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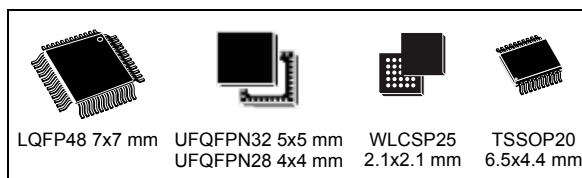


ARM®-based 32-bit MCU with 32 Kbyte Flash, 9 timers, ADC and communication interfaces, 1.8 V

Datasheet - production data

Features

- Core: ARM® 32-bit Cortex®-M0 CPU, frequency up to 48 MHz
- Memories
 - 32 Kbytes of Flash memory
 - 4 Kbytes of SRAM with HW parity
- CRC calculation unit
- Power management
 - Digital and I/Os supply: $V_{DD} = 1.8 \text{ V} \pm 8\%$
 - Analog supply: $V_{DDA} = \text{from } V_{DD} \text{ to } 3.6 \text{ V}$
 - Low power modes: Sleep, Stop
 - V_{BAT} supply for RTC and backup registers
- Clock management
 - 4 to 32 MHz crystal oscillator
 - 32 kHz oscillator for RTC with calibration
 - Internal 8 MHz RC with x6 PLL option
 - Internal 40 kHz RC oscillator
- Up to 38 fast I/Os
 - All mappable on external interrupt vectors
 - Up to 25 I/Os with 5 V tolerant capability
- 5-channel DMA controller
- 1 × 12-bit, 1.0 μs ADC (up to 10 channels)
 - Conversion range: 0 to 3.6V
 - Separate analog supply from 2.4 up to 3.6 V
- Up to 9 timers
 - 1 x 16-bit 7-channel advanced-control timer for 6 channels PWM output, with deadtime generation and emergency stop
 - 1 x 32-bit and 1 x 16-bit timer, with up to 4 IC/OC, usable for IR control decoding
 - 1 x 16-bit timer, with 2 IC/OC, 1 OCN, deadtime generation and emergency stop
 - 1 x 16-bit timer, with IC/OC and OCN, deadtime generation, emergency stop and modulator gate for IR control



- 1 x 16-bit timer with 1 IC/OC
- Independent and system watchdog timers
- SysTick timer: 24-bit downcounter
- Calendar RTC with alarm and periodic wakeup from Stop
- Communication interfaces
 - 1 x I²C interface, supporting Fast Mode Plus (1 Mbit/s) with extra current sink, SMBus/PMBus, and wakeup from Stop mode
 - 1 x USART supporting master synchronous SPI and modem control, ISO7816 interface, LIN, IrDA capability, auto baud rate detection and wakeup feature
 - 1 x SPI (18 Mbit/s) with 4 to 16 programmable bit frames, with I²S interface multiplexed
- Serial wire debug (SWD)
- 96-bit unique ID
- Extended temperature range: -40 to +105°C
- All packages ECOPACK®2

Table 1. Device summary

Reference	Part number
STM32F038x6	STM32F038C6, STM32F038E6, STM32F038F6, STM32F038G6, STM32F038K6

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1 Introduction

This datasheet provides the ordering information and mechanical device characteristics of the STM32F038x6 microcontrollers.

This document should be read in conjunction with the STM32F0xxxx reference manual (RM0091). The reference manual is available from the STMicroelectronics website www.st.com.

For information on the ARM® Cortex®-M0 core, please refer to the Cortex®-M0 Technical Reference Manual, available from the www.arm.com website.



2 Description

The STM32F038x6 microcontrollers incorporate the high-performance ARM® Cortex®-M0 32-bit RISC core operating at up to 48 MHz frequency, high-speed embedded memories (32 Kbytes of Flash memory and 4 Kbytes of SRAM), and an extensive range of enhanced peripherals and I/Os. All devices offer standard communication interfaces (one I²C, one SPI/ I²S and one USART), one 12-bit ADC, five 16-bit timers, one 32-bit timer and an advanced-control PWM timer.

The STM32F038x6 microcontrollers operate in the -40 to +85 °C and -40 to +105 °C temperature ranges at a 1.8 V ± 8% power supply. A comprehensive set of power-saving modes allows the design of low-power applications.

The STM32F038x6 microcontrollers include devices in five different packages ranging from 20 pins to 48 pins with a die form also available upon request. Depending on the device chosen, different sets of peripherals are included.

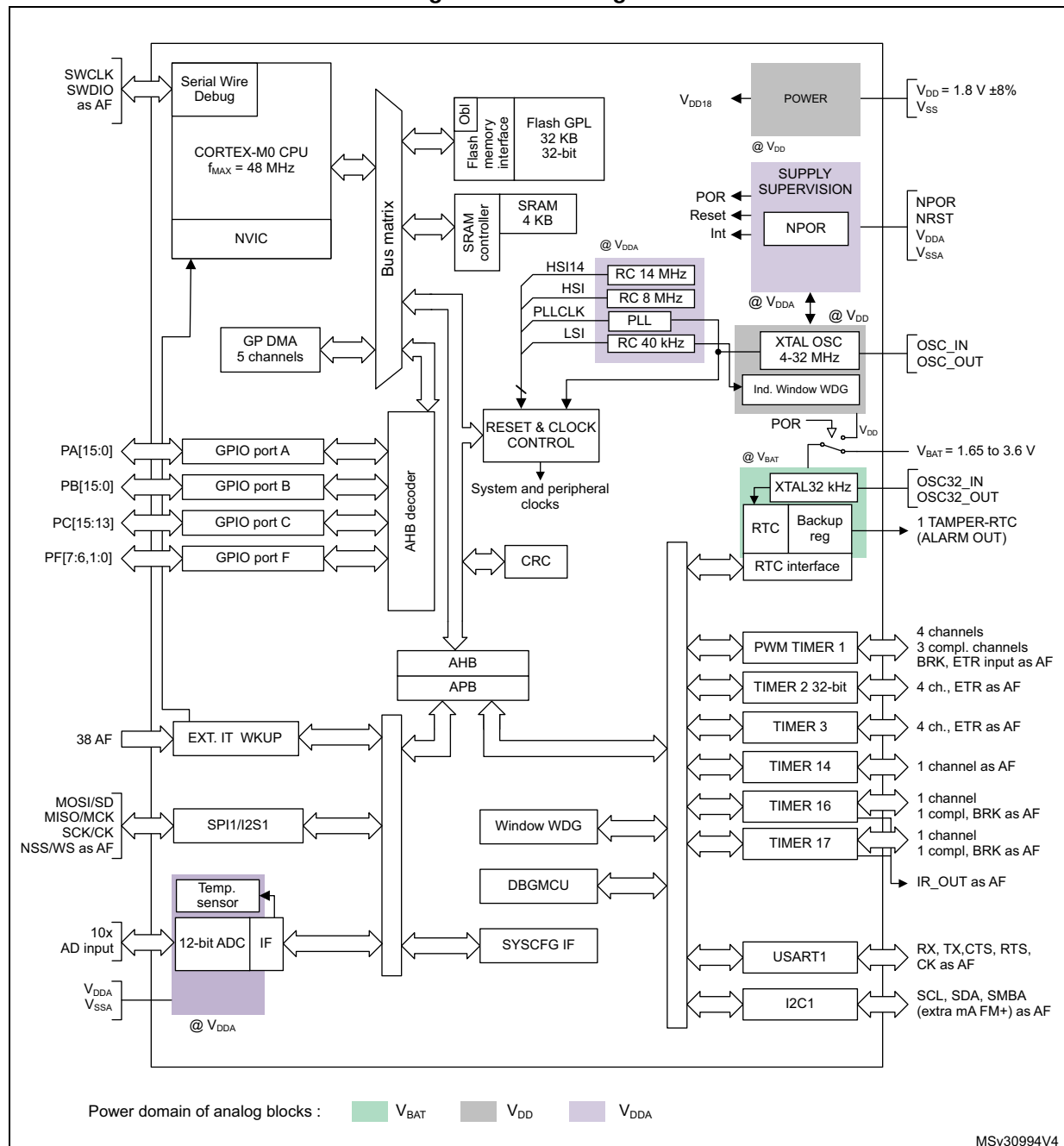
These features make the STM32F038x6 microcontrollers suitable for a wide range of applications such as application control and user interfaces, hand-held equipment, A/V receivers and digital TV, PC peripherals, gaming and GPS platforms, industrial applications, PLCs, inverters, printers, scanners, alarm systems, video intercoms and HVACs.

Table 2. STM32F038x6 family device features and peripheral counts

Peripheral		STM32F038Fx	STM32F038Ex	STM32F038Gx	STM32F038Kx	STM32F038Cx
Flash memory (Kbyte)		32				
SRAM (Kbyte)		4				
Timers	Advanced control	1 (16-bit)				
	General purpose	4 (16-bit) 1 (32-bit)				
Comm. interfaces	SPI [I ² S] ⁽¹⁾	1 [1]				
	I ² C	1				
	USART	1				
12-bit ADC (number of channels)		1 (8 ext. + 3 int.)	1 (9 ext. + 3 int.)	1 (10 ext. + 3 int.)	1 (10 ext. + 3 int.)	1 (10 ext. + 3 int.)
GPIOs		14	19	22	26	38
Max. CPU frequency		48 MHz				
Operating voltage		V _{DD} = 1.8 V ± 8%, V _{DDA} = from V _{DD} to 3.6 V				
Operating temperature		Ambient operating temperature: -40°C to 85°C / -40°C to 105°C Junction temperature: -40°C to 105°C / -40°C to 125°C				
Packages		TSSOP20	WLCSP25	UFQFPN28	UFQFPN32	LQFP48

1. The SPI interface can be used either in SPI mode or in I²S audio mode.

Figure 1. Block diagram



3 Functional overview

Figure 1 shows the general block diagram of the STM32F038x6 devices.

3.1 ARM[®]-Cortex[®]-M0 core

The ARM[®] Cortex[®]-M0 is a generation of ARM 32-bit RISC processors for embedded systems. It has been developed to provide a low-cost platform that meets the needs of MCU implementation, with a reduced pin count and low-power consumption, while delivering outstanding computational performance and an advanced system response to interrupts.

The ARM[®] Cortex[®]-M0 processors feature exceptional code-efficiency, delivering the high performance expected from an ARM core, with memory sizes usually associated with 8- and 16-bit devices.

The STM32F038x6 devices embed ARM core and are compatible with all ARM tools and software.

3.2 Memories

The device has the following features:

- 4 Kbytes of embedded SRAM accessed (read/write) at CPU clock speed with 0 wait states and featuring embedded parity checking with exception generation for fail-critical applications.
- The non-volatile memory is divided into two arrays:
 - 32 Kbytes of embedded Flash memory for programs and data
 - Option bytes

The option bytes are used to write-protect the memory (with 4 KB granularity) and/or readout-protect the whole memory with the following options:

- Level 0: no readout protection
- Level 1: memory readout protection, the Flash memory cannot be read from or written to if either debug features are connected or boot in RAM is selected
- Level 2: chip readout protection, debug features (Cortex[®]-M0 serial wire) and boot in RAM selection disabled

3.3 Boot modes

At startup, the boot pin and boot selector option bit are used to select one of the three boot options:

- boot from User Flash memory
- boot from System Memory
- boot from embedded SRAM

The boot loader is located in System Memory. It is used to reprogram the Flash memory by using USART on pins PA14/PA15 or PA9/PA10.

3.4 Cyclic redundancy check calculation unit (CRC)

The CRC (cyclic redundancy check) calculation unit is used to get a CRC code from a 32-bit data word and a CRC-32 (Ethernet) polynomial.

Among other applications, CRC-based techniques are used to verify data transmission or storage integrity. In the scope of the EN/IEC 60335-1 standard, they offer a means of verifying the Flash memory integrity. The CRC calculation unit helps compute a signature of the software during runtime, to be compared with a reference signature generated at link-time and stored at a given memory location.

3.5 Power management

3.5.1 Power supply schemes

- $V_{DD} = V_{DDIO1} = 1.8\text{ V} \pm 8\%$: external power supply for I/Os (V_{DDIO1}) and digital logic. It is provided externally through VDD pins.
- V_{DDA} = from V_{DD} to 3.6 V: external analog power supply for ADC, RCs and PLL (minimum voltage to be applied to V_{DDA} is 2.4 V when the ADC is used). It is provided externally through VDDA pin. The V_{DDA} voltage level must be always greater or equal to the V_{DD} voltage level and must be established first.
- $V_{BAT} = 1.65$ to 3.6 V: power supply for RTC, external clock 32 kHz oscillator and backup registers (through power switch) when V_{DD} is not present.

For more details on how to connect power pins, refer to [Figure 11: Power supply scheme](#).

3.5.2 Power-on reset

To guarantee a proper power-on reset, the NPOR pin must be held low until V_{DD} is stable. When V_{DD} is stable, the reset state can be exited either by:

- putting the NPOR pin in high impedance (NPOR pin has an internal pull-up), or by
- forcing the pin to high level by connecting it to V_{DDA}

3.5.3 Low-power modes

The STM32F038x6 microcontrollers support two low-power modes to achieve the best compromise between low power consumption, short startup time and available wakeup sources:

- **Sleep mode**

In Sleep mode, only the CPU is stopped. All peripherals continue to operate and can wake up the CPU when an interrupt/event occurs.

- **Stop mode**

Stop mode achieves very low power consumption while retaining the content of SRAM and registers. All clocks in the 1.8 V domain are stopped, the PLL, the HSI RC and the HSE crystal oscillators are disabled.

The device can be woken up from Stop mode by any of the EXTI lines. The EXTI line source can be one of the 16 external lines, RTC, I2C1 or USART1.

USART1 and I2C1 peripherals can be configured to enable the HSI RC oscillator so as to get clock for processing incoming data.

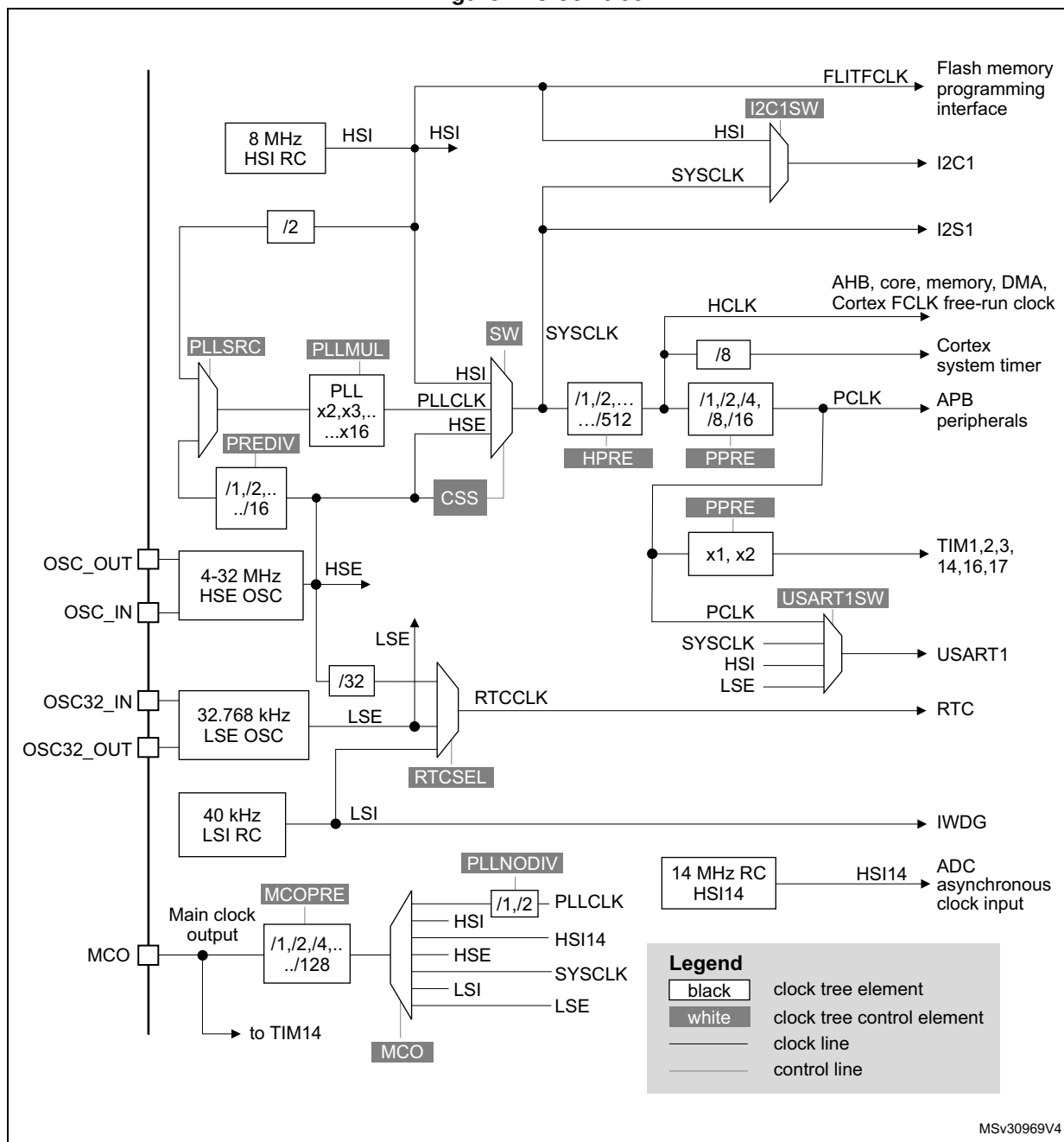
Note: The RTC, the IWDG, and the corresponding clock sources are not stopped by entering Stop mode.

3.6 Clocks and startup

System clock selection is performed on startup, however the internal RC 8 MHz oscillator is selected as default CPU clock on reset. An external 4-32 MHz clock can be selected, in which case it is monitored for failure. If failure is detected, the system automatically switches back to the internal RC oscillator. A software interrupt is generated if enabled. Similarly, full interrupt management of the PLL clock entry is available when necessary (for example on failure of an indirectly used external crystal, resonator or oscillator).

Several prescalers allow the application to configure the frequency of the AHB and the APB domains. The maximum frequency of the AHB and the APB domains is 48 MHz.

Figure 2. Clock tree



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3.7 General-purpose inputs/outputs (GPIOs)

Each of the GPIO pins can be configured by software as output (push-pull or open-drain), as input (with or without pull-up or pull-down) or as peripheral alternate function. Most of the GPIO pins are shared with digital or analog alternate functions.

The I/O configuration can be locked if needed following a specific sequence in order to avoid spurious writing to the I/Os registers.

3.8 Direct memory access controller (DMA)

The 5-channel general-purpose DMAs manage memory-to-memory, peripheral-to-memory and memory-to-peripheral transfers.

The DMA supports circular buffer management, removing the need for user code intervention when the controller reaches the end of the buffer.

Each channel is connected to dedicated hardware DMA requests, with support for software trigger on each channel. Configuration is made by software and transfer sizes between source and destination are independent.

DMA can be used with the main peripherals: SPIx, I2Sx, I2Cx, USARTx, all TIMx timers (except TIM14) and ADC.

3.9 Interrupts and events

3.9.1 Nested vectored interrupt controller (NVIC)

The STM32F0xx family embeds a nested vectored interrupt controller able to handle up to 32 maskable interrupt channels (not including the 16 interrupt lines of Cortex[®]-M0) and 4 priority levels.

- Closely coupled NVIC gives low latency interrupt processing
- Interrupt entry vector table address passed directly to the core
- Closely coupled NVIC core interface
- Allows early processing of interrupts
- Processing of late arriving higher priority interrupts
- Support for tail-chaining
- Processor state automatically saved
- Interrupt entry restored on interrupt exit with no instruction overhead

This hardware block provides flexible interrupt management features with minimal interrupt latency.

3.9.2 Extended interrupt/event controller (EXTI)

The extended interrupt/event controller consists of 24 edge detector lines used to generate interrupt/event requests and wake-up the system. Each line can be independently configured to select the trigger event (rising edge, falling edge, both) and can be masked independently. A pending register maintains the status of the interrupt requests. The EXTI can detect an external line with a pulse width shorter than the internal clock period. Up to 38 GPIOs can be connected to the 16 external interrupt lines.

3.10 Analog-to-digital converter (ADC)

The 12-bit analog-to-digital converter has up to 10 external and 3 internal (temperature sensor, voltage reference, VBAT voltage measurement) channels and performs conversions in single-shot or scan modes. In scan mode, automatic conversion is performed on a selected group of analog inputs.

The ADC can be served by the DMA controller.

An analog watchdog feature allows very precise monitoring of the converted voltage of one, some or all selected channels. An interrupt is generated when the converted voltage is outside the programmed thresholds.

3.10.1 Temperature sensor

The temperature sensor (TS) generates a voltage V_{SENSE} that varies linearly with temperature.

The temperature sensor is internally connected to the ADC_IN16 input channel which is used to convert the sensor output voltage into a digital value.

The sensor provides good linearity but it has to be calibrated to obtain good overall accuracy of the temperature measurement. As the offset of the temperature sensor varies from chip to chip due to process variation, the uncalibrated internal temperature sensor is suitable for applications that detect temperature changes only.

To improve the accuracy of the temperature sensor measurement, each device is individually factory-calibrated by ST. The temperature sensor factory calibration data are stored by ST in the system memory area, accessible in read-only mode.

Table 3. Temperature sensor calibration values

Calibration value name	Description	Memory address
TS_CAL1	TS ADC raw data acquired at a temperature of 30 °C (± 5 °C), $V_{\text{DDA}} = 3.3$ V (± 10 mV)	0x1FFF F7B8 - 0x1FFF F7B9
TS_CAL2	TS ADC raw data acquired at a temperature of 110 °C (± 5 °C), $V_{\text{DDA}} = 3.3$ V (± 10 mV)	0x1FFF F7C2 - 0x1FFF F7C3

3.10.2 Internal voltage reference (V_{REFINT})

The internal voltage reference (V_{REFINT}) provides a stable (bandgap) voltage output for the ADC. V_{REFINT} is internally connected to the ADC_IN17 input channel. The precise voltage of V_{REFINT} is individually measured for each part by ST during production test and stored in the system memory area. It is accessible in read-only mode.

Table 4. Internal voltage reference calibration values

Calibration value name	Description	Memory address
VREFINT_CAL	Raw data acquired at a temperature of 30 °C (± 5 °C), $V_{\text{DDA}} = 3.3$ V (± 10 mV)	0x1FFF F7BA - 0x1FFF F7BB

3.10.3 V_{BAT} battery voltage monitoring

This embedded hardware feature allows the application to measure the V_{BAT} battery voltage using the internal ADC channel ADC_IN18. As the V_{BAT} voltage may be higher than V_{DDA} , and thus outside the ADC input range, the V_{BAT} pin is internally connected to a bridge divider by 2. As a consequence, the converted digital value is half the V_{BAT} voltage.

3.11 Timers and watchdogs

The STM32F038x6 devices include up to five general-purpose timers and an advanced control timer.

[Table 5](#) compares the features of the different timers.

Table 5. Timer feature comparison

Timer type	Timer	Counter resolution	Counter type	Prescaler factor	DMA request generation	Capture/compare channels	Complementary outputs
Advanced control	TIM1	16-bit	Up, down, up/down	integer from 1 to 65536	Yes	4	3
General purpose	TIM2	32-bit	Up, down, up/down	integer from 1 to 65536	Yes	4	-
	TIM3	16-bit	Up, down, up/down	integer from 1 to 65536	Yes	4	-
	TIM14	16-bit	Up	integer from 1 to 65536	No	1	-
	TIM16 TIM17	16-bit	Up	integer from 1 to 65536	Yes	1	1

3.11.1 Advanced-control timer (TIM1)

The advanced-control timer (TIM1) can be seen as a three-phase PWM multiplexed on six channels. It has complementary PWM outputs with programmable inserted dead times. It can also be seen as a complete general-purpose timer. The four independent channels can be used for:

- input capture
- output compare
- PWM generation (edge or center-aligned modes)
- one-pulse mode output

If configured as a standard 16-bit timer, it has the same features as the TIMx timer. If configured as the 16-bit PWM generator, it has full modulation capability (0-100%).

The counter can be frozen in debug mode.

Many features are shared with those of the standard timers which have the same architecture. The advanced control timer can therefore work together with the other timers via the Timer Link feature for synchronization or event chaining.

3.11.2 General-purpose timers (TIM2, 3, 14, 16, 17)

There are five synchronizable general-purpose timers embedded in the STM32F038x6 devices (see [Table 5](#) for differences). Each general-purpose timer can be used to generate PWM outputs, or as simple time base.

TIM2, TIM3

STM32F038x6 devices feature two synchronizable 4-channel general-purpose timers. TIM2 is based on a 32-bit auto-reload up/downcounter and a 16-bit prescaler. TIM3 is based on a 16-bit auto-reload up/downcounter and a 16-bit prescaler. They feature 4 independent channels each for input capture/output compare, PWM or one-pulse mode output. This gives up to 12 input captures/output compares/PWMs on the largest packages.

The TIM2 and TIM3 general-purpose timers can work together or with the TIM1 advanced-control timer via the Timer Link feature for synchronization or event chaining.

TIM2 and TIM3 both have independent DMA request generation.

These timers are capable of handling quadrature (incremental) encoder signals and the digital outputs from 1 to 3 hall-effect sensors.

Their counters can be frozen in debug mode.

TIM14

This timer is based on a 16-bit auto-reload upcounter and a 16-bit prescaler.

TIM14 features one single channel for input capture/output compare, PWM or one-pulse mode output.

Its counter can be frozen in debug mode.

TIM16 and TIM17

Both timers are based on a 16-bit auto-reload upcounter and a 16-bit prescaler.

They each have a single channel for input capture/output compare, PWM or one-pulse mode output.

TIM16 and TIM17 have a complementary output with dead-time generation and independent DMA request generation.

Their counters can be frozen in debug mode.

3.11.3 Independent watchdog (IWDG)

The independent watchdog is based on an 8-bit prescaler and 12-bit downcounter with user-defined refresh window. It is clocked from an independent 40 kHz internal RC and as it operates independently from the main clock, it can operate in Stop mode. It can be used either as a watchdog to reset the device when a problem occurs, or as a free running timer for application timeout management. It is hardware or software configurable through the option bytes. The counter can be frozen in debug mode.

3.11.4 System window watchdog (WWDG)

The system window watchdog is based on a 7-bit downcounter that can be set as free running. It can be used as a watchdog to reset the device when a problem occurs. It is clocked from the APB clock (PCLK). It has an early warning interrupt capability and the counter can be frozen in debug mode.

3.11.5 SysTick timer

This timer is dedicated to real-time operating systems, but could also be used as a standard down counter. It features:

- a 24-bit down counter
- autoreload capability
- maskable system interrupt generation when the counter reaches 0
- programmable clock source (HCLK or HCLK/8)

3.12 Real-time clock (RTC) and backup registers

The RTC and the five backup registers are supplied through a switch that takes power either on V_{DD} supply when present or through the V_{BAT} pin. The backup registers are five 32-bit registers used to store 20 bytes of user application data when V_{DD} power is not present. They are not reset by a system or power reset.

The RTC is an independent BCD timer/counter. Its main features are the following:

- calendar with subseconds, seconds, minutes, hours (12 or 24 format), week day, date, month, year, in BCD (binary-coded decimal) format
- automatic correction for 28, 29 (leap year), 30, and 31 day of the month
- programmable alarm with wake up from Stop mode capability
- on-the-fly correction from 1 to 32767 RTC clock pulses. This can be used to synchronize the RTC with a master clock
- digital calibration circuit with 1 ppm resolution, to compensate for quartz crystal inaccuracy
- two anti-tamper detection pins with programmable filter. The MCU can be woken up from Stop mode on tamper event detection
- timestamp feature which can be used to save the calendar content. This function can be triggered by an event on the timestamp pin, or by a tamper event. The MCU can be woken up from Stop mode on timestamp event detection
- reference clock detection: a more precise second source clock (50 or 60 Hz) can be used to enhance the calendar precision

The RTC clock sources can be:

- a 32.768 kHz external crystal
- a resonator or oscillator
- the internal low-power RC oscillator (typical frequency of 40 kHz)
- the high-speed external clock divided by 32

3.13 Inter-integrated circuit interface (I²C)

The I²C interface (I2C1) can operate in multimaster or slave modes. It can support Standard mode (up to 100 kbit/s), Fast mode (up to 400 kbit/s) and Fast Mode Plus (up to 1 Mbit/s) with extra output drive.

It supports 7-bit and 10-bit addressing modes, multiple 7-bit slave addresses (two addresses, one with configurable mask). It also includes programmable analog and digital noise filters.

Table 6. Comparison of I²C analog and digital filters

Aspect	Analog filter	Digital filter
Pulse width of suppressed spikes	≥ 50 ns	Programmable length from 1 to 15 I2Cx peripheral clocks
Benefits	Available in Stop mode	–Extra filtering capability vs. standard requirements –Stable length
Drawbacks	Variations depending on temperature, voltage, process	Wakeup from Stop on address match is not available when digital filter is enabled.

In addition, I2C1 provides hardware support for SMBUS 2.0 and PMBUS 1.1: ARP capability, Host notify protocol, hardware CRC (PEC) generation/verification, timeouts verifications and ALERT protocol management. I2C1 also has a clock domain independent from the CPU clock, allowing the I2C1 to wake up the MCU from Stop mode on address match.

The I2C peripheral can be served by the DMA controller.

Table 7. STM32F038x6 I²C implementation

I ² C features ⁽¹⁾	I2C1
7-bit addressing mode	X
10-bit addressing mode	X
Standard mode (up to 100 kbit/s)	X
Fast mode (up to 400 kbit/s)	X
Fast Mode Plus with extra output drive I/Os (up to 1 Mbit/s)	X
Independent clock	X
SMBus	X
Wakeup from STOP	X

1. X = supported.

3.14 Universal synchronous/asynchronous receiver/transmitter (USART)

The device embeds one universal synchronous/asynchronous receiver/transmitter (USART1) which communicates at speeds of up to 6 Mbit/s.

It provides hardware management of the CTS, RTS and RS485 DE signals, multiprocessor communication mode, master synchronous communication and single-wire half-duplex communication mode. USART1 supports also SmartCard communication (ISO 7816), IrDA SIR ENDEC, LIN Master/Slave capability and auto baud rate feature, and has a clock domain independent of the CPU clock, allowing to wake up the MCU from Stop mode.

The USART interface can be served by the DMA controller.

Table 8. STM32F038x6 USART implementation

USART modes/features ⁽¹⁾	USART1
Hardware flow control for modem	X
Continuous communication using DMA	X
Multiprocessor communication	X
Synchronous mode	X
Smartcard mode	X
Single-wire half-duplex communication	X
IrDA SIR ENDEC block	X
LIN mode	X
Dual clock domain and wakeup from Stop mode	X
Receiver timeout interrupt	X
Modbus communication	X
Auto baud rate detection	X
Driver Enable	X

1. X = supported.

3.15 Serial peripheral interface (SPI) / Inter-integrated sound interface (I²S)

The SPI is able to communicate up to 18 Mbit/s in slave and master modes in full-duplex and half-duplex communication modes. The 3-bit prescaler gives 8 master mode frequencies and the frame size is configurable from 4 bits to 16 bits.

One standard I²S interface (multiplexed with SPI1) supporting four different audio standards can operate as master or slave at half-duplex communication mode. It can be configured to transfer 16 and 24 or 32 bits with 16-bit or 32-bit data resolution and synchronized by a specific signal. Audio sampling frequency from 8 kHz up to 192 kHz can be set by an 8-bit programmable linear prescaler. When operating in master mode, it can output a clock for an external audio component at 256 times the sampling frequency.

Table 9. STM32F038x6 SPI/I²S implementation

SPI features ⁽¹⁾	SPI
Hardware CRC calculation	X
Rx/Tx FIFO	X
NSS pulse mode	X
I ² S mode	X
TI mode	X

1. X = supported.

3.16 Serial wire debug port (SW-DP)

An ARM SW-DP interface is provided to allow a serial wire debugging tool to be connected to the MCU.

4 Pinouts and pin description

Figure 3. LQFP48 package pinout

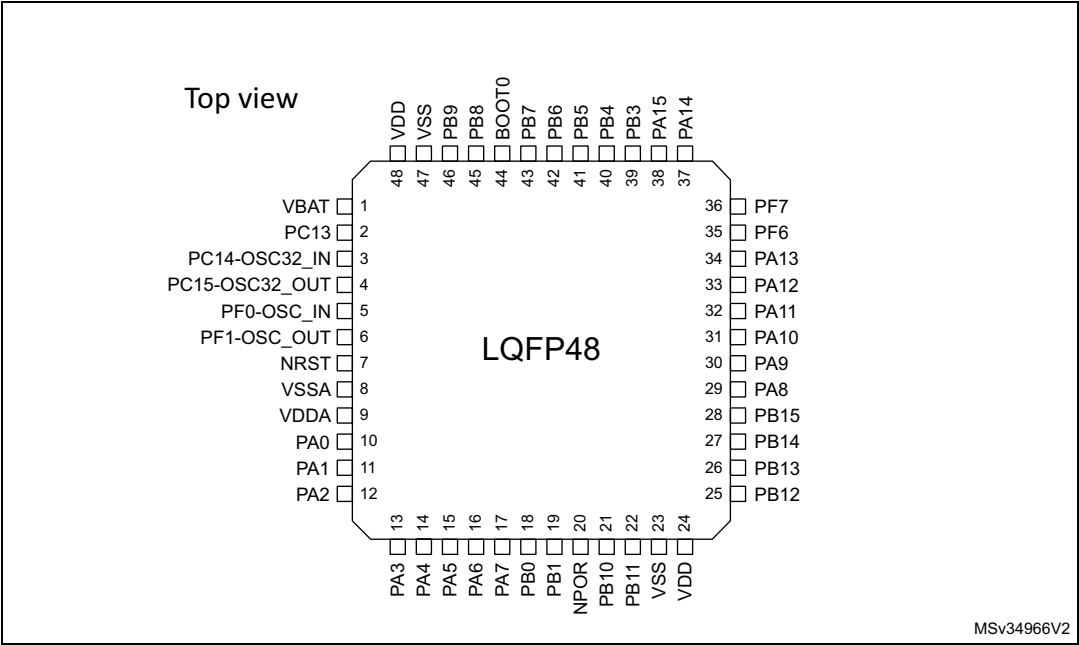


Figure 4. UFQFPN32 package pinout

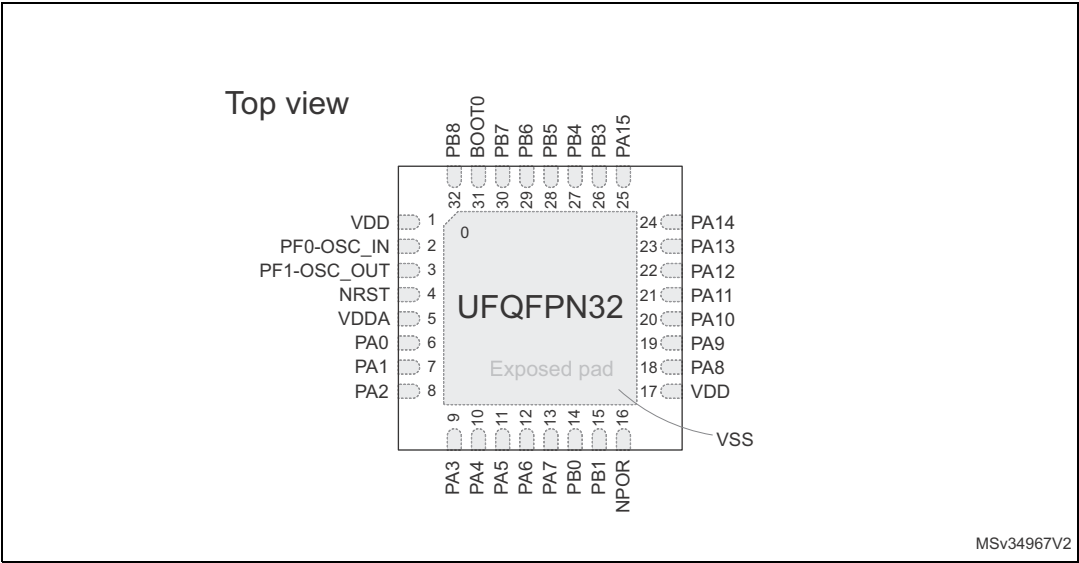


Figure 5. UFQFPN28 package pinout

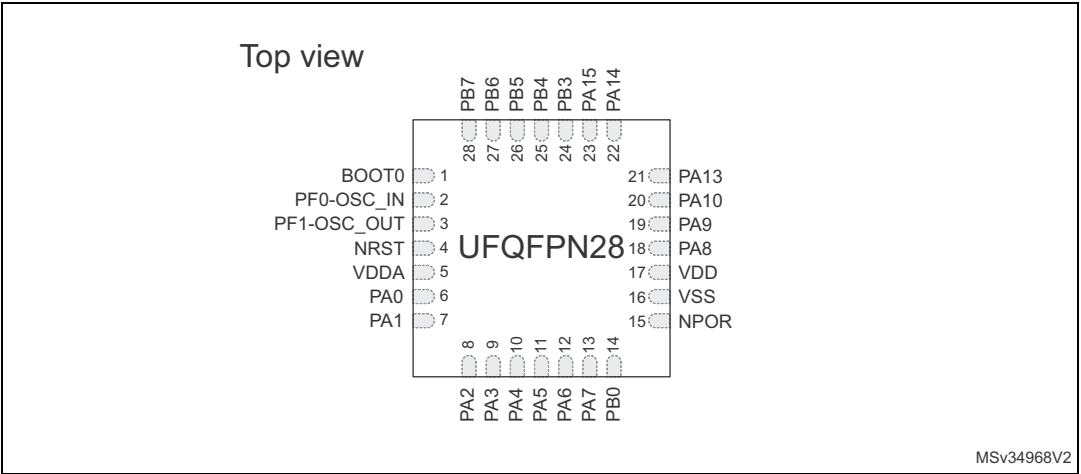
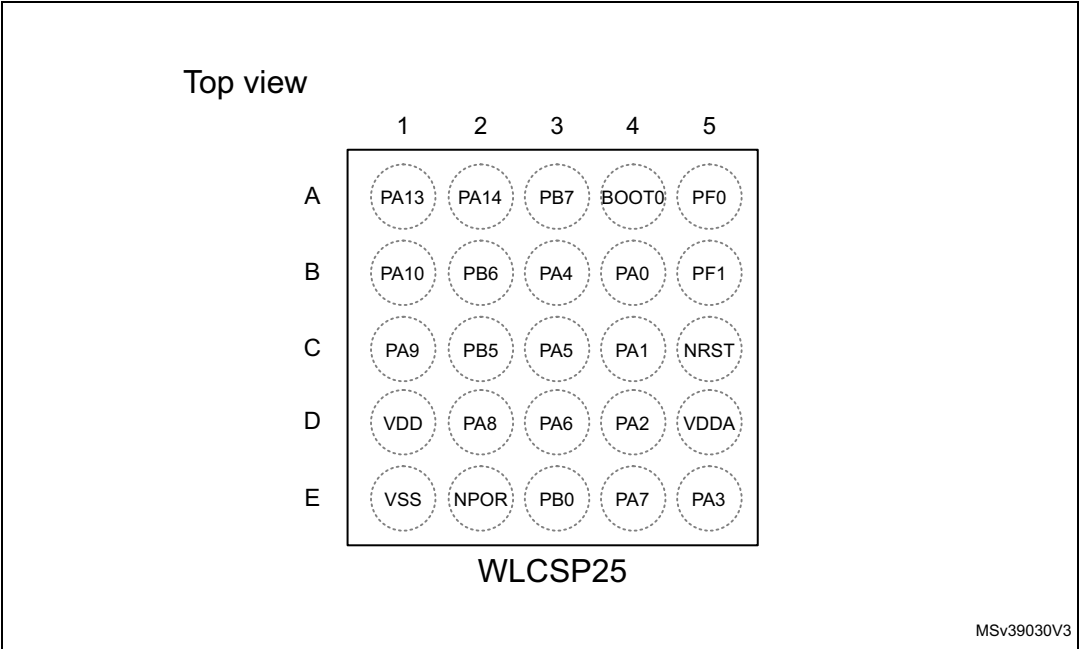


Figure 6. WLCSP25 package pinout



1. The above figure shows the package in top view, changing from bottom view in the previous document versions.

Figure 7. TSSOP20 package pinout

