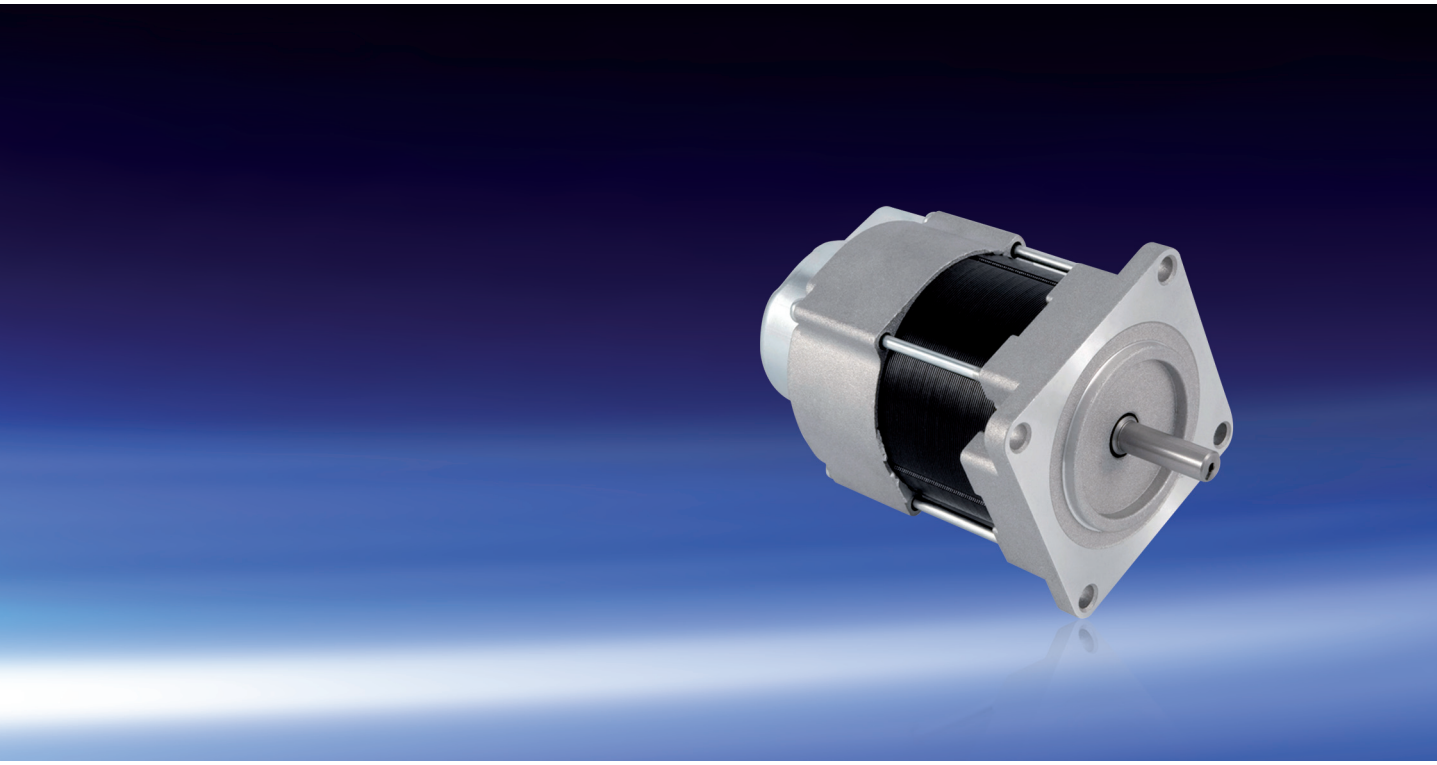
Motor control

Reference guide



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High efficiency, reduced noise, extended lifetime, rapid time to market - and all at optimum cost. This is the challenge currently facing the many industries which use electric motors.

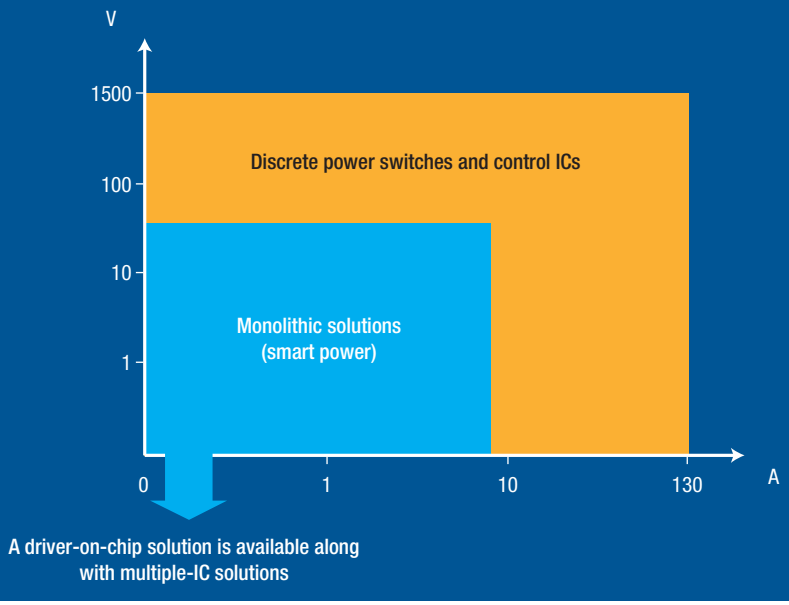
Today, the demand for electronic motor control is increasing rapidly, not only in the automotive and computer peripherals markets, but also in industrial applications and home appliances such as heating and ventilation systems, power tools, vacuum cleaners and white goods. All these mass-market applications need cost-effective solutions without compromising reliability.

STMicroelectronics was among the first to recognize this trend and today offers a full range of components for optimizing motor control systems. Whatever motor technology you use, this reference guide will help you to make the right choice of components.

Single-chip versus multi-chip solution

ST is universally acknowledged as offering the most comprehensive semiconductor portfolio for applications which include:

- Microcontrollers
- Power devices
- Smart-power and dedicated ICs



Product family highlights

Microcontrollers

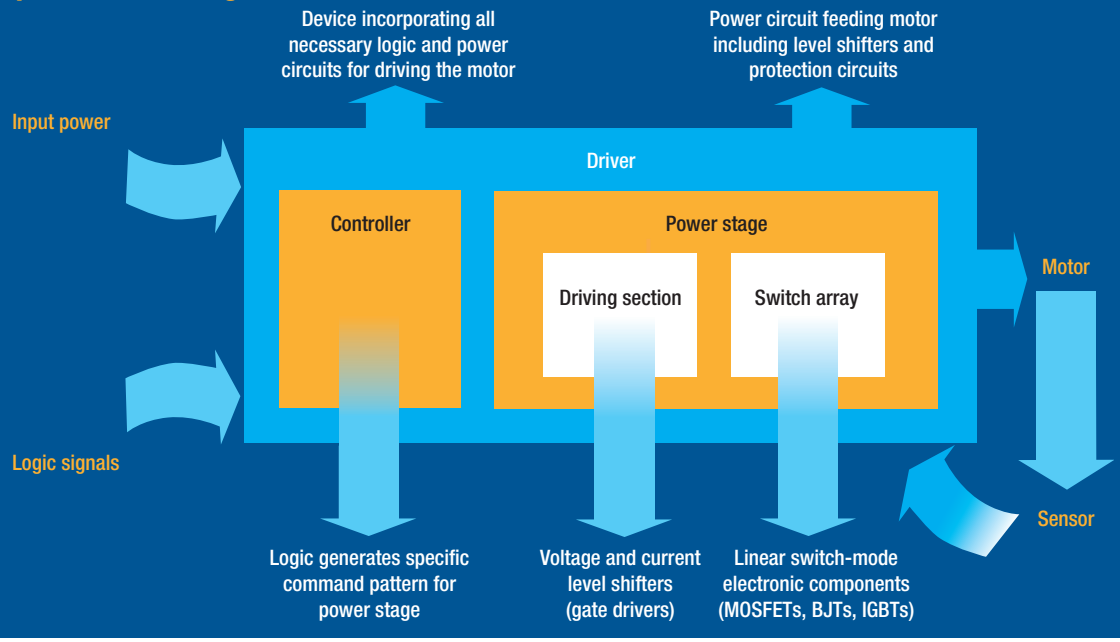
ST supplies 8- and 32-bit microcontrollers which meet the performance requirements for controlling electric motors in various applications. ST's 8-bit STM8 microcontrollers feature a high-performance core (up to 20 MIPS @ 24 MHz), 3.3 V to 5.5 V power supply, embedded true EEPROM and RC oscillator and 4- to 128-Kbyte Flash in 20- to 80-pin packages, and provide a robust, reliable and cost-effective solution. STMicroelectronics' 32-bit STM32 microcontrollers offer 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.
All families and products are supported by a comprehensive range of emulators, development kits, programmers and demonstration boards, plus an integrated development environment, C compilers, and graphical design aids. Flash and OTP versions are available.

Amplifiers and comparators

ST offers an extensive range of op-amps and comparators suitable for motor control applications. The portfolio includes high-voltage bipolar and CMOS op-amps, as well as low-voltage CMOS rail-to-rail input and output op-amps.

ST - committed to motor control

Smart-power IC building blocks



Power devices

ST offers a broad selection of products for power discrete devices: MOSFET and IGBT transistors, thyristors, triacs and AC switches, fast rectifiers and protection devices ranging from 1 to 270 A and 30 to 1,600 V. With products perfectly suited to medium-power motor drive applications, ST is constantly enhancing the performance of its power devices by upgrading process capabilities and product families. ST innovations include:

- enhancing the IGBT family with the new strip layout PowerMESH geometry, and the Turbo 2 diodes family with the new 300 V and 600 V STTH series
- breaking the power MOSFET performance barrier by using the MDmesh/FDmesh, MDmesh II/FDmesh II, MDmesh V, SuperMESH and SuperFREDmesh technologies for high voltage applications, and the latest generation of STripFET (STripFET II, STripFET III, STripFET V) and STripFET DeepGATE technologies for low voltage applications.
- embedding control features into switches with VIPower™ technology for low-voltage motors
- adding overvoltage protection and a separating gate circuit with the ACS™ switch, designed around 500 V and 800 V ASD™ technology

Smart power and dedicated ICs

With ST's proprietary BCD family of processes, which combine bipolar, CMOS and DMOS structures on the same substrate, it is possible to achieve high levels of integration, including monolithic 600 V gate drivers for mains-fed motor drive applications. For low-voltage applications such as automotive and PC peripherals, ST has developed a broad range of complete single-chip motor drivers incorporating control, drivers and power switches. Using a process as fine as 0.35 mm, typical of ST's newest BCD6 process, even relatively complex digital circuits such as microcontrollers, DSP cores and non-volatile memories can be integrated into power ICs, creating advanced smart-power solutions.

Universal motor

Universal motors may be used with an AC or DC supply current. The stator and rotor windings of the motor are connected in series through the rotor commutator so that the mechanical force generated is always in the same direction (as it is proportional to the square of the current flowing). Operating at normal power-line frequencies, the maximum output of universal motors is limited and motors exceeding a few kilowatts are rare. The advantages of universal motors are specifically high starting torque, very compact design and high running speeds. The drawback is the maintenance and short life caused by the commutator.

Typical application parameters

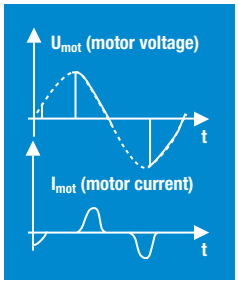
Voltage	Motor power	Speed range	Features
100 to 240 Vac (or corresponding rectified voltage)	100 to 2,200 W	0 to 20,000 RPM	High start-up and low-speed torque capability

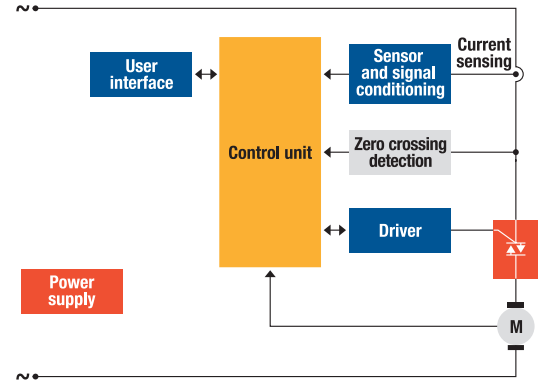
AC universal motor drive

The AC universal motor drive controls the rotation speed by means of phase-angle partialization. This method consists of changing the RMS voltage applied to the motor. In this case, the voltage is a function of the firing angle of the Triac. The high commutation capability of ACST-family device switches enables reliability of operation and use of a low gate-current supply for MCU interfacing.

Main applications

- Vacuum cleaners
- Washing machines
- Power tools
- Food processors





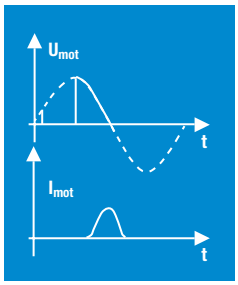
AC universal motor drive

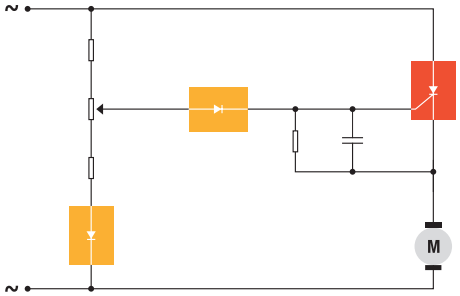
DC universal motor drive

Continuous speed control of a universal motor running on DC is very easily accomplished using a thyristor circuit. A thyristor supplies the motor during the positive mains half cycle. Both the thyristor and its control are connected in such a way that the motor back-EMF compensates the motor load variations to adjust the speed.

Main applications

- Food processors
- Power and garden tools





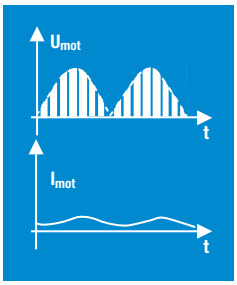
DC universal motor drive

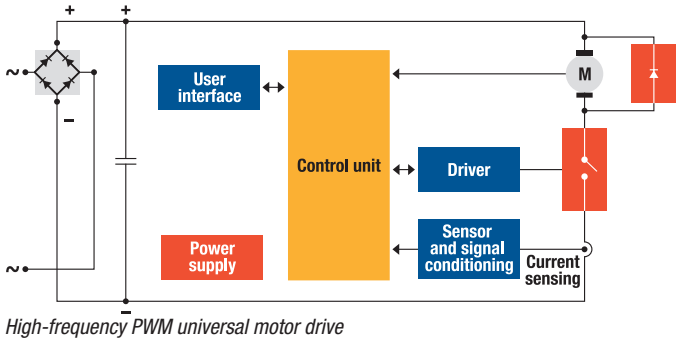
High-frequency PWM universal motor drive

The pulse width modulation (PWM) technique (also known as chopper drive) is used to adjust the voltage applied to the motor. With the variation of the PWM duty cycle, the effective voltage seen by the motor can be changed.
The advantage of PWM modulation with respect to phase-angle partialization is higher efficiency, less acoustic noise and better EMC behavior, but it can have an impact on brush life duration.

Main applications

- Washing machines
- Food processors
- Treadmills
- Industrial motion control





High-frequency PWM universal motor drive

Demonstration boards

Order code	Description
STEVAL-IHM007V1	Universal motor control starter kit (phase-angle partialization)
STEVAL-IHM013V1	Low-end solution for a vacuum cleaner control board up to 2 kW
STEVAL-IHT00441	AC timer based on HT triacs and ST7Lite1b

Product highlights

Microcontrollers	8-bit STM8 microcontrollers featuring a high-performance core (up to 20 MIPS @ 24 MHz), 3.3 V to 5.5 V power supply, embedded true EEPROM and RC oscillator and 4- to 128-Kbyte Flash in 20- to 80-pin packages.
Power transistors	The IGBT is the best 600 V rated device for the PWM brushed DC motor drive. PowerMESH™ IGBTs combine low Vce(sat) with very short turn-off times, and significantly reduce both turn-on and turn-off switching losses. The latest low-voltage STripFET generations and STripFET DeepGATE technology for power MOSFETs for hand tools are also available.
Fast rectifiers	Available at 300 V and 600 V, Turbo 2 diodes feature ultra-fast recovery while maintaining a low dropout voltage. They significantly cut losses in both the diode and transistor at turn-on.
Thyristors	The thyristor (or SCR) delivers both rectification and motor voltage adjustment. A sensitive device (I_{GT} < 200 µA) simplifies the gate drive and reduces overall control circuit dissipation.
AC switches	Triac and ACST switches are suited to this type of drive, offering high surge current and low conduction loss. ST's Snubberless™, logic level Triacs require a low gate-triggering current (10 mA and 35 mA) and run safely without requiring a turn-off aid snubber. The new ACST switches are designed with intrinsic overvoltage robustness, and safely suppress the mains voltage surges described in IEC 61000-4-5.
Amplifiers and comparators	Operating at low voltage with rail-to-rail input and output capability, new op-amps bring innovation with very high merit factors and consumption below 1 mA, while offering high slew rate, 10 V/µs and large product gain bandwidth (up to 20 MHz). For high-voltage operation, standard CMOS or bipolar op-amps and comparators offer single-supply operation, with adequate speed.

Brushed DC motor

Brushed DC motors are internally commutated electric motors designed to run from a DC power source. Generally, the rotational speed of a DC motor is proportional to the voltage applied to it, and the torque is proportional to the current. Speed can be controlled by a variable supply voltage or electronic controls. Controlling the speed of a brushed DC motor is simple - the higher the armature voltage, the faster the rotation. This relationship is linear up to the motor's maximum speed. Here we address the permanent magnet DC motor where the stator is composed of two or more permanent-magnet pole pieces and the rotor is composed of windings that are connected to a mechanical commutator.

Typical application parameters

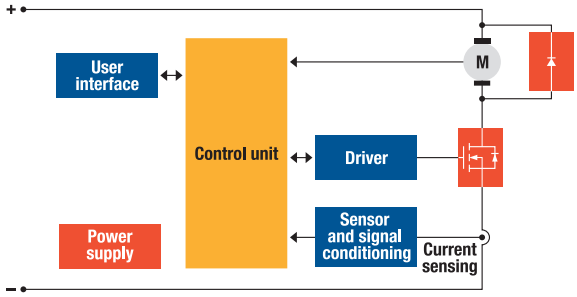
Voltage	Motor power	Speed range
6 to 320 Vdc	Up to 20,000 W	0 to 30,000 RPM

Main applications

- Consumer audio/video
- Shavers
- Toys
- Cordless tools
- Automotive body functions
- Traction
- Servomechanisms
- Factory automation
- Machine tools

Single-switch chopper drive

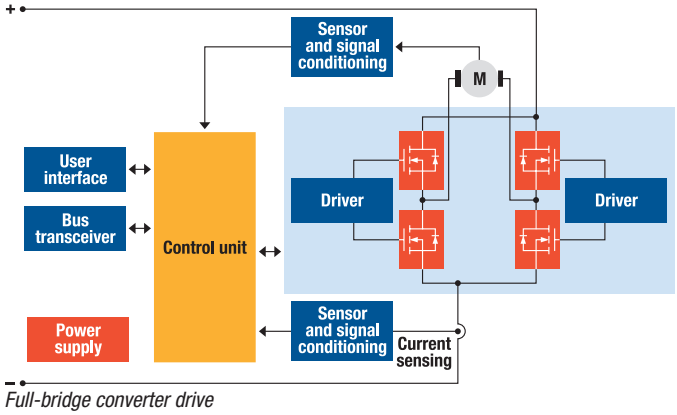
A single-switch chopper can seamlessly control the speed using duty cycle modulation.



Single-switch chopper drive

Full-bridge converter drive

A full-bridge converter drive consists of four power switches that are used to adjust the motor voltage and polarity using the pulse width modulation (PWM) technique. The current can thus be controlled to flow in either direction through the motor windings, allowing the motor to run in both directions.



Full-bridge converter drive

Demonstration boards

Order code	Description
STEVAL-IHM012V1	Cordless-drill evaluation board based on power MOSFET and 8-pin MCU
STEVAL-IHM015V1	Low-voltage motor control demokit
EVAL6205/6/7N	Integrated power stages with Powerspin
EVAL6205N	PowerSpin with PWM current controller (L6205 + L6506)
EVAL6206N/PD	PowerSpin with PWM current controller (L6206 + L6506)
EVAL6207N	PowerSpin with PWM current controller (L6207)
EVAL6225PD	PowerSpin with PWM current controller (L6225 + L6506)
EVAL6227PD/QR	PowerSpin with PWM current controller (L6225)
EVAL6226QR	PowerSpin (L6226)

Product highlights

Microcontrollers	8-bit STM8 microcontrollers featuring a high-performance core (up to 20 MIPS @ 24 MHz), 3.3 V to 5.5 V power supply, embedded true EEPROM and RC oscillator and 4- to 128-Kbyte Flash in 20- to 80-pin packages.
Power transistors	The latest low-voltage STripFET generations and STripFET DeepGATE power MOSFETs are ideal for higher power applications such as cordless tools.
Smart-power ICs	Monolithic motor drivers can be used conveniently in applications where the input voltage does not exceed a few dozen volts and the current feeding the motor windings is limited to a few amps. These devices may include just the power stage, the control section or the full control section, including the PWM current control, plus several protection functions such as thermal shut-down, overcurrent and cross-conduction. ST has developed several types of power IC, suited to different application requirements, working in linear or switch mode.
Gate drivers	Monolithic full-bridge and half-bridge gate drivers are available and include protection, deadtime and supply circuits.
Amplifiers and comparators	Operating at low voltage with rail-to-rail input and output capability, new op-amps bring innovation with very high merit factors and consumption below 1 mA, while offering high slew rate, 10 V/µs and large product gain bandwidth (up to 20 MHz). For high-voltage operation, standard CMOS or bipolar op-amps and comparators offer single-supply operation, with adequate speed.

Single-phase induction motor

The single-phase induction motor is a brushless motor designed either with a single stator coil plus a shaded-pole coil, or two stator coils and a phase-shift capacitor. The rotor is usually made of an aluminum squirrel cage. Speed is controlled either by varying the motor voltage or by changing the number of motor poles.

Typical application parameters

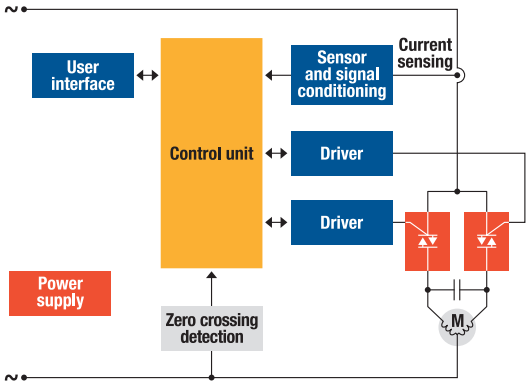
Voltage	Motor power	Speed range	Features
100 to 240 Vac	10 to 2,000 W	0 to 3,600 RPM	Robust, low starting torque

Bidirectional induction motor drive

When a motor with a phase-shift capacitor is used, the direction of rotation can be reversed by means of two AC switches which connect the phase-shift capacitor in series with either of the two stator windings.

Main applications

- Washing machines
- Fridges and washing machines
- Window and door openers



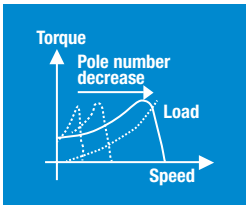
Bidirectional induction motor drive

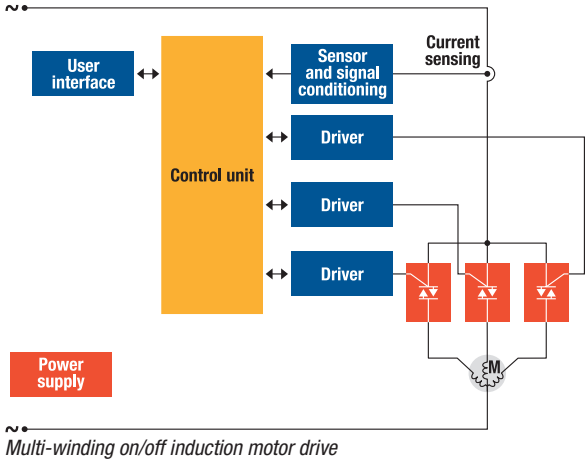
Multi-winding on/off induction motor drive

Here the stator coil is divided into 3 or 4 pairs of windings. The speed is adjusted stepwise by connecting different combinations of these windings to the mains through AC switches in order to change the number of active stator poles and the base speed.

Main applications

- Fans in home appliances





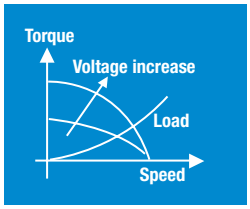
Multi-winding on/off induction motor drive

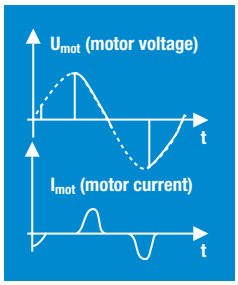
Phase-controlled induction motor drive

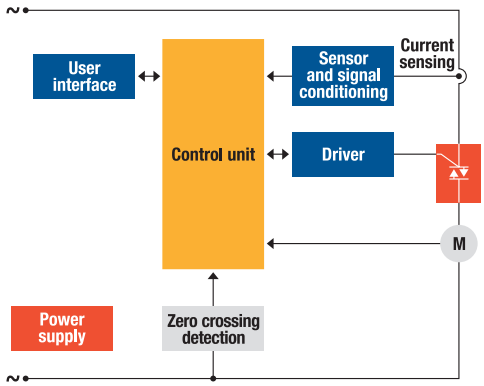
ST offers a silent and cost-effective variable speed drive with a simple topology to control speed. A simple phase-control switch can then be used to vary speed by changing the motor torque profile.

Main applications

- Fans in home appliances
- Domestic water pumps
- Industrial fans and pumps







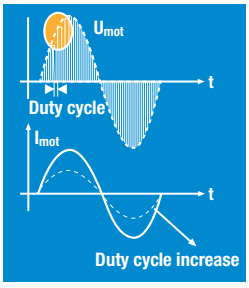
Phase-controlled induction motor drive

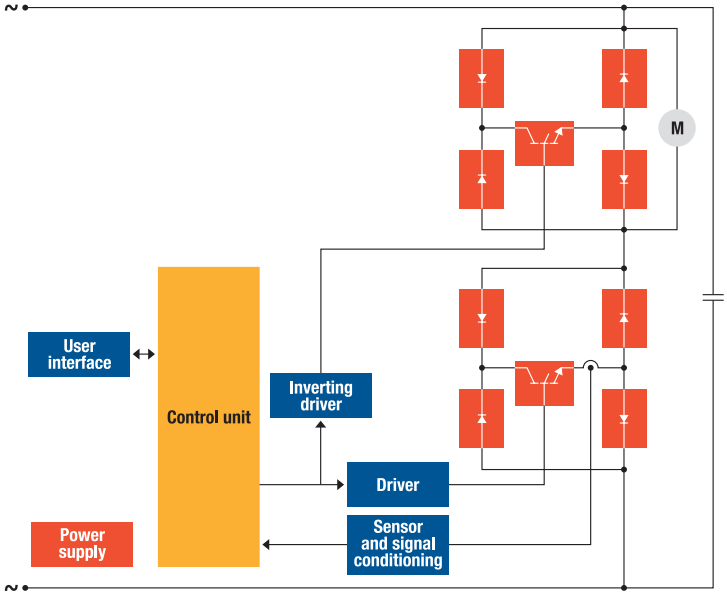
High-frequency PWM induction motor drive

The induction motor is driven in high-frequency mode by an innovative single-switch topology, which delivers a silent and cost-effective variable speed drive. The speed is controlled by the motor voltage: the power switch runs in PWM mode and its duty cycle changes linearly to control the speed according to torque.

Main applications

- Heating, ventilation and air conditioning
- Industrial blowers and compressors





High-frequency PWM induction motor drive

Demonstration boards

Order code	Description
STEVAL-IHT001V1	Cold thermostat control board based on AC switches and ST7Lite39
STEVAL-IHT002V1	Basic thermostat control board for cooling applications based on ST7LITEUS5
STEVAL-IHM006V1	AC-AC chopper driver

Product highlights

Microcontrollers	8-bit STM8 microcontrollers featuring a high-performance core (up to 20 MIPS @ 24 MHz), 3.3 V to 5.5 V power supply, embedded true EEPROM and RC oscillator and 4- to 128-Kbyte Flash in 20- to 80-pin packages.
Power transistors	The IGBT is the best 600 V rated device for PWM induction motor drives. The PowerMESH™ IGBTs combine low Vce(sat) with very short turn-off times and significantly reduce switching losses.
AC switches	With high commutation performance, Snubberless™ Triacs, ACS™ and ACST switches are the best choice. In addition, the latest ACS and ACST switches offer an outstanding overvoltage robustness enabling equipment to comply with the IEC 6100-4-5 standard. The 500 V ACS, also available in array configuration, is suitable for fan drives while the 700-800 V ACST is intended for medium-power motor drives in washers, dryers and refrigerators.

Three-phase induction motor

The three-phase induction motor is a brushless motor. Its stator is copper wound and the rotor is typically an aluminum squirrel cage. The motor is supplied with three alternating voltages which produce a rotating stator field while speed varies with the field frequency. The rotor follows this field with a lag called the *slip*.

Typical application parameters

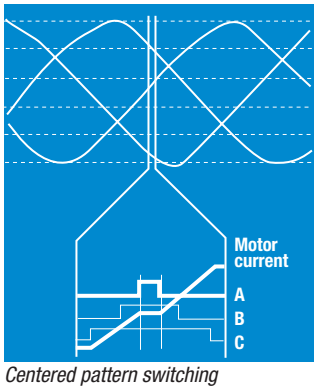
Voltage	Motor power	Speed range	Features
100 to 240 Vac	50 to 2,200 W	0 to 20,000 RPM	Robust, silent and reliable

Scalar V/f drive

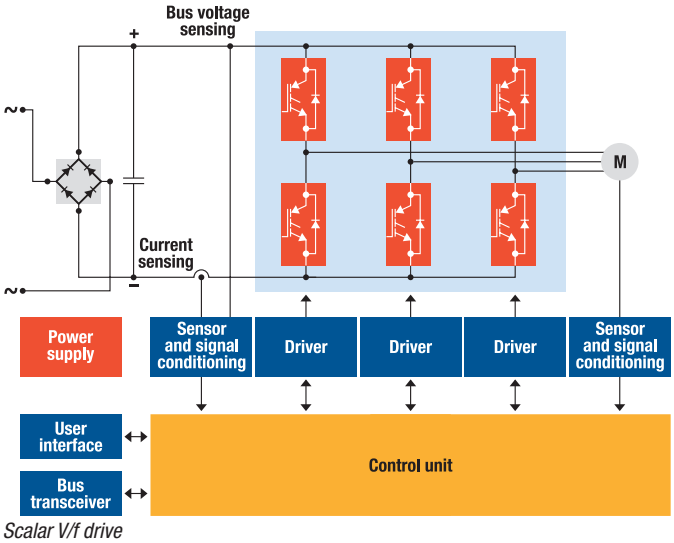
Scalar control is typically achieved by controlling the voltage-to-frequency (V/f) ratio, thus the stator voltage amplitude (V) is adjusted proportionally to the stator current frequency (f).
If rotor-speed feedback is available, slip regulation can be implemented to optimize drive dynamics and efficiency (MTPA - maximum torque per ampere - control).

Main applications

- Washing machines
- Heating, ventilation and air conditioning
- Blowers, fans and pumps
- Industrial control



Centered pattern switching



Scalar V/f drive

Demonstration boards

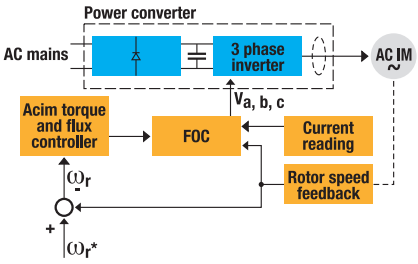
Order code	Description
STEVAL-IHM001V1	BLDC and AC motor control board
STEVAL-IHM003V1	BLDC and AC motor control - 300 W power board
STEVAL-IHM004V1	BLDC and AC motor control - 1 kW power board
STEVAL-IHM005V1	BLDC and AC motor control - 3 kW power board
STEVAL-IHM008V1	Power board based on SEMITOP 2
STEVAL-IHM009V1	Power board based on SEMITOP 3
STEVAL-IHM010V1	IGBT power module kit - ST7MC control board
STEVAL-IHM011V1	IGBT power module kit - SEMITOP 2 power board
STEVAL-IHM017V1	100 W 3-phase inverter for BLDC sensorless motor control
STEVAL-IHM019V1	Complete inverter for low-power 3-phase AC motors
STEVAL-IHM021V1	BLDC and AC sensorless motor control (L6390) - 100 W power board

Vector drive

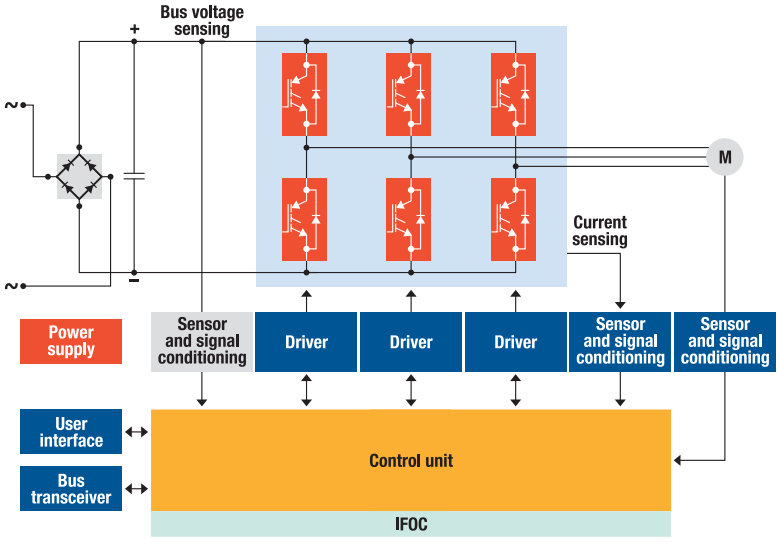
Vector control provides real-time processing of the stator phase current and rotor position. It provides four-quadrant operation and excellent dynamic behavior to give optimum efficiency and speed response time. In in the context of FOC (field-oriented control), if the rotor flux position is indirectly calculated using the transformed equations of the machine and the known motor parameters and stator current measurements, the controller is an indirect controller and is known as an IFOC drive.

Main applications

- Robotics
- High-end industrial control
- Servo drives



FOC block diagram



Vector drive

Demonstration boards

Order code	Description
STM3210B-MCKIT	ST motor control starter kit
STEVAL-IHM017V1	100 W 3-phase inverter for BLDC sensorless motor control
STEVAL-IHM021V1	BLDC and AC sensorless motor control (L6390) - 100 W power board

Product highlights

Microcontrollers	8-bit STM8 microcontrollers featuring a high-performance core (up to 20 MIPS @ 24 MHz), 3.3 V to 5.5 V power supply, embedded true EEPROM and RC oscillator and 4- to 128-Kbyte Flash in 20- to 80-pin packages. 32-bit STM32 microcontrollers based on the breakthrough ARM Cortex™-M3 core offering new degrees of freedom to MCU users: high-performance, real-time, low-power and low-voltage operation, while maintaining full integration and ease of development; six PWM advanced control timers with embedded deadtime generation; numerous PWM outputs allowing multiple motor drives; dual sample and hold ADC, 12-bit resolution and 1 µs conversion time; up to 512 Kbytes of Flash and 64 Kbytes of RAM.
Power transistors	Available at 600 V, PowerMESH IGBTs range from 3 to 50 A. To reduce component count on the board, they can be provided with a built-in Turbo 2 freewheeling diode. The low Vce(sat) combined with very short fall times significantly reduces both on and switching losses, while the fast-recovery diode further reduces the IGBT turn-on losses. For very low current applications, SuperMESH and SuperFREDmesh power MOSFETs are also available.
Fast rectifiers	Available at 300 and 600 V, Turbo 2 diodes feature ultra-fast recovery while maintaining a low dropout voltage.They significantly cut losses in both the diode and the transistor at turn-on.
Gate drivers	Half-bridge gate drivers are 600 V monolithic circuits which may include a bootstrap diode for the floating driver, deadtime circuitry, two UVLO circuits and an uncommitted comparator for protection functions. Signal and power grounds are separated to ensure high noise immunity.
Amplifiers and comparators	Operating at low voltage with rail-to-rail input and output capability, new op-amps bring innovation with very high merit factors and consumption below 1 mA, while offering high slew rate, 10 V/µs and large product gain bandwidth (up to 20 MHz). For high-voltage operation, standard CMOS or bipolar op-amps and comparators offer single-supply operation, with adequate speed.

Brushless DC PMSM

Permanent-magnet synchronous motors (PMSMs) are synchronous brushless motors composed of two main components: a rotor made of permanent magnets and a wound stator. A motor is categorized as a BLDC or brushless DC motor when the stator windings are concentrated into narrow phase belts and the resulting back-EMF voltage induced in each motor phase by the rotor spinning can be modeled quite accurately as a trapezoidal waveform. Due to the back-EMF shape, BLDC motors are specifically optimized to develop nearly constant output torque when excited with a six-step switched current waveform.

Typical application parameters

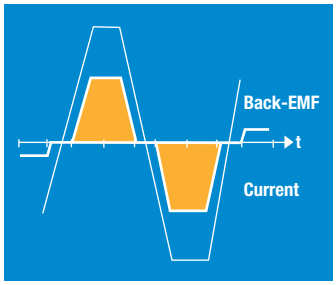
Voltage	Motor power	Speed range	Features
Up to 60 Vdc; 100 to 240 Vac	5 to 2,200 W	0 to 30,000 RPM	High torque capability at start-up and low speed Highly efficient and compact

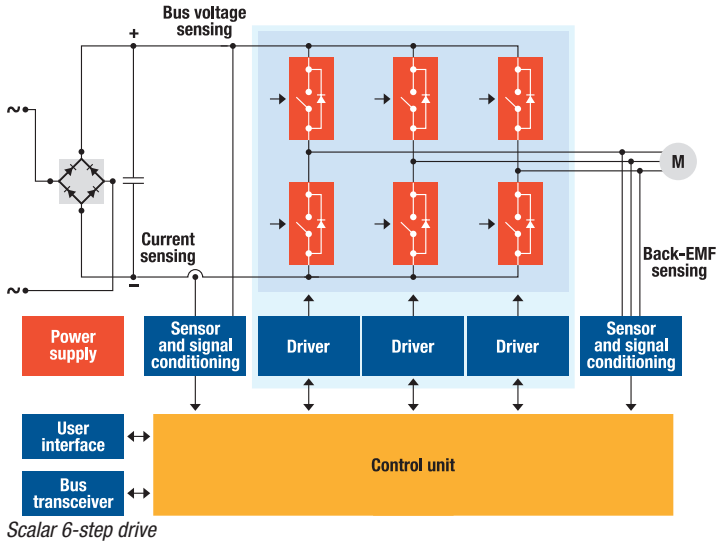
Main applications

- Heating, ventilation and air conditioning
- Refrigerators
- Medical equipment
- Robotics
- Home appliances
- Fans
- Pumps
- Hard disk drives
- CD/DVD drives
- Electric traction

Scalar 6-step drive

The motor is supplied by three trapezoidal 6-step waveforms. During each step, two phases are active. In sensorless mode, the inactive phase is monitored to read the back-EMF.





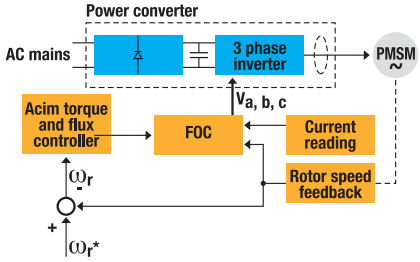
Scalar 6-step drive

Demonstration boards

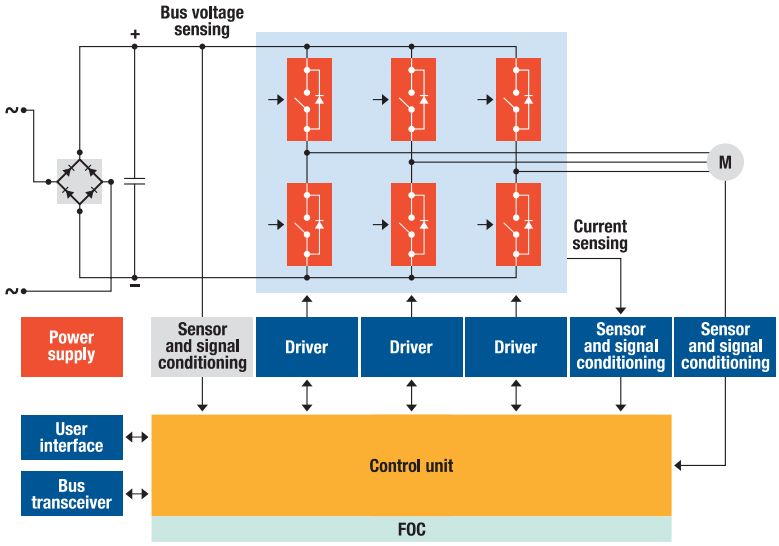
Order code	Description
STEVAL-IHM001V1	BLDC and AC motor control board
STEVAL-IHM003V1	BLDC and AC motor control - 300 W power board
STEVAL-IHM004V1	BLDC and AC motor control - 1 kW power board
STEVAL-IHM005V1	BLDC and AC motor control - 3 kW power board
STEVAL-IHM008V1	Power board based on SEMITOP 2
STEVAL-IHM009V1	Power board based on SEMITOP 3
STEVAL-IHM010V1	IGBT power module kit - ST7MC control board
STEVAL-IHM011V1	IGBT power module kit - SEMITOP 2 power board
STEVAL-IHM017V1	100 W 3-phase inverter for BLDC sensorless motor control
EVAL6235N	Hall-effect sensor monolithic driver
EVAL6229PD	Hall-effect sensor monolithic driver

Vector drive

If the application tolerates a small mechanical torque ripple a sinusoidal shaped current can be used for the drive. From this consideration and with this limitation, the advantages of a field-oriented control could also be extended to BLDC motors (reliability, noise reduction, high torque at start-up and low-speed).



FOC block diagram



Vector drive

Demonstration boards

Order code	Description
STM3210B-MCKIT	ST motor control starter kit
STEVAL-IHM011V1	IGBT power module kit
STEVAL-IHM017V1	100 W 3-phase inverter for BLDC sensorless motor control
STEVAL-IHM021V1	BLDC and AC sensorless motor control (L6390) - 100 W power board

Product highlights

Microcontrollers	32-bit STM32 microcontrollers based on the breakthrough ARM Cortex™-M3 core offering new degrees of freedom to MCU users: high-performance, real-time, low-power and low-voltage operation, while maintaining full integration and ease of development; six PWM advanced control timers with embedded deadtime generation; numerous PWM outputs allowing multiple motor drives; dual sample and hold ADC, 12-bit resolution and 1 µs conversion time; up to 512 Kbytes of Flash and 64 Kbytes of RAM. 8-bit STM8 microcontrollers featuring a high-performance core (up to 20 MIPS @ 24 MHz), 3.3 V to 5.5 V power supply, embedded true EEPROM and RC oscillator and 4- to 128-Kbyte Flash in 20- to 80-pin packages.
Power transistors	The latest STripFET generations and STripFET DeepGATE power MOSFETs are ideal PWM switches for low-voltage buses. As either N-channel or P-channel, they come in a large variety of SMD and through-hole packages. For high-voltage low-current applications, the standard high-voltage technologies can be usefully used as well. For the 600 V range, PowerMESH IGBTs cover all power ratings, both in single configuration or associated with a Turbo 2 fast rectifier.
Fast rectifiers	Available at 300 V and 600 V, Turbo 2 diodes feature ultra-fast recovery while maintaining a low dropout voltage. They significantly cut losses in both the diode and the transistor at turn-on.
Smart power ICs	Monolithic motor drivers can be conveniently used in applications where the input voltage does not exceed a few dozen volts and the current feeding the motor windings is limited to a few amps. These parts may include just the power stage or include the control section. ST has developed several types of power ICs, suited to different application requirements. Some operate in linear and some in switch mode.
Gate drivers	Half-bridge gate drivers are high-voltage monolithic circuits which include a bootstrap diode for the floating driver, deadtime circuitry, two UVLO circuits and an uncommitted comparator for protection functions. Signal and power grounds are separated to ensure high noise immunity.
Amplifiers and comparators	Operating at low voltage with rail-to-rail input and output capability, new op-amps bring innovation with very high merit factors and consumption below 1 mA, while offering high slew rate, 10 V/µs and large product gain bandwidth (up to 20 MHz). For high-voltage operation, standard CMOS or bipolar op-amps and comparators offer single-supply operation, with adequate speed.

Brushless AC PMSM

The motor is categorized as PMSM or sinusoidal PMSM or PMAC when the stator windings are sinusoidally distributed and the magnets are shaped to induce a sinusoidal back-EMF voltage waveform in each motor phase by the rotor spinning. Due to the back-EMF shape, sinusoidal PMSMs are specifically optimized to develop nearly constant output torque when excited with a 3-phase sinusoidal current waveform.

Typical application parameters

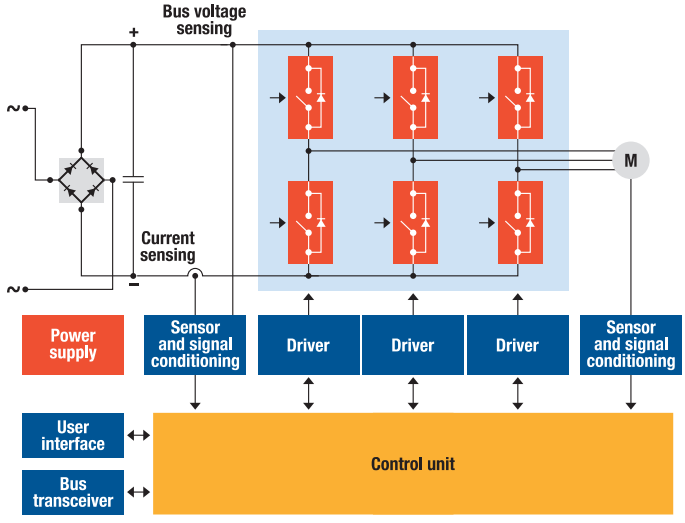
Voltage	Motor power	Speed range	Features
Up to 380 Vac	Up to 3 kW	Up to 30,000 rpm	High torque capability at start-up and low speed Highly efficient and compact

Main applications

- Dishwashers
- Electric traction
- Washing machines
- Robotics

Scalar drive

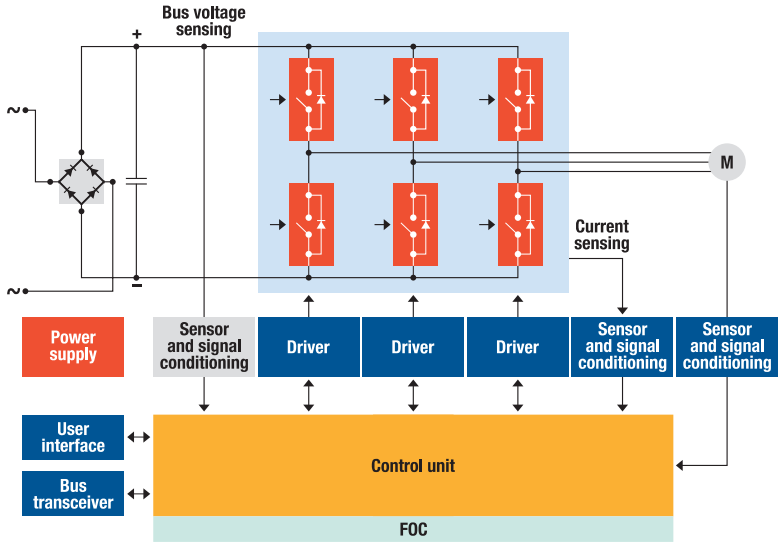
To avoid applying too high a voltage for the current frequency, a V/f limitation curve is used to fix the maximum voltage value supplied for the stator frequency.



Scalar drive

Vector drive

Vector control processes the stator phase current and rotor position in real time. It provides four-quadrant operation and excellent dynamic behavior, to give optimum efficiency, and torque and speed response times. Sensorless algorithms for rotor position detection are available.



Vector drive

Demonstration boards

Order code	Description
STM3210B-MCKIT	ST motor control starter kit
STEVAL-IHM011V1	IGBT power module kit
STEVAL-IHM017V1	100 W 3-phase inverter for BLDC sensorless motor control
STEVAL-IHM021V1	BLDC and AC sensorless motor control (L6390) - 100 W power board

Product highlights

Microcontrollers	32-bit STM32 microcontrollers based on the breakthrough ARM Cortex™-M3 core offering new degrees of freedom to MCU users: high-performance, real-time, low-power and low-voltage operation, while maintaining full integration and ease of development; six PWM advanced control timers with embedded deadtime generation; numerous PWM outputs allowing multiple motor drives; dual sample and hold ADC, 12-bit resolution and 1 µs conversion time; up to 512 Kbytes of Flash and 64 Kbytes of RAM. 8-bit STM8 microcontrollers featuring a high-performance core (up to 20 MIPS @ 24 MHz), 3.3 V to 5.5 V power supply, embedded true EEPROM and RC oscillator and 4- to 128-Kbyte Flash in 20- to 80-pin packages.
Power transistors	The latest STripFET generations and STripFET DeepGATE power MOSFETs are ideal PWM switches for low-voltage buses. As either N-channel or P-channel, they come in a large variety of SMD and through-hole packages. For high-voltage low-current applications, the standard high-voltage technologies can be usefully used as well. For the 600 V range, PowerMESH IGBTs cover all power ratings, both in single configuration or associated with a Turbo 2 fast rectifier.
Fast rectifiers	Available at 300 V and 600 V, Turbo 2 diodes feature ultra-fast recovery while maintaining a low dropout voltage. They significantly cut losses in both the diode and the transistor at turn-on.
Smart power ICs	Monolithic motor drivers can be conveniently used in applications where the input voltage does not exceed a few dozen volts and the current feeding the motor windings is limited to a few amps. These parts may include just the power stage or include the control section. ST has developed several types of power ICs, suited to different application requirements. Some operate in linear and some in switch mode.
Gate drivers	Half-bridge gate drivers are high-voltage monolithic circuits which include a bootstrap diode for the floating driver, deadtime circuitry, two UVLO circuits and an uncommitted comparator for protection functions. Signal and power grounds are separated to ensure high noise immunity.
Amplifiers and comparators	Operating at low voltage with rail-to-rail input and output capability, new op-amps bring innovation with very high merit factors and consumption below 1 mA, while offering high slew rate, 10 V/µs and large product gain bandwidth (up to 20 MHz). For high-voltage operation, standard CMOS or bipolar op-amps and comparators offer single-supply operation, with adequate speed.

Stepper motor

A stepper motor has windings only on the stator, while the rotor usually features permanent magnets. A stepper motor converts digital pulses into fixed angular steps and, for this reason, is normally used in an open loop configuration and is the most cost-effective solution in many positioning applications.

There are two basic types of stepper motor: unipolar and bipolar. In a unipolar motor, the current is allowed to flow in one direction through the motor windings, while in a bipolar motor it flows in both directions. A stepper motor driver typically works in switch mode and includes a current-control circuit allowing the current in the windings to be controlled in such a way that it follows a predetermined profile. In half and full-step modes, the current profile is rectangular, while in micro-step mode it is nearly sinusoidal. A power bridge is needed to drive bipolar stepper motors, but an array of switches is sufficient to drive unipolar stepper motors.

Typical application parameters

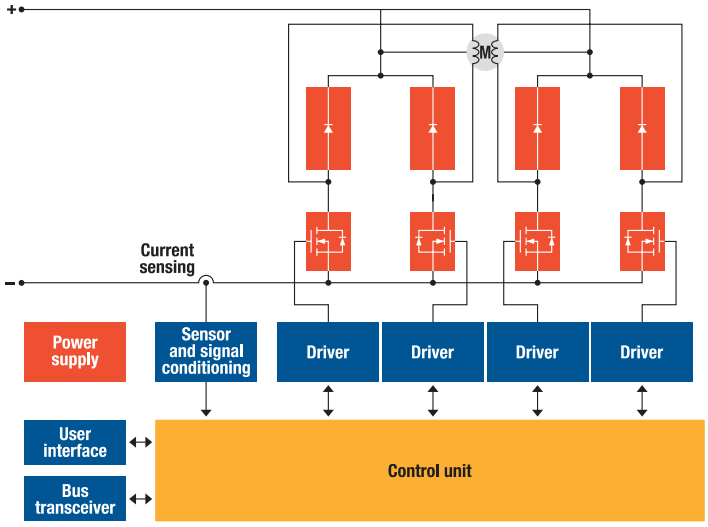
Voltage	Motor power	Speed range	Features
7 to 180 Vdc	Up to 300 W	0 to 1,000 RPM	High torque at rest position Accuracy

Main applications

- Printers
- Automotive applications
- Air conditioning louvers
- Factory automation
- Machine tools

Unipolar stepper motor drive

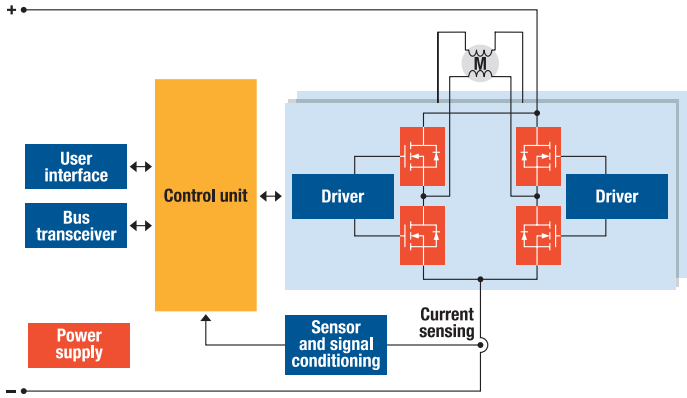
All stator windings share a common terminal, and the free terminal of each winding is connected to a separate power switch. Diodes are used for clamping the voltage across the switches at turn-off.



Unipolar stepper motor drive

Two-phase bipolar stepper motor drive

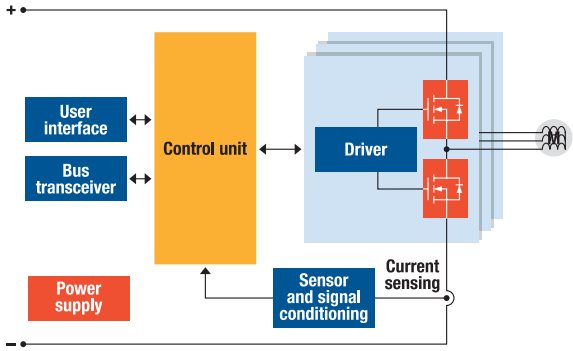
A full-bridge converter is required to drive each of the two windings of a two-phase motor.



Two-phase bipolar stepper motor drive

Multi-phase bipolar stepper motor drive

A three-phase inverter is needed to drive a three-phase motor. Multi-phase stepper motors with many phases tend to have much lower levels of vibration, although the cost of manufacture is higher.



Multi-phase bipolar stepper motor drive

Demonstration boards

Order code	Description
EVAL6205/6/7N	Integrated power stages with PowerSpin
EVAL6205N	PowerSpin with PWM current controller (L6205+L6506)
EVAL6206N/PD	PowerSpin with PWM current controller (L6206+L6506)
EVAL6207N	PowerSpin with PWM current controller (L6207)
EVAL6225PD	PowerSpin with PWM current controller (L6225+L6506)
EVAL6227PD/QR	PowerSpin with PWM current controller (L6225)
EVAL6226QR	PowerSpin (L6226)
EVAL6208N/PD	PowerSpin with stepper translator plus PWM current controller (L6208)
EVAL6228QR	PowerSpin with stepper translator plus PWM current controller (L6208)

Product highlights

Microcontrollers	8-bit STM8 microcontrollers featuring a high-performance core (up to 20 MIPS @ 24 MHz), 3.3 V to 5.5 V power supply, embedded true EEPROM and RC oscillator and 4- to 128-Kbyte Flash in 20- to 80-pin packages. 32-bit STM32 microcontrollers based on the breakthrough ARM Cortex™-M3 core offering new degrees of freedom to MCU users: high-performance, real-time, low-power and low-voltage operation, while maintaining full integration and ease of development; six PWM advanced control timers with embedded deadtime generation; numerous PWM outputs allowing multiple motor drives; dual sample and hold ADC, 12-bit resolution and 1 µs conversion time; up to 512 Kbytes of Flash and 64 Kbytes of RAM.
Power transistors	The latest STripFET generations and STripFET DeepGATE power MOSFETs are suitable for low-voltage stepper motors in automotive and industrial applications. They are ideal for higher power applications such as printers.
Smart-power ICs	Monolithic motor drivers can be conveniently used in applications where the input voltage does not exceed a few dozen volts and the current feeding the motor windings is limited to a few amps. These parts may include just the power stage or the control section as well. ST has developed several types of power IC which suit different application requirements; some work in half/full step and some in micro stepping mode.
Gate drivers	Half-bridge gate drivers are high-voltage monolithic circuits which include a bootstrap diode for the floating driver, deadtime circuitry, two UVLO circuits and an uncommitted comparator for protection functions. Signal and power grounds are separated to ensure high noise immunity.

Switched reluctance motor

A switched reluctance motor (SRM) can be considered as a big step motor where both the stator and the rotor present salient poles. In the SRM, no permanent magnets or brushes are used, so the magnetic flux is produced by the stator coils. The rotor is composed of laminated iron sheets, which are stacked on the shaft. Motor torque is generated by using the magnetic forces between rotor and stator salient poles, and the motor is supplied by current which is switched synchronously with the rotor pole position.

Typical application parameters

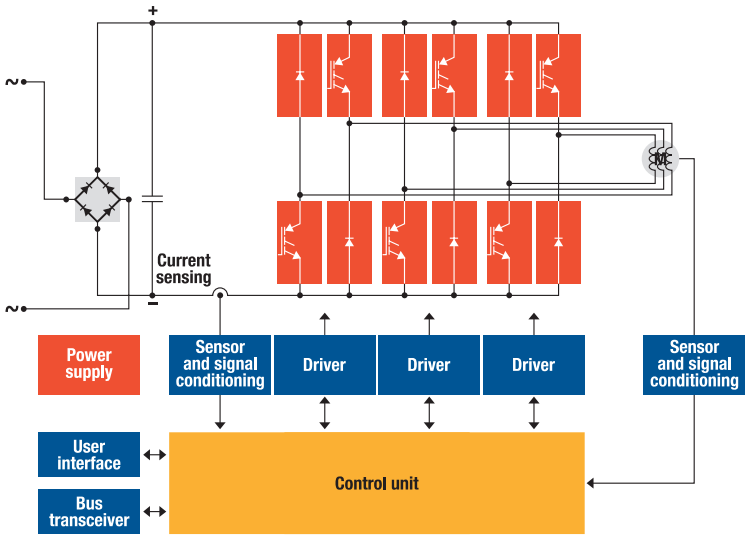
Voltage	Motor power	Speed range	Features
12 to 180 Vdc	Up to 300 W	0 to 1,000 RPM	High torque at rest position Accuracy

Main applications

- Traction
- Industrial and automotive actuators
- Home appliances
- Food processors
- Vacuum cleaners

Asymmetrical half-bridge PWM drive

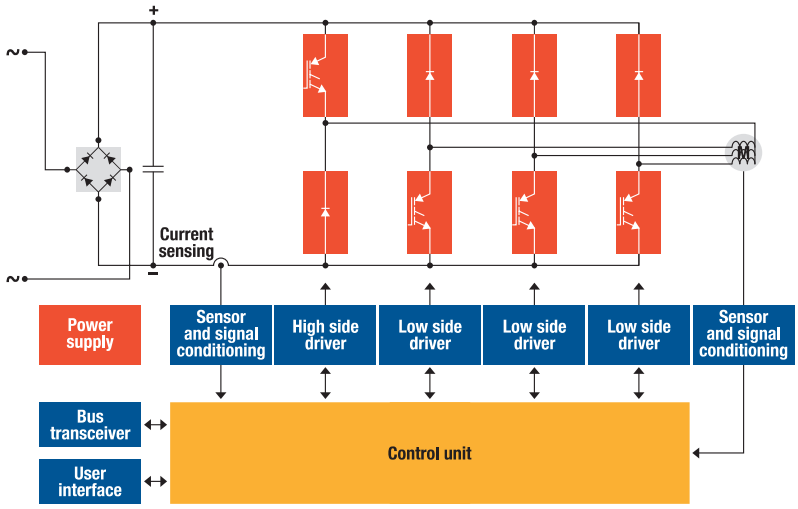
This inverter topology leverages the motor's best features. An independent current loop is implemented for each motor phase so that some phase current overlap is possible for attaining higher speeds.



Asymmetrical half-bridge PWM drive

Simplified asymmetrical half-bridge PWM drive

This inverter topology is cost-effective and well adapted to medium speed operation.

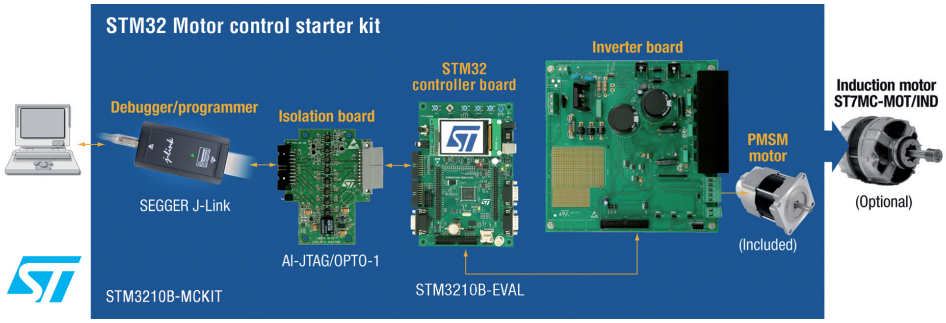


Simplified asymmetrical half-bridge PWM drive

Product highlights

Microcontrollers	8-bit STM8 microcontrollers featuring a high-performance core (up to 20 MIPS @ 24 MHz), 3.3 V to 5.5 V power supply, embedded true EEPROM and RC oscillator and 4- to 128-Kbyte Flash in 20- to 80-pin packages.
Power transistors	Available at 600 V, PowerMESH IGBTs are offered in a high-frequency version for the PWM switch and a low dropout version for the phase control switch. This combination optimizes total losses of each inverter bridge leg. The latest STripFET generations and STripFET DeepGATE power MOSFETs are suitable for low-voltage operation as well.
Fast rectifiers	Available at 300 V and 600 V, Turbo 2 diodes have ultra-fast recovery characteristics while maintaining a low dropout voltage. They significantly cut losses in both the diode and transistor at turn-on.
Gate drivers	Half-bridge gate drivers are high-voltage monolithic circuits which include a bootstrap diode for the floating driver, deadtime circuitry, two UVLO circuits and an uncommitted comparator for protection functions. A triple low-side gate driver can also be conveniently used in this application.
Amplifiers and comparators	Operating at low voltage with rail-to-rail input and output capability, new op-amps bring innovation with very high merit factors and consumption below 1 mA, while offering high slew rate, 10 V/µs and large product gain bandwidth (up to 20 MHz). For high-voltage operation, standard CMOS or bipolar op-amps and comparators offer single-supply operation, with adequate speed.

STM3210B-MCKIT

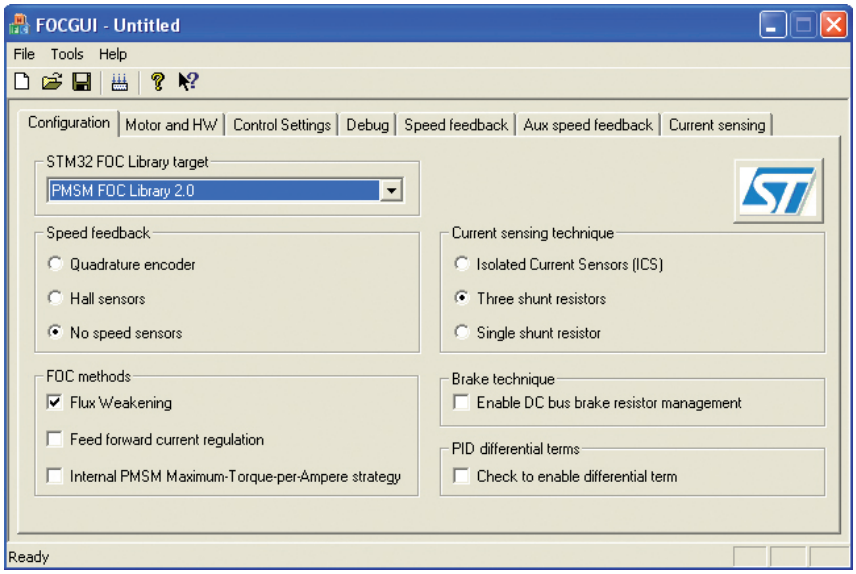


STM32 motor control tool ordering information

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).

FOC GUI 1.0

FOC GUI helps customizing a PMSM application firmware (PMSM FOC library 2.0). It is a parameter file generation tool (FOCGUI) which, starting from the system parameters, automatically generates all that is needed by the motor control firmware library to quickly run the motor, saving time and easing the development phase.



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 highend control systems. These features are supported by additional interrupt vectors and a second DMA controller.

Field weakening and 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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