# Aurora Application Program Interface Guide

Revision 8
July 2018

Revision Status

| Revision Number | Date | Description |
|---|---|---|
| 1 | April 2007 | Initial release. |
| 2 | November 2007 | Added GET command, added dome volume and metal resistance to SFLIST command |
| 3 | July 2010 | Added RESET command |
| 4 | October 2011 | Added TTFG volume to SFLIST command. Deprecated DSTART and DSTOP commands |
| 5 | March 2013 | Added DFLT, GETINFO, SAVE and SET commands; added User Parameters chapter. |
| 6 | September 2013 | PHINF command changes: deprecated reply option 0020; added reply option 0080. Added new user parameters relating to physical port locations. Deprecated VER 8. |
| 7 | November 2016 | Added VSIU chapter, VSIU command, and Param.Tracking parameters |
| 8 | July 2018 | Changes for combined revision 18. BEEP, Bit definition of BX/TX reply, TSTART option |

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# Read Me First!

This guide describes revision D.002.005 of the Aurora Application Program Interface (API). The APIREV (page 22) command returns the revision of the API that is compatible with the firmware in your Aurora System. If the APIREV command is not supported by your system, contact NDI technical support.

For information on changes in implementation from previous versions of the API, please refer to the "Aurora Firmware Guide."

Before sending any commands to the system, read the manual that accompanied your system to ensure that you have a full understanding of the functionality.

## Warnings


In all NDI documentation, warnings are marked by this symbol. Follow the information in the accompanying paragraph to avoid personal injury.

When using reply option 0800 with the BX (page 24) or TX (page 83) command, you must take appropriate action to detect when a tool is out of volume, and determine whether this situation is detrimental to your application. If a tool is out of volume, reply option 0800 enables the system to return data that may lead to inaccurate conclusions and may cause personal injury.

## Disclaimers

Due to the nature of the mathematical model that the Aurora System uses to produce transformations, there is a very infrequent occurrence where the system may randomly return a single frame of significantly inaccurate or misleading data. To reduce the impact of this single frame on a measuring task, be aware of the possibility of this occurrence, and take such data into consideration when collecting transformations.

A complete list of the warnings, classifications, and approvals that apply to the Aurora System is included in the user guide shipped with the system.

## Contact Information

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## Updates

NDI is committed to continuous improvements in the quality and versatility of its software and hardware. To obtain the best results with your NDI system, check the NDI Support Site regularly for update information:

https://support.ndigital.com.

# 1 List of Commands

| Command | Page | Description |
|---|---|---|
| APIREV | 22 | Returns the API revision number that functions with your system. |
| BEEP | 23 | Sounds the system beeper. |
| BX | 24 | Returns the latest tool transformations and system status in binary format. |
| COMM | 29 | Sets the serial communication settings of the system. |
| DFLT | 31 | Restores the user parameters to factory default values. |
| DSTART | 32 | Deprecated. Use TSTART. |
| DSTOP | 33 | Deprecated. Use TSTOP. |
| ECHO | 34 | Returns exactly what is sent with the command. |
| GET | 35 | Returns the values of user parameters. |
| GETINFO | 36 | Returns descriptive information about the user parameters. |
| INIT | 38 | Initializes the system. |
| LED | 39 | Changes the state of visible LEDs on a tool. |
| PDIS | 41 | Disables the reporting of transformations for a particular port handle. |
| PENA | 42 | Enables reporting of transformations for a particular port handle. |
| PHF | 43 | Releases system resources from an unused port handle. |
| PHINF | 44 | Returns information about the tool associated with the port handle. |
| PHSR | 50 | Returns the number of assigned port handles and the port status for each one. Assigns a port handle to a tool. |
| PINIT | 53 | Initializes a port handle. |
| PPRD | 55 | Reads data from the SROM device in a tool. |
| PPWR | 57 | Writes data to the SROM device in a tool. |
| PSEL | 59 | Selects a tool SROM device as the target for reading or writing with PPRD or PPWR. |
| PSOUT | 60 | Sets the status of the GPIO in the Aurora System. |
| PSRCH | 62 | Returns a list of valid SROM device IDs for a tool. |
| PURD | 63 | Reads data from the user section of the SROM device in a tool. |
| PUWR | 65 | Writes data to the user section of the SROM device in a tool. |
| PVWR | 67 | Overrides a tool definition file in a tool, and can be used to test a tool definition file before permanently recording the tool definition file onto the SROM device. |
| RESET | 69 | Resets the system |
| SAVE | 71 | Saves all non-volatile user parameters that have been changed. |
| Serial break | 20 | Resets the system. |
| SET | 72 | Sets user parameter values. |
| SFLIST | 73 | Returns information about the supported features of the system. |
| TSTART | 78 | Starts Tracking mode. |
| TSTOP | 80 | Stops Tracking mode. |

| Command | Page | Description |
|---|---|---|
| TTCFG | 81 | Sets up a configuration for a tool, so that you can test the tool without using a tool definition file. |
| TX | 83 | Returns the latest tool transformations and system status in text format. |
| VER | 87 | Returns the firmware revision number of critical processors installed in the system. |
| VSEL | 89 | Selects a characterized measurement volume. |

# 2 Communicating with an Aurora System

This chapter describes various aspects of communicating with an Aurora System. It contains the following sections:



## 2.1 Communication Overview

From the application perspective, the Aurora System is a serial device, which is listening for incoming commands. Upon receiving a command, the system performs some action and returns the status of this action. The system never initiates communication with the application except on power up or reset, when it returns `RESET<CRC16><CR>`.

Immediately after sending a command, the application can begin to poll the serial buffer for a reply. Most commands reply almost instantaneously. After reaching the end of the reply, the application can send another command. There may be some delay in the response of certain commands; see "Receiving System Replies" on page 5 for details.

**Note** The application must read the complete response from the system before sending another command. Failure to do so may result in an error or in unpredictable system behaviour.

## 2.2 Operating Modes

The Aurora System has two modes of operation: Setup and Tracking. Some commands will only work if they are sent while the system is in a specific mode of operation. If a command is sent when the system is in a mode not valid for that command, the system returns `ERROR0C`.

### Setup

Setup mode allows you to configure the system and tools. Typical Setup mode tasks may include initializing the system, writing to the SROM device on a tool, or checking the system firmware revisions.

The order of the commands sent while in Setup mode is important. For example, a port handle must be initialized (PINIT) before it can be enabled (PENA). Refer to the command documentation in Chapter 5 to see the prerequisites for each command.

The system enters the Setup mode either on successful power up, on sending a reset, or on exiting from Tracking mode.

### Tracking

In Tracking mode, the system measures the positions and orientations of tools in real time and returns the information to the host computer when requested. The BX and TX commands are the most commonly used commands in Tracking mode.

The system enters Tracking mode on successful TSTART command and exits Tracking mode on TSTOP command.

## 2.3 General Syntax

Commands must be sent from the host computer to the system in one of the two following formats.

**Note** To ensure the integrity of data transmission, NDI recommends using format 1, as well as verifying the returned Cyclic Redundancy Check (CRC) on the host computer.

### Format 1

`<Command><:><Parameter1><Parameter2>...<ParameterN><CRC16><CR>`

A `<:>` must be sent with every command even if no parameters are required. There are no characters or spaces separating the parameters or the individual parts of the commands. Commands and parameters are not case-sensitive.

This format requires a 16-bit CRC value and therefore may be more useful in application software. The application software can incorporate a CRC calculation and add it to the command each time a command is sent to the system. Including a CRC provides a communications check to ensure that there are no communication problems between the system and the host computer. The CRC is used in both the commands and replies. It is based on all the characters in the command, up to the CRC itself. It is calculated using the polynomial $x^{16} + x^{15} + x^2 + 1$. See “Sample C Routines” on page 104 for sample code to calculate the CRC.

### Format 2

`<Command><SPACE><Parameter1><Parameter2>...<ParameterN><CR>`

A `<SPACE>` must be sent with every command even if no parameters are required. There are no characters or spaces separating the parameters or the individual parts of the commands. Commands and parameters are not case-sensitive.

It is not necessary to calculate a CRC value when using this format, so this format is useful for sending commands to the system in an application such as troubleshooting.

To ensure the integrity of data transmission, NDI recommends using format 1, as well as verifying the returned CRC on the host computer.

## 2.4 Receiving System Replies

**Note** The Aurora System may take longer to send a response for some commands than for other commands. For example, PINIT and TSTART may take up to five seconds. A reset may take as long as 12 seconds under special circumstances (for example, when a Field Generator is connected for the first time). If a timeout is detected, sending a serial break to the system should return the system to normal operation.

### Binary Replies

The BX command returns binary replies. All other commands return ASCII replies.

If a complete command is received by the system, replies are sent back in the format:

`<Reply><CRC16>`

The system always returns `<CRC16>` in the reply regardless of whether the command was sent in format 1 or format 2. The `<Reply>` will be either the requested data, or `ERROR<error code>`. The `<error code>` is a two-digit hexadecimal error number. See "Error Code Definitions" on page 91 for a listing of all the error messages associated with error numbers.

Binary replies are returned in little endian format. For example, a 32-bit reply is returned in the format:

| Bits | 7 - 0 | 15 - 8 | 23 - 16 | 31 - 24 |
|---|---|---|---|---|
| Reply byte | n | n + 1 | n + 2 | n + 3 |

### ASCII Replies

All commands return ASCII replies except BX, which returns binary replies.

If a complete command is received by the system, replies are sent back in the format:

`<Reply><CRC16><CR>`

The system always returns `<CRC16>` in the reply regardless of whether the command was sent in format 1 or format 2. The `<Reply>` will be either the requested data, `OKAY`, or `ERROR<error code>`. The <error code> is a two-digit hexadecimal error number. See "Error Code Definitions" on page 91 for a listing of all the error messages associated with error numbers.

## 2.5 Best Practices

This section provides guidelines on how to write an application in order to minimize updates required when there are changes to the API. If your application is written correctly, it will still work when additions are made to the API; you will only need to update your application if you wish to take advantage of the new features.

- Ignore the value of any returned field that is listed as "reserved" in the API guide. The values of reserved fields may change in future API releases.
- Program the application to allow all possible values of a returned field, not only the values that are currently defined. This allows for future expansion. For example, if a field returns one character, but currently only characters 0 and 1 are defined, do not write your

application such that 0 and 1 are the only acceptable values; more values may be defined in the future.

- Use the frame number, and not the host computer clock, to identify when data was collected. The frame number is incremented by 8 at a constant rate of 40 Hz. Associating a time from the host computer clock to replies from the system assumes that the duration of time between raw data collection and when the reply is received by the host computer is constant. This is not necessarily the case. The frame number is returned with the command BX (page 24) or TX (page 83).
- Use both the shape type and the shape parameters to represent the characterized measurement volume graphically. There may be multiple volumes with the same shape type. All volumes of the same shape type use the shape parameters the same way. The shape type and shape parameters are returned with the command SFLIST (page 73).
- When checking the firmware revision, check only the combined firmware revision, not the firmware revision of the individual components. The combined firmware revision ensures that all components in a system have compatible firmware. To check the combined firmware revision, use the command VER 5 (page 87).
- When checking for protocol compatibility, check for the API revision instead of the combined firmware revision. An application written for a particular API revision will function with any system that supports that API revision. See the command APIREV (page 22) for details.

## 2.6 Port Handles

### About Port Handles

The system assigns each tool a port handle. Port handles are two characters in hexadecimal format, 0x0A to 0x31. Port handles can be assigned to tools only while the system is in Setup mode.

### Port Handle Commands

The following commands are used for port handles:

| Command | Description |
|---|---|
| PHSR (page 50) | Returns the number of assigned port handles and the port status for each one. Assigns a port handle to a tool. |
| PVWR (page 67) | Overrides a tool definition file in a tool, and can be used to test a tool definition file before permanently recording the tool definition file onto the SROM device. |
| PINIT (page 53) | Initializes a port handle. |
| PHINF (page 44) | Returns port handle status, and information about the tool associated with the port handle, including physical port location. |

| Command | Description |
|---|---|
| PHF (page 43) | Releases system resources from an unused port handle. This is required if a tool is disconnected. If a tool is disconnected and then reconnected, the system assigns a new port handle to the tool. The old handle is reported as disabled and should be freed using PHF. |
| PENA (page 42) | Enables reporting of transformations for a particular port handle. |
| PDIS (page 41) | Disables the reporting of transformations for a particular port handle. |

The order in which these commands are used is detailed in Figure 2-1 on page 8.

### Disabled Transformations

A transformation may be reported as DISABLED if:

- the port handle was not enabled with PENA (page 42),
- the port handle has been disabled with PDIS (page 41), or
- a tool has been disconnected and the port handle has not been freed.

### Unoccupied Port Handle

A port handle may be reported as UNOCCUPIED if the tool has been disconnected and port handle information is requested using PHINF (page 44).

### Flow Chart for Port Handle Usage

Figure 2-1 on page 8 details the logic for using port handles.

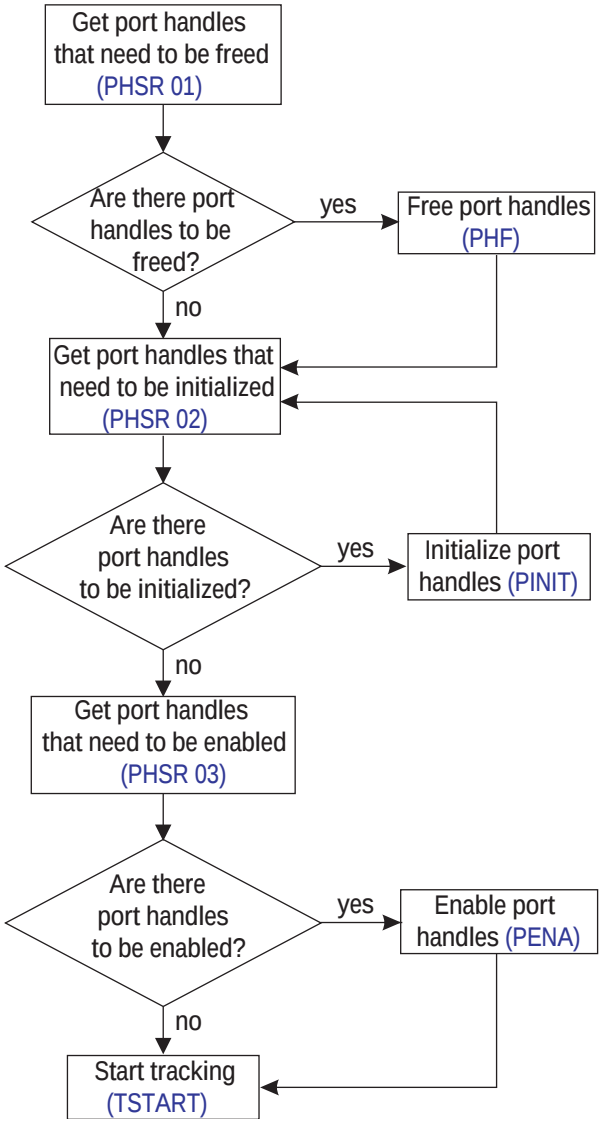



Figure 2-1 Flow Chart for Port Handle Usage

Note For a split port on a dual 5DOF tool, the first PHSR sent will report only one port handle. After the port handle is initialized, it is assigned to channel 0. You must then use PHSR again to assign a port handle to channel 1. The port handle for channel 1 is initialized automatically.

# 3 Virtual Sensor Interface Unit

This chapter describes communication with a Virtual Sensor Interface Unit (VSIU). A VSIU is not a component in the standard Aurora system; it is a custom piece of hardware. VSIUs are usually application- and customer-specific devices with special means of system synchronization.

Care must be taken with the communication to the Aurora, since the VSIUs mean a high strain on the communication bandwidth. The typical amount of transferred measurement data for a single port (2 sensors) using a standard Field Generator is 8kB/s.

## 3.1 Aurora Packet Protocol

The communication channel between the SCU and the VSIU is multiplexed with the normal command communication to the SCU. To ease this interleaved communication the new packet communication protocol has been introduced.

A packet is an atomic block of data. It must not be interrupted during communication.

### Packet Structure

A packet is made of 3 parts:

1. Header: The header contains all information necessary to route the packet from its origin to its destination. It also includes checksums and other means to protect the communication in case of transmission errors.
2. Payload: The payload follows immediately to the header. It might be empty.
3. Endmark (CR (carriage return)): The endmark follows the payload section even if the payload is empty.

### Packet Header

```
struct SVSIUHeader
{
   /* always 0xa7c4 */
   unsigned short m_Preamble;


   /* device identification (for routing purposes, etc.) */
   unsigned char m_Id;


   /* packet type: see enum EPacketType
    *   0 - direct communication
    *   1 - VSIU command protocol (command and reply)
    *   2 - VSIU raw data protocol
    *  -1 - error answer (the error is a 2byte body (okay: 3bytes with CR
   at end))
    *       Errors: see enum EErrorAnswer */
   unsigned char m_Type;
```

```
   /* incremented for each new command; repeated in the answer to the
    * command */
   unsigned short m_Sequence;


   /* length of payload (including the CR at the end!) */
   unsigned short m_PayloadLength;


   /* crc of payload (including the CR at the end!) */
   unsigned short m_PayloadCrc;


   /* crc of this header */
   unsigned short m_HeaderCrc;
};
```

Note All information in the header is in little endian format.

```
/* EPacketType specifies the content of the m_Type member of the
SVSIUHeader */
enum EPacketType
{
   EPTError = 0xff,


   /* direct communication with VSIU */
   EPTDirect = 0,


   /* control communication between SCU and VSIU */
   EPTVSIUCommand = 1,


   /* data sent from VSIU to SCU */
   EPTVSIURaw = 2
};



/* EErrorAnswer specifies the 2byte payload in case m_Type is EPTError */
enum EErrorAnswer
{
   EEUnknownType = 0,


   /* if waiting for new data times out while a packet is still incomplete
   */
   EETimeout = 1,
```

```
    /* if the packet is addressing another target id. Usually this will be
     * checked only for VSIU control commands from the SCU */
    EEInvalidId = 2,


    /* an error in the header crc was detected */
    EEHeaderCrc = 3,


    /* an error in the payload crc was detected */
    EEPayloadCrc = 4
};
```

The packet communication uses a simple error handling. The most recent command packet can be repeated arbitrarily often. The receiver must only execute this command once, but needs to report the same answer. So in case of a transmission error (checksum, missing character, etc.) a simple repetition will correct it without the risk that the command is executed twice.

## 3.2 Packet Routing

There are 4 distinct data channels in a typical VSIU system:

- Aurora API commands between the client software and the Aurora SCU (Aurora API protocol, bidirectional). Each API command is acknowledged by the Aurora. With active packet communication (e.g. when a VSIU is in the system) it is possible that the Aurora may send out packets before the textual or binary answer to the command is sent. This is normal and the client software must be able to work with it.
- Direct commands to the VSIU (Aurora packet protocol, bidirectional). These packets will be always acknowledged with an answer.
- Control commands between the VSIU and the Aurora SCU (Aurora packet protocol, bidirectional). These packets originate in the SCU. These packets will be always acknowledged by the VSIU with an answer.
- Measurement data from the VSIU to the Aurora SCU (Aurora packet protocol, unidirectional). These packets transport the measurement data from the VSIU to the SCU and they will not be repeated. The SCU does not send an acknowledgement after reception. Damaged packets should be dropped. The effect of missing packets are missing transformations for the sensors connected to the VSIU.

## 3.3 Synchronization

For a normal SIU, all synchronization and communication signals are sent via the direct hardware link to the SCU. Since the VSIU does not have this direct link, it is must be synchronized by other means. A VSIU is a custom piece of hardware, so there are no general specifications for how to synchronize it to the SCU. Normally synchronization is achieved by the customer’s system being the timing master for the SCU and for the VSIU. For more information on synchronization with the Aurora system, see the “*Aurora V3 User Guide*.”

# 4 User Parameters

This chapter contains the following sections about user parameters:



## 4.1 About User Parameters

The user parameters store values for different aspects of the Aurora System. Some user parameters store values for the full system configuration; others store values pertaining to a particular hardware device in the system. Some user parameters are read-only parameters that store useful information about the system; some user parameter values can be changed, to allow you to configure the system.

For a full list of user parameters, see page 17.

## 4.2 User Parameter Commands

The following commands are used with the user parameters:

| Command | Description |
|---|---|
| DFLT (page 31) | Restores the user parameters to factory default values. |
| GET (page 35) | Returns user parameter values. |
| GETINFO (page 36) | Returns user parameter values and descriptive information about the user parameters, including use details, possible values, and access rules. |
| SET (page 72) | Sets user parameter values. |
| SAVE (page 71) | Saves all non-volatile user parameters that have been changed. |

See the individual commands for more details.

## 4.3 Device Names

**Note** Device names are supported in API revisions D.001.008 and later.

Each hardware device (each System Control Unit, Field Generator and Sensor Interface Unit) in the system configuration has a unique device name.

### Determining the Devices in the System Configuration

Use the GET command to determine which hardware devices are in your system. To ensure future compatibility if more devices are integrated into your system, your application should read the list of devices every time you connect to a system, or whenever a component is connected or disconnected.

The most general method of reading the list of devices to ensure consistent behaviour in the future is as follows:

*Command:*

```
GET Device.*
```

*Reply:*

```
Device.Type.0=SCU
Device.Instance.0=0
Device.Type.1=FG
Device.Instance.1=0
Device.Type.2=SIU
Device.Instance.2=1
Device.Type.3=SIU
Device.Instance.3=4
```

The reply gives information about every device in the system configuration. For each device, there are two parameters:

- **Device.Type.X** describes the type of connected device. Device types are as follows:

| Device.Type Parameter | Hardware Device |
|---|---|
| SCU | System Control Unit |
| FG | Field Generator |
| SIU | Sensor Interface Unit<br>or Integrated Sensor Interface Unit |

- **Device.Instance.X** describes the instance of that type of device in the configuration.

Parameters with the same X index value (for example, Device.Type.0 and Device.Instance.0) describe the same device. The X values are not necessarily consecutive numbers.

Instance numbers for the SIUs correspond to the port number on the SCU to which they are connected. In the example above, the reply is for an Aurora System with a System Control Unit, a Field Generator, and two SIUs connected to ports 1 and 4 of the System Control Unit.

### Constructing Device Names

User parameters for a particular device can always be accessed using the full device name. To construct the device name for a particular device, use the following syntax:

```
<Device.Type.X>-<Device.Instance.X>
```

For the configuration in the example above, the device names are SCU-0, FG-0, SIU-1 and SIU-4.

### Accessing User Parameters Using Device Names

Each device has its own set of user parameters. To ensure that the user parameters for the correct device are accessed, prefix the parameter with the device name. All references to user parameters for a device can be made using the device name. To access the user parameters for a particular device, use the following syntax:

```
<Device.Type.X>-<Device.Instance.X>.<User Parameter>
```

For example, use `GET SIU-4.Info.Status.New Alerts` to check the alerts for the SIU connected to port 4.

To view information about the parameters supported by the device, use the following commands:

```
GET FG-0.*
GETINFO FG-0.*
```

**Note** See the GET (page 35) and GETINFO (page 36) commands for details.

For compatibility reasons the device name can be omitted for the SCU. The default device name is SCU-0.

For example, `GET Param.System Beeper` will return the reply `Param.System Beeper=141B7` while `GET SCU-0.Param.System Beeper` will return the reply `SCU-0.Param.System Beeper=1B6A0.`

The wild card (*) is not allowed in device names. There is one exception: GET * will report all user parameters from all available devices.

There are a few user parameters which do not belong to a device but are system parameters, e.g. Device.Type.*. These parameters are not prefixed by a device name.

## 4.4 Alerts User Parameters

The alerts user parameters describe the status of a particular hardware device in the system. To access the user parameters for a particular device, prefix the parameter with the device name as described in “Device Names” on page 12.

### Alerts User Parameters

Table 4-1 describes the alerts user parameters.

**Table 4-1 Alerts User Parameters**

| User Parameter | Description |
|---|---|
| Info.Status. Alerts | This user parameter describes the current state of the hardware device by reporting the alerts listed in Table 4-2 (for the System Control Unit), Table 4-3 (for the Field Generator), or Table 4-4 (for the SIUs).<br><br>The bit corresponding to a particular alert is set when the system first detects the condition. This is accompanied by the system response detailed in Table 4-2, Table 4-3, or Table 4-4. The bit is cleared when the condition no longer exists. |

**Table 4-1 Alerts User Parameters (Continued)**

| User Parameter | Description |
|---|---|
| Info.Status. New Alerts | Read this user parameter when the diagnostic pending bit is set (bit 8 in the BX or TX system status). This user parameter lists the current alerts status whenever an alert is set or cleared. The act of reading this parameter clears both this parameter and the diagnostic pending bit. If no other device has a new alert, the diagnostic pending bit (bit 8 in the BX or TX system status) is also cleared. |
| Info.Status. Alerts Overflow | Read this user parameter if the overflow bit is set in the user parameter **Info.Status.Alerts** or **Info.Status.New Alerts** for a particular hardware device. No bits are currently defined in this parameter. |
| Param. Simulated Alerts | Simulates the **Info.Status.Alerts** parameter for the hardware device specified, for testing purposes. To test the response of a particular alert, set the value of this parameter to the value of the alert (see Table 4-2, Table 4-3, or Table 4-4).<br>Simulated alerts can be cleared by "SET Param.Simulated Alerts=0" and reading the **Info.Status.New Alerts** parameter.<br>The overflow bit can be set with simulated alerts, but no bit will be set in the **Info.Status.Alerts Overflow** parameter. |

The command RESET will reset all alert parameters. The command INIT does not reset alert parameters.

If a device is disconnected, the alerts for that device will not be available. This may change the diagnostic pending bit.

## System Control Unit Alerts

Table 4-2 describes the System Control Unit alerts that are returned by the **Info.Status.Alerts** and **Info.Status.New Alerts** user parameters. The returned value is an integer, which you must convert to an 8-character hexadecimal number. The hexadecimal number is made up of the following individual alert values OR'd together:

**Table 4-2 System Control Unit Alerts**

| Device | Hexadecimal Value | Alert | System Response |
|---|---|---|---|
| SCU | 00000001 | Processing unit fault | INIT returns `ERROR15` |
| SCU | 00000002 | Processor periphery fault | INIT returns `ERROR15` |
| SCU | 00000004 | Field Generator driver fault<br>**Note**: Not supported on V1 SCUs. | INIT returns `ERROR15`<br>TSTART returns `ERROR12` |
| SCU | 00000008 | Processor or logic voltage fault.<br>**Note**: Not supported on V1 or V2 SCUs. | INIT returns `ERROR15` |
| SCU | 80000000 | Overflow.<br>Read the value of the user parameter **Info.Status.Alerts Overflow**. | |

## Field Generator Alerts

Table 4-3 describes the Field Generator alerts that are returned by the **Info.Status.Alerts** and **Info.Status.New Alerts** user parameters. The returned value is an integer, which you must convert to an 8-character hexadecimal number. The hexadecimal number is made up of the following individual alert values OR'd together:

**Table 4-3 Field Generator Alerts**

| Device | Hexadecimal Value | Alert | System Response |
|---|---|---|---|
| FG | 00000001 | Communication fault | TSTART returns ERROR14 |
| FG | 00000002 | Defective coil.<br>This can only be detected when tracking.<br>**Note**: Not supported when using a V1 SCU. | Sets diagnostic pending bit (bit 8) in TX or BX system status. |
| FG | 00000004 | No measurement volume compatible with the SCU firmware.<br>This can happen, for example, when a V2 Field Generator is connected to a V1 SCU. | TSTART returns ERROR14<br>VSEL returns ERROR24 |
| FG | 80000000 | Overflow.<br>Read the value of the user parameter **Info.Status.Alerts Overflow**. | |

## Sensor Interface Unit Alerts

Table 4-4 describes the Sensor Interface Unit alerts that are returned by the **Info.Status.Alerts** and **Info.Status.New Alerts** user parameters. The returned value is an integer, which you must convert to an 8-character hexadecimal number. The hexadecimal number is made up of the following individual alert values OR'd together:

**Table 4-4 Sensor Interface Unit Alerts**

| Device | Hexadecimal Value | Alert | System Response |
|---|---|---|---|
| SIU | 00000001 | Processing unit fault.<br>(V3 SIU only) | Sets diagnostic pending bit (bit 8) in TX or BX system status. |
| SIU | 00000002 | Communication fault.<br>(V1 SIU only) | Sets diagnostic pending bit (bit 8) in TX or BX system status. |
| SIU | 00000004 | Analog module fault<br>(V3 SIU only) | Sets diagnostic pending bit (bit 8) in TX or BX system status. |
| SIU | 00000008 | SIU hardware/firmware configuration incompatibility.<br>(V3 SIU only) | Sets diagnostic pending bit (bit 8) in TX or BX system status.<br>System functionality limited. |
| SIU | 80000000 | Overflow.<br>Read the value of the user parameter **Info.Status.Alerts Overflow**. | |

## 4.5 Complete List of User Parameters

Table 4-5 lists the user parameters for the Aurora Systems. To view a complete list of user parameters for your system, use the command GET * (for parameter names and values) or GETINFO * (for parameter names, values, and usage details).

**Table 4-5 Complete List of User Parameters**

| User Parameter Name | Description | Access Rules | Device |
|---|---|---|---|
| Device.Instance.X | Instance of this type of device in the system configuration | Read, write | SCU |
| Device.Type.X | Type of device in the system configuration | Read | SCU |
| Features.Firmware.Version | Firmware version programmed into the device | Read | SCU, SIU |
| Features.Hardware. Characterization Date | Date of most recent FG characterization | Read | FG |
| Features.Hardware. Manufacturing Date | Manufacturing date of the device | Read | SIU |
| Features.Hardware.Max Ports | Number of physical SIU ports on the SCU | Read | SCU |
| Features.Hardware. Max Tool Ports | Number of physical tool ports on the SIU | Read | SIU |
| Features.Hardware.Model | Device model string | Read | All devices |
| Features.Hardware. Serial Number | Device serial number | Read | All devices |
| Features.Hardware.Version | Hardware version string | Read | SCU |
| Info.Path | Physical location of the SIU in the format X.N, where X is the SCU device instance and N is the physical port at the SCU.<br>Possible values: X=0, N ranges from 0 to the value of Features.Hardware.Max Ports | Read | SIU |
| Info.Port Handles.i | Reports a list of port handles assigned to physical tool port i at the SIU, for i = 0 to value of Features.Hardware.Max Tool Ports.<br>Returns 2 hexadecimal characters for each assigned port handle; returns an empty string if no port handles are assigned. | Read | SIU |
| Info.Status.Alerts | System hardware and operating status flags; see “Alerts User Parameters” on page 14 for details. | Read | All devices |
| Info.Status.Alerts Overflow | System hardware and operating status flags overflow; see “Alerts User Parameters” on page 14 for details. | Read | All devices |
| Info.Status.New Alerts | System hardware and operating status flags; see “Alerts User Parameters” on page 14 for details. | Read | All devices |

**Table 4-5 Complete List of User Parameters (Continued)**

| | | | |
|---|---|---|---|
| Info.Status.Port.i | Reports the device instance of the connected SIU at physical port i at the SCU, for i = 0 to value of Features.Hardware.Max Ports.<br>Returns an empty string if no SIUs are connected. | Read | SCU |
| Info.Timeout.<command> | Timeout for the specified command (s) | Read | SCU |
| Param.Page.Rev | Revision describing which parameters are saveable | Read | SCU |
| Param.System Beeper | Enables/disables the beeper sequence on system reset | Read, write, save | SCU |
| Param.Tracking.Frame Sync Source | Sets the frame synchronization source.<br>Valid values:<br><br>0: Auto Mode (default)<br>If the HF signal is available on the sync port, mode 2 (External Mode) is used. If the HF signal is not available on the sync port, mode 4 (Internal Mode) is used.<br><br>1: Reserved<br><br>2: External Mode<br>HF and FR must be stable and continous before issuing the TSTART command.<br><br>3: Slave Mode<br>TSTART returns OKAY even when no sync signals are available on the sync port. Tracking mode starts with the first FR pulse on the sync port. After that the FR pulse is required to run continuously. If tracking has not yet started, sending TX and BX commands will result in ERROR05.<br><br>4: Internal Mode<br>HF and FR signals from sync port are ignored.<br><br>5: reserved<br>See the "*Aurora User Guide*" for information on the sync port signals. | Read, write | SCU |
| Param.Tracking.Ext Sync Available | Reports whether an HF signal can be detected on the sync port.<br>1: The HF signal is detected on the sync port.<br>0: The HF signal is not detected on the sync port.<br>See the "*Aurora User Guide*" for information on the sync port signals. | Read | SCU |
| Param.Tracking.Track Frequency | Reports the tracking frame rate. Only valid when in tracking mode. | Read | SCU |

**Table 4-5 Complete List of User Parameters (Continued)**

| | | | |
|---|---|---|---|
| Param.Tracking.Frame Frequency | Reports the time stamp increase per second. Only valid when in tracking mode. | Read | SCU |
| Param.Simulated Alerts | Simulates the 'Info.Status.Alerts' parameter, for testing purposes | Read, write | All devices |
| Param.User.String | User-defined string (up to 63 chars) | Read, write, save | SCU |

# 5 Commands

Before sending any commands to the system, read the user guide that accompanied your system to ensure that you have a full understanding of the system functionality. The user guide is available on the NDI Support Site at https://support.ndigital.com.

## Resetting the System with a Serial Break

Resets the system.

### Operating Mode

All modes

### Syntax

The method depends on the host computer.

### Reply

`RESET<CRC16><CR>`

### Usage Notes

1. The serial break is a special condition, and is specific to the host computer operating system. Refer to your computer manuals to determine how to generate a serial break.
2. The serial break is a good recovery method in the following situations:
   - System warm boot: the system is powered up, but you don't know the communication setup, or which mode the system is in.
   - Synchronization error: while in the Tracking mode, the BX or TX reply status returns that synchronization errors have occurred.
   - Loss of communication: the host computer and the system can no longer communicate.

**Note** Under normal operation, the Aurora System will return a response to any given command in under 10 seconds. If a timeout is detected, sending a serial break to the system should resolve the problem and return the system to normal operation.

3. After a serial break:
   - All processors receive a hard reset.
   - The system serial communication settings return to the default values: 9600 baud, 8 data bits, no parity, 1 stop bit, and no hardware handshaking.
   - A distinctive 2-beep sequence sounds to indicate that the system is re-initialized.

### Example

*Command:*

N/A

*Reply:*

RESETBE6F<CR>

## APIREV

Returns the API revision number.

### Operating Mode

All modes

### Syntax

APIREV<SPACE><CR>

### Replies

*Upon Success:*
<Family>.<Major Revision Number>.<Minor Revision Number><CRC16><CR>

*On Error:*
ERROR<Error Code><CRC16><CR>

See page 91 for error code definitions.

| Reply Component | Description |
|---|---|
| Family | 1 ASCII character<br>For the Aurora System, this character is always D. (Other types of NDI measurement systems use other characters.) |
| Major Revision Number | 3 ASCII characters<br>The major revision number is incremented whenever there is an incompatible change in the API. (Whenever a command is deprecated or when its response is changed in a way that may break an application.) |
| Minor Revision Number | 3 ASCII characters<br>The minor revision number is incremented whenever there is an addition to the API that is compatible with all existing applications and usage. (Compatible changes are additions to the API command or option set that will not affect any existing applications.) |

### Example

*Command:*
APIREV

*Reply:*
D.001.00855D4

# BEEP

Sounds the system beeper.

## Operating Mode

All modes

## Syntax

`BEEP<SPACE><Number of Beeps><CR>`

| Parameter | Description |
|---|---|
| `Number of Beeps` | **Valid Values:**<br>1 to 9 |

## Replies

*Upon Success:*

`<Beep Status><CRC16><CR>`

*On Error:*

`ERROR<Error Code><CRC16><CR>`

See page 91 for error code definitions.

| Reply Component | Description | |
|---|---|---|
| `Beep Status` | **Possible Values:** | |
| | 0 | The system is busy beeping. |
| | 1 | Beeping has started. |

## Example

*Command:*

`BEEP 1`

*Reply:*

`1D4C1`

# BX

Returns the latest tool transformations and system status information in binary format.

## Operating Mode

Tracking

## Syntax

```
BX<SPACE><Reply Option><CR>
```

| Parameter | Description | |
|---|---|---|
| Reply Option | Optional. Specifies which information will be returned. If no reply option is specified, the system returns information for reply option 0001.<br><br>The reply options are hexadecimal numbers that can be OR'd. Reply option 0800 is not reported separately from reply option 0001.<br><br>**Valid Values:** | |
| | 0001 | Transformation data (default) |
| | 0800 | Out-of-volume transformations |

## Replies

*Upon Success:*

```
<Start Sequence><Reply Length><Header CRC><Number of Handles>
<Handle 1><Handle 1 Status><Reply Option 0001 Data>
...
<Handle n><Handle n Status><Reply Option 0001 Data>
<System Status><CRC16>
```

**Note** The reply for the BX command is binary data.

**Note** If a handle status is "disabled," the system will not return any of the <Reply Option 0001 Data> for that port handle.

*On Error:*

```
ERROR<Error Code><CRC16><CR>
```

See page 91 for error code definitions.

| Reply Component | Description |
|---|---|
| Start Sequence | 2 bytes: A5C4<br><br>Indicates the start of the BX reply. |

| Reply Component | Description | |
|---|---|---|
| `Reply Length` | 2 bytes<br><br>Indicates the number of bytes in the reply body between the <Header CRC> and the <CRC16>, exclusive. | |
| `Header CRC` | 16 bits<br><br>CRC of <Start Sequence> and <Reply Length> | |
| `Number of Handles` | 1 byte<br><br>The number of port handles for which transformations are returned. | |
| `Handle n` | 1 byte<br><br>The port handle whose transformation follows. | |
| `Handle Status` | 1 byte<br><br>**Possible Values:** | |
| | 01 | Valid |
| | 02 | Missing |
| | 04 | Disabled |
| `Reply Option m Data` | The data specific to the requested reply option. See the reply option information below for details: | |
| | Reply option 0001 (transformation data) (default) | |
| | Reply option 0800 (reporting all transformations) | |
| `System Status` | 2 bytes<br><br>**Bit field:** | |
| | bits 0 to 4 | Reserved |
| | bit 5 | Hardware change. This bit is set if the Field Generator is disconnected from the System Control Unit. |
| | bit 6 | Some port handle has become occupied |
| | bit 7 | Some port handle has become unoccupied |
| | bit 8 | Diagnostic pending. This bit is set whenever an alert is detected or cleared. To view the alerts status and clear the diagnostic pending bit, use GET (page 35) to check the Info.Status.New Alerts user parameter for every hardware device in the system. See "Usage Notes" on page 27 for more details. |
| | bit 9 | Reserved |
| | bit 10 | Configuration change. This bit is set when an SIU is added or removed. Currently this bit is only related to the SIU, but other components may be added in the future. This bit is cleared by the commands PHSR (page 50) and INIT (page 38). |
| | bits 11 to 15 | Reserved |

### Reply Option 0001 - Transformation Data

<Reply Option 0001 Data> = <$Q_0$><$Q_x$><$Q_y$><$Q_z$><$T_x$><$T_y$><$T_z$><Indicator Value>
<Port Handle Status><Frame Number>
or
<Reply Option 0001 Data> = <Port Handle Status><Frame Number>

| Reply Component | Description | | |
|---|---|---|---|
| Q0, Qx, Qy, Qz | 4 bytes each<br><br>Rotational components of the transformation, quaternion, unitless, reported as IEEE 32-bit, single precision, floating point numbers. | | |
| Tx, Ty, Tz | 4 bytes each<br><br>Translational components of the transformation, in mm, reported as IEEE 32-bit, single precision, floating point numbers. | | |
| Indicator Value | 4 bytes<br><br>An estimate of how well the Aurora System calculated the transformation. Value range is ≥ 0.<br>For 6DOF tools, the indicator value compares sensor measurements to the tool's design (as described by its SROM device or tool definition file).<br>For 5DOF tools, the indicator value is always zero.<br>Unitless, reported as IEEE 32-bit, single precision, floating point number | | |
| Port Handle Status | 4 bytes<br><br>**Bit field:** | | |
| | bit 0 | Occupied | Bits 0 to 3 are shared for dual, 5DOF tools. |
| | bit 1 | GPIO line 1 closed | |
| | bit 2 | GPIO line 2 closed | |
| | bit 3 | GPIO line 3 closed | |
| | bit 4 | Initialized | |
| | bit 5 | Enabled | |
| | bit 6 | Out of volume | |
| | bit 7 | Partially out of volume. This bit is set only for 6DOF tools, when one sensor is inside the measurement volume and the other sensor is outside the measurement volume. | |
| | bit 8 | A sensor is broken. This bit is set when a sensor lead wire breaks, either along the lead wire length or at its connection points. | |
| | bit 9 | Reserved | |
| | bit 10 | Shorted sensor detected | |
| | bit 11 | Signal too large. Occurs when sensor is too close to Field Generator | |
| | bit 12 | Processing exception | |
| | bits 13 to 31 | Reserved | |

| Reply Component | Description |
|---|---|
| `Frame Number` | 4 byte unsigned number<br><br>The frame number is an internal counter related to data acquisition. The counter starts at power up and does not reset until the system is reset, the system is powered up again, or reply option 80 is sent with the TSTART command. The frame rate is 40 Hz. The frame number corresponds to the frame in which the raw data, used to calculate the accompanying transformation, was collected. The frame number is incremented by 8. |

Note If the handle status is “missing,” the system returns only the port handle status and the frame number.

### Reply Option 0800 - Reporting All Transformations

This option enables the reporting of transformations when the tool is out of volume. This reply option must be OR’d with reply option 0001.

Warning! When using reply option 0800 with the BX command, you must take appropriate action to detect when a tool is out of volume, and determine whether this situation is detrimental to your application. If a tool is out of volume, reply option 0800 enables the system to return data that may lead to inaccurate conclusions and may cause personal injury.

### Usage Notes

1. The BX reply format requires fewer characters than the text format; this allows transformations to be reported more quickly. For replies in text format, use TX (page 83).
2. To use the BX command, the data bits parameter must be set to 0 (8 bits) using COMM (page 29).
3. Replies are returned in little endian format.
4. See the user guide for detailed descriptions of the port handle status and system status bits.
5. By default, transformations will not be reported if the tool is either partially or wholly out of the characterized measurement volume. To report these transformations, you must use reply option 0800 OR’d with reply option 0001. The accuracy of these transformations is unknown.
6. When the “diagnostic pending” bit is set in the system status, use GET (page 35) to read the **Info.Status.New Alerts** user parameter for every hardware device in the system. The act of reading these parameters clears the parameters and the “diagnostic pending” bit. For more information on alerts and their associated user parameters, see “Alerts User Parameters” on page 14.
7. Bit 8 in the <Port Handle Status> section of reply option 0001 may not always indicate when a lead wire is broken. Broken sensors that result in a short will not be detected.

### Example

*Command:*

```
BX 0801
```

*Reply:*

```
A5C4005723130201013F3AF3CABE5B7209BF1C07713E635592C39E831F43332973C500511
33DA5BD9F00000031000002CC02013EA1B5D03D137D21BD787C673F72394A4286B6CB4360
6EF4C50468C13ED4E74100000031000002CD000059C9
```

This is the hexadecimal representation of the binary data being returned. This example returns data for two tools.

# COMM

Sets the serial communication settings for the system.

## Operating Mode

All modes

## Syntax

```
COMM<SPACE><Baud Rate><Data Bits><Parity><Stop Bits><Hardware
Handshaking><CR>
```

| Parameter | Description | |
|---|---|---|
| `Baud Rate` | The data transmission rate between the Aurora System and the host computer, in bits per second.<br><br>**Valid Values:** | |
| | 0 | 9600 Bd (default) |
| | 1 | 14 400 Bd |
| | 2 | 19 200 Bd, see usage note 5. |
| | 3 | 38 400 Bd |
| | 4 | 57 600 Bd |
| | 5 | 115 200 Bd |
| | 6 | 921 600 Bd, see usage note 6. |
| | A | 230 400 Bd, see usage note 7. |
| `Data Bits` | The data bits parameter must be set to 8 bits in order to use the BX command.<br><br>**Valid Values:** | |
| | 0 | 8 bits (default) |
| | 1 | 7 bits |
| `Parity` | **Valid Values:** | |
| | 0 | None (default) |
| | 1 | Odd |
| | 2 | Even |
| `Stop Bits` | **Valid Values:** | |
| | 0 | 1 bit (default) |
| | 1 | 2 bits |
| `Hardware Handshaking` | **Valid Values:** | |
| | 0 | Off (default) |
| | 1 | On |

### Replies

*Upon Success:*
`OKAY<CRC16><CR>`

*On Error:*
`ERROR<Error Code><CRC16><CR>`

See page 91 for error code definitions.

### Usage Notes

1. The system serial communication parameters have a default setting of 00000 (i.e. 9600 baud, 8 data bits, no parity, 1 stop bit, hardware handshaking off).
2. To use the BX command you must set the data bits parameter to 0 (8 bits).
3. If you change the baud rate using the COMM command, you must also change your host computer baud rate; otherwise, a system reset or other unexpected communication behaviour will occur. The host application should wait approximately 100 ms after receiving the OKAY reply from the system before changing its own communication parameters.
4. NDI strongly recommends using hardware handshaking when using the higher baud rates.
5. 19200 baud does not work using the "NDI Aurora SCU" USB serial driver.
6. 921600 baud is only available via USB and with combined firmware revision 009 (API Revision D.001.006) or later. A USB port is available on Aurora V2 and V3 systems.
7. Baud rate parameter "A" is available with combined firmware revision 009 (API Revision D.001.006) or later.

### Example

*Command:*
```
COMM 30001
```

*Reply:*
```
OKAYA896
```

This changes the serial communication parameters to 38400 baud, 8 data bits, no parity, 1 stop bit, hardware handshaking on.

# DFLT

Restores the user parameters to factory default values.

## Operating Mode

All modes

## Syntax

```
DFLT<SPACE><User Parameter Name><CR>
```

| Parameter | Description |
|---|---|
| `User Parameter Name` | A string, identifying the name of the user parameter. May include a trailing wild card character (*)<br>Use **DFLT *** to restore all user parameters to default values.<br><br>User parameter names are case-sensitive. |

## Replies

*Upon Success:*
`OKAY<CRC16><CR>`

*On Error:*
`ERROR<Error Code><CRC16><CR>`

See page 91 for error code definitions.

## Usage Notes

1. The user parameter name may include a trailing wild card character (*).
2. The user parameter values set using the DFLT command persist until the system is reset or initialized. To save the user parameters at their factory default values, use SAVE (page 71) after using the DFLT command.
3. To view a list of user parameters and their current values, use **GET ***.
4. Parameters of type “string” and the alert parameters have no default values.
5. For more information on user parameters, see “User Parameters” on page 12.

## Example

*Command:*
`DFLT *`

*Reply:*
`OKAYA896`

## DSTART

This command is deprecated. Use TSTART (page 78) instead.

# DSTOP

This command is deprecated. Use TSTOP (page 80) instead.

## ECHO

Returns exactly what is sent with the command.

### Operating Mode

All modes

### Syntax

`ECHO<SPACE><Four or more ASCII characters><CR>`

### Replies

*Upon Success:*

Exactly what is sent with the command, with `<CRC16><CR>`.

*On Error:*

`ERROR<Error Code><CRC16><CR>`

See page 91 for error code definitions.

### Example

*Command:*

```
ECHO Testing!
```

*Reply:*

```
Testing!A81C
```

# GET

Returns the values of user parameters.

## Operating Mode

All modes

## Syntax

```
GET<SPACE><User Parameter Name><CR>
```

| Parameter | Description |
|---|---|
| `User Parameter Name` | A string, identifying the name of the user parameter. May include a trailing wild card character (*).<br>Use **GET *** to return all user parameter values.<br><br>User parameter names are case-sensitive. |

## Replies

*Upon Success:*

```
 <User Parameter Name>=<Value><LF>(repeated for each user parameter name)<CRC16><CR>
```

*On Error:*

```
ERROR<Error Code><CRC16><CR>
```

See page 91 for error code definitions.

## Example

*Command:*

```
GET Info.Timeout.PINIT
```

*Reply:*

```
Info.Timeout.PINIT=5A6C2
```

# GETINFO

Returns descriptive information about the user parameters.

## Operating Mode

All modes

## Syntax

`GETINFO<SPACE><User Parameter Name><CR>`

| Parameter | Description |
|---|---|
| `User Parameter Name` | A string, identifying the name of the user parameter. May include a trailing wild card character (*).<br>Use **GETINFO *** to return information for all user parameters.<br><br>User parameter names are case-sensitive. |

## Replies

*Upon Success:*

`<User Parameter Name>=<Value>;<Type>;<Attribute>;<Minimum>;<Maximum>;<Enumeration>;<Description><LF>(repeated for each user parameter, but no line feed after last parameter)<CRC16><CR>`

*On Error:*

`ERROR<Error Code><CRC16><CR>`

See page 91 for error code definitions.

| Reply Component | Description | |
|---|---|---|
| `User Parameter Name` | Variable size<br>Full name of the user parameter | |
| `Value` | Variable size<br>Value of the user parameter | |
| `Type` | 1 hexadecimal character<br>Describes the data type.<br><br>**Possible Values:** | |
| | 0 | Boolean |
| | 1 | Integer |
| | 2 | Float |
| | 3 | String |

| Reply Component | Description | |
|---|---|---|
| `Attribute` | 1 to 4 hexadecimal characters<br>Describes the access rules.<br><br>**Bit field:** | |
| | bit 0 | Read |
| | bit 1 | Write |
| | bit 2 | Save |
| | bit 3 | Volatile |
| | bits 4 to 15 | Reserved (may not all be set to 0) |
| `Minimum` | Minimum allowed value of the user parameter. For a string, the minimum number of characters allowed.<br>If minimum = maximum = 0, no range check is performed. | |
| `Maximum` | Maximum allowed value of the user parameter. For a string, the maximum number of characters allowed.<br>If minimum = maximum = 0, no range check is performed. | |
| `Enumeration` | Comma-separated enumeration list. This is a list of possible values that the user parameter can take, and corresponds to the values in the `<Value>` field (the first item in the list corresponds to value 0, the second item corresponds to value 1, etc.). | |
| `Description` | Describes the user parameter's function. | |

### Usage Notes

1. The user parameter name may include a trailing wild card character (*).
2. Use **GETINFO *** to return information for all user parameters.
3. Numeric user parameter values are returned as decimal strings.
4. User parameter names are case-sensitive.
5. For a list of user parameters and values without descriptive information, use the GET command.
6. For more information on user parameters, see "User Parameters" on page 12.

### Example

*Command:*

```
GETINFO Param.User.String
```

*Reply:*

```
Param.User.String=;3;7;0;64;;User defined string (up to 63 chars)8BFC
```

## INIT

Initializes the system.

### Operating Mode

All modes

### Syntax

`INIT<SPACE><CR>`

### Replies

*Upon Success:*
`OKAY<CRC16><CR>`

*On Error:*
`ERROR<Error Code><CRC16><CR>`

See page 91 for error code definitions.

### Usage Notes

1. During power up or system reset, the system configuration is determined. The configuration includes firmware revisions and the characterized measurement volume for which the Field Generator has been calibrated. The INIT command ensures that the system configuration was determined successfully.
2. The system will automatically return to Setup mode after using the INIT command.

### Example

*Command:*
`INIT`

*Reply:*
`OKAYA896`

# LED

Changes the state of visible LEDs on a tool.

### Operating Mode

All modes

### Prerequisite Command

PINIT (page 53)

### Syntax

`LED<SPACE><Port Handle><LED Number><State><CR>`

| Parameter | Description | |
|---|---|---|
| `Port Handle` | 2 hexadecimal characters<br><br>**Valid Values:**<br>0A to FF | |
| `LED Number` | Specifies the LED. The LED number does not correspond to the GPIO line number. For example, LED 1 corresponds to the first LED on the tool, which may not be on GPIO line 1.<br><br>**Valid Values:**<br>1 to 3 | |
| `State` | Sets the state of the specified LED.<br><br>**Valid Values:** | |
| | B | Blank (not on) |
| | F | Flash |
| | S | Solid on |

### Replies

*Upon Success:*
`OKAY<CRC16><CR>`

*On Error:*
`ERROR<Error Code><CRC16><CR>`

See page 91 for error code definitions.

### Usage Notes

The GPIO line must be defined as “visible LED” in the tool’s tool definition file for the LED command to function.

### Example

*Command:*

```
LED 0A1S
```

*Reply:*

```
0KAYA896
```

This turns on solid the first LED on the tool associated with port handle 0A.

# PDIS

Disables the reporting of transformations for a particular port handle.

### Operating Mode

Setup

### Prerequisite Command

PENA (page 42)

### Syntax

`PDIS<SPACE><Port Handle><CR>`

| Parameter | Description |
|---|---|
| `Port Handle` | 2 hexadecimal characters<br><br>**Valid Values:**<br>0A to FF |

### Replies

*Upon Success:*
`OKAY<CRC16><CR>`

*On Error:*
`ERROR<Error Code><CRC16><CR>`

See page 91 for error code definitions.

### Example

*Command:*
`PDIS 0A`

*Reply:*
`OKAYA896`

# PENA

Enables the reporting of transformations for a particular port handle.

### Operating Mode

Setup

### Prerequisite Command

PINIT (page 53)

### Syntax

`PENA<SPACE><Port Handle><Tool Tracking Priority><CR>`

| Parameter | Description | |
|---|---|---|
| `Port Handle` | 2 hexadecimal characters<br><br>**Valid Values:**<br>0A to FF | |
| `Tool Tracking Priority` | Describes the type of tool.<br><br>**Valid Values:** | |
| | S | Static: a static tool is considered to be relatively immobile, e.g. a reference tool. |
| | D | Dynamic: a dynamic tool is considered to be in motion, e.g. a probe. |
| | B | Button box: a button box can have switches and LEDs, but no sensors. No transformations are returned for a button box tool, but switch status is returned. |

### Replies

*Upon Success:*
`OKAY<CRC16><CR>`

*On Error:*
`ERROR<Error Code><CRC16><CR>`

See page 91 for error code definitions.

### Usage Notes

The tool tracking priority selected does not currently affect tracking behaviour.

### Example

*Command:*
`PENA 0AD`

*Reply:*
`OKAYA896`

# PHF

Releases system resources from an unused port handle.

## Operating Mode

Setup

## Prerequisite Command

PHSR (page 50)

## Syntax

```
PHF<SPACE><Port Handle><CR>
```

| Parameter | Description |
|---|---|
| `Port Handle` | 2 hexadecimal characters<br><br>**Valid Values:**<br>0A to FF |

## Replies

*Upon Success:*
`OKAY<CRC16><CR>`

*On Error:*
`ERROR<Error Code><CRC16><CR>`

See page 91 for error code definitions.

## Usage Notes

1. The PHF command should be used whenever a tool is disconnected. This optimizes the use of system resources. If PHF is not used, the system will be unable to assign a port handle after the maximum number of port handles has been reached.
2. If a tool is disconnected then reconnected, it is assigned a new port handle. The old port handle is no longer in use and should be freed using PHF.

## Example

*Command:*
```
PHF 0A
```

*Reply:*
```
OKAYA896
```

This frees port handle 0A, so it is no longer assigned to a tool.

# PHINF

Returns information about the tool associated with the port handle.

### Operating Mode

Setup

### Prerequisite Command

PHSR (page 50)

### Syntax

```
PHINF<SPACE><Port Handle><Reply Option><CR>
```

| Parameter | Description | |
|---|---|---|
| `Port Handle` | 2 hexadecimal characters<br><br>**Valid Values:**<br>0A to FF | |
| `Reply Option` | Optional. Specifies which information will be returned. If no reply option is specified, the system returns information for reply option 0001.<br><br>The reply options are hexadecimal numbers that can be OR'd. If multiple reply options are used, the replies are returned in order of increasing option value.<br><br>**Valid Values:** | |
| | 0001 | Tool information (default) |
| | 0004 | Tool part number |
| | 0008 | Switch and visible LED information |
| | 0020 | Physical port location |
| | 0040 | GPIO line definitions |
| | 0080 | Sensor configuration and physical port location |

### Replies

*Upon Success:*

**If the port handle has been initialized**:

```
<Reply Option 0001 Data><Reply Option 0004 Data>...<Reply Option 0080
Data><CRC16><CR>
```

**If the tool has been disconnected since the port handle was assigned**:

```
UNOCCUPIED<CRC16><CR>
```

*On Error:*

```
ERROR<Error Code><CRC16><CR>
```

See page 91 for error code definitions.

### Reply Option 0001 - Tool Information

```
<Reply Option 0001 Data> = <Tool Type><Manufacturer's ID><Tool
Revision><Serial Number><Port Handle Status>
```

| Reply Component | Description | | |
|---|---|---|---|
| Tool Type | 8 characters<br><br><Tool Type> = <Main Type><Number of Switches><Number of Visible LEDs><Reserved><Subtype> | | |
| | Main Type | 2 hexadecimal characters<br><br>**Possible Values:** | |
| | | 01 | Reference |
| | | 02 | Probe |
| | | 03 | Button box or foot switch |
| | | 04 | Software-defined |
| | | 05 and 06 | Reserved |
| | | 07 | Calibration device |
| | | 08 to 0A | Reserved |
| | | 0B | Catheter |
| | | 0C to FF | Reserved |
| | Number of Switches | 1 character | |
| | Number of Visible LEDs | 1 character | |
| | Reserved | 2 characters | |
| | Subtype | 2 characters | |
| Manufacturer's ID | 12 characters | | |
| Tool Revision | 3 characters | | |
| Serial Number | 8 hexadecimal characters (32 bits)<br><br>**Bit field:** | | |
| | bits 0 to 9 | Sequence number (one-based) | |
| | bits 10 to 18 | Day of year (zero-based, e.g. Jan 1 is day 0 and Dec 31 is day 364) | |
| | bits 19 to 22 | Month (zero-based) | |
| | bits 23 to 31 | Year (year is <current year> - 1900,e.g. the year 2005 is 105) | |

| Reply Component | Description | |
|---|---|---|
| `Port Handle Status` | 2 hexadecimal characters (8 bits)<br><br>**Bit field:** | |
| | bit 0 | Occupied |
| | bit 1 | GPIO line 1 closed |
| | bit 2 | GPIO line 2 closed |
| | bit 3 | GPIO line 3 closed |
| | bit 4 | Port handle initialized |
| | bit 5 | Port handle enabled |
| | bits 6 and 7 | Reserved |

Reply Option 0004 - Tool Part Number

| Reply Component | Description |
|---|---|
| `Reply Option 0004 Data` | 20 characters<br><br>The part number of the tool. |

Reply Option 0008 - Switch and Visible LED Information

| Reply Component | Description | |
|---|---|---|
| `Reply Option 0008 Data` | 2 hexadecimal characters (8 bits)<br><br>This option reports the information found in the tool definition file. It is not information sensed by the hardware.<br><br>**Bit field:** | |
| | bit 0 | Reserved |
| | bit 1 | Input supported on GPIO line 1 |
| | bit 2 | Input supported on GPIO line 2 |
| | bit 3 | Input supported on GPIO line 3 |
| | bit 4 | Tool tracking LED supported |
| | bit 5 | Visible LED supported on GPIO line 1 |
| | bit 6 | Visible LED supported on GPIO line 2 |
| | bit 7 | Visible LED supported on GPIO line 3 |

### Reply Option 0020 - Physical Port Location

```
<Reply Option 0020 Data> = <System Control Unit Serial Number><Reserved>
<Port Number><Channel Number>
```

| Reply Component | Description |
|---|---|
| System Control Unit Serial Number | 8 characters |
| Reserved | 2 characters |
| Port Number | 2 ASCII characters<br><br>**Possible Values:** depends on the configuration of SIUs. |
| Channel Number | 2 characters<br><br>For a dual, 5DOF tool.<br><br>**Possible Values:** 00 or 01 |

Note Reply option 0020 is deprecated. Use PHINF reply option 0080 instead.

### Reply Option 0040 - GPIO Line Definitions

```
<Reply Option 0040 Data> = <GPIO Line 1><GPIO Line 2><GPIO Line 3>
<Reserved>
```

| Reply Component | Description | |
|---|---|---|
| GPIO Line n | 1 hexadecimal character<br><br>Definition of the $n^{th}$ general purpose input/output line.<br><br>**Possible Values:** | |
| | 0 | Not available, or defined as a tool tracking LED |
| | 1 | Input |
| | 2 | Output |
| | 3 | Visible LED |
| | 4 | Always high |
| Reserved | 1 character | |

### Reply Option 0080 - Sensor configuration and physical port location

```
<Reply Option 0080 Data> = <DOF><Number of Sensors>
<Physical Port Information Sensor 1>
<Physical Port Information Sensor 2 (if present)>
```

| Reply Component | Description | |
|---|---|---|
| Degrees of Freedom (DOF) | 2 characters<br><br>**Possible Values:** | |
| | 05 | 5DOF Sensor(s) |
| | 06 | 6DOF Sensor |
| | 00 | No Sensors |
| Number of Sensors | 2 characters<br><br>**Possible Values:** 00 to 02 | |
| Physical Port Information | SCU Instance | 2 characters: 00 |
| | Port at SCU | 2 characters<br><br>**Possible values**: 00 to value of user parameter Features.Hardware.Max Ports (see page 17 for details). |
| | Tool Port at SIU | 2 characters<br><br>**Possible values**: 00 to value of user parameter Features.Hardware.Max Tool Ports (see page 17 for details). |
| | Channel | 2 hexadecimal digits<br><br>**Possible Values:** 00 or 01 |

### Usage Notes

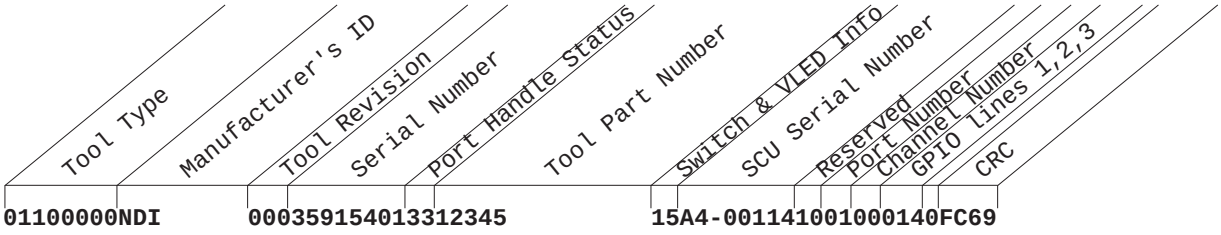
1. With the exception of reply option 0020, reply option 0080 (physical port information) and the port handle status, all of the information returned with this command is read from the tool's SROM device or from a tool definition file assigned to the port handle with PVWR (page 67).
2. If the port handle has not been initialized, the system will correctly report only the SCU serial number and port number (in reply option 0020), the port handle status (in reply option 0020) and the physical port information (in reply option 0080).
3. Reply option 0020 is deprecated. Use PHINF reply option 0080 instead.
4. Reply Option 0040: If a GPIO line is defined as a visible LED, it will also be reported in reply option 0008. The tracking LED will be reported as available and is also reported in reply option 0008.

Example

*Command:*

```
PHINF 0A006D
```

*Reply:*



# PHSR

Returns the number of assigned port handles and the port handle status for each one. Assigns a port handle to a tool.

### Operating Mode

Setup

### Prerequisite Command

INIT (page 38)

### Syntax

`PHSR<SPACE><Reply Option><CR>`

| Parameter | Description | |
|---|---|---|
| `Reply Option` | Specifies which information will be returned. If no reply option is specified, the system returns information for reply option 00.<br><br>The reply options cannot be OR'd.<br><br>**Valid Values:** | |
| | 00 | Reports all allocated port handles (default) |
| | 01 | Reports port handles that need to be freed |
| | 02 | Reports port handles that are occupied, but not initialized or enabled |
| | 03 | Reports port handles that are occupied and initialized, but not enabled |
| | 04 | Reports enabled port handles |

### Replies

*Upon Success:*

```
<Number of Port Handles>
<1st Port Handle><1st Port Handle Status>
<2nd Port Handle><2nd Port Handle Status>
...
<nth Port Handle><nth Port Handle Status>
<CRC16><CR>
```

*On Error:*

`ERROR<Error Code><CRC16><CR>`

See page 91 for error code definitions.

| Reply Component | Description | |
|---|---|---|
| `Number of Port Handles` | 2 hexadecimal characters<br><br>The number of allocated port handles of the type specified in the reply option. If no reply option is specified, the number returned is the total number of allocated port handles. | |
| `n^th Port Handle` | 2 hexadecimal characters<br><br>Specifies the port handle whose status follows. | |
| `n^th Port Handle Status` | 3 hexadecimal characters (12 bits)<br><br>**Bit field:** | |
| | bit 0 | Occupied |
| | bit 1 | GPIO line 1 closed |
| | bit 2 | GPIO line 2 closed |
| | bit 3 | GPIO line 3 closed |
| | bit 4 | Initialized |
| | bit 5 | Enabled |
| | bit 6 to 11 | Reserved |

### Usage Notes

1. When you send the PHSR command, the system will detect and assign port handles to any tools that do not already have a port handle assigned (i.e. any tools that were connected after the last PHSR call). It will then return the requested port handle information.
2. For a split port on a dual 5DOF tool, the first PHSR sent will report only one port handle. After the port handle is initialized, it is assigned to channel 0. You must then use PHSR again to assign a port handle to channel 1. The port handle for channel 1 is initialized automatically. See “Flow Chart for Port Handle Usage” on page 8.
3. If you disconnect a tool while the system is in Tracking mode, the port handle will be reported as “disabled” in the replies to the BX and TX commands. If you reconnect the tool, it will need a new port handle.
4. If you connect a tool to the system while the system is in Tracking mode (either reconnecting a tool that was just disconnected, or connecting a new tool), you will have to take the following steps before the system will report the tool:
   a) Exit Tracking mode (TSTOP).
   b) Assign, initialize, and enable a port handle for the tool, as outlined in Figure 2-1 on page 8.
   c) Re-enter Tracking mode (TSTART).

### Example 1

*Command:*
```
PHSR
```

*Reply:*
```
001414
```

In this case, there are no tools connected to the system.

### Example 2

*Command:*
```
PHSR
```

*Reply:*
```
010A001C1B5
```

In this case, one tool is connected to the system and it has been assigned port handle 0A. This port handle is not initialized or enabled.

### Example 3

*Command:*
```
PHSR 03
```

*Reply:*
```
040A01F0B01F0C01F0D01F2DDB
```

In this case, four tools are connected to the system and have been assigned port handles 0A, 0B, 0C, and 0D. All four port handles are initialized but not enabled.

# PINIT

Initializes a port handle.

## Operating Mode

Setup

## Prerequisite Command

PHSR (page 50)

## Syntax

```
PINIT<SPACE><Port Handle><CR>
```

| Parameter | Description |
|---|---|
| `Port Handle` | 2 hexadecimal characters<br><br>**Valid Values:**<br>0A to FF |

## Replies

*Upon Success:*
`OKAY<CRC16><CR>`

*On Error:*
`ERROR<Error Code><CRC16><CR>`

See page 91 for error code definitions.

## Usage Notes

1. Use PINIT to initialize a port handle for a tool after you have assigned a port handle using PHSR. If you are using PVWR to override the SROM device in a tool, use PINIT after PVWR.
2. For a split port on a dual 5DOF tool, the first PHSR sent will report only one port handle. After the port handle is initialized using PINIT, it is assigned to channel 0. You must then use PHSR again to assign a port handle to channel 1. The port handle for channel 1 is initialized automatically. See "Flow Chart for Port Handle Usage" on page 8.
3. If the tool description is read from a tool definition file that has been loaded using PVWR (page 67), initialization involves unpacking and verifying the tool definition file. This process is almost instantaneous.
4. If the tool description is read from an SROM device, initialization involves reading, unpacking, and verifying the tool definition file contents. This process takes approximately two seconds if successful, or several seconds longer if a problem is encountered and retries are attempted by the system.

5. When the PINIT command is issued, all previous settings for that port handle (e.g. set using TTCFG or PVWR) are reset, and related port handles (e.g. for a dual 5DOF configuration) are invalidated.

### Example

*Command:*

```
PINIT 0A
```

*Reply:*

```
OKAYA896
```

This initializes port handle 0A.

# PPRD

Reads data from the SROM device of a tool.

### Operating Mode

Setup

### Prerequisite Command

PSEL (page 59)

### Syntax

`PPRD<SPACE><Port Handle><SROM Device Address><CR>`

| Parameter | Description |
|---|---|
| `Port Handle` | 2 hexadecimal characters<br><br>**Valid Values:**<br>0A to FF |
| `SROM Device Address` | 4 hexadecimal characters<br><br>**Valid Values:**<br>0000 to 07C0 |

### Replies

*Upon Success:*
`<SROM Device Data><CRC16><CR>`

(The SROM device data is 64 bytes (128 hexadecimal characters) of data.)

*On Error:*
`ERROR<Error Code><CRC16><CR>`

See page 91 for error code definitions.

### Usage Notes

1. The SROM device is a 2-KB write-once device that must be read in 64-byte chunks. An SROM device is considered blank if its contents are all 0xFFs.
2. PPRD reads 64 bytes of data from the SROM device starting at a specified SROM device address.
3. You must select the SROM device as the reading target with PSEL (page 59) before sending the PPRD command.

### Example

*Command:*

```
PPRD 0A0000
```

*Reply:*

```
0100410100000002000000000053CDD33020000000200000000000000000000000000000000
00000000000000000000000000000000008000000780B6D3D9E0F73BE7DE9
```

# PPWR

Writes data to the SROM device in a tool.

### Operating Mode

Setup

### Prerequisite Command

PSEL (page 59)

### Syntax

```
PPWR<SPACE><Port Handle><SROM Device Address><SROM Device Data><CR>
```

| Parameter | Description |
|---|---|
| `Port Handle` | 2 hexadecimal characters<br><br>**Valid Values:**<br>0A to FF |
| `SROM Device Address` | 4 hexadecimal characters<br><br>**Valid Values:**<br>0000 to 07C0 |
| `SROM Device Data` | 64 bytes (128 hexadecimal characters) of data |

### Replies

*Upon Success:*
`OKAY<CRC16><CR>`

*On Error:*
`ERROR<Error Code><CRC16><CR>`

See page 91 for error code definitions.

### Usage Notes

1. PPWR writes 64 bytes of data to the SROM device starting at a specified SROM device address.
2. You must select the SROM device as the writing target with PSEL (page 59) before sending the PPWR command.
3. The data must be formatted into unsigned ASCII characters. Each byte of binary data can be represented by two hexadecimal characters, which are then sent to the system in ASCII (4 bits per ASCII character).
4. The tool description section of a tool SROM device is a 1 KB, write-once area that must be written in 64-byte chunks. If the information being written to the system is less than 64 bytes,

then the remainder of the chunk must be padded out with 1s to maintain the 64-byte size before being written to the SROM device.

5. An SROM device is considered blank if its contents are all 0xFFs.

### Example

*Command:*

```
PPWR 0A00C0000000000000000000000000000000000000000000000000C8410000C8
4100000000000000000000000000000000000000000000000000000002C44
```

*Reply:*

```
OKAYA896
```

# PSEL

Selects an SROM device target for a tool.

### Operating Mode

Setup

### Prerequisite Command

PHSR (page 50)

### Syntax

```
PSEL<SPACE><Port Handle><Tool SROM Device ID><CR>
```

| Parameter | Description |
|---|---|
| `Port Handle` | 2 hexadecimal characters<br><br>**Valid Values:**<br>0A to FF |
| `Tool SROM Device ID` | 16 hexadecimal characters<br><br>Use PSRCH (page 62) to determine the IDs of the tool's SROM device(s). |

### Replies

*Upon Success:*
`OKAY<CRC16><CR>`

*On Error:*
`ERROR<Error Code><CRC16><CR>`

See page 91 for error code definitions.

### Example

*Command:*
```
PSEL 0A0B3876530000005B
```

*Reply:*
```
OKAYA896
```

This selects the SROM device with ID 0B3876530000005B for port handle 0A.

# PSOUT

Sets the states of the general purpose input/output (GPIO) lines in a tool.

## Operating Mode

All modes

## Prerequisite Command

PINIT (page 53)

## Syntax

```
PSOUT<SPACE><Port Handle><GPIO Line 1 State><GPIO Line 2 State>
<GPIO Line 3 State><CR>
```

| Parameter | Description | |
|---|---|---|
| `Port Handle` | 2 hexadecimal characters<br><br>**Valid Values:**<br>0A to FF | |
| `GPIO Line n State` | State of the nth GPIO line<br><br>**Valid Values:** | |
| | N | No change |
| | S | Solid on |
| | P | Pulse |
| | O | Off |

## Replies

*Upon Success:*

```
OKAY<CRC16><CR>
```

*On Error:*

```
ERROR<Error Code><CRC16><CR>
```

See page 91 for error code definitions.

## Usage Notes

You can check the status of an output using PHINF (page 44).

### Example

*Command:*

```
PSOUT 0ANSN
```

*Reply:*

```
0KAYA896
```

This sets the three GPIO lines associated with port handle 0A to no change, solid on, and no change.

# PSRCH

Returns a list of valid SROM device ID(s) for a tool.

### Operating Mode

Setup

### Prerequisite Command

PHSR (page 50)

### Syntax

```
PSRCH<SPACE><Port Handle><CR>
```

| Parameter | Description |
|---|---|
| `Port Handle` | 2 hexadecimal characters<br><br>**Valid Values:**<br>0A to FF |

### Replies

*Upon Success:*

```
<Number of SROM Devices><SROM Device 1 ID><SROM Device 2 ID>...<SROM
Device 7 ID><CRC16><CR>
```

*On Error:*

```
ERROR<Error Code><CRC16><CR>
```

See page 91 for error code definitions.

| Reply Component | Description |
|---|---|
| `Number of SROM Devices` | 1 character |
| `SROM Device n ID` | 16 characters |

### Usage Notes

The tool SROM device has an embedded ID, which is a unique, 16-character, alphanumeric identifier. The SROM device ID is used to select an SROM device as a target with PSEL (page 59).

### Example

*Command:*

```
PSRCH 0A
```

*Reply:*

```
10B3876530000005B7FFF
```

In this case, there is one SROM device, with ID 0B3876530000005B.

# PURD

Reads data from the user section of the SROM device in a tool.

## Operating Mode

Setup

## Prerequisite Command

PHSR (page 50)

## Syntax

```
PURD<SPACE><Port Handle><User SROM Device Address><CR>
```

| Parameter | Description |
|---|---|
| `Port Handle` | 2 hexadecimal characters<br><br>**Valid Values:**<br>0A to FF |
| `User SROM Device Address` | 4 hexadecimal characters<br><br>**Valid Values:**<br>0000 to 03C0 |

## Replies

*Upon Success:*

```
<SROM Device Data><CRC16><CR>
```

(The SROM device data is 64 bytes (128 hexadecimal characters) of data.)

*On Error:*

```
ERROR<Error Code><CRC16><CR>
```

See page 91 for error code definitions.

## Usage Notes

1. The SROM device is automatically selected as the reading target when this command is issued, so you do not need to find and specify the SROM device ID. The SROM device address has an implied offset in the command which reads the user information from the correct SROM device address.
2. The PURD command returns 64 bytes of data at a time.

### Example

*Command:*

```
PURD 0A0000
```

*Reply:*

```
0022446688AACCEE0022446688AACCEE0022446688AACCEE0022446688AACCEE002244668
8AACCEE0022446688AACCEE0022446688AACCEE0022446688AACCEE3CC0
```

# PUWR

Writes data to the user section of the SROM device in a tool.

### Operating Mode

Setup

### Prerequisite Command

PHSR (page 50)

### Syntax

```
PUWR<SPACE><Port Handle><User SROM Device Address><User SROM Device
Data><CR>
```

| Parameter | Description |
|---|---|
| `Port Handle` | 2 hexadecimal characters<br><br>**Valid Values:**<br>0A to FF |
| `User SROM Device Address` | 4 hexadecimal characters<br><br>**Valid Values:**<br>0000 to 03C0 |
| `User SROM Device Data` | 64 bytes of data to write (128 hexadecimal characters) |

### Replies

*Upon Success:*
`OKAY<CRC16><CR>`

*On Error:*
`ERROR<Error Code><CRC16><CR>`

See page 91 for error code definitions.

### Usage Notes

1. The SROM device is automatically selected as the writing target when this command is issued, so you do not need to find and specify the SROM device ID. The SROM device address has an implied offset in the command which places the user information at the correct SROM device address.
2. The data must be formatted into unsigned ASCII characters. Each byte of binary data can be represented by two hexadecimal characters, which are then sent to the system in ASCII (4 bits per ASCII character).
3. The user section of a tool SROM device is a 1-KB, write-once area that must be written in 64-byte chunks. If the information being written to the system is less than 64 bytes, then the

remainder of the chunk must be padded out with 1s to maintain the 64-byte size before being written to the system.

4. Unused portions of the SROM device can be written to by setting the SROM device address appropriately. To determine which portions of the SROM device are unused, read the contents of the SROM device using PURD (page 63).

### Example

*Command:*

```
PUWR 0A00800000000000000000000000000000000000000000000000000000000000000000
0000000000000000000000000000000000000000000000000000000000000A927
```

*Reply:*

```
OKAYA896
```

# PVWR

Allows you to upload a tool definition file for a tool. The Aurora System will use the data in the uploaded tool definition file instead of the data in the tool's SROM device.

### Operating Mode

Setup

### Prerequisite Command

PHSR (page 50)

### Syntax

```
PVWR<SPACE><Port Handle><Start Address><Tool Definition Data><CR>
```

| Parameter | Description |
|---|---|
| `Port Handle` | 2 hexadecimal characters<br><br>**Valid Values:**<br>0A to FF |
| `Start Address` | 4 hexadecimal characters<br><br>Increment the start address by 64 bytes with each chunk of data sent for a particular port handle.<br><br>**Valid Values:**<br>0000 to 03C0 |
| `Tool Definition Data` | 128 hexadecimal characters |

### Replies

*Upon Success:*
`OKAY<CRC16><CR>`

*On Error:*
`ERROR<Error Code><CRC16><CR>`

See page 91 for error code definitions.

### Usage Notes

1. Use PVWR in the following cases:
   - To assign a tool definition file to a tool, to override the SROM device in the tool.
   - To assign a tool definition file to a tool, to test the tool definition file before permanently recording the tool definition file onto the SROM device.

2. The data must be formatted into unsigned ASCII characters. Each byte of binary data can be represented by two hexadecimal characters, which are then sent to the system in ASCII (4 bits per ASCII character).
3. Data is sent to the system in 64-byte chunks (128 hexadecimal characters). The last chunk must be padded out with zeroes to maintain the 64-byte size before being written to the system.
4. After using PVWR, initialize (PINIT) and enable (PENA) the port handle in order to track the tool.
5. If the tool needs to be re-initialized with the tool definition file, the PVWR sequence must be run again before PINIT is used.
6. To permanently write a tool definition file to an SROM device, use PPWR (page 57).

### Example

*Command:*

```
PVWR 0B00004E444900551C000001000000000000010100000001A419335A000000030000
000300000000000040000000000000000000000000000000000000000000000000000000
```

*Reply:*

```
OKAYA896
```

# RESET

Resets the system.

## Operating Mode

All modes

## Syntax

RESET<SPACE><Reset Option><CR>

| Parameter | Description | |
|---|---|---|
| Reset Option | Optional. Specifies the type of reset. If no reset option is specified, the system performs a RESET 1.<br><br>**Valid Values:** | |
| | 0 | Generates a “soft” reset and resets the baud rate to 9600. System will not beep |
| | 1 | Same behaviour as resetting the system with a serial break. See page 20 |

## Replies

*Upon Success:*
RESET 0
OKAY<CRC16><CR>

RESET 1
RESET<CRC16><CR>

*On Error:*
ERROR<Error Code><CRC16><CR>

See page 91 for error code definitions.

## Usage Notes

1. RESET can only be used when the host computer and the Aurora System are at the same baud rate. To reset the system when the baud rates do not match or when the system is in an unknown state use a serial break, see page 20.
2. Reset option 1 (hard reset) is only valid with the Aurora V2 and V3 systems. It is not supported on older Aurora Systems.
3. If the command is successful, the reply will be sent at the default communications setting; 9600 baud, 8 data bits, no parity, 1 stop bit, hardware handshaking off.
4. Errors will be sent with the previous baud rate settings.
5. Successful commands will wait for 100ms before executing the reset. This gives enough time to wait for an error message and to switch to 9600baud to receive the reply.

### Example

*Command:*

```
RESET 1
```

*Reply:*

```
RESETBE6F
```

# SAVE

Saves all non-volatile user parameters that have been changed (on all connected devices).

## Operating Mode

All modes

## Syntax

SAVE<SPACE><CR>

## Replies

*Upon Success:*
OKAY<CRC16><CR>

*On Error:*
ERROR<Error Code><CRC16><CR>

See page 91 for error code definitions.

## Usage Notes

1. To restore the user parameters to factory default values, use the DFLT (page 31) command. To save the user parameters at their factory default values, use the SAVE command after using the DFLT command.
2. To set user parameter values, use the SET (page 72) command.
3. For more information on user parameters, see “User Parameters” on page 12.

## Example

*Command:*
SAVE

*Reply:*
OKAYA896

# SET

Sets user parameter values.

### Operating Mode

All modes

### Syntax

```
SET<SPACE><User Parameter Name>=<Value><CR>
```

| Parameter | Description |
|---|---|
| `User Parameter Name` | A case-sensitive string, identifying the name of the user parameter. |
| `Value` | The value to set.<br>Numerical values are decimal. For boolean values, 1 is true and 0 is false. |

### Replies

*Upon Success:*

```
OKAY<CRC16><CR>
```

*On Error:*

```
ERROR<Error Code><CRC16><CR>
```

See page 91 for error code definitions.

### Usage Notes

1. To view a list of user parameters and their current values, use **GET ***. For a description of the user parameters, use **GETINFO ***.
2. The user parameter values set using the SET command persist until the system is reset or initialized. To save the user parameter values, use SAVE (page 71). To reset user parameters to their default values, use DFLT (page 31).
3. User parameter names are case-sensitive.
4. For more information on user parameters, see “User Parameters” on page 12

### Example

*Command:*

```
SET SCU-0.Param.System Beeper=0
```

*Reply:*

```
OKAYA896
```

This turns off the system beeper on system reset. Note that this example must be followed by the command SAVE in order to take effect.

# SFLIST

Returns information about the supported features of the system.

### Operating Mode

Setup

### Syntax

`SFLIST<SPACE><Reply Option><CR>`

| Parameter | Description | |
|---|---|---|
| `Reply Option` | Specifies which information will be returned.<br><br>The reply options cannot be OR'd.<br><br>**Valid Values:** | |
| | 00 | Summary of supported features |
| | 03 | Number of volumes and volume shapes |
| | 10 | Number of ports |

### Replies

*Upon Success:*
`<Reply Option n Data>`

*On Error:*
`ERROR<Error Code><CRC16><CR>`

See page 91 for error code definitions.

| Reply Component | Description |
|---|---|
| `Reply Option n Data` | The data specific to the requested reply option. See the reply option information below for details:<br><br>Reply Option 00 (Supported Features Summary)<br>Reply Option 03 (Measurement Volumes)<br>Reply Option 10 (Number of ports) |

### Reply Option 00 - Supported Features Summary

| Reply Component | Description | |
|---|---|---|
| `Reply Option 00 Data` | 8 hexadecimal characters (32 bits)<br><br>**Bit field:** | |
| | bits 0 and 1 | Reserved |
| | bit 2 | Multiple volume characterization parameters supported |
| | bits 3 to 15 | Reserved |
| | bit 16 | Magnetic ports available |
| | bits 17 and 18 | Reserved |
| | bit 19 | Field Generator available |
| | bits 20 to 31 | Reserved |

### Reply Option 03 - Measurement Volumes

`<Reply Option 03 Data> =`

`<Number of Volumes><1st Shape Type><1st Shape Parameters><Reserved><Metal Resistant><LF>`

`...`

`<nth Shape Type><nth Shape Parameters><Reserved><Metal Resistant><LF><CRC16><CR>`

| Reply Component | Description | |
|---|---|---|
| `Number of Volumes` | 1 hexadecimal character | |
| `nth Shape Type` | 1 hexadecimal character<br><br>**Possible Values:** | |
| | 9 | Cube volume |
| | A | Dome volume |
| `nth Shape Parameters` | 10 parameters, 7 characters each (a sign, and six digits with an implied decimal in the position XXXX.XX)<br><br>See the shape parameters below. | |
| `Reserved` | 1 hexadecimal character | |
| `Metal Resistant` | 1 hexadecimal character<br><br>**Possible Values:** | |
| | 0 | no information |
| | 1 | metal resistant |
| | 2 | not metal resistant |
| | 3 to F | reserved |

### Shape Parameters

<n$^{th}$ Shape Parameters> in reply option 03 returns the following values (illustrated in Figure 5-1 and Figure 5-2)

Cube Volume:

| Shape Parameter | Description | Value |
|---|---|---|
| D1 | Minimum *x* value | -250 mm |
| D2 | Maximum *x* value | +250 mm |
| D3 | Minimum *y* value | -250 mm |
| D4 | Maximum *y* value | +250 mm |
| D5 | Minimum *z* value | -550 mm |
| D6 | Maximum *z* value | -50 mm |
| D7 to D10 | Reserved | |

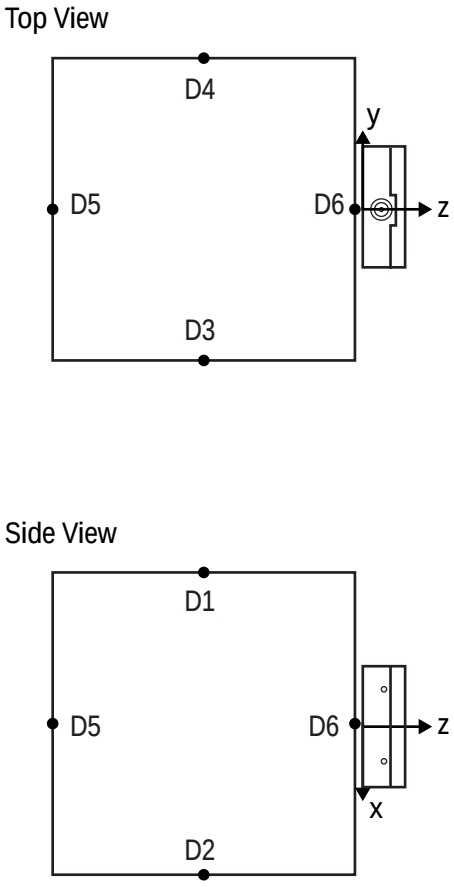



Figure 5-1 Cube Volume Parameters

Dome Volume:

There are currently two Field Generators that support the dome volume, the Planar Field Generator (PFG) and the Tabletop Field Generator (TTFG). The following table details values for both FGs.

| Shape Parameter | Description | Value PFG (mm) | Value TTFG (mm) |
|---|---|---|---|
| D1 | Offset from Field Generator | +50 | +120 |
| D2 | Cylinder radius along x-axis | +480 | +210 |
| D3 | Minimum dome radius | +50 | +120 |
| D4 | Maximum dome radius | +660 | +600 |
| D5 | Cylinder radius along y-axis<br>**Note: If D5 is equal to 0, the y-axis radius is equal to the x-axis radius (circular cylinder)** | 0(+480) | +300 |
| D6 | Maximum offset from Field Generator<br>**Note: If D6 is equal to 0, the maximum offset is equal to D4 (the maximum dome radius)** | 0(+660) | +600 |
| D7 to D10 | Reserved | — | — |

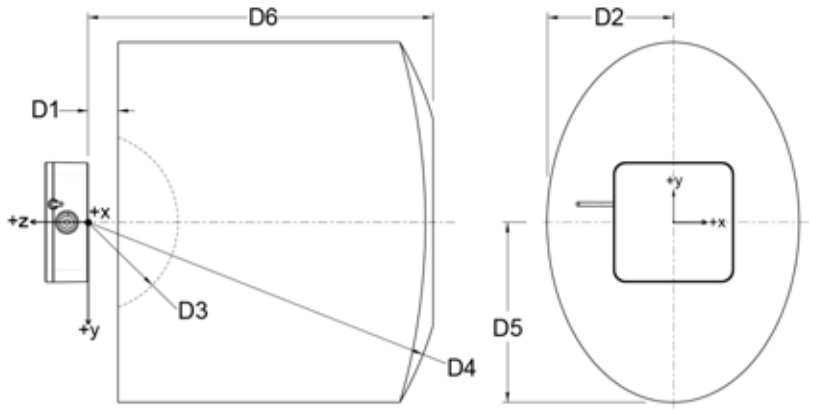



Figure 5-2 Dome Volume Parameters

### Reply Option 10 - Number of Ports Available

| Reply Component | Description |
|---|---|
| `Reply Option 10 Data` | 2 hexadecimal characters<br>This option is deprecated. Use the GET command and the user parameter Features.Hardware.Max Tool Ports instead. |

### Usage Notes

**Reply Option 03** Use both the shape type and the shape parameters to graphically represent the characterized measurement volume. There may be multiple volumes with the same shape type. All volumes of the same shape type use the shape parameters the same way.

### Example

*Command:*

```
SFLIST 03
```

*Reply:*

```
29-025000+025000-025000+025000-055000-005000+000000+000000+000000
+00000011
A+005000+048000+005000+066000+000000+000000+000000+000000+000000+00000011
D3BB
```

# TSTART

Starts Tracking mode.

### Operating Mode

Setup

### Prerequisite Command

INIT (page 38)

### Syntax

`TSTART<SPACE><Reply Option><CR>`

| Parameter | Description |
|---|---|
| `Reply Option` | 00 (Optional, default)<br><br>40 (Optional, starts tracking in faster acquisition mode)<br><br>80 (Optional, resets the frame counter to zero)<br><br>The reply options are hexadecimal numbers that can be OR'd (C0). |

### Replies

*Upon Success:*
`OKAY<CRC16><CR>`

*On Error:*
`ERROR<Error Code><CRC16><CR>`

See page 91 for error code definitions.

### Usage Notes

If reply option 80 is not used, only resetting the system resets the counter for the frame number. The frame number is reported in reply option 0001 of the TX (page 83) and BX (page 24) commands.

Using reply option 40 will result in the following:

- A data acquisition rate of 66 Hz. (It may be lower when serial interface limits the speed.)
- A shorter frame length of 15 ms.
- Precision uncertainty increases by a factor of 2.

Example

*Command:*
TSTART

*Reply:*
0KAYA896

## TSTOP

Stops Tracking mode.

### Operating Mode

Tracking

### Prerequisite Command

TSTART (page 78)

### Syntax

`TSTOP<SPACE><CR>`

### Replies

*Upon Success:*
`OKAY<CRC16><CR>`

*On Error:*
`ERROR<Error Code><CRC16><CR>`
See page 91 for error code definitions.

### Example

*Command:*
`TSTOP`

*Reply:*
`OKAYA896`

# TTCFG

Sets up a configuration for a tool, so that you can test the tool without using a tool definition file.

### Operating Mode

Setup

### Prerequisite Command

PHSR (page 50)

### Syntax

`TTCFG<SPACE><Port Handle><CR>`

| Parameter | Description |
|---|---|
| `Port Handle` | 2 hexadecimal characters<br><br>**Valid Values:**<br>0A to FF |

### Replies

*Upon Success:*
`OKAY<CRC16><CR>`

*On Error:*
`ERROR<Error Code><CRC16><CR>`

See page 91 for error code definitions.

### Usage Notes

1. TTCFG internally sets up a test configuration for a tool, so that it can be tested without having a tool definition file. This is useful for testing the wiring in the tool before characterizing the tool.
2. After sending the TTCFG command, you will need to initialize (PINIT) and enable (PENA) the port handle before using any other commands that list these as prerequisites.
3. TTCFG configures the tool as dual, 5DOF. After initializing the port handle, a second port handle will be automatically generated. This second port handle will be already initialized but not enabled.
4. If the tool needs to be re-initialized with the test configuration, the TTCFG sequence must be run again before PINIT is used.

### Example

*Command:*
`TTCFG 0A`

*Reply:*
`OKAYA896`

# TX

Returns the latest tool transformations and system status information in text format.

## Operating Mode

Tracking

## Syntax

```
TX<SPACE><Reply Option><CR>
```

| Parameter | Description | |
|---|---|---|
| `Reply Option` | Optional. Specifies which information will be returned. If no reply option is specified, the system returns information for reply option 0001.<br><br>The reply options are hexadecimal numbers that can be OR'd. Reply option 0800 is not reported separately from reply option 0001.<br><br>**Valid Values:** | |
| | 0001 | Transformation data (default) |
| | 0800 | Out-of-volume transformations |

## Replies

*Upon Success:*

```
<Number of Handles><Handle 1><Reply Option 0001 Data><LF>
...
<Handle n><Reply Option 0001 Data><LF>
<System Status><CRC16><CR>
```

Note If the port handle is disabled, the system returns the string DISABLED instead of <Reply Option 0001 Data>.

*On Error:*

```
ERROR<Error Code><CRC16><CR>
```

See page 91 for error code definitions.

| Reply Component | Description |
|---|---|
| `Number of Handles` | 2 hexadecimal characters<br><br>The number of port handles for which transformations are returned. |
| `Handle n` | 2 hexadecimal characters<br><br>The port handle whose transformation follows. |

| Reply Component | Description | |
|---|---|---|
| `Reply Option m Data` | The data specific to the requested reply option. See the reply option information below for details: | |
| | Reply option 0001 (transformation data) (default) | |
| | Reply option 0800 (reporting all transformations) | |
| `System Status` | 4 hexadecimal characters (16 bits)<br><br>The status of the system.<br><br>**Bit field:** | |
| | bits 0 to 4 | Reserved |
| | bit 5 | Hardware change. This bit is set if the Field Generator is disconnected from the System Control Unit. |
| | bit 6 | Some port handle has become occupied |
| | bit 7 | Some port handle has become unoccupied |
| | bit 8 | Diagnostic pending. This bit is set whenever an alert is detected or cleared. To view the alerts status and clear the diagnostic pending bit, use GET (page 35) to check the Info.Status.New Alerts user parameter for every hardware device in the system. See "Usage Notes" on page 86 for more details. |
| | bit 9 | Reserved |
| | bit 10 | Configuration change. This bit is set when an SIU is added or removed. Currently this bit is only related to the SIU, but other components may be added in the future. This bit is cleared by the commands PHSR (page 50) and INIT (page 38). |
| | bits 11 to 15 | Reserved |

### Reply Option 0001 - Transformation Data

```
<Reply Option 0001 Data> = <Q0><Qx><Qy><Qz><Tx><Ty><Tz><Indicator Value>
<Port Handle Status><Frame Number>
or
<Reply Option 0001 Data> = MISSING<Port Handle Status><Frame Number>
```

| Reply Component | Description |
|---|---|
| `Q0, Qx, Qy, Qz` | 6 characters each<br>(a sign, and 5 decimal digits with an implied decimal in the position X . XXXX)<br><br>Rotational component of the transformation, quaternion, unitless. |
| `Tx, Ty, Tz` | 7 characters each<br>(a sign, and 6 decimal digits with an implied decimal in the position XXXX . XX)<br><br>Translational components of the transformation, in mm. |

<table>
<tr><th>Reply Component</th><th>Description</th></tr>
<tr><td>Indicator Value</td><td>6 characters<br>(a sign, and 5 decimal digits with an implied decimal in the position X . XXXX)<br><br>An estimate of how well the Aurora System calculated the transformation. Values range from 0 to 9.9. A higher value indicates a higher error.<br>For 6DOF tools, the indicator value compares sensor measurements to the tool’s design (as described by its SROM device or tool definition file).<br>For 5DOF tools, the indicator value is always zero.</td></tr>
<tr><td>Port Handle Status</td><td>8 hexadecimal characters (32 bits)<br><br>Bit field:
<table>
<tr><td>bit 0</td><td>Occupied</td><td rowspan="4">Bits 0 to 3 are shared for dual, 5DOF tools.</td></tr>
<tr><td>bit 1</td><td>GPIO line 1 closed</td></tr>
<tr><td>bit 2</td><td>GPIO line 2 closed</td></tr>
<tr><td>bit 3</td><td>GPIO line 3 closed</td></tr>
<tr><td>bit 4</td><td colspan="2">Initialized</td></tr>
<tr><td>bit 5</td><td colspan="2">Enabled</td></tr>
<tr><td>bit 6</td><td colspan="2">Out of volume</td></tr>
<tr><td>bit 7</td><td colspan="2">Partially out of volume. This bit is set only for 6DOF tools, when one sensor is inside the measurement volume and the other sensor is outside the measurement volume.</td></tr>
<tr><td>bit 8</td><td colspan="2">A sensor is broken.<br>This bit is set when a sensor lead wire breaks, either along the lead wire length or at its connection points.</td></tr>
<tr><td>bit 9</td><td colspan="2">Reserved</td></tr>
<tr><td>bit 10</td><td colspan="2">Shorted sensor detected</td></tr>
<tr><td>bit 11</td><td colspan="2">Signal too large. Occurs when sensor is too close to Field Generator.</td></tr>
<tr><td>bit 12</td><td colspan="2">Processing exception</td></tr>
<tr><td>bits 13 to 31</td><td colspan="2">Reserved</td></tr>
</table></td></tr>
<tr><td>Frame Number</td><td>8 hexadecimal characters<br><br>The frame number is an internal counter related to data acquisition. The counter starts at power up and does not reset until the system is reset, the system is powered up again, or reply option 80 is sent with the TSTART command. The frame number corresponds to the frame in which the raw data, used to calculate the accompanying transformation, was collected. The frame number is incremented by 8.</td></tr>
</table>

Note — If a transformation cannot be determined, the system returns the string MISSING, followed by the port handle status and frame number.

### Reply Option 0800 - Reporting All Transformations

This option enables the reporting of transformations or translations when the tool is out of volume. This reply option must be OR’d with reply option 0001.

**Warning!** When using reply option 0800 with the TX command, you must take appropriate action to detect when a tool is out of volume, and determine whether this situation is detrimental to your application. If a tool is out of volume, reply option 0800 enables the system to return data that may lead to inaccurate conclusions and may cause personal injury.

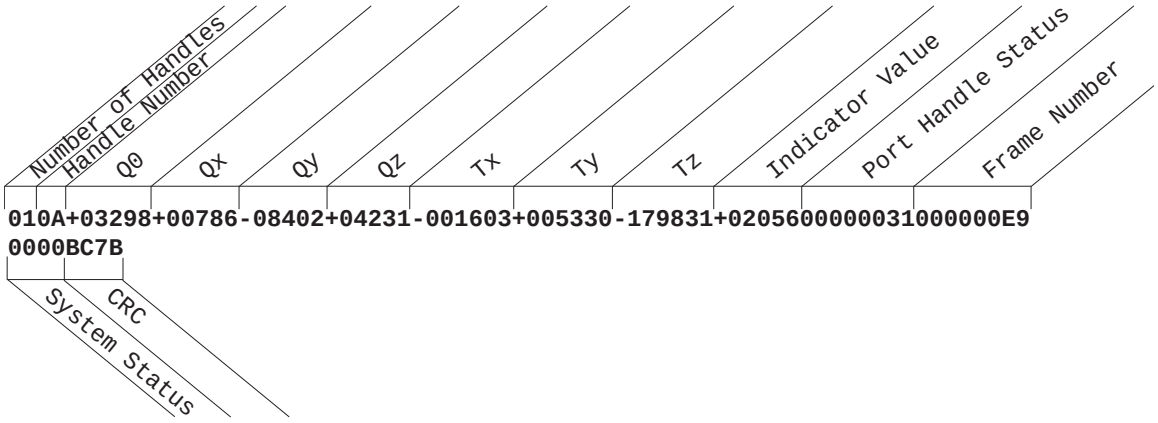
### Usage Notes

1. The TX format is easier to parse than the binary format; it is useful when troubleshooting, or observing data as it is collected. For replies in binary format, use BX (page 24).
2. See the user guide for detailed descriptions of the port handle status and system status bits.
3. By default, transformations will not be reported if the tool is either partially or wholly out of the characterized measurement volume. To report these transformations, you must use reply option 0800 OR'd with reply option 0001. The accuracy of these transformations is unknown.
4. When the "diagnostic pending" bit is set in the system status, use GET (page 35) to read the **Info.Status.New Alerts** user parameter for every hardware device in the system. The act of reading these parameters clears the parameters and the "diagnostic pending" bit. For more information on alerts and their associated user parameters, see "Alerts User Parameters" on page 14.
5. Bit 8 in the <Port Handle Status> section of reply option 0001 may not always indicate when a lead wire is broken. Broken sensors that result in a short will not be detected.

### Example

*Command:*
TX

*Reply:*




The system returned transformation data for one tool.

# VER

Returns the firmware revision number of critical processors installed in the system.

## Operating Mode

Setup

## Syntax

```
VER<SPACE><Reply Option><CR>
```

| Parameter | Description | |
|---|---|---|
| Reply Option | Specifies which information will be returned.<br><br>The reply options cannot be OR'd.<br><br>**Valid Values:** | |
| | 0 | System Control Processor |
| | 4 | System Control Processor, with enhanced revision numbering.<br>The revision numbering is XXX.YYY, where XXX = major revision and YYY = minor revision. The major revision number is always the same as the revision number for reply option 0. |
| | 5 | Combined firmware revision number.<br>The revision numbering format is XXX. Only the number is reported; there is no information about the type of system. |
| | 7 | Field Generator information |

## Replies

*Upon Success:*

```
<Reply Option Data><CRC16><CR>
```

*On Error:*

```
ERROR<Error Code><CRC16><CR>
```

See page 91 for error code definitions.

### Reply Option 0 - System Control Processor

```
<Reply Option 0 Data> =
<Type of Firmware><LF>
<NDI Serial Number><LF>
<Characterization Date><LF>
<Freeze Tag><LF>
<Freeze Date><LF>
<Copyright Information><LF>
```

### Reply Option 4 - System Control Processor with Enhanced Revision Numbering

```
<Reply Option 4 Data> =
<Type of Firmware><LF>
```

```
<NDI Serial Number><LF>
<Characterization Date><LF>
<Freeze Tag><LF>
<Freeze Date><LF>
<Copyright Information><LF>
```

### Reply Option 5 - Combined Firmware Revision Number

```
<Reply Option 5 Data> = <Combined Firmware Revision>
```

### Reply Option 7 - Field Generator Information

```
<Reply Option 7 Data> =
<Field Generator Serial Number><LF>
<Field Generator Model><LF>
<Characterization Date><LF>
```

### Reply Option 8 - Sensor Interface Unit Information

This reply option is deprecated. To read the firmware version of the SIU, use GET (page 35) to read the value of the Features.Firmware.Version user parameter. See “User Parameters” on page 12 for details.

### Usage Note

If you send the command VER 5 after the INIT command has replied with `ERROR2E`, the reply will be “???”, because component versions are incompatible.

### Examples

*Command:*

```
VER 5
```

*Reply:*

```
0061994
```

# VSEL

Selects a characterized measurement volume.

### Operating Mode

Setup

### Prerequisite Command

INIT (page 38)

### Syntax

```
VSEL<SPACE><Volume Number><CR>
```

| Parameter | Description |
|---|---|
| `Volume Number` | 1 hexadecimal character<br><br>**Valid Values**:<br>1 to the maximum returned by SFLIST (page 73) |

### Replies

*Upon Success:*

```
OKAY<CRC16><CR>
```

*On Error:*

```
ERROR<Error Code><CRC16><CR>
See page 91 for error code definitions.
```

### Usage Notes

Use SFLIST (page 73) to determine which measurement volumes are available.

### Example

*Command:*

```
VSEL 1
```

*Reply:*

```
OKAYA896
```

# VSIU

Registers or unregisters a VSIU with the Aurora system.

### Operating Mode

Setup

### Prerequisite Command

INIT (page 38)

### Syntax

`VSIU<SPACE><Parameter><CR>`

| Parameter | Description |
|---|---|
| 1 | Registers a new VSIU with the Aurora.<br>The reply is the VSIU instance number (X). This instance number is equivalent to the instance number used for the 'SIU-X' user parameters.<br>'ERROR2A' is returned if the maximum number of VSIUs is exceeded. Currently Aurora systems support up to 4 VSIUs. |
| 0X | Unregister VSIU instance X from the Aurora.<br>On success 'OKAY' is returned.<br>Trying to unregister an unknown instance will return 'ERROR42'. |

### Replies

*Upon Success:*

`<SIU Instance X><CRC16><CR>`
`or`
`OKAY<CRC16><CR>`

*On Error:*

`ERROR<Error Code><CRC16><CR>`

See page 91 for error code definitions.

### Usage Notes

1. Once the VSIU has been successfully registered, the client software must to query the device using `GET Device.*` until 'SIU-X' appears in the list of devices. Once it appears, the device can be checked directly to ensure initialization was successful.
2. The SCU starts the initialization 250 ms after the successful VSIU command. This gives the client application enough time to configure the packet routing.
3. Any problems during the initialization process will be shown in the SIU-X alert information. See “Alerts User Parameters” on page 14 for more information.
4. Upon INIT, RESET or a serial break, all configured VSIUs are automatically unregistered from the Aurora system.

# 6 Error Code Definitions

If the system receives an invalid command, it responds to the host with the message ERROR<Error Code><CRC>. Table 6-1 identifies the error codes and their definitions.

Table 6-1 Error Code Definitions

| Error Code | Definition |
|---|---|
| 01 | Invalid command. |
| 02 | Command too long. |
| 03 | Command too short. |
| 04 | Invalid CRC calculated for command; calculated CRC does not match the one sent. |
| 05 | Time-out on command execution. |
| 06 | Unable to set up new communication parameters. This occurs if one of the communication parameters is out of range. |
| 07 | Incorrect number of parameters. |
| 08 | Invalid port handle selected. |
| 09 | Invalid mode selected. Either the tool tracking priority is out of range, or the tool has sensors defined and 'button box' was selected. |
| 0A | Invalid LED selected. The LED selected is out of range. |
| 0B | Invalid LED state selected. The LED state selected is out of range. |
| 0C | Command is invalid while in the current operating mode. |
| 0D | No tool is assigned to the selected port handle. |
| 0E | Selected port handle not initialized. The port handle needs to be initialized before the command is sent. |
| 0F | Selected port handle not enabled. The port handle needs to be enabled before the command is sent. |
| 10 | System not initialized. The system must be initialized before the command is sent. |
| 11 | Unable to stop tracking. This occurs if there are hardware problems. Please contact NDI. |
| 12 | Unable to start tracking. This occurs if there are hardware problems. Please contact NDI. |
| 13 | Unable to initialize the port handle. |
| 14 | Invalid Field Generator characterization parameters or incompatible hardware. |
| 15 | Unable to initialize the system. This occurs if:<br>• the system could not return to Setup mode<br>• there are internal hardware problems. Please contact NDI. |
| 16 to 18 | Reserved. |

Table 6-1 Error Code Definitions (Continued)

| Error Code | Definition |
|---|---|
| 19 | Unable to read device's firmware revision information. This occurs if:<br>• the processor selected is out of range<br>• the system is unable to inquire firmware revision information from a processor |
| 1A | Internal system error. This occurs when the system is unable to recover after a system processing exception. |
| 1B to 1C | Reserved. |
| 1D | Unable to search for SROM device IDs. |
| 1E | Unable to read SROM device data. This occurs if the system is:<br>• unable to auto-select the first SROM device on the given port handle as a target to read from<br>• unable to read a page of SROM device data successfully |
| 1F | Unable to write SROM device data. This can occur if:<br>• the SROM device starting address is out of range<br>• the system is unable to auto-select the first SROM device on the given port handle as a target for writing to<br>• an SROM device on the given port handle has not previously been selected with the PSEL command as a target to write to<br>• the system is unable to write a page of SROM device data successfully |
| 20 | Unable to select SROM device for given port handle and SROM device ID. |
| 21 to 22 | Reserved. |
| 23 | Command parameter is out of range. |
| 24 | Unable to select parameters by volume. This occurs if:<br>• the selected volume is not available<br>• there are internal hardware errors. Please contact NDI. |
| 25 to 28 | Reserved. |
| 29 | Main processor firmware is corrupt. |
| 2A | No memory is available for dynamic allocation (heap is full). |
| 2B | The requested port handle has not been allocated. |
| 2C | The requested port handle has become unoccupied. |
| 2D | All handles have been allocated. |
| 2E to 30 | Reserved. |
| 31 | Invalid input or output state. |
| 32 | Reserved. |
| 33 | Feature not available. |
| 34 | User parameter does not exist. |
| 35 | Invalid value type (e.g. string instead of integer). |
| 36 | User parameter value set is out of valid range. |

Table 6-1 Error Code Definitions (Continued)

| Error Code | Definition |
|---|---|
| 37 | User parameter array index is out of valid range. |
| 38 | User parameter size is incorrect. |
| 39 | Permission denied; file or user parameter is read-only. |
| 3A | Reply buffer too small. |
| 3B to 41 | Reserved. |
| 42 | Device not present. This occurs when the command is specific to a device that is not connected to the system. |
| 43 to C4 | Reserved. |
| C5 | The data bits parameter (set using COMM (page 29)) must be set to 8 bits in order to use the BX command. |
| C6 to F3 | Reserved |
| F4 | Unable to erase Flash SROM device. |
| F5 | Unable to write Flash SROM device. |
| F6 | Unable to read Flash SROM device. |
| F7 to FF | Reserved. |

# Appendix A For Polaris Users

The Aurora System shares a large part of its API with the NDI Polaris System. If you have written an application for use with the Polaris System, you can adapt it to function with the Aurora System. The following sections list the differences between the Aurora API and various versions of the Polaris API.

Read the section that corresponds to the type of Polaris System and version of Polaris firmware for which your application is designed:

- "Differences Between the Aurora System and the Polaris System (Rev 18)" on page 95
  Read this section if your application is written for use with a Polaris System with combined firmware revision 018.
- "Differences Between the Aurora System and the Polaris System (Rev 24)" on page 98
  Read this section if your application is written for use with a Polaris System with combined firmware revision 022 to 024.
- "Differences Between the Aurora System and the Polaris Vicra or Polaris Spectra System" on page 101
  Read this section if your application is written for use with a Polaris Vicra System or a Polaris Spectra System.

To determine the combined firmware revision of your Polaris System, use the command VER 5. If your application is written for a Polaris System that uses a combined firmware revision other than Rev 22-24 or Rev 18, contact NDI technical support for more information.

## A.1 Differences Between the Aurora System and the Polaris System (Rev 18)

Read this section if your application is written for use with a Polaris System with combined firmware revision 018.

### Deprecated Commands

- GX, replaced by BX (page 24) and TX (page 83)
- PSTAT, replaced by PHSR (page 50) and PHINF (page 44)
- PVCLR, replaced by PHF (page 43)
- PVTIP, no replacement for the Aurora System

### New Commands

- APIREV (page 22) returns the API revision number.
- DFLT (page 31) restores the user parameters to factory default values.
- ECHO (page 34) returns exactly what is sent with the command.
- GET (page 35) returns the user parameter values.
- GETINFO (page 36) returns descriptive information about the user parameters.
- RESET (page 69) resets the system (can specify either a hard reset or a soft reset).
- SAVE (page 71) saves all non-volatile user parameters that have been changed.
- SET (page 72) sets user parameter values.

### Changed Command

- PHINF (page 44): in reply option 0001, the size of the <tool type> field increases from 7 to 8 characters.

### Polaris-Only Commands

These commands function only with the Polaris System. Sending these commands to the Aurora System will generate an error:

| | |
|---|---|
| 3D | IRINIT |
| IRATE | PFSEL |
| IRCHK | PHRQ |
| IRED | TCTST |

### Aurora-Only Command

PSOUT (page 60) functions only with the Aurora System.

## Commands with Differences Between Polaris and Aurora

These commands function differently with the Aurora System than with the Polaris System:

### PHINF (page 44)

- **Polaris-only option:** As of Aurora combined firmware revision 013, reply option 0020 is deprecated for the Aurora system (use reply option 0080 instead)
- **Aurora-only option:** The following reply option is valid only with the Aurora System: reply option 0080 (Sensor configuration and physical port location)

### SFLIST (page 73)

- **Polaris-only options:** The following reply options are valid only for the Polaris System:
  reply option 01 (number of wired tool ports)
  reply option 02 (number of wireless tool ports)
  reply option 04 (number of wired tool ports available which support tool-in-port detection from current sensing)
- **Aurora-only options:** The following reply option is valid only with the Aurora System: reply option 10 (number of ports)

### SSTAT

- This command will work with the Aurora System, but won't return any useful data. This command will return the following data:

  SSTAT 0001 returns 00
  SSTAT 0002 returns 00
  SSTAT 0004 returns 00
  SSTAT 0100 returns 00000000
  SSTAT 0200 returns 00000000

### VER (page 87)

- **Polaris-only options:** The following reply options are valid only with the Polaris System:
  reply option 1 (left sensor processor)
  reply option 2 (right sensor processor)
  reply option 3 (Tool Interface Unit processor)
  reply option 6 (Tool Docking Station)
- **Aurora-only options:** The following reply option is valid only with the Aurora System: reply option 7 (Field Generator information)

## Differences in Concepts

Port handles: Previous versions of the Polaris API distinguished between wired tool ports (corresponding to wired tools that were physically connected to the system) and wireless tool ports (corresponding to passive tools and active wireless tools). Wired tool ports were assigned a port number, and wireless tool ports were assigned a port letter.

The API no longer supports the concept of tool ports, and instead assigns each tool a port handle. Port handles are independent of the physical port numbering. Port handles provide greater flexibility than port numbers and replace port numbers and port letters in most commands. Port handles range from 0x0A to 0xFF with the Aurora System. (With the Polaris System, port handles range from 0x01 to 0xFF.)

For a split port on a dual 5DOF tool, the first PHSR (page 50) sent will report only one port handle. After the port handle is initialized, it is assigned to channel 0. You must then use PHSR again to assign a port handle to channel 1, and then initialize the port handle using INIT (page 38). See "Flow Chart for Port Handle Usage" on page 8.

GPIO: General purpose input/outputs can be used as either an input or an output with the Aurora System. With the Polaris System, GPIOs can only be used as inputs.

API revisions: The API now has a revision number. If you upgrade the firmware, you can check the API revision to determine whether your application software may need to be updated. In the event of a firmware change that does not affect the API, the API revision number will remain the same, and any application software written using that API revision will continue to function with the new firmware revision. To determine the API revision programmed into your system, use the command APIREV (page 22).

## A.2 Differences Between the Aurora System and the Polaris System (Rev 24)

Read this section if your application is written for use with a Polaris System with combined firmware revision 022 to 024.

### New Commands

- APIREV (page 22) returns the API revision number.
- DFLT (page 31) restores the user parameters to factory default values.
- ECHO (page 34) returns exactly what is sent with the command.
- GET (page 35) returns the user parameter values.
- GETINFO (page 36) returns descriptive information about the user parameters.
- RESET (page 69) resets the system (can specify either a hard reset or a soft reset).
- SAVE (page 71) saves all non-volatile user parameters that have been changed.
- SET (page 72) sets user parameter values.

### Polaris-Only Commands

These commands function only with the Polaris System. Sending these commands to the Aurora System will generate an error:

| | |
|---|---|
| 3D | IRINIT |
| GETIO | PFSEL |
| IRATE | PHRQ |
| IRCHK | SETIO |
| IRED | TCTST |

### Aurora-Only Command

PSOUT (page 60) functions only with the Aurora System.

### Commands with Differences Between Polaris and Aurora

These commands function differently with the Aurora System than with the Polaris System:

#### BX (page 24) and TX (page 83)

- **Polaris-only options:** The following reply options are valid only with the Polaris System:
  reply option 0002 (tool and marker information)
  reply option 0004 (3D position of a single stray active marker)
  reply option 1000 (3D positions of stray passive markers)
- **Polaris-only bit:** The following bit is valid only with the Polaris System:
  <system status> bit 1 (too much external IR)

- **Aurora-only bits:** The following bits are valid only with the Aurora System:
  <system status> bit 5 (hardware change)
  <port handle status> bit 8 (broken sensor)

PHINF (page 44)

- **Polaris-only options:** The following reply options are valid only with the Polaris System:
  reply option 0002 (wired tool electrical information)
  reply option 0010 (tool marker type and wavelength)
  reply option 0020 (physical port location) - as of Aurora combined firmware revision 013, this option is deprecated for Aurora system (use reply option 0080 instead)
- **Aurora-only option:** The following reply option is valid only with the Aurora System:
  reply option 0040 (GPIO status)
  reply option 0080 (Sensor configuration and physical port location)

PHSR (page 50)

- **Polaris-only bit:** The following bit is valid only with the Polaris System:
  <port handle status> bit 7 (tool detected from current sensing)

SFLIST (page 73)

- **Polaris-only options:** The following reply options are valid only for the Polaris System:
  reply option 01 (number of wired tool ports)
  reply option 02 (number of wireless tool ports)
  reply option 04 (number of wired tool ports available which support tool-in-port detection from current sensing)
- **Aurora-only options:** The following reply option is valid only with the Aurora System:
  reply option 10 (number of ports)

SSTAT

- This command will work with the Aurora System, but won't return any useful data. This command will return the following data:

  SSTAT 0001 returns 00
  SSTAT 0002 returns 00
  SSTAT 0004 returns 00
  SSTAT 0100 returns 00000000
  SSTAT 0200 returns 00000000

VER (page 87)

- **Polaris-only options:** The following reply options are valid only with the Polaris System:
  reply option 1 (left sensor processor)
  reply option 2 (right sensor processor)
  reply option 3 (Tool Interface Unit processor)
  reply option 6 (Tool Docking Station)

- **Aurora-only options:** The following reply option is valid only with the Aurora System: reply option 7 (Field Generator information)

## Differences in Concepts

Port handles: Port handles range from 0x0A to 0xFF with the Aurora System. With the Polaris System, port handles range from 0x01 to 0xFF.

For a split port on a dual 5DOF tool, the first PHSR (page 50) sent will report only one port handle. After the port handle is initialized using PINIT, it is assigned to channel 0. You must then use PHSR again to assign a port handle to channel 1. The port handle for channel 1 is initialized automatically. See “Flow Chart for Port Handle Usage” on page 8

GPIO: General purpose input/outputs can be used as either an input or an output with the Aurora System. With the Polaris System, GPIOs can only be used as inputs.

API revisions: The API now has a revision number. If you upgrade the firmware, you can check the API revision to determine whether your application software may need to be updated. In the event of a firmware change that does not affect the API, the API revision number will remain the same, and any application software written using that API revision will continue to function with the new firmware revision. To determine the API revision programmed into your system, use the command APIREV (page 22).

## A.3 Differences Between the Aurora System and the Polaris Vicra or Polaris Spectra System

Read this section if your application is written for use with a Polaris Vicra System or a Polaris Spectra System.

### Polaris-Only Commands

These commands function only with the Polaris Vicra and Polaris Spectra Systems. Sending these commands to the Aurora System will generate an error:

| | |
|---|---|
| 3D | PFSEL |
| GETIO | PHRQ |
| GETLOG | SETIO |
| IRATE | SYSLOG |
| IRCHK | TCTST |
| IRED | VGET |
| IRINIT | VSNAP |

### Commands with Differences Between Polaris and Aurora

These commands function differently with the Aurora System than with the Polaris Vicra and Spectra Systems:

BX (page 24) and TX (page 83)

- **Polaris-only options:** The following reply options are valid only with the Polaris Vicra and Spectra Systems:
  reply option 0002 (tool and marker information)
  reply option 0004 (3D position of a single stray active marker)
  reply option 0008 (3D positions of markers on tools)
  reply option 1000 (3D positions of stray passive markers)
- **Polaris-only bits:** The following bits are valid only with the Polaris Vicra and Spectra Systems:
  <system status> bit 8 (diagnostic pending)
  <system status> bit 9 (temperature)
  <port handle status> bit 8 (algorithm limitation)
  <port handle status> bit 9 (IR interference)
  <port handle status> bit 12 (processing exception)
  <port handle status> bit 14 (fell behind while processing)
  <port handle status> bit 15 (data buffer limitation)
- **Aurora-only bits:** The following bits are valid only with the Aurora System:
  <system status> bit 5 (hardware change)
  <port handle status> bit 8 (broken sensor)

PHINF (page 44)

- **Polaris-only options:** The following reply options are valid only with the Polaris System:
  reply option 0002 (wired tool electrical information)
  reply option 0010 (tool marker type and wavelength)
  reply option 0020 (physical port location) - as of Aurora combined firmware revision 013, this option is deprecated for Aurora system (use reply option 0080 instead)
- **Aurora-only option:** The following reply option is valid only with the Aurora System:
  reply option 0040 (GPIO status)
  reply option 0080 (Sensor configuration and physical port location)

PHSR (page 50)

- **Polaris-only bit:** The following bit is valid only with the Polaris System:
  <port handle status> bit 7 (tool detected from current sensing)

PSOUT (page 60)

- **Aurora-only option:** The GPIO line state “P” (pulse) is only with the Aurora System.

SFLIST (page 73)

- **Polaris-only options:** The following reply options are valid only for the Polaris System:
  reply option 01 (number of wired tool ports)
  reply option 02 (number of wireless tool ports)
  reply option 04 (number of wired tool ports available which support tool-in-port detection from current sensing)
- **Aurora-only options:** The following reply option is valid only with the Aurora System:
  reply option 10 (number of ports)

SSTAT

- This command will work with the Aurora System, but won’t return any useful data. This command will return the following data:

  SSTAT 0001 returns 00
  SSTAT 0002 returns 00
  SSTAT 0004 returns 00
  SSTAT 0100 returns 00000000
  SSTAT 0200 returns 00000000

VER (page 87)

- **Polaris-only options:** The following reply options are valid only with the Polaris System:
  reply option 1 (left sensor processor)
  reply option 2 (right sensor processor)
  reply option 3 (Tool Interface Unit processor)
  reply option 6 (Tool Docking Station)

- **Aurora-only options:** The following reply option is valid only with the Aurora System: reply option 7 (Field Generator information)

## Differences in Concepts

**Port handles** Port handles range from 0x0A to 0xFF with the Aurora System. With the Polaris System, port handles range from 0x01 to 0xFF.

For a split port on a dual 5DOF tool, the first PHSR (page 50) sent will report only one port handle. After the port handle is initialized using PINIT, it is assigned to channel 0. You must then use PHSR again to assign a port handle to channel 1. The port handle for channel 1 is initialized automatically. See “Flow Chart for Port Handle Usage” on page 8

**GPIO** General purpose input/outputs can be used as either an input or an output with the Aurora System. With the Polaris System, GPIOs can only be used as inputs.

# Appendix B Sample C Routines

The following sample C routines are included for reference:

**Table 6-2 Sample C Routines**

| Routine | Description |
|---|---|
| CalcCRC16 | Calculates a running CRC16 using the polynomial X^16 + X^15 + X^2 + 1. |
| EulerAngleTrig | Determines the sine and cosine of the Euler angles. |
| DetermineR | Calculates the 3x3 rotation matrix which corresponds to the given Euler angles. |
| CvtQuatToRotationMatrix | Determines the rotation matrix that corresponds to the given quaternion values. |
| DetermineEuler | Calculates the Euler angles given the 3x3 rotation matrix. |
| CvtQuatToEulerRotation | Determines the rotation in Euler angles (degrees) that corresponds to the given quaternion rotation. |

The following defines are used by the sample C routines:

```
/*
 * Conversion factors.
 */
#define RAD_TO_DEGREES        (180 / 3.1415926)

/*
 * Defined data types.
 */
typedef float
    RotationMatrix[3][3];

typedef struct Rotation
{
    float
        fRoll, /* rotation about the object's z-axis (Euler angle) */
        fPitch, /* rotation about the object's y-axis (Euler angle) */
        fYaw; /* rotation about the object's x-axis (Euler angle) */
} Rotation;

typedef struct QuatRotation
{
    float
        fQ0,
        fQX,
        fQY,
        fQZ;
} QuatRotation;
```

## B.1 CalcCRC16

The following is a sample C routine, for calculating a running 16 bit CRC, as used in communications between the host computer and the Aurora System.

```
/*****************************************************************
Name:        CalcCRC16

Input Values:
    int
        data :Data value to add to running CRC16.
    unsigned int
        *puCRC16    :Ptr. to running CRC16.

Output Values:
    None.

Returned Value:
    None.

Description:
    This routine calculates a running CRC16 using the polynomial
    X^16 + X^15 + X^2 + 1.

*****************************************************************/
void CalcCRC16( int data, unsigned int *puCRC16 )
{
    static int
        oddparity[16] = { 0, 1, 1, 0, 1, 0, 0, 1, 1, 0, 0, 1, 0, 1, 1, 0 };

    data = (data ^ (*puCRC16 & 0xff)) & 0xff;
    *puCRC16 >>= 8;

    if ( oddparity[data & 0x0f] ^ oddparity[data >> 4] )
    {
    *puCRC16 ^=0xc001
        /* if */
    }
    data <<= 6;
    *puCRC16 ^= data;
    data <<= 1;
    *puCRC16 ^= data;

} /* CalcCRC16 */
```

## B.2 EulerAngleTrig

```
/*****************************************************************
Name:        EulerAngleTrig

Input Values:
    Rotation
        *pdtRotationAngle :Ptr to struct containing the roll, pitch, yaw
        Euler angles which define the required rotation.
```

```
Output Values:
    Rotation
        *pdtSinAngle :Ptr to struct containing the sine of the roll, pitch,
        yaw Euler angles.
        *pdtCosAngle :Ptr to struct containing the cosine of the roll, pitch,
        yaw Euler angles.

Returned Value:
    None.

Description:
    This routine determines the sine and cosine of the Euler angles.

*********************************************************************/
static void EulerAngleTrig( Rotation *pdtRotationAngle,
                Rotation *pdtSinAngle,
                Rotation *pdtCosAngle )
{
    pdtSinAngle->fRoll= sin( pdtRotationAngle->fRoll );
    pdtSinAngle->fPitch= sin( pdtRotationAngle->fPitch );
    pdtSinAngle->fYaw = sin( pdtRotationAngle->fYaw );
    pdtCosAngle->fRoll= cos( pdtRotationAngle->fRoll );
    pdtCosAngle->fPitch= cos( pdtRotationAngle->fPitch );
    pdtCosAngle->fYaw= cos( pdtRotationAngle->fYaw );

} /* EulerAngleTrig */
```

## B.3 DetermineR

```
/*********************************************************************
Name:        DetermineR

Input Values:
    Rotation
        *pdtRotationAngle :Ptr to struct containing the roll, pitch, yaw
        Euler angles which define the required rotation.

Output Values:
    RotationMatrix
        dtRotationMatrix :The 3x3 rotation matrix to be determined.

Returned Value:
    None.

Description:
    This routine calculates the 3x3 rotation matrix which corresponds to the
    given Euler angles.

*********************************************************************/
void DetermineR( Rotation *pdtRotationAngle, RotationMatrix
         dtRotationMatrix )
{
    Rotation
        dtSinAngle, /* the sine of the roll, pitch, and yaw angles */
        dtCosAngle; /* the cosine of the roll, pitch, and yaw angles */
```

```
/*
* Might as well determine the sine and cosine of the given Euler angles right from
the start
*/
EulerAngleTrig( pdtRotationAngle, &dtSinAngle, &dtCosAngle );

/*
* Fill in the rotation matrix.
*/
dtRotationMatrix[0][0] = dtCosAngle.fRoll * dtCosAngle.fPitch;
dtRotationMatrix[0][1] = dtCosAngle.fRoll * dtSinAngle.fPitch*
    dtSinAngle.fYaw - dtSinAngle.fRoll * dtCosAngle.fYaw;
dtRotationMatrix[0][2] = dtCosAngle.fRoll * dtSinAngle.fPitch *
    dtCosAngle.fYaw + dtSinAngle.fRoll * dtSinAngle.fYaw;
dtRotationMatrix[1][0] = dtSinAngle.fRoll * dtCosAngle.fPitch;
dtRotationMatrix[1][1] = dtSinAngle.fRoll * dtSinAngle.fPitch *
    dtSinAngle.fYaw + dtCosAngle.fRoll * dtCosAngle.fYaw;
dtRotationMatrix[1][2] = dtSinAngle.fRoll * dtSinAngle.fPitch *
    dtCosAngle.fYaw - dtCosAngle.fRoll * dtSinAngle.fYaw;
dtRotationMatrix[2][0] = - dtSinAngle.fPitch;
dtRotationMatrix[2][1] = dtCosAngle.fPitch * dtSinAngle.fYaw;
dtRotationMatrix[2][2] = dtCosAngle.fPitch * dtCosAngle.fYaw;

} /* DetermineR */
```

## B.4 CvtQuatToRotationMatrix

```
/*****************************************************************
Name:        CvtQuatToRotationMatrix

Input Values:
    QuatRotation
        *pdtQuatRot :Ptr to the quaternion rotation.

Output Values:
    RotationMatrix
        dtRotationMatrix :The 3x3 determined rotation matrix.

Returned Value:
    None.

Description:
    This routine determines the rotation matrix that corresponds
    to the given quaternion.

    Let the quaternion be represented by:

        | Q0 |
    Q = | Qx |
        | Qy |
        | Qz |

    and the rotation matrix by:
```

```
            | M00 M01 M02 |
        M = | M10 M11 M12 |
            | M20 M21 M22 |

        then assuming the quaternion, Q, has been normalized to convert
        Q to M we use the following equations:

        M00 = (Q0 * Q0) + (Qx * Qx) - (Qy * Qy) - (Qz * Qz)
        M01 = 2 * ((Qx * Qy) - (Q0 * Qz))
        M02 = 2 * ((Qx * Qz) + (Q0 * Qy))
        M10 = 2 * ((Qx * Qy) + (Q0 * Qz))
        M11 = (Q0 * Q0) - (Qx * Qx) + (Qy * Qy) - (Qz * Qz)
        M12 = 2 * ((Qy * Qz) - (Q0 * Qx))
        M20 = 2 * ((Qx * Qz) - (Q0 * Qy))
        M21 = 2 * ((Qy * Qz) + (Q0 * Qx))
        M22 = (Q0 * Q0) - (Qx * Qx) - (Qy * Qy) + (Qz * Qz)

******************************************************************/
void CvtQuatToRotationMatrix( QuatRotation *pdtQuatRot,
                RotationMatrix dtRotMatrix )
{
    float
        fQ0Q0,
        fQxQx,
        fQyQy,
        fQzQz,
        fQ0Qx,
        fQ0Qy,
        fQ0Qz,
        fQxQy,
        fQxQz,
        fQyQz;

    /*
     * Determine some calculations done more than once.
     */
        fQ0Q0 = pdtQuatRot->fQ0 * pdtQuatRot->fQ0;
        fQxQx = pdtQuatRot->fQX * pdtQuatRot->fQX;
        fQyQy = pdtQuatRot->fQY * pdtQuatRot->fQY;
        fQzQz = pdtQuatRot->fQZ * pdtQuatRot->fQZ;
        fQ0Qx = pdtQuatRot->fQ0 * pdtQuatRot->fQX;
        fQ0Qy = pdtQuatRot->fQ0 * pdtQuatRot->fQY;
        fQ0Qz = pdtQuatRot->fQ0 * pdtQuatRot->fQZ;
        fQxQy = pdtQuatRot->fQX * pdtQuatRot->fQY;
        fQxQz = pdtQuatRot->fQX * pdtQuatRot->fQZ;
        fQyQz = pdtQuatRot->fQY * pdtQuatRot->fQZ;

    /*
     * Determine the rotation matrix elements.
     */
        dtRotMatrix[0][0] = fQ0Q0 + fQxQx - fQyQy - fQzQz;
        dtRotMatrix[0][1] = 2.0 * (-fQ0Qz + fQxQy);
        dtRotMatrix[0][2] = 2.0 * (fQ0Qy + fQxQz);
        dtRotMatrix[1][0] = 2.0 * (fQ0Qz + fQxQy);
        dtRotMatrix[1][1] = fQ0Q0 - fQxQx + fQyQy - fQzQz;
        dtRotMatrix[1][2] = 2.0 * (-fQ0Qx + fQyQz);
        dtRotMatrix[2][0] = 2.0 * (-fQ0Qy + fQxQz);
```

```
        dtRotMatrix[2][1] = 2.0 * (fQ0Qx + fQyQz);
        dtRotMatrix[2][2] = fQ0Q0 - fQxQx - fQyQy + fQzQz;

} /* CvtQuatToRotationMatrix */
```

## B.5 DetermineEuler

```
/*****************************************************************
Name:         DetermineEuler

Input Values:
    RotationMatrix
        dtRotationMatrix :The 3x3 rotation matrix to convert.

Output Values:
    Rotation
        *pdtEulerRot :Rotation is Euler angle format.
            Roll, pitch, yaw Euler angles which define the required rotation.

Returned Value:
    None.

Description:
    This routine calculates the Euler angles given the 3x3 rotation matrix.

*****************************************************************/
void DetermineEuler( RotationMatrix dtRotMatrix, Rotation *pdtEulerRot )
{
    float
        fRoll,
        fCosRoll,
        fSinRoll;

    fRoll    = atan2( dtRotMatrix[1][0], dtRotMatrix[0][0] );
    fCosRoll = cos( fRoll );
    fSinRoll = sin( fRoll );

    pdtEulerRot->fRoll  = fRoll;
    pdtEulerRot->fPitch = atan2( -dtRotMatrix[2][0],
     (fCosRoll * dtRotMatrix[0][0]) + (fSinRoll *
     dtRotMatrix[1][0]) );
    pdtEulerRot->fYaw   = atan2(
     (fSinRoll * dtRotMatrix[0][2]) -
     (fCosRoll * dtRotMatrix[1][2]),
     (-fSinRoll * dtRotMatrix[0][1]) +
     (fCosRoll * dtRotMatrix[1][1]) );

} /* DetermineEuler */
```

## B.6 CvtQuatToEulerRotation

```
/*************************************************************
Name:        CvtQuatToEulerRotation
```

```
Input Values:
    QuatRotation
        *pdtQuatRot :Ptr to the quaternion rotation.

Output Values:
    Rotation
        *pdtEulerRot :Ptr to the determined rotation Euler angles.

Returned Value:
    None.

Description:
    This routine determines the rotation in Euler angles (degrees)that
    corresponds to the given quaternion rotation.

*****************************************************************/
void CvtQuatToEulerRotation( QuatRotation *pdtQuatRot, Rotation *pdtEulerRot )
{
    RotationMatrix
        dtRotMatrix;

    CvtQuatToRotationMatrix( pdtQuatRot, dtRotMatrix );

    DetermineEuler( dtRotMatrix, pdtEulerRot );

    pdtEulerRot->fYaw   *= RAD_TO_DEGREES;
    pdtEulerRot->fPitch *= RAD_TO_DEGREES;
    pdtEulerRot->fRoll  *= RAD_TO_DEGREES;

} /* CvtQuatToEulerRotation */
```

# Abbreviations and Acronyms

| Abbreviation or Acronym | Definition |
|---|---|
| API | Application Program Interface |
| CRC | Cyclic Redundancy Check |
| FG | Field Generator |
| GPIO | General Purpose Input/Output |
| IEEE | Institute of Electrical and Electronic Engineers |
| ISIU | V3 Sensor Interface Unit |
| LED | Light Emitting Diode |
| PFG | Planar Field Generator |
| RMS | Root Mean Square |
| SCU | System Control Unit |
| SIU | Sensor Interface Unit |
| SROM | Serial Read Only Memory |
| TTFG | Tabletop Field Generator |
| V1 | First generation Aurora System.<br>**FG**: Aurora V1 Field Generators (V1 FG) have serial numbers starting with F4, e.g. F4-xxxxx or with FGb, e.g. FGb0-Sxxxxx.<br>**SCU**: Aurora V1 System Control Units (V1 SCUs) have serial numbers starting with A3 or A4. e.g. A4-xxxxxx.<br>**SIU**: Aurora V1 Sensor Interface Units (V1 SIU) have serial numbers starting with S4, e.g. S4-xxxxxx. Some older V1 SIUs have only a lot number. |
| V2 | Second generation Aurora System.<br>**FG**: Aurora V2 Field Generators (V2 FG) have serial numbers starting with FGc, FGd, or FGe e.g. FGc0-Sxxxxx.<br>**SCU**: Aurora V2 System Control Units (V2 SCUs) have serial numbers starting with SCb or SCe, e.g. SCb2-Sxxxxx.<br>**SIU**: Aurora V1 SIUs are used with the V2 system. |
| V3 | Third generation Aurora System.<br>**FG**: Aurora V2 FGs are used with the V3 system.<br>**SCU**: Aurora V3 System Control Units (V3 SCU) have serial numbers starting with SCd, e.g. SCd0-Sxxxxx.<br>**SIU**: Aurora V3 Sensor Interface Units (V3 SIU) have serial numbers starting with SIf or SIg, e.g. SIg0-Sxxxxx. |
| WFG | Window Field Generator |

# Index

## Numerics



## A



## B



## C



## D



## E



## F

## G



## H



## I



## L



## M



## N



## O



## P

## Q



## R



## S

## T



## U



## V



## W