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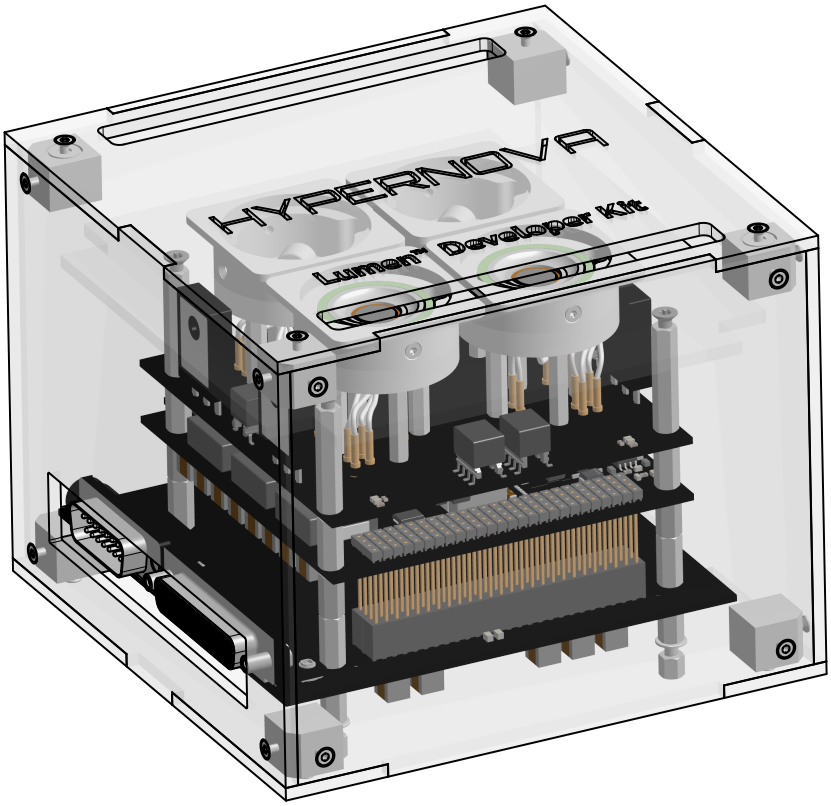

Lumen™ Developer Kit [V1.0]

GUI Quickstart Guide

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II. Document History

Revision	Date	Change details	Sections
0.1	2023-08-03	First Draft	All

III. Acronyms, Abbreviations and Symbols

The ECSS glossary of terms (ECSS-S-ST-00-01) is used as the normative reference for this document. The table below intends to add to or highlight the terms described in ECSS S-ST-00-01.

Term	Description
ACK	Acknowledge
ADC	Analogue to Digital Converter
COTS	Custom Off The Shelf
CRC	Cyclic Redundancy Check
CU	Control Unit
FIFO	First-In First-Out
FPGA	Field Programmable Gate Array
FW	Firmware
GSE	Ground Support Equipment
HW	Hardware
IGBT	Insulated-Gate Bipolar Transistor
NAK	Negative Acknowledgment
PPU	Power Processing Unit
PWM	Pulse Width Modulation
SRAM	Static Random-Access Memory
SW	Software
TBD	To Be Defined
TC	Telecommand
TM	Telemetry
TU	Thruster Unit
UART	Universal Asynchronous Receiver-Transmitter
UTC	Coordinated Universal Time

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1 INTRODUCTION

The Lumen™ Developer Kit [Version 1.0] (otherwise referred to as “the Kit”) is a modular benchtop system for delivering pulsed plasma jets in a controlled and precise manner. The Kit layout described in this document is for the standard configuration containing a total of four (4) thruster modules located on top of the Kit PCB boards.

This document explains how to interface with and control the Developer Kit in a lab benchtop setup using a PC and the Developer Kit GUI.

2 DOCUMENTS

2.1 Applicable Documents

The following documents are applicable and are referred to as [ADxx] in the text. Documents are applicable in their entirety. For unspecified issues of document, the latest signed version should be used. For specified issues, subsequent amendments to or revisions of any of these publications do not apply. However, parties to the agreement based on this document are encouraged to investigate the possibility of applying the most recent issue.

Table 2-1: Applicable Documents

Reference	Document Number	Issue/Date	Title
AD01	HST/ICD10010	1.0	Developer Kit - ICD
AD02			

2.2 Reference Documents

The following documents are referenced for supporting information only and are referred to as [RDxx] in the text. For unspecified issues of a document, the latest issue should be used. Any sections that are applicable will be referenced directly in the requirements section of this technical specification.

Table 2-2: Reference Documents

Reference	Document Number	Issue/Date	Title
RD01	HST/US10011	1.0	Developer Kit - User Manual
RD02			

3 PREPARATION

3.1 List of Equipment

The following equipment is required for running the Kit:

1) Lumen Developer Kit with GSE board
2) Lab power supply
3) Waveshare USB TO RS232 / RS485 / TTL industrial isolated converter, or similar
4) Cables:
   a) Comms test harness: USB to TTL/RS485 converter to DB25 male.
   b) Power cable: 4mm banana plugs or D-sub connector to DB15 female
5) Laptop with Windows 10 and the following software installed:
   a) Lumen Developer Kit GUI V0.7.2.exe (or later)

3.2 Benchtop Setup

This section explains how to setup the Lumen on a benchtop.

As shown in the figure below,

1. Ensure that the Lumen is plugged onto the PC104 connector on the GSE board,
2. Connect the power cable between the DB15 on the GSE board and a lab power supply. Set the current limits on the power supply as follows:

Table 3-1: Lumen Power Supply Requirements

Power Up Sequence	Voltage Rail	Nominal Current	Current Limit
1	+5V	50mA	150mA
2	+3V3	110mA	250mA
3	+12V	10mA	< 3A

Since 12V is only used for supplying the power electronics on the Lumen, it will still be possible to communicate with and configure the Kit if it is not supplied – it will just not be possible to fire the thrusters. +5V and +3V3 are required for basic operation of the Lumen Kit. As shown in the table above, +5V should be applied first, followed by +3V3, then +12V.

3. Connect the provided comms cable between the DB25 on the GSE board and the USB port on a PC.

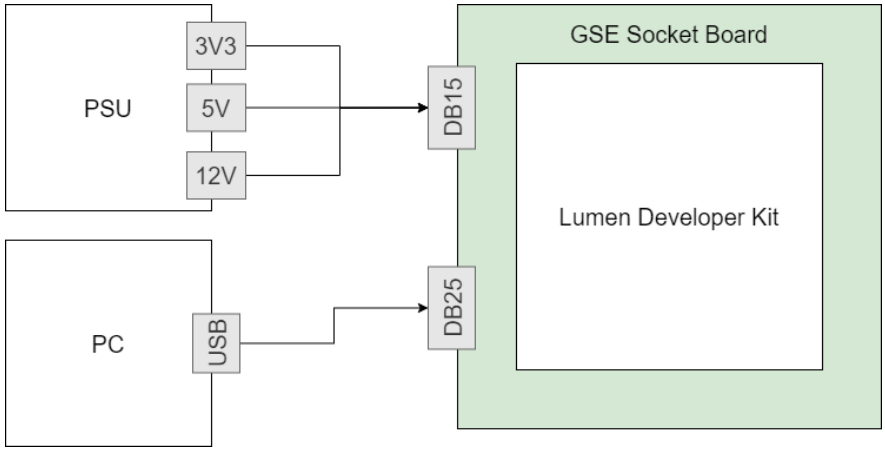

Figure 3-1: Lumen™ Developer Kit Benchtop Setup

4. Switch on the power supply and observe the current on the power supply is within 10% of the nominal current given in Table 3-1.

4 USING THE GUI

4.1 GUI Overview

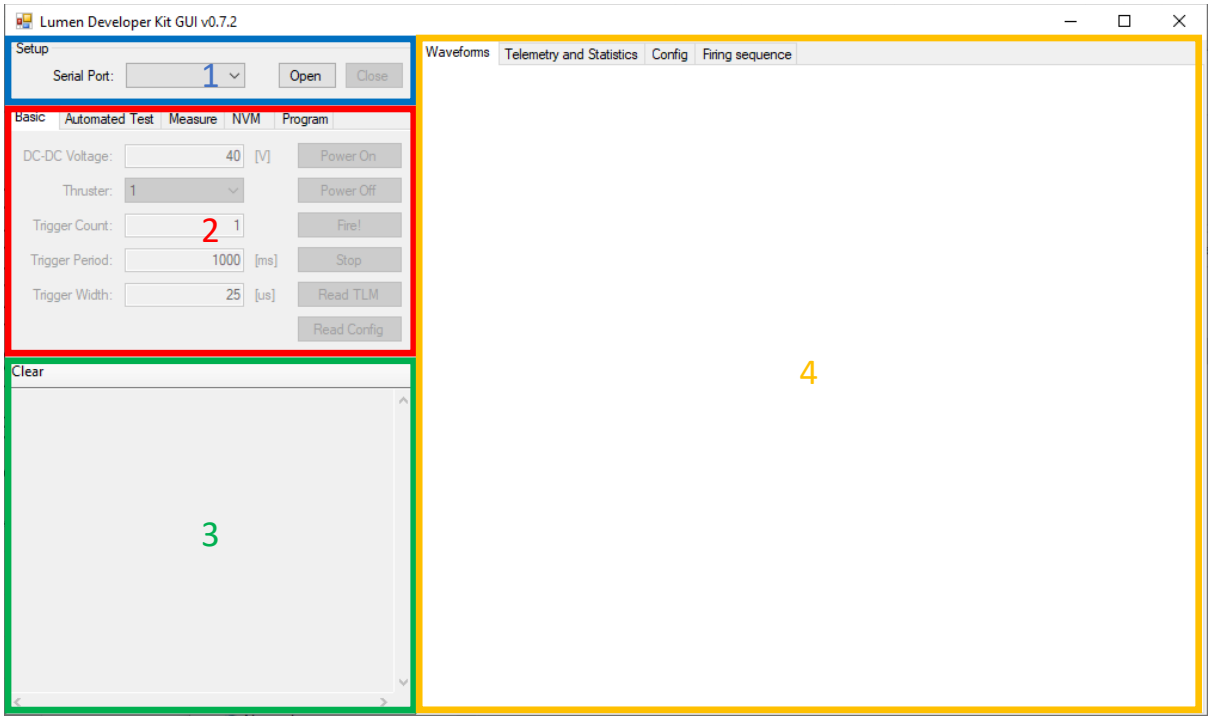

Figure 4-1: Parts of the Developer Kit GUI

As shown in Figure 4-1, the GUI is divided into four main sections, namely:

1. **The Setup Panel**. The setup panel is used to select the communication port that the PC uses to communicate with the Kit. After selecting the desired com port, one must click the "Open" button, this opens the com port and checks communication with the Kit. If communication is successful, the Developer Kit part number and serial number will be printed in the log panel.

The list of com ports in the drop down box only refreshes when the GUI is first executed so the USB interface adaptor to the Developer Kit should be plugged into the PC before executing the GUI.
The Developer Kit has a bootloader that runs for the first five seconds after the Developer Kit is powered. The main program only runs after the bootloader exits. One should therefore wait for five seconds after the Developer Kit powers on before trying to communicate with it.
Clicking the "Close" button closes the com port on the PC.

2. **The Control Panel**: The control panel has a number of tabs for controlling the various features of the Developer Kit. Each of these tabs is described in detail in Section 4.2.
3. **The Log Panel**: The log panel log events and displays information about the Developer Kit whenever communcation with the unit occurs.
4. **The Report Panel**: The report panel has a number of tabs for displaying information received from the Developer Kit. Each of these tabs is described in detail in Section 4.3.

4.2 The Control Panel

This section describes the various tabs in the control panel.

4.2.1 The Basic Control Tab

The Basic Control tab is used for the following functions:

1. Setting the voltage of the DC-DC converter.
2. Setting the firing parameters and firing the thrusters.
3. Reading telemetry ("TLM").
4. Reading config information

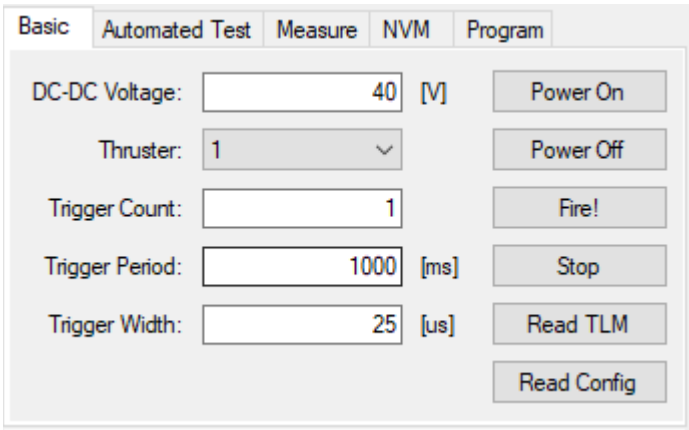

Figure 4-2: The Basic Control Tab

4.2.1.1 Setting the DC-to-DC Voltage

The DC-to-DC voltage value can be set in the input box labelled "DC-DC Voltage". The default value is 40V but it can be set to any value up to 140V. Setting it above 70V produces a warning message prompting the user for confirmation. To apply the given DC-DC voltage value, the user should click on the "Power On" button. Any changes to the voltage value in the input box should be applied by clicking on the "Power On" button again. To check that the DC-DC voltage has been applied and is correct,

one can read the DC-DC converter output voltage via telemetry as described below. To disable the DC-DC converter, click the "Power Off" button.

4.2.1.2 Setting the Firing Parameters and Firing the Thrusters

The following firing parameters can be configured through the Basic Control Panel:

1. **Thruster:** This parameter selects which thruster to fire. The user can select TU1 to TU4 or "All". Selecting "All" fires each of the thrusters in order starting with TU 1 and ending with TU4.
2. **Trigger Count:** This parameter defines the number of times to fire each thruster.
3. **Trigger Period:** This parameter defines the firing period in milliseconds (default = 1000 ms).
4. **Trigger Width**: This parameter sets the enable time of the IGBT used to initiate an arc (default = 25 us). This is a nominally defined value determined from practice and should not be altered under normal circumstances. The hardware contains circuitry that prevents over-current in the IGBT should someone enter a trigger width large that is too large.

After enabling the DC-DC converter and setting the above parameters, one can fire the thruster by clicking on the "Fire!" button. To stop a firing sequence, click the "Stop" button.

4.2.1.3 Reading the Telemetry

To read all of the onboard telemetry from the Developer Kit, click on the "Read TLM" button. All of the telemetry information is displayed in the Telemetry Report Tab, as described in Section 4.3.2.

4.2.1.4 Reading the Config Information

To read all of the config information from the Developer Kit, click on the "Read Config" button. All of the config information is displayed in the Config Report Tab, as described in Section 4.3.3.

4.2.2 The Automated Test Tab

The Automated Test Tab contains a button to start an automatic firing sequence which is loaded in the "Firing sequence" Panel as described in Section 4.3.4. This firing sequence can be started by pressing the "Start Firing Sequence" button as show in Section 4.3.4.

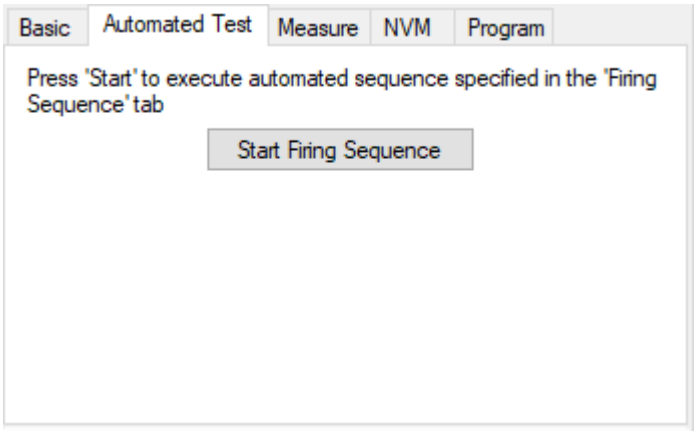

Figure 4-3: Automated Test Tab

4.2.3 The Measure Control Tab

The Measure Control tab is used to configure the measurement sub-system in the Developer Kit. The "Continuous" checkbox sets the current threshold to 0 Amps in the background and allows one to see the waveforms captured in pseudo-real-time. Because the current threshold is 0 Amps in continuous mode, the statistics are invalid and therefore not displayed.

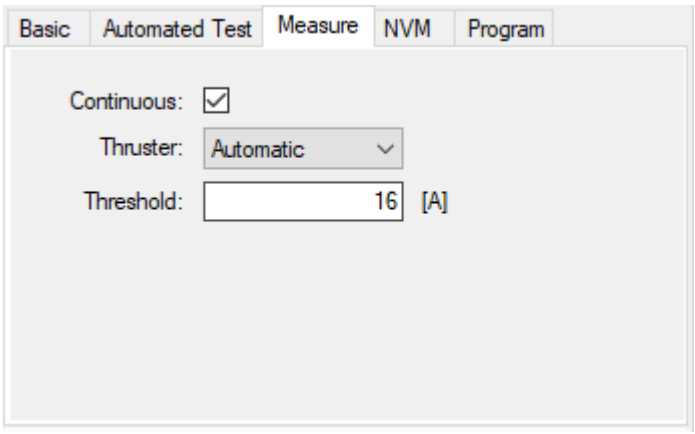

Figure 4-4: The Measure Control Tab

If the "Continuous" checkbox is left unchecked when one fires the thruster, then the given current threshold applies and only the first valid waveform is captured. Statistics are displayed on the Statistics Report Tab (see Section 4.3.2) after a firing sequence has completed. The Thruster dropdown box selects which thruster's waveform to capture. If "Automatic" is selected, then the thruster index on the basic control tab is used for selecting which thruster's waveform to capture. Waveforms and statistics are captured from the start of a trigger to when the current dips below the given threshold.

4.2.4 The NVM Control Tab

The CU contains non-volatile memory (NVM) that is used for storing config information, as well as the trigger counts. Figure 4-5 shows the NVM Control Tab used for setting the config information in the

CU and clearing the trigger counters. The "Comms Address" input boxes are used for storing the communication addresses of the Developer Kit for the different interfaces. The first address is for the TTL UART (Default = 1) and the second one is for the RS485 interface (Default = 2). The last two comms address are reserved for future use e.g. SPI, I2C, CAN etc. The Part Number (default = "Developer Kit") is a string of up to 32 bytes long. The serial number (default = "0000") is a string of up to 32 bytes long. The hardware version contains fields for the major version, minor version and mod status. To program the NVM with the inputted config information, click the "Program NVM" button. Config information programmed into the NVM is only read into memory when the CU boots, so to apply the changes one must power-cycle the CU or click the "Reset CU" button.

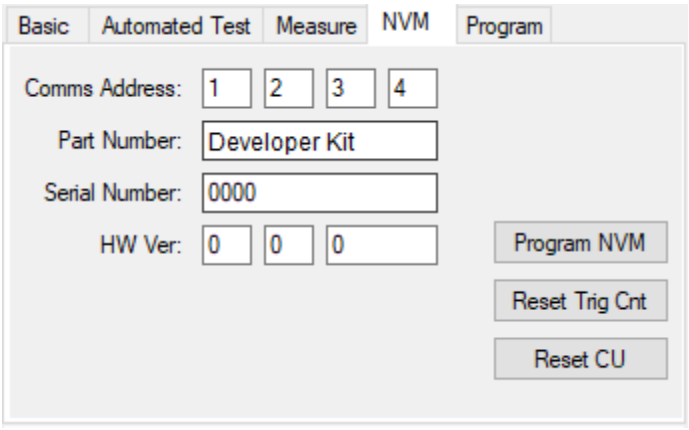

Figure 4-5: The NVM Control Tab

4.2.5 The Program Control Tab

The CU micro-processor has a bootloader which runs for the first five seconds after the CU boots. This allows in-flight updates of the micro-processor software. To update the micro-processor software via the GUI, click on the "Program" button under the Program Control Tab. The contents of the Program Control Tab is shown in Figure 4-6 below.

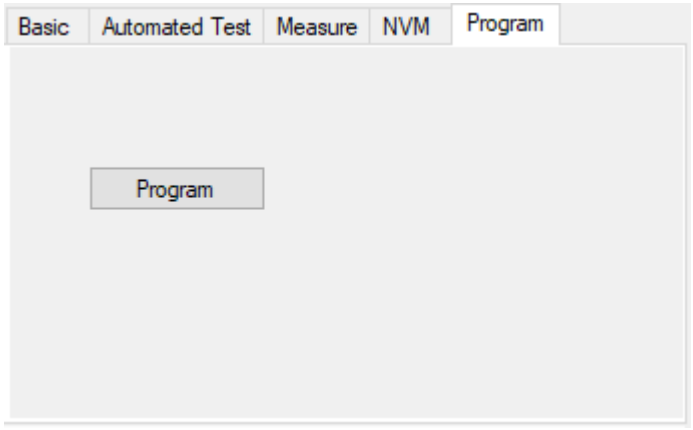

Figure 4-6: The Program Control Panel

Clicking on the "Program" button, opens a dialog for selecting an Intel Hex file. Selecting a hex file and clicking "Open" will initiate programming that consists of the following steps:

i. Check the integrity of the Intel Hex file and load the contents into memory.
ii. Reset the CU and wait 2 seconds for the bootloader to initiate.
iii. Program the given hex file to NVM via the bootloader. After the first valid command, the CU will remain in the bootloader code region.
iv. Reset the CU and wait five seconds for the Bootloader to exit.

4.3 The Report Panel

This section describes the various tabs in the report panel.

4.3.1 The Waveform Report Tab

The Waveform Report Tab displays the waveforms during or after firing. Figure 4-7 shows a typical waveform capturing during firing. The blue waveform shows the current and the red waveform shows the voltage. Configuration of the measurements is done via the Measurement Control Panel, as described in Section 4.2.3. If the measurement is setup for continuous, then the GUI tries to capture and update the voltage and current waveforms continuously during firing. If the measurement is not setup for continuous then the GUI only downloads the first valid waveform for the selected thruster after a firing sequence has completed.

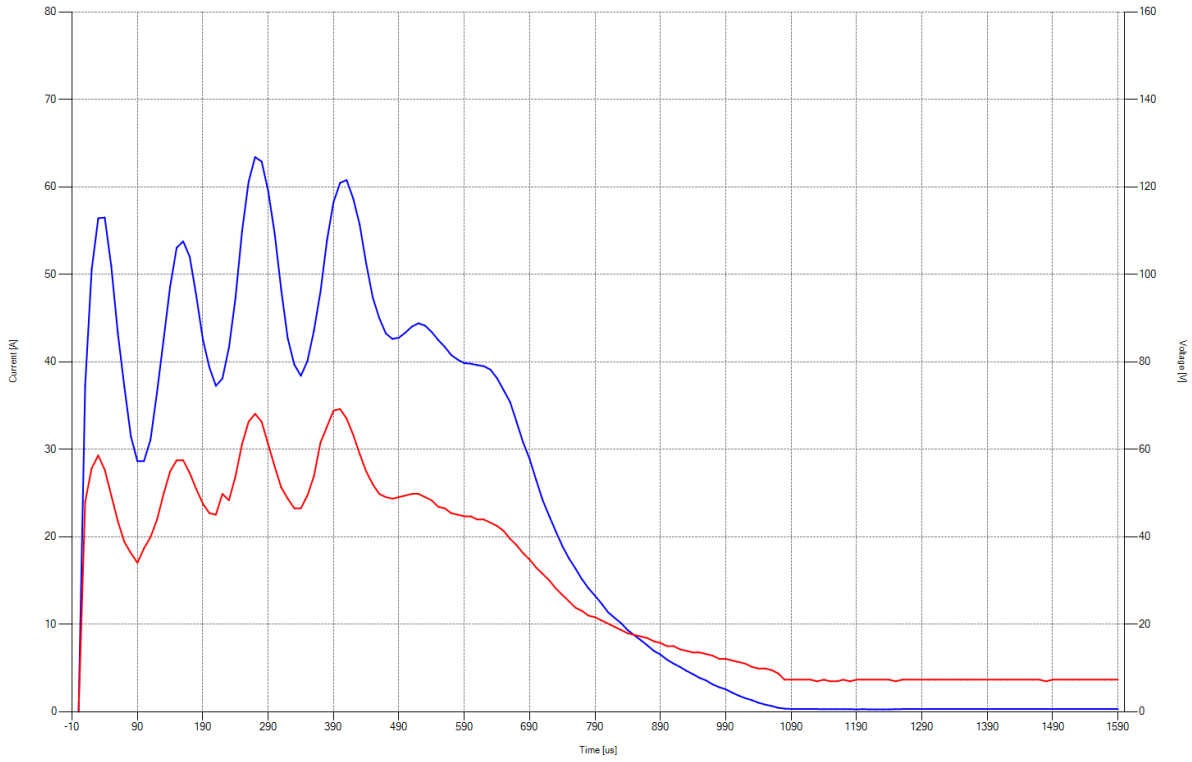

Figure 4-7: The Waveform Report Panel

4.3.2 The Telemetry and Statistics Report Tab

Telemetry

Clicking on the "Read TLM" button in the Basic Control Tab as described in Section 4.2.1, reads the telemetry. The telemetry values are displayed in the Telemetry Heading of the Telemetry and Statistics Panel as shown in Figure 4-8. The Telemetry Report Panel displays the following telemetry values:

i. Voltages and current for the +3V3, +5V, +12V supplies on the PPU.
ii. Temperatures of the DC-DC converter IGBT, PFN final inductor and trigger IGBT on the PPU.
iii. Temperatures of the thrusters.
iv. Voltages for the +3V3, +5V and +1V2 supplies on the CU.
v. Current for the +1V2 supply on the CU.
vi. Temperature of the CU.
vii. Total firings count and firing count of each thruster since last the last counter reset. Firing counters can be cleared on the NVM Control Tab.
viii. Total firings count and firing count of each thruster in the lifetime of the unit.

The "Open" button on the Telemetry and Statistics Panel is used to read telemetry files which have been previously generated from the Kit.

Waveforms | Telemetry and Statistics | Config | Firing sequence

Telemetry

Description	Raw	Value	Unit	Description	Raw	Value	Unit
Runtime	0x00000...	770	s				
Channel0 [PPU +3V3]	0x0A74	3,27	V	DC-DC Converter Output Voltage	0x043F	39,8	V
Channel1 [PPU +5V]	0x0A37	4,98	V	Firings TOTAL	0x00000...	421	
Channel2 [PPU +12V]	0x08EC	11,99	V	Firings TU1	0x006F	111	
Channel3 [PPU BATT-RAW]	0x0000	0,00	V	Firings TU2	0x006E	110	
Channel4 [PPU +3V3 Current]	0x01FA	124	mA	Firings TU3	0x0064	100	
Channel5 [PPU +5V Current]	0x00CF	51	mA	Firings TU4	0x0064	100	
Channel6 [PPU +12V Current]	0x000B	22	mA	Lifetime Firings TOTAL	0x00000...	3001	
Channel7 [DC-DC Temperature]	0x07CF	26,1	°C	Lifetime Firings TU1	0x00000...	790	
Channel8 [IGBT Temperature]	0x0837	23,8	°C	Lifetime Firings TU2	0x00000...	731	
Channel9 [PFN Inductor Temperature]	0x0845	23,5	°C	Lifetime Firings TU3	0x00000...	743	
Channel10 [TU1 Temperature]	0x0E9C	23,9	°C	Lifetime Firings TU4	0x00000...	737	
Channel11 [TU2 Temperature]	0x0EA0	23,6	°C				
Channel12 [TU3 Temperature]	0x084A	82,8	°C				
Channel13 [TU4 Temperature]	0x085F	82,2	°C				

Figure 4-8: The Telemetry Report Panel

Statistics

During firing the CU calculates statistics for each pulse. Statistics for each pulse are calculated from the time of triggering until the current dips below the current level specified in the Measurement

Control Panel. These statistics are stored in internal memory and can be downloaded after a firing sequence is complete. This is done once the firing sequence is completed when the CU calculates the statistics. The statistics are only captured if an automated test is run using the Firing Sequence and Automated Test button.

Figure 4-9 shows a typical set of statistics captured and calculated during firing. For each pulse, the following statistics are recorded:

i. The thruster index
ii. The pulse width
iii. Peak voltage
iv. Average voltage
v. Peak current
vi. Average current

Configuration of the measurements is done via the Measurement Control Panel, as described in Section 4.2.2. If the measurement is set to continuous, then the statistics values are invalid, and the GUI does not download and display the results. If the measurement is not set to continuous capture, then the GUI downloads and displays the statistics at the end of a firing sequence.

Thruster	Pulse Width [us]	Peak Voltage [V]	Avg Voltage [V]	Peak Current [A]	Avg Current [A]
1	750	214	49	64.7	42.2
2	760	215	49	64.5	41.8
3	770	211	49	61.9	41.4
4	760	217	49	63.9	42.2
1	750	216	49	64.4	42.6
2	760	220	49	64.3	42.6
3	750	212	49	64.7	42.3
4	760	215	49	65.0	42.6

Figure 4-9: The Statistics Report Panel

4.3.3 The Config Report Tab

Clicking on the “Read Config” button in the Basic Control Tab as described in Section 4.2.1, reads the config information from the unit. The config information is displayed in the Config Report Panel as shown in Figure 4-10. The Config Report Panel displays the following config information:

i. Product Part Number
ii. Product Serial Number
iii. Hardware Version: major version, minor version and mod status.
iv. Software Version: major version, minor version and build. This is the version of the software running in the Cortex-M3 microprocessor on the CU.
v. Firmware Version: major version, minor version and build. This is the version of the firmware

running in the FPGA fabric of the CU.

vi. Processor Serial Number. This is the unique 128-bit device serial number of the processor on the CU.

vii. Processor User Code. This is the 32-bit user code complied into the firmware of the CU.

viii. Processor Design Version. This is the 16-bit design version of the firmware on the CU.

As explained in Section 4.2.4, the product part number, the product serial number and hardware version can be programmed via the NVM Control Panel of the GUI.

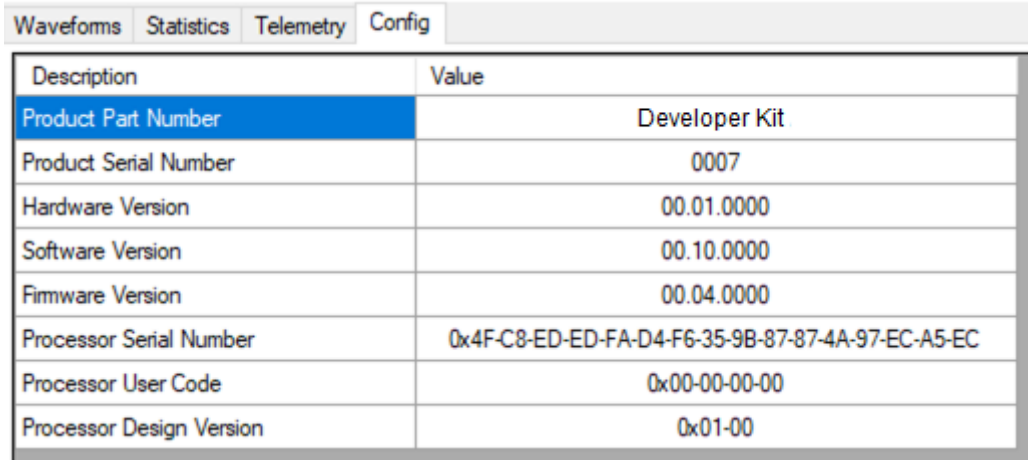

Figure 4-10: The Config Report Panel

4.3.4 The Firing sequence Tab

The "Firing sequence" tab allows the user to adjust the firing settings of the Kit which are used in the automated test sequence tab in Section 4.2.2. Hypernova will supply a default switch table and trigger sequence which can be used to fire the thrusters.

Figure 4-11 below shows an example of a firing sequence where TU1 (address '0') through to TU4 (address '3') are fired 100 ms apart (dwell time). The sequence is only executed once (repeat "0").

IMPORTANT NOTE: The default settings in the switch table have been determined from practice and should not be altered under normal circumstances. Experienced/advanced users may adjust these parameters, but do so at their own risk.

IMPORTANT NOTE: Although it is possible to command the thrusters to fire at a high firing frequency for brief periods of time (as represented by the dwell time in the Trigger table), it is recommended to keep above a dwell time of 50 ms so that (i) the PPU board has sufficient time to charge up for the next firing event, and (ii) heat generation in the thruster components and PPU board is kept within safe operational limits. Users may adjust these parameters, but do so at their own risk.

Each parameter is as follows:

i. Switch table: used to control the charging time and discharge to the thruster to create the arc. Under nominal use, the default values do not need to be adjusted.

ii. Selected Switch Table Entry: used to adjust the Switch table entries.
iii. Switch Config: controls the entries of the Switch table which are executed in listed order by the unit.
iv. Trigger table: used to control which thruster is fired and at what firing rate.
v. Selected Trigger Table Entry: used to adjust the Trigger table entries.
vi. Trigger Config: controls which entries are executed in listed order by the unit in the Trigger table and how often to repeat the entire sequence.
vii. PPU Config: used to set the DC-DC Voltage, enable the 12V, enable DC-DC Converter, enable the DC-DC Over Current Reset and enable the Trigger IGBT Over Current Reset.
viii. Measurement Config: used to set the threshold current for measurement and on which thruster this is set. Used to enable the Clear Raw FIFO, Clear Status FIFO and Clear Trigger Count of the Kit.

The top panel allows the user additional features as explained:

i. New: creates a new blank firing sequence
ii. Open: allows the use to open a previously saved firing sequence
iii. Save: saves the current firing sequence as a bin file.
iv. Add Switch table entry: Adds a new Switch Table entry with the values entered under ‘Selected Switch Table Entry’
v. Add Trigger table entry: Adds a new Trigger Table entry with the values entered under ‘Selected Trigger Table Entry’
vi. Delete: Deletes the selected Switch or Trigger entry
vii. Up: Moves the selected Switch or Trigger entry Up
viii. Down: Moves the selected Switch or Trigger entry Down

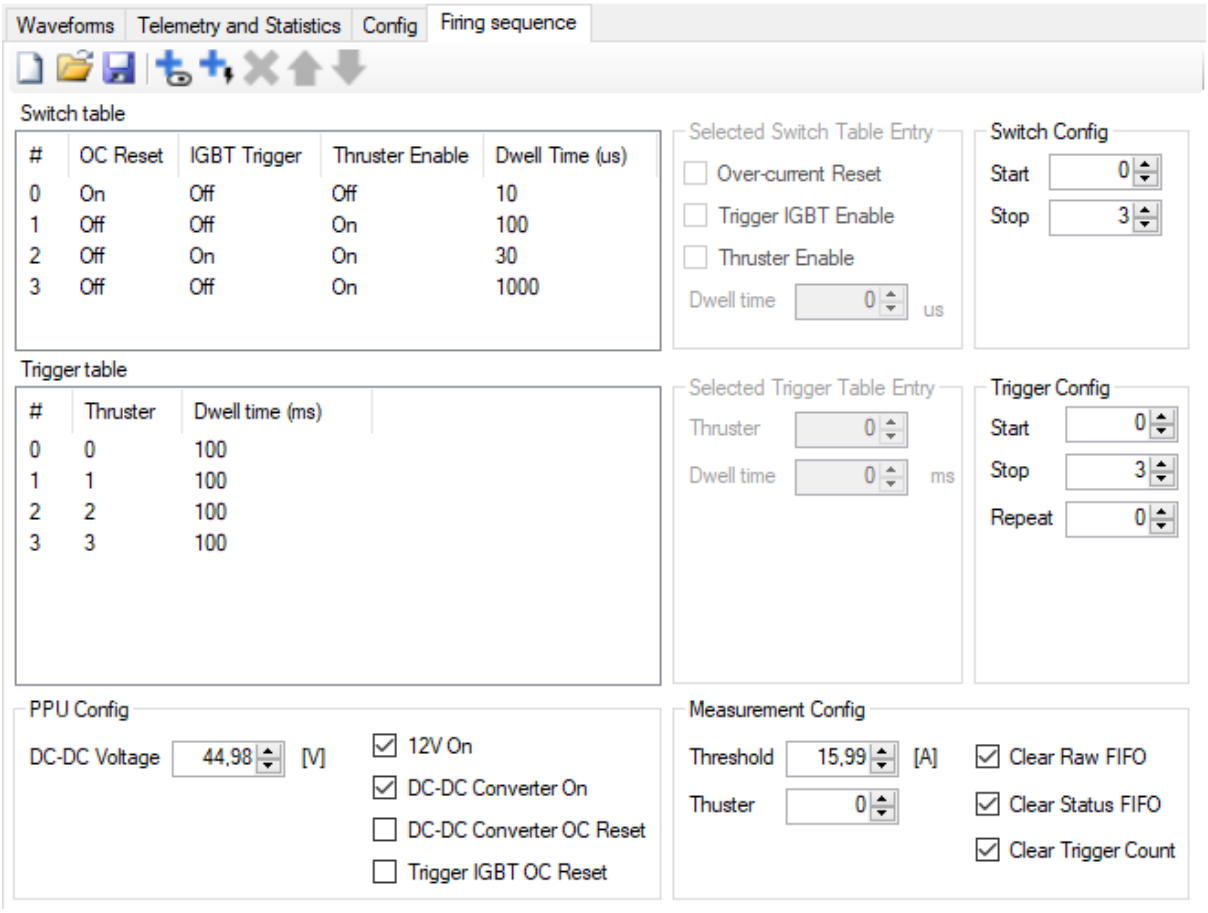

Figure 4-11: The Firing Sequence Panel