HDSoC DAQ Manual

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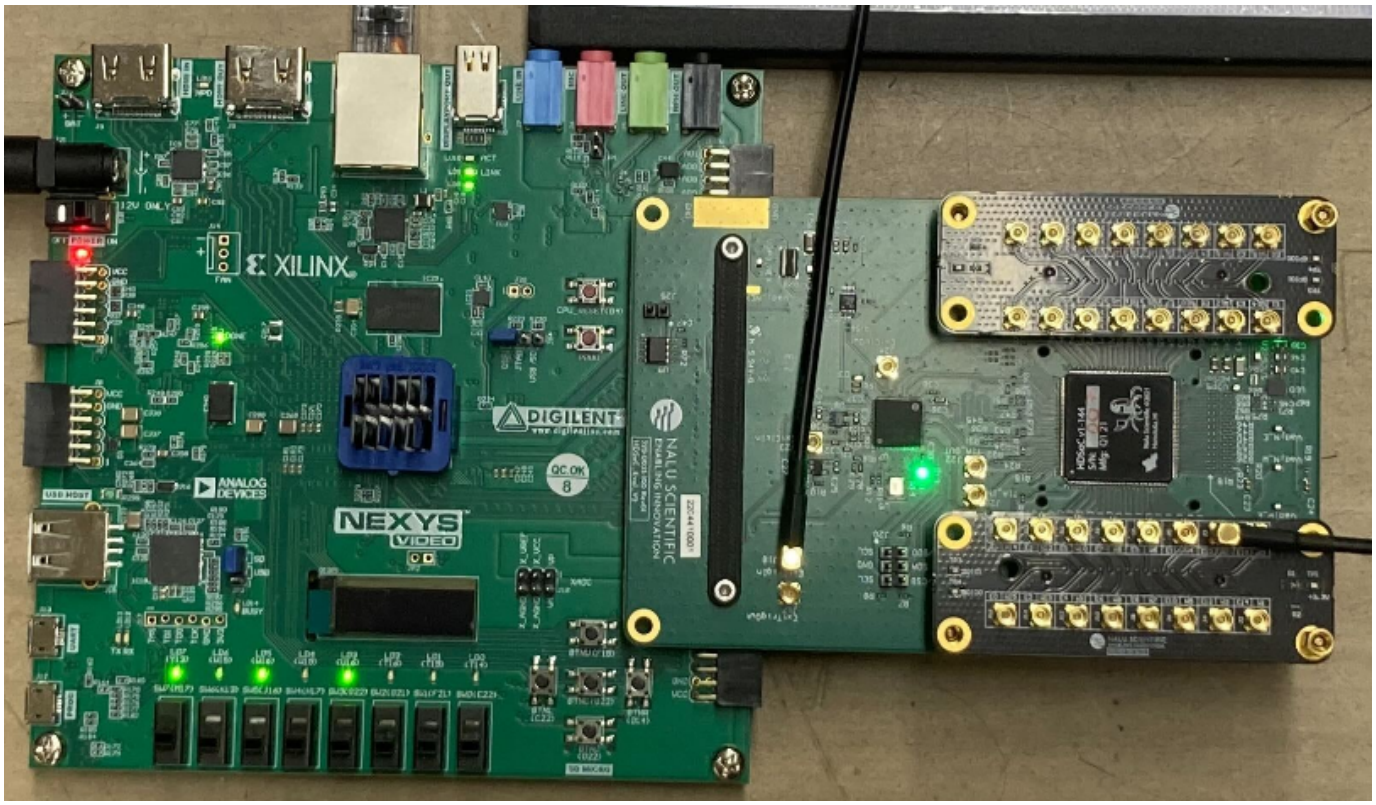
1. Welcome to the HDSoC DAQ Manual



The purpose of this manual is to aid users with setup, usage, and debugging of the HDSoC data acquisition (DAQ) system. This DAQ's purpose is to be used for readout of the Nalu's HDSoC FMC boards (and possibly other boards). Most topics are simplified to only include information needed for operating this DAQ. Some external links are provided for additional, generalized information.

Many of the guides on this webpage are thorough, as they are aimed to give solutions to problems I've encountered. However, every system is different; there may be some additional debugging to be done on the user's end.

1.1 PDF Version

A pdf version of this manual is automatically generated using MkDocs with pdf plugin.

1.2 Contact

Manual Written by Jack Carlton.
Ph.D. Candidate, Department of Physics and Astronomy, University of Kentucky.
Email: j.carlton@uky.edu
GitHub: jaca230

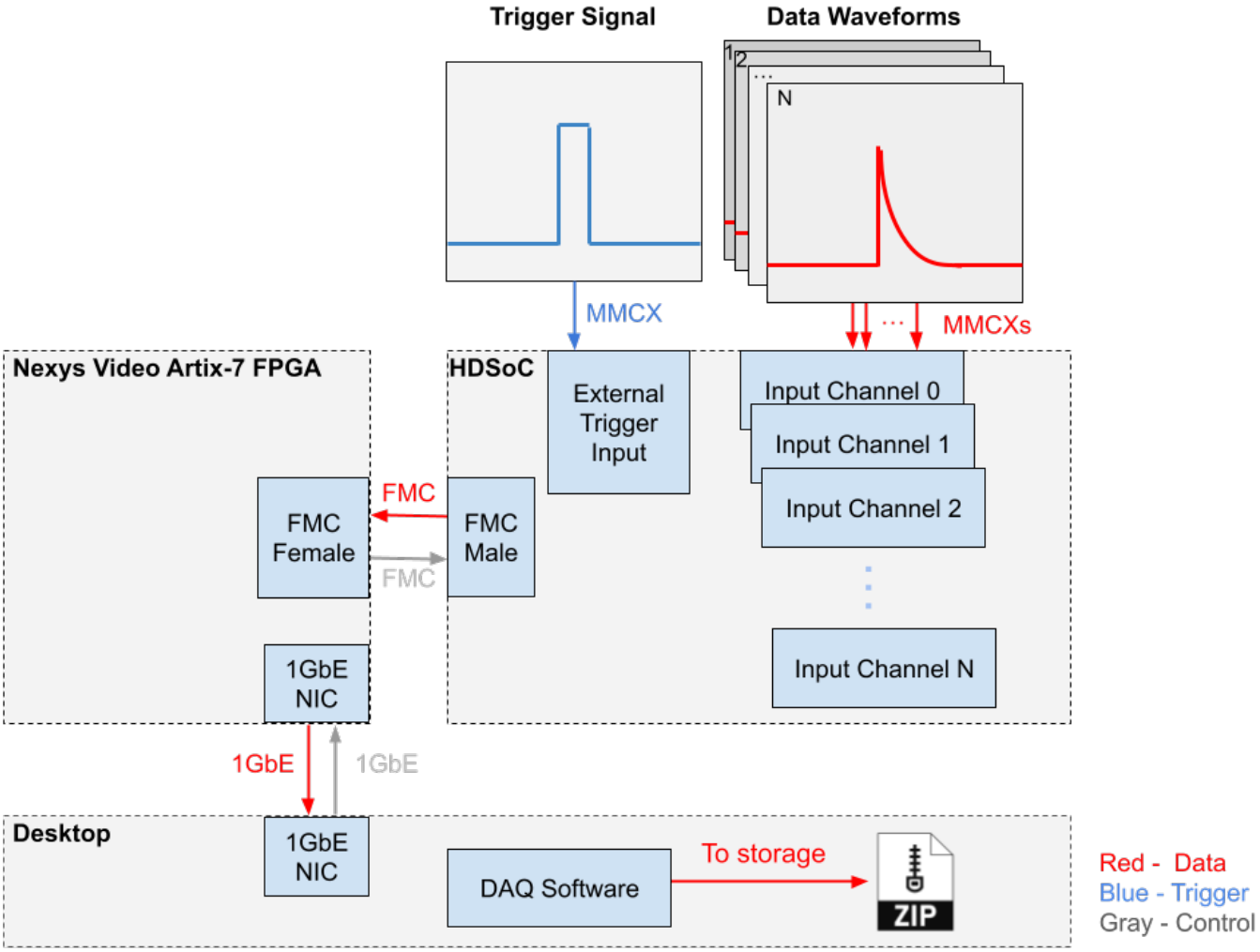
Feel free to reach out with any questions, to correct mistakes, point out missing information, or otherwise. Feel free to contribute additional information on github or otherwise.

Last update: September 9, 2025

2. Hardware

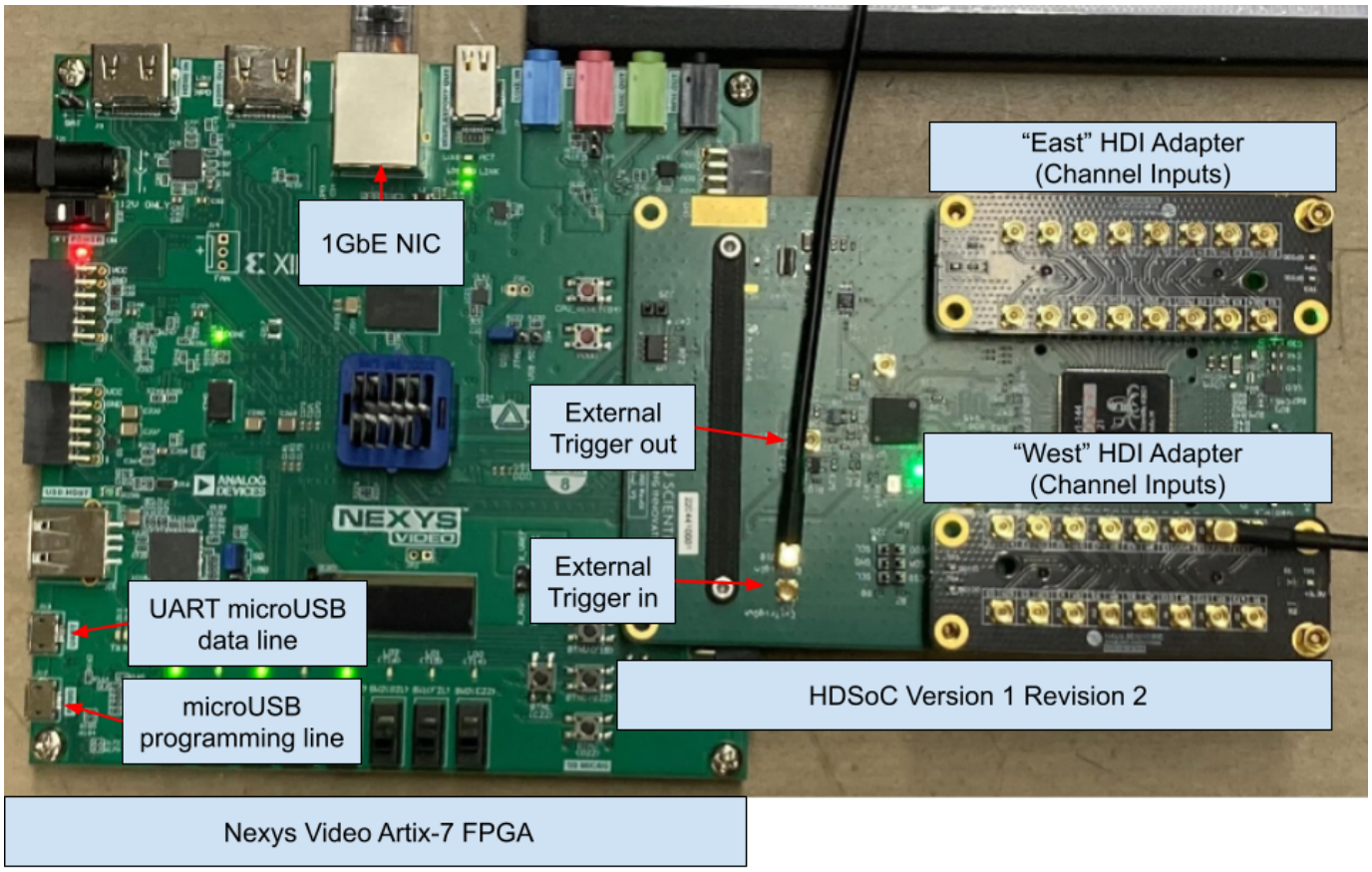
2.1 General Hardware Overview

2.1.1 Conceptual Diagram



- **Trigger Signal**: An external signal to tell the board when to digitize the input waveforms. Should be LVCMOS25 (0-2.5V) with width 10-100 ns.
- **Waveforms**: Analog signal to be digitized. Should be LVCMOS25 (0-2.5V). Max width is 1984 nanoseconds by default, but this depends on the sampling rate (default 1Gsps).
- **HDSoC**: Digitization board that handles inputs across multiple channels. Can be set to trigger on external or internal (self) signals.
- **Nexys Video Artix-7 FPGA**: Acts as a parent board to the HDSoC. Handles 1GbE communication and firmware storage among other things.
- **Desktop**: Receives and processes events that are effectively streamed from the digitization system.

2.1.2 Labled Picture



2.2 1GbE NIC (Gigabit Ethernet Network Interface Card)

2.2.1 Overview

These NICs are generally PCIe Cards that are "plug and play". They provide a 1 gigabit per second ethernet connection for the host computer.

2.2.2 Configuration

If you machine has a GUI, you may find it easier to edit network settings that way. Otherwise, you can edit settings from command line. For example for UKY's teststand we use:

```
nmcli connection modify enp3s0 \
    ipv4.addresses 192.168.1.1/24 \
    ipv4.method manual \
    connection.autoconnect yes \
    ipv6.method ignore
```

You may need to create a connection configuration file first if it doesn't exist. For example for UKY's teststand we use:

```
nmcli connection add type ethernet con-name enp3s0 ifname enp3s0
```

In particular, the `ipv4.addresses` is important. Here the port is specified to accept any traffic on the 192.168.1.xxx subnet. See the networking page for more details.

2.3 Nexys A7 Video Card

2.3.1 Overview

The Nexys A7 is a versatile and high-performance FPGA development board from Digilent, featuring the Xilinx Artix-7 FPGA. It is like the "mother board" for the HDSoC. For this use case it will provide power, an interface to update firmware, and an interface for data transfer. You can read more about this board on diligent's Nexys Video Artix-7 FPGA page.

2.3.2 FMCs

HDSoC

The HDSoC (or other nalu board) connects to the FPGA board via an FMC connector. See HDSoCv1 rev 2 for more info.

2.3.3 Wired Connections

USB A to microUSB

A USB A to microUSB can be used for UART communication. This can be used for data transfer via UART (very slow, limited to ~100 KB/s) and uploading firmware to the board. See the hardware diagram for port locations.

1GbE Connection

Connect an ethernet cable between the board and a host desktop computer. Most modern ethernet cables should work. See the hardware diagram for port locations.

2.3.4 Configuration

To congfigure the board, the appropriate firmware must be uploaded to it. This can be retrieved from nalu scientific's board downloads page. There are several options, the easiest two are:

1. Use microSD card with loaded firmware (see HDSoC quickstart guide)
2. Upload the firmware via Vivado

Steps to complete step 2 are below.

Downloading the firmware

Navigate to Nalu Scientific's support website. Go to the page for the HDSoCv1-evalr2 (or appropriate board). Download the most recent firmware version. This DAQ has been tested with firmware version 938. The file should be something like `HDSoC_eval_v938.bit`.

Downloading Vivado

Note: Vivado may take a *long* time to install because it is a very large program. This step could take serveral hours. A full Vivado installation can be around 200 GB. Below is a "minimal" installation that is ~50GB

The easiest way to upload firmware to the board is via Vivado. Download the most recent version of Vivado for your system from Xilinx's download page. You will need to make an account with AMD to install. This is easiest on a machine with a GUI. For a simple install follow these steps:

1. Run installer. On linux run the bin file with `/path/to/.../installer.bin`.
2. On the welcome page, hit next
3. Enter credentials, download and install now, hit next
4. Under products to install select Vivado, hit next
5. For customizing the installation.

a. Under "Design Tools" select only "Vivado Design Suite"

b. Under "Devices" select only "Production Devices">"7 Series"

c. Under "Installation Options", make sure you have "Install Cable Drivers" selected. Hit next.

6. Agree to License agreements, hit next.
7. Select which directory to install to. Hit next. Begin installation.

Uploading Firmware

Once Vivado is installed run it. On linux you may need to source the settings file with `source /path/to/.../Xilinx/Vivado/202x.x/settings64.sh`, then you can run the command `vivado` to launch vivado.

A new project needs to be created. This can be a "dummy" project since we're just uploading firmware. Step 1 of this guide gives all the details needed to createae new project.

To load firmware onto the Nexys A7 using Vivado, plug the USB A to microUSB connection into the program port of the Nexys A7 board. See the hardware diagram for port locations. Follow these steps to upload firmware such that it persists when the board reboots:

1. **Open Vivado Hardware Manager and Connect to the Board**
2. Open Vivado and go to **Tools > Hardware Manager**. **Hardware Manager** should also be visible on the left sidebar of the project page.
3. In the **Hardware Manager** window, click **Open Target** and select **Auto Connect** or choose the appropriate JTAG or USB connection to connect to your board. If the board is connected properly, Vivado should automatically detect it.
4. **Convert the Bitstream to a Binary File** To program the flash, you need to convert the bitstream to a binary file. Nalu provides a `.bit` files, but we can convert the `.bit` file into a `.bin` file. Here's how you can do it:
5. After the bitstream is generated, open a the TCL Console (**Window>Tcl Console**) and use the following command to generate the `.bin` file from the `.bit` file:

   ```
   bash
    write_flash -force -file /path/to/output/firmware.bin -bitstream /path/to/input/firmware.bit
   ```

   Replace the paths with the appropriate file locations for your system.

   Example:

   ```
   bash
    write_flash -force -file /home/pioneer/vivado_stuff/Nexsys_Video_A7_For_HDSoc/HDSoC_eval_v938.bin -bitstream /home/pioneer/
   vivado_stuff/Nexsys_Video_A7_For_HDSoc/HDSoC_eval_v938.bit
   ```

6. **Add Configuration Memory Device** Once the `.bin` file is ready, go back to the **Hardware Manager** in Vivado and:
7. Right-click on your connected device in the **Devices** pane (in the Hardware Manager).
8. Click **Add Configuration Memory Device**.
9. In the dialog box, select the appropriate part for your flash device. For the Nexys A7, the part number will likely be something like **S25FL256Sxxxxxx0-SPI-x1_x2_x4**.
10. Click **OK** to confirm.
11. **Program the Flash Memory** After selecting the configuration memory device:
12. Vivado will prompt you to **program the flash memory**.
13. Select the **firmware `.bin` file** you generated earlier.
14. Click **Program** to start the flashing process. The process will take some time depending on the size of your firmware file and the connection speed.
15. **Power Cycle the Device** After programming is complete, power down the device and power it back on. Once powered on, you should see indicators (such as green lights on the HDSoC board) signaling that the firmware has been loaded successfully.

2.4 HDSoCv1 rev 2

2.4.1 Overview

The HDSoC is a high density digitizer system on a chip evaluation board. It provides a flexible digitization system. The high density part makes it appealing to for use in the ATAR DAQ, as the ATAR will have thousands of channels. You can read more in the HDSoC product sheet or on Nalu Scientific's HDSoC page.

2.4.2 Wired Connections

MMCX connector

The HDSoC's inputs (channel inputs and external trigger) and outputs (external trigger output) use a MMCX connectors. See the labeled picture and conceptual diagram to see where these inputs are on the board.

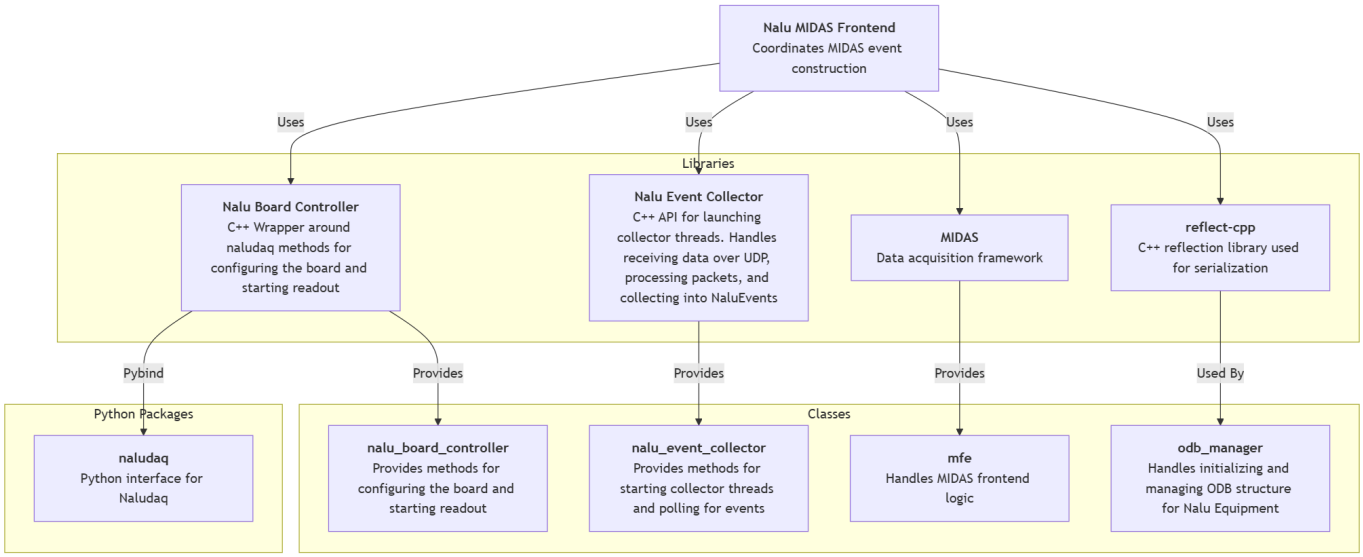
2.4.3 Configuration

See the HDSoC quickstart guide. You don't need to worry about using the SD card to boot the firmware if you've already uploaded it.

Last update: April 1, 2025

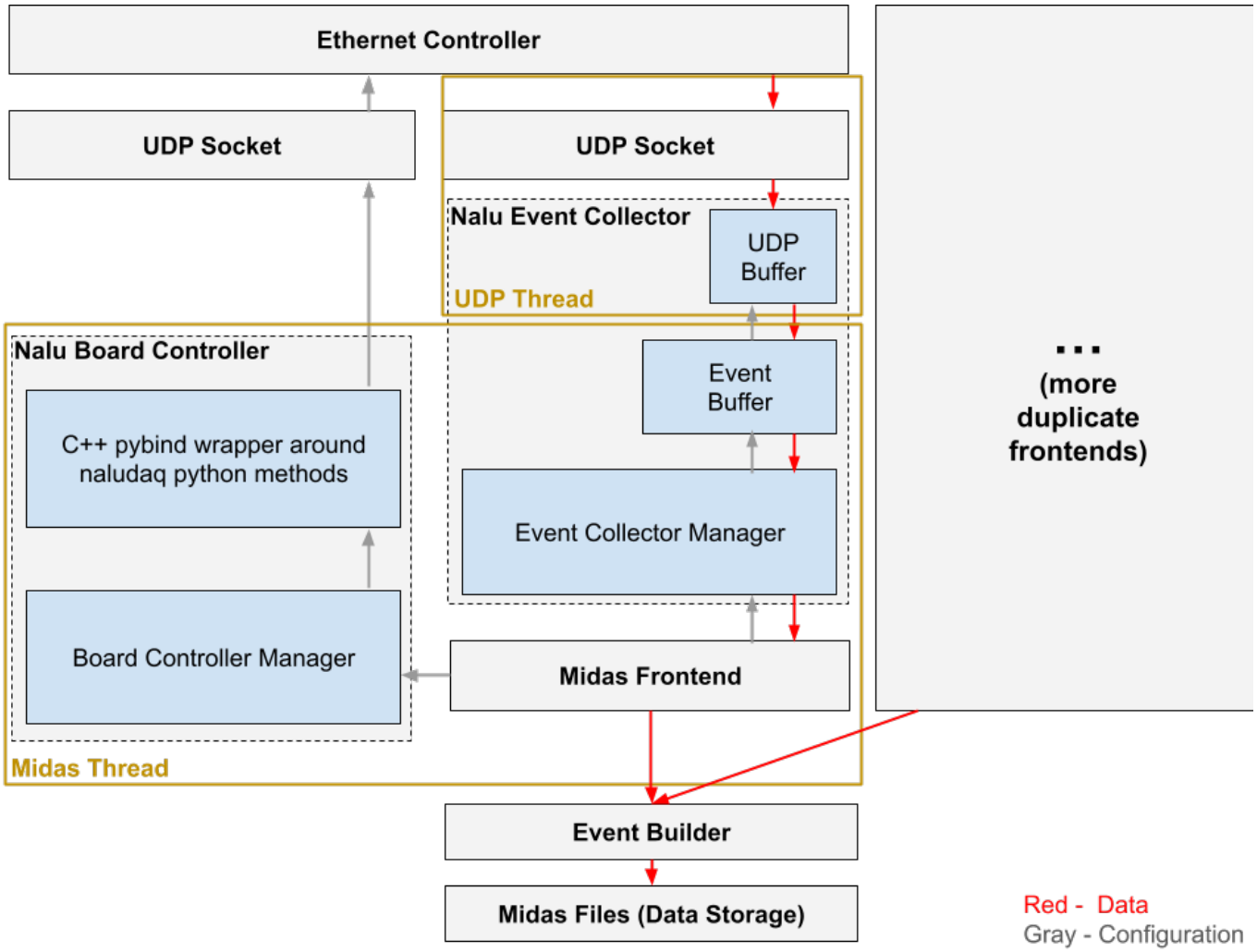
3. General Sofware Overview

3.1 Software Dependency Diagram



Note: an SVG version of this diagram with links to each repository is avaiable here.

3.2 Software Data and Control Flow Diagram



- **Ethernet Controller**: The systems ethernet controller which sockets are formed on.
- **UDP Socket**: Two sockets are constructed. One by naludaq python package to communicate with the board. And one by the UDP receiver to receive data.
- **Nalu Event Collector**: A library to collect events from a UDP socket receiving events from a nalu scientific board
- **UDP Buffer**: Receives UDP packets and puts them in a buffer to be processed.
- **Event Buffer**: Processes UDP packets into events and puts them in a buffer.
- **Event Collector Manager**: Manages interfacing with the buffers. I.e. getting data, configuration, etc.
- **Nalu Board Controller**: C++ methods to configure the nalu scientific board to prepare for data taking.
- **C++ pybind wrapper**: C++ wrapper around some methods from the naludaq python package.
- **Board Controller Manager**: Manages interfacing with the board from another C++ program.
- **Midas Frontend**: Handles run control, configuration via ODB, data bank creation, etc. Interfaces with the board controller and event collector.
- **Event Builder**: Builds events from data banks provided by potentially multiple frontends. Not necessary if only using one frontend.

3.3 ATAR_DAQ

3.3.1 Overview

The ATAR DAQ software is a midas frontend that interfaces with several other softwares (see software dependencies page) to read out events from a nalu scientific board while working within the midas framework.

3.3.2 Installation

Make sure you have installed the development tools, python packages, and midas before continuing. Furthmore, make sure you have set-up access to the pioneer experiment repository first.

1 **Clone the repository:**

```
git clone git@github.com:PIONEER-Experiment/atar_daq.git
```

2 **Set up the enviromment**

```
cd atar_daq/scripts/environment_setup
./detect_environment.sh
```

`environment_variables.txt` should have been generated. Check it to make sure it contains the write paths, for example, mine looks like this:

```
MIDASSYS=/home/pioneer/packages/midas
MIDAS_EXPTAB=/home/pioneer/packages/online/exptab
MIDAS_EXPT_NAME=ATAR_DAQ
ATAR_DAQ_DIR=/home/pioneer/packages/experiments/atar_daq
```

For more information on what the correct paths should look like, check TRIUMF's midas quickstart guide.

After verifying the paths are correct:

```
source ./setup_environment.sh --add
```

Note: If you want this environment to be setup everything a user logs in on your profile, add it to your bashrc with:

```
echo 'source /path/to/.../atar_daq/scripts/environment_setup/setup_environment.sh --add --quiet' >> ~/.bashrc
```

replacing the above with the correct path to the script.

3 **Installed additionally dependencies:**

These are the dependencies neeeded to build this software. The aforementioned dependencies are more general.

```
$ATAR_DAQ_DIR/scripts/install_libraries/install_dependencies.sh
```

4 **Build**

```
$ATAR_DAQ_DIR/scripts/build.sh --overwrite
```

3.3.3 Running

Starting a Midas Webpage

Midas provides a great user interface via their webpage. To start it, use the helper script:

```
$ATAR_DAQ/scripts/webpage_scripts/start_midas_webpage.sh
```

Then navigate to `localhost:8080` in your favorite web browser.

Note: For some reason, this script may need to be run twice sometimes for it to work properly.

Note: If the webpage doesn't appear, manually run `mhttpd` to debug the error output

Manually Starting the Frontend

I recommend doing this the first time to make sure everything is working properly.

```
$ATAR_DAQ_DIR/scripts/run.sh
```

Starting the Frontend as a Screen

Use the screening helper script

```
$ATAR_DAQ_DIR/scripts/screen_control/screen_frontend.sh -i {index}
```

Note: Exclusing `-i` flag will set the index to 0. This is the frontend index to support running multiple frontends.

to stop the screen

```
$ATAR_DAQ_DIR/scripts/screen_control/stop_screen.sh -i {index}
```

Starting the Frontend as Midas Program

See the g-2 modified DAQ Manual's guide for adding program startup scripts. For the start command, use the screen command above.

3.3.4 Configuration

See the ODB configuration page for a description of each ODB setting.

Last update: April 1, 2025

4. Software Dependencies

4.1 PIONEER Repository

Some installations are on the PIONEER repository, which requires access to pull from. See how to get access.

4.2 Development Tools

4.2.1 Overview

These tools include compilers, libraries, and other utilities that facilitate software development and installation.

4.2.2 Installation Guide

This guide should work for ALMA9. You can use `dnf` for ALMA9, but I prefer to work with `yum`

1 **Install yum package manager**

```
sudo dnf install yum
```

2 **Update the package index**:

```
sudo yum update
```

3 **Enable the EPEL repository**:

```
sudo yum install epel-release
```

4 **Install Development Tools and Dependencies**:

```
sudo yum groupinstall "Development Tools"
sudo yum install cmake gcc-c++ gcc screen subversion binutils libX11-devel libXpm-devel libXft-devel libXext-devel
```

5 **Install Python3**

```
sudo yum install python3-devel
```

6 **Install CMake from Source**

If the installed CMake version is **not** `>=3.23`, (you can check with `cmake --version`) follow these steps to install CMake manually:

6.1. **Remove Old CMake (If Installed)**

```
sudo yum remove -y cmake
```

Verify removal:

```
cmake --version  # Should return "command not found"
```

6.2. **Install Required Dependencies**

```
sudo yum groupinstall -y "Development Tools"
sudo yum install -y gcc gcc-c++ make openssl-devel
```

6.3. **Download and Install the Latest CMake from Source**

1. **Download the latest version** (Check Kitware's website for the latest version): `wget https://github.com/Kitware/CMake/releases/download/v3.29.0/cmake-3.29.0.tar.gz`
2. **Extract the archive**: `tar -xvzf cmake-3.29.0.tar.gz`
   `cd cmake-3.29.0`
3. **Build and install**: `./bootstrap`
   `make -j$(nproc)`
   `sudo make install`
4. **Verify the New Installation**: `cmake --version`

4.3 Python Packages

4.3.1 Overview

Although this DAQ is written mostly in C++, it interfaces with with Nalu Scientific's "naludaq" package, which is a python module used for interfacing with the board. However, our use case requires C++. To avoid rewriting all of Nalu Scientific's methods in C++, pybind is used to wrap some C++ methods around existing naludaq python methods.

4.3.2 Installation Guide

Install any needed packages with pip. Two that are needed are:

```
pip install pybind11 naludaq
```

4.4 ROOT

4.4.1 Overview

ROOT is an open-source data analysis framework developed by CERN. It is widely used in high-energy physics for data processing, statistical analysis, visualization, and storage. It is needed for some features of Midas.

4.4.2 Installation Guide

General installaiton guides are provided by ROOT at their Installing ROOT and Building ROOT from source pages.

Using `yum` Package Manager

1 **Enable the EPEL repository**:

```
sudo yum install epel-release
```

2 **Download and Install ROOT**:

```
sudo yum install root
```

Building from source

1 **Example building latest stable branch from source**

```
git clone --branch latest-stable --depth=1 https://github.com/root-project/root.git root_src
mkdir root_build root_install && cd root_build
cmake -DCMAKE_INSTALL_PREFIX=../root_install ../root_src # && check cmake configuration output for warnings or errors
```

```
cmake --build . -- install -j4 # if you have 4 cores available for compilation
source ../root_install/bin/thisroot.sh # or thisroot.{fish,csh}
```

Note: Adjust the ROOT version and the download URL as needed. Always check for the latest version on the official ROOT website. Furthermore, if you are not building from source you are installing precompiled binaries, which may not be up to date versions of ROOT. For specific versions, you may need to build root from source.

4.5 Midas

4.5.1 Overview

Midas is a data acquisition system used in high-energy physics experiments. Midas provides the following functionalities:

- Run control
- Experiment configuration
- Data readout
- Event building
- Data storage
- Slow control
- Alarm systems
- ... much more ...

4.5.2 Installation Guide

For a general Midas installation, you can follow this Linux Quick Start Guide. For the g-2 modified DAQ, we use a custom version of midas, which can be cloned and installed as follows:

1 **Set experiment name environment variable**

```
export MIDAS_EXPT_NAME=DAQ
```

2 **Create exptab file**

```
mkdir online
cd online
touch exptab
echo "$MIDAS_EXPT_NAME $(pwd) system" >> exptab
export MIDAS_EXPTAB=$(pwd)/exptab
```

3 **Install Midas**

```
cd ..
mkdir packages
git clone --recursive git@github.com:PIONEER-Experiment/midas-modified.git midas
cd midas
mkdir build
cd build
cmake ..
make -j$(nproc) install
cd ..
```

4 **Set `MIDASSYS` environment variable and add to path**

```
export MIDASSYS=$(pwd)
export PATH=$PATH:$MIDASSYS/bin
```

Note: you can hardcode the environment variables `MIDASSYS` (and add to path), `MIDAS_EXPTAB`, and `MIDAS_EXPT_NAME` by adding the appropriate commands to your .bashrc file. This way, the environment variables are set with each new terminal session for that user.

5 **(Optional) it is recommended to also install the midas python package**:

```
pip install -e $MIDASSYS/python --user
```

4.6 Nalu Board Controller

4.6.1 Overview

The Nalu Board Controller library is a C++ library that uses pybind to wrap around some existing naludaq python methods. It allows the midas frontend to use C++ methods to configure nalu scientific's boards. You can read more in on the github page for this library.

4.6.2 Installation Guide

This should be automatically installed when installing the ATAR DAQ midas frontend. If you want to manually install, see the installation guide on the github's readme.

4.7 Nalu Event Collector

4.7.1 Overview

The Nalu Event Collector library is a C++ library that handles event collection from a nalu scientific board at high data rates. It has been internally tested to handle data rates as high as 300 MB/s. The HDSoCv1 board can send at most ~55 MB/s (due to an internal hardware limit), so this software handles virtually all uses cases. The library can automatically handle collecting UDP packets from a nalu scientific board, parsing them, and collecting them into events. The library holds a buffer of these events that midas can pull from to form its own events. You can read more in on the github page for this library.

4.7.2 Installation Guide

This should be automatically installed when installing the ATAR DAQ midas frontend. If you want to manually install, see the installation guide on the github's readme.

4.8 reflect-cpp

4.8.1 Overview

Reflect-cpp is a C++ library that achieves some level of reflection in C++. For our use case, we just use it to convert C++ structs to json and json to C++ structs. This removes a lot of boiler plate code that would otherwise go into the ODB management. You can read more in on the github page for this library.

4.8.2 Installation Guide

This should be automatically installed when installing the ATAR DAQ midas frontend. If you want to manually install, see reflect-cpp's installation guide. I suggest compiling using cmake.

Last update: April 1, 2025

5. Software Add-ons

Last update: March 25, 2025

6. Midas' Online Data Base Configuration Parameters

6.1 ODB Basics

See the g-2 modified DAQ's ODB Basics section for some general midas ODB settings.

6.2 HDSoC DAQ specific ODB Configuration

6.2.1 Nalu Event Collector

Absolute Window Mask

Field	Description
Path	`/Equipment/HDSoC-{frontend #}/Settings/nalu_event_collector/nalu_packet_parser/abs_wind_mask`
Description	Bit mask on the absolute window position bits
Valid Values	any bit mask (ex. 63 = `0x3F` = `0011 1111)
Suggested Value	`63`

Channel Mask

Field	Description
Path	`/Equipment/HDSoC-{frontend #}/Settings/nalu_event_collector/nalu_packet_parser/chan_mask`
Description	Bit mask on the channel index bits
Valid Values	Any bit mask (ex. 63 = `0x3F` = `0011 1111)
Suggested Value	`63`

Channel Shift

Field	Description
Path	`/Equipment/HDSoC-{frontend #}/Settings/nalu_event_collector/nalu_packet_parser/chan_shift`
Description	Global shift in channel indices
Valid Values	Any positive integer
Suggested Value	`0`

Check Packet Integrity

Field	Description
Path	`/Equipment/HDSoC-{frontend #}/Settings/nalu_event_collector/nalu_packet_parser/check_packet_integrity`
Description	Whether or not each recieved UDP packet should be checked to see if it matches the expected format
Valid Values	`yes` or `no`
Suggested Value	`yes`

Note: You can get slight performance improvement by setting this to `no`. However, the performance with it set to `yes` should be good enough to handle any data rate the HDSoC can achieve.

Constructed Packet Footer

Field	Description
Path	`/Equipment/HDSoC-{frontend #}/Settings/nalu_event_collector/nalu_packet_parser/constructed_packet_footer`
Description	Footer bytes for packets constructed. Potentially useful to consumer programs looking for a specific byte sequence.
Valid Values	Any 4 byte unsigned integer
Suggested Value	`65535`

Constructed Packet Footer

Field	Description
Path	`/Equipment/HDSoC-{frontend #}/Settings/nalu_event_collector/nalu_packet_parser/constructed_packet_header`
Description	Header bytes for packets constructed. Potentially useful to consumer programs looking for a specific byte sequence.
Valid Values	Any 4 byte unsigned integer
Suggested Value	`43690`

Event Window Mask

Field	Description
Path	`/Equipment/HDSoC-{frontend #}/Settings/nalu_event_collector/nalu_packet_parser/evt_wind_mask`
Description	Bit mask on the event window position
Valid Values	Any bit mask (ex. 63 = `0x3F` = `0011 1111)
Suggested Value	`63`

Event Window Shift

Field	Description
Path	`/Equipment/HDSoC-{frontend #}/Settings/nalu_event_collector/nalu_packet_parser/evt_wind_shift`
Description	Global shift on event window values
Valid Values	Any positive integer
Suggested Value	`6`

Packet Size

Field	Description
Path	`/Equipment/HDSoC-{frontend #}/Settings/nalu_event_collector/nalu_packet_parser/packet_size`
Description	How big one "packet" of channel information is
Valid Values	Any positive integer
Suggested Value	`74`

Start marker

Field	Description
Path	`/Equipment/HDSoC-{frontend #}/Settings/nalu_event_collector/nalu_packet_parser/start_marker`
Description	Start marker a packet of channel information
Valid Values	Any string representation of hexidecimal
Suggested Value	0E

Stop marker

Field	Description
Path	`/Equipment/HDSoC-{frontend #}/Settings/nalu_event_collector/nalu_packet_parser/stop_marker`
Description	Stop marker a packet of channel information
Valid Values	Any string representation of hexidecimal
Suggested Value	FA5A

Timing Mask

Field	Description
Path	`/Equipment/HDSoC-{frontend #}/Settings/nalu_event_collector/nalu_packet_parser/timing_mask`
Description	Bit mask on timing information
Valid Values	Any string representation of hexidecimal
Suggested Value	`4095`

Timing Shift

Field	Description
Path	`/Equipment/HDSoC-{frontend #}/Settings/nalu_event_collector/nalu_packet_parser/timing_shift`
Description	Global shift in timing information
Valid Values	Any positive integer
Suggested Value	`12`

UDP buffer size

Field	Description
Path	`/Equipment/HDSoC-{frontend #}/Settings/nalu_event_collector/nalu_udp_receiver/buffer_size`
Description	Number of bytes in the UDP buffer before it throws an overflow error
Valid Values	Any positive integer
Suggested Value	`104857600`

UDP buffer size

Field	Description
Path	`/Equipment/HDSoC-{frontend #}/Settings/nalu_event_collector/nalu_udp_receiver/max_packet_size`
Description	Max number of bytes in a UDP packet that the UDP receiver will consider
Valid Values	Any positive integer
Suggested Value	`1040`

UDP Timeout

Field	Description
Path	`/Equipment/HDSoC-{frontend #}/Settings/nalu_event_collector/nalu_udp_receiver/timeout_sec`
Description	Number of seconds the UDP thread will wait before quitting due to timeout
Valid Values	Any positive integer
Suggested Value	`3`

Event Header

Field	Description
Path	`/Equipment/HDSoC-{frontend #}/Settings/nalu_event_collector/nalu_event_builder/event_header`
Description	Header for each constructed event. Potentially userful for consumer programs looking for specific byte sequences.
Valid Values	Any non-negative 4 byte integer
Suggested Value	`48059`

Event Trailer

Field	Description
Path	`/Equipment/HDSoC-{frontend #}/Settings/nalu_event_collector/nalu_event_builder/event_trailer`
Description	Header for each constructed event. Potentially userful for consumer programs looking for specific byte sequences.
Valid Values	Any non-negative 4 byte integer
Suggested Value	`61166`

Max Event in the Event Buffer

Field	Description
Path	`/Equipment/HDSoC-{frontend #}/Settings/nalu_event_collector/nalu_event_builder/max_events_in_buffer`
Description	Maximum number of events in the buffer. Should be set to a within the total RAM constraints of your system.
Valid Values	Any positive integer
Suggested Value	`50000`

Max Lookback

Field	Description
Path	`/Equipment/HDSoC-{frontend #}/Settings/nalu_event_collector/nalu_event_builder/max_lookback`
Description	Maximum number of events the event builder will retroactively look back at to try to find a match for a packet.
Valid Values	Any positive integer
Suggested Value	`2`

Note: Look backs only occur "shortly" after new events begin just in case packets are received out of order. See this file if you're curious.

Max Trigger Time

Field	Description
Path	`/Equipment/HDSoC-{frontend #}/Settings/nalu_event_collector/nalu_event_builder/max_trigger_time`
Description	The maximum number of clock ticks the board will report before restarting at 0.
Valid Values	Any positive integer
Suggested Value	`16777216`

Time Threshold

Field	Description
Path	`/Equipment/HDSoC-{frontend #}/Settings/nalu_event_collector/nalu_event_builder/time_threshold`
Description	The maximum number of clock ticks two packets can be seperated by and still be considered part of the same event
Valid Values	Any positive integer
Suggested Value	`500`

Note: If this is set too high or too low, events will stop forming and the frontend will crash. For most use cases, `500` is fine. For the HDSoC `there are about 23843000 clock ticks a second.

Event Collection Time

Field	Description
Path	`/Equipment/HDSoC-{frontend #}/Settings/nalu_event_collector/nalu_event_builder/event_collection_time_us`
Description	The amount of time in microseconds an event will allow new packets to be added to it before being marked complete (given that those packets have HDSoC trigger timestamps seperated by an amount less than the time threshold above). Self trigger mode only.
Valid Values	Any positive integer
Suggested Value	`10000`

Note: This will also act as a delay before events start forming. The first event must wait this time before. This setting is only relevant for the self triggering mode.

6.2.2 Nalu Board Controller

Channel DAC Value

Field	Description
Path	`/Equipment/HDSoC-{frontend #}/Settings/nalu_board_controller/nalu_capture/channels/{channel_index}/dac_value`
Description	The digital analog converter value for the channel
Valid Values	Any non-negative integer
Suggested Value	`0`

Note: These won't be applied unless Assign DAC values is set to yes.

Channel Enabled

Field	Description
Path	`/Equipment/HDSoC-{frontend #}/Settings/nalu_board_controller/nalu_capture/channels/{channel_index}/enabled`
Description	Whether that channel is enabled for readout
Valid Values	`yes` or `no`
Suggested Value	`yes`

Channel Trigger Value

Field	Description
Path	`/Equipment/HDSoC-{frontend #}/Settings/nalu_board_controller/nalu_capture/channels/{channel_index}/trigger_value`
Description	The threshold used for the internal or self triggering mode
Valid Values	Any non-negative integer
Suggested Value	`0`

Assign DAC Values

Field	Description
Path	`/Equipment/HDSoC-{frontend #}/Settings/nalu_board_controller/nalu_capture/assign_dac_values`
Description	Whether the DAC values are assigned and used by the board
Valid Values	`yes` or `no`
Suggested Value	`no`

Digitization Lookback

Field	Description
Path	`/Equipment/HDSoC-{frontend #}/Settings/nalu_board_controller/nalu_capture/lookback`
Description	The number of windows (32 samples) to "look back" after digitizing "write after trigger" more windows.
Valid Values	any positive integer between `1` and `62` (for the HDSoC)
Suggested Value	`4`

Note: See page 18 of the NaluScope manual for a better explanation of the lookback parameter

Digitization Lookback Mode

Field	Description
Path	`/Equipment/HDSoC-{frontend #}/Settings/nalu_board_controller/nalu_capture/lookback_mode`
Description	The number of windows (32 samples) to "look back" after digitizing "write after trigger" more windows.
Valid Values	`forced`, `trig` or empty (empty defaults to `trig`)
Suggested Value	""

Note: See page 17 of the NaluScope manual for a better explanation of the lookback mode parameter

Target IP Port

Field	Description
Path	`/Equipment/HDSoC-{frontend #}/Settings/nalu_board_controller/nalu_capture/target_ip_port`
Description	The IP address (with port) that the board will send data to over 1GbE
Valid Values	any valid IP with port
Suggested Value	`192.168.1.1:12345`

Trigger Mode

Field	Description
Path	`/Equipment/HDSoC-{frontend #}/Settings/nalu_board_controller/nalu_capture/trigger_mode`
Description	What trigger mode (external, self, or immediate) to use. External is from an external signal, self is based on a threshold for the channel, and immediate is automatic triggers as fast as possible.
Valid Values	`ext`, `self`, or `imm`
Suggested Value	`ext`

Digitization Windows

Field	Description
Path	`/Equipment/HDSoC-{frontend #}/Settings/nalu_board_controller/nalu_capture/windows`
Description	The number of windows (32 samples) that will be digitized
Valid Values	any positive integer between `1` and `62` (for the HDSoC)
Suggested Value	`4`

Note: See page 18 of the NaluScope manual for a better explanation of the windows parameter

Digitization Write After Trigger

Field	Description
Path	`/Equipment/HDSoC-{frontend #}/Settings/nalu_board_controller/nalu_capture/write_after_trig`
Description	The number of windows (32 samples) to continue to digitize following the trigger event
Valid Values	any positive integer between `1` and `62` (for the HDSoC)
Suggested Value	`4`

Note: See page 18 of the NaluScope manual for a better explanation of the write after trig parameter

Board IP

Field	Description
Path	`/Equipment/HDSoC-{frontend #}/Settings/nalu_board_controller/nalu_board/board_ip_port`
Description	The IP address (with port) of the board.
Valid Values	Any valid IP and port
Suggested Value	`192.168.1.59:4660`

Note: For the HDSoC, this is currently hardcoded to `192.168.1.59:4660`. I.e. you cannot change this.

Board Clock File

Field	Description
Path	`/Equipment/HDSoC-{frontend #}/Settings/nalu_board_controller/nalu_board/clock_file`
Description	Path to a clock file for the board
Valid Values	Any valid path or empty string
Suggested Value	""

Board Configuration File

Field	Description
Path	`/Equipment/HDSoC-{frontend #}/Settings/nalu_board_controller/nalu_board/config_file`
Description	Path to a configuration file for the board
Valid Values	Any valid path or empty string
Suggested Value	""

Host IP

Field	Description
Path	`/Equipment/HDSoC-{frontend #}/Settings/nalu_board_controller/nalu_board/host_ip_port`
Description	The IP address (with port) of the host. For communication with the board (not data).
Valid Values	Any valid IP
Suggested Value	`192.168.1.1:4660`

Board Model

Field	Description
Path	`/Equipment/HDSoC-{frontend #}/Settings/nalu_board_controller/nalu_board/board`
Description	The name of the board model used
Valid Values	Any valid board model, select from AARDVARCv3, HDSOCv1_evalr2, ASOCv3, AODSv2, TRBHM, AODSOC_AODS, AODSOC_ASOC, or UPAC32. However, only HDSOCv1_evalr2, ASOCv3, and TRBHM support UDP transfer.
Suggested Value	`HDSOCv1_evalr2`

6.2.3 Midas Parameters

Midas Data Bank Prefix

Field	Description
Path	`/Equipment/HDSoC-{frontend #}/Settings/midas_params/data_bank_prefix`
Description	The 2 letter prefix for midas data bank containing event data
Valid Values	Any 2 letter string
Suggested Value	`AD`

Note: Midas data banks can only be 4 characters. The first 2 characters we use for identification, the second 2 for indexing. So if there is 1 frontend, the data will be in `AD00` for example.

Webpage Initializing Frontend Status Color

Field	Description
Path	`/Equipment/HDSoC-{frontend #}/Settings/midas_params/init_color`
Description	The color the frontend status light will be while the frontend is initializing
Valid Values	Any 3 byte hex RGB value
Suggested Value	`#8A2BE2`

Logging Level

Field	Description
Path	`/Equipment/HDSoC-{frontend #}/Settings/midas_params/log_level`
Description	The log level for information printed by the frontend software
Valid Values	`debug, info, warn, error`
Suggested Value	`debug`

Note `debug` will show all output, `info` will show most ouput, `warn` will only show warnings and errors, `error` will only show errors.

Minimum Bytes to Trigger on

Field	Description
Path	`/Equipment/HDSoC-{frontend #}/Settings/midas_params/min_bytes_to_trigger_on`
Description	The minimum bytes needed to be present in the UDP buffer before the midas thread will trigger collection
Valid Values	any non-negative integer
Suggested Value	`1000`

Note: Higher values may see some performance gain, at the cost of events coming in batches

Polling Interval in Microseconds

Field	Description
Path	`/Equipment/HDSoC-{frontend #}/Settings/midas_params/polling_interval_us`
Description	The minimum number of microseconds between two consecutive triggers
Valid Values	any non-negative integer
Suggested Value	`1000`

Note: Higher values may see some performance gain, at the cost of events coming in batches

Webpage Ready Status Color

Field	Description
Path	`/Equipment/HDSoC-{frontend #}/Settings/midas_params/ready_color`
Description	The color the frontend status light will be while the frontend is ready
Valid Values	Any 3 byte hex RGB value
Suggested Value	`greenLight`

Midas Timing Bank Prefix

Field	Description
Path	`/Equipment/HDSoC-{frontend #}/Settings/midas_params/timing_bank_prefix`
Description	The 2 letter prefix for midas data bank containing event data
Valid Values	Any 2 letter string
Suggested Value	`AD`

Note: Midas data banks can only be 4 characters. The first 2 characters we use for identification, the second 2 for indexing. So if there is 1 frontend, the timing information will be in `AT00` for example.

Last update: September 9, 2025

7. Scripts

7.1 Top Level

7.1.1 build.sh

Field	Description
Path	`$ATAR_DAQ_DIR/scripts/build.sh`
Description	Builds the project using CMake and Make. If the `--overwrite` flag is used, it cleans the previous build first.
Flags	`-o, --overwrite` → Remove the existing build directory before building.
Example Usage	`./build.sh` `./build.sh --overwrite`

7.1.2 run.sh

Field	Description
Path	`$ATAR_DAQ_DIR/scripts/run.sh`
Description	Runs the `frontend` executable. Supports running in background mode, with debugging, and setting an index.
Flags	`--debug` → Runs the executable in GDB. `-i <number>` → Specifies an index (default: 0). `--help` → Displays usage help.

Example Usage	`./run.sh`
	`./run.sh --debug`
	`./run.sh -i 2`

7.2 Data management

7.2.1 delete_data.sh

Field	Description
Path	`$ATAR_DAQ_DIR/scripts/delete_data.sh`
Description	Deletes MIDAS data files in the experiment directory. If `--dry-run` is used, it lists files without deleting them.
Flags	`--dry-run` → Lists files that would be deleted without removing them.
Example Usage	`./delete_data.sh` `./delete_data.sh --dry-run`

7.2.2 find_data_dir.sh

Field	Description
Path	`$ATAR_DAQ_DIR/scripts/find_data_dir.sh`
Description	Finds the experiment data directory and writes it to `experiment_dir.txt`.
Flags	*(None)*
Example Usage	`./find_data_dir.sh`

7.3 Environment Setup

7.3.1 clear_environment.sh

Field	Description
Path	`$ATAR_DAQ_DIR/scripts/environment_setup/clear_environment.sh`
Description	Clears the MIDAS environment variables by unsetting `MIDASSYS`, `MIDAS_EXPTAB`, and `MIDAS_EXPT_NAME`.
Flags	*(None)*
Example Usage	`./clear_environment.sh`

7.3.2 detect_environment.sh

Field	Description
Path	`$ATAR_DAQ_DIR/scripts/environment_setup/detect_environment.sh`
Description	Searches for the `midas` directory and `exptab` file, sets `MIDASSYS`, `MIDAS_EXPTAB`, and `MIDAS_EXPT_NAME`, and saves them to `environment_variables.txt`.
Flags	*(None)*
Example Usage	`./detect_environment.sh`

7.3.3 setup_environment.sh

Field	Description
Path	`$ATAR_DAQ_DIR/scripts/environment_setup/setup_environment.sh`
Description	Reads `environment_variables.txt` to set environment variables and optionally adds `MIDASSYS/bin` to the `PATH`.
Flags	`-a, --add` → Adds `MIDASSYS/bin` to `PATH` if `MIDASSYS` is set. `-q, --quiet` → Suppresses all output. `-h, --help` → Displays usage help.

Example Usage	`./setup_environment.sh`
	`./setup_environment.sh --add`
	`./setup_environment.sh --quiet`

7.4 Install Libraries

7.4.1 install_dependencies.sh

Field	Description
Path	`$ATAR_DAQ_DIR/scripts/install_libaries/install_dependencies.sh`
Description	Installs all required dependencies by calling their respective installation scripts.
Flags	(None)
Example Usage	`./install_dependencies.sh`

7.4.2 install_reflect_cpp.sh

Field	Description
Path	`$ATAR_DAQ_DIR/scripts/install_libaries/install_reflect_cpp.sh`
Description	Installs the Reflect-C++ library, allowing customization of installation directory, C++ standard, and build type.
Flags	`-o, --overwrite` → Removes the previous build before installing. `-p, --prefix <path>` → Specifies the installation directory (default: /usr/local). `-s, --cxx-standard <version>` → Sets the C++ standard (default: 20). `-b, --build-type <type>` → Sets the build type (default: Release).

Example Usage	`./install_reflect_cpp.sh`
	`./install_reflect_cpp.sh --overwrite`
	`./install_reflect_cpp.sh --prefix /opt/custom`
	`./install_reflect_cpp.sh --cxx-standard 17 --build-type Debug`

7.5 ODB

7.5.1 set_enabled_channels.py

Field	Description
Path	`$ATAR_DAQ_DIR/scripts/odb/set_enabled_channels.py`
Description	Updates the enabled channels in the ODB by setting the number of enabled channels from the start (0) and disabling the rest.
Flags	`num_enabled_channels` → The number of enabled channels (between 0 and 32).
Example Usage	`./set_enabled_channels.py 16` Enables the first 16 channels and disables the rest.

7.6 Screen Control

7.6.1 screen_frontend.sh

Field	Description
Path	`$ATAR_DAQ_DIR/scripts/screen_control/screen_frontend.sh`
Description	Starts a specified script inside a `screen` session, optionally passing an index value.
Flags	`-i` → Index for the session name (defaults to 0).
Example Usage	`./screen_frontend.sh -i 1` Starts the script `run.sh` inside a `screen` session with index 1.

7.6.2 stop_screen.sh

Field	Description
Path	`$ATAR_DAQ_DIR/scripts/screen_control/stop_screen.sh`
Description	Stops a running `screen` session specified by the index.
Flags	`-i` → Index for the session name (defaults to 0).
Example Usage	`./stop_screen.sh -i 1` Stops the `screen` session with index 1.

7.7 Webpage Scripts

7.7.1 start_midas_webpage.sh

Field	Description
Path	`$ATAR_DAQ_DIR/scripts/webpage_scripts/start_midas_webpage.sh`
Description	Starts processes in the background, each inside a `screen` session, using process names from a `screen_names.txt` file.
Flags	None.
Example Usage	`./start_midas_webpage.sh` Starts all processes defined in `screen_names.txt`.

7.7.2 stop_midas_webpage.sh

Field	Description
Path	`$ATAR_DAQ_DIR/scripts/webpage_scripts/stop_midas_webpage.sh`
Description	Stops processes running in `screen` sessions based on names listed in `screen_names.txt`.
Flags	None.
Example Usage	`./stop_midas_webpage.sh` Stops all processes defined in `screen_names.txt`.

Last update: April 8, 2025

8. Debugging Common Errors

Last update: March 25, 2025

9. Miscellaneous

9.1 Additional Notes

If you're feeling desperate (or perhaps lucky), you can sift through Jack Carlton's work notes. **I warn you that these are not well organized and contain lots of information not about this DAQ**. However, they do contain some documentation of my assembly and troubleshooting of this DAQ.

9.2 Initialism Cheatsheet

See the g-2 modified DAQ's initialism cheatsheet, many of the initialisms are still applicable to this DAQ.

9.3 Networking Tutorial

See the g-2 modified DAQ's networking tutorial for basics. There are many additional (and probably better) online resources as well.

9.4 Useful Midas Information

See the g-2 modified DAQ's midas information page for some general midas tips. There is much more information available on TRIUMF's Midas Wiki page.

9.5 Getting Access to the PIONEER repository

See the g-2 modified DAQ manual's accessing the pioneer repository section and setting up a github ssh token section.

9.6 Port Forwarding an SSH Connection

See the g-2 modified DAQ's port forwarding an SSH connection section.

9.7 Using Screens in Linux

See the g-2 modified DAQ's using screens in linux page.

Last update: April 1, 2025