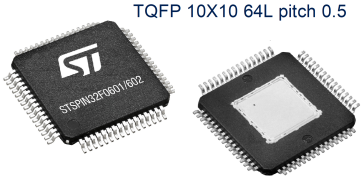
STSPIN32F0601, STSPIN32F0602

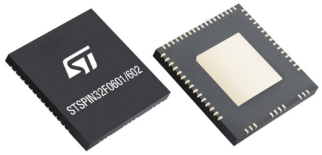
Datasheet

Advanced 600 V three-phase BLDC controller with embedded STM32 MCU

TQFP 10X10 64L pitch 0.5



QFN 10X10 72L pitch 0.5



Product status link
STSPIN32F0601
STSPIN32F0601Q
STSPIN32F0602
STSPIN32F0602Q

Product label
SUSTAINABLE TECHNOLOGY

Features

- Three-phase gate drivers
  - High voltage rail up to 600 V
  - dV/dt transient immunity ±50 V/ns
  - Gate driving voltage range from 9V to 20V
- Driver current capability:
  - STSPIN32F0601/Q: 200/350 mA source/sink current
  - STSPIN32F0602/Q: 1/0.85 A source/sink current
- 32-bit ARM® Cortex®-M0 core:
  - Up to 48 MHz clock frequency
  - 4-kByte SRAM with HW parity
  - 32-kByte Flash memory with option bytes
  - used for write/readout protection
- 21 general-purpose I/O ports (GPIO)
- 6 general-purpose timers
- 12-bit ADC converter (up to 10 channels)
- I^2C, USART and SPI interfaces
- Matched propagation delay for all channels
- Integrated bootstrap diodes
- Comparator for fast over current protection
- UVLO, Interlocking and deadtime functions
- Smart shutdown (smartSD) function
- Standby mode for low power consumption
- On-chip debug support via SWD
- Extended temperature range: -40 to +125 °C
- Package:
  - TQFP 10x10 64L pitch 0.5 Creepage 1.2 mm
  - QFN 10x10 72L pitch 0.5 Creepage 1.8 mm

Applications

- Home and Industrial refrigerators compressors
- Industrial drives, pumps, fans
- Air conditioning compressors & fans
- Corded power tools, garden tools
- Home appliances
- Industrial automation

Description

The STSPIN32F060x system-in-package is an extremely integrated solution for driving three-phase applications, helping designers to reduce PCB area and overall bill-of-material.

It embeds an STM32F031x6x7 featuring an ARM® 32-bit Cortex®-M0 CPU and a 600 V triple half-bridge gate driver, able to drive N-channel power MOSFETs or IGBTs.

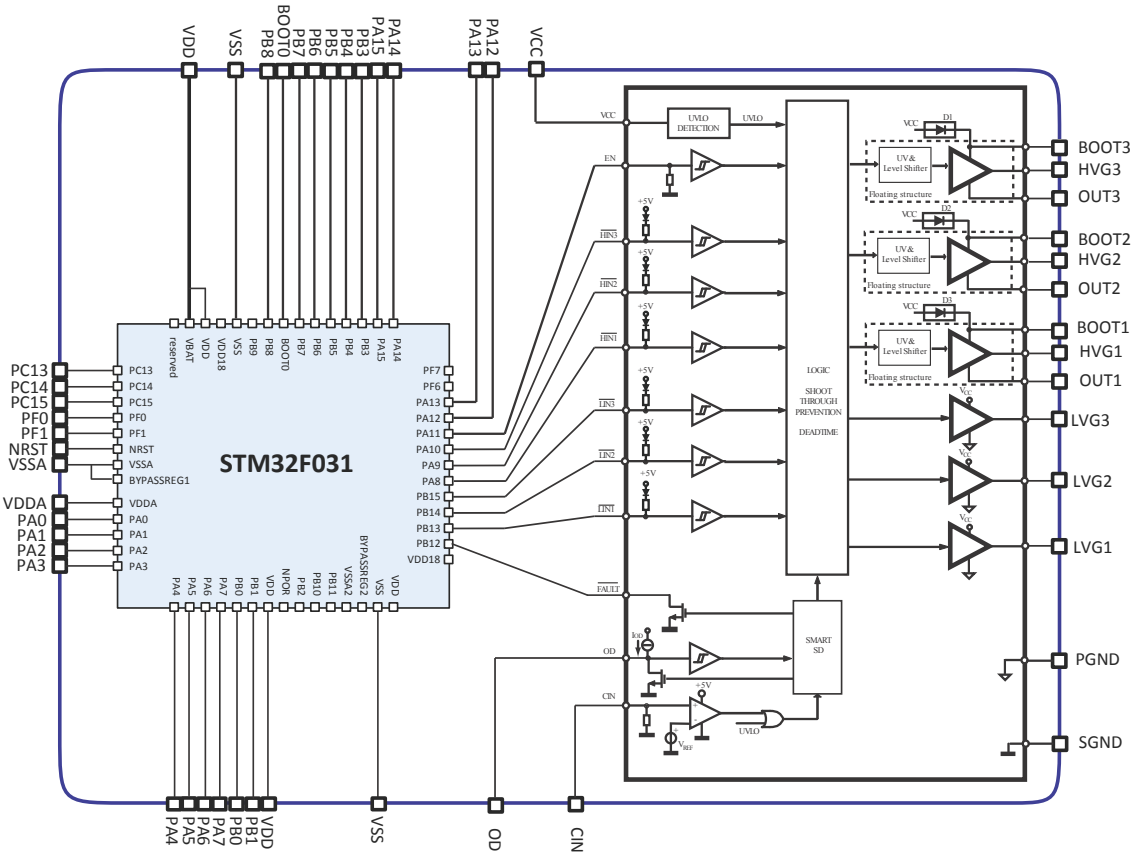
A comparator featuring advanced smartSD function is integrated, ensuring fast and effective protection against overload and overcurrent.

The high-voltage bootstrap diodes are also integrated, as well as anti cross-conduction, deadtime and UVLO protection on both the lower and upper driving sections, which prevents the power switches from operating in low efficiency or dangerous conditions. Matched delays between low and high-side sections guarantee no cycle distortion.

The integrated MCU allows performing FOC, 6-step sensorless and other advanced driving algorithms including the speed control loop.

1 Block diagram

Figure 1. **STSPIN32F060x SiP block diagram**



2 Pin description and connection diagram

Figure 2. **STSPIN32F060x pin connection (TQFP top view)**

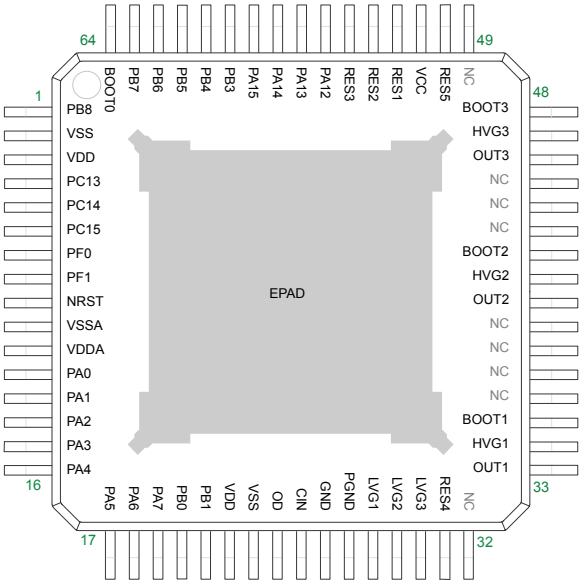


Figure 3. **STSPIN32F060x pin connection (QFN top view)**

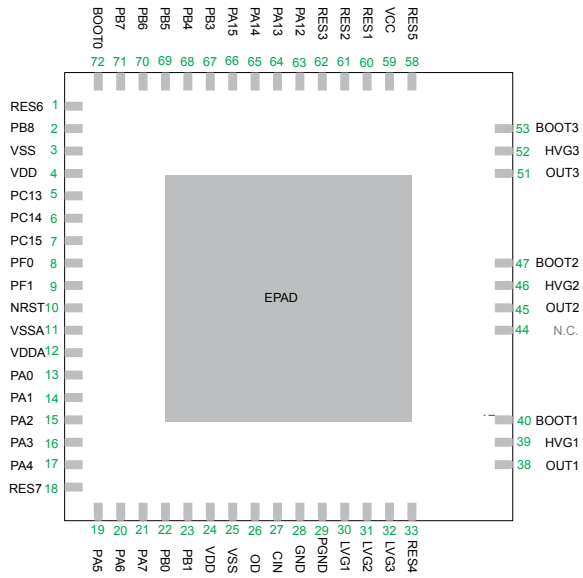


Table 1. Legend/abbreviations used in the pin description table

Name	Abbreviation	
Pin name	Unless otherwise specified in brackets below the pin name, the pin function during and after reset is the same as the actual pin name	
Pin type	AO	Gate Driver Analog Output
	P	Gate Driver Supply\GND pin
	S	Supply pin
	I	Input-only pin
	I/O	Input / output pin
I/O structure	FT	5 V-tolerant I/O
	FTf	5 V-tolerant I/O, FM+ capable
	TTa	3.3 V-tolerant I/O directly connected to ADC
	TC	Standard 3.3V I/O
	B	Dedicated BOOT0 pin
	RST	Bidirectional reset pin with embedded weak pull-up resistor
Notes	Unless otherwise specified by a note, all I/Os are set as floating inputs during and after reset	
Pin functions	Alternate Functions	Functions selected through GPIOx_AFR registers
	Additional functions	Functions directly selected/enabled through peripheral registers

Table 2. STSPIN32F060x MCU-Driver internal connections

MCU pad	Type	controller pad	Function
PB12	I/O - FT	$\overline{\text{FAULT}}$	Gate Driver Fault output
PB13	I/O - FT	$\overline{\text{LIN1}}$	Gate Driver Low Side input driver 1
PB14	I/O - FT	$\overline{\text{LIN2}}$	Gate Driver Low Side input driver 2
PB15	I/O - FT	$\overline{\text{LIN3}}$	Gate Driver Low Side input driver 3
PA8	I/O - FT	$\overline{\text{HIN1}}$	Gate Driver High Side input driver 1
PA9	I/O - FTf	$\overline{\text{HIN2}}$	Gate Driver High Side input driver 2
PA10	I/O - FTf	$\overline{\text{HIN3}}$	Gate Driver High Side input driver 3
PA11	I/O - FT	EN	Gate Driver shut down input

Note: Each unused GPIO inside the SiP should be configured in OUTPUT mode low level after startup by software

3 Pin description table

Table 3. **Pin description**

TQFP N.	QFN N.	Name	Type	Function
-	1	RES6	Reserved	Pin must be left floating
1	2	PB8	I/O - FTf	MCU PB8
2	3	VSS	Supply	MCU digital ground
3	4	VDD	Supply	MCU digital power supply
4	5	PC13	I/O - TC	MCU PC13
5	6	PC14	I/O - TC	MCU PC14
6	7	PC15	I/O - TC	MCU PC15
7	8	PF0	I/O - FT	MCU PF0
8	9	PF1	I/O - FT	MCU PF1
9	10	NRST	I/O - RST	MCU Reset pin
10	11	VSSA	Supply	MCU analog ground
11	12	VDDA	Supply	MCU analog power supply
12	13	PA0	I/O - TTa	MCU PA0
13	14	PA1	I/O - TTa	MCU PA1
14	15	PA2	I/O - TTa	MCU PA2
15	16	PA3	I/O - TTa	MCU PA3
16	17	PA4	I/O - TTa	MCU PA4
-	18	RES7	Reserved	Pin must be left floating
17	19	PA5	I/O - TTa	MCU PA5
18	20	PA6	I/O - TTa	MCU PA6
19	21	PA7	I/O - TTa	MCU PA7
20	22	PB0	I/O - TTa	MCU PB0
21	23	PB1	I/O - TTa	MCU PB1
22	24	VDD	Supply	MCU digital power supply
23	25	VSS	Supply	MCU digital ground
24	26	OD	Analog OD Output	Open Drain comparator output
25	27	CIN	Analog Input	Comparator positive input
26	28	SGND	Power	Driver signal ground
27	29	PGND	Power	Driver power ground
28	30	LVG1(1)	Analog Out	Phase 1 low-side driver output
29	31	LVG2(1)	Analog Out	Phase 2 low-side driver output
30	32	LVG3(1)	Analog Out	Phase 3 low-side driver output
31	33	RES4	Reserved	Pin must be left floating
33	38	OUT1	Power	Phase 1 high-side (floating) common voltage
34	39	HVG1(1)	Analog Out	Phase 1 high-side driver output
35	40	BOOT1	Power	Phase 1 bootstrap supply voltage

TQFP N.	QFN N.	Name	Type	Function
40	45	OUT2	Power	Phase 2 high-side (floating) common voltage
41	46	HVG2(1)	Analog Out	Phase 2 high-side driver output
42	47	BOOT2	Power	Phase 2 bootstrap supply voltage
46	51	OUT3	Power	Phase 3 high-side (floating) common voltage
47	52	HVG3(1)	Analog Out	Phase 3 high-side driver output
48	53	BOOT3	Power	Phase 3 bootstrap supply voltage
50	58	RES5	Reserved	Pin must be left floating
51	59	VCC	Power	Driver low side and logic supply voltage
52	60	RES1	Reserved	Pin must be left floating
53	61	RES2	Reserved	Pin must be left floating
54	62	RES3	Reserved	Pin must be left floating
55	63	PA12	I/O - FT	MCU PA12
56	64	PA13	I/O - FT	MCU PA13/SWDIO (System debug data)
57	65	PA14	I/O - FT	MCU PA14/SWDCLK (System debug clock)
58	66	PA15	I/O - FT	MCU PA15
59	67	PB3	I/O - FT	MCU PB3
60	68	PB4	I/O - FT	MCU PB4
61	69	PB5	I/O - FT	MCU PB5
62	70	PB6	I/O - FTf	MCU PB6
63	71	PB7	I/O - FTf	MCU PB7
64	72	BOOT0	I - B	Boot memory selection
32, 36, 37, 38, 39, 43, 44, 45, 49	44	NC		Not Connected
-	-	EPAD	Power	Exposed pad, internally connected to SGND

1. *The circuit guarantees less than 1 V on the LVG and HVG pins (at I_{sink} = 10 mA), with VCC > 3 V. This allows omitting the "bleeder" resistor connected between the gate and the source of the external MOSFETs normally used to hold the pin low. When the EN is set low, gate driver outputs are forced low and assure low impedance.*

4 Electrical data

4.1 Absolute maximum ratings

(Each voltage referred to SGND unless otherwise specified)

Table 4. Absolute maximum ratings

Symbol	Parameter	Test Condition	Min	Max	Unit
VCC	Power supply voltage		-0.3	21	V
V_{PGND}	Low-side driver ground		VCC – 21	VCC + 0.3	V
V_{PS} (1)	Low-side driver ground		-21	21	V
V_{OUT}	Output voltage		V_{BOOT} – 21	V_{BOOT} + 0.3	V
V_{BOOT}	Bootstrap voltage		-0.3	620	V
V_{HVG}	High side gate output voltage		V_{OUT} – 0.3	V_{BOOT} + 0.3	V
V_{LVG}	Low side gate output voltage		V_{PGND} – 0.3	VCC + 0.3	V
V_{CIN}	Comparator input voltage		-0.3	20	V
V_{OD}	Open-drain voltage (OD, FAULT)		-0.3	21	V
dV_{OUT}/dt	Common mode transient Immunity			50	V/ns
V_{IO}	MCU logic input voltage	TTa type(2)	-0.3	4	V
	Logic input voltage	FT, FTf type(2)	-0.3	VDD + 4 (3)	V
I_{IO}	MCU I/O output current	(2)	-25	25	mA
ΣI_{IO}	MCU I/O total output current	(2)	-80	80	mA
VDD	MCU digital supply voltage	(2)	-0.3	4	V
VDDA	MCU analog supply voltage	(2)	-0.3	4	V
T_{stg}	Storage temperature		-50	150	°C
T_J	Junction temperature		-40	150	°C
P_{TOT}	Total power dissipation			4.5	W
ESD	Human Body Model	TQFP 10x10 64L package	2(4)		kV
		QFN 10x10 72L package	2		

1. $V_{PS} = V_{PGND} - V_{SGND}$
2. *For details see Table 15 and 16 in the STM32F031x6x7 datasheet www.st.com*
3. *Valid only if the internal pull-up/pull-down resistors are disabled. If the internal pull-up or pull-down resistor is enabled, the maximum limit is 4 V.*
4. *Pins 33 to 48 have HBM ESD rating 1C conforming to ANSI/ESDA/JEDEC JS-001-2014.*

4.2 Thermal data

Table 5. Thermal data

Symbol	Parameter	Value	Unit
$R_{th(JA)}$	Thermal resistance junction to ambient(1) TQFP 10x10 64L package	27.6	°C/W
	Thermal resistance junction to ambient (1) QFN 10x10 72L package	22.4	

1. *JEDEC 2s2p PCB in still air.*

4.3 Recommended operating conditions

Table 6. Recommended operating conditions

Symbol	Parameter	Test Condition	Min	Typ	Max	Unit
VCC	Power supply voltage		$(V_{CCthON})_{MAX}$		20	V
V_{LS} (1)	Low-side driver supply voltage		4		20	V
V_{PS} (2)	Low-side driver ground		-5		5	V
V_{BO}(3)	Floating supply voltage		$(V_{BOthON})_{MAX}$		20	V
V_{CIN}	Comparator input voltage		0		15	V
V_{OUT}	DC Output voltage		-10(4)		580	V
F_{SW}	Maximum switching frequency (5)				800	kHz
VDD	Standard MCU operating voltage		3.0	3.3	3.6	V
VDDA	MCU analog operating voltage (ADC not used)	Must have a potential equal to or higher than VDD	VDD		3.6	V
	MCU analog operating voltage (ADC used)		VDD		3.6	V
T_J	Operating junction temperature		-40		125	°C

1. $V_{LS} = VCC - V_{PGND}$
2. $V_{PS} = V_{PGND} - V_{SGND}$
3. $V_{BO} = V_{BOOT} - V_{OUT}$
4. *LVG off. VCC = 9 V. Logic is operational if* $V_{BOOT} > 5$ *V*
5. *Actual maximum* F_{SW} *depends on power dissipation.*

5 Electrical characteristics

(VCC=15 V; VDD=3.3 V; PGND = SGND; T_J = +25 °C, unless otherwise specified)

Table 7. Electrical characteristics

Symbol	Parameter	Test condition	Min	Typ	Max	Unit
Power supply and standby mode						
I_{QCCU}	VCC under-voltage quiescent supply current	VCC = 7 V; EN = 5 V; CIN = SGND		430	744	µA
I_{QCC}	VCC quiescent supply current	EN = 5 V; CIN = SGND LVG & HVG: OFF		950	1450	µA
VCC_{thON}	VCC UVLO turn-on threshold		8	8.5	9	V
VCC_{thOFF}	VCC UVLO turn-off threshold		7.5	8	8.5	V
VCC_{hys}	VCC UVLO threshold hysteresis		0.4	0.5	0.6	V
I_{DD} (1)	VDD current consumption (Supply current in Run mode, code executing from Flash memory)	VDD = 3.6 V HSE bypass, PLL off f_{HCLK} = 1 MHz		0.8		mA
		VDD = 3.6 V HSI clock, PLL on f_{HCLK} = 48 MHz		18.9		
I_{DDA} (1)	VDDA current consumption	VDD = 3.6 V HSE bypass, PLL off f_{HCLK} = 1 MHz		2.0		µA
		VDD = 3.6 V HSI clock, PLL on f_{HCLK} = 48 MHz		220		
V_{POR}	VDD Power on reset threshold	Rising edge	1.84 (2)	1.92	2.00	V
V_{PDR}	VDD Power down reset threshold	Falling edge	1.80	1.88	1.96 (2)	V
$V_{PDRhyst}$	VDD PDR hysteresis			40		mV
High-side floating section supply						
I_{QBOU}	VBO under-voltage quiescent supply current	VCC = VBO = 6.5 V; EN = 5 V; CIN = SGND		25	62	µA
I_{QBO}	VBO quiescent supply current	VBO = 15 V EN = 5 V; CIN = SGND LVG OFF; HVG = ON		84	150	µA
V_{BOthON}	VBO UVLO turn on threshold		7.5	8	8.5	V

Symbol	Parameter	Test condition		Min	Typ	Max	Unit
$V_{BOthOff}$	VBO UVLO turn-off threshold			7	7.5	8	V
V_{BOhys}	VBO UVLO threshold hysteresis			0.4	0.5	0.6	V
I_{LK}	High voltage leakage current	BOOT = HVG = OUT = 620 V				15	µA
R_{Dboot}	Bootstrap diode on resistance	TJ = 25 °C	LVG ON		215	240	Ω
			LVG OFF		215	250	
Output driving buffers							
I_{SO}	Source peak current						
	STSPIN32F0601/Q	TJ = 25 °C		160	200	300	mA
		Full temperature range(3)		130		350	mA
	STSPIN32F0602/Q	TJ = 25 °C		0.88	1.0	1.33	A
		Full temperature range(3)		0.72		1.48	A
I_{SI}	Sink peak current						
	STSPIN32F0601/Q	TJ = 25 °C		230	350	430	mA
		Full temperature range(3)		200		500	mA
	STSPIN32F0602/Q	TJ = 25 °C		0.71	0.85	1.02	A
		Full temperature range(3)		0.51		1.15	A
R_{DSonON}	Source R_{DSon}	I = 10mA					
	STSPIN32F0601/Q	TJ = 25 °C		24	35	46	Ω
		Full temperature range(3)		20		56	Ω
	STSPIN32F0602/Q	TJ = 25 °C		5	6.4	7.6	Ω
		Full temperature range(3)		4.2		10.3	Ω
$R_{DSonOFF}$	Sink R_{DSon}	I = 10mA					
	STSPIN32F0601/Q	TJ = 25 °C		11	16	21	Ω
		Full temperature range(3)		8		27	Ω
	STSPIN32F0602/Q	TJ = 25 °C		5.5	6.7	8	Ω
		Full temperature range(3)		4.5		11.2	Ω
Logic Inputs							
V_{il}	Low level logic threshold voltage	TTa type (4)				0.3·VDD+ 0.07	V
		FT, FTf type (4)				0.475 ·VDD –0.2	V
V_{ih}	High level logic threshold voltage	TTa type (4)		0.45 ·VDDIOx + 0.398			V
		FT, FTf type (4)		0.5 ·VDDIOx +0.2			V
V_{hyst}	Schmitt trigger hysteresis	TTa type (4)		200			mV
		FT, FTf type (4)		100			mV

Symbol	Parameter	Test condition	Min	Typ	Max	Unit
I_{lkg}	Input leakage current	TC, FT and FTf I/O TTa in digital mode VSS ≤ VIN ≤ VDDIOx			± 0.1	µA
		TTa in digital mode VDDIOx ≤ VIN ≤ VDDA			1	
		TTa in analog mode VSS ≤ VIN ≤ VDDA			± 0.1	
		FT and FTf I/O VDDIOx ≤ VIN ≤ 5 V			10	
V_{SSDh}	SmartSD restart threshold		3.5	4	4.3	V
V_{SSDl}	SmartSD unlatch threshold			0.56	0.75	V
Sense Comparator and FAULT						
V_{REF}	Internal voltage reference		410	460	510	mV
CIN_{hyst}	Comparator input hysteresis		40	70		mV
CIN_{PD}	Comparator input pull-down current	VCIN = 1 V	7	10	13	µA
I_{OD}	OD internal current source		2.5	5	7.5	µA
R_{ON_OD}	OD On resistance	IOD = 16 mA	19	25	36	W
I_{SAT_OD}	OD saturation current	V_{OD} = 5 V		95		mA
V_{FLOAT_OD}	OD floating voltage level	OD connected only to an external capacitance	4.4	4.8	5.2	V
I_{OL_OD}	OD low level sink current	V_{OD} = 400 mV	11	16	21	mA
R_{ON_F}	FAULT On resistance	I_{FAULT} = 8 mA		50	100	Ω
I_{OL_F}	FAULT low level sink current	V_{FAULT} = 400mV	4	8	12	mA
t_{OD}	Comparator propagation delay	Rpu = 100 kΩ to 5 V; 0 to 3.3 V voltage step on CIN 50% CIN to 90% OD		350	500	ns
t_{CIN-F}	Comparator triggering to FAULT	0 to 3.3 V voltage step on CIN; 50% CIN to 90% FAULT		350	500	ns
t_{CINoff}	Comparator triggering to high/low side driver propagation delay	0 to 3.3 V voltage step on CIN 50% CIN to 90% LVG/HVG		360	510	ns
t_{FCIN}	Comparator input filter time		200	300	400	ns
SR	Slew rate	CL = 1 nF; Rpu = 1 kΩ to 5 V; 90% to 10% OD	4	7.7	10.3	V/µs

Symbol	Parameter	Test condition	Min	Typ	Max	Unit
Driver dynamic characteristics						
t_{on}	High/Low-side driver turn-on propagation delay	OUT = 0 V BOOT = VCC CL = 1 nF Vin = 0 to 3.3 Vsee Figure 4	45	85	120	ns
t_{off}	High/Low-side driver turn-off propagation delay		45	85	120	ns
t_{EN}	Enable to high/low side driver propagation delay		245	345	520	ns
t_r	Rise time	CL= 1 nF				
	STSPIN32F0601/Q			120		ns
	STSPIN32F0602/Q			19		
t_f	Fall time	CL= 1 nF				
	STSPIN32F0601/Q			50		ns
	STSPIN32F0602/Q			17		
MT	Delay matching high/low side turn-on/off (6)			0	30	ns
DT	Deadtime	CL= 1 nF	200	300	400	ns
MDT	Matching deadtime (7)	CL= 1 nF		0	50	ns

1. *The current consumption depends on the firmware loaded in the microcontroller. See STM32F031x6x7 datasheet.www.st.com*
2. *Data based on characterization results, not tested in production.*
3. *Values provided by characterization, not tested*
4. *Data based on design simulation only. Not tested in production.*
5. *Comparator is disabled when VCC is in UVLO condition.*
6. *MT = max. ($|t_{on}(LVG) - t_{off}(LVG)|$, $|t_{on}(HVG) - t_{off(}HVG)|$, $|t_{off(}LVG) - t_{on}(HVG)|$, $|t_{off}(HVG) - t_{on}(LVG)|$)*
7. *MDT = | DTLH - DTHL |, refer to Figure 4.*

Figure 4. **Propagation delay timing definition**

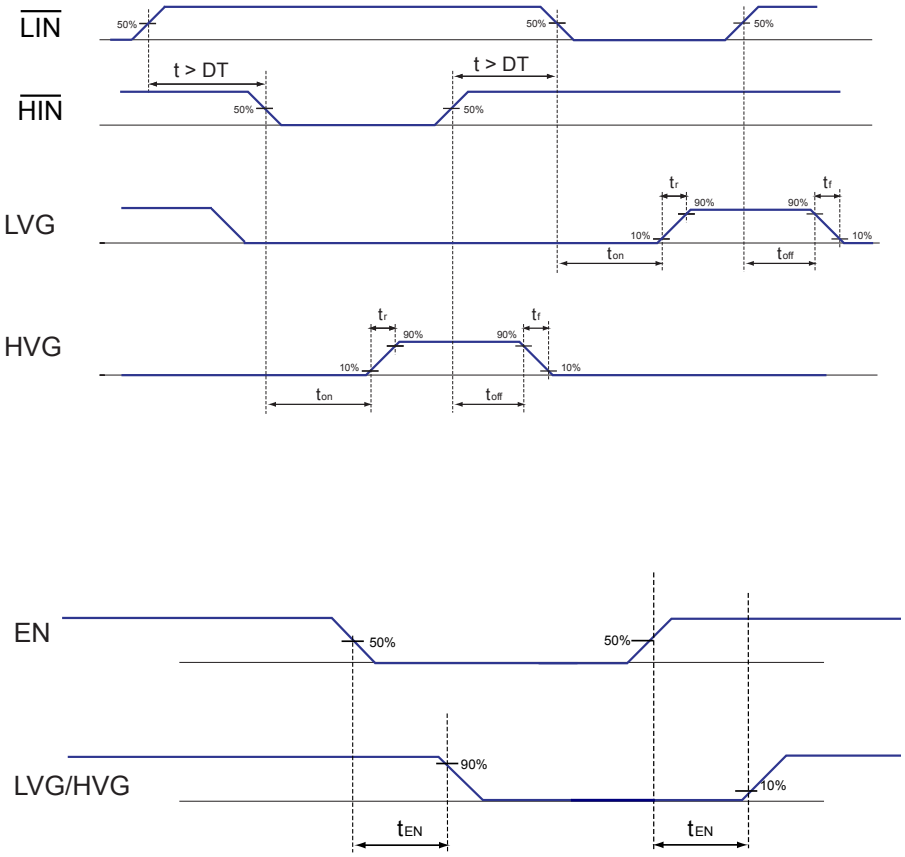


Figure 5. **Deadtime timing definitions**

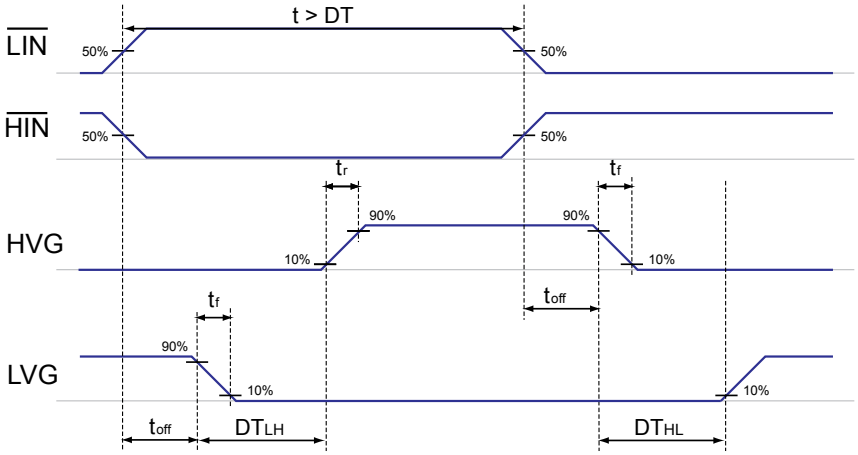
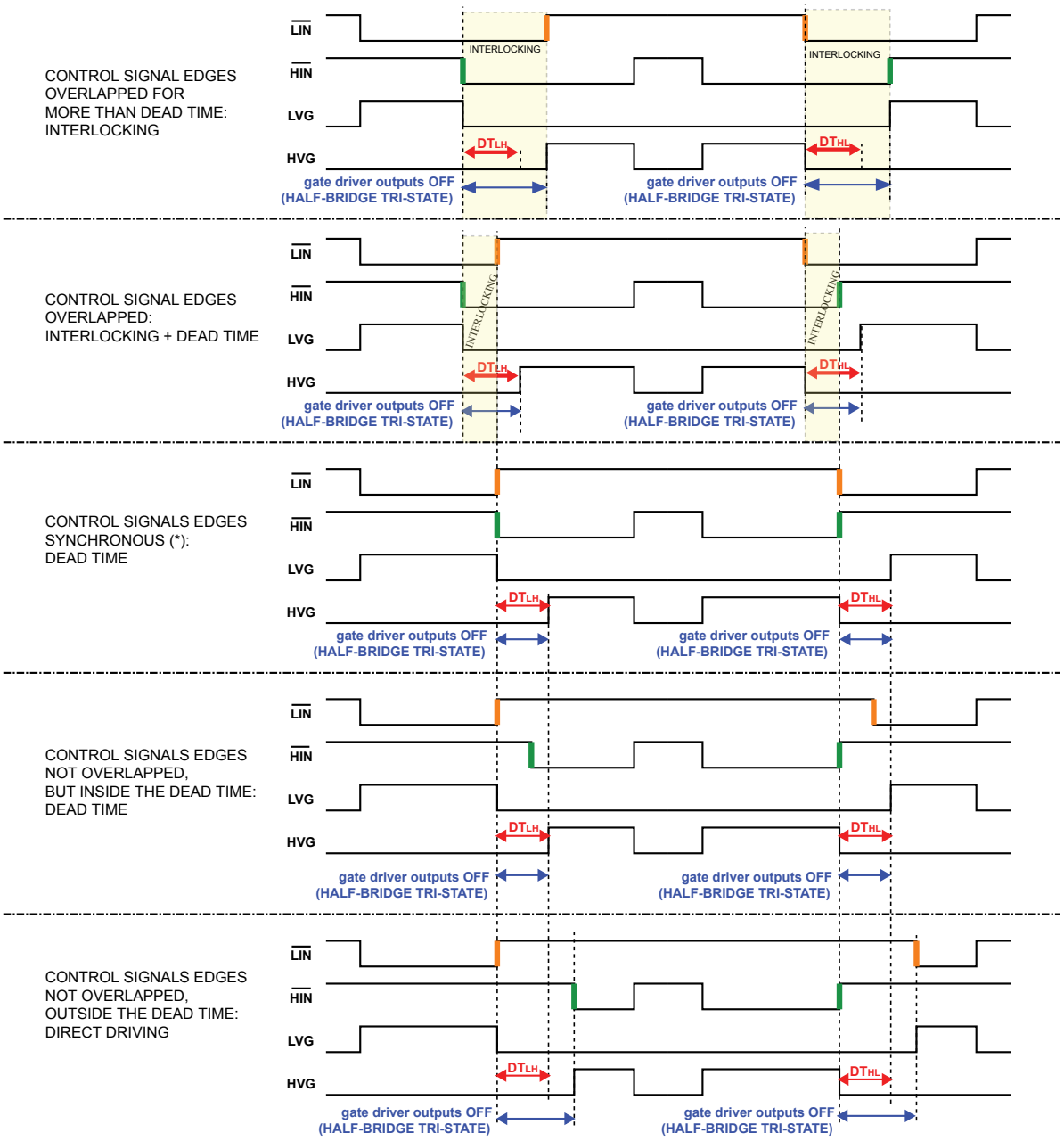


Figure 6. Deadtime and interlocking waveforms definition



6 Device description

The STSPIN32F060x is a system-in-package providing an integrated solution suitable for driving high-voltage 3-phase applications.

6.1 Gate driver

The STSPIN32F060x integrates a triple half-bridge gate driver able to drive N-channel power MOSFETs or IGBTs. The high-side section is supplied by a bootstrapped voltage technique with integrated bootstrap diode.

All the inputs lines are connected to a pull-down resistor with typical value of 60 kΩ.

The high- and low-side outputs of same half-bridge cannot be simultaneously driven high thanks to an integrated interlocking function.

6.1.1 Inputs and outputs

The device is controlled through the following logic inputs:

- EN: enable input, active high;
- LIN: low-side driver inputs, active low;
- HIN: high-side driver inputs, active low.

Table 8. Inputs truth table (applicable when device is not in UVLO or SmartSD protection)

	Input pins			Output pins	
	EN	**$\overline{\text{LIN}}$**	**$\overline{\text{HIN}}$**	**LVG**	**HVG**
	L	X	X	Low	Low
	H	H	H	Low	Low
	H	L	H	**HIGH**	Low
	H	H	L	Low	**HIGH**
Interlocking	H	L	L	Low	Low

Note: X : Don't care

The FAULT and OD pins are open-drain outputs. The FAULT signal is set low in case VCC UVLO is detected, or in case the SmartShutDown comparator triggers an event. It is only used to signal a UVLO or SmartSD activation to external circuits, and its state does not affect the behavior of other functions or circuits inside the driver. The OD behavior is explained in Section 6.1.5 .

6.1.2 Deadtime

The deadtime feature, in companion with the interlocking feature, guarantees that driver outputs of the same channel are not high simultaneously and at least a DT time passes between the turn-off of one driver's output and the turn-on of the companion output of the same channel. If a deadtime longer than the internal DT is applied to LIN and HIN inputs by the external controller, the internal DT is ignored and the outputs follow the deadtime determined by the inputs. Refer to Figure 4 for the deadtime and interlocking waveforms.

6.1.3 VCC UVLO protection

Undervoltage protection is available on VCC and BOOT supply pins. In order to avoid intermittent operation, a hysteresis sets the turn-off threshold with respect to the turn-on threshold.

When VCC voltage goes below the $V_{CCthOFF}$ threshold all the outputs are switched off, both LVG and HVG. When VCC voltage reaches the V_{CCthON} threshold the driver returns to normal operation and sets the LVG outputs according to actual input pins status; HVG is also set according to input pin status if the corresponding VBO section is not in UVLO condition. The FAULT output is kept low when VCC is in UVLO condition. The following figures show some examples of typical operation conditions.

Figure 7. **VCC power ON and UVLO, LVG timing**

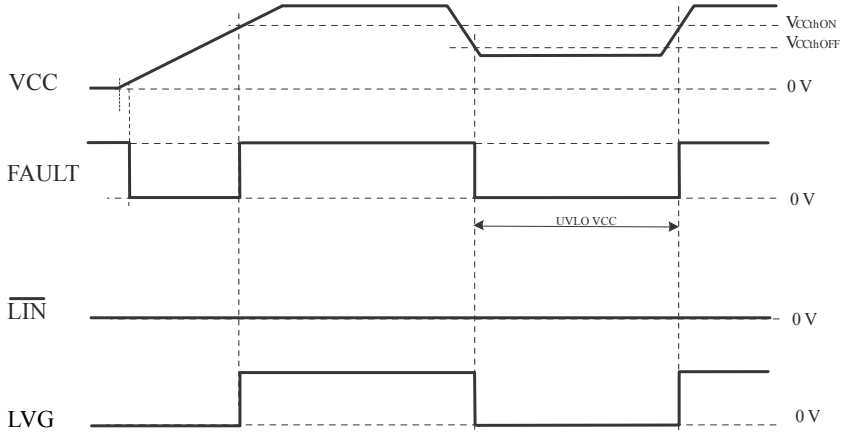
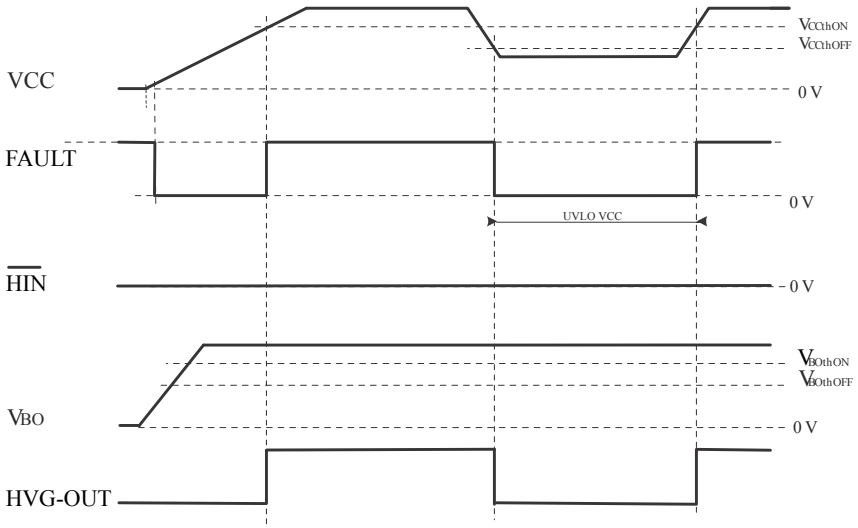


Figure 8. **VCC power ON and UVLO, HVG timing**

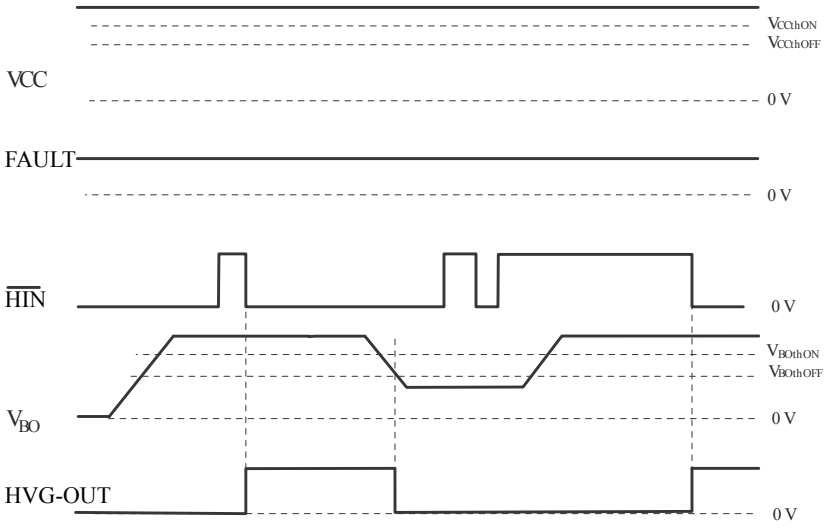


6.1.4 V_{BO} UVLO protection

Dedicated undervoltage protection is available on each bootstrap section between BOOTx and OUTx supply pins. In order to avoid intermittent operation, a hysteresis sets the turn-off threshold with respect to the turn-on threshold.

When VBO voltage goes below the $V_{BOthOFF}$ threshold, the HVG output of the corresponding bootstrap section is switched off. When VBO voltage reaches the V_{BOthON} threshold the device returns to normal operation and the output remains off up to the next input pins transition that requests HVG to turn on.

Figure 9. **VBO Power-ON and UVLO timing**



6.1.5 Comparator and Smart shutdown

The STSPIN32F060x integrates a comparator committed to the fault protection function, thanks to the SmartShutDown (SmartSD) circuit.

The SmartSD architecture allows immediate turn-off of the gate driver outputs in the case of overload or overcurrent condition, by minimizing the propagation delay between the fault detection event and the actual output switch-off. In fact, the time delay between the fault detection and the output turn-off is not dependent on the value of the external components connected to the OD pin, which are only used to set the duration of disable time after the fault.

This provides the possibility to increase the duration of the output disable time after the fault event up to very large values without increasing the delay time of the protection. The duration of the disable time is determined by the values of the external capacitor C_{OD} and of the optional pull-up resistor connected to the OD pin.

The comparator has an internal voltage reference V_{REF} connected to the inverting input, while the non-inverting input is available on the CIN pin. The comparator's CIN input can be connected to an external shunt resistor in order to implement a fast and simple overcurrent protection function. The output signal of the comparator is filtered from glitches shorter than t_{FCIN} and then fed to the SmartSD logic.

If the impulse on the CIN pin is higher than V_{REF} and wider than t_{FCIN}, the SmartSD logic is triggered and immediately sets all of the driver outputs to low-level (OFF).

At the same time, FAULT is forced low to signal the event (for example to a MCU input) and OD starts to discharge the external C_{OD} capacitor used to set the duration of the output disable time of the fault event.

The FAULT pin is released and driver outputs restart following the input pins as soon as the *output disable time* expires.

The overall disable time is composed of two phases:

- The OD *unlatch time* (t_1 in Figure 10), which is the time required to discharge the C_{OD} capacitor down to the V_{SSDl} threshold. The discharge starts as soon as the SSD comparator is triggered.
- The OD *Restart time* (t_2 in Figure 10), which is the time required to recharge the C_{OD} capacitor up to the V_{SSDh} threshold. The recharge of C_{OD} starts when the OD internal MOSFET is turned-off, which happens when the fault condition has been removed (CIN < V_{REF} - $C_{INhyst)}$ and the voltage on OD reaches the V_{SSDl} threshold. This time normally covers most of the overall output disable time.

If no external pull-up is connected to OD, the external C_{OD} capacitor is discharged with a time constant defined by C_{OD} and the internal MOSFET's characteristic (Equation 1), and the Restart time is determined by the internal current source I_{OD} and by C_{OD} (Equation 2).

Equation 1

$$t_1 \cong R_{ON\_OD} \cdot C_{OD} \cdot \ln\left(\frac{V_{OD}}{V_{SSDl}}\right) \quad (1)$$

Equation 2

$$t_2 \cong \frac{C_{OD} \cdot V_{SSDh}}{I_{OD}} \cdot \ln\left(\frac{V_{SSDl} - V_{OD}}{V_{SSDh} - V_{OD}}\right) \quad (2)$$

Where $V_{OD} = V_{FLOAT\_OD}$ In case the OD pin is connected to VCC by an external pull-up resistor R_{OD_ext}, the OD discharge time is determined by the external network R_{OD_ext} C_{OD} and by the internal MOSFET's R_{ON_OD} (Equation 3), while the Restart time is determined by current in R_{OD_ext} (Equation 4)

Equation 3

$$t_1 \cong C_{OD} \cdot \left(R_{OD\_ext} // R_{ON\_OD}\right) \cdot \ln\left(\frac{V_{OD} - V_{on}}{V_{SSDl} - V_{on}}\right) \quad (3)$$

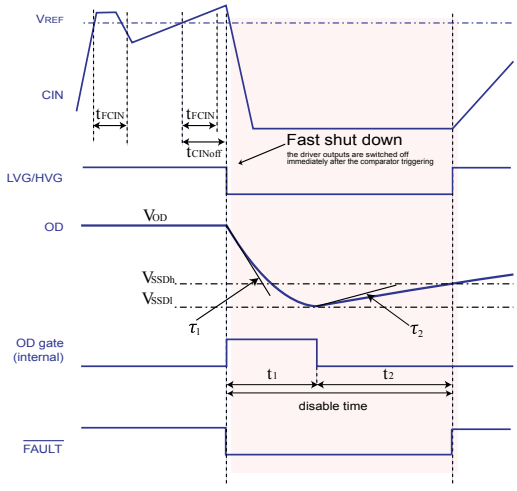
Equation 4

$$t_2 \cong C_{OD} \cdot R_{OD\_ext} \cdot \ln\left(\frac{V_{SSDl} - V_{OD}}{V_{SSDh} - V_{OD}}\right) \quad (4)$$

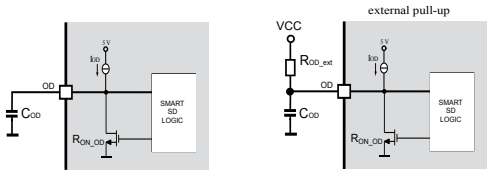
where

$$V_{on} = \frac{R_{ON\_OD}}{R_{OD\_ext} + R_{ON\_OD}} \cdot V_{cc} \;\; ; \quad V_{OD} = V_{cc}$$

Figure 10. Smart shutdown timing waveforms



SMART SHUTDOWN CIRCUIT



6.2 Microcontroller unit

The integrated MCU is the STM32F031x6 with the following main characteristics:

- Core: ARM® 32-bit Cortex® -M0 CPU, frequency up to 48 MHz
- Memories: 4kB of SRAM, 32 kB of Flash Memory
- CRC calculation unit
- Up to 21 fast I/Os
- Advanced-control timer dedicated for PWM generation
- Up to 6 general purpose timers
- 12-bit ADC (up to 10 channels)
- Communication interfaces: I^2C, USART, SPI
- Serial Wire Debug (SWD)
- Extended temperature range: -40 to 125°C

Note: For more details refer to the STM32F031x6 datasheet on www.st.com

6.2.1 Memories and boot mode

The device has the following features:

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

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

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

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

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

The boot loader is located in System Memory, programmed by ST during production. It is used to reprogram the Flash memory by using USART on pins PA14/PA15.

6.2.2 Power management

The VDD pin is the power supply for I/Os and the internal regulator.

The VDDA pin is power supply for ADC, Reset blocks, RCs and PLL. The VDDA voltage is provided externally through VDDA pin

Note: The VDDA voltage level must be always greater or equal to the VDD voltage level and must be established first.

The MCU has integrated power-on reset (POR) and power-down reset (PDR) circuits. They are always active, and ensure proper operation above a threshold of 2 V. The device remains in reset mode when the monitored supply voltage is below a specified threshold, VPOR/PDR, without the need for an external reset circuit.

- The POR monitors only the VDD supply voltage. During the startup phase it is required that VDDA should arrive first and be greater than or equal to VDD.
- The PDR monitors both the VDD and VDDA supply voltages, however the VDDA power supply supervisor can be disabled (by programming a dedicated Option bit) to reduce the power consumption if the application design ensures that VDDA is higher than or equal to VDD.

The device features an embedded programmable voltage detector (PVD) that monitors the VDD power supply and compares it to the VPVD threshold. An interrupt can be generated when VDD drops below the VPVD threshold and/or when VDD is higher than the VPVD 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.

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

- **Sleep mode**

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

- **Stop mode**

  Stop mode achieves very low power consumption while retaining the content of SRAM and registers. All clocks in the 1.8 V domain are stopped, the PLL, the HSI RC and the HSE crystal oscillators are disabled. The voltage regulator can also be put either in normal or in low power mode.

  The device can be woken up from Stop mode by any of the EXTI lines (one of the 16 external lines, the PVD output, RTC, I^2C1 or USART1).

- **Standby mode**

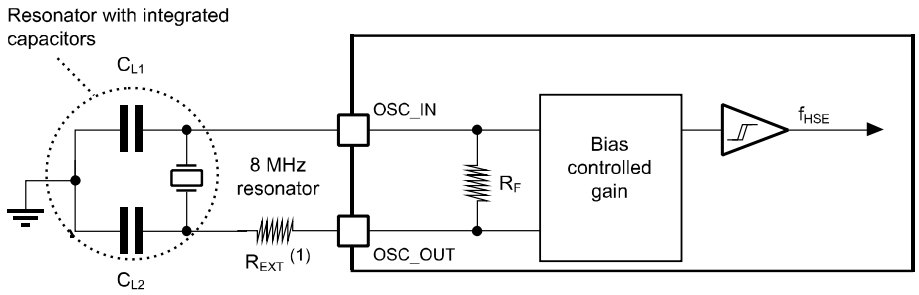
  The Standby mode is used to achieve the lowest power consumption. The internal voltage regulator is switched off so that the entire 1.8 V domain is powered off. The PLL, the HIS RC and the HSE crystal oscillators are also switched off. After entering Standby mode, SRAM and register contents are lost except for registers in the RTC domain and Standby circuitry.

  The device exits Standby mode when an external reset (NRST pin), an IWDG reset, a rising edge on the WKUP pins, or an RTC event occurs.

6.2.3 High-speed external clock source

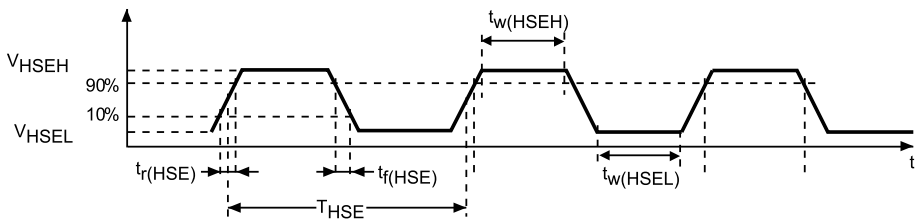
The high-speed external (HSE) clock can be generated from external clock signal or supplied with a 4 to 32 MHz crystal/ceramic resonator oscillator (see Figure 11). In the application, the resonator and the load capacitors have to be placed as close as possible to the oscillator pins in order to minimize output distortion and startup stabilization time.

Figure 11. Typical application with 8 MHz crystal



1. The REXT value depends on the crystal characteristics (refer to the crystal resonator manufacturer for more details on them).
2. The external clock signal has to respect the I/O characteristics and follows recommended clock input waveform (refer to Figure 12).

Figure 12. HSE clock source timing diagram



6.3 Advanced-control timer (TIM1)

The advanced-control timer (TIM1) can be seen as a three-phase PWM multiplexed on six channels. It has complementary PWM outputs with programmable inserted deadtimes.

This timer is used to generate the PWM signal for the three half-bridge gate drivers as shown in Table 9.

Table 9. TIM1 channel configuration

MCU I/O	ASIC input	TIM1 channel
PB13	LIN1	TIM1_CH1N
PB14	LIN2	TIM1_CH2N
PB15	LIN3	TIM1_CH3N
PA8	HIN1	TIM1_CH1
PA9	HIN2	TIM1_CH2
PA10	HIN3	TIM1_CH3

7 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.

7.1 TQFP 10x10 64L package information

Figure 13. TQFP mechanical data

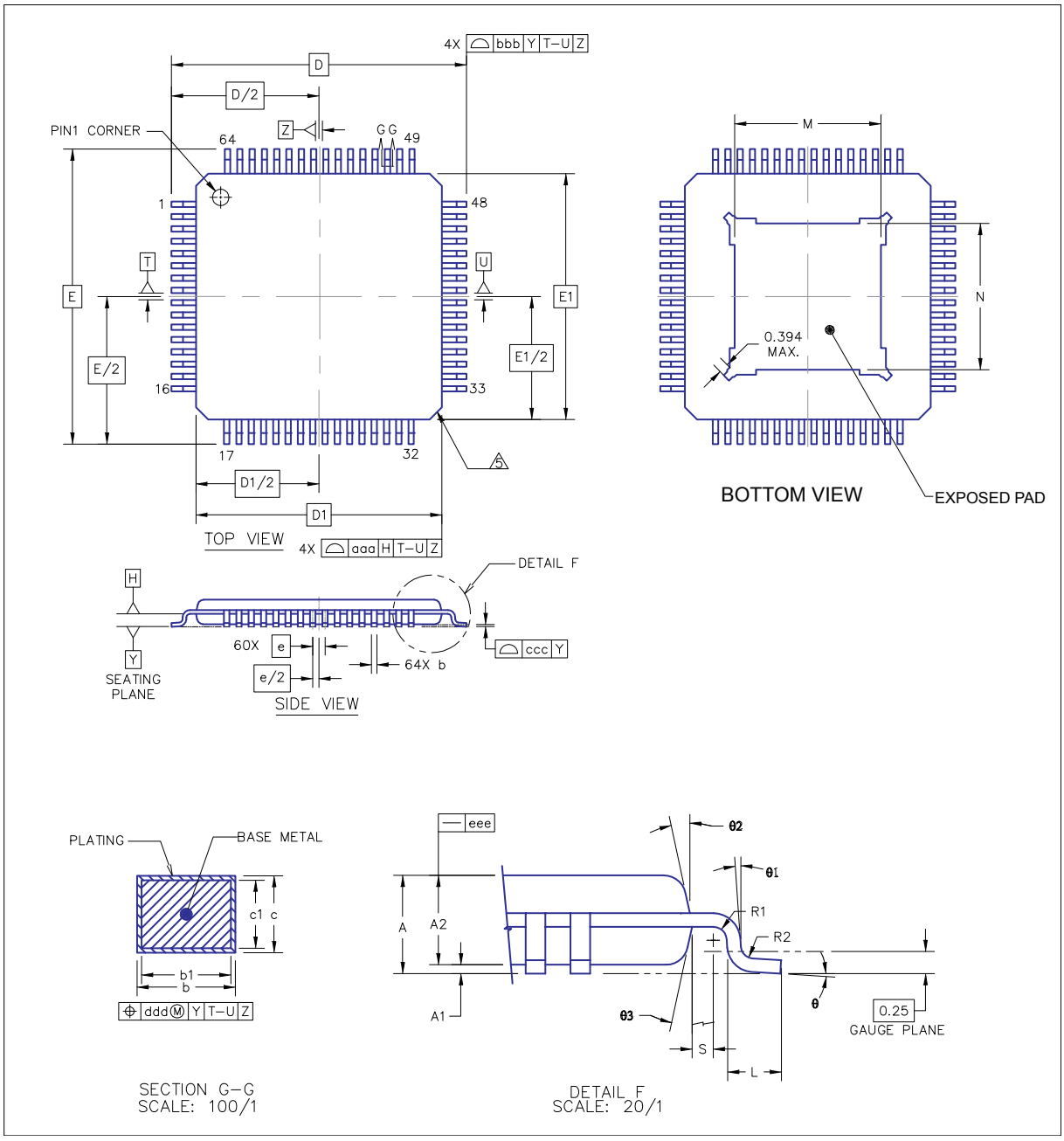


Table 10. TQFP package dimensions

		Symbol	Min	Nom	Max
TOTAL THICKNESS		A	-	-	1.2
STAND OFF		A1	0.05	-	0.15
MOLD THICKNESS		A2	0.95	-	1.05
LEAD WIDTH(PLATING)		b	0.17	0.22	0.27
LEAD WIDTH		b1	0.17	0.2	0.23
L/F THICKNESS(PLATING)		c	0.09	-	0.2
L/F THICKNESS		c1	0.09	-	0.16
	X	D	-	12	-
	Y	E	-	12	-
BODY SIZE	X	D1	-	10	-
	Y	E1	-	10	-
LEAD PITCH		e	-	0.5	-
		L	0.45	0.6	0.75
		θ	0°	3.5°	7°
		θ1	0°	-	-
		θ2	11°	12°	13°
		θ3	11°	12°	13°
		R1	0.08	-	-
		R2	0.08	-	0.2
		S	0.2	-	-
EP SIZE	X	M	5.85	5.95	6.05
	Y	N	5.85	5.95	6.05
PACKAGE LEAD TOLERANCE		aaa	0.2		
LEAD EDGE TOLERANCE		bbb	0.2		
COPLANARITY		ccc	0.08		
LEAD OFFSET		ddd	0.08		
MOLD FLATNESS		eee	0.05		

Note: All dimensions are mm unless otherwise specified

Figure 14. QFN mechanical data

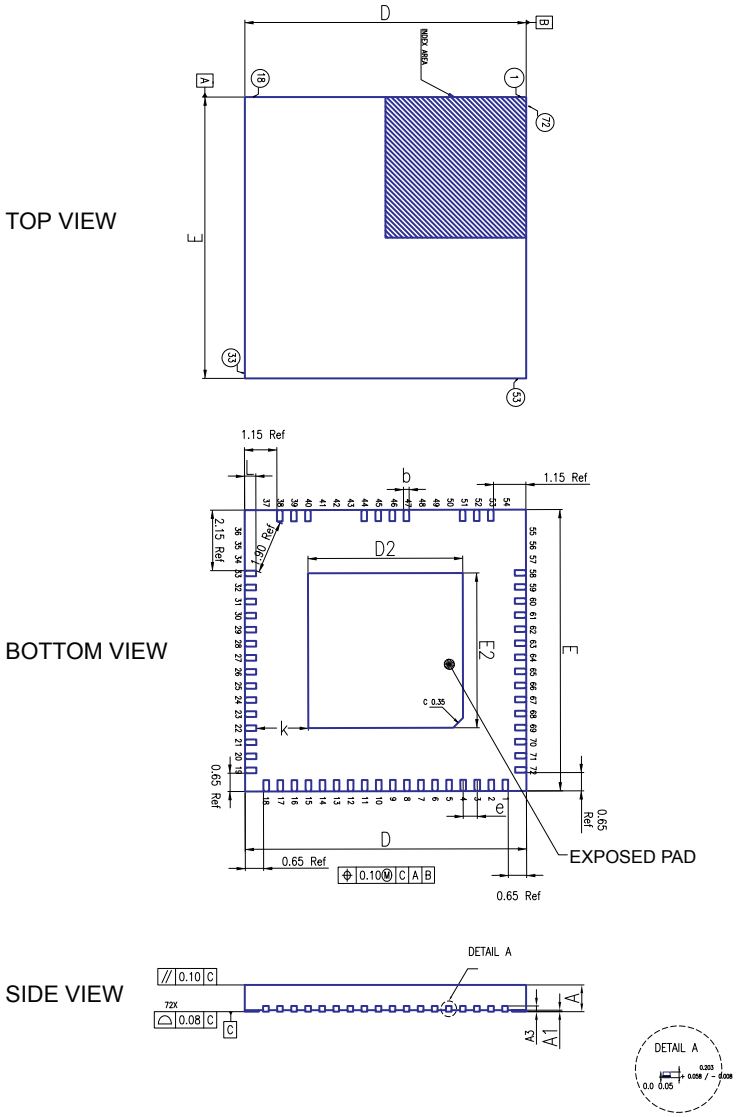


Table 11. QFN package dimensions

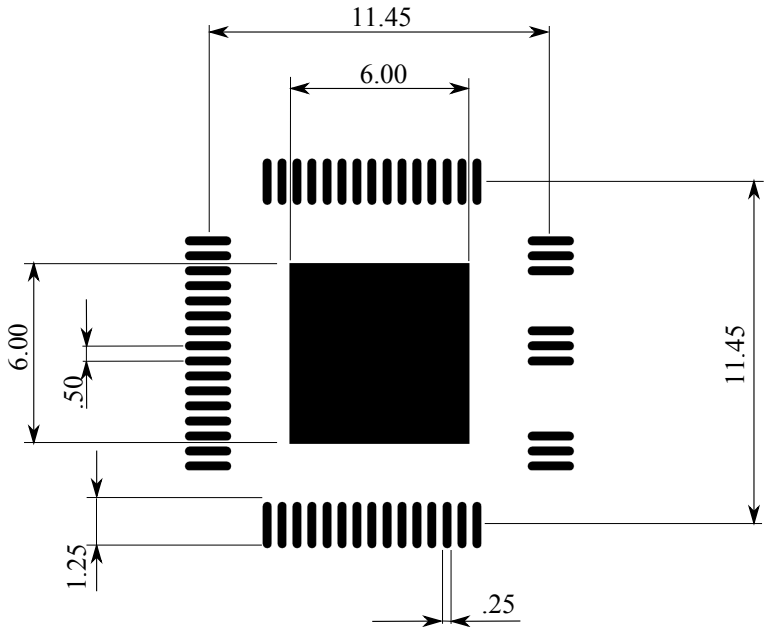
	Symbol	Min	Non	Max
TOTAL THICKNESS	A	0.90	0.95	1.00
STAND OFF	A1	0		0.05
L/F THICKNESS	A3		0.20 Ref.	
LEAD WIDTH	b	0.15	0.20	0.25
BODY LENGTH X	D	9.90	10.00	10.10
EP LENGTH X	D2	5.40	5.50	5.60
LEAD PITCH	e		0.50 BSC	
BODY WIDTH Y	E	9.90	10.00	10.10
EP WIDTH Y	E2	5.40	5.50	5.60
LEAD LENGTH	L	0.30	0.40	0.50

	Symbol	Min	Non	Max
	K		1.85 Ref.	

Note: All dimensions are mm unless otherwise specified

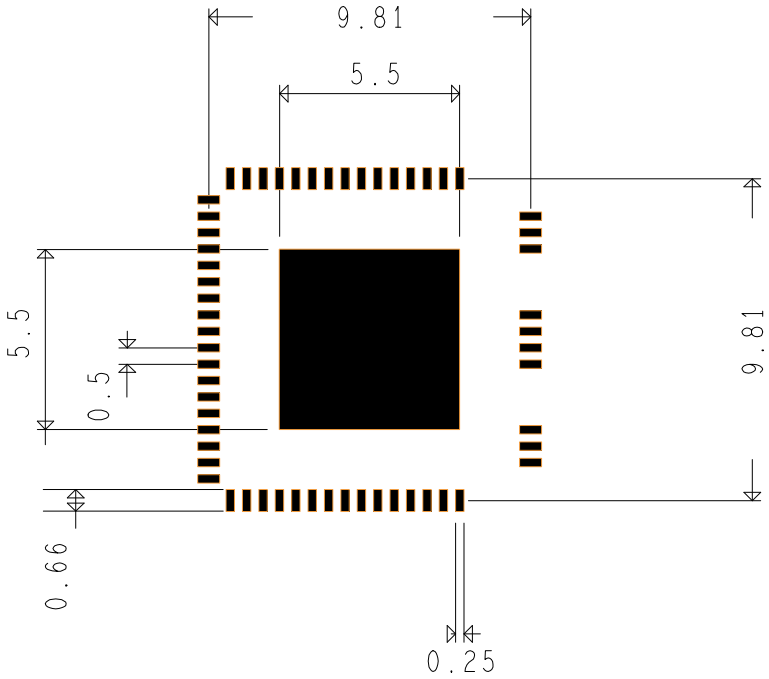
7.2 Suggested land pattern

Figure 15. TQFP 10x10 64L suggested land pattern



Note: All dimensions are mm unless otherwise specified

Figure 16. QFN 10x10 72L suggested land pattern



8 Ordering information

Table 12. **Order codes**

Order code	Package	Package marking	Packaging
STSPIN32F0601	TQFP 10x10 64L	STSPIN32F0 601	Tray
STSPIN32F0601TR	TQFP 10x10 64L	STSPIN32F0 601	Tape and Reel
STSPIN32F0602	TQFP 10x10 64L	STSPIN32F0 602	Tray
STSPIN32F0602TR	TQFP 10x10 64L	STSPIN32F0 602	Tape and Reel
STSPIN32F0601Q	QFN 10 x 10 72L	SPINF601Q	Tray
STSPIN32F0601QTR	QFN 10 x 10 72L	SPINF601Q	Tape and Reel
STSPIN32F0602Q	QFN 10 x 10 72L	SPINF602Q	Tray
STSPIN32F0602QTR	QFN 10 x 10 72L	SPINF602Q	Tape and Reel

Revision history

Table 13. **Document revision history**

Date	Version	Changes
12-Jun-2019	1	Initial release.
29-Aug-2019	2	Minor text changes
04-Sept-2019	3	Minor change to Table 10
28-Oct-2020	4	Added QFN package version
20-Feb-2021	5	Updated Table 5, Table 7. Updated Figure 6, 7, 8, 9, and 10.

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