11

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EDITION 11

HYBRID TECHNOLOGY

IN THIS ISSUE

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INTRODUCTION

Why choose a hybrid vehicle?

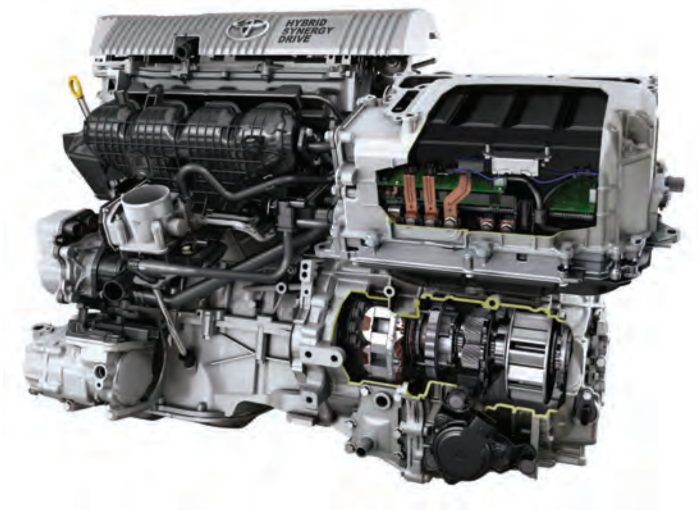
The purpose of combining an internal combustion engine with an electric motor is to achieve increased efficiency, since the electrical system can accumulate the energy generated by braking in the form of electricity and store it in a battery.

While in vehicles with combustion engines, this energy is lost in the form of heat generated by the friction between the brake pads and discs, in addition to the heat generated by the friction in the moving parts of the combustion engine when it holds back the vehicle during deceleration.

The electrical energy generated by braking and accumulated in the battery will be used to provide traction force during acceleration.

This operating strategy results in clear energy savings, especially when driving conditions require multiple deceleration and acceleration (driving in heavy traffic, between traffic lights, roundabouts, etc.). However, it is no longer beneficial at constant speeds in scenarios driving on flat roads with no changes of elevation.

On the other hand, the increase in fuel prices, pollution levels, and new protocols for episodes of high contamination in large cities, which ban vehicles that pollute the most from driving in the centre of the city, have prompted many drivers to lean towards the purchase of vehicles that are more environmentally sustainable.



Advantages

- They operate with fuel that is available at any petrol station.
- Lower fuel consumption in city driving.
- Low pollutant emissions.
- Efficient in cities.
- Quieter in comparison with vehicles with internal combustion engines.
- Recovery of the energy generated by braking.
- The electric motor and battery provide a much longer guarantee than internal combustion engines.

Disadvantages

- High purchase price with respect to vehicles with internal combustion engines.
- Repairs must be done by specialized technicians.
- Batteries have a large environmental impact if they are not recycled properly.
- Repairs to the electrical system have an additional cost.
- Limited range of vehicles available.

DEFINITION OF A HYBRID VEHICLE

A hybrid vehicle or machine is one that uses two different technologies to function. In general, hybrid vehicles are equipped with two types of engines to participate in the traction-propulsion system. They are also able to generate energy from the deceleration of the vehicle itself and accumulate that energy.

In most cases, the idea is to combine a combustion engine with an electric motor. The purpose of the combustion engine is to provide power to the traction system, increasing the speed of the vehicle when it is already

moving, while the electric motor is responsible for adding engine torque and its purpose is to begin accelerating the vehicle from a stop.

Although hybrid vehicles are currently on the rise, it is important to remember that this technological concept is as old as the history of the car itself. The first hybrid vehicle recorded was in 1900, the Lohner-Porsche Mixte hybrid, which was equipped with an electric motor on each front wheel, with the rear wheels driven by an internal combustion engine.

On the other hand, there are also hybrid-fuel vehicles. These vehicles are outfitted with an internal combustion engine that can run on two different types of fuel, as in the case of LPG (Liquefied Petroleum Gas) and CNG (Compressed Natural Gas).

These vehicles can be outfitted with a hybrid fuel system as a standard option, or the modification can be made in an authorized workshop. Due to the type of gas combustion, a petrol engine is used, with an injection ramp installed on the intake manifold.

The biggest difference is that they are equipped with two independent fuel tanks - one for petrol and the other for the gas. They also have two openings for refuelling.

FUNCTIONAL CLASSIFICATION

Car manufacturers have chosen different technological lines depending on the degree of electrical integration incorporated into the vehicles. These different technological lines will depend on the cost and complexity of the systems used. Basically, hybrid variations can be classified based on the operating voltages and capacities of their batteries, and therefore the functions that they can provide to the motor-propulsion set and the energy management system.

According to these criteria, they can be classified into the following groups:

- Micro Hybrids
- Mild Hybrids
- Full Hybrids
- Plug-In Hybrids.

The degree of electrical integration is determined based on whether or not they are equipped with the following functions:

- Start-Stop.
- Regenerative braking.
- Electric assistance.
- 100% electric traction.
- External battery charging.

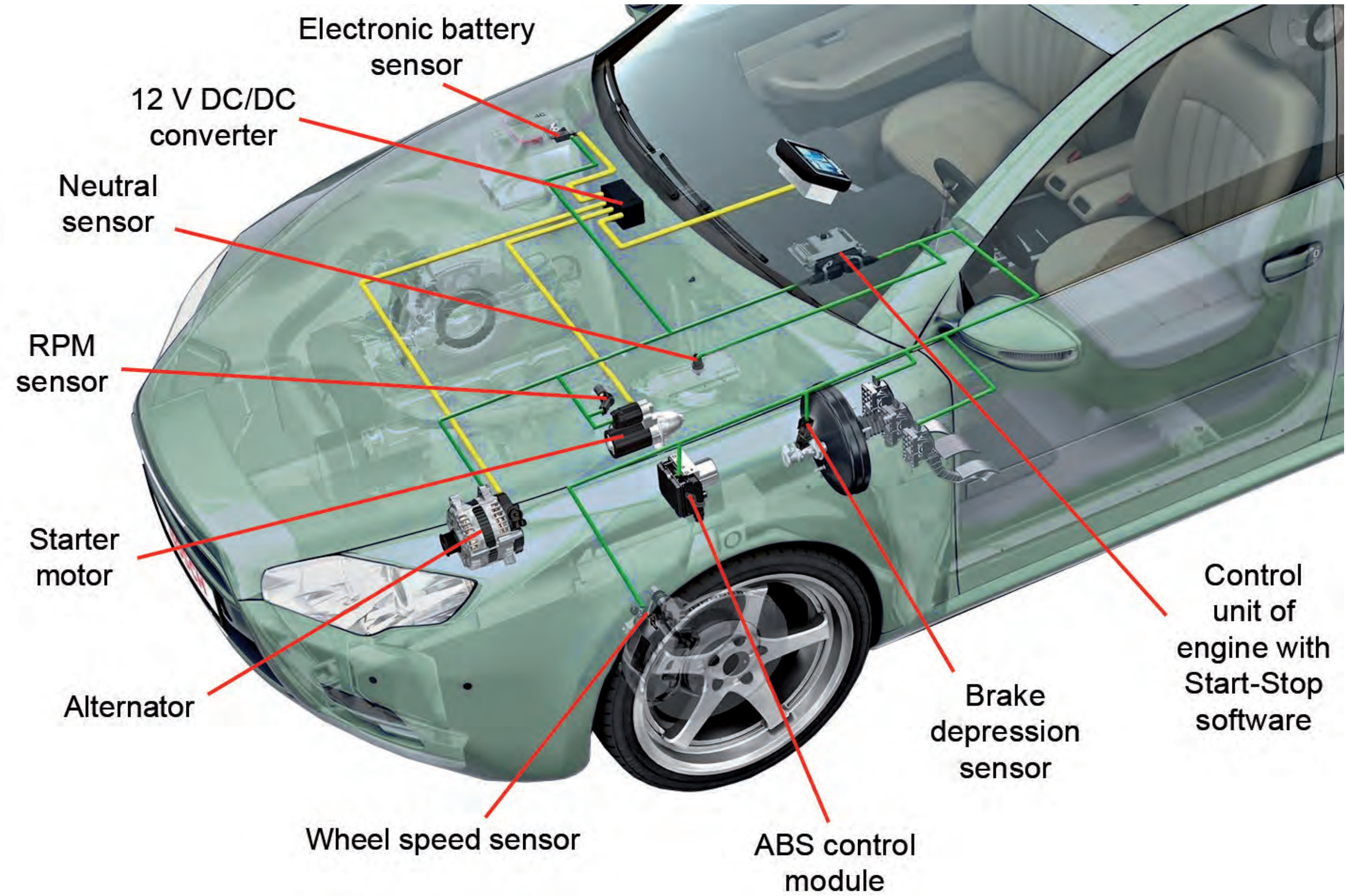
Type	Start-Stop	Regenerative braking	Electric assistance	100% electric traction.	External battery charging
Micro hybrid	Yes	Yes	No	No	No
Mild hybrid	Yes	Yes	Yes	No	No
Full hybrid	Yes	Yes	Yes	Yes	No
Plug-in hybrid	Yes	Yes	Yes	Yes	Yes

Micro Hybrids

Pollution emission regulations have had a significant influence on manufacturers to equip vehicles with an automatic start-stop system that reduces fuel consumption and emissions in urban areas.
Micro hybridization is the cheapest and most widespread technological formula that manufacturers have been integrating into most of their vehicles since 2010. The energy system takes advantage of the 12-volt low-voltage power network but uses AGM batteries with VRLA technology, which have greater energy capacity to withstand a larger number of starts.
Micro hybrid vehicles have a charge strategy that mostly takes advantage of deceleration of the vehicle to allow the alternator to regenerate the battery charge, without reducing power to the combustion engine when it accelerates.

Also, the electrical energy management has to guarantee automatic starting of the combustion engine depending on the different operating conditions. The most characteristic conditions of micro hybrid vehicles are:

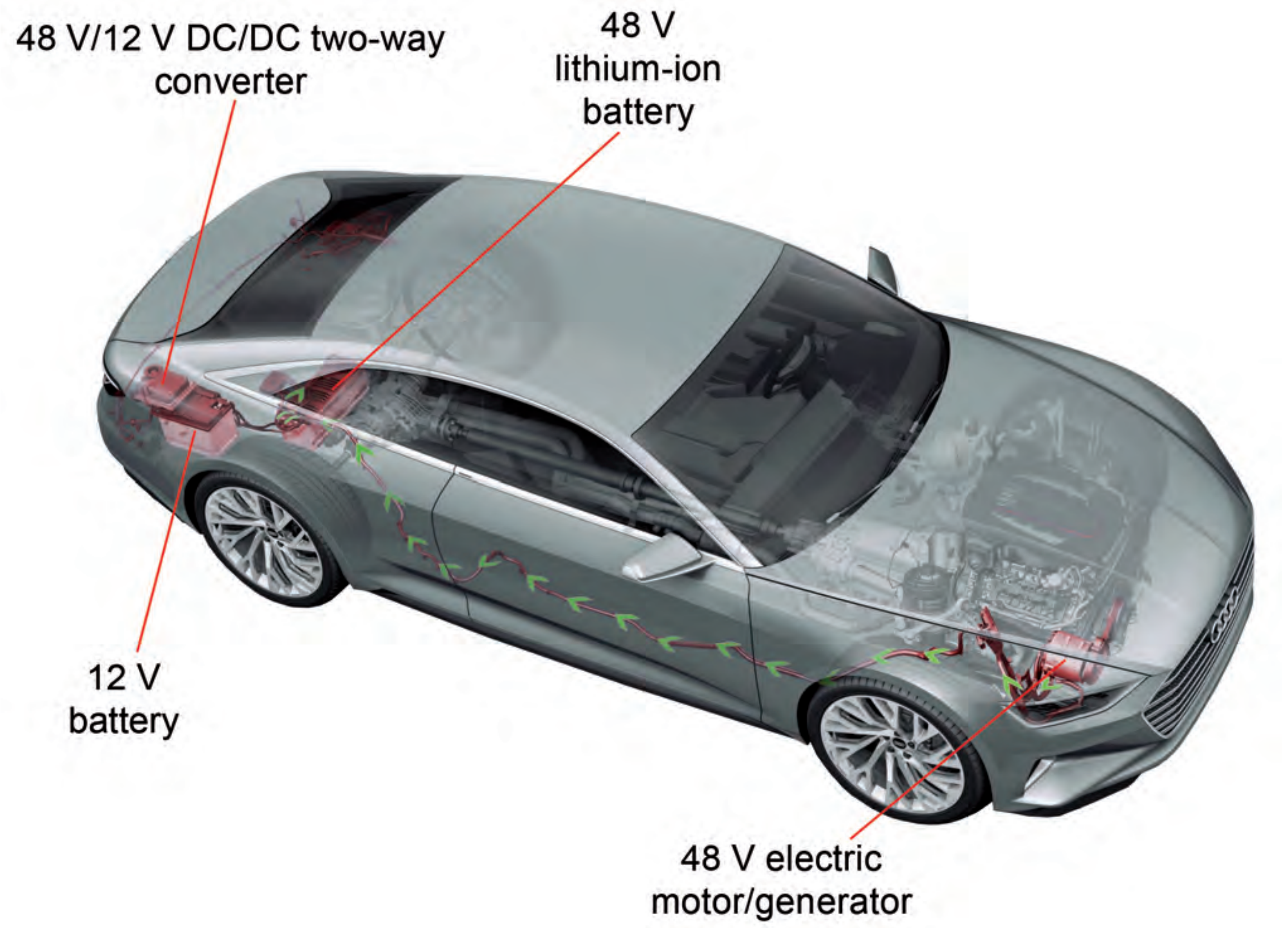
- Automatic start-stop.
- Regeneration during braking.



Mild Hybrids

The idea is to go one step beyond the technology of the Start-Stop systems, trying to avoid increasing the cost of the vehicle too much. Normally a reversible alternator or motor/generator is incorporated into the vehicle's transmission system. This not only starts the combustion engine and recharges the battery, it can also contribute a degree of traction assistance during initial startup.
To support this assistance, the vehicle's conventional 12 V electrical network is insufficient. For this reason, manufacturers such as Valeo and Bosch decided to incorporate a second 42-48 volt electrical network with a larger capacity lithium-ion battery to power the electric motor/generator directly. Also, a DC-DC converter drops the voltage to 12 V to charge the conventional battery and power the rest of the consumers of the vehicle's electrical network.
In this case, the motor/generator does not have enough power to move the entire vehicle itself, but it does provide some degree of assistance, which reduces fuel consumption and emissions by up to 15%. The most characteristic functions of mild hybrids are:

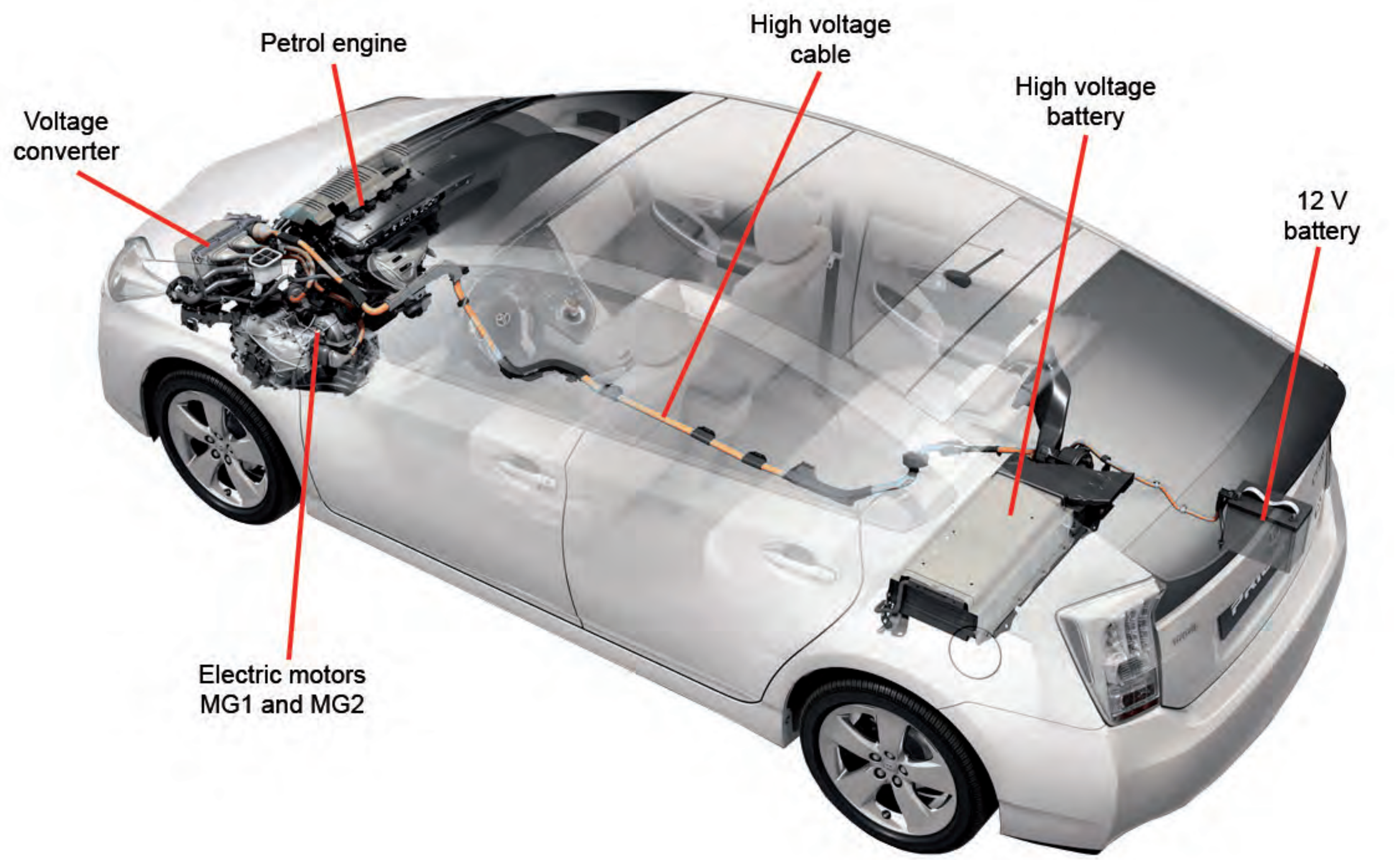
- Automatic start-stop.
- Regeneration during braking.
- Assistance during starts and initial acceleration.



Full Hybrids

Full hybrids are equipped with a high-voltage battery with sufficient energy capacity to propel the vehicle with an electric traction motor, but subject to a series of limited use conditions.
The battery technology used is normally nickel-metal hydride. The nominal voltage of the battery in hybrid vehicles ranges from 101 Volts (0.6 kWh) in the Honda Insight, to 201.6 Volts (1.3 kWh) of the Toyota Prius. Normally, fully-electric traction is used at the start of motion, without dependence on the combustion engine, which are the situations that consume and pollute the most. For example, the Toyota Prius has an autonomy of approximately 2 km with a maximum speed of 50 km/h.
In intercity travel, the vehicle is propelled by the combustion engine, with the electric motor contributing only during times of maximum effort. Likewise, during the phases of deceleration, hybrid vehicles can revert the use of the electric motor to generator mode to transform the kinetic energy into electricity that is stored in the battery. This means that the recovered energy can be used to power the electric motor during the next acceleration.
This strategy significantly reduces pollutant emissions, not only during starts and stops, but also during assisted acceleration or acceleration using only electric propulsion. The most characteristic functions of full hybrids are:

- Automatic start-stop.
- Regeneration during braking.
- Assistance during starts and initial acceleration.
- Reduced full electric traction.



Plug-In Hybrids

In the case of plug-in hybrid vehicles, the operating voltage of the battery is similar to or greater than that of hybrid vehicles, for example, 207 Volts in the case of the Plug-in Toyota Prius and 345 Volts in the case of the Volkswagen GTE.

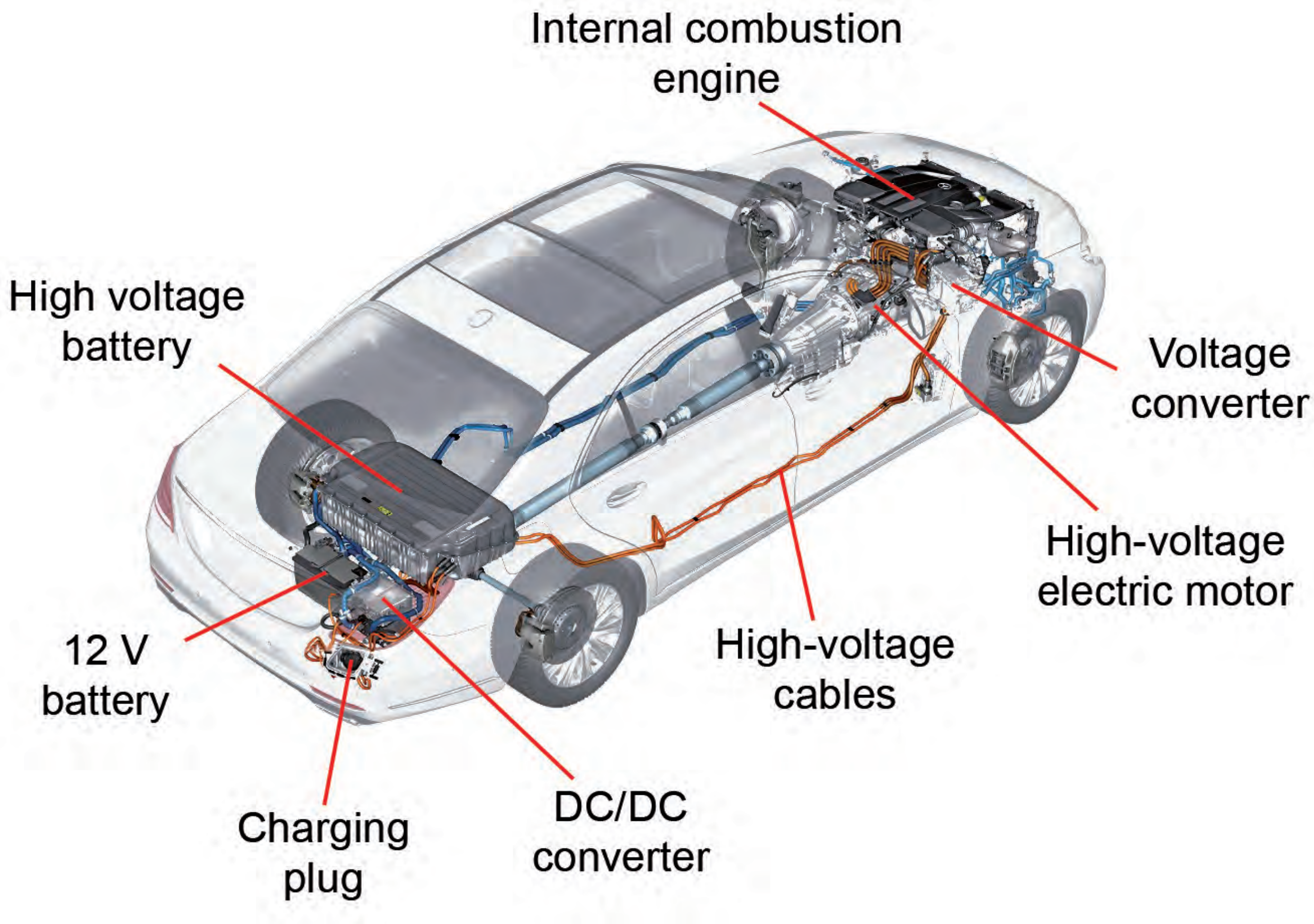
The predominant battery technology is lithium ion, which provides higher energy density than nickel-metal hydride batteries. Its energy capacity is significantly greater, between 5.2 kWh in the case of the Prius, and 8.8 kWh in the case of the VW GTE.

The operating strategy of these vehicles is similar to that of hybrids, with the difference being that they can travel longer distances in full-electric mode, between 30 and 50 km. This increased electric capacity makes it possible to alternate more, and for a longer time, with a full-electric driving mode in comparison with hybrid vehicles.

The principal characteristic in comparison with hybrids is that they can be plugged into the power grid to recharge the battery, which significantly reduces fuel consumption significantly when a cycle of comfortable driving is started with the battery fully charged. On the other hand, they have the advantage over electric vehicles in that they do have not range problems even if the battery charge level drops.

However, recharging the battery through the combustion engine with diesel or petrol is not viable. The most important functions of Plug-in hybrid vehicles are:

- Automatic start-stop.
- Regeneration during braking.
- Assistance during starts and initial acceleration.
- Limited full electric traction.
- External battery charging.



Abbreviations

Another way that the market classifies vehicles that use electricity partially or completely to function is through abbreviations:

- **MH (Micro Hybrids):** These are models with conventional combustion mechanics that include a Start-Stop system to reduce fuel consumption and emissions in the city. They add an energy recovery device to recharge the battery.One example of this type of vehicle is the C5 e-HDi.

- **MHEV / IHEV (Mild Hybrid Electric Vehicle / Intelligent Hybrid Electric Vehicle):** These are models that are equipped with a 48 V electric grid. They are also equipped with an additional 48 V battery and an alternator that can also put the vehicle in motion.One example of this type of vehicle is the Honda Civic IMA.

- **EV / ZE (Electric Vehicle / Zero Emissions):** Vehicles in which electric energy is used for all or part of the traction (along with another source of thrust). One example of this type of vehicle is the Renault ZOE.

- **HEV (Hybrid Electric Vehicle):** This category covers all hybrid vehicles that are made up of an internal combustion engine and one or more electric motors. One example of this type of vehicle is the Toyota Prius.

- **PHEV (Plug-in Hybrid Electric Vehicle):** This is the next step in the technology of classic hybrids, with the difference that the batteries can be recharged in charging stations. They carry larger, more powerful batteries that allow them to cover the first 20 to 40 kilometres using only the stored electric energy. It is possible to drive using the internal combustion engine and reserve the batteries for driving in the city. One example of this type of vehicle is the Volkswagen GTE.

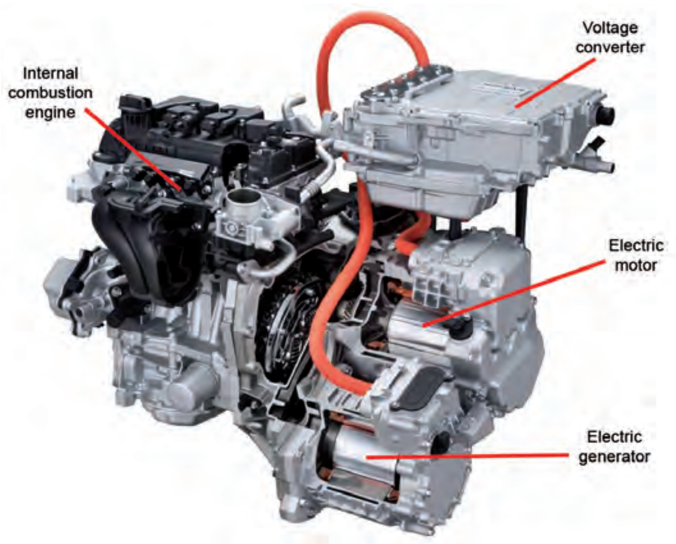
- **EREV (Extended Range Electric Vehicle):** These are full hybrids, but their principal feature is that they can travel approximately 60 km with the electricity in their batteries, and when they run out, the vehicles have a conventional combustion engine.Unlike other hybrids, this engine does not offer traction and acts only as a generator to provide the electricity that the electric motor needs to propel the vehicle.

CLASSIFICATION BY STRUCTURE

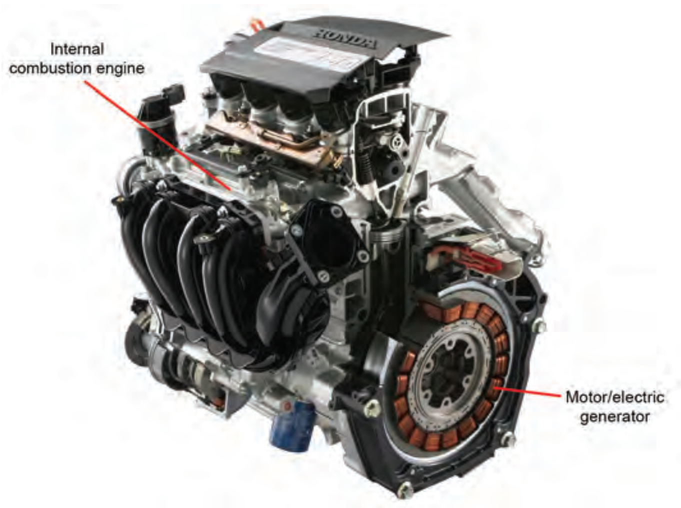
When working with batteries, resistors, and other electrical components, there are several different ways in which they can be interconnected to achieve different results. The same is true of hybrid vehicles. They are equipped with an internal combustion engine and one or more electric motors. These can be combined in the following ways:

- Combination in series.
- Parallel combination.
- Series/parallel combination.

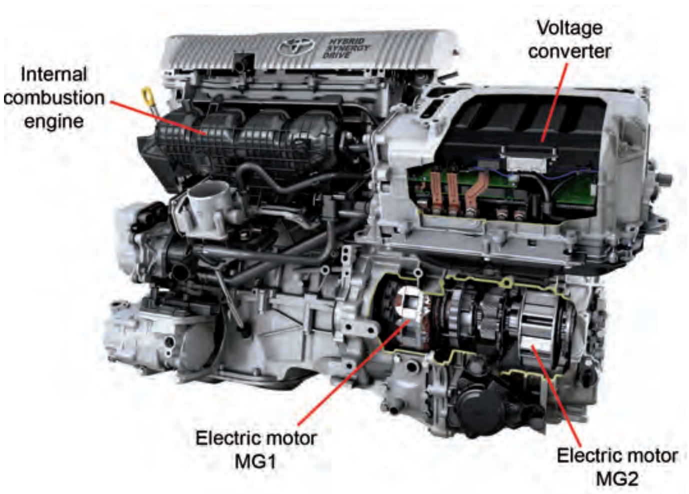
This type of classification is aimed at the configuration of the energy flow and the kinematic chain. From the moment that the energy begins to flow through the chain until it is transmitted to the wheels. And the way in which the vehicle's engines and motors participate in that flow.



Mechanics of a hybrid vehicle in series (Motor of the Nissan Note e-Power)



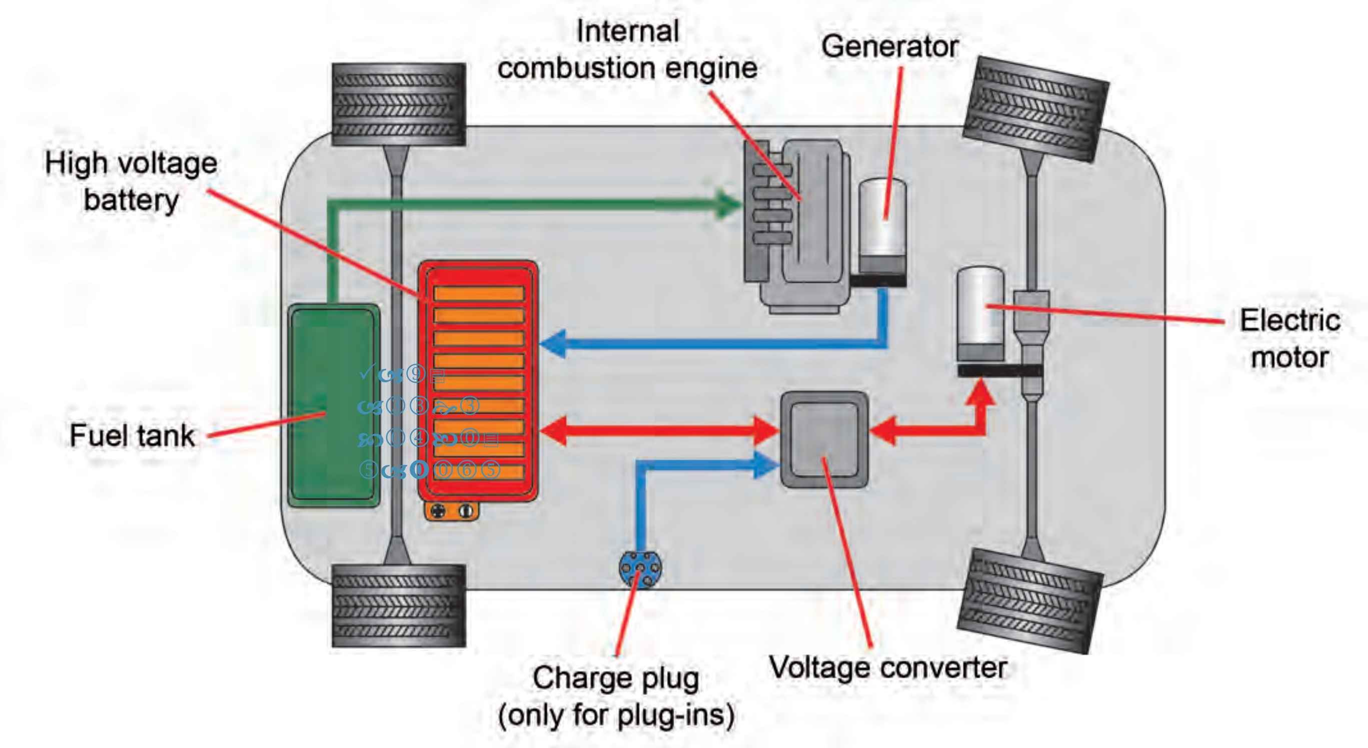
Mechanics of a parallel hybrid vehicle (Motor of the Honda Civic IMA)



Mechanics of a mixed hybrid vehicle Motor 2ZR-FXE from Toyota

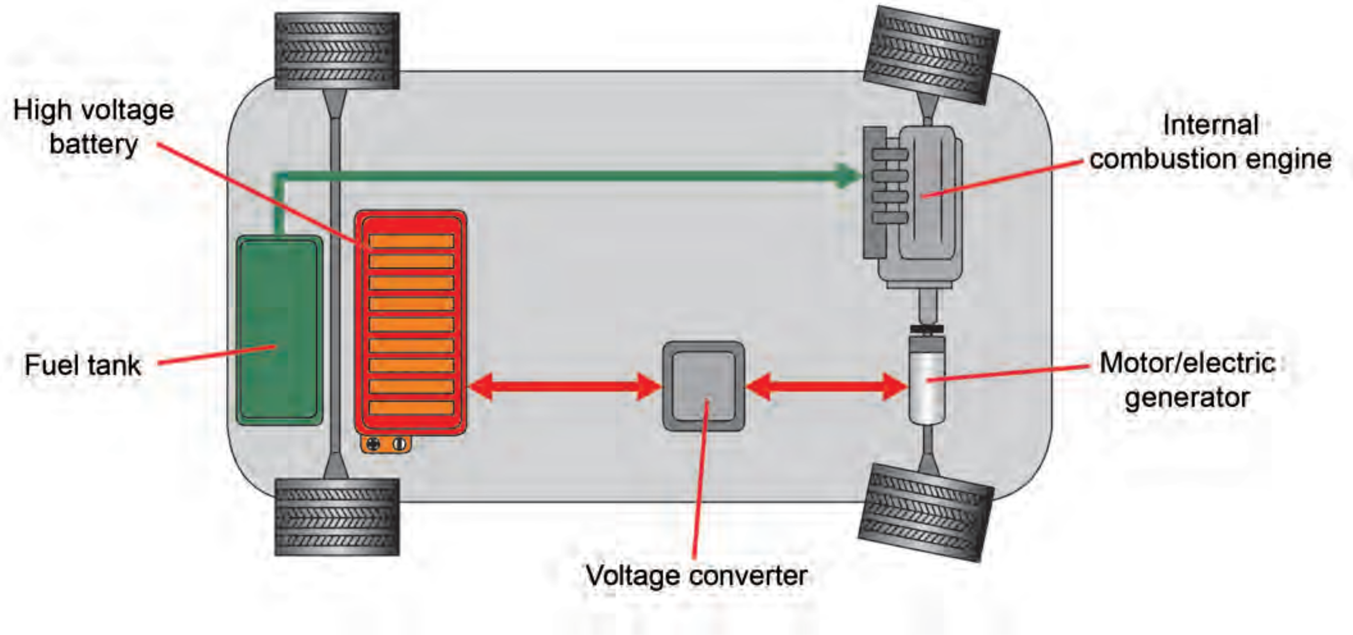
Combination in series

In a configuration in series, mechanical energy is applied to the wheels from a single motor, normally the electric motor.
The internal combustion engine is used only to start the electric generator that generates electric energy that is stored in the battery and is then transmitted to the electric traction motor, which is the only motor that is responsible for moving the wheels.
In this configuration, the energy is transmitted from one state to another sequentially following a single kinematic chain. In other words, the wheels cannot be driven by both motors at the same time.
An example of this configuration is the Opel Ampera and the Nissan Note e-Power. Also, to recharge the battery during deceleration, the electric motor becomes a generator and charges the battery.



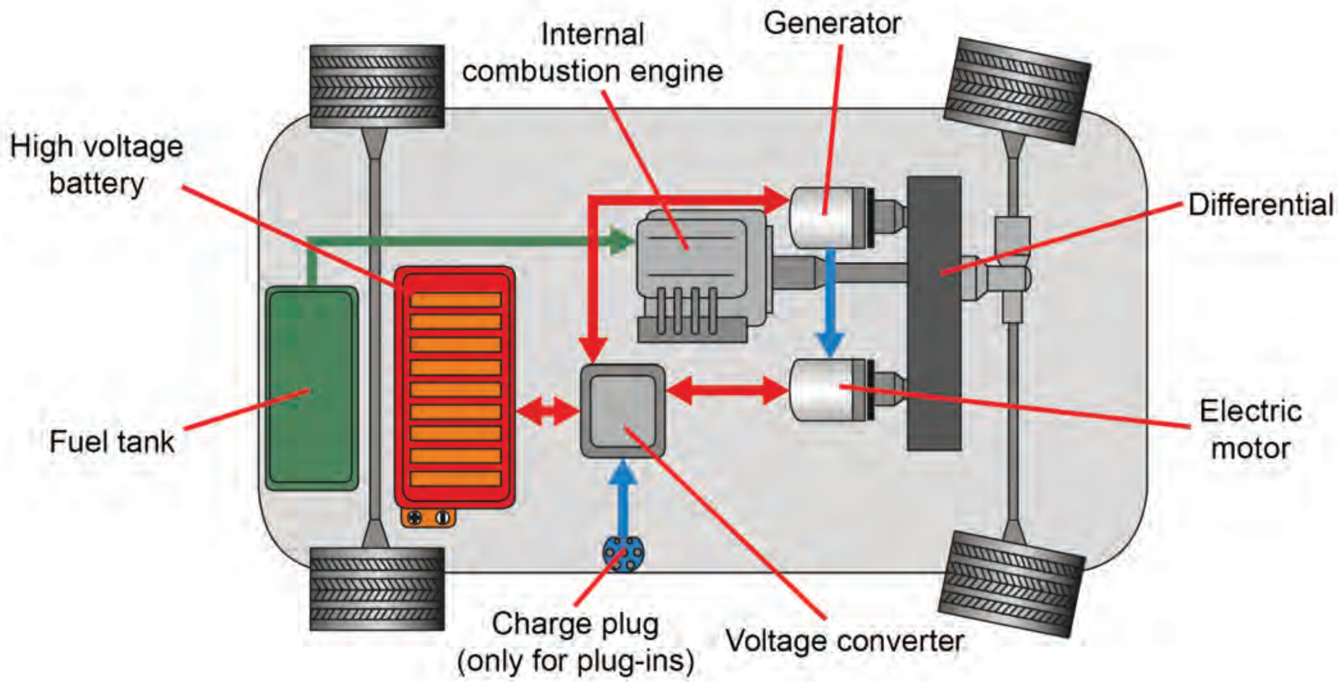
Parallel combination

This is the most common hybrid system used by car manufacturers. In this configuration, the vehicle can function with hybrid traction that includes the contribution of both the internal combustion engine and the electric motor, which drive the wheels at the same time. This represents an energy flow in parallel by means of two distinct kinematic chains.
Also, depending on the operating conditions, the vehicle's wheels may be driven by the combustion engine alone while the battery charges at the same time. Or by just the electric motor, using the energy accumulated in the battery and saving fuel.
The electric motor is installed at a point in the kinematic chain, normally between the motor and the transmission. When the energy flow is inverted during braking, the electric motor regenerates the battery.
Examples of this configuration include the HONDA Civic and the HONDA Insight, in which the IMA system (Integrated Motor Assist) allows the electric motor installed between the flywheel and the clutch to drive the transmission together with the combustion engine.



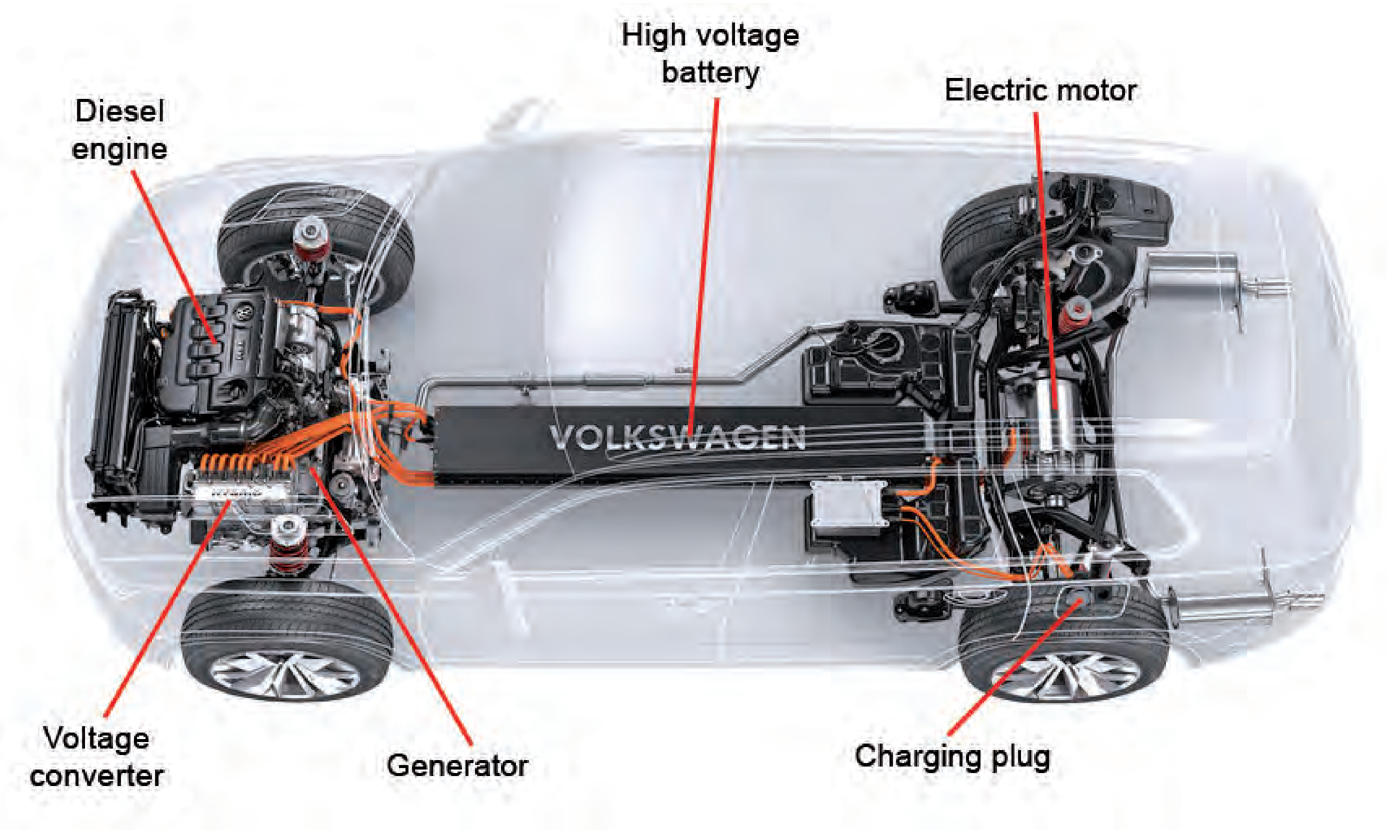
Series/parallel combination

The mixed hybrid system can use both configurations to transmit the energy flow to the wheels: in series and in parallel. To do this, the system uses a power split mechanism that manages the contribution of the electric motor and the contribution of the internal combustion engine to move the wheels.
This mechanism consists of a system of planetary gears. These gears make it possible to combine the flow of the transmission of forces in series or in parallel from both motors based on the torque and power demanded by the driver.
Normally, during the initial starts, the configuration tends to begin in series, because the electric motor begins to move the wheels. Once the vehicle has reached a certain speed, if the power demand continues, the internal combustion engine joins in with the electric motor to move the wheels and the configuration switches to parallel.
At times of low power demand, the vehicle can operate with 100% electric power, and depending on the battery charge level, the combustion engine will be turned off, as long as an optimum charge level is maintained. If not, the internal combustion engine will go into operation to charge the battery, without transmitting movement to the wheels, and the configuration will switch to in series.
In this type of combination, reverse is always fully electric and then the transmission of flow of forces is normally in series. During regenerative braking, the power split mechanism allows the electric motor to recharge the battery disconnecting the combustion engine from the kinematic chain.
Examples of vehicles that operate with a mixed transmission flow are the Toyota Prius and the Lexus RX400h.



STRUCTURE WITH DIESEL ENGINE

There are currently several car manufacturers in the market that are backing hybrid vehicles with diesel engines. The idea of installing a diesel engine in a hybrid vehicle is based on the low fuel consumption of this type of engine. They generally use a parallel combination, but the electric motor can be installed on the front or rear axle. Despite its low fuel consumption, this hybrid combination is being disregarded in utility vehicles because the diesel engines pollute more, and in the future, they may not comply with the minimum emissions in European regulations in comparison with hybrid vehicles with petrol engines.
Also, new hybrid diesel engines are being developed for industrial vehicles, as in the case of the Volvo 7900 Hybrid Electric bus, which combines a 4-cylinder 240 HP diesel engine and a 150 kW electric motor with a maximum torque of 1200 Nm.
In combination with the manufacturer Siemens, the bus has been equipped with a new high-output charging system that allows it to recharge its batteries in 6 minutes at charging stations located along the route.
It carries a lithium ion battery with a total capacity of 19 kWh, which allows it to cover a distance of up to 7 km in electric mode between charges. The bus runs mainly in electric mode, but if additional power is needed, or the battery drops to a preset level, the bus switches to hybrid operation propelled by both engines.

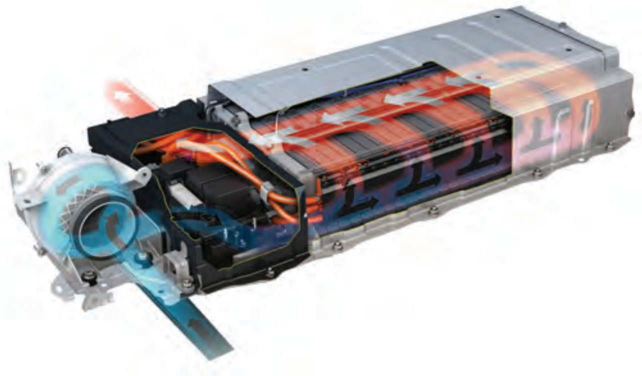


HIGH VOLTAGE BATTERY

Description

A battery is any device that can accumulate energy in chemical form, to later supply that energy in the form of electric energy when connected to an electrical circuit for the purpose of doing work. It is usually located underneath the floor of the vehicle, which helps to balance the weight between the front and rear of the vehicle and maintain a low centre of mass. This facilitates optimum traction and gives the vehicle excellent stability.
In hybrid or electric vehicles, the batteries used for the high voltage system are called traction or HV (High Voltage) batteries and they normally range between 150 and 450 volts.
In order to improve energy efficiency, these batteries are equipped with an autonomous cooling system that keeps the cells at the optimum operating temperature.To do this, they can circulate air driven by a turbine, with the air cooled by the vehicle's air-conditioning system, or not.

For safety in these batteries, a bipolar circuit breaker is included which allows the positive and negative terminals of the traction battery to be disconnected from the rest of the vehicle installation. It is a safety system which prevents hazardous currents in the rest of the wiring and high voltage components.



Classification based on recharging

Batteries are also classified by how they are recharged, and may be primary or secondary.

Primary batteries

These cannot be recharged, so they can only be used once. These normally have low self-discharge levels and high energy density. In hybrid and electric vehicles, tests have been done that demonstrate that they can almost double the autonomy of a secondary battery, but they have been disregarded because of their high replacement cost because they cannot be recharged.

Secondary batteries

Secondary batteries can be recharged after each discharge. They perform well in high-current discharges. The most well-known are lead-acid, nickel-metal hydride, lithium ion, etc. These are used in the automotive industry in both conventional 12 V vehicles, as well as in hybrid and electric vehicles.

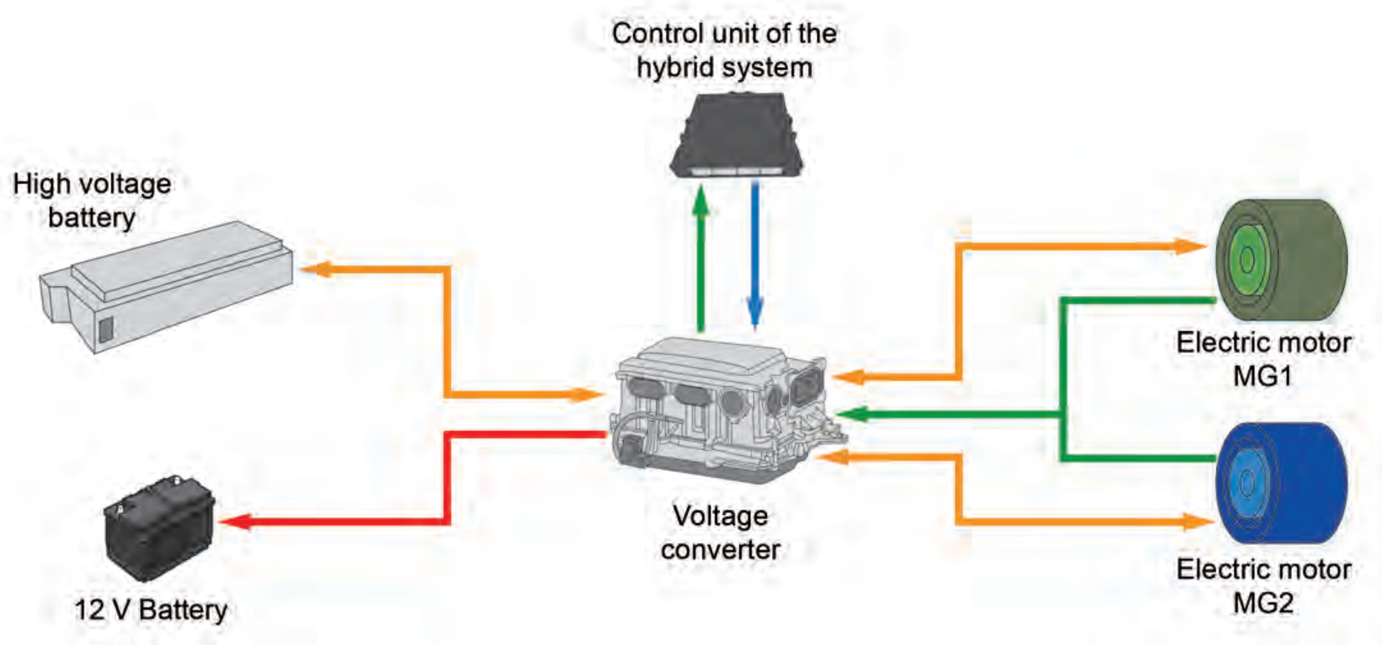
Materials used for manufacture

The principal difference between the batteries, as well as the power and the nominal voltage that are delivered, lies basically in the material used to manufacture the electrodes and the electrolyte used. The batteries used most commonly on the market are the following:

Type of battery	Lead-acid	Nickel-cadmium	Nickel-metal hydride	Sodium-nickel (Zebra)	Lithium-ion
Material of the negative electrode	Lead	Cadmium	Metal hydrides	Sodium	Graphites, nitrides and lithium alloys
Material of the positive electrode	Lead oxide	Nickel hydroxide	Nickel hydroxide	Nickel	Lithium cobalt oxide, vanadium oxide…
Electrolyte	Sulphuric acid	Potassium hydroxide	Potassium hydroxide	Sodium-nickel-chloride	Organic solvent + lithium salt
Energy/weight (Wh/kg)	30 - 50	48 - 80	60 - 120	120	110 - 160
Voltage per element (V)	2	1.25	1.25	2.6	3.70
Duration (charge/discharge cycles)	1000	500	1000	1000-2000	4000
Charging time (h)	8 - 16	10 - 14	2 - 4	-	2 - 4
Self-discharge per month (% of total)	5	30	20	-	25
Charge efficiency	82.5	72.5	70	92.5	90

CURRENT CONVERTER

This is responsible for transforming the direct current from the high-voltage battery into three-phase alternating current so that the electric motor can run. Additionally, when decelerating, it converts the electrical energy generated by the motor back into direct current to return it for storage in the battery.
The converter also reduces the high voltage from the traction battery to low voltage to supply the consumers on the 12-volt network, also charging a small 12-volt battery.
Communication between the converter unit and the electric motor is via special wiring. All of the high-voltage cables are shielded to avoid eddy currents as much as possible.
In turn, the converter manages the switching on of the phases of the stator depending on the rotor position, the power demand, the regenerative braking and whether or not the vehicle is moving forwards or in reverse.
In order to prevent the components of the powertrain from overheating (converter unit, charger, electric motor, reduction assembly, etc.), a water cooling system is installed. The temperature in this cooling system varies around 50 °C, with a simple temperature sensor avoiding the need for a thermostat.

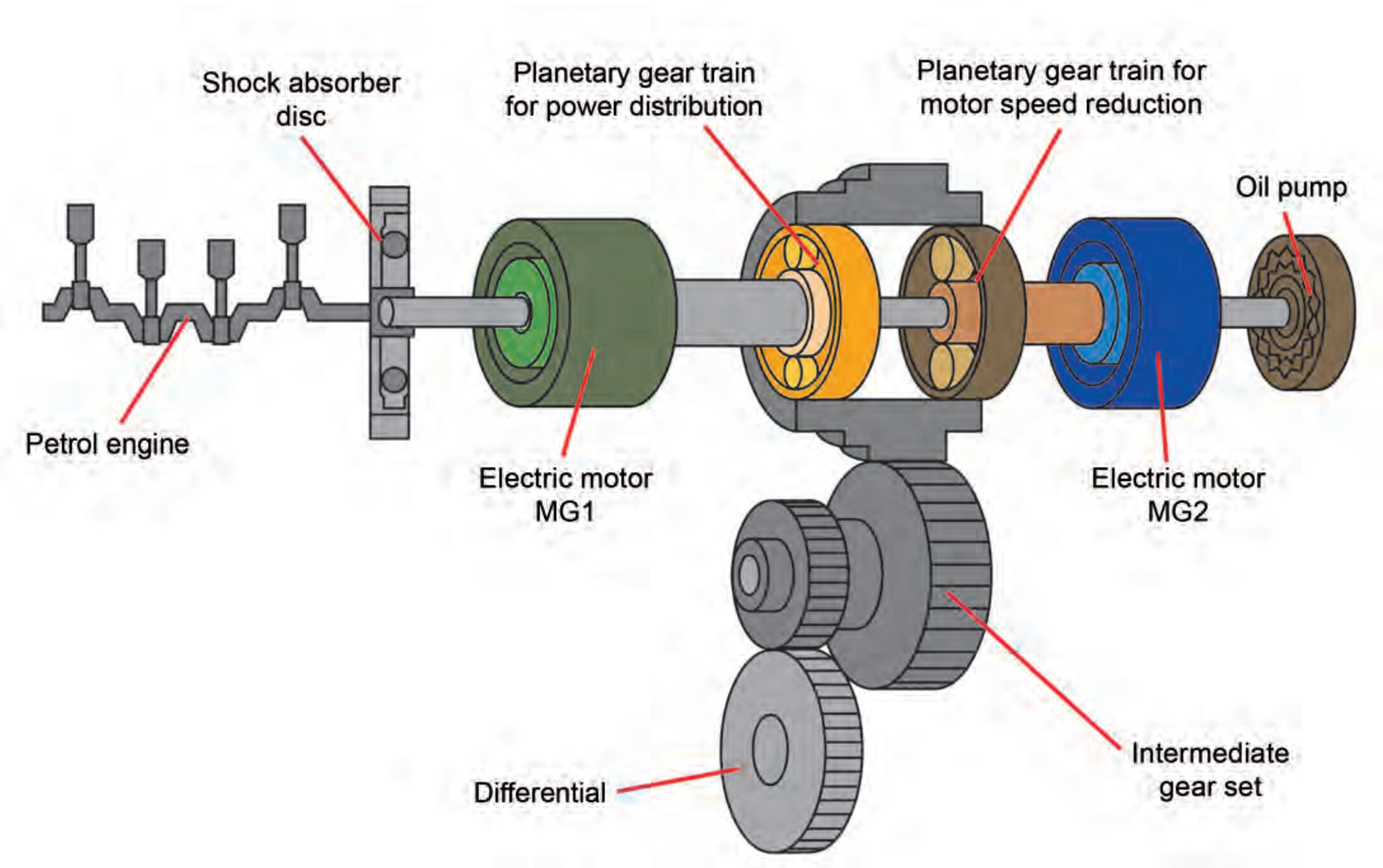


TRACTION SYSTEMS FOR HYBRID VEHICLES

In order to transmit the movement to the wheels, some type of gearbox is required to carry out the gear reductions for different speeds. Each manufacturer selects the type of gearbox to install in the vehicle, which may be:

- Manual gearbox
- CVT gearbox
- Automatic gearbox
- Sequential gearbox (DSG, Powershift, etc.)

Toyota has also designed a gear box that uses planetary gear trains for the gear reduction. Depending on the year of manufacture, one or two planetary gear trains are used, referred to as power distribution and motor speed reduction. ATF oil is used to lubricate the gearbox.
The driving feel with this type of gearbox is similar to an automatic CVT gearbox, because the gear reduction is continuous and the speed changes are imperceptible.
Electric motors MG1 and MG2, the planetary gear trains, the oil pump, the intermediate gear train, and the differential are located inside. The electric motors used in hybrid vehicles may be synchronous or asynchronous. The image below shows a diagram of the gearbox of a Toyota Auris Hybrid.
The difference between them lies in how they operate. In synchronous motors, the rotational speed of the rotor is the same as the rotational speed of the magnetic field of the stator. In asynchronous or induction motors, the rotor speed is always slower than the rotational speed of the stator's magnetic field.



CLIMATE CONTROL SYSTEM

The climate-control systems of hybrid vehicles are similar to those in vehicles with internal combustion engines, with the only difference being that they are equipped with an electrically driven compressor. This is due to the fact that the internal combustion engine is not always running during travel.

With this type of compressor, the internal combustion engine does not lose power when it is connected. Another advantage that they offer is that they can continue to function despite the fact that the internal combustion engine is stopped, and can even operate at the optimum revolutions at any given time, regardless of whether the driver is accelerating, braking, etc.

In order to optimize their size, they are scroll compressors and operate using the high-voltage current, and the oil used is POE (Polyolester) instead of PAG (Polyalkylene Glycol) oils used in conventional climate control circuits. It has specific electrical insulation properties that protect the compressor against electrical discharges produced by the motor.
A small number of car manufacturers use combination air-conditioning compressors. These consist of two compressors integrated into the same housing, one is electric and the other mechanical, driven by the auxiliary belt of the internal combustion engine.
The refrigerant gas used depends on the regulations in force at the time of approval, and may include R-134a and R-1234yf.

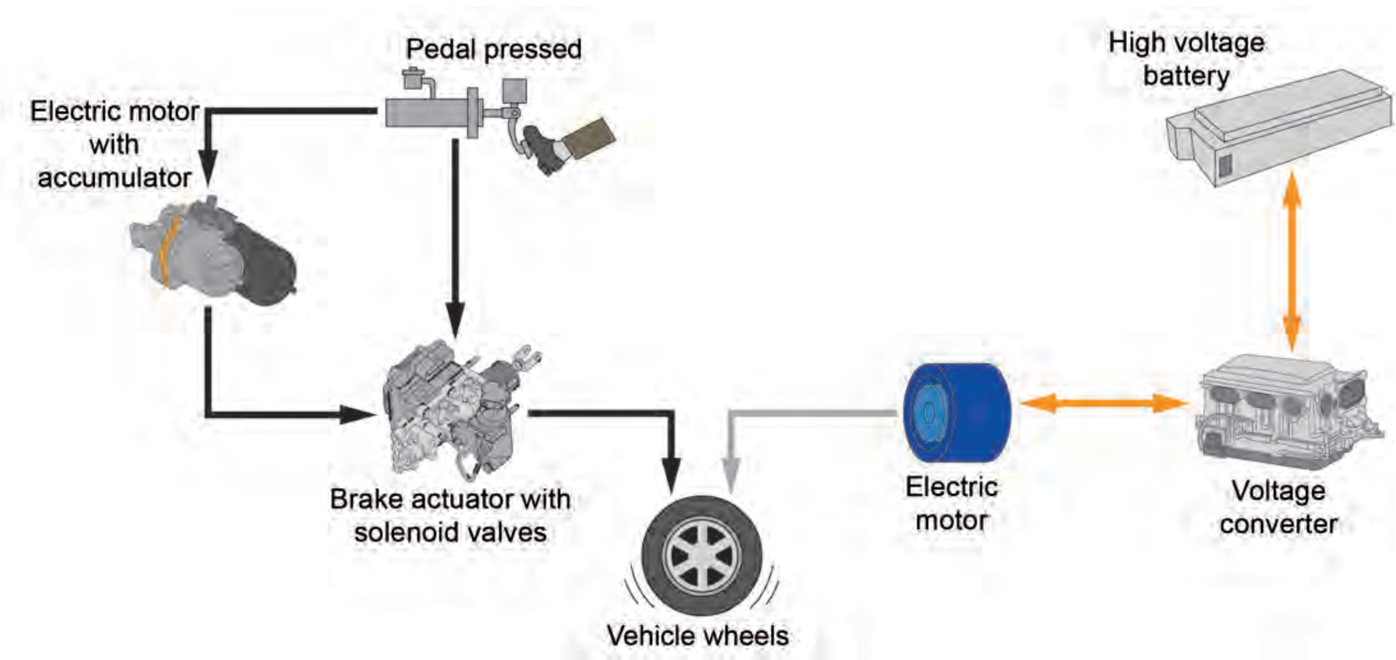
In regard to heating, the system is the same as for a conventional vehicle. The heat generated by the internal combustion engine is used to heat the inside of the compartment, through the heating radiator.
Since the water pump of the internal combustion engine stops turning when the engine stops, and consequently the coolant stops circulating, hybrid vehicles are equipped with an electric water pump that allows recirculation between the motor and the radiator of the heating. It is also common to have electric PTC heating resistors for when the engine water is cold or the heater’s effectiveness is insufficient.

BRAKING SYSTEM

A hybrid vehicle is equipped with two different braking systems, although for the purposes of the driver, the braking system must behave as if there were a single system. The braking system is made up of a classic hydraulic system and the regenerative braking system, in which the electric motor is involved when it behaves as a current generator.
The conventional hydraulic braking system normally includes a vacuum-based braking amplifier. Hybrid vehicles can travel a certain distance with the internal combustion engine stopped, so the vacuum is generally generated in two ways:

- By an electric vacuum pump, which is activated based on a signal from a depression sensor mounted on the braking amplifier itself.
- By an electric motor that generates pressure and an accumulator.

The regenerative brake would be the equivalent to the motor brake of a conventional vehicle. When the vehicle is in retention (moving without traction torque), the electric motor acts as a generator, transforming part of the kinetic energy into electricity, which is accumulated in the high-voltage battery.
In order for the braking of an electric vehicle to be effective and also take maximum advantage of the regenerative braking to recharge the high-voltage battery, braking systems that continuously combine both braking systems are needed.
The distribution of the braking force between the hydraulic braking and the regenerative braking varies depending on the speed of the vehicle and the braking moment. The following diagram shows the functioning of a braking system in a hybrid vehicle.



SYSTEM WITH LPG

Liquefied Petroleum Gas (LPG) is made up of a mixture of hydrocarbons (propane, butane, propylene, etc.) and is a gas at atmospheric pressure. It is stored liquefied at moderate pressure (3-10 bar) at ambient temperature. It is colourless and odourless, but an "odourizing" agent is added to easily detect leaks.

Advantages

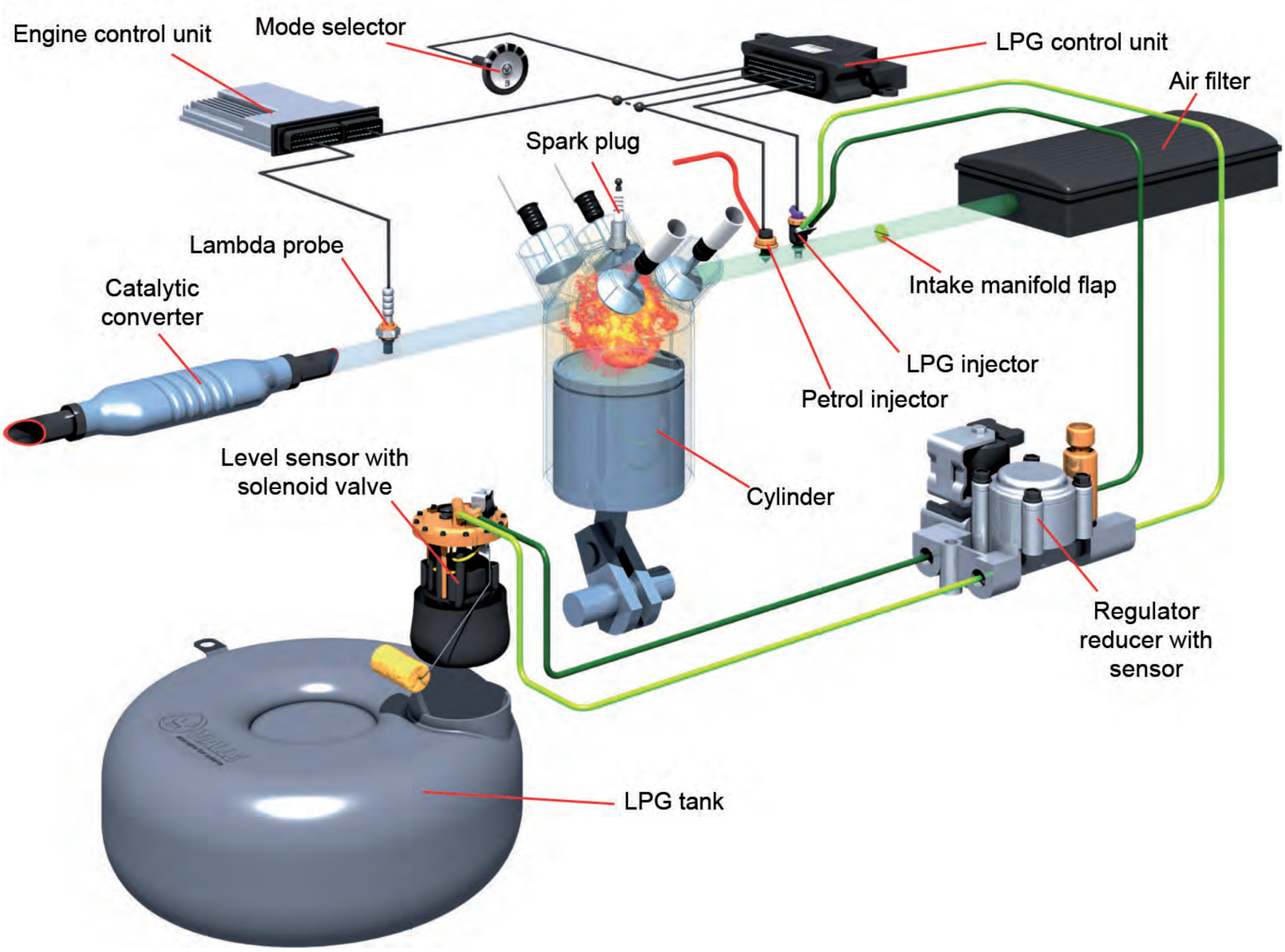
- Economical fuel price.
- More environmentally friendly than petrol.
- Extends life of the engine.

Disadvantages

- Supply network insufficient.
- Higher fuel consumption in comparison with petrol.
- Additives must be used in some engines.
- Reduced usable space and increased weight in the vehicle.
- Parking restrictions for vehicles.
- Loss of power greater than 10% approximately.

These have two feed systems, one for operation with petrol and the other for LPG. Because the fuel is sensitive to temperature, the vehicle always starts with petrol, and when it reaches a specific temperature, the system automatically switches to LPG. The user can select the operating mode with a switch.

The LPG is stored in a tank in liquid form at a temperature of approximately 8 - 10 bar, and can only be filled to 80% of its total capacity. The ramp pressure of gas injectors is approximately 1 bar higher than the pressure at the intake manifold. The pressure is regulated by a solenoid valve and a reducer. The gas injection system is controlled by an independent control unit.



SYSTEM WITH CNG

Compressed natural gas (CNG) is essentially natural gas stored at high pressure, normally between 200 and 250 bar, depending on the regulations in each country. It is comprised mainly of methane gas (CH_4).

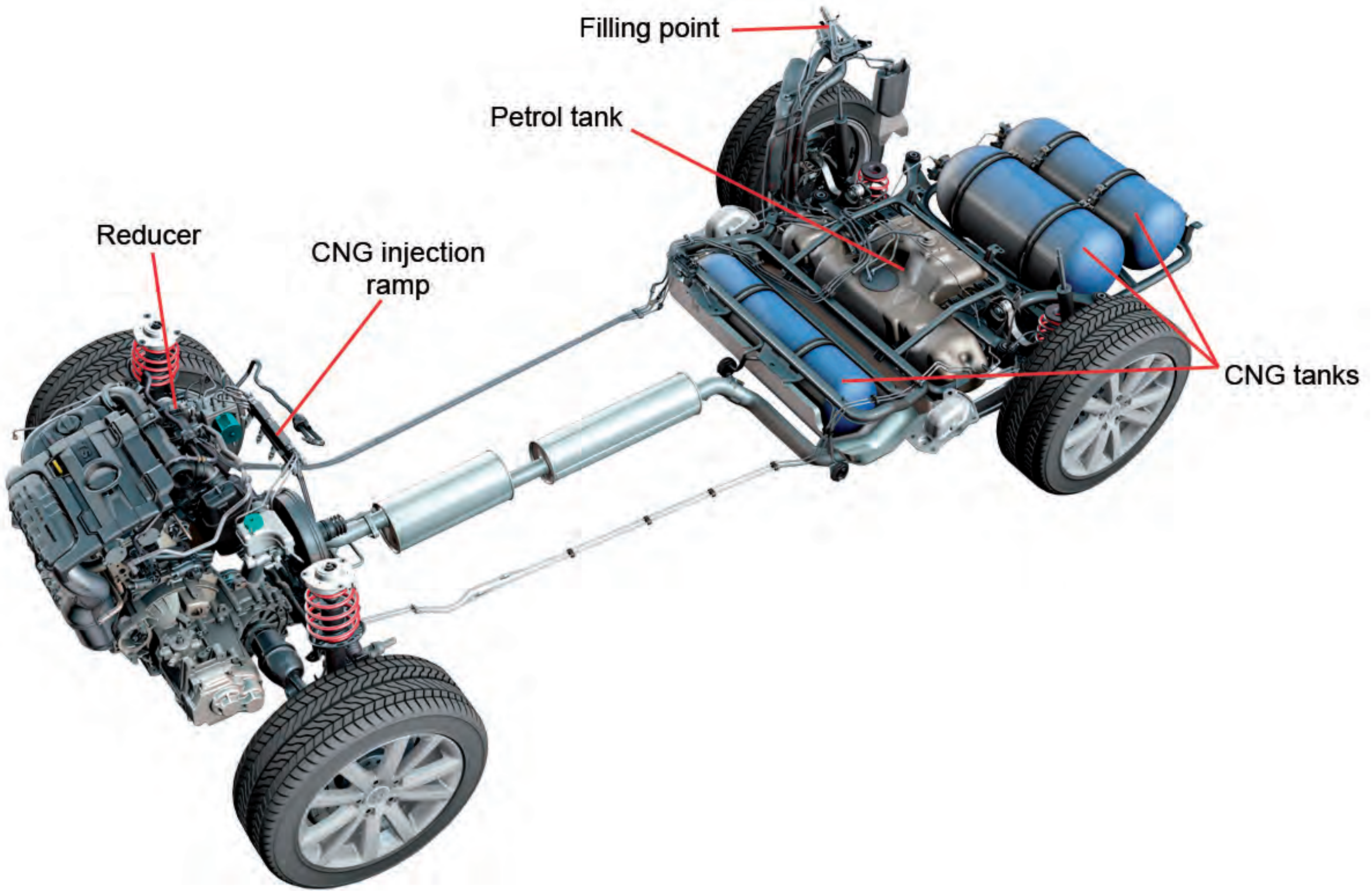
Advantages

- Engines run quieter.
- Low fuel consumption (3.5 kg/100 km).
- More environmentally friendly than petrol.
- Extends life of the engine.

Disadvantages

- Large volume tanks.
- Supply network insufficient.
- Approximate power loss of 10%.
- Reduced usable space and increased weight in the vehicle.
- Maintenance must be done by specialized technicians.

Operation is similar to LPG, but at much higher pressure. The vehicle is started with petrol if the temperature of the cooling liquid is less than 15 °C; if the temperature is higher, the engine can be started with the gas. After refuelling, the engine is always started with petrol. The switchover to natural gas is done with the activation of lambda regulation, or after the engine has been running for approximately 3 minutes at the latest. It is stored as a gas in the tank at a pressure of approximately 200 bar. The ramp pressure of the gas injectors is approximately 6 bar; a reducer and solenoid valve, which operate similar to the case of LPG, carry out this reduction in pressure. The gas injection system is controlled by a control unit.



COMMON FAILURES

The high-voltage systems of hybrid vehicles malfunction infrequently over the course of the lifetime, but they may be related to insulation and continuity issues in electric motors, malfunctions in the current converter, seizing of the air-conditioning compressor, etc.

HIGH-VOLTAGE BATTERY

The most common malfunctions are related to wear on the high-voltage battery, and more specifically, the cells. All batteries have a lifetime that depends on the charge-discharge cycles and the manufacturing material.
As these charge-discharge cycles are completed, some of the battery's cells may deteriorate, progressively diminishing the duration of the battery. The driver perceives that the battery discharges very quickly and the range in electric mode is shorter and shorter.

To locate the affected cells, each one of the cells that makes up the battery must be measured individually with a voltmeter. The voltage obtained should be similar in all cells. Deteriorated cells normally have lower than average voltage.

Replace affected cells with new ones. Some manufacturers do not allow the option of replacing cells, so the entire battery must be replaced.

LOW-VOLTAGE BATTERY

If the 12 V battery is uncharged or deteriorated, the motor cannot be started. This is because the control units that manage the internal combustion engine and the hybrid system operate at low voltage.

Use a battery tester to verify the condition of the battery. A voltmeter can also be used to measure the voltage of the 12 V battery. A battery is considered to be in poor condition if the average voltage is less than 9 V.

Replace the 12 V battery with a new one.

TECHNICAL NOTES

This section describes the most common malfunctions in relation to the mechanical components and electronics of hybrid systems. Depending on the manufacturer and the different models, the number of faults occurring over the years can be considerable.

These faults are selected from the online platform: www.einavts.com. This platform has a series of sections that specify: make, model, line, system affected, and subsystem, which can be selected independently depending on the desired search.

TOYOTA

TOYOTA PRIUS Fastback, TOYOTA PRIUS (ZVW30), TOYOTA PRIUS Sedan (NHW11_)	
Symptoms	P3000 - Malfunctioning of the battery control system. Malfunction light of the hybrid system lit.
Cause	Deep discharge of the high-voltage battery and the internal combustion engine cannot be started. Deep discharge of a battery may be caused by the following: Defect in the hybrid control system, either the failure of the transmission assembly or the battery itself. Improper use of the vehicle: Driving without fuel and keeping the vehicle in READY, which causes the hybrid system to continue to try to start the combustion engine even though EV mode (full-electric driving) is not available. Incorrect refuelling with diesel or poor quality fuel, the hybrid system attempts to start the combustion engine until the battery is dead.
Solution	Recharge the high-voltage battery. NOTE: The high-voltage battery charger is only available at origin.

KIA

KIA MAGENTIS (MG)	
Symptoms	P0456 - Steam emission leak system detected (Very small leak). Malfunction indicator lamp (MIL) on. NOTE: This announcement applies only to hybrid vehicles (HEV).
Cause	Defect in the leak detection valve of the fuel vapour system (NVLD).
Solution	Repair procedure: Check the condition of the leak detection valve of the fuel vapour system (NVLD). Replace the leak detection valve of the fuel vapour system (NVLD).

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