Evolution vs. revolution: the building blocks of automotive body electronics

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In the past few generations of automobiles, there have been significant advancements in vehicle traction systems and other systems that provide road, vehicle, and entertainment information to drivers and passengers.

Another significant trend that is expanding rapidly is features designed to make occupants inside the vehicle more comfortable. Collectively known as body electronics, these comfort and convenience systems allow vehicle occupants to *feel* comfortable inside the vehicle, and enable them to conveniently adjust various settings.

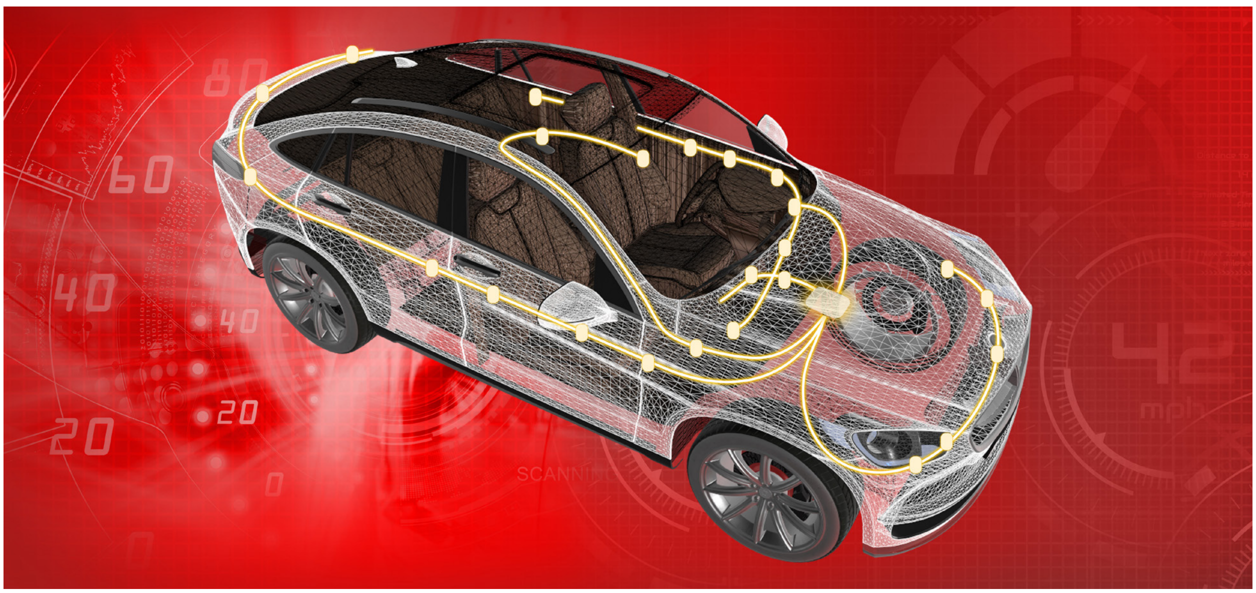

Figure 1*. Vehicle equipped with body electronics related control modules.*

Body electronics include a wide range of systems, some of which are available in almost all car models, while others are available only in premium cars, and yet other systems are still in development. Note that body electronics systems comprise not only systems inside the car but also access systems that enable occupants to enter and exit more easily and securely. **Figure 1** shows conceptual location of various body electronics related control modules inside of a car.

Society takes for granted some of the conveniences available in modern automobiles. Take for example heating, ventilation and air conditioning (HVAC) systems, now found in almost all vehicles. Another example is power windows; just a decade ago, many passenger cars came equipped with a lever beneath the window, which occupants had to crank in order to move the window up and down. However, in today's vehicles, windows can be effortlessly moved up and down with a switch.

Figure 2. Power seat controls, sunroof and power seats.

Furthermore, some window systems incorporate an anti-pinch feature to detect obstructions while the window is closing and automatically opens the window.

Many vehicles now come equipped with power seats; instead of moving the seat manually with levers, occupants use switches to adjust the seat height, distance from the pedals, seat tilt and headrest position, as shown in **Figure 2**. Premium vehicles also include features such as lumbar support and seat length and width adjustment. Moreover, these vehicles also have dynamic seat control, a feature that prevents passengers from slipping in the front seats while the car is making a turn. All these position adjustments are realized using direct current (DC) motors fitted inside the seats. Semiconductor technology mounted in seat control modules control these DC motors. In addition, power seats with memory include sensors that allow the seat to move to a specific position with the touch of a button.

Auto-dimming rearview interior and side mirrors also fall within the body electronics category as well. Auto-dimming technology is designed to reduce the brightness of reflected light coming from headlights behind the vehicle during nighttime driving; this prevents glare in the driver's eyes. While drivers can manually adjust mirrors to prevent glare, auto-dimming mirrors rely on optical sensors and a special electrochromic gel inside them.

From remote keyless entry (RKE) to passive entry passive start (PEPS) systems, car access systems have made entry into vehicles effortless, convenient and secure. These systems use radio frequency (RF) signals to enable the locking and unlocking of doors and the starting of the engine with a press of a button. Some systems enable drivers to start the engine from outside the vehicle so the interior is heated or cooled before anyone even enters it.

Body electronics trends

While many comfort and convenience features are already available, new developments in automotive ecosystems enable occupants to feel more comfortable as well as fine-tune settings effortlessly. We will explore these trends in the next few sections.

Continued motorization

Motors are already ubiquitous inside the car. This trend will continue to expand. For example, power trunk or lift gate systems are expected to grow at an annual rate of 12 percent, according to Strategy Analytics. These systems not only enable the closing of a vehicle trunk or lift gate using motors, but latching and locking of the trunk lid automatically. These systems also include obstacle detection that prevents the closing of the trunk lid on an object, like a hand.

Another interesting feature allows for doors and trunk lids to close more softly. When someone pulls the door or trunk to an almost-closed position, motors then complete the task. Motors controlled by semiconductors make this “cinching” operation possible.

Finally, while steering, wheel height and tilt are manually adjustable in many cars today, and many mid-level and economy vehicles are now incorporating motorized adjustments. Similarly, motorizing the adjustment or folding of external side mirrors to avoid dents in congested parking spaces is becoming more common.

Advanced HMI

In today’s vehicles, occupants interact with various switches, buttons and knobs. These human machine interface (HMI) systems are also undergoing some exciting changes – not just with infotainment and cluster systems, but across body electronics systems as well.

As the number of comfort options implemented in a vehicle increases, so does the number of switches, buttons and knobs. Whether it is a switch to close the trunk, buttons to adjust HVAC airflow or a knob to control wiper speed, these interfaces are all necessary to enable occupants to quickly make adjustments to their environment.

Various HMI switches, buttons and knobs in a car have backlight light-emitting diodes (LEDs) that enable occupants to see controls even when there is not enough light inside the cabin. Ambient light sensors automatically adjust the intensity of backlight LEDs so the occupants, and especially the driver, are not blinded by brightly lit interior HMI systems in dark conditions.

Gesture recognition implemented in cars enables drivers and passengers to open and close sunroofs or adjust the radio volume with a simple hand gesture. These systems, which rely on optical or radar technology to detect motion, interpret the intent and then control a motor with an operational amplifier (op amp) to execute the desired action. These systems make interacting with vehicle systems easier.

Car access

Passive entry systems enable drivers to access a vehicle without operating the key fob directly. When someone attempts to unlock the vehicle by pressing a button on the handle, body electronics inside the car detect the touch and communicate with the key fob (which must be in proximity), verifying the key fob and unlocking the door. The same concept can be used to lock the vehicle.

The deployment of passive entry systems based on a kick-to-open gesture, as illustrated in **Figure 3** are

Figure 3*. Kick-to-open gesture for car access.*

also rapidly expanding. These systems open the trunk when a user taps their foot underneath the bumper. Kick-to-open systems rely on capacitive sensors, although automakers are now investigating alternative technologies such as ultrasonic and radar for improved system sensitivity.

Also gaining traction is the use of smartphones to lock and unlock car doors and even interact with the adjustable parameters inside the vehicle. In traditional RKE or PEPS systems, the car access system sends low-frequency RF signals to the key fob, which then sends ultra-high-frequency (UHF) signals back. Given the omnipresence of smartphones, they can replace the traditional key fob – but use *Bluetooth*® technology to communicate with the car access system instead. Bluetooth low energy-based (BLE) key fobs will likely expand in popularity because a key fob must have low power consumption. Resolving technical challenges in BLE-based car access technology will pave the way toward BLE key fobs, as well as Bluetooth-enabled smartphones replacing UHF-based key fobs.

Smartphones can also function as an alternative to vehicle HMI systems, controlling such interior parameters as temperature inside the cabin, seat position or steering wheel position.

Automatic tinting

The number of vehicles fitted with auto-dimming mirrors based on electrochromic mirror technology is growing. Another complementary technology is automatic glass tinting; automakers are now installing it in side windows, rear windshields and sunroofs. These tint systems rely on special glass and electronics to control the amount of tint, enabling optimal light conditions inside the cabin as well as appropriate visibility. These systems also rely on optical sensors to detect light conditions and automatically adjust glass tint levels.

More electrification

The growing prevalence of electric vehicles (EVs), including hybrid EVs (HEVs), conceptually illustrated in **Figure 4**, bring a corresponding increase in the electrical architecture of body electronics systems.

Figure 4. *Growing prevalence of the electric vehicle and the connected car.*

For example, in traditional internal combustion engine-based vehicles, the engine drives the HVAC compressor, and excess engine heat is used to heat the cabin. With the use of electric motors for vehicle traction, a high-voltage vehicle battery drives both the HVAC compressor and cabin heater. This implies that the electronics that are required to control the compressor and heater will also change.

The availability of high-voltage power in a vehicle impacts the type of motors and other actuation technologies, and how engineers design body electronics systems. Whether the architectures are centralized or decentralized, for efficiency and cost reasons, engineers will choose implementations in which the high-voltage battery drives body electronics directly in order to improve efficiency.

Evolution is key to body electronics systems

Comfort and convenience features in a car will continue to evolve over time. Incremental additions or changes to body electronics control modules not only have the advantage of lower overall development costs but also minimize impact on the existing board.

Adding semiconductor technology on the circuit board can help realize new features in body electronics systems. For example, the addition of anti-pinch technology to sunroof control modules necessitates the addition of current monitors using op amps or instrument amplifiers. These amplifiers implement circuits to detect motor motion by counting DC motor ripple, or detect motor stall using current measurements that indicate obstacles in the path of a moving sunroof. Still, the addition of op amps to a sunroof control module that already includes power management, communication interfaces and motor driver devices is only an incremental change.

Another example of an incremental change is side mirror control. The mirror may already have a control unit that enables adjustment horizontally and vertically. The addition of a motorized mirror fold-in feature in a circuit board could involve adding an additional motor driver, while the rest of the circuitry remains intact in the mirror control unit.

Most control units in body electronics use low dropout regulators (LDOs) to convert an automotive battery voltage to the voltage levels needed by semiconductor devices in the control module. However, the addition of more and more comfort and convenience features and the migration to electric traction will only increase the need for more efficient power management. In order to make designs more energy efficient, designers should consider a switch-mode power-supply solution. Increasing efficiency allows for electric vehicles to travel longer distances or for internal combustion engine-based vehicles to improve fuel efficiency.

A similar energy-wasting scenario occurs in reverse-voltage protection diodes. Almost all control units in a car use these diodes in order to prevent damage to electronics when the car battery terminals are accidentally reversed. One approach to reducing energy waste in the diode is to replace it with a "smart" diode solution, including a metal-oxide semiconductor field-effect transistor (MOSFET) and a MOSFET driver. Changing from a diode to a smart diode is once again incremental, and does not involve changing the rest of the circuitry and components in the control unit.

Importance of building-block general purpose ICs in body electronics systems

These examples show that as new features are added to body electronics systems, circuitry on existing control units will only need to change incrementally. In order to make these evolutionary changes, engineers will use general purpose ICs such as switch-mode power supplies, op amps, communication transceivers, analog multiplexers and logic devices, as shown in **Figure 5**. These semiconductor categories play a key role in enabling engineers to develop cost-effective body electronics systems. Furthermore, these devices enable engineers to take their systems to production faster. In other words, rather than wait for new application-specific semiconductor devices that support new features, you can implement incremental changes to your circuitry with building-block devices.

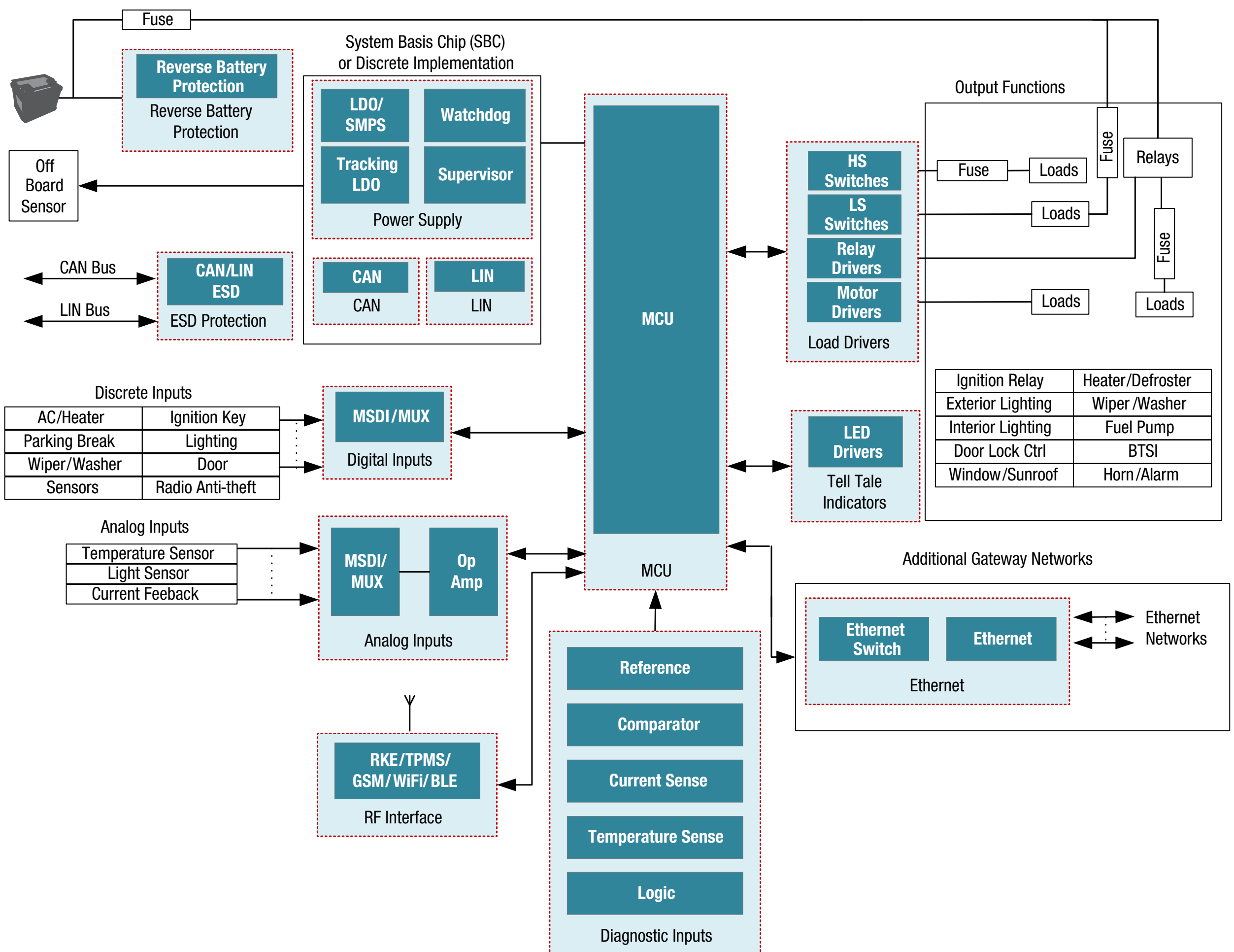

***Figure 5**. Body control module (BCM) end equipment reference diagram.*

TI provides the building blocks for body electronics systems require to optimize passenger comfort and convenience

TI has a broad portfolio of automotive-qualified power management and signal chain general purpose ICs, including:

- High-speed, low-offset or high-voltage op amps.
- Boost and buck DC/DC converters with features such as spread spectrum that enable EMI-friendly designs.
- Voltage references that enable precise analog-to-digital conversion.
- Analog multiplexers that allow an increased number of switch inputs to be connected to a microcontroller (MCU).

You can choose from these solutions to optimally architect electronic control units (ECUs) for the purpose of adding new features; for example, a new architecture for a system such as a high-voltage HVAC compressor.

TI also develops reference designs to show you how to use general purpose ICs to implement incremental features and evolve your body electronics systems. For example, the Automotive Brushed-Motor Ripple Counter Reference Design for Sensorless Position Measurement illustrates the use of the ripple-counter feature to implement anti-pinching; it's a very good starting point for understanding the design trade-offs and board space needed for implementing such a solution.

Similarly, the Automotive Pre-Buck, Post-Boost with CAN Discrete SBC Reference Design and Automotive Discrete SBC Pre-Boost, Post-Buck with CAN Reference Design showcase optimal system-basis chip solutions that can be developed with general purpose ICs if an option does not exist in a single chip, or existing single-chip devices are more expensive than implementing the solution with discrete general purpose ICs.

Conclusion

Body electronics systems are behind the growing number of comfort and convenience features in a vehicle. These systems, which could be centralized or decentralized implementations, include HVAC systems, car access systems, power seats, power trunks and auto-dimming mirrors. While some features are available only in premium vehicles, they are slowly making their way into mid-level and economy vehicles as well. Furthermore, more features are being added to make the car environment more comfortable for vehicle occupants.

Since the addition of new features are most often incremental and evolutionary, you have the choice of either redesigning the entire control unit to add a new feature, or adding additional circuitry to an existing board. Making incremental changes to an existing board could be advantageous from both the development cost as well as time-to-market perspectives. You can use TI's broad portfolio of general purpose ICs to realize additional circuitry, or use TI reference designs as a starting point for making incremental changes in body electronics systems.

For more information, see Body Electronics and Lighting Systems Solutions on TI.com.

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