* is the jerk
$V_n = Vn-1 + FdSpd * A_n$ — A_n is the acceleration at sample *n*
$X_n = X_{n-1} + FdSpd * V_n$ — V_n is the velocity at sample *n*

X_n is the command position at sample *n*
FdSpd is the feed speed

Motion profiles are created on the *cam_axis* in the same way that motion profiles are created on non-cammed axes, except that the *execution rate* of the motion profile (for the *cam_axis)* is based on the absolute value of the *velocity* of the master_axis, and not the *time* (of the master_axis).

When configuring a *master_axis* for camming with *source* = CAM_ACTUAL, we are really just creating a velocity-based encoder. Be sure not to mix a cammed *master_axis* with a dual-loop *velocity_axis*.

The **boot functions** store/read the feedback configuration for each axis in boot memory. These are loaded on power-up or **dsp_reset(...)**. Be sure to call **mei_checksum(...)** after the boot memory is modified.

RETURN VALUES

	Returns
set_cam(...) **set_boot_cam**(...)	Error return codes (see *Error Handling* on page 3-13)

SAMPLE CODE

This code configures 2 axes for camming, and executes a motion profile on the cam.

```
# include "pcdsp.h"
int main()
{
     if (dsp_init(PCDSP_BASE))    /* any problems initializing? */
            return dsp_error;     /* just terminate the program. */

     set_cam(0, 1, TRUE, CAM_ACTUAL);   /* axis 0 = master, axis 1 = cam */
/* load a trapezoidal profile on the cam axis */
     start_r_move(1, 2000., 5000., 10000.);

     set_velocity(0, 1250.);   /* move the master at 1 count/sample */
     while (!motion_done(1))   /* wait for the cam profile completion */
            ;
     set_velocity(0, 0.);         /* stop the master axis */
```

```
    return dsp_error ;        /* global variable provided by the library */
}
```

NOTES

When using camming for the first time, rotate the master encoder *manually* to get a feel for the response of the profile on the cam axis.

Feed Speed Override

dsp_feed_rate	change the feed rate for all axes
axis_feed_rate	change the feed rate for one axis

SYNTAX

int16 **dsp_feed_rate**(double *feed_rate*)
int16 **axis_feed_rate**(int16 *axis*, double *feed_rate*)

PROTOTYPE IN

pcdsp.h

DESCRIPTION

dsp_feed_rate(...) sets the *feed_rate* of all the axes. **axis_feed_rate(...)** sets the *feed_rate* of one axis. The velocity, acceleration and jerk are increased/decreased by a *feed_rate* factor. The range of the *feed_rate* is from a complete stop (*feed_rate* = 0.0) up to twice the speed (*feed_rate* = 2.0). *feed_rate* is a percentage of the command velocity, acceleration, and the jerk. For example, a value of 0.5 (50%) runs an axis at half speed.

Every sample the DSP updates the trajectory:

$T_n = T_{n-1} + FdSpd$	T_n is the time at sample *n*
$A_n = A_{n-1} + FdSpd * J$	*J* is the jerk
$V_n = V_{n-1} + FdSpd * A_n$	A_n is the acceleration at sample *n*
$X_n = X_{n-1} + FdSpd * V_n$	V_n is the velocity at sample *n*

X_n is the command position at sample *n*

FdSpd is the feed speed

RETURN VALUES

	Returns
dsp_feed_rate(...) **axis_feed_rate**(...)	Error return codes (see *Error Handling* on page 3-13)

SAMPLE CODE

This code reads the states of the first 2 bits of user I/O (configured as inputs) to change the feed speed of all the axes. Input bit 0 decreases the speed by 1% and input 1 increases the speed by 1% each time the loop is updated. The program ends when a key is pressed.

```
# include "pcdsp.h"

int main()
{
     double rate = 1.0;

     if (dsp_init(PCDSP_BASE))   /* any problems initializing? */
            return dsp_error;    /* just terminate the program. */

     init_io(0, IO_INPUT);       /* configure port 0 as inputs */

     while (! kbhit())
     {       if (bit_on(0) && rate < 2.0)
                    rate += .01;      /* increase the rate by 1% */
            if (bit_on(1) && rate > 0.0)
                    rate -= .01;      /* decrease the rate by 1% */
            dsp_feed_rate(rate);    /* change the feed rate */
     }
     getch();

     return dsp_error ;       /* global variable provided by the library */
}
```

Feed Speed Override

dsp_feed_rate

NOTES

The feed rate should be changed slowly to avoid abrupt velocity changes. A common application of the feed speed override is to pause the motion. By reducing the feed speed to zero the motion will be halted and can be continued by increasing the feed rate back to 100%.

Position Latching

arm_latch	enables the DSP interrupt and resets a *position-ready* flag
latch_status	returns FALSE until the latched positions are ready
get_latched_position	returns the latched position of an axis
latch	initiate a position latch from software

SYNTAX

int16 **arm_latch**(int16 *enable*)
int16 **latch_status**(void)
int16 **get_latched_position**(int16 *axis*, double * *position*)
int16 **latch**(void)

PROTOTYPE IN

pcdsp.h

DESCRIPTION

arm_latch(...) configures the DSP to capture the actual positions of all the axes when a DSP interrupt is generated. Latching is enabled when *enable* = TRUE, and disabled when *enable* = FALSE. The position latching is activated when user I/O bit 22 transitions from a high (+5V) to a low signal (0V). All of the axes actual positions are captured within 4 microseconds. **latch_status(...)** returns TRUE when the position latch is complete. g**et_latched_position(...)** retrieves the latched position of an axis.

To generate a position latch from software, initialize port 2 as outputs with **init_io(...)**. Then call **arm_latch(...)** and **latch(...)**. **latch(...)** tries to set user I/O bit 22 low, generating a DSP interrupt. If user I/O bit 22 is not pulled low then the latch will fail. Make sure there are no external connections to user I/O bit 22.

SERCOS

The position latching functions are applicable to SERCOS controllers. However, the actual position capture time is based on the SERCOS loop update rate.

Many SERCOS drives support local internal position latching. For more information, please consult the drive manufacturer's documentation.

PINOUTS

See the appropriate *Install Guide*.

RETURN VALUES

	Returns
arm_latch(...)	Error return codes (see *Error Handling* on page 3-13)
latch_status(...)	Value (Returns FALSE until the position's latch finishes)
get_latched_position(...) **latch**(...)	Error return codes (see *Error Handling* on page 3-13)

SEE ALSO

init_io(...)

SAMPLE CODE

This code continuously latches the positions for all axes and displays the actual position for axis 0. Press the ESC key to exit the program.

```
# include "pcdsp.h"
# include <conio.h>

int main()
{
     int16 done = 0 ;
     double p ;

     if (dsp_init(PCDSP_BASE))    /* any problems initializing? */
            return dsp_error;     /* just terminate the program. */

     init_io(2, IO_OUTPUT);       /* configure port 2 as outputs */
     set_io(2, 0xFF);                /* set all bits high */

     v_move(0, 8000.0, 80000.0);  /* accelerate to constant velocity */
     arm_latch(TRUE);

     while (! done)
     {       if (kbhit())
             {       done = getch() == 0x1B ;
                     if (! done)
                     {       latch() ;
                             while (! latch_status())
                             ;
                             get_latched_position(0, &p) ;
                             arm_latch(TRUE);       /* reset the latch. */
                             printf("%12.0lf\r", p) ;
                     }
             }
     }
     return 0;
}
```

arm_latch

NOTES

When using the STD/DSP motion controller, the position latching is activated when user I/O bit 22 transitions from a low (0V) to a high signal (+5V).

On-Board Jogging

jog_axis — enable on-board *analog-controlled* jogging for one axis

SYNTAX

int **jog_axis**(int *axis*, int *jog_channel*, int *c*, int *d*, double *m1*, double *m2*, int *enable*)

PROTOTYPE IN

pcdsp.h

DESCRIPTION

The PC, PCX, STD, CPCI, V3U, V6U DSP Series controllers have 8 undedicated 12-bit analog input channels which are numbered 0 to 7. The DSPpro-Serial, DSPpro-PC, and DSPpro-VME also have 8 12-bit analog input channels. The 104, LC, and EXM DSP Series controllers and the SERCOS controllers do NOT have analog-to-digital converters. These functions are not applicable to the 104, LC, EXM, and SERCOS DSP Series.

The analog-to-digital conversion operates by writing a control word to the A/D component, waiting at least 15 microseconds, and then reading the digital value. The analog inputs can be read by the DSP or directly from the Host CPU. To guarantee proper analog-to-digital conversions, the DSP and the PC cannot read the analog inputs at the same time. If any axis is configured for servo-on-analog, axis analog, or onboard jogging, then the Host CPU must not call the functions **start_analog(...)**, **read_analog(...)** or **get_analog(...)**.

jog_axis(...) configures the DSP to control an axis' command velocity based on an analog input. *jog_channel* (0, 1, or 2) indicates the firmware jog channel. Note that you can map any of the 8 analog channels to any axis, but you must map a jog channel to axes 0, 1 or 2 only- you can only map the jog channels to the first 3 axes. *c* indicates the analog center value corresponding to zero velocity. *d* indicates the deadband in analog counts. *m1* is the linear velocity term. *m2* is the cubic velocity term. Jogging is enabled if *enable* = TRUE and disabled if *enable* = FALSE. No more than 3 axes can be configured for jogging simultaneously.

Each sample the DSP calculates the command velocity based on the analog input and the **jog_axis(...)** parameters:

If the A/D value > (center + deadband), then J = A/D value - center - deadband

If the A/D value < (center - deadband), then J = A/D value - center + deadband

If (center + deadband) > A/D value > (center - deadband), then J = 0

velocity (counts/sec) = (linear term * J/65536 + cubic term * 3.632 * 10^{-12} * J^3) * sample rate

where, *c* = center
d = deadband
linear term = *m1*
cubic term = *m2*
default sample rate = 1250 samples/sec

The analog input channel, and its configuration are set by **set_analog_channel(...)**. The default configuration is *axis* = channel, *differential* = FALSE, and *bipolar* = FALSE. Be sure to configure only one analog input channel per axis. **set_analog_channel(...)** is very useful in systems that need to switch between several analog input channels.

PINOUTS

See the appropriate *Install Guide*.

RETURN VALUES

	Returns
jog_axis(...)	Error return codes (see *Error Handling* on page 3-13)

SEE ALSO

start_analog(...), **read_analog(...)**, **get_analog(...)**, **set_analog_channel(...)**, **get_axis_analog(...)**, **dsp_sample_rate(...)**, **set_sample_rate(...)**

SAMPLE CODE This code initializes analog input channels 0, 1, and 2 for unipolar onboard jogging.

```
# include <stdio.h>
# include "pcdsp.h"

#define      X              0
#define      Y              1
#define      Z              2

#define      XJOG           0
#define      YJOG           1
#define      ZJOG           2

#define      XANALOGCHANNEL 0
#define      YANALOGCHANNEL 1
#define      ZANALOGCHANNEL 2

#define      XCENTER        2048
#define      YCENTER        2048
#define      ZCENTER        2048

#define      XDEADBAND      5
#define      YDEADBAND      20
#define      ZDEADBAND      50

#define      XLINEAR        10
#define      YLINEAR        100
#define      ZLINEAR        1000

#define      XCUBIC         10
#define      YCUBIC         50
#define      ZCUBIC         100

int main()
{
     if (dsp_init(PCDSP_BASE))    /* any problems initializing? */
            return dsp_error;     /* just terminate the program. */

     set_analog_channel(X, XANALOGCHANNEL, FALSE, FALSE);
     set_analog_channel(Y, YANALOGCHANNEL, FALSE, FALSE);
     set_analog_channel(Z, ZANALOGCHANNEL, FALSE, FALSE);

     jog_axis(X, XJOG, XCENTER, XDEADBAND, XLINEAR, XCUBIC, TRUE);
     jog_axis(Y, YJOG, YCENTER, YDEADBAND, YLINEAR, YCUBIC, TRUE);
     jog_axis(Z, ZJOG, ZCENTER, ZDEADBAND, ZLINEAR, ZCUBIC, TRUE);

     return dsp_error ;        /* global variable provided by the library */
}
```

Multiple Controllers

m_setup	initialize pointers to access multiple motion controller boards
m_board	switch pointers to access a particular board
m_axis	switch pointers to access a particular axis

SYNTAX

int16 **m_setup**(int16 *boards*, int16 * *controller_addresses*)

int16 **m_board**(int16 *board_number*)

int16 **m_axis**(int16 *actual_axis*)

PROTOTYPE IN

pcdsp.h, mboard.h

DESCRIPTION

The controller maintains a structure called DSP which contains information pertaining to the base I/O address, and a bunch of other stuff. A library variable called *dspPtr* contains a pointer to the default DSP structure. By varying this pointer, we can get the library to use multiple controllers. In version 2.5, individual axes can be enabled or disabled with software. It is now possible to configure a controller with non-sequential axes.

Use **m_setup(...)** instead of **dsp_init(...)** to initialize several controllers. Simply create an array where each element contains the base I/O address of a controller. Pass that array to this function, and **m_setup(...)** will perform the appropriate software initialization. The *actual_axes* will be numbered according to the order of the controllers in the *controller_addresses* array and the number of axes for each controller found by **dsp_axes(...)**.

m_board(...) modifies the *dspPtr* to point to a particular board. **m_axis(...)** sets the *dspPtr* to point to the desired controller board and returns the physical axis on that controller. The function **m_axis(…)** does not support non-sequential axes. The value returned by **m_axis(...)** should be used as the axis parameter for other library functions. We recommend using **m_board(…)** to switch between controllers.

SEE ALSO

dsp_axes(...), **set_axis(…)**, **get_axis(…)**

RETURN VALUES

	Returns
m_setup(...) **m_board**(...) **m_axis**(...)	Error return codes (see *Error Handling* on page 3-13)

SAMPLE CODE

This code initializes a 3-axis controller and a 4-axis controller. Both controllers are reset and the actual positions are read.

```
# include "pcdsp.h"
# include “mboard.h”
# define            BOARDS  2
int main()
{
     int16 i, axes = 0, addresses[] = {0x300, 0x310};
     double actual;

     if (m_setup(BOARDS, addresses))  /* any problems initializing? */
            return dsp_error;         /* just terminate the program. */

     for (i = 0; i < BOARDS; i++)
     {      m_board(i);
            dsp_reset();
            axes += dsp_axes();
     }
```

```
        for (i = 0; i < axes; i++)
        {       get_position(m_axis(i), &actual);
                printf("\nAxis: %d Actual: %lf", i, actual);
        }
        return dsp_error ;       /* global variable provided by the library */
}
```

Trajectory Frames

dsp_dwell	delay execution of a frame for an axis
dsp_position	update command position and delay execution of next frame
dsp_velocity	update velocity and delay execution of next frame
dsp_accel	update accel and delay execution of next frame
dsp_jerk	update jerk and delay execution of next frame
dsp_end_sequence	clear an axis' in_sequence status bit

SYNTAX

int16 **dsp_dwell**(int16 *axis*, double *duration*)
int16 **dsp_position**(int16 *axis*, double *position*, double *duration*)
int16 **dsp_velocity**(int16 *axis*, double *velocity*, double *duration*)
int16 **dsp_accel**(int16 *axis*, double *accel*, double *duration*)

int16 **dsp_jerk**(int16 *axis*, double *jerk*, double *duration*)
int16 **dsp_end_sequence**(int16 *axis*)

PROTOTYPE IN

pcdsp.h

DESCRIPTION

dsp_dwell(...) downloads a frame to the DSP that does nothing for a set period of time. Its effect is to stall the execution of the next frame in the buffer for a given *duration*. The valid range for the *duration* is from zero seconds (1 sample) to (2^32/sample_rate) seconds. The units for *duration* are seconds.

dsp_position(...) downloads a frame to the DSP that updates an *axis*' command *position* and delays the execution of the next frame in the buffer for given *duration*. Be careful, changes in the command position will cause the motor to jump immediately to the new *position*.

dsp_velocity(...) downloads a frame to the DSP that updates an *axis*' command *velocity* and delays the execution of the next frame in the buffer for given *duration*. The direction is determined by the sign of the *velocity*.

dsp_accel(...) downloads a frame to the DSP that updates an *axis*' command *acceleration* and delays the execution of the next frame in the buffer for given *duration*. The direction is determined by the sign of the *acceleration*.

dsp_jerk(...) downloads a frame to the DSP that updates an *axis*' command *jerk* and delays the execution of the next frame in the buffer for given *duration*. The direction is determined by the sign of the *jerk*.

dsp_end_sequence(...) downloads a frame to the DSP that clears an *axis*' *in_sequence* status bit. **dsp_dwell(...)**, **dsp_position(...)**, **dsp_velocity(...)**, **dsp_accel(...)**, and **dsp_jerk(...)** download a single frame with a time trigger. The DSP executes these single frames from its buffer and updates the status bits based on the execution of the frames. An *axis*' *in_sequence* bit is turned on when a frame is executed.

The command position resolution is 32 bits whole and 32 bits fractional. The actual position resolution is 32 bits whole. The command velocity, acceleration, and jerk all have a resolution of 16 bits whole and 32 bits fractional. On every sample, the DSP updates the trajectory.

Table 3-12 How the DSP Updates the Trajectory

Expression	*Variable Definitions*
$T_n = T_{n-1} + FdSpd$	T_n is the time at sample *n*
$A_n = A_{n-1} + FdSpd * J$	*J* is the command jerk
$V_n = V_{n-1} + FdSpd * A_n$	A_n is the command acceleration at sample *n*
$X_n = X_{n-1} + FdSpd * V_n$	V_n is the command velocity at sample *n*
	X_n is the command position at sample *n*
	FdSpd is the feed speed

To have the frame exit after 1 sample (the shortest period possible), use *duration* = 0. For example, a rudimentary trapezoidal profile motion could be performed by:

```
dsp_accel(axis, accel, time);       /* begin acceleration */
dsp_accel(axis, 0, slewtime);       /* stop accelerating */
dsp_accel(axis, -accel, time);      /* decelerate */
dsp_accel(axis, 0, 0);              /* zero the acceleration */
dsp_velocity(axis, 0, 0);           /* zero the command velocity. */
dsp_end_sequence(axis);             /* clear the in_sequence bit */
```

dsp_velocity(...) is used here to eliminate the possibility of the motor continuing to move due to acceleration/deceleration round-off. In this example, because the accel and decel times are the same, the round-off is 0, but its always a good idea to zero the velocity when you're done.

RETURN VALUES

	Returns
dsp_dwell(...) **dsp_position**(...) **dsp_velocity**(...) **dsp_accel**(...) **dsp_jerk**(...) **dsp_end_sequence**(...)	Error return codes (see *Error Handling* on page 3-13)

SAMPLE CODE

This code loads a sequence of frames that accelerates and decelerates for specific durations. The final command position is calculated by: **`dist = vt + .5(a*t*t)`**

```
# include <stdio.h>
# include "pcdsp.h"

int main()
{
     if (dsp_init(PCDSP_BASE))   /* any problems initializing? */
            return dsp_error;    /* just terminate the program. */

     set_position(0, 0.0);

     dsp_accel(0, 400, 4.0);     /* accelerate for 4.0 seconds */
     dsp_accel(0, -400, 8.0);    /* decelerate for 8.0 seconds */
     dsp_accel(0, 400, 4.0);     /* accelerate for 4.0 seconds */
     dsp_accel(0, 0.0, 0.0);     /* zero acceleration */
     dsp_velocity(0, 0.0, 0.0);  /* zero velocity */
     dsp_position(0, 0.0, 0.0);  /* set command to correct for roundoff */

     return dsp_error ;        /* global variable provided by the library */
}
```

I/O Frames

dsp_io_frame	update the state of an 8-bit user I/O port
dsp_io_trigger	delay execution of next frame until bit level changes to *state*
dsp_io_trigger_mask	delay execution of next frame until the masked port changes to *state*

SYNTAX

int16 **dsp_io_frame**(int16 *axis*, int16 *port*, int16 *ormask*, int16 *andmask*)

int16 **dsp_io_trigger**(int16 *axis*, int16 *bit*, int16 *state*)

int16 **dsp_io_trigger_mask**(int16 *axis*, int16 *port*, int16 *mask*, int16 *state*)

PROTOTYPE IN

pcdsp.h

DESCRIPTION

dsp_io_frame(...) downloads a frame that modifies a user I/O output *port* according to the *ormask* and the *andmask*. The *port* specified will be bitwise ORed with the *ormask* and then bitwise ANDed with the *andmask*. Because this function downloads a frame, the port won't be modified until the DSP executes this frame.

dsp_io_trigger(...) downloads a frame to the DSP that does nothing until a specified user I/O bit becomes the level specified by the state parameter. The state is either TRUE or FALSE, which indicates the active level.

dsp_io_trigger_mask(...) downloads a frame that delays execution of the next frame in the list until the masked bit(s) correspond to the logic of *state*. The bit(s) are decoded by the user I/O port, bitwise ORed with the *mask*. If *state* = TRUE, the next frame is triggered when all the masked bit(s) are high (+5 volts). If *state* = FALSE, the next frame is triggered if any masked bit is low (0 volts).

PINOUTS

See the appropriate *Install Guide*.

RETURN VALUES

	Returns
dsp_io_frame(...) **dsp_io_trigger**(...) **dsp_io_trigger_mask**(...)	Error return codes (see *Error Handling* on page 3-13)

SAMPLE CODE

This code loads a **dsp_io_trigger(...)** frame and a **dsp_dwell(...)** frame for axis 0 followed by a trapezoidal profile move. When bit 0 goes high, then the DSP executes the profile on axis 0.

```
# include <stdio.h>
# include "pcdsp.h"

int main()
{
     if (dsp_init(PCDSP_BASE))    /* any problems initializing? */
             return dsp_error;     /* just terminate the program. */

     init_io(0, IO_OUTPUT);      /* configure port 0 as outputs */
     set_io(0, 0);                 /* set all bits on port 0 to low */

     dsp_io_trigger(0, 0, TRUE);  /* wait for bit 0 to go high */
     dsp_dwell(0, 5.0);              /* wait for 5 seconds */
     start_move(0, 4000.0, 1000.0, 1000.0);

     getch();               /* wait for a key */
     set_bit(0);            /* set bit 0 high */

     return dsp_error ;      /* global variable provided by the library */
}
```

Position-Triggered Frames

dsp_position_trigger — generate an action when a position is exceeded

dsp_actual_position_trigger — delays the next frame until an actual position is exceeded

dsp_command_position_trigger — delays the next frame until a command position is exceeded

SYNTAX

int16 **dsp_position_trigger**(int16 *axis*, int16 *triggeraxis*, double *triggerpos*, int16 *sense*, int16 *actual*, int16 *action*)

int16 **dsp_actual_position_trigger**(int16 *axis*, double *position*, int16 *sense*)

int16 **dsp_command_position_trigger**(int16 *axis*, double *position*, int16 *sense*)

PROTOTYPE IN

pcdsp.h

DESCRIPTION

dsp_position_trigger(...) downloads a frame to an *axis* that can generate an *action* on that *axis*, based upon what the *triggeraxis* is doing. After the *triggeraxis*' position exceeds the *trigger-pos*, the frame generates the *action* on that *axis.*

Table 3-13 Selecting a Trigger for dsp_position_trigger

If actual =	***Then this is used as the trigger***
TRUE	actual position register
FALSE	command position

dsp_actual_position_trigger(...) downloads a frame that delays execution of the next frame in the list until the *axis*' actual position exceeds *pos*.

dsp_command_position_trigger(...) downloads a frame that delays execution of the next frame in the list until the *axis*' command position exceeds *pos*.

If *trigger_sense* = POSITIVE_SENSE, then the frame is triggered by a position >= to *pos*; if *trigger_sense* = NEGATIVE_SENSE, then the frame is triggered by a position < *pos*. The *action* can be one of the following:

Table 3-14 Possible Frame Actions

#define	***Value***	***Description***
NO_EVENT	0	Ignore a condition
NEW_FRAME	2	Begin execution of the next sequenced frame
STOP_EVENT	8	Decelerate to a stop (at specified stop rate)
E_STOP_EVENT	10	Decelerate to a stop (at specified E-stop rate)
ABORT_EVENT	14	Disable PID control and the amplifier for this axis

RETURN VALUES

	Returns
dsp_position_trigger(...) **dsp_actual_position_trigger**(...) **dsp_command_position_trigger**(...)	Error return codes (see *Error Handling* on page 3-13)

SAMPLE CODE

This code commands axis 0 to move at constant velocity. When the command position exceeds 20,000 counts, the axis will decelerate to a stop.

```
# include <stdio.h>
# include "pcdsp.h"
int main()
{
     if (dsp_init(PCDSP_BASE))      /* any problems initializing? */
            return dsp_error;       /* just terminate the program. */

     set_position(0, 0.0);            /* clear command and actual position */
     v_move(0, 1000.0, 10000.0);   /* accelerate to constant velocity */

/* trigger next frame when command position exceeds 200000.0 */
     dsp_command_position_trigger(0, 20000.0, POSITIVE_SENSE);
     v_move(0, 0.0, 10000.0);       /* decelerate to a stop */
     return dsp_error ;        /* global variable provided by the library */
}
```

Looping Sequence Frames

dsp_marker	create a marker frame
dsp_goto	creates frame that points to the marker frame

SYNTAX

int16 **dsp_marker**(int16 *axis*, int16 * *marker*)

int16 **dsp_goto**(int16 *axis*, int16 *marker*)

PROTOTYPE IN

pcdsp.h

DESCRIPTION

These functions are most often used for creating a sequence of frames that constantly execute (in a loop) on the DSP. **dsp_marker(...)** creates a special frame which does nothing. *marker* is the address of the downloaded frame. **dsp_goto(...)** creates a frame which points back to the given *marker*, effectively telling the controller to continue execution at the marker frame. Its return value is the address of the downloaded frame.

dsp_control(...) is used to enable or disable specific control bits in the DSP. Most often it is used in looping sequences to prevent the frames from being released to the free list. A call to **dsp_control(axis, FCTL_RELEASE, FALSE)** prevents the executing frames from being "thrown out" after they have been executed.

When creating a looping frame sequence make sure that the *starting* point is always the same as the *ending* point. The only exception is if the sequence contains relative moves only. **start_r_move(...)** can be used to create a sequence of relative moves. Always make sure that a marker is only used for one axis and not shared by other axes.

dsp_axis_command(...) creates a frame, which when executed will immediately send an action to another axis. The action can be one of the following (the NEW_FRAME action is the most common):

Table 3-15 Possible Frame Actions- Looping Sequence Frames

#define	*Value*	*Description*
NO_EVENT	0	Ignore a condition
NEW_FRAME	2	Begin execution of the next sequenced frame
STOP_EVENT	8	Decelerate to a stop (at specified stop rate)
E_STOP_EVENT	10	Decelerate to a stop (at specified E-stop rate)
ABORT_EVENT	14	Disable PID control and the amplifier for this axis

RETURN VALUES

	Returns
dsp_marker(...) **dsp_goto**(...)	Error return codes (see *Error Handling* on page 3-13)

SEE ALSO

dsp_control(...)

SAMPLE CODE

This code downloads a sequence of frames for axis 0 to move to position 2000.0 and then back to 0.0. The sequence will be repetitively executed by the DSP. This leaves the host processor free to display the positions in real time.

Note:	**This sample program does not disable the looping frame sequence.** You must make sure that the frames are properly returned to the free list *after* the looping sequence is complete. Calling **dsp_reset(...)** is the best method for restoring the frame list.

```
# include <stdio.h>
# include <conio.h>
# include "pcdsp.h"
# include "idsp.h"

int main()
{
     int16 mark;
     double actual;

     if (dsp_init(PCDSP_BASE))     /* any problems initializing? */
            return dsp_error;      /* just terminate the program. */

     set_position(0, 0.0);
     dsp_control(0, FCTL_RELEASE, FALSE);    /* don't throw out frames */
     dsp_marker(0, &mark);                     /* load a marker frame */
     start_move(0, 2000.0, 500.0, 10000.0);
     start_move(0, 0.0, 1000.0, 8000.0);
     dsp_goto(0, mark);           /* loop to the beginning of the sequence */

     while(!kbhit())
     {       get_position(0, &actual);
             printf("Actual: %lf\r", actual);
     }
     getch();

     set_stop(0);             /* trigger a STOP_EVENT */
     while(in_motion(0))
             ;
     clear_status(0);         /* clear the STOP_EVENT */

     return dsp_error ;       /* global variable provided by the library */
}
```

Action Frames

dsp_axis_command	download a frame to send an action to another axis
dsp_home_action	download a frame to set the home logic action
dsp_positive_limit_action	download a frame to set the positive limit action
dsp_negative_limit_action	download a frame to set the negative limit action
dsp_error_action	download a frame to set the position error action

SYNTAX

int16 **dsp_axis_command**(int16 *axis*, int16 *destaxis*, int16 *action*)
int16 **dsp_home_action**(int16 *axis*, int16 *action*)
int16 **dsp_positive_limit_action**(int16 *axis*, int16 *action*)
int16 **dsp_negative_limit_action**(int16 *axis*, int16 *action*)
int16 **dsp_error_action**(int16 *axis*, int16 *action*)

PROTOTYPE IN

pcdsp.h

DESCRIPTION

dsp_axis_command(...) downloads a frame to an *axis* that sends an *action* to the *destaxis*.

dsp_home_action(...) downloads a frame which configures the DSP to generate an action when an axis' home logic is activated. The home logic may be some combination of the home and index inputs. The home and index inputs are logically combined or individually ignored based on the configuration set by **set_home_index_config(...)**.

dsp_positive_limit_action(...) downloads a frame that configures the DSP to generate an action when an axis' positive limit sensor is activated. **dsp_negative_limit_action(...)** downloads a frame that configures the DSP to generate an action when an axis' negative limit sensor is activated.

dsp_error_action(...) downloads a frame that configures the DSP to generate an action when an axis' error limit is exceeded.The *action* can be one of the following:

Table 3-16 Possible Frame Actions in Action Frames

#define	*Value*	*Description*
NO_EVENT	0	Ignore a condition
NEW_FRAME	2	Begin execution of the next sequenced frame
STOP_EVENT	8	Decelerate to a stop (at specified stop rate)
E_STOP_EVENT	10	Decelerate to a stop (at specified E-stop rate)
ABORT_EVENT	14	Disable PID control and the amplifier for this axis

RETURN VALUES

	Returns
dsp_axis_command(...) **dsp_home_action**(...) **dsp_positive_limit_action**(...) **dsp_negative_limit_action**(...) **dsp_error_action**(...)	Error return codes (see *Error Handling* on page 3-13)

SEE ALSO

set_home_index_config(...)

SAMPLE CODE

This code clears the position register when the home sensor becomes active (triggers on the edge of the level change). The frames are downloaded to the DSP leaving the host processor free to display the positions in real time.

```
# include <stdio.h>
# include <conio.h>
# include "pcdsp.h"

int main()
{
     double actual;

     if (dsp_init(PCDSP_BASE))   /* any problems initializing? */
            return dsp_error;    /* just terminate the program. */

     set_home(0, NO_EVENT);                /* disable home logic */
     set_home_index_config(0, HOME_ONLY);  /* home sensor only */

     v_move(0, 1000, 4000);           /* accelerate to constant velocity */
     dsp_home_action(0, NEW_FRAME);  /* set home to execute next frame */
     dsp_dwell(0, 1000000);           /* have dsp wait for home */
     dsp_home_action(0, NO_EVENT);   /* disable home sensor */
     set_position(0, 0.0);             /* set command and actual to 0.0 */
     v_move(0, 0, 4000);               /* decelerate to a stop */

     while(!motion_done(0))
     {       get_position(0, &actual);
            printf("Actual: %lf\r", actual);
     }

     return dsp_error;        /* global variable provided by the library */
}
```

Filter Frames

dsp_set_filter

downloads a frame that sets an axis' PID filter parameters

SYNTAX

int16 **dsp_set_filter**(int16 *axis*, int16 * *coeffs*)

PROTOTYPE IN

pcdsp.h

DESCRIPTION

dsp_set_filter(...) downloads a frame that sets an axis' PID filter parameters. *coeffs* is a pointer to an array of integers, mapped as follows:

Table 3-17 PID Filter Parameter Mapping

#define	*Value*	*Description*
DF_P	0	Proportional gain
DF_I	1	Integral gain
DF_D	2	Derivative gain - damping term
DF_ACCEL_FF	3	Acceleration feed forward
DF_VEL_FF	4	Velocity feed-forward
DF_I_LIMIT	5	Integration summing limit
DF_OFFSET	6	Voltage output offset
DF_DAC_LIMIT	7	Voltage output limit
DF_SHIFT	8	2^(n) divisor
DF_FRICT_FF	9	Friction Feed Forward
COEFFICIENTS	10	Number of elements

RETURN VALUES

	Returns
dsp_set_filter(...)	Error return codes (see *Error Handling* on page 3-13)

SAMPLE CODE

The following code increases the gain before a move, and sets the gain back to the original value after the move is completed:

```
# include "pcdsp.h"
int main()
{
     int16 coeff_a[COEFFICIENTS], coeff_b[COEFFICIENTS];

     if (dsp_init(PCDSP_BASE))    /* any problems initializing? */
            return dsp_error;     /* just terminate the program. */

     get_filter(0, coeff_a);
     get_filter(0, coeff_b);
     coeff_a[DF_P] += 200;

     dsp_set_filter(0, coeff_a);
     start_move(0, 100000, 8000.0, 16000.0);  /* move axis 0 to 100,000 counts */
     dsp_set_filter(0, coeff_b);

     return dsp_error;       /* global variable provided by the library */
}
```

NOTES

Sometimes it's difficult to find a set of tuning parameters that will produce accurate motion without oscillation (often due to poor mechanical systems with servo motors). Thus, it may be necessary to have two sets of tuning parameters. One set of parameters with a low gain might be used when the motor is not in motion and another set of tuning parameters with a higher gain could be used during motion. See the *Installation Manual* for more about finding correct filter parameters.

Frame Control

dsp_control	enable/disable the frame control bits in frames to be downloaded
set_gate	set the gate flag for an axis
reset_gate	clear the gate flag for an axis
set_gates	set the gate flag for several axes
reset_gates	clear the gate flag for several axes

SYNTAX

int16 **dsp_control**(int16 *axis*, int16 *bit*, int16 *state*)

int16 **set_gate**(int16 *axis*)

int16 **reset_gate**(int16 *axis*)

int16 **set_gates**(int16 *length*, int16 * *axes*)

int16 **reset_gates**(int16 *length*, int16 * *axes*)

PROTOTYPE IN

pcdsp.h, idsp.h

DESCRIPTION

dsp_control(...) configures the frame control word used when downloading subsequent frames. Typically, **dsp_control(...)** is used when creating frame sequences with several functions that download a single frame.

A bit is enabled when *state* = TRUE and disabled when *state* = FALSE. The frame structure has 20 words. Word #1 contains the frame control bits. The frame control bits are defined in IDSP.H:

Table 3-18 Frame Control Words

#define	*Value*	*Explanation*
FCTL_RELEASE	0x8000	Releases the frame after execution
FCTL_INTERRUPT	0x4000	Generates an interrupt to the PC
FCTL_HOLD	0x2000	Prevents a frame from executing when the gate is set
FCTL_ADD	0x0100	Configures the frame as an add frame
FCTL_MOVE	0x0200	Configures the frame as a move frame

Frame execution can be halted or started by setting or resetting the gate flag (one per axis). The DSP examines the gate flag and the FCTL_HOLD bit in the control word of the current frame to decide if the frame should be executed. The DSP will not execute a frame while the gate flag is set and the FCTL_HOLD bit is on.

set_gate(...) sets an *axis*' gate flag and increments the *axis*' software gate counter.

reset_gate(...) clears an *axis*' gate flag and decrements the *axis*' software gate counter.
set_gates(...) sets the gate flag and increments the software gate counter for multiple *axes*.
reset_gates(...) clears the gate flag and decrements the software gate counter for multiple *axes*.

Functions that create motion by downloading several frames set the hold bit in the first frame, set the gate(s), download the rest of the frames, and then resets the gate(s). **start_move(...)**, **move(...)**, **start_r_move(...)**, **start_move_all(...)**, etc., use the hold bit and gate flag to create motion.

RETURN VALUES

	Returns
dsp_control(...) **set_gate**(...) **reset_gate**(...) **set_gates**(...) **reset_gates**(...)	Error return codes (see *Error Handling* on page 3-13)

SAMPLE CODE

This code downloads a frame sequence for axis 0. The “hold” bit is turned on in the first frame to prevent execution until the complete sequence is downloaded.

```
# include "pcdsp.h"
# include "idsp.h"

int main()
{
     if (dsp_init(PCDSP_BASE))    /* any problems initializing? */
            return dsp_error;     /* just terminate the program. */

     dsp_control(0, FCTL_HOLD, TRUE);  /* set the hold bit */
     set_gate(0);                        /* set the axis' gate flag */

     dsp_accel(0, 1000.0, .2);          /* acceleration frame */
     dsp_control(0, FCTL_HOLD, FALSE);  /* clear the hold bit */
     dsp_accel(0, -1000.0, .2);         /* deceleration frame */
     dsp_position(0, 40.0, 0.0);         /* update final position */

     reset_gate(0);                /* ready, set, go! */

     return dsp_error ;        /* global variable provided by the library */
}
```

Time

get_dsp_time	returns the DSP's sample timer value
get_frame_time	returns an axis' frame sample timer value

SYNTAX

unsigned16 **get_dsp_time**(void)

unsigned long **get_frame_time**(int16 *axis*)

PROTOTYPE IN

pcdsp.h

DESCRIPTION

get_dsp_time(...) returns the integer value of the DSP's sample timer. **get_frame_time(...)** returns an unsigned long value of an axis's frame sample timer. Whenever a frame is executed by the DSP, the frame sample timer is reset to zero. The units for these values are in terms of samples. The default sample rate is 1250 samples per second.

RETURN VALUE

integer or long value representing the number of samples

	Returns
get_dsp_time(...) **get_frame_time**(...)	Values

SEE ALSO

dsp_sample_rate(...), **set_sample_rate(...)**

SAMPLE CODE

This code prints the sample timer value before and after a simple move.

```
# include <stdio.h>
# include "pcdsp.h"

int main()
{
     if (dsp_init(PCDSP_BASE))    /* any problems initializing? */
             return dsp_error;     /* just terminate the program. */

     if (dsp_reset())          /* resets the controller and sample clock */
             return dsp_error;

     printf("\nSample Clock: %d\n", get_dsp_time());
     r_move(0, 100., 1000., 20000.);
     printf("\nSample Clock: %d\n", get_dsp_time());

     return dsp_error ;        /* global variable provided by the library */
}
```

Direct Memory Access

dsp_read_dm	access the DSP's data memory
dsp_write_dm	modify the DSP's data memory

SYNTAX

int16 **dsp_read_dm**(unsigned16 *addr*)

int16 **dsp_write_dm**(unsigned16 *addr*, int16 *dm*)

PROTOTYPE IN

pcdsp.h

DESCRIPTION

The functions **dsp_read_dm(...)** and **dsp_write_dm(...)** allow direct access to the DSP's external data memory. Most fundamental communication with the controller is via messages passed through this data area.

These functions provide a low-level access to the DSP controller and are typically not needed for normal user programs. These functions can be used to read the peripherals directly:

Table 3-19 Encoder DMA Addresses

Encoder Input	***Address***	***Analog Input***	***Address***
Axis 0	0x0014	Channel 0	0x0020
Axis 1	0x0015	Channel 1	0x0021
Axis 2	0x0016	Channel 2	0x0022
Axis 3	0x0017	Channel 3	0x0023
Axis 4	0x0018	Channel 4	0x0024
Axis 5	0x0019	Channel 5	0x0025
Axis 6	0x001A	Channel 6	0x0026
Axis 7	0x001B	Channel 7	0x0027

Table 3-20 Dedicated I/O DMA Addresses

Dedicated I/O (axes 0 - 3)	***Address***	***Dedicated I/O (axes 4 - 7)***	***Address***
82C55-0 Port 6	0x0030	82C55-1 Port 3	0x0038
82C55-0 Port 7	0x0031	82C55-1 Port 4	0x0039
82C55-0 Port 8	0x0032	82C55-1 Port 5	0x003A
82C55-0 Control	0x0033	82C55-1 Control	0x003B

Table 3-21 User I/O DMA Addresses

User I/O	***Address***
82C55-2 Port 0	0x0040
82C55-2 Port 1	0x0041
82C55-2 Port 2	0x0042
82C55-2 Control	0x0043

Table 3-22 Internal Logic DMA Addresses

Internal Logic	*Address*	*Internal Logic*	*Address*
82C55-3 Port A	0x0048	82C55-4 Port A	0x0050
82C55-3 Port B	0x0049	82C55-4 Port B	0x0051
82C55-3 Port C	0x004A	82C55-4 Port C	0x0052
82C55-3 Control	0x004B	82C55-4 Control	0x0053

RETURN VALUES

	Returns
dsp_read_dm(...) **dsp_write_dm**(...)	Error return codes (see *Error Handling* on page 3-13)

SAMPLE CODE

This code reads the 16-bit value from the encoder circuitry on axis 0 and axis 1.

```
# include "pcdsp.h"

int main()
{
     int16 pos_0, pos_1;

     if (dsp_init(PCDSP_BASE))   /* any problems initializing? */
             return dsp_error;    /* just terminate the program. */

     pos_0 = dsp_read_dm(0x0014);
     pos_1 = dsp_read_dm(0x0015);
     printf("\nEncoder0: %d Encoder1: %d\n", pos_0, pos_1);

     return dsp_error ;        /* global variable provided by the library */
}
```

APPENDIX A ABOUT THE DSP CONTROLLER

Hardware Architecture

The DSP Series controller uses a unique architecture to provide advanced capabilities without excessive complexity. Instead of sending ASCII strings to the controller, the MEI software communicates directly with the controller. The DSP Series controller is mapped into the I/O space of the host CPU and allows *direct binary communication* across the DSP's data bus.

A complete function library and source code is provided with the DSP Series controller. The library functions manipulate and conceal the internal details of the controller, enabling you to concentrate on the application.

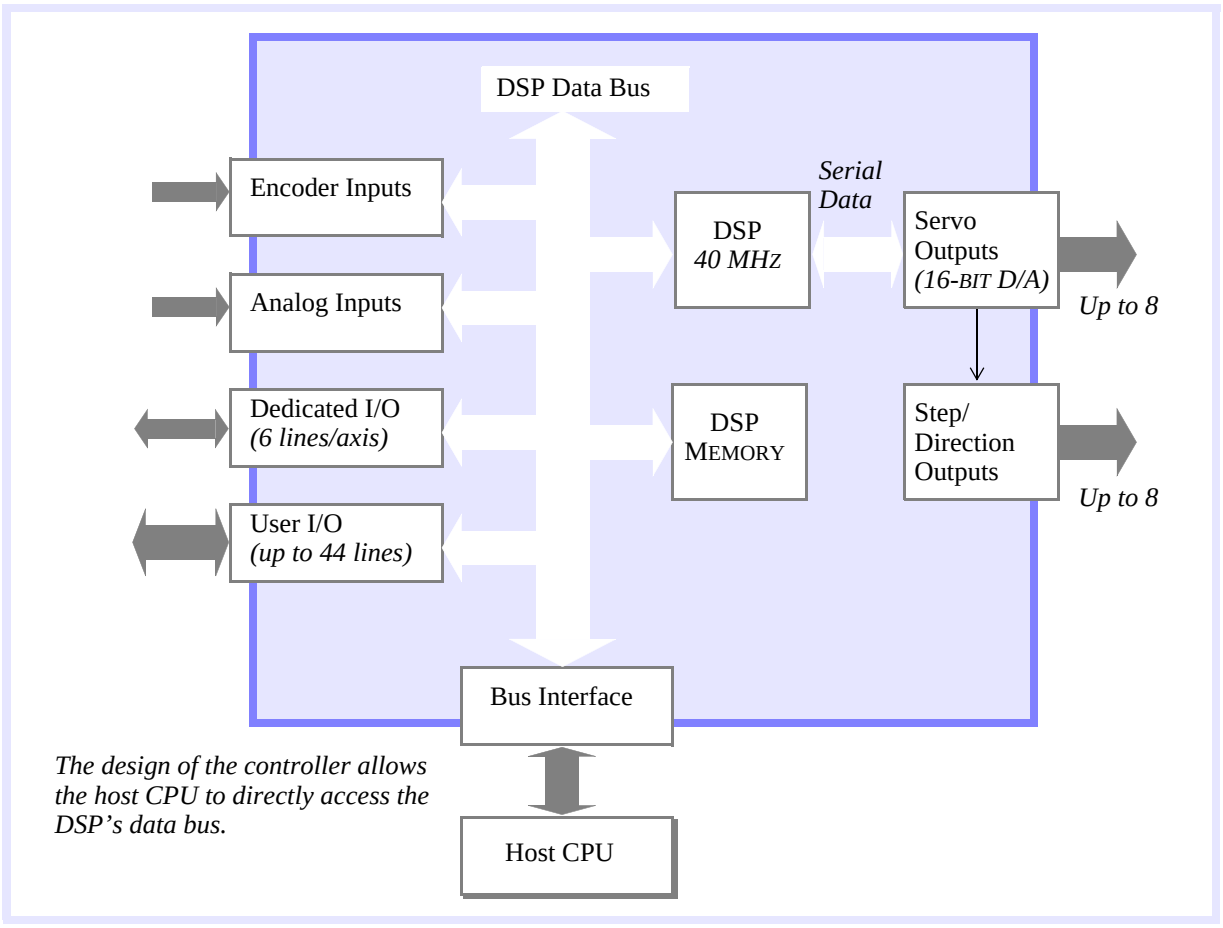
Open architecture takes advantage of the power, memory and abundance of peripherals available with modern computers. It provides an excellent development platform with familiar programming tools and minimal operating system overhead. Users are not restricted by commands stored in EPROM. Applications are not hindered by slow internal ASCII communications. Motion and I/O control can be buffered on-board or executed immediately.

The controller utilizes the Analog Devices 40 MHz ADSP-2105 device for on-board computing power. The DSP handles all servo-loop calculations, command position trajectory calculations, frame buffer execution, response to programmable software limits, hardware limits, and many other features.

On a hardware level, the controller is a small microcomputer unto itself. It has its own address and data bus which the DSP, its data memory, and peripherals use for communication. The host CPU and the DSP have direct access to the data bus enabling fast communication. The host CPU and the DSP do not have direct communication; instead messages are passed through the DSP's external data memory via the data bus. It's like a chalkboard, where they communicate by reading or writing messages, instead of directly modifying DSP registers.

However, the DSP does not require the constant attention of the CPU. The only time the CPU needs to perform reads/writes to the data bus is when your application requests information or commands motion. Commanded motion can be executed immediately or stored in the DSP's memory buffer for later execution.

Figure A-1 DSP Controller Block Diagram



Hardware + Firmware + Software

The hardware consists of a DSP, memory (volatile and non-volatile), 16-bit A/D converter(s), +/-10 volt op-amp output(s), voltage-to frequency-converter(s) (VFC), 8255 chips for user and dedicated I/O, assorted programmable logic and bus interface components. Some versions also have an 8-channel 12-bit A/D converter and an 8254 counter/timer.

The DSPpro Series, which consists of the DSPpro-Serial, DSPpro-PC, and DSPpro-VME, combines an Intel 386EX microprocessor and 387 math coprocessor along with the Analog Devices DSP. High-level decisions and communications with the host processor occur on the 386EX, while the DSP is responsible for numerically intensive calculations. With embedded DOS running on the 386EX, standard programs can execute on the DSPpro, completely independent of the host processor.

The firmware is written in Analog Devices assembly code and is stored in nonvolatile memory. The firmware contains the code necessary to operate the hardware as a motion controller. Without the firmware, the DSP Series controller would simply be a generic I/O, A/D, D/A board. The firmware handles the real-time operation of the motion controller. The controller boot configurations are also stored in the firmware. Firmware can be uploaded to the host CPU and stored in a disk file or downloaded to the controller from a disk file.

The software resides in the host CPU. It contains all of the code necessary to communicate with the controller, configure the controller's hardware, configure its responses, command motion,

and control I/O. The software communicates with the hardware by directly reading and writing through the CPU's I/O space. Responsibilities of the software and firmware also can be swapped, as required by the application.

Internal Boot Sequence

The PC/DSP Series controllers use the hardware reset line from the host CPU to boot the DSP. At power-up, the reset line toggles high (+5V) for 300 milliseconds, which then causes the boot memory to be loaded into the DSP. The surface mount DSP Series controllers boot directly from the +5V power.

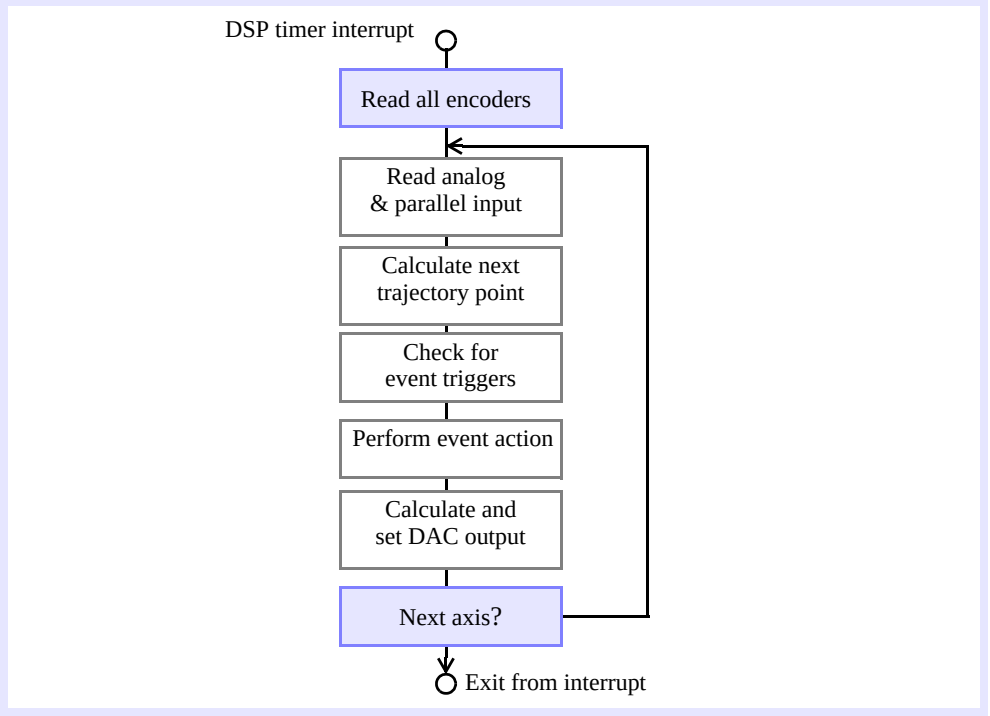
Table A-1 DSP Boot Sequence

Step	***Label***
1	Load firmware from on-board Non-Volatile memory
2	Initialize all variables
3	Reset all peripherals
4	Turn off all outputs (High impedance)
5	Set defaults from on-board Non-Volatile memory

Firmware Execution

After the firmware is loaded, the DSP repeatedly executes the following series:

Figure A-2 The DSP's Main Execution Loop



Read All Encoders

Immediately after the DSP's timer interrupt (the timer interval is determined by the sample rate), the DSP reads the 8 encoder inputs and stores them into memory for future use. Next the DSP runs a series of events for each axis *before* the next timer interrupt.

Read Analog and Parallel Input

If an axis is configured to read an analog input, the DSP writes a control word to the A/D, waits for the conversion, reads the 12-bit digital value, and stores it in memory. If an axis is configured to read the parallel input, the DSP reads the 32 user I/O bits and stores the values in memory.

Calculate Next Trajectory Point

The DSP calculates an axis' command position trajectory. It maintains a command jerk, command acceleration, command velocity, and command position.

Table A-2 Trajectory Calculations at Sample n

Quantity	***Calculation***
Time	$T_n = T_{n-1} + FdSpd$
Command acceleration	$A_n = A_{n-1} + FdSpd * J$
Command velocity	$V_n = V_{n-1} + FdSpd * A_n$
Command position	$X_n = X_{n-1} + FdSpd * V_n$

Where

T_n is the time at sample *n*
A_n is the command acceleration at sample *n*
V_n is the command velocity at sample *n*
X_n is the command position at sample *n*

and

FdSpd is the feed speed
J is the command jerk

The command velocity is the *rate of change* of the command position, the command acceleration is the *rate of change* of the command velocity, and the command jerk is the *rate of change* of the command acceleration.

Check for Event Triggers

The DSP checks an axis' positive limit input, negative limit input, home input, amp fault input, and software position limits. Also, the DSP checks the axis for time limits, position triggers, and I/O triggers to determine if a new frame is to be executed.

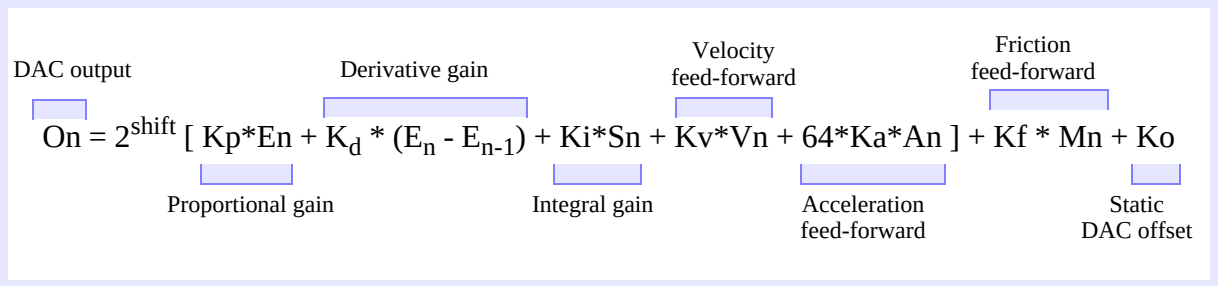
Perform Event Actions

If an event trigger exists for an axis, the DSP performs the associated event. The 4 possible types of events are: Abort Event (highest priority), E-Stop Event, Stop Event, or New Frame Event (lowest priority).

Calculate and Set DAC Output

The DSP calculates an axis' output (analog voltage or pulse rate) based on a PID servo-control algorithm. The input to the PID algorithm is the current *position error*. The current position error equals the difference between the command position and the actual position. The actual position is controlled by the feedback device, while the command position is controlled by the trajectory calculator. The PID algorithm is based on a formula.

Figure A-3 Formula for PID Algorithm



The subscripted $_n$ represent the sample period. The terms are defined:

Sn = Sn-1 + En if -Smax < Sn < Smax
Smax if Sn > Smax
-Smax if Sn < -Smax

Table A-3 PID Terms

Term	***Term***
On = DAC output (control voltage)	shift = overall scale factor
Kp = proportional gain	Kd = derivative gain
Ki = integral gain	Kv = velocity feed-forward
Ka = acceleration feed-forward	Ko = static DAC offset
Kf = friction feed-forward	En = position error
Mn = 0 or 1 based on the command velocity	Vn = command velocity
An = command acceleration	Sn = integrated error
Smax = maximum integrated error	

The error (En) is the basis for changes in control voltage (On). To review how each element of the PID algorithm affects motion, consult the *Installation Manual*. The same PID algorithm is used for open-loop and closed-loop step and servo motor control. Using the same PID algorithm makes the programming the same for both motor types.

Step Motor Control via VFCs

Step motors are controlled via the analog control voltage. The analog control voltage (DAC) is connected to a voltage-to-frequency converter (VFC). The VFC generates a pulse train directly proportional to the input voltage. The relationship between the analog control voltage and the pulse output rate is constant and linear over the entire frequency range. This is a major performance enhancement over timer/divider pulse generators which have exponential pulse output rates, and will cause large changes in step rate at high frequencies.

Since a step motor's torque curve is inversely related to its speed, a step motor is more susceptible to stalling at high speeds. Thus, a VFC at high pulse rates is less likely to stall a step motor. Another advantage of the VFC is the high pulse output resolution.

The step pulse output supports the following speed ranges:

Table A-4 Step Pulse Output Speed Ranges

Controller	***Slow (kHz)***	***Medium (kHz)***	***Fast (kHz)***	***Superfast * (kHz)***
PC/DSP	0 - 125	0 - 500	0 - 2.0 MHz	*N/A*
PCX/DSP	0 - 20	0 - 80	0 - 325	0 - 550
STD/DSP	0 - 20	0 - 80	0 - 325	0 - 550
104/DSP	0 - 20	0 - 80	0 - 325	0 - 550
LC/DSP	0 - 20	0 - 80	0 - 325	0 - 550
V6U/DSP	0 - 20	0 - 80	0 - 325	0 - 550
104X/DSP	0 - 20	0 - 80	0 - 325	0 - 550
DSPpro-Serial	0 - 20	0 - 80	0 - 325	0 - 550
DSPpro-VME	0 - 20	0 - 80	0 - 325	0 - 550
CPCI/DSP	0 - 20	0 - 80	0 - 325	0 - 550
PCI.DSP	0 - 20	0 - 80	0 - 325	0 - 550

* To use the superfast step output speed, you must have version 2.5.05 software, 1.33/2.33 PROMS, and the following hardware board revisions (or higher):

Table A-5 Minimum Hardware Revision Levels Required for Faster Step Output Speed

Controller	***Revision***
PCX/DSP	3
STD/DSP	8
104/DSP	6
104X/DSP	2
LC/DSP	8
CPCI/DSP	1
PCI/DSP	1
VME/DSP	3

The voltage level *at which steps are produced by the VFCs* is determined by the internal DAC offset *set by the CONFIG.EXE program*. This offset is usually required so that the DAC's *output zero* agrees with the VFC's *input zero*. If the analog *zero volt output* is above the VFC *zero input*, the VFC will begin outputting steps.

The firmware guarantees the VFC will not output steps when the command velocity is zero *and* the position error is zero. If the offset is set too high, the firmware will automatically *shut down* the step pulse output at the end of a move. If the offset was set too low, a small delay will occur between the time the command position changes and the step motor actually starts moving. The delay would be minimal, rarely exceeding 2 sample periods and would be based on the acceleration and velocity figures.

One great design advantage is that the *same programming* is used to control either step *or* servo motors. If no motors are connected to the DSP Series controller, you can simulate motors by configuring the axes as open-loop steppers. Refer to the *DSP Series Installation Guide*.

Motion Concepts

What is a Frame?

A frame is the most basic piece of information that the DSP uses to create motion. Each frame contains information about changes in any of the axis' command jerk, acceleration, velocity, or position parameters. The computer queues up motion in a FIFO (first in, first out) buffer called the frame buffer. The frame buffer can store 600 frames. For example, when a **move(...)** function is invoked, the host processor calculates what values are to be put into the frames, then modifies the frames in the buffer. The DSP later executes these frames.

Communication via 3 Words in I/O Space

External data memory is mostly dedicated to the frame buffer containing information about changes in an axis' current trajectory. For example, a constant velocity move will have an acceleration frame, followed by a slowing or constant velocity frame. These 2 frames are downloaded into the buffer for DSP execution.

The library's job is to simplify this interface. While you gain immense flexibility in axis trajectory manipulation, most applications only require simple trapezoidal-profile or similar motion. Rather than being concerned with the low-level details of frames, you need only be concerned with library functions controlling trapezoidal profile or any other type of motion. These functions translate trapezoidal or other motion profiles into frames for you.

Function Execution Time

Because the host processor and the DSP may be tightly integrated, some consideration must be given to the execution time of the functions. The functions communicate with the DSP controller by either of 3 methods:

Table A-6 How Functions Communicate with the DSP

Method	*Description*
1	Downloading frames
2	Reading/writing to the transfer block (makes it possible to read/write to the DSP's internal memory)
3	Reading/writing directly to the external memory or peripherals mapped in the external memory

It is impossible to predict exactly how much time each function will require to execute. Generally, reading/writing to the peripherals is the fastest, followed by downloading frames and reading/writing to the transfer block.

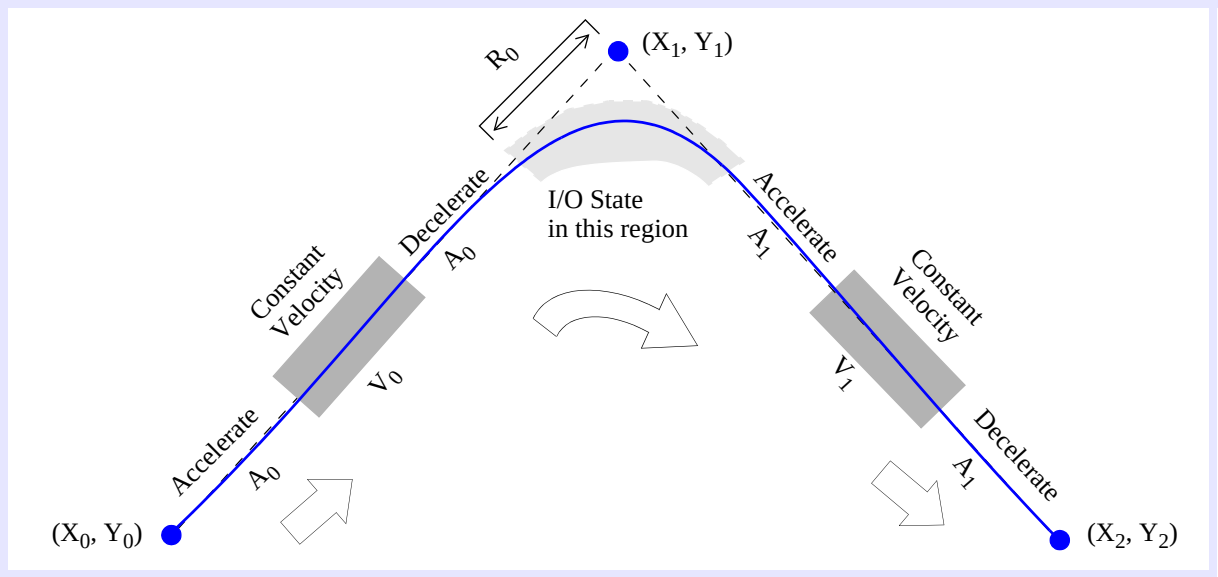
A faster processor will improve the execution speed of the functions but will have no effect on the actual motion executed by the DSP. There are several contributing factors that determine the execution speed. A faster CPU will improve the calculation time and a math coprocessor will greatly improve floating point calculations (recommended for coordinated motion).

The *Applications* diskette contains the sample program *speed.c*. This demonstrates how the CPU clock can be used to find the execution time of a particular function with a specific CPU.

Coordinated Motion

A coordinated move guarantees that all of the chosen axes (2 to 8 axes) are commanded to *start and stop at the same time*. The DSP controller can perform coordinated motion through a series of points (a path), by providing smooth interpolation between the points in the list. As a corner in the path is approached, the controller begins to accelerate toward the new direction of motion *prior to* reaching the corner. This produces a sequence of *blended moves* which approximate a path described by the straight lines joining the points. The next figure illustrates the motion geometry of a two-dimensional example.

Figure A-4 2-Axis Coordinated Motion



The path in the figure represents the motion described by 3 points [(X_0,Y_0),(X_1,Y_1),(X_2,Y_2)]. The motion starts at (X_0,Y_0), proceeds to (X_1,Y_1), and terminates at (X_2,Y_2). The acceleration specified in the first point (A_0) is used during the indicated portions of the motion and around the first corner. The corner radius R_0 is a function of the vector acceleration and the vector velocity:

$$R_0 \approx (Vel^2) / (2 * Accel)$$

Accel is set by **set_move_accel(...)**, and Vel is set by **set_move_speed(...)**. The output value specified in the second point is output by the controller at the *beginning* of the corner acceleration section of the motion.

How to Program Coordinated Motion

Use the following programming steps to generate coordinated motion:

1. Define a map for the coordinate system (x, y, z, ...) to the physical axes (0, 1, 2...)
2. Set the initial speed, acceleration, and arc interpolation angle
3. Initialize the point list
4. Store points in the list
5. Terminate the list

The motion may be started at any time *after* the first point has been stored in the list (before or after the list has been terminated). Once the motion has been started, the host processor must keep adding points to the list *before* the DSP needs them.

How often the host processor needs to send new points to the controller depends on the distance between points and the motion speed. A math coprocessor considerably enhances the number of points/second that can be generated. Generally, it takes longer for a program to compute a point than it takes to load it into the controller.

The DSP controller can buffer several points in the on-board frame buffer. Motion must be started *before* the on-board buffer is full. Generally, during linear and circular coordinated motion the DSP uses roughly 2 frames/point, per axis. The number of points which can be stored in the on-board buffer is limited.

Table A-7 How Many Points Can Be Stored in DSP Buffer?

Number of Axes	***Points***
2	150
3	100
4	75
5	60
6	50
7	43
8	38

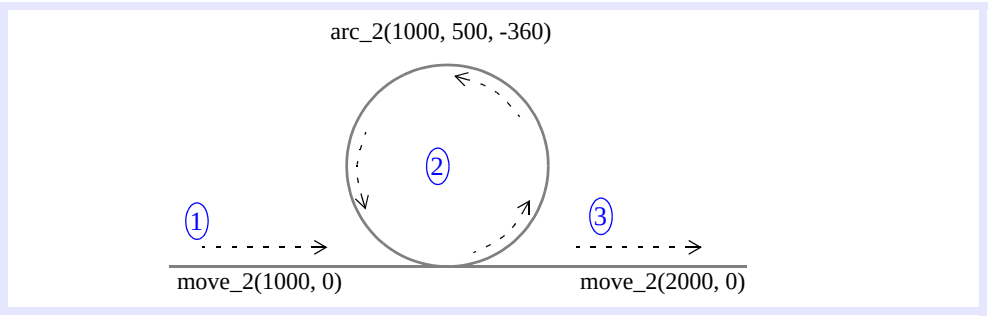
The **start_point_list(…)** function defines the *beginning* of a coordinated motion path, while the **end_point_list(…)** function defines the *end* of a coordinated motion path.

In MEI software version 2.5, **start_point_list(…)** automatically checks to see if a previous point list has been completed. If the previous point list has not been completed, then **end_point_list(…)** will be called internally.

The next code fragment shows a simple coordinate motion sequence:

```
int ax[2] = {0,1};
.
.
map_axes(2,ax);
start_point_list();
move_2(1000.0,0.0);
arc_2(1000.0,500.0,-360.0);
move_2(2000,0.0);
end_point_list();
start_motion();
.
.
```

Figure A-5 Simple Coordinated Move



I/O with Coordinated Motion

The user I/O can be accessed during coordinated motion. The *number of ports* that can be accessed with the coordinated I/O functions is equal to the *number of axes* configured with **map_axes(...)**.

The functions **set_move_bit(...)**, **reset_move_bit(...)**, and **change_move_bit(...)** can be used to set or clear an individual output bit during coordinated motion. The first 16 bits of user I/O (ports 0 and 1) can be set with **set_move_output(...)**. Make sure to call **init_io(...)** to initialize the user I/O before you use any of the user I/O functions.

All of the standard I/O functions (non-coordinated) can be used for immediate access to the I/O during coordinated motion (invoked outside of the point list).

APPENDIX B ABOUT SERCOS

The SERCOS (Serial Real-Time Communication System) protocol was designed specifically for the motion control industry. The protocol uses a ring topology which allows communication to occur at specific assigned times within a predetermined cycle. Thus, SERCOS is **deterministic** allowing the Master (control unit) to synchronize command and feedback values to and from all of the Slaves (drives). Major topics in this chapter include

Brief Intro

About the MEI SERCOS Controller

The SERCOS/DSP Series controllers from MEI are an extension of the DSP Series motion controllers. DSP Series motion controllers support analog motion control outputs, encoder inputs, and discrete digital I/O. SERCOS/DSP Series motion controllers replace these signals with the SERCOS digital fiber optic network interface. The SERCOS interface only requires two fiber optic connections (one output and one input) to connect to a fiber loop containing up to 8 axes of motion.

Both SERCOS and standard DSP Series controllers share the same basic hardware architecture, onboard firmware, host software and many other features. So, for controller installation procedures, *Motion Console* application and C programming information, use the documentation from the *DSP Series Installation* and *C Programming Manuals* for both controllers.

However, because the SERCOS IDNs are actually implemented in the drive (and not in the controller), there are many SERCOS functions not documented in this *Programming Reference*, that are in the drive's documentation (because these functions are associated with the drive and not the controller). Motion Engineering adheres to the specifications set forth by the IEC concerning SERCOS. For more information regarding SERCOS or the SERCOS specification, please contact SERCOS N.A at *www.sercos.com*.

Supported Drives/Modules

MEI currently supports drive and I/O modules from a variety of manufacturers. If you desire support for a drive or I/O vendor not listed, please contact MEI.

Table B-1 Supported Drives and I/O Modules

Manufacturer	***Device***
Indramat	Servo Drives
Modicon	Servo Drives
Lutze	Digital I/O Modules
Pacific Scientific	Servo Drives
Kollmorgen	Servo Drives
Sanyo Denki	Servo Drives

MEI Software

Initialization Structures

During SERCOS initialization, several new structures are used to configure the communication ring. These structures are defined in SERCOS.H.

The DRIVE_INFO structure specifies the drive's axis number, address, operation mode, and the manufacturer:

```
typedef struct {
   int16 drive_axis;
   unsigned16 drive_addr;
   unsigned16 drive_mode;
   unsigned16 drive_mfg;
} DRIVE_INFO;
typedef DRIVE_INFO *DriveInfo;
```

The DRIVE_IDNS structure is used to set the value of an IDN during phase 2 of the communication ring. The DRIVE_IDNS structure specifies a drive's IDN, the IDN value, and a drive's address.

```
typedef struct {
   unsigned16 idn;
   long value;
   unsigned16 drive_addr;
} DRIVE_IDNS;
typedef DRIVE_IDNS *DriveIdns;
```

The CYCLIC_DATA structure is used to specify which IDNs to place in either the Amplifier Telegram (AT) or the Master Data Telegram (MDT).

```
typedef struct {
   unsigned16 idn;
   unsigned16 drive_addr;
} CYCLIC_DATA;
typedef CYCLIC_DATA *CyclicData;
```

Drive Manufacturers

The manufacturers of SERCOS and compatible drives and I/O modules are defined in SERCOS.H. These values are used in the DRIVE_INFO structure.

```
#define   LUTZE 0
#define   PACSCI 1
#define   MODICON 2
#define   INDRAMAT 3
#define   KOLLMORGEN 4
#define   MEI 5
#define   SANYO_DENKI 6
#define   OTHER 32
```

Drive Modes

Note: Any drive mode with _STD appended will not support user-specified cyclic data. *serc_reset(...)* will ignore user specified cyclic data configurations for a drive mode appended with _STD. Several drive modes and drive mode variations are supported:

Table B-2 SERCOS Drive Modes Supported

defines	*Value*	*Description*
TORQMODE	1	Torque mode (telegram type 7)
VELMODE	2	Velocity mode (telegram type 7)
POSMODE	3	Position mode (telegram type 7)
VELOCITY_STD	5	Standard telegram type 3 (no user-specified cyclic data)
POSITION_STD	6	Standard telegram type 4 (no user-specified cyclic data)
POS_VEL_STD	7	Standard telegram type 5 (no user-specified cyclic data)
EXT_VELMODE	9	Indramat drive, Velocity mode, 2nd position encoder (telegram type 7)
DUAL_LOOP_VELMODE	10	Velocity control, dual encoder feedback (telegram type 7)
ANALOG_VELMODE	11	Velocity control, analog feedback (telegram type 7)
ANALOG_TORQUEMODE	12	Torque control, analog feedback (telegram type 7)
USERMAP	13	User-specified cyclic data (telegram type 7)

Initialization Status

During initialization with *serc_reset(…)*, information is written to several status variables and structures. These variables and structures can be very useful in debugging initialization problems.

During initialization, several status messages are copied to *driveMsgs* from IDN 95.

```
typedef struct{
   char msgstr[MAX_ERROR_LEN];
} MsgStr;
extern MsgStr driveMsgs[PCDSP_MAX_AXES][MSGS_PER_AXIS];
```

If *serc_reset(...)* fails to initialize the communication ring, it will return a non-zero error code. This error code, the `driveMsgs`, and the visual display on the drive can be used to troubleshoot initialization problems. Please see the sample SERCOS Initialization programs on the *Applications* diskette and *SERCOS Initialization* on B-27.

Here are some additional variables and arrays that contain status information regarding SERCOS initialization:

```
extern int16 assignedDrive[PCDSP_MAX_AXES];
extern int16 driveCount;    /* number of drives found during
                               serc_reset() */
extern int16 logCount[PCDSP_MAX_AXES];   /* number of drive messages
                                            for each axis */
```

```
/* The following data structures are filled out if serc_reset() fails
during the transition between phase 2 and phase 3. */

extern int16 phase2_idncount[PCDSP_MAX_AXES];    /* number of IDNs
                                                    not set correctly */
extern unsigned16 phase2_idnlist[PCDSP_MAX_AXES][MAX_IDNLIST_LEN];

/* The following data structures are filled out if serc_reset() fails
during the transition between phase 3 and phase 4.*/

extern int16 phase3_idncount[PCDSP_MAX_AXES];   /* number of IDNs not
                                                   set correctly */
extern unsigned16 phase3_idnlist[PCDSP_MAX_AXES][MAX_IDNLIST_LEN];
```

MEI Developer Topics

Service Channel Error Messages

Error messages can be transmitted via the Service Channel of ATs.

Table B-3 Service Channel Error Messages

Error	***Bits*** 15 - 12 ***(Hex)***	***Bits*** 3 - 0 ***(Hex)***	***Description***
General Error	0	0	No error in service channel
		1	Service channel not open
		9	Invalid access to closing the ring
Element 1	1	1	No IDN
		9	Invalid access to element
Element 2 **Names**	2	1	No name
		2	Name transmission too short
		3	Name transmission too long
		4	Name cannot be changed
		5	Name is write-protected
Element 3 **Attributes**	3	2	Attribute transmission too short
		3	Attribute transmission too long
		4	Attribute cannot be changed
		5	Attribute is write-protected
Element 4 **Units**	4	1	No units
		2	Unit transmission too short
		3	Unit transmission too long
		4	Unit cannot be changed
		5	Unit is write-protected
Element 5 **Min Value**	5	1	No minimum value
		2	Min value transmission too short
		3	Min value transmission too long
		4	Min value cannot be changed
		5	Min value is write-protected
Element 6 **Max Value**	6	1	No maximum value
		2	Max value transmission too short
		3	Max value transmission too long
		4	Max value cannot be changed
		5	Max value is write-protected
Element 7 **Operation Data**	7	2	Operation data transmission too short
		3	Operation data transmission too long
		4	Operation data cannot be changed
		5	Operation data is write-protected
		6	Operation data is less than minimum value
		7	Operation data is greater than maximum value
		8	Invalid data (an invalid bit combination for this IDN)

SERCOS Overview

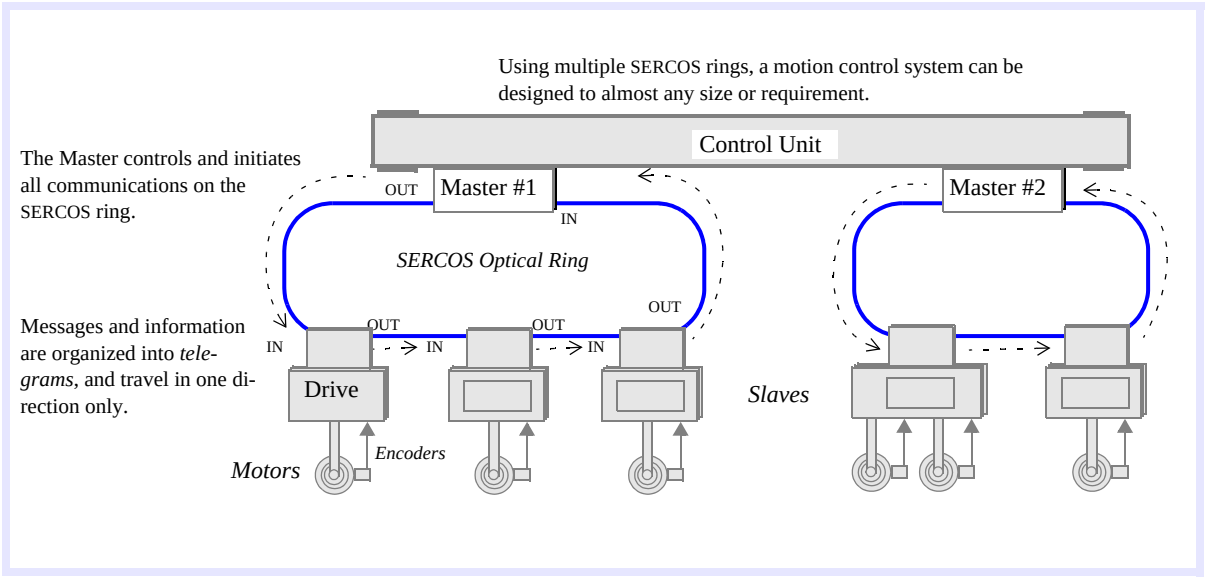
SERCOS (SErial Real-time COmmunication System) is the international standard for optical communication between motion control units and drive modules. It was developed by the International Electrotechnical Commission (IEC) specifically for motion control and is defined by the IEC 1491 standard. SERCOS supports data rates up to 4 Mbits/sec over a fiber optic ring. Data can be transmitted deterministically in real time based on the loop update rate (cyclic), or at lower bandwidths for less critical operations (non-cyclic). A *SERCOS-compatible* communication ring must have a single controller (master) and 1 - 254 drive or I/O modules (Slaves).

Also, data communication can be performed in either a synchronous or asynchronous manner. The protocol allows the user to configure the communication telegrams to send *whatever* data is appropriate synchronously. Data that has not been configured to reside in the communication telegrams can be sent or retrieved asynchronously by use of a *Service Channel* contained within the communication telegrams. Generally, synchronous data is data that is critical to real-time operation (e.g., command and feedback data, status).

SERCOS is a unidirectional serial communications protocol for connecting multiple drives (Slaves) to a motion controller (Master) over a fiber optic ring, in an industrial environment. The control and status information is organized into *telegrams*, and travels in a serial data stream around the SERCOS ring. All messages are synchronized according to the SERCOS cycle time, the timing of which is configured during initialization by the Master. Each Slave on the ring repeats the telegrams sent to it, sending them to the next device on the ring, and inserting its own telegram into the designated time slot in the serial data stream.

Starting at the output port of the Master, the devices are connected in the ring in a daisy-chain fashion, connecting from the output port of one device to the input port of the next device, and so on, until the ring is closed back at the input port of the Master. Up to 254 drives can be connected on a SERCOS ring, although the systems requirements for update rates and data will usually limit the number of devices to many fewer than that. SERCOS networks can operate at 2 or 4 Mbit/sec, with 10 Mbit/sec throughput expected soon. Maximum distances from input port to output port can be 60 meters (plastic fiber) to 250 meters (glass fiber).

Figure B-1 SERCOS Topology



Operation Modes

The SERCOS communication interface supports three main operation modes (Torque, Velocity and Position). The operation mode defines the real-time digital messages sent between the controller and the drive(s).

Table B-4 SERCOS Has 3 Main Operation Modes

Mode	***To Drive***	***To Controller***
Torque	16 bit Command Torque	32 bit Actual Position
Velocity	32 bit Command Velocity	32 bit Actual Position
Position	32 bit Command Position	32 bit Actual Position

In addition to the main operation modes SERCOS supports several variations. Since the communication interface is determined by the firmware/software in the controller and the firmware/software in the drive, the real-time data is configurable.

Currently the SERCOS/DSP Series firmware/software supports several operation modes. Some operation modes are drive specific while others are drive independent. Motion Engineering is constantly testing and certifying compatibility between our controller and SERCOS-compatible drives.

Most drives support the three main operation modes (Torque, Velocity and Position). Please consult your drive specific documentation regarding supported operation modes and variations.

In all modes, the controller calculates a 32 bit command position every sample. The command position is based on the current command jerk, command acceleration and command velocity. Also the controller calculates a 16 bit position error, which is the difference between the command position and the actual position from the drive.

In Torque mode, the controller sends a 16 bit command torque to the drive. The drive sends a 32 bit actual position back to the controller. Every sample, the controller calculates a new command torque based on the position error and the PID algorithm. The controller closes the position and velocity loop and the drive closes the torque loop.

In Velocity mode, the controller sends a 32 bit command velocity to the drive. The drive sends a 32 bit actual position back to the controller. Every sample, the controller calculates a new command velocity based on the position error and the PID algorithm. The controller closes the position loop, and the drive closes the velocity and torque loop.

In Position mode, the controller sends a command position to the drive. The drive sends a 32 bit actual position back to the controller. Every sample, the controller calculates a new command position. The drive closes the position, velocity and torque loop.

Closed-Loop Tuning

A general difference between SERCOS digital drives and conventional analog drives is that digital drives have on-board intelligence and can close position or velocity loops within the drive. **In all operation modes,** "tuning" requires setting parameters in the drive and the controller. Thus, an understanding of both the controller and drive control algorithm is necessary for successful drive tuning.

The controller tuning parameters can be set with *Motion Console* (for Windows-based systems), SETUP (for DOS-based systems), or the *set_filter(…)* function. For more information on the controller's tuning procedures please consult the *Tuning* section in the *DSP Series Installation Manual*.

The drive's tuning parameters must be set using the *set_idn(…)* function and the values are determined from information supplied by the drive manufacturer. Please consult the drive-specific documentation for more information on the drive's tuning parameters. While Motion Engineering has considerable experience with the listed drives and can generally offer tuning guidelines for drive parameters, difficult tuning situations may require support from the drive vendor or manufacturer.

In Velocity mode, the controller's PID output controls the motor's velocity. Therefore, the drive's velocity loop must be tuned and the controller's position loop must be tuned. The tuning procedure is identical to a standard analog output DSP Series controller connected to a velocity-controlled amplifier. Note that the controller's Velocity Feed Forward term is very useful in velocity-controlled systems.

In Position mode, the controller's PID algorithm is not used. The drive is responsible for the closed loop control. Therefore, the drive's velocity and position loop must be tuned. The controller's tuning parameters have no effect on the system's response.

Axis/Drive Assignments

All drives and I/O modules are identified by a unique *drive address*, which is independent of the *axis number*, e.g, axis 0 could use drive address 2 while axis 1 could use drive address 14. Some functions use the axis number to reference the drive, while others use the drive address. Functions that are common to both SERCOS and conventional DSP Series controllers will use the axis number rather than the drive address. Most new SERCOS functions will also use the axis number to reference the drive. Generally, the drive address is only used in functions that are called before the SERCOS communication loop is initialized. For example, *serc_reset(…)* requires the drive addresses for initialization.

Data Transmission

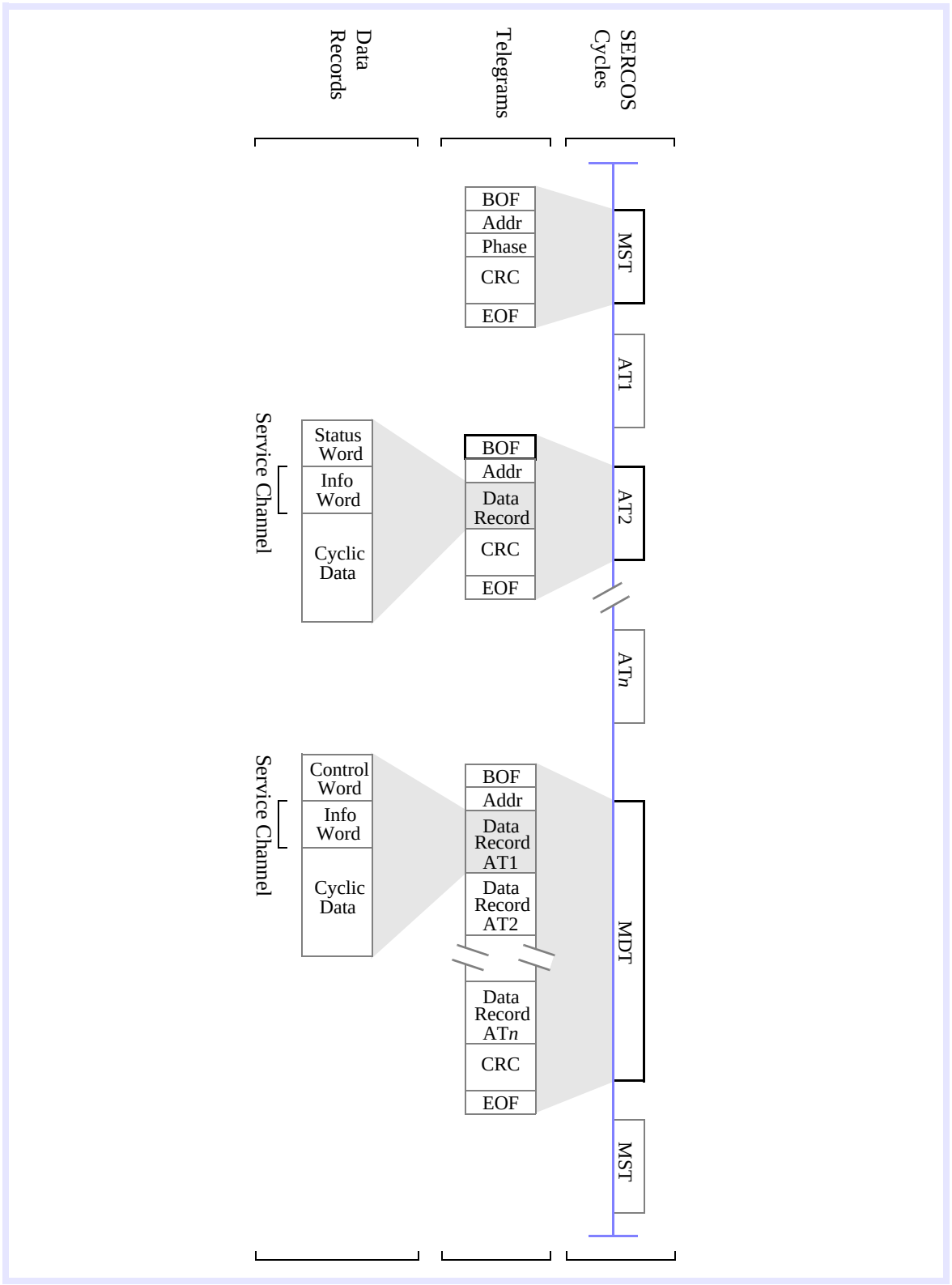
SERCOS supports two types of data transmission, cyclic and non-cyclic.

Cyclic data is the critical real-time synchronized data sent between the Master and the Slaves (drives, I/O modules). In every SERCOS cycle, the Master sends and receives fixed-length messages to the drives and I/O modules. These messages contain the motion control command signal and the feedback response for each drive or the digital I/O commands and responses for each I/O module. The cyclic data is guaranteed to reach each drive and I/O module and return to the Master at a fixed time interval, the SERCOS cycle.

Non-cyclic data is the noncritical asynchronous data. The cyclic fixed-length messages have space (called the *Service Channel*) reserved for non-cyclic data. In each SERCOS cycle, the Master may transmit two bytes of non-cyclic data through the Service Channel to each Slave. Note that it may require several SERCOS cycles for the Master to complete the transmission of the non-cyclic data to the Slaves. Typically, transmitting non-cyclic data is much slower than cyclic data.

SERCOS cycles are built using telegrams, which in turn contain data records for all of the Slave drives. Cyclic data is transferred in the cyclic data part of the data records. Non-cyclic data is transferred in the Service Channel of data records. Refer to the next figure.

Figure B-2 SERCOS Cycles - Telegrams - Data Records



Telegrams

The controller (Master) communicates with the drives and I/O modules (Slaves) using *telegrams*. A telegram is a structure that contains data, error checking and handshaking information. SERCOS supports three types of telegrams: Master Synchronization Telegram (MST), Master Data Telegram (MDT), and Amplifier Telegram (AT).

Each type of telegram contains 5 types of fields: BOF (beginning of frame), ADR (address), message field, FCS (frame check sequence), EOF (end of frame).

Figure B-3 General Telegram Structure

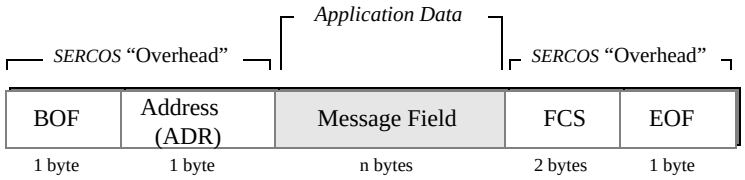
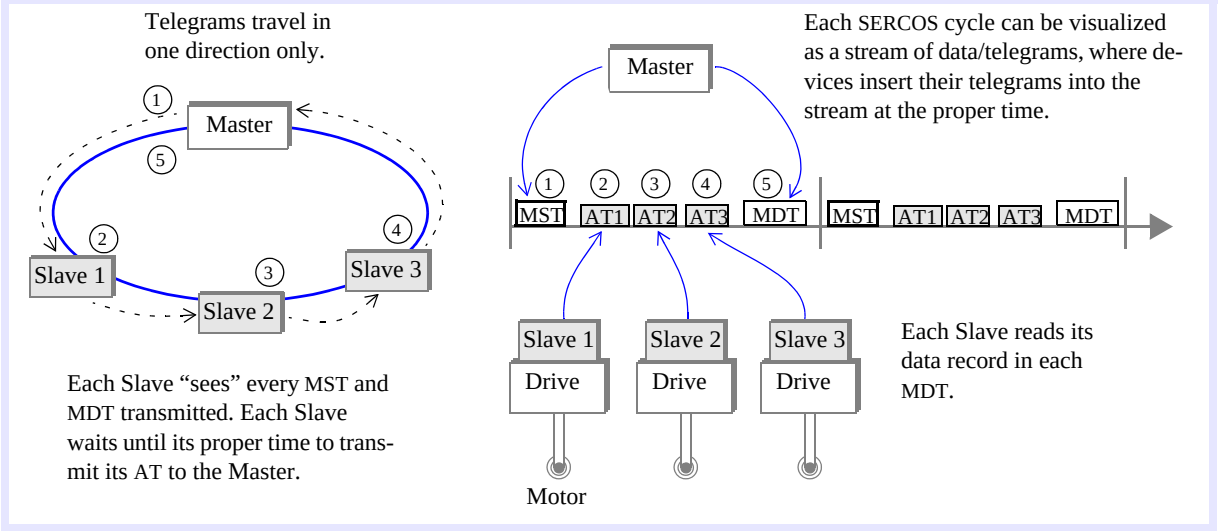


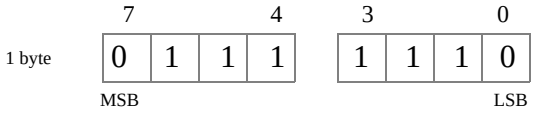
Figure B-4 Telegram Communications



BOF Delimiter

All telegrams have a BOF (beginning of frame) byte denoting the beginning of the telegram. The BOF is always 0111 1110.

Figure B-5 BOF Delimiter



ADR Target Address

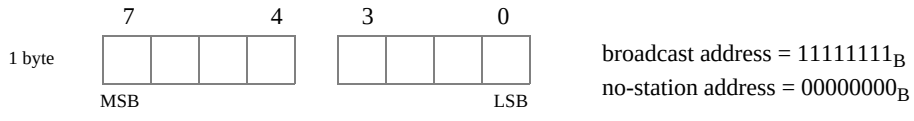
All telegrams have an ADR (address) byte, which denotes the address of a drive (Slave). In a telegram from the Master, the address specifies which drive the information is for. In a telegram from a Slave (drive), the address specifies the sourcing drive. The target addresses for the drives are valid if greater than 0 and less than 255. Typically, a drive's address is set using a selector located physically on the drive.

Address 0 is the "no station" address, and is sometimes used to remove a drive from the ring logically, during troubleshooting. During non-cyclic operations (Phases 0 - 2), the Master can only communicate with one drive per cycle. During cyclic operations (Phases 3, 4), the Master can communicate with all drives.

Table B-5 Address Values vs. Phases During Telegram Transmission

From	***To***	***Telegram***	***Non-Cyclic (Phases 0, 1, 2)***	***Cyclic (Phases 3, 4)***
Master	Slave	MST	255	255
Master	Slave	MDT	1 ≤ ADR ≤ 255	255
Slave	Master	AT	1 ≤ ADR ≤ 254	1 ≤ ADR ≤ 254

Figure B-6 ADR Target Address



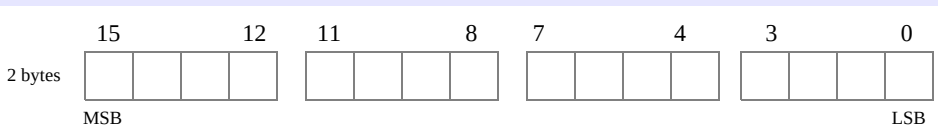
Message Field

Each Telegram (MST, AT, and MDT) contains a message field. The Message Field for the MST consists of one 8-bit word. The lower three bits of the MST contain Phase information. The Message Field for the AT consists of one Data Record. The Message Field for the MDT consists of one Data Record if the MDT's target address is a specific drive. If the MDT's Target address is all drives (255), then the Message Field for the MDT consists of one Data Record per drive in the system.

FCS (Frame Check Sequence)

All telegrams have a two-byte FCS number used to check data integrity. The frame check sequence (16 bits) is implemented according to ISO/IEC 3309, 4.5.2.

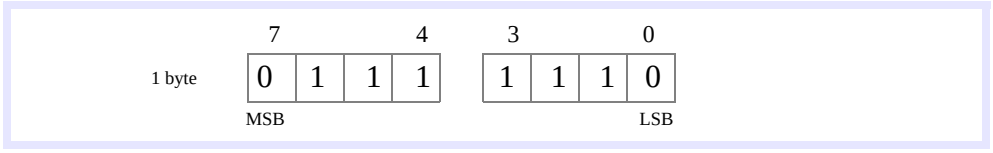
Figure B-7 FCS (Frame Check Sequence)



EOF (End Of Frame) Delimiter

All telegrams have an EOF byte denoting the end of the telegram. The EOF is always 0111 1110.

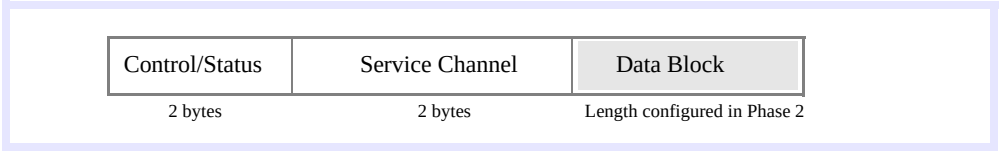
Figure B-8 EOF Delimiter



Data Record

Data Records are used by both the Amplifier Telegram (AT), and the Master Data Telegram (MDT) to send data. Generally, a Data Record consists of a 16-bit Control/Status word, a 16-bit Service Channel, and a Data Block of 16-bit words.

Figure B-9 Data record Structure



Amplifier Telegrams contain only one Data Record, because each Slave sends its own Amplifier Telegram.

During Phase 2, the Master sends a Master Data Telegram that is addressed to a specific Slave. Since only one Slave is to receive the MDT, the Phase 2 MDT has only one Data Record. During Phases 3 and 4, the Master sends a Master Data Telegram that is received by all Slaves on the ring. Since all Slaves receive the Master Data Telegram, the Phase 3-4 MDT has one Data Record for each Slave.

During Phase 2, the Data Block in both the AT and the MDT has a length of 0. This means that all data exchange between Master and Slave must take place using the Service Channel. Because the Service Channel is only 16-bits wide, data exchange can take multiple cycles. Service Channel exchange of data is referred to as **non-cyclic**.

During Phase 2, the Master is responsible for determining the data fields for the Data Blocks in the Phase 3-4 AT and MDT. The size and number of data fields will determine the size of the Data Block. Once defined in Phase 2, the fields and therefore the size of the Data Block is fixed. The data fields in the MDT usually contain command data. The data fields in the AT usually contain feedback data. Because the Data Blocks are configured in Phase 2, there is no overhead using the Data Blocks to send data in Phases 3 and 4. Data exchange using the Data Blocks is referred to as **cyclic**.

Master Synchronization Telegram

The Master Controller uses *master synchronization telegrams* (MST) to coordinate its transmission cycle timing with the Slaves. The Master initiates a SERCOS cycle by transmitting an MST to all of the drives and I/O modules on the ring.The MST message field contains one 8-bit word, of which the three lowest bits determine the communication phase of the system. The MST is sent at the beginning of the SERCOS cycle in all communication phases.

Figure B-10 MST Telegram Structure

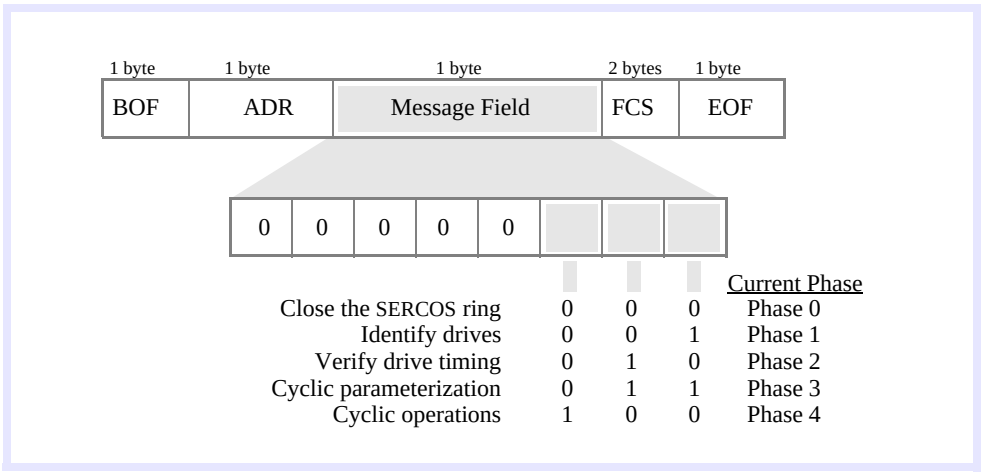


Table B-6 MST Telegram Fields

Field	***Bytes***	***Description***
BOF	1	Beginning of Frame. The BOF marks the start of a telegram.
ADR	1	The target address. In the MST, ADR = 255 (the broadcast address) during Phases 3 and 4.
Current Phase	1	The lower 3 bits designate the SERCOS phase (0 - 4)
FCS	2	Frame check sequence. The FCS field contains circular redundancy check (CRC) information.
EOF	1	End of Frame. The EOF marks the end of the telegram.

Master Data Telegram

During Phase 2, the Master must communicate with the Slaves in order to configure them for operations in Phases 3 and 4. In order to send or request data, the Master will send a Master Data Telegram (MDT) to a specific Slave (the Slave is addressed explicitly). Since only one Slave is to receive the MDT, the MDT Message Field contains only one Data Record, where the length of the Data Block (inside the Data Record) is 0, i.e., the data block is empty. During Phase 2, the Master sends data to each Slave via the Service Channel.

During Phase 2, the Master informs the Slave of the *byte offset* into the MDT at which the Data Record resides for that Slave. The length (in bytes) of the Data Block within each Data Record depends on the data fields configured by the Master during Phase 2. The data fields within the Data Block usually contain command information.

During Phases 3 and 4, once per SERCOS cycle the Master sends a Master Data Telegram (MDT) that has a **global** (broadcast) address. Because the global address is used, all Slaves receive the MDT. Since all Slaves will receive the MDT, the MDT Message Field contains one Data Record for each Slave in the system. During Phases 3 and 4, data is sent to a Slave by using the Data Blocks (cyclic) or the Service Channel (non-cyclic).

Figure B-11 MDT Telegram Structure

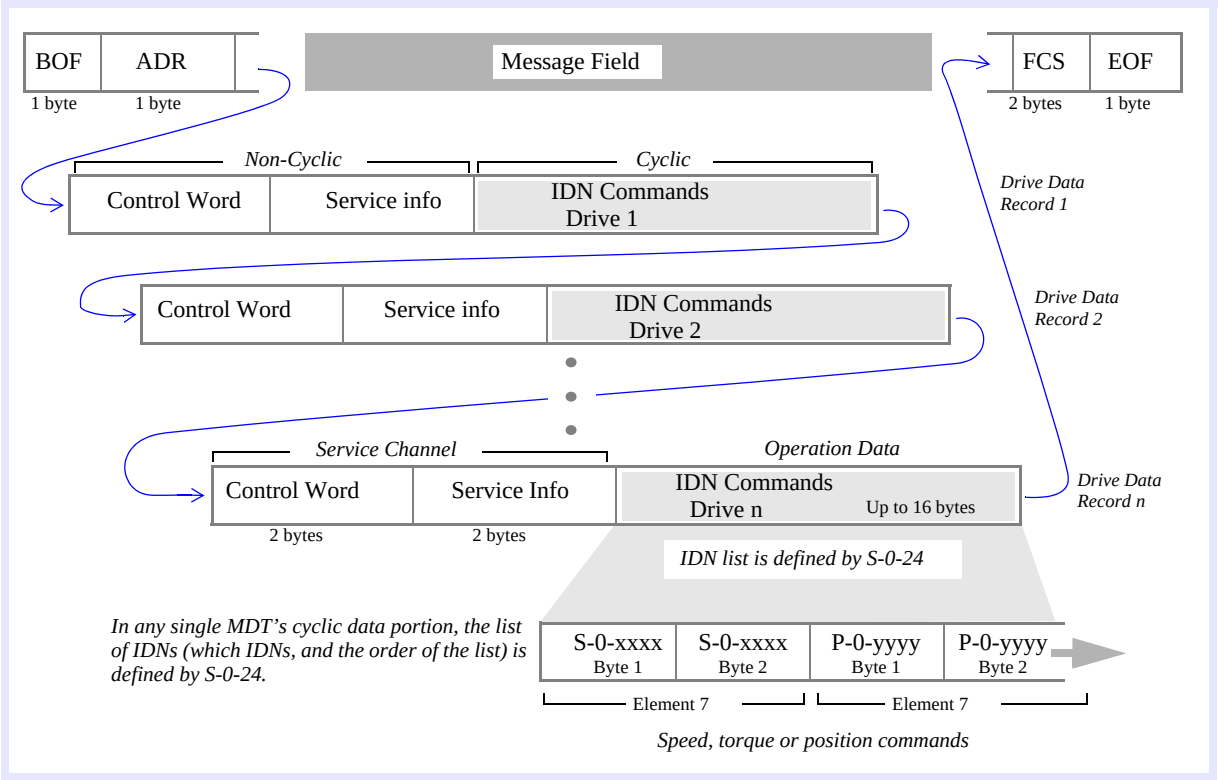


Table B-7 MDT Telegram Fields

Field	Size	Description
BOF	1 byte	Beginning of Frame, which is always 0111 1110. The BOF marks the start of a telegram.
ADR	1 byte	Target address. In the MDT, ADR = 255 (the broadcast address).
*Control Word	2 bytes	Control word for drive *n*. Contains operational data.
*Service Info	2 bytes	Contains the non-cyclic data for drive *n*.
*IDN Commands	Variable[1]	Contains the cyclic data for drive *n*.
FCS	2 bytes	Frame check sequence. Contains circular redundancy check (CRC) info.
EOF	1 byte	End of Frame, which is always 0111 1110. The EOF marks the end of the telegram.

** These fields comprise the data record. There is one data record per drive in the MDT.*
[1] The length if the IDN Commands field is determined during Phase 2.

Table B-8 MDT Telegram Control Word (Same as S-0-134)

Bit	Name & Value	More Detail
15	0 Drive OFF 1 Drive ON	Bit 15-13=111, the drive should follow command values. When 1->0, the drive removes torque from the motor, and allows the motor to spin down.
14	0 Drive Disable 1 Drive Enable	When 1->0, torque is immediately disabled, independent of bits 15 and 13.
13	0 Drive Halt 1 Drive Restart	
12, 11	*Reserved*	
10	Control Unit Synchronization Bit	
9, 8	Operation Mode 00 primary op mode 01 secondary op mode 1 10 secondary op mode 2 11 secondary op mode 3	 Defined byS-0-32 Defined by S-0-33 Defined by S-0-34 Defined by S-0-35
7	Real-time Control Bit 2	S-0-302
6	Real-time Control Bit 1	S-0-300
5, 4, 3	Data Block Element 000 Service channel not active, 001 IDN (number) of the op data 010 Name of operation data 011 Attribute of op data 100 Units of op data 101 Min input value 110 Max input value 111 Operation data	 -Close service channel or break a transmission in progress -The service channel is closed for the previous IDN and opened for a new IDN.
2	0 Transmission in progress 1 Last transmission	
1	0 Read service info 1 Write service info	
0	Master Service Transport Handshake	A toggle bit

Amplifier Telegram

During Phase 2, the Slave sends an Amplifier Telegram (AT) **only** when it receives a Master Data Telegram (MDT) that contains that Slave's address. The AT contains one Data Record where the length of the Data Block is 0, i.e., the data block is empty. During Phase 2, the Master sends data to each Slave via the Service Channel.

During Phases 3 and 4, each Slave sends an Amplifier Telegram (AT) every SERCOS cycle, at the time designated by the Master during Phase 2. The AT Message Field contains one Data Record, where the length of the Data Block (inside that Data Record) is determined by the data fields configured by the Master during Phase 2. The data fields within the Data Block usually contain feedback and status information.

During Phases 3 and 4, data is sent to the Master by using the Data Blocks (cyclic) or the Service Channel (non-cyclic).

Figure B-12 AT Telegram Structure

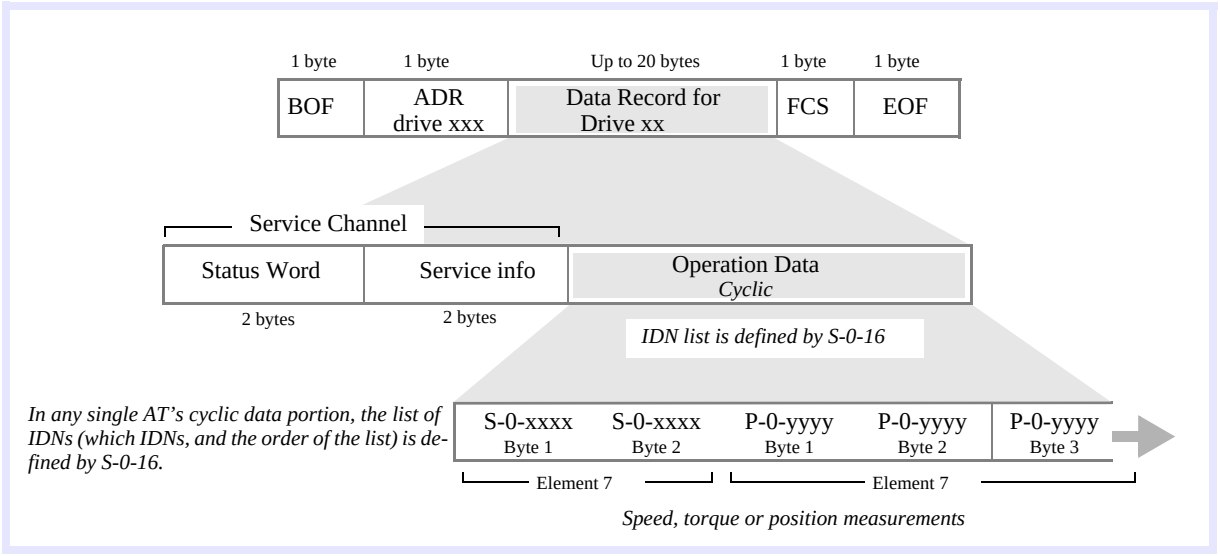


Table B-9 AT Telegram Fields

Field	*Bytes*	*Description*
BOF	1	Beginning of Frame. The BOF marks the start of a telegram.
ADR	1	Sender's address.
Status	2	Status word for drive *n*. Contains the operational and current condition data.
Service Info	2	Contains the non-cyclic data for drive *n*.
Operation Data	Variable[1]	Contains the cyclic data for drive *n*.
FCS	2	Frame check sequence. Contains circular redundancy check (CRC) info.
EOF	1	End of Frame. The EOF marks the end of the telegram.

[1] *The length of the Operation Data field is determined during Phase 2.*

Table B-10 AT Telegram Status Word (Same as S-0-135)

Bit	***Name & Value***	***More Detail***
15, 14	Ready to operate 00 drive not ready for power-up 01 drive ready for power-up 10 drive power ready 11 drive ready to operate	
13	Drive Shutdown Error, Class 3 Diags	See S-0-11
12	Change Bit for Class 2 Diags	See S-0-12
11	Change Bit for Class 3 Diags	See S-0-13
9, 8	Actual Operation Mode 00 primary op mode 01 secondary op mode 1 10 secondary op mode 2 11 secondary op mode 3	 Defined by S-0-32 Defined by S-0-33 Defined by S-0-34 Defined by S-0-35
7	Real-time Status Bit 2	See S-0-306
6	Real-time Status Bit 1	See S-0-304
5	Change Bit Commands 0 No Change in Command Status 1 Changing Command Status	
4, 3	*Reserved*	
2	Error 0 No Error 1 Error in Service Channel	 Error message is in drive's Service Channel.
1	Busy 0 Step Finished 1 Step in Progress	
0	Master Service Transport Handshake	A Toggle bit

SERCOS Data Types

There are 4 basic types of data in the SERCOS scheme: operation data, parameters, procedure commands, and command and feedback values.

Operation data are assigned *identification numbers* (IDNs or IDNumbers), with operation data being either parameters, procedure commands, command values, or feedback values. Parameters are used to make adjustments in the drives and the Master to ensure error-free operations. Procedure commands are used to activate functions in the drives or between the Master and the drives. Command and feedback values are used as cyclic data and are included in the telegrams.

Data Block Structure

The SERCOS protocol is designed to handle many different types of data, characterized by two fundamental types: fixed length data and variable length data.

Fixed length data is either 2 bytes or 4 bytes wide and can be used to represent signed or unsigned integers, hexadecimal values, binary codes, IDNumbers (identification numbers) of other Data Blocks, and procedure commands.

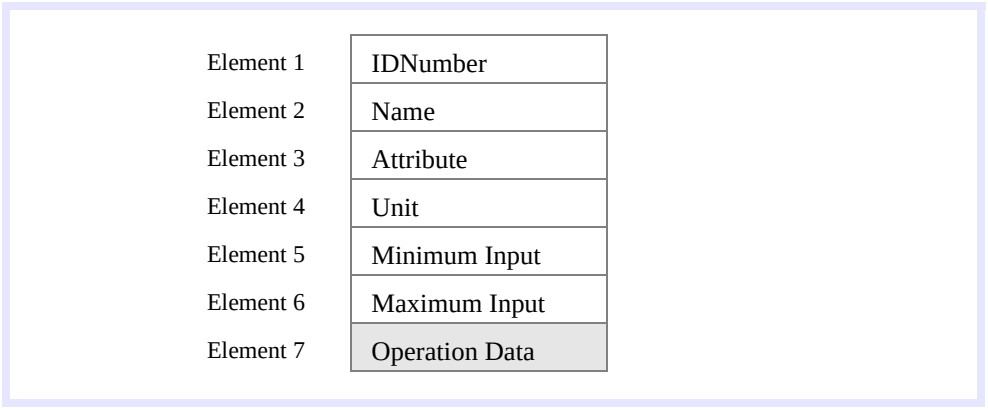
The length of *variable length data* depends on what type of data is present, and is defined by the first two words (32 bits), which specify the actual and maximum length of the data. Variable length data can be used to represent character strings, lists of IDNumbers of Data Blocks, lists of signed or unsigned integers (both 2 or 4 bytes wide), lists of hexadecimal values, etc.

All data (fixed and variable length) can be sent or received via the Service Channel. However, **only** fixed length data is allowed to be configured into a communication telegram (MDT, AT). When a communication telegram is configured to send or receive fixed length data, it is only Element 7 data that will be either sent or received.

Data Block Structure of IDNs

Data is accessed through data blocks referred to as IDNs. An IDN consists of 7 elements:

Figure B-13 Data Block Structure of IDNs



All data exchanged between Master and Slaves has an IDNumber (IDN number) assigned to it. Every IDN has an associated data block which consists of 7 elements. All IDN elements are placed inside predefined telegrams. The Master can only write Element 7 data; the Master cannot write Elements 1 - 6. Elements 1 - 6 are defined by the drive itself.

Table B-11 The 7 Elements of an IDN

Element	Description	Data Type
1	IDNumber (Identification number)	*binary* Expressed as either S-X-XXXX or P-X-XXXX. S denotes IDNs that are defined by the SERCOS Specification. P denotes IDNs that are defined by the manufacturer of the device.
2	Name	*variable length string* Contains the name of the IDN.
3	Attribute	*32 bit binary* Contains information about conversion factors and data representation (signed or unsigned integer, fixed or variable length data, etc.)
4	Unit	*variable length string* Contains a representation of the units for the data.
5	Minimum input value	1 or 2 words
6	Maximum input value	1 or 2 words
7	Operation Data	1 or 2 words, or string

Element 1: IDNumbers

Each Data Block has a number assigned to it for identification purposes, called the IDNumber. The IDNumber is represented as either S-X-XXXX or P-X-XXXX. S denotes a Data Block that is defined by the *SERCOS Specification*. P denotes a Data Block that is defined by the manufacturer. The first 'X' identifies the "data set" that the Data Block belongs to. According to the *SERCOS Specification*, it is possible to switch between data sets.

Up to 65,536 (2^{16}) IDNumbers can be used to identify data. The first half of the possible IDNumbers (0 - 32,767 or 2^{15}) are reserved for standard IDNs (or S-x-xxxx), while the second half (32768 - 65535) are reserved for product-specific IDNs (or P-x-xxxx, as specified by the device manufacturer).

Figure B-14 IDNumber Structure

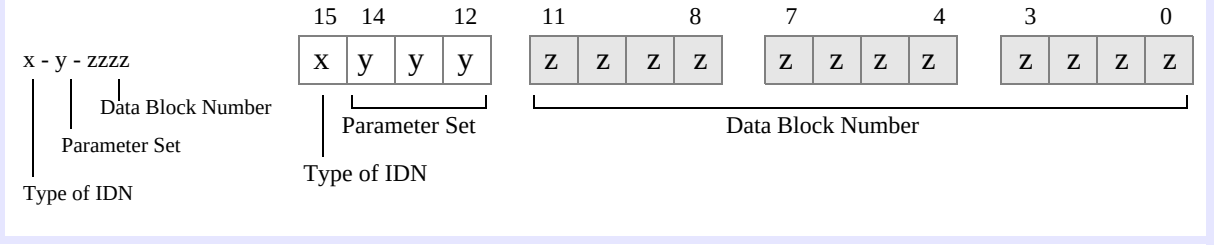


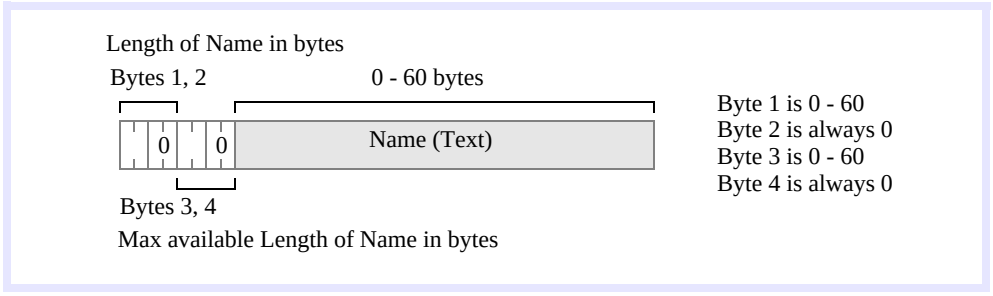
Table B-12 IDNumber Structure

Bit	Name	Values
15	*Type of IDN*	0 S - Standard data 1 P - Product-specific data as the "S" or "P" part of the IDN notation S-y-zzzz or P-y-zzzz.
14 - 12	*Parameter Set*	0 - 7, as the "y" part of the IDN notation S-y-zzzz or P-y-zzzz.
11 - 0	*Data Block Number*	0 - 4095, as the "zzzz" part of the IDN notation S-y-zzzz or P-y-zzzz.

Element 2: Name of Operation Data

The name of operation data is 64 bytes maximum, with 2 length specifications of 2 bytes each, and a character string of 60 characters maximum. Bytes 1 and 2 contain the number of characters in the text. Bytes 3 and 4 contain the maximum number of characters in the text. Since this element is *READ-Only*, bytes 3 and 4 will contain the same values as bytes 1 and 2.

Figure B-15 Operation Data Name Structure



Element 3: Attributes of Operation Data

Every data block has an attribute (4 bytes) which contains all of the information required to display operation data, using universal routines. If data needs to be scaled (to be displayed), then specific scaling parameters are supplied in the attribute.

Figure B-16 Operation Data Attribute Structure

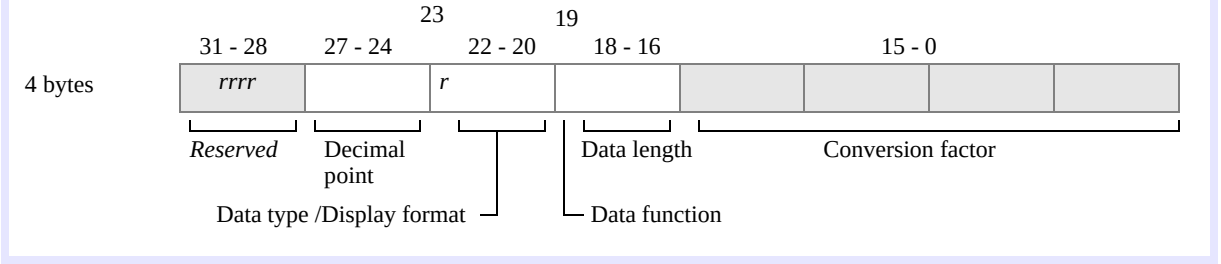


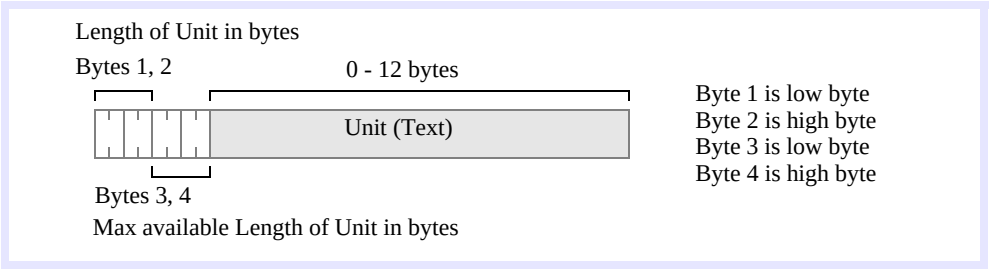
Table B-13 Operation Data Attribute Structure

Bits	Name	Values
31 - 28	*Reserved*	
27 - 24	Number of places after the decimal point Indicates the position of the decimal point in the data to be displayed. Basically, it's the exponent "x" in 10^{-x}.	000 No places after decimal point 001 1 place after decimal point 010 2 places after decimal point * 111 15 places after decimal point
23	*Reserved*	
22 - 20	Data Type & Display Format Used to convert the operation data, and min/max input values to the correct display format.	Data Type / Display Format 000 binary number / binary 001 unsigned integer / unsigned decimal 010 integer / signed decimal 011 unsigned integer / hexadecimal 100 extended char set / text 101 unsigned integer / IDN number 010 *Reserved* 111 *Reserved*
19	Function of Operation Data Indicates whether this data calls a procedure in a drive	0 Operation data or parameter 1 Procedure command
18 - 16	Data Length The data length is required so that the Master is able to complete Service Channel data transfers correctly.	*000 Reserved* 001 Operation data is 2 bytes long 010 Operation data is 4 bytes long *011 Reserved* 100 Variable length with 1-byte data strings 101 Variable length with 2-byte data strings 110 Variable length with 4-byte data strings *111 Reserved*
15 - 0	Conversion Factor	An unsigned integer used to convert numeric data to display format. Is set to 1 when it is not needed for data display (e.g., binary display or a character string).

Element 4: Operation Data Unit

The operation data unit is 16 bytes maximum, with 2 length specifications of 2 bytes each, and a character string of 12 characters maximum. Bytes 1 and 2 contain the number of characters in the text. Bytes 3 and 4 contain the maximum number of characters in the text. Since this element is *READ-Only*, bytes 3 and 4 will contain the same values as bytes 1 and 2.

Figure B-17 Operation Data Unit Structure



Element 5: Minimum Input Value of Operation Data

The minimum input value is the smallest numerical value for operation data that the drive can process. When the Master writes a value to the drive that *is less than* the minimum value, the drive *ignores* it and continues to use the *previous* operation data.

When the operation data is of variable length or a binary number is used, there is no minimum input value of operation data.

Element 6: Maximum Input Value of Operation Data

The maximum input value is the largest numerical value for operation data that the drive can process. When the Master writes a value to the drive that is *more than* the maximum value, the drive *ignores* it and continues to use the *previous* operation data.

When the operation data is of variable length or a binary number is used, there is no maximum input value of operation data.

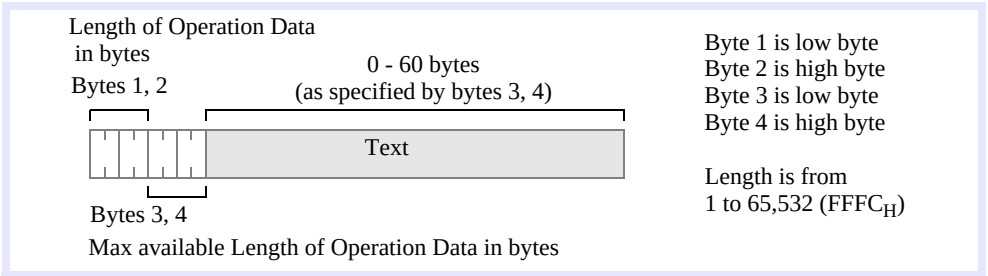
Element 7: Operation Data

In terms of length, there are 3 types of operation data:

fixed length with 2 bytes
fixed length with 4 bytes
variable length up to 65,532 bytes
in 1 byte (char), 2 byte, or 4 byte values

Bytes 1 and 2 contain the number of bytes in the text. Bytes 3 and 4 contain the max number of bytes available in the text. Data in the text may be 1 byte, 2 bytes, or 4 bytes wide.

Figure B-18 Operation Data Variable Length Structure



Procedures

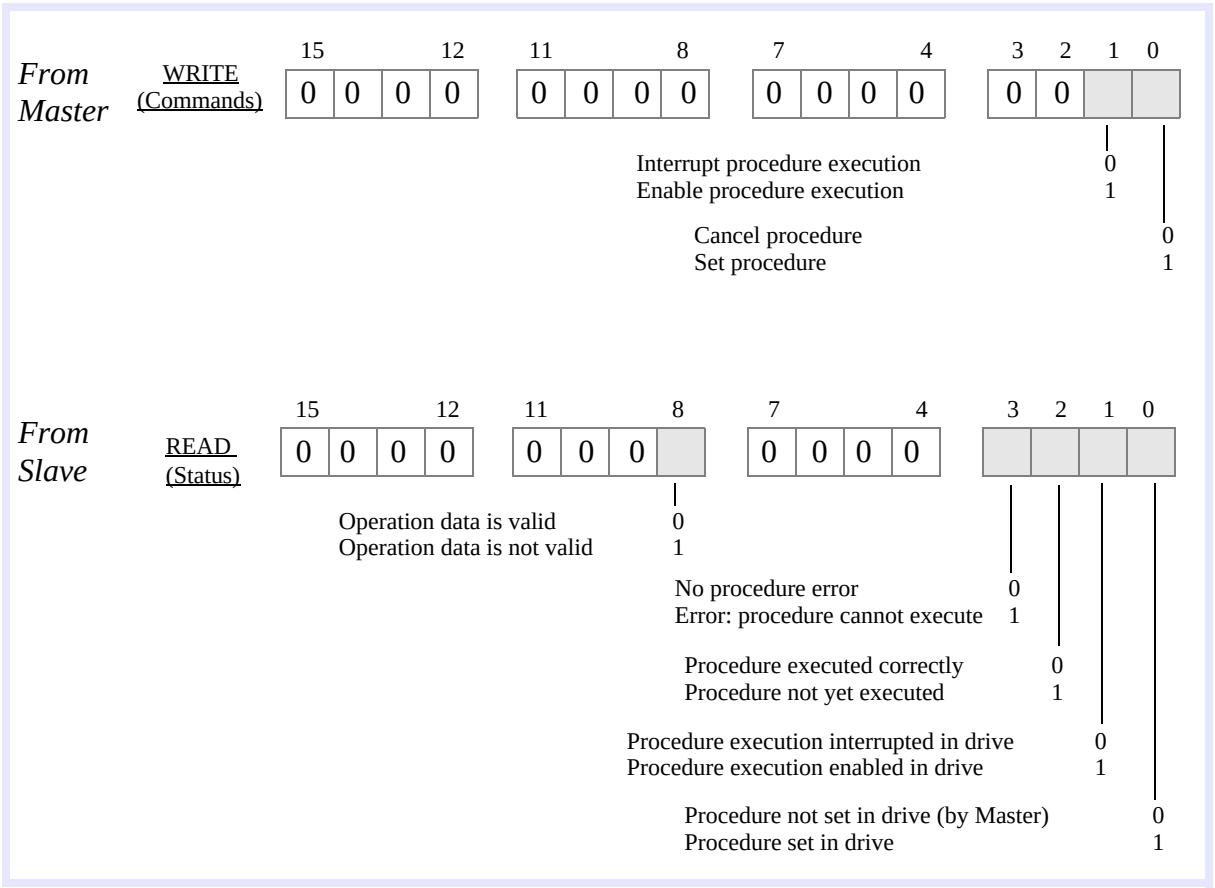
Many Slaves (drives) come with preprogrammed procedures that the Slave is able to execute without assistance from the Master. Each of these procedures is assigned a Data Block. The Master controls a procedure by reading and writing to Element 7 of the procedure's Data Block. The Master can initiate, interrupt, or cancel a procedure at any time by setting or clearing bits in Element 7 of the procedure's Data Block.

Bits 0 and 1 are responsible for respectively setting and enabling the procedure command. Once set and enabled, the Slave will begin execution of the procedure. To indicate that the procedure is executing, the Slave sets bit 2. When the procedure has finished executing, the Slave clears bit 2 and sets the *Procedure Command Change Bit* in the *Drive Status Word* S-0-134. If an error has occurred when executing the procedure, the Slave will set bit 3 of Element 7 of the procedure's Data Block and will also set the *Procedure Command Change Bit* in the *Drive Status Word* S-0-135. In either case (successful execution or failure), the Master must cancel the procedure by clearing bits 0 and 1 of the procedure.

In SERCOS, in order for a Master to execute a procedure,

1. The Master writes **0x3** to Element 7 of the desired IDN procedure, which sets and enables the procedure.
2. The Master reads Element 7 of the desired IDN procedure and checks bits 2 & 3 to see if the procedure has finished executing or if there is an error.
3. After reading that the procedure has executed, the Master writes **0x0** to Element 7 of the particular procedure, which cancels the procedure.

Figure B-19 Procedure Element 7: Bit Definitions



SERCOS Communications

Synchronization

The Master is responsible for sending a synchronization telegram (MST) at the beginning of each communication cycle. All Slaves (drives) will receive the MST and reset their clocks. In this way, all Slaves will run in *phase lock* with the Master's clock.

Because all Slaves are in phase lock with the Master's clock, commands can be made active in all of the Slaves *at the same instant*. This means that the Master can coordinate motion between all axes *without* propagation effects distorting the motion profile. Feedback from the Slaves is handled in a similar manner, and is latched in all Slaves at the same instant.

Ring Timing

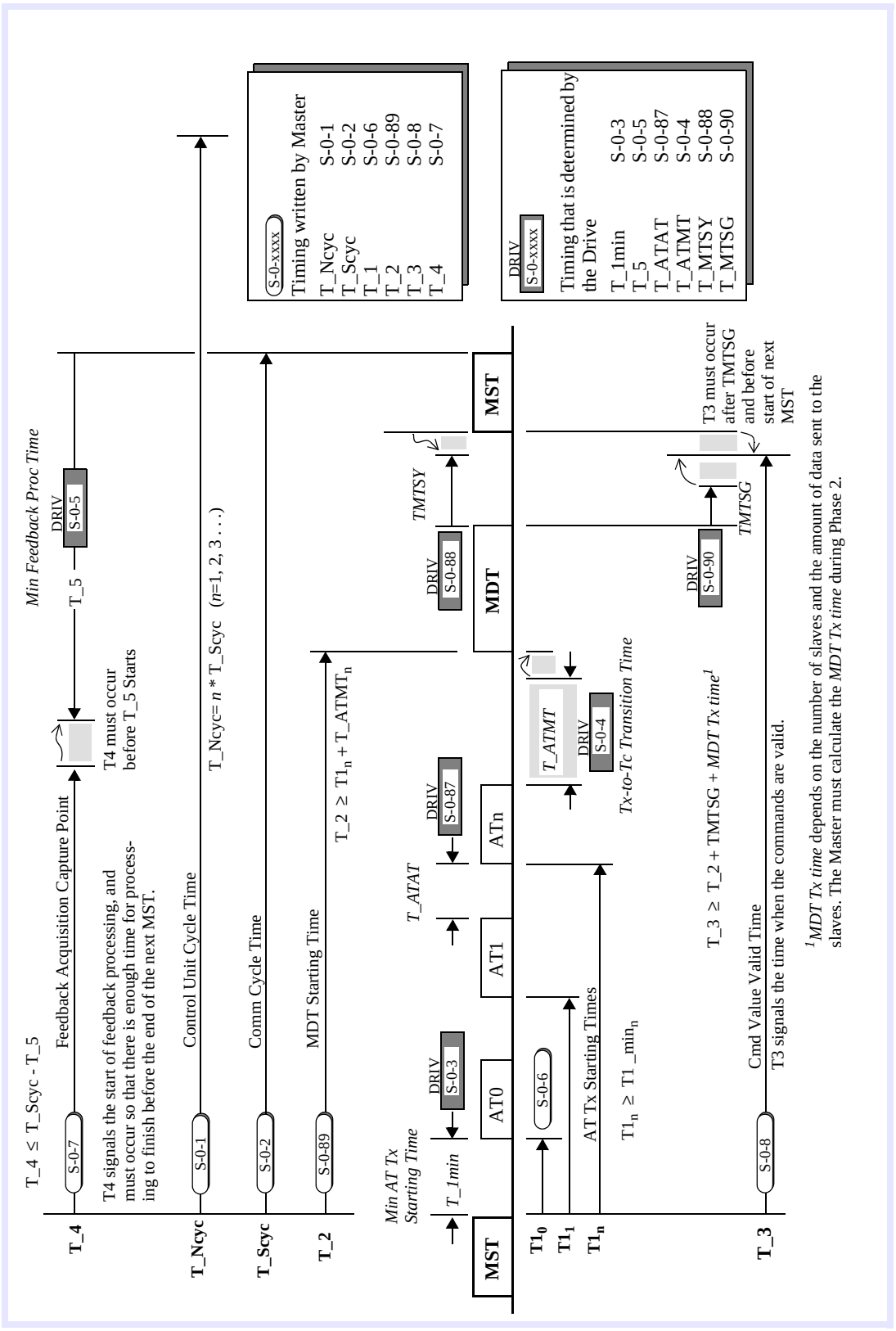
Data is sent and received by the Master and Slaves through communication telegrams. The communication telegrams are organized over the SERCOS cycle in the manner shown in the next figure.

The SERCOS ring timing is based on the data to be placed in the telegrams (AT, MDT), and on 6 drive parameters that are determined by the type and features of a drive (or drives), and 6 parameters that are written from the Master, with some of these parameters derived or calculated from the drive's timing parameters. The times at which the MDT and AT are sent (relative to the sending of the MST) are determined by the Master and sent to the Slaves during initialization.

During Phase 2, the Master reads parameters from the drives that determine what and when the drives are able to transmit and receive. Using this information and the desired telegram contents, baud rate and cycle time, the Master determines the timing and telegram parameters for each drive. The Master then writes these parameters to the drives.

Ring Timing

Figure B-20 SERCOS Ring Timing



SERCOS Initialization

Before true synchronous data transmission can occur, the system must first be initialized. This is done through a series of *communication phases* (or just *phases*) in which data is first transmitted asynchronously. The data transmitted during these early phases is used to configure the Master and Slaves for synchronous data transmissions in later phases. The SERCOS protocol defines five phases.

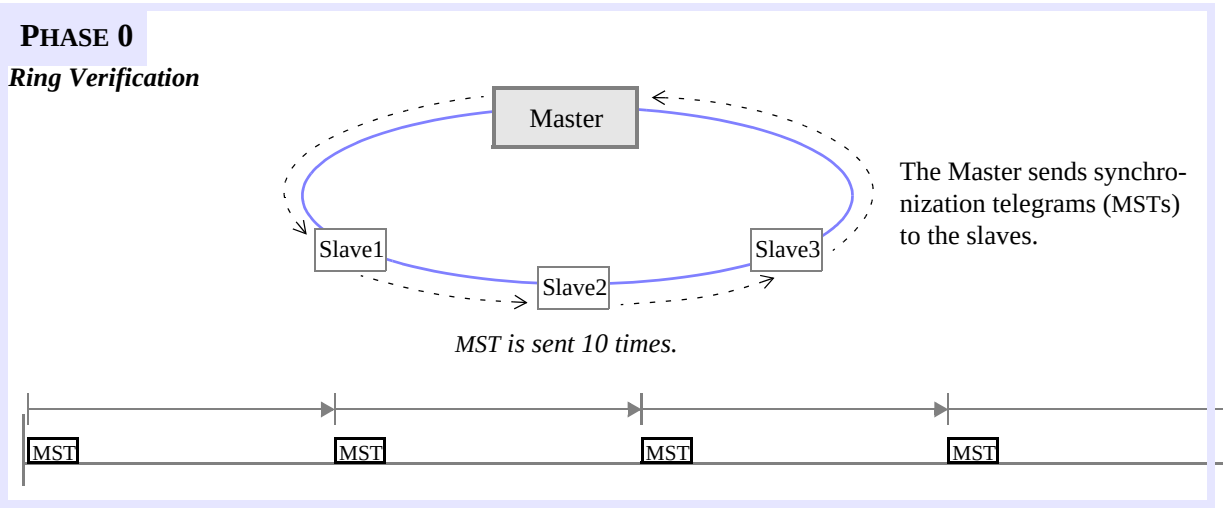
Table B-14 Phases of the SERCOS Cycle

Phase	*Name*	*Action*
0	Ring Verification	Master verifies ring closure
1	Device Verification	Master verifies devices on ring
2	Telegram Set-Up	Master reads timing data from slaves and sets up telegram timing
3	Device Parameterization	Master continues to configure devices
4	Cyclic Operations	Master commands devices cyclically

On power-up, each drive or I/O module begins an initialization sequence. At this time, each drive and I/O module operates as a *repeater*, by simply passing received telegrams to the next device on the SERCOS ring.

The Master is only allowed to set the communication phase to the next logical communication Phase (Phase 0 -> Phase 1 -> Phase 2 -> Phase 3 -> Phase 4) or directly back to Phase 0. If at any time the Master attempts to switch a Slave into a Phase that is not the next logical Phase, then the Slave will immediately return to Phase 0. If at any time the Slave receives two invalid MSTs or MDTs consecutively, the Slave will also switch to Phase 0.

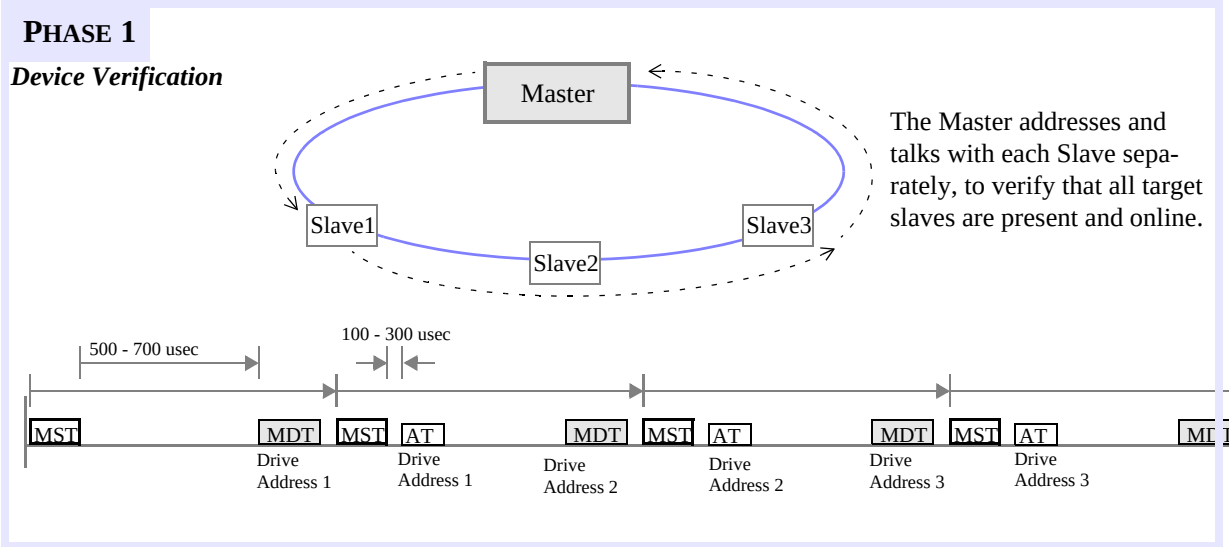
Figure B-21 Phase 0 Operations



During Phase 0 **no data is exchanged** between the Master and the Slaves. All Slaves must be in "repeater" mode. This means that each Slave will retransmit any signal that it receives. In order to verify that the communications ring is intact and capable of sending telegrams, the Master begins sending Master Synchronization Telegrams (MST) through the SERCOS ring.

The Slaves (drives) simply pass the MST to the next drive in the daisy-chained ring, and eventually because of the ring topology, the MST returns to the Master (i.e., Master will receive its own MST). Phase 0 is completed when the Master receives 10 consecutive MSTs. After the tenth consecutive MST, the Master changes the phase information in the MST to 1, which commands all Slaves to switch into Phase 1 operations.

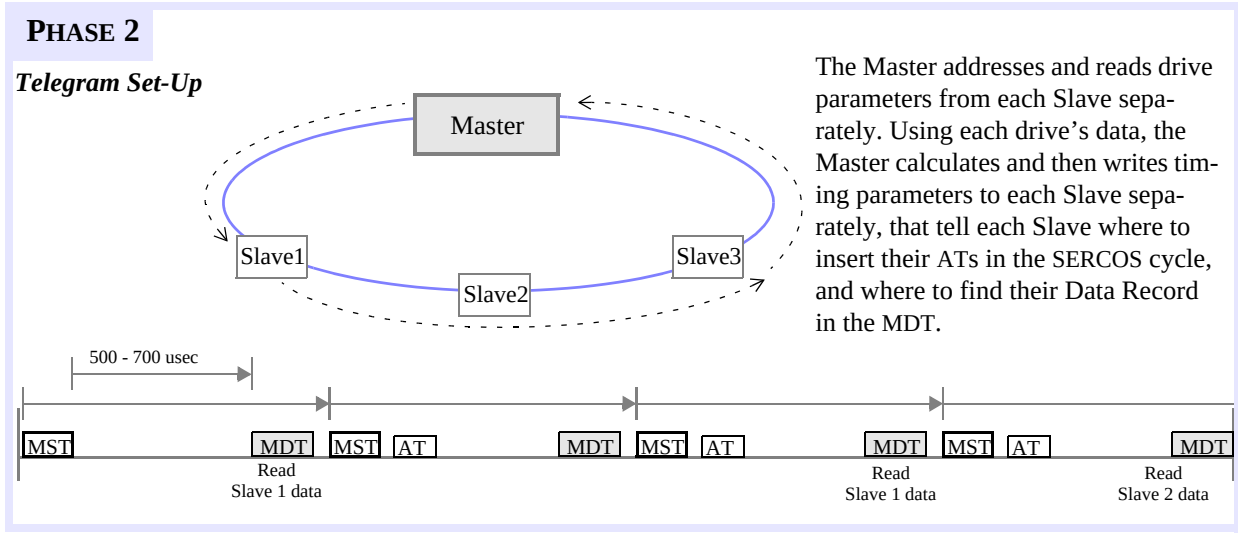
Figure B-22 Phase 1 Operations



During Phase 1, the Master sends out an MDT with the address of a specific Slave in the system. If present within the system, the Slave with the specified address responds by sending an AT back to the Master. The AT that is sent is rudimentary and is intended solely as a confirmation that the addressed Slave is in the system. The Master then repeats this query for all target Slaves. (Note that not all Slaves in the system will be target Slaves. Target Slaves are chosen by the application before initialization begins.)

When the Master receives an AT from each target Slave (in response to a query), the Master changes the phase information in the MST to 2, which commands all Slaves to switch into Phase 2 operations.

Figure B-23 Phase 2 Operations



During Phase 2, the Master sets up the configurable data portion and calculates the duration and time slots within the SERCOS cycle for all telegrams to be used in Phases 3 and 4. The Master also determines the *slave operation mode* for all Slaves. In order to do this, the Master requires certain data from the Slaves. The Master obtains this data by sending an MDT addressed to a specific Slave, that uses the MDT's Service Channel to query the Slave for the required data.

The Slave responds by sending an AT containing the appropriate data, in the AT's Service Channel. Once the Master has determined all parameters, it sends them to each Slave via the MDT's Service Channel. In Phase 2, the Service Channel is active in both MDTs and ATs.

First, the Master configures each drive's communication parameters for real-time synchronous operation; then the Master configures the drive's operational parameters. These operational parameters are specific to each drive, and are based on the drive's operation mode(s), its supported features, and the manufacturer. Note that the drive operation IDNs can be configured during *both* Phase 2 and Phase 3.

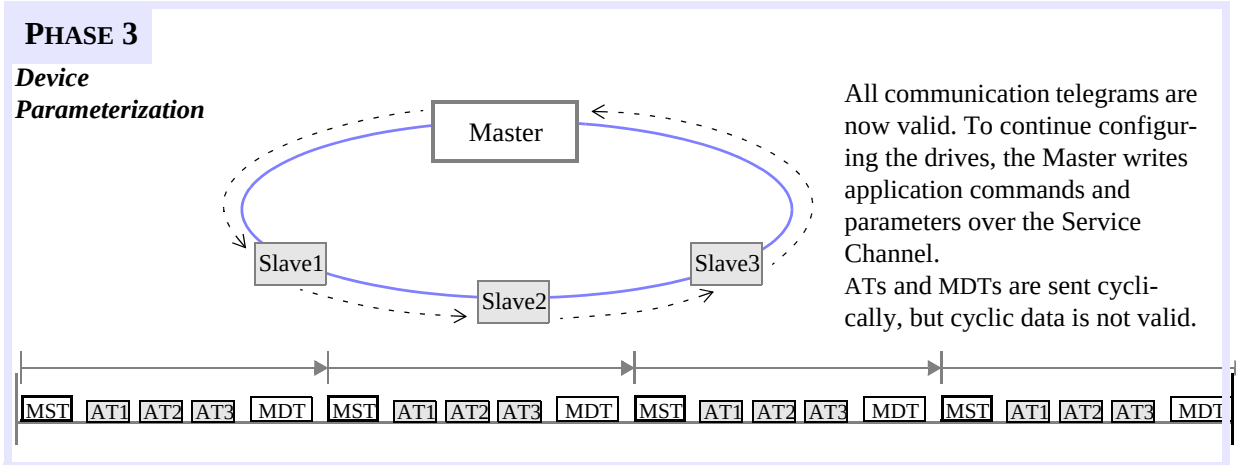
Once all data is transmitted to the Slaves, the Master will initiate the *Communication Phase 3 Transition Check* S-0-127 procedure for each Slave. In order to successfully execute the Phase 3 Transition Check, the following IDNs must contain valid data:

S-0-1	Control Unit Cycle Time (T_NCYC)
S-0-2	Communication Cycle Time (T_SCYC)
S-0-6	AT Transmission Starting Time (T_1)
S-0-7	Feedback Acquisition Capture Point (T_4)
S-0-8	Command Value Valid Time (T_5)
S-0-9	Position of Data Record in MDT
S-0-10	Length of MDT
S-0-15	Telegram Type Parameter
S-0-16	Configuration List of AT
S-0-24	Configuration List of MDT
S-0-32	Primary Operation Mode
S-0-89	MDT Transmission Starting Time (T_2)
P-0-11	DSP Sub Samples
P-0-24	Encoder Counts per Commutation Cycle
P-0-25	Electrical Cycles per Commutation Cycle

Note that for some of the IDNs listed, *the default values are valid*. The *Communication Phase 3 Transition Check* checks the validity of all the data, and if all the data is valid, then the procedure executes successfully. If any data is not valid, the procedure fails and the IDN number of the invalid data is placed in *IDN-List of Invalid Operation Data for CP2* S-0-21.

After all Slaves have completed the procedure successfully, the Master changes the phase information in the MST to 3, which commands all Slaves to switch into communication Phase 3.

Figure B-24 Phase 3 Operations



In Phase 3, the real-time synchronous and asynchronous communication starts, and the Master uses the Service Channel to configure and parameterize (write parameters to) the Slaves. The

parameters set in Phase 3 are *application-oriented* (e.g., conversion factors). During Phase 3, all *communication* telegram parameters sent in Phase 2 become active. Note that although Configurable Data (in ATs and MDTs) is present in the communication telegrams, some of that Configurable Data **may not be valid until Phase 4**.

The Master will still send the MST at the beginning of the SERCOS cycle, but will now also send an MDT with a global address at a specific time (all Slaves will receive a global telegram). Each Slave will transmit *its* AT during *its* specified time slot. The communication telegrams now contain the Control/Status Word, a Service Channel, and the Configurable Data.

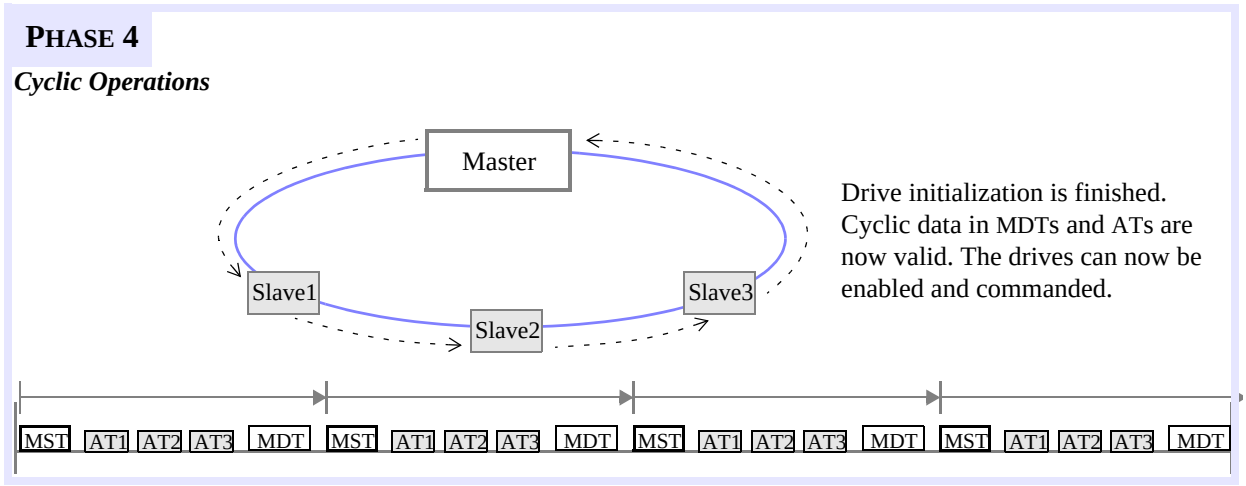
When the Master has finished sending parameters to the Slaves, it will initiate the *Communication Phase 4 Transition Check* S-0-128 procedure for each Slave. After all Slaves have completed the procedure successfully, the Master changes the phase information in the MST to 4, which commands all Slaves to switch into Phase 4. In order to successfully execute the Phase 4 Transition Check, the following IDNs must contain valid data:

S-0-115 Position Feedback Type
S-0-76 Position Data Scaling Type
S-0-118 Resolution of Linear Feedback
S-0-77 Linear Position Data Scaling Factor
S-0-78 Linear Position Data Scaling Exponent
S-0-116 Resolution of Rotational Feedback 1
S-0-79 Rotational Position Resolution
S-0-44 Velocity Data Scaling Type
S-0-45 Velocity Data Scaling Factor
S-0-46 Velocity Data Scaling Exponent
S-0-160 Acceleration Data Scaling Type
S-0-161 Acceleration Data Scaling Factor
S-0-162 Acceleration Data Scaling exponent
S-0-86 Torque/Force Data Scaling Type
S-0-93 Torque/Force Data Scaling Factor
S-0-94 Torque/Force Data Scaling Exponent
S-0-138 Bipolar Acceleration Limit
P-0-3 Enable Default Conversion Factors

Note that for some of the IDNs listed, *the default values are valid*. The *Communication Phase 4 Transition Check* checks the validity of all the data, and if all the data is valid, then the procedure executes successfully. If any data is not valid, the procedure fails and the IDN number of the invalid data is placed in *IDN-List of Invalid Operation Data for CP3* S-0-22.

If the *Communication Phase 4 Transition Check* executes successfully and the Phase information in the MST is equal to 4, the Master switches the drives to Phase 4.

Figure B-25 Phase 4 Operations



In Phase 4, a final verification of error-free drive operation is completed. This completes the drive initialization. The SERCOS communication loop is now operational. During Phase 4, all Control/Status words, Service Channels, and Configurable Data (in ATs and MDTs) are valid for the target Slaves. The Slaves (drives) are ready to follow commands when enabled. Diagnostics (errors, warnings, status) are enabled.

Symbols

1, 2, 3

A

B

C

D

D

E

F

H

I

I

L

M

N

T

T

U

V

W

A

B

C

D

E

F

G

H

I

J

L

M

N

P

R

S

T

T

U

V

W

A

B

B

base I/O address

boot memory

C

checksum

circular arc

command acceleration

command jerk

command position

command position register

command velocity

controller

coordinated motion

counter/timer

cubic spline coordinated motion

D

D/A

DMA (DSP's data memory)

DSP sample rate

dual loop

E

emergency stop event

encoder

encoder feedback fault detection

environment variables

error (last one)

J

T

T

timer

timer (frame sample)

timer (sample)

trajectory frames

trapezoidal motion

trapezoidal motion (multiple axes)

trapezoidal motion (non-symmetrical)

trapezoidal motion (relative)

U

User I/O bit

User I/O monitoring

User I/O port

V

vector acceleration

vector velocity

velocity (command)

velocity move