Driving towards Level 2+ Sensor Fusion for ADAS

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Abstract

Sensor Fusion is one of the key technologies enabling Advanced Driver Assistance Systems (ADAS). It is implemented as a software solution that collects together data provided by a disparate range of sensors to provide a single, consistent picture of the environment around the vehicle. Taking a completed and automotive-ready sensor fusion solution, such as that provided by Baselabs, can result in significant financial savings during the development of ADAS projects thanks to their standardization of this functionality. This allows OEMs and Tier 1s to concentrate on product differentiation, rather than reinventing the wheel. By partnering with the established automotive microcontroller supplier Infineon, a partnership has formed that eases the implementation of Sensor Fusion while, thanks to AURIX, ensures that the expected levels of robust automotive quality, reliability, and system determinism in the ECU are retained, and tool investments continue to be amortized.

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Introduction

Futuristic visions for autonomous vehicles are raising consumer expectations with regard to today's vehicles. Systems that support the driver, or intervene in the event of a hazard, make use of a wide range of sensing technologies ranging from cameras and radar to Lidar. Each provides their insight into the surrounding environment in different ways, at differing update rates, and with different levels of accuracy. In order to generate a coherent view of the vehicle's surroundings, this disparate data must be fused together into a format that can be processed easily. The process of Sensor Fusion allows this data to be combined in such a way that a clear view of the environment around the vehicle can be attained, allowing automotive safety and control systems to make the correct driving decisions at the appropriate time. However, such systems cannot be deemed inherently safe based upon high-quality software alone. The processing platform used must also provide sufficient safety and dependability as a result of its hardware design, as well as offering pedigree in the automotive market.

Advanced Driver Assistance Systems

The term 'autopilot' for describing an autonomous driving capability for automobiles has been largely unhelpful, conjuring up visions of truly self-driving cars. As every driver knows, even local streets driving at moderate speeds are full of dangers, resulting in many minor collisions and accidents on our roads on a daily basis.

Although accidents on our roads have fallen year-on-year, the statistics since 2013 have remained stubbornly flat[1]. The automotive industry is responding with ever more sophisticated driver assistance systems that should help here. Initially, such systems were limited to providing warnings, such as when changing lanes, but have slowly grown in their functionality to intervene in the driving process, such as actively correcting steering. Such Advanced Driver Assistance Systems (ADAS) are seen as the pathway to vehicles that drive fully autonomously, gradually increasing the degree to which the driver can disengage from the responsibility of driving.

Graded in levels from 0 to 5, the majority of vehicles sold in 2020, around 55m units[2], fall into the Level 0 category (no ADAS features). Around 36m units were offering Level 1 ADAS to provide 'feet off' capability through features such as adaptive cruise control (ACC). Here the driver is still expected to take responsibility for the steering. ADAS Level 2 was supported by around 14m units, allowing owners to take advantage of more advanced automation capabilities thanks to the range of complementary sensing technologies that enable these features (Figure 1). These combine the capabilities that support both vehicle acceleration and steering, such as lane centering with ACC.

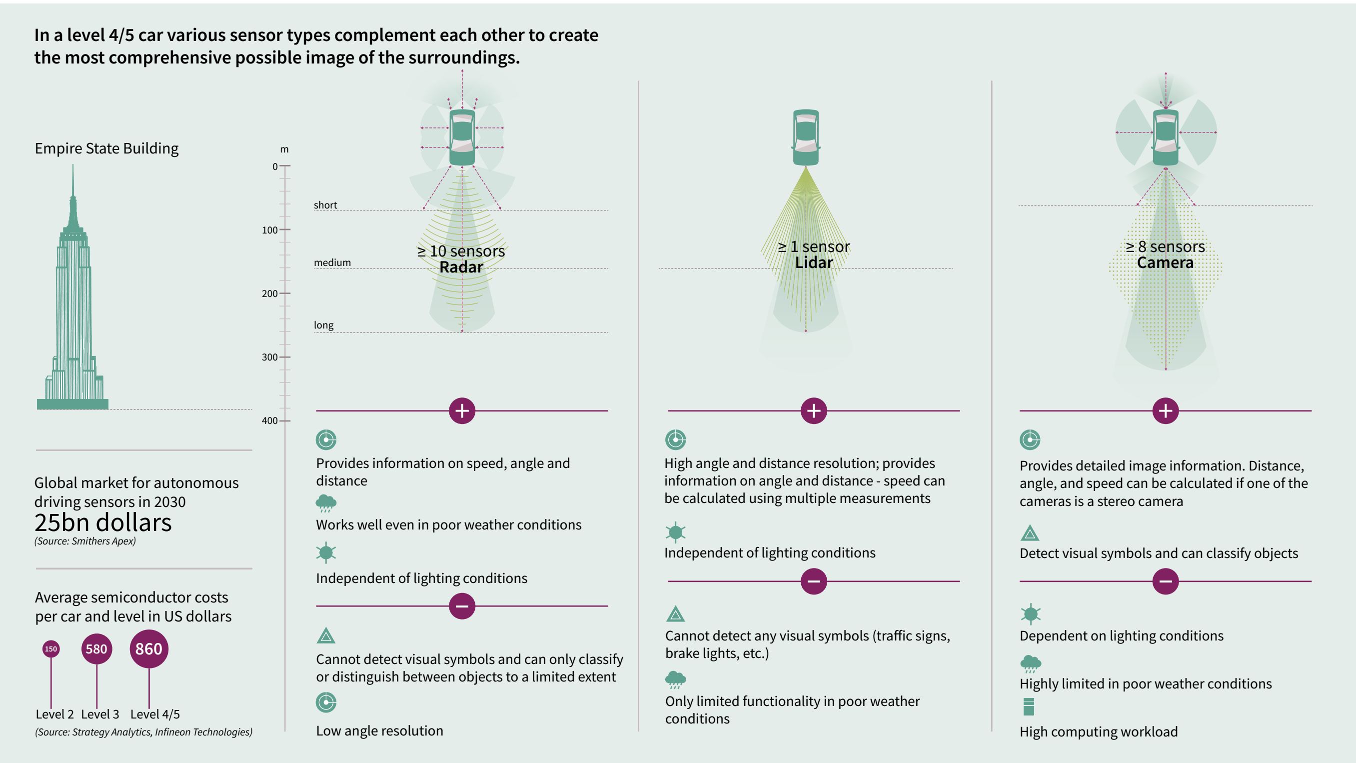


Figure 1: ADAS and AD is driving the demand for advanced sensors within the vehicle, from radar and Lidar to cameras.

Sensing the vehicle's environment

While the industry is to be commended for the advancements it has achieved through these advanced safety features, the cost and effort to develop them have been considerable. Bearing in mind that as of the next step, Level 3 ADAS[3], the vehicle is required to drive itself (with the driver being ready to retake control), many automotive OEMs are breaking the challenge down. This is being undertaken by beefing up Level 2 capabilities through a stage commonly termed Level 2+, without having to make the full step to Level 3.

This allows OEMs to review their existing development process and determine how to optimize their solutions into reusable platforms that can penetrate down into the more price-sensitive motoring segment. Sensing is the critical element here since, without a clear and reliable understanding of the environment around the vehicle, there is no basis for making safety-critical decisions.

The challenge here is dealing with multiple sensors that have different strengths and weaknesses, provide various levels of resolution, react differently to environmental changes (such as rain), and deliver their insights with differing cyclical periods.

Sensor fusion is the name given to software that processes this disparate collection of data to present it in a consistent format (Figure 2). The format used must allow the space around the vehicle to be discerned, providing information about the position of static objects along with the speed and direction of mobile objects.

Ultrasonic sensors form a first ring of perception for some driving functions, allowing the detection of objects close to the vehicle and come into use during a parking assistant, to give an example. However, typical ADAS implementations nowadays start with radar that provides the medium to long-range view, with sensors positioned in each quarter to provide a front and rear view of traffic, as well as a front-mounted long-distance radar providing the outlook for traffic in front of the vehicle. Cameras are also an established sensing technology in such implementations while, increasingly, Lidar is being relied upon to provide added perception. Lidar delivers a point cloud of the environment as determined by the sensor, while powerful image processing in cameras compresses the information collected into objects and their locations.

Not only is sensor fusion a challenging task in and of itself, it needs to be supported by tools that allow it to be quickly and efficiently configured for any new sensor type used. Furthermore, it must integrate seamlessly with the existing software platforms used in the automotive industry today, such as AUTOSAR Classic and Adaptive Platform, and simulation tools. While many automotive Tier 1 suppliers have solutions today, many are searching for better processes that allow them to offer agile solutions to the OEMs. Others are simply looking for a commercial off-the-shelf (COTS) platform upon which they can quickly establish their ADAS portfolio to engage with this next-generation vehicle technology.

Figure 2: Sensor fusion combines the input from a range of sensors (left) to provide a single description of the objects around the vehicle (right).

Ecosystem for Sensor Fusion

The obvious way forward here is to utilize an existing sensor fusion ecosystem that is already capable of handling this complexity, rather than reinventing the wheel. This leaves automotive development teams room to focus on differentiating their solutions and providing unique functionality. The Create Embedded solution from BASELABS provides such a consistent development workflow, starting from predevelopment and prototyping and supporting right through to series production (Figure 3).

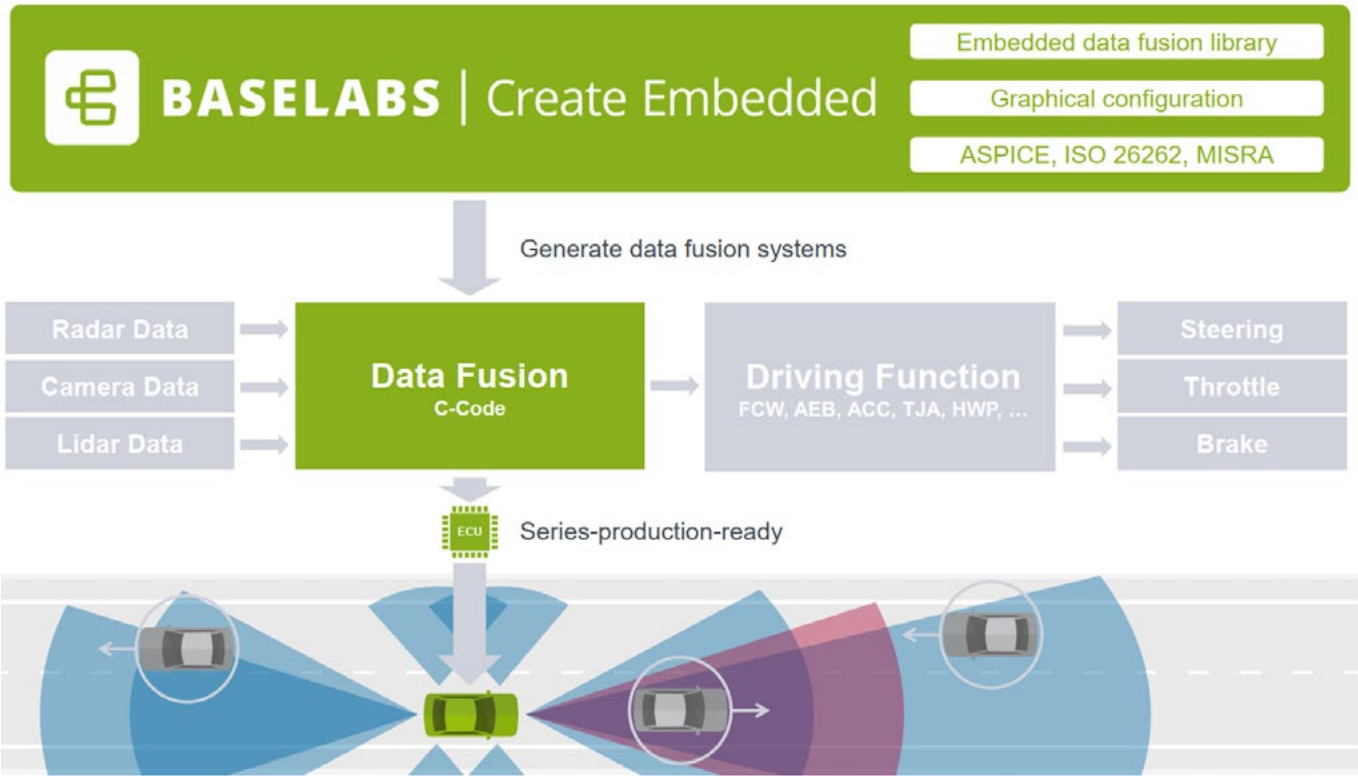


Figure 3: Create Embedded, from BASELABS, is an automotive data fusion library for ADAS applications featuring a graphical configuration tool.

At its core is a sensor agnostic Data Fusion library, generated in human-readable C source code, that can be compiled to execute on PC evaluation platforms or directly for use in an embedded context on an automotive processor, such as the Infineon AURIX (Figure 4). Using a traditional IPO model (input, process, output) it accepts data from a wide variety of sensors. The library can be configured for use using the Data Fusion Designer, a graphical tool that incorporates a range of sensor and object/track interfaces. Custom sensors can also be defined and incorporated into the design while existing sensors can also be extended if required. The environment allows the flexible configuration of anything from two sensors to a complete 360° view setup of many sensors of differing types.

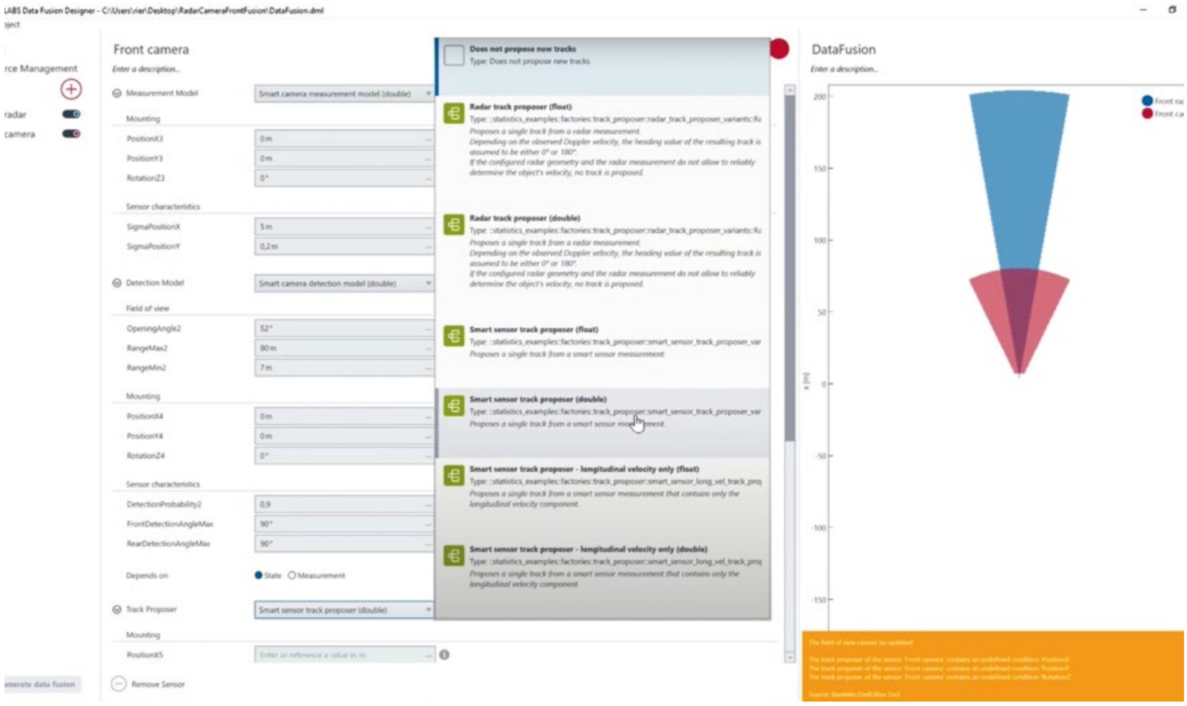


Figure 4: The graphical configuration tool Data Fusion Designer simplifies the configuration of the system prior to generating the data fusion C code.

The processing provided by the Data Fusion includes a wide selection of algorithms to enable the creation of custom object fusion solutions. These range from numerically stable Kalman filters, track management functions, classification fusion, and the synchronization of asynchronous sensor measurements, amongst others. To ensure a rapid and smooth move to embedded hardware, the C code is designed to be runtime- and memory-efficient while also supporting innovation through customizations and extensions. It provides a self-contained solution, without the need for external libraries, and is fully MISRA C:2012 compliant.

At its output, the library fuses its results in a collection of commonly used objects, known as an environment model. These include parameters such as position, velocity, heading, and acceleration, along with object size and classification. These can also be extended with custom parameters to differentiate the solution and accommodate targeted ADAS functions. The output is then passed to the automated driving functions, such as ACC, autonomous emergency braking (AEB), or forward collision warning (FCW) systems, to name but a few.

Safety is a core concern throughout the entire implementation of ADAS technology, from the software through to the silicon upon which is runs. In addition to the software library having been developed according to ASPICE, it has also followed the relevant sub-set of the requirements of ISO 26262:2018 for ASIL B. This drastically reduces the development effort for teams and is the reason why Create Embedded can move from prototype to series production so seamlessly. It also comes with a safety case and safety manual that provide guidelines on the solution's usage in a safety-related context. Parts of Create Embedded can also be considered as software tools that may require qualification when used in the context of ISO 26262. BASELABS also supports such tool qualification. Firstly, the software tools have been developed according to the relevant aspects of this standard and, secondly, a test suite is available that provides tool validation.

Operating on dependable silicon

The Create Embedded sensor fusion platform is the perfect fit for the Infineon AURIX TC3xx family of dependable automotive microcontrollers when approaching the development of ADAS systems that vehicle owners can trust. This scalable family of devices is well established for safety-critical automotive applications and has a development ecosystem that is attuned to their complex and diverse needs. It stems from the TriCore™ processing core itself that was designed for low latency and is a proven control and compute architecture with enhanced with DSP functionality. Core to such applications is its determinism that ensures ADAS decisions are being made both on-time and in-time, delivering data insights that are congruent to the motoring situation.

Best-in-class interrupt handling, fast context switching, and fast interrupt response times are all critical to ensuring a deterministic, robust, and, ultimately, safe platform that can be scaled and reused. This is where industry-standard application cores diverge from the demands of truly embedded applications as virtual memory context switches, slow interrupt handling, and cache line misses result in delays that lead to non-deterministic behavior and worst-case execution times that are challenging to determine.

Example applications tested on an AURIX TC397 (300 MHz, 1/6 cores used) include a 3R1C (3x radar, one camera) implementation that supports 30 tracks and bases its output on the input of 10 measurements from the camera at 25 Mhz and 48 measurements of the radars at 20 Hz (Figure 5). Here, the AURIX is solely responsible for the sensor fusion without recourse to an additional SoC. Such an implementation requires less than 20 kB of RAM and less than 60 KB of ROM. Larger configurations with e.g. more sensors, more tracks, or more measurements can be distributed to multiple CPU cores. Perhaps the most useful capability for software developers and integrators in this type of application is the best-in-class debugging support. The broad selection of observation points within the core and across its peripherals deliver the insights required, through high-speed tracing, to investigate software issues and to check that timing requirements are being fulfilled (Figure 6).

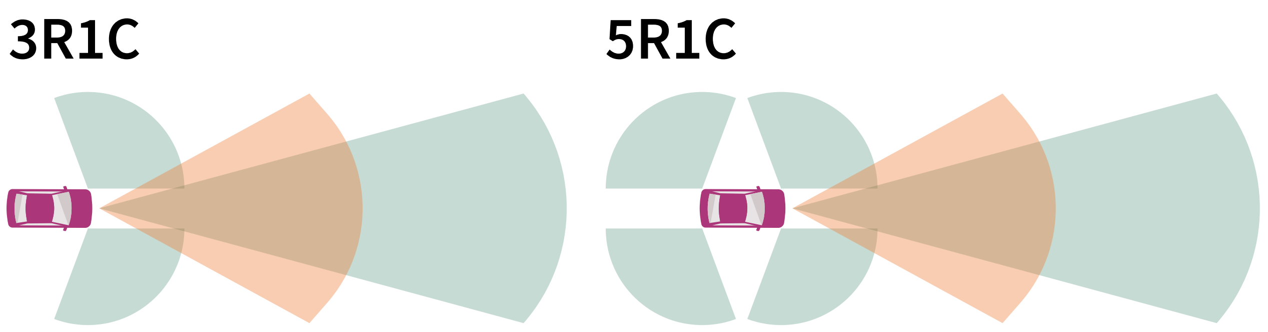
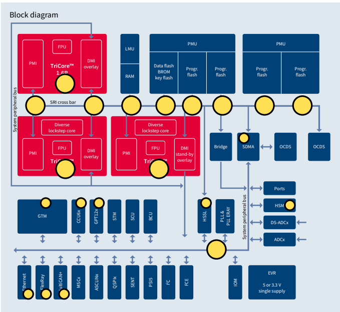


Figure 5: Example configurations for 3R1C and 5R1C ADAS sensor configurations.

Drivers need assurance that such, by their perception, highly invasive assistance systems will work correctly every time they are engaged. The approaches implemented with AURIX provide a holistic safety concept that is baked into the silicon. These range from a superior lockstep CPU concept using an anti-core in inverse logic, a central Safety Management Unit (SMU), and providing three layers of access protection for memories, peripherals, and global registers. The layout of the microcontroller on the die, using approaches such as redundant and spatially separated peripherals, coupled with innovative monitoring and protection mechanisms, are also key to this fully thought-through safety concept (Figure 7).

AURIX™ observation points



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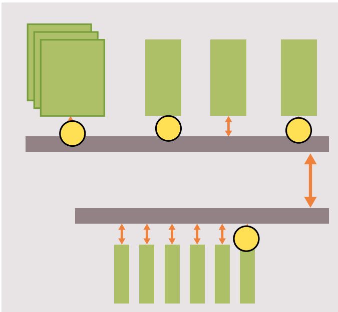
Competitor’s observation points



Proven debug concept	Best value tools	Benefits
› Patented multicore debug solution › High-speed multicore tracing	› Scalable from cost optimized to high performance › Consistently debugging over the whole family › Full trace visibility	› Streamlines development › Thorough validation and less risks › Higher system design quality › Faster safety analysis of software › Faster time-to-market

Figure 6: AURIX automotive microcontrollers provide developers a wealth of access to the internal workings of the device along with best-in-class hardware trace capability

Safety and dependability baked in

In fact, safety across the AURIX ecosystem can be considered to be a cultural mindset. This starts by avoiding systematic faults through the consequential implementation of ISO 26262 methodologies during design, in-depth analysis of IP-level failure modes, and hardening products through the application of stringent design rules. A vehicle's electronic system is notorious for the harsh conditions under which is places its electronic control units (ECU). Therefore, toleration of known abusive circumstances is implemented through double via metallization for redundancy, multi-point power supplies, and redundant internal blocks. Electromagnetic compatibility (EMC) is another key concern for automotive designers. While the performance of AURIX has improved by a factor of 12 over the past decade, and core frequencies have doubled, EMC emissions are now a tenth of what they were. This has been made possible through efficient on-chip capacitive decoupling, clock modulation techniques, and flexible I/O driver scaling.

When failures do occur, it may be possible to recover from them thanks to repair mechanisms in the form of redundant flip-flops, or memory swap concepts to return from failed or partial software updates. Finally, a proven signaling mechanism through the central SMU allows applications to take concrete next steps and flag failure conditions. AURIX is also supported by a fully configurable Failure Modes, Effects, and Diagnostics Analysis (FMEDA) safety documentation that provides customers with all the relevant data and information required for thorough safety analysis.

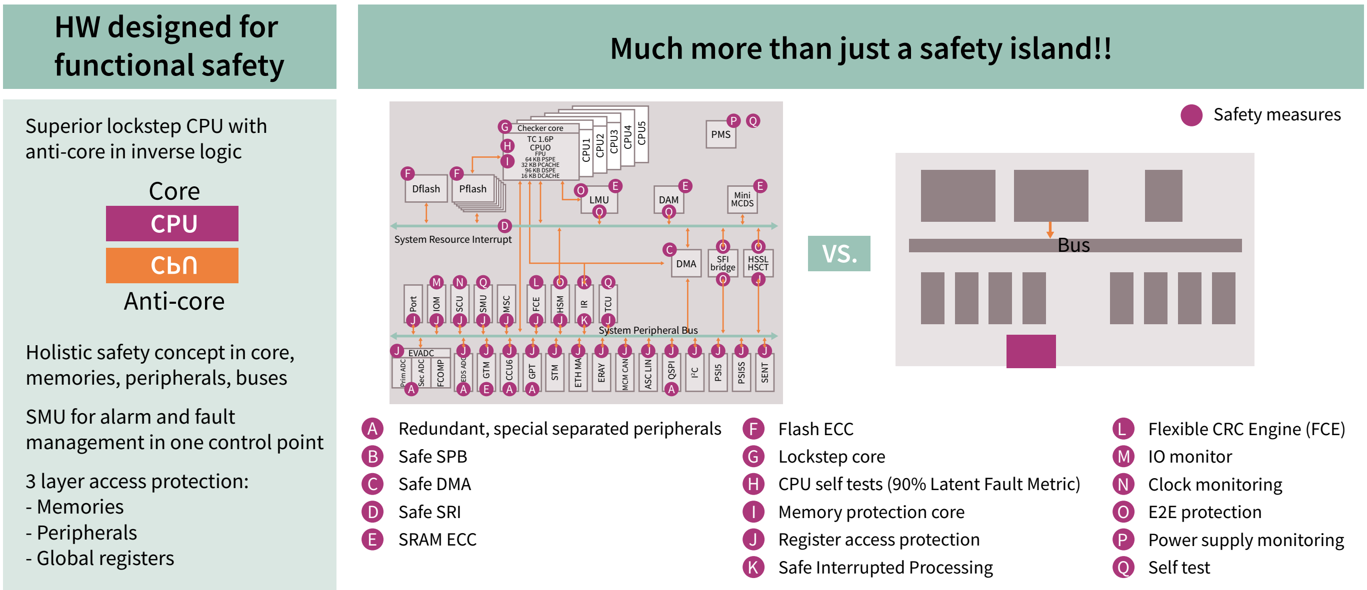


Figure 7: Safety measures, a superior lockstep implementation, and three-layer access protection deliver a dependable processing platform for safety-critical ADAS applications.

Another growing concern with the increase in autonomy of vehicles is cybersecurity and protection against external attacks. Again, the AURIX family is well placed with software security being enforced through hardware security features. A Hardware Security Module (HSM) offers configurable flash memory for the storage of encryption keys and critical data, along with true random number generator (TRNG) and hardware encryption accelerators (AES, ECC, HASH, SHA).

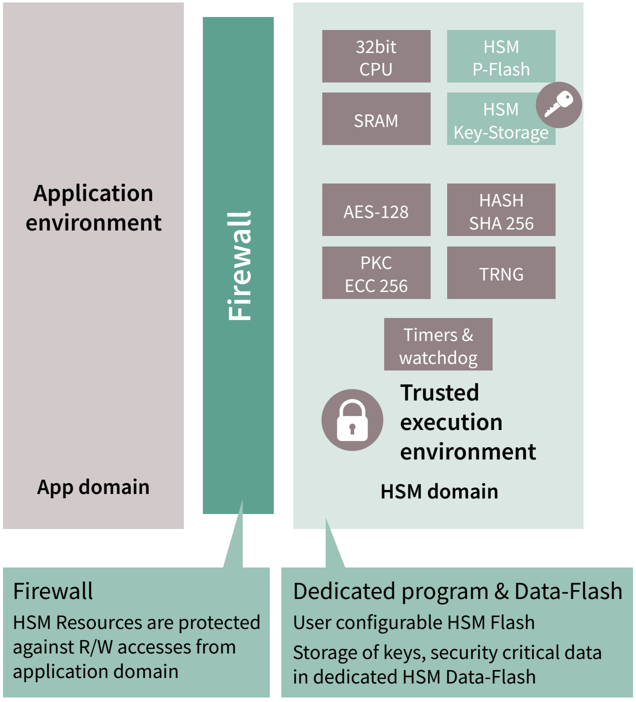


Figure 8: With responsibility for passenger safety passing to the ADAS implementation, the security mechanisms within AURIX protect against cyber-attacks.

Efficient development; safe and reliable results

While ADAS features remain relatively novel for the general consumer, they are established enough within the automotive development community that standardization in some aspects can now be considered. The fusion of the sensor data, a complex undertaking in and of itself, is one such aspect. The Create Embedded approach provided by BASELABS allows development teams to, more or less, tick the box on the sensor fusion block, leaving room to create and differentiate in other aspects of the ADAS solution. This library-driven approach is thought capable of significantly reducing the financial outlay for the data fusion implementation. Furthermore, development time could also drop significantly, require fewer developers, while also offering a notable reduction in the project risks associated with this critical ADAS component.

The selection of the AURIX family of automotive microcontrollers provides an established, dependable computing platform on which to implement BASELABS' sensor fusion technology. Rapidly prototyped concepts can be quickly transferred to this embedded device that can form the reliable core of this critical ADAS capability. The AURIX's historical presence in automotive applications not only makes it a known quantity for developers, its development ecosystem is widespread and well supported. Thus, developer analysis tools can make full use of its advanced debug capabilities to evaluate and fully test the end result for both determinism and robustness.

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