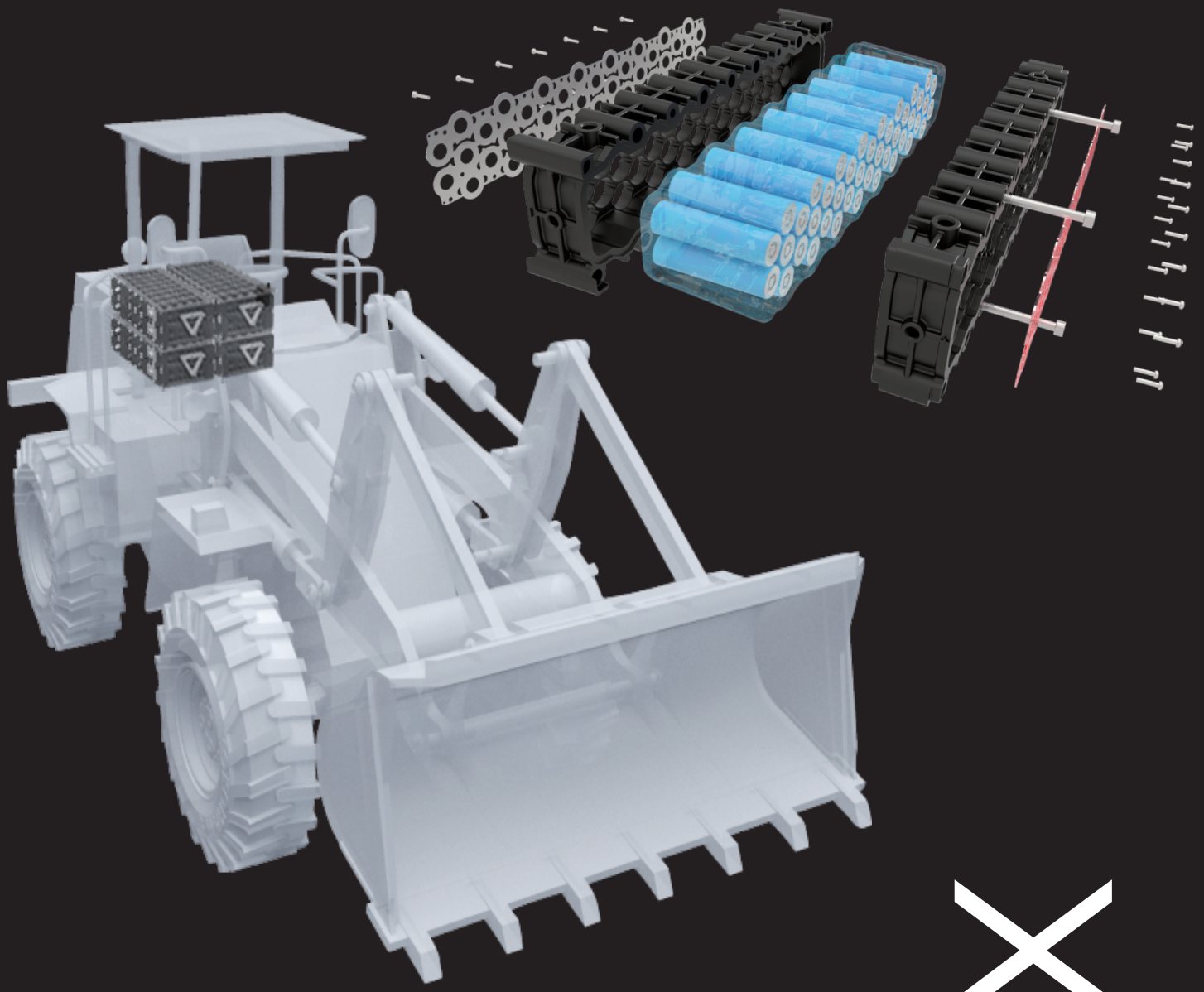
ADVANCED SAFETY

IMMERSIO™ Modular Battery System Safety Features



XING MOBILITY

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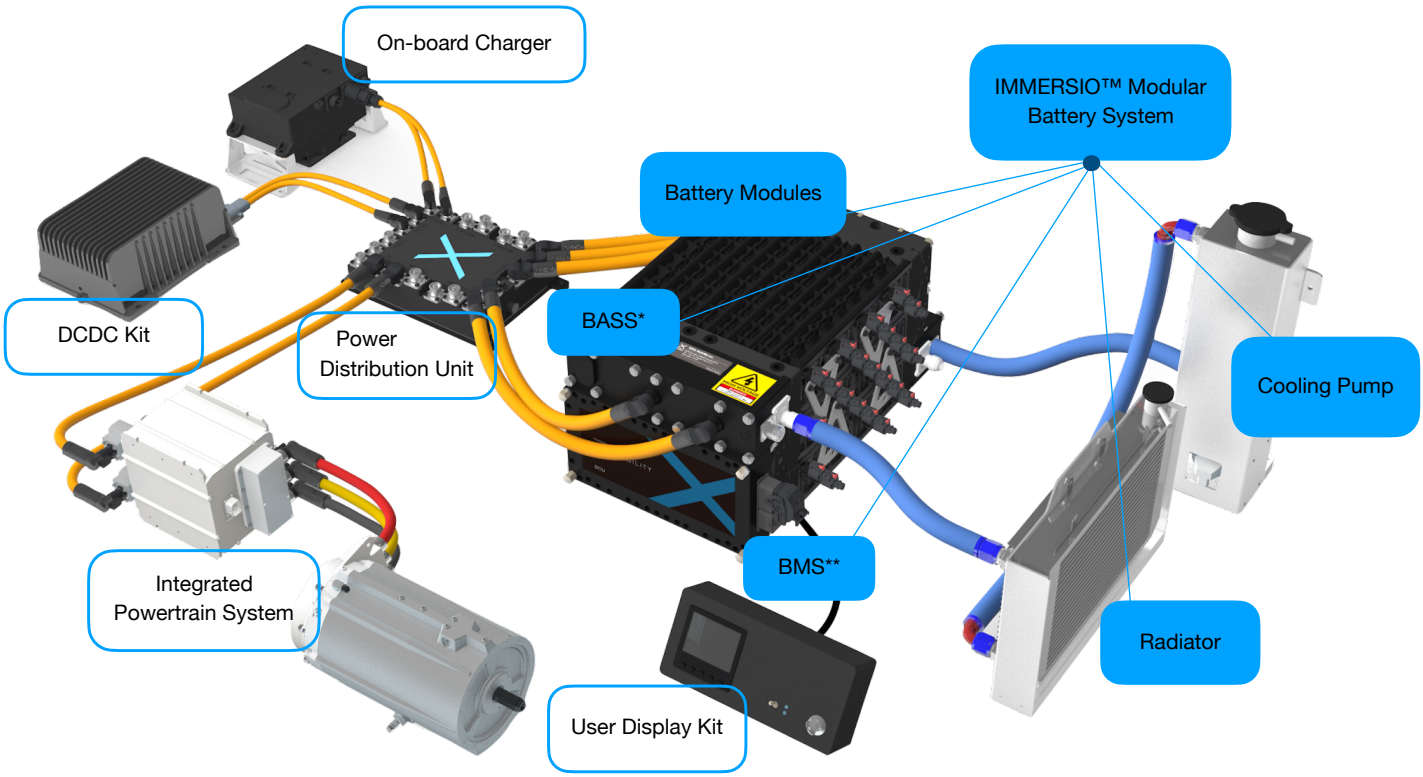
IMMERSIO™ Modular Battery System Overview

The IMMERSIO™ Modular Battery System is designed with three core themes: adaptability, easy-to-use, and advanced safety. Why is safety such an important part of IMMERSIO™ Modular Battery System? This battery system was initially born out of XING Mobility's pure electric supercar, Miss R, which gives the IMMERSIO™ Modular Battery System its durability from the constant testing of speed and extreme conditions.

This breakthrough immersion cooling technology involves submerging lithium-ion battery cells directly in a non-conductive liquid coolant, and in doing so achieving effective heat distribution and temperature homogeneity among all battery cells. IMMERSIO™ uses 3M™ Novec™ Engineered Fluid, a non-flammable, non-conductive engineered fluid. Notably, the flame-retardant nature of this fluid acts as a safety feature, suppressing overheating or fire events before they propagate between cells, and reducing the risk of thermal runaway (the spread of fire from cell to cell).

Within IMMERSIO™, besides the fundamental design of immersing battery cells in coolant, 3M™ Novec™, there are three major components that make this battery system the safest choice on the market: the Cooling System, the Battery Management System ("BMS"), and the Battery Active Safety System ("BASS"). The philosophy that threads these three parts together is XING Mobility's Advanced Safety engineering design. In the later sections, we will go into detail to explain what is so special about the safety features of the IMMERSIO™, and how does it affect your vehicles and operations.



Notice: This diagram only contains partial products of XING Mobility, please contact us to learn more

BASS*: Battery Active Safety System

BMS**: Battery Management System

Extensive Care for Users

One should always take precautions and follow the safety measures suggested on the user manual while operating the IMMERSIO™ Modular Battery System. Yet, the XING Mobility R&D team understands for many to go from operating engines to battery system is not the easiest transition, and that is why we designed our products with extensive care, even with the operating logic of engines in mind. And there are two folds of our extensive care feature: *installation* and *operation*.

Prevention of Human Contact from High Voltage

Firstly, installation is the most commonly demonstrated by mistakenly contacting the internal high voltage components.

The IMMERSIO™ Modular Battery System is designed with a plastic exterior case to first and foremost prevent direct human contact with the internal high voltage components of the battery system when handling, moving, and transporting the battery system.

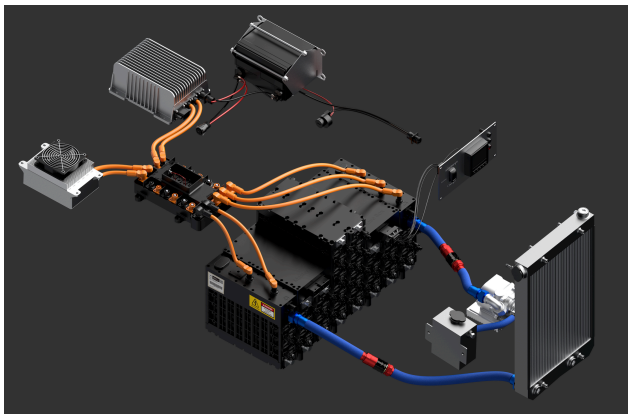
All of the high voltage cables are orange-colored to indicate the presence of high voltage when the battery system is turned on. The orange cables are shielded with two layers of insulation and a metal braid, making it resilient to external wear and tear and greatly reduces the chance of abrasion, cuts, and exposure of metal wires to the exterior.

Easy and Safe Installation Steps

Besides following XING Mobility's well-explained user manual, another design for our users to safely install the system, is its mechanical lifting points that meet the EU and UK standards. A battery system of a standard excavator could be quite heavy, yet one can easily and safely install the XING Mobility's battery system with the designed lifting points.

Mechanical Drop, Shock, and Vibration

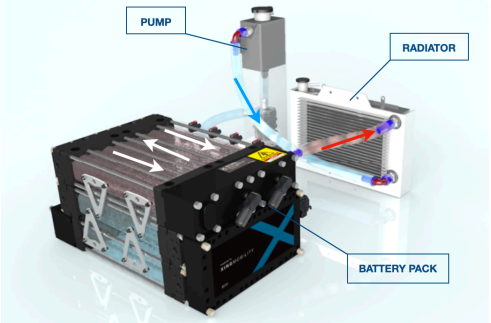
The IMMERSIO™ Modular Battery System have been tested and certified to the UN 38.3 standards for shock and vibration. The maximum G-force acceleration experienced by the battery pack is 50G. After the shock and vibration test, there is no mass loss, no leakage, no venting, no disassembly, no rupture, and no fire during this test



Scenarios	Shock Load	Status
Mild vehicle crash	50G	No mass loss No leakage No venting No disassembly No rupture No fire
Severe vehicle crash	100G	No fire

Superior Thermal Control

Thermal management in battery systems represents one of the most crucial challenges facing the electric vehicle (EV) industry to date, and this is largely due to its impact on a number of key battery features including charging speed, energy density and safety. Therefore it is unsurprising that “thermal control” is the most pressing and urgent matter to resolve for majority of users, here we break down how IMMERSIO™ Modular Battery System can provide one of the safest battery systems on the market due to its superior thermal control ability.



Immersion-Cooling Guarantees Most Effective Result

The conventional method of hybrid battery system cooling is air cooling via fans and air ducts, whereas electric vehicle battery systems are typically liquid-cooled, with extensive coolant channels, cold plates, and coolant pipes in the interior of the battery system, supported by pumps, fans, coolant tanks, and radiators outside of the battery system. At low volume production, designing a manufacturable and safe liquid-cooled is challenging and costly. Moreover, the contact between coolant and the battery cells is still secondary, separated by a coolant jacket, electrical insulators, cold plates, or both.

With the XING Mobility IMMERSIO™ Modular Battery System, the battery cells are directly immersed in a non-conductive, non-flammable, and non-toxic coolant. This coolant is pumped through the system with a dynamic flow rate. In the scenario of a cell failure, the coolant will absorb the heat more effectively with its direct contact with the cell and cut off the thermal stresses onto surrounding cells, preventing thermal runaway and propagation. The coolant with its direct contact with the cell is also more capable of managing the pressure from the release of gases. With immersion cooling, the lower overall temperature in the case of a single cell failure will prevent the gases released from reaching their flash points, eliminating the possibility of further explosions and fire. Because of the fact that the coolant is non-flammable, it also acts as a fire suppressant.

Cooling Method	Air	Liquid (water / glycol)	Refrigerant	Immersion
Thermal performance	Lowest of methods	Good performance	Good performance	Best performance
Thermal homogeneity	Poorest of methods	Better depending on coolant design	Usually poorer than liquid	Best homogenity
Leakage	None	Water can short upon leaking	Requires maintenance	Can leak, but will not short
Cost	Lowest cost option	Increased costs	Lower than liquid	Most expensive method
Weight	Lightest	Heavy	Heavy	Heaviest
Ambient effects	Would require an additional system	Can precondition vehicle using fluid	Can precondition vehicle using fluid	Can precondition vehicle using fluid
Design simplicity	Simplest system	More complex	More complex	Simpler than liquid, sealing can be more difficult

Excellent
Good
Fair
Poor

RENAULT NISSAN TOYOTA Audi GM TESLA BMW ING

Strong Exterior Protection

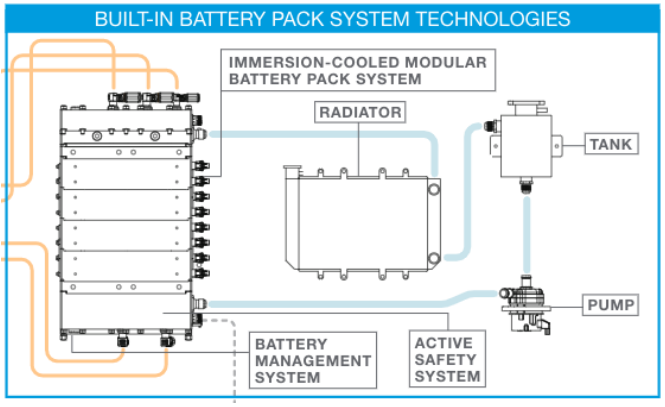
From the beginning, the XING Mobility IMMERSIO™ battery module has been designed with stringent computer-aided-engineering (CAE) structural analysis and analysis on coolant flow rate, temperature, and pressure across wide-ranging applications and environments. The XING Mobility IMMERSIO™ battery module and cooling system have been validated with the UN38.3 certification on mechanical shock, vibration, and thermal test without leaks.

Smart Monitoring

Two of the three major components we mentioned earlier that make the IMMERSIO™ Modular Battery System the safest choice on the market are the Battery Management System (“BMS”) and the Battery Active Safety System (“BASS”), which monitor the performance of the whole system. The BMS and the BASS are the brain and heart of IMMERSIO™ Modular Battery System, and in the following sections explain how they function.

Battery Management System (BMS)

The battery management system (BMS) actively monitors the voltage, current, and temperature of each battery cell and the entire battery system. The BMS checks for anomalies and raises warnings and errors when the anomalies reach a threshold. The BMS also monitors the status of the cooling system and checks for anomalies in pressure, flow rate, fluid level, and temperature. All data monitored by the BMS are uploaded to the cloud server for XING Mobility to be able to detect, diagnose, and prevent safety anomalies.



Battery Active Safety System (BASS)

The XING Mobility IMMERSIO™ Modular Battery System integrates BASS (Battery Active Safety System) onto the modules. The BASS combines current sensors, isolation detection, fuses and contactors to handle faulty conditions like short-circuit, over current, overcharge, over-discharge, and loss of isolation. The BASS brings the battery to a safe disconnected state whenever the system detects a safety critical condition.

React and Protect Under All Hazards

As mentioned earlier, thermal control is one of the most critical features and considerations when designing battery systems for electric vehicles. While a lithium-ion battery cell is powerful to deliver optimal performance to suit versatile needs, it is very sensitive and prone to failure. The design of BMS and BASS can actively protect and react to different scenarios that could have the possibility to cause safety hazards, such as thermal stresses (e.g. overheating), electrical stresses (e.g. overcharge, over discharge, and short-circuit), and mechanical stresses (e.g. penetration, and crush). When encounter external impact and crush, or foreign object penetration, the BMS will detect any loss of isolation, electrolyte leak, and internal short circuit, and it will shut down the battery system to prevent further damage. And if the battery system have underdone overcharge, over discharge, or external short-circuit, the BMS and BASS have protection mechanisms to shut down the battery, preventing any further damage to the battery system and battery cell.

Adaptability in Extreme Conditions

Considering that The IMMERSIO™ Modular Battery System would need to be able to travel and work in a wide range of environments, a snowplow vehicle in Canada, a mining truck in Australia, or a construction excavator in urban area, this battery system is designed to thrive in any condition. In this section, we explain how our battery system react in three different extreme conditions:

High Ambient Temperature

The IMMERSIO™ Modular Battery System have undergone heating tests up to 130°C without any subsequent explosions or fires. The BMS and the BASS have protection mechanisms to shut down the battery when overheated, preventing any further damage to the battery system and battery cell. The battery system can remain operational within the operating temperature range specified in the product datasheet.

Low Ambient Temperature and Freezing

The IMMERSIO™ Modular Battery System have undergone cooling tests down to -40 deg C without any subsequent explosions or fires or risk of lithium plating. The BMS and BASS have protection mechanisms to shut down the battery when cooled beyond the specified operating temperature, preventing any further damage to the battery system and battery cell. The battery system can remain operational within the operating temperature range specified in the product data-sheet. Although -40 deg C is below the freezing point of water, the battery system does not freeze since it is free of water.

When the IMMERSIO™ Modular Battery System is exposed to a subzero ambient temperature (down to -40 deg C), the battery system heater is turned on to prevent charging at low ambient temperature. This eliminates the possibility of lithium plating, which hurts battery life and increases the risk of internal short-circuit.

Submersion in Water and Ingress Protection

The IMMERSIO™ Modular Battery System is designed with to meet the Ingress Protection 67 (IP67) requirements. It is protected against any ingress of dust particles and ingress of water when submerged under 1 meter of water. This means that you should never attempt to submerge the battery system under more than 1 meter of water, and you also don’t need to worry about any solid particles getting into the battery system.

Durability, Resilience, and Strength

During the lifetime operation of the battery system in a moving vehicle, it is likely that the battery system experiences some degree of external impact, or even perhaps serious accident that leads to foreign objects penetrating the system. However, XING Mobility anticipates of all these mishaps ahead, and design our product to lower the destruction as little as possible.

External Impact, Crush & Penetration

The Battery Management System of IMMERSIO™ will detect any loss of isolation, electrolyte leak, and internal short circuit, and the Battery Active Safety System will shut down the battery system to prevent further damage.

As we explained in the section about thermal control, the IMMERSIO™ Modular Battery System has been proved effective in suppressing thermal runaway propagation. Nail penetration tests have been conducted to simulate a violent internal thermal runaway of the lithium-ion battery cells. In a typical non-immersion cooling systems' thermal runaway situation, gases will be generated and vented when the PTC on the lithium-ion battery cell opens. These released gases consist mainly of water, carbon dioxide, carbon monoxide, hydrogen fluoride (HF) and some light hydrocarbons (methane and ethane). Of those gases generated, HF, although is the toxic gas, only exists in trace amounts given its immediate release into the atmosphere. Light hydrocarbons, on the other hand, are not toxic but are combustible. In non-immersion cooled settings, the heat generated during thermal runaway events will pose a risk to further thermal runaway propagation of the remaining cells. The XING Mobility IMMERSIO™ Battery System, however, has the advantage due to the immersion liquid cooling method that the coolant will absorb the heat more effectively and prevent thermal propagation. A lower temperature will also prevent gases reaching flash points, which also prevent further thermal propagation. In either case, the amount of light hydrocarbon would also exist in trace amounts as well.

With the IMMERSIO™ Modular Battery System, the 3M™ Novec™ engineering fluid is odorless, non-toxic, and non-flammable. The fluid has low global warming potential and zero-ozone-depletion potential; in other words, it poses no threat to neither human health nor the environment. Even during the thermal runaway event only, a trace amount of the engineering fluid will be heated up and possibly vaporized; The vaporized liquid will than quickly condense upon releasing into the atmosphere. It has been proved effective by using immersion cooling to prevent thermal runaway propagation, and the study has shown that even during thermal runaway events the temperature is not high enough to cause any further reaction to break down the non-flammable engineering fluid.

External Flame

The IMMERSIO™ Modular Battery System is designed with an exterior compliant to the UL94 V-0 flammability requirements. This means that flames will self-extinguish within 10 seconds. Therefore, external flames do not pose any safety risks of the battery system.

UL94 V-0 flammability requirements:

1. The specimens may not burn with flaming combustion for more than 10 seconds after either application of the test flame
2. The total flaming combustion time may not exceed 50 seconds for the 10 flame applications for each set of 5 specimens.
3. The specimens may not burn with flaming or glowing combustion up to the holding clamp.
4. The specimens may not drip flaming particles that ignite the dry absorbent surgical cotton located 300 mm below the test specimen.
5. The specimens may not have glowing combustion that persists for more than 30 seconds after the second removal of the test flame.

Isolation Protection

The IMMERSIO™ Modular Battery System is designed to provide isolation of >500Ω/V. The BASS, BMS, and the battery structure collectively help achieve this level of isolation. BMS will detect the resistance from HV+ and HV- to 12V negative which connect with vehicle chassis. If the battery system is operating at 400V DC, then the isolation resistance is 200000Ω or 200 kΩ. If the resistance is lower (indicating a loss of isolation), an error code will be raised and the BASS will shut down the battery system. The maximum permissible current at this resistance is 400V/200kOhm = 2 mA. This amount of current is within the safety limit for any discomfort or injury to the human body.

Isolation Protection: >500Ω/V			
Operating voltage	Isolation resistance	Maximum permissible current	Implications
200Vdc	>100kΩ	<2mA	Within the safety limit for human discomfort or injury: 5 mA
400Vdc	>200kΩ		
800Vdc	>400kΩ		
1kVdc	>500kΩ		

International Certifications

United Nations Manual of Tests and Criteria, Part III, Subsection 38.3 (UN38.3)

Test	Description	Criteria	Status
1	Altitude Simulation	No mass loss No exhaust	Passed
2	Thermal Test	No disassembly or disintegration	Passed
3	Vibration	No rupture or fracture No fire	Passed
4	Shock	Open circuit voltage is not less than 90% before the test	Passed
5	External Short Circuit	Surface temperature does not exceed 170°C No disassembly or disintegration	Passed
6	Impact	No rupture or fracture No fire	Passed
7	Overdischarge	No disassembly	Passed
8	Forced Discharge	No fire	Passed

European Commission Low Voltage Directive

The XING Mobility IMMERSIO™ Modular Battery System has been designed to pass the European Commission Low Voltage Directive (LVD). The LVD ensures that the XING Mobility IMMERSIO™ Modular Battery System provides a high level of protection for European citizens from health and safety risks on the IMMERSIO™ Modular Battery System with an input or output voltage of between 75 and 1000V for direct current.

Compatible for Vehicle Integration: ISO 11452

The IMMERSIO™ Modular Battery System has been designed and validated to pass all requirements of the International Organization for Standardization (ISO) 11452-2: Road vehicles — Component test methods for electrical disturbances from narrowband radiated electromagnetic energy — Part 2: Absorber-lined shielded enclosure. The device under test (DUT), the IMMERSIO™ Modular Battery System, together with the wiring harness (prototype or standard test harness), is subjected to an electromagnetic disturbance generated inside an absorber-lined shielded enclosure, with peripheral devices either inside or outside the enclosure. The device under test (DUT), the IMMERSIO™ Modular Battery System, has shown immunity to the electromagnetic disturbance stated above, according to the methods and procedures laid out in the ISO 11452-2 Standard.

The XING Mobility IMMERSIO™ Modular Battery System has been designed and validated to pass all requirements of the International Organization for Standardization (ISO) 11452-5: Road vehicles — Component test methods for electrical disturbances from narrowband radiated electromagnetic energy — Part 5: Stripline. The device under test (DUT), the XING Mobility IMMERSIO™ Modular Battery System, together with the wiring harness (prototype or standard test harness), has been tested to have shown immunity to electrical disturbances from narrowband electromagnetic energy, according to the methods and procedures laid out in the ISO 11452-5 Standard.

EU Electromagnetic Compatibility: EN 61000

Test	Description	Criteria	Status
EN 61000 / IEC 61000 Part 4-4	Electrical Fast Transient / EMC Burst Immunity Test	Full functionality of the battery system when subject to an electrical fast transient / EMC burst	Passed
EN 61000 / IEC 61000 Part 4-8	Power frequency magnetic field immunity test	Full functionality of the battery system when subject to a power frequency magnetic field	Passed
ISO 11452-2	Road vehicles — Component test methods for electrical disturbances from narrowband radiated electromagnetic energy — Part 2: Absorber-lined shielded enclosure	Immunity to the electromagnetic disturbance generated inside an absorber-lined shielded enclosure, with peripheral devices either inside or outside the enclosure	Passed
ISO11452-5	Road vehicles — Component test methods for electrical disturbances from narrowband radiated electromagnetic energy — Part 5: Stripline	Immunity to electrical disturbances from narrowband electromagnetic energy, together with the wiring harness (prototype or standard test harness)	Passed

Empowering Every & Any Vehicle Maker To Go Electric

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