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Lighting Software Design for Software Define Vehicle

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1. Abstract

Software Defined Vehicle are designed based on new centralized E/E architectures. Among numerous advantages provided by such Architectures, updates over the Air and sensor fusion bring new opportunities for evolution over time and new function design. Lighting is necessarily involved in this change. This paper presents how the software in Valeo LIGHT is designed with adaptability for such migration, and a scalable approach. In the meantime, new lighting functionalities are presented.

2. Introduction

Safety is at the heart of Valeo's strategy. Both Core activities like ADAS and Lighting are contributing to a new higher level of road safety.

At the same time, the vehicle architecture is being redrawn to be made more friendly to software and associated business models. This is what we call the Software Defined Vehicle.

Always connected and replacing small stand alone compute units by larger units that share compute power and data across several functions.

Valeo is on the front line of this revolution, both in terms of Hardware and Software systems at our three divisions, delivering central compute systems as well as associated software for ADAS, lighting, powertrain and thermal systems.

Lighting functions, such as high beam with anti glare and light adaptation to adverse weather are extremely important for road safety increase. Such functions are made possible by the fusion of multiple sensors data (including camera), making it possible to adapt Very accurately to the light on the road. Valeo is working on various lighting functions to enhance driver safety, comfort and customization.

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3. Technical environment changes

The automotive industry is undergoing a significant transformation, moving towards a new centralized architecture. Traditionally, vehicles have been built with a distributed architecture,

The new centralized architecture, often referred to as "domain centralized" or "zone-based" architecture (see fig 1), consolidates previous distributed ECUs into fewer, more powerful central computers. These high-performance computers manage multiple functions or entire vehicle domains (e.g., cockpit domain, ADAS domain, vehicle motion domain).

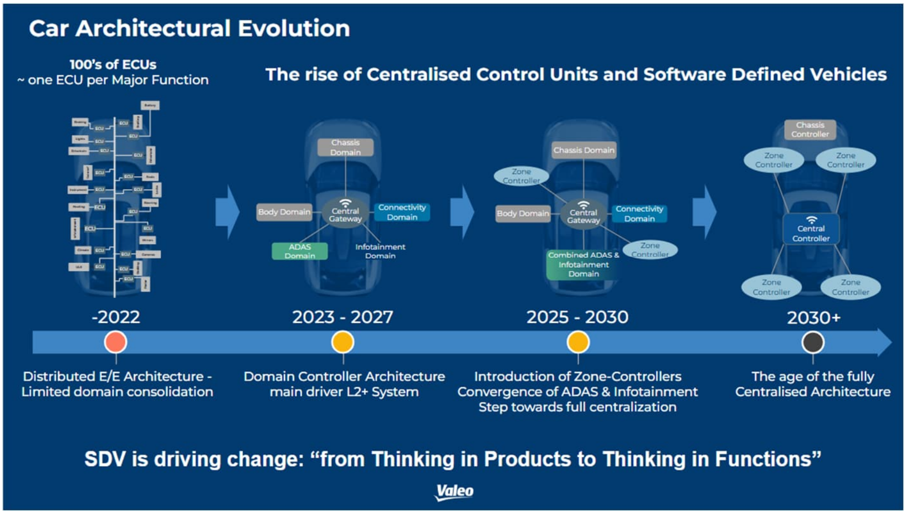

Figure 1: Source Valeo

This shift is driven by several factors: software complexity increase, need for Over-the-Air (OTA) updates (enabling new features and bug fixes without car dealer action), enhanced connectivity (V2X communication and cloud connectivity), improved scalability and flexibility, and finally reduced complexity and cost.

For the Lighting domain, this new architecture will also significantly improve the performances.

Centralization will allow sensor fusion, by combining camera, radar, Lidar (amount many others), the lighting system can not only detect the presence of an oncoming vehicle (as a simple camera would), but also estimate its distance and trajectory more accurately, anticipate turns, identify pedestrians on the side of the road even in poor visibility, or detect low objects on the roadway.

Centralization will also bring more computing capabilities that are needed to manage higher pixel resolutions. High Definition (HD) technology represents a significant leap forward in automotive illumination. It not only enhances traditional lighting functions but also enables substantial performance improvements and facilitates entirely new usages.

The enhanced visibility and the comfort provided by this precisely adapted light coverage directly translate into key safety benefits. Drivers benefit from better illumination of the road, obstacles, and potential hazards, allowing for earlier detection and reaction. The ability to maintain high beam usage more frequently maximizes the illuminated field of view, which is particularly critical for safety during night driving.

Each car maker has his own way to drive the lighting change to centralized architecture. It is expected to have a significant vehicle start of production by 2026. Ultimately, the Lighting peripherals will become totally software less. Consequently all the lighting functions will be located in centralized ECU (see Fig. 2)

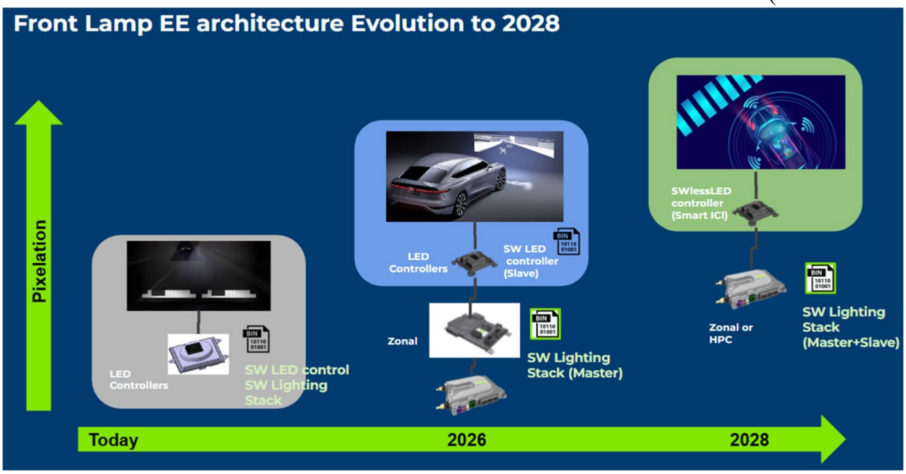

Figure 2: Souce Valeo

4. Lighting functions Evolution

High Definition (HD) is revolutionizing vehicle safety by moving beyond basic illumination to offer advanced functionalities. This technology significantly enhances road safety, provides critical driver assistance, and is a key enabler for the progression towards higher levels of autonomous driving.

4.1 HD benefits on ADB

HD lighting enhances traditional functions while producing significant improvements and creating new usages. An example of a key function is the Adaptive Driving Beam (ADB) which projects in 2D up to 70% more light than a ADB matrix beam and allows the high beam to remain lit on a wider range without dazzling other road users. The comfort provided offers key safety benefits.

4.2 Intelligent Lighting: A New Era of Safety for drivers

Advanced road projection functions dynamically enhance safety and driver awareness by projecting critical information directly onto the road.

Lane Projection enhances safety by projecting predictive guidelines onto the road using precision pixelated light sources and data from front cameras, navigation, and steering wheel angle, thereby helping drivers maintain optimal trajectories, especially in challenging conditions, and also reassuring occupants while assisting in future autonomous driving scenarios.

Road Sign Projection enhances safety by projecting crucial external information like speed limits, warnings, and hazards directly into the driver's primary field of view on the road, which reduces driver distraction, improves reaction time, and enhances situational awareness by minimizing head movements and visual accommodation.

Safety Distance Projection, activated and controlled by front radar or lidar, provides a direct, visual anti-collision warning projected onto the road, indicating unsafe following distances or impending collision risks, thereby offering an intuitive and immediate safety alert to the driver.

2 

Figure 3: Examples of Lane Projection, collision warning and Road-projected signs to the driver

4.3 Intelligent Lighting: A New Era of Safety for other Road users

Advanced lighting technology is revolutionizing vehicle safety by introducing new functionalities for driver assistance and enhanced communication with other road users.

The Spot Marking Light feature actively guides the driver's attention to potential hazards like pedestrians, animals, or objects on the road by utilizing a directed, tight spot beam in conjunction with vehicle sensors to precisely highlight detected vulnerable road users or obstacles, thereby significantly increasing the driver's time to perceive, process, and respond to threats, with advanced systems even illuminating moving objects precisely while avoiding glare for VRUs.

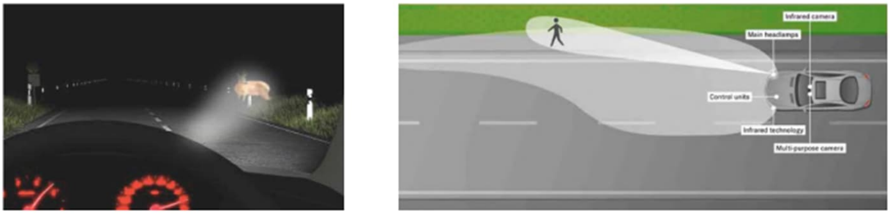

Figure 4: Illumination of a pedestrian or animal

Advanced Signaling, through enhanced lighting with features like higher pixelization and integrated displays, enables vehicles to communicate more complex information to other road users, which is crucial for automation as it replaces traditional human nonverbal cues, preventing misunderstandings and accidents by clearly conveying the vehicle's intentions, state, or detected information, thereby increasing predictability and safety for all road users.

Figure 5: Sign to allow pedestrian to cross the road (Source Audi)

4.4 Intelligent Lighting: Enhancing ADAS and Autonomous Driving

Intelligent and adaptable lighting systems are becoming essential for enhancing Advanced Driver-Assistance Systems (ADAS) performances, addressing low-light limitations by providing photons for robust camera-based image analysis. Within a Software Defined Vehicle, lighting actively contributes to the perception in close loop mode, dynamically controlled by fused sensors and real-time data. This active role enhances safety via targeted illumination (e.g., High-Definition ADB, Spotlight, Marking Light) of Vulnerable Road Users (VRUs) or obstacles, improving system detection, classification, and reaction time. Intensity adjusts to optimize road sign reading, ultimately enabling higher automation (L3-5). For such higher autonomous driving levels, precise object recognition is paramount.

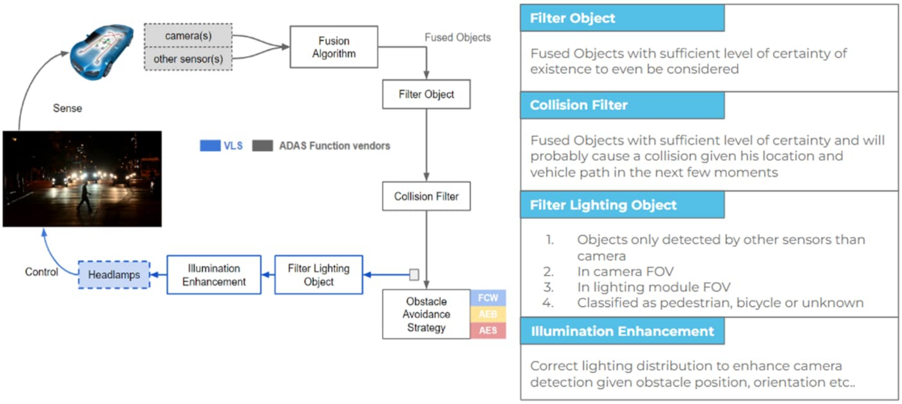

Figure 6: ADAS and Lighting (VALEO) Algorithm for front collision automatic management

5. Lighting SW architecture

Automotive lighting functions, such as Adaptive Driving Beam (ADB) or Dynamic Bending Light (DBL), typically feature a distributed functional architecture, often divided into two main parts, a Master and a Slave or Controller.

The Master component is responsible for collecting inputs from various sources, including the vision system (camera) and other sensors available on the vehicle's CAN network. It processes this information to determine the necessary actions to be performed on the light beam.

The second part, the Slave or Controller, is then tasked with applying these instructions to the light modules within the headlamp. For instance, considering the ADB function, which aims to create "shadow areas" within the light beam to avoid dazzling other drivers and prevent self-glare from reflective road signs:

The ADB Master receives information from the camera (typically the position of detected objects) and the vehicle (speed, function activation permission, etc.). Based on this data, the function determines for each headlamp: the position within the beam where the light intensity should be reduced, the specific intensity value to apply in this zone, the size of the transition area or "blur" around the shadow zone, etc.

The Controller receives these directives and, based on the headlamp technology (standard LEDs or HD pixels), determines which individual LEDs or pixels need to be turned off or dimmed to accurately implement the required light distribution pattern.

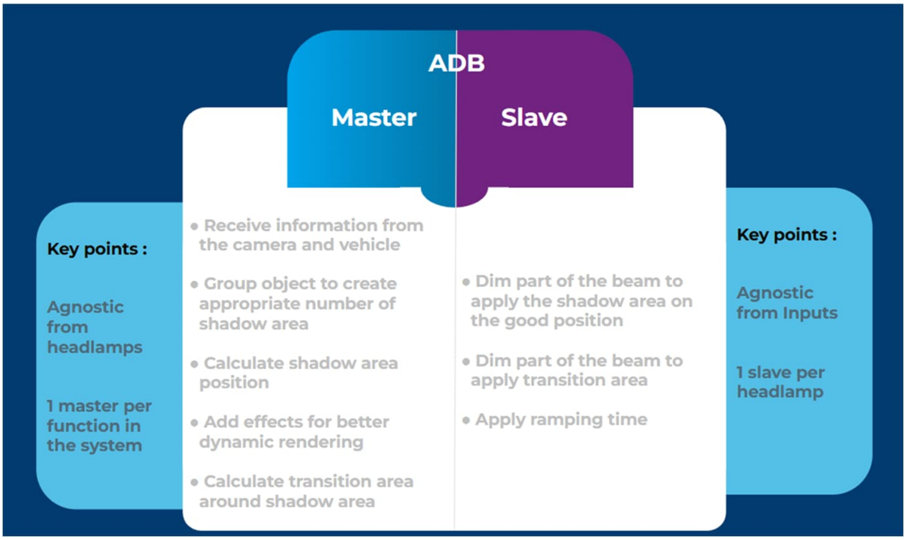

Figure 7: Master/Slave breakdown (Source Valeo)

This functional decomposition offers several significant advantages. Firstly, the Master component is designed to be agnostic to the specific light modules used within the headlamp. This allows a single Master implementation to be utilized across different vehicle applications or headlamp technologies, promoting reusability and reducing development effort. Secondly, employing a single Master to control multiple Slaves (e.g., one for each headlamp) effectively bypasses numerous coordination challenges that might arise with a more distributed control scheme. Finally, the Slave component is agnostic to external inputs. A Slave can be calibrated specifically for a given type of headlamp module and then reused with different Masters. This flexibility simplifies the coexistence of various product ranges (number of pixel scalability), enabling seamless scaling from simplified lighting functions to more premium, feature-rich versions by simply pairing different Master implementations (quality scalability).

This functional architecture can then be mapped onto various hardware architectures in different ways (Software adaptability to customer hardware architecture). Traditionally, the Controller components of lighting functions were implemented within the software of the power drivers responsible for supplying power to the headlamps. The Master components, on the other hand, were typically implemented either within the Electronic Control Unit (ECU) of these same power drivers (most commonly with the left-side driver acting as the master controlling both slaves, and the master functions inhibited on the right side in favor of commands received from the left via CAN messages), or sometimes implemented in a small, dedicated ECU specifically for lighting control master logic.

With the deployment of the Software-Defined Vehicles (SDV), there is an increasing trend for these lighting function software applications to be implemented within the vehicle's Zonal ECUs. Initially, this migration primarily involves relocating the Master algorithms to these Zonal ECUs, while the Slave functions remain closer to the headlamps within the power drivers. This approach helps to minimize communication traffic, particularly the high-bandwidth data required for precise control of numerous LEDs or pixels. However, the emergence of new, more advanced LED control chips suggests the potential for a complete migration of these algorithms, including the Slave functionalities, towards the centralized ECUs of the vehicle in the future.

6. Conclusion

The automotive industry is undergoing a significant transformation with the shift towards Software Defined Vehicles and centralized E/E architectures. This evolution enables enhanced sensor fusion and more sophisticated lighting functions.

High Definition (HD) lighting is transforming vehicle safety by evolving beyond basic illumination to provide advanced functionalities like Adaptive Driving Beam, dynamic road projections, and enhanced communication, actively supporting ADAS performance and enabling higher levels of autonomous driving by improving perception and interaction for all road users. Lighting contributes to ADAS and becomes an active safety component, playing an important role in the vehicle's perception system.

A proper Master/Slave software architecture allows smooth transition to zonal ECUs and makes lighting systems more integrated and scalable while improving reuse and reducing costs.

These new intelligent lighting systems, with adaptable architecture, ensure continued evolution of safety features while maintaining cost-effectiveness. This represents a fundamental shift in how vehicles interact with their environment, supporting new standards for automotive safety and autonomous driving capabilities.