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## Getting started with STM32F4xxxx MCU hardware development

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### Introduction

This application note is intended for system designers who require an overview of the hardware implementation of the development board, with focus on features like

- power supply
- package selection
- clock management
- reset control
- boot mode settings
- debug management.

This document shows how to use the high-density high-performance microcontrollers listed in [Table 1](#), and describes the minimum hardware resources required to develop an application based on those products.

Detailed reference design schematics are also contained in this document, together with descriptions of the main components, interfaces and modes.

**Table 1. Applicable products**

Type	Part numbers and Product lines
Microcontrollers	STM32F401xB / STM32F401xC
	STM32F401xD / STM32F401xE
	STM32F405/415 line
	STM32F407xE / <b>STM32F407xG</b>
	STM32F411xC / STM32F411xE
	STM32F417xE / STM32F417xG
	STM32F427/437 line
	STM32F429xE / STM32F429xG / STM32F429xI
	STM32F439xG / STM32F439xI
	STM32F446xC / STM32F446xE / STM32F446xL
	STM32F469/479 line

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# 1 Reference documents

The following documents are available on [www.st.com](http://www.st.com).

**Table 2. Referenced documents**

Reference	Title
AN2867	Oscillator design guide for ST microcontrollers
AN2606	STM32 microcontroller system memory boot mode
AN3364	Migration and compatibility guidelines for STM32 microcontroller applications

## 2 Power supplies

### 2.1 Introduction

The operating voltage supply ( $V_{DD}$ ) range is 1.8 V to 3.6 V, which can be reduced down to 1.7 V with some restrictions, as detailed in the product datasheets. An embedded regulator is used to supply the internal 1.2 V digital power.

The real-time clock (RTC) and backup registers can be powered from the  $V_{BAT}$  voltage when the main  $V_{DD}$  supply is powered off.

#### 2.1.1 Independent A/D converter supply and reference voltage

To improve conversion accuracy, the ADC has an independent power supply that can be filtered separately, and shielded from noise on the PCB.

- the ADC voltage supply input is available on a separate  $V_{DDA}$  pin
- an isolated supply ground connection is provided on the  $V_{SSA}$  pin  
In all cases, the  $V_{SSA}$  pin should be externally connected to same supply ground than  $V_{SS}$

##### On packages with 100-pins and above

To ensure a better accuracy on low-voltage inputs, the user can connect a separate external reference voltage ADC input on  $V_{REF+}$ . The voltage on  $V_{REF+}$  may range from ( $V_{DDA} - 1.2$  V) to  $V_{DDA}$  with a minimum of 1.7 V.

When available (depending on package),  $V_{REF-}$  must be externally tied to  $V_{SSA}$ .

##### On packages with less than 100-pins

The  $V_{REF+}$  and  $V_{REF-}$  pins are not available, they are internally connected to the ADC voltage supply ( $V_{DDA}$ ) and ground ( $V_{SSA}$ ).

#### 2.1.2 Battery backup

To retain the content of the Backup registers when  $V_{DD}$  is turned off, the  $V_{BAT}$  pin can be connected to an optional standby voltage supplied by a battery or another source.

The  $V_{BAT}$  pin also powers the RTC unit, allowing the RTC to operate even when the main digital supply ( $V_{DD}$ ) is turned off. The switch to the  $V_{BAT}$  supply is controlled by the power down reset (PDR) circuitry embedded in the Reset block.

If no external battery is used in the application, it is highly recommended to connect  $V_{BAT}$  externally to  $V_{DD}$ .

### 2.1.3 Voltage regulator

The voltage regulator is always enabled after reset. It works in three different modes depending on the application modes.

- in Run mode, the regulator supplies full power to the 1.2 V domain (core, memories and digital peripherals)
- in Stop mode, the regulator supplies low power to the 1.2 V domain, preserving the contents of the registers and SRAM
- in Standby mode, the regulator is powered down. The contents of the registers and SRAM are lost except for those concerned with the Standby circuitry and the Backup domain.

*Note:* Depending on the selected package, there are specific pins that should be connected either to  $V_{SS}$  or  $V_{DD}$  to activate or deactivate the voltage regulator. Refer to section "Voltage regulator" in datasheet for details.

## 2.2 Power supply schemes

The circuit is powered by a stabilized power supply,  $V_{DD}$ .

**Caution:** The  $V_{DD}$  voltage range is 1.8 V to 3.6 V (down to 1.7 V with some restrictions, see relative Datasheet for details).

Special precautions must be taken when PDR is ON and  $V_{DD} = 1.8$  V:

1. Inductor bead between LDO regulator and  $V_{DD}$  is forbidden
2. In Rush current on voltage regulator power-on (POR or wakeup from Standby)
  - The  $V_{DD}$  pins must be connected to  $V_{DD}$  with external decoupling capacitors: one single Tantalum or Ceramic capacitor (min. 4.7  $\mu$ F typ. 10  $\mu$ F) for the package + one 100 nF Ceramic capacitor for each  $V_{DD}$  pin. *Where do we put the 10uF capa for the package ?*
  - The  $V_{BAT}$  pin can be connected to the external battery (1.65 V <  $V_{BAT}$  < 3.6 V). If no external battery is used, it is recommended to connect this pin to  $V_{DD}$  with a 100 nF external ceramic decoupling capacitor.
  - The  $V_{DDA}$  pin must be connected to two external decoupling capacitors (100 nF Ceramic + 1  $\mu$ F Tantalum or Ceramic).
  - *Vref needed ?* The  $V_{REF+}$  pin can be connected to the  $V_{DDA}$  external power supply. If a separate, external reference voltage is applied on  $V_{REF+}$ , a 100 nF and a 1  $\mu$ F capacitors must be connected on this pin. In all cases,  $V_{REF+}$  must be kept between ( $V_{DDA}$ -1.2 V) and  $V_{DDA}$  with minimum of 1.7 V must be kept between 1.65 V and  $V_{DDA}$ .
  - $V_{DDUSB}$  can be connected either to  $V_{DD}$  or an external independent power supply (3.0 to 3.6V) for USB transceivers.

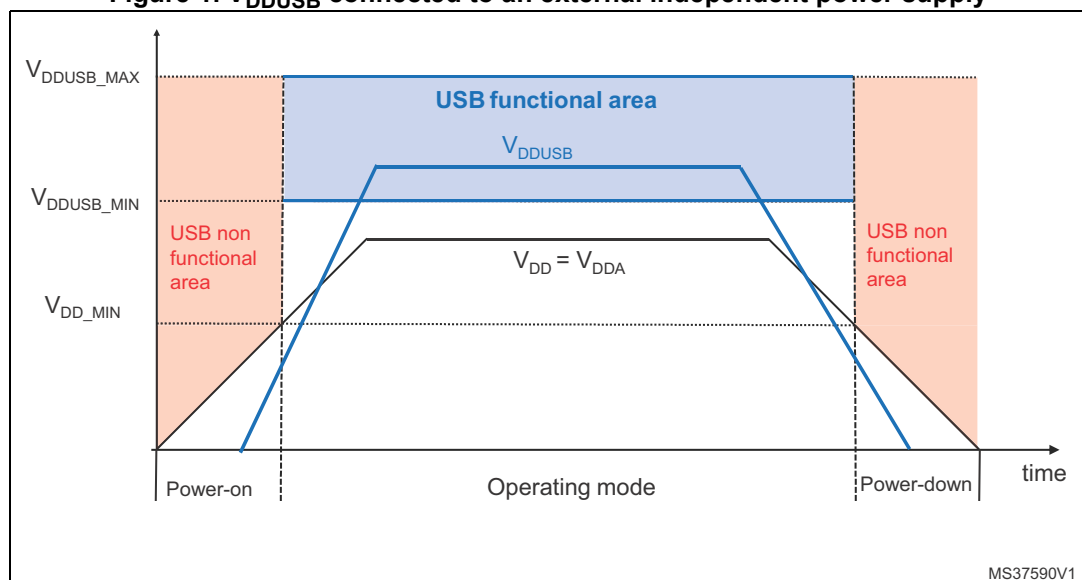
For example, when device is powered at 1.8V, an independent power supply 3.3V can be connected to  $V_{DDUSB}$ . When the  $V_{DDUSB}$  is connected to a separated power supply, it is independent from  $V_{DD}$  or  $V_{DDA}$  but it must be the last supply to be provided and the first to disappear.



The following conditions must be respected:

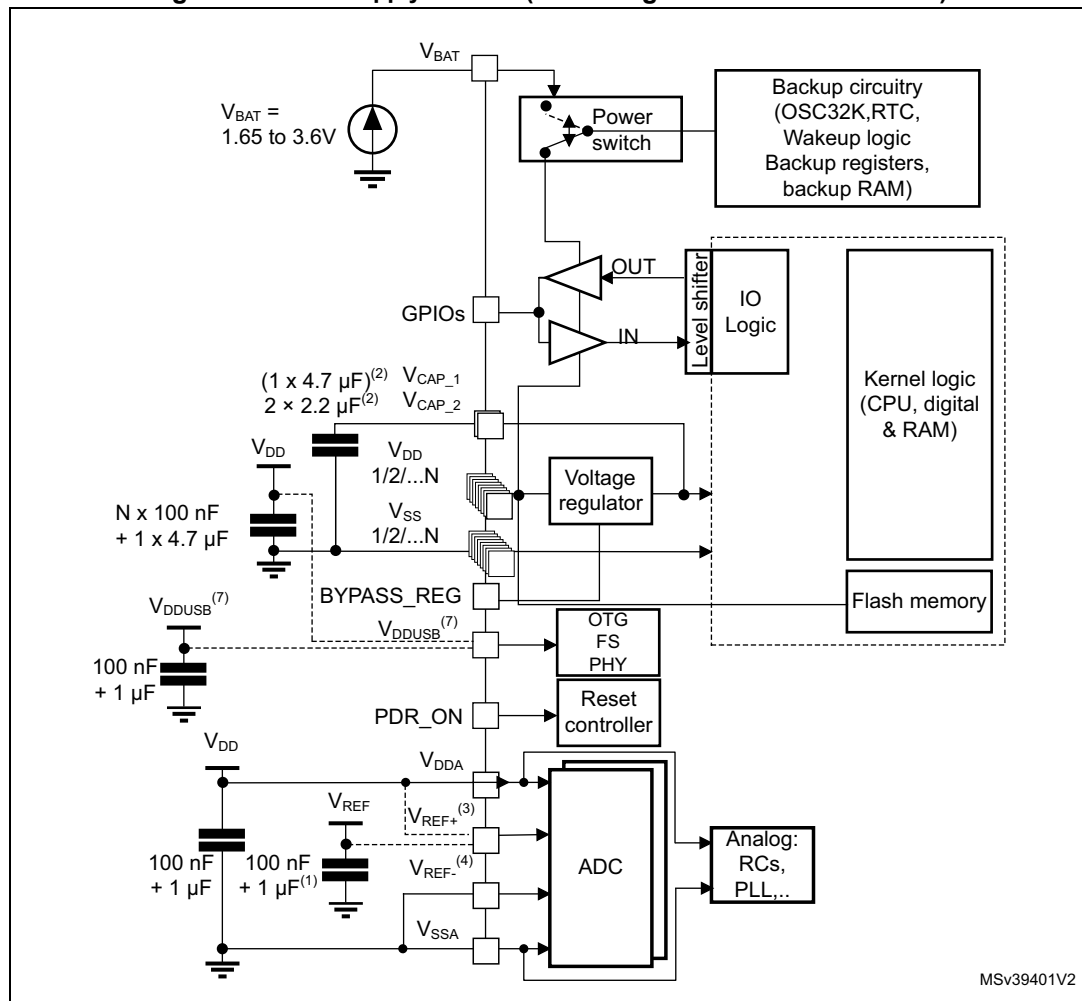
- During power-on phase ( $V_{DD} < V_{DD\_MIN}$ ),  $V_{DDUSB}$  should be always lower than  $V_{DD}$
- During power-down phase ( $V_{DD} < V_{DD\_MIN}$ ),  $V_{DDUSB}$  should be always lower than  $V_{DD}$
- $V_{DDUSB}$  rising and falling time rate specifications must be respected.
- In operating mode phase,  $V_{DDUSB}$  could be lower or higher than  $V_{DD}$ :
  - If USB (USB OTG\_HS/OTG\_FS) is used, the associated GPIOs powered by  $V_{DDUSB}$  are operating between  $V_{DDUSB\_MIN}$  and  $V_{DDUSB\_MAX}$ . The  $V_{DDUSB}$  supplies both USB transceivers (USB OTG\_HS and USB OTG\_FS).
  - If only one USB transceiver is used in the application, the GPIOs associated to the other USB transceiver are still supplied by  $V_{DDUSB}$ .
  - If USB (USB OTG\_HS/OTG\_FS) is not used, the associated GPIOs powered by  $V_{DDUSB}$  are operating between  $V_{DD\_MIN}$  and  $V_{DD\_MAX}$ .

**Figure 1.  $V_{DDUSB}$  connected to an external independent power supply**



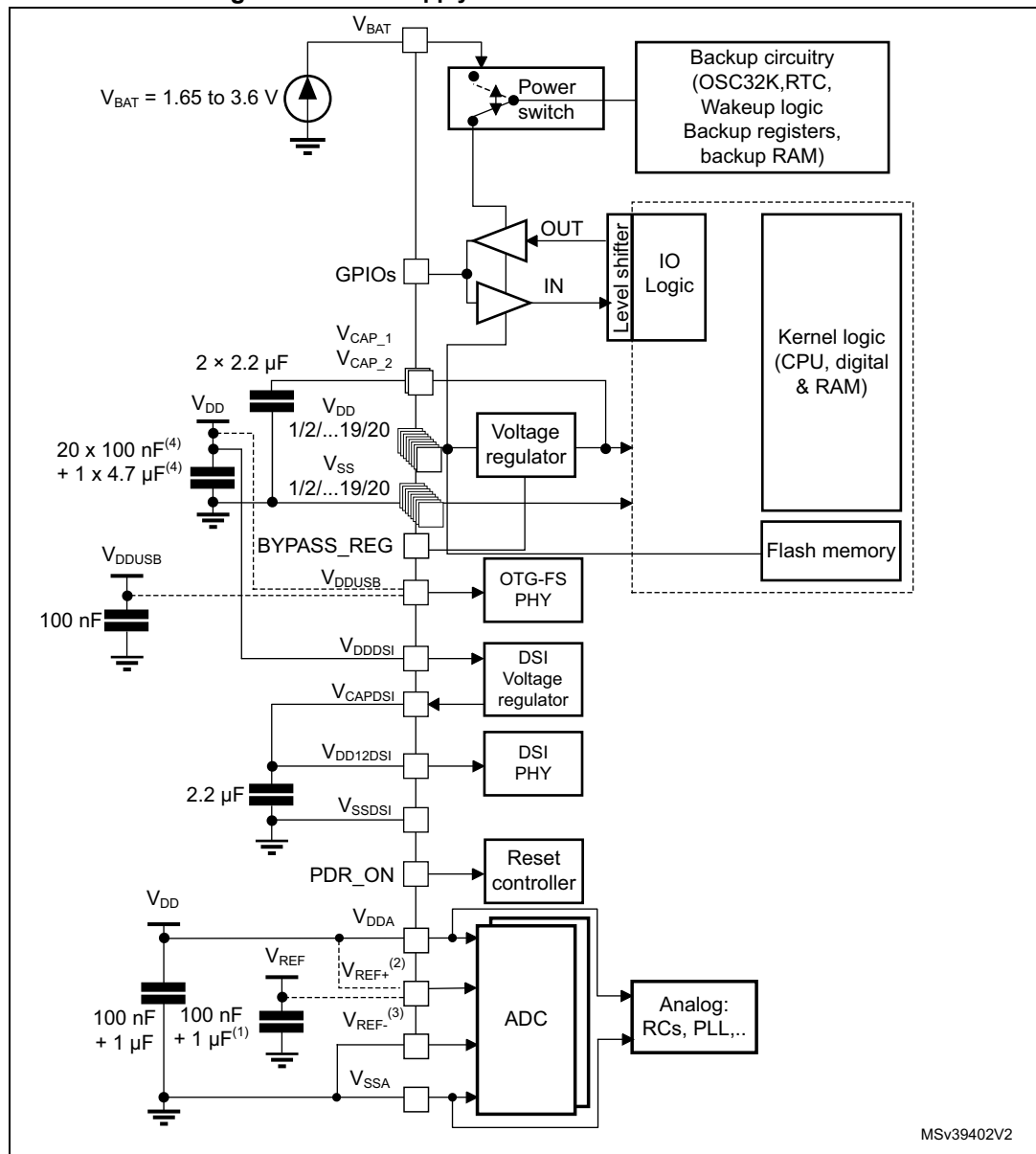
- Additional precautions can be taken to filter analog noise:
  - $V_{DDA}$  can be connected to  $V_{DD}$  through a ferrite bead.
  - The  $V_{REF+}$  pin can be connected to  $V_{DDA}$  through a resistor (typ. 47  $\Omega$ ).
- For the voltage regulator configuration, there is specific BYPASS\_REG pin (not available on all packages) that should be connected either to  $V_{SS}$  or  $V_{DD}$  to activate or deactivate the voltage regulator specific.
  - Refer to [Section 2.3.6](#) and section "Voltage regulator" of the related device datasheet for details.
- When the voltage regulator is enabled,  $V_{CAP1}$  and  $V_{CAP2}$  pins must be connected to 2\*2.2  $\mu F$  LowESR < 2 $\Omega$  Ceramic capacitor (or 1\*4.7  $\mu F$  LowESR < 1 $\Omega$  Ceramic capacitor if only  $V_{CAP1}$  pin is provided on some packages).

**Figure 2. Power supply scheme (excluding STM32F469xx/F479xx)**



- Optional. If a separate, external reference voltage is connected on  $V_{REF+}$ , the two capacitors (100 nF and 1  $\mu$ F) must be connected.
- $V_{CAP2}$  is not available on all packages. In that case, a single 4.7  $\mu$ F (ESR < 1 $\Omega$ ) is connected to  $V_{CAP1}$
- $V_{REF+}$  is either connected to  $V_{REF+}$  or to  $V_{DDA}$  (depending on package).
- $V_{REF-}$  is either connected to  $V_{REF-}$  or to  $V_{SSA}$  (depending on package).
- N is the number of  $V_{DD}$  and  $V_{SS}$  inputs.
- Refer to datasheet for BYPASS\_REG and PDR\_ON pins connection.
- $V_{DDUSB}$  is only available on STM32F446xx.

### Figure 3. Power supply scheme for STM32F469xx/F479xx



- Optional. If a separate, external reference voltage is connected on  $V_{REF+}$ , the two capacitors (100 nF and 1  $\mu$ F) must be connected.
- $V_{REF+}$  is either connected to  $V_{REF+}$  or to  $V_{DDA}$  (depending on package).
- $V_{REF-}$  is either connected to  $V_{REF-}$  or to  $V_{SSA}$  (depending on package).
- Refer to datasheet for BYPASS\_REG and PDR\_ON pins connection.

The DSI (Display Serial Interface) sub-system uses several power supply pins which are independent from the other supply pins:

- $V_{DDDSI}$  is an independent DSI power supply dedicated for DSI Regulator and MIPI D-PHY. This supply must be connected to global  $V_{DD}$ .
- $V_{CAPDSI}$  pin is the output of DSI Regulator (1.2V) which must be connected externally to  $V_{DD12DSI}$ .

- $V_{DD12DSI}$  pin is used to supply the MIPI D-PHY, and to supply clock and data lanes pins. An external capacitor of 2.2  $\mu\text{F}$  must be connected on  $V_{DD12DSI}$  pin.
- $V_{SSDSI}$  pin is an isolated supply ground used for DSI sub-system.
- If DSI functionality is not used at all, then:
  - $V_{DDDSI}$  pin must be connected to global  $V_{DD}$ .
  - $V_{CAPDSI}$  pin must be connected externally to  $V_{DD12DSI}$  but the external capacitor is no more needed.
  - $V_{SSDSI}$  pin must be grounded.

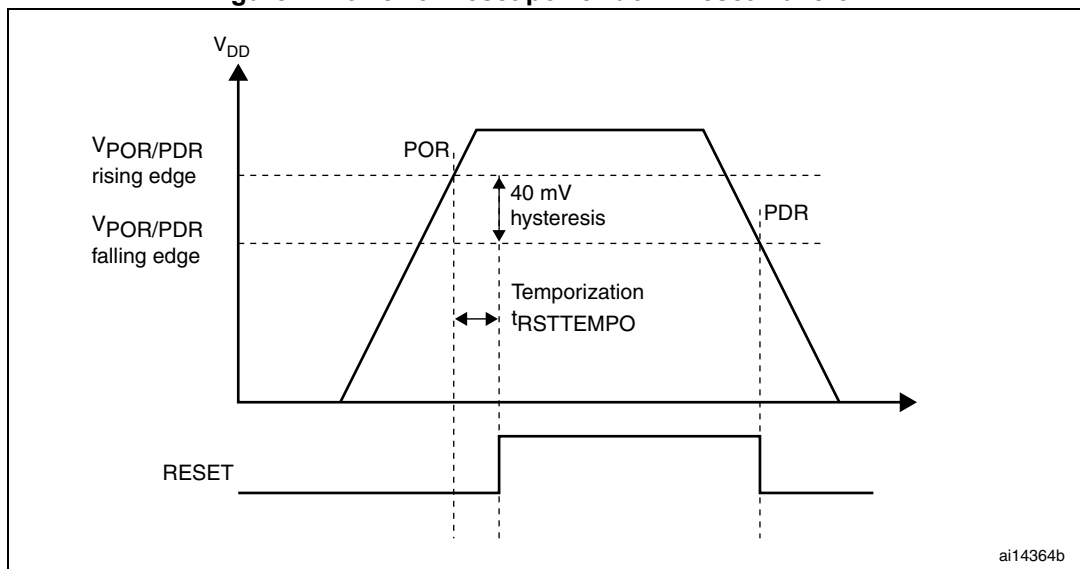
## 2.3 Reset & power supply supervisor

### 2.3.1 Power on reset (POR) / power down reset (PDR)

The device has an integrated POR/PDR circuitry that allows proper operation starting from 1.8 V.

The device remains in the Reset mode as long as  $V_{DD}$  is below a specified threshold,  $V_{POR/PDR}$ , without the need for an external reset circuit. For more details concerning the power on/power down reset threshold, refer to the electrical characteristics in the product datasheets.

**Figure 4. Power-on reset/power-down reset waveform**



1.  $t_{RSTTEMPO}$  is approximately 2.6 ms.  $V_{POR/PDR}$  rising edge is 1.74 V (typ.) and  $V_{POR/PDR}$  falling edge is 1.70 V (typ.). Refer to STM32F4xxxx datasheets for actual value.

The internal power-on reset (POR) / power-down reset (PDR) circuitry is disabled through the PDR\_ON pin. An external power supply supervisor should monitor  $V_{DD}$  and should maintain the device in reset mode as long as  $V_{DD}$  is below a specified threshold. PDR\_ON should be connected to this external power supply supervisor. See [Section 2.3.4](#) and [Section 2.3.5](#) for details.

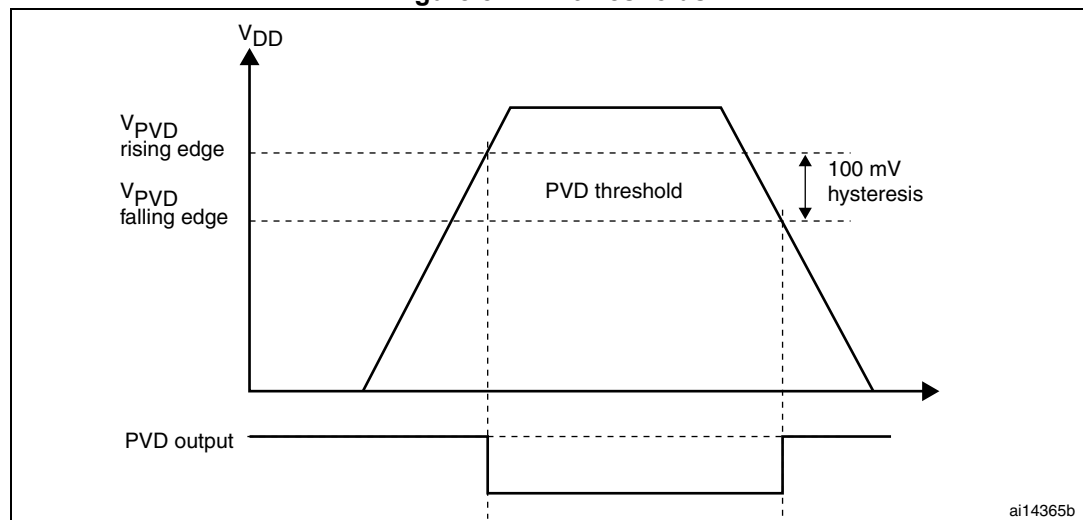
### 2.3.2 Programmable voltage detector (PVD)

You can use the PVD to monitor the  $V_{DD}$  power supply by comparing it to a threshold selected by the PLS[2:0] bits in the Power control register (PWR\_CR).

The PVD is enabled by setting the PVDE bit.

A PVDO flag is available, in the Power control/status register (PWR\_CSR), to indicate whether  $V_{DD}$  is higher or lower than the PVD threshold. This event is internally connected to EXTI Line16 and can generate an interrupt if enabled through the EXTI registers. The PVD output interrupt can be generated when  $V_{DD}$  drops below the PVD threshold and/or when  $V_{DD}$  rises above the PVD threshold depending on the EXTI Line16 rising/falling edge configuration. As an example the service routine can perform emergency shutdown tasks.

Figure 5. PVD thresholds



### 2.3.3 System reset

A system reset sets all registers to their reset values except for the reset flags in the clock controller CSR register and the registers in the Backup domain (see [Figure 2](#)).

A system reset is generated when one of the following events occurs:

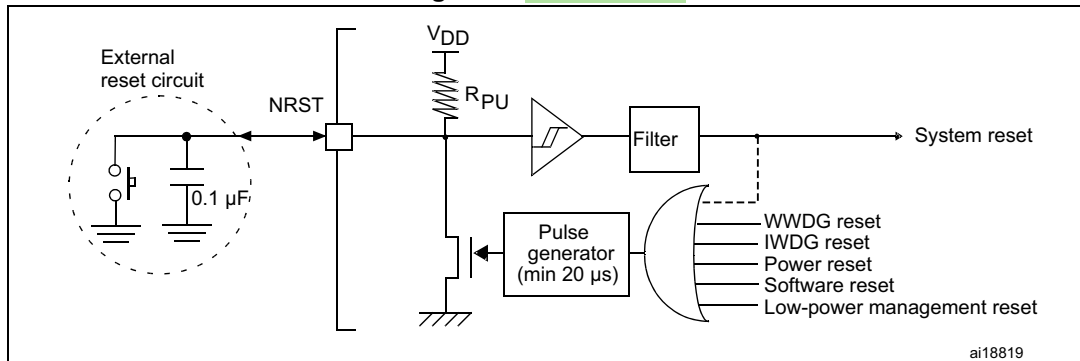
1. A low level on the NRST pin (external reset)
2. window watchdog end-of-count condition (WWDG reset)
3. Independent watchdog end-of-count condition (IWDG reset)
4. A software reset (SW reset)
5. Low-power management reset

The reset source can be identified by checking the reset flags in the Control/Status register, RCC\_CSR.

The products listed in [Table 1](#) do not require an external reset circuit to power-up correctly. Only a pull-down capacitor is recommended to improve EMS performance by protecting the device against parasitic resets, as exemplified in [Figure 6](#).

Charging and discharging a pull-down capacitor through an internal resistor increases the device power consumption. The capacitor recommended value (100 nF) can be reduced to 10 nF to limit this power consumption.

Figure 6. Reset circuit



### 2.3.4 PDR\_ON circuitry example

**Note:** This example doesn't apply to STM32F411xx, STM32F446xx and STM32F469xx/F479xx, where PDR\_ON can be connected to VSS to permanently disable internal reset circuitry (external voltage supervisor required on NRST pin). Thanks to backward compatibility, circuitry built for other STM32F4xxxx products will work for STM32F411xx, STM32F446xx and STM32F469xx/F479xx.

**Note:** Please contact your local STMicroelectronics representative or visit [www.st.com](http://www.st.com) in case you want to use circuitry different from the one described hereafter.

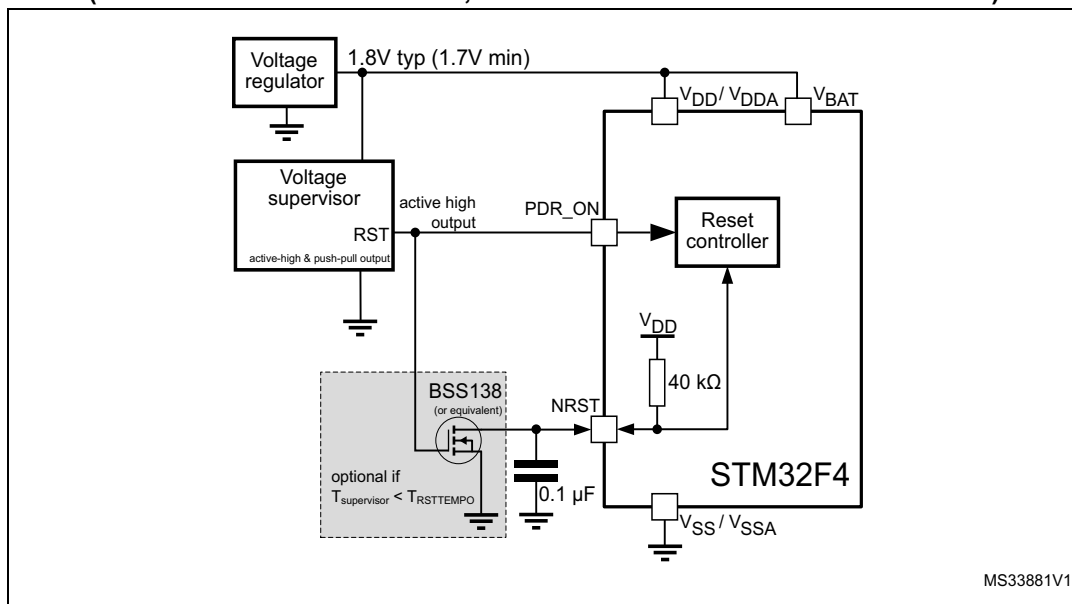
Restrictions:

- PDR\_ON = 0 is mostly intended for  $V_{DD}$  supply between 1.7 V and 1.9V (i.e. 1.8V +/- 5% supply). Supply ranges which never go below 1.8V minimum should be better managed with internal circuitry (no additional component thanks to fully embedded reset controller).
- To ensure safe power down, the external voltage supervisor (or equivalent) is required to drive PDR\_ON=1 during power off sequence.

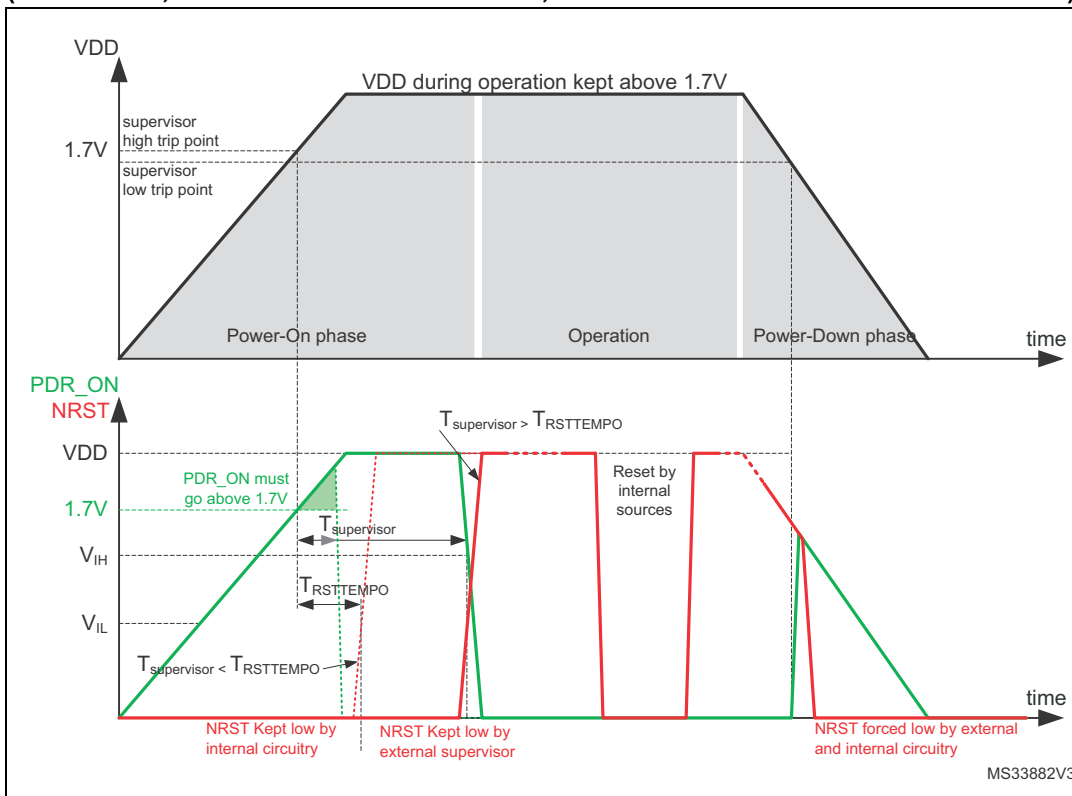
When the internal reset is OFF, the following integrated features are no longer supported:

- The integrated power-on reset (POR) / power-down reset (PDR) circuitry is disabled.
- The brownout reset (BOR) circuitry must be disabled.
- The embedded programmable voltage detector (PVD) is disabled.
- $V_{BAT}$  functionality is no more available and  $V_{BAT}$  pin should be connected to  $V_{DD}$ .

**Figure 7. PDR\_ON simple circuitry example**  
(not needed for STM32F411xx, STM32F446xx and STM32F469xx/F479xx)



**Figure 8. PDR\_ON timings example**  
(not to scale, not needed for STM32F411xx, STM32F446xx and STM32F469xx/F479xx)



### Selection of PDR\_ON voltage supervisor

Voltage supervisor should have the following characteristics

- Reset output **active-high push-pull** (output driving high when voltage is below trip point)
- Supervisor trip point including tolerances and hysteresis should fit the expected  $V_{DD}$  range.  
Notice that supervisor spec usually specify trip point for falling supply, so hysteresis should be added to check the power on phase.

Example:

- Voltage regulator 1.8V +/- 5% mean  $V_{DD}$  min 1.71V
- Supervisor specified at 1.66V +/- 2.5% with an hysteresis of 0.5% mean
  - rising trip max = 1.71V (1.66V + 2.5% + 0.5%)
  - falling trip min = 1.62V (1.66V - 2.5%).

### 2.3.5 NRST circuitry example (for STM32F411xx, STM32F446xx and STM32F469xx/F479xx only)

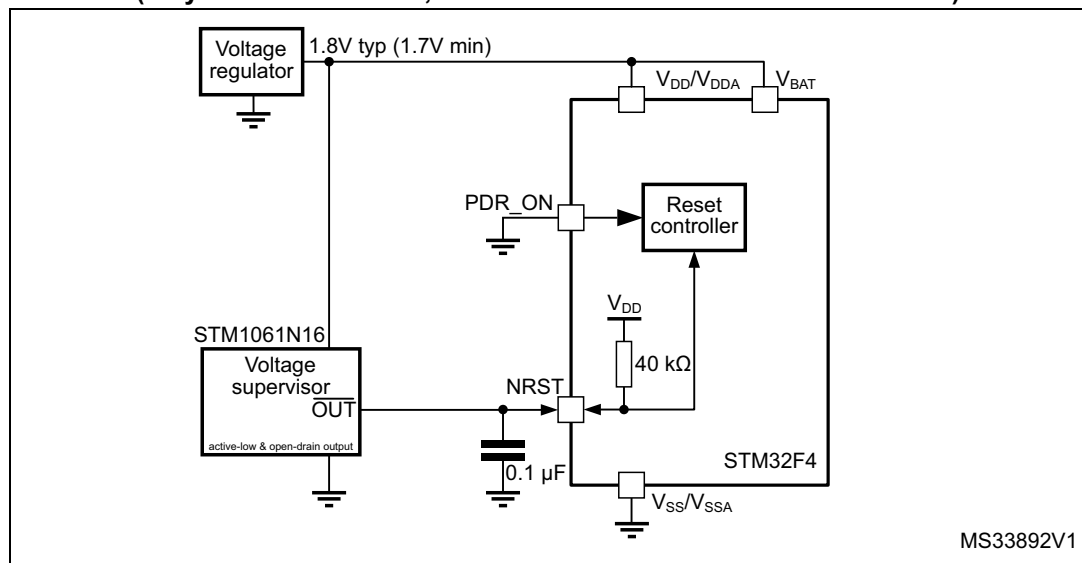
This example applies to STM32F411xx and STM32F446xx where PDR\_ON can be connected to VSS to permanently disable internal reset circuitry.

#### Restrictions:

- PDR\_ON = 0 is mostly intended for  $V_{DD}$  supply between 1.7 V and 1.9V (i.e. 1.8V +/- 5% supply).  
Supply ranges which never go below 1.8V minimum should be better managed by internal circuitry (no additional component needed, thanks to fully embedded reset controller).
- When the internal reset is OFF, the following integrated features are no longer supported:
  - The integrated power-on reset (POR) / power-down reset (PDR) circuitry is disabled.
  - The brownout reset (BOR) circuitry must be disabled.
  - The embedded programmable voltage detector (PVD) is disabled.
  - VBAT functionality is no more available and VBAT pin should be connected to  $V_{DD}$ .

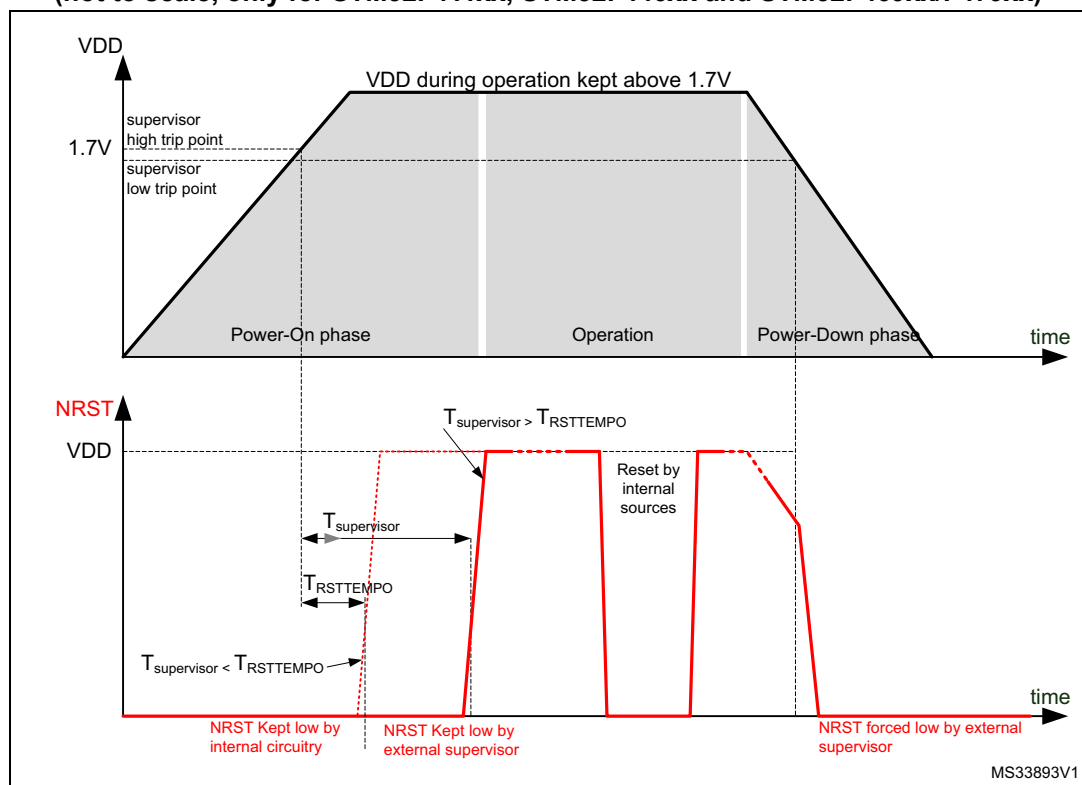


**Figure 9. NRST circuitry example**  
(only for STM32F411xx, STM32F446xx and STM32F469xx/F479xx)



Even with  $PDR\_ON=0$ , during power up, the NRST is driven low by internal Reset controller during  $T_{RSTTEMPO}$  in order to allow stabilization of internal analog circuitry. Refer to STM32F4xxxx datasheets for actual timing value.

**Figure 10. NRST circuitry timings example**  
(not to scale, only for STM32F411xx, STM32F446xx and STM32F469xx/F479xx)



### Selection of NRST voltage supervisor

Voltage supervisor should have the following characteristics

- Reset output **active-low open-drain** (output driving low when voltage is below trip point).
- Supervisor trip point including tolerances and hysteresis should fit the expected  $V_{DD}$  range.

Notice that supervisor spec usually specify trip point for falling supply, so hysteresis should be added to check the power on phase.

Example for STM1061N16:

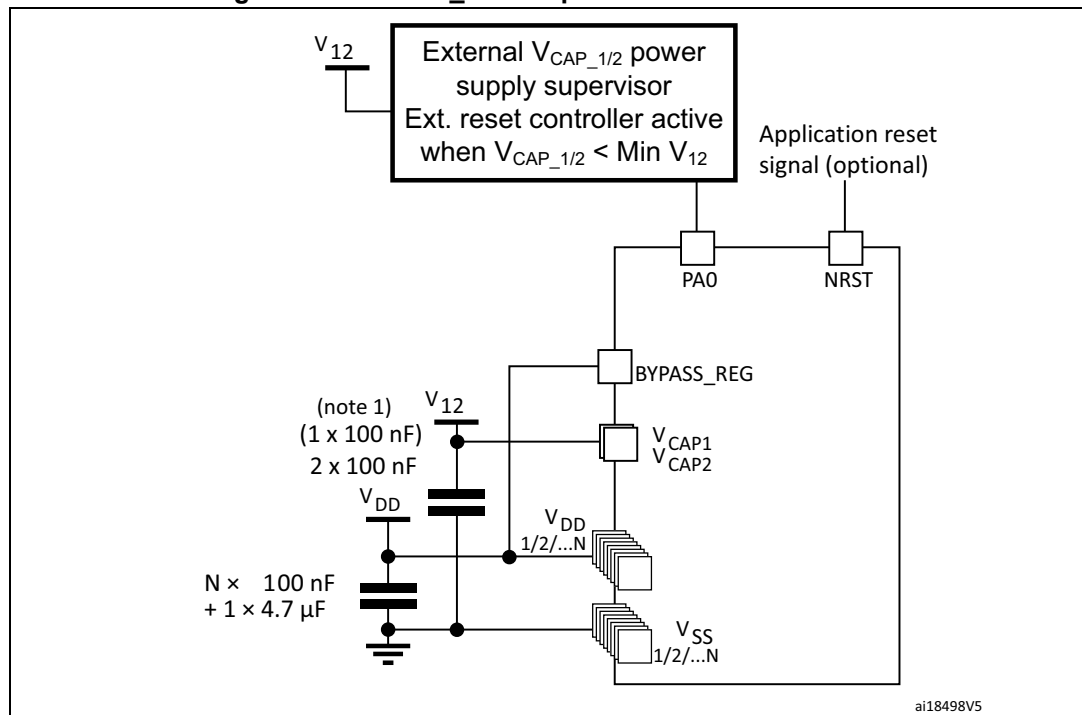
- Voltage regulator 1.8 V +/- 5% mean  $V_{DD}$  min 1.71 V
- Supervisor specified at 1.60 V +/- 2% with an hysteresis of 5% mean
  - rising trip max = 1.71 V (1.60 V + 2% + 5%)
  - falling trip min = 1.57 V (1.60 V - 2%).

### 2.3.6 Regulator OFF mode

Refer to section “Voltage regulator” in datasheet for details.

- When  $BYPASS\_REG = V_{DD}$ , the core power supply should be provided through  $V_{CAP1}$  and  $V_{CAP1}$  pins connected together.
  - The two  $V_{CAP}$  ceramic capacitors should be replaced by two 100 nF decoupling capacitors.
  - Since the internal voltage scaling is not managed internally, the external voltage value must be aligned with the targeted maximum frequency.
  - When the internal regulator is OFF, there is no more internal monitoring on V12. An external power supply supervisor should be used to monitor the V12 of the logic power domain ( $V_{CAP}$ ). PA0 pin should be used for this purpose, and act as power-on reset on V12 power domain.
- In regulator OFF mode, the following features are no more supported:
  - PA0 cannot be used as a GPIO pin since it allows to reset a part of the V12 logic power domain which is not reset by the NRST pin.
  - As long as PA0 is kept low, the debug mode cannot be used under power-on reset. As a consequence, PA0 and NRST pins must be managed separately if the debug connection under reset or pre-reset is required.
  - The over-drive and under-drive modes are not available.
  - The Standby mode is not available.

Figure 11. BYPASS\_REG supervisor reset connection



1.  $V_{CAP2}$  is not available on all packages. In that case, a single 100 nF decoupling capacitor is connected to  $V_{CAP1}$

The following conditions must be respected:

- $V_{DD}$  should always be higher than  $V_{CAP}$  to avoid current injection between power domains.
- If the time for  $V_{CAP}$  to reach  $V12$  minimum value is smaller than the time for  $V_{DD}$  to reach 1.7 V, then PA0 should be kept low to cover both conditions: until  $V_{CAP}$  reaches  $V12$  minimum value and until  $V_{DD}$  reaches 1.7 V.
- Otherwise, if the time for  $V_{CAP}$  to reach  $V12$  minimum value is smaller than the time for  $V_{DD}$  to reach 1.7 V, then PA0 could be asserted low externally.
- If  $V_{CAP}$  goes below  $V12$  minimum value and  $V_{DD}$  is higher than 1.7 V, then PA0 must be asserted low externally.

### 2.3.7 Regulator ON/OFF and internal reset ON/OFF availability

**Table 3. Regulator ON/OFF and internal power supply supervisor availability**

Package	Regulator ON	Regulator OFF	Power supply supervisor ON	Power supply supervisor OFF
LQFP48 LQFP64 LQFP100	Yes <sup>(1)</sup>	No	Yes <sup>(2)</sup>	No
LQFP144			Yes PDR_ON set to V <sub>DD</sub>	Yes PDR_ON external control <sup>(3)</sup>
LQFP176	Yes <sup>(4)</sup>	Yes <sup>(5)</sup>		
LQFP208	Yes <sup>(1)</sup>	No		
BGA100 BGA144 BGA169 BGA176 BGA216	Yes <sup>(4)</sup>	Yes <sup>(5)</sup>		
WLCSP49	Yes <sup>(1)</sup>	No		
WLCSP81 WLCSP90 WLCSP143 WLCSP168	Yes <sup>(4)</sup>	Yes <sup>(5)</sup>		

1. BYPASS\_REG internally connected to V<sub>SS</sub>
2. PDR\_ON internally connected to V<sub>DD</sub>
3. PDR\_ON can be permanently set to VSS for STM32F411xx, STM32F446xx and STM32F469xx/F479xx devices. For other devices, see Chapter 2.3.4
4. BYPASS\_REG set to V<sub>SS</sub>
5. BYPASS\_REG set to V<sub>DD</sub>

## 3 Package

### 3.1 Package Selection

Package should be selected by taking into account the constraints that are strongly dependent upon the application.

The list below summarizes the more frequent ones:

- Amount of interfaces required.  
Some interfaces might not be available on some packages.  
Some interfaces combinations could not be possible on some packages
- PCB technology constraints.  
Small pitch and high ball density could require more PCB layers and higher class PCB
- Package height
- PCB available area
- Noise emission or signal integrity of high speed interfaces.  
Smaller packages usually provide better signal integrity. This is further enhanced as Small pitch and high ball density requires multilayer PCBs which allow better supply/ground distribution.
- Compatibility with other devices.

**Table 4. Package summary (Excluding WLCSP)**

Size (mm) <sup>(1)</sup>	7 x 7	10 x 10	14 x 14	7 x 7	20 x 20	7 x 7	10 x 10	24 x 24	7 x 7	10 x 10	28 x 28	13 x 13
Pitch (mm)	0.5	0.5	0.5	0.5	0.5	0.5	0.8	0.5	0.5	0.65	0.5	0.8
Height (mm)	0.6	1.6	1.6	0.6	1.6	0.6	0.6	1.6	0.6	0.6	1.6	1.1
Sales numbers	UFQFPN48	LQFP64	LQFP100	UFPGA100	LQFP144	UFPGA144	UFPGA144	LQFP176	UFPGA169	UFPGA176	LQFP208	TFBGA216
STM32F405xx / 407xx / 415xx / 417xx	-	X	X	-	X	-	-	X	-	X	-	-
STM32F42xxx / 43xxx	-	-	X	-	X	-	-	X	X	X	X	X
STM32F401xB/C	X	X	X	X	-	-	-	-	-	-	-	-
STM32F401xD/E	X	X	X	X	-	-	-	-	-	-	-	-
STM32F411xx	X	X	X	X	-			-	-	-	-	-
STM32F446XX	-	X	X	-	X	X	X	-	-	-	-	-
STM32F469xx STM32F479xx	-	-	-	-	-	-	-	X	X	X	X	X

1. body size, excluding pins

Table 5. WLCSP Package summary

Sales numbers	Number of balls	Size (mm)	Pitch (mm)	Height (mm)
STM32F405xx /407xx /415xx /417xx	90	4.258 x 4.004	0.4	0.62
STM32F42xxx / 43xxx	143	4.556 x 5.582	0.4	0.585
STM32F401xB/C	49 <sup>(1)</sup>	3 x 3	0.4	0.585
STM32F401xD/E	49 <sup>(1)</sup>	3.064 x 3.064	0.4	0.585
STM32F411xx	49 <sup>(1)</sup>	3.034 x 3.22	0.4	0.585
STM32F446xx	81	3.648 x 3.770	0.4	0.585
STM32F469xx / STM32F479xx	168	4.891 x 5.692	0.4	0.585

1. Same ballout and ball pitch, only package overall dimension changes

## 3.2 Pinout Compatibility

[Table 6](#) allows to select the right package depending on required signals. Note the two different pinouts for 64 and 100 pins which require specific connection in case board compatibility is required. See [Figure 12](#) and [13](#).

Note that Chip Scale Package of different products even with same pinout might have different package dimensions which might be taken into account for PCB clearance. See [Table 5](#).

**Table 6. Pinout summary**

Pin Name	xQFP/xQFN						xBGA					xCSP				
	48	64	100	144	176	208	100	144	169	176	216	49	81	90	143	168
Number of IOs	36	51 <sup>(1)</sup> 50 <sup>(2)</sup>	82 <sup>(1)</sup> 81 <sup>(2)</sup>	114	140	161 <sup>(3)</sup>	81	114	130	140	161 <sup>(3)</sup>	36	63	72	114	128
Specific IOs availability																
PA0-WKUP	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
PB2-BOOT1	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
PC13-ANTI_TAMP	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
PC14-OSC32_IN	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
PC15-OSC32_OUT	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
PH0 - OSC_IN	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
PH1 - OSC_OUT	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
PI8- ANTI TAMP2	-	-	-	-	X	X	-	-	-	X	X	-	-	-	-	-
System related pins																
BOOT0	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
NRST	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
BYPASS_REG	-	-	-	-	X	-	X	X	X <sup>(1)</sup>	X	X	-	X	X	X	-
PDR_ON	-	-	-	X	X	X	X	X	X	X	X	X	X	X	X	X
Supplies pins																
VBAT	X	X	X	X	X	X	X	X	X	X	X	X	-	X	X	X
VDDA	-	-	X	X	X	X	X	X	X	X	X	-	-	-	X	X
VREF+	-	-	X	X	X	X	X	X	X	X	X	-	-	-	X	X
VDDA/VREF+	X	X	-	-	-	-	-	-	-	-	-	X	X	X	-	-
VSSA	-	-	-	-	X <sup>(3)</sup>	X <sup>(3)</sup>	X	X	X	X	X	-	-	-	-	X
VREF-	-	-	-	-	-	-	X	X	X <sup>(1)</sup>	X	X	-	-	-	-	X
VSSA/VREF-	X	X	X	X	X	X	-	-	-	-	-	X	X	X	X	-
VDDUSB	-	-	-	X	X	X	-	X	X	-	X	-	X	-	-	X

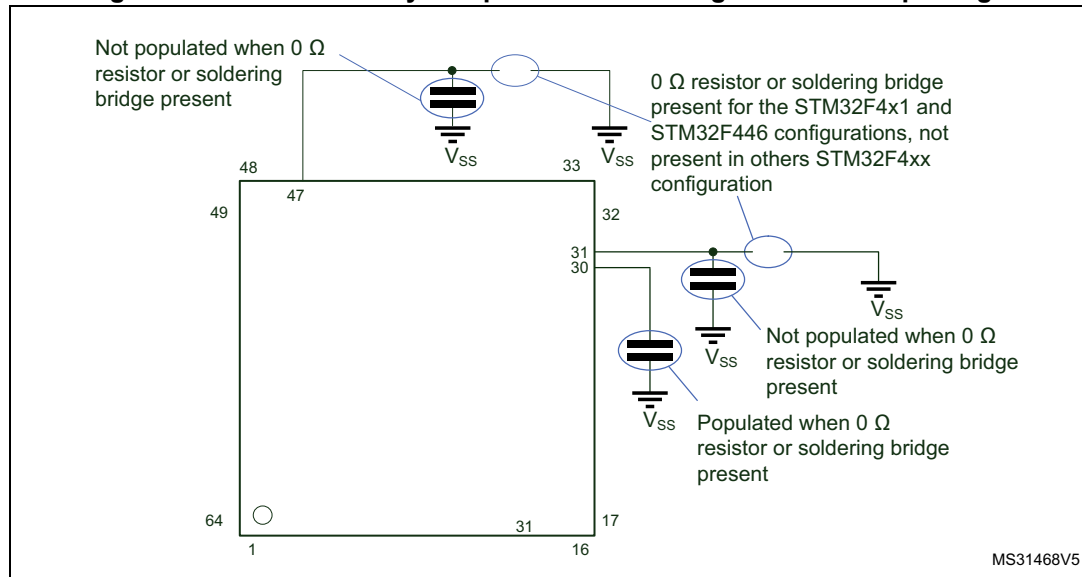
Table 6. Pinout summary (continued)

Pin Name	xQFP/xQFN						xBGA					xCSP				
	48	64	100	144	176	208	100	144	169	176	216	49	81	90	143	168
number of VDD <sup>(4)</sup>	3	4	6	12 <sup>(1)</sup> 11 <sup>(5)</sup>	15 13 <sup>(3)</sup>	17 15 <sup>(3)</sup>	4	12	14 10 <sup>(3)</sup>	14	18 17 <sup>(3)</sup>	3	5	5	13	9
number of VSS	3	2 <sup>(1)</sup> 4 <sup>(6)</sup>	4 <sup>(1)</sup> 5 <sup>(6)</sup>	9	11 10 <sup>(3)</sup>	14 13 <sup>(3)</sup>	4	7	10 11 <sup>(3)</sup>	11	19 18 <sup>(3)</sup>	3	4	4	6	12
VCAP1	X	X	X	X	X	X	X	X	X <sup>(3)</sup>	X	X <sup>(1)(3)</sup>	X	X	X	X	X
VCAP2	-	X <sup>(1)</sup>	X	X	X	X	X	X	X <sup>(3)</sup>	X	X <sup>(1)(3)</sup>	-	X	X	X	X
VDDDSI <sup>(7)</sup>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X
VSSDSI <sup>(7)</sup>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X
VCAPDSI <sup>(7)</sup>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X
VDD12DSI <sup>(7)</sup>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X

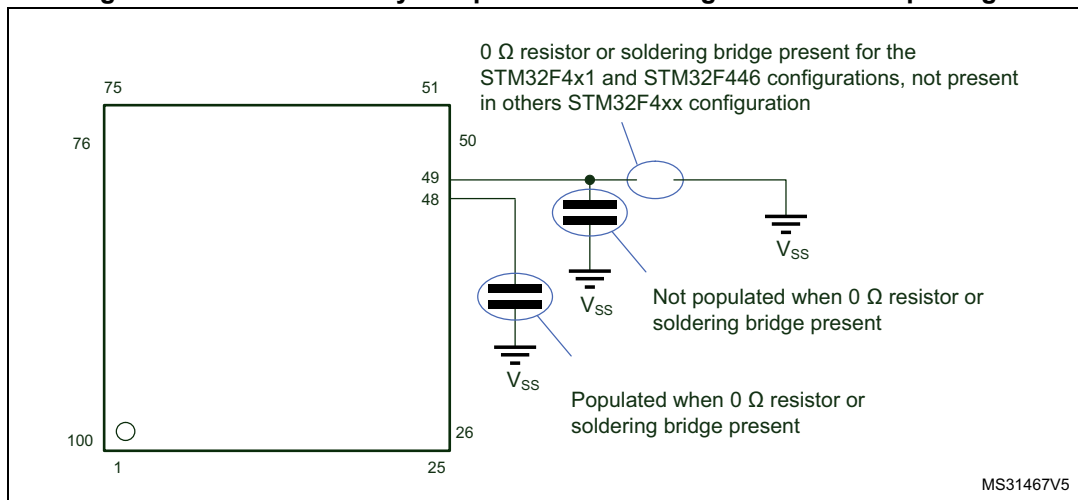
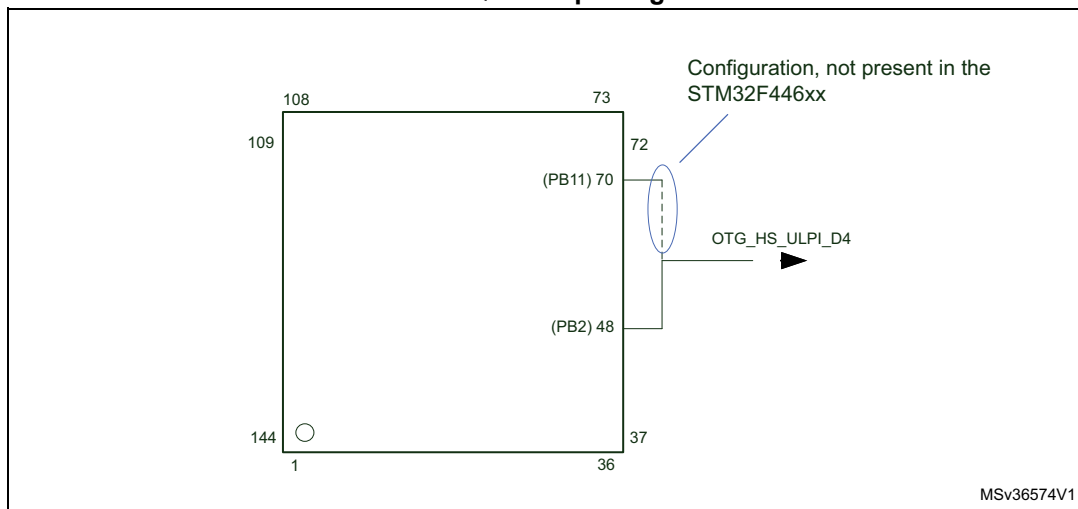
1. Apply to STM32F405xx / F407xx / F415xx / F417xxx / F427xx / F429xx / F437xx / F439xx.
2. PB11 isn't present on STM32F401xx / F411xx for 64 and 100 pins xQFP/xQFN packages.
3. Apply to STM32F469xx / F479xx.
4. One single Tantalum or Ceramic capacitor (min. 4.7  $\mu$ F typ. 10  $\mu$ F) for the package + one 100 nF Ceramic capacitor for each VDD pin.
5. Apply to STM32F446xx.
6. Apply to STM32F401xx / F411xx
7. Apply to STM32F469xx / F479xx

### 3.2.1 Compatibility within STM32F4x family

Figure 12. STM32F4 family compatible board design for LQFP64 package

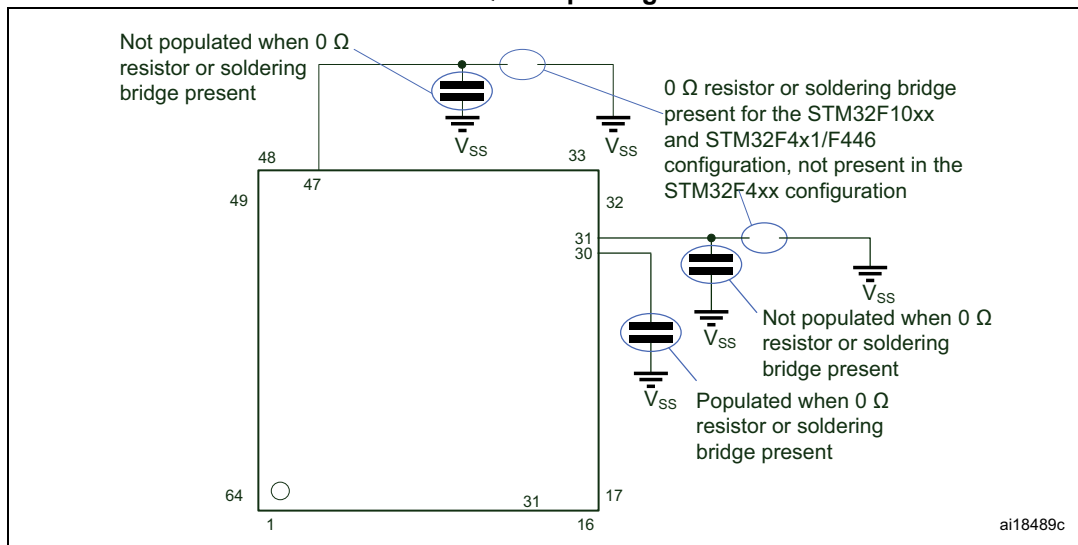




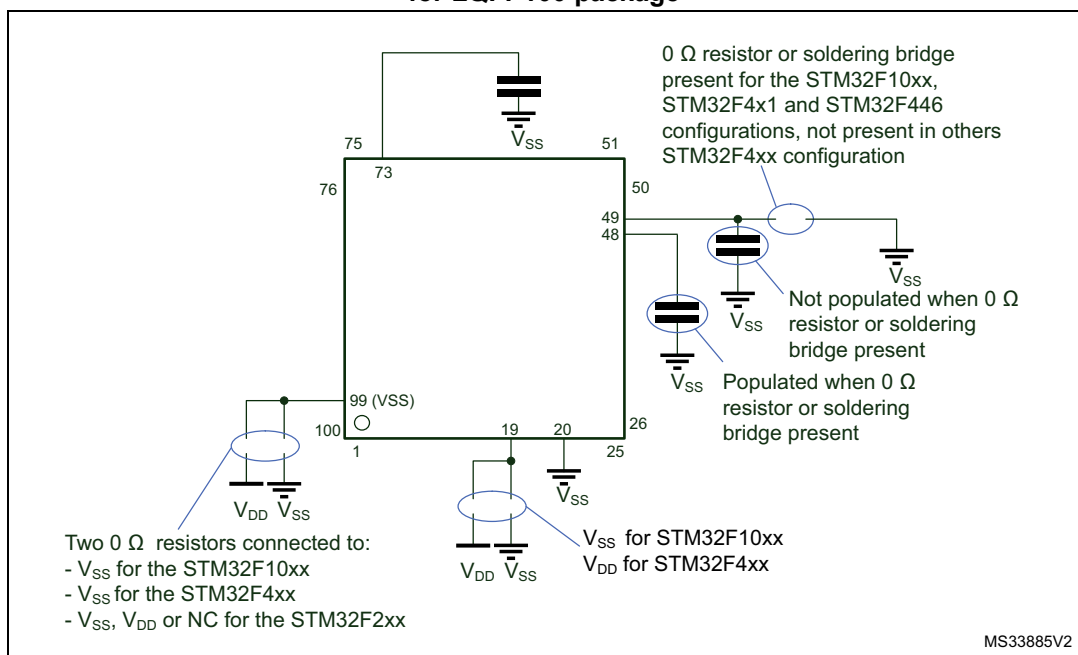
**Figure 13. STM32F4 family compatible board design for LQFP100 package****Figure 14. Compatible board design STM32F4xx / STM32F446xx for LQFP144 package**

### 3.2.2 Compatibility with STM32F1x and STM32F2x families

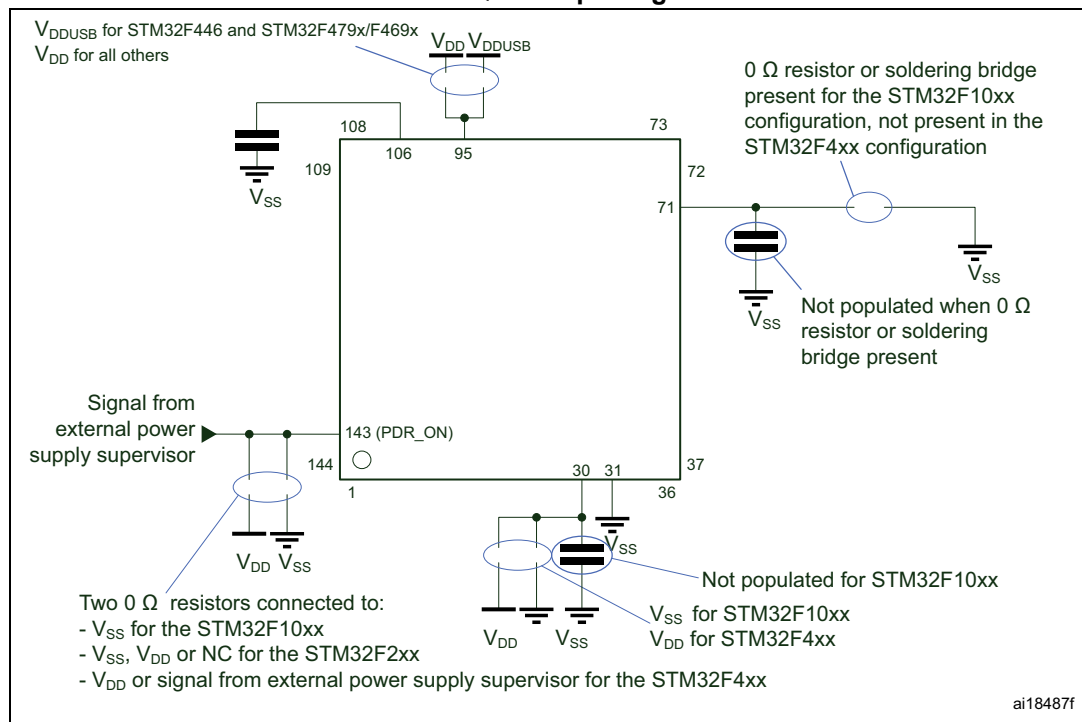
**Figure 15. Compatible board design STM32F10xx/STM32F4xx for LQFP64 package**



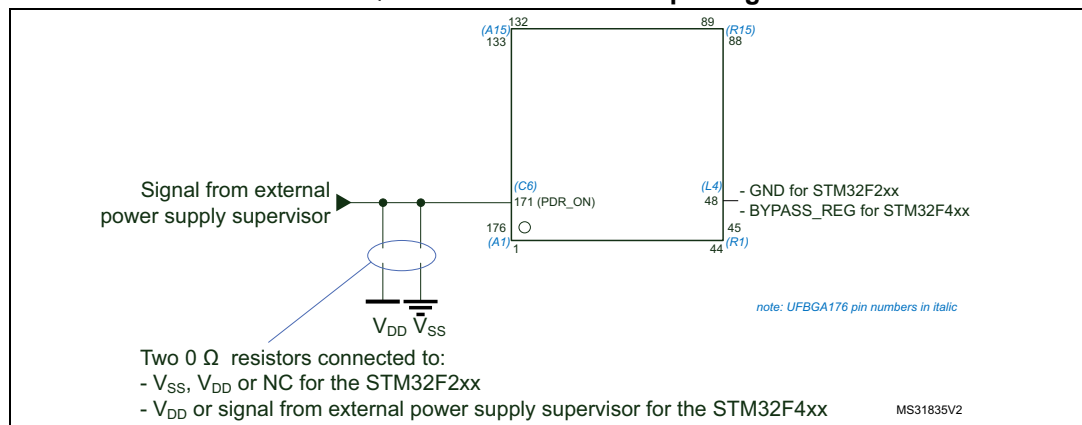
**Figure 16. Compatible board design STM32F10xx/STM32F2xx/STM32F4xx for LQFP100 package**



**Figure 17. Compatible board design STM32F10xx/STM32F2xx/STM32F4xx for LQFP144 package**



**Figure 18. Compatible board design STM32F2xx and STM32F4xx for LQFP176 and UFBGA176 packages**



In order to easily explore Peripheral Alternate Functions mapping to pins, it is recommended to use the STM32CubeMX tool available on [www.st.com](http://www.st.com).

## 4 Clocks

Three different clock sources can be used to drive the system clock (SYSCLK):

- HSI oscillator clock (high-speed internal clock signal)
- HSE oscillator clock (high-speed external clock signal)
- PLL clock

The devices have two secondary clock sources:

- 32 kHz low-speed internal RC (LSI RC) that drives the independent watchdog and, optionally, the RTC used for Auto-wakeup from the Stop/Standby modes.
- 32.768 kHz low-speed external crystal (LSE crystal) that optionally drives the real-time clock (RTCCLK)

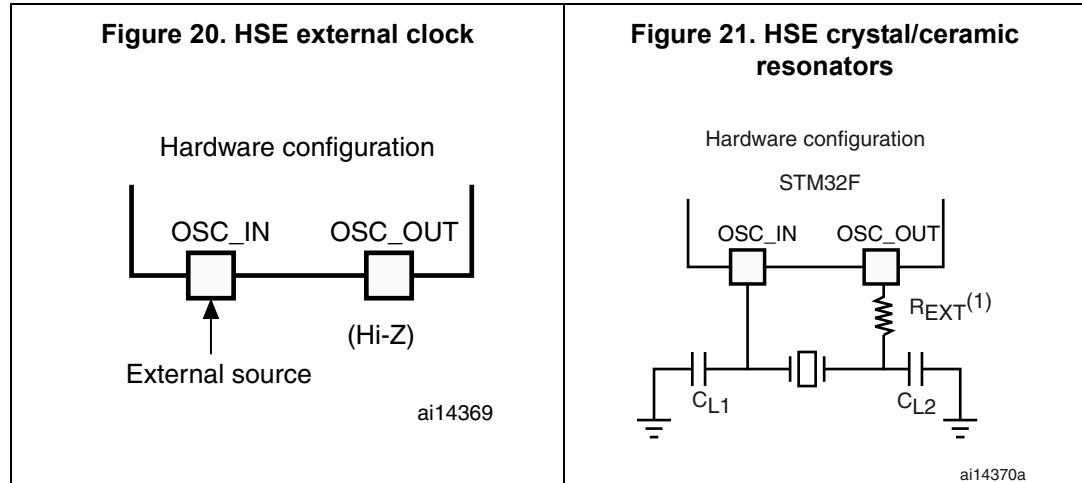
Each clock source can be switched on or off independently when it is not used, to optimize the power consumption.

Refer to the reference manual for the description of the clock tree.

### 4.1 HSE OSC clock

The high-speed external clock signal (HSE) can be generated from two possible clock sources:

- HSE user external clock (see [Figure 20](#))
- HSE external crystal/ceramic resonator (see [Figure 21](#))



1. The value of  $R_{EXT}$  depends on the crystal characteristics. Typical value is in the range of 5 to 6  $R_S$  (resonator series resistance).
2. Load capacitance  $C_L$  has the following formula:  $C_L = C_{L1} \times C_{L2} / (C_{L1} + C_{L2}) + C_{stray}$  where:  $C_{stray}$  is the pin capacitance and board or trace PCB-related capacitance. Typically, it is between 2 pF and 7 pF. Please refer to [Section 7: Recommendations on page 38](#) to minimize its value.

#### 4.1.1 External source (HSE bypass)

In this mode, an external clock source must be provided. It can have a frequency from 1 to 50 MHz (refer to STM32F4xxx datasheets for actual max value).

The external clock signal (square, sine or triangle) with a duty cycle of about 50%, has to drive the OSC\_IN pin while the OSC\_OUT pin must be left in the high impedance state (see [Figure 21](#) and [Figure 20](#)).

#### 4.1.2 External crystal/ceramic resonator (HSE crystal)

The external oscillator frequency ranges from 4 to 26 MHz.

The external oscillator has the advantage of producing a very accurate rate on the main clock. The associated hardware configuration is shown in [Figure 21](#). Using a 25 MHz oscillator frequency is a good choice to get accurate Ethernet, USB OTG high-speed peripheral, and I<sup>2</sup>S.

The resonator and the load capacitors have to be connected as close as possible to the oscillator pins in order to minimize output distortion and startup stabilization time. The load capacitance values must be adjusted according to the selected oscillator.

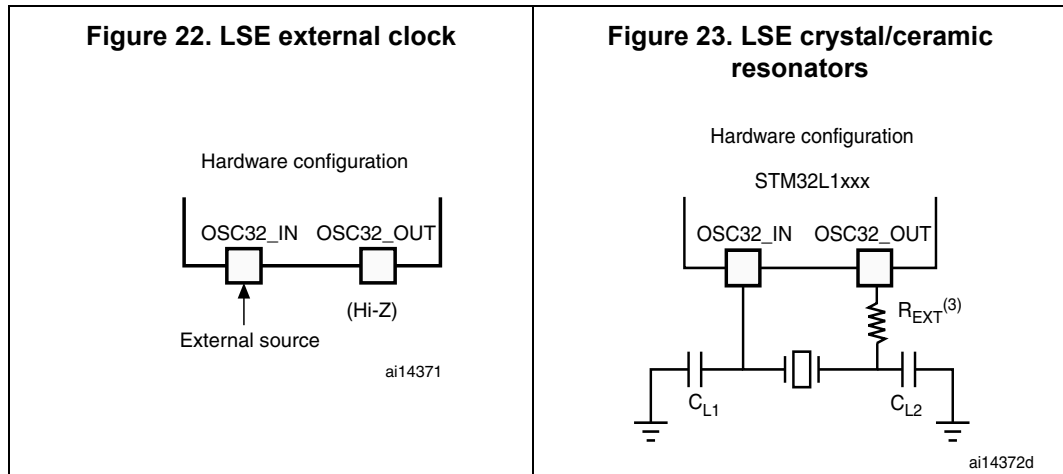
For C<sub>L1</sub> and C<sub>L2</sub> it is recommended to use high-quality ceramic capacitors in the 5 pF-to-25 pF range (typ.), designed for high-frequency applications and selected to meet the requirements of the crystal or resonator. C<sub>L1</sub> and C<sub>L2</sub> are usually the same value. The crystal manufacturer typically specifies a load capacitance that is the series combination of C<sub>L1</sub> and C<sub>L2</sub>. The PCB and MCU pin capacitances must be included when sizing C<sub>L1</sub> and C<sub>L2</sub> (10 pF can be used as a rough estimate of the combined pin and board capacitance).

Refer to the dedicated Application Note (AN2867 - Oscillator design guide for ST microcontrollers) and electrical characteristics sections in the datasheet of your product for more details.

## 4.2 LSE OSC clock

The low-speed external clock signal (LSE) can be generated from two possible clock sources:

- LSE user external clock (see [Figure 22](#))
- LSE external crystal/ceramic resonator (see [Figure 23](#))



1. **“LSE crystal/ceramic resonators” figure:**  
To avoid exceeding the maximum value of  $C_{L1}$  and  $C_{L2}$  (15 pF) it is strongly recommended to use a resonator with a load capacitance  $C_L \leq 7$  pF. Never use a resonator with a load capacitance of 12.5 pF.
2. **“LSE external clock” and “LSE crystal/ceramic resonators” figures:**  
OSC32\_IN and OSC32\_OUT pins can be used also as GPIO, but it is recommended not to use them as both RTC and GPIO pins in the same application.
3. **“LSE crystal/ceramic resonators” figure:**  
The value of  $R_{EXT}$  depends on the crystal characteristics. A 0  $\Omega$  resistor would work but would not be optimal. To fine tune  $R_S$  value, refer to AN2867 - Oscillator design guide for ST microcontrollers ([Table 2](#)).

### 4.2.1 External source (LSE bypass)

In this mode, an external clock source must be provided. It can have a frequency of up to 1 MHz. The external clock signal (square, sine or triangle) with a duty cycle of about 50% has to drive the OSC32\_IN pin while the OSC32\_OUT pin must be left high impedance (see [Figure 22](#)).

### 4.2.2 External crystal/ceramic resonator (LSE crystal)

The LSE crystal is a 32.768 kHz low-speed external crystal or ceramic resonator. It has the advantage of providing a low-power, but highly accurate clock source to the real-time clock peripheral (RTC) for clock/calendar or other timing functions.

The resonator and the load capacitors have to be connected as close as possible to the oscillator pins in order to minimize output distortion and startup stabilization time. The load capacitance values must be adjusted according to the selected oscillator.

Refer to the dedicated Application Note (AN2867 - Oscillator design guide for ST microcontrollers) and electrical characteristics sections in the datasheet of your product for more details.

### 4.3 Clock security system (CSS)

The clock security system can be activated by software. In this case, the clock detector is enabled after the HSE oscillator startup delay, and disabled when this oscillator is stopped.

- If a failure is detected on the HSE oscillator clock, the oscillator is automatically disabled. A clock failure event is sent to the break input of the TIM1 advanced control timer and an interrupt is generated to inform the software about the failure (clock security system interrupt CSSI), allowing the MCU to perform rescue operations. The CSSI is linked to the Cortex<sup>®</sup>-M4 NMI (non-maskable interrupt) exception vector.
- If the HSE oscillator is used directly or indirectly as the system clock (indirectly means that it is used as the PLL input clock, and the PLL clock is used as the system clock), a detected failure causes a switch of the system clock to the HSI oscillator and the disabling of the external HSE oscillator. If the HSE oscillator clock (divided or not) is the clock entry of the PLL used as system clock when the failure occurs, the PLL is disabled too.

For details, see the reference manuals available from the STMicroelectronics website [www.st.com](http://www.st.com).



## 5 Boot configuration

### 5.1 Boot mode selection

In the STM32F4xxx, three different boot modes can be selected by means of the BOOT[1:0] pins as shown in [Table 7](#).

**Table 7. Boot modes**

BOOT mode selection pins		Boot mode	Aliasing
BOOT1	BOOT0		
x	0	Main Flash memory	Main Flash memory is selected as boot space
0	1	System memory	System memory is selected as boot space
1	1	Embedded SRAM	Embedded SRAM is selected as boot space

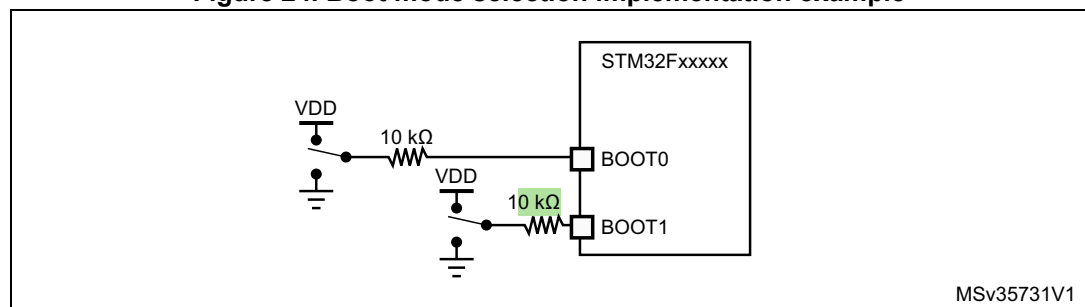
The values on the BOOT pins are latched on the 4<sup>th</sup> rising edge of SYSCLK after a reset. It is up to the user to set the BOOT1 and BOOT0 pins after reset to select the required boot mode.

The BOOT pins are also resampled when exiting the Standby mode. Consequently, they must be kept in the required Boot mode configuration in the Standby mode. After this startup delay has elapsed, the CPU fetches the top-of-stack value from address 0x0000 0000, and starts code execution from the boot memory starting from 0x0000 0004.

### 5.2 Boot pin connection

[Figure 24](#) shows the external connection required to select the boot memory of the STM32F4xxx.

**Figure 24. Boot mode selection implementation example**



1. Resistor values are given only as a typical example.
2. BOOT1 pin not available on all packages.

### 5.3 Embedded boot loader mode

The embedded boot loader is located in the System memory and is programmed by ST during production.

For additional information, refer to AN2606 ([Table 2](#)).

The USART peripheral operates with the internal 16 MHz oscillator (HSI). The CAN and USB OTG FS, however, can only function if an external clock (HSE) multiple of 1 MHz (between 4 and 26 MHz) is present.

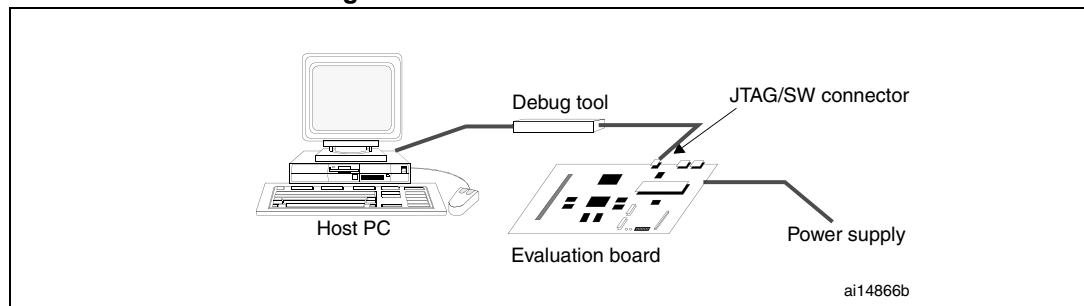
## 6 Debug management

### 6.1 Introduction

The Host/Target interface is the hardware equipment that connects the host to the application board. This interface is made of three components: a hardware debug tool, a JTAG or SW connector and a cable connecting the host to the debug tool.

*Figure 25* shows the connection of the host to the evaluation board.

**Figure 25. Host-to-board connection**



### 6.2 SWJ debug port (serial wire and JTAG)

The STM32F4xxx core integrates the serial wire / JTAG debug port (SWJ-DP). It is an ARM® standard CoreSight™ debug port that combines a JTAG-DP (5-pin) interface and a SW-DP (2-pin) interface.

- The JTAG debug port (JTAG-DP) provides a 5-pin standard JTAG interface to the AHP-AP port
- The serial wire debug port (SW-DP) provides a 2-pin (clock + data) interface to the AHP-AP port

In the SWJ-DP, the two JTAG pins of the SW-DP are multiplexed with some of the five JTAG pins of the JTAG-DP.

### 6.3 Pinout and debug port pins

The STM32F4xxx MCU is offered in various packages with different numbers of available pins. As a result, some functionality related to the pin availability may differ from one package to another.

#### 6.3.1 SWJ debug port pins

Five pins are used as outputs for the SWJ-DP as *alternate functions* of general-purpose I/Os (GPIOs). These pins, shown in *Table 8*, are available on all packages.

Table 8. Debug port pin assignment

SWJ-DP pin name	JTAG debug port		SW debug port		Pin assignment
	Type	Description	Type	Debug assignment	
JTMS/SWDIO	I	JTAG test mode selection	I/O	Serial wire data input/output	PA13
JTCK/SWCLK	I	JTAG test clock	I	Serial wire clock	PA14
JTDI	I	JTAG test data input	-	-	PA15
JTDO/TRACESWO	O	JTAG test data output	-	TRACESWO if async trace is enabled	PB3
JNTRST	I	JTAG test nReset	-	-	PB4

### 6.3.2 Flexible SWJ-DP pin assignment

After reset (SYSRESETn or PORESETn), all five pins used for the SWJ-DP are assigned as dedicated pins immediately usable by the debugger host (note that the trace outputs are not assigned except if explicitly programmed by the debugger host).

However, some of the JTAG pins shown in [Table 9](#) can be configured to an alternate function through the GPIOx\_AFRx registers.

Table 9. SWJ I/O pin availability

Available Debug ports	SWJ I/O pin assigned				
	PA13 / JTMS / SWDIO	PA14 / JTCK / SWCLK	PA15 / JTDI	PB3 / JTDO	PB4 / JNTRST
Full SWJ (JTAG-DP + SW-DP) - reset state	X	X	X	X	X
Full SWJ (JTAG-DP + SW-DP) but without JNTRST	X	X	X	X	
JTAG-DP disabled and SW-DP enabled	X	X			
JTAG-DP disabled and SW-DP disabled	Released				

[Table 9](#) shows the different possibilities to release some pins.

For more details, see the reference manual ([Table 1](#)), available from the STMicroelectronics website [www.st.com](http://www.st.com).

### 6.3.3 Internal pull-up and pull-down resistors on JTAG pins

The JTAG input pins must *not* be floating since they are directly connected to flip-flops to control the debug mode features. Special care must be taken with the SWCLK/TCK pin that is directly connected to the clock of some of these flip-flops.

To avoid any uncontrolled I/O levels, the STM32F4xxxx embeds internal pull-up and pull-down resistors on JTAG input pins:

- JNTRST: Internal pull-up
- JTDI: Internal pull-up
- JTMS/SWDIO: Internal pull-up
- TCK/SWCLK: Internal pull-down

Once a JTAG I/O is released by the user software, the GPIO controller takes control again. The reset states of the GPIO control registers put the I/Os in the equivalent state:

- JNTRST: Input pull-up
- JTDI: Input pull-up
- JTMS/SWDIO: Input pull-up
- JTCK/SWCLK: Input pull-down
- JTDO: Input floating

The software can then use these I/Os as standard GPIOs.

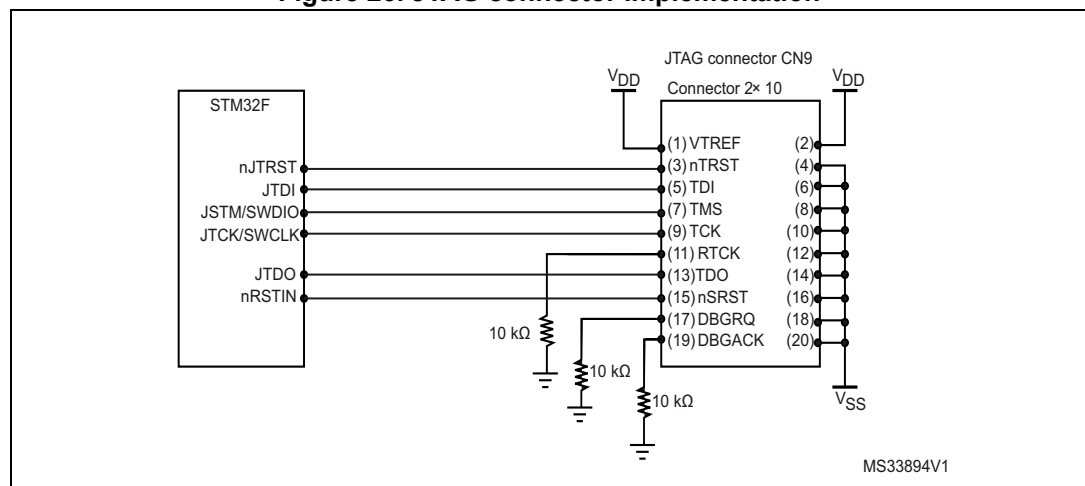
**Note:** *The JTAG IEEE standard recommends to add pull-up resistors on TDI, TMS and nTRST but there is no special recommendation for TCK. However, for the STM32F4xxxx, an integrated pull-down resistor is used for JTCK.*

*Having embedded pull-up and pull-down resistors removes the need to add external resistors.*

### 6.3.4 SWJ debug port connection with standard JTAG connector

Figure 26 shows the connection between the STM32F4xxxx and a standard JTAG connector.

**Figure 26. JTAG connector implementation**



## 7 Recommendations

### 7.1 Printed circuit board

For technical reasons, it is best to use a multilayer printed circuit board (PCB) with a separate layer dedicated to ground ( $V_{SS}$ ) and another dedicated to the  $V_{DD}$  supply. This provides good decoupling and a good shielding effect. For many applications, economical reasons prohibit the use of this type of board. In this case, the major requirement is to ensure a good structure for ground and for the power supply.

### 7.2 Component position

A preliminary layout of the PCB must separate the different circuits according to their EMI contribution in order to reduce cross-coupling on the PCB, that is noisy, high-current circuits, low-voltage circuits, and digital components.

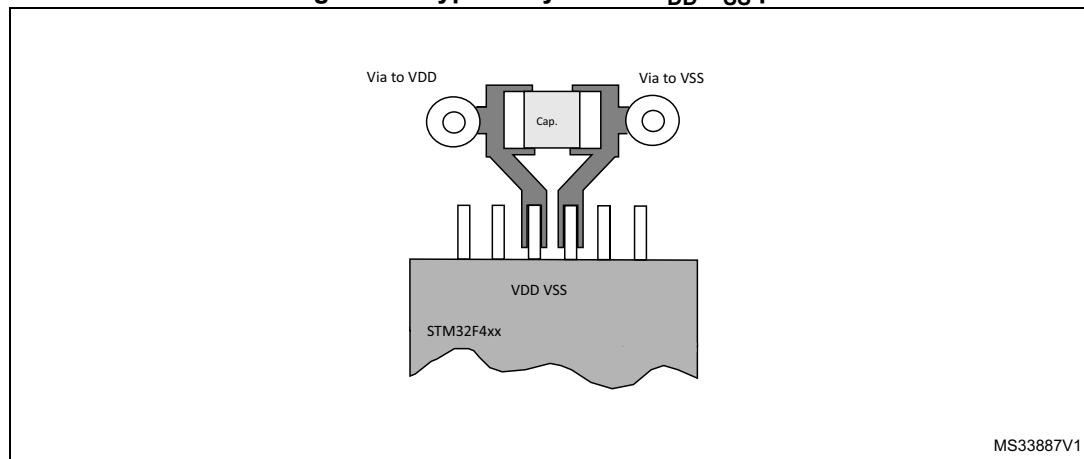
### 7.3 Ground and power supply ( $V_{SS}$ , $V_{DD}$ )

Every block (noisy, low-level sensitive, digital, etc.) should be grounded individually and all ground returns should be to a single point. Loops must be avoided or have a minimum area. The power supply should be implemented close to the ground line to minimize the area of the supply loop. This is due to the fact that the supply loop acts as an antenna, and is therefore the main transmitter and receiver of EMI. All component-free PCB areas must be filled with additional grounding to create a kind of shielding (especially when using single-layer PCBs).

### 7.4 Decoupling

All power supply and ground pins must be properly connected to the power supplies. These connections, including pads, tracks and vias should have as low impedance as possible. This is typically achieved with thick track widths and, preferably, the use of dedicated power supply planes in multilayer PCBs.

In addition, each power supply pair should be decoupled with filtering Ceramic capacitors (100 nF) and one single Tantalum or Ceramic capacitor (min. 4.7  $\mu$ F typ. 10  $\mu$ F) connected in parallel. These capacitors need to be placed as close as possible to, or below, the appropriate pins on the underside of the PCB. Typical values are 10 nF to 100 nF, but exact values depend on the application needs. [Figure 27](#) shows the typical layout of such a  $V_{DD}/V_{SS}$  pair.

**Figure 27. Typical layout for  $V_{DD}/V_{SS}$  pair**

MS33887V1

## 7.5 Other signals

When designing an application, the EMC performance can be improved by closely studying:

- Signals for which a temporary disturbance affects the running process permanently (the case of interrupts and handshaking strobe signals, and not the case for LED commands).  
For these signals, a surrounding ground trace, shorter lengths and the absence of noisy and sensitive traces nearby (crosstalk effect) improve EMC performance.  
For digital signals, the best possible electrical margin must be reached for the two logical states and slow Schmitt triggers are recommended to eliminate parasitic states.
- Noisy signals (clock, etc.)
- Sensitive signals (high impedance, etc.)

## 7.6 Unused I/Os and features

All microcontrollers are designed for a variety of applications and often a particular application does not use 100% of the MCU resources.

To increase EMC performance, unused clocks, counters or I/Os, should not be left free, e.g. I/Os should be set to "0" or "1" (pull-up or pull-down to the unused I/O pins.) and unused features should be "frozen" or disabled.

## 8 Reference design

### 8.1 Description

The reference design shown in [Figure 28](#), is based on the STM32F407IG(H6), a highly integrated microcontroller running at 168 MHz, that combines the Cortex®-M4 32-bit RISC CPU core with 1 Mbyte of embedded Flash memory and 192+4 Kbytes of SRAM including 64-Kbytes of CCM (core coupled memory) data RAM.

This reference design is intended to work with a  $V_{DD}$  from 1.8V minimum (PDR\_ON = VDD\_MCU) and using embedded voltage regulator for 1.2V core supplies (BYPASS\_REG = GND), although BYPASS\_REG = VDD\_MCU is possible with JP1 jumper change, the additional hardware as described in [Section 2.3.6](#) is not present.

This reference design can be tailored to any other device listed in [Table 1](#) with different package, using the pins correspondence given in [Table 12: Reference connection for all packages](#).

#### 8.1.1 Clock

Two clock sources are used for the microcontroller:

- LSE: X2– 32.768 kHz crystal for the embedded RTC
- HSE: X1– 25 MHz crystal for the STM32F4xxxx microcontroller

Refer to [Section 4: Clocks on page 29](#).

#### 8.1.2 Reset

The reset signal in [Figure 28](#) is active low. The reset sources include:

- Reset button (B1)
- Debugging tools via the connector CN1

Refer to [Section 2.3: Reset & power supply supervisor on page 12](#).

#### 8.1.3 Boot mode

The boot option is configured by setting switches SW2 (Boot 0) and SW1 (Boot 1). Refer to [Section 5: Boot configuration on page 33](#).

*Note:* In low-power mode (more specially in Standby mode) the boot mode is mandatory to be able to connect to tools (the device should boot from the SRAM).

#### 8.1.4 SWJ interface

The reference design shows the connection between the STM32F4xxxx and a standard JTAG connector. Refer to [Section 6: Debug management on page 35](#).

*Note:* It is recommended to connect the reset pins so as to be able to reset the application from the tools.

#### 8.1.5 Power supply

Refer to [Section 2: Power supplies on page 7](#).



## 8.2 Component references

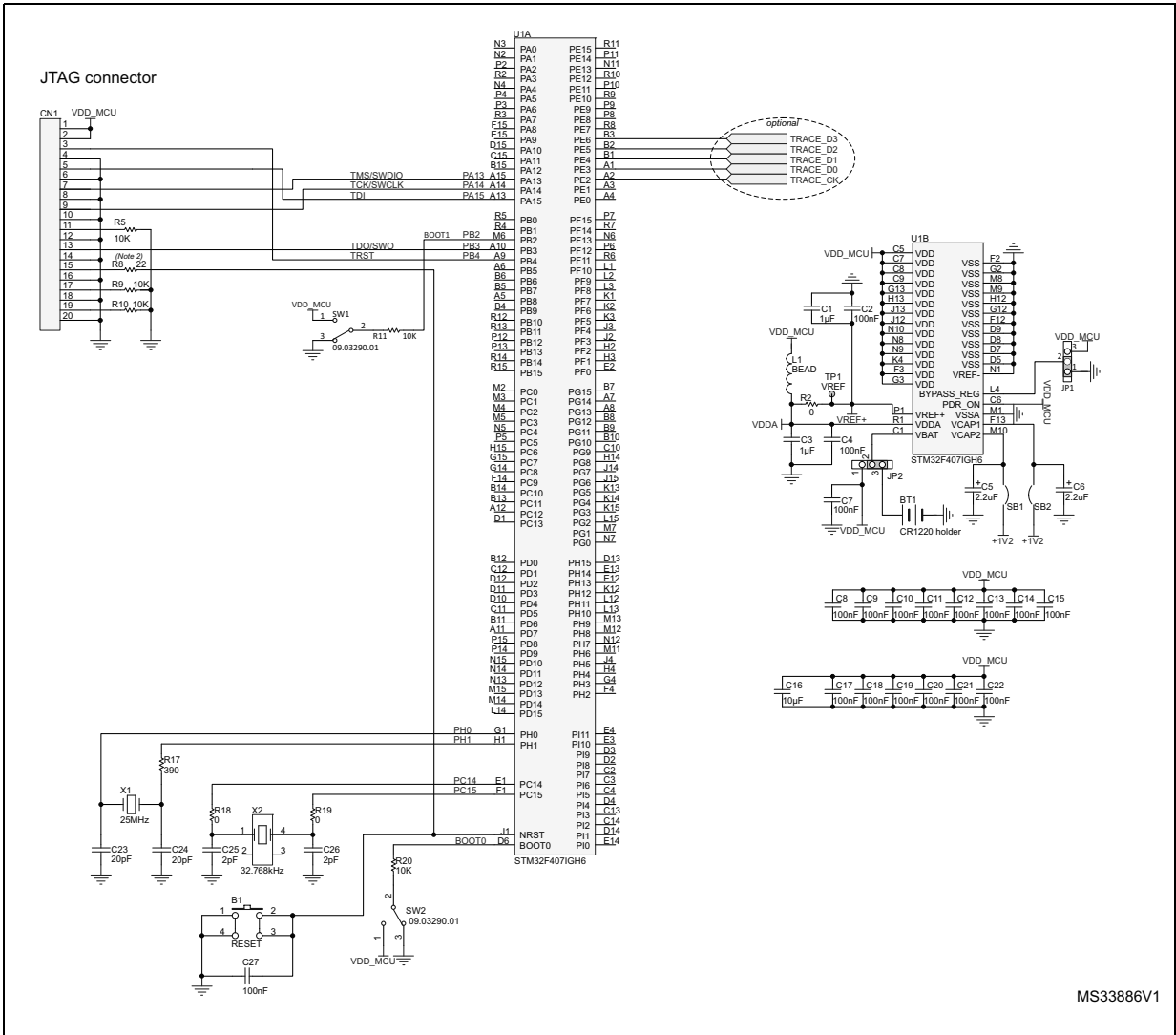
**Table 10. Mandatory components**

Id	Components name	Reference	Quantity	Comments
1	Microcontroller	STM32F407IG(H6)	1	UFBGA176 package
2	Capacitors	100 nF	14	Ceramic capacitors (decoupling capacitors)
3	Capacitor	10 $\mu$ F	1	Ceramic capacitor (decoupling capacitor)

**Table 11. Optional components**

Id	Components name	Reference	Quantity	Comments
1	Resistor	10 k $\Omega$	5	pull-up and pull-down for JTAG and Boot mode.
2	Resistor	390 $\Omega$	1	Used for HSE: the value depends on the crystal characteristics. This resistor value is given only as a typical example.
3	Resistor	0 $\Omega$	3	Used for LSE: the value depends on the crystal characteristics. This resistor value is given only as a typical example. Used as star connection point between $V_{DDA}$ and $V_{REF}$ .
4	Capacitor	100 nF	4	Ceramic capacitor.
5	Capacitor	2 pF	2	Used for LSE: the value depends on the crystal characteristics.
6	Capacitor	1 $\mu$ F	2	Used for $V_{DDA}$ and $V_{REF}$ .
7	Capacitor	2.2 $\mu$ F	2	Used for internal regulator when it is on.
8	Capacitor	20 pF	2	Used for HSE: the value depends on the crystal characteristics.
9	Quartz	25 MHz	1	Used for HSE.
10	Quartz	32.768 kHz	1	Used for LSE.
11	JTAG connector	HE10-20	1	
12	Resistor	22 $\Omega$	1	Debugger reset connection
13	Battery	3V	1	If no external battery is used in the application, it is recommended to connect $V_{BAT}$ externally to $V_{DD}$ .
14	Switch	SPDT	2	Used to select the right boot mode.
15	Push-button	B1	1	Reset button
16	Jumper	3 pins	2	Used to select $V_{BAT}$ source, and BYPASS_REG pin.
17	Ferrite bead	FCM1608KF-601T03	1	Additional decoupling for $V_{DDA}$

**Figure 28. STM32F407IG(H6) microcontroller reference schematic**



1. If no external battery is used in the application, it is recommended to connect  $V_{BAT}$  externally to  $V_{DD}$ .
2. To be able to reset the device from the tools this resistor has to be kept.

Table 12. Reference connection for all packages

Pin Name	Pin Numbers for packages with pins on 4 edges						Pin Numbers for BGA Packages					Chip Scale Packages				
	48 pins	64 pins <sup>(1)</sup>	100 pins <sup>(1)</sup>	144 pins <sup>(2)</sup>	176 pins <sup>(3)</sup>	208 pins <sup>(3)</sup>	100 pins	144 pins	169 pins <sup>(3)</sup>	176 pins	216 pins <sup>(3)</sup>	49 pins	81 pins	90 pins	143 pins	168 pins
PA13	34	46	72	105	124 (128)	147	A11	A12	E12 (A11)	A15	A15	B3	D2	D4	D3	D1
PA14	37	49	76	109	137	159	A10	A11	A11 (A10)	A14	A14	A1	C3	A2	B1	D4
PA15	38	50	77	110	138	160	A9	A10	B11	A13	A13	A2	B2	B3	C2	A2
PB2	20	28	37	48	58	63	L6	J5	L5	M6	M5	G3	J6	J7	L7	P9
PB3	39	55	89	133	161	192	A8	A7	B6 (B5)	A10	A10	A3	A5	B6	B7	A8
PB4	40	56	90	134	162	193	A7	A6	A6 (D6)	A9	A9	A4	B5	A6	C7	C8
PC14-OSC32_IN	3	3	8	8	9	9	D1	B1	E1	E1	E1	C7	C9	B10	D11	E11
PC15-OSC32_OUT	4	4	9	9	10	10	E1	C1	F1	F1	F1	C6	D9	B9	E11	E12
PH0 - OSC_IN	5	5	12	23	29	32	F1	D1	G2	G1	G1	D7	E9	F10	J11	K11
PH1 - OSC_OUT	6	6	13	24	30	33	G1	E1	G1	H1	H1	D6	F9	F9	H10	K12
BOOT0	44	60	94	138	166	197	A4	D5	A5	D6	E6	A5	A7	A7	C9	F8
NRST	7	7	14	25	31	34	H2	F1	H2	J1	J1	E7	D8	G10	H9	H9
BYPASS_REG	-	-	-	-	48	-	E3	H5	M1 (-)	L4	L5	-	J8	D9	N11	-
PDR_ON	-	-	-	143	171	203	H3	E5	C3	C6	E5	B6	B8	A8	A11	D9
VBAT	1	1	6	6	6	6	E2	C2	E5	C1	C1	B7	B9	A10	C11	C12
VDDA	-	-	22	33	39	42	M1	M1	J4 (J3)	R1	R1	-	-	-	L10	M12
VREF+	-	-	21	32	38	41	L1	L1	J3 (-)	P1	P1	-	-	-	L11	-
VDDA/VREF+	9	13	-	-	-	-	-	-	-	-	-	F7	H8	G9	-	-
VSSA	-	-	-	-	- (37)	- (40)	J1	J1	J1 (J2)	M1	M1	-	-	-	-	L11

Table 12. Reference connection for all packages (continued)

Pin Name	Pin Numbers for packages with pins on 4 edges						Pin Numbers for BGA Packages					Chip Scale Packages				
	48 pins	64 pins <sup>(1)</sup>	100 pins <sup>(1)</sup>	144 pins <sup>(2)</sup>	176 pins <sup>(3)</sup>	208 pins <sup>(3)</sup>	100 pins	144 pins	169 pins <sup>(3)</sup>	176 pins	216 pins <sup>(3)</sup>	49 pins	81 pins	90 pins	143 pins	168 pins
VREF-	-	-	-	-	-	-	K1	K1	J2 (-)	N1	N1	-	-	-	-	-
VSSA/VREF-	8	12	20	31	37 (-)	40 (-)	-	-	-	-	-	E6	F7	H10	K10	-
VDDUSB33	-	-	-	- (95)	- (118)	- (137)	-	C11	- (G11)	-	- (G11)	-	E1	-	-	F1
VDDDSI	-	-	-	-	99	118	-	-	K13	-	H11	-	-	-	-	L1
VSSDSI	-	-	-	-	103 (109)	122 (128)	-	-	K11 (H11)	-	G12 (-)	-	-	-	-	H1 (-)
VDD12DSI	-	-	-	-	- (106)	- (125)	-	-	- (J11)	-	G13 (-)	-	-	-	-	K2 (-)
VCAPDSI	-	-	-	-	100	119	-	-	K12	-	K12	-	-	-	-	K1
VDD	-	-	-	-	15	15	-	-	F4	F3	F4	-	-	-	E10	G11
VDD	-	-	11	17	23	26	G2	D3	G8	G3	H5	-	-	B8	-	J12
VDD	-	-	19	30	36	39	-	-	-	-	J5	-	H9	-	G7	-
VDD	-	19	28	39	49	52	-	F4	J11 J4	K4	K5	-	-	E4	J8	P12
VDD	-	-	-	-	-	59	-	-	-	-	L7	-	-	-	J7	-
VDD	-	-	-	52	62	73	-	G5	D10 (K6)	N8	L8	-	-	-	-	P8
VDD	-	-	-	62	72	83	-	G6	G10 (L6)	N9	L9	-	-	-	J5	-
VDD	24	32	50	72	82	94	G12	G7	F8 (L9)	N1 0	L10	F2	J2	-	J6	P3
VDD	-	-	-	-	91 (-)	103	-	-	H8 (-)	J12	K11	-	-	-	-	-
VDD	-	-	-	84	103 (96)	115	-	F8	F7 (K10)	J13	J11	-	-	-	L1	-
VDD	-	-	-	-	- (99)	124 (118)	-	-	- (K13)	-	H11	-	-	-	-	L1
VDD	-	-	-	95 (-)	114 (118)	137	-	F10	E6 (G11)	H1 3	G11	-	-	-	G1	F1

Table 12. Reference connection for all packages (continued)

Pin Name	Pin Numbers for packages with pins on 4 edges						Pin Numbers for BGA Packages					Chip Scale Packages				
	48 pins	64 pins <sup>(1)</sup>	100 pins <sup>(1)</sup>	144 pins <sup>(2)</sup>	176 pins <sup>(3)</sup>	208 pins <sup>(3)</sup>	100 pins	144 pins	169 pins <sup>(3)</sup>	176 pins	216 pins <sup>(3)</sup>	49 pins	81 pins	90 pins	143 pins	168 pins
VDD	36	48	75	108	127 (131)	150	G11	F9	H4 (D10)	G13	F11	B2	A1	E6	C1	C2
VDD	-	-	-	-	- (136)	158	-	-	D3 (-)	-	E10	-	-	-	A1	B5
VDD	-	-	-	-	136 (149)	171	-	F7	D6 (F7)	C9	E9	-	-	-	C5	-
VDD	-	-	-	121	149 (159)	185	-	F6	L6 (-)	C8	E8	-	-	F7	E6	A7
VDD	-	-	-	131	159 (172)	204	-	F5	D3	C7	E7	-	A8	A1	D7	A11
VDD	48	64	100	144	172 (-)	-	-	-	-	C5	- (G5)	A7	-	-	-	-
VDD	-	-	-	-	-	-	C4	-	-	-	F5	-	-	-	-	-
VCAP1	22	31 (30)	49 (48)	71	81	92	L11	H7	N9	M10	L11	G2	J3	F4	N2	N4
VCAP2	-	47 (-)	73	106	125 (129)	148	C11	G9	D12	F13	E11	-	C2	B1	D1	D2
VSS	-	-	-	-	14	14	-	-	F6 (F5)	F2	F2	-	-	-	E7	F12
VSS	-	-	10	16	22	25	F2	D2	G7	G2	H6	-	-	C9	H7	J11
VSS	-	18	27	38	-	-	-	-	-	-	J6	-	G8	-	-	-
VSS	-	-	-	-	-	51	-	G4	- (J1)	-	K6	-	-	E5	-	-
VSS	-	-	-	51	61 (-)	60	-	-	-	M8	L6	-	-	-	-	N11
VSS	-	-	-	61	71 (61)	72	-	-	G9 (J6)	M9	K7	-	-	-	-	-
VSS	23	- (31)	- (49)	-	- (71)	82	F12	H6	J6 (J7)	-	K8	D3	-	-	H3	N8
VSS	-	-	-	-	-	93	-	-	- (M9)	-	K9	-	H3	-	H2	-
VSS	-	-	-	-	-	-	-	-	E7 (-)	-	K10	-	-	-	-	P4

Table 12. Reference connection for all packages (continued)

Pin Name	Pin Numbers for packages with pins on 4 edges						Pin Numbers for BGA Packages					Chip Scale Packages				
	48 pins	64 pins <sup>(1)</sup>	100 pins <sup>(1)</sup>	144 pins <sup>(2)</sup>	176 pins <sup>(3)</sup>	208 pins <sup>(3)</sup>	100 pins	144 pins	169 pins <sup>(3)</sup>	176 pins	216 pins <sup>(3)</sup>	49 pins	81 pins	90 pins	143 pins	168 pins
VSS	-	-	-	-	- (95)	114	-	G8	- (J10)	-	J10	-	-	-	-	H7
VSS	-	-	-	-	-	125 (-)	-	-	-	-	H10	-	-	-	-	M1
VSS	-	-	-	-	90 (117)	136	-	-	J7 (G9)	H1 2	G10	-	-	-	D2	-
VSS	-	-	-	83	102 (130)	149	-	G10	J10 (D11)	-	F10	-	B1	E7	-	F2
VSS	-	-	-	-	- (135)	-	-	-	D11 (-)	-	F9	-	-	-	F5	C1
VSS	-	-	-	94	113	170	-	E7	-	G1 2	F8	-	-	-	-	-
VSS	35	- (47)	74	107	126	184	F11	-	D7	F12	F7	B1	-	E8	-	A4
VSS	-	-	-	-	135	-	-	-	-	D9	-	-	-	-	-	B7
VSS	-	-	-	120	148	202	-	E6	F5	D8	F6	-	B7	-	-	B10
VSS	-	-	-	130	158	-	-	-	-	D7	G6	-	-	-	-	-
VSS	47	63	99	-	-	-	-	-	-	D5	-	A6	-	-	-	-
VSS	-	-	-	-	-	-	D3	-	-	-	G5	-	-	-	-	-

1. Pins in parenthesis apply to STM32F401xx / F411xx.

2. Pin in parenthesis apply for STM32F446xx.

3. Pin in parenthesis apply for STM32F469xx/F479xx.

## 9 Revision history

**Table 13. Document revision history**

Date	Revision	Changes
20-Jun-2014	1	Initial release.
28-Oct-2014	2	Added STM32F411xC/xE in <a href="#">Table 1</a> Added footnote in <a href="#">Table 3</a> Updated <a href="#">Table 6</a> and <a href="#">Table 12</a> Updated <a href="#">Figure 2</a> , <a href="#">Figure 7</a> and <a href="#">Figure 8</a> Updated <a href="#">Section 2.3.4</a> Added <a href="#">Section 2.3.5</a> for STM32F411xC/xE Added <a href="#">Figure 9</a> and <a href="#">Figure 10</a>
20-Mar-2015	3	Updated <a href="#">Table 1: Applicable products</a> ; Updated <a href="#">Table 3: Regulator ON/OFF and internal power supply supervisor availability</a> , <a href="#">Table 4: Package summary (Excluding WLCSP)</a> , <a href="#">Table 5: WLCSP Package summary</a> , <a href="#">Table 6: Pinout summary</a> and <a href="#">Table 12: Reference connection for all packages</a> ; Updated <a href="#">Figure 12: STM32F4 family compatible board design for LQFP64 package</a> , <a href="#">Figure 13: STM32F4 family compatible board design for LQFP100 package</a> , <a href="#">Figure 15: Compatible board design STM32F10xx/STM32F4xx for LQFP64 package</a> , <a href="#">Figure 16: Compatible board design STM32F10xx/STM32F2xx/STM32F4xx for LQFP100 package</a> , <a href="#">Figure 17: Compatible board design STM32F10xx/STM32F2xx/STM32F4xx for LQFP144 package</a> ; Added <a href="#">Figure 14: Compatible board design STM32F4xx / STM32F446xx for LQFP144 package</a> .
21-Aug-2015	4	Updated – <a href="#">Figure 2: Power supply scheme (excluding STM32F469xx/F479xx)</a> – <a href="#">Figure 3: Power supply scheme for STM32F469xx/F479xx and related notes</a> . – <a href="#">Table 1: Applicable products</a> ; – <a href="#">Table 3: Regulator ON/OFF and internal power supply supervisor availability</a> – <a href="#">Table 4: Package summary (Excluding WLCSP)</a> , – <a href="#">Table 5: WLCSP Package summary</a> – <a href="#">Table 12: Reference connection for all packages</a> Added – Note 2 in <a href="#">Figure 24: Boot mode selection implementation example</a>

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