

### STM32 Nucleo expansion board for power consumption measurement

#### Introduction

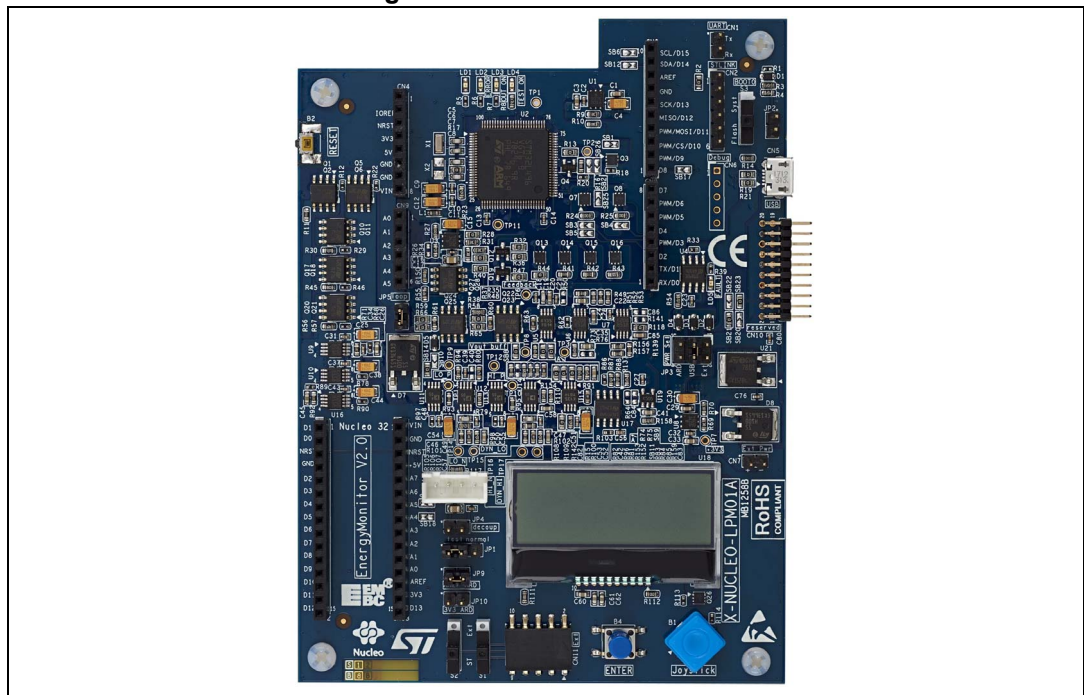
The X-NUCLEO-LPM01A expansion board is a programmable power supply source (from 1.8 V to 3.3 V) with advanced power consumption measurement capability.

It performs consumption averaging (static measurement up to 200 mA) as well as real-time analysis (dynamic measurement up to 50 mA with 100 kHz bandwidth).

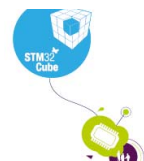
The X-NUCLEO-LPM01A operates either in standalone mode (using its LCD, joystick and button to display static measurements), or in controlled mode connected to a host PC via USB (using the STM32CubeMonitor-Power software tool with its comprehensive graphical user interface).

It can be used to supply and measure the consumption of STM32 Nucleo-32, Nucleo-64 or Nucleo-144 boards using Arduino™ connectors. Alternatively, it can be used to supply and measure the consumption of any target connected by wires via the basic connector.

Figure 1. X-NUCLEO-LPM01A



1. Picture is not contractual



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# 1 Features

The X-NUCLEO-LPM01A expansion board has the following features:

- Data acquisition and data treatment unit: STM32L496VGT6 Ultra-low-power MCU with 80 MHz/100 DMIPS Arm<sup>®</sup> Cortex<sup>®</sup>-M4 core, 1 Mbyte of Flash memory, 320 Kbytes of SRAM, 3x 12-bit ADC at 5 Msamples/s, 2 x comparators
- Programmable voltage source from 1.8 V to 3.3 V
- Static current measurement from 1 nA to 200 mA
- Dynamic measurements:
  - 100 kHz bandwidth, 3.2 Msamples/s sampling rate
  - Current from 100 nA to 50 mA
  - Power measurement from 180 nW to 165 mW
  - Energy measurement computation by power measurement time integration
- Target board connections:
  - Arduino<sup>™</sup> Nano connector (for example to connect a Nucleo-32)
  - Arduino<sup>™</sup> Uno connector (for example to connect a Nucleo-64 or a Nucleo-144)
  - Basic connector for wire connection to any target board
- Expansion board power supply input sources (selectable via jumper) through:
  - USB micro-B
  - External power (Ext Pwr) connector: from 7 V to 10 V
  - Arduino Uno or Arduino Nano: pin 5 V
- Standalone mode:
  - Monochrome LCD, 2 lines of 16 characters with back light
  - 4-direction joystick with selection button
  - Enter and Reset push-buttons
- Host-controlled mode:
  - Connection to a PC through USB FS micro-B receptacle
  - Command line (Virtual COM port) or STM32CubeMonitor-Power PC tool.

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## 2 Product marking

Evaluation tools marked as "ES" or "E" are not yet qualified and are therefore not ready to be used as reference designs or in production. Any consequences arising from such usage will not be at ST's charge. In no event will ST be liable for any customer usage of these engineering sample tools as reference designs or in production.

Example "E" or "ES" marking locations:

- On the targeted STM32 that is soldered on the board (for illustrations of STM32 marking, refer to the applicable STM32 datasheet at [www.st.com](http://www.st.com)).
- Next to the evaluation tool ordering part number. This is stuck to, or silkscreen printed on the board.

### 3 System requirements

- Windows® OS (XP, 7, 8, 10), Linux 64-bit or OS X®
- USB Type-A to Micro-B cable



## 4 Software Tool and Embedded Software

### 4.1 Embedded software

The X-NUCLEO-LPM01A expansion board firmware is preloaded.

The latest firmware version (order code: STM32-LPM01-XN) can be downloaded from the following web page: [www.st.com/stm32softwaretools](http://www.st.com/stm32softwaretools).

The firmware controls the board and provides a plug-and-play solution for current measurement. It can be used in two main modes:

- Standalone mode: supply power to the board by a USB cable or an external +5 V source, then follow the instructions on the LCD screen.
- Controlled by host mode: refer to [Section 4.2: PC software tool](#).

For more information on embedded software and the FW upgrade procedure, refer to user manual UM2269 [\[1\]](#).

### 4.2 PC software tool

The X-NUCLEO-LPM01A expansion board can be controlled by a computer through a USB port.

A computer driver for the USB virtual COM port (VCP) is required. The STM32 Virtual COM Port Driver (reference code: STSW-STM32102) can be downloaded from [www.st.com](http://www.st.com).

The board can be controlled either:

- Via a COM port terminal with commands. Type the command 'help' for a list of commands available. For more information on commands, please refer to the X-NUCLEO-LPM01A PowerShield user manual UM2269 [\[1\]](#).
- Via a graphical user interface using the STM32CubeMonitor-Power software tool (order code: STM32CUBEMON-PWR) available at: [www.st.com/stm32softwaretools](http://www.st.com/stm32softwaretools). For more information on STM32CubeMonitor-Power, please refer to user manual UM2202 [\[2\]](#).

### 4.3 Ordering information

To order the STM32™ Nucleo expansion board for power consumption measurement, refer to [Table 1](#).

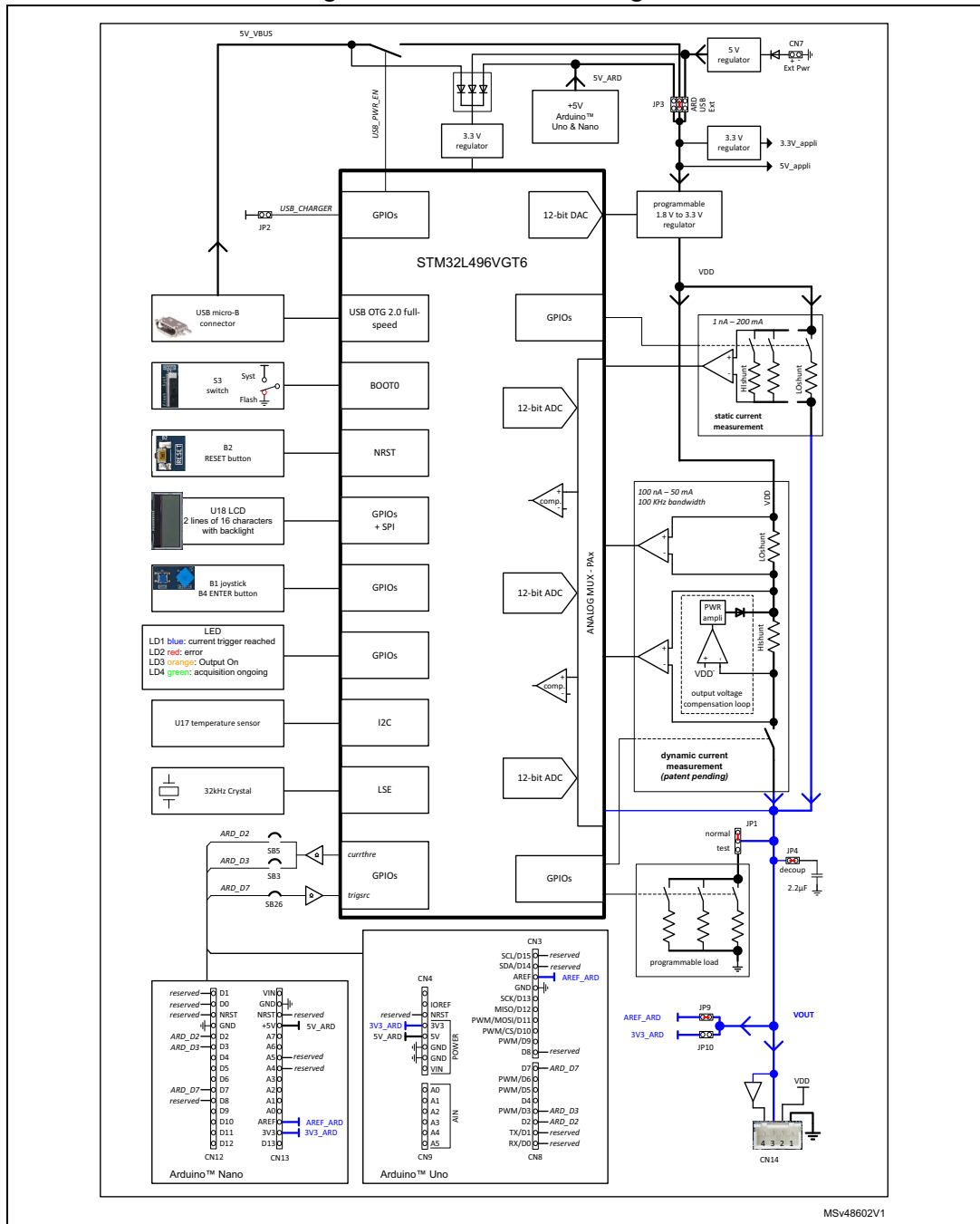
**Table 1. Ordering Information**

Order Code	Description
X-NUCLEO-LPM01A	STM32™ Nucleo expansion board for power consumption measurement

# 5 Hardware layout and configuration

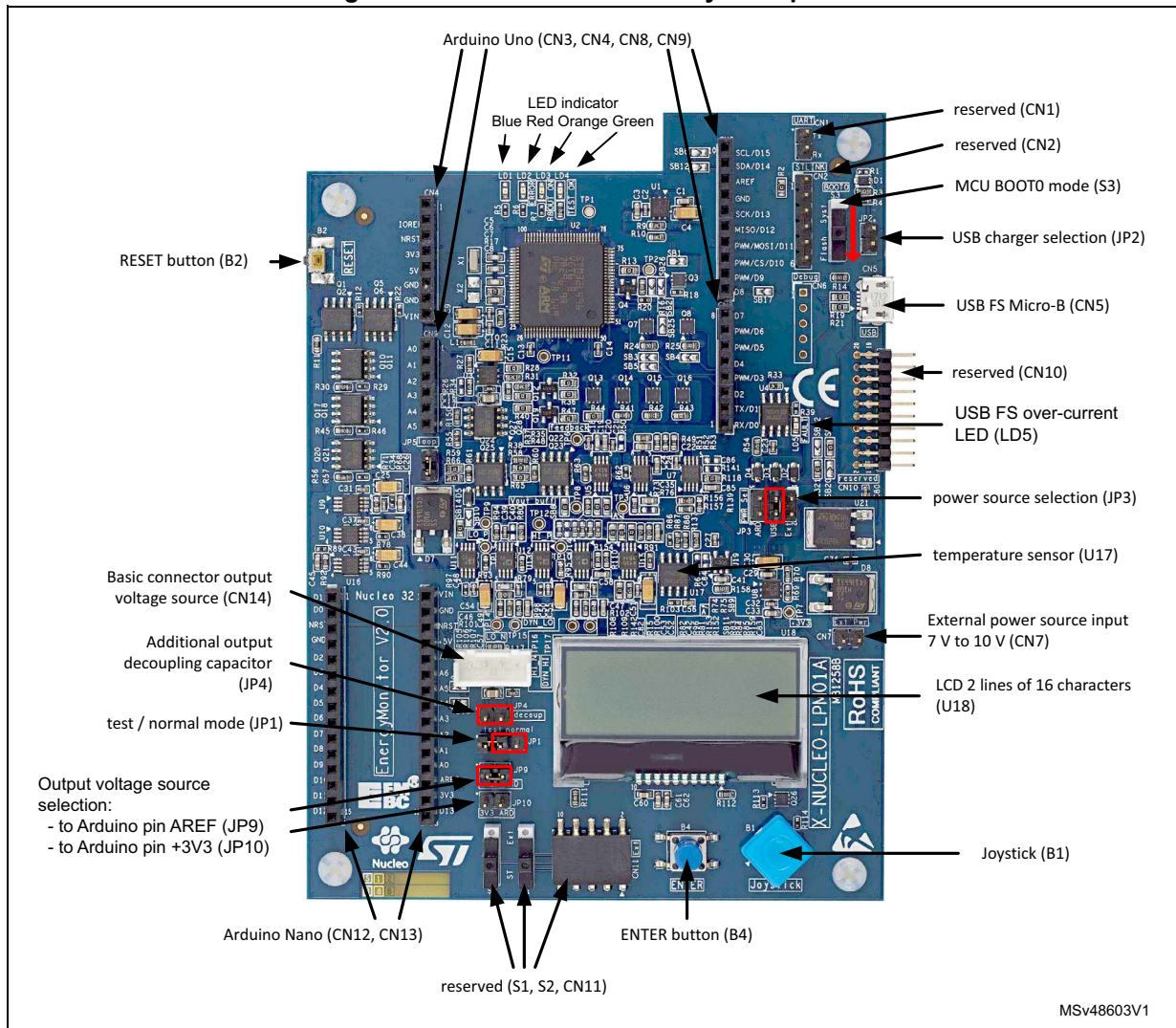
The X-NUCLEO-LPM01A STM32™ Nucleo expansion board is designed around the STM32L496VGT6 (100-pin in LQFP100 package). *Figure 2: Hardware block diagram* illustrates the connection between STM32L496 and peripherals. The *Figure 3: X-NUCLEO-LPM01A layout top view* and *Figure 4: X-NUCLEO-LPM01A layout bottom view* help to locate these features on the X-NUCLEO-LPM01A board.

Figure 2. Hardware block diagram



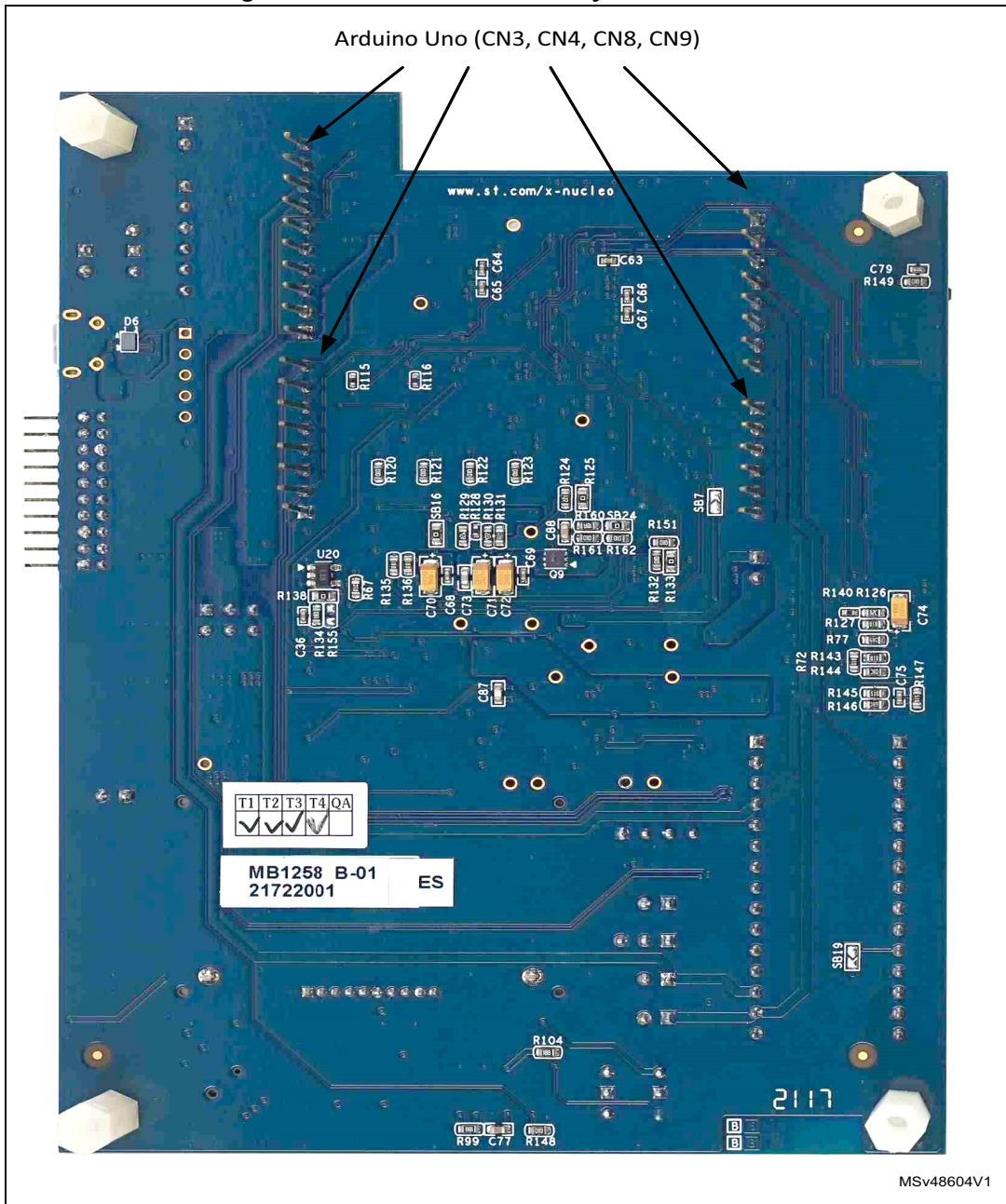
### 5.1 X-NUCLEO-LPM01A layout

Figure 3. X-NUCLEO-LPM01A layout top view



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Figure 4. X-NUCLEO-LPM01A layout bottom view



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## 6 Supplying power to the X-NUCLEO-LPM01A

The X-NUCLEO-LPM01A board is designed to be powered from one of the three following power sources:

- USB FS micro-B connector (either USB host port or USB charger) via CN5
- External DC power supply via CN7
- Arduino Uno (CN4) connector or Arduino Nano (CN13) connector via the 5V pin

See [Figure 2: Hardware block diagram](#) for details regarding the power tree, and [Figure 3: X-NUCLEO-LPM01A layout top view](#) for connector locations.

**Table 2. Power input source setting summary**

Power source from	Power connection	JP3 setting			JP2 setting
		ARD	USB	Ext	
USB host	CN5: USB Type micro-B connector	open	closed	open	open
USB charger	CN5: USB Type micro-B connector	open	closed	open	closed
Ext power supply	CN7: 7 V to 10 V DC pin + CN7: GND pin -	open	open	closed	open
Arduino Uno connectors	CN4: pin 5V CN4: pin GND	closed	open	open	open
Arduino Nano connectors	CN13: pin +5V CN13: pin GND	closed	open	open	open

*Note:* Regardless of the power supply input source, the X-NUCLEO-LPM01A board must be powered by a power supply unit or by an auxiliary equipment complying with the standard EN-60950-1: 2006+A11/2009, and must be Safety Extra Low Voltage (SELV) with limited power capability.

### 6.1 Power source from an USB host port (default setting)

A jumper should be inserted in the 'USB' position of JP3 as shown in [Figure 5: JP3 \(USB setting\)](#). No jumper should be inserted in JP2.

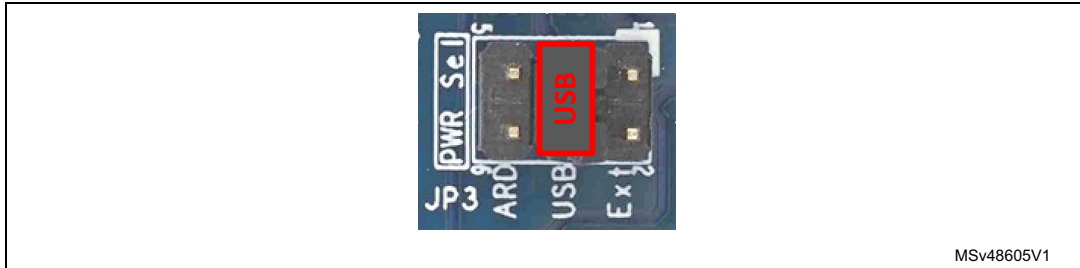
A USB Type-A to USB Type micro-B cable is required to supply the X-NUCLEO-LPM01A board (CN5: USB FS micro-B connector) to a PC host USB port.

When the USB cable is connected, 5 V DC is provided by VBUS from the USB host port of the PC. At this step, only the embedded MCU of X-NUCLEO-LPM01A is supplied. A USB enumeration is performed between the embedded MCU and the host PC to negotiate 500 mA on VBUS. If USB enumeration succeeds, X-NUCLEO-LPM01A peripherals are supplied and the target board supply can be enabled. Otherwise (if USB enumeration fails), the X-NUCLEO-LPM01A peripherals are not supplied, the red LED (LD2) is turned ON and a message is displayed on the LCD display.

If an abnormal current higher than 600 mA is drawn from the USB connector (CN5) by the X-NUCLEO-LPM01A, an embedded current protection clamps the current and LED LD5

(USB FS over-current LED) lights up until the over current disappears (see [Figure 3: X-NUCLEO-LPM01A layout top view](#) to locate LD5).

Figure 5. JP3 (USB setting)



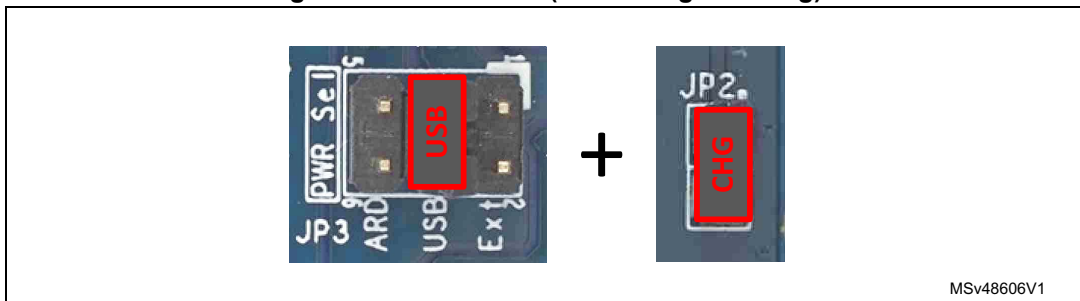
## 6.2 Power source from a USB charger

A jumper should be inserted in the 'USB' position of JP3 and an additional jumper should be inserted in JP2 as shown in [Figure 6: JP3 and JP2 \(USB charger setting\)](#).

A USB charger (5 V DC 500 mA minimum) should be connected to the USB FS micro-B connector, CN5. As JP2 is closed, X-NUCLEO-LPM01A peripherals are supplied (and the target board can be supplied) from USB connector, CN5, regardless of whether or not USB enumeration succeed.

If an abnormal current higher than 600 mA is drawn by the X-NUCLEO-LPM01A from USB connector CN5, an embedded current protection clamps the current and an LED (LD5, USB FS over-current LED) lights up until the over current is removed. (See [Figure 3: X-NUCLEO-LPM01A layout top view](#) to locate LD5).

Figure 6. JP3 and JP2 (USB charger setting)

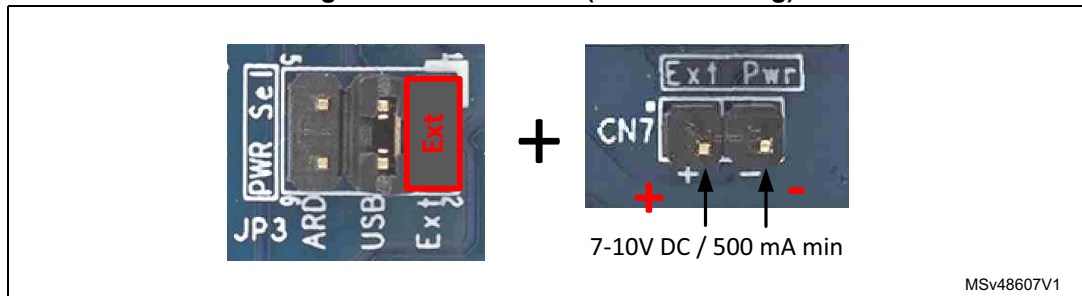


**Note:** *It is not recommended to connect a USB host port from a PC when JP2 is closed, as the X-NUCLEO-LPM01A supplies power to its peripherals regardless of whether or not the USB port of the PC is able to provide 500 mA on VBUS as the USB enumeration result is ignored.*

### 6.3 Power source from an external DC power supply.

A jumper should be inserted in the 'EXT' position of JP3 as shown in [Figure 7: JP3 and CN7 \(Ext Pwr setting\)](#). An external DC power supply with an output voltage of 7 to 10 V with 500 mA minimum current capability is connected to connector CN7. Take care about the positive and negative polarities of the CN7 connector pins, as shown in [Figure 7](#). Nevertheless, the X-NUCLEO-LPM01A has a series-connected reverse-polarity protection diode to prevent damage in the event of an inadvertent reversed polarity connection (see [Figure 2: Hardware block diagram](#)).

Figure 7. JP3 and CN7 (Ext Pwr setting)

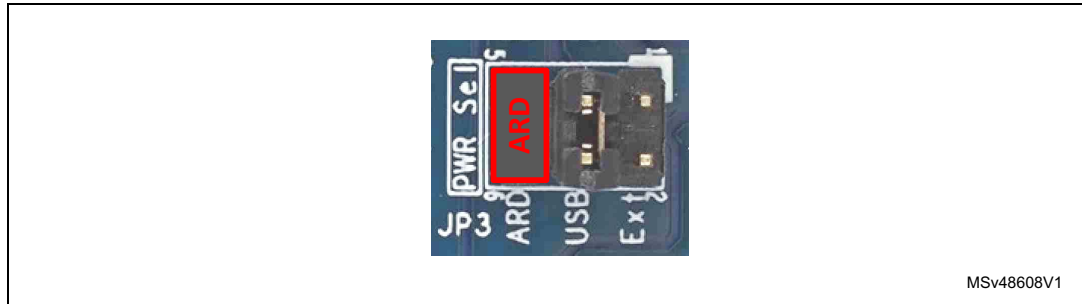


**Note:** *The X-NUCLEO-LPM01A external voltage range has been limited to 10 V maximum to limit self-heating of the board, and so limit measurement variations. Nevertheless, a standard L7805 voltage regulator is used to convert the DC voltage from CN7 to 5 V. Thus the input voltage can be extended to 16 V without risk of damaging the board.*

### 6.4 Power source from the 5 V pin of the Arduino Uno or Arduino Nano connectors

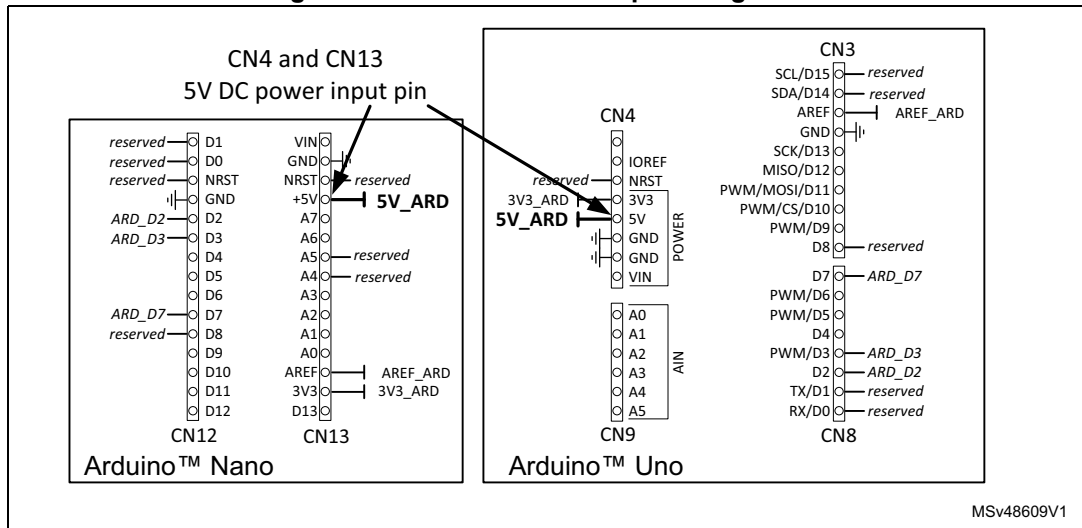
A jumper should be inserted in the 'ARD' position of JP3 as shown in [Figure 9: CN4 and CN13 +5V pin assignment](#). The X-NUCLEO-LPM01A is supplied by a 5 V DC source from either the Arduino Uno connector (CN4) or the Arduino Nano connector (CN13). See [Figure 3: X-NUCLEO-LPM01A layout top view](#) for the CN4 and CN13 placements.

Figure 8. JP3 (power from Arduino setting)



MSv48608V1

Figure 9. CN4 and CN13 +5V pin assignment



MSv48609V1

### 6.5 X-NUCLEO-LPM01A power consumption

- 140 mA max (700 mW with 5 V power source); static or dynamic mode during acquisition, no target board load.
- 340 mA max (1700 mW with 5 V power source); static measurement mode during acquisition, target board at full load (200 mA)
- 190 mA max (950 mW with 5 V power source); static measurement mode during acquisition, target board at full load (50 mA)

Note: Current consumptions are the same regardless power supply input source (USB, Ext pwr, Arduino 5 V pin).



## 7 Power supply connections of a target board

The X-NUCLEO-LPM01A can power supply a target board from 1.8 V to 3.3 V and measure its consumption (current, power, energy) using one of the following connections:

- Arduino Uno connector (CN3, CN4, CN8, CN9) either:
  - by the pin 3.3 V
  - by the pin AREF
- Arduino Nano connector (CN12, CN13) either:
  - by the pin 3.3 V
  - by the pin AREF
- Basic connector (CN14) for wire connection to any target.

See [Figure 2: Hardware block diagram](#) for an overview of the power output distribution on the Arduino 3.3V pin or Arduino™ AREF or generic connector (CN14), and the related jumper connection. See [Figure 3: X-NUCLEO-LPM01A layout top view](#) for connector and jumper locations.

*Note:* Power supply to a target board through Arduino Uno, or Nano connectors via the AREF power pin is not common but is specifically suitable for STM32™ Nucleo32, Nucleo64 and Nucleo144 boards. It allows, after a few modifications to the Nucleo target board, to power supply only the STM32™ MCU. In other words, it allows the removal of quiescent or leakage current of board peripherals (like the on board ST-LINK debugger, voltage regulator, and so on) without removing peripheral ICs from the target board.

*Reciprocally, power supplied to a target board through Arduino Uno, or Nano via the +3.3 V power pin supplies the complete target board and its peripherals.'*

**Table 3. Power output related jumper and connector settings**

Power output on	Output connectors and pins	JP9 AREF_ARD jumper	JP10 3V3_ARD jumper	JP4 Additional decoupling capacitor jumper
Arduino Uno connector, pin 3V3	<b>3V3:</b> CN4 pin4 <b>GND:</b> CN4 pin6 or pin7	open	closed	<b>Open:</b> no decoupling capacitor
				<b>Closed:</b> 2.2 µF decoupling capacitor
Arduino Uno connector, pin AREF	<b>AREF:</b> CN3 pin8 <b>GND:</b> CN4 pin6 or pin7	closed	open	<b>Open:</b> no decoupling capacitor
				<b>Closed:</b> 2.2 µF decoupling capacitor
Arduino Nano connector, pin 3V3	<b>3V3:</b> CN13 pin14 <b>GND:</b> CN13 pin2	open	closed	<b>Open:</b> no decoupling capacitor
				<b>Closed:</b> 2.2 µF decoupling capacitor
Arduino Nano connector, pin AREF	<b>AREF:</b> CN13 pin13 <b>GND:</b> CN13 pin2	closed	open	<b>Open:</b> no decoupling capacitor
				<b>Closed:</b> 2.2 µF decoupling capacitor
Basic connector CN14	<b>Vout:</b> CN14 pin3 <b>GND:</b> CN14 pin1	open	open	<b>Open:</b> no decoupling capacitor
				<b>Closed:</b> 2.2 µF decoupling capacitor

Note: For measurements, jumper JP1 should be always in the 'normal', and not in the 'test' position. Otherwise it may impact the current measurements results.

Note: As shown in Figure 2: Hardware block diagram, inserting a jumper in the JP4 'decoup' position adds a 2.2  $\mu\text{F}$  decoupling capacitance on the power output voltage (VOUT). It is recommended to keep JP4 jumper inserted most of the time to avoid X-NUCLEO-LPM01A dynamic measurement oscillation, especially when the target board has a decoupling capacitance of less than 1  $\mu\text{F}$  on its input power supply path.

Figure 10. Pins AREF and 3V3 of Arduino Uno connectors CN4 and CN3

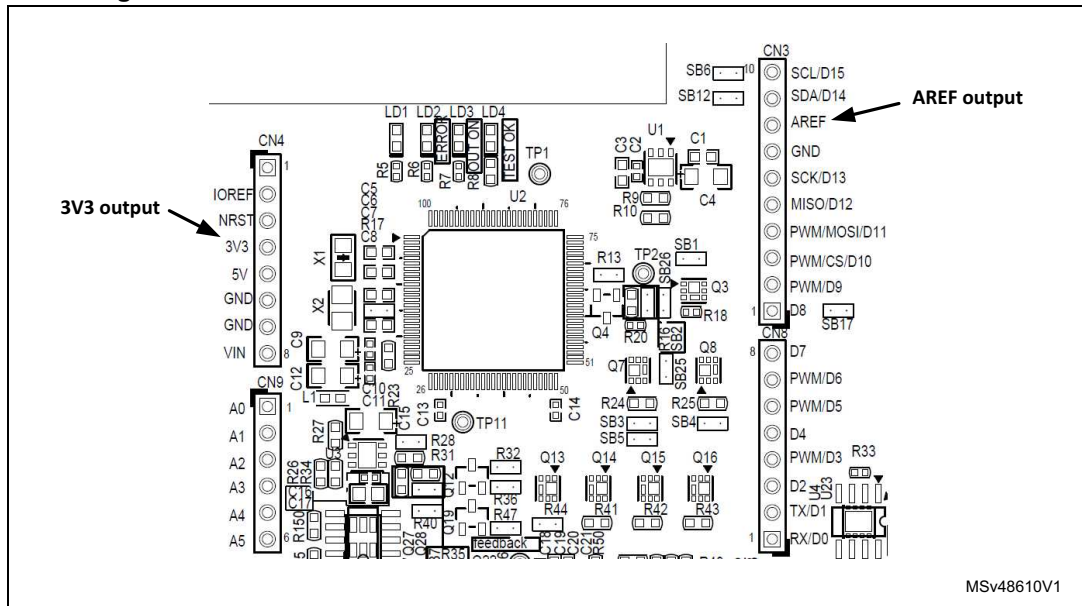
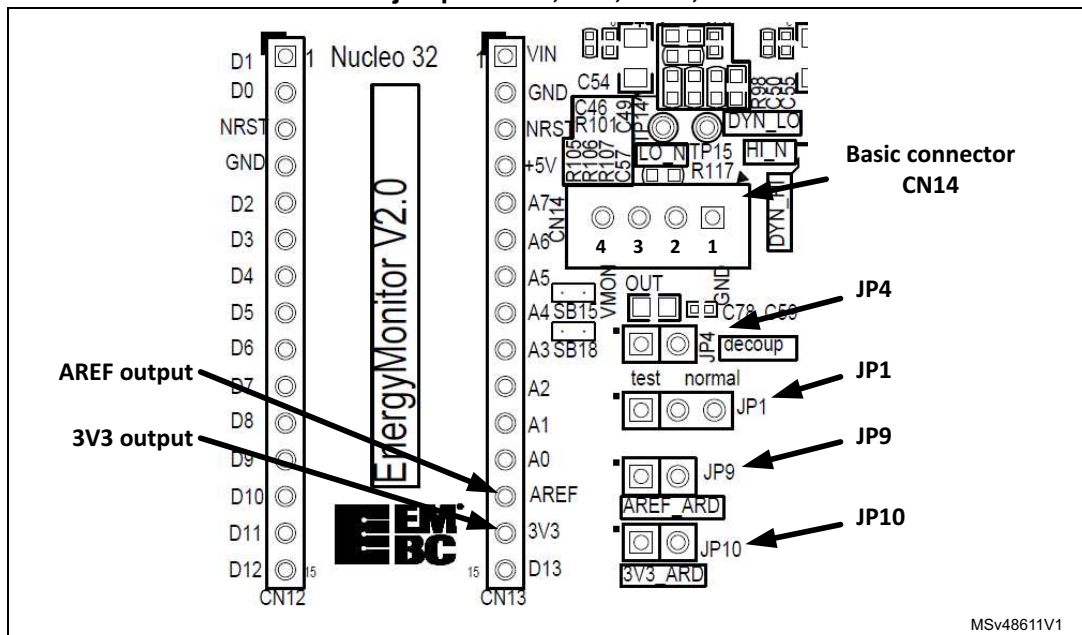


Figure 11. Pins AREF and 3V3 of Arduino Nano connectors, output connector CN14 and jumpers JP1, JP9, JP10, JP4



## 7.1 Settings for use of the Arduino Uno connectors with Nucleo64 and Nucleo144 use cases

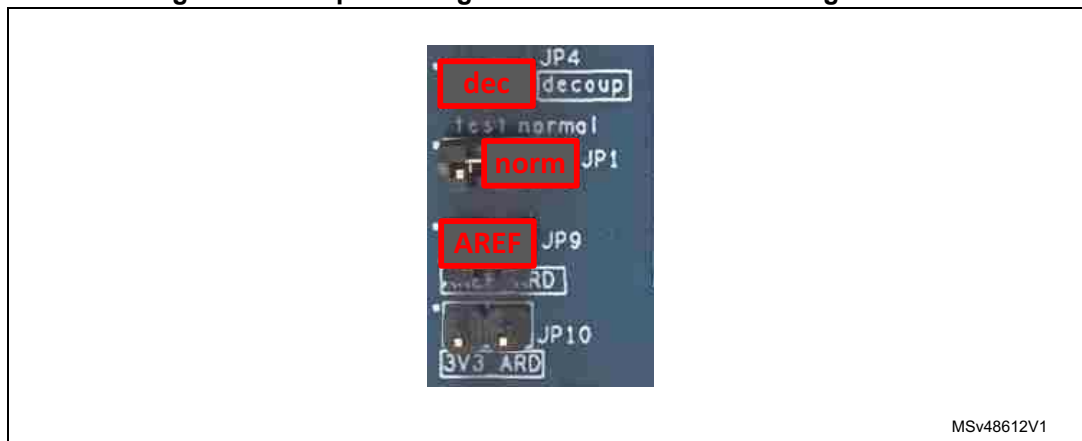
The STM32 Nucleo64 or Nucleo144 target board should be adapted to be powered via the AREF pin of the Arduino Uno connector (CN3 pin8) prior to connection to the X-NUCLEO-LPM01A. This adaptation is needed to power supply the STM32 MCU only, so that only the MCU consumption is measured. In other words, this adaptation removes the consumption of peripherals such as ST-LINK.

Please refer to the targeted Nucleo board User Manual to adapt the board to be supplied from AREF. See example in [Appendix A: How to adapt an STM32L432 Nucleo-32 to power the MCU from the Arduino AREF pin](#).

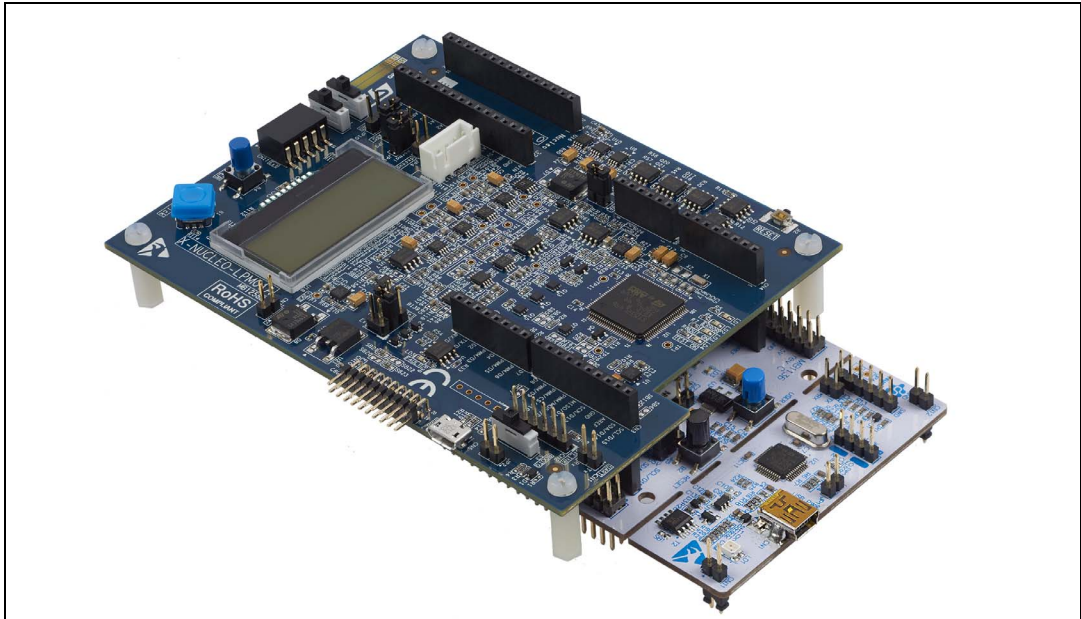
The power sources and the USB connector of the X-NUCLEO-LPM01A must first be disconnected to avoid any electrical conflict or damage.

Then apply the correct X-NUCLEO-LPM01A jumper settings for JP9, JP10 and JP4, following [Table 3: Power output related jumper and connector settings](#), as shown in [Figure 12](#).

**Figure 12. Jumper setting for Arduino with Nucleo target board**



Finally, the male pins of connectors CN3, CN4, CN8, CN9 protruding from the bottom side of the X-NUCLEO-LPM01A board are plugged into the connectors of the Nucleo64 or Nucleo144 board.

**Figure 13. STM32 Nucleo64 target board plugged into the X-NUCLEO-LPM01A**

## 7.2 Settings for use of the Arduino Nano connectors in a Nucleo32 use case

The STM32™ Nucleo32 target board should be adapted to be powered via the AREF pin of the Arduino Nano connector (CN13, pin13) instead of the 3.3 V pin, prior to connection to the X-NUCLEO-LPM01A board.

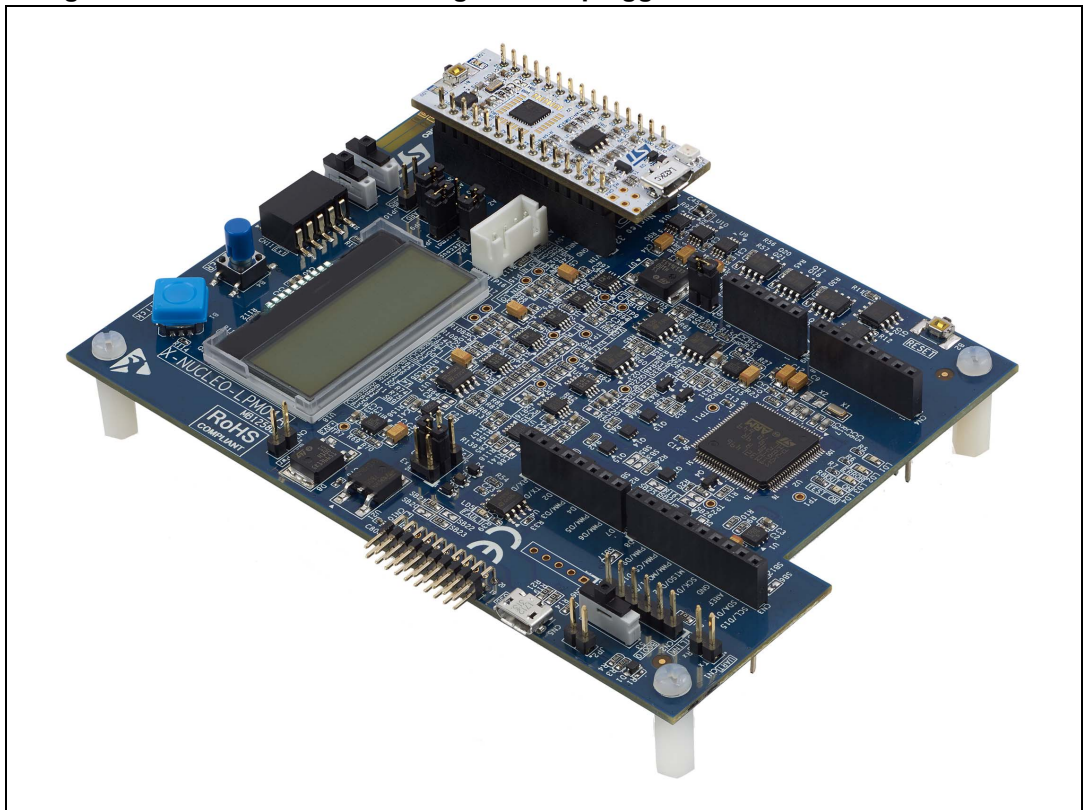
Please refer to the targeted Nucleo board User Manual to adapt the board to be supplied from AREF. See the example in [Appendix B: How to adapt an STM32L476 Nucleo-64 to power the MCU from the Arduino AREF pin](#). This adaptation is needed to supply power to the STM32 MCU only, so that only the MCU consumption is measured. In other words, this adaptation removes the consumption of peripherals such as ST-LINK.

The power sources and the USB connector of the X-NUCLEO-LPM01A must first be disconnected to avoid any electrical conflict or damage.

Then apply the correct X-NUCLEO-LPM01A jumper settings for JP9, JP10 and JP4, following [Table 3: Power output related jumper and connector settings](#). As shown in [Figure 12](#).

Finally, the STM32 Nucleo32 is plugged into the X-NUCLEO-LPM01A using connectors CN12 and CN13. Please check the orientation of the Nucleo32 using the silkscreen printed names on the X-NUCLEO-LPM01A board or by referring to [Figure 14](#).

Figure 14. STM32™ Nucleo32 target board plugged into the X-NUCLEO-LPM01A



### 7.3 Power supply connections of a target board with basic connector CN14

CN14 is a common XH series 4-pin connector with a 2.54 mm pitch. It can be used to supply and measure the target board consumption using a wire connection.

Figure 15. Basic connector CN14

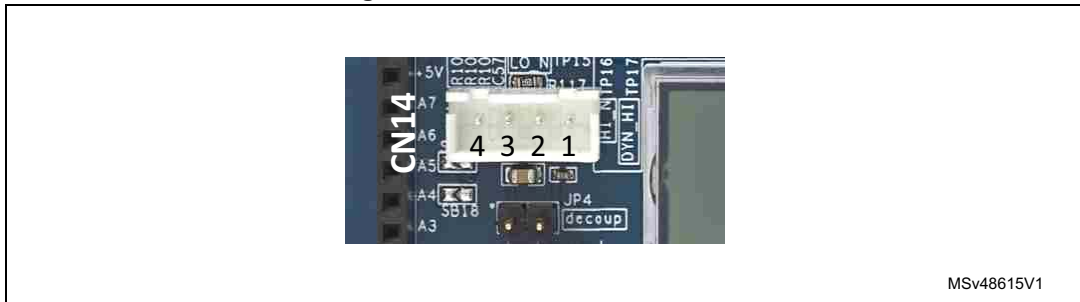


Table 4. Pin description of the basic connector CN14

CN14 pin	Signal	Usage
Pin 1	<b>GND</b> (-)	Ground of the target
Pin 2	VDD	Alternate power supply source (not measured)
Pin 3	<b>VOUT</b> (+)	Positive connection of the target, current is measured
Pin 4	<u>VOUT_MONITORING</u>	Mirror of VOUT. Allows VOUT monitoring without impacting current/power measurements

The target board should be supplied through GND (pin1) and VOUT (pin3) of CN14.

VOUT\_MONITORING (pin4) is a buffered copy of the output voltage VOUT. It can be used to monitor VOUT with a voltmeter or oscilloscope without impacting the current/power measurements.

Alternatively, VOUT\_MONITORING can be used as a reference with a voltage divider to generate a bias voltage without impacting the current consumption.

*Note:* VOUT\_MONITORING output has 150 ohms serial resistance to protect it output buffer.

VDD (pin2) can be used as an alternate power source to supply some peripherals of the target board. The VDD voltage is equal to VOUT (with no load on VOUT). VDD is slightly higher (30 mV maximum in dynamic mode and 60 mV maximum in static mode) than VOUT when VOUT is fully loaded. The VDD output current should not exceed 500 mA.

**Caution:** When the X-NUCLEO-LPM01A is supplied from a PC (USB host port), and VDD supplies the target board peripherals, do not exceed the 500 mA total budget allowed by the USB port.

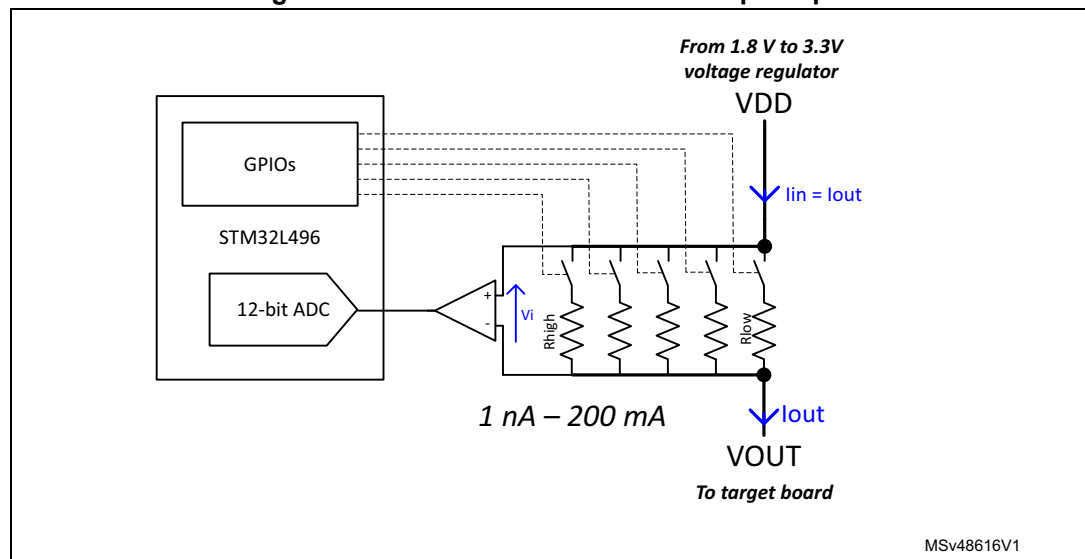
See also [Figure 2: Hardware block diagram](#) for further details.

## 8 Static current measurement principle

The static measurement mode allows a stable current to be measured over a wide range from 1 nA to 200 mA, with an accuracy of better than 2%. To use this mode properly, the target board current should not vary by more than 10% of its average value during measurement acquisition.

It is also recommended to remove JP4 jumper (additional 2.2  $\mu\text{F}$  capacitor needed for dynamic measurement) especially for current consumption measurements below 50 nA.

**Figure 16. Static current measurement principle**



The static current measurement principle is based on a shunt method: Due to Ohm's law, the current flowing in the shunt resistor causes a voltage drop ( $V_i$  in static current measurement principle) to occur. This voltage is amplified by a differential amplifier to deliver a voltage in single-ended mode referenced to ground. The voltage is converted by one analog-to-digital converter (ADC) of the embedded MCU, and is finally processed to deliver the current measurement information.

To allow a wide dynamic range, the STM32L496 MCU's firmware first performs an auto-calibration, then switches-in the appropriate shunt resistor among five (ranging from few hundred mohms for high current measurement, to several kohms for the highest ohmic shunt) in order to read the appropriate value on the ADC. This circuitry is designed to not exceed 60 mV dropout on  $V_{OUT}$ . In other words, if the output voltage ( $V_{DD}$ ) is set at 3.3 V,  $V_{OUT}$  does not drop below 3.24 V during static measurements.

## 9 Dynamic current measurement principle

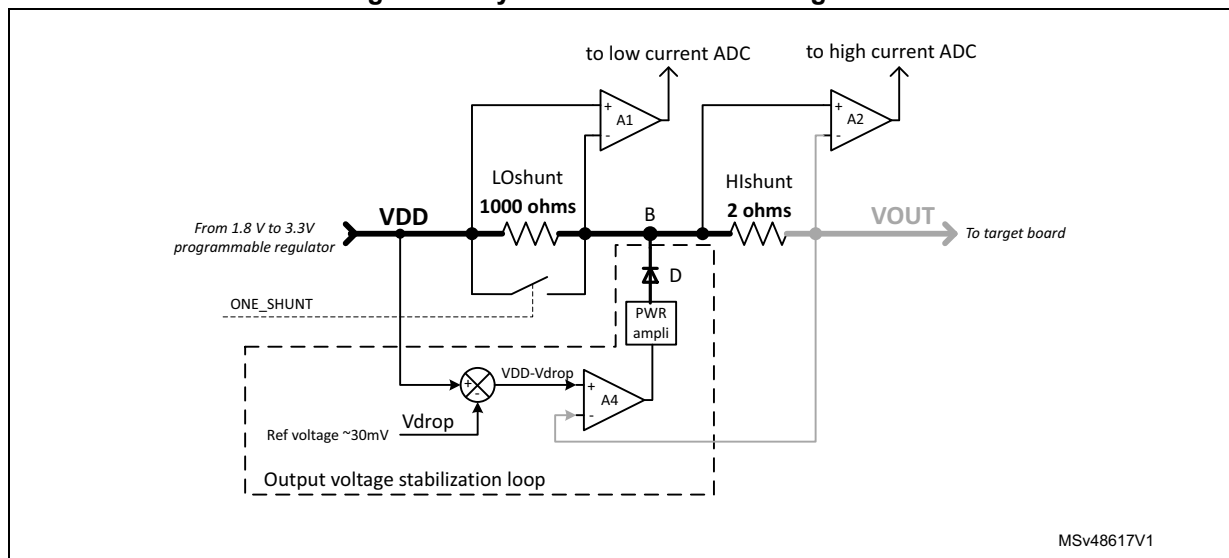
The dynamic measurement mode allows measurement of fluctuating currents from 100 nA to 50 mA with an accuracy in the range of 2%.

Measurement acquisitions are performed using three 12-bit ADCs working in parallel at 3.2 Msamples/s each and with 100 kHz bandwidth on the analog circuit path. This high sampling rate allows fast current variations (transient current, peak current activities on target board side) to be caught.

The dynamic current measurement principle is based on the shunt method as for the static measurement. Nevertheless, a specific and complex architecture performs dynamic measurement with a 100 kHz bandwidth covering the wide current measurement range of about 110 dB (from 100 nA to 50 mA) by keeping the output voltage stable.

The dynamic current circuitry has built-in overcurrent protection that operates from 59 mA. Therefore some transient current spikes of up to 75 mA and less than few milliseconds are allowed.

Figure 17. Dynamic current block diagram<sup>(1)</sup>



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1. Patent pending



## 9.1 Dynamic current block diagram description

In [Figure 17: Dynamic current block diagram](#), VDD is generated from a programmable voltage regulator (see [Figure 2: Hardware block diagram](#)). VDD is set from 1.8 V to 3.3 V by the user to supply the target VOUT. Two shunt resistors called 'LOshunt' and 'HIshunt', are in the series path from the voltage source VDD to the output, VOUT.

'LOshunt' has a value of typically 1000 ohms and the related differential amplifier, A1, deals with the measurement of 'low' currents. The second shunt, 'HIshunt', of typically 2 ohms and the related differential amplifier, A2, handle the measurement of 'high' currents. Without defining 'low' and 'high' current limits, it is sufficient to note that there is a threshold between 'low' and 'high' currents.

Inside the dashed rectangle, the voltage stabilization loop injects a current at point B in order to maintain the output voltage at a given value, VDD-Vdrop. Vdrop is the maximum voltage drop acceptable for the highest current of the range, and is typically 30 mV. Diode D guarantees that if the output voltage is higher than the limit VDD-Vdrop, the loop has no effect (there is no leakage current).

## 9.2 Behavior for dynamic current measurements

The boundary between low and high currents is the output current to give a voltage drop of typically 30 mV (Vdrop) in the LOshunt resistor (1000 ohms), that is, 30  $\mu$ A.

For output currents from 100 nA to 30  $\mu$ A, the stabilization loop does not inject current at point B; the embedded MCU measures the current by reading the output of amplifier A1. For currents higher than 30  $\mu$ A, the stabilization loop injects current at point B and acts as a voltage regulator to ensure that the output voltage does not drop by more than 30 mV compared to the target VDD current value. The embedded MCU reads the output of the amplifier A2.

The LOshunt resistor can be shorted by a power switch controlled from the MCU (the ONE\_SHUNT signal in [Figure 17](#)) when the common current measurement method by one shunt and without a stabilization loop is required by the system.

For further details regarding dynamic current measurement data acquisition pre-processing and post-processing, please refer to the X-NUCLEO-LPM01A PowerShield firmware user manual [\[1\]](#).

### 9.3 Dynamic current measurements special care

To guarantee the stability of the output voltage stabilization loop (see [Figure 17](#)), it is recommended to insert JP4 jumper to add additional 2.2  $\mu\text{F}$  capacitor on output voltage VOUT (see [Figure 2](#) for more details). Otherwise the output voltage stabilization loop might oscillate, reducing the accuracy of current and power measurements.

Jumper JP4 is not needed if the target board has 1  $\mu\text{F}$  minimum decoupling capacitance at its input power path. In this case, jumper JP4 can be removed or kept inserted.

This additional 2.2  $\mu\text{F}$  decoupling capacitance has no effect on energy measurements (as energy measurement is integration of power measurement over time).

Nevertheless, the 2.2  $\mu\text{F}$  decoupling capacitance has some effect on instantaneous current measurements  $i(t)$ , as it acts as low-pass filter; the current waveform is smoothed. This might be possible when performing fast current measurement acquisitions using the STM32CubeMonitor-Power tool, then zooming into the range of approximately 10 to 100  $\mu\text{s}$  of measurement samples.

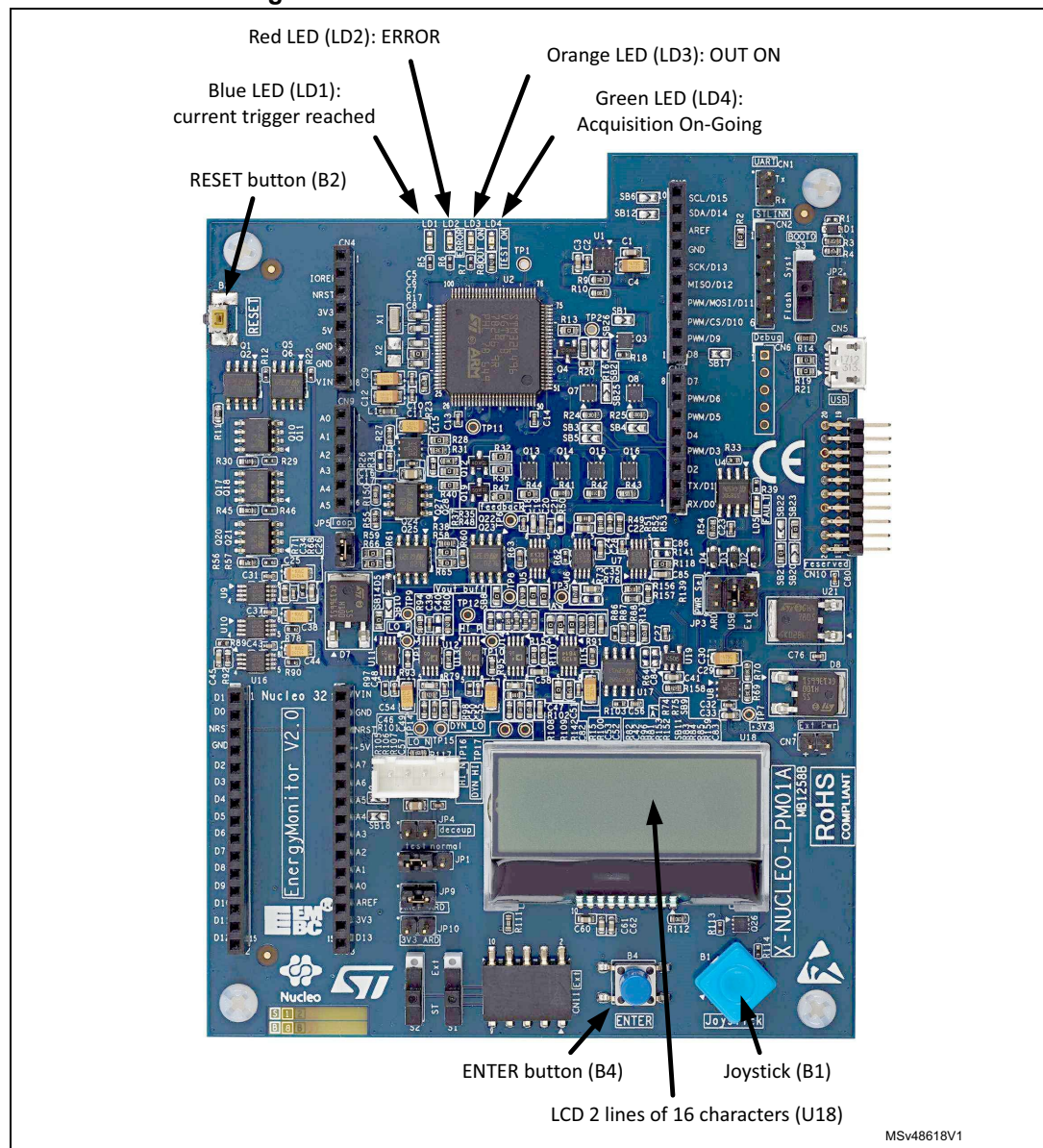
# 10 Standalone mode using embedded user interface

By default, when the STM32CubeMonitor-Power software PC tool not used, the X-NUCLEO-LPM01A expansion board runs in standalone mode. In this case, the embedded user interface composed of an LCD (U18), a joystick (B1), a button (B4), 4x color LEDs (LD1, LD2, LD3, LD4) and a Reset button B2 are used to work with the X-NUCLEO-LPM01A.

In standalone mode, both static and dynamic measurements are possible.

Please refer to the X-NUCLEO-LPM01A PowerShield firmware user manual [1] for details on measurement features available and use of the X-NUCLEO-LPM01A user-interface menus with the embedded firmware.

Figure 18. Embedded user interfaces elements



## 11 Host-controlled mode with a PC

To work in Host-controlled mode, the X-NUCLEO-LPM01A expansion board needs to be connected to a PC via a USB cable (common USB Type-A to USB micro-B cable).

The X-NUCLEO-LPM01A supports two controlled modes:

- Host-controlled mode with command lines sent by a COM port terminal:
  - Please refer to the X-NUCLEO-LPM01A PowerShield firmware user manual [\[1\]](#)
- Host-controlled mode with the STM32CubeMonitor-Power graphic user interface
  - Please refer to the STM32CubeMonitor-Power user manual [\[2\]](#).

Both modes require installation of the USB VCP (Virtual COM port) 'STM32 Virtual COM Port Driver' driver on the PC. Please refer to the X-NUCLEO-LPM01A PowerShield firmware user manual [\[1\]](#) for the driver reference.

## 12 Trigger signals between the X-NUCLEO-LPM01A and the target board

This section describes the optional signals between the X-NUCLEO-LPM01A and the target board that allow an event to be triggered. Trigger signals are available on both Arduino Nano and Arduino Uno pins D2, D3 and D7:

- D7 is a trigger signal from the target board to the X-NUCLEO-LPM01A
- D2 and D3 are trigger signals from the X-NUCLEO-LPM01A to the target board.

See [Figure 2](#) for an overview of these signal connections.

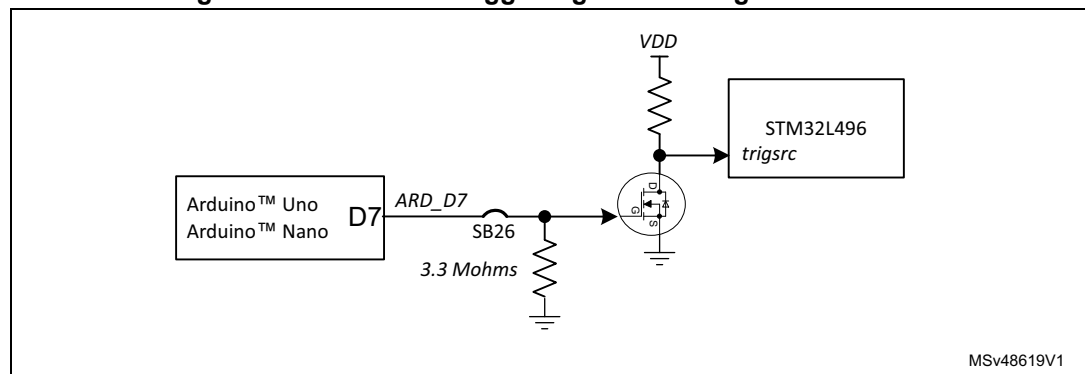
### 12.1 Trigger signal from the target board to the X-NUCLEO-LPM01A

The trigger signal on Arduino connector alias D7 is controlled from the target board to trigger the X-NUCLEO-LPM01A for a conversion start or event trigger. Please refer to the X-NUCLEO-LPM01A PowerShield firmware user manual [\[1\]](#) for a detailed description of the use of this trigger signal in standalone and controlled modes.

The trigger signal D7 is active high. A 3.3 Mohm pull down resistor in the circuitry avoids uncontrolled trigger events if D7 signal is not connected or floating on the target board side.

Solder bridge SB26 is closed by default. If it needs to be opened, see [Figure 20: Arduino Uno D7 trigger signal from target and solder bridges SB26](#).

**Figure 19. Arduino D7 trigger signal from target schematics**



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Figure 20. Arduino Uno D7 trigger signal from target and solder bridges SB26

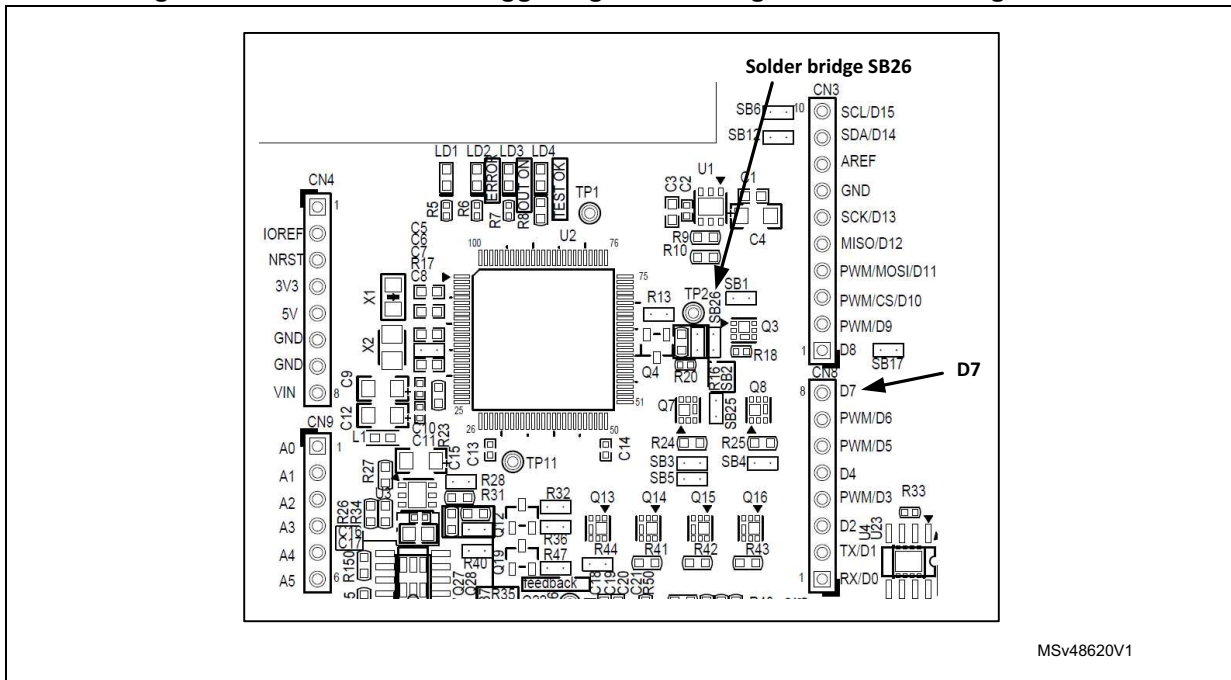
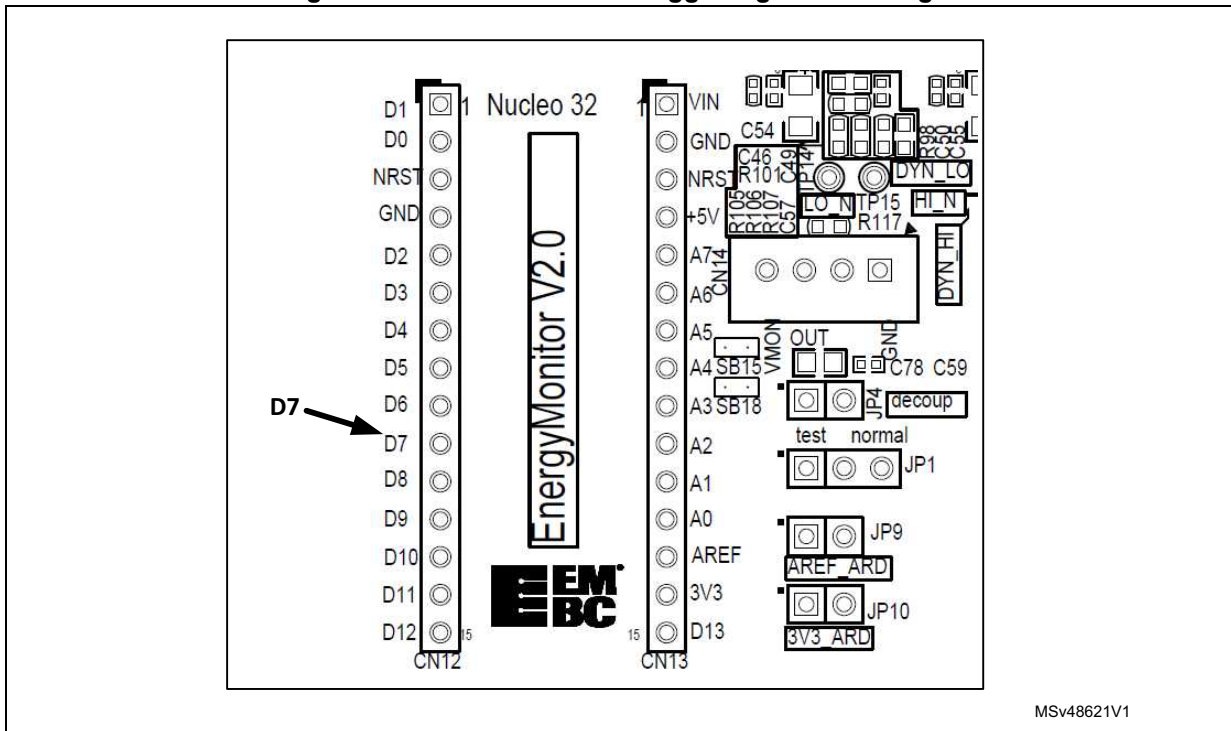


Figure 21. Arduino Nano D7 trigger signal from target



## 12.2 Trigger signal from X-NUCLEO-LPM01A to target board

D2 and D3 on the Arduino connector are controlled from the X-NUCLEO-LPM01A to trigger the target board for an event.

For example, a programmable current threshold can be set (only in controlled mode) to trigger the D2 or D3 signal when the target board power consumption crosses this threshold.

Please refer to the X-NUCLEO-LPM01A PowerShield firmware user manual [1] for a detailed description of how this trigger signal is used in standalone and controlled modes.

The trigger signals D2 and D3 are active low. A 100 kohm pull up resistor to VOUT biases D2 and D3.

Solder bridges SB5 and SB3 (respectively for D2 and D5) are open by default. One of them must be closed to enable this trigger feature, see Figure 23.

Figure 22. Arduino D2, D3 trigger signal to target schematics

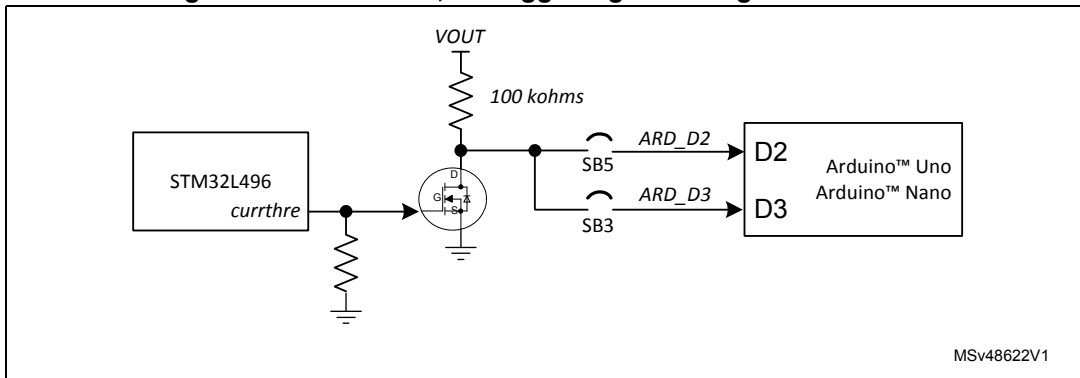


Figure 23. Arduino Uno D2, D3 trigger signal to target and solder bridges SB3, SB5

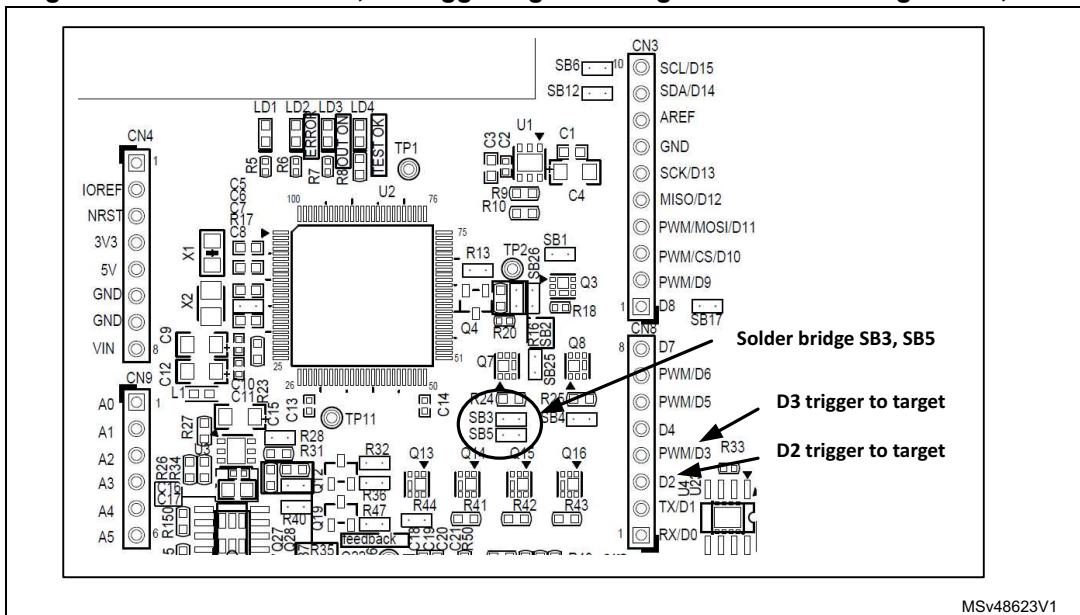
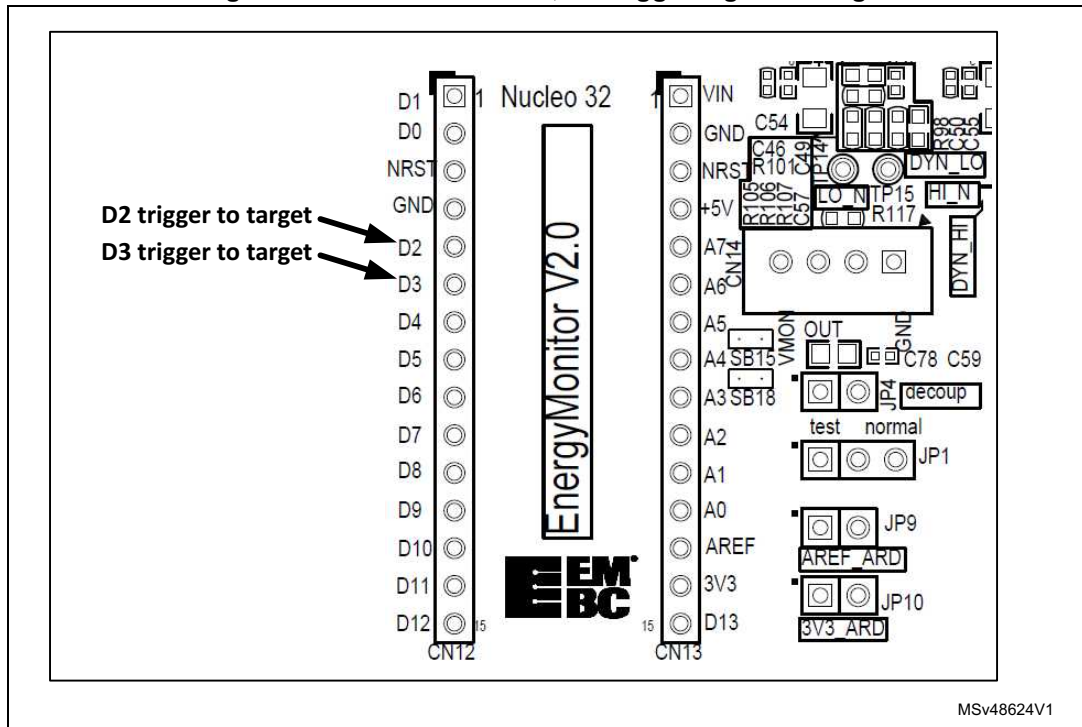


Figure 24. Arduino Nano D2, D3 trigger signal to target



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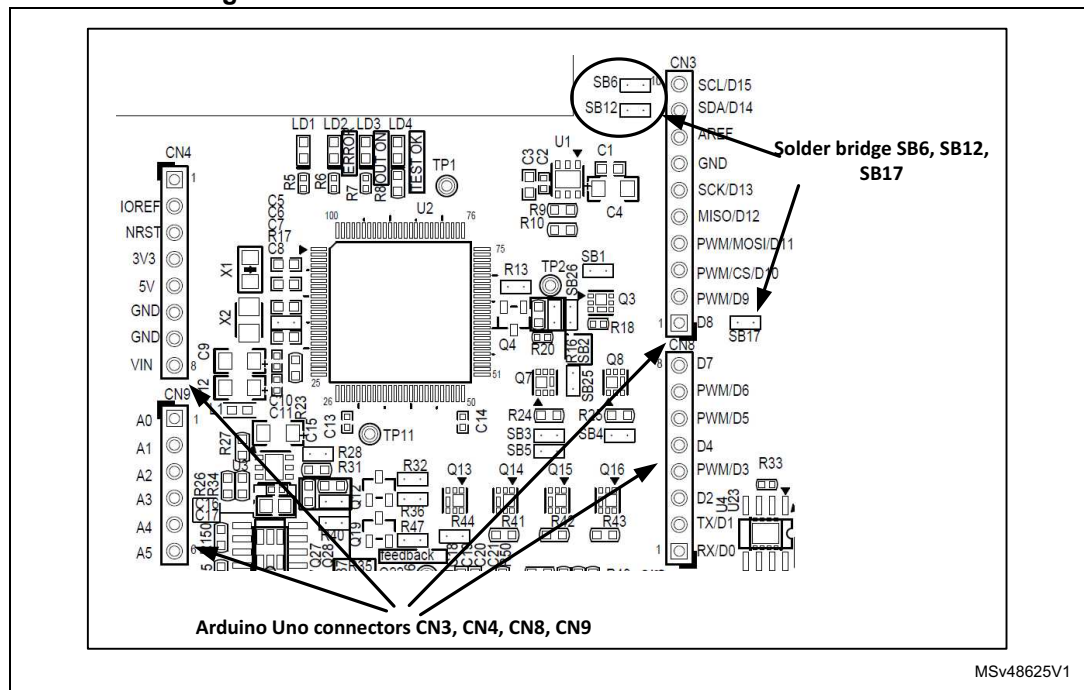
# 13 Extension connector CN11

Specific daughter boards can be connected to the I2C bus and pin D8 of the Arduino connector sets of the X-NUCLEO-LPM01A using the extension connector CN11. By default, CN11 is not connected to the Arduino I2C bus and D8 because this connector has a reserved use which is not described here.

## 13.1 Extension connector used with Aduino Uno connectors

To use a specific daughterboard connected to CN11 controlled by a board plugged into the Arduino Uno set of connectors CN3, CN4, CN8 and CN9, the solder bridges SB6, SB12, SB17 must be closed.

Figure 25. Extension connector CN11 with Arduino Uno

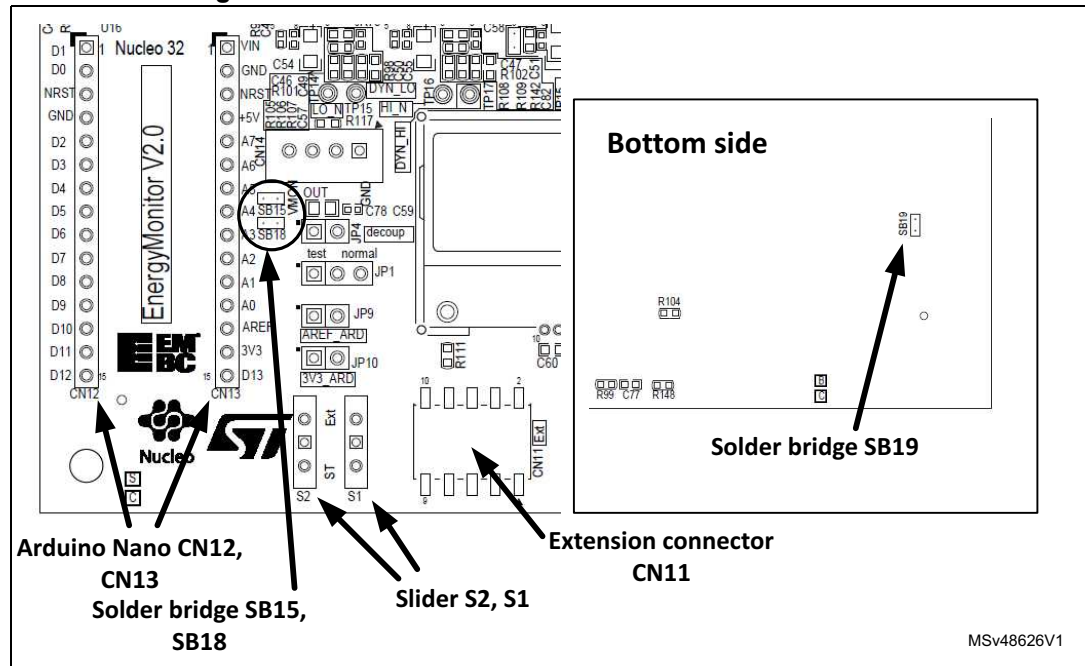


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### 13.2 Extension connector used with Arduino Nano connectors

To use a specific daughterboard connected to CN11 controlled by a board plugged into the Arduino Nano set of connectors CN12 and CN13, the solder bridges SB15, SB18, SB19 must be closed.

Figure 26. Extension connector CN11 with Arduino Nano



### 13.3 Switch to select the type of daughterboard

Two kinds of daughterboard can be used with CN11: ST or External. Move the slider of switches S1 and S2 to select the right mode. The position is silkscreen printed on the PCB between the two switches.

## Appendix A How to adapt an STM32L432 Nucleo-32 to power the MCU from the Arduino AREF pin

This appendix provides an example to adapt an STM32L432 Nucleo-32 board to power the MCU only from the Arduino AREF pin, instead of the Arduino 3.3 V pin. This adaptation allows the isolation of the MCU supply from peripherals (ST-LINK) in order to measure only the MCU power consumption.

This example refers to the NUCLEO-L432KC schematics (MB1180) available from the [www.st.com/stm32nucleo](http://www.st.com/stm32nucleo) web page:

1. Remove jumper JP1: Disconnect VDD from +3V3 power source
2. Open SB9: T\_NRST reset MCU from ST-LINK
3. Open SB4 and SB17: MCO clock from ST-LINK to MCU (set HSI or use external crystal as MCU clock reference)
4. Open SB2: STLINK\_RX of Virtual Com Port
5. Open SB3: STLINK\_TX of Virtual Com Port.

*Note:* *SWCLK and SWDIO cannot be disconnected. STM32L432 software should set these two signals (PA14 and PA13 respectively) to high impedance.*

## Appendix B How to adapt an STM32L476 Nucleo-64 to power the MCU from the Arduino AREF pin

This appendix provides an example to adapt an STM32L476 Nucleo-64 board to power the MCU from only the Arduino AREF pin, instead of the Arduino 3.3 V pin. This adaptation allows the MCU supply to be isolated from peripherals (ST-LINK) in order to measure the MCU power consumption only.

This example refers to NUCLEO-L476RG schematics (MB1136) available from the [www.st.com/stm32nucleo](http://www.st.com/stm32nucleo) webpage:

1. Remove jumper JP6: Disconnect VDD from +3V3 power source
2. Remove jumper JP5: +5V power source selection; to disconnect +5 V from E5V and U5V
3. Open SB13: STLINK\_RX of Virtual Com Port
4. Open SB14: STLINK\_TX of Virtual Com Port
5. Open SB16: MCO clock from ST-LINK to MCU (set HSI or use external crystal as MCU clock reference)
6. Remove jumper CN2\_1-2: SWCLK from ST-LINK to MCU
7. Remove jumper CN2\_3-4: SWDIO from ST-LINK to MCU
8. Open SB15: SWO from ST-LINK to MCU
9. Open SB12: NRST from ST-LINK to MCU.

## Appendix C How to adapt an STM32L496 Nucleo-144 to power the MCU from the Arduino AREF pin

This appendix provides an example to adapt a STM32L496 Nucleo-144 to power the MCU only from the Arduino AREF pin instead of Arduino 3.3V pin. This adaptation allows to isolate MCU supply from peripherals (ST-LINK) in order to only measure MCU power consumption.

This example refers to the NUCLEO-L496ZG schematics (MB1312) available from the [www.st.com/stm32nucleo](http://www.st.com/stm32nucleo) webpage.

1. Remove jumper JP5: IDD measurement, to disconnect the MCU's VDD from +3V3
2. Remove jumper JP6: +5V power source selection, to disconnect +5V from VIN\_5V, U5V, and E5V
3. Ensure that SB152 and SB158 are closed, and that SB167 is open: AVDD is connected to VDD; AVDD is not connected to VDD\_MCU
4. SB122 is closed; SB1, SB8, SB121 and SB127 are open. In this example, discrete SMPS are not used. There is a direct bypass between VDD and VDD\_MCU. PG10, PG11, PG12, and PG13 should be set in high impedance by the STM32L496 software.
5. SB198, SB199, SB200, SB201, SB134, SB135, SB142 and SB143 are open: remove connection to USB.
6. Remove jumper CN4\_1-2: SWCLK from ST-LINK to MCU
7. Remove jumper CN4\_3-4: SWDIO from ST-LINK to MCU
8. Remove jumper JP3: NRST from ST-LINK to MCU
9. Open SB141: SWO from ST-LINK to MCU
10. Open SB109: MCO clock from ST-LINK to MCU (set HSI or use external crystal as the MCU clock reference)
11. Open SB131: STLK\_RX of Virtual Com Port
12. Open SB130: STLK\_TX of Virtual Com Port

## Appendix D Federal Communications Commission (FCC) and Industry Canada (IC) Compliance

### D.1 FCC Compliance Statement

#### D.1.1 Part 15.19

This device complies with Part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) this device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

#### D.1.2 Part 15.105

This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates uses and can radiate radio frequency energy and, if not installed and used in accordance with the instruction, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception which can be determined by turning the equipment off and on, the user is encouraged to try to correct interference by one or more of the following measures:

- Reorient or relocate the receiving antenna.
- Increase the separation between the equipment and receiver.
- Connect the equipment into an outlet on circuit different from that to which the receiver is connected.
- Consult the dealer or an experienced radio/TV technician for help.

#### D.1.3 Part 15.21

Any changes or modifications to this equipment not expressly approved by STMicroelectronics may cause harmful interference and void the user's authority to operate this equipment.

### D.2 IC Compliance Statement

Industry Canada ICES-003 Compliance Label: CAN ICES-3 (B) / NMB-3 (B)

Etiquette de conformité à la NMB-003 d'Industrie Canada: CAN ICES-3 (B) / NMB-3 (B).

## 14 Reference documents

**Table 5. Reference documents**

<b>Reference</b>	<b>Version</b>	<b>Title</b>
[1]	Latest version	X-NUCLEO-LPM01A PowerShield firmware user manual, UM2269
[2]	Latest version	STM32CubeMonitor-Power user manual, UM2202

## 15 Revision history

**Table 6. Document revision history**

Date	Version	Changes
18-Oct-2017	1	Initial release



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