

# System In Package STSPIN32F0 3-phase controller with STM32F0

Technical training



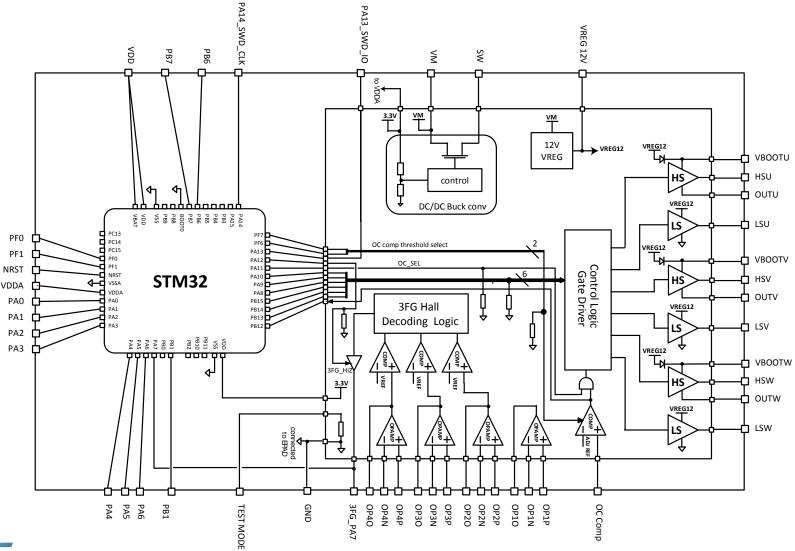
## Designed for 3-phase BLDC applications

- FAN, vacuum cleaner
- Drones
- Power Tools
- Home appliances
- Robots
- Key points:
  - Small size 7x7 package
  - Field Oriented Control 1 shunt/3 shunt





# STSPIN32F0 Block Diagram



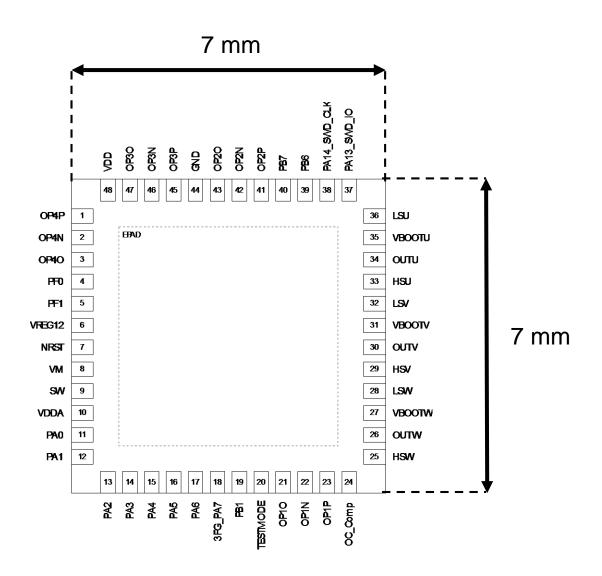


## STSPIN32F0 – Main features

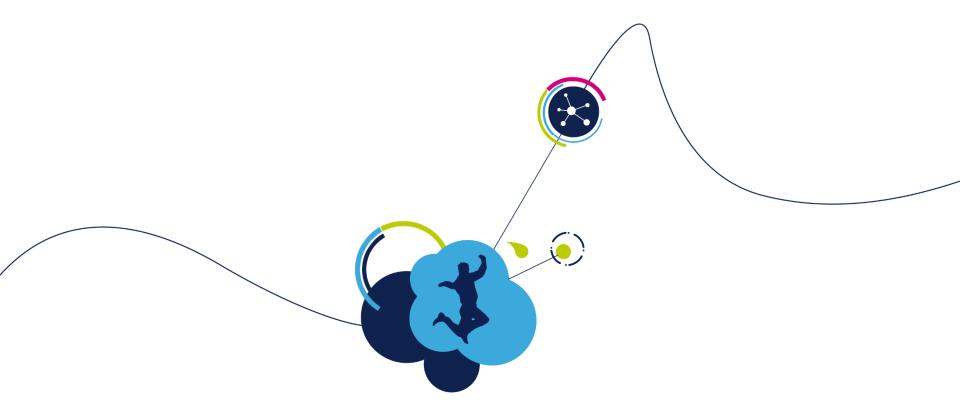
- Operating voltage from 8 to 45 V
- Three phase gate drivers
  - 600 mA sink/source current capability
  - Embedded bootstrap diode
  - Interlocking protection
- Embedded STM32F031x6x7
- 3.3 V buck converter
- 12 V LDO linear regulator
- 4x Operation Amplifiers
- Comparator for over-current protection
- Analog Hall sensor decoding with 3FG open-drain output
- UVLO protection on all supply voltages
- Internal over-temperature shut down



## STSPIN32F0 - Pinout







# Embedded STM32F031

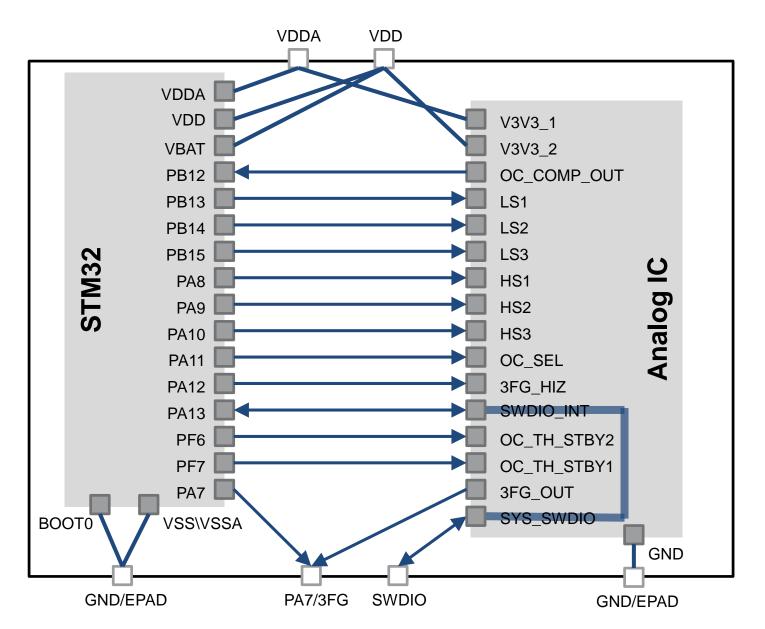


## STM32F031x6x7 MCU characteristics

- 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 16 fast I/Os
- Advanced-control timer dedicated for PWM generation
- Up to 5 general purpose timers
- 12-bit ADC (up to 9 channels)
- Communication interfaces: I2C, USART, SPI
- Serial Wire Debug (SWD)
- Extended temperature range: -40 to 125°C



### Internal connections





## Internal connections

Some GPIOs of the STM32F0 are directly connected to the Analog IC.

For this reason it is mandatory to properly setup these GPIOs at the very beginning of the MCU initialization.

STM32 Pin	Analog IC	Function and notes
PA7	3FGOUT	When 3FG_HIZ is low, PA7 can be set in any mode When 3FG_HIZ is high, PA7 must be set as input
PB12	OC_COMP_INT	Input → TIM1_BKIN
PB13	LS1	Output Push-Pull → TIM1_CH1N
PB14	LS2	Output Push-Pull → TIM1_CH2N
PB15	LS3	Output Push-Pull → TIM1_CH3N
PA8	HS1	Output Push-Pull → TIM1_CH1
PA9	HS2	Output Push-Pull → TIM1_CH2
PA10	HS3	Output Push-Pull → TIM1_CH3
PA11	OC_SEL	Output Push-Pull
PA12	3FG_HIZ	Output Push-Pull
PF6	OC_TH_STBY2	Output Push-Pull
PF7	OC_TH_STBY1	Output Push-Pull



**NOTE**: Input configuration is always allowed. All the Analog IC inputs integrates a pull-down resistor.

## Advanced-control timer – TIM1

The Advanced-control timer (TIM1) is a 16-bit auto-reload up/downcounter with a 16-bit prescaler.

In the device TIM1 is reserved to the interfacing between the STM32F0 IC and the gate driving inputs of the Analog IC.

In fact TIM1 can be seen as a three-phase PWM multiplexed on six channels. It has complementary PWM outputs with programmable inserted dead times.

STM32 pin	Analog IC	TIM1	In-application function
PB12	OC_COMP_INT	BKIN	Emergency input forcing used-defined status of the timer outputs (overcurrent protection).
PB13	LS1	Channel 1N	PWM generation for phase U (low side driving)
PB14	LS2	Channel 2N	PWM generation for phase V (low side driving)
PB15	LS3	Channel 3N	PWM generation for phase W (low side driving)
PA8	HS1	Channel 1	PWM generation for phase U (high side driving)
PA9	HS2	Channel 2	PWM generation for phase V (high side driving)
PA10	HS3	Channel 3	PWM generation for phase W (high side driving)

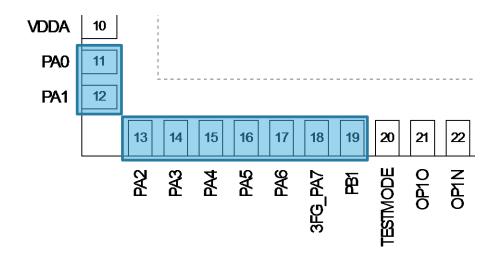


## **ADC** channels

#### The device make available up to 9 ADC channels:

- Current sensing
- BEMF sensing
- VBUS monitoring
- T<sub>PCB</sub> monitoring

STM32 pin	ADC channel	
PA0	Channel 0	
PA1	Channel 1	
PA2	Channel 2	
PA3	Channel 3	
PA4	Channel 4	
PA5	Channel 5	
PA6	Channel 6	
PA7	Channel 7	
PB1	Channel 9	



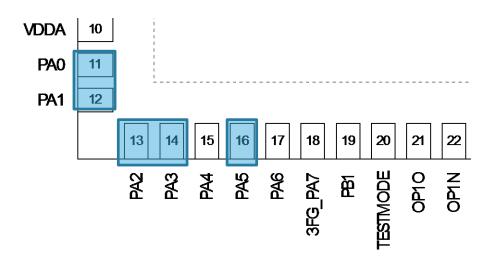


## Hall sensors and encoder – TIM2

The general purpose timer TIM2 is capable of handling quadrature (incremental) encoder signals and the digital outputs from 1 to 3 hall-effect sensors.

It is based on a 32-bit auto-reload up/downcounter and a 16-bit prescaler.

STM32 pin	TIM2
PA0	Channel 1
PA1	Channel 2
PA2	Channel 3
PA3	Channel 4
PA5	Channel 1 ETR





## Other timers

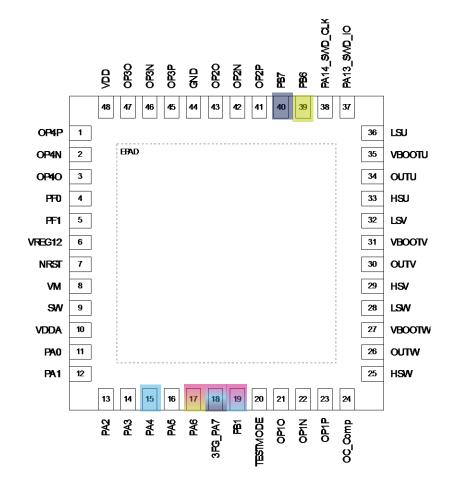
	TIM3	TIM14	TIM16	TIM17
Counter	16bit up/down with 16 bit prescaler	16bit up with 16 bit prescaler	16bit up with 16 bit prescaler	16bit up with 16 bit prescaler
# of channels(*)	3	1	1	1
Timer Link	Yes	No	No	No
Complementary output with dead time generation	No	No	Yes	Yes
Quadrature encoder mode	Yes	No	No	No
DMA	Yes	No	Yes	Yes



(\*) All channels features input capture/output compare, PWM or one-pulse mode output

## Other timers

STM32 pin	TIM3	
PA6	Channel 1	
PA7	Channel 2	
PB1	Channel 4	
STM32 pin	TIM14	
PA4\PB1\PA7	Channel 1	
STM32 pin	TIM16	
PA6	Channel 1	
PB6	Channel 1N	
STM32 pin	TIM17	
PA7	Channel 1	
PB7	Channel 1N	



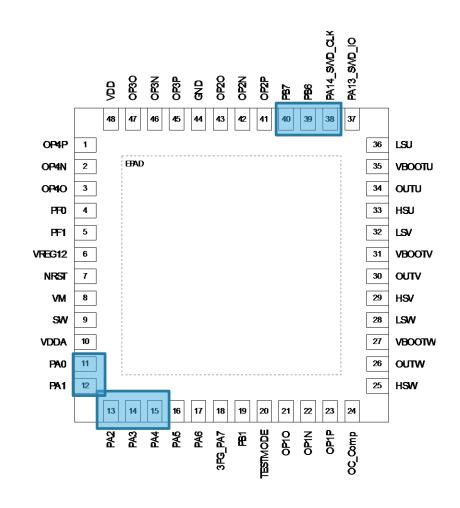


## Interfaces – USART

The device provides a complete universal synch/asynchronous receiver/transmitter which communicates at speeds of up to 6 Mbit/s.

It supports a wide range of communication protocols including hardware management of CTS and RTS

STM32 pin	USART	
PA0	CTS	
PA1	RTS	
PA2\PB6\PA14	TX	
PA3\PB7	RX	
PA4	CK	



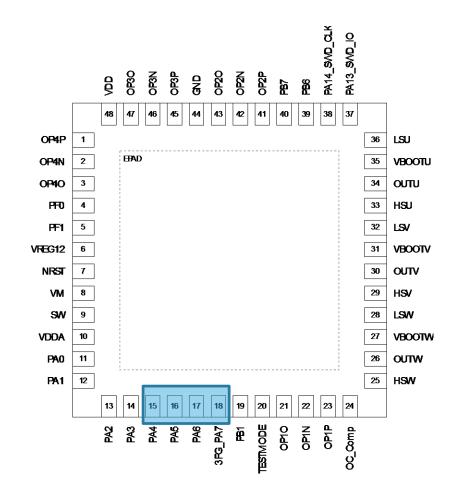


### Interfaces – SPI

The device provides a SPI interface communicating up to 18 Mbit/s in master\slave and full\half duplex modes.

The 3-bit prescaler gives 8 master mode frequencies and the frame size is configurable from 4 bits to 16 bits.

STM32 pin	SPI
PA4	NSS
PA5	SCK
PA6	MISO
PA7	MOSI



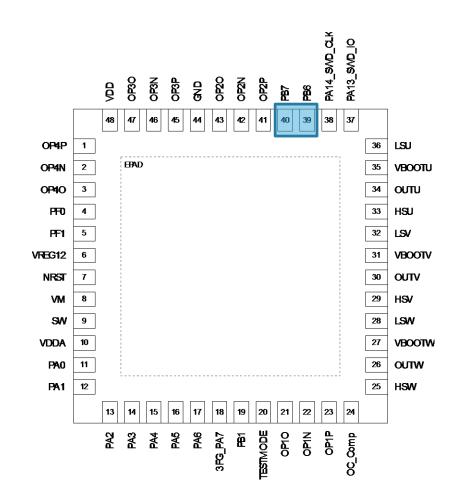


### Interfaces – I2C

The I2C interface can operate in multimaster or slave modes. Standard mode (up to 100 kbit/s), Fast mode (up to 400 kbit/s) and Fast Mode Plus (up to 1 Mbit/s) communication speeds are available.

It supports 7-bit addressing and 10-bit addressing. It also includes programmable analog and digital noise filters.

STM32 pin	I2C
PB6	SCL
PB7	SDA



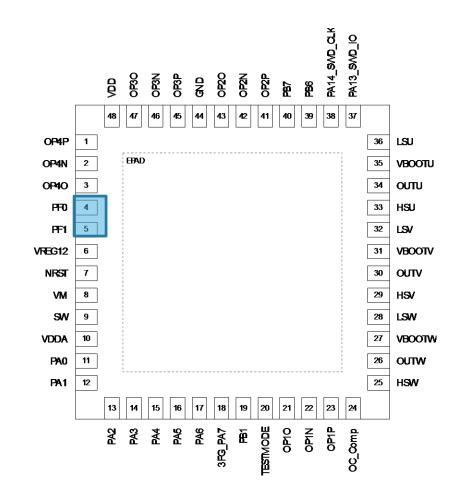


## External clock source

The embedded STM32F0 can operate using as main clock source:

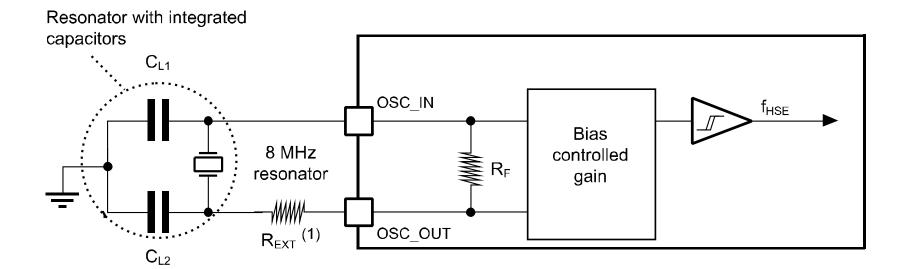
- The integrated RC 8 MHz oscillator
- An external clock source (OSC\_IN) ranging from 4 to 32 MHz
- An external crystal/resonator ranging from 4 to 32 MHz

STM32 pin	
PF0	OSC_IN
PF1	OSC_OUT

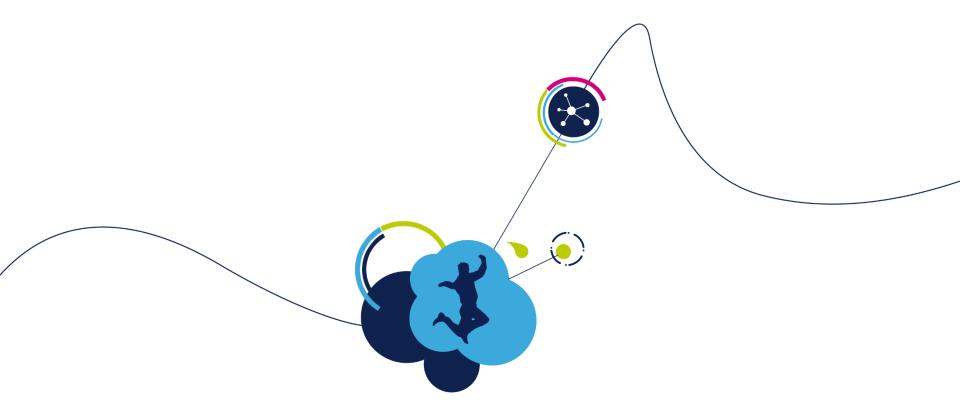




## External clock source







# Analog IC

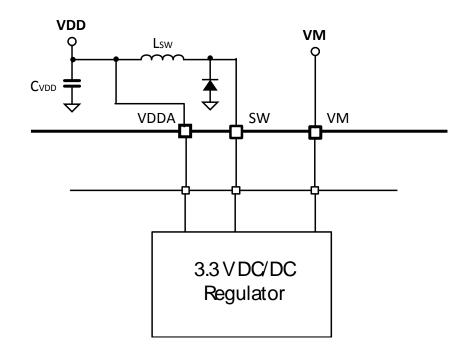


# Analog IC characteristics

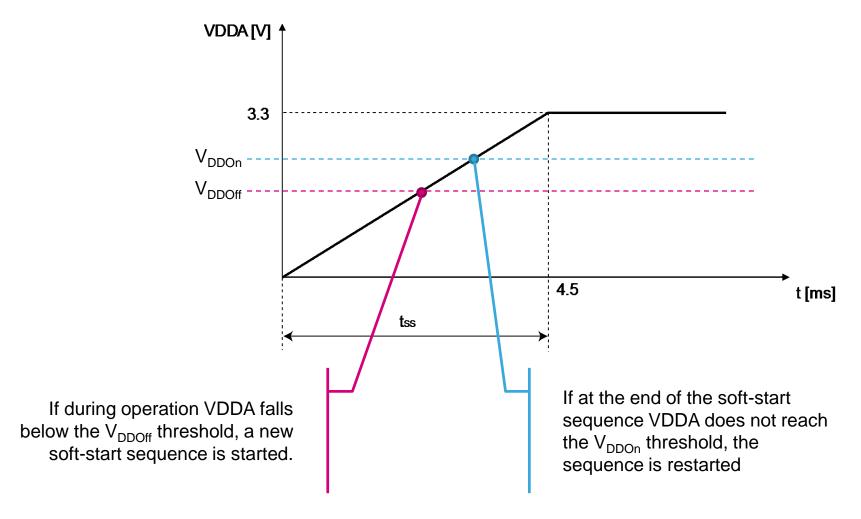
- Triple half-bridge gate drivers for N-channel power MOSFETs
  - Integrated bootstrap diode to generate high side supply voltages
  - Interlocking function: no high- and low-side outputs of same half bridge simultaneously turned on
- 3.3 V DC/DC buck regulator
- 12 V LDO linear regulator
- 3FG open-drain output
- Operation Amplifiers for analog Hall Effect sensors decoding and current sensing
- Comparator for over-current protection with adjustable threshold
- UVLO and OT protections



- Input supply voltage: V<sub>M</sub> = 8 to 45 V
- Provide the 3.3 V suitable to supply the integrated MCU and other external devices
- A soft-start function with fixed startup time
- Overcurrent and short-circuit protection
- Embeds thermal protection

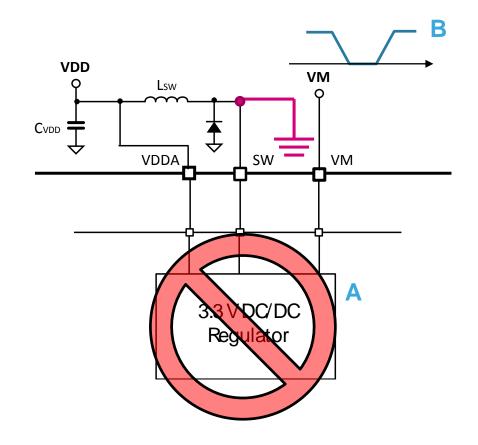






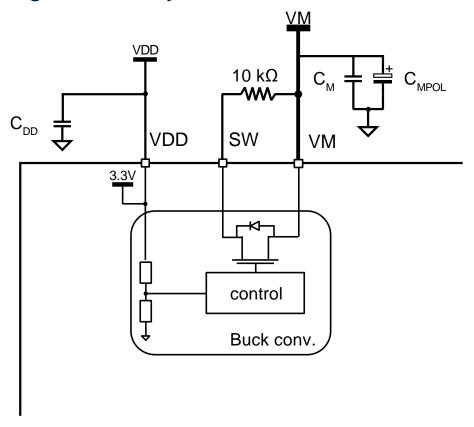


- A. In case of an overcurrent/short failure event on the SW pin, the regulator is latched off.
- B. To restart the DC/DC regulator a power-down and power-up cycle of device supply voltage (VM) is required.





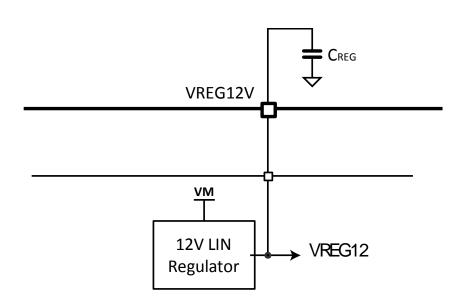
It is possible to bypass the embedded 3.3 V buck regulator forcing the VDD/VDDA voltage externally.





# 12 V LDO linear regulator

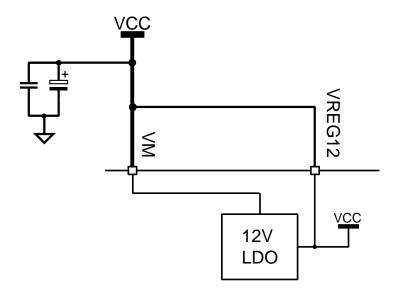
- Provide the 12 V supply voltage for gate drivers section
- UVLO protection
- Embeds thermal protection





# 12 V LDO linear regulator

It is possible to bypass the embedded 12 V LDO linear regulator connecting the VREG12 pin to VM, when VM is lower than 15 V.

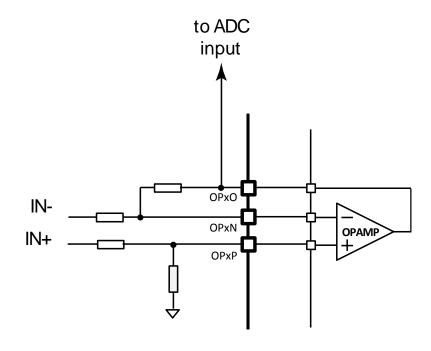


**NOTE:**  $V_{CC}$  < 15 V



# **Operational Amplifiers**

- 4x rail-to-rail operational amplifiers suitable for signal conditioning:
  - sensorless FOC
  - manage Hall sensors feedback
- Output stage with fast recovery in saturation condition
- Input offset voltage 1 mV @ 25°C
- Wide bandwidth 20 MHz
- Stable for gain ≥ 4 or ≤ -3





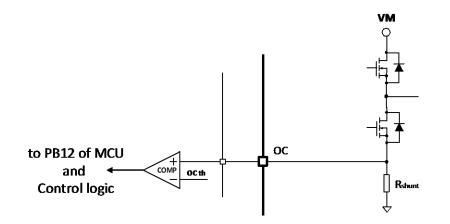
# Over Current Comparator

- A comparator is available to perform an over-current protection
- If OC\_SEL pin is 'HIGH' the OC event is acting directly on the control logic of gate driver switching off all the outputs
- OC threshold adjustable
- Input offset voltage:1 mV @ 25°C
- Propagation delay 80 ns

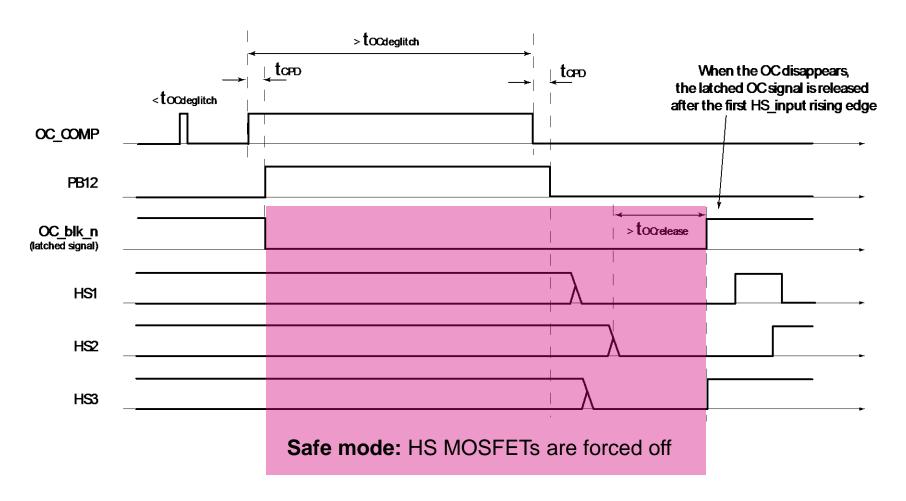
OC_TH_STBY1 (PF7)	OC_TH_STBY2 (PF6)	OC threshold [mV]
0	0	(*)
1	0	100
0	1	250
1	1	500







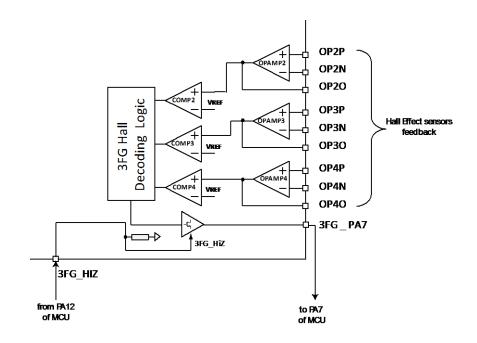
# **Over Current Comparator**





# 3FG output function

- The 3FG\_PA7 pin have a different function according the 3FG\_HiZ (PA12 from MCU) status:
  - 3FG\_HiZ = '0': 3FG function disabled (PA7 can be used as output)
  - 3FG\_HiZ = '1': 3FG decoding logic output enabled (PA7 should be set as input)
- The 3FG function is an open-drain output. The 3FG signal is generated from the analog Hall Effect sensors feedback applied to the Op Amp inputs.





# 3FG output function

- The analog output of Op Amp is converted into a logic signal through internal comparators ( $V_{ref} = V_{DD}/2$ ) and provided to Hall decoding logic.
- The 3FG resulting output signal is an exclusive-or function of the three Hall sensors

COMP4 output	COMP3 output	COMP2 output	3FG_PA7 pin
0	0	0	0
0	0	1	1
0	1	0	1
0	1	1	0
1	0	0	1
1	0	1	0
1	1	0	0
1	1	1	0



# **UVLO** and **OT** protections

- The device provides UVLO protections on each power supplies
- The device embeds an over temperature shutdown protection. The thermal sensors are placed next to the DC/DC and linear regulator blocks.
- The table below summarize the UVLO and OT protection management

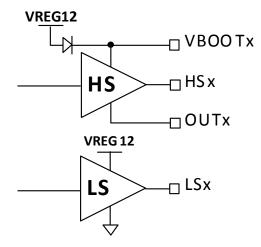
Block	V <sub>M</sub> UVLO	V <sub>DD</sub> UVLO	V <sub>REG</sub> UVLO	V <sub>BOOT</sub> UVLO	Lin Reg OT	DC/DC Reg OT
DC/DC regulator						OFF
Linear regulator	OFF	OFF			OFF	
Op Amps and OC Comp	OFF	OFF				
HSU, HSV, HSW output	LOW	LOW	LOW	LOW (1)		
LSU, LSV, LSW output	LOW	LOW	LOW			

<sup>(1)</sup> Only the high side gate driver in UVLO condition



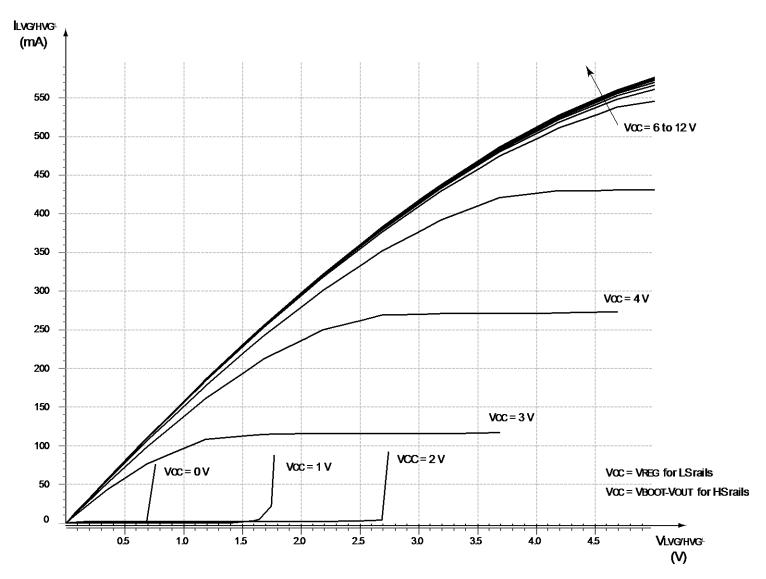
## Gate drivers

- Triple half-bridge gate drivers for N-channel power MOSFETs
- 600 mA Sink/Source capability
- Propagation delay 20 ns (typ)
  - Matching time 20 ns (max full temp. range)
- Integrated bootstrap diode
- Interlocking function





## Gate drivers





# Application example

