

14HSAI4

14-bit, 4 A/D channels, 50M S/S/Ch

PMC66-14HSAI4

Linux Device Driver And API Library User Manual

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Preface

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1. Introduction

1.1. Purpose

The purpose of this document is to describe the interface to the 14HSAI4 API Library and to the underlying Linux device driver. The API Library software provides the interface between "Application Software" and the device driver. The driver software provides the interface between the API Library and the actual 14HSAI4 hardware. The API Library and driver interfaces are based on the board's functionality.

1.2. Acronyms

The following is a list of commonly occurring acronyms which may appear throughout this document.

Acronyms	Description
ADC	Analog-to-Digital Converter
API	Application Programming Interface
BMDMA	Block Mode DMA
DMA	Direct Memory Access
DMDMA	Demand Mode DMA
GSC	General Standards Corporation
PCI	Peripheral Component Interconnect
PIO	Programmed I/O
PMC	PCI Mezzanine Card
PMC66	This is a PMC formfactor device that can operate at up to 66MHz over the PCI bus.

1.3. Definitions

The following is a list of commonly occurring terms which may appear throughout this document.

Term	Definition
...	This is a shortcut representation of the 14HSAI4 installation directory or any of its subdirectories.
14HSAI4	This is used as a general reference to any device supported by this driver.
API Library	This is a library that provides application-level access to 14HSAI4 hardware.
Application	This is a user mode process, which runs in user space with user mode privileges.
Driver	This is the 14HSAI4 device driver, which runs in kernel space with kernel mode privileges.
Library	This is usually a general reference to the API Library.

1.4. Software Overview

1.4.1. Basic Software Architecture

This section describes the general architecture for the basic components that comprise 14HSAI4 applications. The overall architecture is illustrated in Figure 1 below.

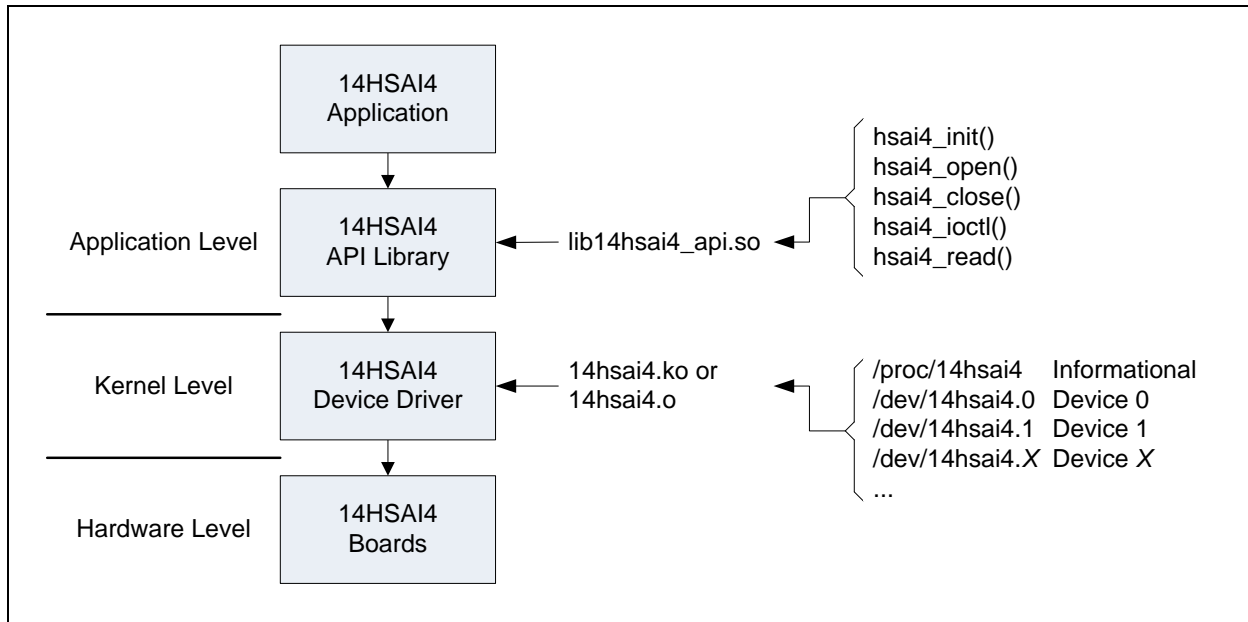


Figure 1 Basic architectural representation.

1.4.2. API Library

The primary means of accessing 14HSAI4 boards is via the 14HSAI4 API Library. This library forms a layer between the application and the driver. Additional information is given in section 3.2.3 (page 17). With the library, applications are able to open and close a device and, while open, perform I/O control and read operations.

1.4.3. Device Driver

The device driver is the host software that provides a means of communicating directly with 14HSAI4 hardware. The driver executes under control of the operating system and runs in Kernel Mode as a Kernel Mode device driver. The driver is implemented as a standard dynamically loadable Linux device driver written in the C programming language. While applications can access the driver directly without use of the API Library, it is recommended that all access is made through the library.

1.5. Hardware Overview

The 14HSAI4 is a high-performance, 14-bit analog I/O board that incorporates up to four input channels. The host side connection is PCI based and the form factor is according to the model ordered. The board is capable of acquiring and generating data at up to 50M samples per second over each channel. Internal clocking permits sampling rates from 50M samples per second down to about 1,000 samples per second. Onboard storage permits data buffering of up to 256K 32-bit wide data values, for all input channels collectively, between the cable interface and the PCI bus. This allows the 14HSAI4 to sustain continuous throughput over the cable interface independent of the PCI bus interface. The 14HSAI4 also permits multiple boards to be synchronized so that all boards sample data in unison. In addition, the board includes autocalibration capability.

1.6. Reference Material

The following reference material may be of particular benefit in using the 14HSAI4. The specifications provide the information necessary for an in depth understanding of the specialized features implemented on this board.

- The applicable *14HSAI4 User Manual* from General Standards Corporation.
- The *PCI9056 PCI Bus Master Interface Chip* data handbook from PLX Technology, Inc.

PLX Technology Inc.
870 Maude Avenue
Sunnyvale, California 94085 USA
Phone: 1-800-759-3735
WEB: <http://www.plxtech.com>

1.7. Licensing

For licensing information please refer to the text file `LICENSE.txt` in the root installation directory.

2. Installation

2.1. CPU and Kernel Support

The driver is designed to operate with Linux kernel versions 6.x, 5.x, 4.x, 3.x, 2.6, 2.4 and 2.2 running on a PC system with one or more x86 processors. This release of the driver supports the below listed kernels.

Kernel	Distribution
6.2.9	Red Hat Fedora Core 38
6.0.7	Red Hat Fedora Core 37
5.17.5	Red Hat Fedora Core 36
5.14.10	Red Hat Fedora Core 35
5.11.12	Red Hat Fedora Core 34
5.8.15	Red Hat Fedora Core 33
5.6.6	Red Hat Fedora Core 32
5.3.7	Red Hat Fedora Core 31
5.0.9	Red Hat Fedora Core 30
4.18.16	Red Hat Fedora Core 29
4.16.3	Red Hat Fedora Core 28
4.13.9	Red Hat Fedora Core 27
4.11.8	Red Hat Fedora Core 26
4.8.6	Red Hat Fedora Core 25
4.5.5	Red Hat Fedora Core 24
4.2.3	Red Hat Fedora Core 23
4.0.4	Red Hat Fedora Core 22
3.17.4	Red Hat Fedora Core 21
3.11.10	Red Hat Fedora Core 20
3.9.5	Red Hat Fedora Core 19
3.6.10	Red Hat Fedora Core 18
3.3.4	Red Hat Fedora Core 17
3.1.0	Red Hat Fedora Core 16
2.6.38	Red Hat Fedora Core 15
2.6.35	Red Hat Fedora Core 14
2.6.33	Red Hat Fedora Core 13
2.6.31	Red Hat Fedora Core 12
2.6.29	Red Hat Fedora Core 11
2.6.27	Red Hat Fedora Core 10
2.6.25	Red Hat Fedora Core 9
2.6.23	Red Hat Fedora Core 8
2.6.21	Red Hat Fedora Core 7
2.6.18	Red Hat Fedora Core 6
2.6.15	Red Hat Fedora Core 5
2.6.11	Red Hat Fedora Core 4
2.6.9	Red Hat Fedora Core 3
2.4.18	Red Hat 8.0

NOTE: Some older kernel versions are supported (the sources are maintained), but are not tested.

NOTE: While only Red Hat Fedora distributions are listed, numerous other distributions are supported and have been tested on an as needed basis.

NOTE: The driver will have to be built before being used as it is provided in source form only.

NOTE: The driver has not been tested with a non-versioned kernel.

NOTE: The driver is designed for SMP support, but has not undergone SMP specific testing.

2.1.1. 32-bit Support Under 64-bit Environments

This driver supports 32-bit applications under 64-bit environments. The availability of this feature in the kernel depends on a 64-bit kernel being configured to support 32-bit application compatibility. Additionally, 2.6 kernels prior to 2.6.11 implemented 32-bit compatibility in a way that resulted in some drivers not being able to take advantage of the feature. (In these kernels a driver's IOCTL command codes must be globally unique. Beginning with 2.6.11 this requirement has been lifted.) If the driver is not able to provide 32-bit support under a 64-bit kernel, the "32-bit support" field in the `/proc/14hsai4` file will be "no".

2.2. The `/proc/` File System

While the driver is running, the text file `/proc/14hsai4` can be read to obtain information about the driver and the boards it detects. Each file entry includes an entry name followed immediately by a colon, a space character, and the entry value. Below is an example of what appears in the file, followed by descriptions of each entry.

```
version: 2.9.111.50
32-bit support: yes
boards: 1
models: 14HSAI4
```

Entry	Description
version	This gives the driver version number in the form <code>x.x.x.x</code> .
32-bit support	This reports the driver's support for 32-bit applications. This will be either "yes" or "no" for 64-bit driver builds and "yes (native)" for 32-bit builds.
boards	This identifies the total number of boards the driver detected.
models	This gives a comma separated list of the basic model number for each board the driver detected. The model numbers are listed in the same order that the boards are accessed via the API Library's open function.

2.3. File List

This release consists of the below listed primary files. The archive content is described in following subsections.

File	Description
<code>14hsai4.linux.tar.gz</code>	This archive contains the driver, the API Library and all related files.
<code>14hsai4_linux_um.pdf</code>	This is a PDF version of this user manual, which is included in the archive.

2.4. Directory Structure

The following table describes the directory structure utilized by the installed files. During installation the directory structure is created and populated with the respective files.

Directory	Description
<code>14hsai4/</code>	This is the driver root directory. It contains the documentation, the Overall Make Script (section 2.7, page 13) and the below listed subdirectories.
<code>.../api/</code>	This directory contains the API Library source files (section 3.2.3, page 17).
<code>.../docsrc/</code>	This directory contains the source files for the code samples given in this document (section 6, page 50).

.../driver/	This directory contains the device driver source files (section 5, page 46).
.../include/	This directory contains the header files for the various libraries.
.../lib/	This directory contains all of the libraries built from the installed sources.
.../samples/	This directory contains the sample application subdirectories and all of their corresponding source files (section 9, page 54).
.../utils/	This directory contains the source files for the utility libraries used by the sample applications (section 7, page 51).

2.5. Installation

Perform installation following the below listed steps. This installs the device driver, the API Library and all related sources and documentation.

1. Create and change to the directory where the files are to be installed, such as `/usr/src/linux/drivers/`. (The path name may vary among distributions and kernel versions.)
2. Copy the archive file `14hsai4.linux.tar.gz` into the current directory.
3. Issue the following command to decompress and extract the files from the provided archive. This creates the directory `14hsai4` in the current directory, and then copies all of the archive's files into this new directory.

```
tar -xzvf 14hsai4.linux.tar.gz
```

2.6. Removal

Perform removal following the below listed steps. This removes the device driver, the API Library and all related sources and documentation.

NOTE: The following steps may require elevated privileges.

1. Shutdown the driver as described in section 5.6 (page 49).
2. Change to the directory where the driver archive was installed, which may have been `/usr/src/linux/drivers/`. (The path name may vary among distributions and kernel versions.)
3. Issue the below command to remove the driver archive and all of the installed driver files.

```
rm -rf 14hsai4.linux.tar.gz 14hsai4
```

4. Issue the below command to remove all of the installed device nodes.

```
rm -f /dev/14hsai4.*
```

5. If the automatic startup procedure was adopted (section 5.3.2, page 47), then edit the system startup script `rc.local` and remove the line that invokes the 14HSAI4's start script. The file `rc.local` should be located in the `/etc/rc.d/` directory.

2.7. Overall Make Script

An Overall Make Script is included in the root installation directory. Executing this script will perform a make for all build targets included in the release. The script also loads the driver and copies the API Library to `/usr/lib/`. The script is named `make_all`. Follow the below steps to perform an overall make and to load the driver.

NOTE: The following steps may require elevated privileges.

1. Change to the driver root directory (.../14hsai4/).
2. Remove existing build targets using the below command. This does not unload the driver.

```
./make_all clean
```

3. Issue the following command to make all archive targets and to load the driver.

```
./make_all
```

2.8. Environment Variables

Some build environments may require compiler or linker options not present in the provided make files. To accommodate local environment specific requirements, the provided make files incorporate support for the following set of GSC specific environment variables.

2.8.1. GSC_API_COMP_FLAGS

This environment variable accommodates adding compiler command line options when compiling source files for the API Library. The compiler used by the API Library make file is “gcc”. The content of this environment variable is noted in the make file’s output to the screen. The table below shows a portion of the screen output. The “xxx” in the table refers to the contents of the environment variable. This environment variable has no effect on compiling any other distributed source files or linking of any object files.

Undefined or Empty	== Compiling: init.c	
	== Compiling: ioctl.c	
	== Compiling: open.c	
Defined and Not Empty	== Compiling: init.c (added 'xxx')	
	== Compiling: ioctl.c (added 'xxx')	
	== Compiling: open.c (added 'xxx')	

2.8.2. GSC_API_LINK_FLAGS

This environment variable accommodates adding linker command line options when linking object files for the API Library. The linker used by the API Library make file is “ld”. The content of this environment variable is noted in the make file’s output to the screen. The table below shows a portion of the screen output. The “xxx” in the table refers to the contents of the environment variable. This environment variable has no effect on compiling of any source files or linking of any other object files.

Undefined or Empty	==== Linking: ../lib/lib14hsai4_api.so
Defined and Not Empty	==== Linking: ../lib/lib14hsai4_api.so (added 'xxx')

2.8.3. GSC_LIB_COMP_FLAGS

This environment variable accommodates adding compiler command line options when compiling source files for the utility libraries. The compiler used by the utility library make files is “gcc”. The content of this environment variable is noted in the make files’ output to the screen. The table below shows a portion of the screen output. The “xxx” in the table refers to the contents of the environment variable. This environment variable has no effect on compiling any other distributed source files or linking of any object files.

Undefined or Empty	== Compiling: close.c == Compiling: init.c == Compiling: ioctl.c
Defined and Not Empty	== Compiling: close.c (added 'xxx') == Compiling: init.c (added 'xxx') == Compiling: ioctl.c (added 'xxx')

2.8.4. GSC_LIB_LINK_FLAGS

This environment variable accommodates adding linker command line options when linking object files for the utility libraries. The linker used by the utility library make files is “ld”. The content of this environment variable is noted in the make files’ output to the screen. The table below shows a portion of the screen output. The “xxx” in the table refers to the contents of the environment variable. This environment variable has no effect on compiling of any source files or linking of any other object files.

Undefined or Empty	==== Linking: ../lib/14hsai4_utils.a
Defined and Not Empty	==== Linking: ../lib/14hsai4_utils.a (added 'xxx')

2.8.5. GSC_APP_COMP_FLAGS

This environment variable accommodates adding compiler command line options when compiling source files for the sample applications. The compiler used by the sample application make files is “gcc”. The content of this environment variable is noted in the make files’ output to the screen. The table below shows a portion of the screen output. The “xxx” in the table refers to the contents of the environment variable. This environment variable has no effect on compiling any other distributed source files or linking of any object files.

Undefined or Empty	== Compiling: main.c == Compiling: perform.c
Defined and Not Empty	== Compiling: main.c (added 'xxx') == Compiling: perform.c (added 'xxx')

2.8.6. GSC_APP_LINK_FLAGS

This environment variable accommodates adding linker command line options when linking object files for the sample applications. The linker used by the sample application make files is “gcc”. The content of this environment variable is noted in the make files’ output to the screen. The table below shows a portion of the screen output. The “xxx” in the table refers to the contents of the environment variable. This environment variable has no effect on compiling of any source files or linking of any other object files.

Undefined or Empty	==== Linking: id
Defined and Not Empty	==== Linking: id (added 'xxx')

3. Main Interface Files

This section gives general information on the suggested device interface files to use when developing 14HSAI4 based applications.

3.1. Main Header File

Throughout the remainder of this document references are made to various header files included as part of the 14HSAI4 driver installation. For ease of use it is suggested that applications include only the single header file shown below rather than individually including those headers identified separately later in this document. Including this header file pulls in all other pertinent 14HSAI4 specific header files. Therefore, sources may include only this one 14HSAI4 header and make files may reference only this one 14HSAI4 include directory.

Description	File	Location
Header File	14hsai4_main.h	.../include/

3.2. Main Library File

Throughout the remainder of this document references are made to various statically linkable libraries included as part of the 14HSAI4 driver installation. For ease of use it is suggested that applications link only the single library file shown below rather than individually linking those libraries identified separately later in this document. Linking this library file pulls in all other static libraries included with the driver. Therefore, make files may reference only this one 14HSAI4 static library and only this one 14HSAI4 library directory.

Description	File	Location
Static Library	14hsai4_main.a	.../lib/
	14hsai4_multi.a	

NOTE: For applications using the 14HSAI4 and no other GSC devices, link the 14hsai4_main.a library. For applications using multiple GSC device types, link the xxxx_main.a library for one of the devices and the xxxx_multi.a library for the others. Linking multiple xxxx_main.a libraries may likely produce link errors due to duplicate symbols being defined. While it may make little or no difference, it is recommended that one choose the xxxx_main.a library from the driver with the largest number in positions three (x.x.X.x.x) and/or four (x.x.x.X.x) in the driver release version number.

NOTE: The 14HSAI4 API Library is implemented as a shared library and is thus not linked with the 14HSAI4 Main Library. The API Library must be linked with applications by adding the argument -l14hsai4_api to the linker command line.

3.2.1. Build

The main library is built via the Overall Make Script (section 2.7, page 13). However, the main library can be built separately following the below steps.

1. Change to the directory where the main library resides (.../lib/).
2. Remove existing build targets using the below command.

```
make clean
```

3. Build the main library by issuing the below command.

```
make
```


3.2.2. System Libraries

In addition to linking the static library named above, as well as the API Library shared object file, applications may need to also link in additional system libraries as noted below.

Library	gcc Link Flag
Math	-lm
POSIX Thread	-lpthread
Real Time	-lrt

3.2.3. Shared Object Script: Build the Main Libraries as Shared Object Files

The main libraries built via the Overall Make Script (section 2.7, page 13) are static library files. Some applications however, require that the Main Libraries be accessed as shared object files. Generating shared object files require that all of the static libraries be recompiled for this purpose and linked as .so files. This is done using the Shared Object Script named below. When run, the script invokes the Overall Make Script to clean all existing build targets, deletes the two shared object files named below, if they exist, defines an environment variable used by all of the static library make files, invokes the Overall Make Script again to rebuild all existing build targets then invokes make on the library make file (.../lib/makefile) to link the shared object files. The required manual steps are as follows.

1. Change to the directory where the main library files reside (.../lib/).
2. Execute the below script.

```
./static_to_shared.sh
```

Running the above-named Shared Object Script produces the files given in the table below. These shared object files fulfill the same purpose as the similarly named static libraries as described in the note under section 3.2 above. Refer to that note when selecting which shared object file to use.

Description	File	Location
Shared Object Files	lib14hsai4_main.so	.../lib/
	lib14hsai4_multi.so	
	lib14hsai4_all.so†	

† This library includes all generated libraries, including the API Library shared object file content.

The shared object files can be linked via two different methods. In the first method, the application linker command line can explicitly name the file in the same manner as is done were it a static library. This is the method used by the sample applications, all of which use the 14HSAI4 API Library, which itself is a shared object file. This file is also found in the .../lib/ subdirectory. In the second method, the .so files are copied to the /usr/lib/ subdirectory and are referenced on the application's linker command line as given in the table below.

Library	gcc Link Flag
lib14hsai4_main.so	-l14hsai4_main
lib14hsai4_multi.so	-l14hsai4_multi
lib14hsai4_all.so†	-l14hsai4_all

† This library includes all generated libraries, including the API Library shared object file content.

4. API Library

The 14HSAI4 API Library is the software interface between user applications and the 14HSAI4 device driver. The interface is accessed by including the header file `14hsai4_api.h`.

NOTE: Contact General Standards Corporation if additional library functionality is required.

4.1. Files

The library files are summarized in the table below.

Description	File	Location
Source Files	*.c, *.h/api/
Header File	<code>14hsai4_api.h</code>	.../include/
Library File	<code>lib14hsai4_api.so</code>	.../lib/ /usr/lib/ †

† The shared object library is automatically copied to `/usr/lib/` when it is built.

4.2. Build

The API Library is built via the Overall Make Script (section 2.7, page 13), but can be built separately following the below steps.

NOTE: The following steps may require elevated privileges.

1. Change to the directory where the library sources are installed (`.../api/`).
2. Remove existing build targets using the below command.

```
make clean
```

3. Compile the source files and build the library by issuing the below command. This step copies the API Library file to `/usr/lib/`.

```
make
```

4.3. Library Use

The library is used at application compile time, at application link time and at application run time. At compile time include the below listed header file in each source file using a component of the Library interface. Also, edit the include file search path to locate the header file in the below listed directory. At link time the Library's shared object file is linked via the linker command line. This can be done by naming the `.so` file explicitly or by adding the below linker command line argument. At run time the library is found in the directory `/usr/lib/`. (The shared object file is automatically copied to `/usr/lib/` when it is built.)

Description	File	Location	Linker Argument
Header File	<code>14hsai4_api.h</code>	.../include/	
Shared Object Library	<code>lib14hsai4_api.so</code>	.../lib/ /usr/lib/	<code>-l14hsai4_api</code>

4.4. Macros

The API Library and driver interfaces include the following macros, which are defined in `14hsai4.h`.

4.4.1. IOCTL Services

The IOCTL macros are documented in section 4.7 (page 24).

4.4.2. Registers

The following gives the complete set of 14HSAI4 registers.

4.4.2.1. GSC Registers

The following table gives the complete set of GSC specific 14HSAI4 registers. Please note that the set of registers supported by any given device may vary according to model and firmware version. For the set of supported registers and their detailed definitions refer to the appropriate *14HSAI4 User Manual*.

NOTE: Refer to the output of the “id” sample application (.../id/) for a complete list of the registers supported by the device being accessed.

Macro	Description
HSIAI4_GSC_AVR	Autocal Values Register (AVR)
HSIAI4_GSC_BCFGR	Board Configuration Register (BCFGR)
HSIAI4_GSC_BCTLR	Board Control Register (BCTLR)
HSIAI4_GSC_BSIZE	Burst Size Register (BSIZE)
HSIAI4_GSC_BUFSTR	Buffer Size Register (BUFSTR)
HSIAI4_GSC_CSCR	Clocking and Sync Control Register (CSCR)
HSIAI4_GSC_DFR	Decimation Factor Register (DFR)
HSIAI4_GSC_IBCR	Input Buffer Control Register (IBCR)
HSIAI4_GSC_IDBR	Input Data Buffer Register (IDBR)
HSIAI4_GSC_PSIZE	Pretrigger Size Register (PSIZE)
HSIAI4_GSC_PSTR	Primary Status Register (PSTR)
HSIAI4_GSC_RDR	Rate Divisors Register (RDR)
HSIAI4_GSC_RGAR	Rate Generator Adjust Register (RGAR)
HSIAI4_GSC_TUR	Test Utility Register (TUR)

4.4.2.2. PCI Configuration Registers

Access to the PCI registers is seldom required so these registers are not listed here. For the complete list of the PCI register identifiers refer to the driver header file `gsc_pci9056.h`, which is automatically included via `14hsai4_api.h`.

4.4.2.3. PLX Feature Set Registers

Access to the PLX registers is seldom required so these registers are not listed here. For the complete list of the PLX register identifiers refer to the driver header file `gsc_pci9056.h`, which is automatically included via `14hsai4_api.h`.

4.5. Data Types

The data types used by the API Library are described with the IOCTL services with which they are used. For additional information refer to section 4.7 (page 24).

4.6. Functions

The interface includes the following functions. The return values reflect the completion status of the requested operation. A return value less than zero always reflects an error condition. The table below summarizes the error

status values. For the I/O function, read, non-negative return values reflect the number of bytes transferred between the application and the interface. A value equal to the requested transfer size indicates complete success. Return values less than the requested transfer size indicate that the I/O timeout expired. For the other API function calls a return value of zero indicates success.

Return Value	Description
< 0	This is the value “(-errno)” (see errno.h).

4.6.1. hsai4_close()

This function is the entry point to close a connection made via the API's open call (section 4.6.4, page 22). The device is put in an initialized state before this call returns.

Prototype

```
int hsai4_close(int fd);
```

Argument	Description
fd	This is the file descriptor obtained from the open service (section 4.6.4, page 22).

Return Value	Description
0	The operation succeeded.
< 0	An error occurred. See error value description above.

Example

```
#include <stdio.h>

#include "14hsai4_dsl.h"

int hsai4_close_dsl(int fd)
{
    int errs;
    int ret;

    ret = hsai4_close(fd);

    if (ret)
        printf("ERROR: hsai4_close() returned %d\n", ret);

    errs = ret ? 1 : 0;
    return(errs);
}
```

4.6.2. hsai4_init()

This function is the entry point to initializing the 14HSAI4 API Library and must be the first call into the Library. This function may be called more than once, but only the first successful call actually initializes the library. Subsequent calls perform no operation at all. All other API calls return a failure status when the API Library is not initialized.

Prototype

```
int hsai4_init(void);
```

Return Value	Description
0	The operation succeeded.
< 0	An error occurred. See error value description above.

Example

```
#include <stdio.h>

#include "14hsai4_dsl.h"

int hsai4_init_dsl(void)
{
    int errs;
    int ret;

    ret = hsai4_init();

    if (ret)
        printf("ERROR: hsai4_init() returned %d\n", ret);

    errs = ret ? 1 : 0;
    return(errs);
}
```

4.6.3. hsai4_ioctl()

This function is the entry point to performing setup and control operations on a 14HSAI4. This function should only be called after a successful open of the respective device. The specific operation performed varies according to the request argument. The request argument also governs the use and interpretation of the arg argument. The set of supported options for the request argument consists of the IOCTL services supported by the driver, which are defined in section 4.7 (page 24).

NOTE: IOCTL operations are not supported for an open on device index -1.

Prototype

```
int hsai4_ioctl(int fd, int request, void* arg);
```

Argument	Description
fd	This is the file descriptor obtained from the open service (section 4.6.4, page 22).
request	This specifies the desired operation to be performed (section 4.7, page 24).
arg	This is specific to the IOCTL operation specified by the request argument.

Return Value	Description
0	The operation succeeded.
< 0	An error occurred. See error value description above.

Example

```
#include <stdio.h>

#include "14hsai4_dsl.h"

int hsai4_ioctl_dsl(int fd, int request, void* arg)
```

```

{
    int errs;
    int ret;

    ret = hsai4_ioctl(fd, request, arg);

    if (ret)
        printf("ERROR: hsai4_ioctl() returned %d\n", ret);

    errs    = ret ? 1 : 0;
    return(errs);
}

```

4.6.4. hsai4_open()

This function is the entry point to open a connection to a 14HSAI4 board. Before returning, the initialize IOCTL service is called to reset all hardware and software settings to their defaults.

Prototype

```
int hsai4_open(int device, int share, int* fd);
```

Argument	Description						
device	This is the zero-based index of the 14HSAI4 to access. †						
share	Open the device in Shared Access Mode? If non-zero the device is opened in Shared Access Mode (see below). If zero the device is opened in Exclusive Access Mode (see below).						
fd	The device handle is returned here. The pointer cannot be NULL. Values returned are as follows. <table border="1"> <tr> <th>Value</th><th>Description</th></tr> <tr> <td>>= 0</td><td>This is the handle to use to access the device in subsequent calls.</td></tr> <tr> <td>-1</td><td>There was an error. The device is not accessible.</td></tr> </table>	Value	Description	>= 0	This is the handle to use to access the device in subsequent calls.	-1	There was an error. The device is not accessible.
Value	Description						
>= 0	This is the handle to use to access the device in subsequent calls.						
-1	There was an error. The device is not accessible.						

† The index value -1 can also be given to acquire driver information (section 2.2, page 12).

Return Value	Description
0	The operation succeeded.
< 0	An error occurred. See error value description above.

Example

```

#include <stdio.h>

#include "14hsai4_dsl.h"

int hsai4_open_dsl(int device, int share, int* fd)
{
    int errs;
    int ret;

    ret = hsai4_open(device, share, fd);

    if (ret)
        printf("ERROR: hsai4_open() returned %d\n", ret);
}

```

```

    errs    = ret ? 1 : 0;
    return(errs);
}

```

4.6.4.1. Access Modes

The value of the `share` argument determines the device access mode, as follows.

Shared Access Mode:

Shared Access Mode allows multiple applications to access the same device simultaneously. In this mode, the first successful open request returns with the device in an initialized state. Subsequent successful Shared Access Mode open requests do not affect the state of the device. Once opened in Shared Access Mode, the device access remains in this mode until all Shared Access Mode accesses release the device with a close request.

Exclusive Access Mode:

Exclusive Access Mode allows a single application to acquire exclusive access to a device. In this mode, a successful open request returns with the device in an initialized state. While open in this mode all subsequent open requests will fail regardless of the access mode requested. Once opened in Exclusive Access Mode, the device access remains in this mode until released by the application with a close request.

4.6.5. `hsai4_read()`

This function is the entry point to reading data from an open connection. The function reads up to `bytes` bytes.

NOTE: If an open was performed using an index of `-1`, then read requests will acquire information from the driver (section 2.2, page 12) rather than data from a device.

NOTE: For additional information refer to the Data Transfer Modes section (section 8.3, page 52).

Prototype

```
int hsai4_read(int fd, void* dst, size_t bytes);
```

Argument	Description
<code>fd</code>	This is the file descriptor obtained from the open service (section 4.6.4, page 22).
<code>dst</code>	The data read is put here.
<code>bytes</code>	This is the desired number of bytes to read. When reading from a device, this must be a multiple of four (4).

Return Value	Description
0 to <code>bytes</code>	The operation succeeded. When reading from a device, a value less than <code>bytes</code> indicates that the I/O timeout period lapsed (section 4.7.48, page 41) before the entire request could be satisfied.
< 0	An error occurred. See error value description above.

Example

```

#include <stdio.h>

#include "14hsai4_dsl.h"

```

```

int hsai4_read_dsl(int fd, void* dst, size_t bytes, size_t* qty)
{
    int errs;
    int ret;

    ret = hsai4_read(fd, dst, bytes);

    if (ret < 0)
        printf("ERROR: hsai4_read() returned %d\n", ret);

    if (qty)
        qty[0] = (ret < 0) ? 0 : (size_t) ret;

    errs = (ret < 0) ? 1 : 0;
    return(errs);
}

```

4.7. IOCTL Services

The 14HSAI4 API Library and device driver implement the following IOCTL services. Each service is described along with the applicable `hsai4_ioctl()` function arguments.

4.7.1. HSAI4_IOCTL_AI_BUF_CLEAR

This service immediately clears the current content from the input buffer. It also clears the associated overflow and underflow status bits. This service does not halt input sampling.

Usage

Argument	Description
request	HSAI4_IOCTL_AI_BUF_CLEAR
arg	Not used.

4.7.2. HSAI4_IOCTL_AI_BUF_ENABLE

This service enables or disabled data flow into the input data buffer.

Usage

Argument	Description
request	HSAI4_IOCTL_AI_BUF_ENABLE
arg	s32*

Valid argument values supplied to the service are as follows.

Value	Description
-1	Retrieve the current state.
HSAI4_AI_BUF_ENABLE_NO	Input to the buffer is disabled.
HSAI4_AI_BUF_ENABLE_YES	Input to the buffer is enabled.

4.7.3. HSAI4_IOCTL_AI_BUF_LEVEL

This service returns the current number of 32-bit data items in the input buffer.

Usage

Argument	Description
request	HS AI4_IOCTL_AI_BUF_LEVEL
arg	s32*

The value returned will be from zero to 256K (262,144).

4.7.4. HSAI4_IOCTL_AI_BUF_OVERFLOW

This service operates on the Input Buffer Overflow status.

Usage

Argument	Description
request	HS AI4_IOCTL_AI_BUF_OVERFLOW
arg	s32*

Valid argument values supplied to the service are as follows.

Value	Description
-1	Retrieve the current state.
HS AI4_BUF_ERROR_CLEAR	Clear the overflow status.
HS AI4_BUF_ERROR_IGNORE	Ignore the current status.

The current state is reported as one of the following values.

Value	Description
HS AI4_BUF_ERROR_NO	The buffer has not experienced an overflow condition.
HS AI4_BUF_ERROR_YES	The buffer has experienced an overflow condition.

4.7.5. HSAI4_IOCTL_AI_BUF_THR_LVL

This service configures the input buffer threshold level.

Usage

Argument	Description
request	HS AI4_IOCTL_AI_BUF_THR_LVL
arg	s32*

Valid argument values are from zero to 0x3FFFF, and -1. A value of -1 will return the current threshold level setting.

4.7.6. HSAI4_IOCTL_AI_BUF_THR_STS

This service retrieves the current input buffer threshold level status, which indicates whether or not there is more than Threshold Level number of 32-bit data items in the input buffer.

Usage

Argument	Description
request	HS AI4_IOCTL_AI_BUF_THR_STS
arg	s32*

The current status is reported as one of the following values.

Value	Description
HS_AI_BUF_THR_STS_CLEAR	The input buffer contains Threshold Level number of data items, or fewer.
HS_AI_BUF_THR_STS_SET	The input buffer contains more than Threshold Level number of data items.

4.7.7. HSAI4_IOCTL_AI_BUF_UNDERFLOW

This service operates on the Input Buffer Underflow status.

Usage

Argument	Description
request	HS_AI_IOCTL_AI_BUF_UNDERFLOW
arg	s32*

Valid argument values supplied to the service are as follows.

Value	Description
-1	Retrieve the current state.
HS_AI_BUF_ERROR_CLEAR	Clear the underflow status.
HS_AI_BUF_ERROR_IGNORE	Ignore the current status.

The current state is reported as one of the following values.

Value	Description
HS_AI_BUF_ERROR_NO	The buffer has not experienced an underflow condition.
HS_AI_BUF_ERROR_YES	The buffer has experienced an underflow condition.

4.7.8. HSAI4_IOCTL_AI_BURST_MARKER

This service enables or disabled insertion of the Burst Marker into the input buffer when bursting is enabled.

Usage

Argument	Description
request	HS_AI_IOCTL_AI_BURST_MARKER
arg	s32*

Valid argument values supplied to the service are as follows.

Value	Description
-1	Retrieve the current state.
HS_AI_BURST_MARKER_DISABLE	Insertion of the Burst Marker is disabled.
HS_AI_BURST_MARKER_ENABLE	Insertion of the Burst Marker is enabled.

4.7.9. HSAI4_IOCTL_AI_BURST_MODE

This service enables and disables input burst mode operation.

Usage

Argument	Description
request	HSIAI4_IOCTL_AI_BURST_MODE
arg	s32*

Valid argument values are as follows.

Value	Description
-1	Retrieve the current setting.
HSIAI4_BURST_MODE_DISABLE	This option disables input bursting.
HSIAI4_BURST_MODE_ENABLE	This option enables input bursting.

4.7.10. HSIAI4_IOCTL_AI_BURST_SINGLE

This service enables and disables Single Burst operation when bursting is enabled.

Usage

Argument	Description
request	HSIAI4_IOCTL_AI_BURST_SINGLE
arg	s32*

Valid argument values are as follows.

Value	Description
-1	Retrieve the current setting.
HSIAI4_BURST_SINGLE_DISABLE	This option disables Single Burst operation.
HSIAI4_BURST_SINGLE_ENABLE	This option enables Single Burst operation.

4.7.11. HSIAI4_IOCTL_AI_BURST_SIZE

This service configures the size of a single input burst (the count is in scans, which is an A/D conversion of all active input channels).

Usage

Argument	Description
request	HSIAI4_IOCTL_AI_BURST_SIZE
arg	s32*

Valid argument values are from zero to 0xFFFFF, or -1 to retrieve the current setting. A value of zero means perform continuous sampling after receiving the sync trigger.

4.7.12. HSIAI4_IOCTL_AI_BURST_STATUS

This service reports on the board's input burst status.

Usage

Argument	Description
request	HSIAI4_IOCTL_AI_BURST_STATUS
arg	s32*

The value returned will be one of the following.

Value	Description
HSIAI4_BURST_STATUS_ACTIVE	A burst operation is in progress.
HSIAI4_BURST_STATUS_IDLE	The board is ready to start an input burst operation.

4.7.13. HSAI4_IOCTL_AI_BURST_TRIGGER

This service initiates a manual trigger cycle for input bursting. The driver returns immediately and does not wait for completion.

Usage

Argument	Description
request	HSIAI4_IOCTL_AI_BURST_TRIGGER
arg	Not used.

4.7.14. HSAI4_IOCTL_AI_CHAN_SEL

This service configures the set of active input channels. If a bit is set, then that channel is enabled. If a bit is clear, then that channel is disabled.

Usage

Argument	Description
request	HSIAI4_IOCTL_AI_CHAN_SEL
arg	s32*

Valid argument values are from zero to 0xF for four channel boards, from zero to 0x3 for two channel boards, or -1 to retrieve the current setting.

4.7.15. HSAI4_IOCTL_AI_CHAN_TAG

This service enables and disables insertion of the Channel Tag into the input data stream.

Usage

Argument	Description
request	HSIAI4_IOCTL_AI_CHAN_TAG
arg	s32*

Valid argument values are as follows.

Value	Description
-1	Retrieve the current setting.
HSIAI4_AI_CHAN_TAG_DISABLE	Do not insert the Channel Tag.
HSIAI4_AI_CHAN_TAG_ENABLE	Insert the Channel Tag.

4.7.16. HSAI4_IOCTL_AI_CLOCK_SRC

This service selects the source for Analog Input clocking.

Usage

Argument	Description
request	HSIAI4_IOCTL_AI_CLOCK_SRC
arg	s32*

Valid argument values are as follows.

Value	Description
-1	Retrieve the current setting.
HSIAI4_AI_CLOCK_SRC_EXTERNAL	Use the clock provided at the cable interface.
HSIAI4_AI_CLOCK_SRC_INTERNAL	Use the internal clock.

4.7.17. HSIAI4_IOCTL_AI_CLOCKING

This service enables or disables ADC clocking.

Usage

Argument	Description
request	HSIAI4_IOCTL_AI_CLOCKING
arg	s32*

Valid argument values are as follows.

Value	Description
-1	Retrieve the current setting.
HSIAI4_AI_CLOCKING_DISABLE	This disables ADC clocking.
HSIAI4_AI_CLOCKING_ENABLE	This enables ADC clocking.

4.7.18. HSIAI4_IOCTL_AI_DATA_PACKING

This service enables or disables data packing into the input buffer.

Usage

Argument	Description
request	HSIAI4_IOCTL_AI_DATA_PACKING
arg	s32*

Valid argument values are as follows.

Value	Description
-1	Retrieve the current setting.
HSIAI4_AI_DATA_PACKING_DISABLE	Each 32-bit input buffer entry stores one sample.
HSIAI4_AI_DATA_PACKING_ENABLE	Each 32-bit input buffer entry stores two samples.

4.7.19. HSIAI4_IOCTL_AI_MODE

This service configures the board's Analog Input Mode.

Usage

Argument	Description
request	HSIAI4_IOCTL_AI_MODE
arg	s32*

Valid argument values are as follows.

Value	Description
-1	Retrieve the current setting.
HSIAI4_AI_MODE_SYSTEM	Configure the input channels for analog input operation.
HSIAI4_AI_MODE_VREF	Configure the input channels for +VREF input testing. †
HSIAI4_AI_MODE_ZERO	Configure the input channels for Zero input testing. †

† These modes are not available on boards configured with Transformer-Coupled inputs.

4.7.20. HSIAI4_IOCTL_AI_PRETRIG_MODE

This service enables or disables the Pretrigger Input operating mode.

Usage

Argument	Description
request	HSIAI4_IOCTL_AI_PRETRIG_MODE
arg	s32*

Valid argument values are as follows.

Value	Description
-1	Retrieve the current setting.
HSIAI4_AI_PRETRIG_MODE_DISABLE	This disables the Pretrigger Input operating mode.
HSIAI4_AI_PRETRIG_MODE_ENABLE	This enables the Pretrigger Input operating mode.

4.7.21. HSIAI4_IOCTL_AI_PRETRIG_SIZE

This service configures the number of Pretrigger samples per active channel to collect while the Pretrigger mode is enabled.

Usage

Argument	Description
request	HSIAI4_IOCTL_AI_PRETRIG_SIZE
arg	s32*

Valid argument values are from two to 0x3FFFF, or -1 to retrieve the current setting.

4.7.22. HSIAI4_IOCTL_AI_PRETRIG_STS

This service reports the status of the Pretrigger data collection.

Usage

Argument	Description
request	HSIAI4_IOCTL_AI_PRETRIG_STS
arg	s32*

The value returned will be one of the following.

Value	Description
HS AI4 AI PRETRIG STS DONE	The Pretrigger data has been collected.
HS AI4 AI PRETRIG STS WAITING	The board is waiting to collect the configured amount of Pretrigger data.

4.7.23. HSAI4_IOCTL_AI_RANGE

This service configures the analog input voltage range.

Usage

Argument	Description
request	HS AI4 IOCTL AI RANGE
arg	s32*

Valid argument values are as follows on boards configured with Wideband inputs.

Value	Description
-1	Retrieve the current setting.
HS AI4 AI RANGE 0 625V	Set the input voltage range to ± 0.625 volts.
HS AI4 AI RANGE 1 25V	Set the input voltage range to ± 1.25 volts.
HS AI4 AI RANGE 2 5V	Set the input voltage range to ± 2.5 volts.

Valid argument values are as follows on boards configured with High-Level inputs.

Value	Description
-1	Retrieve the current setting.
HS AI4 AI RANGE 2 5V	Set the input voltage range to ± 2.5 volts.
HS AI4 AI RANGE 5V	Set the input voltage range to ± 5 volts.
HS AI4 AI RANGE 10V	Set the input voltage range to ± 10 volts.

Valid argument values are as follows on boards configured with Transformer-Coupled inputs.

Value	Description
-1	Retrieve the current setting.
HS AI4 AI RANGE 1 0VPP	Set the input voltage range to 1.0 volts peak-to-peak.
HS AI4 AI RANGE 2 0VPP	Set the input voltage range to 2.0 volts peak-to-peak.

4.7.24. HSAI4_IOCTL_AI_SOL_CHAN

This service configures the input channel to use for Sync-On-Level burst operation.

Usage

Argument	Description
request	HS AI4 IOCTL AI SOL CHAN
arg	s32*

Valid argument values are from zero to one for two channel boards and zero to three for four channel boards, or -1 to retrieve the current setting.

4.7.25. HSAI4_IOCTL_AI_SOL_HOLDOFF

This service configures the minimum number of scans between successive sync events for Sync-On-Level operation.

Usage

Argument	Description
request	HSAI4_IOCTL_AI_SOL_HOLDOFF
arg	s32*

Valid argument values are as follows.

Value	Description
-1	Retrieve the current setting.
HSAI4_AI_SOL_HOLDOFF_8	The minimum number of scans is eight.
HSAI4_AI_SOL_HOLDOFF_64	The minimum number of scans is 64.
HSAI4_AI_SOL_HOLDOFF_512	The minimum number of scans is 512.
HSAI4_AI_SOL_HOLDOFF_INF	The minimum number of scans is infinite, which forces only a single sync to occur.

4.7.26. HSAI4_IOCTL_AI_SOL_INT

This service configures the minimum number of successive scans required before a sync is generated when using Sync-On-Level burst operations.

Usage

Argument	Description
request	HSAI4_IOCTL_AI_SOL_INT
arg	s32*

Valid argument values are as follows.

Value	Description
-1	Retrieve the current setting.
HSAI4_AI_SOL_INT_1	The minimum number of scans is one.
HSAI4_AI_SOL_INT_4	The minimum number of scans is four.
HSAI4_AI_SOL_INT_16	The minimum number of scans is 16.
HSAI4_AI_SOL_INT_64	The minimum number of scans is 64.

4.7.27. HSAI4_IOCTL_AI_SOL_LEVEL

This service configures the threshold level for Sync-On-Level burst operations.

Usage

Argument	Description
request	HSAI4_IOCTL_AI_SOL_LEVEL
arg	s32*

Valid argument values are from zero to 0x3FFF, or -1 to retrieve the current setting.

4.7.28. HSAI4_IOCTL_AI_SYNC_SRC

This service configures the sync clocking source for burst operations.

Usage

Argument	Description
request	HSAI4_IOCTL_AI_SYNC_SRC
arg	s32*

Valid argument values are as follows.

Value	Description
-1	Retrieve the current setting.
HSAI4_AI_SYNC_SRC_BCR	Generate a sync event manually.
HSAI4_AI_SYNC_SRC_EXTERNAL	Generate sync events based on external input clocking.
HSAI4_AI_SYNC_SRC_INTERNAL	Generate sync events based on internal clocking.
HSAI4_AI_SYNC_SRC_SOL_ABOVE	Generate sync events when the input from the configured Sync-On-Level input channel is above the configured Sync-On-Level value.
HSAI4_AI_SYNC_SRC_SOL_BELOW	Generate sync events when the input from the configured Sync-On-Level input channel is below the configured Sync-On-Level value.

4.7.29. HSAI4_IOCTL_AUTOCAL

This service initiates an autocalibration cycle. Most configuration settings should be made before running an autocalibration cycle. The driver waits for the operation to complete before returning. This service is not available on boards configured for Transformer-Coupled operation.

NOTE: This service overwrites the current interrupt selection in order to detect the Autocalibration Done interrupt.

NOTE: When an error is encountered, the service writes a brief, descriptive error message to the system log.

Usage

Argument	Description
request	HSAI4_IOCTL_AUTOCAL
arg	Not used.

4.7.30. HSAI4_IOCTL_AUTOCAL_STATUS

This service reports the status of the most recent autocalibration cycle. This service is not available on boards configured for Transformer-Coupled operation.

Usage

Argument	Description
request	HSAI4_IOCTL_AUTOCAL_STATUS
arg	s32*

The current status is reported as one of the following values.

Value	Description
HSAI4_AUTOCAL_STATUS_ACTIVE	Autocalibration is in progress.
HSAI4_AUTOCAL_STATUS_FAIL	Autocalibration failed.
HSAI4_AUTOCAL_STATUS_PASS	Autocalibration passed.

4.7.31. HSAI4_IOCTL_CBL_CLK_SYNC_DIR

This service configures the direction of the cable's Sync and Clock signals.

Usage

Argument	Description
request	HSAI4_IOCTL_CBL_CLK_SYNC_DIR
arg	s32*

Valid argument values are as follows.

Value	Description
-1	Retrieve the current setting.
HSAI4_CBL_CLK_SYNC_DIR_INPUT	The cable Clock and Sync signals operate as inputs.
HSAI4_CBL_CLK_SYNC_DIR_OUTPUT	The cable Clock and Sync signals operate as outputs.

4.7.32. HSAI4_IOCTL_DATA_FORMAT

This service sets the data encoding format.

Usage

Argument	Description
request	HSAI4_IOCTL_DATA_FORMAT
arg	s32*

Valid argument values are as follows.

Value	Description
-1	Retrieve the current setting.
HSAI4_DATA_FORMAT_2S_COMP	Select the Twos Complement data format.
HSAI4_DATA_FORMAT_OFF_BIN	Select the Offset Binary encoding format.

4.7.33. HSAI4_IOCTL_GEN_INT_CLK_STATUS

This service reports the readiness status of the onboard clocking logic. This status is most applicable when onboard clocking rate changes are made as a settling time is required for some changes.

NOTE: Applications do not need to use this service when the driver is used to make clocking changes. The driver automatically waits the appropriate period of time.

Usage

Argument	Description
request	HSAI4_IOCTL_GEN_INT_CLK_STATUS
arg	s32*

The current status is reported as one of the following values.

Value	Description
HSIAI4_GEN_INT_CLK_STATUS_BUSY	The clocking logic is busy due to programmed changes.
HSIAI4_GEN_INT_CLK_STATUS_READY	The clocking logic is stable and ready for use.

4.7.34. HSAI4_IOCTL_GEN_NDEC

This service configures the NDEC parameter used by the onboard clocking logic.

Usage

Argument	Description
request	HSIAI4_IOCTL_GEN_NDEC
arg	s32*

Valid argument values are from one to 1000, or -1 to retrieve the current setting.

4.7.35. HSAI4_IOCTL_GEN_NDIV_CLK

This service configures the NDIV-CLK parameter used by the onboard clocking logic.

Usage

Argument	Description
request	HSIAI4_IOCTL_GEN_NDIV_CLK
arg	s32*

Valid argument values are from one to 25, or -1 to retrieve the current setting.

4.7.36. HSAI4_IOCTL_GEN_NDIV_SYNC

This service configures the NDIV-SYNC parameter used by the onboard clocking logic.

Usage

Argument	Description
request	HSIAI4_IOCTL_GEN_NDIV_SYNC
arg	s32*

Valid argument values are from 10 to 0xFFFFF, or -1 to retrieve the current setting.

4.7.37. HSAI4_IOCTL_GEN_NREF

This service configures the NREF parameter used by the onboard clocking logic.

Usage

Argument	Description
request	HSIAI4_IOCTL_GEN_NREF
arg	s32*

Valid argument values are from 20 to 1000, or -1 to retrieve the current setting.

4.7.38. HSAI4_IOCTL_GEN_NVCO

This service configures the NVCO parameter used by the onboard clocking logic.

Usage

Argument	Description
request	HSAI4_IOCTL_GEN_NVCO
arg	s32*

Valid argument values are from 20 to 1000, or -1 to retrieve the current setting.

4.7.39. HSAI4_IOCTL_INITIALIZE

This service returns all driver interface settings for the board to the state they were in when the board was first opened. This includes both hardware-based settings and software-based settings.

NOTE: If the initialization service returns an error status, an error message will be posted to the system log briefly describing the error condition.

Usage

Argument	Description
request	HSAI4_IOCTL_INITIALIZE
arg	Not used.

4.7.40. HSAI4_IOCTL_IRQ_ENABLE

This service enables and disables interrupts. If a bit is set, then the interrupt is enabled. If a bit is clear, then the interrupt is disabled. The level sensitive interrupts are disabled by the driver when an interrupt is generated. The edge sensitive interrupts remain enabled until disabled by the application.

Usage

Argument	Description
request	HSAI4_IOCTL_IRQ_ENABLE
arg	s32*

Valid argument values include any bitwise combination of the following bits.

Value	Description
-1	Retrieve the current setting.
HSAI4_IRQ_AI_BUF_ERROR	There has been a buffer overflow and/or underflow. †
HSAI4_IRQ_AI_BUF_THRESH	The input buffer threshold flag is set. †
HSAI4_IRQ_AI_BUF_THRESH_H2L	The buffer threshold flag transitioned from high to low.
HSAI4_IRQ_AI_BUF_THRESH_L2H	The buffer threshold flag transitioned from low to high.
HSAI4_IRQ_AI_BURST_ACTIVE	An input burst operation is in progress. ‡
HSAI4_IRQ_AI_BURST_BEGIN	An input burst operation began.
HSAI4_IRQ_AI_BURST_END	An input burst operation ended.
HSAI4_IRQ_AI_PRETRIG_ACTIVE	Pretrigger data has been stored and the board is waiting for an input sync trigger. ‡
HSAI4_IRQ_AI_PRETRIG_ARM	Pretrigger data has been stored and the board began waiting for an input sync trigger.
HSAI4_IRQ_AUTOCAL_ACTIVE	An autocalibration cycle is in progress. † ‡

HS_AI4_IRQ_AUTO_CAL_DONE	An autocalibration cycle ended. †
--------------------------	-----------------------------------

† These interrupt sources are not available on boards configured with Transformer-Coupled inputs.

‡ These interrupts are level sensitive and are disabled by the driver when the interrupt occurs.

4.7.41. HSAI4_IOCTL_QUERY

This service queries the driver for various pieces of information about the board and the driver.

Usage

Argument	Description
request	HS_AI4_IOCTL_QUERY
arg	s32*

Valid argument values are as follows.

Value	Description
HS_AI4_QUERY_AI_RANGE_MAX	This is the highest supported input voltage range setting. Refer to the HS_AI4_IOCTL_AI_RANGE_IOCTL service options beginning in section 4.7.23 on page 31.
HS_AI4_QUERY_AI_RANGE_MIN	This is the lowest supported input voltage range setting. Refer to the HS_AI4_IOCTL_AI_RANGE_IOCTL service options beginning in section 4.7.23 on page 31.
HS_AI4_QUERY_AUTO_CAL	This indicates if the board supports Autocalibration.
HS_AI4_QUERY_AUTO_CAL_MS	This returns the maximum duration of the Autocalibration cycle in milliseconds.
HS_AI4_QUERY_CHANNEL_AI_MAX	This returns the maximum number of input channels supported by the board, which may be more than the board's current configuration.
HS_AI4_QUERY_CHANNEL_AI_QTY	This returns the actual number of input channels on the current board.
HS_AI4_QUERY_COUNT	This returns the number of query options supported by the IOCTL service.
HS_AI4_QUERY_DEVICE_TYPE	This returns the identifier value for the board's type. This should be GSC_DEV_TYPE_14HSAI4.
HS_AI4_QUERY_FGEN_MAX	This returns the maximum supported FGEN value.
HS_AI4_QUERY_FGEN_MIN	This returns the minimum supported FGEN value.
HS_AI4_QUERY_FIFO_SIZE_RX	This returns the size of the input buffer in 32-bit A/D values.
HS_AI4_QUERY_FREF_DEFAULT	This returns the master clock frequency, FREF, in hertz.
HS_AI4_QUERY_FSAMP_AGG	This gives the maximum aggregate sample rate for the board.
HS_AI4_QUERY_FSAMP_MAX	This gives the maximum FSAMP value in S/S.
HS_AI4_QUERY_FSAMP_MIN	This gives the minimum FSAMP value in S/S.
HS_AI4_QUERY_FSYNC_MAX	This returns the maximum supported FSYNC value.
HS_AI4_QUERY_FSYNC_MIN	This returns the minimum supported FSYNC value.
HS_AI4_QUERY_INIT_MS	This returns the duration of a board initialization in milliseconds.
HS_AI4_QUERY_INPUT_CONFIG	This returns the board's analog input configuration. The values returned are given in the appropriate table below.
HS_AI4_QUERY_INPUT_IMPED	This returns the board's analog input impedance. The values returned are given in the appropriate table below.
HS_AI4_QUERY_NDEC_MAX	This returns the maximum supported FDEC value.
HS_AI4_QUERY_NDEC_MIN	This returns the minimum supported FDEC value.
HS_AI4_QUERY_NDIV_CLK_MAX	This returns the maximum supported NDIV-CLK value.
HS_AI4_QUERY_NDIV_CLK_MIN	This returns the minimum supported NDIV-CLK value.

HSIAI4_QUERY_NDIV_SYNC_MAX	This returns the maximum supported NDIV-SYNC value.
HSIAI4_QUERY_NDIV_SYNC_MIN	This returns the minimum supported NDIV-SYNC value.
HSIAI4_QUERY_NREF_MAX	This returns the maximum supported FREF value.
HSIAI4_QUERY_NREF_MIN	This returns the minimum supported FREF value.
HSIAI4_QUERY_NVCO_MAX	This returns the maximum supported NVCO value.
HSIAI4_QUERY_NVCO_MIN	This returns the minimum supported NVCO value.
HSIAI4_QUERY_RATE_GEN_MS	This refers to the maximum amount of settling time, in milliseconds, required for onboard clock rate changes.

Valid return values are as indicated in the above table and as given in the below tables.

Value	Description
HSIAI4_IOCTL_QUERY_ERROR	Either there was a processing error or the query option is unrecognized.

Valid return values for the HSIAI4_QUERY_INPUT_CONFIG query are as indicated in the below table.

Value	Description
HSIAI4_INPUT_CONFIG_HIGH_LEVEL	The board is configured with High-Level inputs.
HSIAI4_INPUT_CONFIG_TRANSFORMER	The board is configured with Transformer-Coupled inputs.
HSIAI4_INPUT_CONFIG_WIDEBAND	The board is configured with Wideband inputs.

Valid return values for the HSIAI4_QUERY_INPUT_IMPED query are as indicated in the below table.

Value	Description
HSIAI4_INPUT_IMPED_50	The board is configured with 50-ohm inputs.
HSIAI4_INPUT_IMPED_2M	The board is configured with 2M ohm inputs.

4.7.42. HSIAI4_IOCTL_REG_MOD

This service performs a read-modify-write of a 14HSAI4 register. This includes only the GSC firmware registers. The PCI and PLX Feature Set Registers are read-only. Refer to `14hsai4.h` for the complete list of GSC firmware registers.

Usage

Argument	Description
request	HSIAI4_IOCTL_REG_MOD
arg	<code>gsc_reg_t*</code>

Definition

```
typedef struct
{
    u32 reg;
    u32 value;
    u32 mask;
} gsc_reg_t;
```

Fields	Description
reg	This is set to the identifier for the register to access.
value	This contains the value for the register bits to modify.
mask	This specifies the set of bits to modify. If a bit here is set, then the respective register bits is modified. If a bit here is zero, then the respective register bit is unmodified.

4.7.43. HSAI4_IOCTL_REG_READ

This service reads the value of a 14HSAI4 register. This includes the PCI registers, the PLX Feature Set Registers and the GSC firmware registers. Refer to `14hsai4.h` and `gsc_pci9056.h` for the complete list of accessible registers.

Usage

Argument	Description
request	HSAI4_IOCTL_REG_READ
arg	<code>gsc_reg_t*</code>

Definition

```
typedef struct
{
    u32 reg;
    u32 value;
    u32 mask;
} gsc_reg_t;
```

Fields	Description
reg	This is set to the identifier for the register to access.
value	This is the value read from the specified register.
mask	This is ignored for read request.

4.7.44. HSAI4_IOCTL_REG_WRITE

This service writes a value to a 14HSAI4 register. This includes only the GSC firmware registers. The PCI and PLX Feature Set Registers are read-only. Refer to `14hsai4.h` for a complete list of the GSC firmware registers.

Usage

Argument	Description
request	HSAI4_IOCTL_REG_WRITE
arg	<code>gsc_reg_t*</code>

Definition

```
typedef struct
{
    u32 reg;
    u32 value;
    u32 mask;
} gsc_reg_t;
```

Fields	Description
reg	This is set to the identifier for the register to access.
value	This is the value to write to the specified register.
mask	This is ignored for write request.

4.7.45. HSAI4_IOCTL_RX_IO_ABORT

This service aborts an ongoing read request.

Usage

Argument	Description
request	HSIAI4_IOCTL_RX_IO_ABORT
arg	s32*

The results are reported as one of the following values.

Value	Description
HSIAI4_IOCTL_ABORT_NO	A read request was not aborted as none were ongoing.
HSIAI4_IOCTL_ABORT_YES	An ongoing read request was aborted.

4.7.46. HSIAI4_IOCTL_RX_IO_MODE

This service sets the I/O mode used for data read requests.

Usage

Argument	Description
request	HSIAI4_IOCTL_RX_IO_MODE
arg	s32*

Valid argument values are as follows.

Value	Description
-1	Retrieve the current setting.
GSC_IOCTL_MODE_BMDMA	Use Block Mode DMA.
GSC_IOCTL_MODE_DMDMA	Use Demand Mode DMA (transfer data as it becomes possible to do so).
GSC_IOCTL_MODE_PIO	Use PIO mode, which is repetitive register access. This is the default.

4.7.47. HSIAI4_IOCTL_RX_IO_OVERFLOW

This service configures the read service to check for an input buffer overflow before performing read operations. Sampled data is lost when there is an overflow. If the check is performed and an overflow is detected, then the read service immediately returns an error.

NOTE: The check for an overflow is performed upon entry to the read service. The read service does not check for overflows that occur while the read is in progress. For in-progress overflows an application must perform the check manually or wait for the check performed by a subsequent read request.

Usage

Argument	Description
request	HSIAI4_IOCTL_RX_IO_OVERFLOW
arg	s32*

Valid argument values are as follows.

Value	Description
-1	Retrieve the current setting.
HSIAI4_IOCTL_OVERFLOW_CHECK	Perform the check. This is the default.
HSIAI4_IOCTL_OVERFLOW_IGNORE	Do not perform the check.

4.7.48. HSAI4_IOCTL_RX_IO_TIMEOUT

This service sets the timeout limit for read requests. The value is expressed in seconds.

Usage

Argument	Description
request	HSAI4_IOCTL_RX_IO_TIMEOUT
arg	s32*

Valid argument values are in the range from zero to 3600, -1, and HSAI4_IOCTL_TIMEOUT_INFINITE. A value of zero tells the driver not to sleep in order to wait for more data, and should only be used with PIO mode reads. A value of -1 is used to retrieve the current setting. If the option HSAI4_IOCTL_TIMEOUT_INFINITE is used, then the driver will wait indefinitely rather than timing out. The default is 10 seconds.

4.7.49. HSAI4_IOCTL_RX_IO_UNDERFLOW

This service configures the read service to check for an input buffer underflow before performing read operations. Indeterminate data is obtained when there is an underflow. If the check is performed and an underflow is detected, then the read service immediately returns an error.

NOTE: The check for an underflow is performed upon entry to the read service. The read service does not check for underflows that occur while the read is in progress. For in-progress underflows an application must perform the check manually or wait for the check performed by a subsequent read request.

Usage

Argument	Description
request	HSAI4_IOCTL_RX_IO_UNDERFLOW
arg	s32*

Valid argument values are as follows.

Value	Description
-1	Retrieve the current setting.
HSAI4_IOCTL_UNDERFLOW_CHECK	Perform the check. This is the default.
HSAI4_IOCTL_UNDERFLOW_IGNORE	Do not perform the check.

4.7.50. HSAI4_IOCTL_WAIT_CANCEL

This service resumes all threads blocked via HSAI4_IOCTL_WAIT_EVENT IOCTL calls (section 4.7.51, page 42), according to the provided criteria. When a blocked thread is waiting for any event specified in the structure, then the thread is resumed.

NOTE: The driver itself makes use of the wait services for various internal operations. Driver initiated waits are unaffected by application cancel requests.

Usage

Argument	Description
request	HSAI4_IOCTL_WAIT_CANCEL
arg	gsc_wait_t*

Definition

```
typedef struct
{
    u32  flags;
    u32  main;
    u32  gsc;
    u32  alt;
    u32  io;
    u32  timeout_ms;
    u32  count;
} gsc_wait_t;
```

Fields	Description
flags	This is unused by wait cancel operations.
main	This specifies the set of GSC_WAIT_MAIN_* events whose wait requests are to be cancelled. Refer to section 4.7.51.2 on page 43.
gsc	This specifies the set of HSAI4_WAIT_GSC_* events whose wait requests are to be cancelled. Refer to section 4.7.51.3 on page 43.
alt	This is unused by the 14HSAI4 driver and should be zero.
io	This specifies the set of HSAI4_WAIT_IO_* events whose wait requests are to be cancelled. Refer to section 4.7.51.4 on page 44.
timeout_ms	This is unused by wait cancel operations.
count	Upon return this indicates the number of waits that were cancelled.

4.7.51. HSAI4_IOCTL_WAIT_EVENT

This service blocks a thread until any one of a specified set of events occurs, or until a timeout lapses, whichever occurs first. The set of possible events to wait for are specified in the structure's `main`, `gsc` and `io` fields. All field values must be valid and at least one event must be specified. If the thread is resumed because one of the referenced events has occurred, then the bit for the respective event is the only event bit that will be set. All other event bits and fields will be zero. (Multiple event bits will be set only if the events occur simultaneously.)

NOTE: The service waits only for the first of the specified events, not for all specified events.

NOTE: A wait timeout is reported via the `gsc_wait_t` structure's `flags` field having the `GSC_WAIT_FLAG_TIMEOUT` flag set, rather than via an `ETIMEDOUT` error.

Usage

Argument	Description
request	HSAI4_IOCTL_WAIT_EVENT
arg	<code>gsc_wait_t*</code>

Definition

```
typedef struct
{
    u32  flags;
    u32  main;
    u32  gsc;
    u32  alt;
    u32  io;
    u32  timeout_ms;
    u32  count;
```

```
} gsc_wait_t;
```

Fields	Description
flags	This must initially be zero. Upon return this indicates the reason that the thread was resumed. Refer to section 4.7.51.1 on page 43.
main	This specifies any number of GSC_WAIT_MAIN_* events that the thread is to wait for. Refer to section 4.7.51.2 on page 43.
gsc	This specifies any number of HSAI4_WAIT_GSC_* events that the thread is to wait for. Refer to section 4.7.51.3 on page 43.
alt	This is unused by the 14HSAI4 driver and must be zero.
io	This specifies any number of HSAI4_WAIT_IO_* events that the thread is to wait for. Refer to section 4.7.51.4 on page 44.
timeout_ms	This specified the maximum amount of time, in milliseconds, that the thread is to wait for any of the referenced events. A value of zero means do not timeout at all. If non-zero, then upon return the value will be the approximate amount of time actually waited.
count	This is unused by wait event operations and must be zero.

4.7.51.1. gsc_wait_t.flags Options

Upon return from a wait request the wait structure's flags field will indicate the reason that the thread was resumed. Only one of the below options will be set.

Fields	Description
GSC_WAIT_FLAG_CANCEL	The wait request was cancelled.
GSC_WAIT_FLAG_DONE	One of the referenced events occurred.
GSC_WAIT_FLAG_TIMEOUT	The timeout period lapsed before a referenced event occurred.

4.7.51.2. gsc_wait_t.main Options

The wait structure's main field may specify any of the below primary interrupt options. These interrupt options are supported by the 14HSAI4 and other General Standards products.

Fields	Description
GSC_WAIT_MAIN_DMA0	This refers to the DMA Done interrupt on DMA engine number zero.
GSC_WAIT_MAIN_DMA1	This refers to the DMA Done interrupt on DMA engine number one.
GSC_WAIT_MAIN_GSC	This refers to any of the Interrupt Control/Status Register interrupts.
GSC_WAIT_MAIN_OTHER	This generally refers to an interrupt generated by another device sharing the same interrupt as the 14HSAI4.
GSC_WAIT_MAIN_PCI	This refers to any interrupt generated by the 14HSAI4.
GSC_WAIT_MAIN_SPURIOUS	This refers to board interrupts which should never be generated.
GSC_WAIT_MAIN_UNKNOWN	This refers to board interrupts whose source could not be identified.

4.7.51.3. gsc_wait_t.gsc Options

The wait structure's gsc field may specify any combination of the below interrupt options. These are the interrupt options referenced in the Primary Status Register. Applications are responsible for enabling the desired interrupt options. Refer to HSAI4_IOCTL_IRQ_ENABLE (section 4.7.40, page 36). Level triggered interrupts are disabled by the driver when the interrupt occurs. Edge triggered interrupts remain enabled.

Fields	Description
HSAI4_WAIT_GSC_AI_BUF_ERROR	There has been a buffer overflow and/or underflow. ‡
HSAI4_WAIT_GSC_AI_BUF_THRESH	The input buffer threshold flag is set. ‡
HSAI4_WAIT_GSC_AI_BUF_THRESH_H2L	The buffer threshold flag transitioned from high to low. †

HSIAI4_WAIT_GSC_AI_BUF_THRESH_L2H	The buffer threshold flag transitioned from low to high. †
HSIAI4_WAIT_GSC_AI_BURST_ACTIVE	An input burst operation is in progress. ‡
HSIAI4_WAIT_GSC_AI_BURST_BEGIN	An input burst operation began. †
HSIAI4_WAIT_GSC_AI_BURST_END	An input burst operation ended. †
HSIAI4_WAIT_GSC_AI_PRETRIG_ACTIVE	Pretrigger data has been stored and the board is waiting for an input sync trigger. ‡
HSIAI4_WAIT_GSC_AI_PRETRIG_ARM	Pretrigger data has been stored and the board began waiting for an input sync trigger. †
HSIAI4_WAIT_GSC_AUTOCAL_ACTIVE	An autocalibration cycle is in progress. ‡
HSIAI4_WAIT_GSC_AUTOCAL_DONE	An autocalibration cycle ended. †

† These are edge triggered interrupts.

‡ These are level triggered interrupts.

4.7.51.4. gsc_wait_t.io Options

The wait structure's io field may specify any of the below event options. These events are generated in response to application board data read requests.

Fields	Description
HSIAI4_WAIT_IO_RX_ABORT	This refers to read requests which have been aborted.
HSIAI4_WAIT_IO_RX_DONE	This refers to read requests which have been satisfied.
HSIAI4_WAIT_IO_RX_ERROR	This refers to read requests which end due to an error.
HSIAI4_WAIT_IO_RX_TIMEOUT	This refers to read requests which end due to the timeout period lapse.

4.7.52. HSAI4_IOCTL_WAIT_STATUS

This service counts the number of threads blocked via HSAI4_IOCTL_WAIT_EVENT IOCTL calls (section 4.7.51, page 42), according to the provided criteria. Any application thread waiting on any of the referenced event options is included in the count.

NOTE: The driver itself makes use of the wait services for various internal operations. Driver initiated waits are not included in the status count.

Usage

Argument	Description
request	HSIAI4_IOCTL_WAIT_STATUS
arg	gsc_wait_t*

Definition

```
typedef struct
{
    u32  flags;
    u32  main;
    u32  gsc;
    u32  alt;
    u32  io;
    u32  timeout_ms;
    u32  count;
} gsc_wait_t;
```

Fields	Description
flags	This is unused by wait status operations.

main	This specifies the set of GSC_WAIT_MAIN_* events whose wait requests are to be counted. Refer to section 4.7.51.2 on page 43.
gsc	This specifies the set of HSAI4_WAIT_GSC_* events whose wait requests are to be counted. Refer to section 4.7.51.3 on page 43.
alt	This is unused by the 14HSAI4 driver and should be zero.
io	This specifies the set of HSAI4_WAIT_IO_* events whose wait requests are to be counted. Refer to section 4.7.51.4 on page 44.
timeout_ms	This is unused by wait status operations.
count	Upon return this indicates the number of threads currently waiting.

4.7.53. HSAI4_IOCTL_XCVR

This service sets the transceiver style used by the cable's sync and clock signals.

Usage

Argument	Description
request	HSAI4_IOCTL_XCVR
arg	s32*

Valid argument values are as follows.

Value	Description
-1	Retrieve the current setting.
HSAI4_XCVR_LVDS	The transceivers are configured for LVDS operation.
HSAI4_XCVR_TTL	The transceivers are configured for TTL operation.

5. The Driver

NOTE: Contact General Standards Corporation if additional driver functionality is required.

5.1. Files

The device driver files are summarized in the table below.

Description	Files	Location
Source Files	*.c, *.h/driver/
Header File	14hsai4.h	
Driver File	14hsai4.ko † 14hsai4.o ‡	

† This is for kernel versions 2.6 and later.

‡ This is for kernel versions 2.4 are earlier.

5.2. Build

NOTE: Building the driver requires installation of the kernel headers and possibly other packages.

The device driver is built via the Overall Make Script (section 2.7, page 13), but can be built separately following the below steps.

1. Change to the directory where the driver and its sources are installed (.../driver/).
2. Remove existing build targets by issuing the below command.

```
make clean
```

3. Build the driver by issuing the below command.

```
make
```

NOTE: Due to the differences between the many Linux distributions some build errors may occur. These errors may include system header location differences, which should be easily corrected.

5.3. Startup

NOTE: The driver will have to be built before being used as it is provided in source form only.

The startup script used in this procedure is designed to load the device driver and create fresh device nodes. This is accomplished by unloading the current driver, if loaded, and then loading the accompanying driver executable. In addition, the script deletes and recreates the device nodes. This is done to ensure that the device nodes in use have the same major number as assigned dynamically to the driver by the kernel, and so that the number of device nodes corresponds to the number of boards identified by the driver.

5.3.1. Manual Driver Startup Procedures

Start the driver manually by following the below listed steps.

NOTE: The following steps may require elevated privileges.

1. Change to the directory where the driver sources are installed (.../driver/).
2. Install the driver module and create the device nodes by executing the below command. If any errors are encountered then an appropriate error message will be displayed.

```
./start
```

NOTE: This script must be executed each time the host is booted.

NOTE: The 14HSAI4 device node major number is assigned dynamically by the kernel. The minor numbers and the device node suffix numbers are index numbers beginning with zero, and increase by one for each additional board installed.

3. Verify that the device driver module has been loaded by issuing the below command and examining the output. The module name `14hsai4` should be included in the output.

```
lsmod
```

4. Verify that the device nodes have been created by issuing the below command and examining the output. The output should include one node for each installed board.

```
ls -l /dev/14hsai4.*
```

5.3.2. Automatic Driver Startup Procedures

Start the driver automatically with each system reboot by following the below listed steps.

1. Locate and edit the system startup script `rc.local`, which should be in the `/etc/rc.d/` directory. Modify the file by adding the below line so that it is executed with every reboot. The example is based on the driver being installed in `/usr/src/linux/drivers/`, though it may have been installed elsewhere.

```
/usr/src/linux/drivers/14hsai4/driver/start
```

NOTE: For `systemd` installations the file `rc.local` may be located under the `/etc/` directory rather than under `/etc/rc.d/`.

2. Load the driver and create the required device nodes by rebooting the system.
3. Verify that the driver is loaded and that the device nodes have been created. Do this by following the verification steps given in the manual startup procedures.

5.3.2.1. File `rc.local` Not Present

Some distributions may not install a default version of `rc.local`. Some may not even create the directory `/etc/rc.d/`. If the directory is not present, then it may be created. The directory must be created with the owner and group set to `root`. The directory permissions must be set to `rwxr-xr-x`. If the file `/etc/rc.d/rc.local` is not present, then it too may be created. The file must also be created with the owner and group set to `root`. Additionally, the file permissions must also be set to `rwxr-xr-x`. After the directory and file are created as described, reboot to verify boot time loading of the driver. Here is an example of a default version of `rc.local`.

```
#!/bin/bash

# Add your local content here.
```

5.3.2.2. Default rc.local File Permissions

The `rc.local` script may fail to run at boot time because some distributions install a default version of the file without execute permissions. Without execute permissions, boot time invocation of the script fails, which inhibits boot time loading of the driver. If this is the case, then change the file permissions to `rxwxr-xr-x`. After the file permissions are adjusted as described, reboot to verify boot time loading of the driver.

5.3.2.3. systemd Installations

With the advent of the `systemd` startup implementation, `rc.local` may be accessed via a `systemd` startup service. The service name may be `rc-local`, `rc-local.service` or something similar. This service may or may not be enabled by default. If the service is disabled, then the script will not execute, which prevents boot time loading of the driver. The service can be enabled with the below command line. After the service is enabled, reboot to verify boot time loading of the driver.

```
systemctl enable rc-local
```

NOTE: For `systemd` installations the file `rc.local` may be located under the `/etc/` directory rather than under `/etc/rc.d/`.

5.3.2.4. systemd and rc.local Timing

If the above steps have been performed but the driver still does not start then examine the `dmesg` output for driver messages. If the output shows that the driver starts and immediately stops, then the problem may be timing. That is, since `systemd` doesn't serialize startup initialization as done in the past, driver loading may fail if required services have not completed their own initialization. If this is the problem, then it may be corrected simply by inserting a delay in `rc.local` prior to it calling the driver's start script (i.e., `sleep` for one or more seconds).

5.3.2.5. SELinux Implications

If not disabled, then SELinux may prevent boot time loading of the driver. If this is the case, then it can be verified and corrected using SELinux related tools and utilities. First, install the necessary software using the below command. (As necessary, replace the `yum` command line with that which is available for your distribution.)

```
yum install setroubleshoot setools
```

Next, run the below command to determine if SELinux is preventing the driver from loading at boot time.

```
sealert -a /var/log/audit/audit.log
```

If SELinux is preventing the driver from loading, then the output from the above command should include a reference to the driver's start script, the `insmod` command that loads the driver or the name of the driver executable. If so, then the output should also indicate the commands necessary to resolve the issue. The following is an example of the instructions given when the culprit is `insmod`, which is the start script command that loads the driver. After running these commands reboot the system to verify boot time loading of the driver.

```
ausearch -c 'insmod' --raw | audit2allow -M my-insmod
semodule -X 300 -i my-insmod.pp
```

5.4. Verification

Follow the below steps to verify that the driver has been properly installed and started.

1. Verify that the file `/proc/14hsai4` is present. If the file is present then the driver is loaded and running. Verify the file's presence by viewing its content with the below command.

```
cat /proc/14hsai4
```

5.5. Version

The driver version number can be obtained in a variety of ways. It is reported by the driver both when the driver is loaded and when it is unloaded (depending on kernel configuration options, this may be visible only in places such as `/var/log/messages`). It is reported in the text file `/proc/14hsai4` while the driver is loaded and running. The version number is also given in the file `release.txt` in the root install directory.

5.6. Shutdown

Shutdown the driver following the below listed steps.

NOTE: The following steps may require elevated privileges.

1. If the driver is currently loaded then issue the below command to unload the driver.

```
rmmod 14hsai4
```

2. Verify that the driver module has been unloaded by issuing the below command. The module name `14hsai4` should not be in the listed output.

```
lsmod
```

6. Document Source Code Examples

The source code examples included in this document are built into a statically linkable library usable with console applications. The purpose of these files is to verify that the documentation samples compile and to provide a library of working sample code to assist in a user's learning curve and application development effort.

6.1. Files

The library files are summarized in the table below.

Description	Files	Location
Source Files	*.c, *.h/docsrc/
Header File	14hsai4_dsl.h	.../include/
Library File	14hsai4_dsl.a	.../lib/

6.2. Build

The library is built via the Overall Make Script (section 2.7, page 13), but can be built separately following the below steps.

1. Change to the directory where the documentation sources are installed (.../docsrc/).
2. Remove existing build targets by issuing the below command.

```
make clean
```

3. Compile the sample files and build the library by issuing the below command.

```
make
```

4. Rebuild the Main Library (section 3.2.1, page 16).

6.3. Library Use

The library is used both at application compile time and at application link time. At compile time include the above listed header file in each source file using a component of the library interface. At link time include the above listed static library file with the objects being linked with the application.

7. Utilities Source Code

The API Library installation includes a body of utility source code designed to aid in the understanding and use of the interface calls and IOCTL services. Utility sources are also included for device independent and common, general-purpose services. Most of the utilities are implemented as visual wrappers around the corresponding services to facilitate structured console output for the sample applications. The utility sources are compiled and linked into static libraries to simplify their use. An additional purpose of these utility services is to provide a library of working sample code to assist in a user's learning curve and application development effort.

For each API function there is a corresponding utility source file with a corresponding utility service. As an example, for the API function `hsai4_open()` there is the utility file `open.c` containing the utility function `hsai4_open_util()`. The naming pattern is as follows: API function `hsai4_xxxx()`, utility file name `xxxx.c`, utility function `hsai4_xxxx_util()`. Additionally, for each IOCTL code there is a corresponding utility source file with a corresponding utility service. As an example, for IOCTL code `HSAI4_IOCTL_QUERY` there is the utility file `util_query.c` containing the utility function `hsai4_query()`. The naming pattern is as follows: IOCTL code `HSAI4_IOCTL_XXXX`, utility file name `util_xxxx.c`, utility function `hsai4_xxxx()`.

7.1. Files

The utility files are summarized in the table below.

Description	Files	Location
Source Files	*.c, *.h/utils/
Header File	14hsai4_utils.h	.../include/
Library Files	14hsai4_utils.a gsc_utils.a os_utils.a plx_utils.a	.../lib/

7.2. Build

The libraries are built via the Overall Make Script (section 2.7, page 13), but can be built separately following the below steps.

1. Change to the directory where the utility sources are installed (.../utils/).
2. Remove existing build targets by issuing the below command.

```
make clean
```

3. Compile the sample files and build the library by issuing the below command.

```
make
```

4. Rebuild the Main Library (section 3.2.1, page 16).

7.3. Library Use

The library is used both at application compile time and at application link time. At compile time include the above listed header file in each source file using a component of the library interface. At link time include the above listed static library file with the objects being linked with the application.

8. Operating Information

This section explains some basic operational procedures for using the 14HSAI4. This is in no way intended to be a comprehensive guide. This is simply to address a very few issues relating to their use.

8.1. Debugging Aids

The driver package includes the following items useful for development and/or debugging aids.

8.1.1. Device Identification

When communicating with technical support complete device identification is virtually always necessary. The *id* example application is provided for this specific purpose. This is a text only console application. The output can be piped to a file, which can then be emailed to GSC technical support when requested. Locate the application as follows.

Description	File	Location
Application	<i>id</i>	.../id/

8.1.2. Detailed Register Dump

Among the utility services provided is a function to generate a detailed listing of device registers to the console. When used, the function is typically used to verify device configuration. In these cases, the function should be called after complete device configuration and before the first I/O call. When intended for sending to GSC tech support, please set the *detail* arguments to 1. The function arguments are as follows. The utility location is given in the subsequent table.

Argument	Description
<i>fd</i>	This is the file descriptor used to access the device.
<i>detail</i>	If non-zero the register dump will include details of each register field.

Description	File/Name	Location
Function	<i>hsai4_reg_list()</i>	Source File
Source File	<i>util_reg.c</i>	.../utils/
Header File	<i>14hsai4_utils.h</i>	.../include/
Library File	<i>14hsai4_utils.a</i>	.../lib/

8.2. Analog Input Configuration

The basic steps for Analog Input configuration are illustrated in the utility function noted below. The table also gives the location of the source file, the header file and the corresponding library containing the executable code. The referenced files are included via the Main Header and Main Library.

Item	Name/File	Location
Function	<i>hsai4_config_ai()</i>	Source File
Source File	<i>util_config_ai.c</i>	.../utils/
Header File	<i>14hsai4_utils.h</i>	.../include/
Library File	<i>14hsai4_utils.a</i>	.../lib/

8.3. Data Transfer Modes

All device I/O requests move data through intermediate driver buffers on its way between the device and application memory. The data is processed in chunks no larger than the size of this intermediate buffer. The process used to

perform this transfer is according to the I/O mode selection. Movement of data between the application buffers and the intermediate driver buffers is performed by the kernel.

8.3.1. PIO - Programmed I/O

In this mode data is transferred using repetitive register accesses. This is most applicable for low throughput requirements or for small transfer requests. The driver continues the operation until either the I/O request is fulfilled or the I/O timeout expires, whichever occurs first. This is generally the least efficient mode, but for very small transfers it is more efficient than DMA.

8.3.2. BMDMA - Block Mode DMA

For Block Mode DMA the driver initiates DMA transfers only after a sufficient volume of data has been received into the input buffer. In this mode the volume is sufficient when the input buffer content satisfies the request or when it meets or exceeds the threshold value. After that amount of data is in the input buffer the driver initiates a DMA then sleeps until the DMA Done interrupt is received. Using this DMA mode, a user request typically consists of numerous individual DMA transfers.

8.3.3. DMDMA - Demand Mode DMA

This DMA mode is similar to the block mode, except that the transfer is initiated immediately. Here however, the actual movement of data occurs as the data becomes available in the buffer instead of after it has been accumulated. Using this DMA mode, a user request typically consists of a single individual DMA transfer.

9. Sample Applications

The driver archive includes a variety of sample and test applications located under the `samples` subdirectory. While they are provided without support and without any external documentation, any problems reported will be addressed as time permits. The applications are command line based and produce text output for display on a console. All of the applications are built via the Overall Make Script (section 2.7, page 13), but each may be built individually by changing to its respective directory and issuing the commands “`make clean`” and “`make`”. The initial output from each application includes information on its supported command line arguments. The following gives a brief overview of each application.

9.1. `id` - Identify Board - `.../id/`

This application reports detailed board identification information. This can be used with tech support to help identify as much technical information about the board as possible from software.

9.2. `regs` - Register Access - `.../regs/`

This application provides menu based interactive access to the board’s registers, and reports other pertinent information to the console.

9.3. `rxrate` - Receive Rate - `.../rxrate/`

This application configures the board for its highest ADC sample rate then reads the input as fast as possible. The purpose is to measure the peak sustainable input rate for the host, per the provided command line arguments.

9.4. `savedata` - Save Acquired Data - `.../savedata/`

This application configures the board for a modest sample rate, reads a megabyte of data, then saves the data to a hex file.

9.5. `sbtest` - Single Board Test - `.../sbtest/`

This application performs functional testing of the driver and a user specified board, at least to the extent possible with just a single board and no additional equipment.

9.6. `signals` - Digital Signals - `.../signals/`

This application configures the board to drive the digital output signals for a user specified period of time. This is done to facilitate setup of test equipment to capture those signals during actual use.

9.7. `stream` - Stream Rx Data to Disk - `.../stream/`

This application uses multiple threads with an intermediate buffer manager to stream data from the device to a data file. Numerous options are available for measuring performance of device reads, disk writes and buffer handling. Refer to the application file `readme.txt` for example information.

Document History

Revision	Description
August 27, 2024	Updated to release version 2.9.111.50.0. Updated the kernel support table. Numerous minor editorial changes.
August 29, 2023	Updated to release version 2.8.104.47.0. Updated the information for the open and close calls. Updated the kernel support table. Numerous minor editorial changes. Updated the description of the Input Buffer Clear service. Updated the description of the Autocalibration service. Renamed all Auto_Cal content to Autocal. Renamed all Auto_Cal_Sts content to Autocal_Status.
April 28, 2022	Updated to release version 2.7.98.39.1. Minor editorial changes.
April 27, 2022	Updated to release version 2.7.98.39.0. Updated the kernel support table. Minor editorial changes. Added the <code>streams</code> sample application. Added a section on environment variables.
December 22, 2021	Updated to release version 2.6.95.37.0. Expanded automatic startup information. Updated the kernel support table. Minor typographic corrections.
June 10, 2020	Updated to release version 2.5.91.32.0. Updated the kernel support table. Various editorial changes. Some document reorganization. Added a licensing subsection. Added WAIT_EVENT note. Expanded automatic startup information.
April 26, 2019	Updated to release version 2.4.85.27.0. Minor editorial changes.
November 14, 2018	Updated to release version 2.4.81.26.0. Updated Block Mode DMA macro and associated information. Minor editorial changes.
July 3, 2018	Updated to version 2.3.77.23.0. Updated the inside cover page. Updated the CPU and kernel support section. Minor editorial changes. Document reorganization
November 28, 2016	Updated to version 2.2.68.18.0. Removed the <code>built</code> field from the <code>/proc/</code> file. Updated the kernel support table. Organized the sample applications alphabetically. Updated the usage of the Wait Event <code>timeout_ms</code> field. Updated material on the open call. Added open access mode descriptions. Added support for infinite I/O timeouts. Added a section for general operating information. Made various miscellaneous updates. Some document reorganization.
September 11, 2015	Updated to version 2.1.60.8.0.
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February 27, 2014	Updated to version 1.5.52.0. Updated the kernel support data.
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November 14, 2013	Updated to version 1.4.50.0.
July 3, 2013	Updated to version 1.4.45.0. Updated the kernel support data.
July 18, 2012	Updated to version 1.4.39.0. Updated the kernel support data.
January 10, 2012	Updated to version 1.3.35.0.
October 29, 2011	Updated to version 1.2.30.0.
January 6, 2011	Updated to version 1.1.21.0. Various editorial updates.
September 20, 2010	Updated to version 1.1.18.0. Removed the IRQ_SEL IOCTL service and added the IRQ_ENABLE IOCTL service. Updated the CPU and Kernel Support information. Updated the comments for the Initialize IOCTL service. Changed the spelling of various Autocalibration related software items.
May 7, 2010	Initial release.