New Automotive E/E architecture and how TC4xx enables it

From domain-based to zone-based approach

Dr. **Karel Heurtefeux**, **Manoj Kumar**, **Marco Cassol**,
Infineon technologies, Neubiberg

Abstract

The automotive industry is facing daunting challenges such as connected cars, expansion of new functionalities like ADAS or infotainment, electrification and stricter requirements in terms of safety, security, energy consumption or $CO2$ emission. Consequently, the number of Electronic Control Units (ECU) per vehicle is increasing as well as the wiring, software complexity and finally, the cost. To tackle these new challenges, more optimized, software-oriented E/E architectures are introduced. In this article, Infineon Technologies describes how to address new Electrical/Electronic (E/E) architectures with a focus on its cornerstone, the Zone Controller Unit (ZCU) by showing how the AURIX™ microcontroller possess a set of features that satisfy the ZCU requirements.

Transition to new architecture

Vehicles are traditionally divided into functional domains such as body, chassis, powertrain or infotainment. Driven by security, safety or performance requirements, these domains generally operate independently and are connected via separate bus systems. The current E/E architectures with domain controllers and a central gateway have grown over time and became very complex. As an illustration, the weight of the E/E architecture is now considered as the third heaviest part of a vehicle with up to 80 kg and with an absolute length up to 5 km of wires. This increase in complexity and length has not only a significant impact on the vehicle cost due to the components and the production labor but also in terms of vehicle power consumption and performances. In addition to the existing complexity, the current trends such as automation driving, electric vehicle, safety and security concerns and reduced power consumption increase heavily the demand in new actuators and sensors, data processing capabilities, data bandwidth, network security, redundancy, re-configurability and intelligent power distribution. Such domain-based architectures are lacking flexibility and modularity when it comes to assigning new functions to ECUs, updating or enhancing existing vehicle functions and allow dynamic configurations. Additionally, more vehicle functions need to be

fed with sensor data from different domains and the traditional architectures are not suitable for cross-domain interactions. Finally, increasing safety requirements demand networking redundancy that is hardly reachable with such organization. Scalable, centralized and cross-domain E/E architectures better fit those needs. It is on the basis of this understanding that the zonal E/E architecture has been recently introduce.
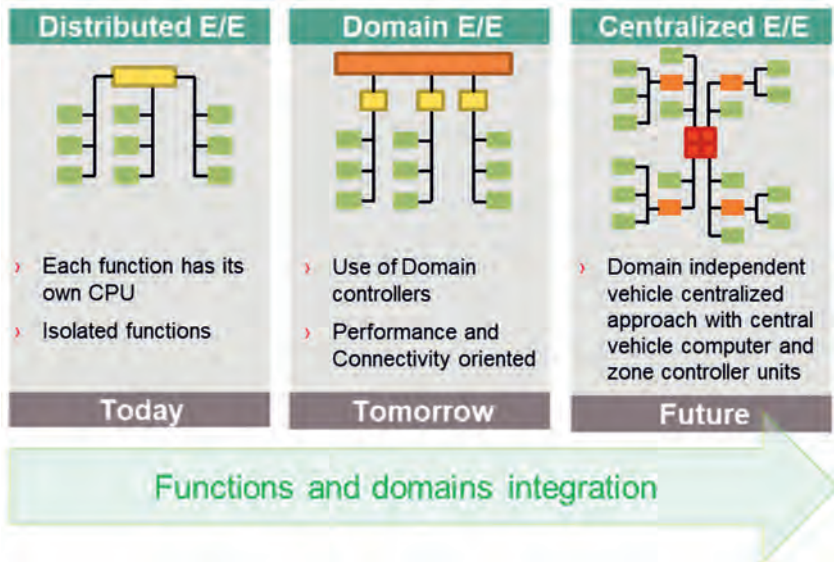

Fig. 1: Automotive E/E architecture trends

New E/E Architectures

The Zone architecture is a disruption in traditional domain-oriented architecture. The E/E architecture is no longer strictly separated per domain (powertrain, chassis, body, etc.) but based on specific geographical portions of the vehicle (such as rear, front, right side, etc.). Functions from different domains and with different criticality are shared across different ECUs and different networks. For instance, a single function will be composed by services that can be provided by different ECUs. As illustrated in Fig. 2, a typical zonal E/E architecture is organized based 3 levels of ECUs:

- Computing Platforms: SoCs-based control unit with high-speed interfaces that act as in-car application server supporting Service-Oriented Architecture (SOA). They

generally possess specific SoCs (e.g. for image or radar signal processing, AI, etc.) and are fully scalable and upgradable;

- Zone Controller Units: ensure the connectivity between the mechatronic rim (composed by sensors, actuators and specialized ECUs) and the computing platforms. They also provide functionalities for a specific vehicle area such as local gateway for legacy automotive buses (CAN, LIN, FlexRay) and Ethernet backbone, eFuse functionality, power supply, supports any kind of interface for sensors and actuators;

- Sensors, actuators and specialized ECUs: highly specialized ECUs such as engine control, radar, ultrasonic sensors, transmission, brakes, steering, doors, windows, seats or light modules.
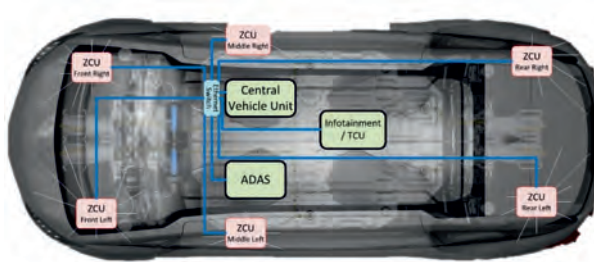

Fig. 2: New Car Architecture

According to a Tier1 case study (Klaus-Wagenbrenner, 2019), zonal architectures can help to save 50% and more in terms of wiring harness length for control, distribute data and power distribution. The study also shows that the savings is higher with premium vehicles with a larger number of sensors and actuators. The first step of this architectural evolution is already under development even if implementations by the major vehicle manufacturers is not expected before the middle of the next decade.

Zone Controller ECU

To determine the requirements of a typical ZCU, we first need to understand its role. As illustrated in Fig. 3, a typical ZCU has 3 main roles:

1. Local gateway: collect data from its specific zone and send it to the central vehicle computer but also to interpret and distribute commands from the central vehicle computer to local ECUs and actuator. This also means that a ZCU has to ensure the communication security (authentication, encryption and key management) and the local network monitoring (partial networking, network configuration and initialization,

bus synchronization and time management). To these usual functions, diagnostic server or I/O abstraction role can be also in its attribution.

2. Local actuation: depending the E/E architecture concept, a zone controller may support applications in its specific vehicle zone such as body actuation, battery management, LED control engine control or other chassis and powertrain functions. These functions can be safety-critical. It is important to note that not every vehicle function will be supported by the central computing platforms.

3. Local Power Supply and Monitoring: ZCU will act as a smart power switch to distribute and monitor power to its zone.

The list above enumerates the main roles of a typical ZCU. However, this is not meant to be an exhaustive list and some more specific chassis, powertrain or ADAS domain-related functions could be supported in the future depending the vehicle class.

To implement local gateway functions like routing data from automotive buses to the Ethernet backbone, ZCUs shall implement connectivity features, in combination with the highest level of security. It has to be able to support as well high accuracy time synchronization, low-latency routing below 2-digit microseconds and partially dynamic network configuration. Regarding the interfaces, a standard ZCU shall provide high-speed Ethernet with the most common TSN features. It shall also support a large number of automotive buses interfaces such as LIN, CAN, 10BaseT1s Ethernet and FlexRay.
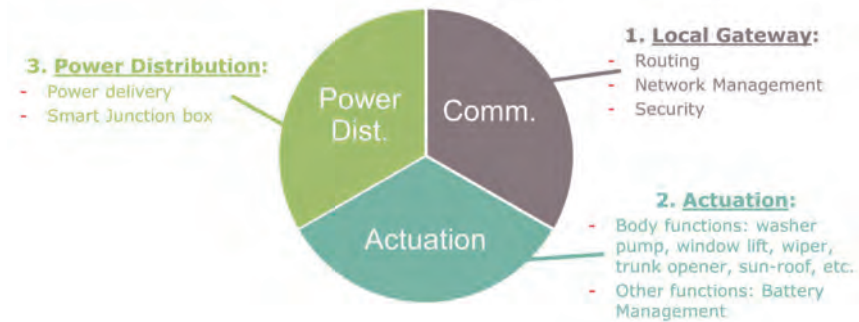

Fig. 3: Functions of a standard zone controller unit

For power supply and monitoring, a ZCU shall also support any kind of interface for sensors and actuators (PWM, SPI, UART, GPIO, etc.) with low-latency ADC capabilities.

As a zone controller unit is likely to support local actuation as well as safety and non-safety critical functions, it needs to meet SIL/ASIL safety standards to achieve a high reliability in harsh automotive environments.

How AURIX™ Microcontrollers address the ZCU requirements?

Infineon has already released the AURIX™ TC3xx microcontroller in embedded flash 40 nm technology that is suitable for ZCU as it offers up to 2 high-speed TSN Ethernet interfaces, a wide range of automotive bus communication options: up to 20 CAN-FD, 4 FlexRay, 24 LIN and 5 SPI and an integrated Hardware Security Module (HSM) compliant eVita full.

Recently, Infineon developed the AURIX™ TC4xx with the ambitious target of increasing the performance, memory sizes, connectivity and scalability to address the new automotive trends and challenges.

In terms of connectivity, additional richer connectivity adds two 8 GT/s PCIe 3.0 interfaces, two 5 Gbps TSN Ethernet MACs, four 100Mbps/10BaseT1s Ethernet MACs, xSPI and automotive buses (20 CAN-FD, 4 FlexRay, 24 LIN and 8 SPI). To further improve performance and offload the CPU of the routing and frame formatting task, a dedicated hardware routing engine and two Ethernet bridges have been integrated. The routing engine deals with the high number of incoming frames from CAN interfaces and fully manages the routing to several possible destinations (memory, CAN, Ethernet or PCIe interfaces). It also supports the automatic encapsulation and de-encapsulation of CAN frames tunneled into Ethernet frames using the IEEE 1722 standard. Such hardware mechanism allows a seamless forwarding of latency critical CAN frames through Ethernet without involving CPU. The Ethernet bridges allow the packet forwarding between the six Ethernet interfaces proposed in the AURIX™ TC4Dx.

In terms of security, the TC4xx includes the Cybersecurity Real-time Module (CSRM) which is the enhanced HSM concept powered by TriCore™ with higher performance, secure storage of long-term keys, generation of short-term keys and key transfer. The TC4xx also includes a crypto satellites security module (CSS), a multi-channel crypto accelerator specially designed to support latency-critical symmetric cryptographic operations (such as AES or ChaCha) and hash functions (such as SHA and SHAKE) used in communication protocols (MACsec, IPSec, (D)TLS, SecOC, etc.).

With these new features and capabilities, the AURIX™ TC4xx is particularly suitable for Zone Controller Unit as it associates high-speed and automotive buses connectivity, security and keeps the highly successful family functional safety capability at ASIL-D ISO 26262.

With the AURIX™ TC4xx family, it provides the most scalable portfolio of safety microcontroller and is able to cover the multiple ZCU concepts.

Conclusion

The Zone Controller Units are the cornerstones ECU of the new E/E architectures. They will be the local gateways that provide and distribute data and power across the vehicle and support the demands of scalable and service-oriented architectures. In order to serve this purpose, ZCUs have specific requirements in terms of safety, security, performances and interfaces. As presented in this article, with the AURIX™ Real-time Microcontrollers Infineon offers right fitting microcontrollers to these requirements.

Bibliography

Klaus-Wagenbrenner, J. (24. September 2019). Zonal EE Architecture: Towards a Fully Automotive Ethernet–Based Vehicle Infrastructure.