BLDC Motor Control with the Atmel ATA6843 and ATA6844

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With BLDC motors it is possible to realize powertrain designs with optimal efficiency, long lifetimes, precise rotation speeds, space-saving design footprints, and low weight. Placed directly on the motor, the power and control electronics make a large number of simple and low-cost applications possible. Atmel® components enable BLDC motor operation within a wide supply voltage range, which includes the crank pulse and jump start. Atmel Grade0-qualified microcontrollers and the Atmel ATA6844 system basis gate driver IC with high-temperature capability of up to 200°C $T_{junction}$ are available for applications in thermally demanding areas of internal combustion engines.

All applications in the automotive industry are expected to work preferably with no malfunctions; this applies in particular to BLDC motors. Since the most decisive developments in automotive motor controls almost always involve BLDC motors, providing comprehensive support to developers in a large number of applications is of key importance.

In addition to the appropriate components—such as microcontrollers, gate driver ICs and MOSFETs—plug-and-play design kits and software are important tools that give application designers more rapid access and help to speed up the design-in process.

The system basis predriver devices have a universal architecture; comfort applications can be realized with the standard version Atmel ATA6843, while the high-temperature version Atmel ATA6844 targets applications in the hot motor compartment. The Atmel microcontroller ATmega32M1 is Grade0-qualified and a cost-effective system solution when combined with the corresponding driver IC. The microcontroller's tasks consist of position detection with Hall sensors or sensorless position detection using Back EMF so that the predriver selected can be used universally for both types of three-phase BLDC motors.

Among the many possible applications for BLDC motors, those within the powertrain area pose the greatest challenge because the objective is to ensure reliable operation with ambient temperatures of up to approx. 150°C. Atmel SOI-on-BDC technology allows the overtemperature switch-off threshold of the ATA6844 system basis predriver to be set to 200°C. Thanks to the Ni/Au layer used on the aluminum pads, the gold wire bonding is not endangered by intermetallic corrosion (avoiding the Kirkendall effect). By using the system basis H-bridge driver ATA6824, which has been in production for some time, it is possible to reference successful high-temperature applications.

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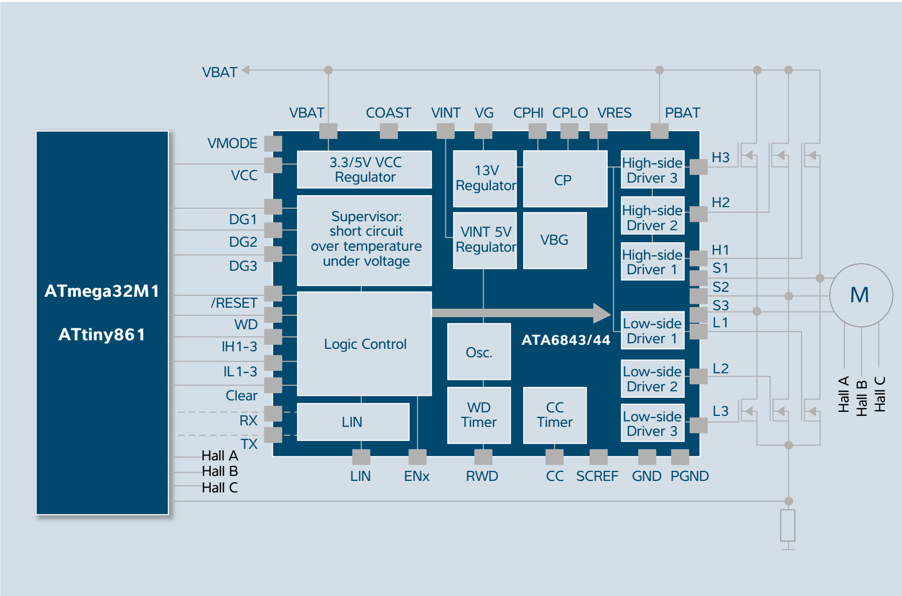

Figure 1. Block Diagram of a BLDC Motor Control System Comprising a Microcontroller and a System Basis Gate Driver IC

BLDC Motor Control Applications

Powertrain

- Variable geometry turbo chargers
- Exhaust gas recirculation
- Waste gates
- Oil/fuel/coolant pumps
- Radiator fans
- Electronic throttle controls
- Variable manifolds
- Variable valve controls
- Synchronous rectifiers
- Clutch actuators
- Gear selection

Safety and Chassis

- ABS/ESP pumps
- Power steering (EPS)
- Park brakes (EPB)
- Adaptive headlights
- Windscreen wipers

Comfort

- HVAC fans
- Seat adjustment
- Sun roofs
- Power windows
- Door locks
- Power sliding doors

Hybrid and Electrical Vehicles

- Engine cooling pumps
- AC pumps

Regardless of the application, all automotive devices need to guarantee maximum robustness against interference from the vehicle's power supply.

On the other hand, they should not contaminate the on-board system with excessive interference levels. For this reason measures for suppressing and avoiding interference are indispensable. So that the user is not faced with unreasonable component and configuration costs, an application can be especially convincing if the devices being used are designed with low noise levels.

Sources of interference in BLDC motor controls are the switching edges of the MOSFETs, which are switched in PWM operation at up to 50kHz (see ATA6843/44 datasheet). In addition, the charge pump required for operation of the high-side MOSFETs may cause undesirable disturbances to the on-board system. The switching frequency of the ATA6843/44 charge pump is typically 400kHz. Already during the development phase of this IC measures have been taken to keep radiated emission low.

EMC: Conducted Emission Measurements of Components/ Modules According to CISPR25 (Voltage Method)

In general, EMC (electromagnetic compatibility) measurements at the component or module level are used to ensure that modules of this kind operate properly in an electromagnetically distorted environment while keeping their own distortions below certain thresholds so that other components do not suffer any serious adverse effects. EMC issues tend to become more and more expensive the later they are discovered, so that tests of the electronic control units (ECU) before their deployment in vehicles help to reduce the risk of unpleasant surprises at later stages.

EMC testing includes the assessment

of emission as well as susceptibility performance. Two general measurement types have been standardized for both test cases:

- Radiated measurements using an antenna, a coupling clamp, a magnetic or electric probe, a strip line, or a TEM cell
- Conducted measurements using galvanic coupling to certain ports to measure or inject RF signals

Especially at lower frequencies such as car radio AM band and even up to FM band, conducted measurements often turn out to be more critical than their radiated counterpart because the length of coupling structures (wiring or antennas) is rather small compared to the wavelength, and conducted voltage measurements usually ensure more dynamic range than radiated measurements.

To evaluate emission performance, the international standard CISPR25 provides a test set-up for voltage-based conducted measurements. CISPR stands for "Comité International Spécial des Perturbations Radioélectriques" (in English: International Special Committee on Radio Interference). Voltage measurements are able to characterize the emissions on single leads only. Therefore, this test method cannot be used to characterize the coupling of any antenna structures performed on printed boards or the efficiency of shieldings, for example. It is, however, well suited to calculate emissions of a module via its supply lines or any bus lines, which are quite often the main source of distortions at lower frequencies.

The basic idea is to operate the module in an environment that is almost "real life" but still relatively easy to realize on a lab bench. For that purpose the wiring harness of a car is emulated by an LISN (Line Impedance Stabilization Network) or in short: artificial network (AN). The unit under test is supplied via such an artificial network that also incorporates a measurement path for the emitted RF disturbances. The entire test set-up uses two ANs, one for the supply, and one for the ground line. It can be slightly simplified using only one AN if the return line is locally grounded (see figure 2).

The EUT (equipment under test) as well as the connected supply and bus lines are placed above the ground plane on a non-conductive, 50mm thick plate with low relative permittivity. The power supply lines between the connector of the AN(s) and the connector(s) of the EUT (Ip) have a standard length of 200mm, although the wiring type is determined by the actual application requirements. It is also important that the total length of the test harness (excluding power lines) be kept below 2m and all leads and cables located at a minimum distance of 100mm from the edge of the ground plane. Deviations from this basic set-up are possible but need to be agreed upon and described in the test report.

While the general arrangement of the EUT, connecting harnesses, AN, etc. is clearly described in the standard, it is also stated that the "EUT shall be made to operate under typical loading and other conditions as in the vehicle such that the maximum emission state occurs." Such operating conditions need to be mutually agreed between supplier and customer, and must be clearly specified in a test plan. The voltage measurements are performed on each lead (supply and return) relative to the ground plane. The measuring instrument, usually a spectrum analyzer or a dedicated EMC test receiver, is connected to the relative AN while the other AN is terminated with a 50Ω load. In a simplified test set-up with local grounding as shown in figure 2, only the supply line is measured.

Atmel Microcontrollers – The Command Centers for the System Basis Gate Drivers

The Atmel AVR® automotive microcontroller family is the perfect

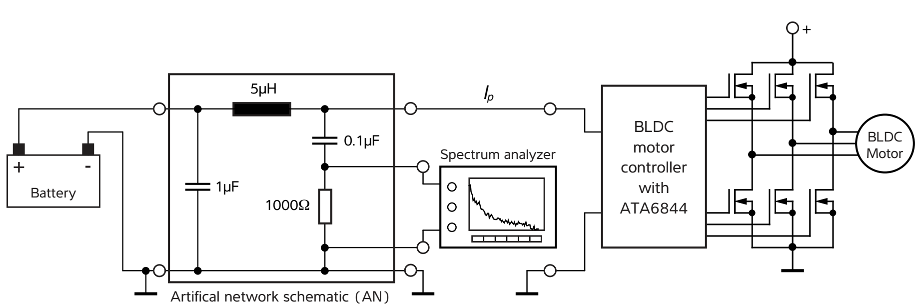

Figure 2. Test Set-up According to CISPR25

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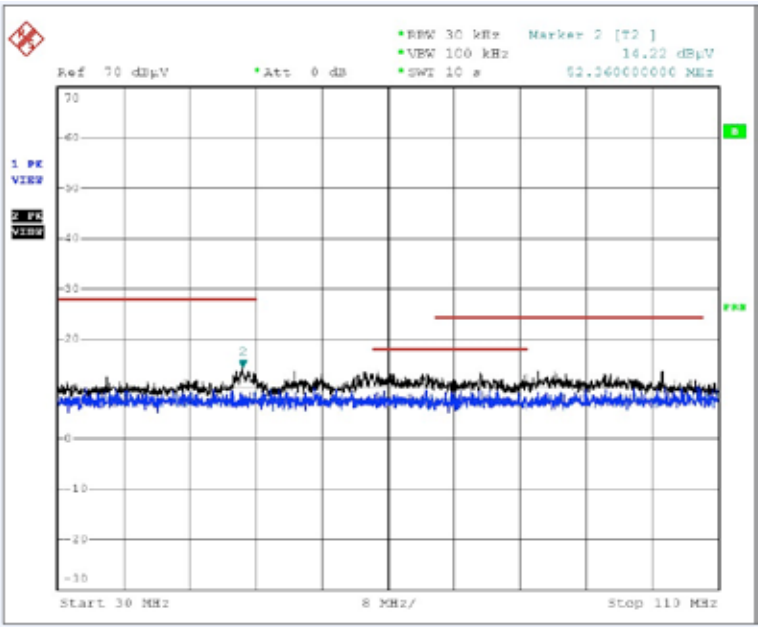

Figure 3. Measurement of an ATA6844 System Basis Gate Driver in Accordance with CISPR25

This illustrates the excellent results of the ATA6844 conducted emission measurement according to CISPR25 (voltage method) with disturbances of the charge pump staying well below the most stringent class 5 narrowband limits. The black trace shows the measurement result, whereas the blue trace is a reference measurement without powering the IC to determine the noise floor, while the class 5 limit lines are marked in red. CPOUT were loaded with 3kΩ for the measurement.

solution for generating the required control signals for the ATA6843/44 brushless DC motor (BLDC) predrivers.

A variety of 8-bit derivatives is Grade0-qualified according to AEC-Q100, i.e., these devices can be operated with guaranteed reliability in harsh environments with ambient temperatures ranging from -40°C to +150°C.

This enables system designers to place the control logic in the direct neighborhood of actuators that are operated at high temperature, thus avoiding the disadvantages of a long interposed wiring harness. By doing so, cost, weight, and losses are reduced significantly and mechanical reliability is increased.

In order to obtain efficient and reliable commutation of the BLDC motor, the actual rotor position needs to be detected. This can either be achieved by a Hall-sensor-based or a sensorless control loop.

The first method uses digital signals; the latter exploits the effect of a coil that induces a correlated analog voltage when exposed to a varying magnetic field. This signal is also known as Back ElectroMotive Force (BEMF).

Two Grade0 AVR families are specifically suited for three-phase motor control in combination with ATA6843/44: the Atmel ATtiny261/461/861 and the Atmel ATmega16M1/ 32M1/ 64M1.

ATtiny261/461/861

Cost-efficient microcontrollers with 2, 4, or 8 kilobytes of Flash memory for Hall-sensor-based solutions. The external control of the microcontroller can be achieved by, for instance, a one-wire PWM signal for the motor speed plus one digital signal for the motor direction.

The motor timer (Timer1) features the required complementary outputs, a 10-bit resolution, and can be clocked with up to 64MHz by an integrated PLL. An on-chip analog comparator can be configured to switch off the PWMs in case of overcurrent.

ATmega16M1/ 32M1/ 64M1

Full-featured microcontrollers with 16, 32 or 64 kilobytes of Flash memory. Those derivatives comprise both CAN and LIN logical interfaces, an ideal combination together with the physical LIN interface of ATA6843/44.

A power-stage controller offers a highly flexible 12-bit timer that can be operated at up to 64MHz. Using special synchronizing features of the high-speed analog-to-digital converter during motor start-up enables smart BEMF measuring. At higher motor speeds the output signals of three analog comparators can be used for triggering the power-stage controller with the required response time. One additional comparator can still be used for emergency shut-down. For further system design optimization, three operational amplifiers and a 10-bit DAC converter are implemented, enabling fast control loops within switch-mode applications.

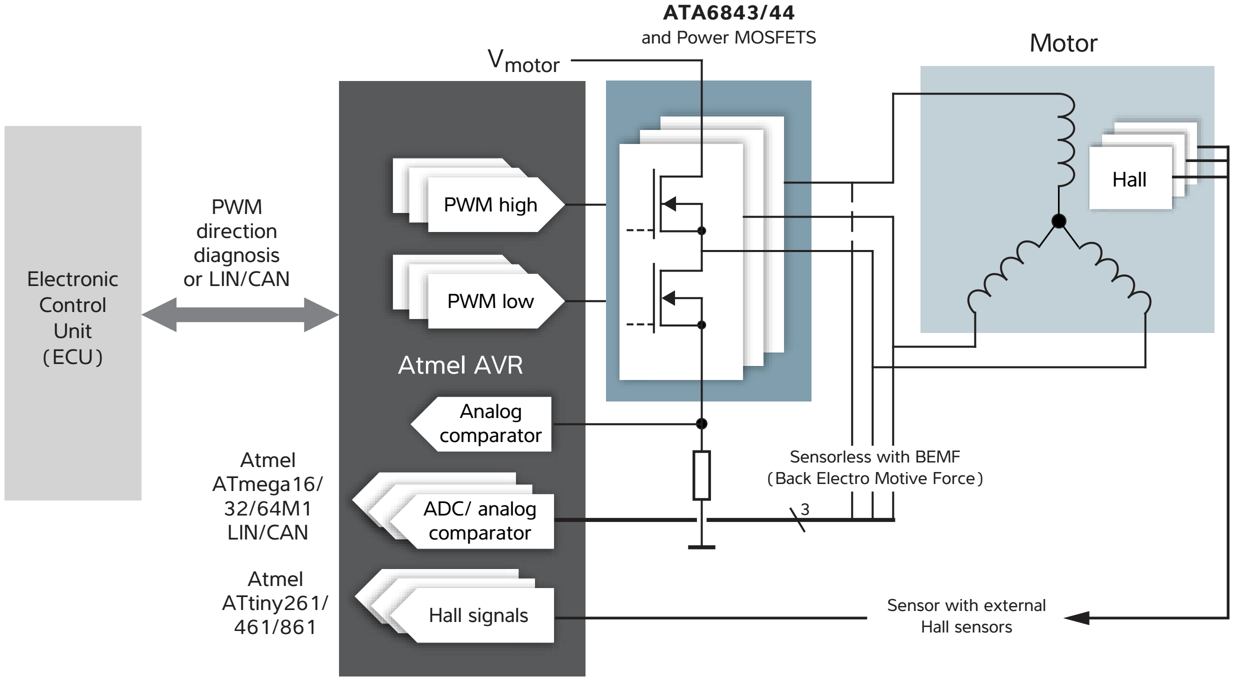

Figure 4

All automotive AVR 8-bit microcontrollers integrate a calibrated, precise RC oscillator, temperature sensor, on-chip Flash, and EEPROM, and are in-system programmable over the complete temperature range. ATmega16M1/ 32M1/ 64M1 additionally offer boot loader capability for firmware upgrades in the field, e.g., via LIN or CAN. Third-party protocol stacks are available.

Debugging can be efficiently done via one signal line only (DebugWire).

The AVR 8-bit microcontrollers presented are perfectly suited for distributed architectures in high-temperature environments, and meet growing demand for brushless DC motor control in automotive applications in the power train, chassis, and body segments.

Conclusion

For the growing market of brushless DC motor control applications, Atmel provides system solutions consisting of a microcontroller and a system basis gate driver IC. Such system solutions are well suited and qualified for use in the standard temperature range as well as in challenging high-temperature applications as typically found in the hot motor compartment.

Circuit design techniques enable excellent noise level results when tested according to CISPR25. This significantly contributes to minimizing external interference suppression efforts on the part of the customer.

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