UM2032
User manual

Discovery kit with STM32F412ZG MCU

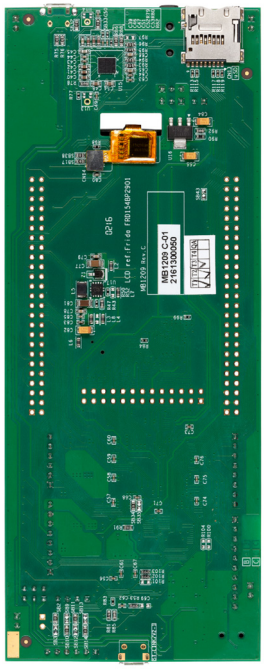
Introduction

The 32F412GDISCOVERY Discovery kit is a complete demonstration and development platform for STMicroelectronics Arm® Cortex®-M4 core-based STM32F412ZGT6 microcontroller. This microcontroller features four I^2C buses, four USART ports, five SPI ports with two multiplexed full-duplex I^2S buses, SDIO interface, USB OTG full-speed 2.0 port, two CAN buses, FMC parallel interface, two digital filters for sigma-delta modulators, PDM interface for two digital microphones, one 12-bit ADC, dual Quad-SPI interface, JTAG and SWD debugging support. This Discovery kit offers everything required for users to get started quickly and develop applications easily.

A full range of hardware features on the board helps users to evaluate on-board peripherals such as: USB OTG FS, microSD™ card, full-duplex I^2S with an audio codec and stereo jack for headset including analog microphone, DFSDM with a pair of ST-MEMS digital microphones on board, Quad-SPI Flash memory device, 1.54" TFT LCD using FMC interface with capacitive touch panel.
The ARDUINO® Uno V3 compatible connectors expand the functionality with a wide choice of specialized shields. The extension connectors allow easy connection of a daughterboard for specific customer applications. The integrated ST-LINK/V2-1 provides an embedded in-circuit debugger and programmer for the STM32.

Figure 1. 32F412GDISCOVERY (top view)

Figure 2. 32F412GDISCOVERY (bottom view)



Pictures are not contractual.

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1 Features

- STM32F412ZGT6 microcontroller, based on the Arm®(a) Cortex®-M4 processor, featuring 1 Mbyte of Flash memory and 256 Kbytes of RAM in an LQFP144 package
- 1.54-inch, 240x240 pixel TFT color LCD with parallel interface and capacitive touch panel
- USB OTG FS
- I^2S audio codec
- Stereo digital ST-MEMS microphones
- 128-Mbit Quad-SPI NOR Flash memory
- Reset push-button and joystick
- 4 color user LEDs
- Board connectors
  - microSD™ card
  - User USB with Micro-AB
  - Stereo headset jack with analog microphone input and a loudspeaker output
  - I^2C expansion connector
  - ARDUINO® Uno V3 expansion connectors
  - 2.54 mm pitch expansion connector for direct access to various features of the STM32F412ZGT6 microcontroller
- Flexible power-supply options:
  - ST-LINK/V2-1
  - User USB FS connector
  - VIN from ARDUINO® Uno V3
  - +5 V from ARDUINO® Uno V3
- 2.0 V and 3.3 V supply voltage options for the STM32F412ZGT6
- Comprehensive free software libraries and examples available with the STM32Cube MCU Package
- On-board ST-LINK/V2-1 debugger/programmer with USB re-enumeration capability: mass storage, Virtual COM port, and debug port
- Support of a wide choice of Integrated Development Environments (IDEs) including IAR Embedded Workbench®, MDK-ARM, and STM32CubeIDE

arm

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2 Ordering information

To order the 32F412GDISCOVERY Discovery kit, refer to *Table 1*. Additional information is available from the datasheet and reference manual of the target microcontroller.

Table 1. Ordering information

Order code	Board reference	Target STM32
STM32F412G-DISCO	MB1209	STM32F412ZGT6

2.1 Codification

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

Table 2. Codification explanation

STM32F4XXY-DISCO	Description	Example: STM32F412G-DISCO
STM32F4	MCU series in STM32 32-bit Arm Cortex MCUs	STM32F4 Series
XX	MCU product line in the series	STM32F412
Y	STM32 Flash memory size: – G for 1 Mbyte	1 Mbyte
DISCO	Discovery kit	Discovery kit

3 Development environment

3.1 System requirements

- Multi.OS support: Windows® 10, Linux® [a] 64-bit, or macOS® [b]
- USB Type-A or USB Type-C® to Micro-B cable

3.2 Development toolchains

- IAR Systems® - IAR Embedded Workbench® [c]
- Keil® - MDK-ARM[c] [d]
- STMicroelectronics - STM32CubeIDE

4 Conventions

Table 3 provides the definition of some conventions used in the present document.

Table 3. ON/OFF conventions

Convention	Definition
Jumper JPx ON	Jumper fitted
Jumper JPx OFF	Jumper not fitted
Solder bridge SBx ON	SBx connections closed by solder
Solder bridge SBx OFF	SBx connections left open

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b. macOS® is a trademark of Apple Inc. registered in the U.S. and other countries.

c. On Windows® only.

d. All other trademarks are the property of their respective owners.

5 Hardware layout and configuration

The 32F412GDISCOVERY Discovery kit is designed around the STM32F412ZGT6 (144-pin TQFP package). The hardware block diagram shown in *Figure 3*, illustrates the STM32F412ZGT6 connections with the peripherals. *Figure 4* and *Figure 5* show the location of the main components on the Discovery kit.

Figure 3. Hardware block diagram

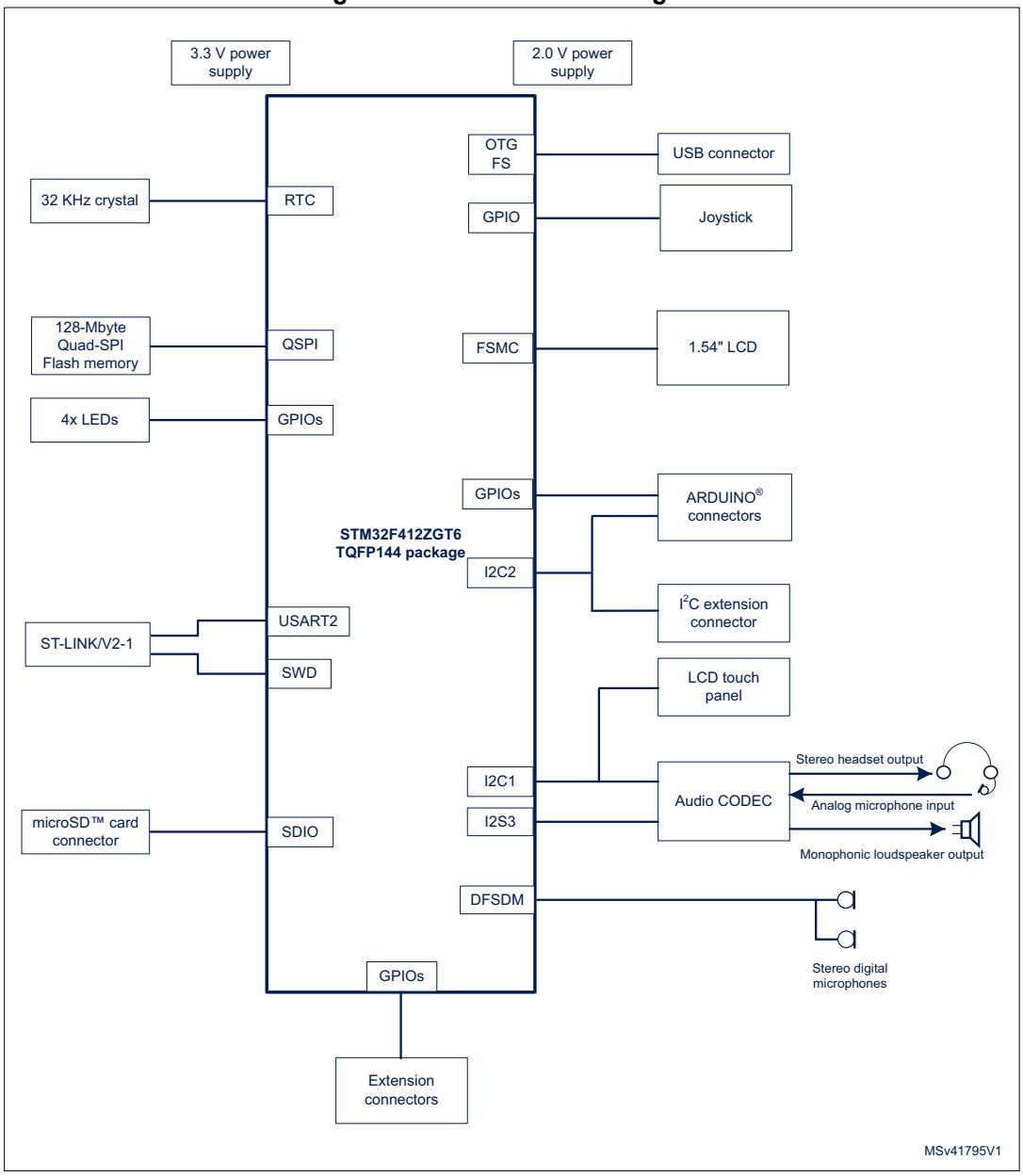


Figure 4. 32F412GDISCOVERY top layout

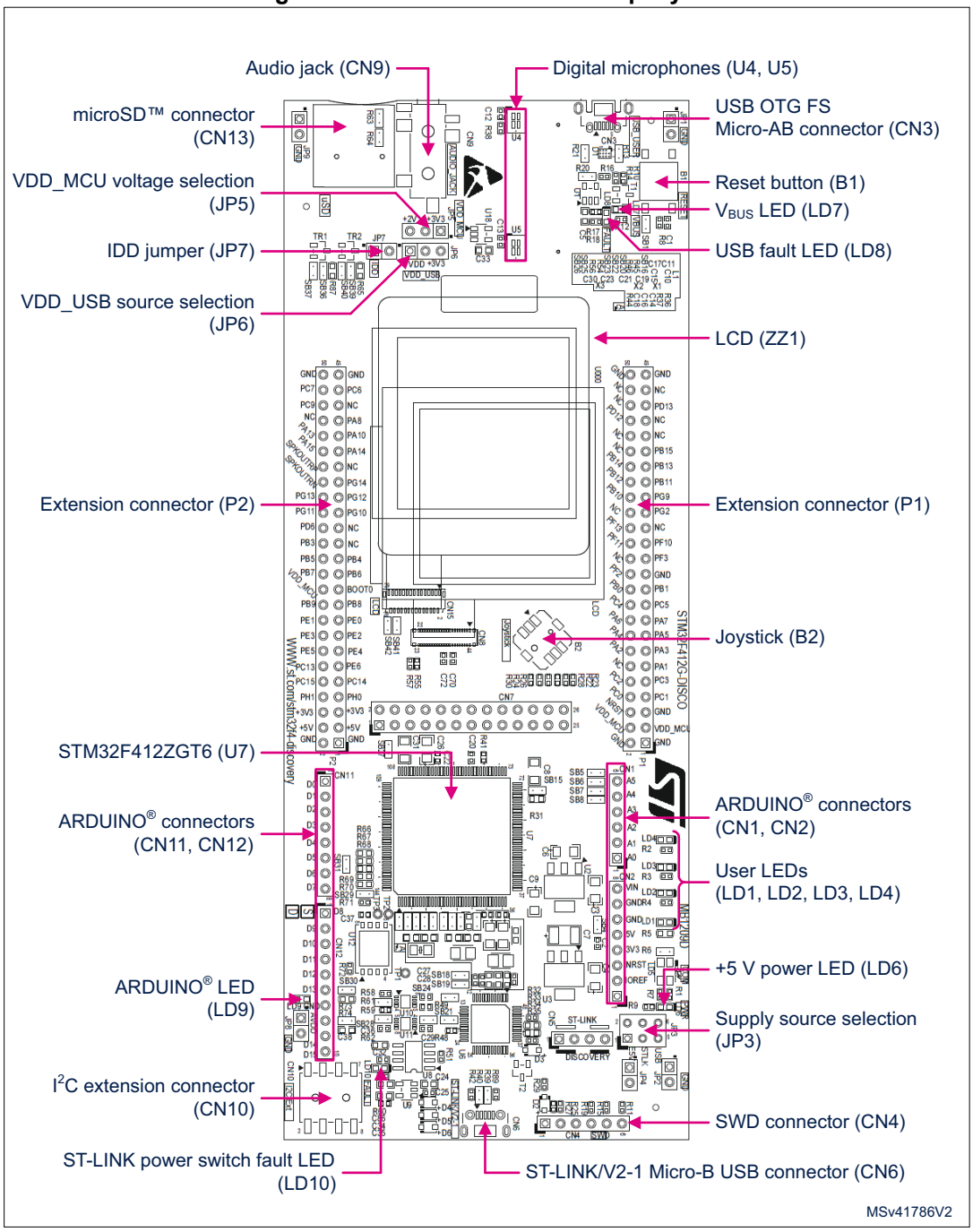
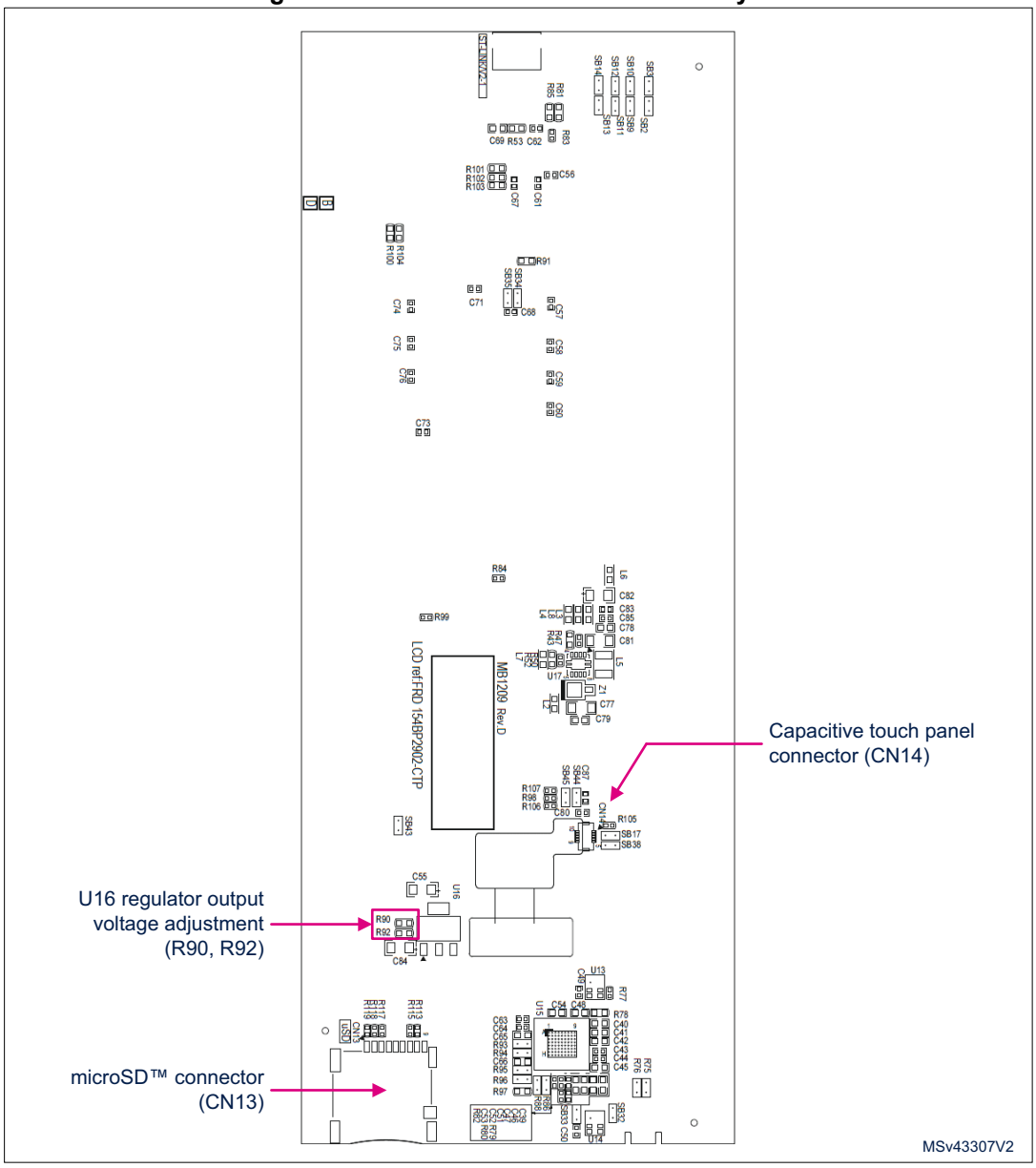
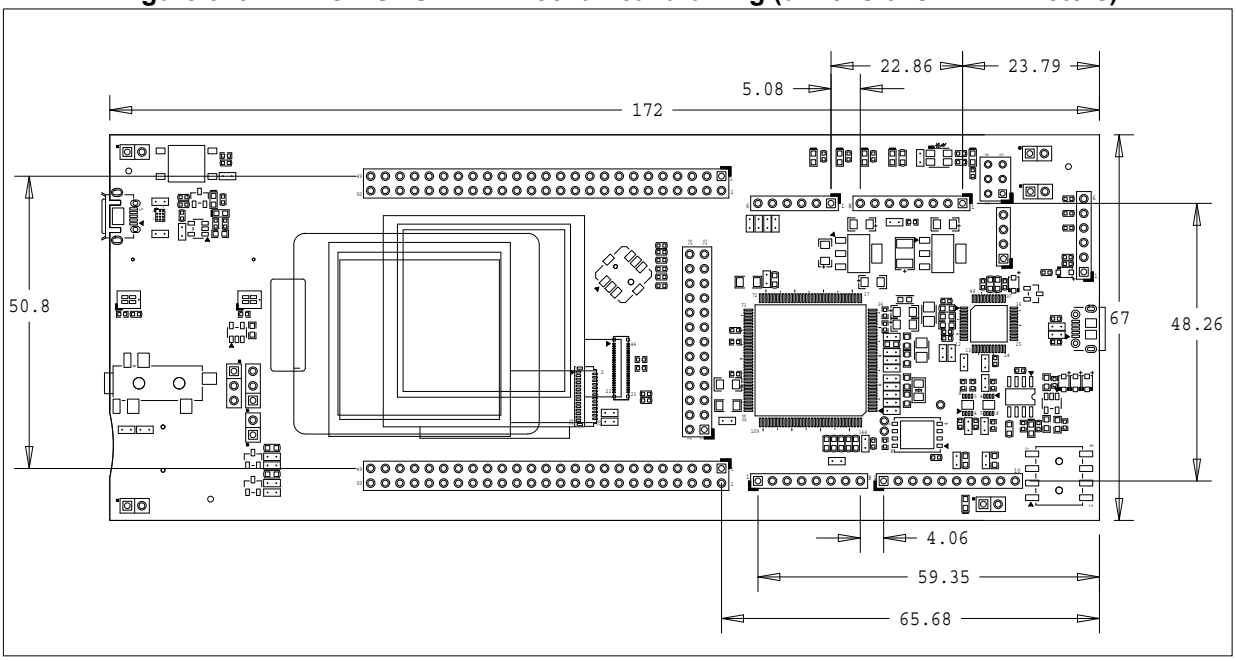


Figure 5. 32F412GDISCOVERY bottom layout



5.1 32F412GDISCOVERY Discovery kit mechanical drawing

Figure 6. 32F412GDISCOVERY mechanical drawing (dimensions in millimeters)



5.2 Embedded ST-LINK/V2-1

ST-LINK/V2-1 programming and debugging tool is integrated into the 32F412GDISCOVERY Discovery kit.

For information about the debugging and programming features, refer to the *ST-LINK/V2 in-circuit debugger/programmer for STM8 and STM32* user manual (UM1075). For a comparison of the various ST-LINK solutions, refer to the *Overview of ST-LINK derivatives* technical note (TN1235).

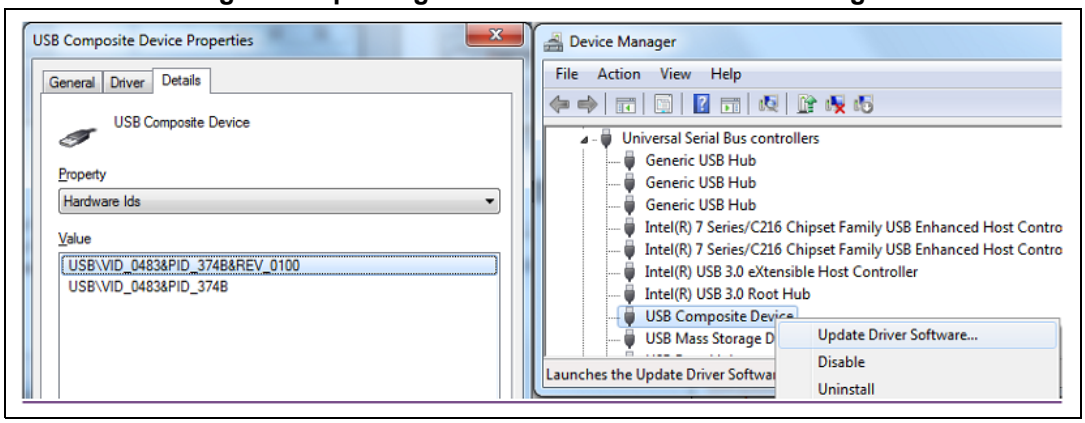
5.2.1 Drivers

ST-LINK/V2-1 requires a dedicated USB driver, which, for Windows® 7, Windows® 8 and Windows® 10, is available from *www.st.com*.

In cases where the STM32F412 Discovery board is connected to the PC before the driver is installed, some STM32F412 Discovery board interfaces might be declared as “Unknown” in the PC device manager. In such cases, the user must install the dedicated driver files and update the driver of the connected device from the device manager, as shown in *Figure 7*.

Note: It is preferable to use the “USB Composite Device” handle for a full recovery.

Figure 7. Updating the list of drivers in device manager



5.2.2 ST-LINK/V2-1 firmware upgrade

ST-LINK/V2-1 embeds a mechanism for in-situ firmware upgrade through the USB port. As firmware may evolve during the lifespan of the ST-LINK/V2-1 product (for example new functionalities, bug fixes, support for new microcontroller families), visiting the *www.st.com* website is recommended before starting to use the STM32F412 Discovery board, then periodically to stay up-to-date with the latest firmware version.

5.3 Power supply

5.3.1 Power supply sources

The 32F412GDISCOVERY Discovery kit is designed to be powered by the following sources:

- 5 V DC from the ST-LINK/V2-1 USB connector CN6 with 500 mA current limitation. Power mechanism of supplying the Discovery kit by the ST-LINK/V2-1 is explained in *Section 5.3.4: Supplying the 32F412GDISCOVERY through the ST-LINK/V2-1 USB port*. A jumper should be placed in location STLK of JP3, connecting pins 3 and 4. The green LED LD6 is lighted on to confirm the presence of +5 V voltage.
- 5 V DC from the user USB FS connector CN3. A jumper should be placed in location USB of JP3, connecting pins 5 and 6. The green LED LD6 is lighted on to confirm the presence of +5 V voltage.
- 6 V to 9 V DC from VIN pin of ARDUINO® Uno V3 compatible connector CN2. The voltage is limited to 9 V to keep the temperature of the regulator U3 within his thermal safe area. A jumper should be placed in location E5V of jumper JP3, connecting pin 1 to pin 2 of JP3. The green LED LD6 is lighted on to confirm the presence of +5 V voltage.
- 5 V DC from +5 V pin of ARDUINO® Uno V3 connector (CN2 pin 5) with limitations. The jumpers on JP3 and CN5 have to be removed, SB21 (NRST) and SB28 (SWO) have to be OFF. In such configuration the ST-LINK/V2-1 MCU is not powered, as consequence the 8 MHz of the ST-LINK/V2-1 cannot be used as external input clock for the STM32.

For details on JP3 jumper setting refer to *Table 4: Power-supply-related jumper settings*.

5.3.2 STM32 power supply options

The 32F412GDISCOVERY offers the possibility to supply the STM32 under 2.0 V or 3.3 V. A jumper must be placed in location 2.0 V of JP5 to supply the STM32 under 2.0 V, then pins 2 and 3 are connected. Similarly the jumper must be placed in 3.3 V to supply the STM32 with 3.3 V, then pins 1 and 2 of JP5 are connected.

For details on JP5 jumper setting refer to *Table 4: Power-supply-related jumper settings*.

5.3.3 Modification of STM32 voltage

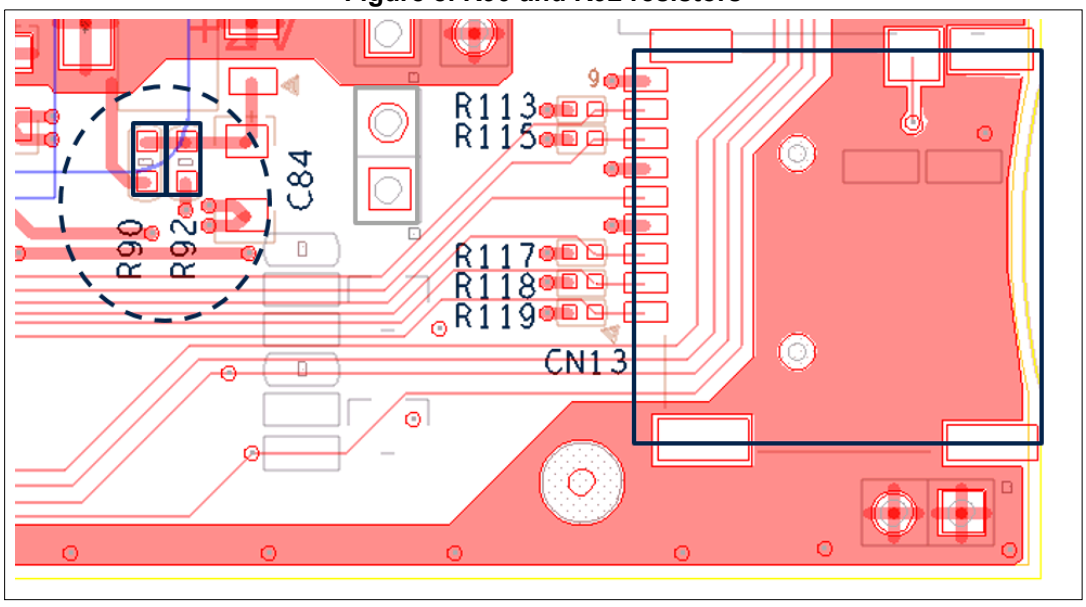
Regulator U16 is dedicated to the 2.0 V supply. The output voltage of U16 is by default 2.0 V but it is adjustable depending on the resistors R90 and R92 which are by default 120 and 68 ohms respectively. The output voltage is calculated as follows:

$$VOUT = VREF \times (1 + (R92) \div (R90))$$

with VREF = 1.25 V.

If necessary, resistors R90 and R92 can be changed to modify the STM32 supply voltage. R90 and R92 are easily located bottom side of the Discovery kit near U16 (see *Figure 5* and *Figure 8*).

Figure 8. R90 and R92 resistors



5.3.4 Supplying the 32F412GDISCOVERY through the ST-LINK/V2-1 USB port

To power the 32F412GDISCOVERY through the ST-LINK/V2-1, the USB host (a PC) gets connected with the 32F412GDISCOVERY Micro-B USB receptacle CN6, via a USB cable. This event starts the USB enumeration procedure. In its initial phase, the current supply capability of the USB port located on the host, is limited to 100 mA. It is enough because only the ST-LINK/V2-1 part of the 32F412GDISCOVERY Discovery kit draws power at that time. If the solder bridge SB18 is OFF (default configuration), the U8 ST890 power switch is set to OFF position, and only the ST-LINK/V2-1 is powered. In the next phase of the enumeration procedure, the host PC informs the ST-LINK/V2-1 facility of its capability to supply up to 500 mA of current. If the answer is positive, the ST-LINK/V2-1 sets the U8 switch to ON position to supply power to the remainder of the 32F412GDISCOVERY Discovery kit. If the PC USB port is not capable of supplying up to 500 mA of current, another power source should be used like VIN pin of connector CN2.

Should a short-circuit occur on the Discovery kit, the power switch protects the USB port of the host against current demand exceeding 600 mA. In such an event, the red LED FAULT LD10 lights on.

The 32F412GDISCOVERY Discovery kit can also be supplied from a USB power source not supporting enumeration, such as a USB charger. In this particular case, SB18 solder bridge must be ON. ST-LINK/V2-1 turns the power switch ON regardless of the enumeration procedure result and passes the power unconditionally to the Discovery kit.

The green LED LD6 turns on whenever the Discovery kit is powered.

5.3.5 Programming/debugging when the power supply is not from ST-LINK/V2-1

Before connecting the USB cable from the ST-LINK/V2-1 USB connector CN6 to the PC, it is mandatory to power the Discovery kit using the user USB FS connector CN3 or the VIN pin of the ARDUINO® Uno V3 connector CN2. Proceeding this way, ensures that the enumeration succeeds thanks to the external power source.

The following power sequence procedure must be respected:

1. Put a jumper in JP3 at location USB to use power from the user USB CN3 or at location E5V to use power from VIN of ARDUINO® Uno V3 connector CN2.
2. Connect the corresponding external power source.
3. Check that the green LED LD6 is turned ON
4. Connect the PC to the ST-LINK/V2-1 USB connector CN6

If this order is not respected, the Discovery kit may be powered by V_{BUS} first from ST-LINK/V2-1, and the following risks may be encountered:

1. If more than 500 mA current is needed by the Discovery kit, the PC may be damaged or current can be limited by PC. As a consequence the Discovery kit is not powered correctly.
2. 500 mA is requested at the enumeration. If the PC cannot provide such current there is a risk that the request is rejected and the enumeration does not succeed.

5.3.6 Measurement of current IDD drawn by the microcontroller

The jumper JP7 should be ON by default to supply the STM32F412ZGT6. To measure the current IDD drawn by the microcontroller STM32F412ZGT6 only, remove the jumper JP7 and replace it by a multimeter (see *Table 4*).

Table 4. Power-supply-related jumper settings

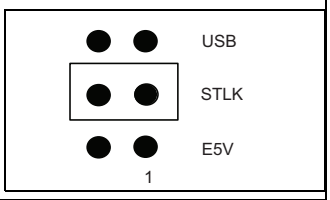
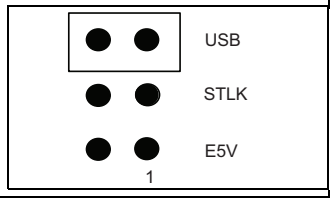
Jumper	Description
JP3	**Default Setting** 32F412GDISCOVERY is supplied through the Micro-B ST-LINK/V2-1 connector CN6. Jumper in STLK place. 
	32F412GDISCOVERY is supplied through CN3 Micro-AB USB FS connector. Jumper in USB place. 

Table 4. Power-supply-related jumper settings (continued)

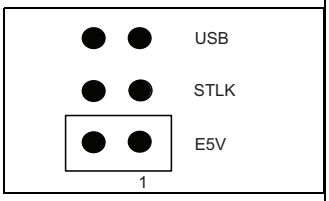
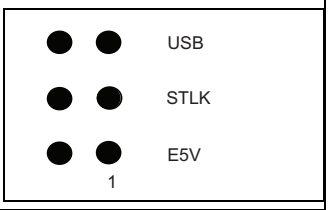
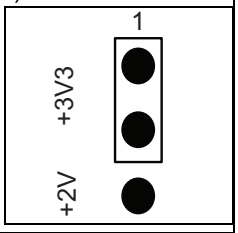
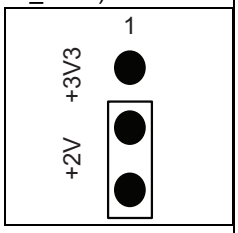
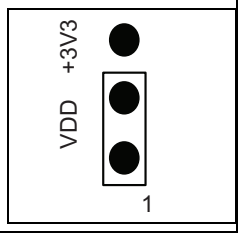
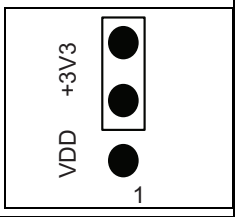
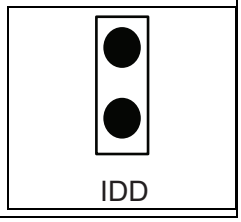
Jumper	Description
JP3	32F412GDISCOVERY is supplied through the VIN pin of the ARDUINO® Uno V3 compatible connector CN2. Jumper in E5V place. 
	32F412GDISCOVERY is supplied by +5 V pin of ARDUINO® Uno V3 compatible connector CN2 (pin 5) or by pins 3 or 4 of the extension connector P2. No jumper in JP3. 
JP5	**Default Setting** STM32F412ZGT6 is supplied with a +3.3 V voltage (VDD_MCU). 
	STM32F412ZGT6 STM32 is supplied with a +2.0 V voltage (VDD_MCU). 
JP6	**Default Setting** VDD_USB power pin of STM32F412ZGT6 is supplied with same voltage VDD_MCU as remainder supply pins of STM32. 

Table 4. Power-supply-related jumper settings (continued)

Jumper	Description
JP6	VDD_USB power pin of STM32F412ZGT6 is supplied with a fix voltage of +3V3 independently of the remainder of supply pins of STM32. 
JP7	**Default Setting** JP7 IDD is ON by default to supply the STM32F412ZGT6 and when removed, it offers the possibility to insert an ammeter to measure the current drawn by the STM32 only. 

5.4 Clock source

5.4.1 HSE clock source

By default the 8 MHz clock source is provided to the STM32F412ZGT6 by the MCO output of the ST-LINK/V2-1 MCU U6. In that case the solder bridge SB20 is ON, resistors R45 and R46 are not soldered, solder bridge SB22 is OFF. The pins PH0 and PH1 are not available for the extension connector P2.

Alternatively, the Discovery kit offers the possibility to use a crystal to provide the 8 MHz HSE clock source of the STM32F412ZGT6 U7. In that case, PH0 and PH1 are used as OSC_IN and OSC_OUT respectively. The solder bridges SB20, SB22, SB16 must be OFF, 0 ohm resistors should be soldered to R45 and R46 and a crystal must be soldered in place X2. Regarding component selection of X2, capacitors C19 and C21 (8.2 pF) are optimized for a 8 MHz crystal and they are OFF. The pins PH0 and PH1 are not available for the extension connector P2.

5.4.2 LSE clock source

By default, the 32.768 kHz crystal X3 is connected to pins PC14-OSC32_IN and PC15-OSC32_OUT of STM32F412ZGT6 for the RTC clock. Solder bridges SB25 and SB23 must be OFF.

If LSE clock is not used, it is possible to use PC14-OSC32_IN and PC15-OSC32_OUT of STM32F412ZGT6 and to access by the extension connector P2. In that case, solder bridges SB25 and SB23 must be ON and resistors R54, R56 removed.

5.5 Reserved use of solder bridges

The following solder bridges must not be changed otherwise the microcontroller STM32F412ZGT6 U7 or other parts of the Discovery kit may be damaged:

- Solder bridges must be left ON: SB34, SB26
- Solder bridges must be left OFF: SB27, SB35

5.6 Reset source

The reset signal of 32F412GDISCOVERY Discovery kit is low active and the reset sources include:

- Reset button B1, providing solder bridge SB1 is ON (default setting)
- Embedded ST-LINK/V2-1, providing solder bridge SB21 is ON (default setting)
- ARDUINO® Uno V3 compatible connector CN2 pin 3
- Extension connector P1 pin 6

5.7 Boot options

After reset, the STM32F412ZGT6 boots from the following embedded memory locations depending on bits BOOT0 and BOOT1 (see *Table 5*):

- User Flash memory (non-protected)
- System Flash memory (protected) for In Circuit Programming
- RAM for debugging

Table 5. Boot options

BOOT0	BOOT1	Boot Memory
0	X	User Flash
1	0	System Flash
1	1	RAM

BOOT0 is set by the input pin BOOT0 of the STM32F412ZGT6. Its level is set by default to 0 by closing the solder bridge SB31 and keeping R69 unfitted. BOOT1 is shared with the GPIO PB2 used as QSPI_CLK and is sampled by the STM32F412ZGT6 only at RESET phase. At start-up, BOOT1 level depends on the resistors R104 and R100. By default R100 and R104 are not fitted on the Discovery kit to avoid any influence on the QSPI_CLK signal using same pin as BOOT1.

The application note "*STM32 microcontroller system memory boot mode*" Application note (AN2606) details the bootloader mechanism and configurations.

Boot-related solder bridge and resistor settings are reported in *Table 6*:

Table 6. Boot-related solder bridge and resistor settings

Resistors, solder bridge		Description
SB31 ON R69 not fitted **BOOT0=0**	R100 and R104 not fitted BOOT1=X	**Default Setting** Microcontroller STM32F412ZGT6 boots from user Flash memory.
SB31 OFF R69 fitted (any value from 0 to 10K) BOOT0=1	R100 not fitted R104 fitted (1) **BOOT1=0**	Microcontroller STM32F412ZGT6 boots from system Flash. R104 is a pull-down resistor on PB2 shared between BOOT1 and QSPI_CLK.
	R100 fitted(1) R104 not fitted **BOOT1=1**	Microcontroller STM32F412ZGT6 from RAM. R100 is a pull-up resistor on PB2 shared between BOOT1 and QSPI_CLK.

1. To keep Quad-SPI functionality after boot-up phase, the user should select a resistor value of R100 or R104 insuring a weak pull-down or weak pull-up respectively.

5.8 Audio codec

An audio codec U15 connected to the I2S3 interface of the microcontroller STM32F412ZGT6 offers the possibility to connect a stereo headphone or headset with a mono-analog microphone. A loudspeaker can be connected to the extension connector.

The digital audio output from the microcontroller is handled by the port of the microcontroller PB5 called CODEC_I2S3_SD while the other direction is handled by port PB4 called CODEC_I2S3ext_SD.

The I^2C-bus address of the codec is 0b0011010.

5.8.1 Stereo headset and headphone jack

A stereo headphone or a stereo headset with analog microphone can be plugged into the 3.5 mm standard jack socket CN9.

The stereo digital audio streamed from pin PB5 of the microcontroller STM32F412ZGT6 is transformed in a stereo analog output by the codec and is delivered to the headphone or headset through the pins 6 and 4 of the jack socket CN9.

If a headset is plugged into CN9, the bias of the microphone is driven by the output MICBIAS1 of the codec and the analog audio enters into the codec by the pin IN1LN.

The corresponding digital audio output from the codec is connected to the microcontroller STM32F412ZGT6 by the port PB4.

5.8.2 Loudspeaker output

The 32F412GDISCOVERY Discovery kit can deliver a monophonic audio to a loudspeaker connected to pins 36 and 38 of the extension connector P2. It is recommended to use the codec loudspeaker outputs SPKOUTRN and SPKOUTRP in linear mode called "class AB". This mode is compatible with 4-ohm to 8-ohm impedance loudspeakers. Use of the switching mode called "class D" requires to use an appropriate filter to maximize rejection of unwanted frequencies and efficiency. To select the mode "class AB" of the codec, set to 1 the bit 8 of the register 0x23.

5.9 Digital microphones

Two digital microphones U4 and U5 are available on the 32F412GDISCOVERY Discovery kit. The two microphones are located at a distance of 21 mm each other. The microphones are connected to the DFSDM of the STM32 by the port PC2 generating the clock and by the port PB1 collecting the PDM interleaved data.

5.10 USB OTG FS

A USB OTG full-speed communication is available at USB Micro-AB receptacle connector CN3.

Limitations: the USB-related operating supply voltage of STM32F412ZGT6 (VDD_USB line) must be within the range from 3.0 V to 3.6 V. Therefore, in case the STM32F412ZGT6 is supplied with 2 V by JP5 set in +2 V position, the USB of the STM32 works only if the VDD_USB power pin is supplied independently by +3.3 V. This is done by closing pins 2 and 3 of the jumper JP6 (refer to *Table 4: Power-supply-related jumper settings*).

5.10.1 32F412GDISCOVERY is USB device

When the 32F412GDISCOVERY is USB device, the Discovery kit is powered by the 5 V of the CN3 USB OTG FS Micro-AB connector. In this case a jumper must be put in USB location of jumper JP3 and the green LEDs LD7 V_{BUS} and LD6 PWR light on to confirm the 5 V presence.

5.10.2 32F412GDISCOVERY is USB host

When the 32F412GDISCOVERY is USB host it supplies the 5 V for the USB peripheral using one of the following sources:

- ST-LINK/V2-1 USB Micro-B connector CN6, putting a jumper in STLK location of JP3
- An external +5 V source connected to pins 3 or 4 of the extension connector P2, with no jumper in JP3.
- An external +5 V source connected to 5 V pin of ARDUINO® Uno V3 connector CN2, with no jumper in JP3.
- An external source between +7 to +11 V connected to VIN pin of ARDUINO® Uno V3 connector CN2, putting a jumper in E5V location of JP3.

The green LED LD6 is lighted to confirm the presence of the +5 V source.

The power switch is controlled by the port PG8 of STM32 to deliver the 5 V power to the USB device connected to the USB connector CN3. It is recommended to use PG8 in open-drain mode. When PG8 is closed to ground, the power switch is closed, and the green LED LD7 confirms the 5 V to the USB Device.

The red LED LD8 FAULT is lit when an overcurrent occurs.

For more details refer to *Section 5.3: Power supply*.

5.11 microSD™ card

microSD™ cards with a capacity of 4 Gbytes or more can be inserted in the receptacle CN13. The four bits of the SDIO interface including CLK and CMD signals of the STM32F412ZGT6 are used to communicate with the microSD™ card. The card detection is read by the GPIO PD3: when a microSD™ card is inserted, the logic level is 0, otherwise it is 1.

Note that port PC9 used as uSD_D1 can be routed also to the pin 46 of the extension connector P2, by closing the solder bridge SB43 for other usage like the alternate function MCO2. Therefore the use of the microSD™ card is exclusive with MCO2 output.

Limitations: The microSD™ card is not working when the STM32 is supplied with 2 V.

5.12 I²C extension connector

The I2C2 bus is available on the I²C extension connector CN10. I2C2-SDA (port PB9) is available on pin 1 and I2C2-SCL is available on pin 3. Pins 5 and 7 of CN10 are the VDD and GND supplying the microcontroller. I2C2 voltage levels follows also VDD.

5.13 Quad-SPI NOR Flash memory

A 128-Mbit Quad-SPI NOR Flash memory is connected to the Quad-SPI interface of the STM32F412ZGT6 microcontroller.

Note that QSPI_CLK (port PB2) is sampled by the STM32F412ZGT6 at start-up as the BOOT1 bit. If necessary, the user can set the BOOT1 state by fitting one of the resistors R100 or R104. By default R100 and R104 are not fitted. Refer to *Section 5.7: Boot options* for more details.

Limitations: The Quad-SPI memory is not working when the STM32 is supplied with 2 V.

5.14 Virtual COM port

The serial interface USART2 is directly available through a USB Virtual COM port of the ST-LINK/V2-1. The USB connector is CN6.

5.15 ARDUINO® Uno V3 connectors

CN1, CN2, CN11 and CN12 are female connectors compatible with ARDUINO® Uno V3 standard. Most shields designed for ARDUINO® Uno V3 can fit to the 32F412GDISCOVERY Discovery kit.

Caution: The I/Os of STM32 microcontroller are 3.3 V compatible instead of 5 V for ARDUINO® Uno V3.

Table 7. ARDUINO® Uno V3 compatible connectors

Left connectors					Right connectors				
CN No.	**Pin No.**	**Pin name**	**STM32 pin**	**Function**	**Function**	**STM32 pin**	**Pin name**	**Pin No.**	**CN No.**
-	-	-	-	-	I2C2_SCL	PB10	D15	10	CN12 Digital
-					I2C2_SDA	PB9	D14	9	
-	-	-	-	-	AVDD	-	AVDD	8	
-	-	-	-	-	Ground	-	GND	7	
CN2 Power	1	-	-	Not connected	SPI1_SCK	PA5	D13	6	
	2	IOREF	-	3.3 V	SPI1_MISO	PA6	D12	5	
	3	NRST	NRST	Reset	TIM3_CH2, SPI1_MOSI	PA7	D11	4	

Table 7. ARDUINO® Uno V3 compatible connectors (continued)

Left connectors					Right connectors				
CN No.	Pin No.	Pin name	STM32 pin	Function	Function	STM32 pin	Pin name	Pin No.	CN No.
CN2 Power	4	+3V3	-	+3.3 V input/output (see *Note:1*)	TIM2_CH1, SPI1_NSS	PA15	D10	3	CN12 Digital
	5	+5 V	-	+5 V input/output (see *Note:4*)	TIM4_CH3	PB8	D9	2	
	6	GND	-	Ground	-	PG10	D8	1	
	7	GND	-	Ground	-	-	-	-	
	8	VIN	-	+6 V to +9 V power input (see *Note:2*)	-	PG11	D7	8	CN11 Digital
-	-	-	-	-	TIM5_CH1	PF3	D6	7	
CN1 Analog	1	A0	PA1	ADC1_IN1	TIM5_CH4	PF10	D5	6	
	2	A1	PC1	ADC1_IN11	-	PG12	D4	5	
	3	A2	PC3	ADC1_IN13	TIM5_CH2	PF4	D3	4	
	4	A3	PC4	ADC1_IN14	-	PG13	D2	3	
	5	A4	PC5 or PB9 (see *Note:3*)	ADC1_IN15 or I2C2_SDA (see *Note:3*)	USART6_TX	PG14	D1	2	
	6	A5	PB0 or PB10 (see *Note:3*)	ADC1_IN8 or I2C2_SCL (see *Note:3*)	USART6_RX	PG9	D0	1	

Note:1 *Important, before using pin 4 of CN2 as +3.3 V input, insure that the solder bridge SB4 is removed. Otherwise the 32F412GDISCOVERY Discovery kit could be damaged by the overcurrent.*

Note:2 *The external voltage applied to pin VIN should be in the range 6 to 9 V at 25°C ambient temperature. If a higher voltage is applied, the regulator U3 may overheat and could be damaged.*

Note:3 *By default pin 5 and pin 6 of connector CN1 are connected respectively to the port PC5 (ADC1_IN15) and BP0 (ADC1_IN8) of the STM32. They are enabled by the default configuration of the solder bridges: SB8 and SB6 ON, SB7 and SB5 OFF. In case it is necessary to have an I^2C interface instead of ADC inputs on pins 5 and 6 of CN1, have SB8 and SB6 OFF, and SB7 and SB5 ON.*

Note:4 *Important, before using pin 4 of CN2 as +5 V input, insure the jumpers and solder bridges are configured according to 5 V DC power input defined in Section 5.3.1: Power supply sources. Otherwise the 32F412GDISCOVERY Discovery kit could be damaged by the overcurrent.*

5.16 Extension connectors P1 and P2

The extension connectors consist in male pin headers P1 and P2 (not soldered by default). They provide access to the following IPs of the STM32F412ZGT6:

- SPI
- I^2C with SMBA and FM+ (1 MHz speed)
- Full USART (Rx, Tx, RTS, CTS)
- CAN
- ADC inputs
- TIMERs channels
- I^2S full duplex with SD and extSD alternate functions.
- DFSDM input for stereo PDM digital microphones

Most of the ports connected to the extension connectors P1 and P2 are the same for the 32F401CDISCOVERY and 32F411EDISCOVERY Discovery kits, to maximize the compatibility with the previous designs. In *Table 8*, *Table 9* and in the 32F412GDISCOVERY schematics (see on *www.st.com*), the pin numbers corresponding to these ports, are annotated with the star symbol: “*”.

In *Table 8*, *Table 9* and in the 32F412GDISCOVERY schematics (see on *www.st.com*) the pins belonging to the extension connectors P1 and P2 annotated with a letter, are shared with a peripheral of the 32F412GDISCOVERY (for example, S means that the port PC9 corresponding to pin 46 is also used for microSD™, see *Table 9*).

Table 8. Pin assignment for the extension connector P1

P1 odd pins			P1 even pins		
Pin No.	**Name**	**Note**	**Pin No.**	**Name**	**Note**
1	GND	*	2	GND	*
3	VDD_MCU	*	4	VDD_MCU	*
5	GND	*	6	NRST	*
7	PC1	*A	8	PC0	*
9	PC3	*A	10	PC2	*D
11	PA1	*A	12	-	-
13	PA3	*V	14	PA2	*V
15	PA5	*A	16	PA4	*C
17	PA7	*A	18	PA6	*A
19	PC5	*A	20	PC4	*A
21	PB1	*D	22	PB0	*A
23	GND	*	24	PF2	-
25	PF3	A	26	-	-
27	PF10	A	28	PF11	-
29	-	-	30	PF13	-
31	PG2	C	32	-	-

Table 8. Pin assignment for the extension connector P1 (continued)

P1 odd pins			P1 even pins		
Pin No.	**Name**	**Note**	**Pin No.**	**Name**	**Note**
33	PG9	A	34	PB10	*A
35	PB11	*D	36	PB12	*C
37	PB13	*	38	PB14	*
39	PB15	*	40	-	-
41	-	-	42	-	-
43	-	-	44	PD12	*
45	PD13	*	46	-	-
47	-	-	48	-	-
49	GND	*	50	GND	*

Table 9. Pin assignment for the extension connector P2

P2 odd pins			P2 even pins		
Pin No.	**Name**	**Note**	**Pin No.**	**Name**	**Note**
1	GND	*	2	GND	*
3	+5 V	*	4	+5 V	*
5	+3V3	*	6	+3V3	*
7	PH0	*	8	PH1	*
9	PC14	*	10	PC15	*
11	PE6	*	12	PC13	*
13	PE4	*	14	PE5	*
15	PE2	*	16	PE3	*
17	PE0	*	18	PE1	*
19	PB8	*A	20	PB9	*A
21	BOOT0	*	22	VDD_MCU	*
23	PB6	*TC	24	PB7	*TC
25	PB4	*C	26	PB5	*C
27	-	-	28	PB3	*
29	-	-	30	PD6	*
31	PG10	A	32	PG11	A
33	PG12	A	34	PG13	A
35	PG14	A	36	SPKOUTRN	-
37	-	-	38	SPKOUTRP	-
39	PA14	*	40	PA15	*A

Table 9. Pin assignment for the extension connector P2 (continued)

P2 odd pins			P2 even pins		
Pin No.	**Name**	**Note**	**Pin No.**	**Name**	**Note**
41	PA10	*	42	PA13	*
43	PA8	*D	44	-	-
45	-	-	46	PC9	*S
47	PC6	*	48	PC7	*C
49	GND	*	50	GND	*

Note:1 The star symbol "" means pin compatible with the 32F401CDISCOVERY and 32F411EDISCOVERY Discovery kits.*

Note:2 Meaning of the letters: "A": shared with ARDUINO® Uno V3 connectors; C: shared with codec; D: shared with digital microphones; V: shared with Virtual COM port; T: shared with capacitive touch panel; S: shared with microSD™.

5.17 LCD display, backlight and touch panel

5.17.1 LCD display

The display is a 1.54-inch, 240x240 pixels TFT color LCD with capacitive touch panel. It displays up to 262 K colors. The LCD parallel interface is connected to the FMC of the STM32F412ZGT6 by the connector CN15 (see *Table 10*).

To enable the data bus of the LCD display in 16-bit mode, the solder bridges SB41 and SB42 are OFF and ON respectively by default. In this way the IM signal of the LCD is set to high.To use the LCD in 8-bit mode, SB41 must be ON and SB42 OFF.

The selection of the LCD is performed by FMC_NE1 (PD7), write-enable signal is FMC_NWE (PD5) and read-enable is FMC_NOE (PD4). The address bit A0 of the FMC (Flexible Static Memory Controller) is used to select data/command access to the LCD.

The port PG4 should be used as an input of the microcontroller connected to the LCD signal TE (Tearing Effect). To avoid visible artifacts on the display, TE signal is used to synchronize the refresh of the LCD memory done by the microcontroller with the LCD scan.

The port PD11 of the STM32F412ZGT6 controls the reset of the LCD display LCD_RESET.

Table 10. Pin assignment for connector CN15

CN15 pin	Signal name	Description	STM32 pin involved
1	GND	Ground	GND
2	LCD_TE	Tearing Effect output pin to send an interrupt to STM32	PG4
3	D15	Data connected to FMC	PD10
4	D14	Data connected to FMC	PD9
5	D13	Data connected to FMC	PD8

Table 10. Pin assignment for connector CN15 (continued)

CN15 pin	Signal name	Description	STM32 pin involved
6	D12	Data connected to FMC	PE15
7	D11	Data connected to FMC	PE14
8	D10	Data connected to FMC	PE13
9	D9	Data connected to FMC	PE12
10	D8	Data connected to FMC	PE11
11	D7	Data connected to FMC	PE10
12	D6	Data connected to FMC	PE9
13	D5	Data connected to FMC	PE8
14	D4	Data connected to FMC	PE7
15	D3	Data connected to FMC	PD1
16	D2	Data connected to FMC	PD0
17	D1	Data connected to FMC	PD15
18	D0	Data connected to FMC	PD14
19	/RD	Read of LCD connected to FMC_NOE	PD4
20	/WR	Write of LCD connected to FMC_NWE	PD5
21	RS	Data/Command select connected to A0	PF0
22	/CS	Chip Select of LCD connected to FMC_NE1	PD7
23	RESET	LCD RESET	PD11
24	IM	8-bit (low)/16-bit (high) mode selection pin	n/a
25	IOVCC	LCD I/Os power supply connected to VDD	n/a
26	VCI	Power supply connected to +3.3 V	n/a
27	GND	Ground	GND
28	LEDA	Anode of backlight LED	n/a
29	LEDK	Cathode of backlight LED	n/a

5.17.2 LCD signal access (CN7)

CN7 is the footprint of a dual-row, through-hole, 26-pin header with 2.54 mm pitch. The header CN7 gives an easy access to the FMC signals of the LCD (see *Table 11*).

Table 11. Pin assignment for connector CN7

CN7 odd pins	Signal name	CN7 even pins	Signal name
1	A0	2	LCD_BLCTRL
3	FMC_NWE	4	GND
5	FMC_NE1	6	FMC_NOE
7	D0	8	D1

Table 11. Pin assignment for connector CN7 (continued)

CN7 odd pins	Signal name	CN7 even pins	Signal name
9	D2	10	+3.3 V
11	D3	12	VDD
13	LCD_TE	14	LCD_RESET
15	D4	16	D5
17	D6	18	D7
19	D8	20	D9
21	D10	22	D11
23	D12	24	D13
25	D14	26	D15

5.17.3 Backlight

LEDK and LEDA signals of the LCD module are the cathode and the anode respectively of the backlight LEDs.

The backlight requires a current source of typically 15 mA capable to deliver a voltage up to 10 V. This function is handled by the backlight-driver circuit that is a switching-mode-boost converter, supplied by the +5 V rail of the Discovery kit.

The high level on the signal LCD_BLCTRL (PF5) lights the backlight on. It is possible to dim the backlight intensity by applying a low-frequency PWM signal to LCD_BLCTRL (1 to 10 kHz).

5.17.4 Touch panel

The touch panel is a capacitive touch panel using an I^2C interface. The 10-pin connector CN14 of the touch panel is located at the bottom side of the Discovery kit (see *Figure 5: 32F412GDISCOVERY bottom layout*). The I^2C SDA line is connected to PB7 and the I^2C SCL line is connected to PB6. An interrupt output CTP_INT is connected to port PG5 to be used as an interruption input of the microcontroller. Port PF12 is the reset of the capacitive touch panel.

5.18 Joystick and LEDs

The blue button B2 is a 4-direction joystick with a selection mode when pressed in the center. The logic state is high when one of the five-position switches (Left, Right, Up, Down, Selection) is pressed. The center position is connected to a wake-up pin of the microcontroller PA0. This offers the possibility to wake-up the microcontroller by pressing the center of the joystick.

Four LEDs located near the ARDUINO® Uno V3 connectors CN1 and CN2 are available for the user (refer to the *Figure 4: 32F412GDISCOVERY top layout*). From left to right the user finds LD1, LD2, LD3 and LD4 with their colors green, orange, red and blue respectively. To light a LED a low-logic state 0 must be written in the corresponding GPIO.

Table 12 gives the assignment of control ports to the LED indicators.

Table 12. Port assignment to the LED indicators

LED	Controlled by STM32 port	Color
LD1	PE0	Green
LD2	PE1	Orange
LD3	PE2	Red
LD4	PE3	Blue

6 Connectors

6.1 I²C extension connector CN10

Figure 9. I²C extension connector CN10 (front view)

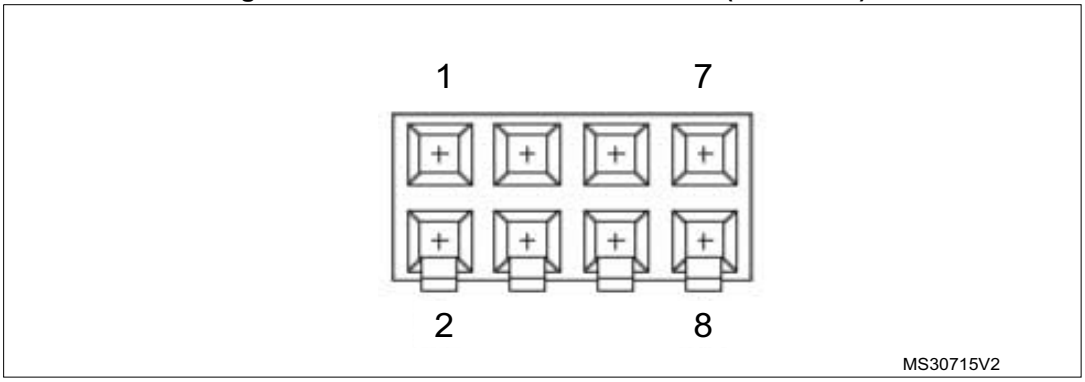


Table 13. I²C extension connector pinout CN10

Pin number	Description	Pin number	Description
1	I2C1_SDA (PB9)	5	VDD
2	NC	6	NC
3	I2C1_SCL (PB10)	7	GND
4	EXT_RESET (PF11)	8	NC

6.2 USB OTG FS Micro-AB connector CN3

Figure 10. USB OTG FS Micro-AB connector CN3 (front view)

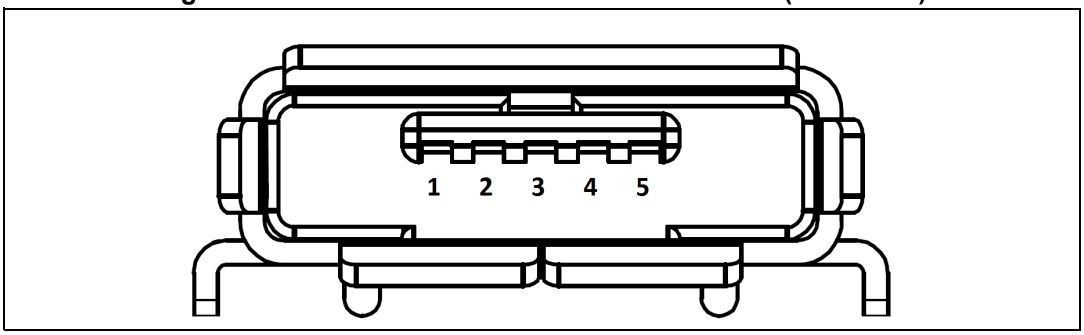


Table 14. USB OTG FS Micro-AB connector CN3

Pin number	Description	Pin number	Description
1	VBUS (PA9)	4	ID (PA10)
2	DM (PA11)	5	GND
3	DP (PA12)	-	-

6.3 microSD™ connector CN13

Figure 11. microSD™ connector CN13 (front view)

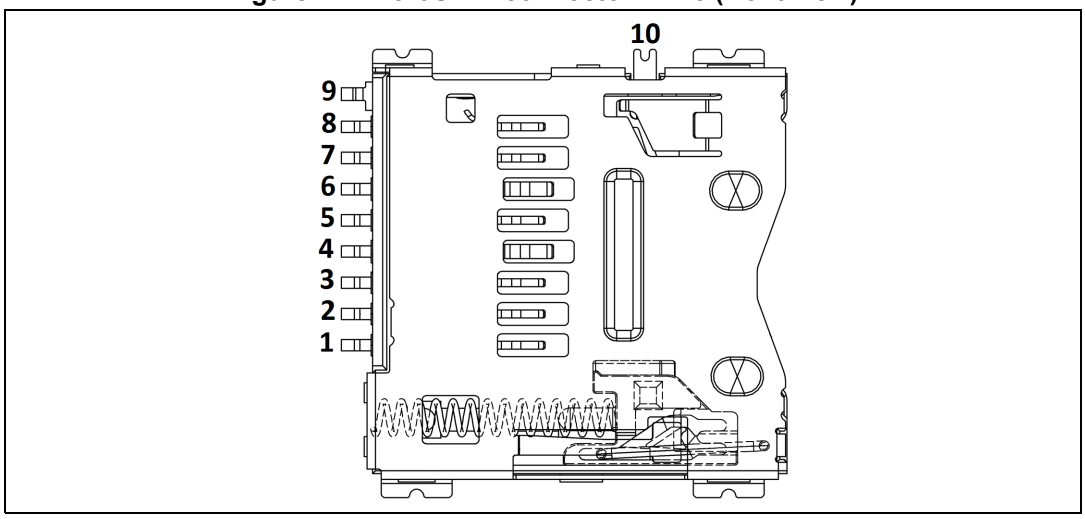


Table 15. microSD™ connector CN13

Pin number	Description	Pin number	Description
1	SDIO_D2 (PC10)	6	GND
2	SDIO_D3 (PC11)	7	SDIO_D0 (PC8)
3	SDIO_CMD (PD2)	8	SDIO_D1 (PC9)
4	+3.3 V	9	GND
5	SDIO_CLK (PC12)	10	MicroSDcard_detect (PD3)

6.4 ST-LINK/V2-1 USB Micro-B connector CN6

Figure 12. USB Micro-B connector CN6 (front view)

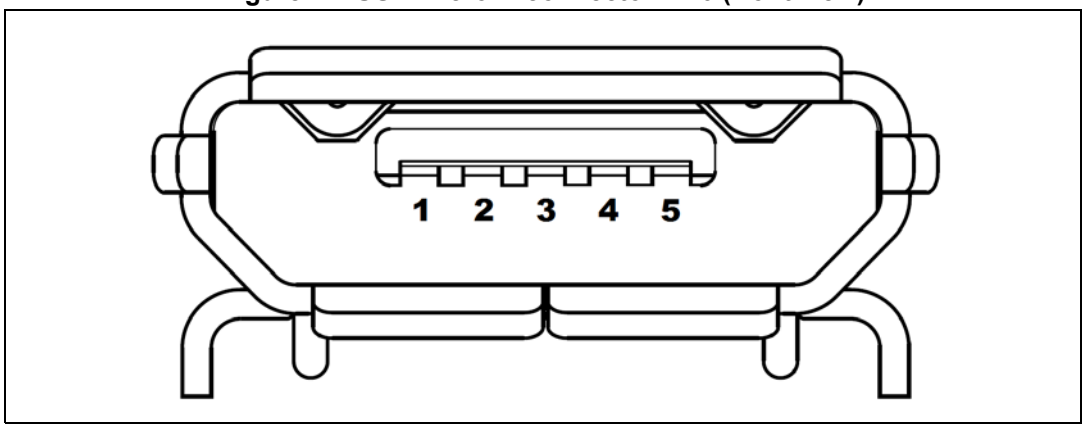


Table 16. USB Micro-B connector CN6

Pin number	Description	Pin number	Description
1	VBUS (power)	4	GND
2	DM	5,6	Shield
3	DP	-	-

7 32F412GDISCOVERY Discovery kit information

7.1 Product marking

The stickers located on the top or bottom side of the PCB provide product information:

- Product order code and product identification for the first sticker
- Board reference with revision, and serial number for the second sticker

On the first sticker, the first line provides the product order code, and the second line the product identification.

On the second sticker, the first line has the following format: “MBxxxx-Variant-yzz”, where “MBxxxx” is the board reference, “Variant” (optional) identifies the mounting variant when several exist, "y" is the PCB revision and "zz" is the assembly revision, for example B01. The second line shows the board serial number used for traceability.

Evaluation tools marked as “ES” or “E” are not yet qualified and therefore 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 designs or in production.

“E” or “ES” marking examples of location:

- On the targeted STM32 that is soldered on the board (For an illustration of STM32 marking, refer to the STM32 datasheet “Package information” paragraph at the *www.st.com* website).
- Next to the evaluation tool ordering part number that is stuck or silk-screen printed on the board.

Some boards feature a specific STM32 device version, which allows the operation of any bundled commercial stack/library available. This STM32 device shows a "U" marking option at the end of the standard part number and is not available for sales.

In order to use the same commercial stack in his application, a developer may need to purchase a part number specific to this stack/library. The price of those part numbers includes the stack/library royalties.

7.2 32F412GDISCOVERY product history

7.2.1 Product identification 32F412GDISCO/

This product identification is based on the mother board MB1209-F412ZGT6-D02

It embeds the STM32F412ZGT6 microcontroller with silicon revision code "C". The limitations of this silicon revision are detailed in the errata sheet *STM32F412xE/xG device errata* (ES0305).

7.2.2 Product identification DK32F412G$AU1

This product identification is based on the mother board MB1209-F412ZGT6-D04.

It embeds the STM32F412ZGT6 microcontroller with silicon revision code "C" or “1”. The limitations of these silicon revisions are detailed in the errata sheet *STM32F412xE/xG device errata* (ES0305).

7.3 Board revision history

7.3.1 MB1209 revision D-02

The revision D-02 of the MB1209 board is the initial release.

7.3.2 MB1209 revision D-04

The revision D-04 of the MB1209 board corresponds to:

- ZZ1 (touch panel) replaced with FRIDA FRD154B2902-D-CTQ with impact on firmware
- Several part references updated due to obsolescence (such as MEMS microphones or others, see bill of materials for details)

7.4 Board known limitations

7.4.1 MB1209 revision D-02

None.

7.4.2 MB1209 revision D-04

No demonstration software is provided from this revision.

8 Federal Communications Commission (FCC) and ISED Canada Compliance Statements

8.1 FCC Compliance Statement

8.1.1 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.

8.1.2 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.

8.1.3 Part 15.105

This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.

Responsible party (in the USA)

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8.2 ISED Compliance Statement

Compliance Statement

ISED Canada ICES-003 Compliance Label: *CAN ICES-3 (A) / NMB-3 (A)*.

Déclaration de conformité

Étiquette de conformité à la NMB-003 d'ISDE Canada : *CAN ICES-3 (A) / NMB-3 (A)*.

9 CE conformity

EN 55032 / CISPR32 (2012) Class A product

Warning: This device is compliant with Class A of EN55032 / CISPR32. In a residential environment, this equipment may cause radio interference.

Avertissement : cet équipement est conforme à la Classe A de la EN55032 / CISPR 32. Dans un environnement résidentiel, cet équipement peut créer des interférences radio.

Revision history

Table 17. Document revision history

Date	Revision	Changes
28-Jul-2016	1	Initial version.
08-Nov-2016	2	Added sections: *Section Appendix B: Federal Communications Commission (FCC) and Industry Canada (IC) Compliance Statements*, *Section Appendix C: CISPR32*.
27-Oct-2021	3	Removed *Schematics*, *Technology partner* and *Demonstration software*. Added *Chapter 7: 32F412GDISCOVERY Discovery kit information*. Updated *Figure 3: Hardware block diagram*, *Figure 4: 32F412GDISCOVERY top layout*, *Figure 5: 32F412GDISCOVERY bottom layout*, *Section 5.2: Embedded ST-LINK/V2-1*, *Section 5.8: Audio codec*, *Chapter 8: Federal Communications Commission (FCC) and ISED Canada Compliance Statements* and *Chapter 9: CE conformity*. Revised the beginning of the document: – Updated *Introduction*, *Chapter 1: Features*, *Chapter 2: Ordering information*, *Section 3.1: System requirements* and *Section 3.2: Development toolchains* – Added *Section 2.1: Codification* and *Chapter 4: Conventions*