

“With growing acceptance of BLDC, controller solutions will tend towards higher processing power in programmable implementations, as well as greater integration and sensorless motor control.”

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The road to

Migrating automotive subsystems to brushless dc motor control.

By **Pascal Lefebvre**.

Brushless dc motors are penetrating automotive applications as the costs of motor control IP and hardware continue to fall. But system developers must also satisfy wider needs within the vehicle industry if the technology is to deliver its full potential.

The brushless dc (BLDC) motor is quieter than a brushed motor and can be made smaller and more reliable because there is no commutation mechanism. These are attractive attributes for the automotive industry.

Most European cars use brushed dc motors in such areas as vehicle body, comfort, chassis and powertrain. Tasks range from headlamp orientation, door locking and window actuation to anti lock braking systems (ABS) and electric power steering (EPS). All benefit from the increased performance and reliability of BLDC operation. Converting these to a BLDC implementation indicates a potential market for at least 400million BLDC motor and controller combinations per year for Europe.

However, car makers and system developers are unlikely to make wholesale replacements of proven subsystems that use brushed dc motors, even though BLDC is a technically superior solution. Safety and reliability must be proven and the cost of BLDCs capable of

generating sufficient torque for applications, such as EPS or operating folding hard tops for example, remains high.

Component vendors therefore need to prove the technology by offering solutions that allow BLDCs to penetrate non critical vehicle applications. That will begin to unlock the economies of scale that will deliver more powerful BLDC motors at cost effective prices.

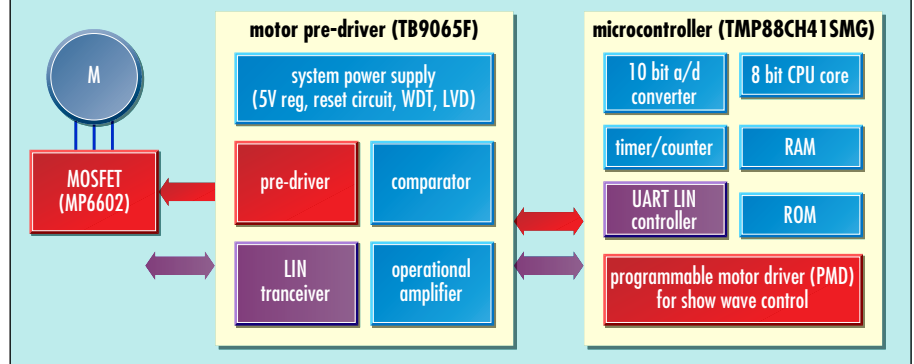
Partitioning and control

A BLDC control solution which meets the automotive industry's requirements for low cost, high reliability, system flexibility and fault tolerance and reparability must combine high levels of integration with sensible partitioning. The relatively low noise and control positioning requirements of fan or flap control in the HVAC system or headlamp orientation put these amongst the first targets.

A suitable system partition, capable of providing optimal cost, reliability and flexibility, is to take use readily available BLDC motor control and driver IP alongside highly integrated pre driver functions and modular and discrete power electronic components in a variety of ratings. Figure 1 illustrates a partitioning scheme based upon a CMOS motor drive MCU, a mixed signal pre driver IC including LIN physical layer circuitry, and a discrete MOSFET power electronic stage.

The MCU is Toshiba's automotive grade TMP88CH41, with a 20MHz 8bit core, eight channel 10bit a/d converter and multiple integrated timer/counters supporting motor control implementation, as well as Toshiba's Programmable Motor Driver (PMD) IP on

Figure 1: A possible system partitioning scheme





brushless

chip. The PMD, implemented in dedicated hardware, provides a three phase PWM output, motor position detection and a built in timer to enable motor control without placing too much load on the CPU. The timer function is linked with the position sensing circuit to realise 120° commutation control for three phase motors.

With the PMD block implementing most motor control functions in hardware, independently of the CPU, enhanced motor control is possible without diverting processing resources from application level functions. Figure 2 illustrates the PMD's functional blocks, integrated within the MCU. Importantly, the PMD hardware includes a sine wave generator, enabling smooth motor operation.

Integrated driver solution

An integrated motor pre driver connects to the LIN bus and to the motor power stage – either a discrete MOSFET arrangement or a power module. While the MCU in figure 1 manages the LIN protocol, it makes sense to combine the LIN transceiver functions in the same IC as the motor pre driver using a technology more suited to direct connection to the LIN bus. The TB9065F family pre driver IC in figure 1 is a BiCDMOS component capable of integrating the LIN physical layer alongside the higher voltage circuitry required for motor pre drive.

The pre driver facilitates power management by taking advantage of the LIN bus' wake up capability. Signals on the LIN bus can wake the pre driver, which will then wake up the MCU. It can also control the MCU's 5V power supply, allowing the converter to be powered down to provide even greater savings in nodes that are connected permanently to the vehicle battery supply line (known as Clamp 30).

The motor pre driver functional blocks are mature and widely understood. However, to meet the automotive industry's miniaturisation and high reliability demands, these must be integrated to create a comprehensive pre driver solution. Among those capabilities that are particularly valuable in the automotive context are two on chip operational amplifiers, which allow designers to connect a Hall element for position sensing, for example, as well as constant current loop monitoring for safety purposes, using minimal external components.

By facilitating position sensing in this way, a BLDC solution can replace directly a more complex and expensive stepper motor drive in

a headlamp orientation system. Without position sensing, the BLDC module would need to drive the headlamp to a known reference position before adjusting the headlamp correctly. However, this would be slower than a comparable stepper motor implementation, detracting from the other BLDC advantages.

Automotive MOSFETs

Automotive MOSFET power stages, though broadly similar to any other, demand low $R_{ds(on)}$ for efficient operation with low heat dissipation, as well as high forward transfer admittance and low leakage current. These enhancements are necessary to withstand the electrical and thermal rigours of the automotive environment.

Trench technology is key to improving a MOSFET's forward voltage drop, the IGBT's saturation voltage and $R_{ds(on)}$. A number of developments – including increased fusing current, lower packaging parasitics (such as the connecting resistance between the chip and the lead frame) and more efficient heat dissipation through copper connectors – ease thermal design problems and enable the creation of small, low profile controller implementations suitable for automotive applications. At the same

time, packaging technologies optimised for high speed and efficient assembly, such as Toshiba's WARP technology for power MOSFETs, serve high volume applications at low unit prices. Qualification to automotive standards, such as AEC Q101, is also essential.

The future

As BLDC solutions demonstrate reliability and enhanced performance in comfort and vehicle body applications, car makers and subsystem developers should increase the number of BLDC designs – so long as economies of scale make them attractive in low cost car ranges.

With growing acceptance of BLDC, controllers will tend towards higher processing power in programmable implementations, as well as greater integration and sensorless motor control allowing the advantages of sinewave control without the additional expense of Hall ICs.

As larger BLDCs become cost effective for automotive applications, these subsystems will demand the highest performance in terms of motor power and torque as well as application level complexity. In safety critical applications, more processing power will be necessary to implement vector motor control, moving suitable BLDC controllers toward a 32bit CPU with integrated PMD.

For low cost systems, motor control logic will be integrated into the driver IC. A hardwired solution will reduce development effort and costs and allow system developers to optimise the functionality of BLDC control implementations throughout each vehicle platform.

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