

Getting More Out of Your Motor — Motor Driver ICs Integrate More Functions

By Bob Christie, Allegro MicroSystems Europe Ltd

With the increasing focus on communications and computing the humble electric motor is often overlooked. It has been estimated that in excess of one third of all electricity generated is converted to mechanical energy by electric motors. While a large part of this is by ac induction motors, an increasing amount is by smaller lower-voltage motors driven from a dc supply. The average PC for example will have about ten dc motors to move air, and drive hard disks and CDs. When printers, scanners, and game controllers are taken into account this number can double.

DC motors fall into two general categories; brush motors, which rely on mechanical commutation, and brushless motors, which use electronic commutation. All electric motors can be controlled by simply varying the applied voltage but for improved efficiency and control, pulse-width modulation is often used to control the motor current and thus the torque and speed. A simple linear control system using a variable resistance element in series with the motor will dissipate more power in the controller than in the motor unless the motor is running close to its maximum output. To avoid this inefficiency, pulse-width modulation switches the full supply voltage across the motor, avoiding resistive losses, and relies on the inductance of the motor to filter the applied waveform and average the motor current.

While brush dc motors are still prominent in low-cost and servo systems, brushless motors are increasingly being used due to their mechanical simplicity and reliability. The design of brushless dc motors is optimized for two different categories; the general brushless dc (BLDC) motor intended for continuous rotation such as pumps, fans, disk drives, projectors, etc., and stepper motors, which are optimized for start/stop and positioning systems such as printers, scanners, and angular and x-y positioning.

Due to their higher reliability, BLDC motors are finding increased acceptance in automotive applications such as electronic power steering, electromechanical and electrohydraulic braking, air conditioning, engine cooling, and various pumps.

Automotive applications also place increased requirements on the motor controllers due to the wide voltage range, wide temperature range, increased reliability, and the need for fault diagnosis. For higher power motors, discrete n-channel MOSFETs are used for power switches. These usually require a gate drive of at least 10 V for good conduction even at battery voltages as low as 8 V. In addition, the use of n-channel MOSFETs for the high-side switch mean that the high-side

gate voltage must be 10 V above the battery voltage. This is accomplished by integrating a dc-dc converter into the motor controller. For example, the A3935 from Allegro MicroSystems integrates an inductive boost converter with three pairs of high-side and



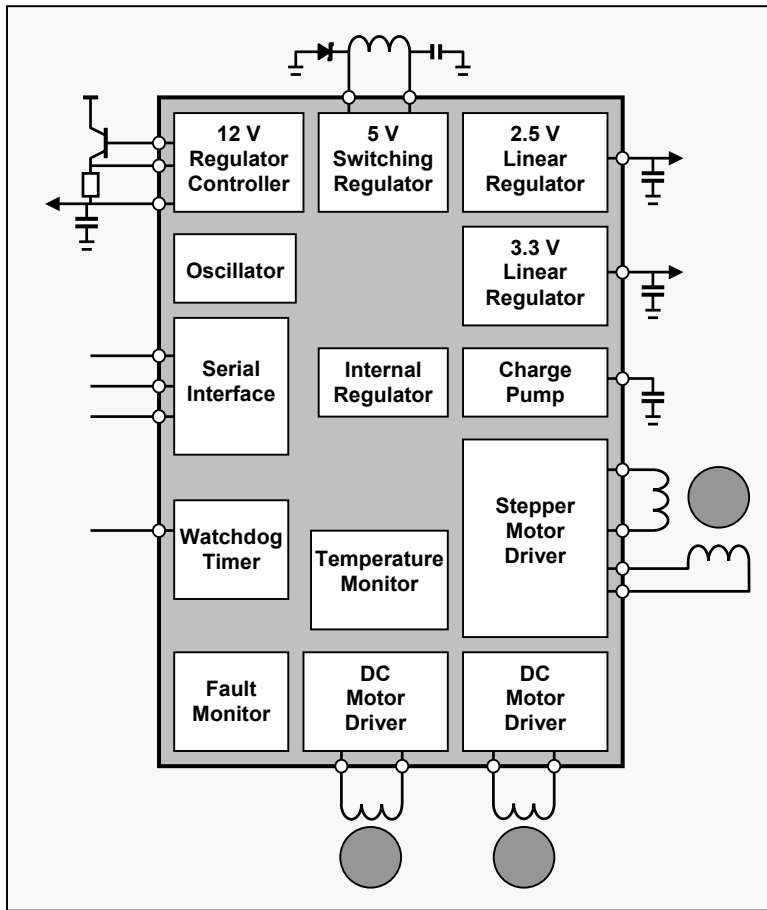
low-side drivers to maintain full gate drive down to 7 V battery voltage. A bootstrap capacitor supplies power to the floating high-side drive, which ensures that the high-side gate drive is above the battery voltage even at the 40 V maximum battery voltage. Similar schemes are used for simple full- and half-bridge drives such as the A3948, which generates the boost voltage using a switched capacitor dc-dc converter.

For stepper motors, the increased use of integration in the controller electronics is providing single-chip solutions with increased accuracy and lower noise. Stepper motors will often use a technique known as microstepping to move the motor by fractions of the full mechanical step giving increased resolution and quieter operation. In addition to a power driver and PWM current controller for each phase, a two-phase stepper motor with microstepping will require a DAC to set the intermediate current levels and a translation from the required microstep position to the DAC input value. Early stepper drivers such as the Allegro MicroSystems' A3966 dual H-bridge simply provide the power transistors and the current-sense comparator. For microstepping using this IC the required phase current is set by an externally provided voltage reference. Newer stepper drivers such as the A3973 integrate a DAC to set the current levels while a full microstepping solution is provided by the A3967 with bipolar Satlington™ outputs and the A3977 with higher power DMOS outputs. These ICs are the first to utilize the interface by integrating all the functions required for microstepping a two-phase stepper motor and are controlled independently of a microprocessor by simply selecting the required resolution and providing direction and step inputs.

In addition to the simple interface, Allegro MicroSystems has incorporated features in the stepper motor drivers, developed over a number of years, which help to improve efficiency, and reduce the acoustic noise from the motor. In the A3977, as in all the Allegro DMOS drivers and external MOSFET drivers, efficiency is improved by providing a synchronous rectification option where the motor current is passed through the power transistors rather than the recirculating diodes during the PWM off time. This results in a much lower dissipation in the power stage and for example allows the A3977 to be packaged in a 28-lead TSSOP package with an exposed thermal pad. To reduce acoustic noise the decay method for the motor current must be selected carefully. If fast decay is used, where the motor voltage is reversed during the PWM off-time, good current control will be achieved but the current ripple will be high leading to increased motor heating. If slow decay is used, where the motor windings are simply shorted during the PWM off-time, current ripple will be low but current control may be poor. To get the best of both worlds the A3967 and A3977 automatically use slow decay when the current is increasing and a mixed decay when the current is falling. Mixed decay is where the decay starts in fast mode then changes to slow mode after a user defined delay, thus minimizing ripple without compromising current control.

Increased integration is also a feature of a number of application-specific power interface products developed by Allegro. Many stand-alone systems such as printers, tape drives, and CD players for example, require control of several motors plus a number of power-management functions. Typically such a system will require a stepper motor, one or two dc motors plus switched and linear regulators. The required power sections are usually controlled through a parallel or serial digital interface that also reports fault conditions back to the controller. The figure shows typical blocks that are combined for application-specific solutions.





In this conceptual example, a stepper motor driver and two dc motor drivers are integrated with 3.3 V and 2.5 V LDO regulators that are supplied by a 5 V switching regulator. A higher power 12 V regulator controller drives an external transistor and includes current limit. All blocks are controlled independently through the serial interface, which also provides feedback of the chip temperature status and faults such as overcurrent, undervoltage and overvoltage. A charge-pump regulator is also included to maintain operation and control at low supply voltages.

The current range of motor-driver solutions, based on bipolar and DMOS technologies are capable of controlling motor currents up to about 3 A. Above this level, solutions based on a controller plus external power transistors is usually more cost effective. Smaller-geometry power processes currently in development are unlikely to increase the maximum current much above 3 A but will provide the ability to integrate more intelligence in the driver and further reduce the total solution cost. In addition, improvements in packaging are helping to reduce the size and cost of motor-driver systems while increasing the operating temperature range. Further process developments will push the voltage capability of the drivers above 80 V providing the ability to drive motors in the emerging 42 V automotive systems.

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