by **Adam Prengler** | NEC Electronics America, Inc.

CONTROLLING POWER IN AUTOMOTIVE BODY SYSTEMS

Body control modules or BCMs are used to drive a variety of loads in modern automobiles. Designing reliable and cost-effective module requires a good understanding of the control and power sections. In this article, the author will examine the features available in new MCUs and intelligent power devices (IPDs), and how designers can implement them in such applications.

The amount and sophistication of electronics in cars is increasing at a fast pace, driven by two goals: to increase the functionality and the safety of the vehicle. Implementing these new functions in electronics is a cost-effective way to achieve these goals with a level of reliability that consumers have come to expect. There are a variety of subsystems in the car, such as the chassis electronics, driver information electronics and body electronics. Body electronics subsystems are responsible for functions such as seat positions, interior lighting and wiper control. Intelligent design allows body control modules (BCMs) to drive loads more efficiently and reliably.

The BCM is fast becoming one of the most important modules in a vehicle. The purpose of the BCM is to control common "body" functions that don't require a dedicated controller, such as functions to control windows, mirrors, door locks and lights or RF receiver functions that receive information from key fobs and tire monitors. The BCM can also act as the gateway to transmit data between different modules on the various network buses. Because of its connection to multiple vehicle buses, the BCM is an ideal place to add new functionality to a vehicle. When vehicle architects want to implement a new function, but don't have the time, space or budget to add a new module, they can often add the software to the BCM and take advantage of its networking capabilities to implement the feature.

While BCM requirements vary from vehicle to vehicle, the trend for carmakers is to develop a single module that covers multiple carlines. By doing this, carmakers reduce their development and maintenance costs, which offset the slightly higher module cost. The single module can be deployed more quickly across multiple platforms with minimal configuration done on the actual vehicle, reducing the complete time to market.

The operation of a BCM can be divided into two categories: the control section that includes microcontrollers (MCUs), sensor inputs and in-vehicle networking, and the power section that includes the devices capable of supplying the high-power signals to drive the various loads. Designing the power section requires an understanding of the different types of loads that are used in body electronics. For example, LEDs are quickly replacing incandescent lights in interior and exterior lighting due to their low power, superior robustness and reliability. Electric motors are being used for mechanical functions to raise and lower windows, change seat positions and adjust mir-

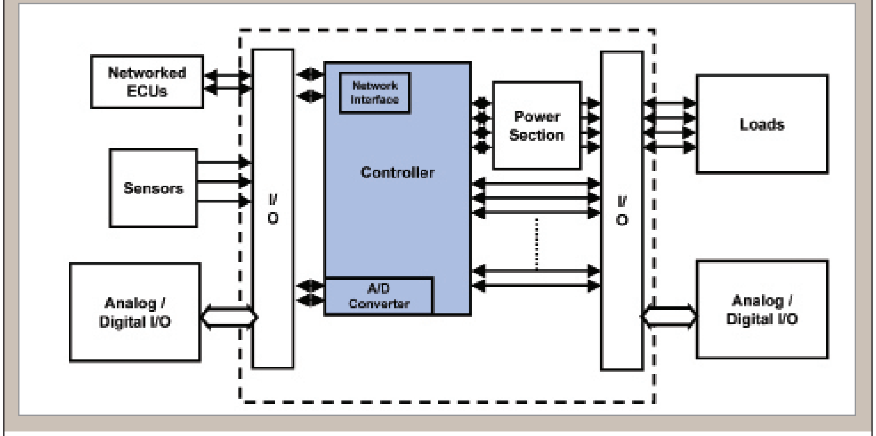

Figure 1. Body control module example with V850ES/Fx3 32-bit MCU.

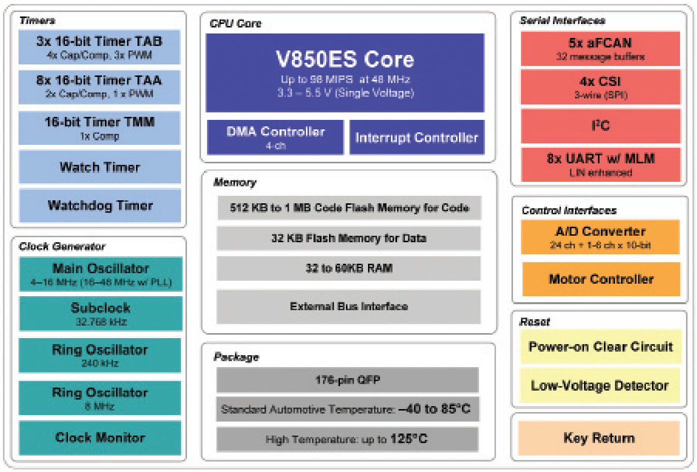

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Figure 2. V850ES/Fx3 MCU superset block diagram.

rors. Resistive elements are used in heat seating and rear-window defrosters. The challenge exists in merging the control and power section into a single module. When BCM designers start a new design, they must consider all possible components that can be used for the control and power sections. Then they must determine the combination that best meets the requirements, while taking into consideration all system constraints. Some of the major constraints designers have to be concerned with when choosing the right combination of parts are power budgets, thermal behaviors, robustness and cost. For example, power sections have traditionally been implemented exclusively using power relays, but recent designs have demonstrated a migration trend toward solid-state solutions. Solid-state electronics can offer more robust solutions that can lead to lower overall costs. In addition, by combining these solid-state devices with intelligent digital controllers, designers can introduce diagnostics and fault protections that haven't been possible before. The designer's goal is to create a cost-effective BCM that meets the application requirements and provides high reliability to meet stringent automotive standards.

A general block diagram of a BCM module (Figure 1) shows the module connected to sensor inputs, and also to the power section. The advantage a microcontroller brings is the ability to partition the control problem between the hardware peripherals and the software routines. This gives the module designer much more flexibility than if the control were implemented in hardware. Using an MCU not only adds more flexibility and function to the system, it can also increase the robustness by allowing for diagnostics within the system, even to the extent of having a self-test capability.

When implementing the control portion of the body module, the most critical decision is selecting an MCU with the right peripherals that can meet the performance and cost targets of the application. NEC Electronics, for instance, has recognized the trends in body electronics and has developed solutions such as the V850ES/Fx3 MCUs, which are based on the company's V850 32-bit CPU core and optimized for body automotive applications. Developed for embedded systems, the real-time performance of the V850 core delivers high-performance processing capability, fast interrupt response time and efficient transfer of data. The core also includes a dedicated interrupt controller with individual vectors for each interrupt source, enabling fast servicing of requests. The on-chip direct memory access (DMA) unit has access to memory and system buses, allowing for autonomous transfer of data without CPU intervention.

The V850ES/Fx3 MCUs integrate a number of advanced peripherals necessary for body modules in particular (Figure 2). For instance, timers are critical to body applications as they are used for scheduling tasks, capturing external signals like RF pulses and, most important, generating pulse-width modulated (PWM) signals for controlling loads such as interior LEDs. The V850ES/Fx3 MCUs offer numerous timer macros with programmable flexibility to run in various modes, as well as capabilities to synchronize timers to increase PWM capabilities. To support the growing networking requirements of OEMs, the lineup incorporates up to five controller area network (CAN) channels, each with individual message buffers and mask registers that filter messages without CPU intervention. For the slower-speed, local interconnect network (LIN) applications, the MCUs support up to eight LIN channels with an additional multi-LIN-master (MLM) unit that handles the LIN protocol in hardware, removing the overhead from the CPU. For analog signals, there are up to 40 channels of analog-to-digital converters with features including pin diagnostics, automatic discharge, and flexible trigger sources.

In addition to the requirements for intelligent on-chip peripherals, the trend in embedded automotive electronics is to use flash memory. For instance, the V850ES/Fx3 MCUs offer flash memory for code in sizes ranging from 64 kB to 1 MB, as well as separate on-chip memory that can be used as data memory for high-endurance data.

One of the most demanding constraints for MCUs in body electronics is the need to continue running while the vehicle is turned off. In this situation, the MCU has to support a standby mode that provides the necessary functionality at the right power consumption level. The V850ES/Fx3 MCUs feature NEC Electronics' MF2 embedded flash process technology for low-power modes that enable the MCU to run only the necessary peripherals, such as internal clocks and periodic timers required by the system, while consuming as little as 10 to 15 microamperes of power to meet even the toughest power budget. Combining the benefits of high-density flash memory with low-leakage logic enables the overall MCU to exceed in performance-to-cost ratio while also managing to consume little power.

CONTROLLING POWER

The second challenge in designing a BCM module is creating the power section. This portion of the design is tied to the types of loads the module must drive. One common type of load is a simple LED light. Controlling an LED can be as straightforward as using an MCU output pin to switch on and off the current supplied to the LED. Another approach is to use PWM signals to create a more pleasant lighting effect. Using a PWM signal allows the LED to be switched on at a frequency that, to the human eye, appears to always be on. By increasing or decreasing the duty cycle, designers can increase or decrease the average current to the LED, effectively dimming and brightening the light. By using red, green and blue LEDs, each under PWM control, designers can create a blended light of an arbitrary color. This function further increases the needs for PWM channels in the MCU.

A second type of load for a BCM module is a motor, such as a fan motor in a heating ventilation and air-conditioning (HVAC) system. Motors are also used to adjust car seat positions, and are the driving force for the wiper system. Similar to controlling LEDs, by using a PWM, designers can ramp the speed of a standard dc motor up or down efficiently. In addition, sampling the PWM signal with an analog-to-digital converter (ADC) allows designers to detect potential failures. A variety of motors are found in body electronics applications. These include brushed dc, brushless dc and even three-phase motors. Each motor type requires unique control characteristics, which must be taken into account during the design of the power section.

A third type of load used in body electronics is a heating element. These are high-power resistors, which put a large demand on the body module to source enough current to effectively heat the seat. Traditionally, simple 12 V relays were required to supply the current for power-hungry applications. Relays are electromechanical devices that are large, heavy and not as reliable as an all-electronic solution—a critical shortcoming in a device for automotive applications. Given these limitations, some of the traditional relay applications have been replaced with power MOSFETs, which are designed to carry the high current required and provide a complete solid-state solution. MOSFETs solve the problems of size, weight and reliability that exist with a relay. A further refinement of this solid-state switch is adding intelligence, also called an intelligent power device or IPD. IPDs typically contain a power MOSFET combined with a control circuit in one package. Just like MOSFETs, IPDs are a smaller, lighter weight and lower-power-consuming replacement for a typical relay. They go one step further by combining the high-current capability and high reliability of a MOSFET with protection and diagnostic features for thermal runaway and short-circuit detection.

Figure 3 illustrates a high-side IPD with built-in short-circuit and overtemperature protection and load-current sensing. Additionally, for reducing EMI within the module,

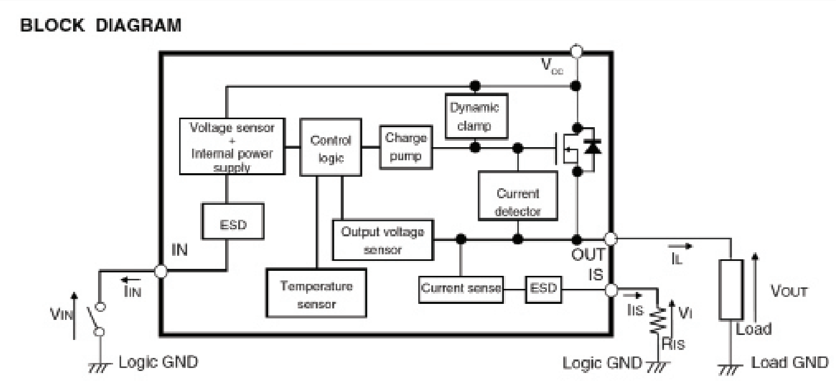

Figure 3. Functional schematic of µPD166007 IPD.

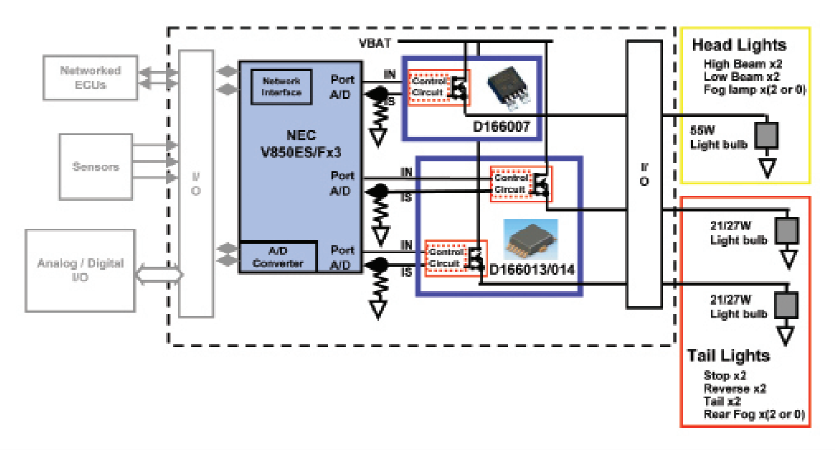

Figure 4. Illustration of a body control module (BCM) with IPDs used to drive headlights and tail lights.

the IPD has a switching control function that limits rapid fluctuations in output current.

This type of IPD is often used to replace relays for body applications such as exterior and interior lighting and heating elements (Figure 4). Due to the small size of the IPD die, it is possible to replace up to four standard relays with a single quad-package IPD. In this example, the four relays used to drive the stoplights and turn signals could be replaced by a single IPD. Additionally, due to the smaller size and height of IPDs compared to relays, ECU designers can reduce the PCB and overall module size. Reducing the module size and number of components, combined with the increased reliability of using an IPD, can lead to a higher-quality and more cost-effective end product.

As IPDs are relatively new to many designers, it is important to understand their key features when making the decision on which kind to use. Typically, the first step is to determine how much current the IPD has to support and at what voltage. Most suppliers will list their devices according to these features first. Once that decision is made, there are a number of features to consider when deciding on a specific IPD. As mentioned, IPDs are capable of providing diagnostics data to the control section. This can be done over a network protocol, such as a serial peripheral interface (SPI), or by discrete port communication. A SPI connection can be convenient for systems that employ a SPI bus. However, using standard port signals can also be preferred for systems that need to receive feedback from the IPDs faster than a SPI can support. There are IPDs that support either method, so a module designer has to consider the overall system requirements before choosing the communication method that works best.

On-resistance, sometimes referred to as R(ON), is the equivalent resistance across the device when it is operating. A large on-resistance is disadvantageous, as it creates a significant voltage drop across the device, causing larger power dissipation and elevated device temperature. To address this, devices in production provide R(ON) values as low as 8 milliOhms. When choosing an IPD, a designer should look for the device that meets the system requirements with the lowest R(ON). Another important factor is the connection of the control circuit to the analog power portion. Two common types of IPDs include: monolithic and multi-die. In monolithic IPDs, the control and the power portions of the device are developed on the same piece of silicon. In multi-die IPDs, it is the opposite: the control portion is a separate die than the power portion. The reason for the two methods is due to the underlying technology. The process technology for high-density logic is not capable of supporting high current, creating the need for a multi-die approach for higher-current devices. When the current requirements are not as high, the power and logic can be designed in the same technology, and designers can avoid the cost and complexity of two separate dies and the associated bonding and packaging. While the choice for monolithic vs. multi-die is often fixed by the IPD suppliers, designers should be aware of the process technology used to ensure the device will meet their requirements.

Last, packaging is important. IPDs are being manufactured in smaller and smaller processes, allowing for small packages and support for multichannel packages. Designers almost always look for the smallest packaging, as well as any opportunity to replace multiple IPDs with a multichannel package.

In summary, to design a reliable, cost-effective system requires an understanding of both main portions of the design, the control section and the power section. Each section has its challenges when trying to choose the components that will work best together in the complete system.

ABOUT THE AUTHOR

Adam Prengler is a platform solutions engineer with NEC Electronics America's Automotive Strategic Business Unit. Prengler holds a Bachelor of Science degree in Electrical Engineering from The University of Texas at Dallas.