Motor control with STM32 32-bit ARM®-based MCU

For 3-phase brushless motor vector drives

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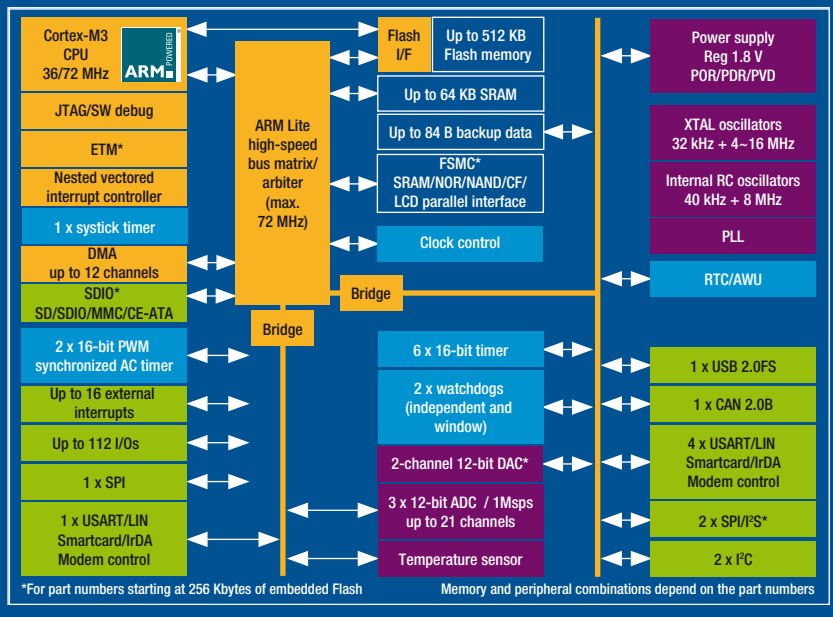
Vector control made simple

STMicroelectronics' STM32 offers the performance of the industry-standard Cortex™-M3 core at the service of vector (or field-oriented) control algorithms. Vector-control algorithms are widely used in high-performance drives. They provide precise and responsive torque and speed control, and guarantee optimized efficiency during transient operations. Practically, they also have the advantage of using the same framework to control an asynchronous or synchronous motor. This is interesting for development teams that have to deal with various applications and motor types. Finally, the sensorless algorithms for rotor speed and position detection are also of interest when trying to reduce the cost of the drive. The benefits of the ARM™ architecture combined with motor-control dedicated peripherals makes the STM32 Performance line MCU family ideally suited to optimize the overall performance of execution while reducing the overall system cost.

Applications

- Appliances
  - Washing machines
  - Dishwasher pumps
  - Refrigerators
  - Air conditioners
- Industrial
  - Electric vehicles
  - Low-end and medium-range industrial drives
  - Office automation
  - HVAC actuators and fans
  - Pumps
  - Blowers
  - Vending and cash machines



AWU:	Auto wake-up capability with RTC alarm	IrDA:	Infrared Data Association	PVD:	Programmable voltage detector
CAN:	Controller area network	I²S:	Inter-IC sound	RTC:	Real-time clock
CF:	CompactFlash	LIN:	Local interconnect network	SDIO:	Secure digital input output
DMA:	Direct memory access	MMC:	MultiMediaCard	SD:	Secure digital
ETM:	Embedded Trace Macrocell	PDR:	Power-down reset	USART:	Universal sync/async receiver transmitter
FSMC:	Flexible static memory controller	POR:	Power-on reset		

Motor control

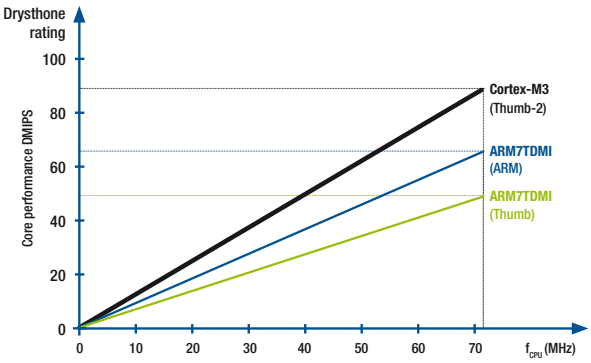
- The STM32 Performance line embeds features that are perfectly suited to three-phase brushless motor control:
  - Powerful Cortex-M3 core
  - 6 PWM advanced control timers with embedded dead-time generation
  - Numerous PWM outputs allowing multiple DC-brush, stepper or universal motor drives
  - Dual sample and hold ADC, 12-bit resolution, 1 µs conversion time
- Free motor control firmware libraries supporting AC induction motor (sensored) and PMSM motor (sensorless, Hall-sensor or encoder) vector control
- Less than 21 µs for sensorless vector control loop
- Class B compliancy with the EN/IEC60335-1 norm:
  - Pre-certified full set of self-test routines
- Run your motor in just a few steps:
  - STM3210B-MCKIT full developer kit for vector drives
- In the Performance line, for devices starting at 256 Kbytes of Flash, two advanced control PWM timers and three ADCs are on board for dual motor control, triple sample and hold capabilities.

STM32 key benefits

Leading-edge architecture with Cortex-M3 core

- Harvard architecture
- 1.25 DMIPS/MHz and 0.19 mW/MHz
- Thumb-2 instruction set brings 32-bit performance with 16-bit code density
- Single cycle multiply and hardware division
- Embedded, fast interrupt controller is now inside the core allowing:
  - Excellent real-time behaviour
  - Low latency down to six CPU cycles inter-interrupt
  - Six CPU cycles wake-up time from low-power mode
- Up to 35% faster and up to 45% less code than ARM7TDMI®

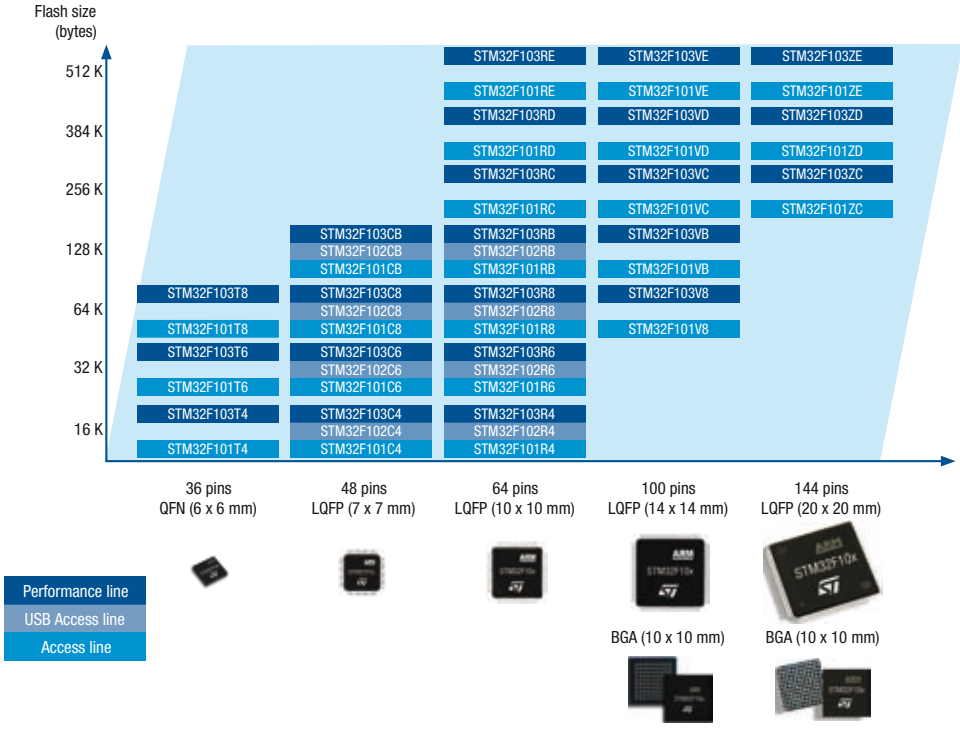
Cortex-M3 performance versus ARM7TDMI



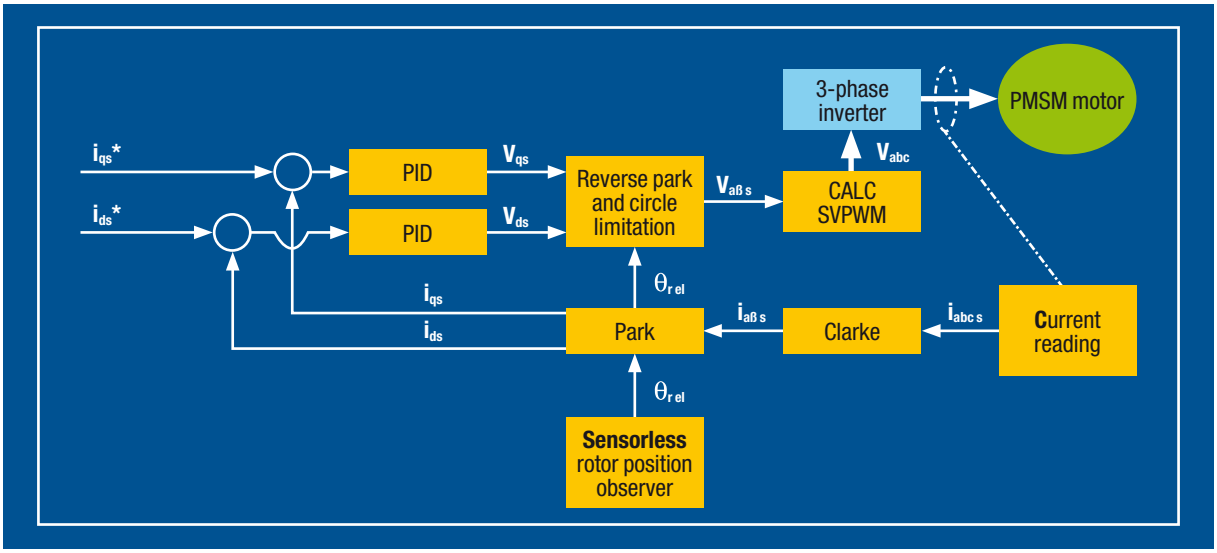
High level of integration

- Built-in supervisor reduces need for external components:
  - Power-on reset, low-voltage detect, brown-out detect, watchdog timer with independent clock
- One main crystal drives entire system:
  - Inexpensive 4-16 MHz crystal drives CPU, USB and all peripherals
  - Embedded PLL generates multiple frequencies
  - Optional 32 kHz crystal for RTC
- Embedded factory trimmed 8 MHz RC oscillator can be used as main clock
- Additional low-frequency RC oscillator for RTC or watchdog
- Only 7 external passive components required for base system on LQFP100 package

STM32F10x portfolio



Field-orientation in sensorless torque control – PMSM



Vector control drive

- Theory
  - Changing reference coordinates from fixed stator coils to the moving rotor frame greatly simplifies the equation describing the motor
- Method
  - Clark and Park transformations convert variables with fixed 3-axis, 120° shifted coordinates into 2-axis orthogonal rotating coordinates
  - These last variables are DC, or slowly varying values, which can be regulated by means of simple PID controllers and then transformed back to the fixed stator windings frame using reverse transforms, as shown in the diagram above
- Requirements
  - Intensive math computations (trigonometric functions, multiple PID regulators, speed calculation)
  - Minimum resolution of 16 bits for the main control variables, with a need for 32-bit intermediate results, such as integral terms
  - Free CPU load must be kept for the remaining applicative tasks, such as communication and user interface

STM32 safety features for greater control robustness

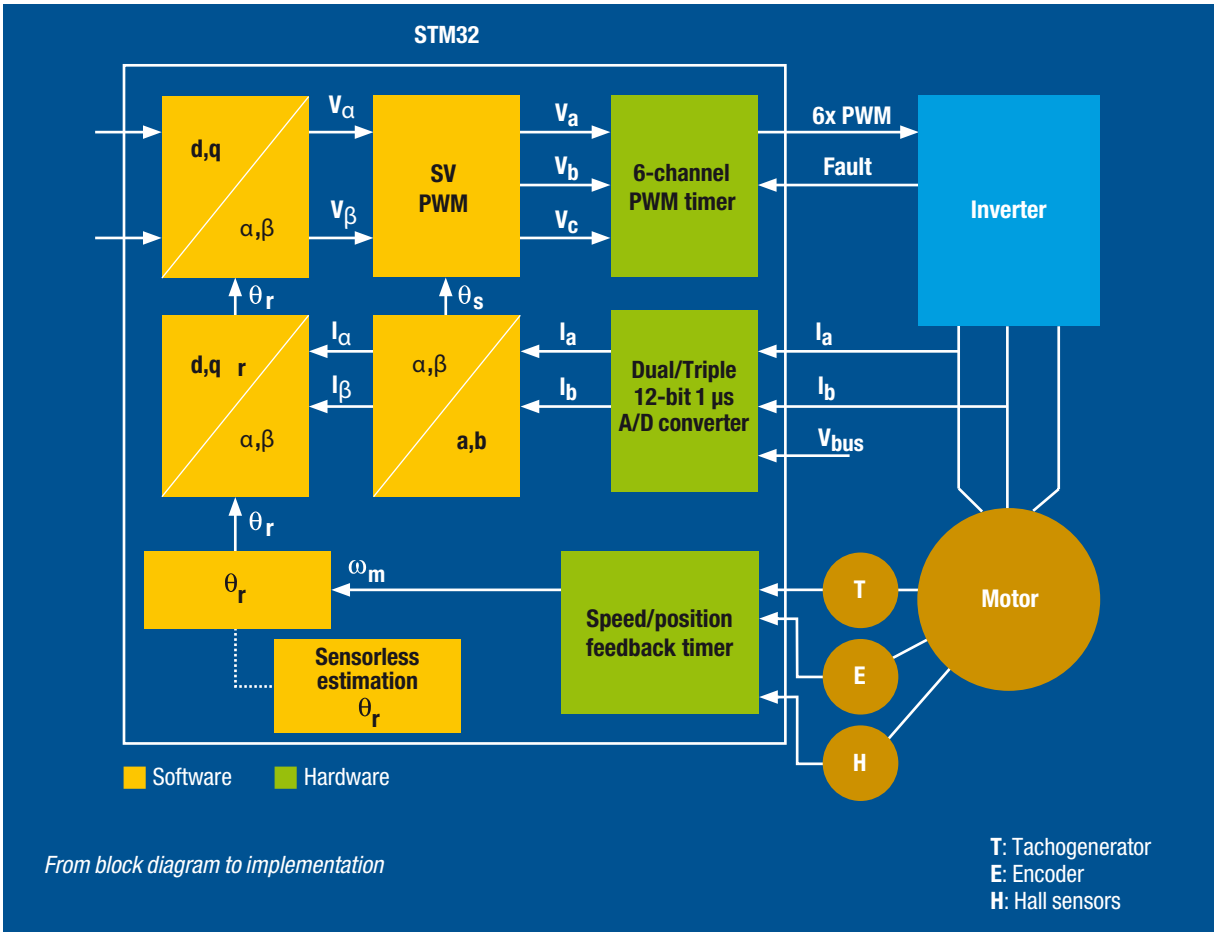
Features

- Safety critical registers can be locked to prevent power stage damage (software runaway)
  - Deadtime, PWM output polarity, emergency input enable
- All target registers are read/write until lock activation (and then read-only if protected)
  - Once the two lock bits are written, they cannot be modified until next MCU reset (write-once bits)
- If main clock fails, an internal RC oscillator (FREEOSC, ~5 MHz average frequency) starts immediately
- Interrupt can be generated for shut-down or safe restart sequences
- Dual watchdog architecture with independent clock sources
- Embedded reset circuitry (power-on reset, power-down reset, programmable voltage detector)
- Emergency stop dedicated input pin with programmable state

Benefits

- Strengthens control algorithm to protect motor operation from external disturbance
- Protects safety-critical registers in case of system hang
- Quick error diagnosis and fault management
- Hardware protection of power stage whatever the status of MCU oscillator
- Safety hardware features to comply with IEC60335-1 norm

Vector control with STM32



STM32 dedicated peripherals for 3-phase brushless motor control

PWM timer features

- Motor control timer clock
  - Maximum input clock is 72 MHz to provide 13.9 ns edge resolution (12-bit @ 16 kHz edge-aligned PWM)
- Double-update mode
  - No loss of resolution in center-aligned mode
  - Done thanks to an additional interrupt per PWM cycle or DMA transfers
- Burst mode
  - Possibility to update several registers of the peripheral using a single DMA stream
- Programmable reload rate
- Versatile PWM output management
  - Individually selectable polarities
  - Redirection circuitry for 6-step drives
- Programmable hardware deadtime generation
  - 8-bit register with 13.9 ns resolution at 72 MHz

Dual ADC features

- Dual/triple ADC with simultaneous conversion mode
- 12-bit resolution
- Down to 1 µs conversion time
- Up to 21 channels, plus internal temperature sensor and V_{ref}
- External and internal trigger (including PWM timer)
- Versatile channel sequencer
- DMA capable
- Programmable sampling rate

Benefits

- Suitable for three-phase brushless PMSM or AC induction motors
- Sensor and sensorless configurations

Speed feedback

- Handled by the general-purpose timers
- Direct interface with incremental encoder and 1 to 3 Hall sensor logic outputs

STM3210B-MCKIT

Run your motor in just a few steps

In just a few minutes, you can run the kit's PM synchronous motor with the standalone demo, in torque-control or speed-control mode, using the LCD and the joystick on the STM3210B-EVAL control board.

You can then fine tune or change many parameters using the LCD user interface (as shown on LCD screen captures below) and run the PM synchronous motor, or an induction motor:

- Real-time tuning of torque, flux and speed PIDs
- B-EMFs observer gains tuning (for sensorless control)
- Variation of target speed (speed control) or target torque and flux (torque control)
- Bus-voltage and power-stage temperature monitoring
- Selection of variables to put on output for DAC functionality implementation

You can apply changes to real-time settings to tune the drive parameters on-the-fly and get feedback values from the changed settings.

Once familiar with the demo, you will be able to explore our motor control library that supports FOC (field-oriented control) drive of PMSM and induction motors.

The library sources are free upon request, and help speed up development of motor control applications. With the free 32-Kbyte evaluation version of IAR's EWARM, you just open the libraries, develop the application, fine tune the code and parameters and compile. You can fine tune the application while running the motor thanks to the real-time debugging capability of the Segger J-Link.

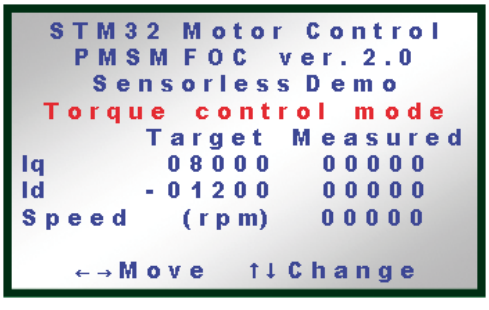
Application-specific requirements

Using the same hardware and firmware platform, you may incorporate application-specific requirements by taking advantage of the STM3210B-EVAL control board and the inverter board extension features (USART/LIN port, standalone operation potentiometer, wrapping area).

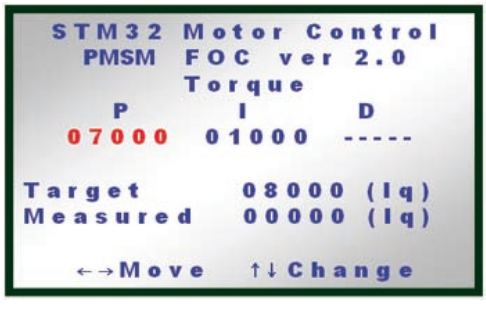
Start LCD menu – speed control demo

Speed control can be modified during run-time using joystick

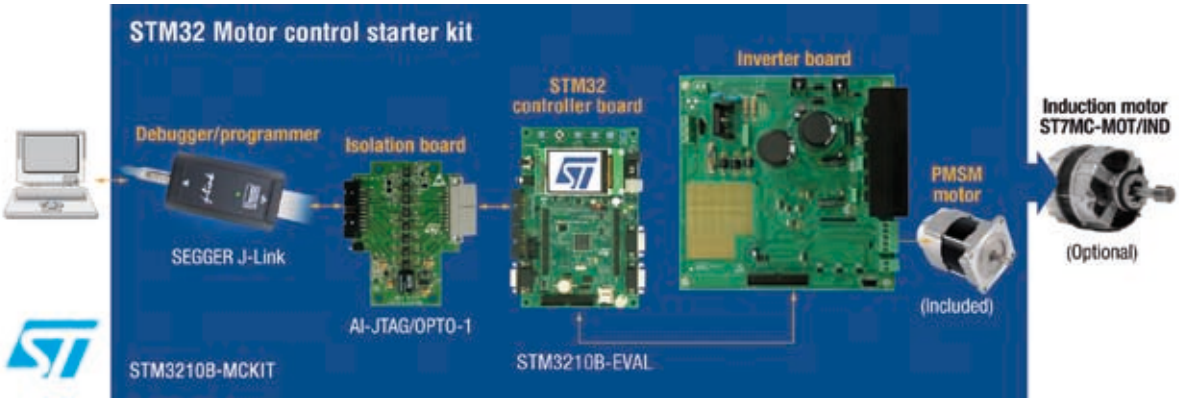
Torque control demo – Iq and Id parameters can be adjusted



PID regulators can be adjusted during run-time



STM3210B-MCKIT



STM32 Motor control tool ordering information

Partnumber	Description
STM3210B MC library	Optimized, documented C firmware libraries for control of 3-phase PMSM or AC induction brushless motors. In torque or speed control with STM32, sensor mode, sensorless for PMSM. These are the standalone libraries of the STM3210B-MCKIT.
AI-JTAG/OPTO-1	The isolation board included in the STM3210B-MCKITcan also be ordered separately. It provides galvanic isolation between the J-Link from Segger and any high-voltage target board. The isolation board has two JTAG connectors (in/out). Available from distributors and ST sales offices.
STM3210B-MCKIT	Demonstration, evaluation and development kit for STM32 includes firmware, LCD user interface, STM3210B-EVAL board (control board), 7 A three-phase inverter board, isolation board (AI-JTAG/OPTO-1), Segger J-Link debugger/programmer and 24 VDC Shinano PMSM motor. Available from distributors and ST sales offices.
ST7MC-MOT/IND	240 V/800 W Selni 3-phase induction motor for use with STM3210B-MCKIT, or with the ST7MC-KIT using induction motor default values (for evaluation purposes).

Vector control libraries

STM32 library

Optimized and documented C firmware libraries for control of both PMSM (sensor and sensorless mode) and AC induction (sensor mode) brushless motors are available for free upon request.
These libraries support IAR (EWARM), KEIL and Greenhills toolchain.
These modular libraries support both types of motor in standalone mode using the hardware of the STM3210B-MCKIT. The source files are provided free of charge upon request. These libraries offer:

- Different current sensing methodologies
  - Isolated current sensing
  - Three shunt resistors
  - Single shunt topology with dual sample and hold utilization and advanced methodology for better bus voltage exploitation
- Different rotor-position feedback
  - Tachometer (AC motor)
  - Hall sensors (60° and 120° placement)
  - Sensorless (PMSM motor only)

Total execution time of the field-oriented control in sensorless mode for PMSM motor is less than 21 µs Total CPU load at 10 kHz sampling time is below 25 % – code size is less than 14 Kbytes.

Single-shunt Current sensing

The STM32 motor control library version 2.0 supports single-shunt current sensing, for applications requiring lowest system costs. The proposed solution maximizes the DC bus voltage use, while minimizing current distorsion and acoustical noise, and has been patented by ST. The STM32-MCKIT can be easily reconfigured in one-shunt mode, for evaluation purposes.

Internal Permanent Magnet motors (IPM)

Thanks to their higher power density and very high speed capabilities, brushless IPM motors are used in an increasing number of designs (vs. their surface mounted magnets counterpart). The STM32 MC library supports this kind of motors with specific algorithms, such as MTPA (Maximum Torque Per Ampere) control strategy.

Dual Motor Control and Triple ADC system

The High-density STM32 devices embed three ADCs and two motor control capable timers. This allows to drive simultaneously two brushless motors, or to have a triple Sample & hold current acquisition for very high-end control systems. These features are supported by additional interrupt vectors and a second DMA controller.

Field weakening & feed-forward control

The stator voltage closed loop Field Weakening control implemented is able to expand the operating limits of both surface mounted and internal PMSM, as many applications require. This algorithm strongly reduces sensitivity to motor parameter and environmental variations.
On top of this, feed forward control allows improved bus voltage ripple compensation and better currents regulation during high speed flux weakening operations.

Class B Compliancy – how do we help?

Two key features help compliance with the EN/IEC60335-1 norm: the dual watchdog architecture and the internal clock circuitry. In order to make certification even simpler with the STM32, a set of self-test routines has been developed to fulfill most of table H11.12.7 requirements. These routines have been certified by the VDE, a worldwide recognized test institute, and do not need to be re-evaluated if left unchanged.

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Order code: BRSTM32MC0808