UM2269
User manual

Getting started with PowerShield firmware

Introduction

The STM32-LPM01-XN is an STMicroelectronics energy meter firmware dedicated to power consumption measurements for microcontrollers and boards.

It runs on X-NUCLEO-LPM01A and STM32L562E-DK boards.

In this document the firmware and its associated boards are referred to as “PowerShield”.

PowerShield is a a plug-and-play solution intended to ease power consumption measurements, used to supply and measure current consumption of boards such as STM32 Nucleo and Arduino®.

This document guides the user through the firmware characteristics and specific use cases.

This document must be read in conjunction with the following documents, available on *www.st.com*:

- User manuals of boards:
  - *STM32 Nucleo expansion board for power consumption measurement* (UM2243) for standalone board X-NUCLEO-LPM01A
  - *Discovery board with STM32L562E MCU* (UM2617) for STM32L5 discovery kit,
- User manuals of software tool:
  - *STM32CubeMonitor-Power software tool for power and ultra-low-power measurements* (UM2202).

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1 Boards overview

For of complete description of PowerShield boards, refer to user manuals:

- For standalone board X-NUCLEO-LPM01A: *STM32 Nucleo expansion board for power consumption measurement* (UM2243).
- For STM32L5 discovery kit: *Discovery board with STM32L562E MCU* (UM2617).

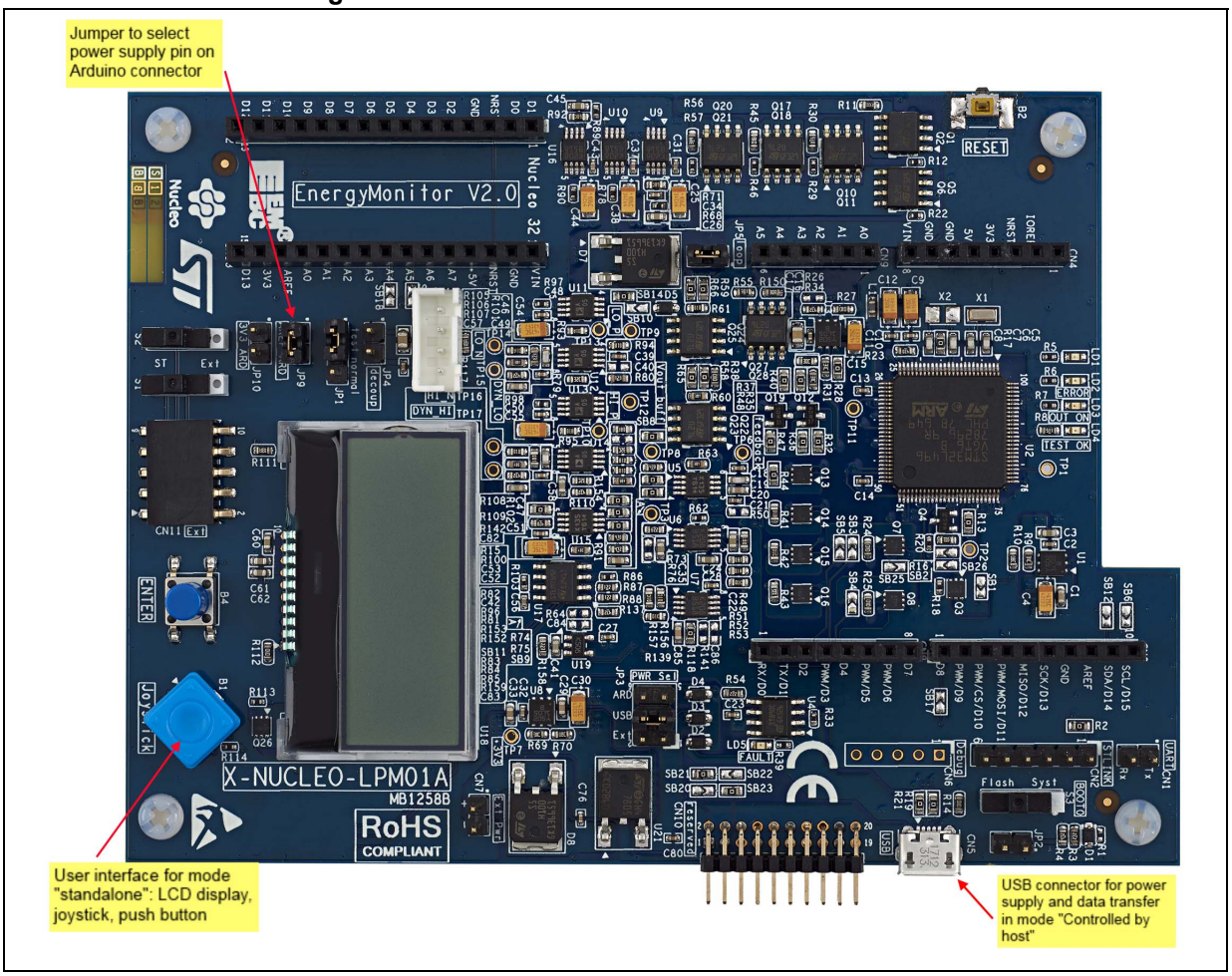
These boards and related firmware support STM32 Arm®-based devices.

Note: Arm is a registered trademark of Arm Limited (or its subsidiaries) in the US and/or elsewhere

1.1 PowerShield standalone board X-NUCLEO-LPM01A

PowerShield board is designed in a user-friendly mode. All features can be controlled by few buttons on board or USB interface.

Figure 1. PowerShield board main interface items



PowerShield board offers three connectors to supply target board: Nucleo64 connector, Nucleo32 connector, basic connector for any target.

Power supply interface

Nucleo connectors have two different pins for power supply:

- +3V3: Power supply for the whole board
- AVDD (AREF): Power supply for the MCU only

PowerShield supply to one of these two pins can be selected by jumpers JP9 and JP10.

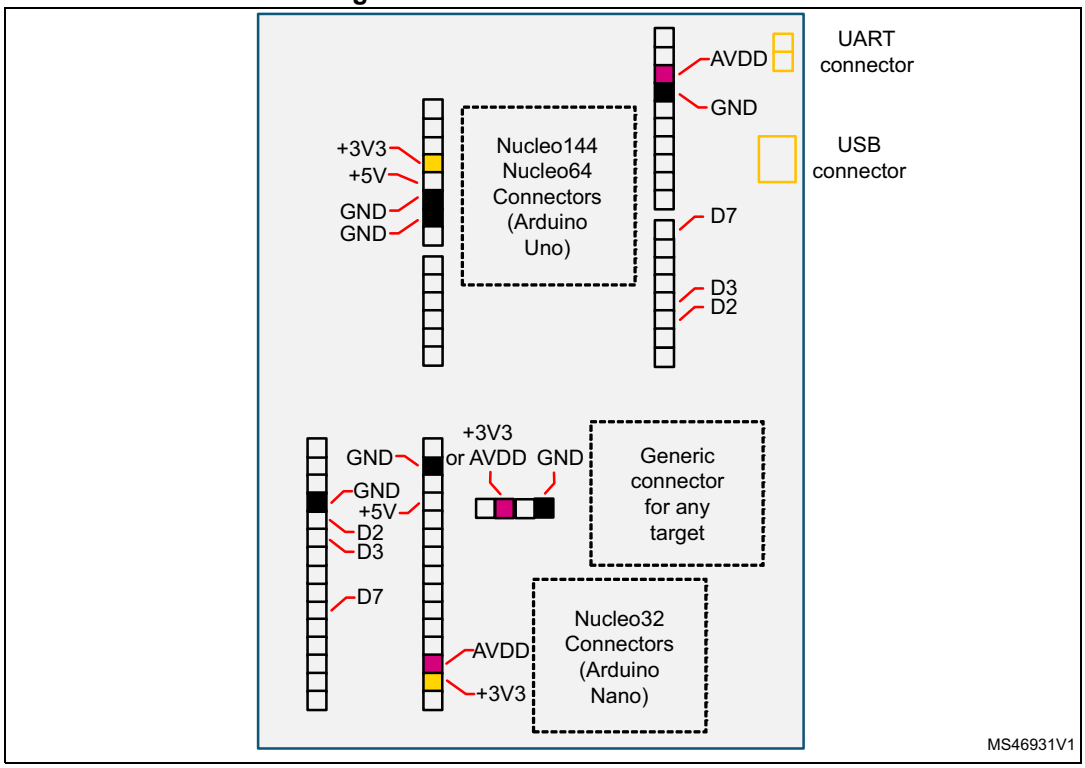
- JP10 closed: Power supply on connector +3V3
- JP9 closed: Power supply on connector AVDD

Note: Power can be supplied to one or to both pins (+3V3 and AVDD), depending on target board configuration to be monitored.

Communication interface

Two physical interfaces are available: USB and UART (reserved for future use).

Figure 2. PowerShield connectors



LED information

The board embeds four LED to inform user on PowerShield state, in standalone mode and controlled by host mode:

- LED green (LD4): Acquisition ongoing
- LED orange (LD3): Power supply to target board (in controlled by host mode, the board can remain supplied when the acquisition is completed)
- LED blue (LD1): Current measured above defined threshold
- LED red (LD2): Error

1.2 Quick setup to measure current on board Nucleo64 with standalone board X-NUCLEO-LPM01A

Refer to user manual *STM32 Nucleo-64 boards (MB1136)* (UM1724) for a complete description of Nucleo64 board.

Setup to measure current consumption of MCU only:

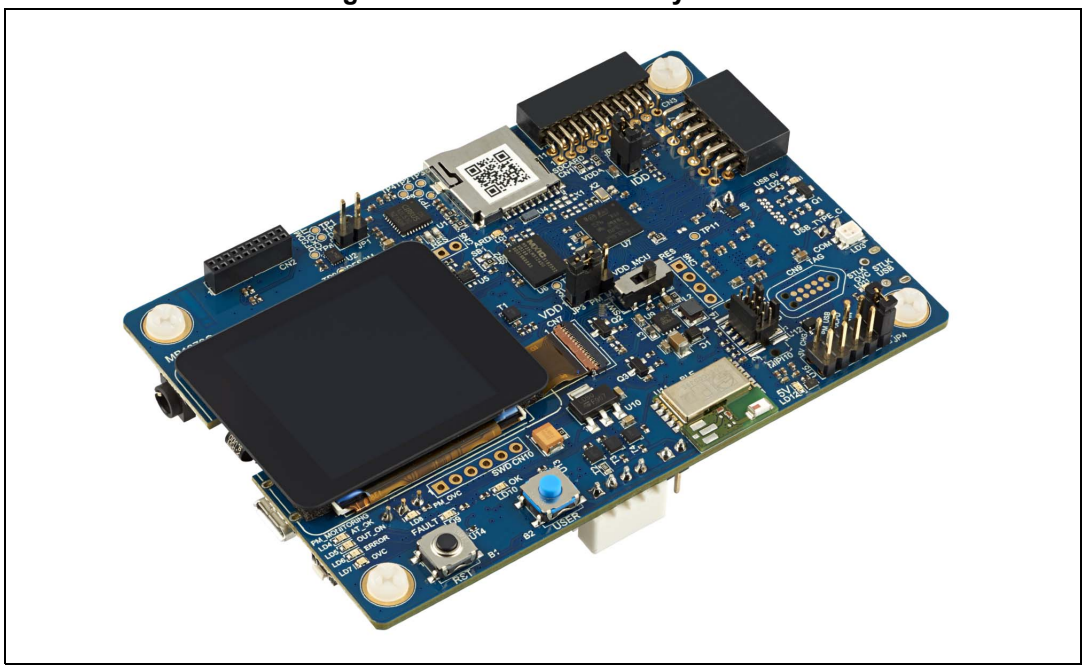
- On PowerShield:
  - Jumpers of power supply pin: Close jumper AREF_ARD, open jumper 3V3_ARD
- On board Nucleo64:
  - Load the desired code to be executed on target board.
  - Remove solder bridge SB12 to disconnect reset signal from ST-Link part (ST-Link can still be used with this configuration to load and debug a program, software tool option “Connect during reset” may be needed).
  - Open jumper IDD

1.3 STM32L5 discovery board STM32L562E-DK

STM32L5 discovery board embeds a PowerShield circuitry to measure the STM32L5 MCU power consumption.

It has the same features as PowerShield standalone board except that the STM32L5 discovery board must be used in host mode with computer through USB interface, moreover the acquisition mode static is not available (dynamic mode only). Refer to *Section 2: PowerShield modes and requirements* and *Section 5: PowerShield acquisition mode dynamic characteristics* for more details.

Figure 3. STM32L5 discovery board



2 PowerShield modes and requirements

The PowerShield features up to three modes.

2.1 Standalone mode

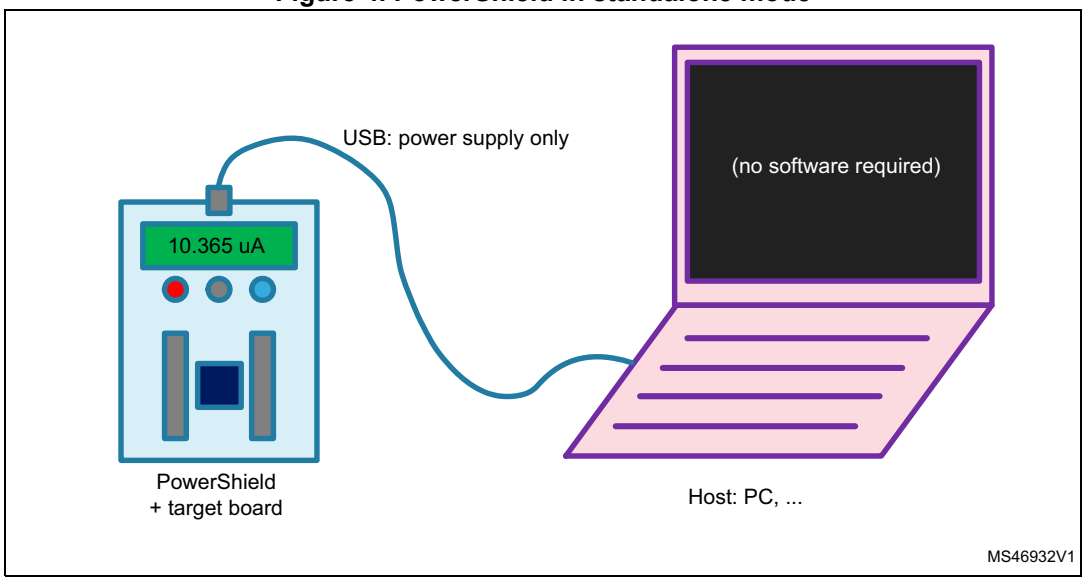
This mode is available only on standalone board X-NUCLEO-LPM01A.

PowerShield is controlled with board buttons, joystick and LCD display.

It must be connected to a USB port only to get power supply from USB (does not use USB data).

This mode can be used for quick measurements with basic settings, or for demonstrations.

Figure 4. PowerShield in standalone mode



Requirements:

- No communication interface requirement: user buttons and LCD displays are available on board
- Power supply: 5 V must be provided either by:
  - An USB connector:
    a) Computer: in this case, USB enumeration is performed but USB remains unused.
    b) Charger or power bank: in this case, no USB enumeration is performed.
  - A generic connector (to input 5 V):
    a) External power supply
    b) Battery
  - Arduino connector:
    a) Shield Lithium Arduino (Arduino pin +5 V)

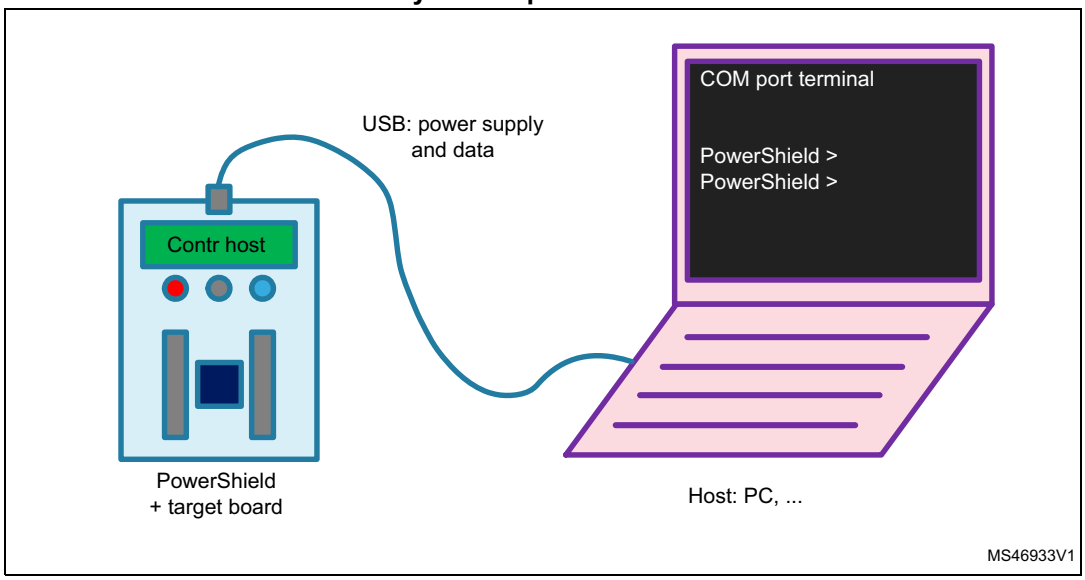
2.2 Controlled by host mode with commands sent by a COM port terminal

Host computer controls PowerShield through USB VCP (Virtual COM port).

The interface is a standard terminal.

This mode can be used for quick measurements with customized settings or for automation of tests, by sending a script with PowerShield commands.

Figure 5. PowerShield in controlled by host mode with commands sent by a COM port terminal



Requirements:

- Computer driver for USB VCP (Virtual COM port) "STM32 Virtual COM Port Driver". Refer to driver STSW-STM32102 on STMicroelectronics web site www.st.com.

  Note: On operating system Microsoft Windows 10, this driver is optional (since PowerShield FW revision 1.0.2). By default, PowerShield can use the operating system USB VCP driver. STMicroelectronics USB VCP driver can be installed, in this case it takes priority over operating system driver.

- Software terminal (large variety of free terminals available on the Internet)

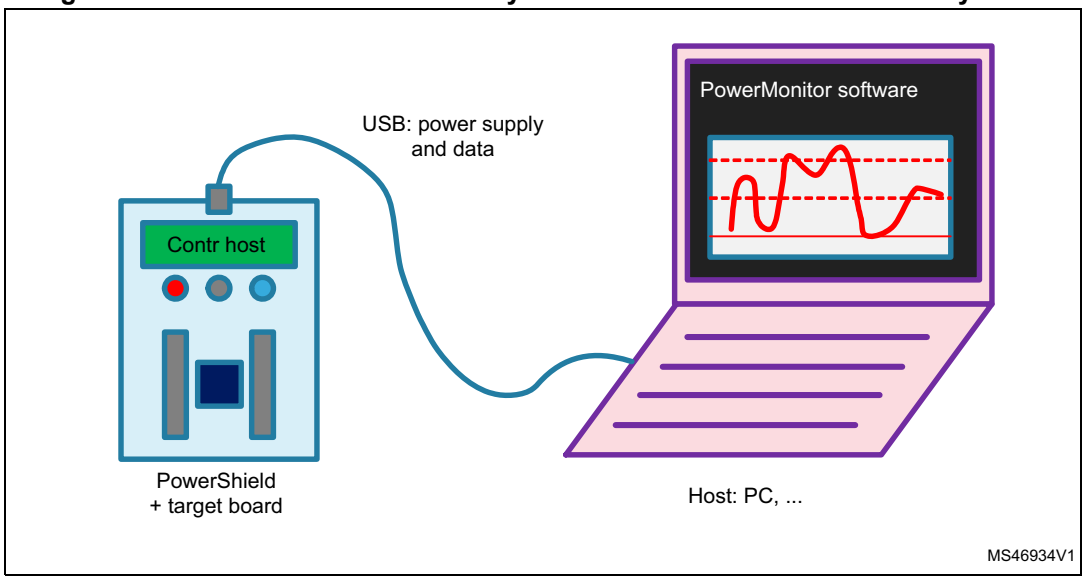
2.3 Controlled by host mode with commands sent by a GUI

PowerShield is controlled from host computer through USB VCP (Virtual COM port).

The interface is a dedicated GUI software.

This mode can be used to benefit of full capability of PowerShield measurement data: graphical data outcomes, statistical data.

Figure 6. PowerShield in controlled by host mode with commands sent by a GUI



Requirements:

- Computer driver for USB VCP (Virtual COM port) "STM32 Virtual COM Port Driver". Refer to driver STSW-STM32102 on STMicroelectronics web site www.st.com.

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- STMicroelectronics PowerShield GUI software STM32CubeMonitor-Power. Refer to user manual *STM32CubeMonitor-Power software tool for power and ultra-low-power measurements* (UM2202).

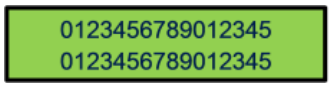
3 PowerShield standalone mode

The communication interface available on board features:

- Two buttons:
  - Reset
  - Enter / Start
- One joystick.
  The joystick embeds five push buttons: four directions and one in the center of joystick. The button in the center of joystick has the same function as button “ENTER” of keyboard.
- One LCD display: Monochrome, two lines of 16 characters

Note: A third button “reset” is available on board. It is not used as communication interface, but to perform a reset of PowerShield FW (similar to unplug and plug the board power supply).

The following scheme describes standalone mode interface navigation.

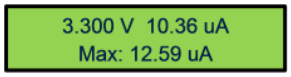
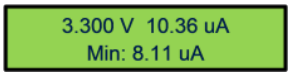
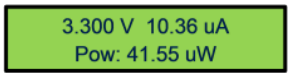
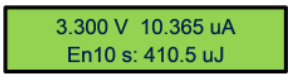
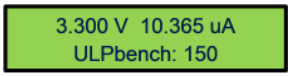
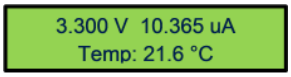
<table>
<tr><td colspan="2"> 
</td></tr>
<tr><td>1) PowerShield power-up

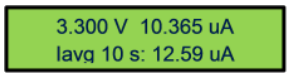
Welcome message for approximately two seconds.

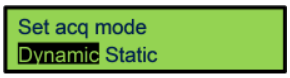
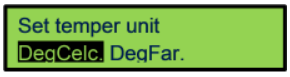
PowerShield waits for user action.</td><td> 

Wait two seconds
 
</td></tr>
</table>

<table>
<tr>
<td>2) Acquisition mode dynamic: starts measurement and views different data (average, power, energy, …)

When user presses on button “enter”, PowerShield powers-up supply of target board and starts measurement.
Default parameters:
– Power-up board, voltage: 3.0 V
– Integration time: 1 s
First line {voltage, current} is always displayed.
Voltage and current are instantaneous values (0.1 s averages).
Second line displays different data, circularly:
– Current average with integration time
– Current max
– Current min
– Power (Watt)
– Energy (Joule) with integration time
– ULP bench score: calculation of score depending on energy.
Prerequisite: board target must run an ULP bench compliant program
– Temperature</td>
<td>From measurement stopped:
Button “enter”:
 
Joystick down
 
Joystick down
 
Joystick down
 
Joystick down
 
Joystick down
 
Joystick down
 
(Joystick up doing the same in reverse order)</td>
</tr>
</table>

3) Acquisition mode static: starts measurement and views data To start a new acquisition without switching-off the power supply of target: press joystick up or down	From measurement stopped: Button “enter”:  Wait few tens of ms 
4) Acquisition mode dynamic and static: stops and starts new measurement Button “enter” toggles stop and start measurement. When measurement is stopped, power supply of target is switched-off.	From measurement ongoing: Button “enter”:  From measurement stopped: Button “enter”: 

5) Changes measurement settings: configuration menu. Rolling menu with configuration items one by one. Each item has few parameters selectable. Cursor moving: joystick to the right (after last parameter, roll back to first parameter). Back (Exit from configuration menu): joystick to the left. 6) Changes configuration: voltage Applies for acquisition mode: dynamic and static. Parameters: – 1.8 V – 2.4 V – 3.0 V – 3.3 V 5) Integration time. Applies for acquisition mode: dynamic. Parameters: – 1 s – 10 s – 100 s In data display, “Iavg xxx” and “Energ xxx” show the selected value. 8) Change configuration: acquisition mode. Parameters: – Dynamic (default) – Static 9) Changes configuration: trigger source. Applies for acquisition mode: dynamic and static. Parameters: – None – Board Arduino connector D7 (other name: EXT_A) 10) Changes configuration: trigger delay. Applies for acquisition mode: dynamic and static. Parameters: – None – 0.1 s – 1 s – 10 s 11) Changes configuration: current threshold. Applies for acquisition mode: dynamic. Parameters: – None – 1 mA – 10 mA 12) Changes configuration: temperature unit. Parameters: – Deg Celsius – Deg Fahrenheit	Joystick to the right  Joystick down  Joystick down  Joystick down  Joystick down  Joystick down  Joystick down 

13) Error message check and release. When LED red is turned-on, it indicates that an error is present. From main screen, moves joystick to the left allows the user to check error message. The message remains displayed for 4 s, then error status is released: message cleared, LED red turned-off.	From main screen (all except configuration menu): Joystick to the left: Case of no error:  Message displayed 1s Case of error present:  Message displayed 4s

4 PowerShield controlled by host mode

To enter in controlled by host mode, user must configure the host with the serial port described settings and sends a command to take control of PowerShield (commands description below).

PowerShield controlled by host mode functionality:

- Power Shield enters in slave mode, master is the host.
- Role of PowerShield is to send data of measurements to host. All calculations are done on host side.
- Message “Host control” is displayed on LCD.
- All buttons are disabled.

4.1 Serial COM port configuration

PowerShield uses the communication interface of serial COM port, USB-VCP (Virtual COM port):

- Serial COM port configuration of USB-VCP (main interface):
  - Baud rate: 3.6 Mbit/sec (3686400 bauds)[(a)]
  - Data: 8 bit
  - Stop: 1 bit
  - Parity: none
  - Flow control: none

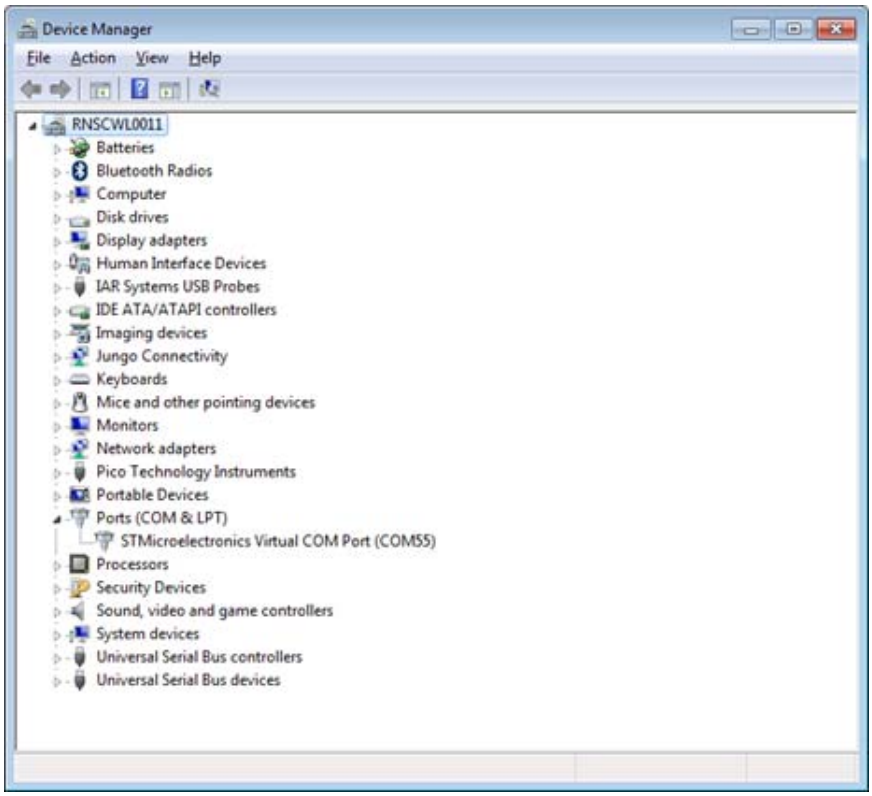
Note: The other communication interface UART is reserved for future use.

Host must use the same serial port configuration for software part (terminal, …).

Once PowerShield is plugged to host through USB, enumeration process is performed. Enumeration process requests to host a current capability of 500 mA. Host detects the PowerShield as peripheral “STMicroelectronics Virtual COM port”.

a. On host USB virtual COM port, configuration of baud rate may be not needed since replaced by USB maximum baudrate

Figure 7. Host detection of PowerShield



4.2 PowerShield shell

4.2.1 Transfer protocol of commands

Commands are formatted in ASCII format.

Each command sent to PowerShield must end by ASCII characters “\r\n” (carriage return, line feed).

In case of usage of a serial COM port terminal, it must be configured accordingly.

Figure 8. Example of serial COM port terminal configuration

Each command received from PowerShield also ends by ASCII characters “\r\n”.

4.2.2 Transfer protocol of measurement data stream

Refer to *Section 4.3.2: Command description*. Several data format are available, among them ASCII and binary.

4.2.3 Command management

The shell always replies to a command sent.

Feedback can be either:

- Acknowledge: string “ack” is sent back with the command string.
  The acknowledge is followed by the command effectively applied or command returned data.
- Error: string “err” is sent back with the command string.
  On following lines, a description of the error can be sent.

The commands can take some arguments, either string or numerical values.

Numerical values of arguments can be formatted with:

- Numerical characters only (possible when numbers are ≥ 1)
- Numerical characters with unit characters 'u', 'm', 'k', 'm'
- Numerical characters with powers of ten '-xx' or '+xx' (xx: number on two digits maximum)

Example: Value '2 milliseconds' can be entered with: '2 m' or '2-3'

4.3 Interface commands

Interface commands are available when PowerShield is in controlled by host mode.

4.3.1 Command list summary

When sending command “help” to PowerShield firmware, it returns back the list of available commands and a short description for each command.

Table 1. List summary as displayed by firmware when entering command “help”

PowerShield commands	
Command	**Description**
Common operation	
help	Displays list of commands
echo <arg1>	Loopback to check functionality of communication Rx and Tx. <arg1>: string of characters
powershield	Check PowerShield device availability, can be used to scan on which serial port is connected the PowerShield. Response: “PowerShield present” with board unique ID
version	Get PowerShield FW revision. Response: “<main>.<sub1>.<sub2>”

Table 1. List summary as displayed by firmware when entering command “help” (continued)

PowerShield commands	
Command	**Description**
htc	Host take control (goes from standalone mode to controlled by host mode)
htc	Host release control (goes from controlled by host mode to standalone mode)
lcd	Displays a custom string on LCD display when PowerShield is controlled by host. <arg1>: LCD line. Numerical value among list: {1, 2} <arg2>: string to be displayed, surrounded by double quotes and with 16 characters maximum. Example: lcd 1 “custom display” Note: Available only on standalone board X-NUCLEO-LPM01A.
psrst	Reset PowerShield (hardware reset, host communication have to be restored)
Measurement acquisition configuration	
volt <arg1>	Set or gets power supply voltage level, unit: V. <arg1>: set voltage: numerical value in range [1800 m; 3300 m] Default value: 3300 m Get voltage: string “get” (*Section 4.2.3: Command management*)
freq <arg1>	Set sampling frequency, unit: Hz. <arg1>: Numerical value among list: {100 k, 50 k, 20 k, 10 k, 5 k, 2 k, 1 k, 500, 200 100, 50, 20, 10, 5, 2, 1} Default value: 100 Hz (*Section 4.2.3: Command management*)
acqtime <arg1>	Set acquisition time, unit: s. <arg1>: For limited acquisition duration: numerical value in range: [100 µs; 10] For infinite acquisition duration: numerical value “0” or string “inf” Caution: maximum acquisition time depends on other parameters. Refer to *Table 2*. Default value: 10 s (*Section 4.2.3: Command management*)
acqmode <arg1>	Set acquisition mode: dynamic or static. Dynamic: current can vary, range [100 nA; 10 mA] Static: current must be constant, range [2 nA; 200 mA] <arg1>: string among list: {dyn, stat} available only on standalone board X-NUCLEO-LPM01A. Default value: “dyn”

Table 1. List summary as displayed by firmware when entering command “help” (continued)

PowerShield commands	
Command	**Description**
funcmode <arg1>	Set optimization of acquisition mode dynamic (applicable only with command “output” set to parameter “current”): optim: priority on current resolution (100 nA-10 mA), max sampling frequency at 100 kHz. high: high current (30 µA–10 mA), high sampling frequency (50-100 kHz), high resolution. <arg1>: String among list: {optim, high} Default value: “optim”
output <arg1>	Set output type. Current: instantaneous current. Energy: integrated energy, reset after each sample sent (integration time set by parameter “freq”, limited at 100 Hz max (⇔ 10 ms min)). <arg1>: string among list: {current, energy} Default value: “current”'
format <arg1>	Set measurement data format. Data format 1: ASCII, decimal basis. Format readable directly, but sampling frequency limited to 10 kHz. Decoding: 6409-07 ⇔ 6409 x 10^-7 = 640.9 µA Data format 2: Binary, hexadecimal basis. Format optimized data stream size. Decoding: 52A0 ⇔ (2A0)16 x 16^-5 = 640.9 µA <arg1>: string among list: {ascii_dec, bin_hexa} Caution: Data format depends on other parameters. Refer to *Table 2*. Default value: 'ascii_dec'
trigsrc <arg1>	Set trigger source to start measurement acquisition. Software trigger source (immediate trig after software start), trigger from signal rising edge on Arduino connector D7 (via solder bridge). <arg1>: string among list: {sw, d7} Default value: “sw”
trigdelay <arg1>	Set trigger delay between target power-up and starts measurement acquisition, unit: s, resolution: 1 ms. <arg1>: numerical value in range [0; 30] Default value: 1 m
currthre <arg1>	Set current threshold to trig an event, unit: A. Event triggered when threshold exceeded: signal generated on Arduino connector D2 or D3 (via solder bridge) and LED4 (green) turned on. <arg1>: Numerical value in range [0; 10 m] Default value: 1 m

Table 1. List summary as displayed by firmware when entering command “help” (continued)

PowerShield commands	
Command	**Description**
pwr <arg1> <arg2>	Set target power supply connection. – Automatic: On first run, power-on when acquisition start.Then, power state depends on command 'pwrend'. – Manual: Force power state. Note: Can be used during acquisition. To perform successive power off and on, it is preferable to use command 'targrst'. Optionally, connection status can be sent at the beginning and end of acquisition data stream. <arg1>: Set pwr: String among list: {'auto', 'on', 'off'} Default value: 'auto' Get pwr: String 'get' (response: state 'on' or 'off') <arg2>: Optional, string among list: {'nostatus', 'status'} Default value: 'nostatus'
pwrend <arg1>	Set target power supply to be applied after current measurement acquisition: power-on or power-off. <arg1>: String among list: {on, off} Default value: “on”
Measurement acquisition operation	
start	Starts current measurement
stop	Stops current measurement
targrst <arg1>	Reset target by disconnecting power supply during a configurable duration, unit: s. *Note: can be performed during acquisition to monitor target transient current consumption during its power-up.* <arg1>: numerical value in range [1 m; 1] or value “0” to let target powered-down
temp <arg1>	Gets temperature from temperature sensor on PowerShield board, on unit: Celsius or Fahrenheit degrees <arg1>: String among list: {degc, degf} Default value: “degc”
Note: Numerical values of arguments can be formatted in: – Numerical characters only, when numbers are ≥ 1) – Numerical characters with unit characters “u”, “m”, “k”, “m” – Numerical characters with power of ten “-xx” or “+xx” (xx: number on two digits maximum) Example: Value “2 milliseconds” can be entered with: “2 m” or “2-3”	

Table 2. Maximum acquisition time possible for a baudrate of 3686400 bauds

Format	Frequency	Acqtime max	Correspondent number of samples
ascii_dec	≤ 5 kHz	unlimited	(unlimited)
ascii_dec	10 kHz	1 s	(10000)
ascii_dec	20 kHz	500 ms	(5000)
bin hexa	≤ 100 kHz	unlimited	(unlimited)

4.3.2 Command description

1. Commands: common operation
   These commands can be sent to PowerShield in both the functional standalone mode or controlled by host mode.

Table 3. “help” command (1)

Argument	(none)
Description	Displays list of commands

1. This command can be used when PowerShield is controlled in standalone mode.

Table 4. “echo” command

Argument	1. String of characters
Description	Loopback to check functionality of communication Rx and Tx

Table 5. “powershield” command(1)

Argument	(none)
Description	Checks PowerShield device availability, can be used to scan on which serial port is connected the PowerShield. Response: “PowerShield present” with board unique ID. Example of shell feedback: *PowerShield > ack powershield 540619864-1110659081-4784204*

1. This command can be used when PowerShield is controlled in standalone mode

Table 6. “version” command(1)

Argument	(none)
Description	Gets PowerShield firmware revision. Response: “<main>.<sub1>.<sub2>” Example of shell feedback: `PowerShield > ack version: 1.0.0`

1. This command can be used when PowerShield is controlled in standalone mode.

Table 7. “status” command(1)

Argument	(none)
Description	Gets PowerShield status. Response: “ok” or “error: <error description>” In case of error, running this command releases error status: turn-off LED red, clear PowerShield state machine error state.

1. This command can be used when PowerShield is controlled in standalone mode.

Table 8. “htc” command

Argument	(none)
Description	Host takes control (goes from standalone mode to controlled by host mode)

Table 9. “hrc” command

Argument	(none)
Description	Host releases control (goes from controlled by host mode to standalone mode)

Table 10. “lcd” command

Argument	1. LCD line. Numerical value among list: {1, 2} 2. String to be displayed, surrounded by double quotes with 16 characters maximum. Example of command sent to shell: `lcd 1 "  custom display"`
Description	Display a custom string on LCD display when PowerShield is controlled by host. Note: Available only on standalone board X-NUCLEO-LPM01A.

Table 11. “psrst” command(1)

Argument	(none)
Description	Reset PowerShield (hardware reset, host communication have to be restored).

1. This command can be used when PowerShield is controlled in standalone mode.

2. Commands: measurement acquisition configuration

Table 12. “volt” command

Argument	1. Set voltage: Numerical value in range [1800 m; 3300 m] Default value: 3000 m Get voltage: String “get”
Description	Set or gets power supply voltage level, unit: V.

Table 13. “freq” command

Argument	1. Numerical value among list: {100 k, 50 k, 20 k, 10 k, 5 k, 2 k, 1 k, 500, 200, 100, 50, 20, 10, 5, 2, 1} Default value: 100 Hz
Description	Set sampling frequency, unit: Hz

Table 14. “acqtime” command

Argument	1. For limited acquisition duration: – Numerical value in range: [100 µ; 10] For infinite acquisition duration: – Numerical value “0” or string “inf” Caution: Maximum acquisition time depends on other parameters. Refer to *Section 5.2.1: Acquisition frequency limitations*. Default value: 10 s
Description	Set acquisition time, unit: s

Table 15. “acqmode” command

Argument	1. String among list: {dyn, stat} Default value: “dyn”
Description	Set acquisition mode: dynamic or static. dynamic: current can vary, range [100 nA; 10 mA] static: current must be constant, range [2 nA; 200 mA], available only on standalone board X-NUCLEO-LPM01A.

Table 16. “funcmode” command

Argument	1. String among list: {optim, high} Default value: “optim”
Description	Set optimization of acquisition mode dynamic (applicable only with command “output” set to parameter “current”): optim: priority on current resolution (100 nA-10 mA), max sampling frequency at 100 kHz. high: high current (30 µA–10 mA), high sampling frequency (50-100 kHz), high resolution. *Note: In mode optimized for amplitude, the benefit is to have complete dynamic of signal [100 nA; 10 mA] but with drawback of timing artifacts (few ms max)*

Table 17. “output” command

Argument	1. String among list: {current, energy} Default value: “current”
Description	Set output type. current: instantaneous current energy: integrated energy, reset after each sample sent (integration time set by parameter “freq”, limited at 100 Hz max (⇔ 10 ms min)).

Table 18. “format” command

Argument	1. String among list: {ascii_dec, bin_hexa} Caution: Data format depends on other parameters. Refer to *Section 5.2.1: Acquisition frequency limitations*. Default value: “ascii_dec”
Description	Set measurement data format. Data format 1: ASCII, decimal basis. – Format readable directly, but sampling frequency limited to 10 kHz. Decoding: 6409-07 ⇔ 6409 x 10^-7 = 640.9 µA Data format 2: Binary, hexadecimal basis. – Format optimized data stream size. Decoding: 52A0 ⇔ (2A0)16 x 16^-5 = 640.9 µA

Table 19. “trigsrc” command

Argument	1. String among list: {sw, d7} Default value: “sw”
Description	Set trigger source to start measurement acquisition: trigger source software (immediate trig after software start), trigger from external signal rising or falling edge on Arduino connector D7 (via solder bridge). *Note: Trigger from external signal also requires command “start” (similar software start) to arm the trigger, then following triggers are effective without any command.* Command “stop” disarms the trigger (acquisition stop after acquisition time elapsed does not disarm the trigger). *Note: When trigger source from Arduino connector D7 is used, the alternate communication interface with UART connector cannot be used after trigger is armed (due to Arduino connector D7 and UART Rx sharing the same input).*

Table 20. “trigdelay” command

Argument	1. Numerical value in range [0; 600] Default value: 1 m
Description	Set trigger delay between target power-up and starts measurement acquisition, unit: s, resolution: 1 ms. This command allows the voltage and current to stabilize before start of current acquisition.

Table 21. “currthre” command

Argument	1. Numerical value in range [0; 10 m] Default value: 1 m
Description	Set current threshold to trig an event, unit: A. Event triggered when threshold exceeded: signal generated on Arduino connector D2 or D3 (via solder bridge) and LED4 (green) turned on.

Table 22. “pwr” command

Argument	1. Set pwr: String among list: {'auto', 'on', 'off'} Default value: 'auto' Get pwr: String 'get' (response: state 'on' or 'off') 2. Optional, string among list: {'nostatus', 'status'} Default value: 'nostatus'
Description	Set target power supply connection. – Automatic: • On first run, power-on when acquisition start. • Then, power state depends on command 'pwrend'. – Manual: • Force power state. *Note: Can be used during acquisition. To perform successive power off and on, it is preferable to use command 'targrst'.* Optionally, connection status can be sent at the beginning and end of acquisition data stream. *Note: This command is available since PowerShield FW revision 1.0.2.*

Table 23. “pwrend” command

Argument	1. String among list: {on, off} Default value: “on”
Description	Set target power supply to be applied after current measurement acquisition: power-on or power-off.

3. Commands: Measurement acquisition operation

Table 24. “start” command

Argument	(none)
Description	Starts acquisition (measurement of current or energy depending on configuration).

Table 25. “stop” command

Argument	(none)
Description	Stops acquisition. If acquisition is set to a finite duration, it stops when reaching the target duration.

Table 26. “targrst” command

Argument	1. Numerical value in range [1 m; 1] or value “0” to let target power-down.
Description	Reset target by disconnecting power supply during a configurable duration, unit: s. *Note: can be performed during acquisition to monitor target transient current consumption during its power-up.*

Table 27. “temp” command

Argument	1. String among list: {degc, degf} Default value: “degc”
Description	Gets temperature from temperature sensor on PowerShield board, on unit: Celsius or Fahrenheit degrees. *Note: reported temperature is an approximation of ambient temperature; measured temperature corresponds to temperature on board surface, which is higher than ambient temperature of approximatively 3 Celsius degrees (due to board self-heating with surrounding components), therefore this value is subtracted to measured temperature on board surface.* *In case of specific conditions (for example, forced convection in a laboratory oven), user must apply a temperature offset to reported temperature.*

4. Commands: Board state operation

Table 28. “autotest” command

Argument	1. Optional: string among list: {start, status} or no argument equivalent to value: “start”
Description	Performs board auto-test and display auto-test results. *Note: auto-test is done at PowerShield power-up.* *Argument “status” can be used to check results of auto-test done at PowerShield power-up.*

Table 29. “calib” command

Argument	(none)
Description	Performs board self-calibration. *Note: new calibration should be performed when temperature shifts of more than 5 °C since the previous calibration.*

4.4 Data stream format

Measurement data contain the main information: current or energy (depending on configuration sent to PowerShield shell).

Note: Information of voltage is not sent. Effective voltage is assumed to be close to targeted voltage (tolerance approximatively ±1%).

Note: Information of timing is not sent and must be deduced from data count. For example, if the acquisition frequency is set at 10 kHz, the first data corresponds to 10 µs, the second data to 20 µs, the third data to 30 µs, and so on.

4.4.1 Data format 1: ASCII, decimal basis

1. Measurement data of current or energy
   Format intended when PowerShield is used with a COM port terminal: data are formatted in ASCII characters, values are in decimal basis.

Note: Due to higher data size in ASCII format and to data bandwidth constraints, this data format can be used with a sampling up to 10 ksamples/sec.

Each measurement data is formatted on eight ASCII characters:

Table 30. ASCII characters description

Byte on serial port	Byte number	Description
ASCII [0; 9]	1	Current measurement digit 4
ASCII [0; 9]	2	Current measurement digit 3
ASCII [0; 9]	3	Current measurement digit 2
ASCII [0; 9]	4	Current measurement digit 1
ASCII {'-';'+'}	5	Current measurement power of 10 sign
ASCII [0; 9]	6	Current measurement power of 10 value
ASCII [0; 9]	7	Current measurement power of 10 value
ASCII '\r'	8	Carriage return
ASCII '\n'	9	Line feedback

Example of data stream and corresponding conversion to decimal values:

$6409*10^{-7}$

$$(6409)_{10} \times 10^{-7} = 640.9 \cdot 10^{-6} = 640.9 \quad \mu A$$

2. Metadata inserted into data stream
   Metadata are inserted into data stream to provide other information.
   Data must be filtered in data stream to isolate measurement data (current or energy values) versus metadata.

Differentiator of measurement data versus metadata:

– Measurement data are beginning by a number in ASCII format (first byte corresponding to decimal values from 48 to 57).
– Metadata are beginning with a letter in ASCII format (first byte corresponding to decimal value other than a number, described above).

Metadata: Timestamp and buffer Tx load

Each 1000 samples, a timestamp is sent.

It can be used to check data count matches with each timestamp occurrence, and to resynchronize timing if some data have been lost.

Timestamp also includes information of time elapsed in milliseconds.

Additionally, the information of PowerShield buffer Tx load is added after time elapsed.

It is useful in case host encounters a delay on USB bus (can occur when host is busy by CPU load or file access delay), to take appropriate action before buffer overload and acquisition stop.

Timestamp format: ASCII, decimal format

Table 31. Timestamp, format 1: ASCII characters description

Byte on serial port	Byte number	Description
ASCII ‘\r’	1	Carriage return
ASCII ‘\n’	2	Line feedback
ASCII ‘T’	3	Timestamp tag characters
ASCII ‘i’	4	Timestamp tag characters
ASCII ‘m’	5	Timestamp tag characters
ASCII ‘e’	6	Timestamp tag characters
ASCII ‘s’	7	Timestamp tag characters
ASCII ‘t’	8	Timestamp tag characters
ASCII ‘a’	9	Timestamp tag characters
ASCII ‘m’	10	Timestamp tag characters
ASCII ‘p’	11	Timestamp tag characters
ASCII ‘:’	12	Timestamp tag characters
ASCII ‘ ’	13	Timestamp tag characters
ASCII [0; 9]	14	Timestamp value in s, digit 2
ASCII [0; 9]	15	Timestamp value in s, digit 1
ASCII [0; 9]	16	Timestamp value in s, digit 0
ASCII ‘s’	17	Timestamp value character
ASCII ‘ ‘	18	Timestamp value character
ASCII [0; 9]	19	Timestamp value in ms, digit 2
ASCII [0; 9]	20	Timestamp value in ms, digit 1
ASCII [0; 9]	21	Timestamp value in ms, digit 0

Table 31. Timestamp, format 1: ASCII characters description (continued)

Byte on serial port	Byte number	Description
ASCII ‘m’	22	Timestamp value character
ASCII ‘s’	23	Timestamp value character
ASCII ‘,‘	24	Timestamp tag characters
ASCII ‘ ‘	25	Timestamp tag characters
ASCII ‘b‘	26	Timestamp tag characters
ASCII ‘u‘	27	Timestamp tag characters
ASCII ‘f‘	28	Timestamp tag characters
ASCII ‘f‘	29	Timestamp tag characters
ASCII ‘ ‘	30	Timestamp tag characters
ASCII [0; 9]	31	Buffer Tx load value in percent, digit 1
ASCII [0; 9]	32	Buffer Tx load value in percent, digit 0
ASCII ‘%‘	33	Timestamp tag characters
ASCII ‘\r‘	34	Carriage return
ASCII ‘\n ‘	35	Line feedback

Metadata: Error

An error message (voltage drop) can be sent as a stream of ASCII characters.

Table 32. Error, format 1: ASCII characters description

Byte on serial port	Byte number	Description
ASCII ‘\r‘	1	Carriage return
ASCII ‘\n ‘	2	Line feedback
ASCII ‘e‘	3	Error tag characters
ASCII ‘r‘	4	Error tag characters
ASCII ‘r‘	5	Error tag characters
ASCII ‘o‘	6	Error tag characters
ASCII ‘r‘	7	Error tag characters
ASCII char	8	Message content: ASCII character
ASCII char	...	Message content: ASCII character
ASCII char	x	Message content: ASCII character
ASCII char	x + 1	Message content: ASCII character
ASCII ‘\r’	x + 2	Carriage return
ASCII ‘\n’	x + 3	Line feedback

Metadata: End of acquisition

Metadata send when acquisition is completed: integration time reached or command “stop” sent by user, and all data in Tx buffer sent to host.

Table 33. End of acquisition, format 1: ASCII characters description

Byte on serial port	Byte number	Description
ASCII ‘\r‘	1	Carriage return
ASCII ‘\n ‘	2	Line feedback
ASCII ‘e‘	3	End of acquisition tag characters
ASCII ‘n‘	4	End of acquisition tag characters
ASCII ‘d‘	5	End of acquisition tag characters
ASCII ‘\r‘	6	Carriage return
ASCII ‘\n ‘	7	Line feedback

Metadata: Power to target connection

Metadata sent as acknowledge and data of command “pwr get”.

Metadata also sent at the beginning (after metadata of acquisition start) and end (before metadata of acquisition end) of each acquisition if second parameter of command “pwr” is set to argument “status” (optional).

Power to target connection status is coded on two or three characters:

“off” <=> power off (power supply disconnected from target)

“on” <=> power on (power supply connected to target)

Table 34. Power to target, format 1: ASCII characters description

Byte on serial port	Byte number	Description
ASCII ‘\r‘	1	Carriage return
ASCII ‘\n ‘	2	Line feedback
ASCII ‘p‘	3	Power to target tag characters
ASCII ‘w‘	4	Power to target tag characters
ASCII ‘r‘	5	Power to target tag characters
ASCII ‘ ‘	6	Power to target tag characters
ASCII char	7	Power to target connection status characters
ASCII char	8	Power to target connection status characters
ASCII char	...	Power to target connection status characters
ASCII ‘\r‘	x	Carriage return
ASCII ‘\n ‘	x	Line feedback

Metadata: Summary

After end of acquisition, a summary is displayed between tags “summary begin” and “summary end”.

Description and data sent in ASCII: acquisition mode, sampling frequency

Table 35. Summary, format 1: ASCII characters description

Byte on serial port	Byte number	Description
ASCII ‘\r‘	1	Carriage return
ASCII ‘\n ‘	2	Line feedback
ASCII ‘s‘	3	Summary tag characters
ASCII ‘u‘	4	Summary tag characters
ASCII ‘m‘	5	Summary tag characters
ASCII ‘m‘	6	Summary tag characters
ASCII ‘a‘	7	Summary tag characters
ASCII ‘r‘	8	Summary tag characters
ASCII ‘y‘	9	Summary tag characters
ASCII ‘ ‘	10	Summary tag characters
ASCII ‘b‘	11	Summary tag characters
ASCII ‘e‘	12	Summary tag characters
ASCII ‘g‘	13	Summary tag characters
ASCII ‘\r‘	14	Carriage return
ASCII ‘\n ‘	15	Line feedback
ASCII [0; 9]	16	current measurement min digit 4
ASCII [0; 9]	17	current measurement min digit 3
ASCII [0; 9]	18	current measurement min digit 2
ASCII [0; 9]	19	current measurement min digit 1
ASCII {‘-’; ‘+’}	20	current measurement min power of 10 sign
ASCII [0; 9]	21	current measurement min power of 10 value
ASCII [0; 9]	22	current measurement min power of 10 value
ASCII ‘\r‘	23	Carriage return
ASCII ‘\n ‘	24	Line feedback
ASCII [0; 9]	25	current measurement max digit 4
ASCII [0; 9]	26	current measurement max digit 3
ASCII [0; 9]	27	current measurement max digit 2
ASCII [0; 9]	28	current measurement max digit 1
ASCII {‘-’; ‘+’}	29	current measurement max power of 10 sign
ASCII [0; 9]	30	current measurement max power of 10 value
ASCII [0; 9]	31	current measurement max power of 10 value

Table 35. Summary, format 1: ASCII characters description (continued)

Byte on serial port	Byte number	Description
ASCII '\r'	32	Carriage return
ASCII '\n '	33	Line feedback
ASCII 's'	34	Summary tag characters
ASCII 'u'	35	Summary tag characters
ASCII 'm'	36	Summary tag characters
ASCII 'm'	37	Summary tag characters
ASCII 'a'	38	Summary tag characters
ASCII 'r'	39	Summary tag characters
ASCII 'y'	40	Summary tag characters
ASCII ' '	41	Summary tag characters
ASCII 'e'	42	Summary tag characters
ASCII 'n'	43	Summary tag characters
ASCII 'd'	44	Summary tag characters
ASCII '\r'	45	Carriage return
ASCII '\n '	46	Line feedback

4.4.2 Data format 2: Binary, hexadecimal basis

1. Measurement data of current or energy

   Format intended when PowerShield is used with host software "Power Monitor": software must decode data from hexadecimal to decimal.

   This data format is optimized to have to lowest data width per measurement data.

   Each measurement data is formatted on two bytes (binary value, not ASCII):

   – Data size of two bytes characters compresses data size as much as possible (it allows the user to transmit a data stream of 50 ksamples/sec at bit rate 921.600 kbps).

   – Each data is coded in hexadecimal: 12 bits of data and four bits of negative power of 16.

Data accuracy: Decimation error of base 16 is data ±0.20% worst case.

Table 36. Serial byte 1

Serial data 1	Serial data 2	Serial data 3	Serial data 4	Serial data 5	Serial data 6	Serial data 7	Serial data 8	Serial stop bit
Current neg pow16 bit 3	Current neg pow16 bit 2	Current neg pow16 bit 1	Current neg pow16 bit 0	Current value bit 11	Current value bit 10	Current value bit 9	Current value bit 8	

Table 37. Serial byte 2

Serial data 1	Serial data 2	Serial data 3	Serial data 4	Serial data 5	Serial data 6	Serial data 7	Serial data 8	Serial stop bit
Current value bit 7	Current value bit 6	Current value bit 5	Current value bit 4	Current value bit 3	Current value bit 2	Current value bit 1	Current value bit 0	

Example of measurement data sent on serial port and corresponding conversion to decimal values:

52A0:

$$(2A0)_{16} \times 16^{-5} = (672)_{10} / 16^{5} = 640.9 \cdot 10^{-6} = 640.9 \quad \mu A$$

3145:

$$(145)_{16} \times 16^{-3} = (325)_{10} / 16^{3} = 793.5 \cdot 10^{-4} = 79.35 \quad mA$$

Note: Negative power of 16 is typically in the range of [-10; -3], allowing a current range of [0.2 nA; 999 mA].

Note: Negative power of 16 is limited to range {0 (0x0; 14 (0xE)}. Value 15 (0xF) is reserved as an information tag (refer to time stamp description).

2. Metadata inserted into data stream
   Metadata is inserted into data stream to provide other information.
   Data must be filtered in data stream to isolate measurement data (current or energy values) versus metadata.
   Differentiator of measurement data versus metadata:
   - Metadata
     - Metadata start: two consecutive bytes starting by 0xF (measurement data can have only one of the bytes having this value): 0xF0 and 0xFx (value depending on metadata type, see *Table 38*)
     - Metadata stop: two consecutive bytes at value 0xFF.
   - Measurement data: All other data

Metadata: Error

An error message (voltage drop) can be sent as a stream of ASCII characters.

Table 38. Metadata error

Byte on serial port	Byte number	Description
0xF0	1	Metadata beginning tag
0xF1	2	Metadata ASCII error message tag
ASCII char	3	Message content: ASCII character
ASCII char	...	Message content: ASCII character

Table 38. Metadata error (continued)

Byte on serial port	Byte number	Description
ASCII char	x	Message content: ASCII character
ASCII char	x + 1	Message content: ASCII character
‘\r’	x + 2	Message content: ASCII value of carriage return, for indication in case of data stream watched in terminal
‘\n’	x + 3	Message content: ASCII value of line feedback, for indication in case of data stream watched in terminal
0xFF	x + 4	Metadata end tag (1/2)
0xFF	x + 5	Metadata end tag (2/2)

Metadata: Information

Similar to error message, with a different metadata tag.

Table 39. Metadata information

Byte on serial port	Byte number	Description
0xF0	1	Metadata beginning tag
0xF2	2	Metadata ASCII information message tag
ASCII char	3	Message content: ASCII character
ASCII char	...	Message content: ASCII character
ASCII char	x	Message content: ASCII character
ASCII char	x + 1	Message content: ASCII character
‘\r’	x + 2	Message content: ASCII value of carriage return, for indication in case of data stream watched in terminal
‘\n’	x + 3	Message content: ASCII value of line feedback, for indication in case of data stream watched in terminal
0xFF	x + 4	Metadata end tag (1/2)
0xFF	x + 5	Metadata end tag (2/2)

Metadata: Timestamp

Each 1000 samples, a timestamp is sent.

It can be used to check data count matches with each timestamp occurrence and resynchronize timing in case of some data have been lost.

Timestamp also includes information of time elapsed in milliseconds.

Additionally, the information of PowerShield buffer Tx load is added after time elapsed.

It is useful in case of host encounters a delay on USB bus (can occur when host is busy by CPU load or file access delay), to take appropriate action before buffer overload and acquisition stop.

Timestamp format: Binary, nine bytes

Table 40. Metadata timestamp

Byte on serial port	Byte number	Description
0xF0	1	Metadata beginning tag
0xF3	2	Metadata timestamp message tag
x	3	Timestamp value in ms, byte 3
x	4	Timestamp value in ms, byte 2
x	5	Timestamp value in ms, byte 1
x	6	Timestamp value in ms, byte 0
x	7	Buffer Tx load value in percent, byte 0
0xFF	8	Metadata end tag (1/2)
0xFF	9	Metadata end tag (2/2)

Note: Timestamp value is coded on four bytes:
- Timing value is coded on 31 bits (value from 0 to 2147483647: allowing unique timestamps up to two million of seconds, equivalent to 23 days)
- Bit 32 is used to indicate counter overflow. In case of overflow, bit 32 is set and timing value is restarting from zero.

Metadata: End of acquisition

Metadata send when acquisition is completed: integration time reached or command “stop” sent by user, and all data in Tx buffer sent to host.

Metadata format: Binary, four bytes

Table 41. Metadata end of acquisition

Byte on serial port	Byte number	Description
0xF0	1	Metadata beginning tag
0xF4	2	Metadata end of acquisition tag
0xFF	3	Metadata end tag (1/2)
0xFF	4	Metadata end tag (2/2)

Metadata: Overcurrent

Metadata send when current sinked by target device exceeds board maximum suply capacity

Metadata format: Binary, four bytes

Table 42. Metadata overcurrent

Byte on serial port	Byte number	Description
0xF0	1	Metadata beginning tag
0xF4	2	Metadata overcurrent tag
0xFF	3	Metadata end tag (1/2)
0xFF	4	Metadata end tag (2/2)

Metadata: Acknowledge and data of command “target reset (target power down)”

Metadata send (in format binary) after command from host is received (in format ASCII), only under conditions:

– Acquisition is ongoing

Metadata format: Binary, four bytes

Table 43. Metadata target power down

Byte on serial port	Byte number	Description
0xF0	1	Metadata beginning tag
0xF6	2	Metadata target power down tag
0xFF	3	Metadata end tag (1/2)
0xFF	4	Metadata end tag (2/2)

Metadata: Acknowledge and data of command “Voltage get”

Metadata send (in binary format) after command from host is received (in ASCII format), only under conditions:

– Acquisition is ongoing

Metadata format: Binary, six bytes

Voltage is coded on two bytes on format unsigned:

0x0CE4 ⇔ 3300 mV

0x0708 ⇔ 1800 mV

Table 44. Metadada Acknowledge and data command “voltage get”

Byte on serial port	Byte number	Description
0xF0	1	Metadata beginning tag
0xF7	2	Metadata voltage tag
x	3	Voltage value in mV, byte 1
x	4	Voltage value in mV, byte 0
0xFF	5	Metadata end tag (1/2)
0xFF	6	Metadata end tag (2/2)

Metadata: Acknowledge and data of command “Temperature”

Metadata send (in binary format) after command from host is received (in ASCII format),

only under conditions:

– Acquisition is ongoing

Metadata format: Binary, six bytes

Temperature is coded on two bytes on format signed:

0x000A ⇔ +10 degC

0xFFFD ⇔ -3 degC

Table 45. Metadata temperature

Byte on serial port	Byte number	Description
0xF0	1	Metadata beginning tag
0xF8	2	Metadata temperature tag
x	3	Temperature value in degC, byte 1
x	4	Temperature value in degC, byte 0
0xFF	5	Metadata end tag (1/2)
0xFF	6	Metadata end tag (2/2)

Metadata: Acknowledge and data of command “pwr get”

Metadata send (in format binary) after command from host is received (in format ASCII),

only under conditions:

- Acquisition is on going
- Acquisition is armed and not started (case of trigger D7 selected, command “start” sent and signal event of connector D7 not yet occurred).

Metadata also sent at the beginning (after metadata of acquisition start) and end (before metadata of acquisition end) of each acquisition if second parameter of command “pwr” is set to argument “status” (optional).

Metadata format: Binary, 5 bytes

Power to target connection status is coded on 1 byte:

0x0 <=> power off (power supply disconnected from target)

0x1 <=> power on (power supply connected to target)

Table 46. Metadata power to target connection

Byte on serial port	Byte number	Description
0xF0	1	Metadata beginning tag
0xF9	2	Metadata power to target connection tag
x	3	Power to target connection, byte 1

Table 46. Metadata power to target connection (continued)

Byte on serial port	Byte number	Description
0xFF	4	Metadata end tag (1/2)
0xFF	5	Metadata end tag (2/2)

Metadata reserved

Metadata reserved for potential future usage:

{0xF0; 0xF5}

{0xF0; 0xFE}

Example of data stream

Measurement with 150 data.

Table 47. Example of data stream in format 2: Binary, hexadecimal basis

Byte on serial port	Byte number	Description
0xF0	1	Metadata: Timestamp 0 ms
0xF3	2	
0x00	3	
0x00	4	
0x00	5	
0x00	6	
0x00	7	
0xFF	8	
0xFF	9	
0x3A	10	Measurement data 1 (1/2)
0xB8	11	Measurement data 1 (2/2)
0x3C	12	Measurement data 2 (1/2)
0x86	13	Measurement data 2 (2/2)
...	...	...
...	...	...
0x47	208	Measurement data 99 (1/2)
0x16	209	Measurement data 99 (2/2)

Table 47. Example of data stream in format 2: Binary, hexadecimal basis (continued)

Byte on serial port	Byte number	Description
0xF0	210	Metadata: Timestamp 0 ms
0xF1	211	
0x00	212	
0x00	213	
0x00	214	
0x01	215	
0xFF	216	
0xFF	217	
0x5E	218	Measurement data 100 (1/2)
0xB1	219	Measurement data 100 (2/2)
0x5C	220	Measurement data 101 (1/2)
0x27	221	Measurement data 101(2/2)
...	...	...
...	...	...
0x47	-	Measurement data 150 (1/2)
0x16	-	Measurement data 150 (2/2)
0xF0	-	Metadata: end of acquisition
0xF4	-	
0xFF	-	
0xFF	-	
0xF0	-	Data post-acquisition: summary
...	-	
...	-	
...	-	
...	-	
...	-	
...	-	
...	-	

4.5 Examples of typical use cases

4.5.1 Minimal mandatory commands

The not used commands are implicitly used with default settings.

Table 48. Minimal mandatory commands

Data sent by host	Data sent by PowerShield
(Not displayed)	COM port terminal
htc	
start	*PowerShield > ack htc* *PowerShield > ack start*
(delay)	*1958-09* *2041-09* *...* *1853-09* *1742-09* *end*
hrc	*PowerShield > ack hrc*

4.5.2 Continuous measurement (infinite samples) with target reset during acquisition

Table 49. Continuous measurement

Data sent by host	Data sent by PowerShield
(Not displayed)	COM port terminal
htc	
volt 3300 m (or “volt 3300-3”) *freq 1 k (or “freq 1000", or “freq 1+3”)* *acqtime inf (or “acqtime 0")*	*PowerShield > ack htc* *PowerShield > ack volt 3300 m* *PowerShield > ack freq 1 k* *PowerShield > ack acqtime inf*
start	*PowerShield > ack start*
(delay)	*11958-09* *2041-09* *...* *1853-09*
targrst 100 m	*PowerShield > ack targrst 100 m*
(delay)	*0023-10* *0008-10* *...* *1742-09* *2013-09* *end*
hrc	*PowerShield > ack hrc*

4.5.3 Two single measurements of 100 samples with power-down of board under test at the end of acquisition

Table 50. Two single measurements of 100 samples

Data sent by host	Data sent by PowerShield
(Not displayed)	COM port terminal
htc	
volt 3300 m	*PowerShield > ack htc* *PowerShield > ack volt 3300 m*
freq 1 k	*PowerShield > ack freq 1 k*
acqtime 100 m	*PowerShield > ack acqtime 100 m*
pwrend off	*PowerShield > pwrend off*
start	*PowerShield > ack start*
(delay)	*1958-09* *2041-09* *...* *1853-09* *end*
start	*PowerShield > ack start*
(delay)	*1958-09* *2041-09* *...* *1853-09* *end*
hrc	*PowerShield > ack hrc*

5 PowerShield acquisition mode dynamic characteristics

5.1 Acquisition range and frequency

5.1.1 Pre-processing: acquisition of raw data from ADC

Refer to *Figure 9* illustrating acquisition principle.

Acquisition principle from hardware:

- Acquisition of current is performed with several sensing stages: three ADC are monitoring voltage on two shunt resistors (shunt low, shunt high) through three amplifiers (amplifier for shunt resistor low, amplifier 1 for shunt resistor high, amplifier 2 for shunt resistor high).
  PowerShield hardware features a regulation circuitry ensuring voltage drop compensation without current leakage: all sensed current is going to the target.
- Acquisition of voltage is performed with a unique stage: one ADC is monitoring voltage through an amplifier.

Acquisition range:

- Acquisition of current range is from 100 nA to 50 mA for standalone board X-NUCLEO-LPM01A, from 300 nA to 150 mA for STM32L562E Discovery board. These are approximate values: Current thresholds are determined during calibration.
  Below minimum range threshold, the acquisition of current is not valid due to floor noise.
  Above maximum range threshold, the acquisition of current is not valid due to protection of overcurrent.
  Note: A protection of over-current is available on board to avoid hardware damage. It is a hardware circuitry powering down power supply when current range maximum threshold is exceeded. This circuitry has low pass filter to avoid untimely trigs, therefore some transient current spikes of less than few milliseconds are allowed (approximatively 10% above range maximum threshold, refer to board user manual for more details).
  This circuitry has low pass filter to avoid untimely trigs, therefore some transient current spikes of less than few milliseconds can be measured, up to 75 mA.
- Acquisition of voltage range is from 1.8 V to 3.3 V. This is the range of power supply voltage that can be set.

Acquisition frequency:

- Current is monitored at high frequency: 3.2 Msamples/sec. This high frequency allows the user to catch fast current variations (transient currents, current peaks of buck-boost power supply, …).
- Voltage is monitored at a lower frequency: 100 ksamples/sec. A high frequency is not needed for voltage due to decoupling capacitors smoothing voltage signal.

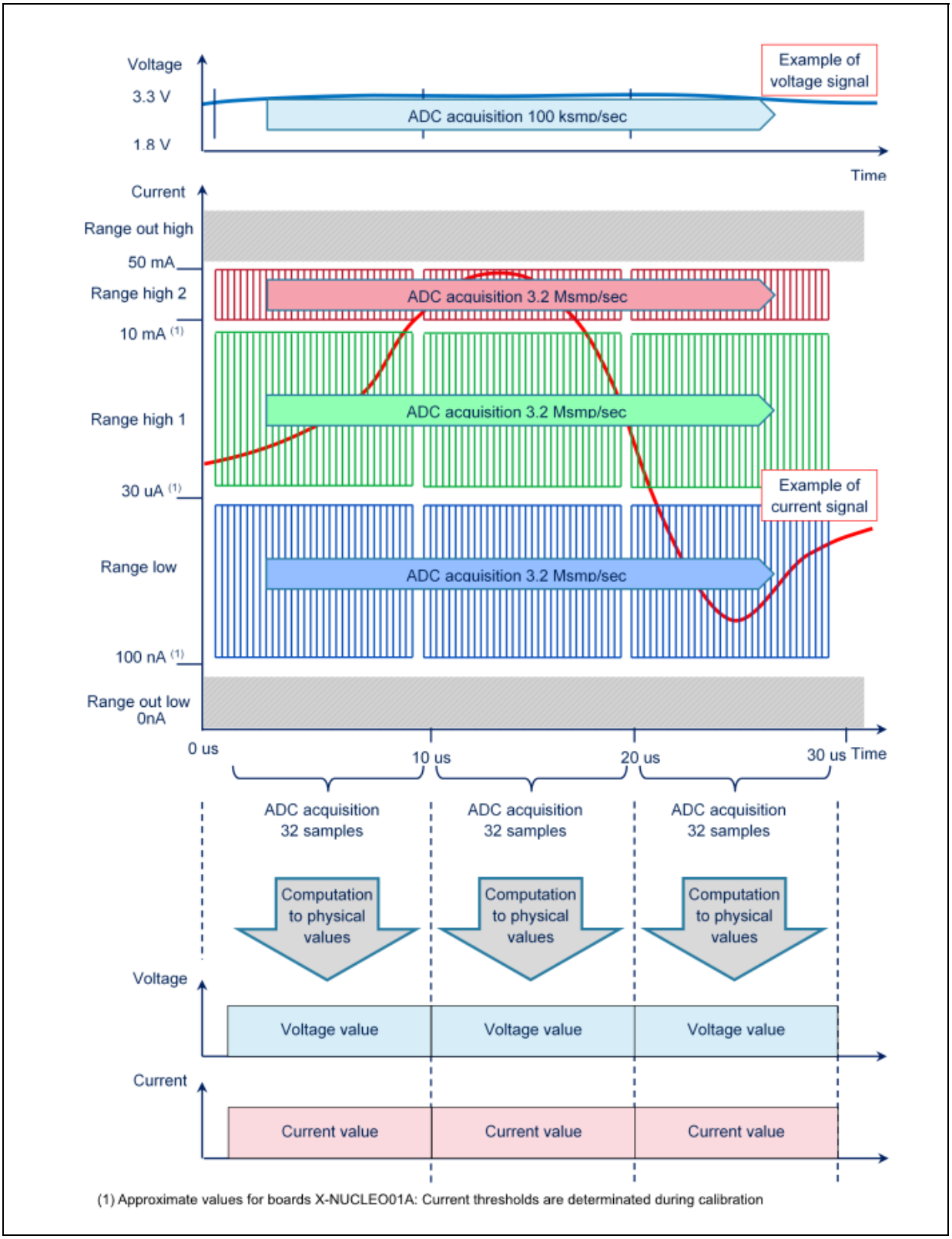
5.1.2 Post-processing: Computation to physical values

At a frequency of 100 kHz, current and voltage are computed from raw data of ADC to physical values.

Computation takes into account multiple parameters: amplifiers gain and offset values, sensing resistors values, ADC reference voltage. These parameters are computed during calibration.

In the case of current, computation also manages the data from the three ADC instances and ADC oversampling.

Figure 9. Acquisition range and frequency



5.1.3 Data sent to user interface

Usage of acquisition frequency of 100 kHz depends on PowerShield configuration:

- Functional standalone mode
  - Acquisition done at maximum frequency 100 ksamples/sec.
- Functional controlled by host mode
  - Acquisition mode current: user sampling frequency configurable is taking a subset of maximum frequency.
    For example, if user sampling frequency is set to 1 kHz, output data sent to user interface is the sampling of 1 out of 100 acquisition data (99 data are not used).
  - Acquisition mode energy: acquisition is done at maximum frequency 100 ksamples/sec, energy is computed from integration of each data. The frequency of output data sent to user interface is independent of acquisition frequency.
    For example, if user sampling frequency is set to 1 kHz, output data sent to user interface is the integration of acquisition data at 100 ksamples/sec (all data are used).

In all configuration, current min and max values are memorized from acquisition at maximum frequency 100 ksamples/sec.

5.2 Acquisition limitations

5.2.1 Acquisition frequency limitations

Maximum possible acquisition frequency depends on sampling frequency and data format.

If these parameters induce a theoretical data baud rate exceeding physical interface baudrate, then acquisition is still possible but during a limited duration: PowerShield firmware sends data at the physical baudrate, and buffers the over data.

Then, when acquisition is stopped, PowerShield firmware is still transferring data until buffer is empty. *Table 51* shows maximum acquisition time possible in function of sampling frequency and data format, for a baudrate of 3686400 bauds (interface USB-CDC VCP)

Table 51. Maximum acquisition time possible for a baudrate of 3686400 bauds

Format	Acquisition frequency (samples/sec)	Acquisition time max possible (corresponding nb of samples)
Ascii_dec	≤ 50 k	Unlimited (unlimited)
Bin_hexa	≤ 100 k	Unlimited (unlimited)

5.2.2 Transfer latency

USB interface is controlled by host and is a non-real time protocol: host activity has an impact on USB packets transfers, therefore transfer latency depends on host and is unpredictable.

Therefore, data stream received by PowerShield cannot be used as a real time data stream.

It must be used at posteriori: first receives the data, then processes it on host computer.

5.2.3 Transfer overflow

Due to USB transfer latency, acquisition data cannot always be sent in real time.

PowerShield firmware manages a buffer to dynamically store data when host is holding transfer, and free them when host is resuming transfer, while acquisition is still ongoing and data arrive at periodic intervals.

Buffer has a limited size: If host is holding transfer too long, buffer overflows occur.

The timing depends on acquisition frequency and data format, refer to *Section 5.2.1: Acquisition frequency limitations*.

When a transfer overflow occurs, acquisition is stopped and the remaining data in buffer is transmitted.

Then, a new acquisition can be started.

6 PowerShield acquisition mode static characteristics

This mode is available only on standalone board X-NUCLEO-LPM01A.

Acquisition mode static can be used from functional standalone mode and controlled by host mode.

Acquisition principle: current is measured through five shunt resistors and six amplifiers. Current value is evaluated from each shunt resistor successively. Once the appropriate shunt resistor is identified, an accurate measurement is done on high number of samples (average on more than 5000 measurements).

Range of current measurable is wider than acquisition dynamic: from 1 nA to 200 mA.

Target board must have a stable current: variations must not exceed 10% of the average current.

Caution: To measure very low currents in range [1 nA; 100 n], decoupling capacitor 2.2 uF on board should be disconnected (remove jumper JP4), otherwise a leakage current of few nA is present permanently and can be significant versus measured current.

Acquisition time is not intended to be fast in this mode: it requires long stabilization time and it depends on measured current, due to shunt resistors to be successively closed. Acquisition time can vary from 100 ms to 8 s approximatively, depending measured current (a target with a high impedance requires longer stabilization time).

A typical usage case of this acquisition mode is to measure current of a target board in low-power mode (standby and shutdown modes): current is stable and it has a low value.

7 PowerShield interface with target board

The PowerShield board can communicate with target board with a few signals on Arduino connector.

These signals are isolated through MOS transistor to limit leakage currents.

Signals from PowerShield to target board:

- Current over threshold: Arduino connector D2 and-or D3 (depending on solder bridge, open by default). This signal can be activated in controlled by host mode and using currthre command .

Signals from target board to PowerShield:

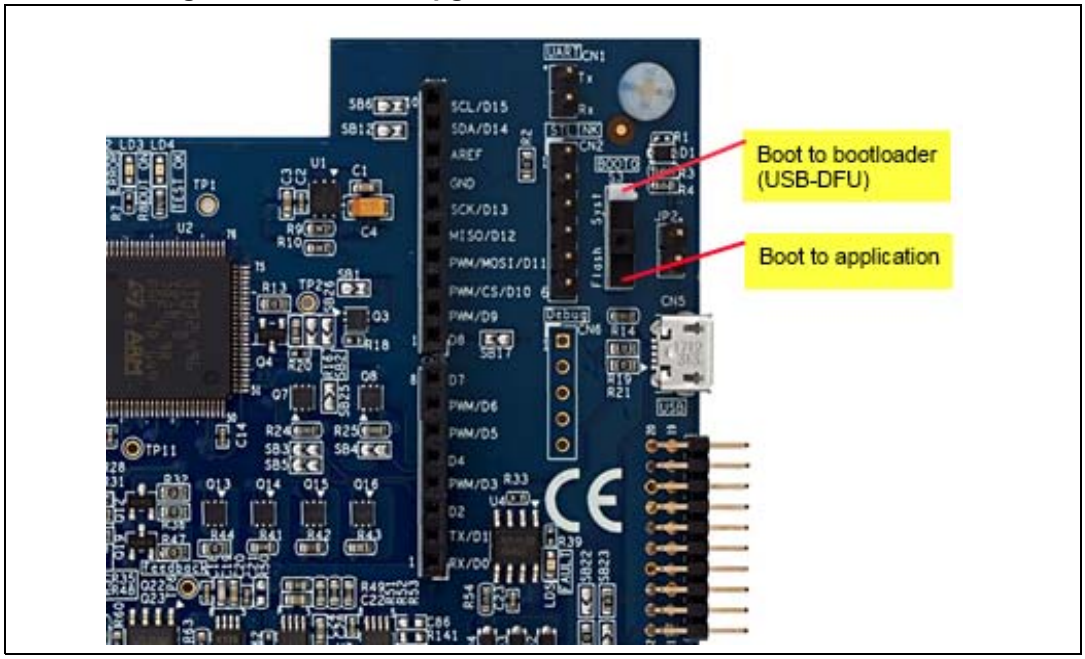
- Trigger of conversion start or event trigger: Arduino connector D7 (via solder bridge, closed by default). This signal can be activated in standalone mode using configuration menu, and controlled by host mode and standalone mode using trigsrc command.

8 Firmware upgrade

PowerShield firmware can be upgraded with the following procedure:

1. PowerShield firmware binary file
   Get the PowerShield firmware binary file on www.st.com:
   firmware binary file has the extension ".dfu" (device firmware upgrade) or ".hex" (hexadecimal object file format).
2. Set board in bootloader mode
   – For board X-NUCLEO-LPM01A: On connector CN2, place jumper switch to side "Syst".
   – For board STM32L562E Discovery: On connector SW2, place jumper switch to side "BOOT"

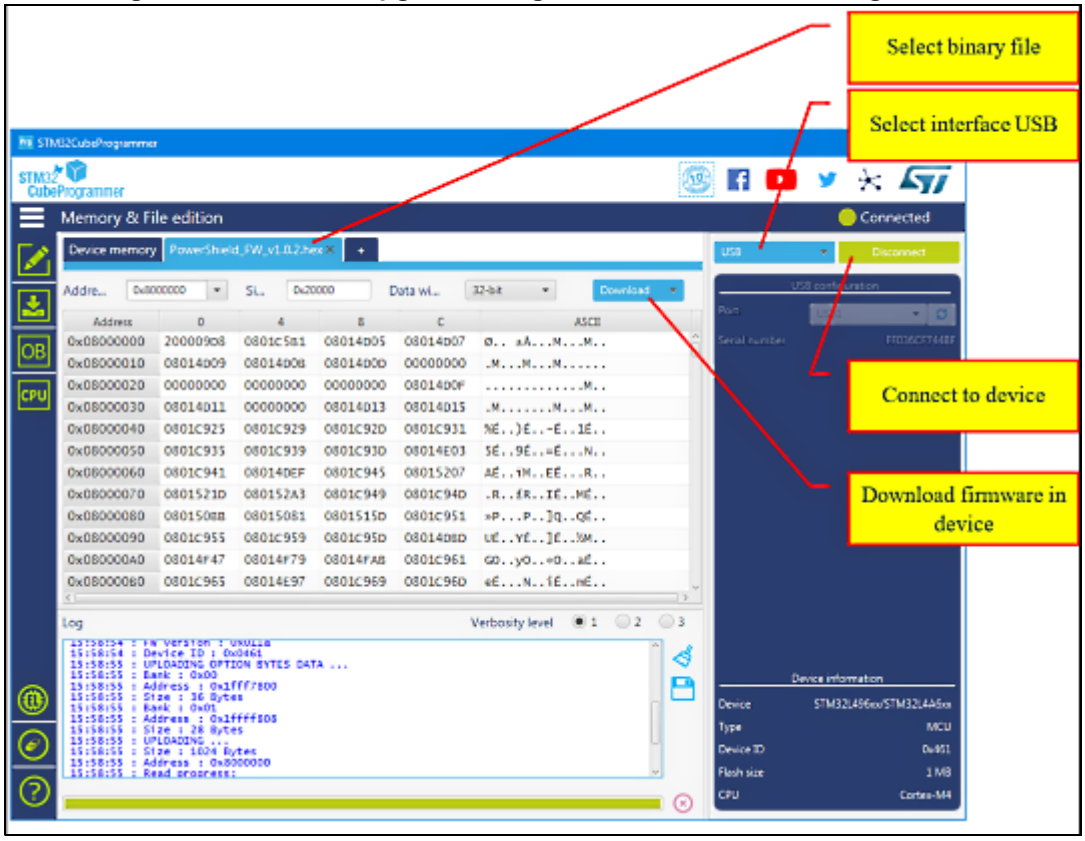
Figure 10. Firmware upgrade switch on board X-NUCLEO01A



3. Download binary file in the device. There are two solutions to download binary file:
   a) Download using STM32CubeProgrammer software
   This is the recommended solution for recent operating systems managing natively USB-DFU generic drivers (Microsoft® Windows®10 for example).
   STM32CubeProgrammer can be found on *www.st.com*
   Connect PowerShield board with USB cable, launch STM32CubeProgrammer software.

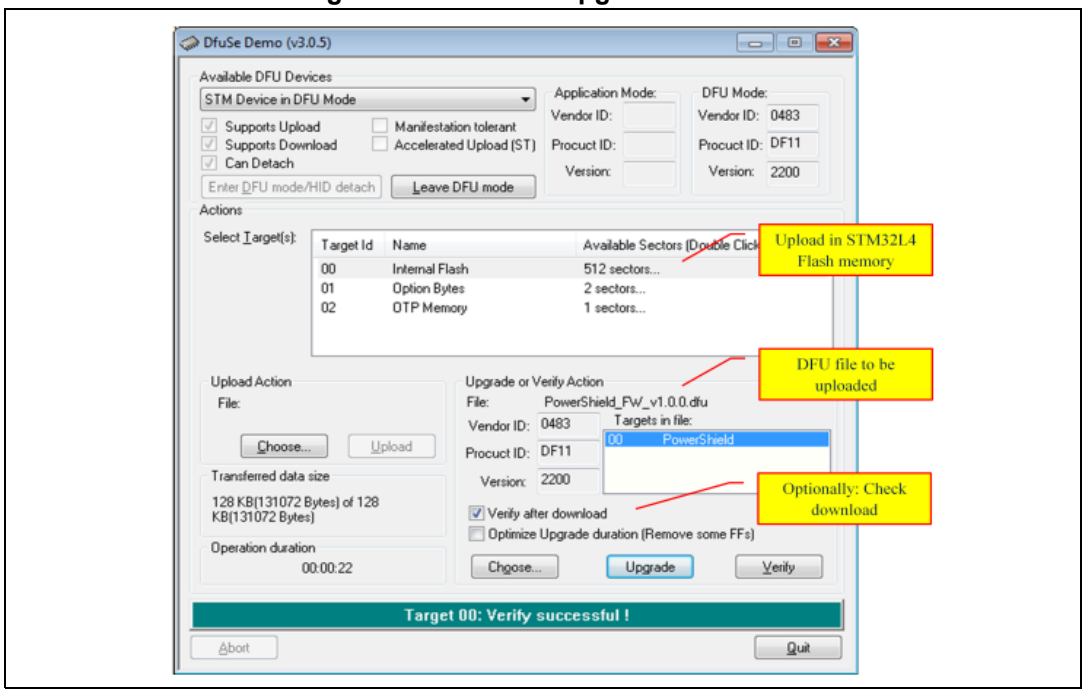
Select binary file (".hex" file), connect to device with interface USB-DFU and download firmware in device (refer to figure below).

Figure 11. Firmware upgrade using software STM32CubeProgrammer



b) Download using DfuSe software
DfuSe software can be found on *www.st.com* (software reference: STSW-STM32080).
It includes USB-DFU driver and utility software.
Connect PowerShield board with USB cable, launch USB-DFU utility software.
Select the binary file (".dfu" file) and download firmware in device (refer to figure below)

Figure 12. Firmware upgrade software



4. Set board in application mode
   - For board X-NUCLEO-LPM01A: On connector CN2, place switch to side “Flash”.
   - For board STM32L562E Discovery: On connector SW2, place jumper switch to side “APPLI”

Reset board by pressing button “RESET” or unplug and plug USB cable.

9 Troubleshooting

9.1 Error reporting

In case of error, LED red is turned-on.

Error description and error state release:

- Standalone mode:
  Press joystick to the left.
  For more information, refer to *Figure 4: PowerShield in standalone mode*.
- Controlled by host mode:
  Enter command status.
  For more information, refer to *Table 1* as displayed by firmware when entering command help.

9.2 Most common possible errors

9.2.1 USB overflow

Problem: In PowerShield controlled by host mode, connection between computer and PowerShield is lost during acquisition.

Probable cause: Computer has not processed USB data in time, due to computer busy by a higher priority process or due to USB throughput not sufficient.

At maximum PowerShield acquisition frequency 100 ksamples/sec, with data format binary, data baudrate is quite important: 1.8 Mbits/s.

Solution: Reduce acquisition frequency. For example, a frequency of 10 ksamples/sec is much less demanding in term of computer USB throughput and data processing.

For more information, refer to *Section 5.2: Acquisition limitations*.

9.2.2 Target board not starting-up

Problem: When starting acquisition, target does not starts-up.

Probable cause: Target current exceeding maximum allowed current. This may be only a transient current peak at target power-up.

Solution: In case of transient current peak at target power-up: tries to disconnect PowerShield decoupling capacitor (jumper JP4) to remove its current load at power-up and decrease the overall current peak amplitude.

In case of steady current of target: PowerShield maximum current in acquisition mode dynamic is 50 mA, therefore the target must be selected to have a lower current consumption.

9.2.3 Host driver USB-VCP installation issue

Problem: Once PowerShield is plugged to host through USB, host detects the PowerShield as an unknown device (should detect it as peripheral “STMicroelectronics Virtual COM port” (VCP)).

Probable cause: Driver USB-VCP installation issue.

Solution: Required computer driver for USB-VCP, “STM32 Virtual COM Port Driver”.

Caution: Installation must be done in two steps. First execution to unzip driver files, then a second execution of the unzipped files is needed to install the driver.

Typically, driver files to execute are in folder “C:\Program Files (x86)\STMicroelectronics\Software\Virtual comport driver\Win8”. Depending on computer system 32 or 64 bits, “dpinst_x86.exe” or “dpinst_amd64.exe” must be executed.

Note: On operating system Microsoft Windows 10, this driver is optional (since PowerShield FW revision 1.0.2). By default, PowerShield can use the operating system USB VCP driver. STMicroelectronics USB VCP driver can be installed, in this case it takes priority over operating system driver.

10 Revision history

Table 52. Document revision history

Date	Revision	Changes
23-Oct-2017	1	Initial release.
31-Oct-2017	2	Updated *Introduction* in cover page, *Section 1: Boards overview*
17-Jan-2018	3	Updated *Table 1: List summary as displayed by firmware when entering command "help"* Added note on *Section 2.2: Controlled by host mode with commands sent by a COM port terminal*, note on *Section 2.3: Controlled by host mode with commands sent by a GUI*, *Table 22: "pwr" command*, *Section : Metadata: Power to target connection*, *Section : Metadata: Acknowledge and data of command "pwr get"*, note on *Section 9.2.3: Host driver USB-VCP installation issue*
03-Jan-2020	4	Updated: – *Introduction* – *Section 1: Boards overview*, *Section 2.1: Standalone mode*, *Section 5.1.1: Pre-processing: acquisition of raw data from ADC*, *Section 6: PowerShield acquisition mode static characteristics*, *Section 8: Firmware upgrade* – title of: *Section 1.1: PowerShield standalone board X-NUCLEO-LPM01A*, *Section 1.2: Quick setup to measure current on board Nucleo64 with standalone board X-NUCLEO-LPM01A*, *Table 38: Metadata error*, *Table 39: Metadata information*, *Table 40: Metadata timestamp*, *Table 41: Metadata end of acquisition*, *Table 43: Metadata target power down*, *Table 44: Metadada Acknowledge and data command "voltage get"*, *Table 45: Metadata temperature*, *Table 46: Metadata power to target connection*, *Table 47: Example of data stream in format 2: Binary, hexadecimal basis* – *Table 1: List summary as displayed by firmware when entering command "help"*, *Table 10: "lcd" command*, *Table 15: "acqmode" command* – *Figure 9: Acquisition range and frequency* Added *Section 1.3: STM32L5 discovery board STM32L562E-DK*, *Metadata: Overcurrent*
14-May-2020	5	Updated *Section 8: Firmware upgrade* Added *Figure 11: Firmware upgrade using software STM32CubeProgrammer*
28-Oct-2020	6	Replaced STM320803 with STM32080 in *Section 8: Firmware upgrade*