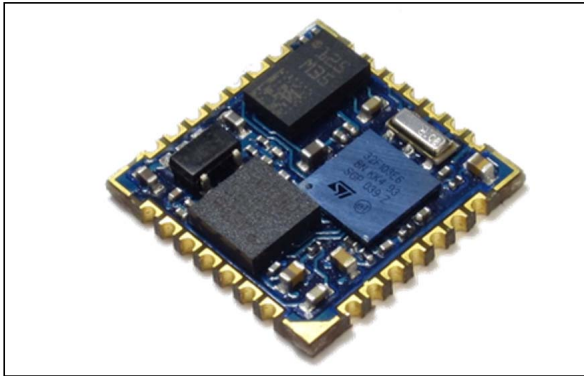


**iNEMO system-on-board**

Datasheet - production data

**Features**

- Two power supply options: internal regulator ( $V_{in}$ : 3.6 V to 6 V), external regulated voltage ( $V_{in}$ : 2.4 V to 3.6 V)
- STM32F103REY6: WLCSP package, high-density performance line ARM<sup>®</sup>-based 32-bit MCU
- LSM303DLHC: 6-axis digital e-compass module,  $\pm 2g$ ,  $\pm 4g$ ,  $\pm 8g$ ,  $\pm 16g$  linear acceleration programmable full scale, from  $\pm 1.3$  gauss to  $\pm 8.1$  gauss, I<sup>2</sup>C digital output
- L3GD20: 3-axis digital gyroscope (roll, pitch, yaw), 16-bit data output,  $\pm 250^{\circ}/s$ ,  $\pm 500^{\circ}/s$ ,  $\pm 2000^{\circ}/s$  selectable full scale
- LDS3985M33R: ultra-low drop, low-noise BiCMOS 300 mA onboard voltage regulator.
- Flexible interfaces: CAN, USART, SPI and I<sup>2</sup>C serial interfaces; full-speed USB 2.0
- Up to 8 ADC channels for external analog inputs
- Low-power modes
- In-system ceramic resonator
- In-application programming interfaces for firmware upgrading
- Compact design: 13 x 13 x 2 mm
- Surface-mount device (SMD) module

**Applications**

- Robotics and industrial automated systems
- Body motion reconstruction, rehabilitation, virtual reality and gaming
- Personal navigation devices and location-based services
- Wearable sensors for healthcare, fitness, sports training and analysis

**Description**

The INEMO-M1 is the first 9-axis motion sensing system-on-board (SoB) of the iNEMO module family.

It integrates multiple MEMS sensors from ST and a powerful computational core: a 6-axis digital e-compass, a 3-axis digital gyroscope and an ARM<sup>®</sup> Cortex<sup>™</sup>-M3 32-bit MCU.

This 9-DoF inertial system represents a fully integrated solution that can be used in a broad variety of applications such as robotics, personal navigation, gaming and wearable sensors for healthcare, sports and fitness.

A complete set of communication interfaces and motion-sensing capabilities in a very small size form factor (13x13x2 mm) and the possibility to embed ST's sensor fusion software make the INEMO-M1 system-on-board a flexible solution for high-performance, effortless orientation estimation and motion-tracking applications.

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# 1 Introduction

The INEMO-M1 is a 9-degrees-of-freedom system-on-board (SoB), combining the latest advances in ST MEMS-based technology with the powerful computational core of the STM32 family. The INEMO-M1 platform has been designed to target miniaturization, flexibility, low power consumption and cost effectiveness to provide a high-performance and versatile module suitable for a wide range of applications.

INEMO-M1 embeds the 6-axis digital e-compass module LSM303DLHC, the 3-axis digital gyroscope L3GD20 and the STM32F103REY6 high-density performance line ARM-based 32-bit microcontroller.

The INEMO-M1 exploits the wide set of peripherals supported by the STM32F103REY6 in order to offer maximum flexibility in communication. Thanks to this wide set of communication peripherals and its extremely reduced dimensions, the INEMO-M1 can be directly integrated into a large variety of advanced motion-sensing platforms allowing a simplification of the platform itself and increasing performance by distributing system intelligence.

The INEMO-M1 may be used in combination with ST's leading edge sensor fusion software to seamlessly implement high-performance 9-degrees-of-freedom applications

The INEMO-M1 can operate with an externally regulated power supply in the range of 2.4 V - 3.6 V or, by using the onboard LDS3985M33R voltage regulator, it could be supplied by an external voltage in the range of 3.6 up to 6 V.

For more information and detailed specifications of ST's inertial sensors integrated on INEMO-M1 (L3GD20 and LSM303DLHC), please refer to the datasheet of each device and the specific technical documentation available on the STMicroelectronics website at [www.st.com](http://www.st.com).

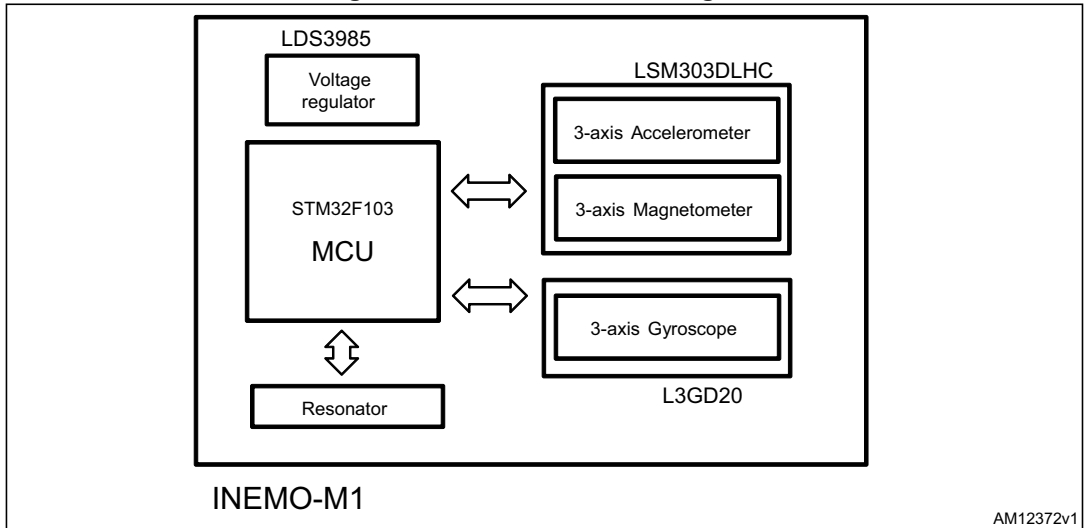
For more information and detailed specifications of the STM32F103xx high-density performance line microcontroller used on INEMO-M1, please refer to the datasheet of the device, reference manual and specific documentation available on the STMicroelectronics website at [www.st.com](http://www.st.com).

For information on programming, erasing and protection of the internal Flash memory, please refer to the STM32F103xx Flash programming manual available from the STMicroelectronics website at [www.st.com](http://www.st.com).

## 2 Block diagram and pin description

### 2.1 Block diagram

Figure 1. Functional block diagram



### 2.2 Pin description

Figure 2. Pin description by layout

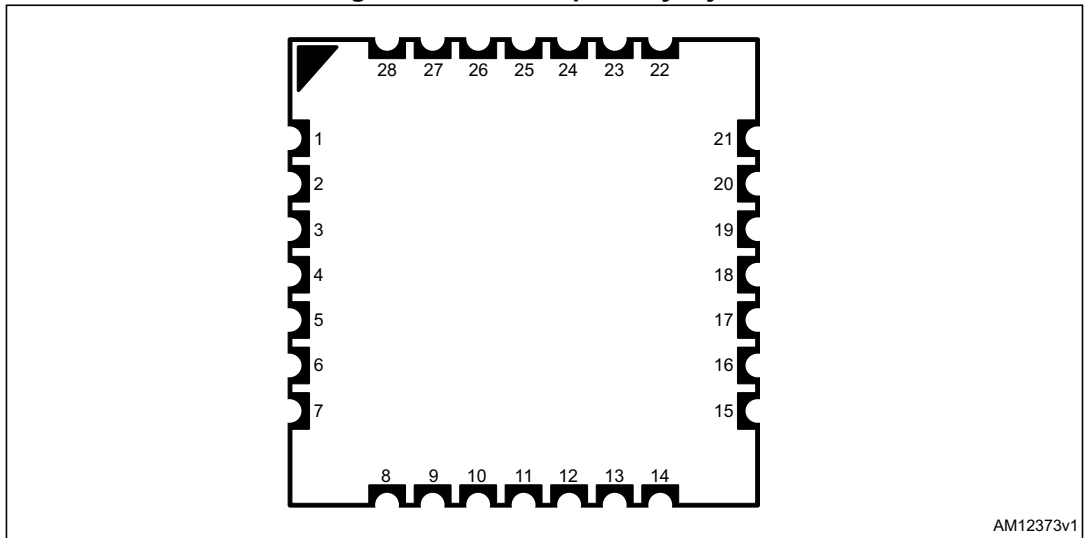


Table 1. Pin description

Pin#	Main function (after reset)	Basic function	Remap	MCU pin name	Type (1) (2)	I/O level(3)
1	VDD (2.4 – 3.6 V) <sup>(4)</sup>			-	S	
2	BOOT0			BOOT0	I	
3	nRESET			NRST	I	
4	GPIO_PA3	USART2_RX / TIM5_CH4 / ADC123_IN3 / TIM2_CH4		PA3	I/O	
5	GPIO_PA2	USART2_TX / TIM5_CH3 / ADC123_IN2 / TIM2_CH3		PA2	I/O	
6	GND			-	S	
7	GPIO_PA0	WKUP / USART2_CTS / ADC123_IN0 / TIM2_CH1_ETR / TIM5_CH1 / TIM8_ETR		PA0-WKUP	I/O	
8	GPIO_PA11	USART1_CTS / USBDM / CAN_RX / TIM1_CH4		PA11	I/O	FT
9	GPIO_PA12	USART1_RTS / USBDP / CAN_TX / TIM1_ETR		PA12	I/O	FT
10	GPIO_PB6	I2C1_SCL / TIM4_CH1	USART1_TX	PB6	I/O	FT
11	GPIO_PB7	I2C1_SDA / TIM4_CH2	USART1_RX	PB7	I/O	FT
12	GPIO_PB9	TIM4_CH4	I2C1_SDA / CAN_TX	PB9	I/O	FT
13	GPIO_PB8	TIM4_CH3	I2C1_SCL / CAN_RX	PB8	I/O	FT
14	GND			-	S	
15	GND			-	S	
16	GPIO_PA10	USART1_RX / TIM1_CH3		PA10	I/O	FT
17	JTDO <sup>(5)</sup>	JTDO	PB3 / TRACESWO / TIM2_CH2 / SPI1_SCK	PB3	I/O	FT
18	GPIO_PA9	USART1_TX / TIM1_CH2		PA9	I/O	FT
19	JTMS <sup>(5)</sup>	JTMS-SWDIO	GPIO_PA13	PA13	I/O	FT
20	JTCK <sup>(5)</sup>	JTCK-SWCLK	GPIO_PA14	PA14	I/O	FT
21	VEXT (3.6 – 6 V) <sup>(6)</sup>			-	S	
22	GPIO_PA4	SPI1_NSS / USART2_CK / DAC_OUT1 / ADC12_IN4		PA4	I/O	
23	GPIO_PA5	SPI1_SCK / DAC_OUT2 / ADC12_IN5		PA5	I/O	
24	GPIO_PA6	SPI1_MISO / TIM8_BKIN / ADC12_IN6 / TIM3_CH1	TIM1_BKIN	PA6	I/O	



Table 1. Pin description (continued)

Pin#	Main function (after reset)	Basic function	Remap	MCU pin name	Type (1) (2)	I/O level(3)
25	GPIO_PA7	SPI1_MOSI / TIM8_CH1N / ADC12_IN7 / TIM3_CH2	TIM1_CH1N	PA7	I/O	
26	GPIO_PA1	USART2_RTS / ADC123_IN1 / TIM5_CH2 / TIM2_CH2		PA1	I/O	
27	VDD (2.4 – 3.6 V) <sup>(1)</sup>			-	S	
28	GND			-	S	

1. I = input, O = output, S = supply.
2. All the pins of the INEMO-M1 module indicated as I=input or O=output or I/O=input/output are directly connected to the pins of the onboard STM32F103REY6 microcontroller. For these pins apply the electrical specifications, absolute maximum rating, functionalities and notes described in the datasheet of the STM32F103RE available on [www.st.com](http://www.st.com)
3. FT = 5 V tolerant. For more details on 5 V tolerant pins, please refer to the STM32F103RE datasheet.
4. When using an externally regulated supply voltage, these pins are input supply pins, with voltage in the range 2.4 to 3.6 V. When using the internal voltage regulator, these pins are @3.3 V (output) and can be used to supply other ICs.
5. The JTAG interface is not available on INEMO-M1. The available debugging interface is the SWD. The pins of the JTAG interface can be reconfigured via software to the alternate functions
6. When using an externally regulated supply voltage, this pin shall be left floating. When using the internal voltage regulator, this pin is used as supply input in the range 3.6 V- 6 V

For more and specific details on pin functionalities of the embedded STM32F103RE, please refer to technical documentation available on [www.st.com](http://www.st.com).

## 3 Electrical characteristics

### 3.1 Absolute maximum rating

Stresses above the absolute maximum ratings listed in [Table 2](#) may cause permanent damage to the device. These are stress ratings only and functional operation of the device at these conditions is not implied. Exposure to maximum rating conditions for extended periods may affect device reliability.

**Table 2. Absolute maximum rating**

Symbol	Parameter	Test condition / comments	Min.	Max.	Unit
VDD	Supply voltage (input)	Using externally regulated supply voltage	-0.3	4	V
VEXT	Supply voltage (input)	Using internal voltage regulator	-0.3	6	V
V <sub>IN</sub>	Input voltage on digital I/O	On 5 V tolerant pins <sup>(1)</sup>	-0.3	5.5	V
		On any other pin	-0.3	VDD+0.3	V
T <sub>STG</sub>	Storage temperature range		-40	+85	°C
T <sub>OP</sub>	Operating temperature range		-40	+85	°C

1. Please refer to [Table 1](#) for the list of 5 V tolerant pins and to the STM32F103RE datasheet for more details on 5 V tolerant pins.

## 3.2 General operating conditions

**Table 3. General operating conditions**

Symbol	Parameter	Test condition / comments	Min.	Typ. <sup>(1)</sup>	Max.	Unit
VDD	Supply voltage (input)	Using externally regulated supply voltage	2.4	3.3	3.6	V
	Supply voltage (output)	Using internal voltage regulator		3.3		V
VEXT		Using externally regulated supply voltage <sup>(2)</sup>		-		
	Supply voltage (input)	Using internal voltage regulator	3.6	5	6	V
I <sub>dd</sub>	Supply current in run mode <sup>(3)</sup>	Using externally regulated supply voltage (VDD = 3.3 V)		46.20		mA
		Using internal voltage regulator (VEXT = 4.2 V)		46.30		mA
I <sub>ddSL</sub>	Supply current in stop mode <sup>(4)</sup>	Using externally regulated supply voltage (VDD = 3.3 V)		0.22		mA
		Using internal voltage regulator (VEXT = 4.2 V)		0.30		mA
I <sub>out</sub>	Output current <sup>(5)</sup>	Maximum output current from internal LDO			300	mA
OSC	In-system embedded resonator			8		MHz
T <sub>OP</sub>	Operating temperature range		-40		+85	°C

1. Typical specifications are not guaranteed.
2. In this condition VEXT shall be left floating.
3. MCU clock @72 MHz, code running from Flash, sensor data acquisition @50 Hz, and USB transmission.
4. MCU in stop mode, sensors in power-down mode
5. The total current, including the onboard ICs (MCU, sensors, etc...) and the possible external loads, shall not exceed the specified limit under any circumstance. This limit has to be carefully adjusted, taking into account the power dissipation constraints of the onboard LDS3985M33R voltage regulator IC specified in its datasheet available on [www.st.com](http://www.st.com).

Table 4. I/O operating characteristics

Symbol	Parameter	Test condition/ comments	Min.	Max.	Unit
$V_{IL}$	Input low-level voltage <sup>(1)</sup>	TTL ports <sup>(2)</sup>	-0.5	0.8	V
$V_{IH}$	Standard IO input high-level voltage <sup>(1)</sup>		2	$V_{DD}^{(3)}+0.5$	V
	IO FT <sup>(4)</sup> input high-level voltage <sup>(1)</sup>		2	5.5	V
$V_{IL}$	Input low-level voltage <sup>(1)</sup>	CMOS ports <sup>(2)</sup>	-0.5	$0.35 V_{DD}^{(3)}$	V
$V_{IH}$	Input high-level voltage <sup>(1)</sup>		$0.65 V_{DD}^{(3)}$	$V_{DD}^{(3)}+0.5$	
$V_{OL}$	Output low-level voltage <sup>(1)</sup>	TTL ports <sup>(2)(5)</sup>	-	0.4	V
$V_{OH}$	Output high-level voltage <sup>(1)</sup>		$V_{DD}^{(3)}-0.4$		V
$V_{OL}$	Output low-level voltage <sup>(1)</sup>	CMOS ports <sup>(2)(5)</sup>		0.4	V
$V_{OH}$	Output high-level voltage <sup>(1)</sup>		2.4		V

- As detailed in [Table 1](#), the INEMO-M1 I/Os are directly connected to the onboard STM32F103RE pins. The details and notes on the I/O electrical specifications and on I/O absolute maximum ratings, which are described in the datasheet of the STM32F103RE available on [www.st.com](http://www.st.com), apply to the INEMO-M1 I/Os.
- All I/Os are CMOS and TTL compliant (no software configuration required), their characteristics consider the most strict CMOS or TTL parameters. Refer to STM32F103RE datasheet for more details
- When using the onboard voltage regulator,  $V_{DD} = 3.3V$ . Using an external power supply,  $V_{DD}$  can be in the range 2.4 V - 3.6 V.
- FT = 5 V tolerant voltage. Refer to [Table 1](#) for the list of 5 V tolerant pins and to the STM32F103RE datasheet for more details on 5 V tolerant pins.
- $I_{IO}=+8mA$ .  $2.7 < V_{DD} < 3.6 V$ . Max 8 pins sourced/sunk at same time. Please refer to the STM32F103RE datasheet for more details

**Table 5. LSM303DLHC e-compass module mechanical and electrical characteristics  
@ Vdd = 3.3 V, T = 25 °C**

Symbol	Parameter	Test condition	Min.	Typ. <sup>(1)</sup>	Max.	Unit
LA_FS	Linear acceleration measurement range <sup>(2)</sup>	FS user-selectable		±2 / ±4 / ±8 / ±16		g
M_FS	Magnetic measurement range	GN user-selectable		±1.3 / ±1.9 / ±2.5 / ±4.0 / ±4.7 / ±5.6 / ±8.1		gauss
LA_So	Linear acceleration sensitivity	FS = ±2 g		1		mg/LSB
		FS = ±4 g		2		
		FS = ±8 g		4		
		FS = ±16 g		12		
M_GN	Magnetic gain setting	GN = ±1.3 Gauss (X, Y)		1100		LSB/ Gauss
		GN = ±1.3 Gauss <sup>(2)</sup> (Z)		980		
		GN = ±1.9 Gauss <sup>(2)</sup> (X, Y)		855		
		GN = ±1.9 Gauss <sup>(2)</sup> (Z)		760		
		GN = ±2.5 Gauss <sup>(2)</sup> (X, Y)		670		
		GN = ±2.5 Gauss <sup>(2)</sup> (Z)		600		
		GN = ±4.0 Gauss <sup>(2)</sup> (X, Y)		450		
		GN = ±4.0 Gauss <sup>(2)</sup> (Z)		400		
		GN = ±4.7 Gauss <sup>(2)</sup> (X, Y)		400		
		GN = ±4.7 Gauss <sup>(2)</sup> (Z)		355		
		GN = ±5.6 Gauss <sup>(2)</sup> (X, Y)		330		
		GN = ±5.6 Gauss <sup>(2)</sup> (Z)		295		
		GN = ±8.1 Gauss <sup>(2)</sup> (X, Y)		230		
		GN = ±8.1 Gauss <sup>(2)</sup> (Z)		205		
LA_TCSO	Linear acceleration sensitivity change vs. temperature	FS = ±2 g		±0.01		%/°C
LA_TyOff	Linear acceleration typical Zero-g level offset accuracy	FS = ±2 g		±60		mg
LA_TCOff	Linear acceleration Zero-g level change vs. temperature	Max. delta from 25 °C		±0.5		mg/°C
LA_An	Acceleration noise density	FS bit set to ±2 g, normal operating mode, ODR bit set to 1.344 kHz		220		μg/ sqrt (Hz)
M_R	Magnetic resolution			2		mgauss

**Table 5. LSM303DLHC e-compass module mechanical and electrical characteristics @ Vdd = 3.3 V, T = 25 °C (continued)**

Symbol	Parameter	Test condition	Min.	Typ. <sup>(1)</sup>	Max.	Unit
M_EF	Maximum exposed field	No permanent effect on zero reading			10000	Gauss
M_DF	Disturbance field	Sensitivity starts to degrade. Automatic S/R pulse restores sensitivity <sup>(3)</sup>			20	Gauss
ODR_Acc	Accelerometer digital output data rate	Normal mode		1 / 10 / 25 / 50 / 100 / 200 / 400 / 1344		Hz
		Low-power mode		1 / 10 / 25 / 50 / 100 / 200 / 400 / 1620 / 5376		
ODR_Mag	Magnetometer digital output data rate			0.75 / 1.5 / 3 / 7.5 / 15 / 30 / 75 / 220		Hz

1. Typical specifications are not guaranteed.
2. Verified by wafer level test and measurement of initial offset and sensitivity.
3. Set/Reset pulse is automatically applied at each conversion cycle.

Table 6. L3GD20 gyroscope mechanical and electrical characteristics @ Vdd = 3.3 V, T = 25 °C

Symbol	Parameter	Test condition	Min.	Typ. <sup>(1)</sup>	Max.	Unit
FS	Measurement range	User-selectable		±250		dps
				±500		
				±2000		
So	Sensitivity	FS = 250 dps		8.75		mdps/digit
		FS = 500 dps		17.50		
		FS = 2000 dps		70		
SoDr	Sensitivity change vs. temperature	From -40 °C to +85 °C		±2		%
DVoff	Digital zero-rate level	FS = 250 dps		±10		dps
		FS = 500 dps		±15		
		FS = 2000 dps		±75		
OffDr	Zero-rate level change vs. temperature	FS = 250 dps		±0.03		dps/°C
		FS = 2000 dps		±0.04		
NL	Non-linearity	Best-fit straight line		0.2		% FS
Rn	Rate noise density			0.03		dps/sqrt (Hz)
ODR	Digital output data rate			95 / 190 / 380 / 760		Hz

1. Typical specifications are not guaranteed.

For more detailed information concerning the electrical and mechanical characteristics of the embedded MCU (STM32F103REY6) and sensors (L3GD20 and LSM303DLHC), please refer to technical documentation available on [www.st.com](http://www.st.com).

## 4 Internal blocks

The main blocks of the INEMO-M1 include:

- High-density performance line ARM<sup>®</sup>-based 32-bit microcontroller STM32F103REY6
- 6-axis digital e-compass module LSM303DLHC
- 3-axis digital gyroscope L3GD20
- Voltage regulator LDS3985M33R

The following sections detail the description of each block.

For further details and information on the embedded MCU (STM32F103REY6) and sensors (L3GD20 and LSM303DLHC), the description of the registers and operating modes, please refer to the respective datasheet of the MCU and sensors and the technical documentation available on [www.st.com](http://www.st.com).

## 5 MCU

The STM32F103REY6 high-density performance line microcontroller is the computational core of the INEMO-M1 module: it operates as the system coordinator for the onboard sensors and the several communication interfaces.

Exploiting the features of the MCU, the INEMO-M1 offers a wide set of peripherals and functions such as 12-bit ADCs, DAC, general-purpose 16-bit timers plus PWM timers, I<sup>2</sup>C, SPI, I<sup>2</sup>S, USART, USB and CAN, that enable different operative conditions and several communication options, making the module a flexible solution for effortless orientation estimation and motion-tracking in embedded applications.

The following paragraphs describe the main features and peripherals supported by the STM32F103 microcontroller family and exploited by the INEMO-M1. More details on the STM32F103xx high-density performance line microcontroller family are provided in specific technical documents, such as datasheets or reference manuals, available from the STMicroelectronics website at [www.st.com](http://www.st.com).

### 5.1 ARM<sup>®</sup> Cortex<sup>™</sup>-M3 core with embedded Flash and SRAM

The INEMO-M1 STM32F103REY6 microcontroller has an ARM Cortex<sup>™</sup>-M3 processor core, the latest generation of ARM processors for embedded systems. With its 72 MHz maximum frequency, a 512-Kbyte embedded Flash and a 64-Kbyte SRAM accessed (read/write) at CPU clock speed with 0 wait states, it is suitable for storing programs and data.

The following table gives a short overview of the INEMO-M1 microcontroller characteristics.



**Table 7. INEMO-M1 microcontroller main characteristics**

Characteristics	Description
Max CPU frequency	72 MHz
Flash memory in Kbytes	512
SRAM in Kbytes	64
Package	WLCSP64

## 5.2 Clock

The INEMO-M1 embeds an 8 MHz resonator to provide the reference clock for the STM32F103REY6.

## 5.3 Reset

The reset signal of the INEMO-M1 STM32F103REY6 microcontroller is low-active and can be used to perform a system reset of the STM32F103REY6.

**Table 8. INEMO-M1 reset function**

Peripheral	INEMO-M1 function	INEMO-M1 pin number	STM32F103REY6 pin name	Description
Reset	nRESET	3	NRST	System reset

## 5.4 Wake-up

The wake-up feature can be implemented by the INEMO-M1 STM32F103REY6 microcontroller wake-up function.

**Table 9. INEMO-M1 wake-up function**

Peripheral	INEMO-M1 function	INEMO-M1 pin number	STM32F103REY6 pin name	Description
Wake-up	WKUP	7	PA0-WKUP	System wake-up

## 5.5 GPIOs

Most of the INEMO-M1 GPIO pins are shared with digital or analog alternate functions. So each of the 19 main functions can be also configured by software as general-purpose output (push-pull or open-drain), digital input (with or without pull-up or pull-down), or as alternate function output (push-pull or open-drain), or analog input.

## 5.6 Timers

The high-density STM32F103REY6 performance line microcontroller includes two advanced control timers (TIM1 and TIM8), four general-purpose timers (TIM2, TIM3, TIM4 and TIM5), two basic timers (TIM6 and TIM7), two watchdog timers and a SysTick timer.

On the INEMO-M1, 15 pins can be enabled for external timer functions, as described in [Table 1](#). These timers are based on a 16-bit auto-reload up/down counter, a 16-bit pre-scaler, and can be configured for input capture/output compare functionalities, PWM or one-pulse mode output.

## 5.7 SPI

The STM32F103REY6 microcontroller is equipped with an SPI interface able to communicate up to 18 Mbits/s in slave and master modes in full-duplex and simplex communication modes. The 3-bit pre-scaler gives 8 master mode frequencies and the frame is configurable to 8 bits or 16 bits.

All SPIs can be served by the DMA controller. There are 2 SPI peripherals available on the INEMO-M1: SPI1 has been assigned for enabling an external communication channel with remote devices using the same peripheral, while SPI2 has been set for enabling the internal communication with the onboard digital gyroscope L3GD20.

[Table 10](#) provides the pin description of the INEMO-M1 SPI peripherals.

**Table 10. INEMO\_M1 SPI pin description**

Peripheral	INEMO-M1 function	INEMO-M1 pin number	STM32F103REY6 pin name	Feature
SPI1	SPI1_CS	22	PA4	SPI for communication with external devices
	SPI1_SCK	23	PA5	
	SPI1_MISO	24	PA6	
	SPI1_MOSI	25	PA7	
SPI2	SPI2_CS	-	PB12	SPI for onboard communication with gyroscope
	SPI2_SCK	-	PB13	
	SPI2_MISO	-	PB14	
	SPI2_MOSI	-	PB15	

## 5.8 I<sup>2</sup>C

Two I<sup>2</sup>C bus interfaces can operate in master and slave modes on the STM32F103REY6 microcontroller. They can support standard and fast modes. Both can be served by DMA and they support SMBus 2.0/PMBus.

The INEMO-M1 exploits both I<sup>2</sup>C peripherals provided by the STM32F103REY6: I2C1 has been chosen for enabling the external communication and can be configured in two different sets of pins. In fact, it is available on INEMO-M1 pins 10 and 11, or can be remapped respectively on pins 13 and 12.

On the other hand, I2C2 has been selected for enabling the internal communication with the onboard digital e-compass module.

[Table 11](#) provides the pin description of the INEMO-M1 I<sup>2</sup>C peripherals.

**Table 11. INEMO-M1 I<sup>2</sup>C pin configuration**

Peripheral	INEMO-M1 function	INEMO-M1 pin number	STM32F103REY6 pin name	Feature
I2C1	I2C1_SCL	10	PB6	I <sup>2</sup> C for communication with external devices
	I2C1_SDA	11	PB7	
	I2C1_SCL (remapped)	13	PB8	
	I2C1_SDA (remapped)	12	PB9	
I2C2	I2C2_SCL	-	PB10	I <sup>2</sup> C for onboard communication with e-compass module
	I2C2_SDA	-	PB11	

## 5.9 USART

The STM32F103REY6 performance line family embeds three universal synchronous/asynchronous receiver transmitters (USART1, USART2 and USART3) and two universal asynchronous receiver transmitters (UART4 and UART5). The USART1 interface is able to communicate at speeds of up to 4.5 Mbit/s. The other available interfaces communicate at up to 2.25 Mbit/s. USART1, USART2 and USART3 also provide hardware management of the CTS and RTS signals. All interfaces can be served by the DMA controller except for UART5.

The INEMO-M1 module exploits the USART1 and the USART2 peripherals as in-application programming (IAP), application controller interfaces (ACI) or as simple communication standards.

The USART1 main functions (receiver and transmitter) can be dually configured on module pins 10 and 11 or 16 and 18, while USART1 CTS and RTS functions can be enabled on module pins 8 and 9. Alternatively, the USART1 configured on pins 16 and 18 can be used as serial interfaces for the in-application programming interface when using “system memory” boot configuration (refer to [Section 5.15: Boot modes](#)).

[Table 12](#) provides the pin description of the INEMO-M1 USART peripherals.

**Table 12. INEMO-M1 USART pin configuration**

Peripheral	INEMO-M1 function	INEMO-M1 pin number	STM32F103REY6 pin name	Feature
USART1	USART1_TX	18	PA9	USART1 for in-application programming or for external communication
	USART1_RX	16	PA10	
	USART1_TX (remapped)	10	PB6	USART1 for external communication
	USART1_RX (remapped)	11	PB7	
	USART1_CTS	8	PA11	
	USART1_RTS	9	PA12	
USART2	USART2_TX	5	PA2	USART2 for external communication
	USART2_RX	4	PA3	
	USART2_CTS	7	PA0	
	USART2_RTS	26	PA1	

## 5.10 CAN

The INEMO-M1 STM32F103REY6 is equipped with a CAN peripheral, compliant with specifications 2.0 A and B (active) with a bit rate up to 1 Mbit/s. It can receive and transmit standard frames with 11-bit identifiers as well as extended frames with 29-bit identifiers and has three transmit mailboxes, two receive FIFOs with 3 stages and 14 scalable filter banks.

The pin description of the INEMO-M1 CAN peripheral is given in [Table 13](#).

**Table 13. INEMO-M1 CAN pin configuration**

Peripheral	INEMO-M1 function	INEMO-M1 pin number	STM32F103REY6 pin name	Feature
CAN	CAN_TX	9	PA12	CAN for external communication
	CAN_RX	8	PA11	
	CAN_TX (remapped)	12	PB9	
	CAN_RX (remapped)	13	PB8	

## 5.11 USB

The STM32F103xE performance line family embeds a USB device peripheral compatible with the USB full-speed 12Mbit/s.

*Table 14* provides the pin description of the INEMO-M1 USB peripheral.

**Table 14. INEMO-M1 USB pin configuration**

Peripheral	INEMO-M1 function	INEMO-M1 pin number	STM32F103REY6 pin name	Feature
USB	USB_DM	8	PA11	USB for external communication
	USB_DP	9	PA12	

## 5.12 Analog to digital converter (ADC)

The INEMO-M1 provides three 12-bit analog-to-digital converters embedded in the STM32F103xE performance line devices for a total of 16 available external channels, performing conversions in single-shot or scan modes. In scan mode, automatic conversion is performed on a selected group of analog inputs. The ADCs can be served by the DMA controller.

The pin description of the INEMO-M1 ADC is given in *Table 15*.

**Table 15. INEMO-M1 ADC pin configuration**

Peripheral	INEMO-M1 function	INEMO-M1 pin number	STM32F103REY6 pin name	Feature
ADC	ADC123_IN0	7	PA0	ADC for external data acquisition
	ADC123_IN1	26	PA1	
	ADC123_IN2	5	PA2	
	ADC123_IN3	4	PA3	
	ADC12_IN4	22	PA4	
	ADC12_IN5	23	PA5	
	ADC12_IN6	24	PA6	
	ADC12_IN7	25	PA7	

## 5.13 Digital-to-analog converter (DAC)

The STM32F103REY6 available in the INEMO-M1 embeds two 12-bit digital-to-analog output (DAC) converters. The DAC can be configured in 8- or 12-bit mode and may be used in conjunction with the DMA controller. In 12-bit mode, the data may be left- or right-aligned. The DAC has two output channels, each with its own converter. In dual DAC channel mode, conversions may be done independently or simultaneously when both channels are grouped together for synchronous update operation.

The pins description of INEMO-M1 DAC is given in [Table 16](#).

**Table 16. INEMO-M1 DAC pin configuration**

Peripheral	INEMO-M1 function	INEMO-M1 pin number	STM32F103REY6 pin name	Feature
DAC	DAC_OUT1	22	PA4	DAC for external voltage output
	DAC_OUT2	23	PA5	

## 5.14 DMA

The two direct memory access (DMA) controllers have 12 channels in total (7 for DMA1 and 5 for DMA2), each dedicated to managing memory access requests from one or more peripherals.

The DMA feature can be used with the main peripherals previously described: SPI, I<sup>2</sup>C, USART, general-purpose, basic and advanced-control timers TIMx, ADC and DAC.

## 5.15 Boot modes

There are two main boot configuration modes for the INEMO-M1 STM32F103REY6 microcontroller: user Flash and system memory. These two options are selectable by the INEMO-M1 BOOT0 pin, as shown in [Table 17](#).

The embedded boot loader, located in the system memory, can be used to reprogram the Flash memory by using the USART1, through INEMO-M1 pins 16 and 18.

**Table 17. INEMO-M1 boot modes**

INEMO-M1 pin name	INEMO-M1 pin number	STM32F103REY6 pin name	Boot pin mode	Boot mode	Description
BOOT0	2	BOOT0	0	Main Flash memory	Main Flash memory is selected as boot space
			1	System memory	System memory is selected as boot space

## 5.16 Serial wire debug (SWD)

The ARM SWD interface is embedded in the INEMO-M1 STM32F103REY6 microcontroller and enables a serial wire debug probe to be connected to the target. The main pins configuring the SWD interface on the INEMO-M1 are shown in [Table 18](#) and an application hint on SWD is shown in [Figure 9](#).

**Table 18. INEMO-M1 SWD pin configuration**

Function	INEMO-M1 pin function	INEMO-M1 pin number	STM32F103REY6 pin name
SWD	SWO (optional)	17	PB3-TRACESWO (remapped)
	SWDIO	19	PA13-SWDIO
	SWCLK	20	PA14-SWCLK

## 5.17 Low-power modes

The INEMO-M1 STM32F103REY6 microcontroller supports three low-power modes to achieve the best compromise between low-power consumption, short startup time and available wake-up sources:

- Sleep mode
- Stop mode
- Standby mode

A comprehensive set of power-saving modes can be enabled in order to develop low-power applications.

# 6 Sensors

The INEMO-M1 embeds two sensors: the LSM303DLHC, 3-axis accelerometer and 3-axis magnetometer in one single package, and the 3-axis digital gyroscope L3GD20.

## 6.1 The LSM303DLHC e-compass module

The e-compass module LSM303DLHC is a system-in-package featuring a 3D digital linear acceleration sensor and a 3D digital magnetic sensor. The accelerometer has full scales of  $\pm 2g/\pm 4g/\pm 8g/\pm 16g$  and the magnetometer has full scales of  $\pm 1.3/\pm 1.9/\pm 2.5/\pm 4.0/\pm 4.7/\pm 5.6/\pm 8.1$  gauss. All full scales available are selectable by the user.

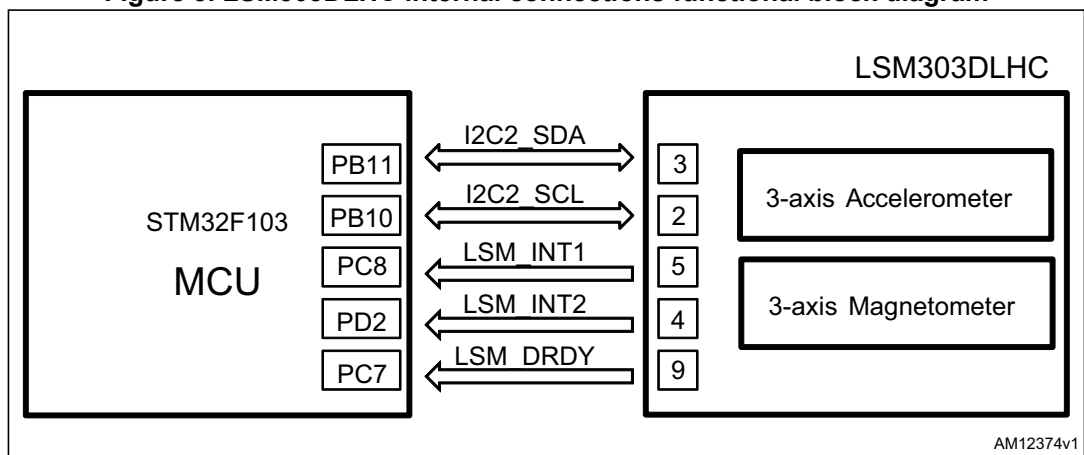
[Table 5](#) shows the main mechanical characteristics of the INEMO-M1 LSM303DLHC e-compass module.

As previously described in [Section 5.8](#), the e-compass module LSM303DLHC is connected to the STM32F103REY6 microcontroller via the I<sup>2</sup>C peripheral. Furthermore, the three independent programmable interrupts, enabling the sensor data-ready, the free-fall or the motion detection features, are respectively connected to three microcontroller GPIOs, as shown in [Table 19](#) and in [Figure 3](#).

Table 19. LSM303DLHC pin configuration

Peripheral/function	Peripheral/function tag	STM32F103REY6 GPIO name	LSM303DLHC pin number	Feature
I <sup>2</sup> C	I2C2_SCL	PB10	2	I <sup>2</sup> C for onboard communication with e-compass module
	I2C2_SDA	PB11	3	
Interrupt	LSM_INT1	PC8	5	Accelerometer data ready interrupt or inertial interrupt 1
	LSM_INT2	PD2	4	Inertial interrupt 2
	LSM_DRDY	PC7	9	Magnetometer data ready interrupt

Figure 3. LSM303DLHC internal connections functional block diagram



## 6.2 The L3GD20 digital gyroscope

The L3GD20 is a low-power digital gyroscope able to sense the angular rate on the three axes. It has a full scale of  $\pm 250$  /  $\pm 500$  /  $\pm 2000$  dps and is capable of measuring rates with several bandwidths, selectable by the user.

[Table 6](#) provides the main mechanical characteristics of the INEMO-M1 L3GD20 gyroscope.

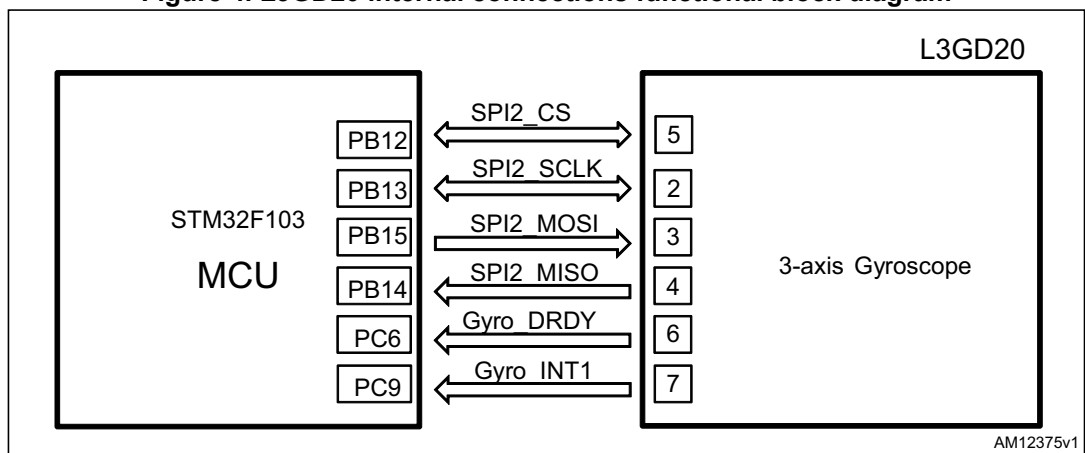
As previously described in [Section 5.7](#), the 3-axis digital gyroscope L3GD20 is connected to the STM32F103REY6 microcontroller via the SPI peripheral. Moreover, the two independent programmable interrupts, enabling the sensor data ready or FIFO interrupt, are connected to two microcontroller GPIOs, as shown in [Table 20](#) and in [Figure 4](#).



Table 20. L3GD20 pin configuration

Peripheral/ function	Peripheral/ function tag	STM32F103REY6 GPIO name	L3GD20 pin number	Feature
SPI	SPI2_CS	PB12	5	SPI for onboard communication with gyroscope
	SPI2_SCK	PB13	2	
	SPI2_MISO	PB14	4	
	SPI2_MOSI	PB15	3	
Interrupt	Gyro_INT1	PC9	7	Programmable interrupt
	Gyro_DRDY	PC6	6	Data ready / FIFO interrupt

Figure 4. L3GD20 internal connections functional block diagram



## 7 Voltage regulator

The INEMO-M1 embeds the ultra-low drop, low-noise voltage regulator LDS3985M33R, able to provide up to 300 mA, from 3.6 V to 6 V input voltage, with an output voltage equal to 3.3 V.

Thanks to its low drop voltage, low quiescent current and low noise characteristics, the LDS3985M33R makes the INEMO-M1 suitable for low-power applications and battery-operated systems.

When using the onboard regulator, the input voltage is applied on INEMO-M1 pin 21 (VEXT), and the output voltage (3.3 V) is available on INEMO-M1 pins 1 and 27, through which it is possible to supply other ICs, as shown in [Figure 5](#). In this case, the INEMO-M1 works at 3.3 V.

*Note: The total current, including the onboard ICs (MCU, sensors) and external loads and ICs, if any, shall not exceed 300 mA. This limit has to be adjusted, taking into account the power dissipation constraint of the LDS3985M33R voltage regulator detailed in its datasheet.*

When the INEMO-M1 is supplied with an externally regulated voltage (in the range 2.4 V to 3.6 V), INEMO-M1 pin 27 (VEXT) shall be left floating, as shown in [Figure 6](#).

## 8 INEMO-M1 application hints

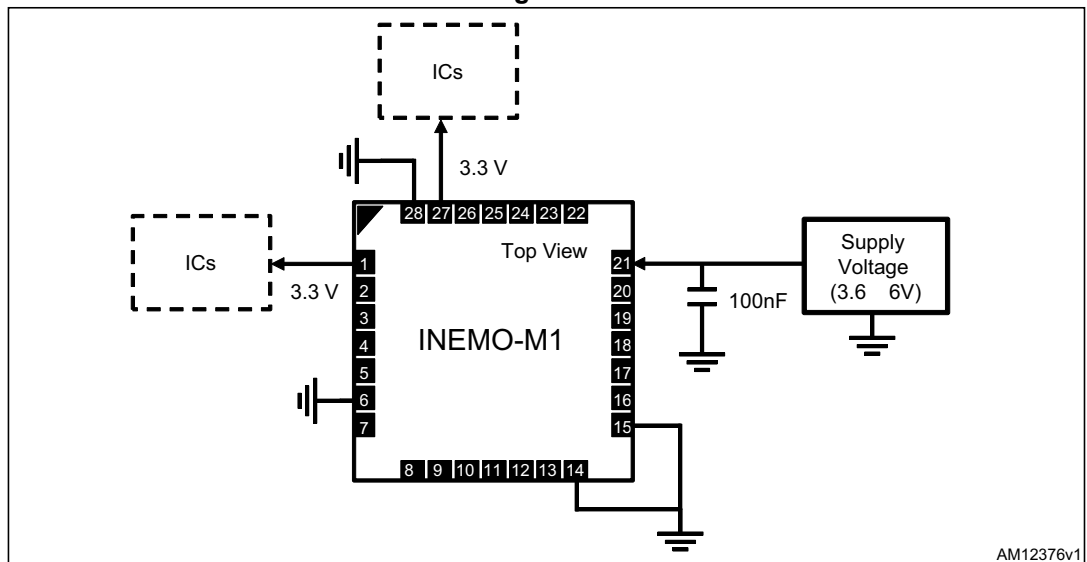
### 8.1 Power supply application hint

#### 8.1.1 Case: internal regulator

When using the internal regulator, a supply voltage is applied to pin 21 (VEXT) in the range 3.6 to 6 V, as shown in [Figure 5](#). In this case, the INEMO-M1 works @3.3 V.

Pins 1 and 27, can be used to supply other ICs @3.3 V. Make sure the total current consumption (including also the current consumption for the onboard ICs) does not exceed 300 mA, and also be careful of the limit in power dissipation of the voltage regulator when supplying other ICs.

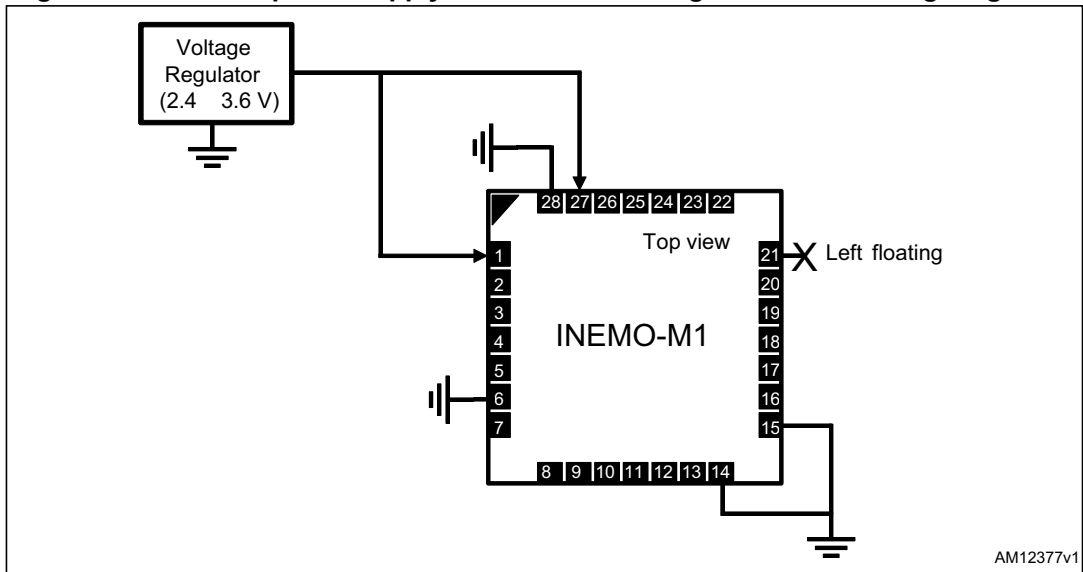
**Figure 5. INEMO-M1 power supply scheme when using the embedded voltage regulator**



#### 8.1.2 Case: external regulator

When using an external regulator to supply the INEMO-M1, the voltage is applied to pins 1 and 27, as shown in [Figure 6](#), and pin 21 must be left floating. The voltage range is between 2.4 V and 3.6 V.

Figure 6. INEMO-M1 power supply scheme when using an external voltage regulator



## 8.2 Boot modes application hint

As already indicated in [Table 17](#), to boot from main Flash memory, pin 2 (BOOT0) must be tied to ground through a 10 kΩ pull-down resistor, as shown in [Figure 7](#).

To use the embedded boot loader located in the system memory, pin 2 must be tied to VDD through a 10 kΩ pull-up resistor, as shown in [Figure 8](#). In this case, pins 16 and 18 are used as serial interfaces to reprogram the Flash memory.

Figure 7. INEMO-M1 boot modes - boot from Flash

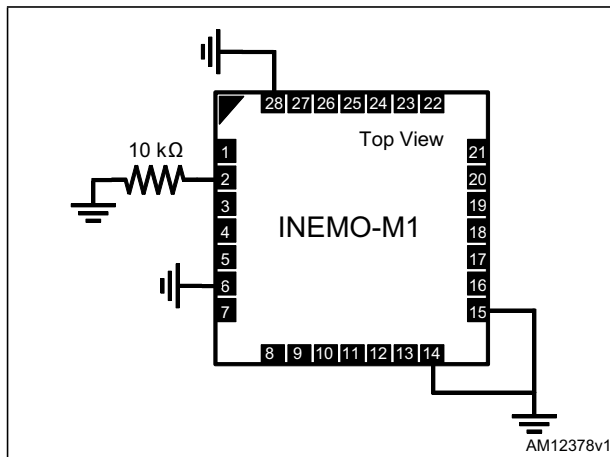
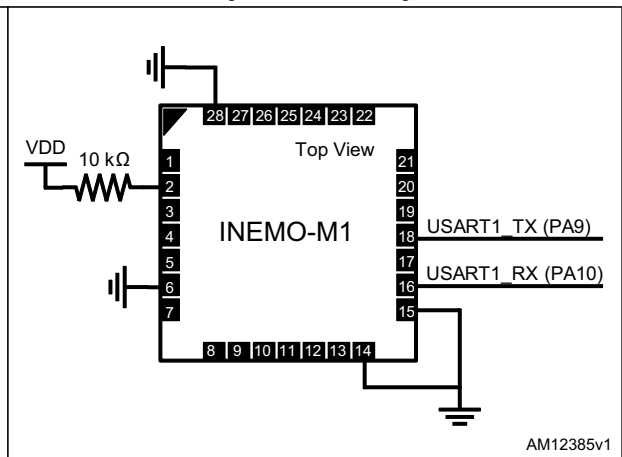


Figure 8. INEMO-M1 boot modes - boot from system memory

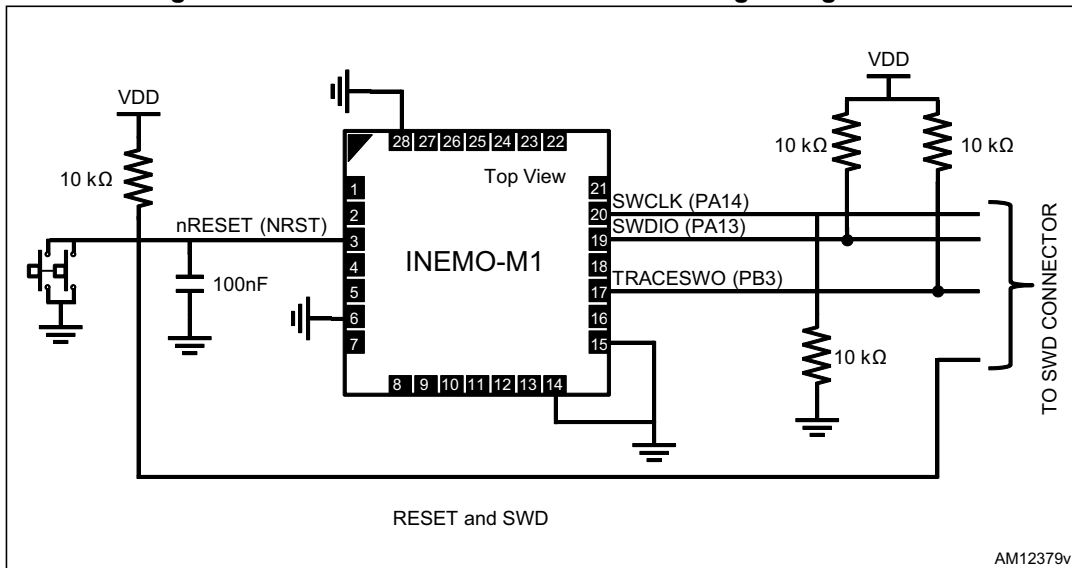


### 8.3 Reset and SWD application hint

The INEMO-M1 supports only the serial wire debug as the debugging and programming interface. *Figure 9* shows how to configure INEMO-M1 pins for SWD and reset functions.

VDD and GND are added to the SWD connector. As underlined in *Section 5.16*, the TRACESWO pin is optional.

**Figure 9. INEMO-M1 reset and serial wire debug configurations**



### 8.4 I<sup>2</sup>C application hint

As already mentioned in *Section 5.8*, the I2C1 peripheral can be used as a communication peripheral to connect external devices or platforms. To enable this feature, external pull-up resistors are required to support the I<sup>2</sup>C standard and fast speed modes.

As shown in *Figure 10*, the I2C1 peripheral is available on INEMO-M1 pins 10 and 11, or can be remapped to INEMO-M1 pins 12 and 13, as shown in *Figure 11*.

Figure 10. INEMO-M1 I2C1 standard configuration

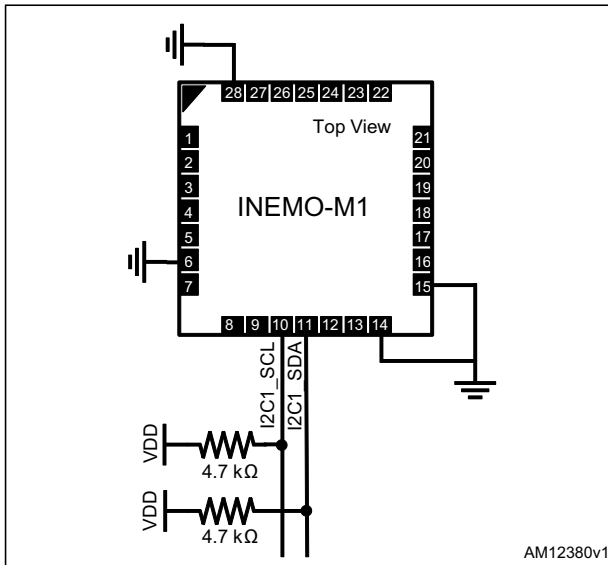
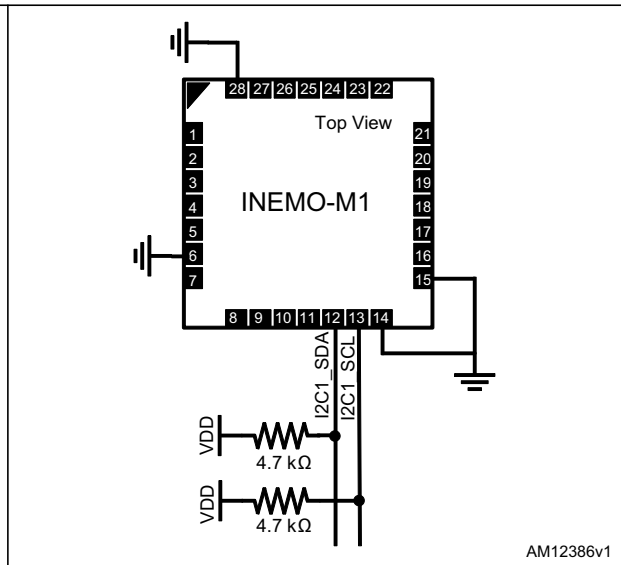


Figure 11. INEMO-M1 I2C1 configuration through remapping

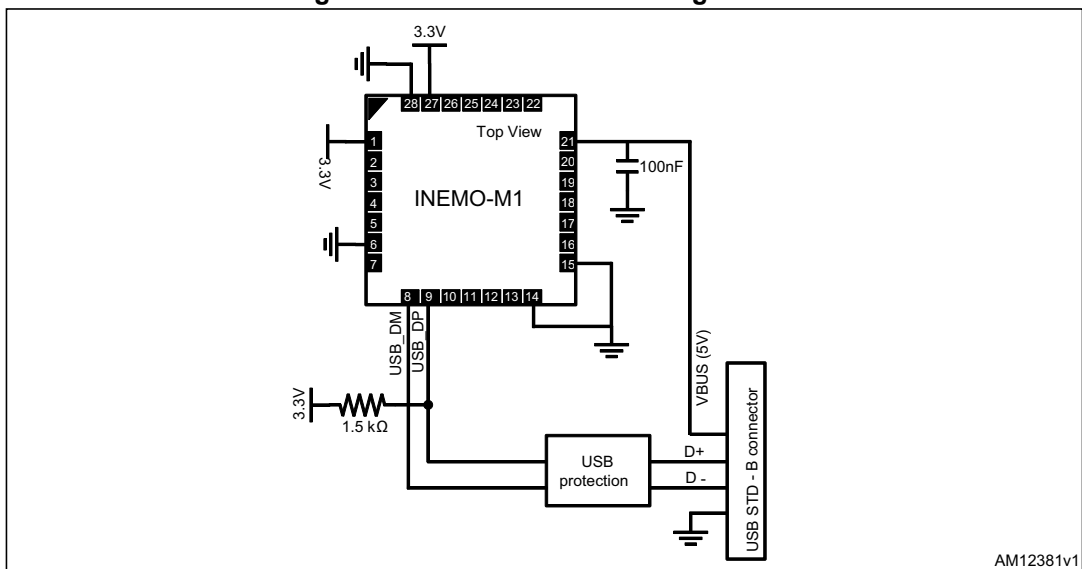


### 8.5 USB application hint

As already mentioned in [Section 5.11](#), the INEMO-M1 STM32F103REY6 embeds a USB device peripheral compatible with the USB full-speed 12 Mbit/s.

[Figure 12](#) shows how to configure, from a hardware point of view, the USB device peripheral in full-speed mode as the serial communication interface, using, in the meantime, the USB voltage as supply voltage.

Figure 12. INEMO-M1 USB configuration



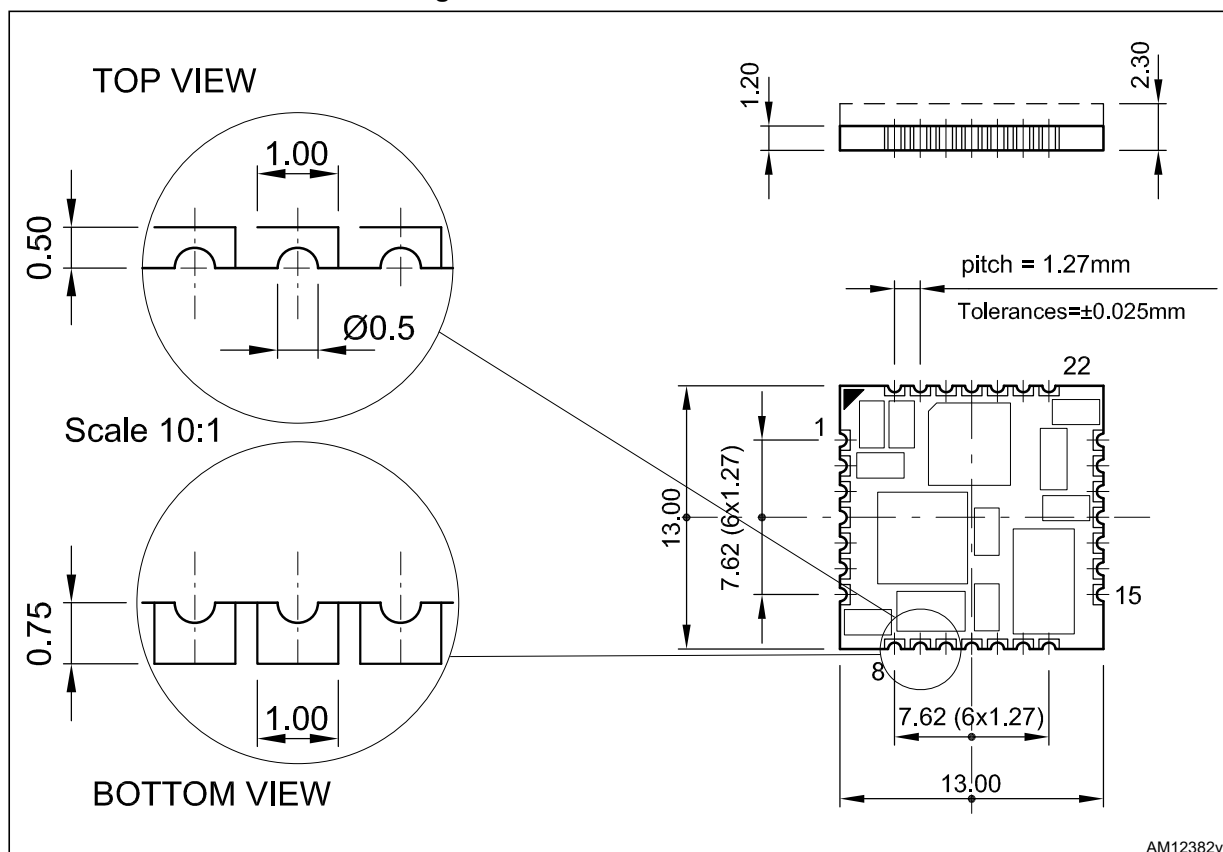
## 9 Package information

ST modules are compliant with ECOPACK<sup>®</sup> norms. ECOPACK<sup>®</sup> is an ST trademark.

### 9.1 INEMO-M1 mechanical data and package dimensions

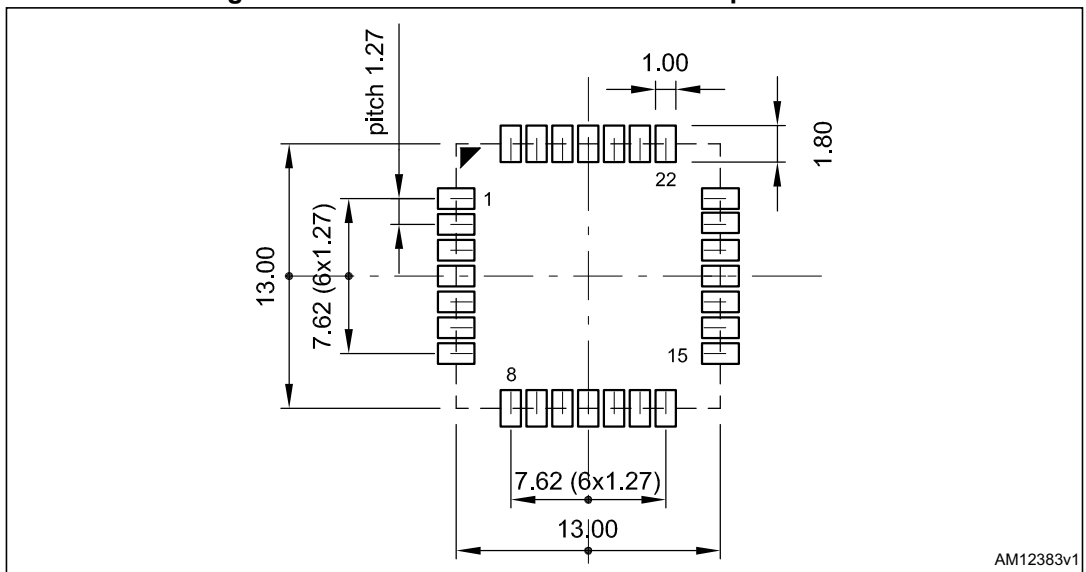
Mechanical dimensions in *Figure 13* and *Figure 14* are typical values<sup>(a)</sup>.

**Figure 13. INEMO-M1 mechanical dimensions**



a. Typical specifications are not guaranteed.

Figure 14. INEMO-M1 recommended land pattern view





# 10 Soldering information

The INEMO-M1 is a surface-mount module supplied on a 28-pin, 4-layer PCB. The final assembly recommended reflow profiles are indicated here below.

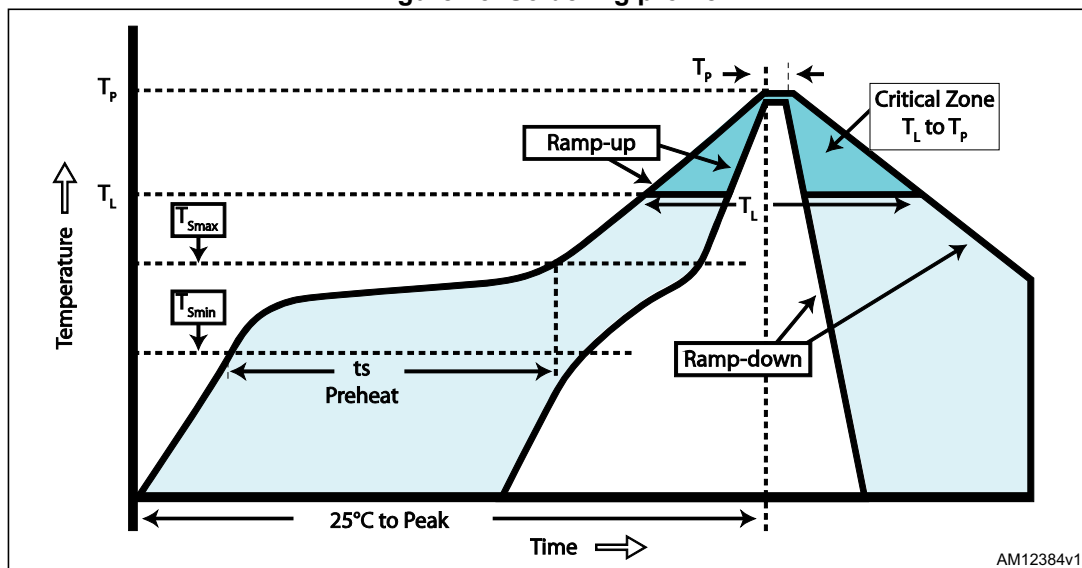
The soldering phase must be executed with care: in order to avoid undesired melting, particular attention must be paid to the setup of the peak temperature.

The following are some suggestions for the temperature profile based on IPC/JEDEC JSTD-020C, July 2004 recommendations.

**Table 21. Soldering**

Profile features	PB-free assembly
Average ramp-up rate ( $T_{Smax}$ to $T_P$ )	3 °C/sec max
Preheat: – Temperature min. ( $T_{Smin}$ ) – Temperature max. ( $T_{Smax}$ ) – Time ( $t_s$ min. to $t_s$ max.)( $t_s$ )	150 °C 200 °C 60-100 sec
Time maintained above: – Temperature $T_L$ – Temperature $T_L$	217 °C 60-70 sec
Peak temperature ( $T_P$ )	240 + 0 °C
Time within 5 °C of actual peak temperature ( $T_P$ )	10-20 sec
Ramp-down rate	6 °C/sec
Time from 25 °C to peak temperature	8 minutes max.

**Figure 15. Soldering profile**



AM12384v1

## 11 Ordering information

Table 22. Ordering information

Order code	Description
INEMO-M1	INEMO <sup>®</sup> M1 system-on-board

## 12 Revision history

Table 23. Document revision history

Date	Revision	Changes
24-Oct-2013	1	Initial release.

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