Atmel® has more than 25 years of in-depth automotive design expertise. The automotive specialist supplies drivers, predrivers, microcontrollers, and software for DC and brushless DC (BLDC) motor control solutions. This article describes Atmel system basis predriver ICs and emphasizes its most recently developed BLDC motor driver device.

One of the key fields Atmel specializes in is application development for controlling brushed DC motors. There are a large number of suppliers offering a wide variety of automotive-qualified DC motors. Automotive applications continue to see a high demand for brushed DC motors. In most cases, these durable motors, based on proven technology, meet the customers’ application requirements and failure rates are low. But brushless DC motor applications are now emerging, and market analysts have assigned them the highest growth rate. The extended functionalities of BLDC motors are becoming more attractive.

Regardless of whether DC-brush or brushless DC motors are used, the challenge in electronic motor control is to design for new functionality while maintaining reliability and high-performance. Atmel smart drivers and bridges enable a myriad of electronic applications. Manufactured using 0.8μm BCD-on-SOI process technology, they support operation up to 40V and can be optimized for motor control applications in harsh environments such as the engine compartment.

The Atmel systems basis predriver ICs are of particular interest in managing the shift to brushless motors. To enable new, additional BLDC motor applications, a next generation of advanced system basis B6 predrivers has been developed. Together with Atmel microcontrollers and software, these predrivers will support successful design of future BLDC motor control ICs.
Brushed DC Motor Advantages

Brushed DC motors are a proven technology offering several advantages. In addition to low initial cost, brushed DC motors also stand out for their reliability, the high volume of production possible with this technology, as well as the ease with which brushed DC motor speed can be controlled.

The low initial cost involved is perhaps the most important benefit. Customers still prefer brushed motor control in price-sensitive applications, which comprise almost all convenience electronics in small and mid-sized vehicles. In addition, many functions in this environment still run without semiconductor driver ICs, making them simpler and cheaper.

Brushed DC Motor Disadvantages

On the other hand, this technology has its drawbacks. One disadvantage is that carbon brush wear can reduce the motor’s service life. Also, brush fire of the DC motor may cause EMI.

In addition, as indicated above, the low effort and cost of electronic control with brushed DC motors is associated with the use of relays, and a trend is underway to replace relays with transistors. While relays have sufficient reliability in most cases, particularly when motors are rarely switched on, they do have disadvantages. Transistors are increasingly preferred when the following variables are considered:

- Mechanical stress, vibration
- Switching frequency
- High coil current
- Speed control
- Size, space
- Clicking noise

In summary, relay control is still the simplest method of controlling brushed DC motors, but perhaps performs better for certain applications with unidirectional operation, i.e., radiator fans, as well as for those with reversed operation, such as power windows.

DC Motor Control in H-bridge

Typically, half-bridge drivers are employed for brushed DC motor control, so it is important to utilize the right combination of microcontroller and driver. In reversed DC motor applications, for example, the DC motor is typically in H-bridge configuration with four power MOSFETs forming the bridge. The ATA6836, a fully protected hex half-bridge driver designed in the Atmel Smart Power SOI technology, can be used by a microcontroller to control up to six different loads.

Up to a current limit of about 650mA, the Atmel® ATA6836 can be used to drive up to 5DC motors directly in H-bridge configuration. This applies, for example, to flaps in air conditioning systems and side mirrors. In the case of DC motors with higher wattage (about 10W to 800W), Atmel recommends using an integrated gate driver (Atmel ATA6823 or Atmel ATA6824), an Atmel AVR® microcontroller (e.g., Atmel ATmega32M1), and four discrete N-channel power MOSFET to be selected according to the DC motor’s wattage.

The H-bridge driver ICs currently available are often simple predrivers that activate and deactivate the gates of discrete power MOSFETs. The approach taken by Atmel, however, is more complex. Based on its extensive experience with stand-alone watchdog ICs and system basis chips – including LIN transceivers, low drop voltage regulators, and window
watchdogs in different partitioning – Atmel has combined these IPs with push-pull drivers. The drivers are designed using a very robust SOI technology (Atmel® SMART-I.S.™). The numerous advantages of this technology have been described in great detail in several previous issues of Automotive Compilation and there is no need to detail them here. They include:

- Low leakage currents
- High-temperature and high-voltage capability
- Excellent radiation hardness
- Improved latch-up immunity
- High switching frequency

In summary, smart H-bridge drivers from Atmel offer a more robust and flexible approach to controlling multiple brushed DC motors.

**High-Temperature Applications**

When designing brushed DC motor control systems, high-temperature is a second consideration. Taking advantage of Atmel SOI technology’s high-temperature capability, the company has designed the Atmel ATA6824. Specifically for the high demands of engine compartment applications where electronic control units are specified for ambient temperatures of 150°C or higher. However, a system basis predriver with an integrated 100mA, 3.3/5V linear regulator (designed for such an environment) needs to be qualified for a junction temperature of up to 200°C.

**Protection**

Protection is also an important consideration, particularly when customers are hesitant to adopt a new technology, as with migrating from relays to semiconductor solutions. With such as shift, the user expects that manufacturers guarantee full protection. Discrete power MOSFETs, for example, need to be protected against overcurrent conditions. This is typically done by monitoring the drain source voltage that is fed to a comparator integrated in the predriver. A high short-circuit current will flow if a high-side and a low-side power MOSFET are activated simultaneously within the same branch. As a countermeasure, Atmel system basis gate drivers feature implemented shoot-through protection. The dead time can be adjusted individually by choosing an R/C combination at the CC pin of the cross conduction timer. This allows the engineer to flexibly adapt the dead time to the switching characteristic of the power MOSFETs used.

**Shift to Brushless Motors**

As stated above, BLDC motors are only now emerging in automotive applications, although they have been popular in disk drives, industrial applications and hobby electronics for several years. Automotive industry studies reveal that about 80% of DC motor applications is still equipped with brushed DC motors. Market analysis conclusively shows, however, that brushless DC motor applications are growing at the fastest rate. This
means that BLDC motors will soon take the lion's share of new motor control electronics R&D.

The advantages of BLDC motors over brushed motors are obvious:

- Improved speed vs. torque characteristics
- High dynamic response
- High efficiency
- Noiseless and interference-free operation
- Extended speed ranges
- Long operation life

Maintenance-free operation is a very important advantage for all systems that operate continuously while the engine is running, such as fuel pumps or variable vanes in turbo chargers. Also, the smaller size and reduced weight are plus factors for BLDC motors.

On the other hand, the increased effort and cost of electronic control (including both hardware and software) could slow the replacement of proven DC motors with BLDC technology. Customer resistance to BLDC can be overcome, however, if the motor control ECU cost is effectively managed by using a BLDC motor control system approach comprising a microcontroller, a system basis gate driver, and the necessary software.

The B6 Predrivers

Currently, vehicle applications mainly incorporate highly efficient 3-phase brushless DC motors. Such motors typically need a B6 bridge to control three high-side and three low-side power MOSFETs. As with the system basis H-bridge predrivers Atmel® ATA6823/24, the B6 bridge predrivers Atmel ATA6833/34 include all the elements needed to form a complete system. The system consists of a pin-programmable linear voltage regulator (100mA, 3.3/5V); a LIN transceiver; and a window watchdog, in combination with six push-pull stages. The stages are needed to control the six discrete N channel power MOSFETs which operate 3-phase brushless DC motors.

These predrivers also offer outstanding space saving on the PC board, helping the designer minimize board size. And because the system basis predrivers are assembled in QFN packages with exposed pad, the board design can easily be optimized for perfect heat transfer. The QFN48 7x7 mm package features a thermal resistance of $R_{thjc} = 5K/W$, and thus a thermal resistance of $R_{thja} = 20K/W$ can be achieved with an elaborate board layout.

Inputs/Outputs for all Kind of Commutations

Flexibility is also a must for motion control of power MOSFETs in 3-phase brushless DC motors. In a B6-predictor, it makes no sense to use a 2-pin motion control (as with the Atmel ATA6823 or Atmel ATA6824) because flexibility in the control of the power MOSFETs is mandatory for different kinds of commutation. Therefore, power MOSFETs should be controlled from the μC separately via the three high-side and three low-side inputs of the Atmel predrivers ATA6833/34.
Operation During Crank Pulses

In order to enable operation of BLDC motor systems during the crank pulse (as defined by ISO 7637, see Figure 4), the minimum supply voltage must be as low as 5V and the predriver must be able to activate the high-side and low-side N-channel power MOSFETs. Hence the charge pump needs to be powerful enough to operate both the high-side and the low-side FETs via the internal voltage regulator. Because of this, the Atmel® ATA6833/34 devices are ideal for systems which need to be in operation during engine start, e.g., fuel pumps.

B6 Driver Versions

As with as the H-bridge predrivers ATA6823/24, which are both available for the standard and the extended maximum temperature range, there are also two high-temperature B6 bridge driver types available for 3-phase BLDC motor control.

The ATA6833 is rated for a maximum junction temperature of 150°C. For all convenience applications, and also some powertrain applications, this temperature is sufficient.

The ATA6834 targets high-temperature applications with an ambient temperature of 150°C or more. The device is designed and qualified for a continuous maximum junction temperature of 200°C. Power dissipation calculations can be found in the application note “Estimated junction temperature rise due to power dissipation during operation” (see http://www.atmel.com/dyn/resources/prod_documents/doc9181.pdf)

With temperature warning functionality and switch-off thresholds adapted to high junction temperature, and also with a special bond pad coating, the ATA6834 is perfectly suited for ECUs attached to coolant pumps, turbo chargers with variable geometry, or exhaust gas recirculation systems (EGR).

Universal Use

Because BLDC motor applications involve multiple types of signal conditioning, universal use of system basis gate drivers is recommended. These drivers do not handle Hall sensors and BEMF signals, for example, but can be used universally to make stock-keeping easier. And although system basis devices incorporate a broad range of functionalities, some functions should be intentionally assigned to the microcontroller.

In case of motor current measurement to detect overcurrent, the designer should feed the voltage drop via a shunt resistor to the analog comparators of one of the microcontrollers (e.g., the Atmel ATmega32M1). These comparators can be used to condition either the Hall sensor signals of a sensor-type motor or the BEMF signals of a sensorless motor.

New Generation: Atmel ATA6843, Atmel ATA6844

To enable new, additional BLDC motor applications that take advantage of extended functionalities, a next generation of advanced system basis B6 predrivers has been developed. Like their predecessors, they consist of six push-pull stages combined with a 100mA, 3.3/5V pin-programmable linear voltage regulator; a window watchdog with a separate time base that is independent of the microcontroller; and a LIN transceiver. Since this LIN transceiver is based on the stand-alone LIN transceiver IP, Atmel ATA6663, the system basis gate driver’s LIN section meets the high ESD protection requirements at the 8kV LIN pins and complies with all relevant conformance testing requirements.

The increased functionalities of the next-generation devices Atmel ATA6843/44 include:

- Expanded overvoltage detection threshold (up to 30V). This is an important feature for all applications requiring full functionality during jump-start
conditions, such as fuel pumps. In this case, the supply voltage is in the range of 5V to 30V.

• Adjustable and very low short-circuit-detection threshold for increased compatibility with low-impedance power MOSFETs. The drain source monitoring can be adjusted by feeding a voltage in the range of 0.5V to 3.3V to pin SCREF. An internal voltage divider sets the detection threshold to 2.5V if the pin is left open. Note that the devices Atmel® ATA6833/34 do not provide this pin.

• A digital input at pin COAST connected to the logic control. If this input is activated, all power MOSFETs are switched off, allowing the motor to coast. In some situations, the motor is asked to coast until it stops. Also, the coast function may be used in the case of overvoltage (e.g., load dump) or to reduce speed before reversing the BLDC motor. Note that this pin is not available in ATA6833/34.

The new predrivers include 6-pin control (as with the ATA6833/34), providing freedom to control discrete power MOSFETs, e.g., for sinusoidal commutation. The new predrivers also allow simple and cost-effective control of MOSFETs via the microcontroller’s three command lines: the gate driver ICs’ high-side and low-side inputs are designed with opposite input logic (ILx and /IHx).

High-temperature ICs for Hot Applications

These automotive applications are located within hot environments and can therefore be equipped with BLDC motors:

- Electronic throttle control
- Exhaust gas recirculation
- Turbo charger with variable geometry
- Dual clutch
- Automated manual transmission
- Fuel pump
- Coolant pump
- Radiator fan
- Variable manifold
- Synchronous rectifier
- Electric power steering

Unlike the standard-temperature version Atmel ATA6843, the warning threshold of the ATA6844 is set to 150°C, and its excess temperature switch-off threshold is set to 200°C. This makes this IC able to cope with the environment of electronic devices attached to parts of the engine, such as coolant pumps, EGR, or turbo chargers. Using NiAu plating on the Aluminum pads, the Atmel high-temperature ICs are able to withstand the challenges of high ambient temperatures over a product’s complete life cycle. The plating avoids dangerous gold-aluminum corrosion (“purple plaque”).
To support the growing demand for BLDC motors, Atmel® supplies not only systembasis gate drivers, but microcontrollers with software support as well. The automotive market for electronics is growing rapidly as the demand for comfort, safety and reduced fuel consumption increases. All of these new functions require local intelligence and control, which can be optimized by the use of small, powerful microcontrollers.

Taking advantage of its unsurpassed experience in embedded Flash memory microcontrollers, with a large number of devices of Atmel AVR® devices from 8- to 32- bit microcontrollers. Atmel brings innovative solutions, whether for sensor or actuator control or more sophisticated networking applications. These microcontrollers are fully-engineered to fulfill OEMs’ quality requirements towards zero defects. Several AVR microcontrollers are qualified for operation up to +150°C ambient temperature (AEC-Q100 Grade0).

Designers can distribute intelligence and control functions directly into or near gearboxes, transfer cases, engine sensors actuators, turbo chargers and exhaust systems.

### Table 1. System Basis B6 Predrivers Overview

<table>
<thead>
<tr>
<th></th>
<th>$T_j$</th>
<th>Operating Range</th>
<th>Drain Source Monitoring</th>
<th>Coast Function</th>
<th>3-pin Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>ATA6833</td>
<td>150°C</td>
<td>5-20V</td>
<td>4V</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>ATA6834</td>
<td>200°C</td>
<td>5-20V</td>
<td>4V</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>ATA6843</td>
<td>150°C</td>
<td>5-30V</td>
<td>0.5-3.3V</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>ATA6844</td>
<td>200°C</td>
<td>5-30V</td>
<td>0.5-3.3V</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

### Links
- **System basis B6 predrivers:** Atmel ATA6833 Data Sheet: http://www.atmel.com/dyn/resources/prod_documents/doc9122.pdf
- **Application note:** http://www.atmel.com/dyn/resources/doc9143.pdf