EOS Documentation

Release 4

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CONTENTS

CHAPTER

ONE

SYSTEM COMPONENTS

A typical Single Quantum EOS closed cycle single-photon detection system compromises the following:

- Cryostat with detectors and cold head.
- Air- or water-cooled compressor. The compressor provides high-pressure helium gas to the cold head and includes a cold head drive unit to provide power to the cold head motor. The environmental and electrical requirements can be found in the installation protocol (see appendix).
- Pressurized gas lines. The gas lines connect the compressor and the cold head. Helium gas is supplied from the compressor to the cold head and returned from the cold head to the compressor. A gas line is flexible and includes quick disconnect fittings on both ends.
- Atlas SNSPD driver that controls the detectors, reads the detector countrates and the temperature of the cryostat.
- Accessories: coaxial cables, DC Fischer cable, Ethernet cable, Usb to Ethernet adapter and power supply.

Optional components are:

- Turbo Pumping station.
- Polarization controllers.
- Housing rack.

In addition we advise the users to have an optical fiber cleaning kit and a fiber inspection microscope.

CHAPTER

TWO

SAFETY

High gas pressure is present within the system and can cause serious injury if suddenly vented. Follow specified procedures when assembling and disassembling the self-sealing gas couplings on the flexible gas lines. Use caution to avoid puncturing the flexible gas lines.

Follow these instructions to ensure operator safety:

- Disconnect all components from the electrical power source before making component interconnections.
- Shut off the compressor power (with the switch) before connecting it to a power source.
- Do not connect the cold head power cable to the cold head while the compressor is running.

CHAPTER

THREE

INSTALLATION

Important: Before the system installation, please read the technical manual of the compressor.

3.1 Setting up

The compressor has a transport bolt installed for shipping, before use this has to be removed. To remove the transport bolt raise the left rear corner of the compressor to locate the hex head shipping bolt. Support the compressor base with blocks just high enough to gain access to the bolt.

Caution: Do not raise the corner more than 50 mm (2”).

Use a 17-mm wrench to remove the bolt and retain the bolt for future use. The shipping bolt must be reinstalled prior to shipment.

Place the cryostat on a stable surface. The cryostat does not require to be positioned on an optical table. The compressor must remain upright all the time with a level of less than 5 degree. Space and electrical requirements are described in the installation protocol (see appendix) and the compressors manual.

The optional HiCube 80 Eco pumping station has a transport protection lock and has PE-foam padding that protects the pump during shipment. The hexagon nut has to be loosened and the foam padding has to be removed before first use.

3.2 Power requirements

- **HC-4A Zephyr air-cooled helium compressor** 1 phase power, 200 V, 220 V, 230/240 V at 50 Hz or 220 V at 60 Hz Typical power consumption is 3.0 kW at 50 Hz or 3.4 kW at 60 Hz NEMA L6-20P power plug Power should be provided through a separately fused safety switch with 20A SLO-BLO fuses
- **HC-4E water-cooled compressor** 1 phase power, 200 V, 230/240 V at 50 Hz or 208/230 V at 60 Hz Typical power consumption is 2.6 kW at 50 Hz or 3.0 kW at 60 Hz
- The Atlas SNSPD driver operates at 100-240 V, uses a maximum of 70 W and should only be used with the supplied power adapter. The 2 and 4 channel drivers use a 2.5 A fuse and the 8 channel driver uses a 3.15 A fuse. The screw cap fusholder is accessible from the back of the driver.
- HiCube 80 Eco pumping station. The pumping station has a switch to switch if between different voltage range. Switch position “115” is for the voltage raine 90..126 V;50/60 Hz and switch position “230” is for 180..254 V;50/60 Hz.

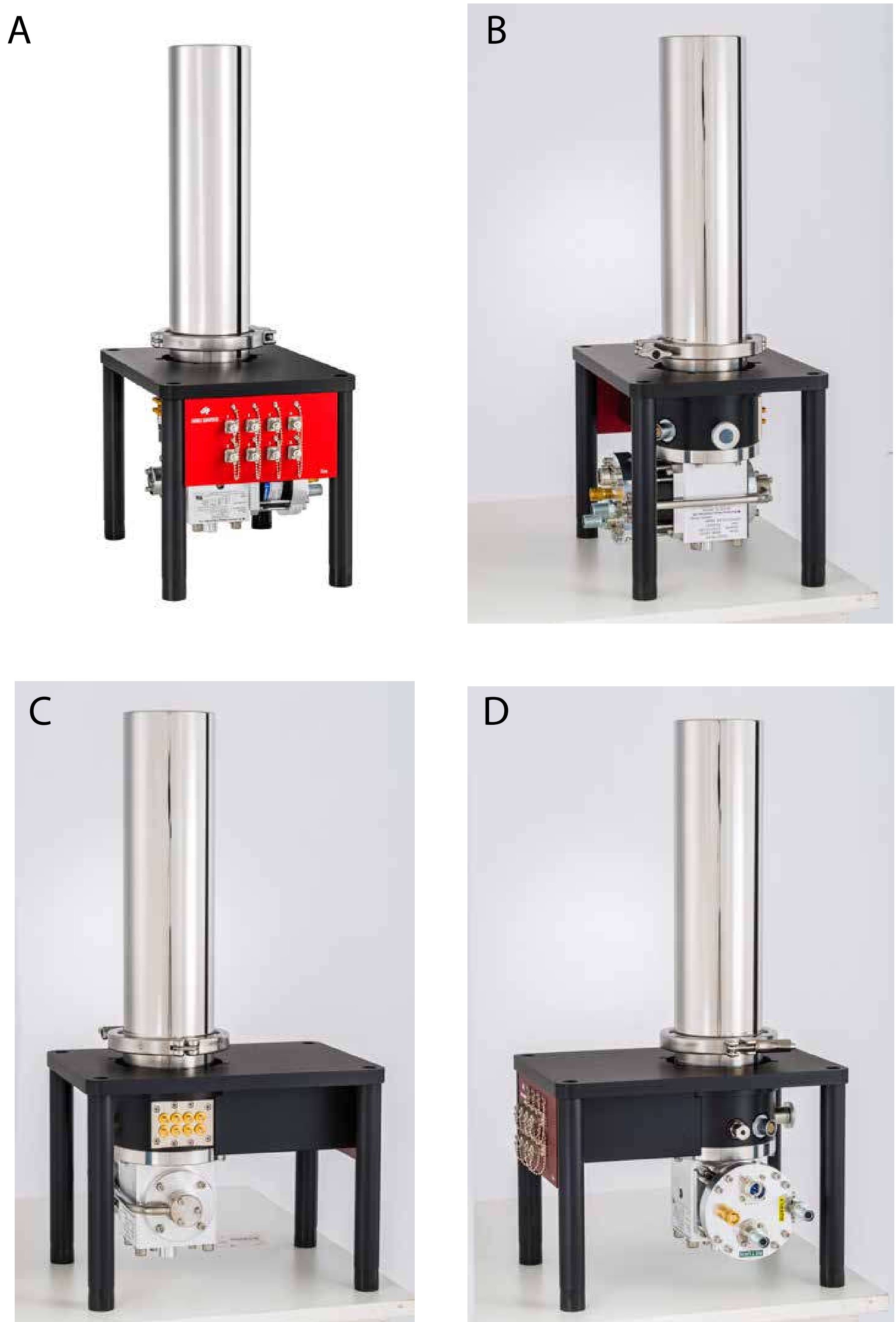

Figure 3.1: Pictures of the EOS cryostat. (A) Front view of the system showing the fiber inputs. (B) rear view of the system showing the vacuum port and the dc connector. (C) Left view of the system showing the sma connections. (D) Right view of the system showing the ports for connecting the helium tubes and the connector for the cold head motor.

3.3 Compressor environmental requirements

3.3.1 Ambient conditions

The HC-4A air-cooled compressor requires ambient an air temperature of 4 - 32 °C (40 - 90 °F). Cooling capacity may degrade if ambient temperature is above 28 °C (82 °F). Do not block the inlet or the exhaust panels of the compressor. The HC-4A air-cooled compressor will add approximately 3.2kW of heat to the room air when operating so adequate cooling is required.

Keep at least 600 mm (24") space at the top, front, back, left and right sides of the air-cooled compressor for air flow and maintenance. Air leaving from the top side of the compressor must be able to flow away from the compressor without going down toward the air inlets.

3.3.2 Cooling water

The HC-4E water-cooled compressor requires an air temperature of 4 - 40 °C (40 - 104 °F). Cooling capacity may degrade if ambient temperature is above 28 °C (82 °F). The cooling water inlet needs to provide a flow rate of 2.7 L/min and a water temperature of 4-27 °C (40-80 °F). For more detailled information about the cooling water requirements please check the manufacturer's manual.

3.4 System interconnections

The cryostat needs to be evacuated before starting the cooldown cycle. Connect a turbo pumping station to the cryostat's vacuum port using a corrugated stainless steel hose (see Figure 3.1). The vacuum port of the system has a KF-16 vacuum fitting. Untighten the transport lock before first time use of the turbo pumping station. Please also refer to the vacuum pump manual.

3.5 Gas Lines

To interconnect the helium supply and return gas-Iines, follow this sequence:

1. Connect the return line to the compressor return fitting
2. Connect the supply line to the compressor supply fitting
3. Connect the return line to the cold head return fitting
4. Connect the supply line to the cold head supply fitting

To make each connection, tighten the fittings several turns by hand. Use two wrenches to tighten the fittings, and support the gas lines to prevent gas leakage during assembly. Please keep the dust caps for future use. Cold Head Power Make sure the power of the compressor is off. Connect the supplied cable between the cold head and the cold head power connector on the drive unit.

3.6 SNSPD driver

The Atlas electronic driver should be connected in the following sequence:

1. Connect the electrical feedthroughs on the cryostat to the SMA connectors labelled "input" at the front side of the electronic driver with the blue SMA cables;

2. Connect the cryostat to the electronic driver with the Fischer cable ;
3. Connect the power supply to the electronic driver;
4. Connect the USB to Ethernet adapter to the computer
5. Connect the Network cable between the adapter and the electronic driver.

The SMA connectors labelled “output” at the front side of the electronic driver give the direct output of the amplifiers. They can be used to connect to an external counter or a TCSPC device. The driver also has an internal counter, the countrates can be read in the software.

3.7 Optical fibers

Clean the optical fibers and the inside of the fiber connector. Connect the optical fibers to the fiber ports (FC connectors). For inspecting the fibers it is a advised to use a fiber microscope.

Tip: Minimize reconnecting fiber patch cables to the front panel to avoid damaging the bulkhead connectors.

CHAPTER

FOUR

OPERATION

4.1 Cryostat cool down

4.1.1 Evacuation

Prior to cool down, connect a turbo molecular or diffusion pump to the valve or port and evacuate the shroud to base pressure (about 1E-5 mbar). It is possible to keep pumping during operation. Outgassing and O-ring permeation will cause the pressure to rise slowly over time; therefore, periodic re-evacuation may be necessary. Re-evacuation is required when the minimum temperature that can be reached begins to increase.

4.1.2 Cool down

1. Switch on the electronic driver, start the software (see *The WebSQ Interface*) and observe the temperature reading. The typical temperature value ranges from 290 K to 300 K.
2. Choose the proper frequency (50 or 60 Hz) using the toggle switch located on the cold head drive unit. Make sure that the toggle switch marked "cold head drive switch" located at the lower right rear of the compressor is turned off. This switch is only used during maintenance, and should remain off during normal operation. The main power switch on the front panel of the compressor should now be turned on, followed by the drive switch on the front panel. The temperature should begin to drop within a few seconds. The base temperature is reached after about 5 hours.

4.1.3 Warm-up

To shutdown the system, turn off the compressor and the electronic driver. If the interconnecting gas lines need to be removed for any reason, allow the system to completely warm-up to room temperature before the gas lines can be disconnected. This takes approximately 5 hours.

CHAPTER

FIVE

SOFTWARE OPERATION

The following steps will guide you through the features of the WebSQ driver software running on your Single Quantum system.

The software was developed to make your work as convenient and efficient as possible. We achieve this by omitting any software installation on your computer as it is controlled through the Web Browser of your choice!

This innovative concept makes the control of the superconducting single photon detectors

- operating system independent,
- device independent,
- location independent,
- stable,
- multi-user access friendly, and,
- long term operational, as only backwards compatible web standards are used.

All these features together allow for a complete new way of using scientific equipment:

- No time is wasted of installing and setting up proprietary software and drivers which only run on a limited set of operating systems.
- The operator can use a mobile device such as a tablet or a mobile phone right at the work place for a faster and more convenient alignment procedure.
- The software is running where you are - it runs at same time on multiple browsers on multiple platforms.
- You can change it! The software is Open Source and allows you to change it to your wishes allowing integration into the most demanding applications.

5.1 Connection

The WebSQ driver is connected over an Ethernet connection either directly with a computer or through a router.

Its default configuration is:

- IP Address: 192.168.1.1 or sq.local
- Runs a DHCP server providing the address range 192.168.1.5 till 192.168.1.200
- Username: user
- Password: websq

If you connect directly to your computer just enter the IP address (192.168.1.1) in your browser and you can start working. Or even more conveniently, it is also possible to access the WebSQ driver through its default name:

```
sq.local/
```

with your browser. In general, you can reach the system at 'hostname.local/', the hostname can be changed in the 'Networking' tab in 'Config' (wrench symbol on top of the page).

If you are connecting to a router with Wifi access you can directly access the driver with any computer or mobile device. Please make sure that in this case you have to disable the DHCP server ('Networking' tab). For more details about networking configuration, see *Network Setup*.

5.2 The WebSQ Interface

5.2.1 Login

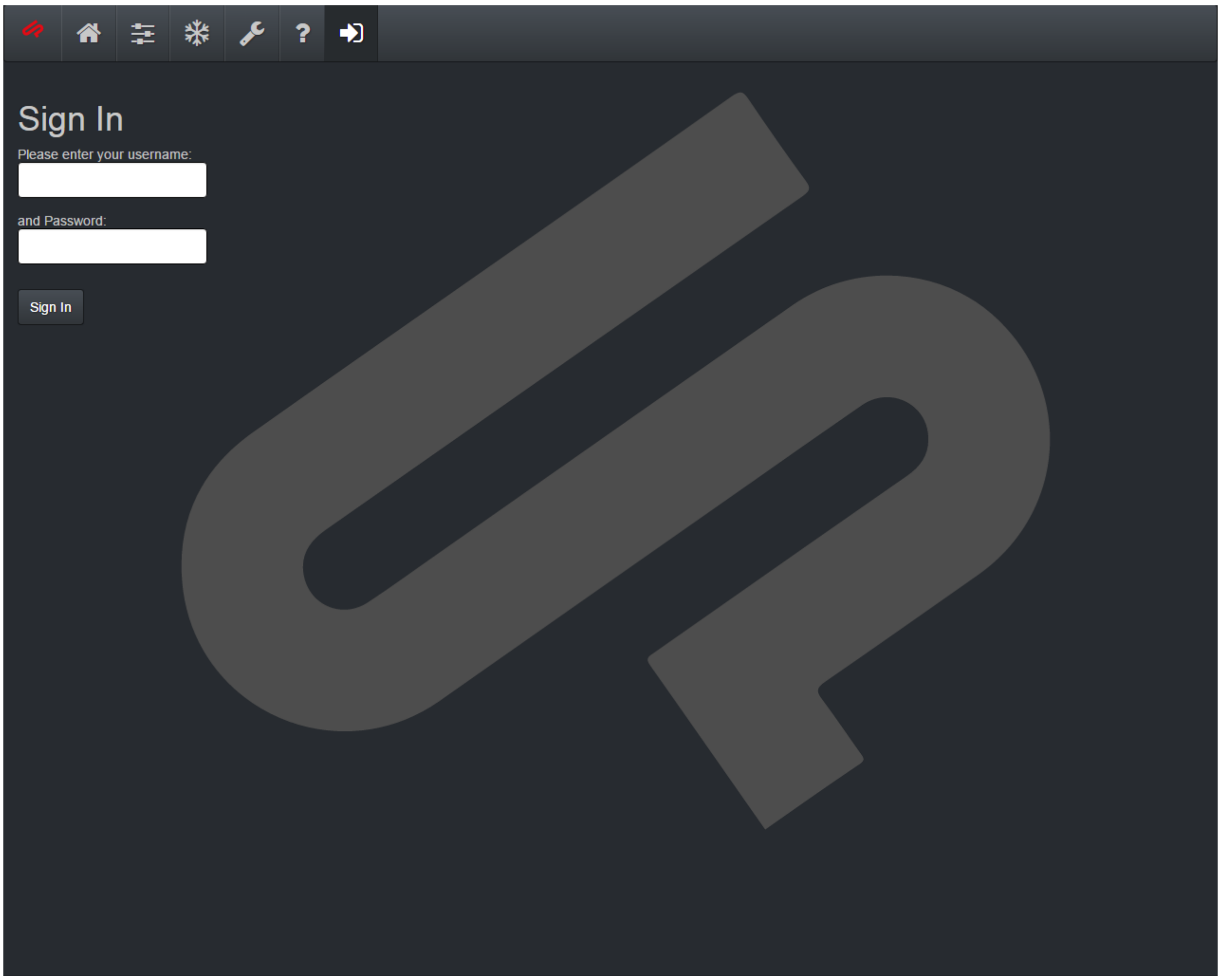

Figure 5.1: Login Screen.

Once you have successfully connected a browser with your WebSQ driver you will see the above login prompt. For the first login you should use the standard credentials:

- Username: user

- Password: websq

You can change the username/password in the 'Access Control' tab in 'Config' (wrench symbol on top of the page).

The icons on the top of the page allow you to navigate between different windows:

- Home window where the detected photons are displayed and the most important settings can be accessed.
- Tune window to find optimal working conditions of the SNSPDs.
- ✱ Temperature window showing the temperature history of the cryostat.
- Configuration window.
- ? Help window where you find the manual and example code.
- / Login/Logout button.
- Shutdown button.

5.2.2 Home Window

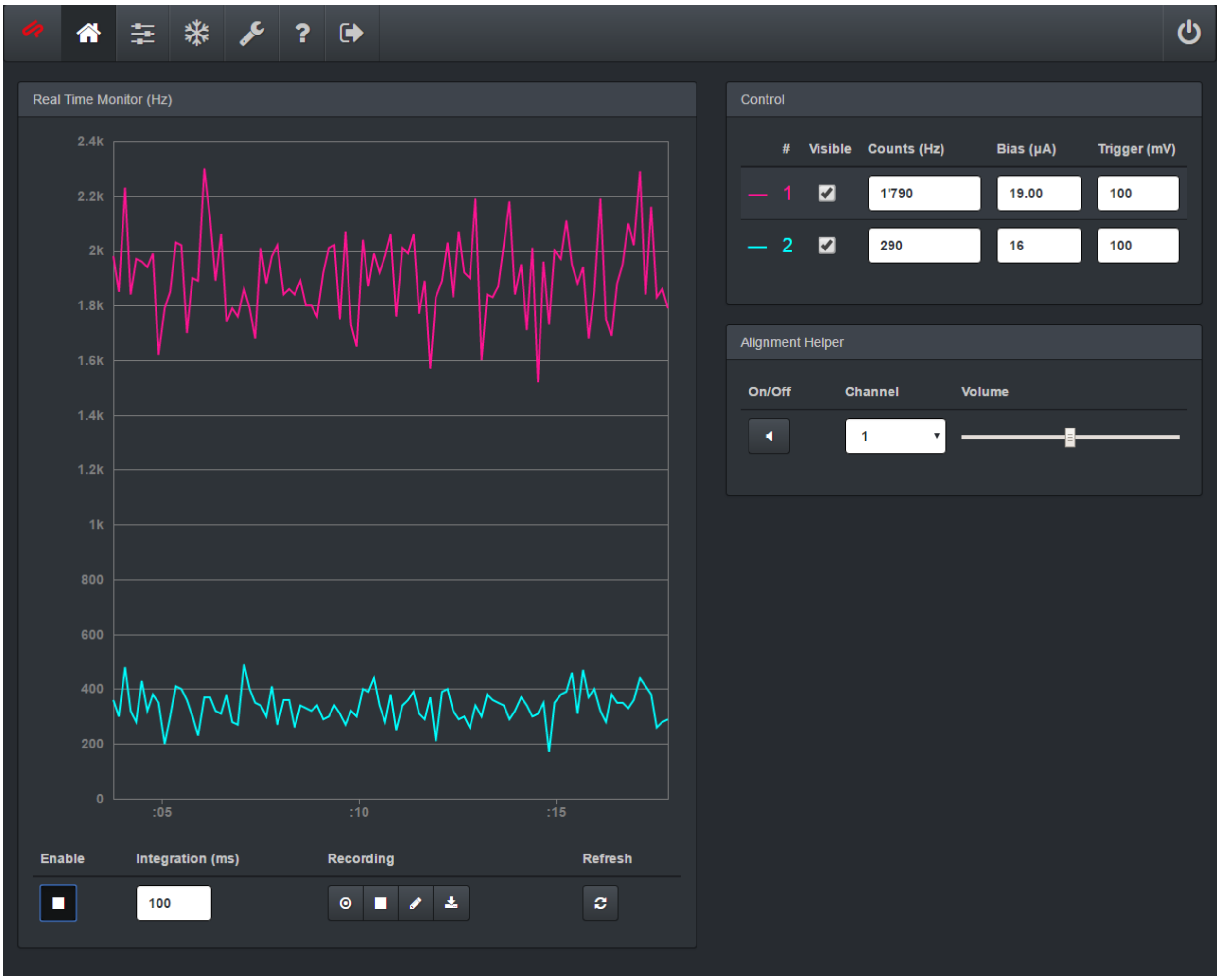

Figure 5.2: Home Window

The home window displays the most important features used to control and monitor the function of the superconducting nanowire single photon detectors (SNSPD). It is divided into three groups:

- Real Time Monitor
- Control
- Alignment Helper

Real Time Monitor.

The Real Time Monitor window displays a time trace of the detected photons for each detector. A right click on the plot window opens a a dialog to choose 'Automatic' or 'Manual' Y-axis scaling.

There are four input groups underneath the plot window:

- The ▶ symbol is used to switch on the detection system by enabling the SNSPDs' bias currents.
- The input field sets the photon counting integration time.
- The Recording group (⦿ ■✎⤓) allows you to record the measured counts and download them to your computer:
  - ⦿ Starts the recording (Limit: 1'000'000 lines based on first in last out),
  - ■ Stops recording and deletes the stored file,
  - ✎ Allows to name the file and add comments,
  - ⤓ Downloads the recorded file.
- the ⟳ button clears the plot window from old data points. That's especially helpful to speed up automatic rescaling of the y-axis.

Tips for Keyboard shortcuts: Three preset values of the integration time (10, 100, 1000 ms) are mapped onto the keys 'q', 'w', and 'e'. The 'delete key' clears the plot window.

Control

This window shows the counted photons, allows to control the SNSPDs' bias currents, and the corresponding trigger levels. The column names **Visible**, **Bias Current (μA)**, **Trigger Level (mV)**, as well as the **Photon Counts** are all clickable.

Click on:

- **Counts**: Shows the photon counts large on the screen - ideal for alignment.
- **Visible**: Toggles the visibility of the plot lines.
- **Bias Current (μA)**: Opens a dialog to select the increments.
- **Trigger Level (mV)**: Opens a dialog to select the increments.

Tip: Click on a photon counts field and the value will be displayed large on the screen - ideal for alignment.

Alignment Helper

Clicking on the 🔈 symbol activates a tone. Its frequency is proportional to the photon counts of the selected channel.

To give the most accurate feedback there is a photon count rollover implemented (standard value: 1 MCnts). When more photons than the rollover value are measured the audio frequency rolls over and starts from the lowest tone again. The rollover value and the tone type (square, sine, sawtooth, triangle) can be changed in 🔧 under the *Sound* tab.

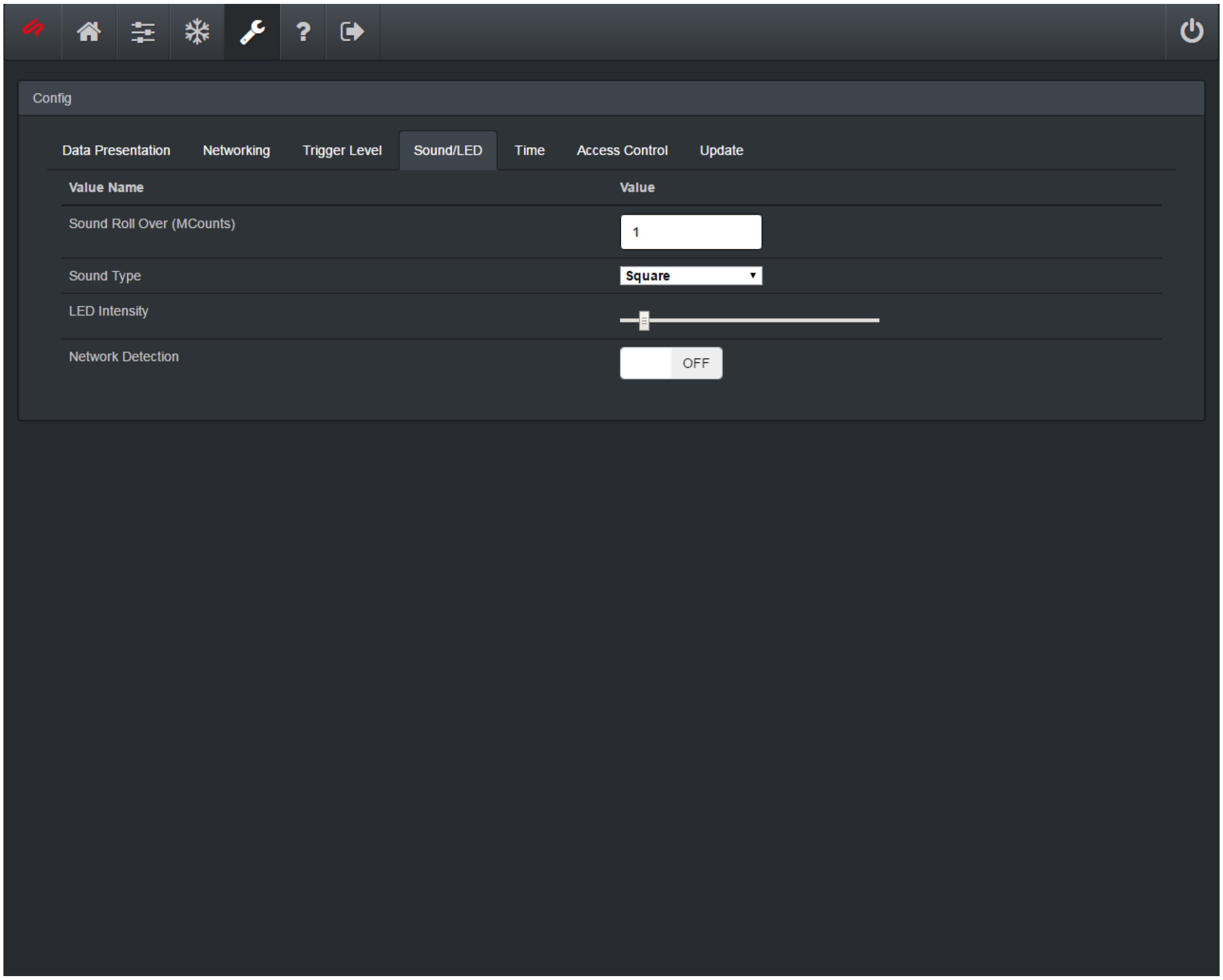

Figure 5.3: Setting for the sound rollover and for the LED in the on/off button.

5.2.3 Detector operation

A SNSPD needs a properly set bias current to operate at peak performance - highest detector efficiency is achieved when the SNSPD is biased closely to the critical-current. The critical current represents the transition between the superconductive and the resistive state of the detector. Once the detector is biased with a current higher than the critical current, a sharp rise of the detector voltage is observed. For example, the critical current of detector 2 is 11.40 μA as shown on the tooltip in Figure 5.4. The detector tuning tab helps finding the proper bias current. The easiest way is the Auto Search tool, see Figure 5.5. This can be evoked by clicking on the magnifying glass. In the Auto Search dialog you specify the required dark count rate per detector. It is important to make sure that no light is reaching the detector during this search. If the Auto Search can not find the right bias-current it will be indicated with a "-" sign.

Figure 5.4: Detector Tuning tab showing measured current-voltage and current-counts graph. Tooltips provide the precise measured data at the mouse pointer's position.

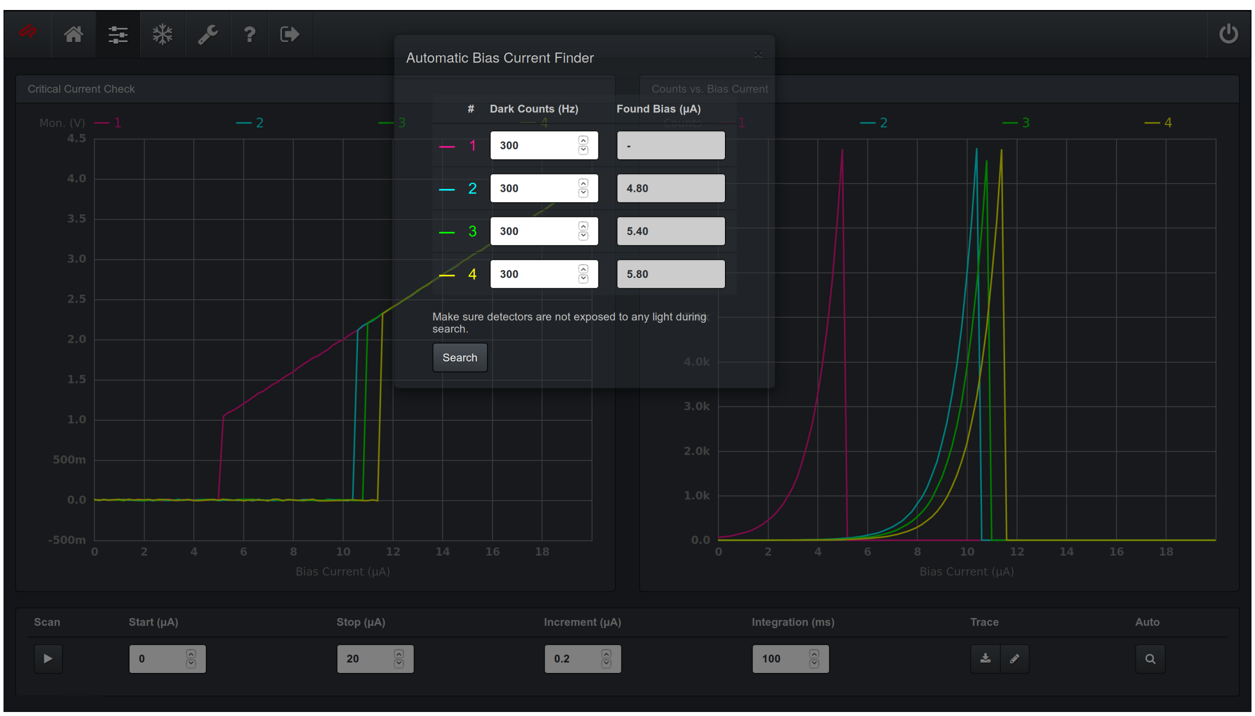

Figure 5.5: Detector current auto search dialog. If a bias current can not be found it is indicated with a "-" sign.

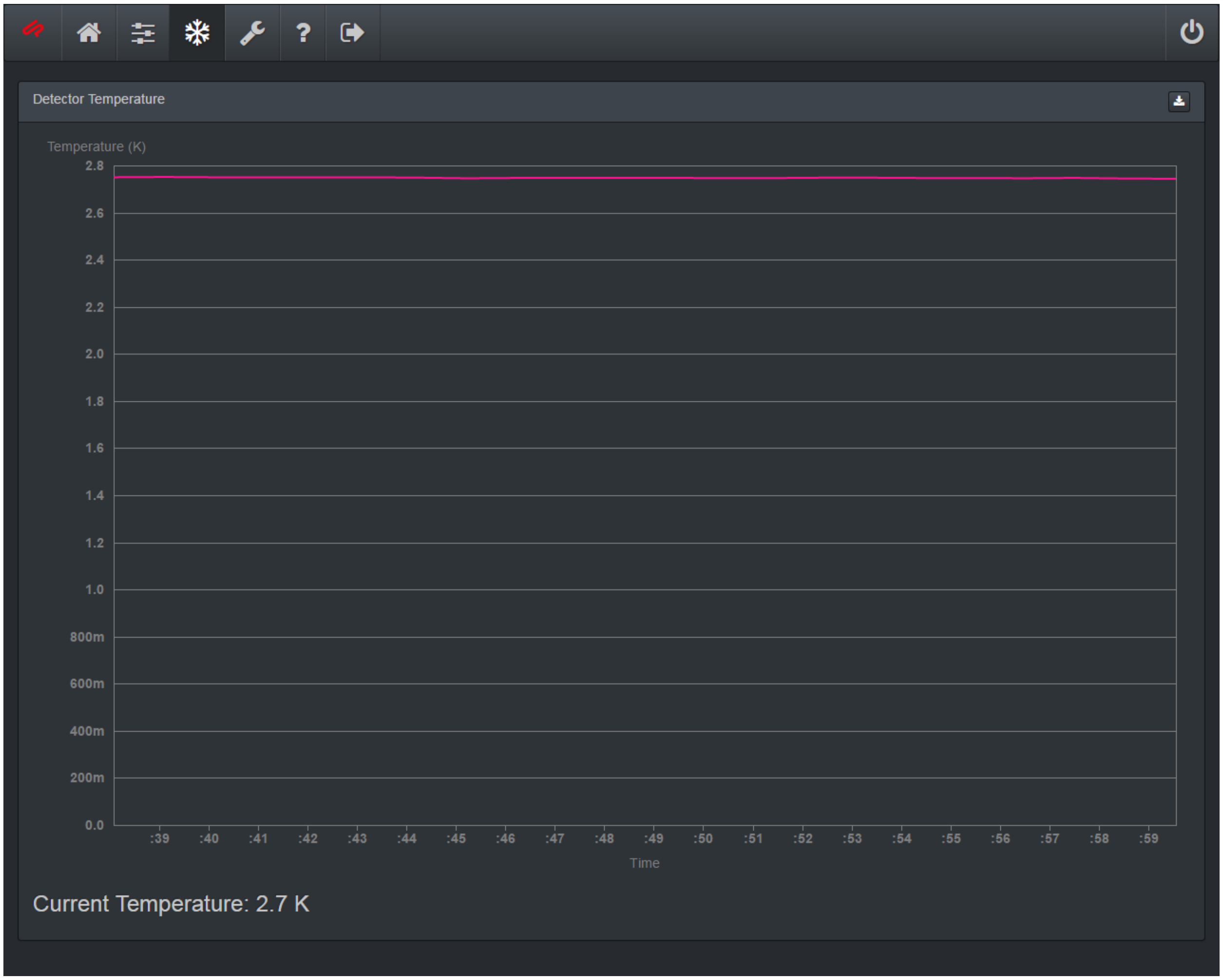

Figure 5.6: Detector temperature trace.

5.2.4 Detector Temperature

The detector temperature trace is especially useful to check the temperature of the detectors during cool-down and warm-up. By clicking on the download icon in the upper right corner of the temperature plot window the temperature history can be downloaded, see Figure 5.6. Note, the temperature history spans the time since the last startup, i.e. switching off the driver will delete all temperature data. The maximum file length is limited to one million temperature entries. If this length is reached incoming temperature data will be kept on a first in last out basis.

5.2.5 Configuration

Here you can configure the following settings:

- Data Presentation
- Networking
- Trigger level
- Sound/LED
- Time
- Access Control
- Update

Data Presentation

The settings here will affect all graphs. The X- and Y-Axis font size as well as the graph line width can be configured here. Furthermore, the detected photons can be normalized to photons per 1 second (Hz). Note, this setting does not affect the counts recording (see, *Real Time Monitor.*) to keep the recorded file consistent.

Networking

The networking tab allows to configure the network access to the WebSQ driver and it is in detailed explained in *Network Setup*.

Trigger Level

The WebSQ driver needs to convert the analog pulses from the SNSPDs to a digital signal for counting. This is done by choosing the appropriate trigger level. If the analog signal crosses on its rising edge the trigger level a digital pulse is generated. Generally, a good trigger level is at half the peak value. The peak value can be easily found by rising the trigger level until no photons are register anymore. Let's assume this happens at 630 mV. In that case set the trigger level to 315 mV. Repeat this process for all detector channels. Note, that the internal counters were specially optimized for high speed. They can count up to 2 GHz and have therefore a negligible dead time of only 500 ps.

Sound/LED

The sound tab allows you to choose the type of sound (Square, Sine, Sawtooth, Triangle) and the rollover frequency. In case your diver is equipped with a LED button you can also dim the LED here for the least light pollution in your lab.

Time

Allows to set the time and timezone. The time is used for time-stamping all the generated files and their entries.

Access Control

Allows to change the username and password.

Update

Upload and install an update zip package. The update may take several minutes. Never switch off the driver during update as it might break the system.

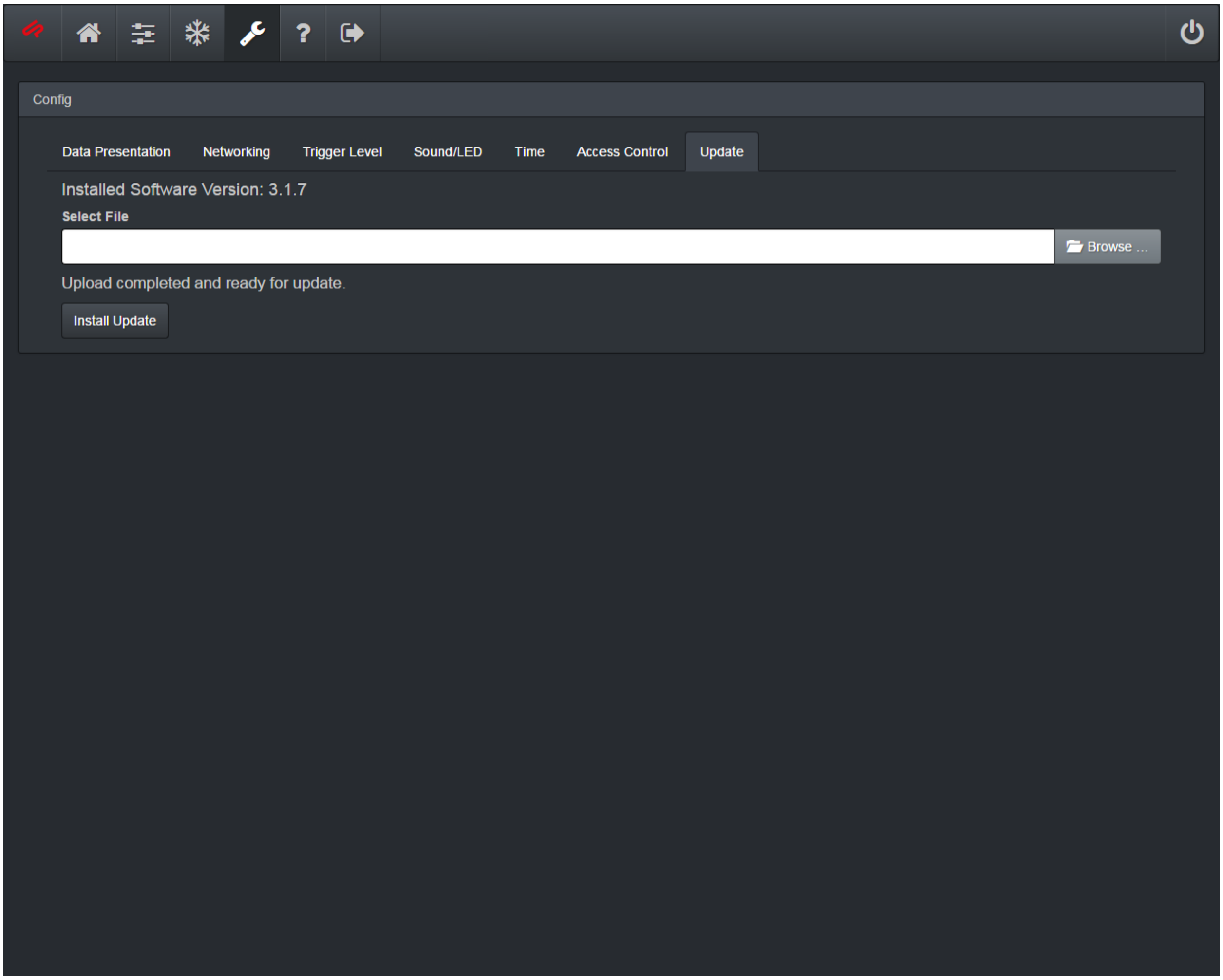

Figure 5.7: Window to upload and install a new software version.

5.2.6 Help

In the help tab you can browse or download the manual, access sample code how to communicate with the WebSQ driver, and review the license of the installed software.

5.2.7 Advanced Settings

There is a hidden configuration menu to change system settings only needed to be calibrated at the factory. However, as we are all adults, we describe their functionality here as we want to keep the system as open and configurable as possible.

The advanced settings can be reached by entering driver_ip_address/advanced_settings in your browser's address field.

In the following only parameters which are not self-explanatory are described:

Settings

# of Detectors Number of channels present in the system. When changed wait 1 minute before restart to make sure that the settings have been saved.

Latch time Time a latched detector is switched off to put it back to normal operation.

Simulation Mode Emulates the detection system. Useful for showing the driver's capabilities without a system connected at conferences/shows.

Firmware Firmware version of the internal driver card.

Resistors

The bias currents are generated by a voltage applied to the bias resistors. The resistor values here need to correspond with the actual built in resistors to enable the software to calculate the bias currents.

Trigger

Trigger level to allow the driver to detect a photon. A small part of the detected signal is tabbed and fed to a high-speed comparator which is capacitively coupled. A resistor divider network pulls to the tabbed signal to about 640 mV. As the resistors' value vary slightly the offset needs to be calibrated. Also the trigger gain, the fraction of the tabbed signal to the set trigger level, has to be calibrated. Standard value 0.325.

Calibration procedure:

1. On driver_ip_address/index change the trigger level till your have maximal dark counts.
2. Change the Trigger Level Offset in advanced_settings till the trigger level shows highest counts at zero.
3. Repeat 1. and 2. until the count rates are the highest for zero trigger. Then the offset level is calibrated correctly. Repeat for each detector.
4. Take an oscilloscope and measure the pulse hight of the SNSPD signal.
5. Increase the trigger level until no counts are detected anymore. This level corresponds to the pulse peak hight.
6. Change the trigger gain and repeat 5. till the counts drop-off happens at the measured (4) amplitude. Repeat for each detector.
7. The trigger level is calibrated correctly.

Voltage Latch

Trigger level for latch detection. When an SNSPD does not return it self to the superconducting state, it is said to have "latched". To detect a latch we monitor the voltage over the SNSPDs. When they are not superconducting anymore the voltage drop is non zero anynore. The Latch Level describes which SNSPD voltage should trigger a detected latch. In that case the detector will be power off for a short amount of time.

Frequency Latch

Experimental feature: A latch detect will be triggered if the count rate of a detector falls below or above a certain frequency.

Monitor Bias Voltage

Set Bias Voltage (V) Overwrites the bias current calculation. The biasing circuitry will be powered by the specified voltage. Useful for connection tests.

Monitor Bias Voltage (V) Shows the measured voltage across the SNSDPs. This voltage is used for latch detection.

Temp Diode

Temp. Avrg. Factor Value between 0 and 1. Each temperature reading is added by a fraction of 1-Averaging Factor to the averaged temerature value. That means, a Temp. Avrg. Factor of 0 does not average at all. And a Temp. Avrg. Factor of 1 does not add new data.

Temp. Diode (V) Voltage measured across the temperature diode.

Temp. Diode (K) Temperature calculated based on linear interpolation between the data points in the calibration file.

Bias Voltage Resistor Voltage across the bias voltage resistor used for a PID feedback loop to maintain an accurate bias current.

Set Bias Current The temperature diode's bias current.

Cali Points Used to shift the calibration file by hand. Legacy.

Temp Cali Upload

Tab to upload the temperature diode's calibration file.

Board

Shows the history of the DAQ card temperature and shows the maximal recordered temperature.

Manage Config

Download/Upload system configuration file. This file contains all the settings (without the temperature calibration files) of the whole system. Ideal for system setting backup.

Reset

Don't do it if you have not taken a system backup under Manage Config. Completely overwrites all system specific settings by standard values not necessarily corresponding to your system configuration!

CHAPTER

SIX

MAINTENANCE

The coldhead requires replacement of moving parts when the performance of the detector is observed to degrade after 10000 hours of operation. Contact Single Quantum when the 10000 hours are reach to plan the maintenance.

CHAPTER

SEVEN

APPENDIX PRINCIPLE OF OPERATION

Superconducting-nanowire single-photon detectors transition from the superconducting state to the normal state upon the absorption of a photon. This transistion gives a fast electrical pulse that is amplified by the SNSPD driver. The operation principle of an SNSPD is outlined in the figure below.

The superconducting nanowire is biased with a direct current (Ibias) close to the critical current (Ic), meaning that the current density flowing through the wire is near the critical current density, above which the superconductivity of the nanowire breaks down. When an incident photon of sufficient energy is absorbed by the wire, the superconductivity in that region is disrupted and a part of the detector becomes resistive (Rn >1 kΩ). This is modelled as a switch which is closed when the SSPD is superconducting and opened after a photon is absorbed. When the detector is resistive, the bias current is reflected towards the amplification electronics, in the SNSPD driver, and creates a voltage pulse. Quickly after the detection event takes place the superconductivity is recovered, the biasing current returns through the nanowire and the device is ready to detect the next incoming photon.

CHAPTER

EIGHT

APPENDIX SOFTWARE CONFIGURATION

The following sections will explain in detail how to configure the WebSQ software on the Beagle Bone.

8.1 Software Updates

Once the WebSQ software is running it can be reached through a browser. Updates can be performed through the web interface. To do that, navigate to 'Config' and open the tab 'Update'. There, a zip file of the WebSQ software package can be uploaded and installed.

8.2 Network Setup

8.2.1 Standard

The driver is set by standard to function as a DHCP-server to set up a local network. The driver can be reached under:

```
192.168.1.1 or sq.local/
```

8.2.2 Configuration

The driver can be configured in three modes::

- *DHCP-server*
- *DHCP-client*
- *Static IP address*

To choose and configure the corresponding mode go to the configuration menu and select the network tab. Each setting change is confirmed by pressing the Apply button. For the changes to take effect the driver will restart after pressing the apply button.

DHCP-Server

To setup the DHCP-server, an IP range for it's clients has to be selected. Note that these range should comply with the drivers own IP address and should end with a higher number than the start number of the range. For example if the drivers IP is:

```
192.168.3.1
```

The DHCP-server range could be set for example to:

```
From 192.168.3.20 to 192.168.3.40
```

The driver will now supply connecting computers with an IP-address ending between 20 and 40. Please make sure that your computer is setup properly to function as a DHCP-client. Also be mindful that a network can be disrupted when there are several DHCP-servers inside one network.

DHCP-Client

Switch the DHCP-Client button to on. With the DHCP-Client on the driver will get an ip address from the DHCP server on the network.

Static IP-address

Disable the DHCP-client and the DHCP-server and select your fixed IP address.

Lockout

If you can't access the driver anymore, press the reset button on the backside for 5 seconds and the default settings will be loaded. The default ip address is 192.168.1.1

8.2.3 More information

For more information concerning networking, please visit the following address:

```
http://tldp.org/LDP/nag/node3.html
```

8.3 Clean (or Fresh) Installation

For the initial installation it is the easiest to connect the mini-USB on the Beagle Bone with a computer where the WebSQ software folder is available. This will emulate an ethernet connection and the Beagle Bone is reachable at "192.168.7.2". On Unix machines you execute the following command in a terminal:

```
scp -r websq_folder root@192.168.7.2:./
```

This will copy the folder to the board. As a next step you have to login to the board and perform the installation. For this step internet access is needed that the installation routine can download all the necessary libraries. Connect an ethernet cable to the ethernet port of the board providing internet access. Login to the Beagle Bone via the terminal:

```
ssh root@192.168.7.2
```

Open the folder:

```
cd websq_folder
```

And start the installation:

```
sudo python setup.py install
```

This will install the software and it will be started automatically after a reboot:

```
reboot
```

For debugging purposes the software can be started:

```
systemctl start websq.service
```

stopped:

```
systemctl stop websq.service
```

or its status acquired by:

```
systemctl status websq.service
```

CHAPTER

NINE

APPENDIX EXTERNAL ACCESS

The WebSQ driver can be accessed and controlled over its Ethernet connection. There are two open ports, by default 12345 and 12000. The first one only emits the measured counts. The second one allows to control the WebSQ driver basically in the same way as over the web interface. In the following, the two access ways are explained in detail.

9.1 Receiving Counts

The counts per measurement time are emitted by default on port 12345 with the TCP/IP protocol. Note, that this port only sends data any data which is written to it is discarded. The port number can be changed under the configuration tab in the web interface. The format of the emitted data is comma separated starting with a UNIX time-stamp in seconds followed by the counts of the detectors and ended with the newline character '\n':

```
unix time-stamp,counts detector 1,counts detector 2,...\n
```

For example, on a system with four detectors the data looks like:

```
1462820844.64,200.0,238.0,234.0,212.0\n
```

The driver emits the counts to all connected clients starting automatically once the connection is established. On a Unix system the connection to the driver can be tested by the following command:

```
netcat ip_address 12345
```

Here, ip_address should be replaced with the IP address of the driver.

9.2 External Control

The default way of controlling the driver is through its built in web browser interface. To access, simply open a web browser of your choice and enter the IP address 192.168.1.1 (standard address) of the driver in the address field. However, your application might demand finer or automated control over the detectors. In that case, you can directly access it through precisely the same JSON protocol over which also the web browser is communicating with the driver.

In the following, this protocol is outlined in detail but it might be beneficial to also check example projects downloadable on the help page of the WebSQ driver.

The WebSQ sever listens by default for incoming connections on port 12000. If this number is inconvenient it can be changed in the web interface under config in the network section.

On a Unix system the communication can be tested by the following command:

```
netcat ip_address 12000
```

Each full reply is terminated with one or several '\x17' end of transmission block characters. This simplifies merging TCP IP messages which have been split during network passage.

9.2.1 Command Structure

Each value which is accessible in the WebSQ interface can be transparently accessed externally.

There are three types of commands:

- Requests
- Commands
- And access to labels, for example the integration time

In the following each of these three types is outlined.

Please be aware that the JSON protocol requires always double quotes " single quotes ' will result in errors.

9.2.2 Requests

Possible requests are:

- *GetSystemTime*
- *Style info*
- *labelProps*
- *BroadcastCounters*
- *BroadcastBiasCurrents*
- *BroadcastBiasVoltages*
- *TemperatureHistory*
- *IVHistory*
- *SoftwareVersion*
- *pong*
- or a label name like "NumberOfDetectors"

A request looks like:

```
{"request":"request_name"}
```

where the *request_name* is one of the above possible keywords. For example:

```
{"request":"GetSystemTime"}
```

will return the system time.

A request will always results in a *value-label* JSON structure:

```
{"value": "requested_value", "label": "requested_identifier"}
```

Please note that the commands:

- *BroadcastCounters*
- *BroadcastBiasCurrents*
- *BroadcastBiasVoltages*

only broadcast to connected websockets (Browsers), e.g. they have no effect for the external access through port 12000.

GetSystemTime

Returns the time in the following JSON form:

```
{"value": "2016-08-07 16:53:12", "label": "SystemTime"}
```

Style info

Returns each label-value pair of *labelProps* separately. The *labelProps*

```
{"value": [12.0, 8.0, 3.0, 8.0], "label": "BiasCurrent"}
{"value": 4, "label": "NumberOfDetectors"}
```

labelProps

Returns the same elements like in *Style info* but with additional information like type, unit, and bounds if available:

```
{"value": {"value": [12.0, 8.0, 3.0, 8.0], "type": ["float", "int"],
  "bounds": [-50.0, 50.0], "unit": "muA"}, "label": "BiasCurrent"}
{"value": {"type": ["int"], "bounds": [0, 8], "value": 4}, "label": "NumberOfDetectors
↪"}
```

TemperatureHistory

Returns the time stamped temperature history in Kelvin:

```
{"value": [{"x": "07-Aug-16 16:48:27.15", "T": 2.5},
{"x": "07-Aug-16 16:48:37.24", "T": 2.55}],
"label": "temperature_long_memory"}
```

IVHistory

Returns the last detector characterization measurement. Two JSON objects will be returned. The first for the bias current versus detector voltage measurement:

```
{"value": {"start": true, "value": [{
"v1": 2.292586295970549,
"v2": 6.6360137175996243,
"v3": 1.230466767850853,
"v4": 5.3691603767536229,
"biasCurrent": 0.0,
"x": "07-Aug-16 17:13:23.279",
"label": "biasVoltage"}],
"label": "IVGraph"},
"label": "iv_scan_history"}
```


and the second one the bias current versus counts characterization:


```
{"value": {"start": true, "value": [{
"biasCurrent": 0.0,
"y1": 1996638.0,
"x": "07-Aug-16 17:13:23.289",
"y3": 3590000.0,
"y2": 2690000.0,
"y4": 39290000.0}],
"label": "ICGraph"},
"label": "ic_scan_history"}
```


SoftwareVersion

Returns the software version:

```
{"value": "4.2.4", "label": "SoftwareVersion"}
```

pong

This is used to ping the driver and check if the connection to the driver is still active. Each pong request is answered by a ping.

```
{"value": "pong", "label": "ping"}
```

A label property

All the data presented on the web interface like integration time, bias currents, etc. are called label properties. Each label can be acquired individually. For example, the numbers of detectors available in the system can be acquired by:

```
{"request":"NumberOfDetectors"}
```

The answer will be:

```
{"value":"4", "label": "NumberOfDetectors"}
```

To query all the available label properties the request “labelProps” can be used, see above.

9.2.3 Commands

Possible commands are:

- *SetMeasurementPeriod*
- *SetBiasCurrent*
- *SetAllBiasCurrents*
- *SetTriggerLevel*
- *SetAllTriggerLevels*
- *SetDiodeCurrent*
- *SetTime*
- *DetectorEnable*
- *RecordCounts*
- *RecordCountsReset*
- *IVScanEnable*
- *SetNetworking*
- *AutoCaliBiasCurrents*
- *SetLEDIntensity*
- *Shutdown*

All commands are illustrated in the following for a system with 4 detectors. In case of a different detector number change the length of the arrays accordingly.

Please note that commands do not alter the labels on the web interface. The labels need to be updated with a separate command. Therefore, you'll find that the commands underneath will contain the label keyword. In this way, only one JSON expression is sent out where the value keyword is used for both the commands and the labels.

Set Measurement Period

JSON command:

```
{"command": "SetMeasurementPeriod", "value": 123, "label": "InptMeasurementPeriod"}
```

Sets the measurement period to 123 ms.

Set Bias Current

Sets only one bias current at a time. Which one is indicated by an index which runs from 0. . . n-1, where n is the number of detectors.

JSON command:

```
{"command": "SetBiasCurrent", "label": "BiasCurrent", "value": [12, 11, 13, 14],
↪"index": 0}
```

Sets the bias current of detector 1 (index 0) to 12 µA.

Note: Even though all values seem updated in the web browser only the *one* specified by the index will be physically set. The update is performed upon the next counts measurement.

Set All Bias Currents

Sets all bias currents at once.

JSON command:

```
{"command": "SetAllBiasCurrents", "label": "BiasCurrent", "value": [12, 11, 13, 14]}
```

Sets the bias current of detector 1 to 12 µA, detector 2 to 11 µA and so forth. If the array does not have the same length as the number of detectors in the system nothing will be updated.

Note: The bias currents are not updated immediately. They are automatically updated after the next counts measurement.

Set Trigger Level

Sets only one trigger level at a time. Which one is indicated by an index which runs from 0. . . n-1, where n is the number of detectors.

JSON command:

```
{"command":"SetTriggerLevel","label":"TriggerLevel","value":[100, 110, 120, 130],
↪"index":0}
```

Sets the trigger level of detector 1 (index 0) to 100 mV.

Note: Even though all values seem updated in the web browser they will be only updated when the *one* specified by the index is physically set. The update takes place on the following counts measurement.

Set All Trigger Levels

Sets all trigger levels at once.

JSON command:

```
{"command":"SetAllTriggerLevels","label":"TriggerLevel","value":[100, 110, 120, 130]}
```

Sets the trigger level of detector 1 to 100 mV, of detector 2 to 110 mV and so forth. If the array does not have the same length as the number of detectors in the system nothing will be updated.

Note: The trigger levels are not updated immediately. They are automatically updated after the next counts measurement.

Set Diode Current

Sets the bias current of the temperature diode, the value can be positive or negative.

JSON command:

```
{"command": "SetDiodeCurrent", "value": 10, "label": "TempDiodeBiasCurrent"}
```

Sets the temperature measurement diode's bias current to 10 µA.

Note: The diode's bias current is not updated immediately. It is automatically updated after the next counts measurement.

Set Time

First the time zone label needs to be set:

```
{"label": "TimeZone", "value": "strTZ"}
```

where *strTZ* is a string representing your current timezone. This ensures that in the web interface the right timezone is displayed. For all possible timezones see *Timezones*.

You can set the time accordingly:

```
{"command": "SetTime", "value": {"time": "time", "timezone": "strTZ"}}
```

where the variable *time* needs to be in the following format "YYYY-MM-DDTHH:m:ss" and *strTZ* your timezone (see *Timezones*).

Example:

```
{"command": "SetTime", "value": {"time": "2016-08-14T09:47:55", "timezone": "Europe/
↪Amsterdam"}}
```

Detector Enable

To enable/disable the bias current through the detectors send:

```
{"command": "DetectorEnable", "label": "DetectorEnable", "value": true}
```

or:

```
{"command": "DetectorEnable", "label": "DetectorEnable", "value": false}
```

Record Counts

To re-start a count record:

```
{"command": "RecordCounts", "label": "DetectorRecording", "value": true}
```

and to pause:

```
{"command": "RecordCounts", "label": "DetectorRecording", "value": false}
```

Record Counts Reset

Resets the acquired counts:

```
{"command": "RecordCountsReset"}
```

IV Scan Enable

To enable/disable the IV scan do:

```
{"command": "IVScanEnable", "label": "IVScanEnable", "value": true}
```

or:

```
{"command": "IVScanEnable", "label": "IVScanEnable", "value": false}
```

To set the start, stop, and increment current use:

```
{"label": "IVScanStart", "value": 0}
```

Starts IV scan at 0 μA.

```
{"label": "IVScanEnd", "value": 30}
```

Stops IV scan at 30 μA.

```
{"label": "IVScanIncrement", "value": 0.1}
```

Increment IV scan with 0.1 μA.

Automatic Bias Current Calibration

The automatic bias current calibration routine finds the bias current for a given amount of dark counts. Therefore, it is important that the detectors are shielded completely from any light prior to the search and that the dark-counts are set. To set the dark-counts send the following command:

```
{"command": "DarkCountsAutoIV", "label": "DarkCountsAutoIV", "value": [100, 100, 100,␣
↪100]}
```

In this example, all the dark-counts are set to 100 Hz.

Then start the automatic bias current search:

```
{"command": "AutoCaliBiasCurrents", "value": true}
```

To check if the system has completed the search the “StartAutoIV” label can be inquired. The reply will be true if the search is active and false otherwise:

```
{"request": "StartAutoIV"}
```

Set Led Intensity

Set the LED intensity at the front of the driver to maximum brightness send:

```
{"command": "SetLEDIntensity", "label": "SetLEDIntensity", "value": 32000}
```

To switch it off send:

```
{"command": "SetLEDIntensity", "label": "SetLEDIntensity", "value": 0}
```

The intensity value scales between 0 and 32000. Note, this feature is only available on newer devices.

Shutdown

The driver can be shutdown by sending:

```
{"command": "Shutdown"}
```

Note, this feature is only available on newer devices.

9.2.4 Labels

To query all available properties, their bounds, units, and types send:

```
{"request": "labelProps"}
```

You can also access a specific value within *labelProps*, for example the bias voltage measured over the detectors:

```
{"request":"BiasVoltage"}
```

Each label can also individually be set by *label value* pairs, for example:

```
{"label": "InptMeasurementPeriod", "value": 123}
```

Setting a value will transmit the changed value to all connected clients (all browsers and all TCP/IP clients). In this way, a change is always transparent to all clients. However, setting a value never initiates an actual hardware change. This always needs to be done with a command.

Please note that *commands* can be sent together with a label value pair:

```
{"command": "SetMeasurementPeriod", "value": 123, "label": "InptMeasurementPeriod"}
```

CHAPTER TEN

APPENDIX TROUBLESHOOTING

10.1 Vacuum leaks

If the pressure in the system (pressure is indicated on the pump display) cannot be pumped to lower than 1.0E-4 mbar (at T=290K), there is a problem with vacuum. A leak can lead to condensation on the vacuum shield. Inspect the o-rings connecting the system with the pumping system for possible damage and dirt and clean them with alcohol and try again to pump the system.

10.2 Cold-head or compressor problem

Compressor and cryostat failures are characterized either by an inability to operate or by an increase in the minimum achievable temperature. For checking the operation of the compressor please refer to the manual.

CHAPTER

ELEVEN

APPENDIX TIMEZONES

11.1 Timezones

“Africa/Abidjan” “Africa/Accra” “Africa/Addis_Ababa” “Africa/Algiers” “Africa/Asmara” “Africa/Bamako” “Africa/Bangui” “Africa/Banjul” “Africa/Bissau” “Africa/Blantyre” “Africa/Brazzaville” “Africa/Bujumbura” “Africa/Cairo” “Africa/Casablanca” “Africa/Ceuta” “Africa/Conakry” “Africa/Dakar” “Africa/Dar_es_Salaam” “Africa/Djibouti” “Africa/Douala” “Africa/El_Aaiun” “Africa/Freetown” “Africa/Gaborone” “Africa/Harare” “Africa/Johannesburg” “Africa/Kampala” “Africa/Khartoum” “Africa/Kigali” “Africa/Kinshasa” “Africa/Lagos” “Africa/Libreville” “Africa/Lome” “Africa/Luanda” “Africa/Lubumbashi” “Africa/Lusaka” “Africa/Malabo” “Africa/Maputo” “Africa/Maseru” “Africa/Mbabane” “Africa/Mogadishu” “Africa/Monrovia” “Africa/Nairobi” “Africa/Ndjamena” “Africa/Niamey” “Africa/Nouakchott” “Africa/Ouagadougou” “Africa/Porto-Novo” “Africa/Sao_Tome” “Africa/Tripoli” “Africa/Tunis” “Africa/Windhoek” “America/Adak” “America/Anchorage” “America/Anguilla” “America/Antigua” “America/Araguaina” “America/Argentina/Buenos_Aires” “America/Argentina/Catamarca” “America/Argentina/Cordoba” “America/Argentina/Jujuy” “America/Argentina/La_Rioja” “America/Argentina/Mendoza” “America/Argentina/Rio_Gallegos” “America/Argentina/Salta” “America/Argentina/San_Juan” “America/Argentina/San_Luis” “America/Argentina/Tucuman” “America/Argentina/Ushuaia” “America/Aruba” “America/Asuncion” “America/Atikokan” “America/Bahia_Banderas” “America/Bahia” “America/Barbados” “America/Belem” “America/Belize” “America/Blanc-Sablon” “America/Boa_Vista” “America/Bogota” “America/Boise” “America/Cambridge_Bay” “America/Campo_Grande” “America/Cancun” “America/Caracas” “America/Cayenne” “America/Cayman” “America/Chicago” “America/Chihuahua” “America/Costa_Rica” “America/Cuiaba” “America/Curacao” “America/Danmarkshavn” “America/Dawson_Creek” “America/Dawson” “America/Denver” “America/Detroit” “America/Dominica” “America/Edmonton” “America/Eirunepe” “America/El_Salvador” “America/Fortaleza” “America/Glace_Bay” “America/Godthab” “America/Goose_Bay” “America/Grand_Turk” “America/Grenada” “America/Guadeloupe” “America/Guatemala” “America/Guayaquil” “America/Guyana” “America/Halifax” “America/Havana” “America/Hermosillo” “America/Indiana/Indianapolis” “America/Indiana/Knox” “America/Indiana/Marengo” “America/Indiana/Petersburg” “America/Indiana/Tell_City” “America/Indiana/Vevay” “America/Indiana/Vincennes” “America/Indiana/Winamac” “America/Inuvik” “America/Iqaluit” “America/Jamaica” “America/Juneau” “America/Kentucky/Louisville”> “America/Kentucky/Monticello” “America/La_Paz” “America/Lima” “America/Los_Angeles” “America/Maceio” “America/Managua” “America/Manaus” “America/Marigot” “America/Martinique” “America/Matamoros” “America/Mazatlan” “America/Menominee” “America/Merida” “America/Metlakatla” “America/Mexico_City” “America/Miquelon” “America/Moncton” “America/Monterrey” “America/Montevideo” “America/Montreal” “America/Montserrat” “America/Nassau” “America/New_York” “America/Nipigon” “America/Nome” “America/Noronha” “America/North_Dakota/Beulah” “America/North_Dakota/Center” “America/North_Dakota/New_Salem” “America/Ojinaga” “America/Panama” “America/Pangnirtung” “America/Paramaribo” “America/Phoenix” “America/Port_of_Spain” “America/Port-au-Prince” “America/Porto_Velho” “America/Puerto_Rico” “America/Rainy_River” “America/Rankin_Inlet” “America/Recife” “America/Regina” “America/Resolute” “America/Rio_Branco” “America/Santa_Isabel” “America/Santarem” “America/Santiago” “America/Santo_Domingo” “America/Sao_Paulo” “America/Scoresbysund” “America/Shiprock” “America/Sitka” “America/St_Barthelemy” “America/St_Johns” “America/St_Kitts” “America/St_Lucia” “America/St_Thomas” “America/St_Vincent” “America/Swift_Current” “America/Tegucigalpa” “America/Thule” “America/Thunder_Bay” “America/Tijuana”

“America/Toronto” “America/Tortola” “America/Vancouver” “America/Whitehorse” “America/Winnipeg” “America/Yakutat” “America/Yellowknife” “Antarctica/Casey” “Antarctica/Davis” “Antarctica/DumontDUrville” “Antarctica/Macquarie” “Antarctica/Mawson” “Antarctica/McMurdo” “Antarctica/Palmer” “Antarctica/Rothera” “Antarctica/South_Pole” “Antarctica/Syowa” “Antarctica/Vostok” “Arctic/Longyearbyen” “Asia/Aden” “Asia/Almaty” “Asia/Amman” “Asia/Anadyr” “Asia/Aqtau” “Asia/Aqtobe” “Asia/Ashgabat” “Asia/Baghdad” “Asia/Bahrain” “Asia/Baku” “Asia/Bangkok” “Asia/Beirut” “Asia/Bishkek” “Asia/Brunei” “Asia/Choibalsan” “Asia/Chongqing” “Asia/Colombo” “Asia/Damascus” “Asia/Dhaka” “Asia/Dili” “Asia/Dubai” “Asia/Dushanbe” “Asia/Gaza” “Asia/Harbin” “Asia/Ho_Chi_Minh” “Asia/Hong_Kong” “Asia/Hovd” “Asia/Irkutsk” “Asia/Jakarta” “Asia/Jayapura” “Asia/Jerusalem” “Asia/Kabul” “Asia/Kamchatka” “Asia/Karachi” “Asia/Kashgar” “Asia/Kathmandu” “Asia/Kolkata” “Asia/Krasnoyarsk” “Asia/Kuala_Lumpur” “Asia/Kuching” “Asia/Kuwait” “Asia/Macau” “Asia/Magadan” “Asia/Makassar” “Asia/Manila” “Asia/Muscat” “Asia/Nicosia” “Asia/Novokuznetsk” “Asia/Novosibirsk” “Asia/Omsk” “Asia/Oral” “Asia/Phnom_Penh” “Asia/Pontianak” “Asia/Pyongyang” “Asia/Qatar” “Asia/Qyzylorda” “Asia/Rangoon” “Asia/Riyadh” “Asia/Sakhalin” “Asia/Samarkand” “Asia/Seoul” “Asia/Shanghai” “Asia/Singapore” “Asia/Taipei” “Asia/Tashkent” “Asia/Tbilisi” “Asia/Tehran” “Asia/Thimphu” “Asia/Tokyo” “Asia/Ulaanbaatar” “Asia/Urumqi” “Asia/Vientiane” “Asia/Vladivostok” “Asia/Yakutsk” “Asia/Yekaterinburg” “Asia/Yerevan” “Atlantic/Azores” “Atlantic/Bermuda” “Atlantic/Canary” “Atlantic/Cape_Verde” “Atlantic/Faroe” “Atlantic/Madeira” “Atlantic/Reykjavik” “Atlantic/South_Georgia” “Atlantic/St_Helena” “Atlantic/Stanley” “Australia/Adelaide” “Australia/Brisbane” “Australia/Broken_Hill” “Australia/Currie” “Australia/Darwin” “Australia/Eucla” “Australia/Hobart” “Australia/Lindeman” “Australia/Lord_Howe” “Australia/Melbourne” “Australia/Perth” “Australia/Sydney” “Europe/Amsterdam” “Europe/Andorra” “Europe/Athens” “Europe/Belgrade” “Europe/Berlin” “Europe/Bratislava” “Europe/Brussels” “Europe/Bucharest” “Europe/Budapest” “Europe/Chisinau” “Europe/Copenhagen” “Europe/Dublin” “Europe/Gibraltar” “Europe/Guernsey” “Europe/Helsinki” “Europe/Isle_of_Man” “Europe/Istanbul” “Europe/Jersey” “Europe/Kaliningrad” “Europe/Kiev” “Europe/Lisbon” “Europe/Ljubljana” “Europe/London” “Europe/Luxembourg” “Europe/Madrid” “Europe/Malta” “Europe/Mariehamn” “Europe/Minsk” “Europe/Monaco” “Europe/Moscow” “Europe/Oslo” “Europe/Paris” “Europe/Podgorica” “Europe/Prague” “Europe/Riga” “Europe/Rome” “Europe/Samara” “Europe/San_Marino” “Europe/Sarajevo” “Europe/Simferopol” “Europe/Skopje” “Europe/Sofia” “Europe/Stockholm” “Europe/Tallinn” “Europe/Tirane” “Europe/Uzhgorod” “Europe/Vaduz” “Europe/Vatican” “Europe/Vienna” “Europe/Vilnius” “Europe/Volgograd” “Europe/Warsaw” “Europe/Zagreb” “Europe/Zaporozhye” “Europe/Zurich” “Indian/Antananarivo” “Indian/Chagos” “Indian/Christmas” “Indian/Cocos” “Indian/Comoro” “Indian/Kerguelen” “Indian/Mahe” “Indian/Maldives” “Indian/Mauritius” “Indian/Mayotte” “Indian/Reunion” “Pacific/Apia” “Pacific/Auckland” “Pacific/Chatham” “Pacific/Chuuk” “Pacific/Easter” “Pacific/Efate” “Pacific/Enderbury” “Pacific/Fakaofo” “Pacific/Fiji” “Pacific/Funafuti” “Pacific/Galapagos” “Pacific/Gambier” “Pacific/Guadalcanal” “Pacific/Guam” “Pacific/Honolulu” “Pacific/Johnston” “Pacific/Kiritimati” “Pacific/Kosrae” “Pacific/Kwajalein” “Pacific/Majuro” “Pacific/Marquesas” “Pacific/Midway” “Pacific/Nauru” “Pacific/Niue” “Pacific/Norfolk” “Pacific/Noumea” “Pacific/Pago_Pago” “Pacific/Palau” “Pacific/Pitcairn” “Pacific/Pohnpei” “Pacific/Port_Moresby” “Pacific/Rarotonga” “Pacific/Saipan” “Pacific/Tahiti” “Pacific/Tarawa” “Pacific/Tongatapu” “Pacific/Wake” “Pacific/Wallis” “UTC”

CHAPTER

TWELVE

APPENDIX PROTCOL OF INSTALLATION