

# **12AI64**

**64 Channel, 12-Bit Analog Input Board**

**PMC-12AI64**

## **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 12AI64 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 12AI64 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
...	This is a shortcut representation of the 12AI64 installation directory or any of its subdirectories.
BMDMA	Block Mode DMA
DMA	Direct Memory Access
GSC	General Standards Corporation
PCI	Peripheral Component Interconnect
PCIe	PCI Express
PIO	Programmed I/O
PMC	PCI Mezzanine Card
RAG	Rate-A Generator
RBG	Rate-B Generator

## 1.3. Definitions

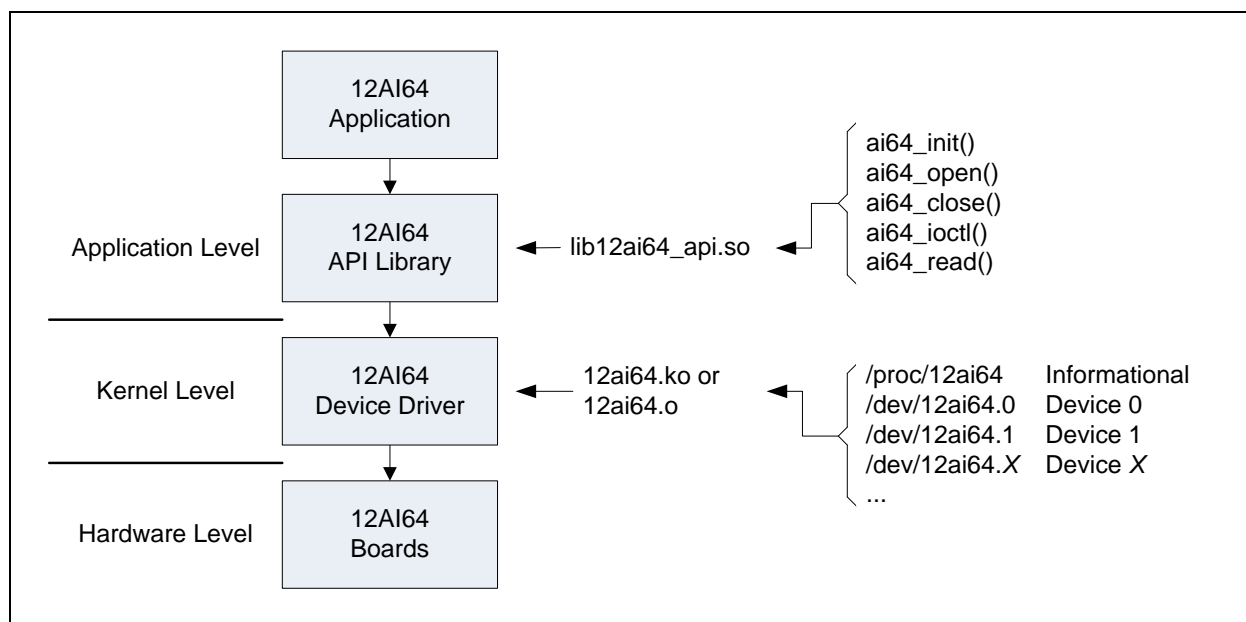
The following is a list of commonly occurring terms which may appear throughout this document.

Term	Definition
12AI64	This is used as a general reference to any board supported by this driver.
API Library	This is a library that provides application level access to 12AI64 hardware.
Application	This is the user mode process, which runs in user space with user mode privileges.
Driver	This is the kernel mode device driver, which runs in kernel space with kernel mode privileges.

## 1.4. Software Overview

### 1.4.1. Basic Software Architecture

This section describes the general architecture for the basic components that comprise 12AI64 applications. The overall architecture is illustrated in Figure 1 below.



**Figure 1** Architectural representation.

### 1.4.2. API Library

The primary means of accessing 12AI64 boards is via the 12AI64 API Library. This library forms a very thin layer between the application and the driver. Additional information is given in section 4 beginning on page 16. 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 12AI64 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 12AI64 is a high-performance 64 channel, 12-bit analog input board. The host side connection is PCI based whose form factor is according to the model ordered. The board is capable of capturing data at up to 1.5M samples per second over a single channel, or with an aggregate rate of up to 1M samples per second when using more than one channel. Sampling rates are configurable down to less than one sample per second. Onboard storage permits data buffering of up to 64K samples, for all channels collectively, between the cable interface and the PCI bus. This allows the 12AI64 to sustain continuous throughput from the cable interface independent of the PCI bus interface. The 12AI64 also permits multiple boards to be synchronized so that all boards sample data in unison. In addition, the board includes auto-calibration capability.

## 1.6. Reference Material

The following reference material may be of particular benefit in using the 12AI64. The specifications provide the information necessary for an in depth understanding of the specialized features implemented on this board.

- The applicable *12AI64 User Manual* from General Standards Corporation. Manuals are available in PDF format at the company website, <http://www.generalstandards.com>



- The *PCI9080 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.

## 1.8. Cautionary Notes

### 1.8.1. IRQ Anomaly

On older firmware, an unintentional interrupt is generated when writing a "1" to an IRQ Request field that is "0". (Refer to the Interrupt Control Register description in the board user manual.) Because of this anomaly, software (including the driver) may miss an interrupt when both IRQ0 and IRQ1 are used and both generate an interrupt almost simultaneously. For applications using IRQ0 and IRQ1 simultaneously it is recommended that firmware with this anomaly not be used. If this is the case, then contact the factory to obtain firmware without this anomaly.

## 2. Installation

### 2.1. CPU and Kernel Support

The driver is designed to operate with Linux kernel versions 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
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

**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 shipped 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/12ai64` file will be "no".

## 2.2. The `/proc/` File System

While the driver is running, the text file `/proc/12ai64` can be read to obtain information about the driver. 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: 1.5.101.44
32-bit support: yes
boards: 1
models: 12AI64
```

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.

## 2.3. File List

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

File	Description
<code>12ai64.linux.tar.gz</code>	This archive contains the driver, the API Library and all related files.
<code>12ai64_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	Content
<code>12ai64/</code>	This is the driver root directory. It contains the documentation, the Overall Make Script (section 2.7, page 12) and the below listed subdirectories.
<code>.../api/</code>	This directory contains the 12AI64 API Library (section 4, page 16).
<code>.../docsrc/</code>	This directory contains the code samples from this document (section 6, page 40).
<code>.../driver/</code>	This directory contains the driver and its sources (section 5, page 36).
<code>.../include/</code>	This directory contains the include files for the various libraries.
<code>.../samples/</code>	This directory contains the sample applications (section 9, page 44).
<code>.../utils/</code>	This directory contains utility source files (section 7, page 41).

## 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 `12ai64.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 `12ai64` in the current directory, and then copies all of the archive's files into this new directory.

```
tar -xzvf 12ai64.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.

1. Shutdown the driver as described in section 5.6 on page 39.
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 12ai64.linux.tar.gz 12ai64
```

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

```
rm -f /dev/12ai64.*
```

5. If the automated startup procedure was adopted (section 5.3.2, page 37), then edit the system startup script `rc.local` and remove the line that invokes the 12AI64'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, and it will also load the driver. 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 (`.../12ai64/`).
2. Remove existing build targets using the below command line. 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.

<b>Undefined or Empty</b>	== Compiling: init.c
	== Compiling: ioctl.c
	== Compiling: open.c
<b>Defined and Not Empty</b>	== 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.

<b>Undefined or Empty</b>	==== Linking: ../lib/lib12ai64_api.so
<b>Defined and Not Empty</b>	==== Linking: ../lib/lib12ai64_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.

<b>Undefined or Empty</b>	== Compiling: close.c
	== Compiling: init.c
	== Compiling: ioctl.c
<b>Defined and Not Empty</b>	== 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.

<b>Undefined or Empty</b>	==== Linking: ../lib/12ai64_utils.a
<b>Defined and Not Empty</b>	==== Linking: ../lib/12ai64_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.

<b>Undefined or Empty</b>	== Compiling: main.c == Compiling: perform.c
<b>Defined and Not Empty</b>	== 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.

<b>Undefined or Empty</b>	==== Linking: id
<b>Defined and Not Empty</b>	==== Linking: id (added 'xxx')

### 3. Main Interface Files

This section gives general information on the suggested device interface files to use when developing 12AI64 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 12AI64 driver archive. 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 12AI64 specific header files. Therefore, sources may include only this one 12AI64 header and make files may reference only this one 12AI64 include directory.

File	Location
12ai64_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 12AI64 driver archive. 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 pertinent 12AI64 specific static libraries. Therefore, make files may reference only this one 12AI64 static library and only this one 12AI64 library directory.

File	Location
12ai64_main.a	.../lib/

**NOTE:** The 12AI64 API Library is implemented as a shared library and is thus not linked with the 12AI64 Main Library.

##### 3.2.1. Build

The main library is built via the Overall Make Script (section 2.7, page 12). However, the main library can be rebuilt 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 line.

```
make clean
```

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

```
make
```

##### 3.2.2. System Libraries

In addition to linking the static library named above, 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

## 4. API Library

The 12AI64 API Library is the software interface between user applications and the 12AI64 device driver. The interface is accessed by including the header file `12ai64_api.h`.

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

### 4.1. Files

The library source files are summarized in the table below.

File	Description
<code>api/*.c</code>	These are library source files.
<code>api/*.h</code>	These are library header files.
<code>api/makefile</code>	This is the library make file.
<code>api/makefile.dep</code>	This is an automatically generated make dependency file.
<code>include/12ai64_api.h</code>	This is the library interface header file.
<code>lib/lib12ai64_api.so</code>	This is the API Library shared library file. *

\* The shared 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 12), but can be built separately following the below steps.

**NOTE:** The API Library shared library is copied to `/usr/lib/`. Therefore, these 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 line.

```
make clean
```

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

```
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. At link time include the below listed linker argument on the linker command line. At link time and at run time the library is found in the directory `/usr/lib/`. (The shared library file is automatically copied to `/usr/lib/` when the library is built.)

File	Location	Linker Argument
<code>12ai64_api.h</code>	<code>.../include/</code>	
<code>lib12ai64_api.so</code>	<code>.../lib/</code>	
	<code>/usr/lib/</code>	<code>-l12ai64_api</code>



## 4.4. Macros

The API Library and driver interfaces include the following macros, which are defined in `12ai64.h`.

### 4.4.1. IOCTL

The IOCTL macros are documented in section 4.7 beginning on page 22.

### 4.4.2. Registers

The following gives the complete set of 12AI64 registers.

#### 4.4.2.1. GSC Registers

The following tables give the complete set of GSC specific 12AI64 registers. For detailed definitions of these registers refer to the relevant *12AI64 User Manual*. Please note that the set of registers supported by any given board may vary according to model and firmware version. For the set of supported registers and detailed definitions of these registers please refer to the appropriate *12AI64 User Manual*.

Macro	Description
AI64_GSC_BCR	Board Control Register
AI64_GSC_BSR	Buffer Size Register
AI64_GSC_FRR	Firmware Revision Register
AI64_GSC_ICR	Interrupt Control Register
AI64_GSC_IDBR	Input Data Buffer Register
AI64_GSC_IBCR	Input Buffer Control Register
AI64_GSC_RAGR	Rate-A Generator Register
AI64_GSC_RBGR	Rate-B Generator Register
AI64_GSC_SSCR	Scan & Sync Control Register

#### 4.4.2.2. PCI Configuration Registers

Access to the PCI registers is seldom required so these registers are not listed here. For a complete list of the PCI register identifiers refer to the driver header file `gsc_pci9080.h`, which is automatically included via `12ai64.h`.

#### 4.4.2.3. PLX PCI9080 Feature Set Registers

Access to the PLX registers is seldom required so these registers are not listed here. For a complete list of the PLX register identifiers refer to the driver header file `gsc_pci9080.h`, which is automatically included via `12ai64.h`.

## 4.5. Data Types

The data types used by the API Library are described with the IOCTL services with which they are used.

## 4.6. Functions

The interface includes the following functions. The return values reflect the completion status of the requested operation. A value of zero indicates success. A negative value indicates that the request could not be completed successfully. The specific value returned is the negative of the corresponding error status value taken from `errno.h`. I/O services return positive values to indicate the number of bytes successfully transferred.

#### 4.6.1. ai64\_close()

This function is the entry point to close a connection to an open 12AI64 board. The board is put in an initialized state before this call returns.

##### Prototype

```
int ai64_close(int fd);
```

Argument	Description
fd	This is the file descriptor of the device to be closed.

Return Value	Description
0	The operation succeeded.
< 0	An error occurred. This is the negative of <code>errno</code> from <code>errno.h</code> .

##### Example

```
#include <stdio.h>

#include "12ai64_dsl.h"

int ai64_close_dsl(int fd)
{
    int err;
    int ret;

    ret = ai64_close(fd);

    if (ret)
        printf("ERROR: ai64_close() returned %d\n", ret);

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

#### 4.6.2. ai64\_init()

This function is the entry point to initializing the 12AI64 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 ai64_init(void);
```

Return Value	Description
0	The operation succeeded.
< 0	An error occurred. This is the negative of <code>errno</code> from <code>errno.h</code> .

##### Example

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

```

#include "12ai64_dsl.h"

int ai64_init_dsl(void)
{
    int err;
    int ret;

    ret = ai64_init();

    if (ret)
        printf("ERROR: ai64_init() returned %d\n", ret);

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

```

### 4.6.3. ai64\_ioctl()

This function is the entry point to performing setup and control operations on a 12AI64 board. 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 on page 22.

#### Prototype

```
int ai64_ioctl(int fd, int request, void* arg);
```

Argument	Description
fd	This is the file descriptor of the device to access.
request	This specifies the desired operation to be performed.
arg	This is a request specific argument. Refer to the IOCTL services for additional information (section 4.7 beginning on page 22).

Return Value	Description
0	The operation succeeded.
< 0	An error occurred. This is the negative of <code>errno</code> from <code>errno.h</code> .

#### Example

```

#include <stdio.h>

#include "12ai64_dsl.h"

int ai64_ioctl_dsl(int fd, int request, void *arg)
{
    int err;
    int ret;

    ret = ai64_ioctl(fd, request, arg);

    if (ret)
        printf("ERROR: ai64_ioctl() returned %d\n", ret);
}

```

```

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

```

#### 4.6.4. ai64\_open()

This function is the entry point to open a connection to a 12AI64 board. The device is initialized before the function returns.

##### Prototype

```
int ai64_open(int device, int share, int* fd);
```

Argument	Description						
device	This is the zero based index of the 12AI64 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>&gt;= 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.						

\* If the index value is -1, then the API Library will access /proc/12ai64.

Return Value	Description
0	The operation succeeded.
< 0	An error occurred. This is the negative of errno from errno.h.

##### Example

```

#include <stdio.h>

#include "12ai64_dsl.h"

int ai64_open_dsl(int device, int share, int* fd)
{
    int err;
    int ret;

    ret = ai64_open(device, share, fd);

    if (ret)
        printf("ERROR: ai64_open() returned %d\n", ret);

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

```

#### 4.6.4.1. Access Modes

##### 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. ai64\_read()

This function is the entry point to reading data from an open 12AI64. This function should only be called after a successful open of the respective device. The function reads up to `bytes` bytes from the board. The return value is the number of bytes actually read.

**NOTE:** For additional information please refer to the I/O Mode section (section 8.2, page 42).

**NOTE:** If an index of -1 was passed to the `ai64_open()` call, then read requests will read from the text file `/proc/12ai64` (section 2.2, page 11).

#### Prototype

```
int ai64_read(int fd, void *buf, size_t bytes);
```

Argument	Description
<code>fd</code>	This is the file descriptor of the device to access.
<code>buf</code>	The data read will be put here.
<code>bytes</code>	This is the desired number of bytes to read. This must be a multiple of four (4).

Return Value	Description
0 to <code>bytes</code>	The operation succeeded. A value less than <code>bytes</code> indicates that the request timed out.
< 0	An error occurred. This is the negative of <code>errno</code> from <code>errno.h</code> .

#### Example

```
#include <stdio.h>

#include "12ai64_dsl.h"

int ai64_read_dsl(int fd, void* dst, size_t bytes, size_t* qty)
{
    int errs;
    int ret;

    ret = ai64_read(fd, dst, bytes);

    if (ret < 0)
        printf("ERROR: ai64_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 12AI64 API Library and device driver implement the following IOCTL services. Each service is described along with the applicable `ai64_ioctl()` function arguments.

### 4.7.1. AI64\_IOCTL\_AI\_BUF\_CLEAR

This service immediately clears the current content from the input buffer. This service does not halt input sampling.

Usage

Argument	Description
request	AI64_IOCTL_AI_BUF_CLEAR
arg	Not used.

### 4.7.2. AI64\_IOCTL\_AI\_BUF\_LEVEL

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

Usage

Argument	Description
request	AI64_IOCTL_AI_BUF_LEVEL
arg	s32*

The value returned will be from zero up to 0xFFFF.

### 4.7.3. AI64\_IOCTL\_AI\_BUF\_THR\_LVL

This service configures the input buffer threshold level.

Usage

Argument	Description
request	AI64_IOCTL_AI_BUF_THR_LVL
arg	s32*

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

### 4.7.4. AI64\_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	AI64_IOCTL_AI_BUF_THR_STS
arg	s32*

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

Value	Description
AI64_AI_BUF_THR_STS_CLEAR	The input buffer contains Threshold Level number of data items, or fewer.
AI64_AI_BUF_THR_STS_SET	The input buffer contains more than Threshold Level number of data items.

## 4.7.5. AI64\_IOCTL\_AI\_CLK\_SRC

This service configures the source for the input sample clock.

## Usage

Argument	Description
request	AI64_IOCTL_AI_CLK_SRC
arg	s32*

Valid argument values are as follows.

Value	Description
-1	Retrieve the current setting.
AI64_AI_CLK_SRC_BCR	This refers to the Board Control Register's Input Sync bit.
AI64_AI_CLK_SRC_EXT	This refers to the external clock input signal.
AI64_AI_CLK_SRC_RAG	This refers to the Rate-A Generator output.
AI64_AI_CLK_SRC_RBG	This refers to the Rate-B Generator output.

## 4.7.6. AI64\_IOCTL\_AI\_MODE

This service configures the board's Analog Input Mode.

## Usage

Argument	Description
request	AI64_IOCTL_AI_MODE
arg	s32*

Valid argument values are as follows.

Value	Description
-1	Retrieve the current setting.
AI64_AI_MODE_DIFF	Configure the input channels for differential operation.
AI64_AI_MODE_SINGLE	Configure the input channels for single-ended operation.
AI64_AI_MODE_VREF	Configure the input channels for +VREF input testing
AI64_AI_MODE_ZERO	Configure the input channels for Zero input testing

#### 4.7.7. AI64\_IOCTL\_AI\_RANGE

This service configures the analog input voltage range.

##### Usage

Argument	Description
request	AI64_IOCTL_AI_RANGE
arg	s32*

Valid argument values are as follows.

Value	Description
-1	Retrieve the current setting.
AI64_AI_RANGE_2_5V	Set the input voltage range to $\pm 2.5$ volts.
AI64_AI_RANGE_5V	Set the input voltage range to $\pm 5$ volt.
AI64_AI_RANGE_10V	Set the input voltage range to $\pm 10$ volts.

#### 4.7.8. AI64\_IOCTL\_AI\_SCAN\_SIZE

This service sets the range and number of active input channels.

##### Usage

Argument	Description
request	AI64_IOCTL_AI_SCAN_SIZE
arg	s32*

Valid argument values are as follows.

Value	Description
-1	Retrieve the current setting.
AI64_AI_SCAN_SIZE_0_1	This sets the active channel range to zero through one.
AI64_AI_SCAN_SIZE_0_3	This sets the active channel range to zero through three.
AI64_AI_SCAN_SIZE_0_7	This sets the active channel range to zero through seven.
AI64_AI_SCAN_SIZE_0_15	This sets the active channel range to zero through 15.
AI64_AI_SCAN_SIZE_0_31	This sets the active channel range to zero through 31.
AI64_AI_SCAN_SIZE_0_63	This sets the active channel range to zero through 63.
AI64_AI_SCAN_SIZE_SINGLE	This sets the active channel to a single user specified channel.

#### 4.7.9. AI64\_IOCTL\_AI\_SYNC

This service initiates an Input Sync operation. The driver does not wait for completion.

##### Usage

Argument	Description
request	AI64_IOCTL_AI_SYNC
arg	Not used.

#### 4.7.10. AI64\_IOCTL\_AUTO\_CAL\_STS

This service returns the status of the most recent Auto-Calibration cycle.



## Usage

Argument	Description
request	AI64_IOCTL_AUTO_CAL_STS
arg	s32*

Argument values returned are as follows.

Value	Description
AI64_AUTO_CAL_STS_ACTIVE	The operation is still in progress.
AI64_AUTO_CAL_STS_FAIL	The operation failed.
AI64_AUTO_CAL_STS_PASS	The operation passed.

**4.7.11. AI64\_IOCTL\_AUTO\_CALIBRATE**

This service initiates an auto-calibration cycle. Most configuration settings should be made before running an auto-calibration cycle. The driver waits for the operation to complete before returning.

## Usage

Argument	Description
request	AI64_IOCTL_AUTO_CALIBRATE
arg	Not used.

**4.7.12. AI64\_IOCTL\_CHAN\_SINGLE**

This service sets the channel number to scan when the scan size is set to a single channel (see AI64\_IOCTL\_AI\_SCAN\_SIZE, section 4.7.8, page 24).

## Usage

Argument	Description
request	AI64_IOCTL_CHAN_SINGLE
arg	s32*

Valid argument values are from zero to 63., and -1. A value of -1 will return the current setting.

**4.7.13. AI64\_IOCTL\_DATA\_FORMAT**

This service sets the data encoding format.

## Usage

Argument	Description
request	AI64_IOCTL_DATA_FORMAT
arg	s32*

Valid argument values are as follows.

Value	Description
-1	Retrieve the current setting.
AI64_DATA_FORMAT_2S_COMP	Select the Twos Complement data format.
AI64_DATA_FORMAT_OFF_BIN	Select the Offset Binary encoding format.

**4.7.14. AI64\_IOCTL\_EXT\_SYNC\_ENABLE**

This service enables or disables external synchronization for configurations which sample data synchronously across multiple boards.

**Usage**

Argument	Description
request	AI64_IOCTL_EXT_SYNC_ENABLE
arg	s32*

Valid argument values are as follows.

Value	Description
-1	Retrieve the current setting.
AI64_EXT_SYNC_ENABLE_NO	This option disables external synchronization.
AI64_EXT_SYNC_ENABLE_YES	This option enables external synchronization.

**4.7.15. AI64\_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.

**Usage**

Argument	Description
command	AI64_IOCTL_INITIALIZE
arg	None

**4.7.16. AI64\_IOCTL\_IRQ0\_SEL**

This service configures the interrupt source selection for interrupt number zero.

**NOTE:**There is an IRQ anomaly in older formware. Please refer to section 1.8.1, page 9 for additional information.

**Usage**

Argument	Description
request	AI64_IOCTL_IRQ0_SEL
arg	s32*

Valid argument values are as follows.

Value	Description
-1	Retrieve the current setting.
AI64_IRQ0_AUTO_CAL_DONE	This refers to the completion of an Auto-Calibration cycle.
AI64_IRQ0_INIT_DONE	This refers to the completion of an initialization cycle.
AI64_IRQ0_SYNC_DONE	This refers to the completion of an input scan operation.
AI64_IRQ0_SYNC_START	This refers to the beginning of an input scan operation.

**4.7.17. AI64\_IOCTL\_IRQ1\_SEL**

This service configures the interrupt source selection for interrupt number one.

**NOTE:**There is an IRQ anomaly in older firmware. Please refer to section 1.8.1, page 9 for additional information.

## Usage

Argument	Description
request	AI64_IOCTL_IRQ1_SEL
arg	s32*

Valid argument values are as follows.

Value	Description
-1	Retrieve the current setting.
AI64_IRQ1_IN_BUF_THR_H2L	This refers to the input buffer threshold status being negated.
AI64_IRQ1_IN_BUF_THR_L2H	This refers to the input buffer threshold status being asserted.
AI64_IRQ1_NONE	This disabled the interrupt.

### 4.7.18. AI64\_IOCTL\_QUERY

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

## Usage

Argument	Description
request	AI64_IOCTL_QUERY
arg	s32*

Valid argument values are as follows.

Value	Description
AI64_QUERY_AUTO_CAL_MS	This returns the maximum duration of the Auto Calibration cycle in milliseconds.
AI64_QUERY_CHANNEL_MAX	This returns the maximum number of input channels supported by the board, which may be more than the board's current configuration.
AI64_QUERY_CHANNEL_QTY	This returns the actual number of input channels on the current board.
AI64_QUERY_COUNT	This returns the number of query options supported by the IOCTL service.
AI64_QUERY_DEVICE_TYPE	This returns the identifier value for the board's type. This should be GSC_DEV_TYPE_12AI64.
AI64_QUERY_FIFO_SIZE	This returns the size of the input buffer in 32-bit A/D values.
AI64_QUERY_FSAMP_MAX	This returns the maximum sample rate, FSAMP, in samples per second.
AI64_QUERY_FSAMP_MIN	This returns the minimum sample rate, FSAMP, in samples per second.
AI64_QUERY_INIT_MS	This returns the duration of a board initialization in milliseconds.
AI64_QUERY_MASTER_CLOCK	This returns the master clock frequency in hertz.
AI64_QUERY_NRATE_MAX	This returns the maximum supported NRATE value.
AI64_QUERY_NRATE_MIN	This returns the minimum supported NRATE value.
AI64_QUERY_RATE_GEN_QTY	This returns the number of Rate Generators on the board.

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

Value	Description
AI64_IOCTL_QUERY_ERROR	Either there was a processing error or the query option is unrecognized.

#### 4.7.19. AI64\_IOCTL\_RAG\_ENABLE

This service enables or disables the Rate-A Generator.

Usage

Argument	Description
request	AI64_IOCTL_RAG_ENABLE
arg	s32*

Valid argument values are as follows.

Value	Description
-1	Retrieve the current setting.
AI64_GEN_ENABLE_NO	This option disables the rate generator.
AI64_GEN_ENABLE_YES	This option enables the rate generator.

#### 4.7.20. AI64\_IOCTL\_RAG\_NRATE

This service configures the NRATE divider value for the Rate-A Generator.

Usage

Argument	Description
request	AI64_IOCTL_RAG_NRATE
arg	s32*

Valid argument values are from 48 up to 0xFFFF, and -1. A value of -1 will return the current setting.

#### 4.7.21. AI64\_IOCTL\_RBG\_CLK\_SRC

This service configures the clock source selection for the Rate-B Generator.

Usage

Argument	Description
request	AI64_IOCTL_RBG_CLK_SRC
arg	s32*

Valid argument values are as follows.

Value	Description
-1	Retrieve the current setting.
AI64_RBG_CLK_SRC_MASTER	This refers to the board's master clock.
AI64_RBG_CLK_SRC_RAG	This refers to the Rate-A Generator output.

#### 4.7.22. AI64\_IOCTL\_RBG\_ENABLE

This service enables or disables the Rate-B Generator.

## Usage

Argument	Description
request	AI64_IOCTL_RBG_ENABLE
arg	s32*

Valid argument values are as follows.

Value	Description
-1	Retrieve the current setting.
AI64_GEN_ENABLE_NO	This option disables the rate generator.
AI64_GEN_ENABLE_YES	This option enables the rate generator.

**4.7.23. AI64\_IOCTL\_RBG\_NRATE**

This service configures the NRATE divider value for the Rate-B Generator.

## Usage

Argument	Description
request	AI64_IOCTL_RBG_NRATE
arg	s32*

Valid argument values are from 48 up to 0xFFFF, and -1. A value of -1 will return the current setting.

**4.7.24. AI64\_IOCTL\_REG\_MOD**

This service performs a read-modify-write of a 12AI64 register. This includes only the GSC firmware registers. The PCI and PLX Feature Set Registers are read-only. Refer to `12ai64.h` for a complete list of GSC firmware registers.

## Usage

Argument	Description
request	AI64_IOCTL_REG_MOD
arg	gsc_reg_t*

## 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.

#### 4.7.25. AI64\_IOCTL\_REG\_READ

This service reads the value of a 12AI64 register. This includes the PCI registers, the PLX Feature Set Registers and the GSC firmware registers. Refer to `12ai64.h` and `gsc_pci9080.h` for the complete list of accessible registers.

##### Usage

Argument	Description
request	AI64_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.

#### 4.7.26. AI64\_IOCTL\_REG\_WRITE

This service writes a value to a 12AI64 register. This includes only the GSC firmware registers. The PCI and PLX Feature Set Registers are read-only. Refer to `12ai64.h` for a complete list of the GSC firmware registers.

##### Usage

Argument	Description
request	AI64_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.

#### 4.7.27. AI64\_IOCTL\_RX\_IO\_ABORT

This service aborts an ongoing `read()` request.

##### Usage

Argument	Description
request	AI64_IOCTL_RX_IO_ABORT
arg	s32*

The results are reported as one of the following values.

Value	Description
AI64_IO_ABORT_NO	A <code>read()</code> request was not aborted as none were ongoing.
AI64_IO_ABORT_YES	An ongoing <code>read()</code> request was aborted.

#### 4.7.28. AI64\_IOCTL\_RX\_IO\_MODE

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

##### Usage

Argument	Description
request	AI64_IOCTL_RX_IO_MODE
arg	s32*

Valid argument values are as follows.

Value	Description
-1	Retrieve the current setting.
GSC_IO_MODE_BMDMA	Use Block Mode DMA.
GSC_IO_MODE_PIO	Use PIO mode, which is repetitive register access. This is the default.

#### 4.7.29. AI64\_IOCTL\_RX\_IO\_TIMEOUT

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

##### Usage

Argument	Description
request	AI64_IOCTL_RX_IO_TIMEOUT
arg	s32*

Valid argument values are in the range from zero to 3600, -1, and `AI64_IO_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 `AI64_IO_TIMEOUT_INFINITE` is used, then the driver will wait indefinitely rather than timing out. The default is 10 seconds.

#### 4.7.30. AI64\_IOCTL\_WAIT\_CANCEL

This service resumes all threads blocked via `AI64_IOCTL_WAIT_EVENT` IOCTL calls (section 4.7.31, page 32), 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	<code>AI64_IOCTL_WAIT_CANCEL</code>
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 is unused by wait cancel operations.
main	This specifies the set of <code>GSC_WAIT_MAIN_*</code> events whose wait requests are to be cancelled. Refer to section 4.7.31.2 on page 33.
gsc	This specifies the set of <code>AI64_WAIT_GSC_*</code> events whose wait requests are to be cancelled. Refer to section 4.7.31.3 on page 34.
alt	This is unused by the 12AI64 driver and should be zero.
io	This specifies the set of <code>AI64_WAIT_IO_*</code> events whose wait requests are to be cancelled. Refer to section 4.7.31.4 on page 34.
timeout_ms	This is unused by wait cancel operations.
count	Upon return this indicates the number of waits that were cancelled.

#### 4.7.31. AI64\_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`, `alt` 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	AI64_IOCTL_WAIT_EVENT
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 must initially be zero. Upon return this indicates the reason that the thread was resumed. Refer to section 4.7.31.1 on page 33.
main	This specifies any number of GSC_WAIT_MAIN_* events that the thread is to wait for. Refer to section 4.7.31.2 on page 33.
gsc	This specifies any number of AI64_WAIT_GSC_* events that the thread is to wait for. Refer to section 4.7.31.3 on page 34.
alt	This is unused by the 12AI64 driver and must be zero.
io	This specifies any number of AI64_WAIT_IO_* events that the thread is to wait for. Refer to section 4.7.31.4 on page 34.
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.

## 4.7.31.1. 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 option 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.

## 4.7.31.2. 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 12AI64 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 12AI64.
GSC_WAIT_MAIN_PCI	This refers to any interrupt generated by the 12AI64.
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.

#### 4.7.31.3. 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 Interrupt Control Register. Applications are responsible for selecting the desired interrupt options. Refer to `AI64_IOCTL_IRQ0_SEL` (section 4.7.16, page 26) and `AI64_IOCTL_IRQ1_SEL` (section 4.7.17, page 26).

Value	Description
AI64_WAIT_GSC_AUTO_CAL_DONE	This refers to the completion of an auto-calibration cycle.
AI64_WAIT_GSC_IN_BUF_THR_H2L	This refers to the input buffer threshold status being negated.
AI64_WAIT_GSC_IN_BUF_THR_L2H	This refers to the input buffer threshold status being asserted.
AI64_WAIT_GSC_INIT_DONE	This refers to the completion of an initialization cycle.
AI64_WAIT_GSC_SYNC_DONE	This refers to the completion of a sync operation.
AI64_WAIT_GSC_SYNC_START	This refers to the beginning of a sync operation.

#### 4.7.31.4. 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
AI64_WAIT_IO_RX_ABORT	This refers to read requests which have been aborted.
AI64_WAIT_IO_RX_DONE	This refers to read requests which have been satisfied.
AI64_WAIT_IO_RX_ERROR	This refers to read requests which end due to an error.
AI64_WAIT_IO_RX_TIMEOUT	This refers to read requests which end due to the timeout period lapse.

### 4.7.32. AI64\_IOCTL\_WAIT\_STATUS

This service count all threads blocked via the `AI64_IOCTL_WAIT_EVENT` IOCTL service (section 4.7.31, page 32), according to the provided criteria. A match is made when a waiting thread's wait criteria matches any of the criteria specified in the structure passed to this service.

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

#### Usage

Argument	Description
<code>request</code>	<code>AI64_IOCTL_WAIT_STATUS</code>
<code>arg</code>	<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 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 4.7.31.2 on page 33.
gsc	This specifies the set of AI64_WAIT_GSC_* events whose wait requests are to be counted. Refer to section 4.7.31.3 on page 34.
alt	This is unused by the 12AI64 driver and should be zero.
io	This specifies the set of AI64_WAIT_IO_* events whose wait requests are to be counted. Refer to section 4.7.31.4 on page 34.
timeout_ms	This is unused by wait status operations.
count	Upon return this indicates the number of waits that met any of the specified criteria.

## 5. The Driver

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

### 5.1. Files

The device driver source files are summarized in the table below.

File	Description
driver/*.c	The driver source files.
driver/*.h	The driver header files.
driver/start	Shell script to install the driver executable and device nodes.
driver/12ai64.h	This is the driver interface header file.
driver/Makefile	This is the driver make file.

### 5.2. Build

**NOTE:** Building the driver requires installation of the kernel sources.

Follow the below steps to build the driver.

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

```
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 insure that the driver module in the install directory is the module that is loaded. This is accomplished by making sure that an already loaded module is first unloaded before attempting to load the module from the disk drive. In addition, the script also deletes and recreates the device nodes. This is done to insure 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 correspond 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 is 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:** The above step must be repeated each time the host is rebooted.

**NOTE:** The 12AI64 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 `12ai64` 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/12ai64.*
```

### 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/12ai64/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 you 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/12ai64` 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/12ai64
```

## 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/12ai64` while the driver is loaded and running.

## 5.6. Shutdown

Shutdown the driver following the below listed steps.

1. Login as root user, as some of the steps require root privileges.
2. If the driver is currently loaded then issue the below command to unload the driver.

```
rmmod 12ai64
```

3. Verify that the driver module has been unloaded by issuing the below command. The module name `12ai64` should not be in the list.

```
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.

File	Description
docsrc/*.c	These are the C source files.
docsrc/makefile	This is the library make file.
docsrc/makefile.dep	This is an automatically generated make dependency file.
include/12ai64_dsl.h	This is the primary utility header file.
lib/12ai64_dsl.a	This is the statically linkable library file.

### 6.2. Build

The library is built via the Overall Make Script (section 2.7, page 12), but can be built separately following the below steps.

1. Change to the directory where the documentation sources are installed (.../docsrc/).
2. Remove all 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
```

### 6.3. Library Use

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

File	Location
12ai64_dsl.h	.../include/
12ai64_dsl.a	.../lib/



## 7. Utility Source Code

The driver archive includes a body of utility services built into a statically linkable library that is usable with console applications. The primary purpose of the services is both for code reuse in the sample applications and to provide wrappers, mostly visual, around the driver's IOCTL services. The aim of the visual wrappers is to facilitate structured console output for the sample applications. 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.

### 7.1. Files

The library files are summarized in the table below.

File	Description
utils/util_*.c	These are device specific utility source files.
utils/gsc_*.c	These are device and OS independent utility source files.
utils/os_*.c	These are OS specific utility source files.
utils/makefile	This is the library make file.
utils/makefile.dep	This is an automatically generated make dependency file.
include/12ai64_utils.h	This is the primary utility header file.
lib/12ai64_utils.a	This is the statically linkable library file.

### 7.2. Build

The library is built via the Overall Make Script (section 2.7, page 12), but can be built separately following the below steps.

1. Change to the directory where the utility sources are installed (.../utils/).
2. Remove all 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
```

### 7.3. Library Use

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

File	Location
12ai64_utils.h	.../include/
12ai64_utils.a	.../lib/

## 8. Operating Information

This section explains some basic operational procedures for using the 12AI64. 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. 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.

Description	Name/File	Location
Function	<code>ai64_config_ai()</code>	Source File
Source File	<code>util_config_ai.c</code>	.../utils/
Header File	<code>12ai64_utils.h</code>	.../include/
Library File	<code>12ai64_utils.a</code>	.../lib/

### 8.2. I/O Modes

All data read requests move the requested data from the board's input buffer, to an intermediate driver buffer, then from there to application memory. The data is processed in chunks no larger than the size of the output buffer. The process used to move data from the input buffer to the intermediate buffer is according to the I/O mode selection.

#### 8.2.1. PIO - Programmed I/O

This involves repetitive register accesses. In this mode the driver will read data from the input buffer one value at a time. As needed, the driver will repeatedly sleep for one system time tick in order to wait for addition data to appear in the input buffer. This process is repeated until the request is satisfied or the I/O timeout expires, whichever occurs first.

#### 8.2.2. BMDMA - Block Mode DMA

For Block Mode DMA transfers, hardware onboard the 12AI64 is used to transfer the data without processor intervention. In this mode the driver checks for available data in the input buffer. Depending on the size of the read request, the driver may break the request into smaller transfers in order to insure data integrity. When sufficient data is available a DMA transfer is performed. The volume of data moved in a single request is based upon the amount of data remaining in the request and the amount of data available in the input buffer. If the remaining request can be satisfied from available data, then the data is transferred. Otherwise, if the threshold flag is clear, then the driver will wait one timer tick before trying again. If the threshold flag is set, then the driver will transfer up to the volume of data available in the input buffer up to the threshold level. The process is repeated until the request is satisfied or the I/O timeout expires, whichever occurs first.

### 8.3. Debugging Aids

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

#### 8.3.1. 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	<code>id</code>	.../id/

### 8.3.2. Detailed Register Dump

Among the utility services provided is a function to generate a detailed listing of the board's registers to the console. When used, the function is typically used to verify the board's configuration. In these cases, the function should be called just prior to the first read or write operation. When intended for sending to GSC tech support, please set the *detail* argument to 1. The function arguments are as follows. The utility location is given in the subsequent table.

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

Description	File/Name	Location
Function	ai64_reg_list()	Source File
Source File	util_reg.c	.../utils/
Header File	12ai64_utils.h	.../include/
Library File	12ai64_utils.a	.../lib/

## 9. Sample Applications

The driver archive includes a variety of sample and test applications. 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 12), but each may be built individually by changing to its respective directory and issuing the commands “make clean” and “make all”. 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. fsamp - Sample Rate - .../fsamp/

This application reports the device configuration required to produce a user specified sample rate.

### 9.2. 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.

### 9.3. regs - Register Access - .../regs/

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

### 9.4. 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.

### 9.5. 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.

### 9.6. 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 binary 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
October 19, 2022	Updated to version 1.5.101.44.0. Updated the kernel support table. Added section on environment variables. Updated the information for the open and close calls. Corrected notes about IRQ anomaly.
February 9, 2022	Updated to version 1.4.96.38.0. Updated the kernel support table. Minor editorial changes. Some reformatting. Added a licensing subsection. Added WAIT_EVENT note. Expanded automatic startup information. Added the Firmware Revision Register.
April 26, 2019	Updated to version 1.3.85.27.0. Updated the inside cover page. Updated the CPU and kernel support section. Minor editorial changes. Updated Block Mode DMA macro and associated information. Some document reorganization.
January 26, 2018	Updated to version 1.2.73.20.0. Implemented API Library. Restructured document.
November 28, 2016	Updated to version 1.1.68.18.0. Updated the command line arguments for the <code>fsamp</code> and <code>savedata</code> sample applications. Updated the usage of the Wait Event <code>timeout_ms</code> field. Updated material on the open call. Added open access mode descriptions. Updated the kernel support table. Added cautionary notes about the IRQ Anomaly present in older firmware. Added support for infinite I/O timeouts. Updated the operating information section. Made various miscellaneous updates. Some document reorganization.
January 11, 2016	Initial release, version 1.0.64.12.0.