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# X-in-1 Electric Drive Unit Platform to Simplify Function Integration in BEV

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**Executive Summary**

Integration of multiple power conversion and control functions into the traction inverter of an Electric Drive Unit (EDU) is a pivotal step towards developing more efficient, compact, and cost-effective electric vehicles. Embedding subsystems such as the DC/DC converter, on-board charger (OBC), and battery management system (BMS) directly into a unified X-in-1 EDU, the overall vehicle power electronics and software architecture is significantly optimized. This approach yields several advantages, including reduced component count, streamlined thermal management, lower weight, and decreased volume. In turn, these benefits translate to shorter development cycles, lower costs, and improved system efficiency for next-generation Battery Electric Vehicles (BEVs). The paper introduces InfiMotion's L40X EDU platform – a scalable 7-to-12-in-1 solution – and explores its hardware/software integration, system architecture, and demonstrated improvements in powertrain performance. Comparative analysis against other integrated EDU platforms is provided in an anonymized manner.

*Keywords: Electric Drive Unit (EDU); X-in-1 integration; Power electronics; Software-defined vehicle; BEV powertrain*

## 1 Introduction

InfiMotion Technology develops, manufactures, and sells high-performance electric drive units for fully electric vehicles, addressing the whole value chain including in-house production of software and key components. The company was founded in 2021 in Wuxi, China, with lead investors such as Geely Auto, Lotus, and Ningbo Luma. It has since grown to over 1700 employees worldwide, with R&D centers in Göteborg, Sweden and Wuxi, China. The InfiMotion team collectively has delivered over 4 million EDU units to date (hundreds of thousands in Europe), and its first new high-performance integrated EDU products are now in high volume production.

Electric vehicles (EVs) are transforming the automotive industry, driven by sustainability goals and regulatory mandates. A core enabler of this transformation is the Electric Drive Unit (EDU), which combines the electric motor, transmission (reducer), power electronics, and control software into a unified module. The shift from traditional distributed components to highly integrated solutions is crucial for achieving higher efficiency, lower cost, and accelerated time-to-market. The **L40X platform** has been developed to meet these evolving needs by offering a scalable and modular EDU architecture capable of integrating numerous vehicle subsystems into a single unit.

Recent research emphasizes that modular integrated EDUs can enhance powertrain efficiency and reduce vehicle complexity [1][2]. In particular, the transition from standalone on-board chargers (OBCs), DC-DC converters, and inverters to integrated “X-in-1” architectures are now recognized as best practice among forward-looking OEMs. This paper introduces the L40X electric drive unit platform, developed in collaboration with a global OEM, which enables integration of **7 up to 12 functions** into a compact package. By consolidating many electrical and electronic functions, the L40X yields substantial improvements in space utilization, weight, and cost at the vehicle level, while maintaining high performance and flexibility.

## 2 BEV Development Challenge

OEMs face strategic choices when designing EV platforms, particularly around the classic “make or buy” decision for key powertrain components. Full vertical integration in-house offers complete control over the value chain but demands significant time and capital investment. Conversely, relying on external suppliers can simplify initial development but may lead to system fragmentation, integration difficulties, and software incompatibilities down the line. Functions such as the OBC, DC/DC converter, Motor Control Unit (MCU/inverter), and BMS are common across all BEVs, which creates an opportunity for standardization at the platform level. Each manufacturer, however, must also address unique requirements for packaging, thermal management, and vehicle control interfaces.

Research indicates that integrating these subsystems into a unified EDU can reduce overall development time by up to **30%** and yield cost savings on the order of **15–20%** [3][4]. Furthermore, customers expect rapid time-to-market and frequent feature updates in the era of software-defined vehicles. This imposes new challenges on OEMs, demanding software expertise and electrical integration strategies that were less critical in traditional vehicle programs. Key strategic questions arise, for example: **How can one EDU platform cover as many vehicle applications as possible? How can integration be optimized to reduce total vehicle cost and complexity? How to keep pace with fast-evolving EV technology without prohibitive re-development for each model?** These challenges are prompting OEMs to seek more **integrated EDU solutions** as an answer.

There are broadly three approaches to address this integration challenge:

- **Full in-house vertical integration:** Some market-leading OEMs design and manufacture the entire EV powertrain stack internally, achieving tight integration at the cost of long development cycles and repeated heavy investments. Even in this scenario, overall vehicle integration (e.g. packaging multiple units) remains complex.
- **Selective make-or-buy:** Many OEMs build certain components (e.g. motor or inverter) in-house and purchase others. This reduces some investment but leaves the burden of system integration on the OEM. Ensuring optimal system efficiency and managing software updates across multi-supplier components can be difficult.
- **Adopt pre-integrated “X-in-1” EDUs:** An increasingly attractive option is to source an already integrated multi-function EDU from a specialist supplier. This approach can dramatically shorten development time and upfront investment, as a single unit comes pre-validated with multiple functions. The trade-off is some dependency on the supplier’s roadmap and interfaces, at least until industry standards for such integrated units mature. However, with growing EV volumes, such

integrated solutions become economically compelling from the start, since development and production costs are amortized over many customers.

## 3 Integration Enablers and Software Architecture

A platform like L40X is made possible by several **integration enablers** in both hardware and software. InfiMotion's development approach leverages full vertical integration: critical hardware components (the inverter/MCU, OBC, DC-DC converter, etc.) are designed to physically co-exist in one housing, and software functions for these components are centralized on a powerful single MCU. This unified architecture improves packaging and eliminates many duplicate components, while also enabling advanced software-based features such as coordinated torque vectoring, integrated regenerative braking control, and holistic thermal management optimization across the powertrain.

The L40X development pipeline follows automotive industry standards to ensure quality despite high integration. In-house software development adheres to AUTOSAR architecture and standards like ISO 26262 (functional safety) and up to ASPICE Level 3 (software process maturity). A **continuous integration (CI)** process employing cloud-based build and test infrastructure allows rapid software iterations. New software functions or updates are validated through Model-in-the-Loop (MIL), Software-in-the-Loop (SIL), and Hardware-in-the-Loop (HIL) testing before deployment. This rigorous toolchain (illustrated in *Figure 1*) ensures that even as multiple applications share the same controller, reliability and real-time performance remain uncompromised. Studies have shown that a centralized, modular software architecture can enhance overall system reliability and simplify over-the-air (OTA) update strategies for EVs [5].

**Software integration** is facilitated by the fact that a traditional 3-in-1 EDU (motor + inverter + gearbox) typically uses only a fraction of modern controller capacity. In L40X, the main MCU's processing headroom (with the core motor control consuming under ~30% CPU in nominal conditions) is utilized to run additional control tasks for charging, DC/DC conversion, battery management, etc. The software is designed with a real-time operating system and clear scheduling domains, so that high-priority traction control tasks are isolated and never interrupted by auxiliary functions. This approach effectively creates a **domain controller** within the EDU, capable of handling powertrain, charging, and even some vehicle-level functions using a single piece of hardware. The result is fewer separate Electronic Control Units (ECUs) in the vehicle and more efficient use of computational resources. All integrated software components (whether developed in-house or integrated from third parties) undergo the same CI validation process, ensuring compatibility and system stability.

On the hardware side, **electrical integration** is achieved through a common high-voltage DC bus structure within the EDU that ties together the inverter, OBC, and DC/DC converter. The L40X design uses integrated busbars and a unified housing to minimize cable lengths and connectors between these components, thereby reducing resistive losses and electromagnetic interference. A shared cooling system within the EDU handles the thermal loads of the motor, inverter, charger, and converter simultaneously, which simplifies the vehicle's overall cooling circuit. This consolidated thermal management, combined with careful isolation design, allows the different subsystems to operate efficiently without overheating or mutual interference.

Innovative integration topologies from recent research have also informed the L40X architecture. For example, advanced **integrated charger** concepts use the traction motor and inverter as part of the charging circuit, essentially repurposing the motor windings as filter inductors during grid charging. Such approaches can eliminate standalone OBC inductors and further reduce component count. While the L40X's OBC is a dedicated unit, the platform's software-centric control means similar functional integration (e.g. using the propulsion inverter for charging) could be explored with software updates in future iterations. In general, the vertical integration of hardware and software in L40X provides a foundation to incorporate new functions (such as vehicle-to-grid interfaces or novel control algorithms) more readily than a traditional distributed design.

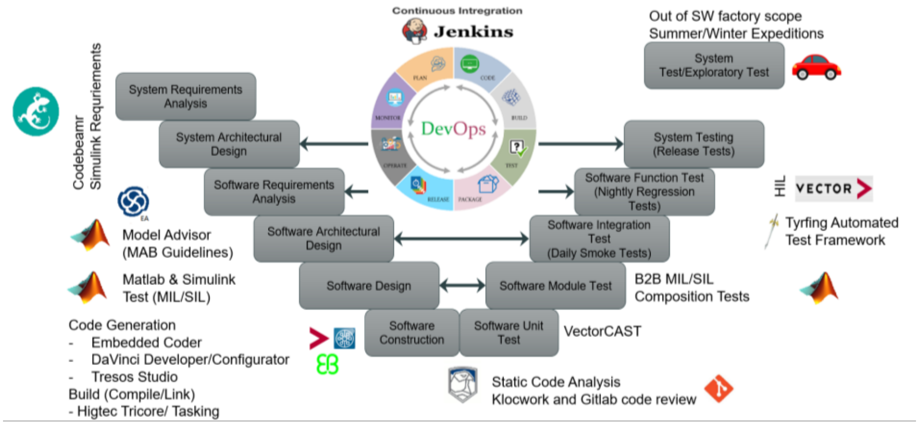


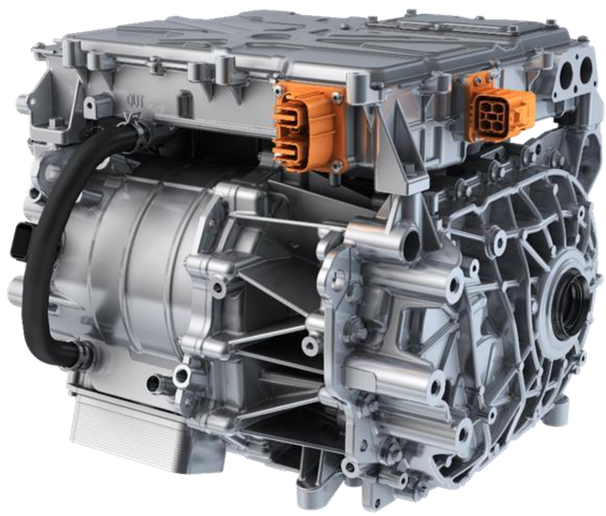

*Figure 1: Software development and integration toolchain for the L40X platform (Continuous Integration framework with MIL/SIL/HIL testing).*

## 4 L40X X-in-1 Platform

The L40X platform was developed in cooperation with a major OEM seeking to capitalize on the benefits of higher integration in its next-generation BEVs. *Figure 2* shows an assembled L40X drive unit. The platform is modular and scalable: **versions L401 through L406** correspond to configurations ranging from **7-in-1 up to 12-in-1** integration, tailored to different vehicle requirements. At minimum, even the 7-in-1 configuration integrates the core traction drive components and key power conversion units. At maximum integration, the unit consolidates virtually all major low-voltage and high-voltage control functions except the battery pack itself. The core hardware and software components integrated in the L40X platform include:

- **Permanent Magnet Synchronous Motor (PMSM):** High-speed 3-phase electric traction machine (400 V class) providing the primary drive torque.
- **Reducer (Gearbox):** Layshaft-style two-stage reduction gear, single-speed, optimized for high input speeds and compact packaging.
- **MCU (Motor Control Unit):** Inverter and motor controller using high-power IGBT modules (in this 400 V implementation) to drive the PMSM. This also serves as the central processing unit for integrated functions.
- **OBC (On-Board Charger):** Bi-directional 3-phase AC charger, capable of vehicle-to-grid (V2G) and vehicle-to-load (V2L) operation, integrated within the EDU housing.
- **DC/DC Converter:** High-voltage to 12 V DC converter supplying the low-voltage system, replacing a separate DC/DC box.
- **PDU (Power Distribution Unit):** Manages distribution of power within the high-voltage system and includes protection devices; integrated into the EDU instead of a separate junction box.
- **BMS (Battery Management System), LV/HV:** The battery management for both low-voltage (auxiliary battery) and high-voltage (traction battery) systems, integrated as software modules (and necessary sensing hardware) within the EDU.
- **VCU (Vehicle Control Unit):** Vehicle-level control functions and sensors interfacing (often OEM-specific). When included, these are run as software on the EDU’s MCU, effectively absorbing the car’s central drive control.
- **TMS (Thermal Management System):** Monitoring and control of thermal loops (coolant pumps, HVAC interactions) related to the powertrain. Key thermal management logic is implemented in the EDU, simplifying coordination between motor, inverter, and battery cooling.
- **WSC (Wheel Slip Control):** Integration of traction control or wheel slip control algorithms at the drive unit level. This can act in conjunction with the ABS/ESP to modulate torque directly for stability and traction.

- **EVCC (Electric Vehicle Communication Controller):** Manages communication for external charging (e.g. PLC communications for EU DC fast charging standards), embedded into the EDU electronics.



*(Figure 2: The L40X integrated EDU platform. This compact unit integrates e-machine, transmission, inverter, charger, DC/DC, and multiple control systems in one housing.)*

Production of L40X EDU units began in May 2024, and as of the end of 2024 the manufacturing capacity reached ~30,000 units per month. This indicates that the platform has transitioned from development into volume deployment, underscoring the practicality of such high integration in a mass-production context.

## 4.1 Space and Weight Efficiency

Integrating multiple hardware and electronic functions into a single EDU yields substantial **space and weight savings** at the vehicle level. In the L40X platform, the elimination of separate enclosures, mounting brackets, and cable harnesses for components like the OBC, DC/DC, and PDU results in a total volume reduction of approximately **5 liters**, which is roughly an **8%** decrease in powertrain packaging volume. Similarly, the consolidated unit is about **3 kg** lighter than an equivalent collection of separate components, corresponding to roughly a **13%** weight reduction for the powertrain assembly. These improvements were achieved without compromising performance by carefully designing shared structures (for example, using the EDU housing as a common enclosure for all components) and avoiding duplication of support hardware.

By consolidating components, the design **eliminates many redundant elements** – separate control boards, multiple fluid coolers, extra connectors and cabling, and housing materials – that standalone systems would each require. This not only simplifies mechanical design but also removes points of inefficiency (for instance, long high-voltage cables and multiple conversion stages). The net effect is an improvement in overall system efficiency due to reduced electrical losses and a lighter powertrain to propel.

Some specific benefits of the space optimization include:

- **Improved Vehicle Design Flexibility:** A more compact base EDU allows manufacturers greater freedom in vehicle layout. The L40X's compact footprint makes it particularly attractive for vehicles where space is at a premium (e.g., compact cars), allowing integration of high-performance components without encroaching on cabin or cargo volume.
- **Simplified Thermal Management:** Consolidating subsystems in one physical unit lets engineers implement a unified cooling loop. This reduces the complexity of hoses, pumps, and heat

exchangers needed. In the L40X, a single coolant circuit can be used to cool the motor, inverter, OBC, and DC/DC, whereas a less integrated design might require two or more separate cooling loops. A single integrated thermal management system is easier to package and can be more efficient, as waste heat from one component (e.g., the inverter) can be more readily distributed or used to warm another (battery or cabin) if needed. Overall, integration helps optimize thermal conditions and potentially reduces the total cooling system size.

An **exploded view of the L40X** (see *Figure 3*) illustrates how these components are packaged tightly together in one housing while maintaining serviceability. By removing extra enclosures and interconnecting cables, the design achieves a cleaner layout. In addition to the measured weight and volume savings, the modular integrated design is expected to support faster vehicle integration cycles (e.g., quicker installation on the assembly line and fewer unique mounting parts), though this benefit is still being quantified in ongoing real-world vehicle programs. Initial benchmarking indicates that L40X's packaging efficiency places it among the top quartile of current-generation EDUs in terms of power density (kW per liter of volume).

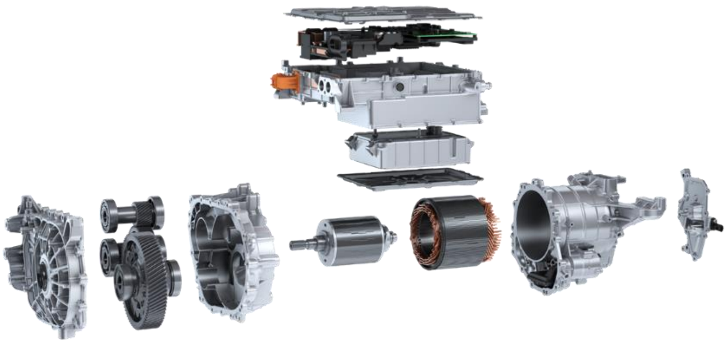


*Figure 3: Exploded view of the L40X EDU, showing the integrated motor, gearbox, power electronics, and auxiliary components in a single housing.*

## 4.2 Cost Reduction

A key motivation for X-in-1 integration is **cost reduction** at both component and system levels. The L40X platform demonstrates on the order of **20% cost reduction** in the EDU and related powertrain components, compared to a conventional setup of separate units. Several factors contribute to this cost efficiency:

- **Reduction of Components:** By integrating the DC/DC converter, OBC, PDU, etc., the need for separate housings, mounting hardware, high-voltage connectors, and lengthy cables is greatly decreased. Each eliminated connector or harness not only saves material cost but also improves reliability. Fewer separate electronic control units mean fewer expensive PCB assemblies and less duplicated processing hardware. In essence, multiple functions share common resources (one housing, one controller, one cooling system), leading to material savings.
- **Streamlined Manufacturing:** With fewer individual parts, the manufacturing process becomes simpler. Instead of assembling and testing, for example, three or four distinct boxes (motor/inverter, charger, DC/DC, PDU) and then integrating them in a vehicle, a single integrated unit is assembled and tested as one. This consolidation can reduce labor hours and tooling complexity on the production line. Moreover, logistics and supply chain overhead are reduced – there are fewer part numbers to procure and track, and a single unit can be shipped and installed in one go.
- **Economies of Scale:** The L40X platform is designed as a common solution that can cater to multiple vehicle models and even different OEMs (with minimal customization). This means production volumes for the core unit are higher than any one model alone would demand,

improving economies of scale. As noted, by late 2024 the L40X production ramped up to ~30k units per month, which drives down unit costs for components and manufacturing.

The cost savings are especially relevant for budget-sensitive EV segments. A 20% cost reduction in the EDU can significantly help automakers meet pricing targets for entry-level EVs without sacrificing functionality. Furthermore, integrated EDUs simplify the **bill of materials** for the vehicle – there are fewer suppliers and contracts to manage, and potentially lower warranty and service costs due to the reduction in parts and connectors (which are common failure points). From a life-cycle perspective, the integrated approach also eases maintenance and part replacement; for example, a single unit can be stockpiled as a service part instead of multiple modules.

It should be noted that achieving these cost benefits required careful up-front engineering to ensure that integrating functions did not lead to excessively complex design or expensive components. The L40X uses a **modular internal design** such that subcomponents (like the charger or DC/DC module) are built onto a common platform but could be individually replaced or upgraded. This modularity helps avoid cost pitfalls that can come with integration (such as scrapping a whole unit if one function fails). In summary, by thoughtful design, the L40X realizes significant cost advantages, making highly integrated EDUs economically attractive in addition to their technical merits.

## 4.3 Enhanced Software Integration

Beyond hardware, the L40X platform exemplifies **enhanced software integration**, wherein multiple control functions are implemented as software on a single MCU. This approach provides several key benefits to functionality and performance:

- **Increased Computational Efficiency:** Consolidating multiple control algorithms (for motor drive, charging, DC/DC conversion, thermal management, etc.) onto one high-performance controller allows the utilization of spare processing capacity that would be idle in a single-purpose ECU. The L40X's Motor Control Unit, for instance, is sized to handle not only real-time motor control but also additional tasks. Leveraging the underutilized MCU capacity eliminates the need for additional processor units, thereby reducing both cost and latency of communication between separate controllers.
- **Faster Software Updates and Feature Deployment:** With a centralized software architecture, over-the-air (OTA) updates and upgrades become simpler. There is only one firmware package (or a tightly integrated set) to update for the EDU, rather than coordinating updates across multiple independent ECUs from different suppliers. This means new features—such as improved torque management algorithms or charging profiles—can be deployed more quickly and consistently across the system. The continuous integration pipeline in development ensures that even frequent software releases are rigorously tested, enabling **agile software upgrades** without compromising safety.
- **Improved System Diagnostics:** An integrated software system can monitor and cross-reference data from what used to be separate domains. For example, the L40X's unified controller has access to motor, inverter, and charger data in one place. This enables more comprehensive diagnostics and prognostics. If there is an issue in charging performance, the system can correlate it with motor/inverter temperature data or DC link voltage behavior to pinpoint root causes. A centralized data log from the EDU provides a holistic view of powertrain health, simplifying troubleshooting and maintenance.

The software integration in L40X also maintains compliance with critical industry standards. By using an AUTOSAR-based architecture, the platform ensures modularity and reusability of software components. Safety-critical functions adhere to ISO 26262 (ASIL requirements), meaning that even though many functions run on one MCU, they are developed with freedom-from-interference and robust fail-safe mechanisms. Cybersecurity is addressed through a unified approach as well—rather than securing multiple devices, one can focus on hardening the single integrated controller gateway.

## 4.4 Performance and Efficiency Optimization

One might question whether combining so many functions could introduce compromises in performance or efficiency, but the L40X platform demonstrates that **powertrain efficiency** can be maintained or even enhanced through integration. Empirical testing of the 3-in-1 core of L40X (motor, inverter, gearbox) shows a **peak efficiency of ~94%** at nominal voltage (360 V) for the drive unit, which is on par with or better than state-of-the-art standalone EDUs based on IGBT power modules. Over standardized driving cycles, the fully integrated L40X achieves high efficiency as well – for example, a measured **90.0% system efficiency** over the China Light-Duty Vehicle Test Cycle (CLTC) has been reported for a domain-controlled L40X unit. These figures indicate that the presence of additional integrated functions does not significantly degrade the efficiency of the core traction system. Efficiency benchmarks place the L40X among the top quartile of current-generation EDUs [6]

In fact, integration can **improve certain efficiency aspects**. With shorter cable paths and consolidated power electronics, electrical losses due to resistance and conversion steps are reduced. In a conventional architecture, power might flow from the battery to an inverter, then through cables to a separate DC/DC converter, and through more cables to the 12 V system. In L40X, these stages are co-located, and the high-voltage bus structure is optimized to feed both the inverter and DC/DC with minimal distribution loss. The elimination of multiple connectors and the improved electromagnetic compatibility design also mean less energy is wasted as heat in interconnections.

From a control standpoint, having all functions in one unit allows for **coordinated control strategies** that can boost efficiency. For example, during regenerative braking, the L40X can intelligently balance the motor regen current, DC/DC operation, and battery charging acceptance to maximize energy recovery. Similarly, thermal management algorithms can pre-emptively limit or redistribute power among components to keep each in its optimal efficiency band (for instance, reducing inverter switching losses by adjusting cooling or switching frequency dynamically when the OBC is active and heating the system). These holistic optimizations are possible only when the subsystems are tightly integrated and share data in real time.

It is also instructive to compare the L40X's efficiency with other integrated EDU platforms in the industry. Published figures for some other X-in-1 drives (with 7–10 functions integrated) show overall system efficiencies in the range of ~89–92% [8], which aligns well with L40X's performance. In other words, despite integrating up to 12 functions, L40X remains competitive in efficiency with the best-in-class integrated drives available. Continuous improvements are being made; for instance, the use of silicon carbide (SiC) MOSFETs in future 800 V variants of the platform is expected to further improve inverter efficiency and reduce switching losses.

Finally, high integration can also improve **transient performance**. The L40X's single controller can react to events (like a sudden torque request or a voltage dip) in a coordinated fashion across subsystems. This means, for example, that when the driver demands a quick acceleration, the inverter and motor respond immediately while the DC/DC temporarily idles (to prioritize traction power), and the entire system manages the voltage to avoid any drop that could reset electronics. Such dynamic coordination enhances the vehicle's responsiveness and robustness, showcasing that integration, when properly engineered, enhances not just packaging but the driving performance and efficiency of the EV powertrain.

## 4.5 Flexibility and Scalability

A major advantage of a platform approach to EDUs is **flexibility across vehicle segments** and ease of scalability. The L40X platform was designed with modularity in mind so that it can be configured for a range of applications from small passenger cars to light commercial vehicles, all using common architecture. The platform supports different levels of integration (7-in-1 through 12-in-1) as needed by the OEM or vehicle program. This adaptability reduces the need for extensive redesign when targeting different vehicle types:

- **Rapid Time-to-Market:** An OEM can adopt the L40X EDU in various models with minimal changes, drastically shortening development cycles for each new EV. For example, if a manufacturer wants to introduce both a compact car and a mid-size SUV on the same technology base, the L40X could be used in both with perhaps only calibration changes. Because the core integrated unit is pre-validated, vehicle integration work (mounting, high-voltage connections, etc.) is streamlined. This pre-integration can easily save months of development time per vehicle and allows parallel development of multiple models using the same EDU platform.
- **Broader Market Applications:** A single EDU platform catering to multiple segments also means an OEM can cover a broad market spectrum without investing in unique powertrain solutions for each. The L40X's scalable nature means the same family can serve a lower 7-in-1 configuration as well as a full 11 or 12-in-1 configuration including all features. This approach not only reduces engineering effort but also simplifies **manufacturing and sourcing**, since all hardware parts are common across high and low variants. InfiMotion's production can thus achieve volume efficiencies by building a common core for diverse customers.

The platform allows **OEM-specific customizations** as well. For instance, an automaker that already has an in-house Battery Management System could opt out of the integrated BMS in L40X and interface their own unit, while still benefiting from the integration of OBC, DC/DC, etc. Conversely, another OEM might request inclusion of a custom Vehicle Control Unit software to align with their existing control strategy – L40X's architecture can accommodate such software plug-ins given its AUTOSAR-compatible framework.

Scalability also extends to power and torque: the L40X series can be offered with different motor sizes and power ratings (for example, differing stator stack lengths or different semiconductor choices like IGBT vs SiC for higher voltage). All these variants remain part of the same design family, sharing most components. This strategy means any improvements (say, a more efficient cooling design or a newer microcontroller) can be rolled into the entire family with minimal fuss, benefitting all configurations.

In summary, the L40X platform exemplifies how an X-in-1 EDU can serve as a **universal drive unit solution** for multiple vehicle categories. This flexibility protects OEMs against technology obsolescence (the platform can evolve) and economic inefficiencies (one platform instead of many). The next section provides a comparative look at how L40X stacks up against other integrated EDUs, and the subsequent section will illustrate hypothetical use-case scenarios highlighting the platform's versatility.

# 5 Comparative Analysis of Integrated EDU Platforms

Highly integrated EDUs (X-in-1 systems) have rapidly emerged, especially in China's EV industry, to reduce cost and complexity. In fact, what was considered cutting-edge in 2020 – the classic 3-in-1 motor, inverter, and gearbox – is now seen as baseline, with many new designs integrating **five or more functions**[8]. As of 2023, numerous manufacturers have introduced EDUs with integration levels of 7-in-1, 8-in-1, and even 10-in-1, incorporating not just the traction drive but also chargers, converters, and more[8]. The trend is undeniable: from 2020 to late 2023, the market share of EDUs with more than 3 functions integrated grew from virtually zero to nearly **20% of China's EV market**[8], while the share of basic 3-in-1 units also increased (from 55% to 67%) at the expense of traditional non-integrated setups[8]. This indicates a strong industry move toward higher integration as the preferred solution.

To objectively compare L40X with other X-in-1 platforms, Table 1 summarizes key features of several representative integrated EDUs currently known, using generic labels (Platform A, B, C) for anonymity. All these examples consolidate multiple high-voltage functions and aim for improved packaging and cost:

| Platform (Integration Level) | Integrated Functions | Reported Efficiency | Notable Characteristics |
|---|---|---|---|
| Platform A (10-in-1) | Motor, Inverter, Gearbox, PDU, OBC, DC/DC, VCU, TCU, BMS, PTC | ~91.6% overall | Developed in 2023 by major OEM; ~40% volume reduction vs. non-integrated [7]. |
| Platform B (8-in-1) | Motor, Inverter, Gearbox, PDU, OBC, DC/DC, VCU, BMS | ~89% overall | Introduced 2023; supplier-developed for multiple brands. |
| Platform C (7-in-1) | Motor, Inverter, Gearbox, PDU, OBC, DC/DC, **BCU** | ~89% overall | Joint venture technology; emphasizes standardized interfaces. |
| **InfiMotion L40X (7–12-in-1)** | Motor, Inverter, Gearbox, PDU, OBC, DC/DC, BMS (LV/HV), VCU, TMS, WSC, EVCC | **94% peak**, ~90% cycle (3-in-1 core) | Production 2024; flexible configuration per OEM needs (supports up to 12 functions). |

**Table 1:** Comparative overview of integrated EDU platforms (functions and performance). *Notes:* VCU = Vehicle Control Unit; TCU = Transmission Control Unit; BMS = Battery Management System; PTC = onboard heater (PTC element); BCU = Battery Charging Unit (charge control ECU). Efficiency values are as reported by respective manufacturers; L40X values are internal test results (peak and cycle efficiency). Volume reduction for Platform A from [7].

In the above comparison, **Platform A** (10-in-1) is an example of an OEM-developed unit which achieved about *40% reduction in installation space* compared to a less integrated design[7]. It integrates almost all powertrain and some thermal functions (including a PTC cabin heater) and reports ~91.6% overall efficiency. **Platform B** and **Platform C** are supplier-developed 8-in-1 and 7-in-1 units respectively, each reporting around ~89% efficiency – indicating that high integration can still maintain efficiency in the high-80s to 90% range. These platforms typically include the main high-voltage conversion functions but may differ in whether they incorporate certain vehicle-domain controls (for example, Platform C includes a **BCU** which manages charging coordination but may not include a full VCU).

The **InfiMotion L40X** is listed with a range of 7–12 integrated functions because it is configurable. Notably, its measured peak efficiency (94% for the core traction system) stands out, underscoring that integration does not inherently reduce efficiency – in fact L40X's core inverter/motor efficiency exceeds that of some competitors, likely due to careful component selection and design optimization. The "~90% cycle" efficiency refers to its performance over a realistic driving cycle (CLTC)[7], which again is on par with the best in industry.

All platforms in the comparison aim to simplify the **E/E architecture** of the vehicle by acting as a domain controller for powertrain and charging. However, there are differences in approach. For example, some integrated EDUs split the functions between two physical units for practicality – one housing might contain motor, gearbox, inverter, and another attached housing contains OBC and DC/DC (this is reportedly the case in at least one 8-in-1 design). In contrast, L40X packages everything in one enclosure, which may complicate thermal design slightly but maximizes integration benefits. The trade-offs in integration often involve balancing thermal, EMC, and service considerations. L40X's design places high-heat components (motor, inverter) and sensitive electronics (VCU, BMS controllers) appropriately within the housing to mitigate thermal and electrical interference, using partitioning and shielding internally.

Another differentiator is production readiness and validation. Many X-in-1 concepts have been announced in the past 2–3 years, but not all have reached mass production. InfiMotion's L40X, having started production in 2024 at scale, demonstrates that such high integration is feasible with current technology. It has also been recognized with industry awards – for instance, an InfiMotion X-in-1 EDU won a **"Electric**

**Drive Innovative Technology Award”** in 2024 for its integration approach, achieving a noted weight of ~79.8 kg for the entire unit [8].

In neutral terms, the **competitive landscape** for integrated EDUs is quickly intensifying. Suppliers and OEMs are racing to set de-facto standards for how many functions can/should be integrated for optimal benefit. Some companies even speak of future **“X-by-wire”** architectures where the EDU becomes not just a drive unit but a node in the vehicle network controlling braking or steering actuators (though that extends beyond current X-in-1 definitions). The L40X positions InfiMotion well in this landscape by offering one of the highest integration counts (up to 12) and demonstrating tangible gains in space, weight, and cost. The comparative analysis suggests that while multiple players have achieved similar integration, the *neutral differentiators* will be things like how flexible the unit is to different vehicles, how mature the software integration is (for reliability and safety), and real-world validation. L40X's design philosophy emphasizes a balance of these factors, which the next section will further illustrate through hypothetical vehicle use cases.

# 7 Conclusion

The integration of functions such as the DC/DC converter, on-board charger, PDU, and even software-defined vehicle controllers into the EDU provides a comprehensive solution to many challenges faced by electric vehicle manufacturers. The InfiMotion **L40X platform** exemplifies how a well-engineered X-in-1 EDU can deliver substantial improvements in **packaging efficiency**, **system weight**, and **cost**, all while maintaining high performance and flexibility. By centralizing hardware and software, the L40X reduces vehicle complexity, accelerates development timelines, and opens new possibilities for cross-function optimization (like coordinated control and simplified thermal management).

Comparative analysis with other integrated EDUs indicates that this approach is becoming mainstream, and the L40X is at the forefront of this trend with one of the highest integration levels in the industry. Neutral benchmarking shows that despite the high integration, L40X's efficiency and functionality remain on par with or better than less-integrated rivals, highlighting that integration done right does not force trade-offs in core performance.

As the EV industry continues to evolve rapidly, innovations like the L40X X-in-1 platform are likely to **set new standards** for electric drive technology. We anticipate that higher levels of integration – both hardware and software – will enable EVs with lower cost, easier manufacturing, and richer feature sets (through unified controllers). The approach also corresponds with emerging **electrical/electronic (E/E) architectures** of vehicles, which are moving toward domain or zone controllers handling multiple tasks. In that sense, an integrated EDU is essentially a powertrain domain controller. Going forward, continued collaboration between EDU suppliers and OEMs will be crucial to define interfaces, safety strategies, and standardization for these multi-function units.

In conclusion, the L40X platform demonstrates that simplifying function integration in BEVs via X-in-1 EDUs is not only feasible but advantageous on multiple fronts. It offers a promising pathway for automakers to deliver efficient, high-performance electric vehicles while managing development costs and complexities. Future work will likely explore even more integration (potentially integrating functions like onboard climate compressors or further chassis control into the EDU) and extending the concept to higher voltage systems and different vehicle classes, heralding a new era of **integrated electric propulsion systems**.

## References


[1] Ehsani, M., Gao, Y., & Longo, S. (2018). *Modern Electric, Hybrid Electric, and Fuel Cell Vehicles*. CRC Press.
[2] Miller, J. M. (2011). *Propulsion Systems for Hybrid Vehicles*. IET Power and Energy Series.
[3] Ma, S., Xu, L., et al. (2022). "System-level Integration Strategies for High-Efficiency EDUs," *IEEE Transactions on Transportation Electrification*, 8(1), pp. 23–34.
[4] Han, D., & Park, C. (2020). "Cost-Driven Design of Integrated Power Modules for BEVs," *Journal of Power Electronics*, 20(2), pp. 450–460.
[5] Smith, R. et al. (2019). "Centralized Control Architectures for EV Platforms," *SAE Technical Paper Series*, DOI:10.4271/2019-01-0345.
[6] VDI Report (2023). *Benchmarking Electric Drive Units*. VDI Technical Publications.
[7] Vogel Communications Group (2023). "'X-in-1': More systems in Chinese electric drives," *All-About-Industries* (Industry article, Nov. 2023).
[8] InfiMotion Technology (2024). "Continuous Progress! InfiMotion received more awards" (Press release, June 24, 2024).


## Presenter Biography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