Marelli Lean Platforms: Fast, Affordable Innovation at Scale

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ABSTRACT

The global automotive industry is facing unprecedented pressure to deliver advanced features, enhanced sustainability and improved cost-efficiency– all while reducing time-to-market in an increasingly competitive landscape.

Marelli's Lean Platform strategy helps automakers tackle these challenges, particularly in entry-level segments where cost and speed are critical to capturing early market share. This comprehensive portfolio of modular hardware and software innovations spans Lighting, Electronics, Displays, Suspension, Propulsion, and Exhaust.

Each Lean Platform applies first-principles engineering – lateral thinking that distills complexity to its core, unlocking more efficient and streamlined solutions that match or exceed existing benchmarks.

This paper details the unique advantages of each Marelli Lean Platform – LeanLight, LeanZone, LeanCore, LeanConnect, LeanDisplay, LeanHorizon, LeanRide, LeanEnergy and LeanExhaust – illustrating how they help automakers create more purpose-built, competitive vehicles.

HARDWARE PLATFORMS INTRODUCTION

Aligning innovation with market demands is central to Marelli's strategy. Today, our modular hardware platforms underpin this strategic model, enabling automakers to rapidly address specific requirements across tiered market segments with high growth, high-market share products.

Leveraging deep cross-domain expertise to deliver integrated or standalone solutions at speed, Marelli's scalable platforms streamline development, optimize investment and support more sustainable vehicle architectures.

Developed to offer greater modularity, each platform targets up to 70% reuse of subsystems and components, significantly compressing R&D timelines and mitigating the risks of clean-sheet designs, while accelerating time to market.

Marelli rapidly advances concepts to the minimum viable product stage and co-engineers with OEMs to introduce future-proof features and functionalities.

As a result, automakers gain a technological edge and the agility to act as first movers, seizing early market share.

In addition to hardware, Marelli has developed software platforms that include standalone, decoupled software applications, as well as software-enabled tools and features that drive Software-Defined Vehicles (SDVs).

This integrated approach further fosters co-creation opportunities with automakers and expands personalization options for buyers.

Tailored to fulfill the diverse needs of different vehicle segments and buyers, Marelli's hardware platforms deliver significant competitive advantages, with scalability, cost efficiency, flexibility and reduced timeframes that help automakers get to market fast.

Platform-powered innovation: Accelerating your time to market

A TIERED SYSTEM: LEAN, PRO AND ELITE

Marelli's hardware platforms are structured around three scalable tiers – Lean, Pro and Elite. Each is designed to offer broad coverage across market segments while providing in-depth capabilities across various vehicle systems. With an emphasis on scalability, this model offers flexible, pre-engineered components that allow automakers to efficiently leverage technology without starting from scratch.

Lean is engineered for base trims, entry-level vehicles and value-driven brands. Its fit-for-purpose technology is focused on affordability, sustainability and speed. Lean emphasizes component simplification, reduced development time and a design-for-manufacturing mindset. The dedicated section below explores Lean in detail.

Pro puts the focus firmly on scalability. It is Marelli's most versatile and adaptable platform. It targets electric vehicles and mainstream vehicles that offer unique features beyond their class. This approach includes up-scaling well-established innovations from our Lean platform, or value-optimizing high-end features developed for premium vehicles. With the broadest range of customization and feature options, Pro is engineered to meet diverse consumer preferences and budgets across a wide array of vehicle segments.

Elite represents the pinnacle of Marelli innovation. A cycle of continuous investment and development keeps Marelli at the forefront of technological advancement, delivering industry-first products that set new benchmarks. As a result, Elite combines sophisticated features and high-content technology to meet the demands of tech-savvy end users and the most premium vehicle brands in the market.

LEAN

TARGET MARKET: **Budget-oriented, fleet buyer**

TARGET VEHICLE SEGMENT: **Affordable**

DESIGN: **Few parts, sustainable**

PROCESS: **Fast cycle time from award to SOP**

REQUIREMENT: **Fit for purpose**

PRO

TARGET MARKET: **Urban commuters, eco-conscious**

TARGET VEHICLE SEGMENT: **EVs, differentiated vehicles**

TECHNOLOGY: **Cost-down versions of first innovations or upward stretch**

SCALABILITY: **Widest feature set between Lean and Elite**

ELITE

TARGET MARKET: **Luxury, tech savvy buyers**

TARGET VEHICLE SEGMENT: **Luxury, premium brands**

INNOVATIONS: **Often industry firsts**

TECHNOLOGY: **High content**

Lean platform

Marelli's Lean platform is engineered to deliver value through affordability, sustainability and rapid time-to-market – from award to Start of Production (SOP). Built around minimal, efficient componentry, it reflects Marelli's commitment to ambitious targets for more accessible and environmentally conscious automotive solutions.

Key outcomes include:

- Fewer components
- Cycle time reduction
- Short timeframe from Start of Development (SOD) to SOP
- Minimized assembly effort
- Weight reduction
- Faster development cycles
- Significant Bill of Materials (BOM) cost savings
- Substantial reduction in prototyping costs
- Capital Expenditure (CapEx) reduction via architecture and process simplification
- Supply-chain optimization through consolidation and sourcing efficiency
- Improved sustainability through weight savings, power efficiency and supply-chain efficiency

Lean's highly pre-developed foundations are tailored for base trims, entry-level vehicles and value-driven brands. It applies across a wide range of technologies and products in high-volume segments – meeting automakers wherever they are to enable fast, cost-effective delivery.

Its fit-for-purpose strategy is driven by simplification while catering to the performance demands of today's entry-level vehicles. Above all, Lean adopts a first-principles engineering approach to achieve excellent performance with fewer resources – BOM costs, development timeframes and energy consumption are all typically reduced.

Optimized, flexible manufacturing processes support faster assembly times and quicker adaptation to changing demand or specifications, making Lean a powerful tool for both engineering and production teams.

Our Lean concept can be applied in close co-creation, so Marelli can support your engineering and production teams with innovative products optimized for manufacturing and designed to reduce costs.

THE LEAN PLATFORM PORTFOLIO

LeanLight

Marelli's LeanLight is a scalable full-lamp concept that delivers performance, efficiency and speed-to-market at an affordable cost. Positioned alongside our ProLight and EliteLight platforms, LeanLight's concept-based approach integrates both product and process innovations – holistically rethinking design, assembly and manufacturing from the ground up.

Componentry can be reduced by more than 50%, resulting in roughly a 30% decrease in CapEx and up to a 20% reduction in weight. Extensive pre-development reduces timelines from SOD to SOP to as little as 11 or eight months, while the modular toolkit supports broad design flexibility.

The LeanLight platform also features upgradeable hardware, including LED-powered optical fibers that deliver cost-effective LASER-like styling possibilities – as explored in detail below.

LeanLight Front

LeanLight Front is an entry-level, high-performance full-LED headlamp concept that offers best-in-class affordability, reduced weight, improved sustainability and shorter production cycle times.

The modular toolkit integrates one low-beam and one high-beam LED module, leveraging both projection and reflection technologies to optimize light distribution and produce a high-flux output of over 1000 lumens (lm) – enough to satisfy the world's most stringent regulatory standards, China's included.

Accommodating lens heights as narrow as 20-24 mm supports modern slimline designs, while essential signaling functions – including Reflector Daytime Running Lights (DRL) and Reflector Turn Indicators (TI) – are configurable components.

With as few as 58 individual parts, LeanLight Front has, on average, 41% fewer components than rival entry-level LED headlamps. Notably, Marelli combines the headlamp's outer and inner lenses into a single unit, contributing to significant reduction in BOM costs.

58
individual parts

41%
fewer components

Overall, simplification reduces average production cycle times by 16% and cuts assembly effort by 20%.

An average weight reduction of 20% represents a further benefit, with LeanLight headlamps typically weighing just 2.5 kg and signal lamps only 1.6 kg.

Extensive pre-development minimizes project timelines to as little as 11 months, with room for customization. This includes styling of LeanLight Front's slimline lens, alterations to its standard 24° x 60° light output pattern and the option of structural foam MuCell® light housings to reduce weight by up to 25%.

Slimline Lighting Design, Outer and Inner Lens into a Single Unit

Additionally, LeanLight Front meets critical sustainability requirements, including eliminating the traditional external chemical protective coating in favor of a more environmentally friendly film. This is compatible with both single- and two-component molding processes and meets durability standards.

Thanks to the newly designed Top Contact LED Module (see Product Spotlight, below), thermal efficiency has increased by up to 18%, contributing to a total reduction of 6 kg in CO_2 emissions over the vehicle's lifespan.

With its Microcontroller Unit (MCU)-free design and simplified hardware architecture, LeanLight Front is future-ready and fully compatible with the centralized domain and zonal controllers used in SDVs.

Need to know: LeanLight Front

Technical overview

- Full LED headlamp with two LED modules: low-beam and high-beam
- 20-24 mm lens height
- High flux output >1000 lm
- Driver unit for MCU-free approach
- Coating-free outer lens with polycarbonate film
- Signal lamp functions for Reflector Daytime Running Lights and Reflector Turn Indicator

Key benefits

- Sustainable solution with optimized CO_2 footprint
- Simplified hardware design
- High-efficiency thermal management
- Slimline appearance
- Compact packaging size
- Reduced Printed Circuit Board (PCB) assembly size
- Weight reduction
- No coating emissions
- Optimized cost & time to market

Use cases/target applications

- Headlamps for basic LED product segments (static high beam)
- Signal Lamps

Benchmark Averages
(compared to similar headlamps)

- 41% component reduction
- 12% cycle time reduction
- 30% CapEx reduction
- Substantial cost reduction
- Up to 6 kg CO_2 footprint reduction per lamp
- 18% increase in thermal efficiency
- Up to 20% weight reduction (equal to around 1.4 kg / car)
- 50% PCB size reduction
- 16% faster cycle times
- 20% lower assembly effort

Product spotlight: Top Contact LED Module

LeanLight Front introduces a new low-beam and high-beam Top Contact LED Module that's 30% more compact, 47% lighter and achieves an 18% improvement in thermal performance compared with conventional LED module designs.
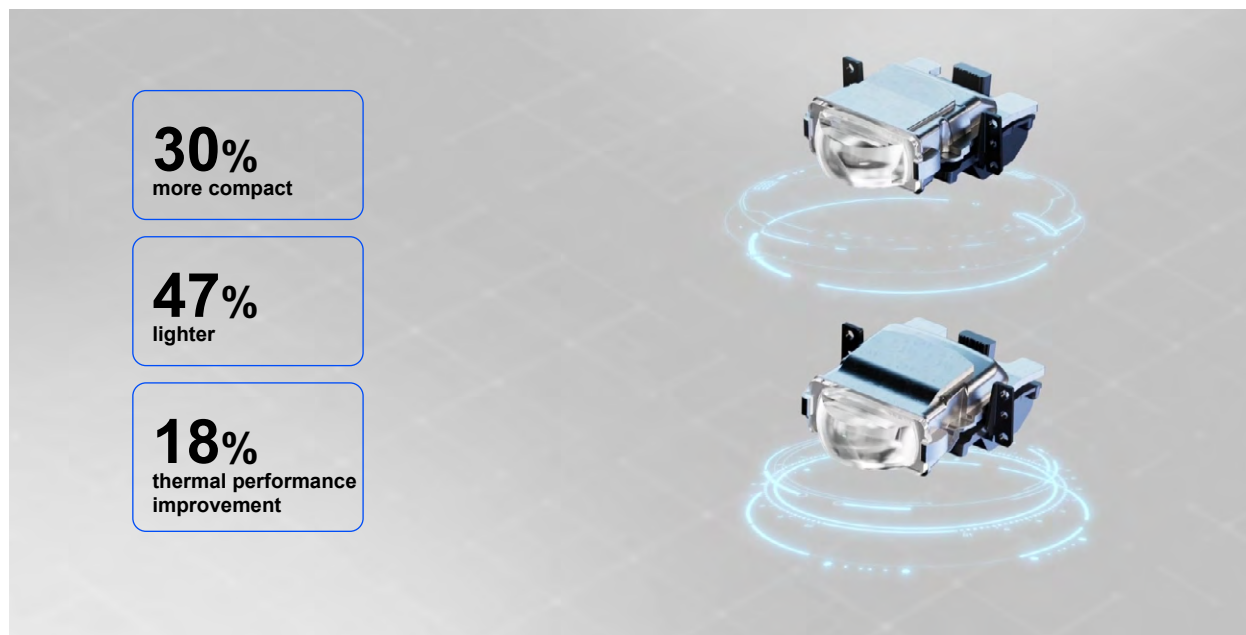
Unlike standard architectures, the Top Contact Module mounts LEDs directly to the heatsink, significantly improving heat dissipation.

As a result, both the heatsink and PCB can be substantially downsized, enabling a more compact, lightweight and thermally efficient module.

LeanLight Rear

LeanLight Rear is Marelli's modular toolkit for an affordable, full-LED rear lamp that consolidates components and supplements LEDs with innovative optics technology. This full-width, slimline solution optimizes light distribution, efficiency and sustainability.

Pre-development reduces time to market to as little as eight months, while retaining ample freedom for functional and aesthetic customization. Lightguide applications support personalization by enabling enhanced performance and design flexibility for turn indicator, reverse light and stop light functions.

Additionally, LeanLight Rear can be configured with more advanced technology on-demand, including Thin Lit Lines (see Product Spotlight below).

At its simplest, LeanLight Rear comprises just five plastic parts and seven LEDs – equating to a >50% component reduction versus competitive architectures. Consolidation of the outer and inner lenses into a single component is a key innovation. Marelli has achieved this while preserving perceived visual depth and concealing the structural weld ribs that are usually visible in exposed inner lens units. Similarly, LeanLight Rear combines the lightguide and light curtain into a single component.

5
plastic parts

7
LEDs

Multiple functions – including the turn indicator and taillight – are also consolidated onto a single electronic board. This MCU-free hardware approach is future-ready and fully compatible with the centralized domain and zonal controllers of SDVs, ensuring seamless compatibility with next-generation electronic architectures.

Thin-wall optimized lightweight design for the housing and bezel unlocks potential cost savings of up to 20% and weight reductions up to 16% – contributing to target lifetime CO_2 emissions under 6 kg.

Hidden Rib by Slim Lens with Free Outer Lens

Need to know: LeanLight Rear

Technical overview

- Full LED rear lighting solution (slim design, full width)
- Thin lightguide application for stop, turn indicator and reverse
- Taillight signature with Thin Lit Lines and Flat Lit Surfaces
- Combination of optical components and outer lens

Key benefits

- Sustainable solution with optimized CO_2 footprint
- Simplified hardware design
- Weight reduction

Use cases/target applications

- Varies based on customer styling request

Benchmark Averages (compared to similar rear lamps)

- >50% component reduction
- Up to 18% cycle time reduction
- Significant CapEx reduction
- Substantial cost reduction
- Up to 6 kg CO_2 footprint reduction
- Up to 16% weight reduction
- Up to 50% power consumption reduction
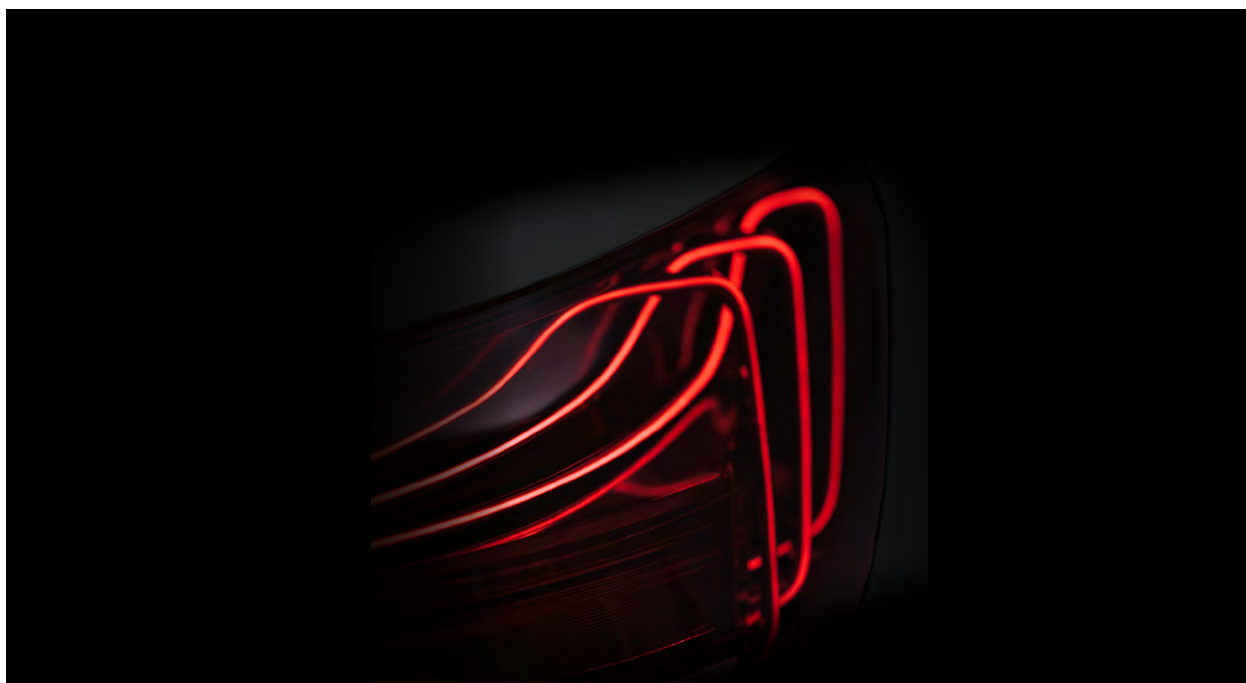
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Product spotlight: Thin Lit Lines

Marelli pioneered the use of LASER technology with thin optical fibers, resulting in its innovative Thin Lit Lines, enabling flexible, space-efficient designs with consistent light and the appearance of multiple illuminated lines.

Now, Marelli offers Thin Lit Lines as an affordable entry-level upgrade for the LeanLight Rear platform – at a cost savings of more than 40% compared to LASER technology. Side-emitting optical fibers are integrated with LED lights, allowing the fiber to diffuse light evenly along its length. This creates a thin, homogeneous illuminated line that imitates the look of far more expensive LASER and optical fiber systems.

A standardized LED-fiber coupling underpins both the design concept and product scalability. Instead of a conventional press-fit approach – where the optical fiber is inserted into a plastic holder – Marelli employs a mechanical fixation system to secure the fiber. Not only does this ensure a continuous line of light is visible from all viewing angles, it also allows Thin Lit Lines to be applied to a wide range of designs by simply altering the shape of the decorative optical fibers.

In addition to BOM savings, Thin Lit Lines offers additional efficiencies. The superior thermal efficiency of LEDs means Thin Lit Lines can use simpler heat-management systems. Mechanical fixation streamlines assembly processes. LEDs also face less onerous regulatory barriers than LASER technology, speeding up certification and validation – helping automakers bring products to market faster.
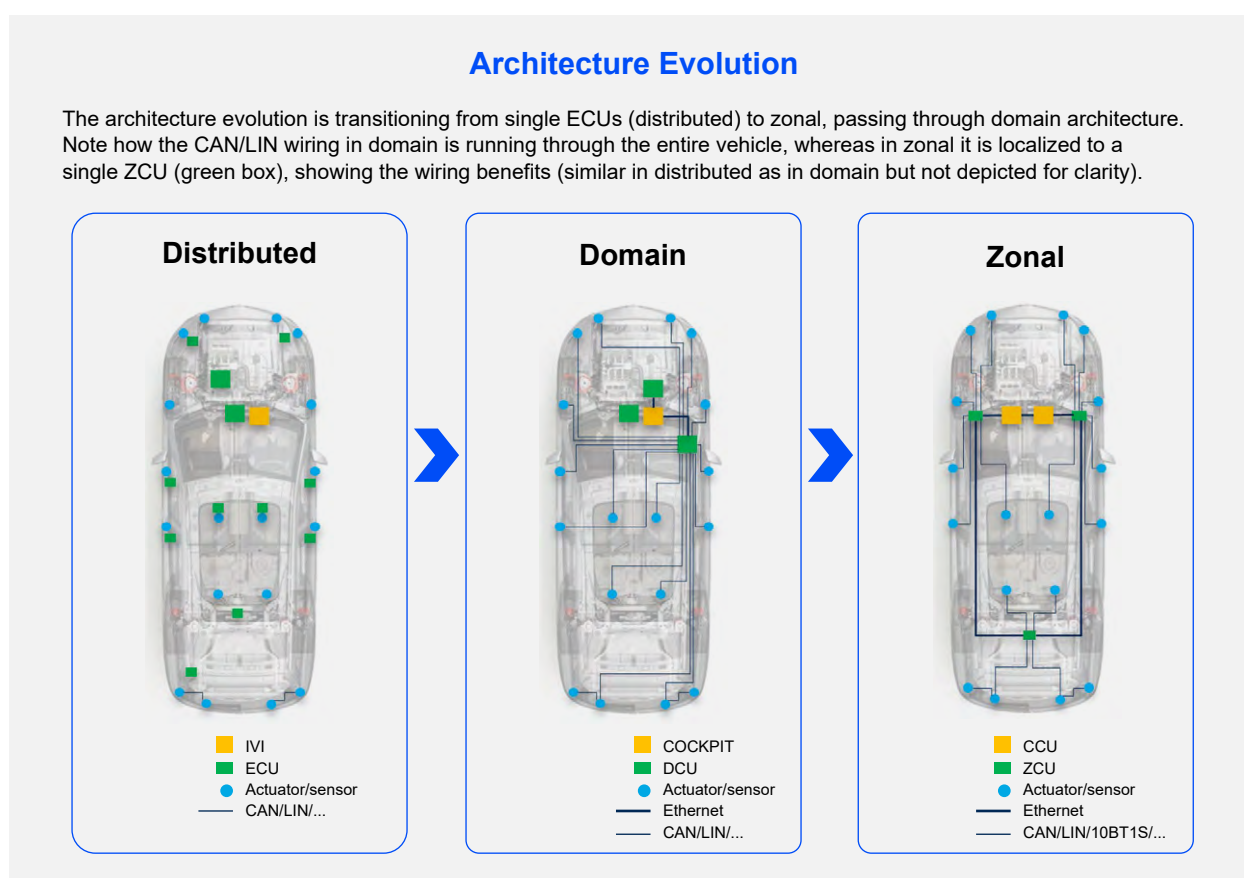
As such, Thin Lit Lines represents an efficient pathway to innovative taillight design signatures.

LeanZone

Marelli introduced zonal technology in 2022 and will be one of the world's largest suppliers of Zone Control Units (ZCUs) by volume from 2026, according to third-party data. Our three-tiered ZCU platforms – LeanZone, ProZone and EliteZone – put us at the forefront of new feature adoption and support the industry's transition to SDVs.

All draw on Marelli's unrivaled cross-domain expertise to consolidate multiple vehicle-function ECUs into single zones. This results in lower vehicle weight, cost and system complexity. The relevant control software is simply downloaded from the Marelli Advantage platform, a portfolio of nearly 300 stand-alone apps offered independently of hardware.

Architecture Evolution

The architecture evolution is transitioning from single ECUs (distributed) to zonal, passing through domain architecture. Note how the CAN/LIN wiring in domain is running through the entire vehicle, whereas in zonal it is localized to a single ZCU (green box), showing the wiring benefits (similar in distributed as in domain but not depicted for clarity).

Distributed	Domain	Zonal
■ IVI	■ COCKPIT	■ CCU
■ ECU	■ DCU	■ ZCU
● Actuator/sensor	● Actuator/sensor	● Actuator/sensor
— CAN/LIN/...	— Ethernet	— Ethernet
	— CAN/LIN/...	— CAN/LIN/10BT1S/...

LeanZone is our scalable, entry-level platform. It is well-suited to support first-generation zonal architecture and ideal for customers seeking modular, friendly technology.

Engineered to consolidate body, smart lighting, in-cabin control and power distribution into a single ZCU, LeanZone can manage multiple real-time functions simultaneously. It supports secure over-the-air updates for efficient software maintenance and new feature deployment.

Additionally, our flexible business model enables LeanZone to operate either as a production-ready ECU or as a modular element within a larger zonal system, supporting both Marelli and third-party software.

Key technology

> 1.5 kDMIPS computing capacity supports real-time, domain-specific processing to manage multiple functions simultaneously.

> 100 MB Ethernet provides low-latency communication across vehicle networks, facilitating seamless data exchange with other electronic systems.

> Controller Area Network (CAN) and Local Interconnect Network (LIN) are both available, offering the choice between robust, fault-tolerant communications necessary for critical systems (CAN), or affordable networking for non-critical systems (LIN).

Case study

A global mass-market automaker recently partnered with Marelli to begin the transition from a domain-based to a zonal architecture. The target was to reduce system complexity and cost while laying the groundwork for future SDV functionality.

Smart lighting and in-cabin control functions – previously managed by separate ECUs – were consolidated into a single LeanZone. This reduced the number of ECUs and eliminated up to ten CAN/LIN lines, with a 100 MB Ethernet backbone providing higher-bandwidth, lower-latency communication within the zone.

Lighting Software Running on ZCU
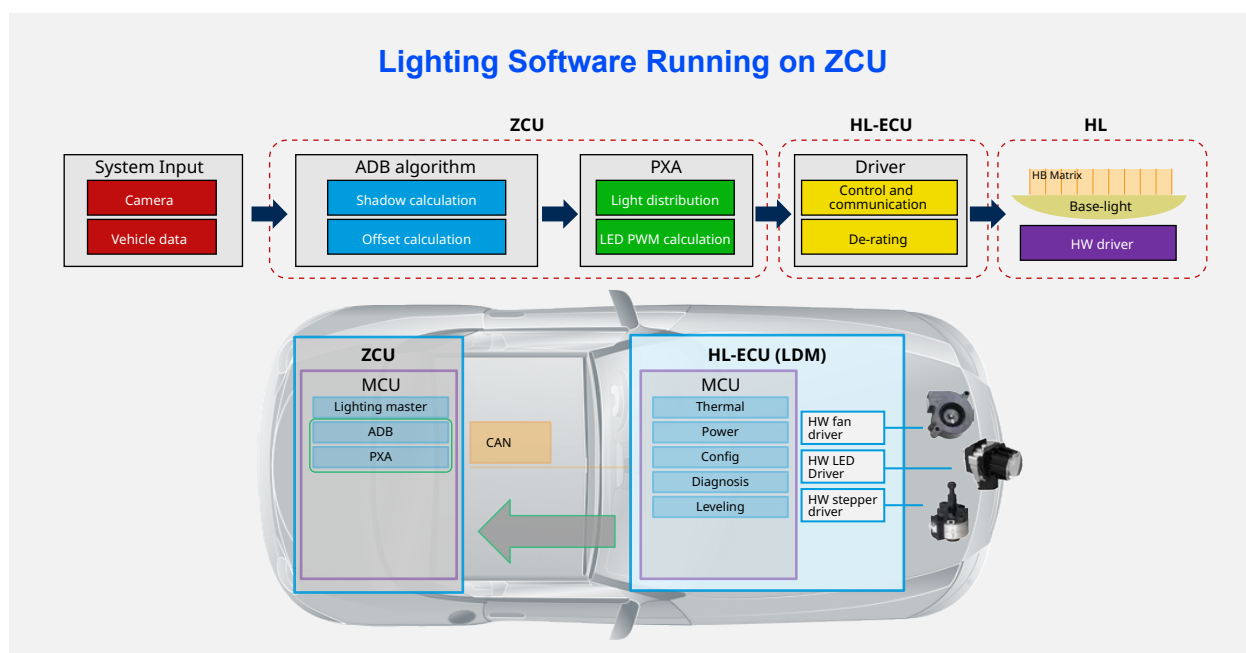
Marelli managed hardware and systems-level integration, including Board Support Package (BSP), while the automaker retained full control of the application software to preserve its unique user experience.

The result was a simplified, more modular architecture, with cost savings, reduced wiring complexity and the introduction of a scalable foundation for future zonal expansion.

Need to know: LeanZone

Technical overview

- 2 domains
- 1.5 kDMIPS
- 100 MB Ethernet
- 10 CAN & LIN
- ASIL B / C
- Mass: 800 g
- Size: 235x145x30 mm

Key benefits

- Domain knowledge in body, lighting, smart power distribution
- Flexibility in business model and technology
- Extremely low latency levels when connecting CAN and Ethernet

Use cases/target applications

- Body, smart lighting, in-cabin control, power

LeanCore

Marelli pioneered the first high-volume integrated cockpit solution in 2020, enabling automakers to manage both digital instrument clusters and In-Vehicle Infotainment (IVI) on a single platform.

Now Marelli's LeanCore platform builds on this expertise to deliver a Central Computing Unit (CCU) to affordable vehicle segments. Part of our scalable Core line-up – alongside ProCore and EliteCore – LeanCore acts as the central "brain" for in-cabin technologies in SDVs. It consolidates traditionally separate ECUs for the instrument cluster and IVI, delivering high performance, cost efficiency and a consistent user experience, all to automotive-grade safety standards.

Two million Marelli CCUs have been produced to date, supported by Digital Twin testing and validation, which reduces investment and accelerates time-to-market.

Like all Core platforms, LeanCore is an off-the-shelf solution that integrates the hardware, Board Support Package (BSP), and middleware into a single unit compatible with multiple operating systems. User-experience software – including HMI with 2.5D graphics – can be created by automakers or developed in-house by Marelli.

Central Computing Unit
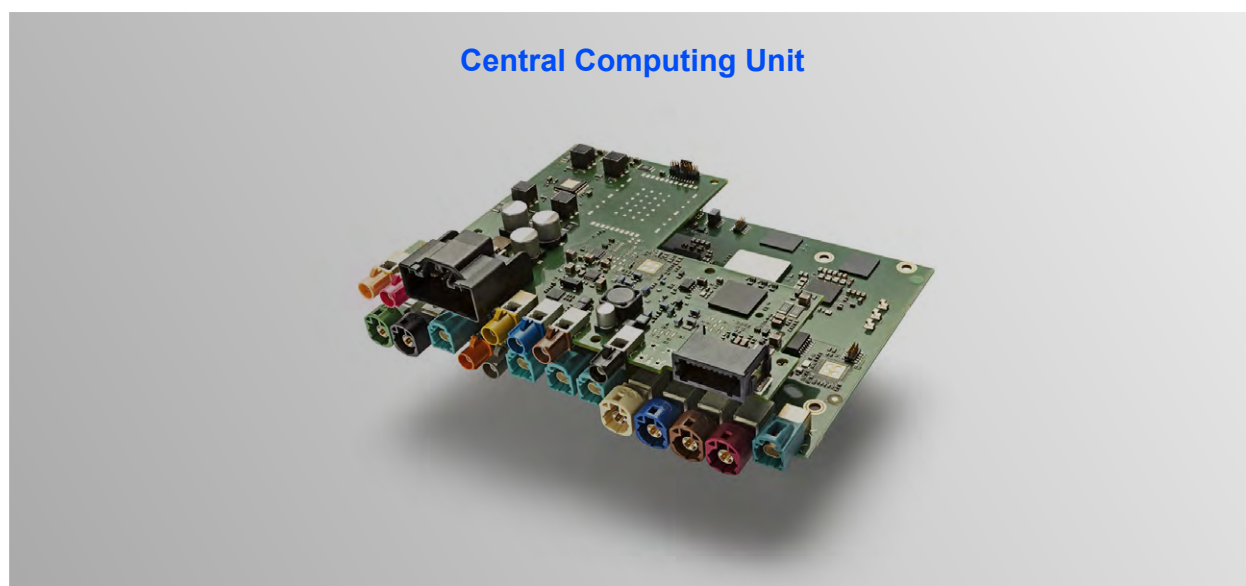
LeanCore can manage two displays of up to 12.3 inches and two cameras – including rear-view and driver monitoring systems – and delivers high-performance processing and excellent adaptability on mature technical foundations. Phone mirroring via Android Auto™ and Apple CarPlay™ is also supported.

A third-generation Qualcomm Technologies System-on-Chip (SoC), with the QNX® Hypervisor for Safety, enables high performance with robust safety partitioning between the cluster and infotainment domains. This software architecture runs QNX for the digital instrument cluster and Android for the IVI system, meeting ASIL B requirements for safety-critical functions while isolating non-safety-critical tasks to Quality Management (QM) standards. This domain isolation reduces integration complexity, shortens testing time and allows multiple operating systems and applications to run securely on a single hardware unit.

The processing capability of 50 kDMIPS ensures LeanCore can manage complex, resource-intensive applications simultaneously. Three CAN interfaces provide robust, efficient communication across multiple subsystems.

LeanCore's flexibility further supports 2D surround view when integrated with additional external camera systems, ensuring its foundation is future-ready.

Digital Twin Development

In partnership with QNX, Marelli was the first to pioneer Digital Twin development for in-cabin technology, leveraging the QNX Hypervisor for Safety to debut our virtual instrument cluster at CES 2023.

Today, Digital Twin virtual simulation provides up to 30% faster development cycles and a 70% reduction in integration testing time, thanks to hypervisor-enabled domain separation and parallel development. Prototyping costs are typically reduced by 50%.

With high-performance processing and robust control of digital instrument clusters and IVIs, LeanCore is an affordable pathway to software-defined zonal architectures and in-cabin technology consolidation.

Need to know: LeanCore

Technical overview

- Qualcomm Technologies 6155 SoC (quad-core 64-bit processor)
- 50 kDMIPS
- Up to 2 displays
- Up to 2 cameras
- QNX Hypervisor for Safety
- 3 CAN
- ASIL B

Benchmarking

- 30% faster development cycles
- 70% reduction in testing
- 50% fewer prototypes

LeanConnect

LeanConnect is the most affordable platform in Marelli's Connect line-up – a tiered family of Connected Cockpit Modules that can manage cluster, IVI and 4G telemetry – also available on the Pro platform. Optimized for entry- and mid-level vehicle segments, LeanConnect is an ECU that drives and interacts with zonal architectures. It can support two screens, two cameras and integrated 4G connectivity – all while reducing system complexity.

Connected Cockpit Module

By consolidating software control of the instrument cluster, IVI and 4G telematics into one control unit powered by a single SoC, LeanConnect replaces three separate ECUs with one. This unique integration eliminates duplication of the MCU and the associated engineering effort in one simplified package.

Cost savings of 30% and a 25% reduction in development time are possible compared with non-integrated solutions. Additional benefits include faster cycle times, thanks to fewer wiring harness connection points, as well as improved sustainability. The latter is achieved through approximately 10 watts of power savings, fewer ECUs, CAN lines and connectors, an approximate 1.2 kg reduction in system weight and streamlined supply chains.

Marelli's flexible approach allows LeanConnect specifications to be tailored to each customer's budgetary and functional needs. It is compatible with Android Auto™ and supports driver monitoring systems. Integration of a 4G modem ensures reliable cellular connectivity, complemented by Wi-Fi 5.0 and Bluetooth 4.1 for over-the-air updates, multimedia streaming and eCall capability across all regions.

Production-ready and adaptable, LeanConnect offers an affordable entry point for managing software-defined cockpit solutions.

Need to know: LeanConnect

Technical overview

- 4G Category 12
- 58 kDMIPS
- 4GB RAM + 16 GB Flash
- 2 displays
- 2 cameras
- Wi-Fi 5.0, BT 4.1
- Qualcomm Technologies SoC

Key benefits

- Cockpit domain control unit with integrated modem
- The System Integrated Package (SIP) is an automotive-certified product
- Addresses EU Next Generation eCall
- Supports Android Auto 13

Use cases/target applications

- Cockpit (cluster and IVI)
- Telematics

Benchmarking

- Costs 30% less than non-integrated solutions
- Up to 25% reduction in development time

LeanDisplay

LeanDisplay complements Marelli's ProDisplay and EliteDisplay platforms as a scalable, entry-level infotainment or cluster screen conceived around three key pillars: affordability, design optimization and supply-chain localization.

Engineered for manufacturing efficiency, LeanDisplay delivers advanced local-dimming performance – achieving up to 1000 Nits luminance and a contrast ratio between 1,000:1 and 30,000:1 – while using 40% fewer components than comparable systems.

This reduction leads to a significant decrease in BOM costs, supporting streamlined assembly and improved manufacturability. Development times can be reduced by up to 25%.

Additionally, LeanDisplay's color gamut of 85% is competitive with leading LED systems and provides approximately 90% of the performance of OLED technology – without its higher cost and complex thermal-management requirements.
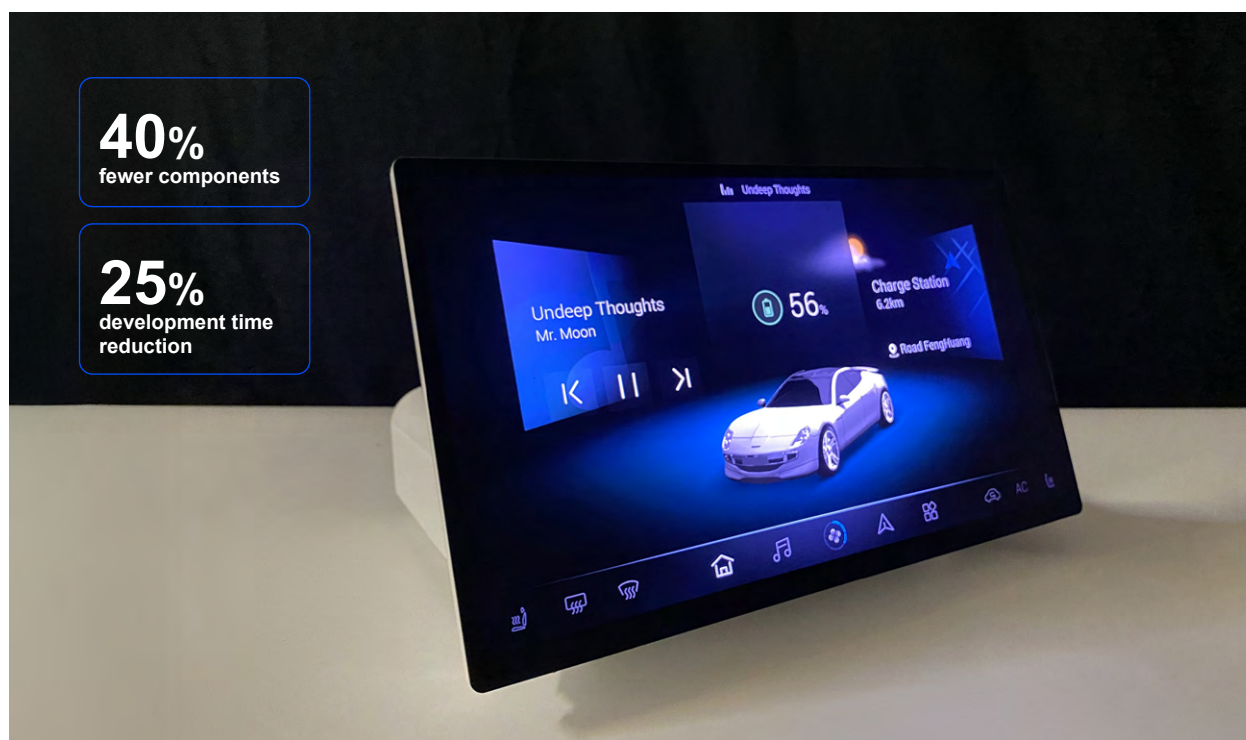
Benefits cascade from Marelli's scalable, optimized backlight technology. The LED count is reduced from the traditional 256 LEDs to just 48, while Marelli's proprietary lenses provide additional homogeneous light distribution without loss of performance.

An 80% reduction in LEDs additionally lowers power consumption and promotes wider hardware simplification – including PCBs and heat sinks – from a typical 25 components to just 15. Suppliers can therefore be consolidated, enabling a streamlined, more localized supply chain with enhanced sustainability.

The design also simplifies the overall display electronics architecture while using non-proprietary serializer protocols. Both reduce the electronics BOM by up to 40%.

Depending on the application, LeanDisplay's simplified design reduces the unit thickness from a typical 25 mm to 15-19 mm. This facilitates integration in space-constrained cabin zones such as the passenger instrument panel and rear-seat headrests. Additionally, the weight is reduced to just 600 g.

While hardware is standardized for cost and manufacturing efficiency, LeanDisplay supports software and user-experience customization to meet OEM-specific needs.

Offering advanced local-dimming capabilities in an affordable, slimline and sustainable package, LeanDisplay represents a compelling entry point to Marelli's scalable display family.

Need to know: LeanDisplay

Technical overview

- Luminance: 800-1000 Nits
- Contrast: from 1,000:1 to 30,000:1
- Color Gamut: 85%
- Thickness: from 15 mm to 19 mm
- Weight: 600 g

Key benefits

- Enhanced optical performance with reduced cost
- Scalable solution

Use cases/target applications

- Cluster Display
- IVI

Benchmarking

- 40% BOM reduction
- 60% reduction in parts compared to a standard display
- 300% contrast improvement
- Up to 25% reduction in development time

LeanHorizon

Marelli's LeanHorizon, positioned alongside ProHorizon and EliteHorizon, is the market's most cost-effective Head-Up Display (HUD), designed to replace the traditional instrument cluster behind the steering wheel. Its standardized, scalable platform accelerates time-to-market and provides structured pricing across entry, mid and premium segments – with flexibility to customize each application.

Designed with minimal components, LeanHorizon's simplified architecture reduces complexity and supports sustainable manufacturing.

A sleek "black blade" design is integrated at the top of the instrument panel. It projects TFT-based, high-contrast images onto the bottom edge of the windshield. The images remain clearly visible in all lighting conditions, including through polarized sunglasses.

Black Blade Design, TFT-based and High-Contrast Images

Dual-depth projection enables the prioritization of primary and secondary information – including Augmented Reality elements – at different depths on the windshield, making information easier for drivers to process.
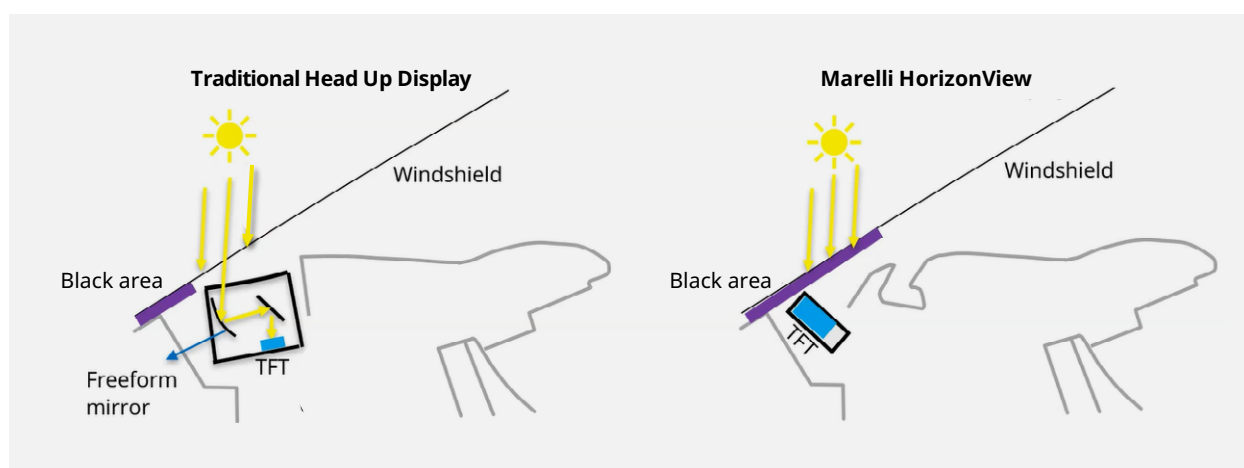
Need to know: LeanHorizon

Technical overview

- <1 liter system, eye box at 1.1 m by 400 mm x 50 mm for a single module
- Visibility requirement (ECE Regulation No. 125)
- Mass: 600-1000 g

Key benefits

- Good visibility with high-contrast images
- Keeps the driver's eyes focused on the road
- Scalable solution
- Highly flexible in-cabin configuration

Use cases/target applications

- Cluster (1 screen)

## LeanRide

LeanRide is an affordable platform embodying Marelli's continuous innovation in electronically controlled shock absorbers, keeping pace with the vehicle dynamics evolution. With a pre-developed foundation and simplified components, LeanRide reduces cost, weight and production cycle times, while actively advancing critical metrics – notably damping ranges in rebound and compression phases.

While LeanRide offers a cost-effective entry point for high-performance semi-active shocks, our EliteRide platform delivers optimal handling and unparalleled ride comfort with electronically controlled actuators that modulate each wheel in real-time.

Product spotlight: Smart Single Valve e-Shocks

Based on a patented semi-active shock absorber design, Smart Single Valve e-Shocks are the latest innovation on Marelli's LeanRide platform. These innovative shock absorbers employ a single electro-hydraulic external valve, which contributes to a typical cost reduction of up to 12.5% and weight savings up to 1.2 kg compared to dual-valve units.

Smart Single Valve e-Shocks achieve these savings while **providing an equivalent tuning range and comparable damping performance to dual-valve shock absorbers** – including **rebound force of over 6000 Newton (N) and more than 9000 N in compression**. The reduced compression performance typical of single-valve dampers is therefore eliminated.

Force at Peak Velocity Diagram of Smart Single Valve e-Shocks
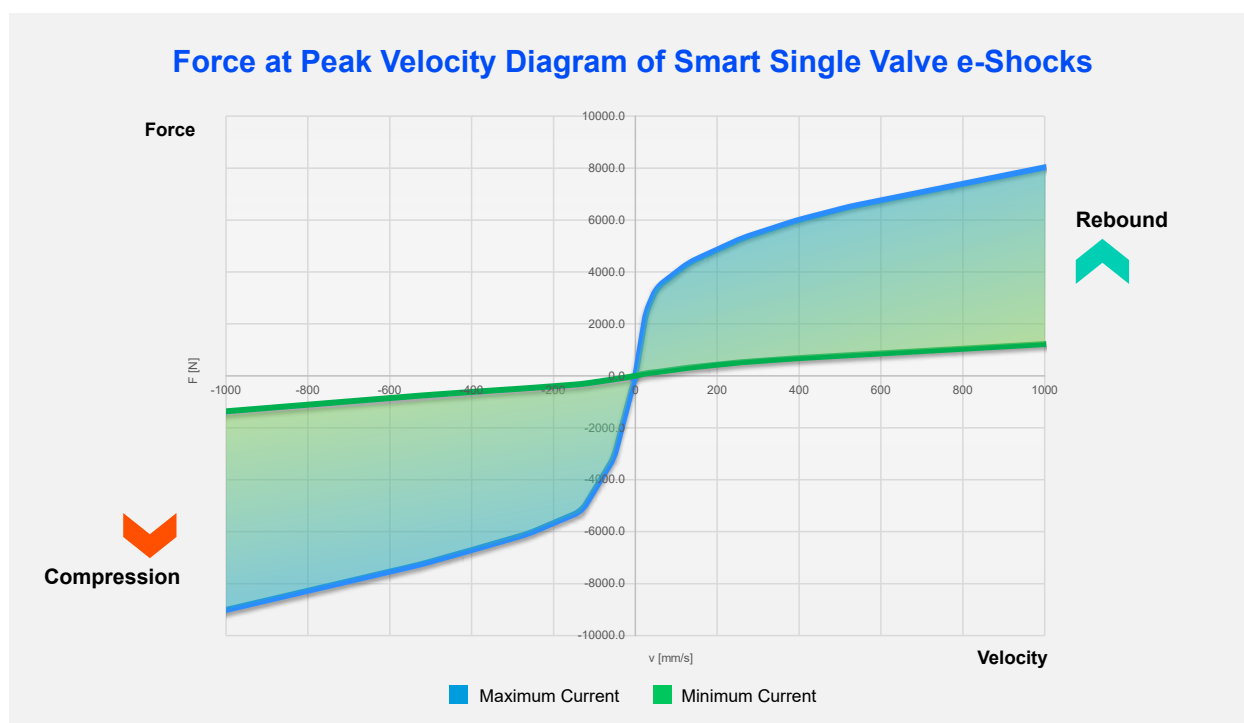
Optimizing the **tri-tube internal architecture** of the Smart Single Valve e-Shocks is key, with Marelli engineers using the piston area – rather than the piston rod – to generate compression damping. Depending on the application, a **100-200% improvement in compression performance** is achievable.
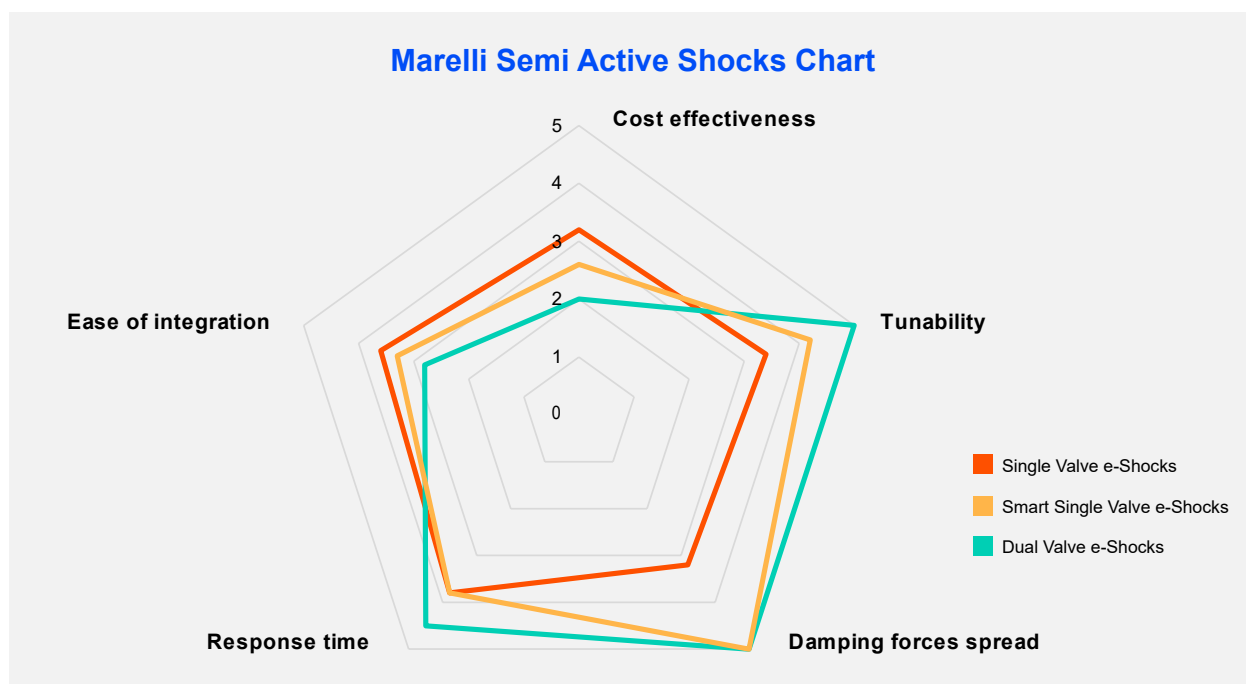
Marelli collaborates with your engineering teams to optimize the fully customizable external packaging specifications of the Smart Single Valve e-Shocks, including valve orientation.

100-200%
improvement in compression performance

Tri-tube internal architecture
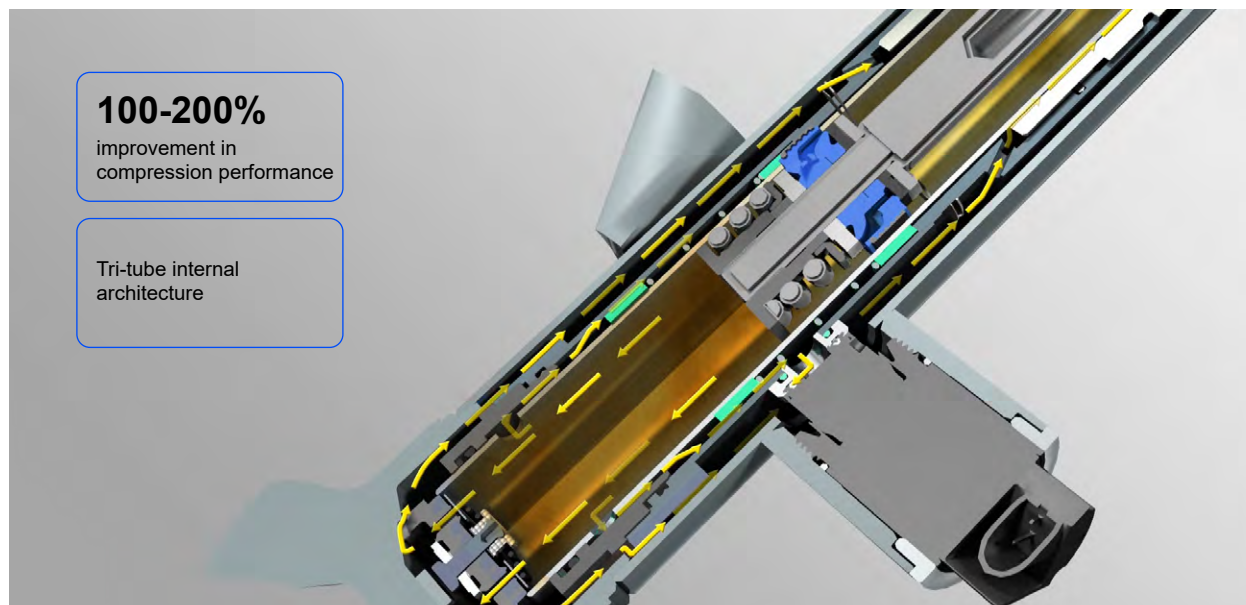
Only a software update is required to upgrade from Marelli's entry-level Single Valve e-Shocks to Smart Single Valve e-Shocks. The same single electrical connector is retained, while the sensor set, wiring harness, ECU and four external electro-valves are identical.

Compared with dual-valve alternatives, this facilitates faster production cycle times from SOP onwards and allows a choice of both Single Valve and Smart Single Valve e-Shocks across model lines with minimal alterations.

Adaptable to bespoke customer specifications and fully compliant with ISO and IATF standards, Smart Single Valve e-Shocks offer an affordable pathway to high-performance shock absorber technology.

Marelli Semi Active Shocks Chart

Legend:
- Single Valve e-Shocks
- Smart Single Valve e-Shocks
- Dual Valve e-Shocks

Axes: Cost effectiveness, Tunability, Damping forces spread, Response time, Ease of integration

Smart Single Valve e-Shocks

Need to know

Technical overview

- Tri-tube internal architecture
- Single external solenoid-operated e-valve with integrated connector
- Flexible external valve orientation
- 1 ECU
- ISO, IATF certified

Key benefits

- Up to 12.5% cost reduction
- Lower assembly times
- Fewer packaging constraints
- "Plug-and-play" upgrade over single valve shock absorbers
- Total weight savings up to 1.2 kg

Use cases/target applications

- Premium mid-size vehicles
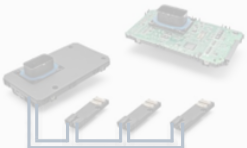
LeanEnergy

As battery technology advances, Marelli's new-generation Battery Management Control Unit (BMCU) addresses the increasing hardware and software complexity in energy management – building on expertise dating back to the pioneering 2010 Nissan Leaf.

The BMCU monitors the condition of battery cells to ensure safety, maximize driving range and prolong battery life. Marelli's solutions for Battery Management Systems (BMS) offer benefits such as reduced system complexity and cost with improved efficiency.

This new generation of BMCU is built on Marelli's scalable Energy platform – an approach designed to streamline development and accelerate time-to-market. The platform strategy is a core part of Marelli's innovation model, enabling automakers to quickly adapt to diverse performance and market requirements.

As illustrated below, our Energy platforms comprise three main product families – LeanEnergy, ProEnergy and EliteEnergy – with architectural variants tailored to specific needs. These solutions are co-developed in close collaboration with our Original Equipment Manufacturer (OEM) partners to meet market demands.

Marelli Energy Platform Portfolio

	LeanEnergy	ProEnergy	EliteEnergy
Architecture	Centralized / Distributed wired	Distributed wired / Distributed wireless	Distributed wired / Distributed wireless
System Voltage	400 V	Up to 1000 V	
SOC/SOH	Cell equivalent model		EIS + AI algorithm with high performance microcontroller
Platform	Microcontroller family, vehicle communication, battery monitoring ICs, I/O		
Custom	Mechanics (connectors, case) and PCB shape, customer-specific contents		

Marelli's approach leverages modular design principles, where foundational components such as the main MCU, communication lines and battery-monitoring integrated circuits are shared across platforms, ensuring consistency and efficiency. Meanwhile, mechanical components are crafted to remain bespoke, enabling customization that aligns with OEM-specific integration requirements.

By targeting up to 70% reusability in our design efforts, Marelli aims to achieve an overall 20-25% reduction in time-to-market and a 20% reduction in bill of materials costs compared to project-specific products, all while capitalizing on economies of scale.

This streamlined approach paves the way for the timely market readiness of energy management solutions.

Product spotlight: Centralized and Distributed Wired BMCU

Our LeanEnergy platform is an affordable, scalable solution for moderately sized battery packs. It is ideally suited for applications with up to 108 cells and a nominal voltage up to 400 V, including mild hybrids, plug-in hybrids, compact battery-electric vehicles and electrified motorbikes.

Available in either centralized or distributed wired architectures, the BMCU on our LeanEnergy platform is designed with a compact footprint and optimized Input/Output (I/O) to meet the specific requirements of mainstream and entry-level vehicles.

Key features of LeanEnergy include all standard battery management functions: State-of-Charge (SOC) and State-of-Health (SOH) calculations, thermal management, charge/discharge control, cell temperature and voltage monitoring, cell balancing, and comprehensive safety management. A seamless interface with the E/E architecture implements functions beyond core battery control, for example safety triggers in the event of an impact.

This cost-effective solution features a standard two-board configuration, enhancing integration simplicity and optimizing space utilization through its compact design.

Flexibility is offered via a set of predefined hardware options, while the electronic solution leverages a fixed microcontroller, chipset and functional drivers for maximum reliability. With design-intent prototypes available within a few months, the BMCU platform enables OEMs to benefit from reduced R&D investment and quick time-to-market with a proven, affordable solution for new electric vehicle programs. Digital twin virtualization can also fast-track design and validation.

Marelli's BMCU roadmap includes the introduction of a microcontroller-free architecture, in which the BMCU will transmit real-time cell data for processing in a zonal control unit. This approach is set to further reduce BMS complexity, cost and dimensions.
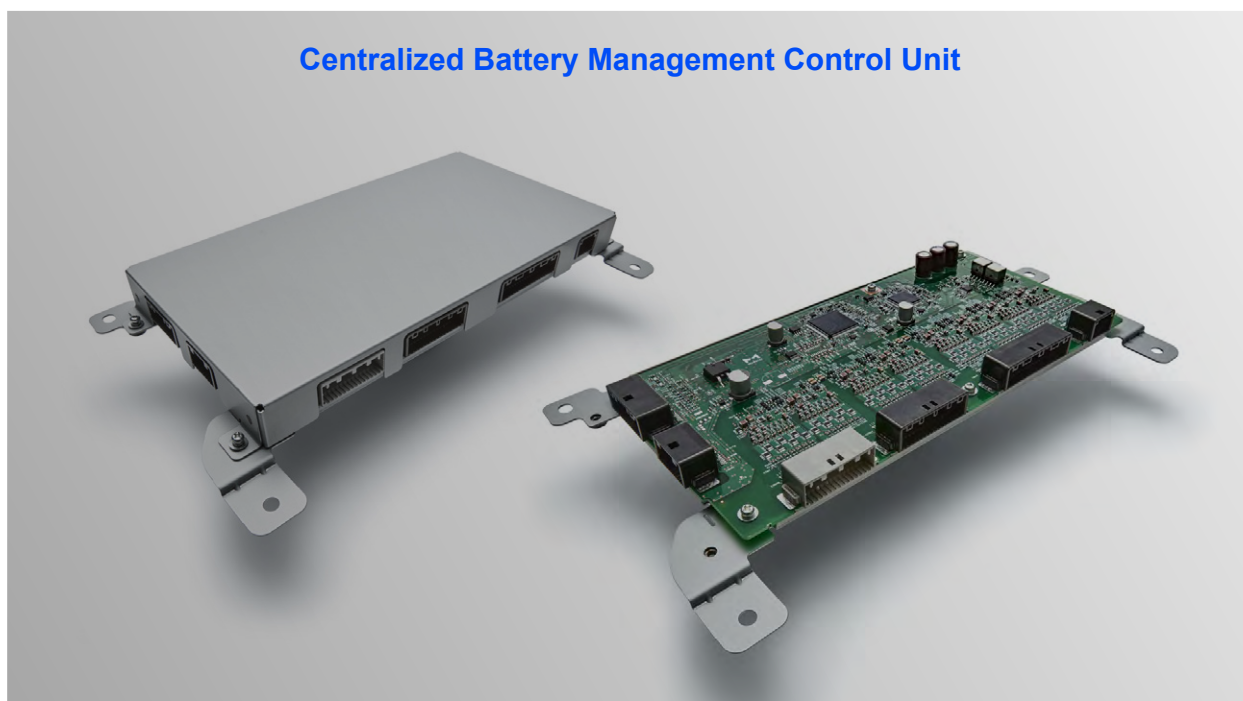
Centralized Architecture

In Marelli's centralized BMCU architecture, a single Battery Management Unit (BMU) is placed near the battery pack, and connects directly to the Cell Supervising Circuits (CSC). This design enables continuous monitoring and active balancing of voltage, temperature and current, for optimal performance.

Designed for small battery pack sizes up to 400 V and vehicle architectures with fewer battery packaging constraints, the centralized BMCU allows for shorter, simpler wiring harnesses. Where space allows, it is the most affordable BMCU solution.

Compact Architecture for Small Battery Packs
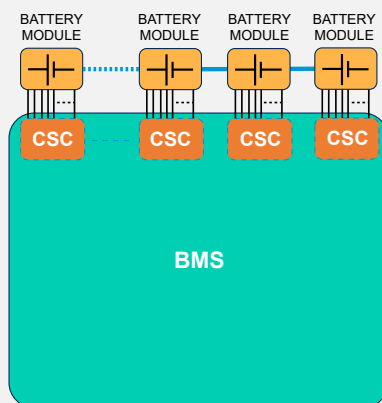
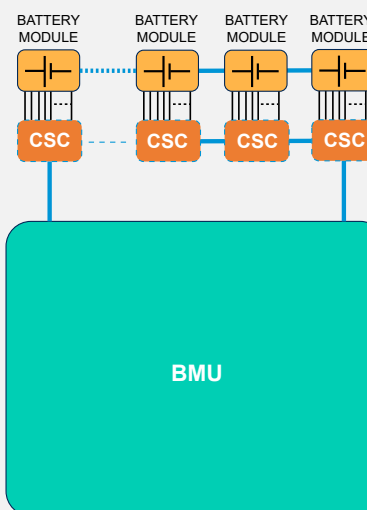**Centralized Battery Management Control Unit**

Distributed Wired Architecture

The Distributed Wired Architecture is optimized for space-constrained vehicle layouts, and for efficient scaling of different battery pack sizes and voltages.

The BMU can be packaged away from the battery pack, with cell monitoring and balancing delegated to modular CSCs mounted directly on battery-pack modules. This results in very short wiring between the CSCs and cells, with a longer wiring harness linking the CSCs to the BMU. A daisy-chain loop transfers data between the two.

Regardless of battery voltage, the BMU remains identical, with the required number of CSCs added or removed to meet pack specifications.

Modular Architecture with Configurable CSCs and Single BMU

Distributed Wired Battery Management Control Unit
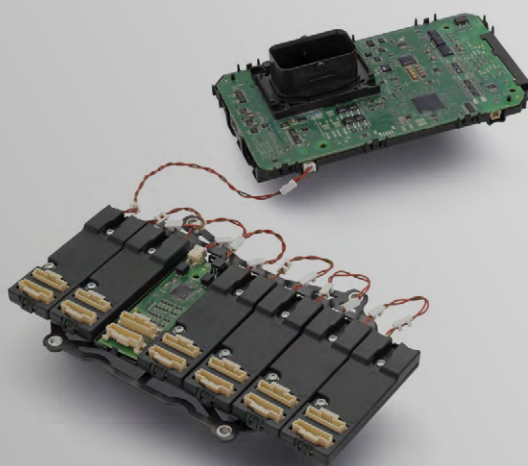
Need to know: Battery Management Control Unit

Technical overview

- Centralized or distributed wired architecture
- Centralized architecture manages up to 108 battery cells (400 V)
- Distributed architecture scales cell count through additional modular CSCs without BMU redesign
- 1x Infineon Aurix TC377 microcontroller
- Fixed-microcontroller electronic solution with dedicated chipset and functional drivers
- Optimized and customizable I/O for cost-sensitive vehicles
- Cell voltage, current and temperature monitoring
- Charge/discharge control and cell balancing
- Thermal management
- Battery State of Charge, Health and Power estimation
- High Voltage (HV) sensing and contactor control
- High Voltage Interlock Loop (HVIL) management
- Support for external current sensing
- Vehicle integration with E/E architecture for safety and system-level functions
- CAN communication
- Loss of insulation diagnosis
- ASIL D and AUTOSAR compliant
- A-Spice certification
- Regulatory-compliant cybersecurity management system
- Standard two-board configuration
- Choice of pre-defined hardware options
- Customizable connectors, case and PCB shape

Key benefits

- Affordable solution for entry-level and mainstream HEV, PHEV and BEV vehicles
- 20-25% reduction in time to market
- Minimizes cell degradation, maximizes battery life
- Estimates State of Charge, Health and Power to optimize performance and longevity
- Compact design, flexible installation
- Modular CSC approach for scalable voltage and cell counts
- Streamlined wiring and simplified vehicle integration
- Reduced R&D investment through platform reuse
- Rapid progression to design-intent prototypes

Use cases/target applications

- Cost-sensitive applications
- PHEV
- HEV
- Compact BEVs
- Electrified motorbikes

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LeanExhaust

LeanExhaust is Marelli's innovative, lightweight and low-cost exhaust solution, developed in direct response to OEM demand for weight and volume reduction in hybrid vehicles.

Its modular component set – the Dual-Layer Converter and Micro-Hole Design Muffler – ensures products can be brought to market faster and are easily adapted to accommodate battery housings, simplifying the vehicle design phase.

Dual-Layer Converter

45%
Weight reduction

46%
Volume reduction

Micro-Hole Design Muffler

27%
Weight reduction

15%
Volume reduction
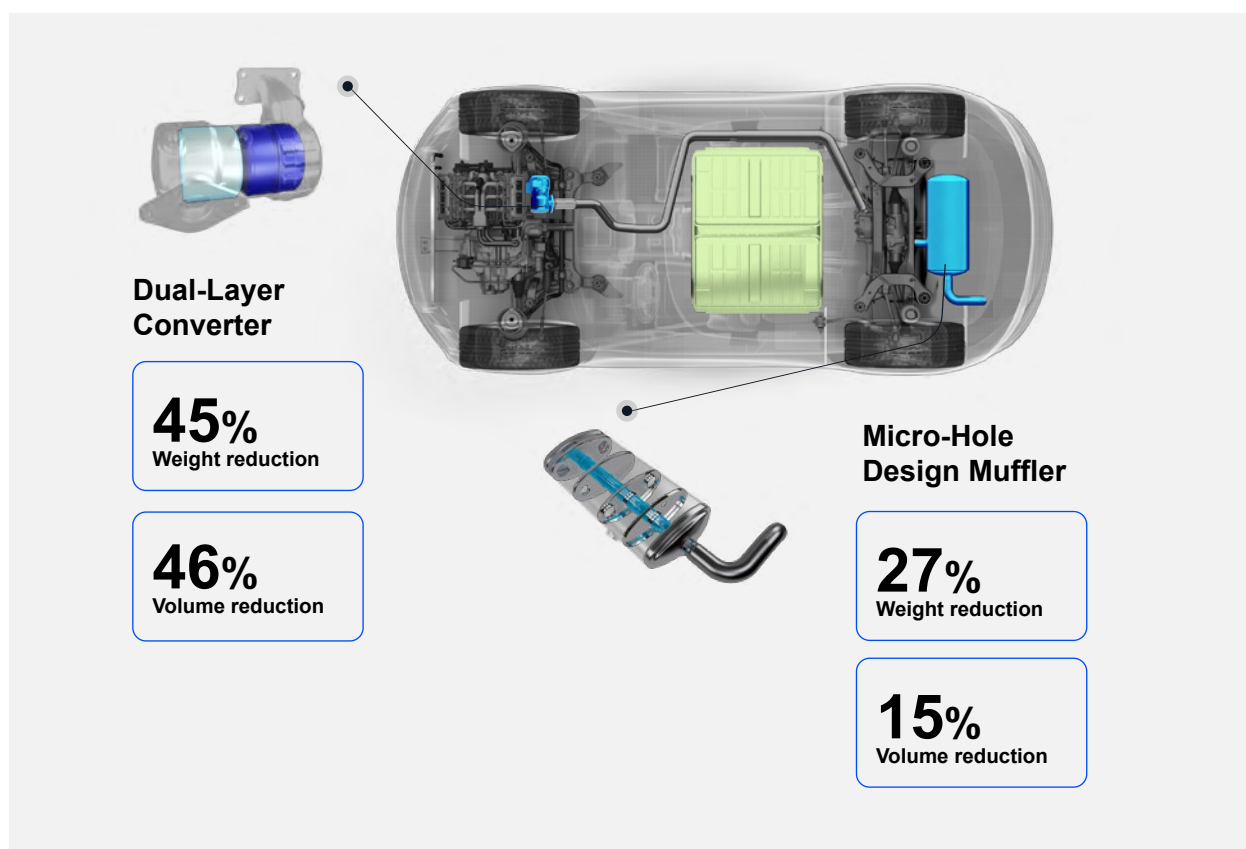
Together with thinner-gauge stainless steel, LeanExhaust's innovations contribute to a 15.6 kg weight reduction compared to conventional exhaust systems, while exceeding or matching emissions-control and noise-reduction performance.

Additional gains include cost reductions of up to 52%, with a 47% decrease in CO_2 emissions compared with current production systems.

PRODUCT SPOTLIGHT

Dual-Layer Converter

The Dual-Layer Converter is an advanced closed-coupled architecture **that combines a Three-Way Catalytic Converter (TWC) and Gasoline Particulate Filter (GPF) in one compact package.**
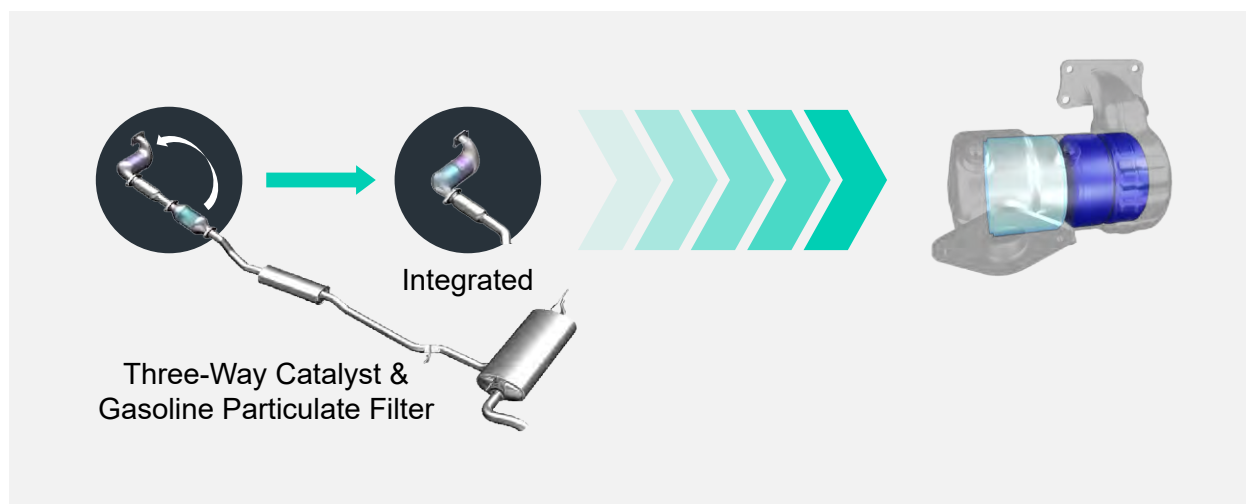
It offers a 45% weight reduction and 46% more compact packaging compared to similar systems.

Compact packaging allows the Dual-Layer Converter to be easily integrated close to the exhaust manifold, helping the catalyst rapidly reach ideal operating temperature following cold-start. The combined temperatures of the TWC and GPF, together with a heat-insulating dual-wall design, retain heat for longer during pure-electric driving. Engine calibration strategies to heat the catalyst can therefore be eliminated, directly benefiting emissions performance and fuel efficiency.

Packaging is flexible, with both the flange position and catalyst angle adaptable on-demand.

Need to know: Dual-Layer Converter

Technical overview

- Integrated, close-coupled catalyst
- Three-way catalyst & gas particulate filter
- Flexible flange position
- Flexible catalyst angle

Key benefits

- Rapid warm-up
- Meets emissions regulations, including Euro 7 and US Tier 4
- Compact packaging, maintains temperature during EV drive
- Flexible, space-saving design

Use cases/target applications

- Hybrid vehicles with central battery packs

Benchmarking

- 45% weight reduction
- 46% size reduction

PRODUCT SPOTLIGHT
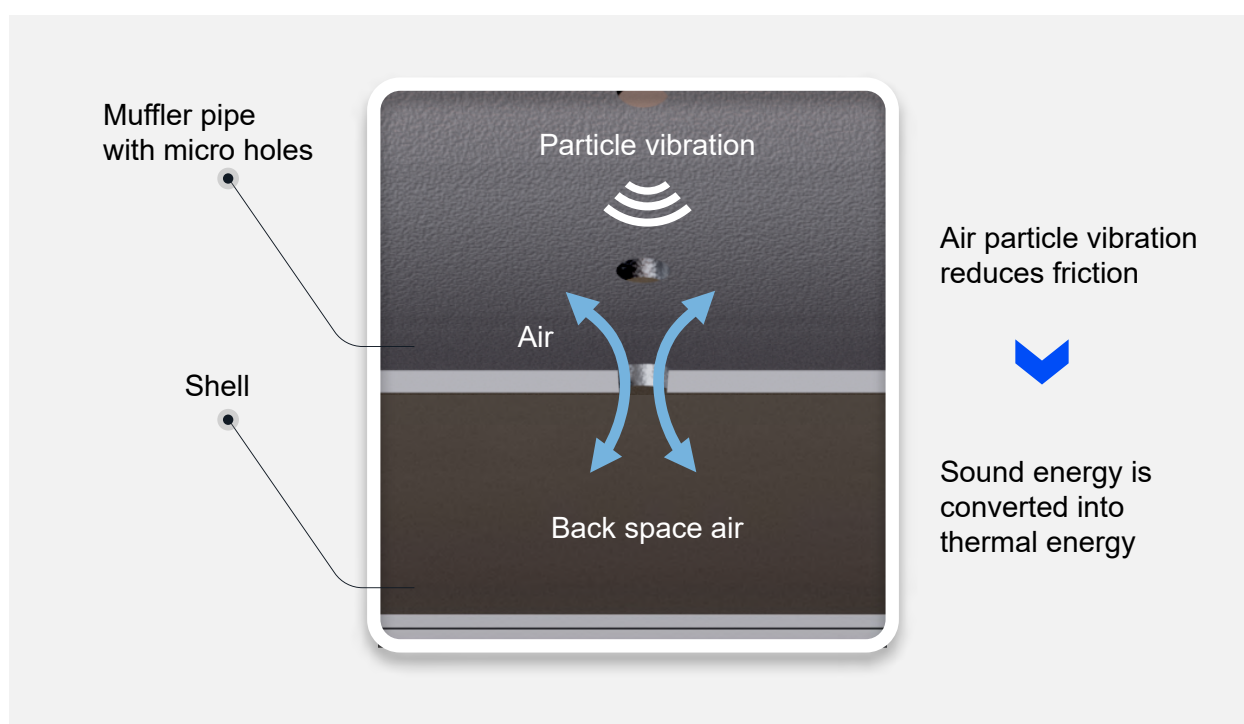
Micro-Hole Design Muffler

By eliminating the non-recyclable glass wool of standard mufflers, the Micro-Hole Design Muffler reduces weight by up to 27% and size by up to 15% while achieving equivalent airflow noise-reduction performance.

Constructed from thin, highly durable materials and inspired by the noise-absorbing sound barriers of urban Japanese highways, the Micro-Hole Design Muffler **integrates a micro-perforated central tube with a series of transverse plates.**

Microperforated Central Tube Integrated with Transverse Plates

This promotes air-particle vibration inside the muffler casing, converts exhaust gas energy into thermal energy and suppresses exhaust sound.

Muffler pipe with micro holes

Shell

Particle vibration

Air

Back space air

Air particle vibration reduces friction

Sound energy is converted into thermal energy

Need to know: Micro-Hole Design Muffler

Technical overview

- Micro-perforation tube

Key benefits

- Meets hybrid vehicle performance requirements
- Lightweight, low-cost and achieves sound reduction
- Thin material
- Fewer components
- Free from glass wool

Use cases/target applications

- Hybrid vehicles

Benchmarking

- 27% Weight reduction
- 15% size reduction

Innovation @Speed.

At Marelli, we believe speed is the new currency in automotive. In a world defined by shifting consumer expectations, rapid tech evolution, and intense competition, getting to market faster isn't just an advantage — it's essential.

Marelli empowers automakers to move with speed and purpose. As a trusted technology partner, we offer scalable platforms, software-defined vehicle enablement tools, production-ready solutions, and fast innovation cycles designed to shorten development timelines and unlock early market opportunities.

We enable speed-to-market in four distinct ways:

- **Platform Products** – Tiered, modular hardware and software solutions engineered for speed, scalability, and smart customization.
- **Software-Defined Vehicle Enablement Tools** – Supporting future-focused E/E architectures with flexible hardware, decoupled software, and cloud virtualization tools that accelerate development.
- **Ready-to-Offer Technologies** – Proven, production-ready innovations built for immediate integration and impact.
- **Minimum Viable Product Innovation** – From concept to working prototype in as little as 90 days, our agile innovation process enables co-creation with automakers for rapid product development.

This paper illustrates how Marelli's Lean platform products accelerate time to market through modular, cost-effective design, pre-validated components, and streamlined integration.