

# Concept\_One

Insights into the drive concepts of  
a purely electric supercar





The Rimac Automobili Concept\_One was designed from the ground up to be a fully electric supercar – the first of its kind. Not impressed? How does 1088 hp and 4 independent electric motors sound? All this power is kept in check by a MicroAutoBox.





The story behind Concept\_One is unique. It is the brainchild of Mate Rimac, a young engineer and inventor from Croatia. He is now 27 years old and employs over 80 people in Rimac Automobili, the Croatian company that designs, engineers, builds, and sells high-performance electric vehicles and technologies around the world. The Concept\_One was introduced in Frankfurt in 2011. It is the first electric supercar in the world, with staggering performance figures.

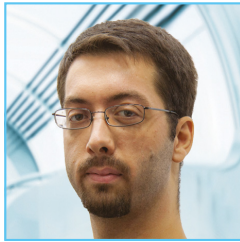
#### Powertrain Design and Concept

Its drivetrain is what makes the Concept\_One so special. Rimac Automobili started with a blank sheet of paper and examined each potential component closely in an effort to decide which one could have a useful place in the car and which would just add weight. Since a four-wheel drive is the only way to take advantage of a full tire grip, all four wheels are driven. Several powerful electric motors provide more power

and weigh less than one large electric machine, so each wheel has its own motor. "This also eliminated the need for a traditional clutch and differential, but we decided the gearbox needed to stay. This makes the Concept\_One the only electric car with a two-speed gearbox for each

has its own gearbox, single-speed for the front and two-speed dual-clutch for the rear. At full power, the front motors can draw up to 400 kW of power and the rear up to 600 kW, which adds up to a full megawatt of battery power," says Mr. Hrvatinic. The battery pack consists of several

hundred lithium-ion battery cells operating at 650 V. At full power, the mo-



"dSPACE ControlDesk has proven invaluable in real-world testing conditions."

*Kruno Hrvatinic, vehicle dynamics engineer, Rimac Automobili*

of the rear wheels, allowing the car to achieve amazing acceleration and still reach a top speed of 325 km/h," states Mr. Kruno Hrvatinic from Rimac Automobili's vehicle dynamics team.

#### Performance Package with Synchronous Motor and High-Voltage Battery

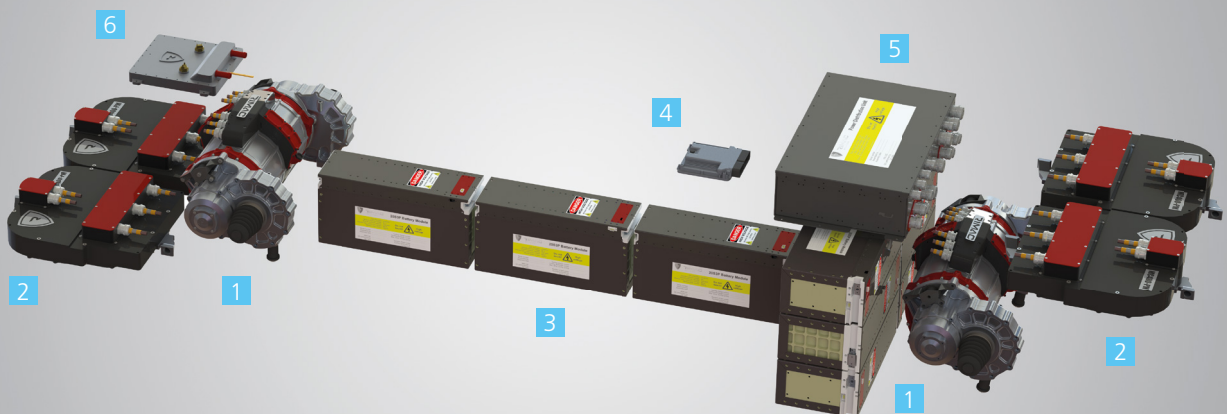
"We opted for two pairs of permanent magnet synchronous motors, each front motor capable of delivering up to 330 Nm of torque and each rear motor up to 440 Nm – a combined 1.540 Nm. There are two proprietary Rimac Automobili motors in each housing, sharing their cooling system to save space and weight. Each motor

tors draw nearly 1600 A of current. But when driving with a range-focused power consumption setting, the battery pack's 82 kWh of energy is estimated to last for about 330 km. The cell voltages and temperatures are managed by the Rimac Active Battery Management System, developed fully in-house by Rimac Automobili and controlled from the central vehicle control unit via CAN bus communication.

#### Why Go Electric?

The best thing about a drivetrain with four independently controllable motors is the degree of freedom such

*The 'drivetrain' consists of two motor units with transmissions (1), inverters (2), and a battery pack (3). Further components: central controller (4), power distribution unit (5), and heating (6).*



a drivetrain allows. A gasoline-powered car must rely on a differential to transmit torque from a central source of power (the engine) to each of the wheels, which means mechanically redirecting power to where it is needed. This incurs losses and is frequently limited by what the differential can physically accomplish. Beyond that, conventional cars have no choice but to utilize the hydraulic brakes, which wastes energy, wears out brake discs and, worst of all, slows the car down more than necessary. Mr. Hrvatinic explains, "Electric motors do not have this problem. Four electric motors means we can adjust the torque to each wheel a hundred times each second and have the motor respond almost as fast as the commands are sent. In electric motors, the direction does not play a role either – and can give negative torque just as easily as positive. This is called regenerative braking and it produces not only heat but also electrical energy, reclaiming part of the power used to accelerate the car. Add to this the 95% efficiency of an electric motor compared to 35% for a gasoline engine and you get a powerful, efficient, flexible, and easily controllable drivetrain."

### Torque Vectoring

The next step was to design a control algorithm that would allow Rimac Automobili to make full use of this drivetrain's great power and flexibility. "Once again starting with a blank sheet of paper, we drew up a physical model of the car and started analyzing its passive behavior and defining the targets we wanted to accomplish with its active control systems. To build a model we could use for testing, we used all the data we were able to measure, from basic physical dimensions to suspension geometry and tire characteristics. This data was then transferred into a software suite for automotive physical simulation where we were able to validate the model data and start developing our dynamic vehicle control algorithm,



*Concept\_One is powered purely electrically and is the world's first all-electric hypercar, not only by performance but by the technology in it.*



*Mate Rimac, inventor of the Concept\_One, beside the opened vehicle rear showing the power distribution unit.*

Rimac All Wheel Torque Vectoring (R-AWTV)," states Mr. Tomislav Šimunić, head of the vehicle dynamics team.

### Vehicle Behavior Under Electronic Control

"R-AWTV combines longitudinal and lateral control into one cohesive whole.

It monitors and adjusts the forces on each wheel to produce a driving experience suited to each individual driver and situation. This is done solely by controlling the torque delivered to/from each of the motors in a way that it results in an improvement over the passive dynamics of

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the car. We use high-precision physical sensors such as accelerometers, gyroscopes and wheel speed and steering wheel angle sensors that are fed into estimation algorithms to monitor the vehicle behavior. This way, we get a clear picture of the vehicle's physical state. The amount of grip, or total available force, on each wheel is estimated and either used as a limit to ensure maximum traction or deliberately exceeded to let the car enter a controlled lateral slide."

#### Driver-Controlled Lateral Dynamics

Rimac Automobili wanted a system that keeps the average driver safe and stable at high speeds and sharp turns, but also one that an expert driver would not feel was overbearing. This meant that the system had to be more configurable and offer more than the standard on-off switch most production cars provide. Concept\_One's aluminum center console is designed to let drivers easily switch between operating modes, i.e., stable or dy-

namic driving behavior, by simply turning a knob. The innovative HMI solution enables the driver to fine-tune the torque distribution so that the car can operate as a pure front-wheel drive or rear-wheel drive, or any setting in between.

#### Role of the MicroAutoBox

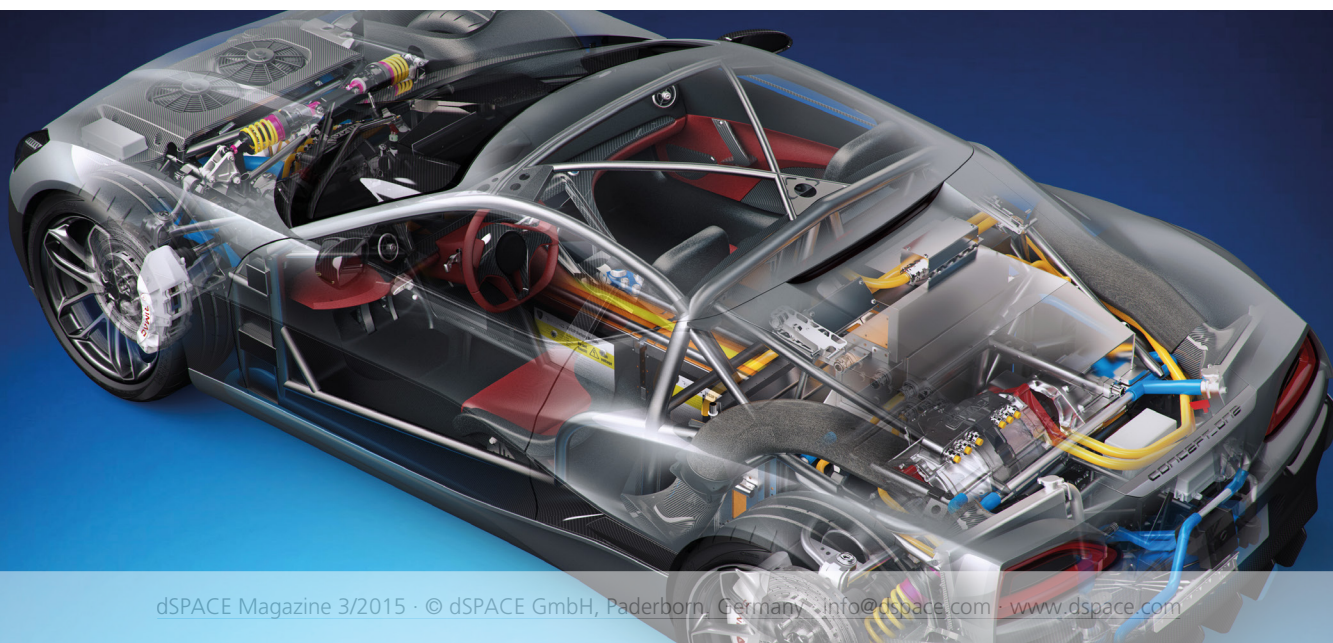
"Of course, in order to make use of the drivetrain's great power and flexibility, clever control solutions had to be implemented on a platform reliable and fast enough to process them. This is why we chose the MicroAutoBox as the prototyping system to develop the central controller for the Concept\_One. Its task is to coordinate the distributed network of secondary control units, provide safety-critical features such as over-temperature protection and device error detection, handle driver inputs and, of course, implement the Rimac All Wheel Torque Vectoring system," Mr. Hrvatinic says. The Concept\_One makes full use of

the MicroAutoBox's four CAN bus channels for communicating with the Rimac Active Battery Management System, the power distribution unit and charger, the four inverters and various chassis control units. The dSPACE RTI CAN Blockset is especially helpful here, making it easy to track and manage the nearly 200 CAN messages sent and received by various devices on the bus. For this, the standard serial communication channels and most of the analog and digital inputs are used. "Converting the control algorithm from a Simulink model compatible with our physical simulation software into a program that can be run on the MicroAutoBox is simple and straightforward, allowing control engineers to do their job without worrying about the underlying C code," concludes Mr. Šimunić.

#### Precise Signal Analysis with ControlDesk

Mr. Hrvatinic remarks, "dSPACE ControlDesk has proven invaluable

*Packed with the latest technology: To connect the various systems of Concept\_One, Rimac Automobili uses a central control unit that was developed using a dSPACE MicroAutoBox.*





"Working with the MicroAutoBox is simple and straightforward, allowing control engineers to focus on controller development without worrying about the underlying code."

*Tomislav Šimunić, head of the vehicle dynamics team, Rimac Automobili*

in real-world testing conditions. The ability to check the value of each signal in real time and record it greatly simplifies debugging, and is also very useful when evaluating the performance of dynamic control systems. We can access and review test data immediately after a test run is completed, which allows us to make the best possible use of a full day on the track." ControlDesk is also very useful for manually fine-tuning algorithm parameters on the fly. Since the values of parameters can also be changed

easily, the time between test runs with different controller setups is reduced. Different experimental subsystems can be turned on and off without the need for any structural changes to the controller model.

#### Outlook

Only eight supercars in the first series Concept\_One World Edition are scheduled to be produced, but the design and control algorithms are constantly being improved. The expertise and components developed and pro-

duced in-house for the Concept\_One, such as the infotainment system, the powertrain and the battery system, to name just a few, are also finding a variety of applications in different B2B projects. Going forward, Rimac Automobili will continue to design and build the most powerful and sophisticated electric vehicles in the world, and find new ways to implement its cutting-edge technology in different fields and industries. ■

*Courtesy of Rimac Automobili, Croatia*

*A touch screen shows the power values during engine operation and provides accurate settings.*

