STSPIN32G4

Datasheet

High performance 3-phase motor controller with embedded STM32G4 MCU



VFQFPN 9x9x1.0 64L

Product status link

STSPIN32G4

Product label

SUSTAINABLE TECHNOLOGY

Features

- Motor supply voltage from 5.5 V to 75 V
- Three-phase gate drivers:
  - 1 A sink/source current capability
  - VDS monitoring of the power stage MOSFETs
  - Integrated bootstrap diodes
  - I2C accessible configuration and status registers for best application fit
  - Cross-conduction prevention
- STM32G431 microcontroller with 32-bit ARM® Cortex®-M4 MCU+FPU core:
  - Up to 170 MHz clock frequency
  - CORDIC mathematical hardware accelerator for trigonometric functions
  - 128 kB Flash memory with proprietary code readout protection (PCROP), securable memory area, 1 kB OTP
  - 32 kB SRAM memory with HW parity check
  - 2 x advanced times for motor control, 16-bit with up to 6 x PWM channels
  - 8 x general purpose timers
  - 2 x ADCs 12-bit resolution (up to 19 channels) with 4 Msps conversion rate
  - 4 x 12-bit DAC channels
  - 4 x ultra-fast rail-to-rail comparators
  - 3 x rail-to-rail operational amplifiers usable also in PGA mode
  - Internal high precision voltage reference
  - Up to 40 GPIOs
  - Full set of interfaces: I2C, SPI, UART and CAN
- Self-supplied thanks to embedded flexible power management
  - VCC buck converter up to 200 mA, with programmable output and embedded MOSFET
  - 3.3 V LDO linear regulator up to 150 mA
  - Low quiescent linear regulator for MCU supply during standby
- Full set of protection features: thermal shutdown, short-circuit, overload and UVLO
- Possibility to control 2 motors simultaneously from the same MCU
- Standby mode for reduced power consumption
- On-chip debug support via SWD or JTAG
- Extended temperature range: -40 to +125°C

Application

- Industrial and home automation
- Home appliances such as vacuum cleaners, dryers and cleaning robots
- Servo drives and e-bikes
- Service and automation robots
- Power and garden tools
- Pumps and fans
- Drones and aero modeling

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Description

The STSPIN32G4 is an extremely integrated and flexible motor controller for driving 3-phase brushless motors, helping designers to choose the most suitable driving mode and reduce PCB area and overall Bill Of Materials.

It embeds a triple half-bridge gate driver able to drive power MOSFETs with a current capability of 1 A (sink and source). Three bootstrap diodes are embedded as well. The high- and low-side switches of the same half-bridge cannot be simultaneously driven high thanks to an integrated interlocking function. An additional protection feature is represented by hardware VDS monitoring circuitry that constantly monitors each of the six external MOSFETs and in case an overvoltage is detected across one of them, switches off all gate driver outputs. The overvoltage threshold is set through a dedicated SCREF pin.

The device is fully self-supplied thanks to an integrated flexible power management structure able to generate all required supplies starting from the motor supply voltage, V_M; the only one to be provided from outside. An embedded programmable buck regulator, with embedded power MOSFET, generates the supply voltage for the gate drivers starting from the motor supply voltage V_M. Four different V_{CC} output values can be selected through a dedicated configuration register, 8 V (default value), 10 V, 12 V and 15 V.

An internal high precision low-drop linear regulator (LDO) is used to generate the 3.3 V supply (V_{REG3V3}) starting from the REGIN input voltage. The 3.3 V output voltage supplies both the gate driver logic and the microcontroller. It is protected against short-circuit, overload and undervoltage conditions.

Both the buck and LDO regulators can be bypassed providing externally V_{CC} and V_{REG3V3} supplies.

An additional very low-quiescent regulator is used when the STSPIN32G4 is in standby mode, allowing to reduce the overall current consumption down to 15 µA typical.

The integrated MCU (STM32G431VBx3) is based on the high-performance 32-bit ARM® Cortex®-M4 core, operating at a frequency up to 170 MHz and featuring a single-precision floating-point unit (FPU), full set of DSP (Digital Signal Processing) instructions and a memory protection unit (MPU), which enhances the application's security.

This microcontroller represents the mainstream choice for advanced motor control applications thanks to the very rich and specific set of features such as: two fast 12-bit ADCs (4 Msps), four comparators, three operational amplifiers, four DAC channels (2 external and 2 internal), an internal voltage reference buffer, one general-purpose 32-bit timer, two 16-bit PWM timers dedicated to motor control, seven general-purpose 16-bit timers, one 16-bit low-power timer.

It also embeds high-speed memories (128 kB of Flash memory, and 32 kB of SRAM) with several protection mechanisms, up to 40 available GPIOs, mathematical/ arithmetic function acceleration peripherals (CORDIC for trigonometric functions and FMAC unit for filter functions), main interfaces (I2C, SPI, UART and CAN), a comprehensive set of power-saving modes and an analog independent supply input for ADC, DAC, operational amplifiers and comparators.

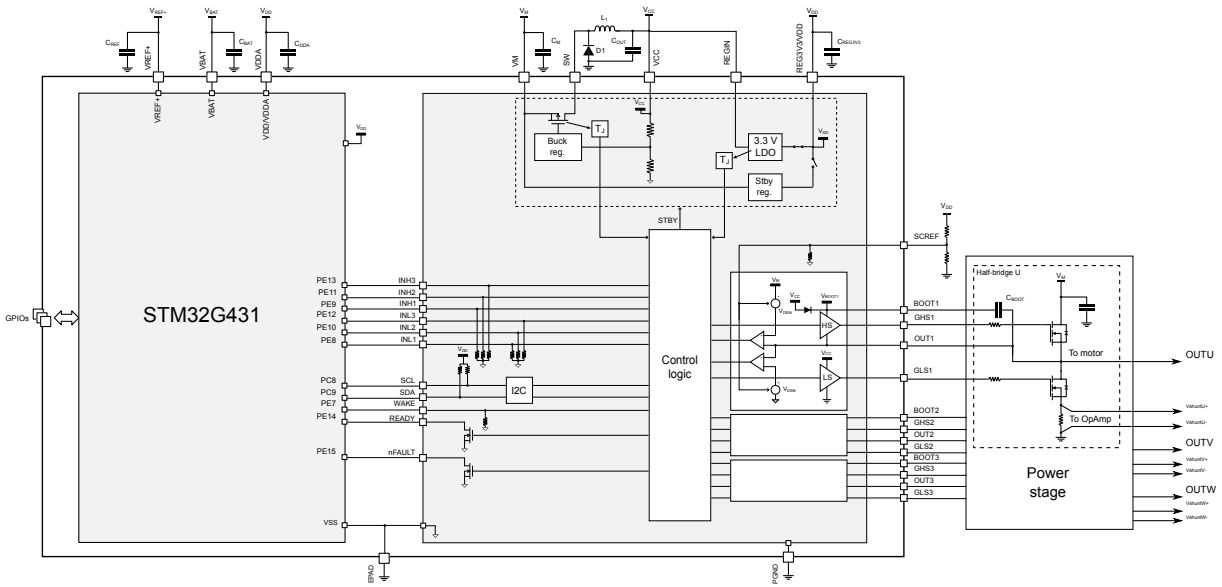
Such a feature rich microcontroller allows running very high-performance motor control algorithms offering unprecedented flexibility in choosing the best fitting control choice even for the most challenging motion control applications. Users can program the STSPIN32G4 to run sensorless or sensored Field Oriented Control (FOC) with one, two or three shunts, more advanced position or torque control algorithms or more traditional six-steps control mode.

The STSPIN32G4 also features the full set of protections and an extended temperature range (-40°C to +125°C), guaranteeing stable operation even in the most demanding industrial applications. Both SWD and JTAG interfaces are provided for microcontroller firmware programming and debugging.
Finally, with an additional external three-phase driver (such as the STDRIVE101) two independent 3-phase BLDC motors can be efficiently driven from the STSPIN32G4, offering an unprecedented BOM saving and application optimization.

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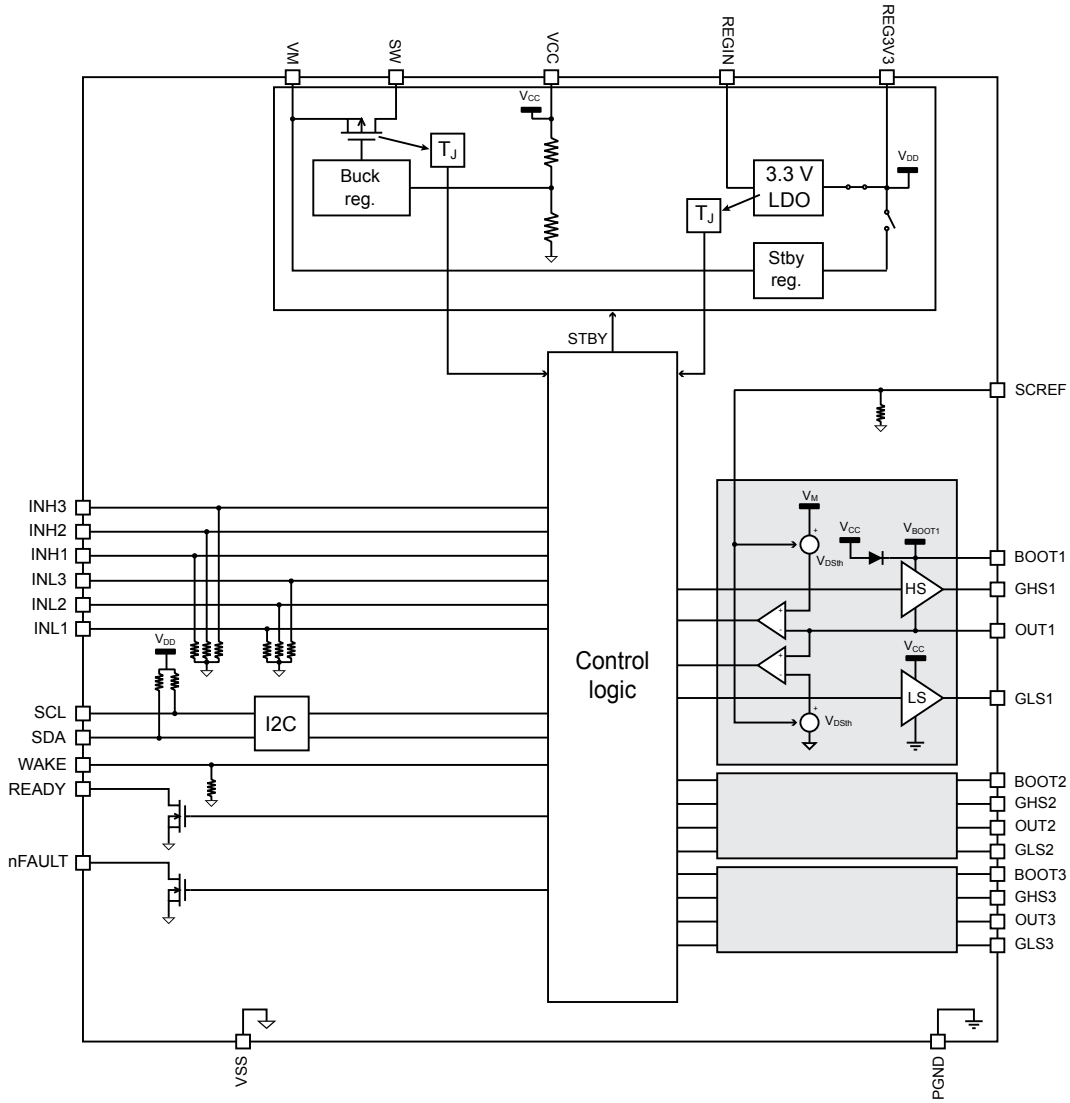
1 Block diagram

Figure 1. **STSPIN32G4 system-in-package block diagram**



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Figure 2. Gate driver IC block diagram



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2 Electrical data

2.1 Absolute maximum ratings

Stresses above the absolute maximum ratings listed in Table 1 may cause permanent damage to the device. Exposure to maximum rating conditions for extended periods may affect device reliability.

All voltages referred to ground pins unless otherwise specified.

Table 1. Absolute maximum ratings

Symbol	Parameter	Test Condition	Value	Unit
V_M	Motor supply voltage		-0.3 to 78	V
V_{CC}	Gate driving supply voltage		-0.3 to 20	V
V_{SW}	SW pin voltage		-2 to V_M	V
V_{REGIN}	3.3 V LDO linear regulator input		-0.3 to 20	V
V_{REG3V3}	Logic supply voltage		-0.3 to 3.6	V
$V_{REG3V3,drop}$	3.3 V linear regulator voltage drop	V_{REGIN} - V_{REG3V3}	-0.3 to 20	V
$P_{d,REG3V3}$	3.3 V LDO linear regulator power dissipation		Up to 1	W
V_{OUTx}	OUTx pins voltage		-2 to V_M + 2	V
V_{BOOTx}	Bootstrap pins voltage		-0.3 to 98	V
V_{BOx}	High-side driver supply voltage	V_{BOOTx} – V_{OUTx}	-0.3 to 20	V
V_{GHSx}	High-side gates voltage		V_{OUT}-0.3 to V_{BOOT}+0.3	V
V_{GLSx}	Low-side gates voltage		-0.3 to V_{CC}+0.3	V
dV_{OUT}/dt	Output slew rate		± 20	V/ns
V_{SCREF}	SCREF input		-0.3 to 3.6	V
V_{DD}, V_{DDA}, V_{BAT}	MCU main supply voltages(1)		-0.3 to 4.0	V
V_{IO}	MCU logic input voltage (1) (2)	FT_xxx pins except FT_c pins	V_{SS}-0.3 to min(V_{DD},V_{DDA}) + 4.0(3)	V
		FT_c pins	V_{SS}-0.3 to 5.5	V
		TT_xx pins and other pins	V_{SS}-0.3 to 4.0	V
I_{IO}	MCU I/O output current(1)		-20 to 20	mA
ΣI_{IO}	MCU I/O total output current(1) (4)		-100 to 100	mA
T_{STG}	Storage temperature		-55 to 150	°C
T_J	Junction temperature		-40 to 150	°C

1. *Refer to the Absolute maximum ratings section in the STM32G431VBx3 datasheet.*
2. *All main power (VDD, VDDA, VBAT) and ground (VSS, VSSA) pins must always be connected to the external power supply, in the permitted range.*
3. *To sustain a voltage higher than 4 V the internal pull-up/pull-down resistors must be disabled.*
4. *This current consumption must be correctly distributed over all I/Os and control pins.*

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2.2 Recommended operating conditions

All voltages referred to ground pins unless otherwise specified.

Table 2. Recommended operating conditions

Symbol	Parameter	Test Condition	Min.	Typ.	Max.	Unit
V_M	Supply voltage		5.5(1)		75	V
dV_M /dt	Supply voltage slope				10	V/ µs
V_{CC}	VCC Buck converter output and gate driving supply voltage	Internally generated, set to 8 V		8		V
		Internally generated, set to 10 V		10		V
		Internally generated, set to 12 V		12		V
		Internally generated, set to 15 V		15		V
		Externally provided	5.5(1)		15	V
I_{CC}	VCC Buck converter output current				200(2)	mA
V_{REGIN}	3.3 V LDO linear regulator input		3.3		15	V
V_{REG3V3}	Logic supply voltage			3.3		V
I_{REG3V3}	3.3 V linear regulator output current				150(2)	mA
$I_{REG3V3,Stby}$	Standby regulator output current	$V_M \geq 8V$			6	mA
V_{SCREF}	SCREF input	Protection enabled	0.2		2.5	V
		Protection disabled	2.9		3.3	V
V_{DDA}	MCU analog supply voltage	ADC or COMP used	1.62		3.6	V
		DAC 1 MSPS or DAC 15 MSPS	1.71		3.6	V
		Op-amp used	2.0		3.6	V
		VREFBUS used	2.4		3.6	V
		ADC, DAC, Op-amp, COMP, VREFBUF not used	0		3.6	V
V_{BAT}	MCU backup operating voltage		1.55		3.6	V
V_{REF+}	ADC positive reference voltage	$V_{DDA} \geq 2$ V	2		V_{DDA}	V
		$V_{DDA} < 2$ V	V_{DDA}			V
T_{amb}	Operative ambient temperature		-40		125(2)	°C

1. *Actual operative range can be limited by UVLO protections.*
2. *Actual operative range can be limited by thermal shutdown.*

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2.3 Thermal data

Thermal values are calculated by simulation with the following boundary conditions: 2s2p board as per the std. JEDEC (JESD51-7) in natural convection, board dimensions: 114.3 x 76.2 x 1.6 mm, ambient temperature: 25°C.

Table 3. Thermal data

Symbol	Parameter	Conditions	Value	Unit
R_{thJA}	Junction-to-ambient thermal resistance	Natural convection, according to JESD51-2a	48.3	°C/W
Ψ_{JT}	Junction-to-top characterization parameter	According to JESD51-2a	1.6	°C/W
ΨJ_B	Junction-to-board characterization parameter	According to JESD51-2a	32.0	°C/W

2.4 Electrical sensitivity characteristics

Table 4. ESD protection ratings

Symbol	Parameter	Test Condition	Class	Value	Unit
HBM	Human Body Model	Conforming to ANSI/ESDA/JEDEC JS-001-2014		2	kV
CDM	Charge Device Model	All pins Conforming to ANSI/ESDA/JEDEC JS-002-2014		500	V
CDM	Charge Device Model	Corner pins only Conforming to ANSI/ESDA/JEDEC JS-002-2014		750	V

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3 Electrical characteristics

Testing conditions: V_M = 60 V, V_{CC} = 12 V, V_{REGIN} = V_{REG3V3} = 3.3 V unless otherwise specified.
Typical values are tested at T_{amb} = 25°C, minimum and maximum values are guaranteed by thermal characterization in the temperature range of -40 to 125°C, unless otherwise specified.

Table 5. Electrical characteristics – Gate driver IC

Symbol	Parameter	Test condition	Min.	Typ.	Max.	Unit
Supply						
$V_{REG3V3(On)}$	Control logic turn-on threshold	V_{REG3V3} rising			2.5	V
$V_{REG3V3(Off)}$	Control logic turn-off threshold	V_{REG3V3} falling	1.9			V
$V_{REG3V3Stby(Off)}$	Control logic turn-off threshold during standby	V_{REG3V3} falling		2.4		V
$I_{REG3V3,qu}$	Control logic quiescent consumption	MCU consumption excluded T_{amb} = 25°C		1.9	3	mA
$V_{CC(On)}$	V_{CC} UVLO turn-on threshold	V_{CC} rising			5.5	V
$V_{CC(Hyst)}$	V_{CC} UVLO hysteresis	V_{CC} falling	70			mV
$I_{CC,qu}$	V_{CC} quiescent consumption			850	1700	µA
$V_{BO(On)}$	V_{BOOT} - V_{OUT} UVLO turn-on threshold	V_{BOOT} rising			5	V
$V_{BO(Hyst)}$	V_{BOOT} - V_{OUT} UVLO hysteresis	V_{BOOT} falling	100			mV
$I_{BO,qu}$	VBOOT - VOUT quiescent current			170	250	µA
$I_{M,qu}$	VM quiescent consumption	V_{CC} = 15 V ext All gate driver outputs low.		1500	3000	µA
VCC buck regulator						
$V_{ON,Buck}$	Regulator turn-on threshold	V_M rising	3		4.5	V
$V_{Hyst,Buck}$	Regulator turn-off hysteresis	V_M falling	50	150	250	mV
$V_{CC,mean}$	Regulated output voltage	Set to 8 V, mean value	7.2	8	8.8	V
		Set to 10 V, mean value	9	10	11	
		Set to 12 V, mean value	10.8	12	13.2	
		Set to 15 V, mean value	13.5	15	16.5	
$V_{CC,PkPk}$	Peak-to-peak output ripple	Percentage referred to target V_{CC}		1.875		%
$I_{peak,Buck}$	Peak current threshold			750		mA
$f_{SW,Buck}$	Switching frequency			500		kHz
$t_{ON,Buck,\ min}$	Minimum buck ON-time				220	ns
$t_{OFF,Buck\ min}$	Minimum buck OFF-time			220		ns
$R_{DS(ON),SW}$	PMOS switch on-resistance			3		Ω
$t_{SS,Buck}$	Soft-start time			3.3		ms
$f_{SW,SS}$	Soft-start switching frequency			60		kHz
$t_{disable,Buck}$	Disable time			4		ms

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Symbol	Parameter	Test condition	Min.	Typ.	Max.	Unit
$I_{OC,Buck}$	Buck converter overcurrent threshold			1.2		A
T_{SD}	Shutdown temperature		140		160	°C
$T_{SD(Hyst)}$	Thermal shutdown hysteresis			30		°C
3.3 V Linear regulator						
V_{REG3V3}	3.3 V linear regulator output and logic supply voltage	V_{REGIN} = 5 V I_{REG3V3} = 150 mA	3.1	3.3	3.5	V
$I_{REG3V3lim}$	3.3 V linear regulator current limit	REG3V3 shorted to ground	151			mA
T_{SD}	Shutdown temperature		140		160	°C
$T_{SD(Hyst)}$	Thermal shutdown hysteresis			30		°C
Gate drivers						
I_{gate}	Sink/source current capabilities	V_{CC} = 5.5 V to 15 V V_{BOx} = 5.5 V to 15 V T_{amb} = 25°C	700	1000	1300	mA
		V_{CC} = 5.5 V to 15 V V_{BOx} = 5.5 V to 15 V Full temperature range	500		1500	mA
R_{PMOS}	PMOS on-resistance	V_{CC} = 12 V, V_{BOx} = 12 V I_{source} = 100 mA T_{amb} = 25°C		3.7		Ω
		V_{CC} = 12 V, V_{BOx} = 12 V I_{source} = 100 mA Full temperature range			5.8	Ω
R_{NMOS}	NMOS on-resistance	V_{CC} = 12 V, V_{BOx} = 12 V I_{sink} = 100 mA T_{amb} = 25°C		1.6		Ω
		V_{CC} = 12 V, V_{BOx} = 12 V I_{sink} = 100 mA Full temperature range			2.6	Ω
t_{DT}	Deadtime	Minimum deadtime enabled		150		ns
$I_{OUTx,bias}$	OUTx bias current	V_{OUTx} = V_M = 60 V, V_{BOx} = 15 V		180	260	µA
		V_{OUTx} = 0 V, V_{BOx} = 15 V		180	260	µA
t_{on}, t_{off}	Input to output propagation delay	V_{CC} = 5.5 V to 15 V V_{BOx} = 5.5 V to 15 V		30	60	ns
		V_{CC} = 5.5 V to 15 V V_{BOx} = 5.5 V to 15 V Full temperature range			120	ns
MT	Delay matching, HS and LS turn-on/off	(1)		0	50	ns

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Symbol	Parameter	Test condition	Min.	Typ.	Max.	Unit
MT_{CH}	Delay matching between channels	(2)		0	50	ns
R_{DS_diode}	Bootstrap diode on-resistance			100	200	Ω
R_{PDin}	Input lines pull-down resistor			500		kΩ
$t_{FAULT,reset}$	Fault reset time				160	µs
R_{PU,I^2C}	I2C lines pull-up resistors			4		kΩ
I^2C speed	I2C speed		0.1		1	Mbps
Standby						
I_{STBY}	Overall standby consumption from VM	V_M = 75 V Standby regulator enabled, MCU consumption excluded		15	30	µA
t_{STBY}	Standby time			100		µs
$V_{REGStby}$	Standby regulator output voltage	V_M = 5 V I_{REG3V3} = 1 mA	3	3.3	3.6	V
$I_{REGStby,lim}$	Standby regulator current limit	V_M = 5.5 V, T_{amb} = 25°C	5			mA
$t_{WAKE,LDO}$	3.3V LDO wake-up time			10		µs
VDS monitoring protection						
V_{DSth}	VDS monitoring protection threshold	V_{SCREF} = 0.2 V, T_{amb} = 25°C	0.1	0.2	0.3	V
		V_{SCREF} = 1 V, T_{amb} = 25°C	0.8	1	1.2	
		V_{SCREF} = 2.5 V, T_{amb} = 25°C	2.2	2.5	2.8	
$V_{SCREF,en}$	VDS monitoring protection enable voltage				2.55	V
$V_{SCREF,dis}$	VDS monitoring protection disable voltage		2.9			V
R_{SCREF}	VDS monitoring protection reference pull-down resistor			400		kΩ
t_{DFSC}	VDS monitoring protection deglitch filter time	VDS_P_DEG = 00		6		µs
		VDS_P_DEG = 01		4		
		VDS_P_DEG = 10		3		
		VDS_P_DEG = 11		2		

1. *MT = max. ($|t_{on(GLS)} - t_{off(GLS)}|$, $|t_{on(GHS)} - t_{off(GHS)}|$, $|t_{off(GLS)} - t_{on(GHS)}|$, $|t_{off(GHS)} - t_{on(GLS)}|$).*
2. *MT_{CH} is the difference between the t_{on} and t_{off} of a channel and the same timings of any other channel.*

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4 Pin description

Figure 3. **STSPIN32G4 pin connection (top view)**

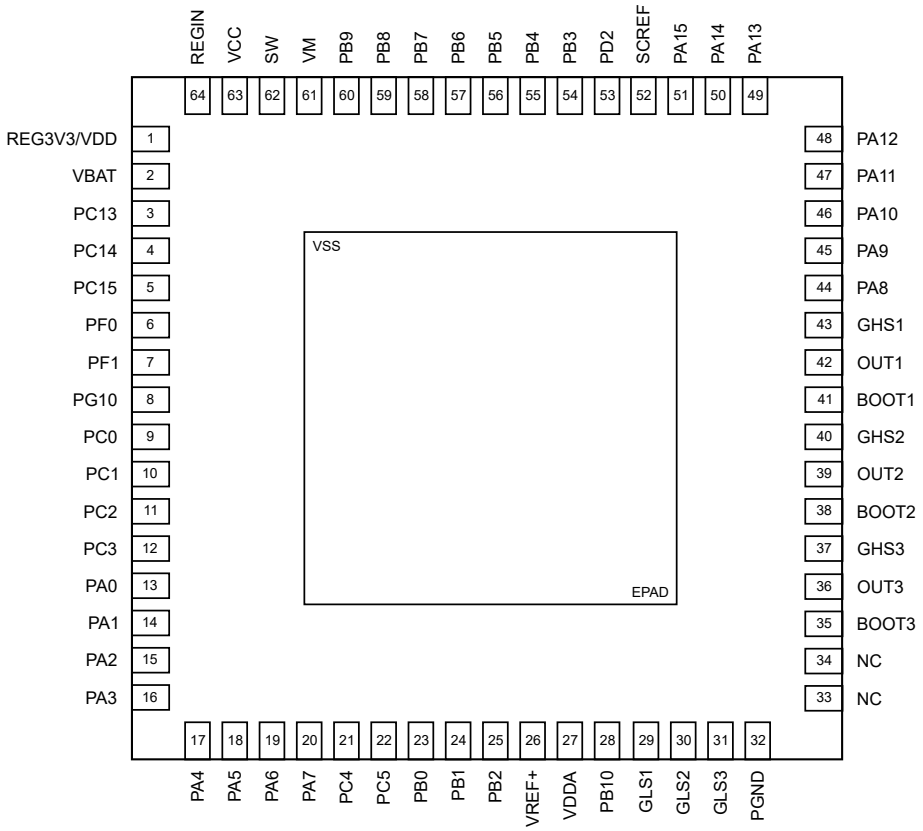


Table 6. **STSPIN32G4 pin list**

N.	Name	Type	Function[1]
1	REG3V3/VDD	Power	3.3V LDO regulator output and control logic supply voltage
2	VBAT	Power	MCU backup supply
3	PC13	I/O – FT	TIM8_CH4N, TIM1_BKIN, EVENTOUT, WKUP2, RTC_TAMP1, RTC_TS, RTC_OUT1
4	PC14	I/O – FT	EVENTOUT, OSC32_IN
5	PC15	I/O – FT	EVENTOUT, OSC32_OUT
6	PF0	I – FT_fa	I2C2_SDA, SPI2_NSS/I2S2_WS, EVENTOUT, ADC1_IN10, OSC_IN
7	PF1	O – FT_a	SPI2_SCK/I2S2_CK, EVENTOUT ADC2_IN10, COMP3_INM, OSC_OUT
8	PG10	I/O - FT	MCO, EVENTOUT, NRST
9	PC0	I/O – FT_a	LPTIM1_IN1, LPUART1_RX, EVENTOUT, ADC12_IN6, COMP3_INM
10	PC1	I/O – TT_a	LPTIM1_OUT, LPUART1_TX, SAI1_SD_A, EVENTOUT, ADC12_IN7, COMP3_INP
11	PC2	I/O – FT_a	LPTIM1_IN2, COMP3_OUT, EVENTOUT, ADC12_IN8

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N.	Name	Type	Function(1)
12	PC3	I/O – FT_a	TIM1_BKIN2, LPTIM1_ETR, SAI1_D1, SAI1_SD_A, EVENTOUT, ADC12_IN9
13	PA0	I/O – TT_a	TIM2_CH1, USART2_CTS, COMP1_OUT, TIM8_BKIN, TIM8_ETR, TIM2_ETR, EVENTOUT, ADC12_IN1, COMP1_INM, COMP3_INP, RTC_TAMP2, WKUP1
14	PA1	I/O – TT_a	RTC_REFIN, TIM2_CH2, USART2_RTS_DE, TIM15_CH1N, EVENTOUT, ADC12_IN2, COMP1_INP, OPAMP1_VINP, OPAMP3_VINP
15	PA2	I/O – TT_a	TIM2_CH3, USART2_TX, COMP2_OUT, TIM15_CH1, LPUART1_TX, UCPD1_FRSTX, EVENTOUT, ADC1_IN3, COMP2_INM, OPAMP1_VOUT, WKUP4/LSCO
16	PA3	I/O – TT_a	TIM2_CH4, SAI1_CK1, USART2_RX, TIM15_CH2, LPUART1_RX, SAI1_MCLK_A, EVENTOUT, ADC1_IN4, COMP2_INP, OPAMP1_VINM/ OPAMP1_VINP
17	PA4	I/O – TT_a	TIM3_CH2, SPI1_NSS, SPI3_NSS/I2S3_WS, USART2_CK, SAI1_FS_B, EVENTOUT, ADC2_IN17, DAC1_OUT1, COMP1_INM
18	PA5	I/O – TT_a	TIM2_CH1, TIM2_ETR, SPI1_SCK, UCPD1_FRSTX, EVENTOUT, ADC2_IN13, DAC1_OUT2, COMP2_INM, OPAMP2_VINM
19	PA6	I/O – TT_a	TIM16_CH1, TIM3_CH1, TIM8_BKIN, SPI1_MISO, TIM1_BKIN, COMP1_OUT, LPUART1_CTS, EVENTOUT, ADC2_IN3, OPAMP2_VOUT
20	PA7	I/O – TT_a	TIM17_CH1, TIM3_CH2, TIM8_CH1N, SPI1_MOSI, COMP2_OUT, UCPD1_FRSTX, EVENTOUT, ADC2_IN4, COMP2_INP, OPAMP1_VINP, OPAMP2_VINP
21	PC4	I/O - FT_fa	I2C2_SCL, USART1_TX, EVENTOUT, ADC2_IN5
22	PC5	I/O – TT_a	TIM15_BKIN, SAI1_D3, USART1_RX, EVENTOUT, ADC2_IN11, OPAMP1_VINM, OPAMP2_VINM, WKUP5
23	PB0	I/O – TT_a	TIM3_CH3, TIM8_CH2N, UCPD1_FRSTX, EVENTOUT, ADC1_IN15, COMP4_INP, OPAMP2_VINP, OPAMP3_VINP
24	PB1	I/O – TT_a	TIM3_CH4, TIM8_CH3N, COMP4_OUT, LPUART1_RTS_DE, EVENTOUT, ADC1_IN12, COMP1_INP, OPAMP3_VOUT
25	PB2	I/O – TT_a	RTC_OUT2, LPTIM1_OUT, EVENTOUT, ADC2_IN12, COMP4_INM, OPAMP3_VINM
26	VREF+	Power	MCU VREF+, VREFBUF_OUT
27	VDDA	Power	MCU analog supply voltage
28	PB10	I/O – TT_a	TIM1_BKIN, USART3_TX, LPUART1_RX, SAI1_SCK_A, EVENTOUT, OPAMP3_VINM
29	GLS1	Analog Out	Phase 1 low-side driver output
30	GLS2	Analog Out	Phase 2 low-side driver output
31	GLS3	Analog Out	Phase 3 low-side driver output
32	PGND	Power	Gate drivers power ground
33	NC		Internally not connected
34	NC		Internally not connected
35	BOOT3	Power	Phase 3 bootstrap supply voltage
36	OUT3	Power	Phase 3 high-side (floating) common voltage
37	GHS3	Analog Out	Phase 3 high-side driver output
38	BOOT2	Power	Phase 2 bootstrap supply voltage
39	OUT2	Power	Phase 2 high-side (floating) common voltage

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N.	Name	Type	Function[1]
40	GHS2	Analog Out	Phase 2 high-side driver output
41	BOOT1	Power	Phase 1 bootstrap supply voltage
42	OUT1	Power	Phase 1 high-side (floating) common voltage
43	GHS1	Analog Out	Phase 1 high-side driver output
44	PA8	I/O – FT_f	MCO, I2C2_SDA, I2S2_MCK, USART1_CK, TIM4_ETR, SAI1_CK2, SAI1_SCK_A, EVENTOUT
45	PA9	I/O – FT_fd	I2C2_SCL, I2S3_MCK, USART1_TX, TIM15_BKIN, TIM2_CH3, SAI1_FS_A, EVENTOUT, UCPD1_DBCC1
46	PA10	I/O – FT_da	TIM17_BKIN, USB_CRS_SYNC, I2C2_SMBA, SPI2_MISO, USART1_RX, TIM2_CH4, TIM8_BKIN, SAI1_D1, SAI1_SD_A, EVENTOUT, UCPD1_DBCC2
47	PA11	I/O – FT_u	TIM1_BKIN2, SPI2_MOSI/I2S2_SD, USART1_CTS, COMP1_OUT, FDCAN1_RX, TIM4_CH1, EVENTOUT, USB_DM
48	PA12	I/O – FT_u	TIM16_CH1, I2SCKIN, USART1_RTS_DE, COMP2_OUT, FDCAN1_TX, TIM4_CH2, EVENTOUT, USB_DP
49	PA13 [2]	I/O – FT_f	SWDIO-JTMS, TIM16_CH1N, I2C1_SCL, IR_OUT, USART3_CTS, TIM4_CH3, SAI1_SD_B, EVENTOUT
50	PA14[2]	I/O – FT_f	SWCLK-JTCK, LPTIM1_OUT, I2C1_SDA, TIM8_CH2, TIM1_BKIN, USART2_TX, SAI1_FS_B, EVENTOUT
51	PA15[2]	I/O – FT_f	JTDI, TIM2_CH1, TIM8_CH1, TIM1_BKIN, I2C1_SCL, SPI1_NSS, SPI3_NSS/I2S3_WS, USART2_RX, UART4_RTS_DE, TIM2_ETR, EVENTOUT
52	SCREF	Analog In	Set the threshold voltage of the short-circuit protection. If the voltage pin is higher than $V_{SCREF,dis}$ threshold, the short-circuit protection is disabled.
53	PD2	I/O – FT	TIM3_ETR, TIM8_BKIN, EVENTOUT
54	PB3[2]	I/O – FT	JTDO-TRACESWO, TIM2_CH2, TIM4_ETR, USB_CRS_SYNC, TIM8_CH1N, SPI1_SCK, SPI3_SCK/I2S3_CK, USART2_TX, TIM3_ETR, SAI1_SCK_B, EVENTOUT
55	PB4[2]	I/O – FT_c	JTRST, TIM16_CH1, TIM3_CH1, TIM8_CH2N, SPI1_MISO, SPI3_MISO, USART2_RX, TIM17_BKIN, SAI1_MCLK_B, EVENTOUT, UCPD1_CC2
56	PB5	I/O – FT_f	TIM16_BKIN, TIM3_CH2, TIM8_CH3N, I2C1_SMBA, SPI1_MOSI, SPI3_MOSI/I2S3_SD, USART2_CK, TIM17_CH1, LPTIM1_IN1, SAI1_SD_B, EVENTOUT
57	PB6	I/O – FT_c	TIM16_CH1N, TIM4_CH1, TIM8_CH1, TIM8_ETR, USART1_TX, COMP4_OUT, TIM8_BKIN2, LPTIM1_ETR, SAI1_FS_B, EVENTOUT, UCPD1_CC1
58	PB7	I/O – FT_f	TIM17_CH1N, TIM4_CH2, I2C1_SDA, TIM8_BKIN, USART1_RX, COMP3_OUT, TIM3_CH4, LPTIM1_IN2, UART4_CTS, EVENTOUT, PVD_IN
59	PB8[3]	I/O – FT_f	MCU PB8-BOOT0 TIM1_BKIN, TIM16_CH1, TIM4_CH3, SAI1_CK1, I2C1_SCL, USART3_RX, COMP1_OUT, FDCAN1_RX, TIM8_CH2, SAI1_MCLK_A, EVENTOUT
60	PB9	I/O – FT_f	TIM17_CH1, TIM4_CH4, SAI1_D2, I2C1_SDA, IR_OUT, USART3_TX, COMP2_OUT, FDCAN1_TX, TIM8_CH3, SAI1_FS_A, EVENTOUT
61	VM	Power	Power supply voltage (Motor supply voltage)
62	SW	Power	Buck regulator switching output
63	VCC	Power	Gate driver supply voltage
64	REGIN	Power	3.3 V LDO regulator input

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N.	Name	Type	Function[1]
EPAD	VSS	Power	Control logic ground

1. *Alternate and additional functions for MCU GPIOs. Refer to STM32G431VBx3 MCU documentation for more details.*
2. *After reset, these pins are configured as JTAG/SW debug alternate functions, and the internal pull-up on PA15, PA13, PB4 pins and the internal pull-down on PA14 pin are activated.*
3. *It is recommended to set PB8 in a mode other than analog mode after startup to limit consumption if the pin is left unconnected.*

Table 7. MCU to gate driver internal connection

MCU pads	GD pads	Pinout	Notes
All VSS (VSSA included)	GND	VSS	Exposed pad
All VDD	REG3V3	VDD	
PE7	WAKE		Push-pull output
PE8	INL1		TIM1_CH1N(1)
PE9	INH1		TIM1_CH1(1)
PE10	INL2		TIM1_CH2N(1)
PE11	INH2		TIM1_CH2(1)
PE12	INL3		TIM1_CH3N(1)
PE13	INH3		TIM1_CH3(1)
PE14	READY		Input with pull-up, TIM1_BKIN2(2) (optional)
PE15	NFAULT		Input with pull-up, TIM1_BKIN (2) (optional)
PC8	SCL		I2C3_SCL
PC9	SDA		I2C3_SDA

1. *The gate driver IC is designed to support these GPIOs configuration only. Different configuration could cause device malfunctioning. The GPIO input configuration without pull-up or pull-down is always allowed.*
2. *The lines are protected against conflict configuration. If the MCU GPIO is wrongly configured in push-pull mode, the device is not damaged.*

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5 Device description

The STSPIN32G4 is a system-in-package embedding one MCU (STM32G431) and a triple half-bridge gate driver suitable for high performance 3-phase brushless motor applications.

5.1 Power management section

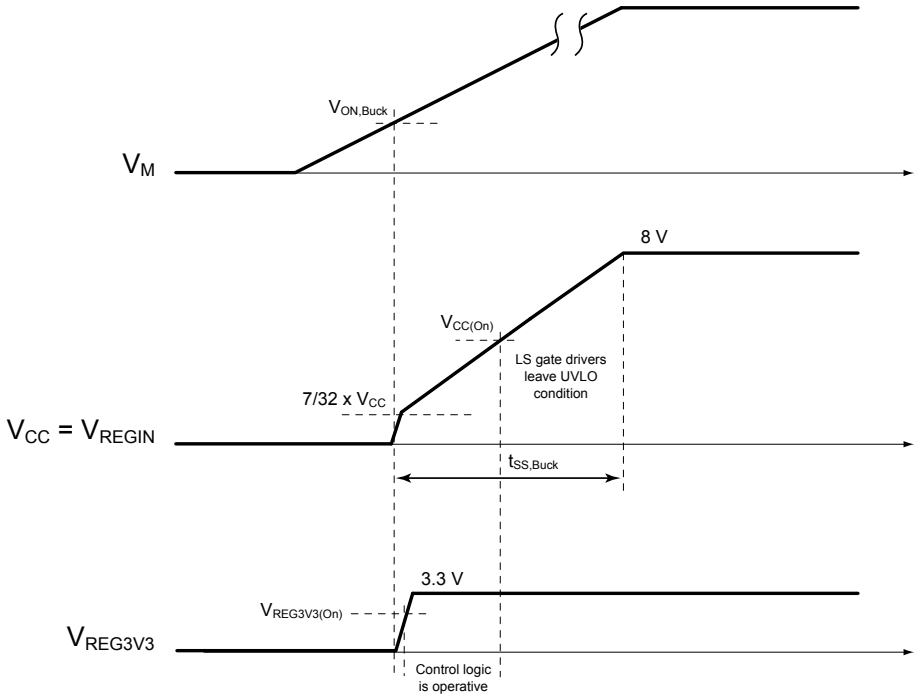
The power management section of the device is composed by:

- One buck regulator generating the VCC voltage (gate driver supply) from the main supply.
- One LDO linear regulator generating 3.3 V (V_{REG3V3}) starting from the V_{REGIN} input voltage (ranging between 3.3 V and 15 V).
- One low quiescent linear regulator generating low precision 3.3 V starting from the main supply.

The VM pin is the main supply voltage of the device.

When the REG3V3 supply is below $V_{REG3V3(On)}$, the control logic is not operative, and the internal registers are reset to the default.

Figure 4. Power-up sequence (REGIN shorted with VCC)

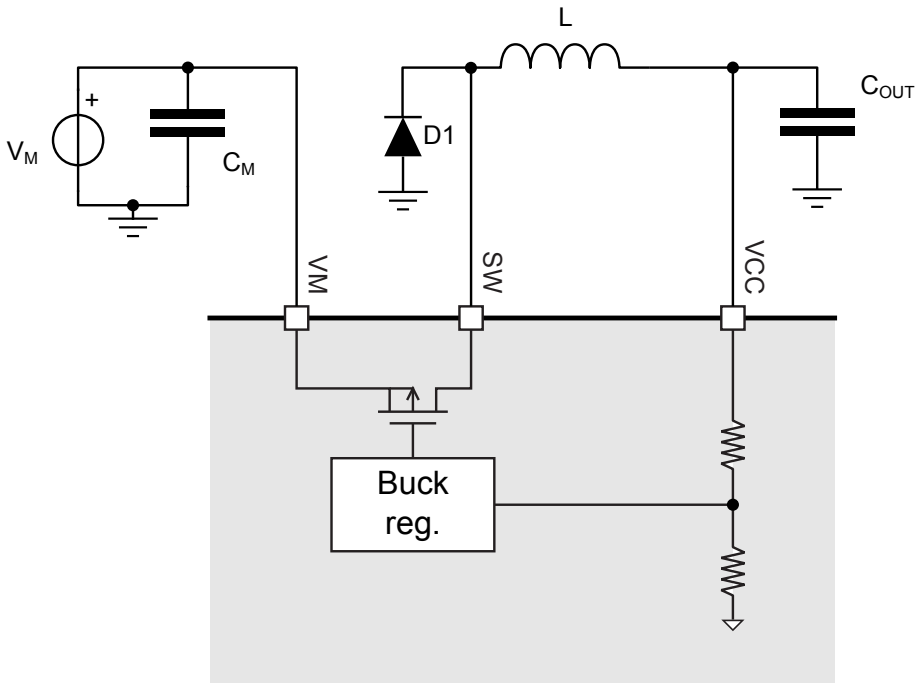


5.1.1 VCC buck regulator

The device integrates a buck regulator generating the supply voltage for the gate drivers (V_{CC}) starting from the motor supply (V_M). The regulated voltage supplies the gate driving circuitry, charges the bootstrap capacitors and supplies external circuitry with a maximum overall consumption of 200 mA.

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Figure 5. **VCC Buck configuration**



The output voltage can be set to different values as listed in Table 8 . The regulator works with a fixed switching frequency of $f_{SW,Buck}$ and a maximum duty cycle of 90%.

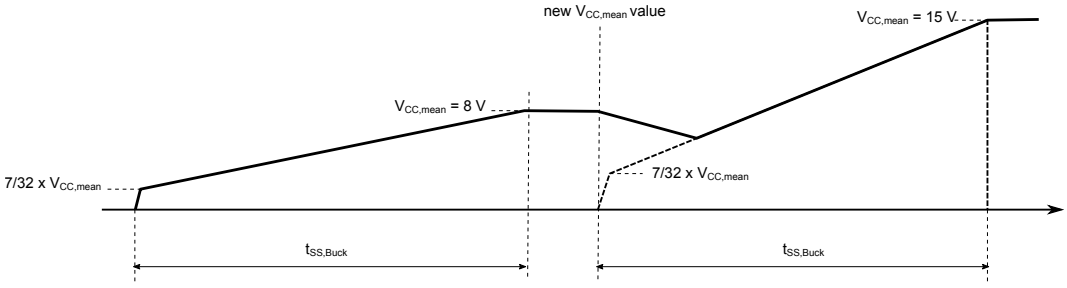
A soft-start is implemented on system power-up or wake-up: the output target voltage is gradually increased up to the target V_{CC} in $t_{SS,Buck}$ time (refer to Figure 6). During the first half of $t_{SS,Buck}$ time the regulator works with a fixed switching frequency of $f_{SW,SS}$.

When the target output voltage is changed, a new soft-start ramp is generated with the new target voltage as final value.

Table 8. **V_{CC} Buck regulator output voltage**

VCC_VAL	V_{CC} regulated value [V]	Note
00	8	default
01	10	
10	12	
11	15	

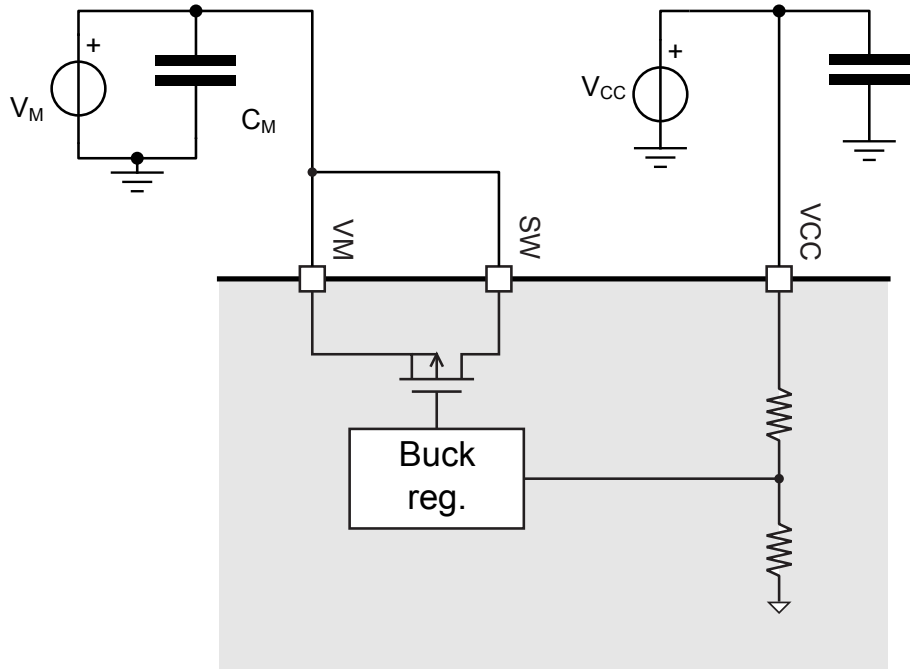
Figure 6. **VCC buck regulator soft-start**



It is possible to provide externally the V_{CC} supply, bypassing the integrated regulator.

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Figure 7. **VCC externally supplied (buck disabled)**

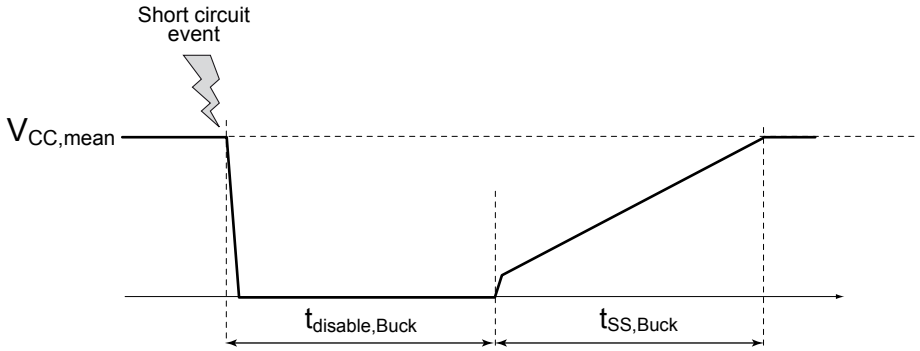


5.1.1.1 *Short-circuit protection*

The regulator is protected against short-circuit of the SW pin. If this condition is detected, the regulator stops for a $t_{disable,Buck}$ time.

At the end of this period, the buck regulator restarts performing a soft-start.

Figure 8. **VCC buck regulator short-circuit protection**



5.1.1.2 *Thermal protection*

If the temperature of the buck converter circuitry exceeds the TSD threshold, it stops operating until the temperature returns below the T_{SD} - $T_{SD(Hyst)}$ level (auto-restart).

When the regulator returns operative, a soft-start is performed.

5.1.2 3.3 V linear regulator

The device integrates a low-drop linear regulator (LDO) to generate the 3.3 V supply starting from the REGIN input voltage. The 3.3 V output voltage supplies both the gate driver logic and the microcontroller.

The LDO output current is limited, making the regulator protected against short-circuit and overload.

An undervoltage monitoring circuit is active on the 3.3 V supply which triggers a reset if the voltage falls below $V_{REG3V3(Off)}$.

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Four configurations are possible for the 3.3 V supply:

1. Internally generated via LDO with REGIN pin connected directly to the buck output VCC (Figure 9).
2. Internally generated via LDO with REGIN pin connected through a resistor to the buck output VCC (Figure 10); with this configuration the power dissipation inside the device can be reduced.
3. Internally generated via LDO with REGIN pin connected to an external supply voltage in the range 15 V to 3.3 V (Figure 11).
4. Externally, provided with REGIN and REG3V3 connected (Figure 12). In this case it is possible to disconnect or tie to ground VM or VCC while providing the 3.3 V supply. When VM is provided again the device restarts from a power-up condition.

Figure 9. 3.3 V LDO regulator supplied through VCC

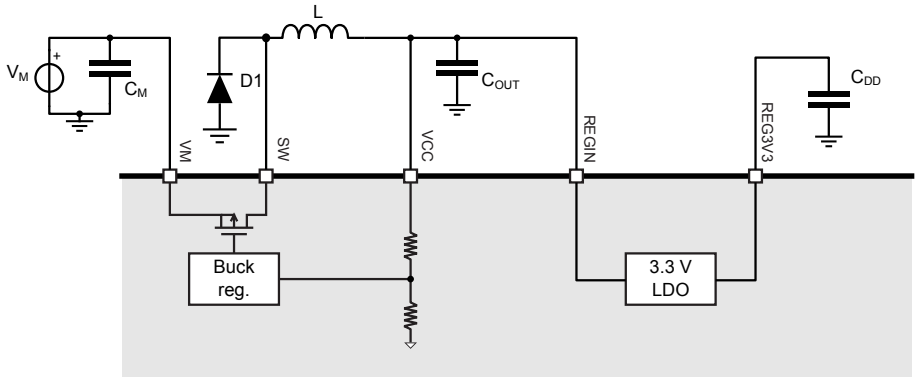


Figure 10. 3.3 V LDO regulator supplied through VCC (external resistor)

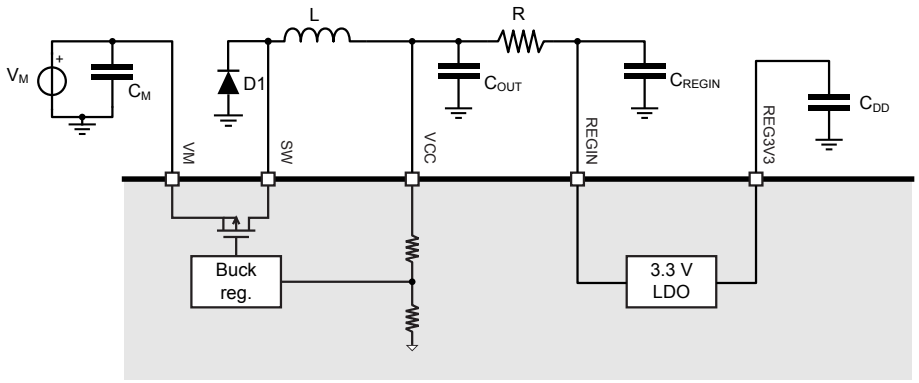
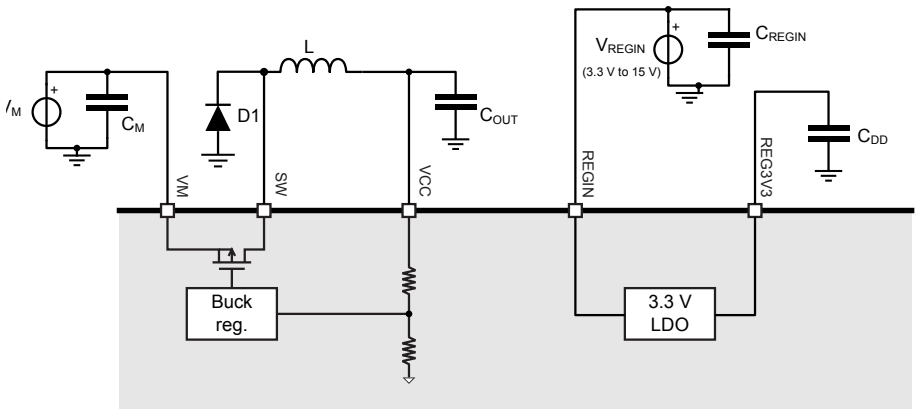
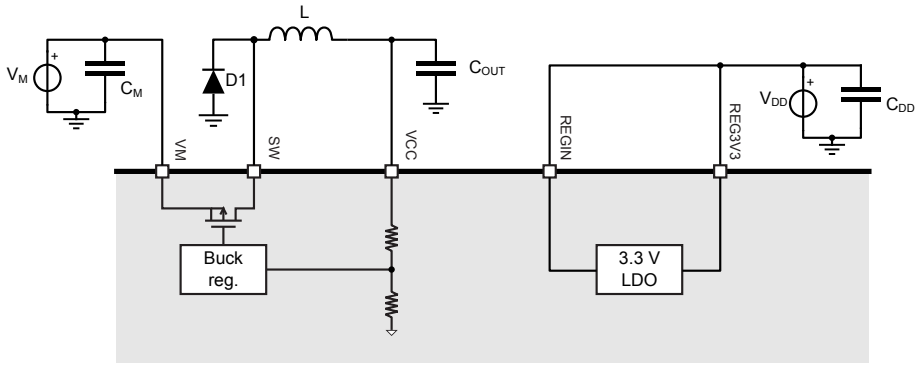


Figure 11. 3.3 V LDO regulator with external supply



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Figure 12. **3.3 V externally supplied (linear regulator disabled)**



5.1.2.1 *Thermal shutdown*

If the temperature of the device exceeds the T_{SD} threshold, all the gate driver outputs are forced low and the 3.3 V linear regulator stops until the temperature returns below the T_{SD} - $T_{SD(Hyst)}$ level (auto-restart).

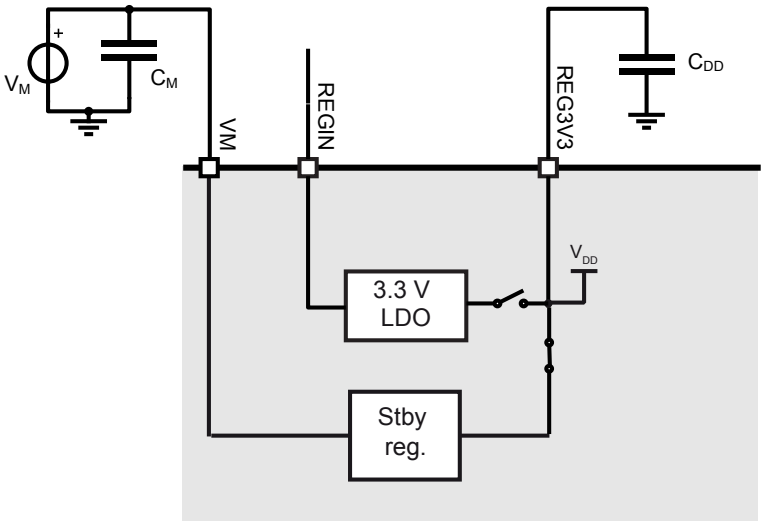
The buck converter has an independent thermal protection as described in Section 5.1.1.2 .

5.1.3 Standby linear regulator

When the device is in low consumption status, the embedded MCU can be supplied through a specifically designed linear regulator generating a $V_{REGStby}$ supply starting from the main supply pin VM. The regulator is designed to provide a maximum supply current of 6 mA with overcurrent protection. If the output current exceeds the regulator limit a reset is triggered.

The regulator output is disabled by default and should be enabled before entering standby condition (see Section 5.4) setting the STBY_REG_EN bit. When the device enters standby condition, the 3.3 V LDO regulator is disabled and disconnected from the REG3V3 pin as shown in Figure 13.

Figure 13. **Standby regulator enabled**

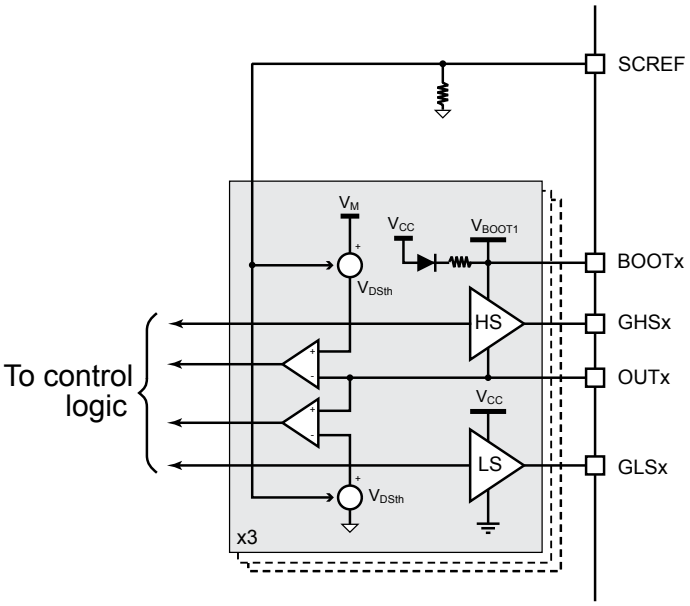


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5.2 Gate drivers

The STSPIN32G4 integrates a triple half-bridge gate driver able to drive N-channel power MOSFETs. The high-side section is supplied by a bootstrapped voltage technique with integrated bootstrap diode.

Figure 14. Half-bridge gate drivers block diagram



A couple of digital inputs drive each half-bridge gate driver: one INLx signal for the low-side driving and one INHx signal for the high-side driving. High input implies the gate driver turns on the respective external MOSFET, with low value the gate driver turns it off.

5.2.1 Interlocking

The gate driver provides interlocking function, so the high-side and low-side MOSFETs of the same half-bridge cannot be both on at the same time.

Table 9. Gate driver control logic with interlocking

INHx	INLx	High-side gate driver	Low-side gate driver
0	0	Sink current (Turn-off)	Sink current (Turn-off)
0	1	Sink current (Turn-off)	Source current (Turn-on)
1	0	Source current (Turn-on)	Sink current (Turn-off)
1	1	Sink current (Turn-off)	Sink current (Turn-off)

The interlocking function can be disabled setting the ILOCK bit. In this case both the high-side and low-side MOSFETs can be turned on at the same time.

Table 10. Gate driver control logic without interlocking

INHx	INLx	High-side gate driver	Low-side gate driver
0	0	Sink current (Turn-off)	Sink current (Turn-off)
0	1	Sink current (Turn-off)	Source current (Turn-on)
1	0	Source current (Turn-on)	Sink current (Turn-off)
1	1	Source current (Turn-on)	Source current (Turn-on)

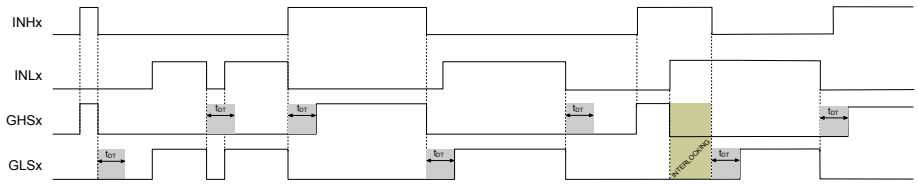
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5.2.2 Minimum deadtime

The device guarantees a minimum deadtime value of t_{DT}, imposing a delay between the turn-off of an external MOSFET and the turn-on of the complementary one.

The deadtime is not added to the one eventually imposed by the MCU, as shown in Figure 15.

Figure 15. Deadtime timing (with interlocking enabled)



The feature is disabled clearing the DTMIN bit (see Table 17) or when the interlocking is disabled (see Section 5.2.1).

5.2.3 Sink/source current

The output stage of the gate drivers provides a maximum sink/source capability of 1 A.

The voltage to current characteristics of the gate driver output stage is described by Figure 16 and Figure 17.

When in UVLO condition, the gate drivers keep their outputs low with the maximum current capability available.

Figure 16. Low-side gate driver output characteristic in UVLO range

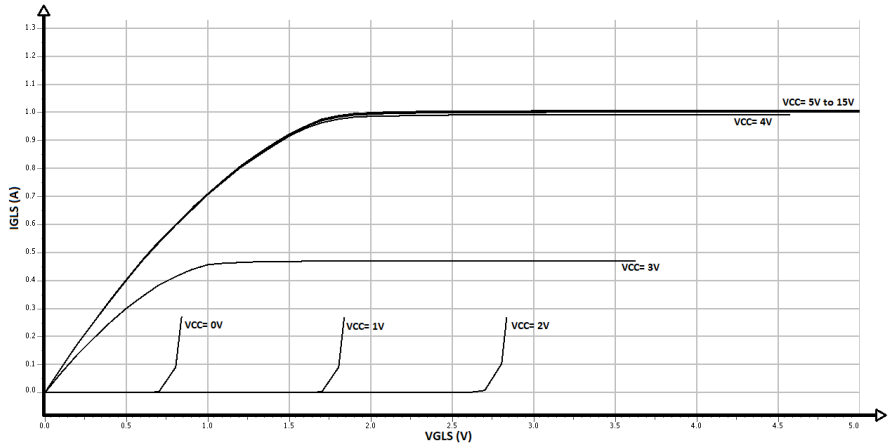
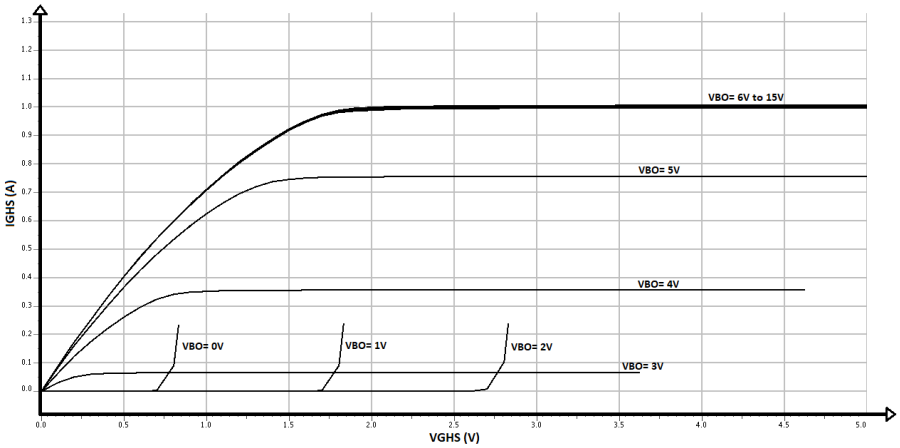


Figure 17. High-side gate driver output characteristic in UVLO range



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5.2.4 Bootstrap section

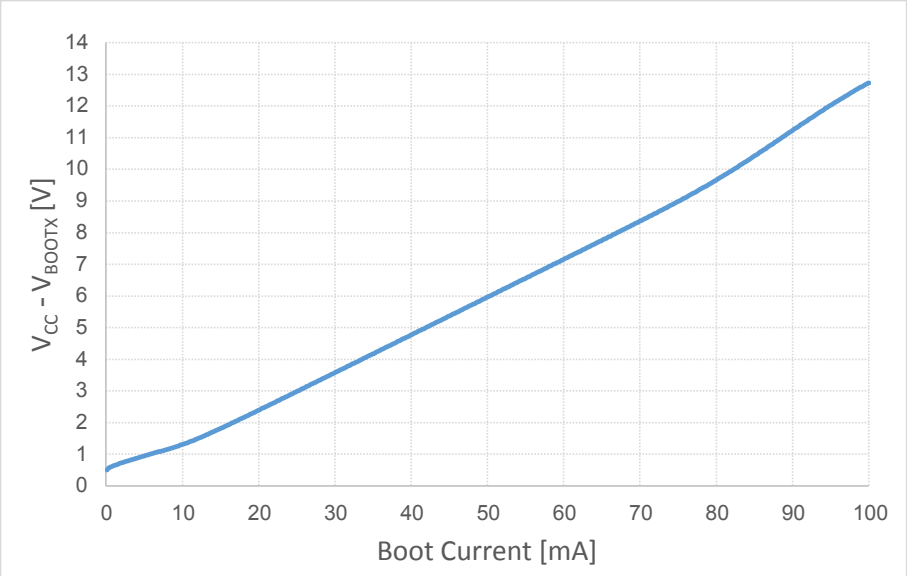
The bootstrap circuitry allows to generate a voltage higher than the supply VM and it is used to supply the high-side drivers. When one high-side MOSFET is turned on, its source voltage (OUTx pin) increases up to VM. Therefore, the gate must be driven at a voltage higher than VM.

The bootstrap capacitor is referred to the OUTx pin:

- When the OUTx pin is forced to GND (i.e. the respective low-side MOSFET is on), the bootstrap capacitor is charged through the bootstrap diode.
- When the OUTx is forced to VM (i.e. the respective high-side MOSFET is on), the bootstrap capacitor supplies the respective high-side driver and discharges.

The typical voltage-current characteristics of the bootstrap circuitry is reported in Figure 18

Figure 18. Voltage-Current characteristics of bootstrap circuitry



The voltage drop on the bootstrap capacitors corresponds to the supply of the high-side drivers. Each bootstrap capacitor must be charged after the corresponding high-side is turned on, otherwise its voltage falls below the $V_{BO(On)}$ - $V_{BO(Hyst)}$ threshold, causing the turning-off of the respective driver (refer to Section 5.2.6).

A limitation in a bootstrap architecture is that the high-side MOSFET cannot stay on for an indefinite amount of time. In fact, when the high-side is on, the respective bootstrap capacitor starts discharging. If not recharged, the bootstrap capacitor voltage falls below the $V_{BO(On)}$ - $V_{BO(Hyst)}$ (i.e. the UVLO on the BOOTx pin). For this reason, working at 100% duty cycle is possible, but only for a limited number of PWM periods. The bigger the bootstrap capacitor, the longer the time the high-side MOSFET can be kept on (for sizing guidelines of bootstrap capacitor refer to *AN5789 - Considerations on bootstrap circuitry for gate drivers*).

To avoid excessive drop on the VCC pin, a proper bypass capacitor is required. Even using an external supply connected to the VCC pin, it is important to have a bypass capacitor with low ESR providing fast current transients when required by the bootstrap capacitors.

The bypass capacitor on the VCC pin must provide the charge for the three bootstrap capacitors: the bigger the bootstrap capacitors, the bigger the VCC capacitor should be (refer to Equation 1 in Section 5.2.4.2).

5.2.4.1 *Power-up and wake-up*

During the power-up or after leaving the standby condition, there may be no charge in the bootstrap capacitors. In these cases, the driver cannot start immediately with normal operation, but the bootstrap capacitor should be charged turning on the low-side MOSFET.

At the beginning of this procedure, a large amount of current could be required. If the internal VCC buck regulator is used, its current is limited at I_{CC} (refer to Table 2).

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5.2.4.2 *Charging time and external bootstrap diodes*

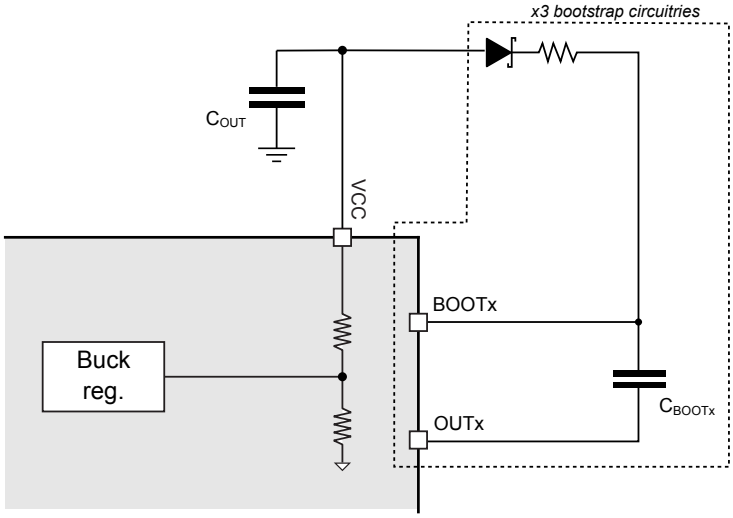
The charging time of the bootstrap capacitors depends on their value but also on the resistance of the bootstrap diode (R_{DS_diode}), which limits the current flow. In order to reduce the minimum time for bootstrap recharge (i.e. the minimum time the low-side MOSFET must be on), external bootstrap diodes can be used as shown in Figure 19.

Each diode is in parallel with the corresponding internal bootstrap diode. An external series resistor, smaller than R_{DS_diode}, can still be used together with each diode to reduce the maximum charging current and helps to limit the voltage drop on the VCC pin. The maximum drop on the C_{OUT} capacitor occurs when the three bootstrap capacitors must be recharged, and no series resistor is used with the external diodes. This drop can be approximated as:

Equation 1

$$\Delta V_{COUT} \approx V_{CC} \cdot \frac{3 \cdot C_{BOOT}}{C_{OUT} + 3 \cdot C_{BOOT}} \quad (1)$$

Figure 19. External bootstrap diode configuration



5.2.5 VDS monitoring protection

The device monitors the V_{DS} of the power stage's MOSFETs in order to detect anomalous conditions. The V_{DS} of each MOSFET is compared to a reference threshold (V_{DSth}).

The reference threshold (V_{DSth}) is generated according to the voltage applied to the SCREF pin (V_{SCREF}).

The SCREF voltage must be in the range between 0.2 V to $V_{SCREF,en}$. If the voltage is above $V_{SCREF,dis}$, the protection is disabled.

When enabled, the protection triggers when one of the following conditions occur:

- GLSx output is expected high and $V_{OUTx} > V_{DSth,LS}$ for more than t_{DFSC}
- GHSx output is expected high and '$V_M - V_{OUTx}$' > $V_{DSth,HS}$ for more than t_{DFSC}

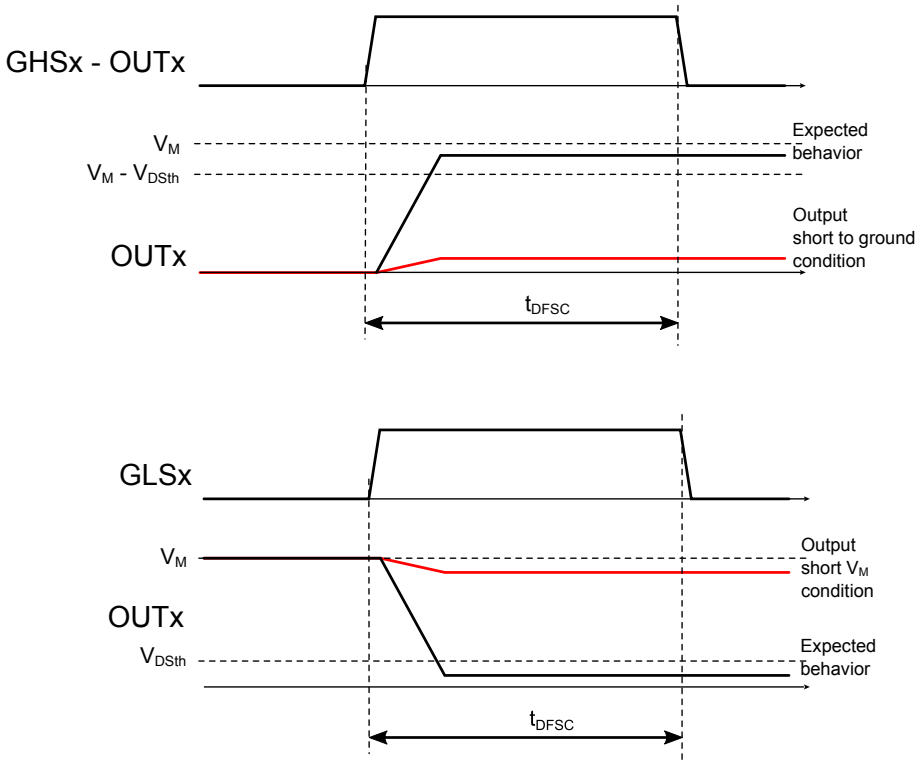
As soon as the protection is triggered, all the gate driver outputs are forced low and the protection is latched. In this condition all the gate driver outputs are kept low whatever the driving inputs.

The device returns operative (i.e. the failure condition is cleared) forcing all the driving inputs low for at least $t_{FAULT,reset}$ or setting all bits of the CLEAR register.

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Note: the VDS monitoring protection does not check the actual status of the GHSx and GLSx pins and operates according to the expected output status that depends on input signals (refer to Section 5.2.1), programmed interlocking (refer to Section 5.2.1), minimum dead time (refer to Section 5.2.2) and V_{CC} UVLO condition (refer to Section 5.2.6).

Figure 20. VDS monitoring protection timings



A deglitch filter is provided which prevents spurious triggering of the protection when the anomalous condition on V_{DS} persists for less than the deglitch time t_{DFSC}. The VDS_P_DEG bits allow to change the deglitch time (as shown in Table 11.

Table 11. VDS monitoring protection deglitch time

VCC_P_DEG	VDS protection deglitch time [µs]	Note
00	6	default
01	4	
10	3	
11	2	

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5.2.6 Undervoltage protection

The device provides undervoltage lockout (UVLO) protections on the supply voltages of the gate drivers. When in UVLO condition, the gate drivers keep their outputs low with the maximum current capability available. During power-up, the device leaves the UVLO condition when the respective supply voltage rises above the turn-on threshold. When the supply voltage is below the on-threshold voltage of a hysteresis, the UVLO condition is set.

Table 12. UVLO protection management

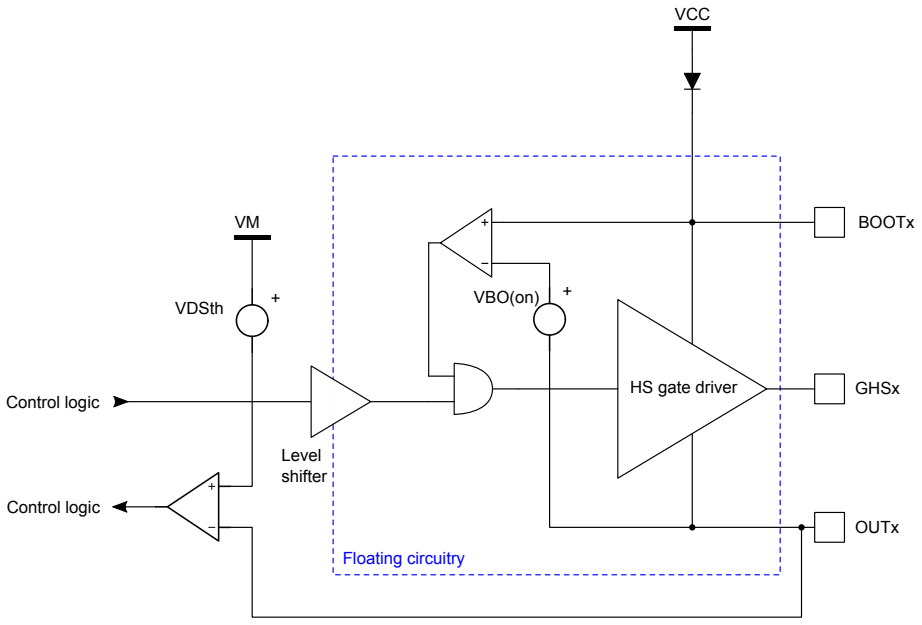
Block	V_{CC} UVLO	V_{BOx} UVLO
HS1, HS2, HS3 output	LOW(1)	LOW(1)(2)
LS1, LS2, LS3 output	LOW(1)	-
READY open-drain output	LOW(3)	

1. *The N-channel of the gate driver is turned ON with all the available supply voltage, refer to Figure 16.*
2. *Each high-side gate driver provides independent UVLO protection (e.g. UVLO on BOOT1 causes the HS1 to turn off only).*
3. *If VCC_UVLO_RDY is set.*

5.2.6.1 *High-side undervoltage and VDS monitoring*

The V_{BO} UVLO is not reported to the main control logic and is directly managed by the floating circuitry as described in Figure 21

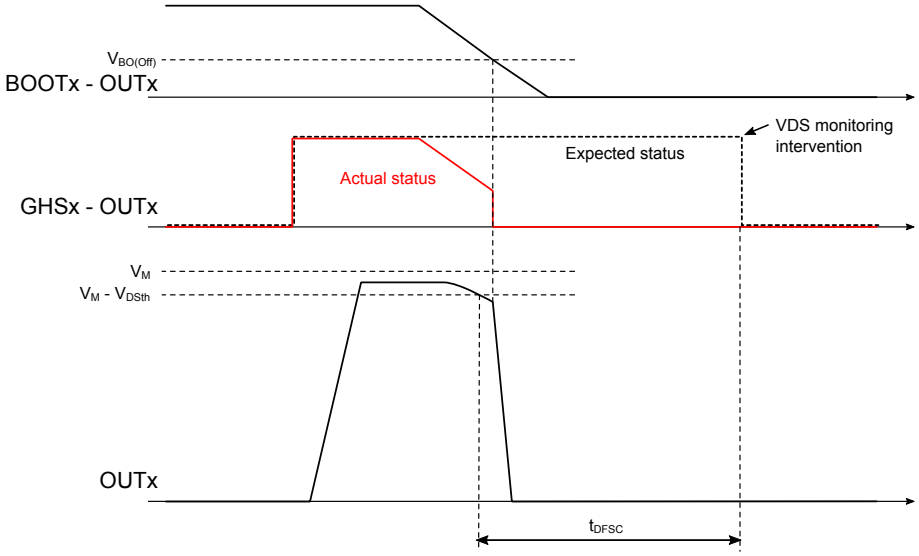
Figure 21. V_{BO} UVLO circuitry and high-side VDS monitoring



For this reason, a V_{BO} UVLO failure may cause the triggering of the VDS monitoring due to the turn-off of the respective MOSFET.

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Figure 22. **VDS monitoring failure caused by V_{BO} UVLO**



5.3 Microcontroller unit

The integrated MCU is the STM32G431VBx3 with the following main characteristics:

- Core: ARM® Cortex®-M4 32-bit CPU + FPU, frequency up to 170 MHz
- 32 kB of SRAM, 128 kB of Flash memory
- 2 x ADCs 16-bit resolution and 0.2 µs sampling time
- 4 x 12-bit DAC channels
- 4 x fast rail-to-rail comparators
- 3 x rail-to-rail operational amplifiers
- Full set of interfaces:
- CAN, UART, I2C, SPI

For more details refer to the STM32G431VBx3 datasheet on www.st.com

5.3.1 Memories and boot mode

The device has the following features:

- 32 kB of embedded SRAM
- The non-volatile memory is dived into two arrays:
  - 128 kB of embedded Flash memory for storing programs and data
  - Option bytes

The Flash memory embeds the error correction code (ECC) feature supporting:

- Single error detection and correction
- Double error detection
- The address of the ECC fail can be read in the ECC register
- 1 kB (128 double word) OTP (one-time programmable) bytes for user data. The OTP area is available in Bank 1 only. The OTP data cannot be erased and can be written only once.

Flexible protections can be configured thanks to the option bytes:

- Readout-protection (RDP) to 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 the debug features are connected or the boot in RAM or bootloader are selected.
  - Level 2: chip readout protection; the debug features (Cortex-M4 JTAG and serial wire), the boot in RAM and the bootloader selection are disabled (JTAG fuse). This selection is irreversible.

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- Write protection (WRP): the protected area is protected against erasing and programming.
- Proprietary code readout protection (PCROP): a part of the Flash memory can be protected against read and write from third parties.
- Securable memory area: a part of the Flash memory can be configured by option bytes to be securable.

At startup, a BOOT0 pin (or nBOOT0 option bit) and an nBOOT1 option bit are used to select one of three boot options:

- Boot from user Flash
- Boot from system memory
- Boot from embedded SRAM

The BOOT0 value may come from the PB8-BOOT0 pin or from an nBOOT0 option bit depending on the value of a user nBOOT_SEL option bit to free the GPIO pad if needed.

The boot loader is located in the system memory. It is used to reprogram the Flash memory by using USART, I2C, SPI, and USB through the DFU (device firmware upgrade).

5.3.2 Power management

V_{DD} is the external power supply for the I/Os, the internal regulator and the system analog such as reset, power management and internal clocks. It is provided externally through the VDD pins.

V_{DDA} is the external analog power supply for A/D converters, D/A converters, voltage reference buffer, operational amplifiers, and comparators. The VDDA voltage level is independent from the VDD voltage and should preferably be connected to VDD when these peripherals are not used.

V_{BAT} is the power supply for RTC, external clock 32 kHz oscillator and backup registers (through power switch) when VDD is not present.

During power-up and power-down, the following power sequence is required:

- When VDD is below 1 V, then VDDA supply must remain below VDD + 300 mV
- When VDD is above 1 V, all power supplies became independent.

During the power-down phase, VDD can temporarily become lower than other supplies only if the energy provided to the MCU remains below 1 mJ. This allows external decoupling capacitors to be discharged with different time constants during the power-down transient phase.

V_{REF+} is the input reference voltage for ADCs and DACs. It is also the output of the internal voltage reference buffer when enabled.

The device has an integrated ultra-low-power Brown-Out reset (BOR) active in all modes (except for Shutdown mode). The BOR ensures proper operation of the device after power-on and during power-down. The device remains in reset mode when the monitored supply voltage V_{DD} is below a specified threshold, without the need for an external reset circuit. The lowest BOR level is 1.71 V at power-on, and other higher thresholds can be selected through option bytes.

The device features an embedded programmable voltage detector (PVD) that monitors the V_{DD} power supply and compares it to the V_{PVD} threshold. An interrupt can be generated when V_{DD} drops below the V_{PVD} threshold and/or when V_{DD} is higher than the V_{PVD} threshold. The interrupt service routine can then generate a warning message and/or put the MCU into a safe state. The PVD is enabled by software.

In addition, the device embeds a peripheral voltage monitor which compares the independent supply voltages V_{DDA}, with a fixed threshold in order to ensure that the peripheral is in its functional supply range.

The MCU supports three low-power modes to achieve the best compromise between low-power consumption, short start-up time and available wake-up sources:

- **Sleep mode**: only the CPU is stopped. All peripherals continue to operate and can wake up the CPU when an interrupt/event occurs.
- **Low-power run mode**: this mode is achieved with VCORE supplied by the low-power regulator to minimize the regulator's operating current.
- **Stop mode**: the device achieves the lowest power consumption while retaining the SRAM and register contents.
- **Standby mode**: is used to achieve the lowest power consumption with Brown-Out reset, BOR. The device exits Standby mode upon external reset event (NRST pin), IWDG reset event, wakeup event (WKUP pin, configurable rising or falling edge) or RTC event (alarm, periodic wakeup, timestamp, tamper), or when a failure is detected on LSE (CSS on LSE).

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- **Shutdown mode**: allows to achieve the lowest power consumption. The BOR is not available in Shutdown mode. No power voltage monitoring is possible in this mode. The device exits Shutdown mode upon external reset event (NRST pin), IWDG reset event, wakeup event (WKUP pin, configurable rising or falling edge) or RTC event (alarm, periodic wakeup, timestamp, tamper).

5.3.3 Advanced-control timer (TIM1)

The advanced motor control timers (TIM1) can be seen as a four-phase PWM multiplexed on 8 channels. It has complementary PWM outputs with programmable inserted deadtimes.

This timer is used to generate the PWM signal for the three half-bridge gate drivers as shown in Table 13.

Table 13. TIM1 channels configuration

MCU I/O	Analog IC inout	TIM1 channel
PE8	INL1	TIM1_CH1N
PE9	INH1	TIM1_CH1
PE10	INL2	TIM1_CH2N
PE11	INH2	TIM1_CH2
PE12	INL3	TIM1_CH3N
PE13	INH3	TIM1_CH3
PE14	READY	TIM1_BKIN2 (optional)
PE15	NFAULT	TIM1_BKIN (optional)

5.4 Standby mode

The STSPIN32G4 provides a standby mode to reduce power consumption, in particular:

- All the outputs driver forced low (external power switches turned off)
- All the embedded protections are disabled
- The buck regulator is disabled
- The 3.3 V LDO linear regulator is switched off
- The I^2C communication is not available

The device enters into low consumption mode setting the STBY bit. When the STBY bit is set, the device switches to low consumption mode after t_{STBY} time. If during this time the WAKE input is high, the device aborts the standby request clearing the STBY bit.

If the STBY_RDY bit is set the READY pin is tied to ground when the STBY request is asserted via I^2C to indicate the upcoming entry into standby condition. After t_{STBY} time when the device switches to low consumption mode the READY pin is released to reduce current consumption.

The device wakes up from standby when the WAKE input goes high. The buck regulator performs a soft-start ramp and the LDO regulator is turned on when the V_{CC} reaches the $V_{CC(On)}$ threshold voltage. If the STBY_RDY bit was set before entering standby, then the READY pin is forced low and released with a $t_{WAKE,LDO}$ delay from $V_{CC} > V_{CC(On)}$ event.

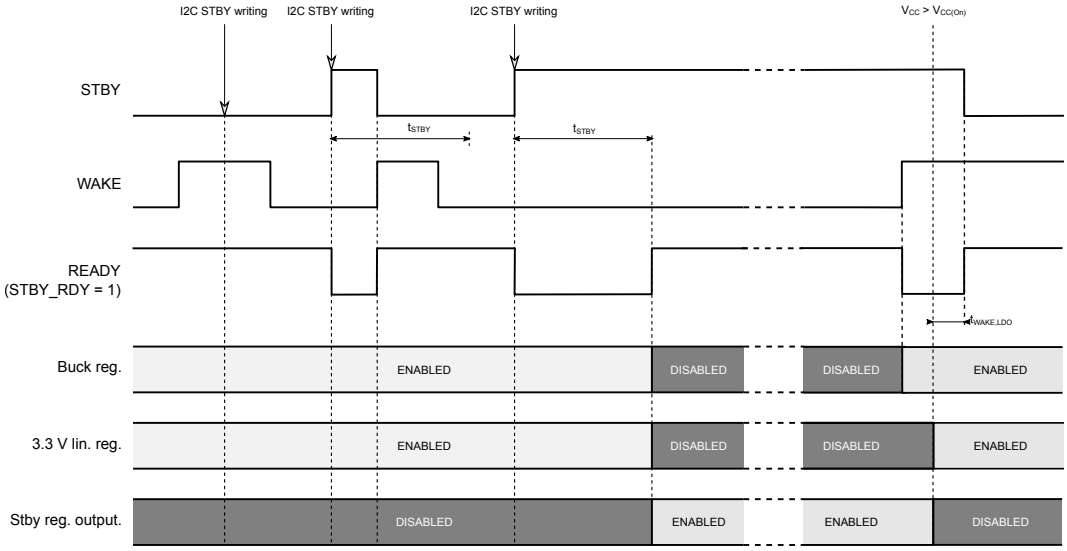
When the device is in low consumption status, the embedded MCU can be supplied through a specifically designed linear regulator setting the STBY_REG_EN bit. The regulator generates $V_{REGStby}$ supply starting from the main supply pin VM and is designed to provide a maximum $I_{REG3V3,Stby}$ supply current.

The standby regulator integrates an overcurrent protection that triggers a device reset in case the supply current exceeds $I_{REGStby,lim}$. During standby a dedicated voltage monitoring circuit is active on the REG3V3 pin which triggers a device reset in case the voltage falls below $V_{REG3V3Stby(Off)}$. In case of reset due to overcurrent or undervoltage, the system restarts from a power-up condition with registers restored to their defaults and both buck and main LDO regulators enabled.

Note: If the internal standby regulator is disabled when the device is in standby mode, only the undervoltage protection on the REG3V3 pin is active.

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Figure 23. **Standby timings**



5.5 Control logic

The MCU drives the high-side and low-side gate drivers independently as listed in Table 14.

Table 14. **INxL and INxH inputs truth table**

INHx	INLx	GHSx	GHLx	'x' half-bridge condition
L	L	L	L	Disabled
L	H	L	H	LS on
H	L	H	L	HS on
H	H	L	L	Disabled (interlocking)
H	H	H	H	Both HS and LS on (no-interlocking)

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The full list of digital inputs and outputs is listed below:

Table 15. INxL and INxH inputs truth table

Signal	Type	Description	Notes
INH1	Input	High-side 1 driving signal	Pull-down
INH2	Input	High-side 2 driving signal	Pull-down
INH3	Input	High-side 3 driving signal	Pull-down
INL1	Input	Low-side 1 driving signal	Pull-down
INL2	Input	Low-side 2 driving signal	Pull-down
INL3	Input	Low-side 3 driving signal	Pull-down
WAKE	Input	Active high for wakeup from standby	Pull-down
READY	Open-drain output	Device ready signal	Conflict protection
nFAULT	Open-drain output	Fault signal	Conflict protection
SCL	Input	I^2C clock	Pull-up
SDA	Input and open-drain output	I^2C data	Pull-up Conflict protection

All the input lines have an internal pull-down to guarantee the low logic level even if no driving input is present.

The open-drain outputs are designed to be protected against driving conflict with the corresponding GPIO of the MCU. If the GPIO is set as push-pull output with high value and the respective open-drain is on, both the GPIO and the open-drain are not damaged by this condition.

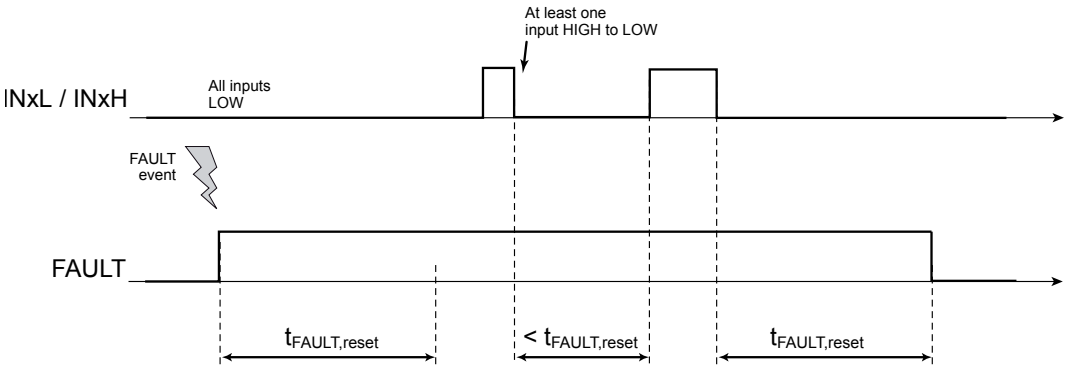
5.5.1 Status and clearing faults

The device status is reported in the STATUS register. In case of thermal shutdown or VCC undervoltage the device automatically returns operative when failure cause is removed.

In case of RESET or VDS monitoring protection triggering, the fault is latched, and the device may return operative in two ways (i.e. clearing fault):

1. Forcing all the driving inputs INxL and INxH low for at least $t_{FAULT,reset}$. The time counting does not start if inputs were already low before the fault occurrence (refer to Figure 24).
2. Setting all bits of the CLEAR register through the I^2C interface.

Figure 24. FAULT clearing via input lines



As a RESET is done on power-up, a clearing of the faults is required to have the device operative.

5.5.2 READY output

The READY open-drain output indicates if the device status does not allow the driving of the external MOSFETs.

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The READY output can be programmed to report one or more of the following conditions:

- The V_{CC} supply is below the undervoltage threshold.
- Thermal shutdown.
- Entering standby mode.

By default, the pin reports the standby and the VCC undervoltage condition (refer to Table 19).

5.5.3 nFAULT output

The nFAULT open-drain output indicates a critical failure condition. The output can be configured to report one or more of the following failures:

- The device performed a RESET (this signaling cannot be masked)
- V_{DS} monitoring protection is triggered
- Thermal shutdown
- The V_{CC} supply is below the undervoltage threshold

By default, the nFAULT pin reports all above failures (refer to Table 20).

5.5.4 I²C interface

The internal registers are available through a standard IIC (I^2C) interface supporting 7-bit addressing and communication speed up to 1 Mbit/s (Fast mode Plus).

The 7-bit address of the device is fixed and equal to 1000111.

Table 16. I^2C address

Device address							
7	**6**	**5**	**4**	**3**	**2**	**1**	**0**
1	0	0	0	1	1	1	R/W bit

5.5.5 Registers

The configuration of the device is set through a list of 8-bit registers. Refer to the following tables for details.

Table 17. Power manager configuration register

Register	Bit #	Bit name	Default	Description
POWMNG Address 0x01 *Protected*	7		0	
	6	REG3V3_DIS	0	3.3V linear regulator: Enabled by default, 1 to disable
	5	VCC_DIS	0	VCC buck regulator: Enabled by default, 1 to disable
	4	STBY_REG_EN	0	Standby linear regulator: Disabled by default, 1 to enable
	3		0	
	2		0	
	1	VCC_VAL	0	Set the output value for the VCC regulator: • 00: VCC set to 8V (default) • 01: VCC set to 10V • 10: VCC set to 12V • 11: VCC set to 15V
	0		0	

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Table 18. **Driving Logic configuration register**

Register	Bit #	Bit name	Default	Description
LOGIC Address 0x02 *Protected*	7		0	
	6		1	
	5		1	
	4		1	
	3	VDS_P_DEG	0	Configures the deglitch time for the VDS protection: • 00: Deglitch set to 6 µs (default) • 01: Deglitch set to 4 µs • 10: Deglitch set to 3 µs • 11: Deglitch set to 2 µs
	2		0	
	1	DTMIN	1	Minimum deadtime insertion: Enabled by default, 0 to disable
	0	ILOCK	1	Interlocking function: Enabled by default, 0 to disable

Table 19. **READY output configuration register**

Register	Bit #	Bit name	Default	Description
READY Address 0x07	7		0	
	6		0	
	5		0	
	4		0	
	3	STBY_RDY	1	Signaling of the standby request status: Enabled by default, 0 to disable
	2		0	
	1	THSD_RDY	0	Signaling of the thermal shutdown status: Disabled by default, 1 to enable
	0	VCC_UVLO_RDY	1	Signaling of the VCC UVLO status: Enabled by default, 0 to disable

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Table 20. **nFAULT output configuration register**

Register	Bit #	Bit name	Default	Description
NFAULT Address 0x08 *Protected*	7		0	
	6		1	
	5		1	
	4		1	
	3		1	
	2	VDS_P_FLT	1	Signaling of the VDS protection triggering: Enabled by default, 0 to disable
	1	THSD _FLT	1	Signaling of the thermal shutdown status: Enabled by default, 0 to disable
	0	VCC_UVLO_FLT	1	Signaling of the VCC UVLO status: Enabled by default, 0 to disable

Table 21. **FAULT clear command register**

Register	Bit #	Bit name	Default	Description
CLEAR Address 0x09	7 to 0	FAULT_CLEAR		Setting high all the bits clears all the latched failure conditions. Any other value is rejected.

Table 22. **Standby register**

Register	Bit #	Bit name	Default	Description
STBY Address 0x0A *Protected*	7 to 1		0	
	0	STBY	0	Setting high the STBY bit requests the device to enter low consumption mode.

Table 23. **LOCK register**

Register	Bit #	Bit name	Default	Description
LOCK Address 0x0B	7 to 4	NLOCK	0	When LOCK is different from the bitwise not of NLOCK, the writing of the protected registers is not allowed. When LOCK is equal to the bitwise not of NLOCK the writing of the protected registers is allowed, and all gate driver outputs are forced low.
	3 to 0	LOCK	0	

Table 24. **RESET command register**

Register	Bit #	Bit name	Default	Description
RESET Address 0x0C *Protected*	7 to 0	RESET		Setting high all the bits resets the registers to the default value (The RESET bit in the STATUS register is not affected).

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Register	Bit #	Bit name	Default	Description
				Any other value is rejected.

Table 25. Device STATUS register

Register	Bit #	Bit name	Default	Description
STATUS Address 0x80 *Read only*	7	LOCK		Indicates if the protected registers are locked: • 0: Unlocked • 1: Locked
	6			
	5			
	4			
	3	RESET		Indicates if the registers had been reset to the default (power-up): • 0: No reset • 1: Reset
	2	VDS_P		Indicates the VDS protection triggering: • 0: VDS protection not triggered • 1: VDS Protection triggered
	1	THSD		Indicates the thermal shutdown status: • 0: Device not in THSD • 1: Device in THSD
	0	VCC_UVLO		Indicates the VCC UVLO status: • 0: Device not in VCC UVLO • 1: Device in VCC UVLO

5.5.5.1 *Command registers*

CLEAR and RESET are command registers. It is only allowed to set all bits to execute the command, other values are rejected.

In case of read the device returns 0xFF.

5.5.5.2 *Read/write registers*

All the registers are read and written using the I^2C standard method.

5.5.5.3 *Protected registers*

All critical registers of the device are protected against unwanted rewriting.

When the content of the LOCK register does not fit the following condition:

$$LOCK = \overline{NLOCK}$$

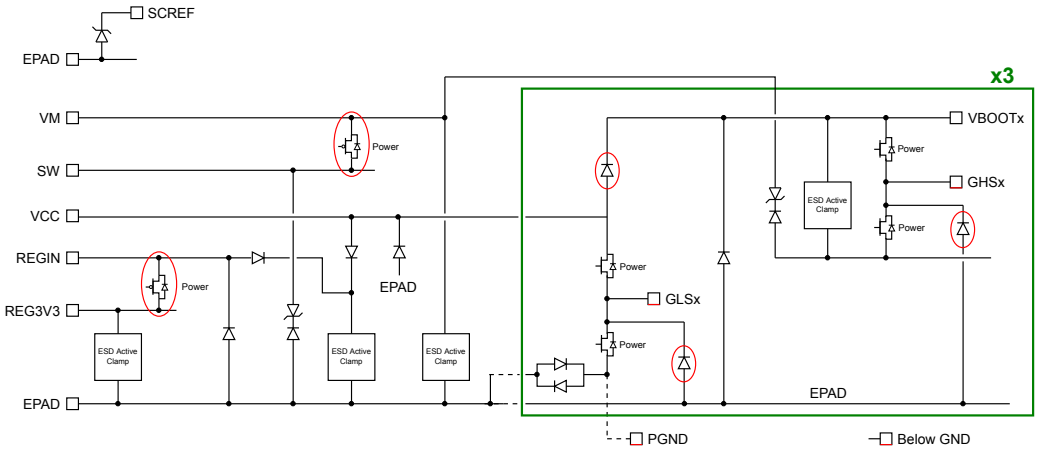
the protected registers are read-only.

When the content fits the above condition, the protected registers can be written, and the power stage is forced into safe condition: all the gate driver outputs are forced low.

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6 ESD protection strategy

Figure 25. **ESD protection strategy**



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7 Application example

Figure 26 shows an application example using the STSPIN32G4 device to drive a three-phase motor with triple shunt configuration and field oriented control algorithm.

The other features implemented are:

- VDD (3.3 V) power supply internally generated via LDO linear regulator
- VCC (programmable, 8 V default value) power supply internally generated via Buck regulator
- Reset dedicated pin
- Overcurrent protection using internal comparators connected to op-amp positive inputs (PA1, PA7, PB0)
- Current sensing using internal operational amplifiers and ADCs:
  - Op-amp 1: PA1, PA3, PA2 (OPP, OPN, OPO)
  - Op-amp 2: PA7, PC5, PA6 (OPP, OPN, OPO)
  - Op-amp 3: PB0, PB2, PB1 (OPP, OPN, OPO)
- Bus voltage monitoring using internal ADC (PA0)
- Application temperature monitoring using internal ADC (PC4)

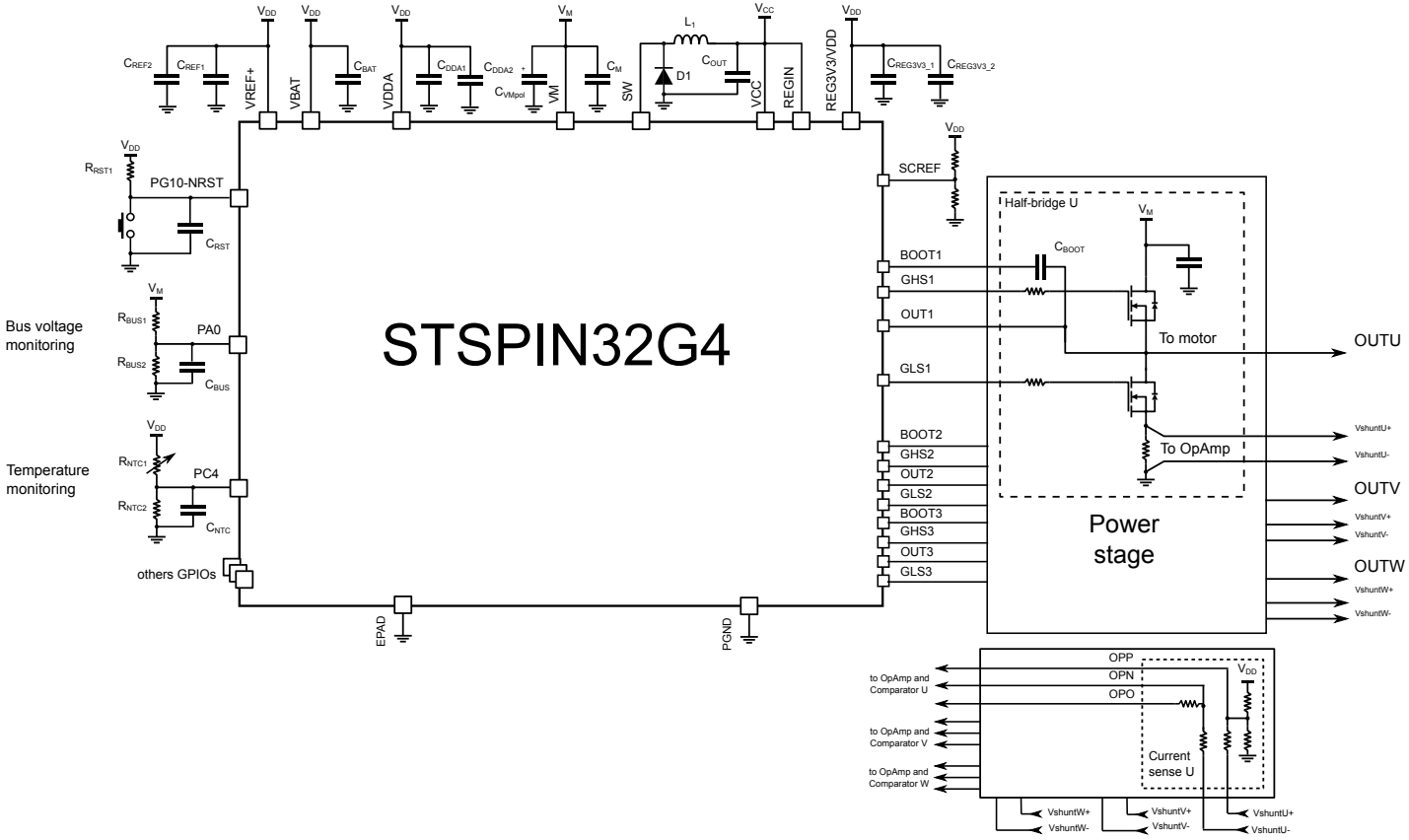
Table 26. Typical application value

Part name	Value
C_{BAT}, C_{REF1}, C_{DDA1}, C_{REG3V3_1}, C_{RST}	100 nF / 6.3 V
C_{REF2}, C_{DDA2}	1 µF / 6.3 V
C_{REG3V3_2}	10 µF / 6.3 V
C_{OUT}	10 µF / 25 V
L_1	18 µH / 1 A
D_1	STPS1H100A / 100 V
C_{VM}	220 nF / 100 V
R_{RST1}	100 kΩ / 5 %
C_{BUS},C_{NTC}	33 nF / 6.3 V
others	Values according to application requirements

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7.1 Application example diagram

Figure 26. **Application example diagram**



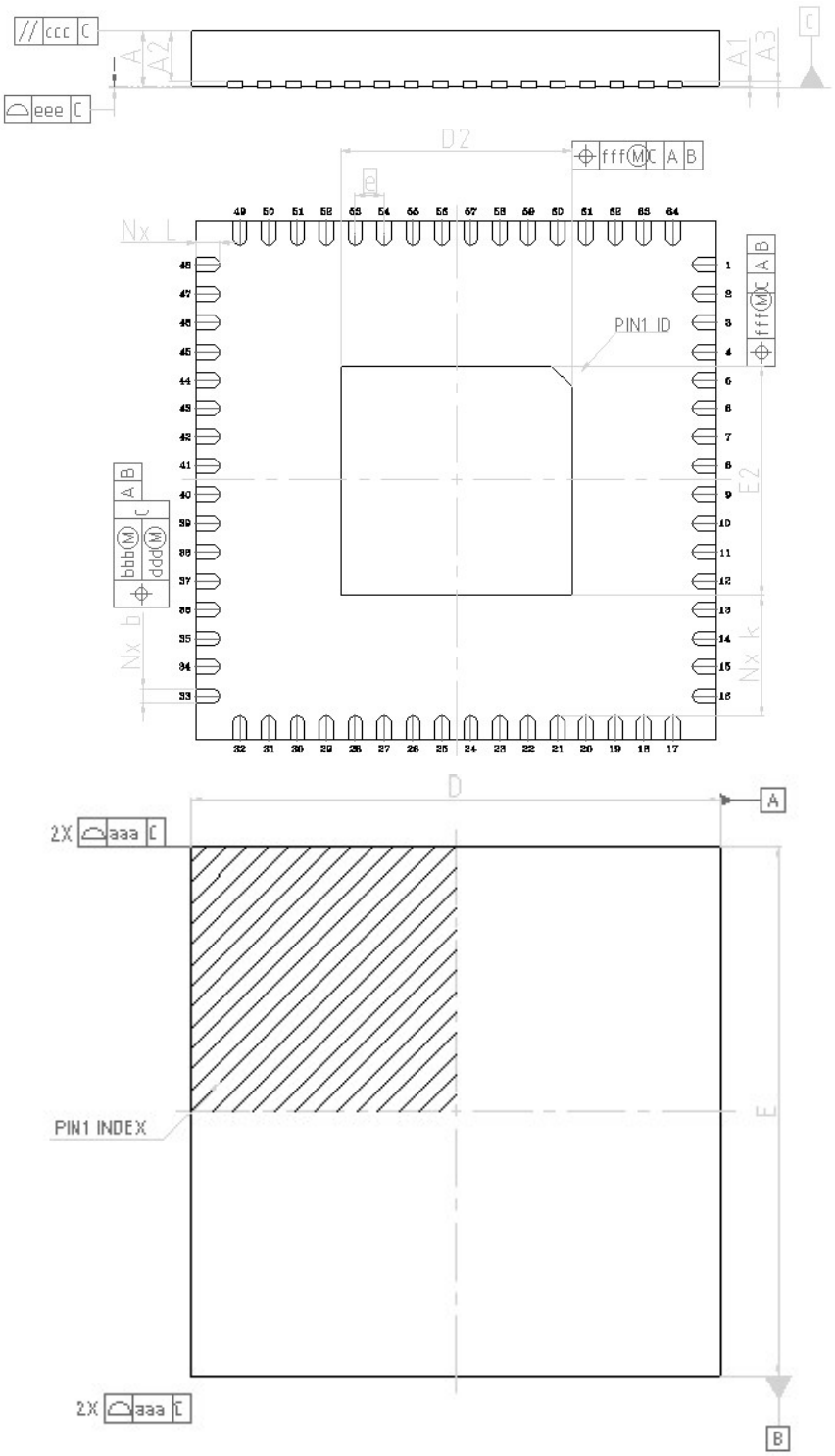
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8 Package information

In order to meet environmental requirements, ST offers these devices in different grades of ECOPACK packages, depending on their level of environmental compliance. ECOPACK specifications, grade definitions and product status are available at: www.st.com. ECOPACK is an ST trademark.

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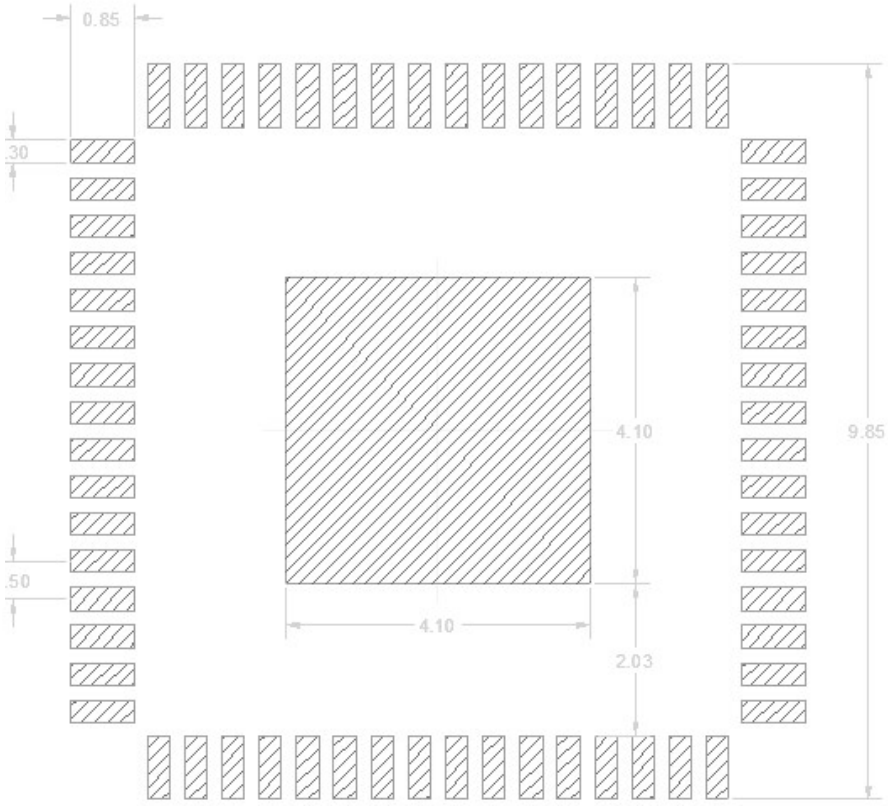
Figure 27. **VFQFPN 9X9X1.0 64 PITCH 0.50 package outline**



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Symbol	Dimensions (mm)		
	Min.	Typ.	Max.
A	0.80	0.90	1.00
A1		0.02	0.05
A3		0.10 REF	
b	0.20	0.25	0.30
D	8.90	9.00	9.10
D2	3.90	4.00	4.10
E	8.90	9.00	9.10
E2	3.90	4.00	4.10
e		0.50	
L	0.30	0.40	0.50
aaa	0.15		
bbb	0.10		
ccc	0.10		
ddd	0.05		
eee	0.08		
fff	0.10		

Figure 28. **VFQFPN 9X9X1.0 64 PITCH 0.50 suggested footprint**



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9 Characterization graphs

The characterization graphs are obtained from measurements on a limited number of samples.

Figure 29. Standby current I_{STBY} vs. temperature (normalized at ambient temperature)

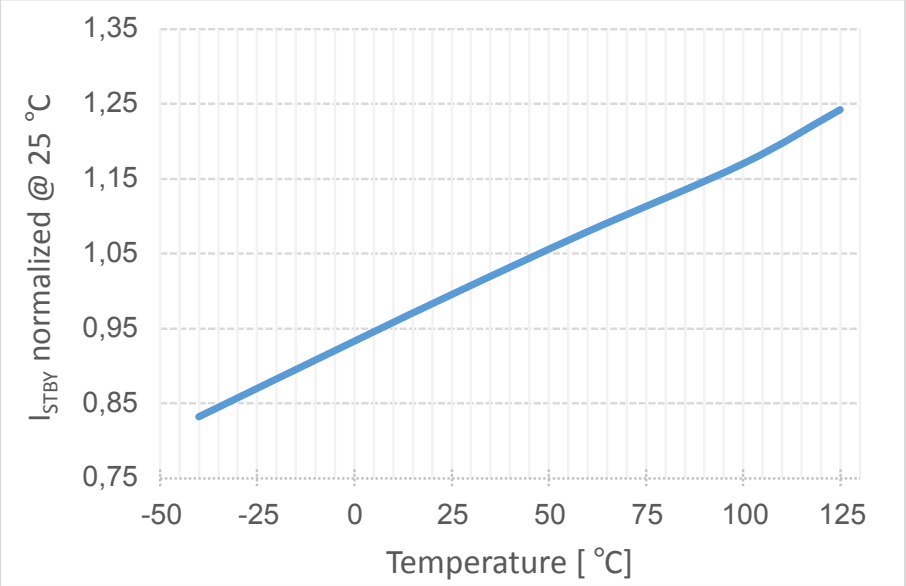
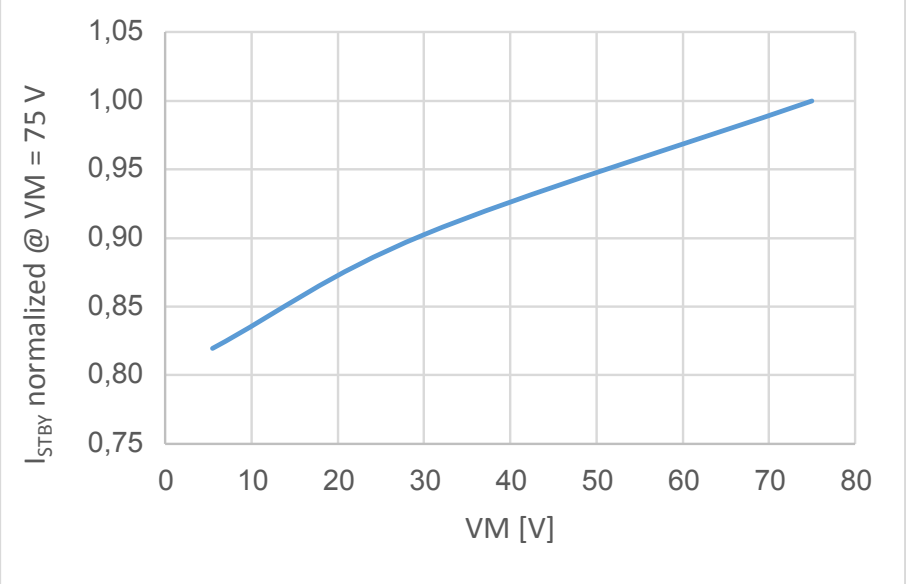
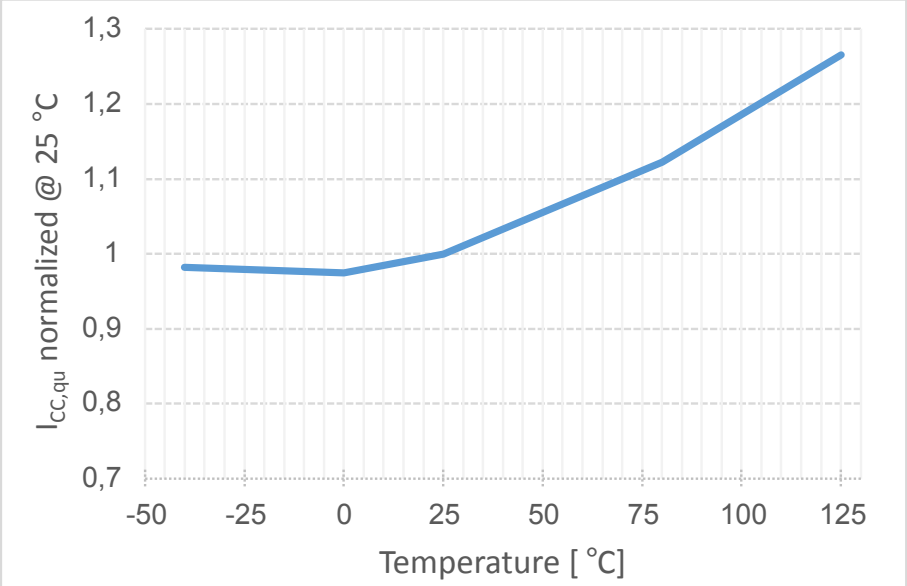


Figure 30. Standby current I_{STBY} vs. supply voltage V_M (normalized at V_M = 75V)



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Figure 31. **VCC quiescent consumption vs. temperature (normalized at ambient temperature)**



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10 Ordering information

Table 27. **Device summary**

Order code	Package	Packaging
STSPIN32G4	VFQFPN 9X9X1.0 64 PITCH 0.50	Tray
STSPIN32G4TR	VFQFPN 9X9X1.0 64 PITCH 0.50	Tape & Reel

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Revision history

Table 28. **Document revision history**

Date	Version	Changes
19-Mar-2021	1	Initial release.
14-Oct-2022	2	Updated Figure 1, Figure 2, Figure 14, Figure 20, Figure 25. Updated Table 2: V_{REF+} test condition; Table 5: $I_{REG3V3,qu}$ unit, $I_{OUTx,bias}$ test condition; Table 6: added TIM1_BKIN and TIM1_BKIN2 functions; Table 24 and Table 25. Updated Section 5.2.4 , Section 5.2.5 and Section 7 , added Section 5.2.6.1 . Minor changes through the document.

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