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Introduction

The STM32 Nucleo-64-P boards (NUCLEO-L433RC-P and NUCLEO-L452RE-P) provide an affordable and flexible way for users to try out new concepts and build prototypes with the STM32 microcontroller and the external SMPS (switched mode power supply), which provides various combinations of performance, power consumption and features.

Arduino™ Uno V3 connectivity and ST morpho headers provide an easy means of expanding the functionality of the Nucleo open development platform with a wide choice of specialized shields.

The STM32 Nucleo-64-P boards do not require any separate probe, as they integrate the ST-LINK/V2-1 debugger/programmer. The STM32 Nucleo-64-P boards come with the comprehensive free STM32 software libraries and examples that are available with the STM32Cube package.
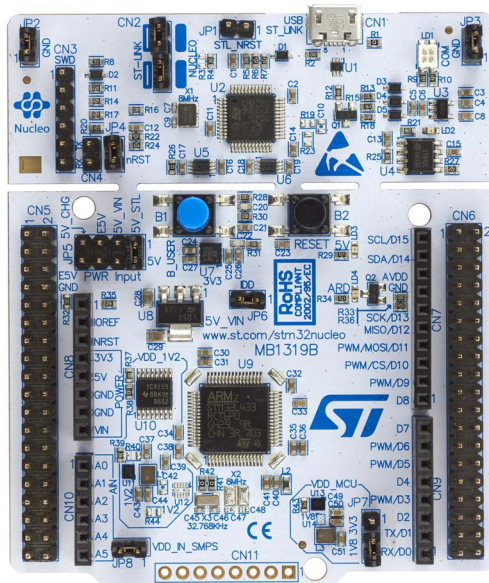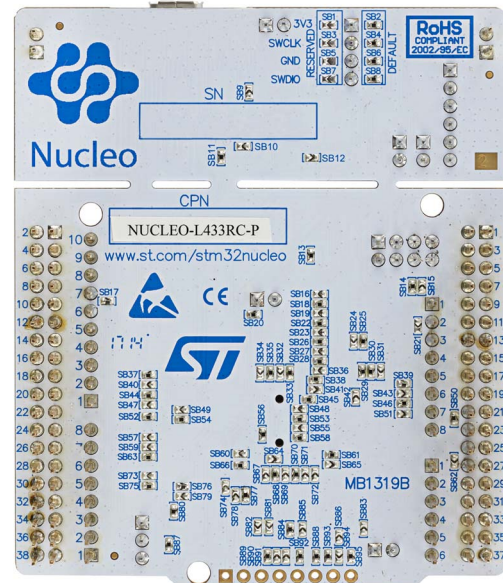
Figure 1. Nucleo-64-P board (top view)	Figure 2. Nucleo-64-P board (bottom view)

1. Pictures are not contractual.

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1 Features

- STM32 microcontroller in LQFP64 package
- SMPS: significantly reduces power consumption in Run mode
- 32.768 KHz LSE crystal oscillator
- One user LED shared with Arduino™
- Two push-buttons: USER and RESET
- Board expansion connectors:
  - Arduino™ Uno V3
  - ST morpho
  - External SMPS experimentation dedicated connector
- Flexible board power supply: ST-LINK/V2-1 USB V_{BUS} or external sources
- On-board ST-LINK/V2-1 debugger/programmer with USB re-enumeration capability: mass storage, virtual COM port and debug port
- Comprehensive free software libraries and examples available with the STM32Cube package
- Support of a wide choice of Integrated Development Environments (IDEs) including IAR™, Keil®, GCC-based IDEs

2 Product marking

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

"E" or "ES" marking examples of location:

- On the targeted STM32 that is soldered on the board (for illustration of STM32 marking, refer to the section "Package characteristics" of the STM32 datasheet at *www.st.com*).
- Next to the evaluation tool ordering part number, that is stuck or silk-screen printed on the board.

3 Ordering information

To order the Nucleo-64-P board corresponding to the targeted STM32, refer to *Table 1*.

Table 1. Ordering information

Order code	Target STM32
NUCLEO-L452RE-P	STM32L452RET6P
NUCLEO-L433RC-P	STM32L433RCT6P

The meaning of the codification is explained in *Table 2*.

Table 2. Codification explanation

NUCLEO-LxxxRy-P	Description	Example: NUCLEO-L452RE-P
Lxxx	STM32 Product line	STM32L452
R	STM32 package pin count	64 pins
y	STM32 Flash memory size (8 for 64 Kbytes, B for 128 Kbytes, C for 256 Kbytes, E for 512 Kbytes, G for 1MKbyte, H for 1.5 Mbytes and I for 2 Mbytes)	E = 512 Kbytes
-P	External SMPS architecture.	

This order code is mentioned on a sticker placed on bottom side of the board.

4 Conventions

Table 3 provides the conventions used for the ON and OFF settings in the present document.

Table 3. ON/OFF convention

Convention	Definition
Jumper JPx ON	Jumper fitted
Jumper JPx OFF	Jumper not fitted
Jumper JPx [1-2]	Jumper should be fitted between Pin 1 and Pin 2
Solder bridge SBx ON	SBx connections closed by 0 ohm resistor
Solder bridge SBx OFF	SBx connections left open

In this document the references for all information that is common to all sale types, are "STM32 Nucleo-64-P board" and "STM32 Nucleo-64-P boards".

5 System requirements

- Windows® OS (7, 8 and 10), Linux® or macOS™
- USB Type-A to Micro-B cable

6 Development toolchains

- Keil® MDK-ARM[a]
- IAR™ EWARM[a]
- GCC-based IDEs including free SW4STM32 from AC6

7 Demonstration software

The demonstration software, included in the STM32Cube package, is preloaded in the STM32 Flash memory for easy demonstration of the device peripherals in standalone mode. The latest versions of the demonstration source code and associated documentation can be downloaded from the www.st.com/stm32nucleo webpage.

8 Quick start

This section describes how to start a development quickly using the STM32 Nucleo-64-P board.

Before installing and using the product, accept the Evaluation Product License Agreement from the www.st.com/epla webpage.

8.0.1 Getting started

The STM32 Nucleo-64-P board is a low-cost and easy-to-use development kit to quickly evaluate and start a development with an STM32 microcontroller in QFP64 package. To start using this board, follow the steps below:

1. Check the jumper position on the board, as showed in the *Table 4: Default jumper settings*
2. For a correct identification of all device interfaces from the host PC, install the Nucleo USB driver available on the www.st.com/ stm32nucleo webpage, prior connecting the board.

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a. On Windows® only.

3. To power the board connect the Nucleo-64-P board to a PC with a USB cable 'type A to micro-B' through the USB connector CN1. As a result the green LED LD3 (5 V PWR) lights up, LD1 (COM) and green LED LD4 blink.

4. Press user button B1 (blue).

5. Observe that the blinking frequency of the three green LED LD4 changes, by clicking on the button B1.

6. The software demonstration and the several software examples, that allow the user to use the Nucleo features, are available at the www.st.com/stm32nucleo webpage.

7. Develop an application using the available examples.

9 Hardware layout and configuration

The STM32 Nucleo-64-P board is designed around the STM32 microcontrollers in a 64-pins LQFP package.

Figure 3 illustrates the connection between the STM32 and the peripherals (ST-LINK/V2-1, push-buttons, LEDs, Arduino Uno V3 connector and ST morpho connectors).

Figure 4 and *Figure 5* show the location of these features on the STM32 Nucleo-64-P board.

The mechanical dimensions of the board are showed in *Figure 6*.

Figure 3. Hardware block diagram
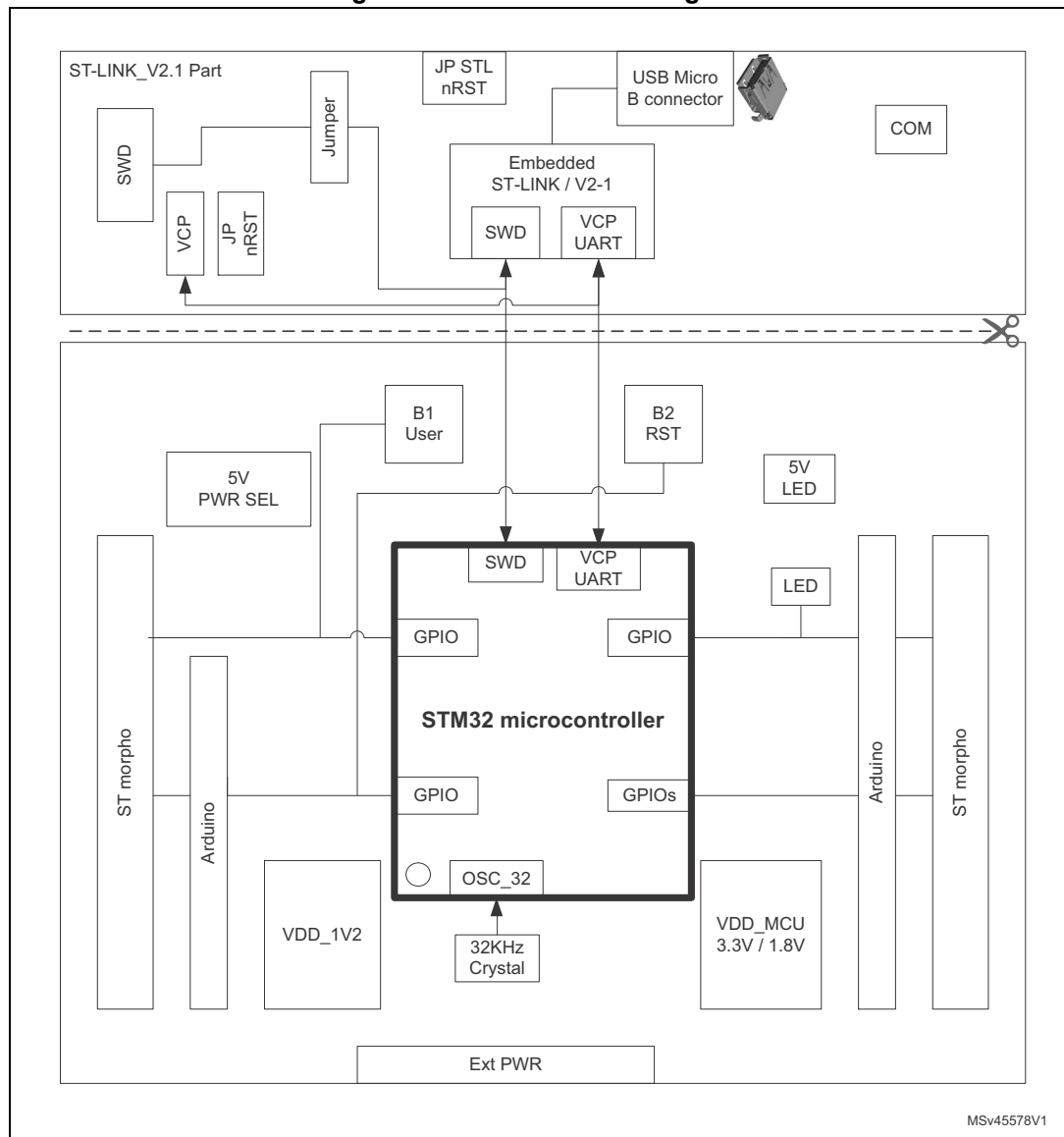
9.1 STM32 Nucleo-64-P board layout

Figure 4. STM32 Nucleo-64-P board top layout
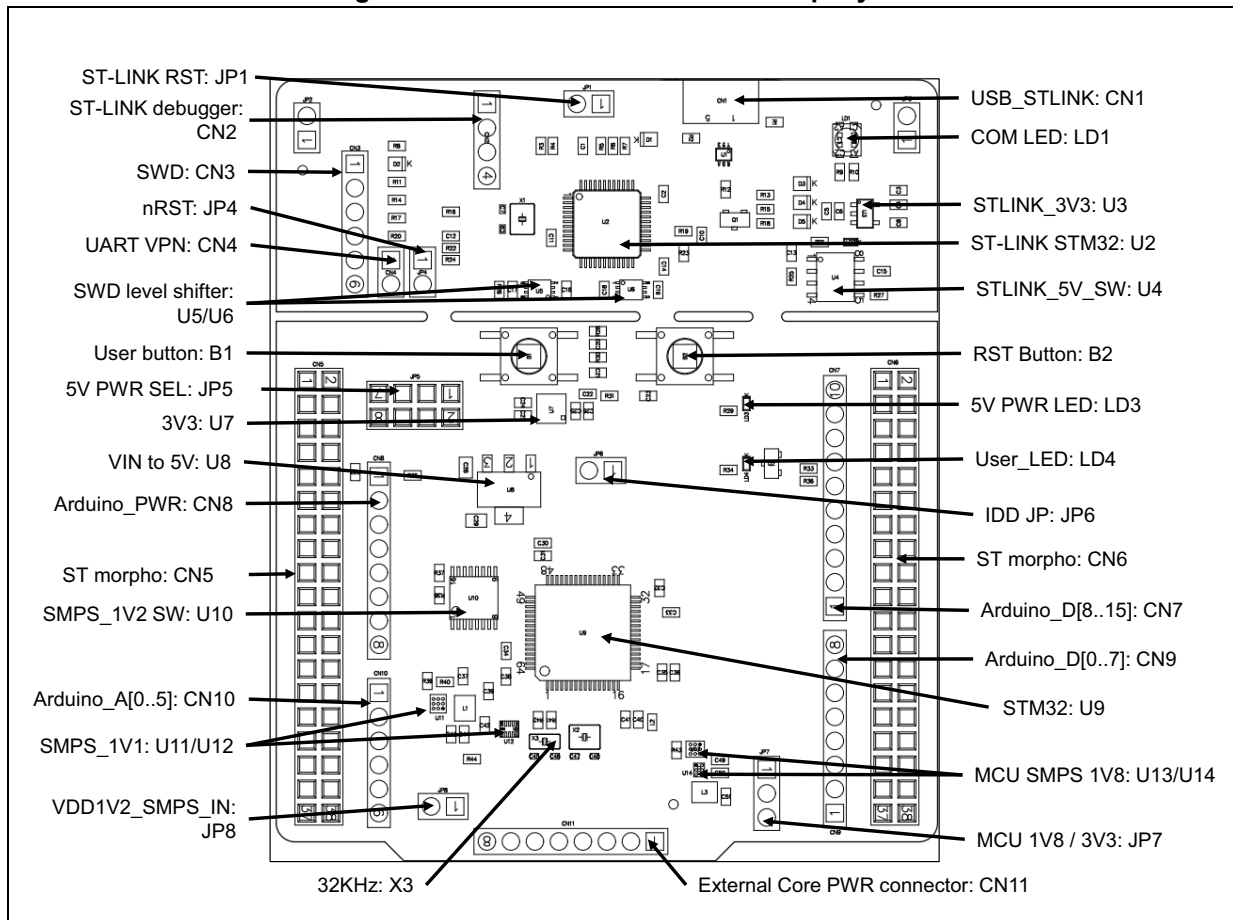
Figure 5. STM32 Nucleo-64-P board bottom layout
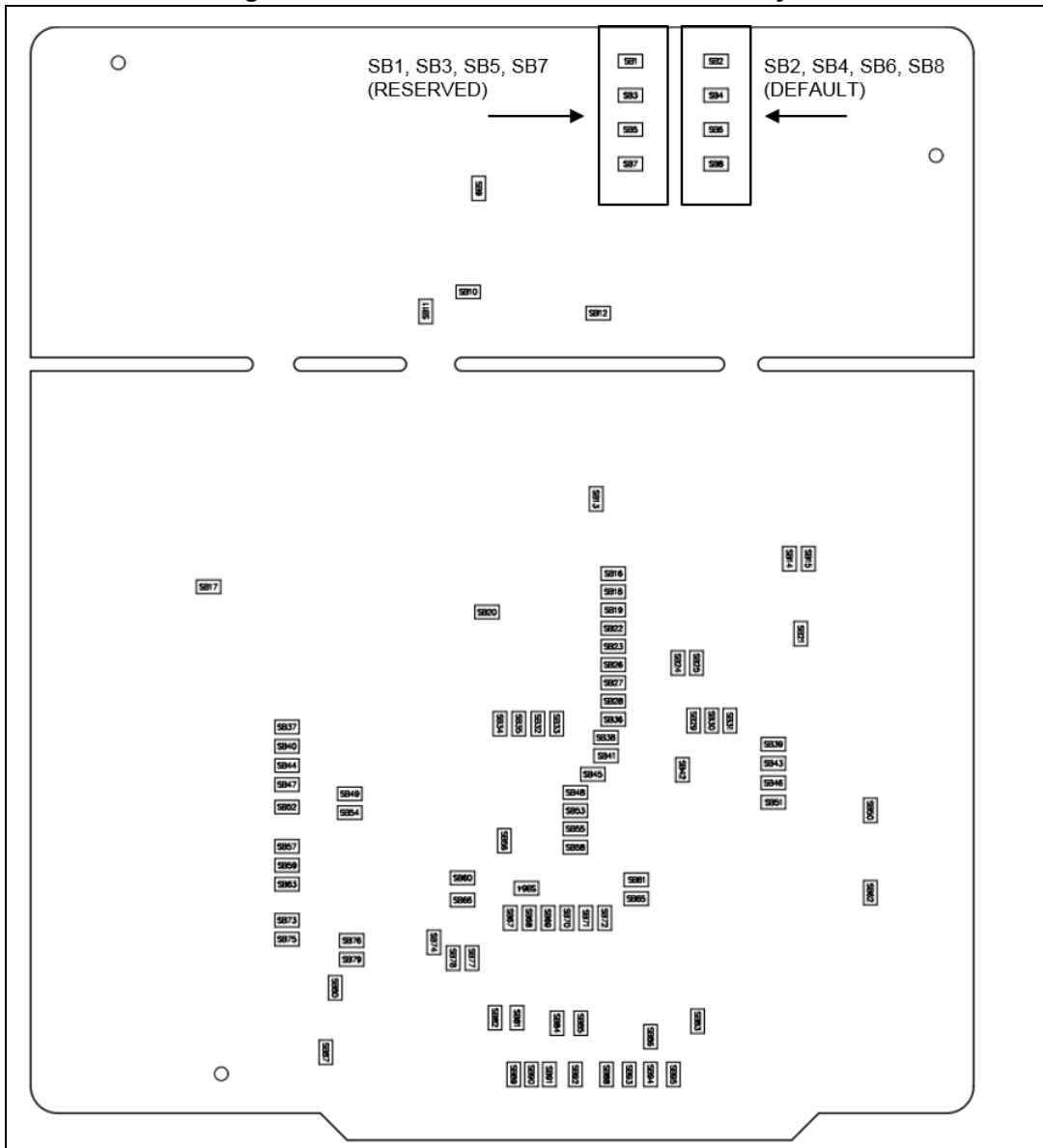
9.2   STM32 Nucleo-64-P board mechanical drawing

Figure 6. STM32 Nucleo-64 -P board mechanical drawing
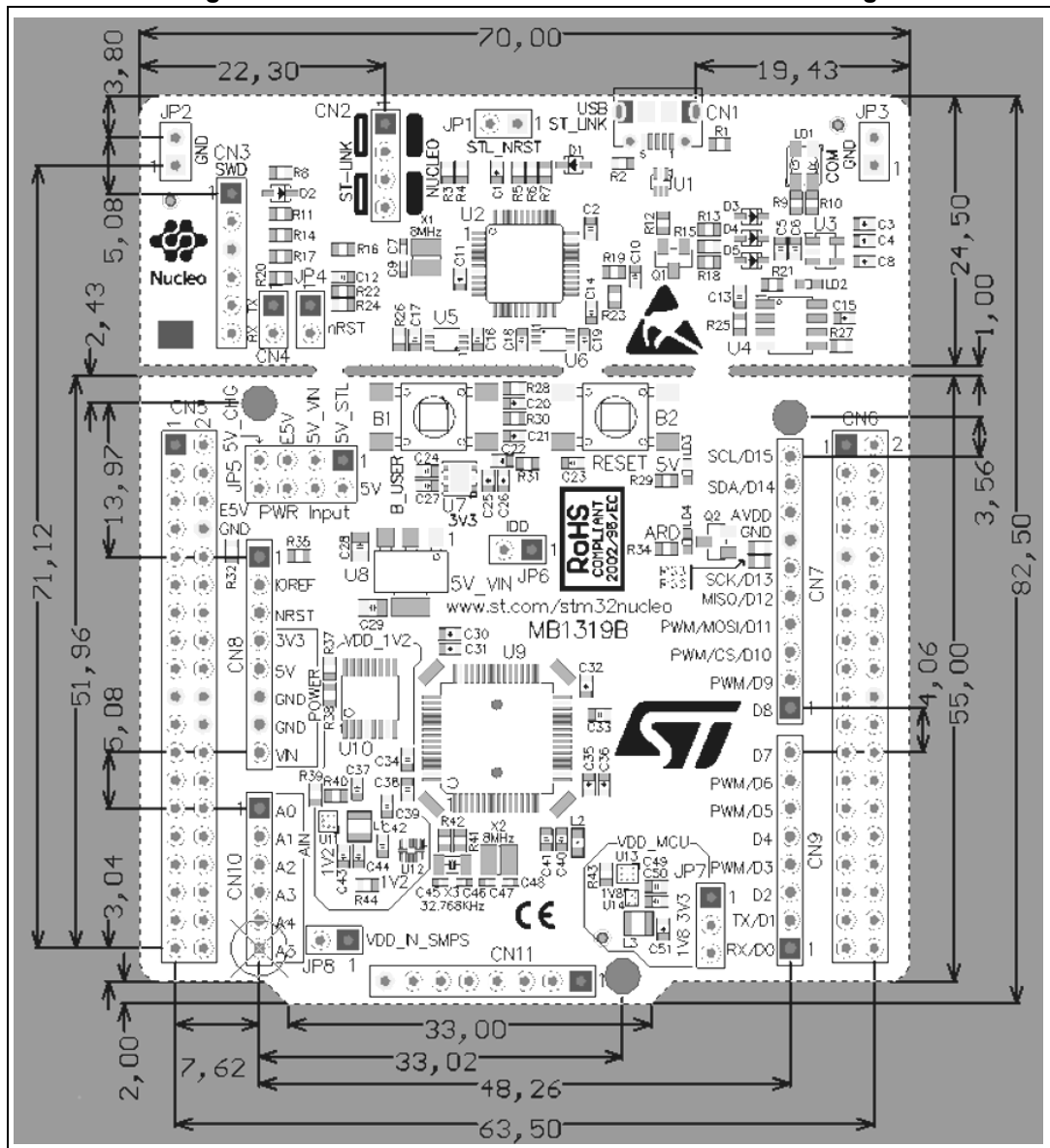
9.2.1   Default board configuration

By default the STM32 Nucleo-64-P board is delivered with the external SMPS 1.1 V enabled and V_{DD}@3.3 V. It is possible to set the board for V_{DD}@1.8 V. Before switching to 1.8 V, the user should check that the extension module and the external shields connected to the Nucleo-64-P board are 1.8 V compatible.

The default jumper configuration and V_{DD}@1.8 V setting is showed in *Table 4*.

Table 4. Default jumper settings

Jumper	Definition	Default position	Comment
CN2	SWD interface	ON [1-2] ON[3-4]	On-board ST-LINK/V2-1 debugger
JP1	STLK_RST	OFF	-
JP4	T_NRST	ON	-
JP5	5 V Power selection	ON [1-2]	5 V from ST-LINK
JP6	I_{DD} measurement	ON	STM32 V_{DD} current measurement
JP7	V_{DD_MCU}	ON [1-2] (default)	V_{DD_MCU} voltage selection 3.3 V
		ON [2-3] (optional)	V_{DD_MCU} voltage selection 1.8 V
JP8	$V_{DD\_IN\_SMPS}$	ON	V_{DD_1V2} SMPS input power supply

9.3 Cuttable PCB

An STM32 Nucleo-64-P board is divided into two parts: ST-LINK and target STM32. The ST-LINK part of the PCB can be cut out to reduce the board size. In this case the remaining target STM32 part can only be powered by V_{IN}, E5V and 3.3 V on the ST morpho connector CN5, or by V_{IN} and 3.3 V Arduino connector CN8.

It is still possible to use the ST- LINK part to program the STM32, using wires between the CN3 and SWD available signals on the ST morpho connector (SWCLK CN5 pin 17, SWDIO CN5 pin 15 and NRST CN5 pin 14, same I/O level as V_{DD_MCU}).

9.4 Embedded ST-LINK/V2-1

The ST-LINK/V2-1 programming and debugging tool is integrated on the STM32 Nucleo-64-P board.

For information about debugging and programming features, refer to *ST-LINK/V2 in-circuit debugger/programmer for STM8 and STM32* User manual (UM1075) at the *www.st.com* website.

The changes versus ST-LINK/V2 version are listed below.

New features supported on ST-LINK/V2-1 are:

- USB software re-enumeration
- Virtual COM port interface on USB
- Mass storage interface on USB
- USB power management request for more than 100mA power on USB

The following features are no more supported on ST-LINK/V2-1:

- SWIM interface
- Application voltage lower than 3 V (need to add level shifter to support it)

The embedded ST-LINK/V2-1 can be used in two different ways according to the jumper states (refer to *Table 5*):

- Program/debug the STM32 on board,
- Program/debug an STM32 in an external application board using a cable connected to SWD connector.

Table 5. ST-LINK jumper configuration

CN	Definition	Default position	Comment
CN3	T_SWCLK / T_SWDIO	ON [1-2] ON [3-4]	ST-LINK/V2-1 functions enabled for on-board programming (default)
	T_SWCLK / T_SWDIO	OFF [1-2] OFF [3-4]	ST-LINK/V2-1 functions enabled from external connector (SWD supported)

9.4.1 Drivers

Before connecting the STM32 Nucleo-64-P board to a Windows® PC (XP, 7, 8 and 10) through USB, install the driver for the ST-LINK/V2-1 that is available at the *www.st.com* website.

In case the STM32 Nucleo-64-P board is connected to the PC before installing the driver, the PC device manager may report some Nucleo interfaces as "Unknown". To recover from this situation, after installing the dedicated driver, the association of "Unknown" USB devices found on the STM32 Nucleo-64-P board to this dedicated driver, must be updated in the device manager manually.

Note: *It is recommended to proceed by using USB Composite Device, as shown in Figure 7.*

Figure 7. USB composite device
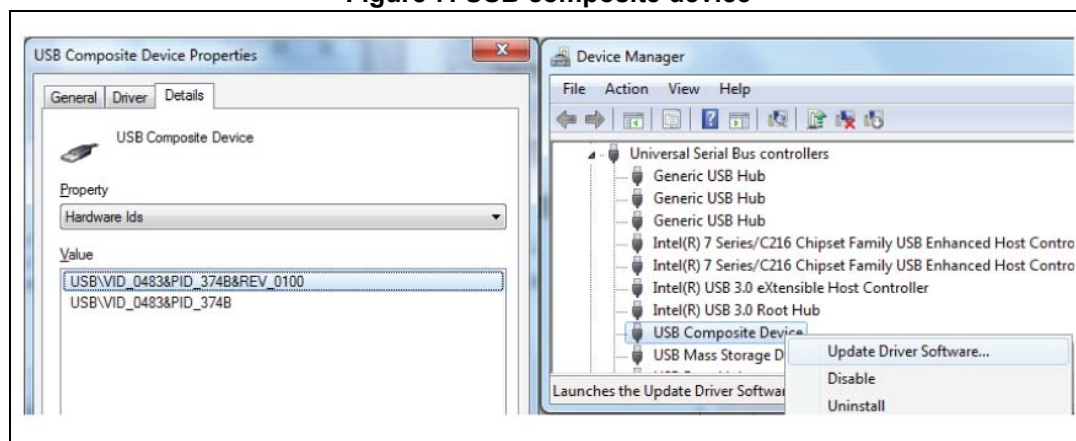
9.4.2 ST-LINK/V2-1 firmware upgrade

The ST-LINK/V2-1 embeds a firmware upgrade mechanism for in-situ upgrade through the USB port. As the firmware may evolve during the lifetime of the ST-LINK/V2-1 product (for example new functionalities, bug fixes, support for new microcontroller families), it is recommended to keep the ST-LINK/V2-1 firmware up to date before starting to use an STM32 Nucleo-64-P board. The latest version of this firmware is available at the *www.st.com* website.

9.4.3 Using the ST-LINK/V2-1 to program/debug the STM32

To program the STM32, place the two jumpers marked in red on the connector CN2, as shown in *Figure 8*. Do not use the SWD connector to not disturb the communication with the STM32 microcontroller of the Nucleo-64-P board.

Figure 8. ST-LINK debugger: jumper configuration for on-board MCU
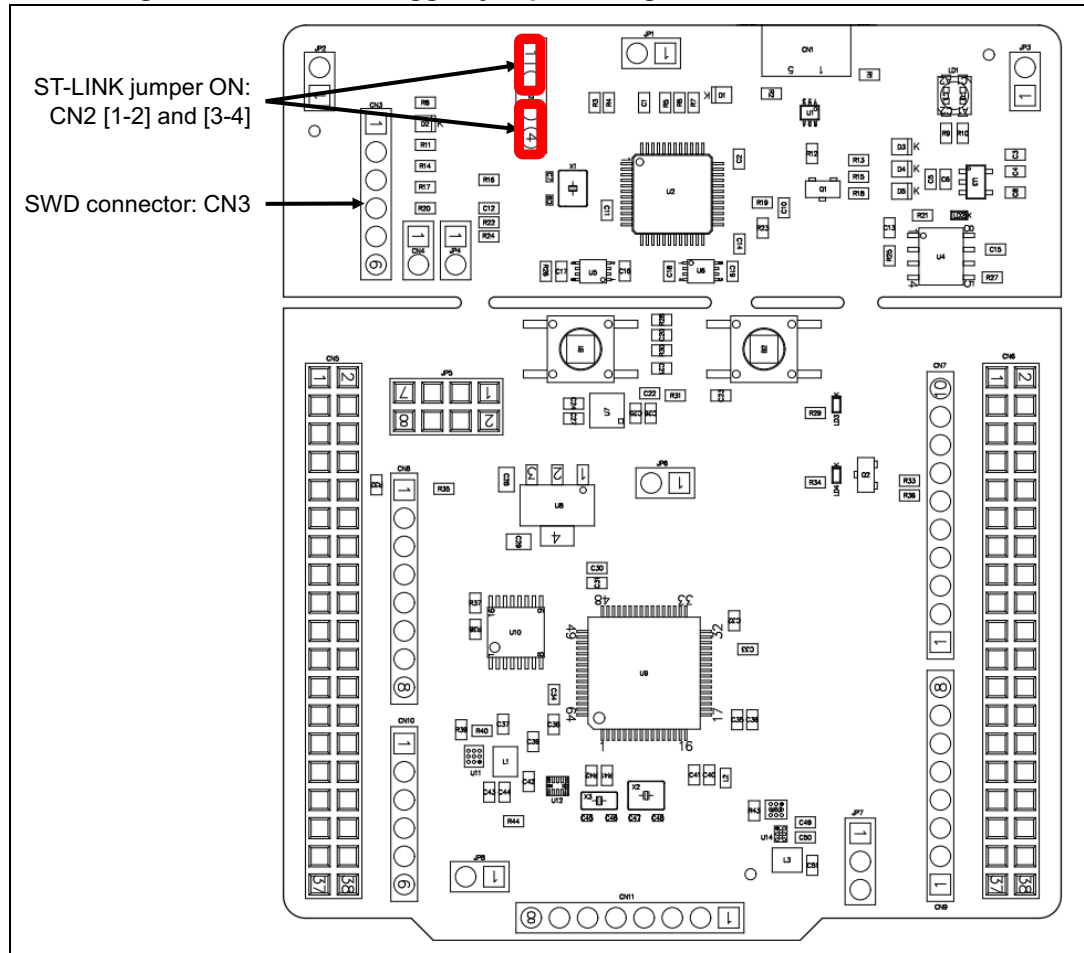
9.4.4 Using the ST-LINK/V2-1 to program/debug an external STM32 application.

It is very easy to use the ST-LINK/V2-1 to program the STM32 on an external application.

Simply remove the two jumpers from CN2, as shown in *Figure 9*, and connect the application to the SWD debug connector according to *Table 6*.

Note: *JP4 NRST (target STM32 RESET) must be opened when CN3 pin 5 is used in an external application.*

Figure 9. ST-LINK debugger: jumper configuration for external MCU
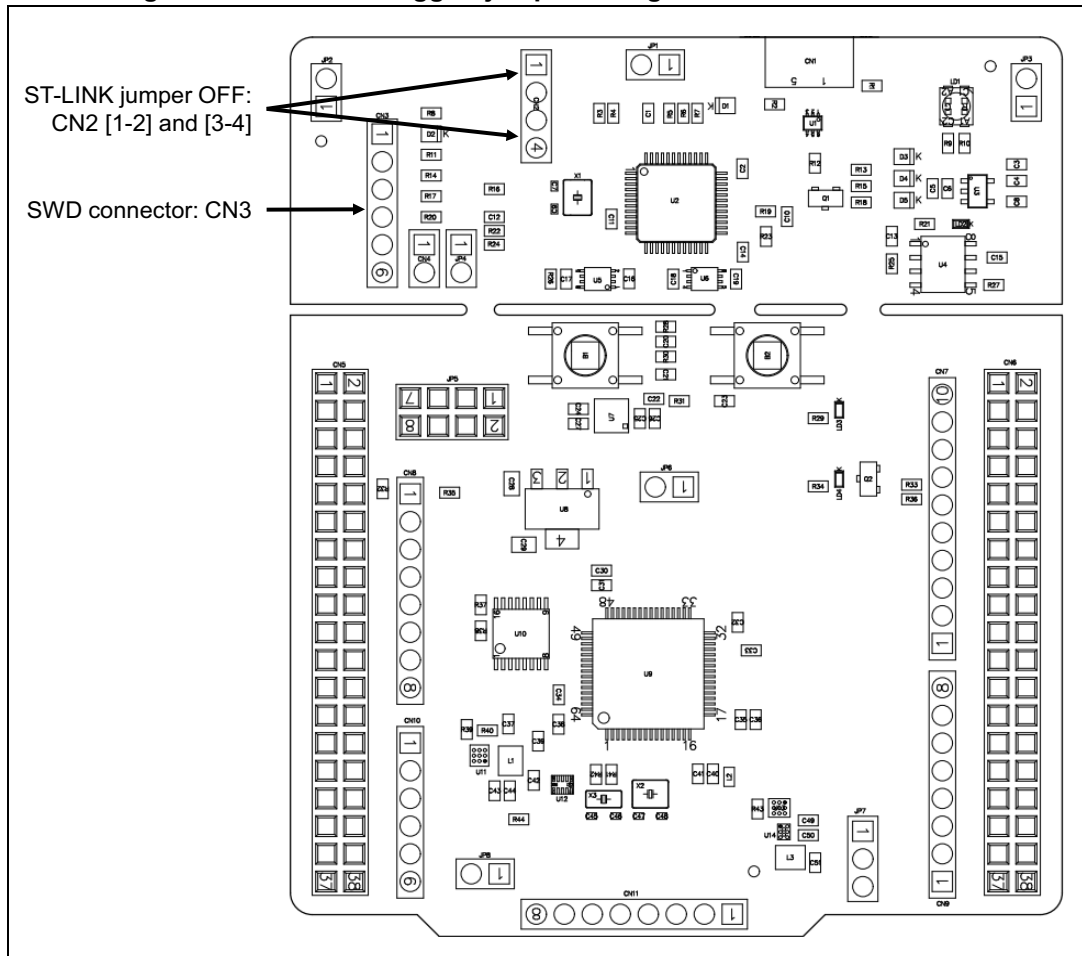
Table 6. Debug connector SWD

Connector	Pin number	Pin name	Signal name	STM32 pin	Function
SWD CN3	1	1	VDD_TARGET: AIN_1	PA0	V_{DD} from application
	2	2	T_JTCK	PA5	SWD clock
	3	3	GND	PA12	Ground
	4	4	T_JTMS	PA14	SWD data input/output
	5	5	T_NRST	PB0	RESET of target STM32
	6	6	T_SWO	PA10	SWD out (optional)

9.5 Power supply and power selection

9.5.1 External Power supply input

The STM32 Nucleo-64-P board is designed to be powered by several DC power supply. It is possible to supply the STM32 Nucleo-64-P board with any of the following sources:

- 5V_ST_LINK from ST-LINK USB connector
- V_{IN} (7 V-12 V) from Arduino connector or ST morpho connector
- E5V from ST morpho connector
- 5V_USB_CHARGER from ST-LINK USB
- 3.3 V on Arduino connector or ST morpho connector

Note: *If an external 5V DC power source is used, the Discovery 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.*

The power supply capabilities are showed in *Table 7.*

Table 7. Power supply capabilities

Input power name	Connector pins	Voltage range	Max current	Limitation
V_{BUS} (5V_STLINK)	CN1 pin 1	4.75 V to 5.25 V	500mA	Max current depends on the USB enumeration: – 100 mA without enumeration – 500 mA with enumeration OK
V_{IN}	CN8 pin 8 CN5 pin 24	7 V to 12 V	800 mA	From 7 V to 12 V only and input current capability is linked to input voltage: – 800 mA input current when V_{IN}=7 V – 450 mA input current when 7 V<V_{IN}<9 V – 300 mA input current when 10 V>V_{IN}>9 V – less than 300 mA input current when V_{IN}>10 V
E5V	CN5 pin 6	4.75 V to 5.25 V	500 mA	
5V_USB_CHG	CN1 pin 1	4.75 V to 5.25 V	500 mA	Max current depends on the USB wall charger used to powered the Nucleo board
3.3V	CN8 pin 4 CN5 pin 16 JP6 pin 2	3 V to 3.6 V	-	Used when ST-LINK part of PCB not used or removed and SB13 OFF

5V_ST_LINK is a DC power with limitation from ST-LINK USB connector (USB type Micro-B connector of ST-LINK/V2-1). In this case JP5 jumper should be on pins 1 and 2 to select 5V_STL power source on silkscreen of JP5. This is the default setting. If the USB enumeration succeeds, the 5V_ST_LINK power is enabled, by asserting the PWR_ENn signal (from STM32F103CBT6). This pin is connected to a power switch ST890, which

powers the board. This power switch also features a current limitation to protect the PC in case of a short-circuit on board (more than 750 mA).

The STM32 Nucleo-64-P board and its shield can be powered from the ST-LINK USB connector CN1, but only ST-LINK circuit is powered before USB enumeration, because the host PC only provides 100 mA to the board at that time. During the USB enumeration, STM32 Nucleo-64-P board requires 500 mA of current to the host PC. If the host is able to provide the required power, the enumeration ends by a "SetConfiguration" command and then, the power transistor ST890 is switched ON, the green LED LD3 is turned ON, thus the STM32 Nucleo-64-P board and its shield request no more than 500 mA current. If the host is not able to provide the required current, the enumeration fails. Therefore the power switch ST890 stays OFF and the MCU part including the extension board is not powered. As a consequence the green LED LD3 stays turned OFF. In this case it is mandatory to use an external power supply.

USB power: 5V_STL configuration: jumper JP5[1-2] should be connected as showed in *Figure 10*.

Figure 10. JP5[1-2]: 5V_STL power source
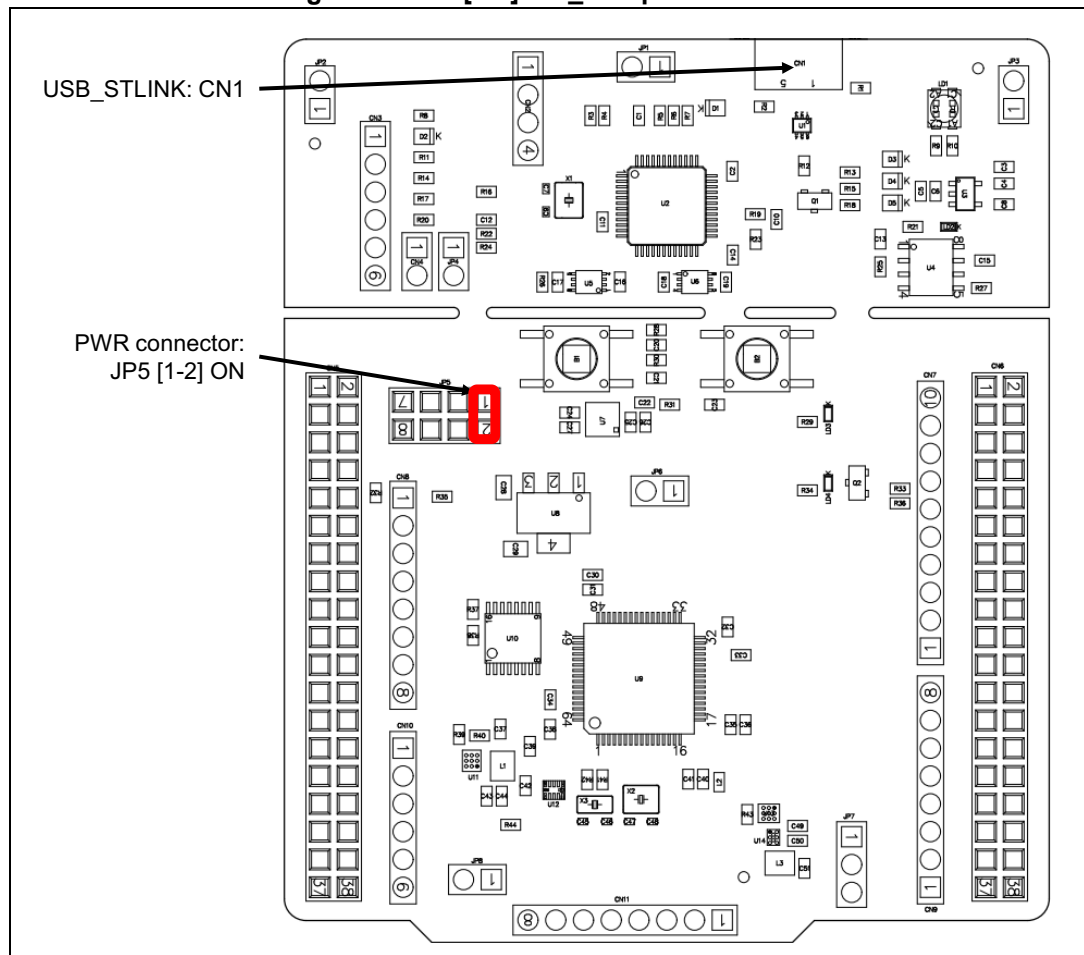
VIN (5V_VIN) is the 7-12 V DC power from Arduino CN8 pin 8 named V_{IN} on Arduino connector silkscreen or from ST morpho connector CN5 pin 24. In this case JP5 jumper

should be on pins 3 and 4 to select 5V_VIN power source on silkscreen of JP5. In that case the DC power comes from the power supply through the Arduino Uno V3 battery shield (compatible with Adafruit PowerBoost 500 shield).

5V_VIN configuration: jumper JP5[3-4] should be connected as showed in *Figure 11*.

Figure 11. JP5[3-4]: 5V_VIN power source
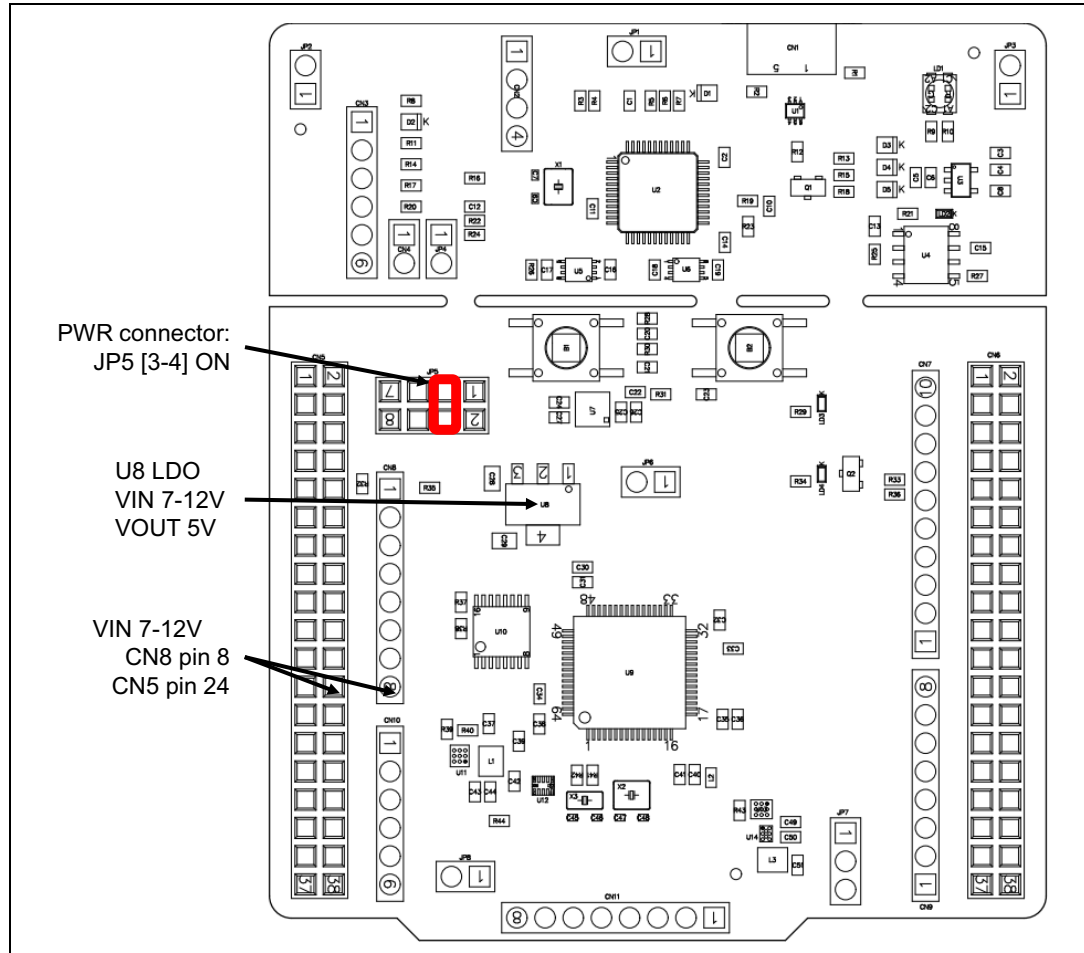
E5V is the DC power coming from external (5V DC power from ST morpho connector CN5 pin 6). In this case JP5 jumper should be on pins 5 and 6 to select E5V power source on silkscreen of JP5.

E5V configuration: Jumper JP5[5-6] should be connected as showed in *Figure 12*.

Figure 12. JP5[5-6]: E5V power source

PWR connector:
JP5 [5-6] ON

E5V: CN5 pin 6
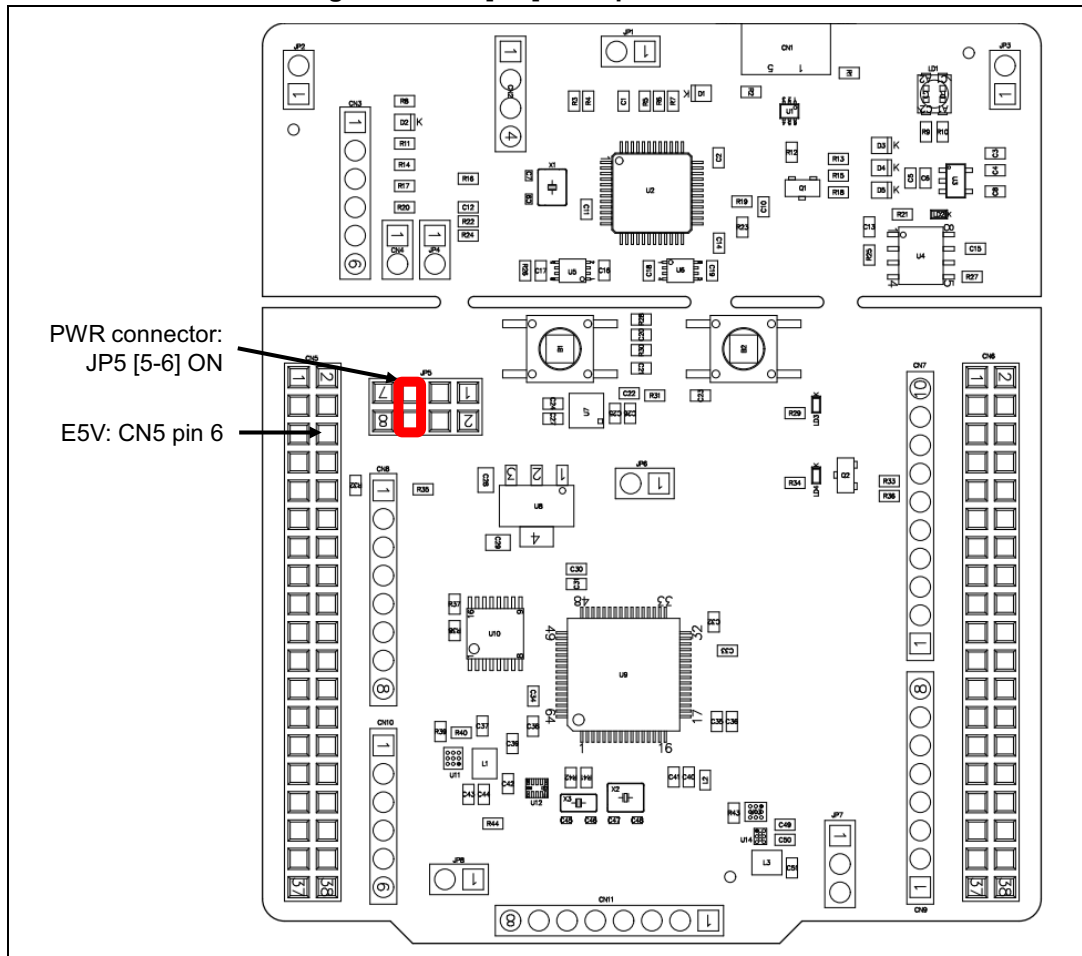
5V_USB_CHARGER is the DC power charger connected to USB ST-LINK (CN1). To select the 5V_USB_CHARGER power source on silkscreen of JP5, the jumper of JP5 should be on pins 7 and 8. In this case, if the STM32 Nucleo-64-P board is powered by an external USB charger the debug is not available. If the PC is connected instead of the charger, the limitation is no more effective, in this case the PC could be damaged.

5V_USB_CHG configuration: jumper JP5[7-8] should be connected as showed in *Figure 13*.

Figure 13. JP6[7-8]: 5V_USB_CHG power source

Caution: Solder bridge SB9 can be used to bypass the USB power protection ST890. (**This is not an ST recommended setting**). SB9 can be set in case the board is powered by the USB of the PC and maximum current consumption on 5V_STLINK **does not exceed 100 mA** (including extension board or Arduino shield power consumption). In such condition USB enumeration will always succeed since no more than 100 mA is requested to the PC. Configurations of SB9 are summarized in *Table 8*.

Table 8. SB9 configurations

Solder bridge	Default position	Power supply	Allowed current
SB9	OFF (not soldered)	USB PWR through CN1	500 mA max limited by ST890
	ON (soldered)		100 mA max
	OFF (not soldered)	VIN or E5V PWR	Whatever current is: no limitation
	ON (soldered)		SB9 must be removed when the board is powered[1]

1. SB9 must be removed when the board is powered by E5V (CN5 pin 6) or by V_{IN} (CN8 pin 8 or CN5 pin 24).

> **Warning:** In case the maximum current consumption of the STM32
> Nucleo-64-P board and its extension boards exceeds 500 mA,
> it is recommended to power the STM32 Nucleo-64-P board
> using an external power supply connected to E5V or V_{IN}.

9.5.2 External power supply output

5 V: the 5 V (CN8 pin 5 or CN5 pin 18) can be used as output power supply for an Arduino shield or an extension board, when the STM32 Nucleo-64-P board is powered by USB, V_{IN} or E5V. In this case the maximum current allowed is showed in *Table 7*.

3.3 V: on CN8 pin 4 or CN5 pin 16 can be also used as power supply output. The current is limited by the maximum current capability of the regulator U7 (LD39050PUR33 from STMicroelectronics). In this condition the maximum consumption of the STM32 Nucleo-64-P board and the connected shield should be less than 500 mA.

9.5.3 SMPS power supply

Power figures in Run mode are significantly improved by:

- Generating V_{core} logic supply from an external SMPS (switched-mode power supply) or from an external connector
- Generating V_{DD_MCU} supply from an external SMPS (switched-mode power supply), or from an external connector

The STM32 Nucleo-64-P board is populated with two SMPSs, U11 and U13, with the following functions:

- SMPS U11 allows to supply dynamically the V_{DD_1V2} pins in Run mode at 1.1 V with a maximum current of 30 mA.
- SMPS U13 allows to supply the V_{DD_MCU} pin at 1.8 V with a maximum current of 50 mA (hysteresis operation mode). The SMPS U13 can deliver higher current (PWM operation mode) but with less efficiency. To set the U13 SMPS in PWM mode remove SB80 and solder SB79. This SMPS is enabled by default.

V_{DD_MCU} configuration:

- 3.3 V (default): JP7 to pins 1 and 2
- 1.8 V: JP7 to pins 2 and 3 (best ULPBench score)

Note: *The ST-LINK is still available in this configuration thanks to the level shifters U5 and U6.*

For all general information concerning design recommendations for the STM32 with external SMPS, refer to the *Design recommendations for STM32L4xxxx with external SMPS, design guide for ultra-low-power applications with performance* Application note (AN4978) available at the *www.st.com* website.

9.6 Programming/debugging when the power supply is not from ST-LINK (5V_ST_link)

V_{IN} or E5V is used as an external power supply in case the current consumption of the STM32 Nucleo-64-P board and its extension boards exceed the allowed current on the USB. In such condition it is still possible to use the USB for communication, programming or debugging only.

In this case it is mandatory to power the board first using V_{IN} or E5V then to connect the USB cable to the PC. Proceeding this way the enumeration succeeds, thanks to the external power source.

The following power sequence procedure must be respected:

1. Connect jumper JP5 between pins 3 and 4 for V_{IN} or pins 5 and 6 for E5V
2. Be sure that SB9 is removed
3. Connect the external power source to V_{IN} or E5V
4. Power ON the external power supply 7 V< V_{IN} < 12 V to V_{IN}, or 5 V for E5V
5. Check that the green LED LD3 is turned ON
6. Connect the PC to the USB connector CN1

If this sequence is not respected, the board may be powered by V_{BUS} first from the ST-LINK, with the following risks:

- If more than 500 mA current is needed by the board, the PC may be damaged or the current supplied may be limited by the PC. As a consequence the board is not powered correctly.
- 500 mA is requested at the enumeration (since SB9 must be OFF): this request can be rejected and the enumeration does not succeed if the PC cannot provide such current, consequently the board is not power supplied (LED LD3 remains OFF).

9.7 OSC clock sources

Three clock sources are listed below:

- LSE which is the 32.768 KHz crystal for the STM32 embedded RTC
- MCO which is the 8 MHz clock from the ST-LINK MCU for the STM32 microcontroller
- HSE which is the 8 MHz oscillator for the STM32 microcontroller. This clock is not implemented on the STM32 Nucleo-64-P board.

9.7.1 LSE: OSC 32 KHz clock supply

There are three ways to configure the pins corresponding to the low-speed clock (LSE):

LSE on-board oscillator X3 crystal (Default configuration). Refer to *Oscillator design guide for STM8S, STM8A and STM32 microcontrollers* Application note (AN2867) for oscillator design guide for STM32 microcontrollers. It is recommended to use NX3215SA manufactured by NDK (32.768 kHz, 6 pF, 20 ppm).

Oscillator from external to PC14 input: from external oscillator through pin 25 of the CN5 connector.

The following configuration is needed:

- SB71 and SB72 ON
- R41 and R42 removed

LSE not used: PC14 and PC15 are used as GPIOs instead as low-speed clock.

The following configuration is needed:

- SB71 and SB72 ON
- R41 and R42 removed

9.7.2 OSC clock supply

There are four ways to configure the pins corresponding to the external-high-speed clock (HSE):

MCO from ST-LINK (Default: not connected): MCO output of ST-LINK MCU is used as an input clock. This frequency cannot be changed, it is fixed at 8 MHz and connected to PH0 OSC_IN of the STM32 microcontroller.

The following configuration is needed:

- SB67, SB69 and SB70 OFF
- SB64 ON

In this configuration PH1 is used as I/O (SB68 ON)

HSE: on-board oscillator X2 crystal (Default: not connected): for typical frequencies and its capacitors and resistors, refer to the STM32 microcontroller datasheet. Refer to the *Oscillator design guide for STM8S, STM8A and STM32 microcontrollers* Application note (AN2867) for oscillator design guide for the STM32 microcontrollers. The X2 crystal has the following characteristics: 8 MHz, 8 pF, 20 ppm. It is recommended to use NX3225GD manufactured by NDK.

The following configuration is needed:

- SB64, SB68, SB70 OFF
- SB67 and SB69 ON
- C47 and C48 soldered with 8.2 pF capacitors

External oscillator to PH0 input (Default: not connected): from an external oscillator through pin 29 of the CN5 connector.

The following configuration is needed:

- SB64, SB67 and SB69 OFF
- SB70 ON
- In this configuration PH1 is used as I/O (SB68 ON)

HSE not used (Default configuration): PH0 and PH1 are used as GPIO and not as clock.

The following configuration is needed:

- SB58 and SB60 OFF
- SB59 and SB61 ON
- R21 removed