TOYOTA PRIUS II HYBRID SYSTEM

INSTRUCTION

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1. WORK SAFETY

1.1. General safety requirements

Attention:

Familiarize yourself with the instruction manual of the training equipment before starting any work on the equipment.

The educational equipment may only be used for the educational purposes specified in the instructions.

Training personnel (teacher, teacher, instructor and others) must be familiar with the instruction of the training equipment, know the methods and principles of using the equipment, settings, management, and be able to turn off (stop) the training equipment in an emergency.

The personnel conducting the training (teacher, teacher, instructor and others) acquaints those working and learning with the educational equipment with the work safety requirements s.

When working with high-voltage systems (hybrid power plants and electric cars), it is mandatory to comply with electrical safety requirements and use personal protective equipment against electric discharge.

It is forbidden for children and unqualified personnel to work with the educational equipment.

Persons under the influence of alcohol or other psychotropic substances are prohibited from working with the training equipment.

It is prohibited for persons without proper qualifications to open electrical input boxes, connect or change anything there.

It is prohibited to improve, modify or otherwise change the design of the educational equipment without the written consent of the manufacturer.

The connection of the power sources of the educational equipment is carried out according to the instructions given in the " Energy sources" section.

Do not ignore the warning signs on the training equipment about potential hazards. Beware of the hazards indicated in the warning signs.

When cleaning educational equipment, it must be completely switched off.

It is forbidden to wash educational equipment with running water or any chemical cleaning agents.

It is forbidden to clean the electronic components of the educational equipment with wet cloths.

When performing maintenance and repair work on educational equipment, the equipment must be completely switched off.

It is forbidden to disconnect the power cords of the electrical elements of the educational equipment. Careless or repeated disconnection of these wires leads to damage to the connectors and loss of contact. The desired electrical measurements can be made in specially designed banana connectors installed in the training equipment. Banana type connectors are resistant to multiple connections.

Before working with the training equipment, check that:

- The equipment is mechanically undamaged, unbroken;
- All protective shields are assembled;
- All hot, rotating parts (such as heating candles, pulleys, gears, etc.) are covered;
- There are all the components (e.g. wires, jumpers, fuses, knobs, etc.);
- Sufficient technical fluids (eg brake fluid, oil, coolant, etc.);
- Liquids do not seep through joints;
- There are no foreign bodies in the equipment components;
- Undamaged electrical wires;
- Neat power sources (battery or bench power unit);
- Are the power sources properly connected (e.g. the terminals of the batteries are screwed, the polarity is not mixed);
- Using training equipment with internal combustion engines ensures the removal of combustibles from the audience;
- The training equipment is properly placed and locked (e.g. the equipment is placed on a sufficiently strong base, the transport wheels are locked);
- During operation, the equipment will not cause any danger to the working personnel;
- There are other factors not provided for in the instruction that may cause health hazards to the personnel working with the equipment and other persons.

When working with the equipment, observe whether:

- Equipment with internal combustion engines removes fuel from the audience smoothly;
- The noise emitted by the equipment is typical for such a work process (there are no extraneous sounds);
- The equipment did not start leaking liquids;
- The amount of technical fluids is sufficient;
- The smell of smoldering, burning things is not smelled;
- Power supplies are working properly;
- Any other factors or processes not provided for in the instruction that may cause health hazards to personnel working with the equipment or other persons do not take place.

Attention:

In stand hybrid cars, the internal combustion engine can start at any moment on its own, as long as the POWER switch is turned on. The start of the engine is controlled and executed by the car's hybrid system control computer by evaluating the battery charge level of the high-voltage batteries. When working with hybrid car stands, before turning on the "POWER" switch, it is mandatory to ensure that the fuel is removed from the room properly and that there are no persons working or foreign objects near the rotating engine parts.

1.2. Safety requirements for working with electric and hybrid cars

Employees, teachers, students, support and service personnel must be familiar with the requirements of work safety instructions for working with electrical devices after listening to the instruction and must sign work safety logs. The training of employees and other personnel is carried out in accordance with the normative legal acts, laws and by-laws in force in that state (country) . Follows the "Safety rules for the operation of electrical equipment".

Only persons with appropriate qualifications can work with high-voltage components and circuits of an electric car.

Elements (wires, connectors, control units, voltage converters, etc.) in which high voltage is constantly or periodically present are marked in orange.

Follow the rules of safe work when operating cars.

The high voltage system may turn on automatically. Before starting work at the stand, it is necessary to make sure that the timer for controlling the air conditioner or charging the batteries is not set.

Warning:

• Since electric vehicles contain high-voltage batteries, improper use of high-voltage components and the vehicle may result in electric shock, electric shock, or similar accidents. Be sure to follow correct operating procedures when performing inspection and maintenance.

• Be sure to remove the maintenance connector (fuse) from the socket in the battery box of the high voltage batteries before checking or servicing the circuits and assemblies of the high voltage system. This will turn off the high voltage circuit.

• Place the maintenance connector in a safe place out of the reach of other persons so that it cannot be accidentally connected by another person while maintenance and service work is in progress.

• Before working with high-voltage components, take care of personal protective equipment and equipment: gloves, shoes, face shield, rubber mat, ground loop, etc.

• Take care of the safety of the workplace around the vehicle: marking, responsible employees, fencing so that other people do not touch the vehicle. When work is not being carried out, high-voltage parts and components must be covered with insulating covers or shields so that other persons do not touch them.

WARNING "CAUTION HIGH VOLTAGE KEEP DISTANCE"

To attract the attention of other workers, put an informational warning sign on the car "Danger! High voltage. Keep your distance".

CAUTION:

HIGH VOLTAGE. DO NOT TOUCH DURING OPERATION

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HIGH VOLTAGE. DO NOT TOUCH DURING OPERATION

The table must be printed, folded into a triangle (the bending points are marked with a dotted line) and placed on the car.

Electric cars do not make any noise. The absence of noise does not mean that the car is turned off.

If necessary, always disconnect the negative terminal of the 12 V battery.

High voltage battery connected to voltage converter, electric motor/generator, air conditioning pump by high voltage (marked in orange) wires. High voltage wires, regardless of their polarity, have orange insulation.

The high-voltage battery is protected by a fuse. Power on and off is controlled by normally open 12 V voltage controlled relays.

Attention:

A high voltage circuit may have residual voltage after it has been switched off. Therefore, after turning off the system, you need to wait at least 10 minutes. During this time, it is forbidden to touch the high-voltage cables, disconnect them, repair or check something.

Both the positive and negative high voltage cables are separated from the car body. Therefore, there is no possibility of receiving an electric discharge by touching the metal parts of the car.

The high-voltage battery is disconnected as soon as the SRS (Supplemental restraint system) system is activated during a car accident. This prevents high voltage leakage into the car body.

When working with high-voltage components, batteries, protective equipment must be used:

- glasses;
- face shield;
- rubber, latex gloves;
- protective clothing and apron;
- rubber boots:
- Rubber mats.

All protective and work equipment must meet the requirements of electrical safety standards, be metrologically checked and have valid metrological inspection documents.

When preparing to work with an electric car, it is necessary to turn off the car by removing the negative terminal of the car's 12 V battery. Using protective equipment (gloves, work clothes, shoes, glasses, mats, etc.), disconnect the high-voltage service connector (fuse): unlock the lever latch, lift the lever up, and pull the entire service connector out of the socket.

After disconnecting high-voltage cables or other electrical connections, it is mandatory to isolate open contacts with insulating materials intended for this purpose.

After disconnecting the electrical components, it is necessary to check whether there is no residual voltage in them.

When working with high-voltage circuits, it is necessary to use protective equipment. Before starting work with electrical components, measure the voltage in them. The devices must show 0 V. It is possible to work with high-voltage circuit elements only after at least 10 minutes after switching off the circuit. The system contains capacitors that must be discharged (discharged).

The SRS system can also be activated 90 seconds after the battery has been disconnected. Care must be taken when handling the system to avoid possible injury from activation of SRS system components.

Attention!

Work safety instructions must be followed when working with electric cars. Employees who work with electric vehicles can be shocked by high-voltage electric currents, be injured by improper handling of measuring and repair equipment due to sparking. At the beginning of the work, it is necessary to ensure that all repair and maintenance work is performed only when the high voltage lines are disconnected.

After disconnecting the high-voltage cables, they must be insulated. This avoids short circuit, self-reclosure and human protection. During work, use only suitable, fully insulated tools.

It is forbidden to remove the orange plastic protective parts from the conductors connecting the battery parts of the high-voltage batteries.

2. GENERAL INFORMATION

2.1. Purpose of educational equipment

Educational equipment is intended for educational activities. It is a visual tool for explaining and demonstrating the structure and operation of various automotive parts, assemblies, structures, systems. The equipment is used as a teaching and learning tool for monitoring and analyzing work processes of various car systems. It is possible to carry out various measurements of the parameters of the system installed in the training equipment, of the ongoing processes, to carry out fault simulations, and to diagnose. Various laboratory tasks can be performed using the educational equipment. The equipment is prepared and manufactured in order to provide students with information about the structure of the unit, the system composition and the principle of operation as clearly and comfortably as possible.

The educational equipment is intended for the demonstration, teaching and learning of the Toyota Prius Hybrid System - II (THS) structure and structure, operating principle, settings and adjustments.

2.2. Parameters of educational equipment

Length	3100 mm;
Width	1745 mm;
Height	1510 mm;
Weight about	~ 960 kg (depends on the configuration);
Energy sources	battery 12 V
	high voltage battery pack ~ 200 V
	gasoline A95

Educational equipment is made using elements of the car:

Manufacturer:	Toyota
Model:	Prius
Year of production:	2003 - 2009
Engine code:	1NZ-FXE
Code:	NHW20
Type of fuel:	gasoline

2.3. Transport and storage conditions

The training equipment is mounted on a dedicated stand, frame, platform or chassis. When transporting equipment that contains an internal combustion engine or any other technical fluids, it is forbidden to tip or lie down. During transportation, it is mandatory to protect the equipment from falling, overturning, shocks, moisture, temperature effects, and vibrations.

Training equipment with its own chassis must be equipped with locked transport wheels during training and storage (as well as during transportation). It is allowed to unlock the castors only when moving the educational equipment to another place.

Educational equipment that does not have its own stand or chassis must be placed on a suitable, solid base (table, cabinet).

When carrying out export or import procedures, it is mandatory to take into account the legal acts between the countries. Import-export procedures and various taxes apply to various technical fluids, oils, batteries, tires and more.

Training equipment must be stored in a room with a minimum ambient temperature of at least +10 °C. Relative humidity not more than 60%.

Training equipment must not be exposed to direct sunlight. The equipment must be covered with protective equipment if the equipment is exposed to direct sunlight.

Unused educational equipment is stored completely switched off. The emergency stop button is deactivated. The training stands are turned off with the control key and by disconnecting the power supply (turning off the power source and/or disconnecting the 12 V battery).

It is recommended to remove the maintenance connector from the high voltage battery pack . Store it together with the control key in a safe place.

Stands with internal combustion engines and stands - cars are turned off with a control key. The key is removed from the lock. Such a stand is stored like a regular car. The battery pack (12 V) is not disconnected.

- It is necessary to take care of and regularly charge the battery of 12 V batteries.
- It is necessary to take care of the charge level of the battery of high-voltage batteries (hybrid cars and electric cars). It must not be lower than the manufacturer's intended (set) minimum allowable voltage.

The training equipment must be turned on at least once in a 30-day period and run for at least 20 minutes. It is a preventive measure designed to reduce the likelihood of stalling and jamming of various engine or car system components. It is not recommended to leave educational equipment unused for more than 2 months. period. If it is necessary to leave the equipment unused for more than two months, it must be properly prepared and preserved.

2.4. Maintenance and service

Training equipment is maintained as normal mechanical, hydraulic, pneumatic, electrical machines and systems. Educational equipment requires minimal maintenance and service.

It is necessary to constantly monitor the presence of fluid leakage from the components of the training equipment.

It is necessary to control and ensure that all the components belonging to the educational equipment are present.

Damaged, broken parts, blown fuses, damaged connecting wires and other parts are replaced with new ones.

In training equipment with internal combustion engines, gearboxes, conditioning systems, maintenance and service is carried out in accordance with the technical requirements and conditions of the manufacturer of the vehicle used in the training equipment.

Engine oil and filter are changed using good quality parts and oils that meet specifications once a year.

In equipment with internal combustion engines, the level of engine oil and coolant must be constantly controlled.

In the stands - the cars must have the engine oil level, the coolant level, the brake fluid level, the clutch fluid level, and the oil level in the gearbox under constant control.

The drive element (chain or belt) of the gas distribution mechanism of the internal combustion engine is changed according to the recommendations of the engine manufacturer. The criterion is time.

In training equipment with pneumatic wheels, the air pressure in the tires is constantly monitored. If the air pressure in the circle is constantly decreasing, the leaky places must be repaired - sealed.

It is necessary to regularly check and monitor the battery charge of 12 V batteries. Strong battery discharge (voltage below 10.5 V) is not allowed. It is forbidden to store a discharged battery for more than 10 days (in a lead-acid battery, irreversible sulphation processes can begin, which causes the battery to fail).

It is necessary to regularly check the battery charge level of high-voltage batteries (hybrid cars and electric cars). The charge level must not be lower than the minimum allowable battery voltage specified by the battery manufacturer. If necessary, the battery pack must be charged with the appropriate means and equipment.

When performing technical maintenance and servicing of educational equipment, it is mandatory to use only technical fluids of suitable quality and meeting the technical specifications (engine, transmission oil, coolant, brake fluid, etc.), high-quality filters and other spare and complete parts.

2.5. Energy sources

The training equipment operates using suitable energy sources:

- mineral fuels
- electricity (self-produced)

Mineral fuels

For educational stands with internal combustion engines, the appropriate type of mineral fuel is selected - gasoline.

The fuel must comply with the 2016 European Standardization Committee. adopted European standard EN 16942:2016 (Fuels –Identification of vehicle compatibility –Graphical expression for consumer information) or newer requirements.

The training equipment uses brand 95 (95 octane number determined by the research method) gasoline that meets the requirements of EN 228:2017.

Attention:

It is forbidden to use biofuels or flammable and other liquids of unknown origin in educational equipment.

Electric power

The 12 V battery must meet the technical conditions of the training equipment: battery terminal arrangement, capacity (Ah), starting current (A), size (length (mm), width (mm), height (mm)).

Disconnect the battery charger for the 12 V batteries when working with the training equipment. The charger can emit electromagnetic noise that affects the operation of training equipment and can be recorded by sensitive measuring devices (oscillograph).

Attention:

When connecting the 12 V battery to the bench, the control key and all other consumers must be turned off. First, the "+" battery contact (terminal) is connected and tightened. Then the "-" battery contact (terminal) is connected and tightened.

When disconnecting the 12 V battery pack from the stand, the stand must be switched off. First release and disconnect the "-" battery contact, then release and disconnect the "+" battery contact.

Attention:

Do not mix up the polarity of the wiring to the 12V batteries. On the battery pack, the wire connectors are marked with "+" (positive) and "-" (negative) contacts (terminals). The contact of the wire marked with the "+" (positive) sign (the color of the wire insulation is red) is connected to the contact of the battery marked with the "+" (positive) sign. The contact of the wire marked with the "-" (negative) sign (the color of the wire insulation is black) is connected to the contact of the battery marked with the "-" (negative) sign.

In this car model with hybrid technology, the 12 V and high voltage batteries are installed in the front passenger seat.

Installation location for 12 V and high voltage storage batteries

WARNING:

Personal protective equipment must always be used when removing and installing the service connector.

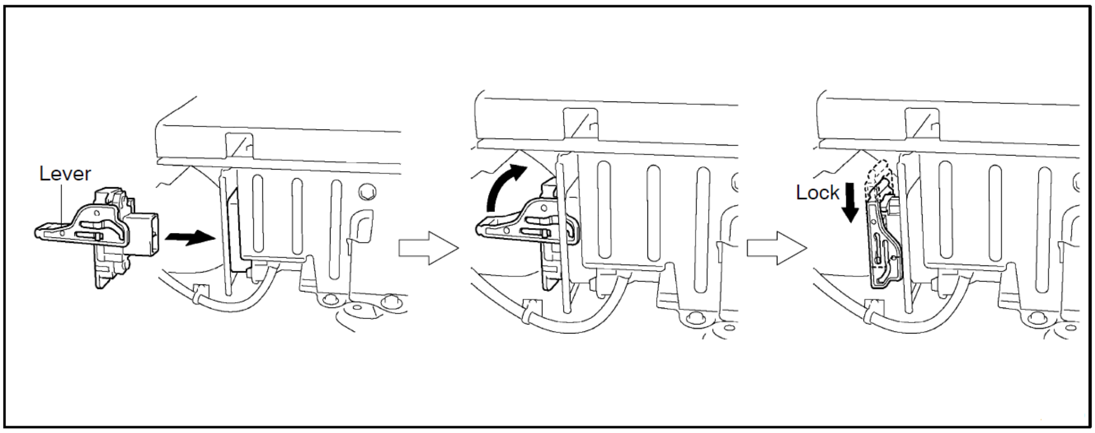
Maintenance connector

When performing any work on the high voltage (~200 V) electrical circuit, it is necessary to remove the service connector.

Maintenance connector (in the middle of the picture, orange)

Before removing the service connector, it is necessary to turn off the hybrid vehicle by pressing the POWER switch. READY should go out on the instrument panel. The following steps disconnect the negative terminal of the 12V batteries.

After removing the maintenance connector only after 10 min. it is possible to start work with high-voltage electrical circuits. This time is required to discharge the high voltage capacitors.



Inserting the maintenance connector into the socket

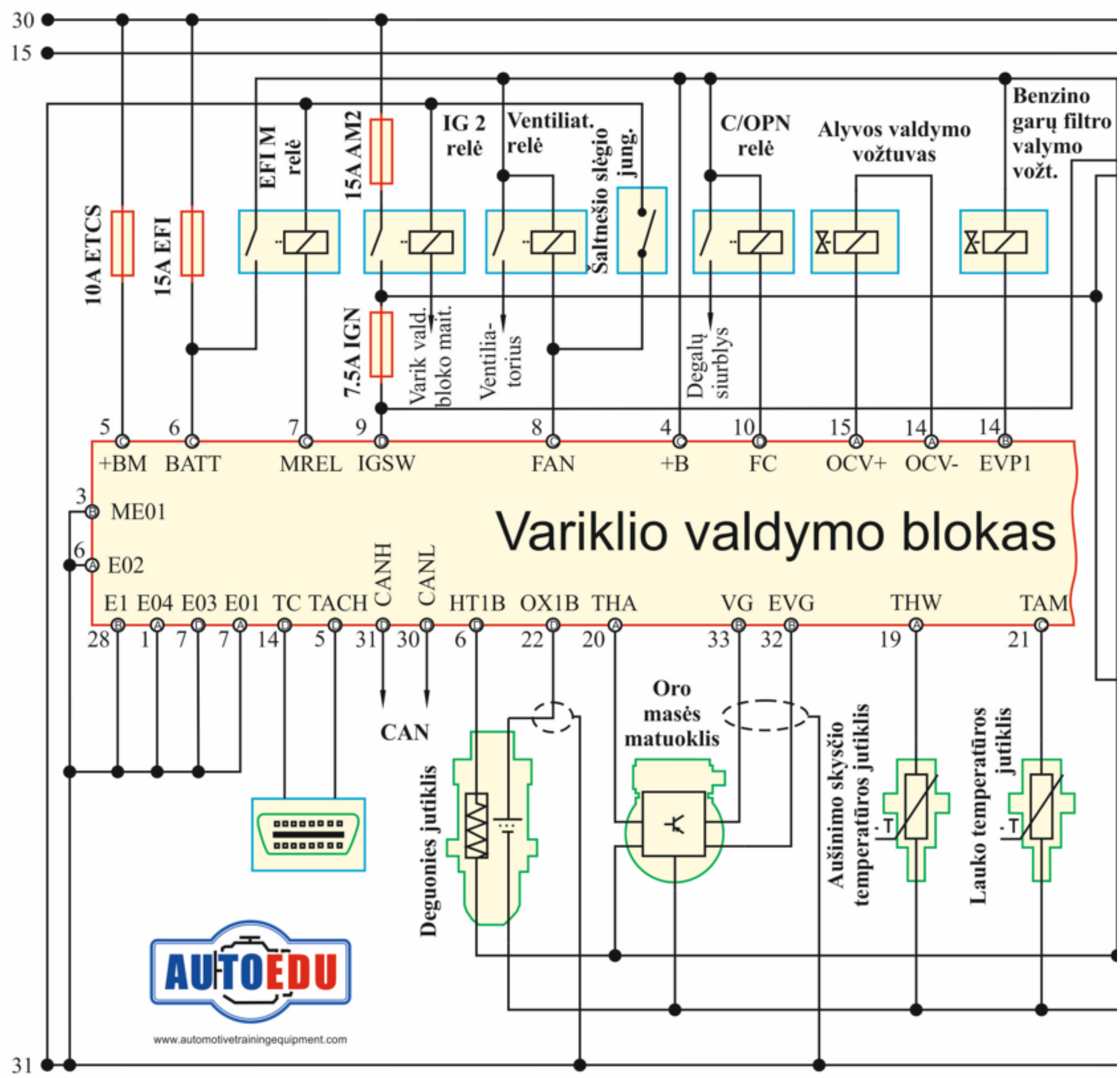
Removal of the maintenance connector is carried out in the opposite direction to installation.

Fuel tank

The fuel tank is installed in the rear part of the car. It can be accessed for refueling by removing the rear cover. The cover is removed after releasing the two rubber latches on the left and right sides. The lid opening switch is then pressed and the lid is lifted slightly. The power cords are disconnected and the cover is placed to the side. If the lid switch does not work, unlock the car with the control key.

2.6. Symbols and markings

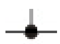
The training equipment uses automotive symbols for marking electrical diagrams and components. The figure below shows an example of marking components in an electrical diagram.



Example of wiring diagram and component labeling.

Designation of car electrical diagrams:

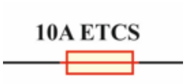
Black line connecting cables;

 wires connected together;

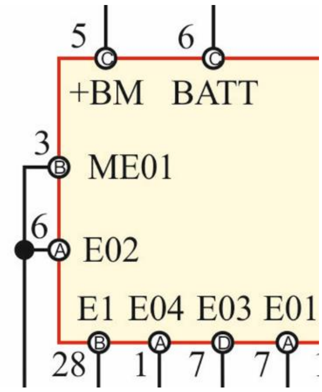
30 the wire marked with a number is the wire of the electric circuit that has a constant voltage of +12 V from the battery;

15 the cable marked with a number is the type of electric circuit cable in which +12 V DC voltage is activated with the help of the ignition key;

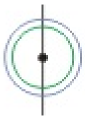
31 the wire marked with a number is the wire of the electric circuit that is connected to the car body and the negative terminal of the battery (ground ⏚);



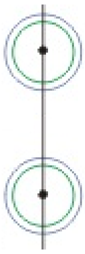
Fuse . 10 A in the ETCS power circuit.



Car control computer (eg: engine, hybrid system, airbags, brakes, ABS or other). The letters (A, B, C, D) in the circle indicate the connection. For example: C6 is the sixth pin of connector C. The power cable from the battery pack BATT is connected to this pin.



A banana 4 mm is installed in the training equipment and connected to that cable. connector (socket) for connecting measuring equipment or a jumper.



Two banana connectors (sockets) are installed on the cable for connecting a jumper. A jumper pulled out of the connectors breaks the circuit of this wire. Electric current cannot flow. The bench wiring diagram doesn't show this wire break because real cars don't have banana plugs. These connectors are installed in the electrical circuit of the training equipment, making it possible to perform measurements and simulate faults.

Shortener. Connector with 2 banana-type 2 (4) mm contacts (plugs) at the bottom and one banana-type 2 (4) mm contact (socket) at the top. All three contacts inside the jumper are connected together.

2.7. Equipment preparation and use

When preparing training equipment for work, it must be properly positioned and secured. Equipment with a chassis is placed on a flat and solid floor. The transport wheels of the equipment are locked by locking the brakes.

Attention:

Equipment with internal combustion engines must be connected to a functioning exhaust system. The room must be well ventilated even when the exhaust system is operating.

Before working with the educational equipment, a suitable , charged 12 V battery is connected.

The technical condition of the equipment, fastening of protective shields, equipment and other details are checked. More detailed information on safe work requirements in the section "Occupational safety →Before working with training equipment, check that:".

Checking the position of the emergency stop switch. If the training equipment has been stopped in an emergency, the emergency stop switch remains pressed and the equipment does not start. To unlock the emergency stop switch, it pops out when the top part is turned clockwise (the top part moves to the right).

Emergency stop switch

If the emergency stop switch needs to be used, it is pressed with a finger or palm. There is no need to spin anything.

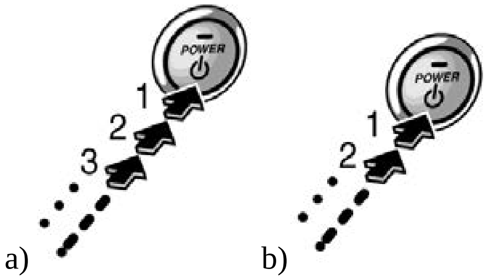
Attention:

After finishing work with the training bench, we recommend that you do not leave the ignition key and maintenance connector on the bench.

In training equipment, all indications about the operation of the equipment are reflected on the instrument panel.

Equipment with a car ignition key is operated in the same way as a normal car. The ignition key is tied to the immobilizer system.

Turning on the educational equipment is done with the help of the POWER key.



a) Pressing the POWER key when the brake pedal is not pressed:
   1. The ACC function is activated when power is supplied to the radio
   2. IGNITION ON. All car systems are working (interior ventilation, window wipers, lights, etc.)
   3. Everything is turned off

b) Pressing the POWER key when the brake pedal is depressed b):
   1. IGNITION ON. All car systems are working (interior ventilation, window wipers, lights, etc.)
   2. READY mode is activated. The hybrid system stand is fully activated.
   3. Pressing the POWER key again turns off the entire hybrid system.

When learning diagnostics, car control computer system scanners (computer diagnostics), it is possible to perform the activation of execution components. Which elements can be activated depends on the capabilities of the available diagnostic and training equipment.

With the help of system scanners, written fault codes/messages can be found in the memory of the car's control computer. These codes/messages are stored in the memory when the sensor, the actuator, the wire is broken, the contacts are lost. All fault codes can be erased from the car's control computer memory using system scanners. As in cars, errors can be deleted from the memory of the control computer only when the fault is physically removed (eg: a jumper is put in its place, a cable is connected, a faulty sensor is replaced, etc.).

3. EDUCATIONAL EQUIPMENT

3.1. General overview of educational equipment

A general view and structure of the training equipment is presented in the illustrations below.

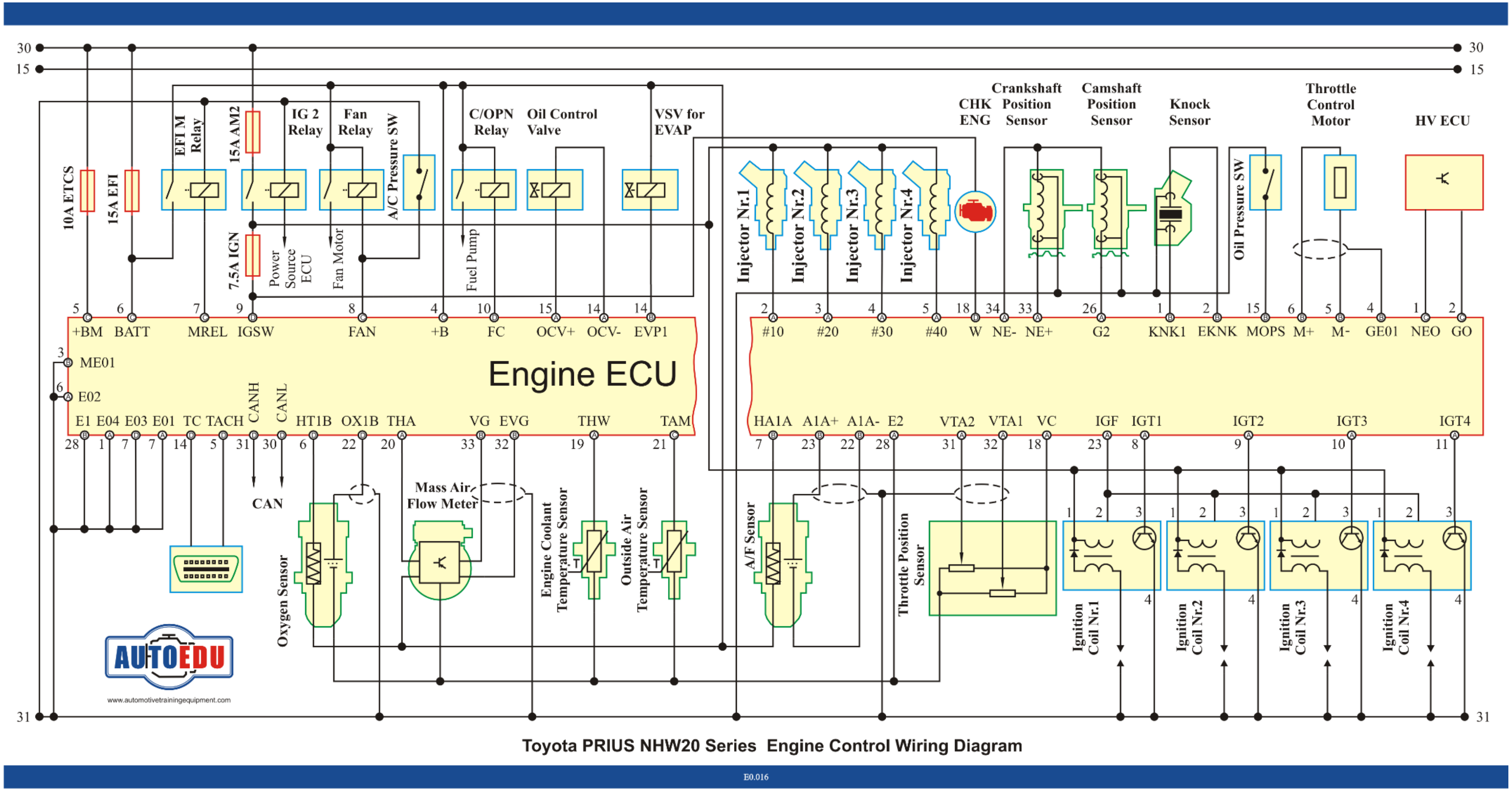
Toyota Prius II hybrid car model

Signal output panel

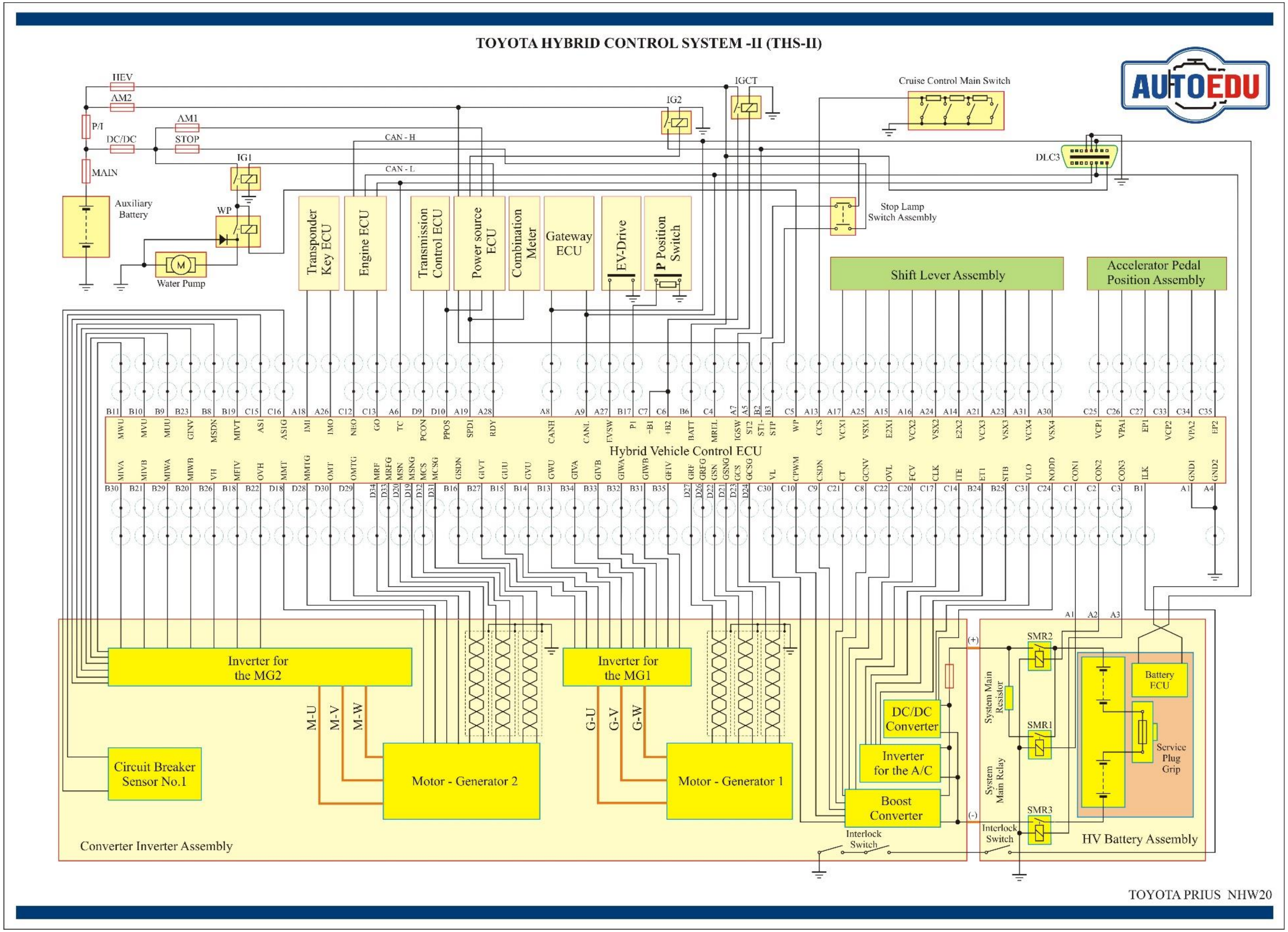
Bug simulator

3.2. Electrical diagram

All elements are presented in the electrical diagram: sensors, execution components, data transmission lines, diagnostic connection. According to this scheme, you can see the connection circuits of the elements, the numbers of the connection contacts, the numbers of the components, the installation locations of the jumpers



Electrical diagram of the internal combustion engine control system



Schematic diagram of the hybrid system

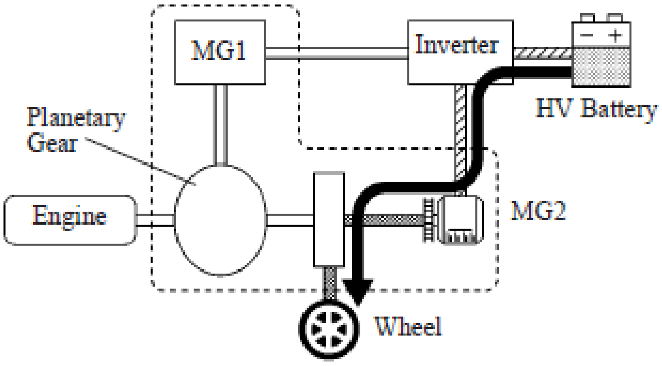
4. COMPONENTS

4.1. Hybrid drive

Basic functions of the hybrid drive

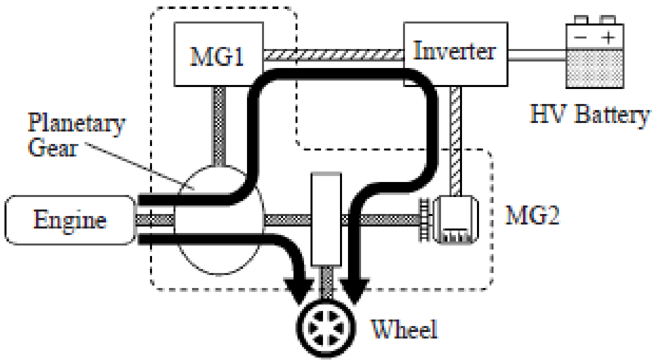
The hybrid system works using 4 basic functions to get the maximum efficiency of the whole system.

1. The torque of the wheels is generated using only electrical energy from the high-voltage battery pack.



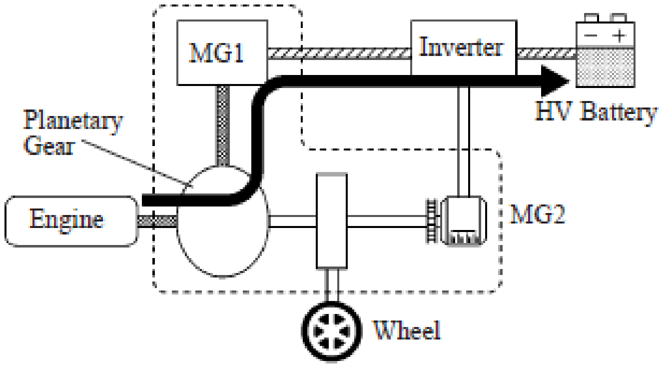
Electric energy - to create the torque of the wheels.

2. The torque generated by the internal combustion engine is transmitted through the planetary gear to the wheels and the MG1 generator. The energy generated by the generator is fed via an inverter to the MG2 electric motor, which also turns the wheels.



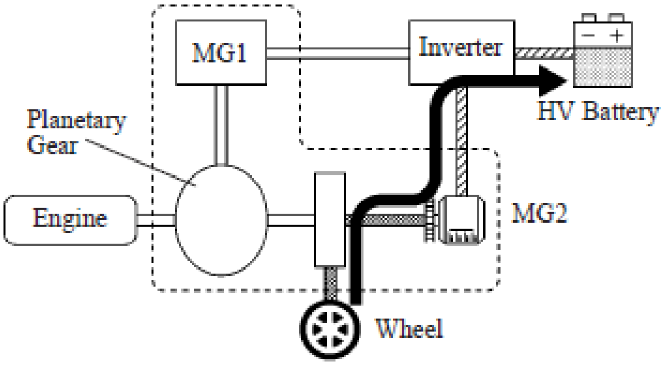
The energy of the internal combustion engine is used to create the torque of the wheels and to obtain electrical energy. Electric energy - to create the torque of the wheels.

3. MG1 is rotated by an internal combustion engine, produces electricity and charges a battery of high-voltage batteries.



Energy from the internal combustion engine is used to charge high-voltage batteries.

4. As the car decelerates, the kinetic energy rotates the MG2 generator, which converts the generated electricity in an inverter into a single-phase DC voltage suitable for charging the high-voltage battery.



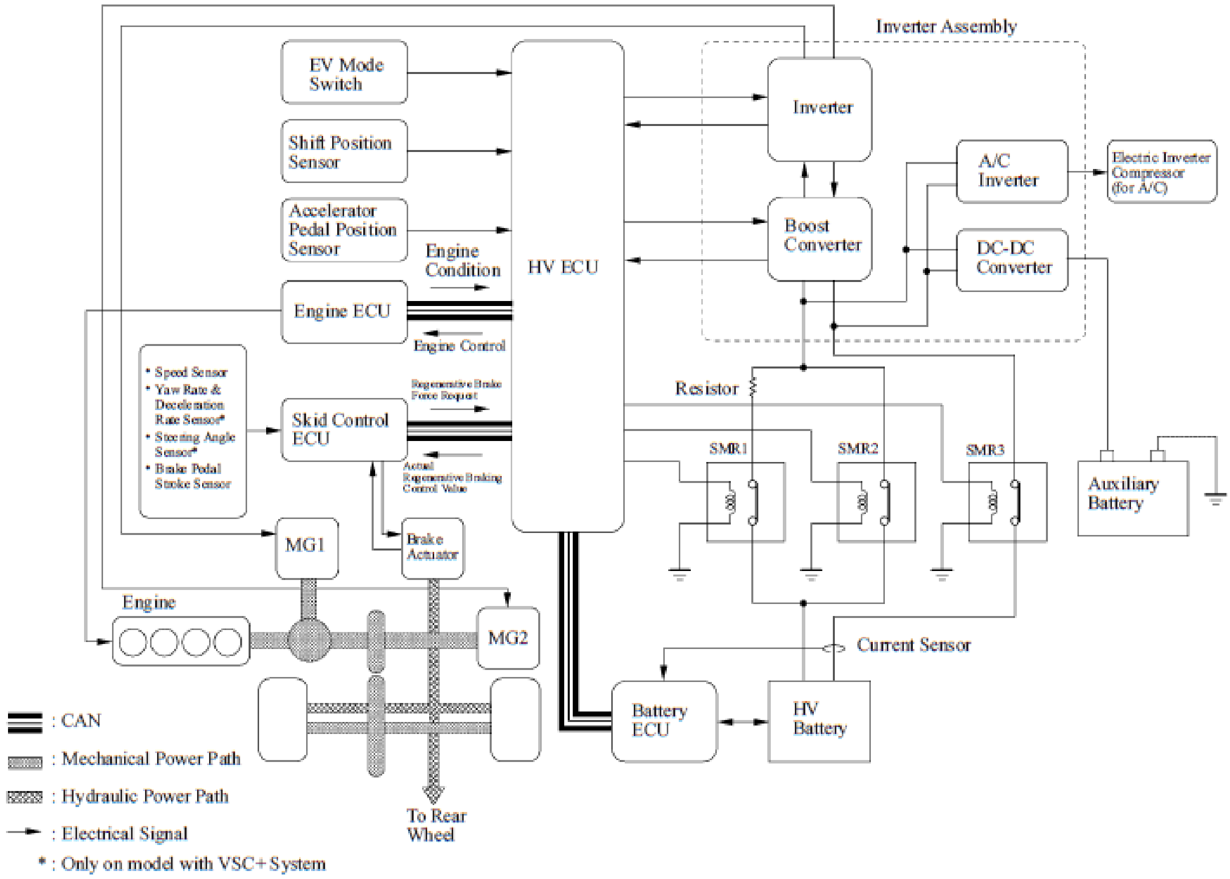
Kinetic energy – for high voltage battery charging.

The control unit of the hybrid system selects the most suitable basic function (1, 2, 3, 4) or their combination (1 + 2 + 3) in order to fulfill the driving conditions set by the driver (driving direction, speed). If necessary, when the battery voltage of the high-voltage batteries is too low, the battery is charged by turning the MG1 generator by the internal combustion engine.

The use of such a hybrid drive saves fuel and reduces emissions compared to conventional cars using internal combustion engines. Also, cars with hybrid drives do not have the disadvantages typical of electric cars (short driving distance, dependence on charging stations, long battery charging time).

Hybrid system control unit

Monitors and controls MG1 (Engine/Generator) MG2 operation, regenerative braking system operation, high voltage battery charge level and charging conditions. The control is carried out according to the selected driving mode, direction, pressing of the accelerator pedal, driving speed. According to the temperature of the batteries, the optimal battery discharge and charge mode is selected, combining the work of MG1 and MG2. When the transmission control unit lever is set to the N position, the hybrid system control unit cuts off the power supply to the MG1 and MG2 motors/generators. If the driving wheels rotate from inertia, the control unit of the hybrid system, with the help of the rotation of the motor rotor MG2, controls the work of the planetary reducer so that the revolutions of the generator MG1 do not exceed the permissible ones and do not generate too high voltage. The control unit of the hybrid system, with the help of three relays, ensures that the system is turned on and off only under safe environmental and working conditions



The structure of the hybrid system

Electric motors / generators

A hybrid drive uses two electric machines that can act as an electric motor or as an electric generator. MG1 and MG2 (Motor / Generator) abbreviations are assigned and used for these machines.

MG1 is powered by an internal combustion engine. MG1 produces AC 500V electricity. This energy is used to power the MG2 and charge a battery of high voltage batteries. MG1 is used as a starter to start an internal combustion engine.

MG2 is primarily used as an additional power source to help the internal combustion engine generate more thrust. During braking, the MG2 operates in generator mode, and the generated electricity is used to charge the high-voltage battery pack. MG2 also generates braking torque used to reduce vehicle speed (regenerative braking mode).

MG1 and MG2 speed sensors (resolvers) determine the speed and position of the rotors and provide this information to the control unit of the hybrid system. MG2 temperature sensor information is also sent to the hybrid system control unit.

The hybrid drive uses two three-phase, synchronous electric motors with permanent magnets. The rotor is a large magnet without any electrical connections.

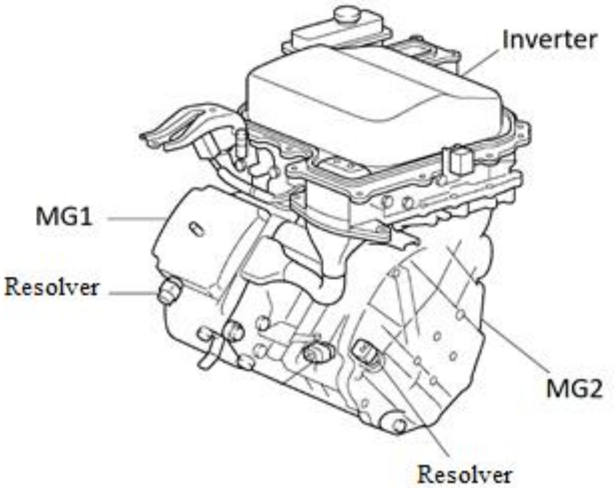
MG1 - 18 kW. MG2 - 50 kW. Both electric motors/generators are liquid cooled.

Inverter

Taking into account the signals of the control unit of the hybrid system, the inverter changes the single-phase direct current to the alternating three-phase current for powering the motors MG1 and MG2. When the engines are working in generator mode, the inverter converts the produced electricity into a single-phase direct current suitable for charging the high-voltage battery. Depending on the working conditions of the car, the inverter supplies the energy produced by MG1 (AC) to the MG2 (AC) motor. By directly supplying electricity from MG1 to MG2, the direct current is converted in the inverter itself.

The control unit of the hybrid system sends signals to the inverter power transistors in such a sequence that the U, V and W windings of the MG1 and MG2 motors are properly energized.

The control unit of the hybrid system turns off the inverter if it detects a fault in the system, too high current, voltage or temperature.



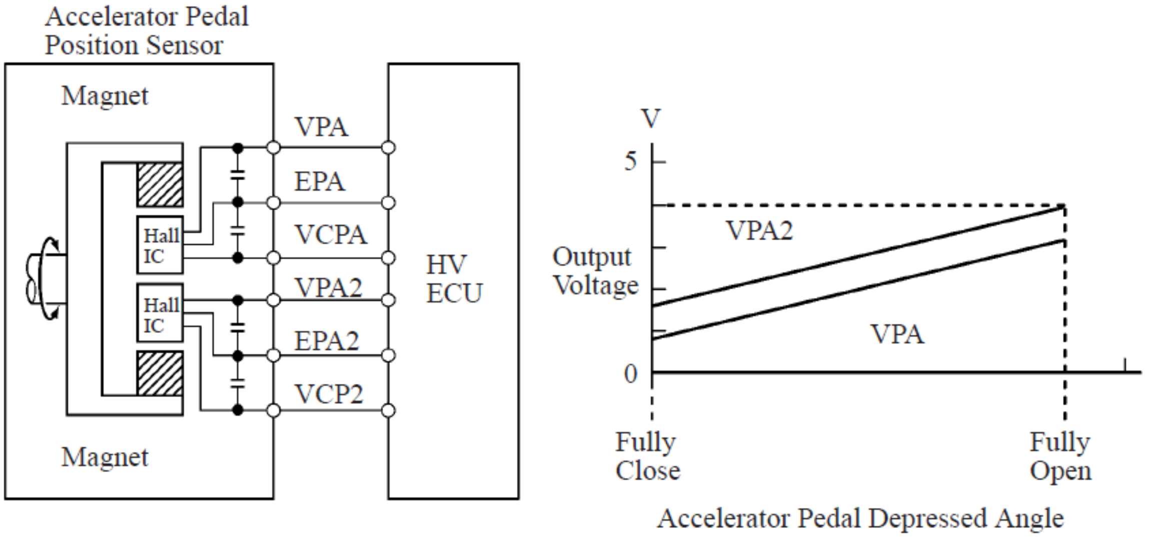
Arrangement of hybrid system components

Step-up converter

In response to signals from the hybrid system control unit, the step-up converter steps the DC high-voltage 201.6 V battery battery voltage up to 500 V. Also, when MG1 and MG2 are in generator mode, the AC 500 V step-down voltage down to 201.6 V and changes to direct current.

Accelerator pedal position sensor

The accelerator pedal position sensor is connected to the control unit of the hybrid system. The pedal sensor position information is processed and evaluated by the hybrid system unit and provides the internal combustion engine with the desired operating conditions of the internal combustion engine. The accelerator pedal position sensor converts the value of the pedal position angle into an electrical signal.



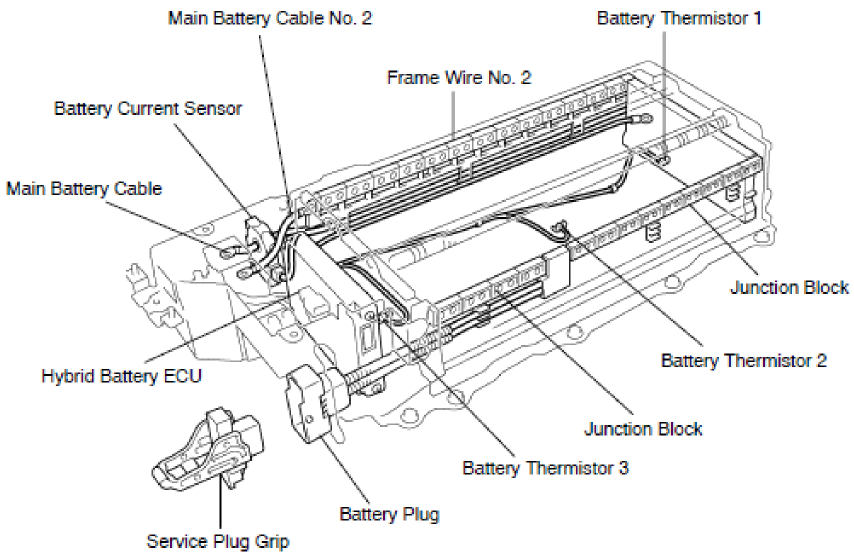
Accelerator pedal sensor and its signal

Converter

The DC/DC converter reduces the battery voltage of the high-voltage batteries to 12 V. This energy is used to charge the 12 V battery and supply other consumers of the car (12 V system). The inverter monitors the voltage of the 12 V battery.

High voltage battery control unit

Monitors and controls battery temperature of high voltage batteries and controls cooling fans. Monitors the charge level and communicates with the control unit of the hybrid system. Communication takes place using the CAN network bus.



Battery structure of high voltage batteries

The high-voltage battery is discharged when the car accelerates, and charged when the driving speed is reduced. The control unit of the accumulator battery calculates charge/discharge cycles, monitors voltage, current, temperature. The calculation data is provided to the control unit of the hybrid system. According to this information, the control unit of the hybrid system decides on the necessity of charging the high-voltage battery.

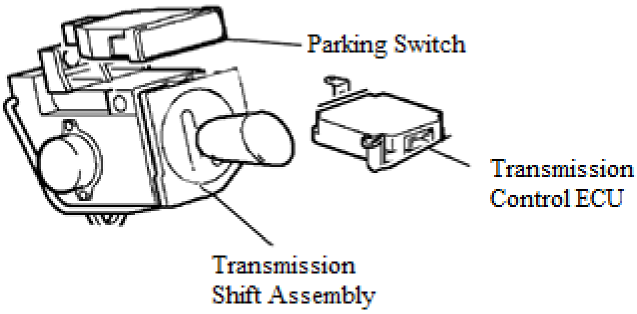
Braking system control unit

The brake system is electronically controlled. During the braking process, the control unit estimates the required braking force. Part of the braking force is generated using the torque of the MG2 generator. Another part of the braking force is created by adjusting the hydraulic fluid pressure in the brake system accordingly.

Transmission control unit

After determining the position of the drive direction selector lever (P, R, N, D or B), the hybrid system control unit combines the work of MG1 and MG2 accordingly to achieve the set driving conditions.

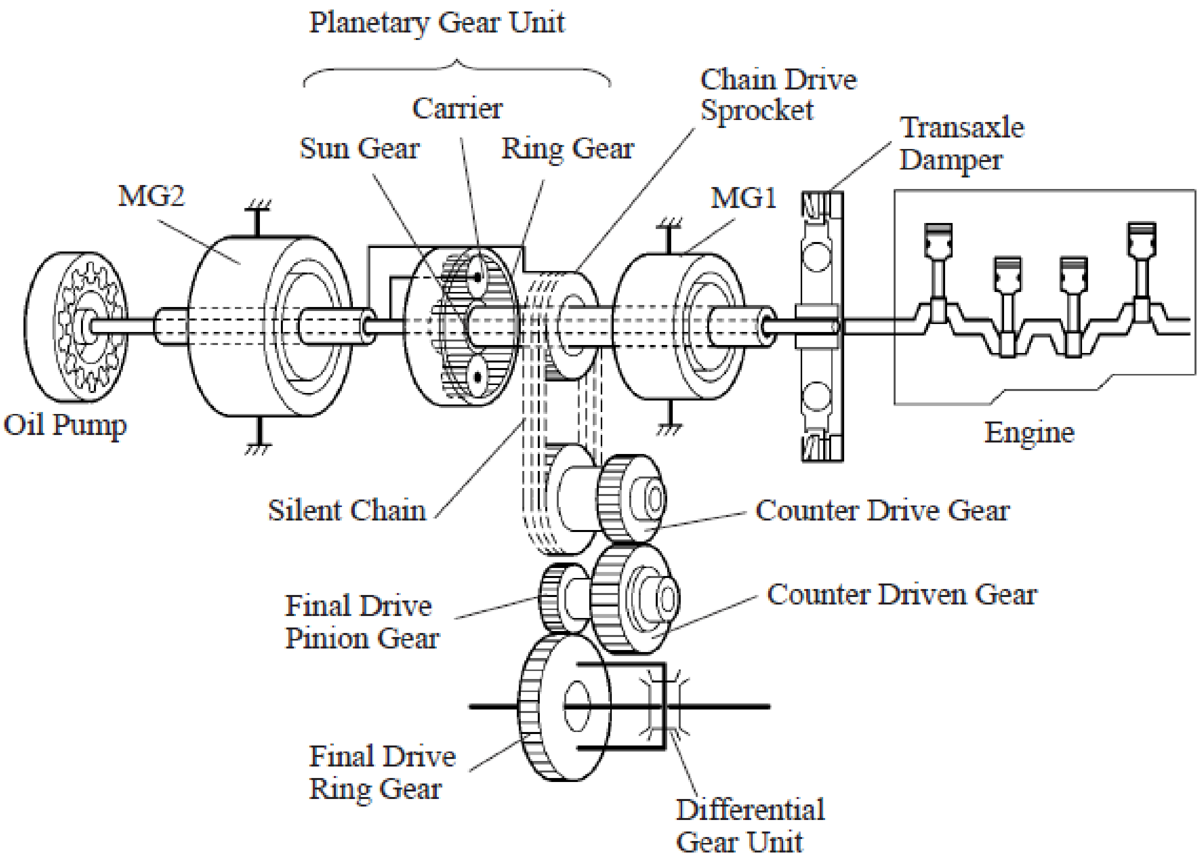
When the transmission control unit detects that the P position is engaged, it informs the control unit of the hybrid system about this. The transmission control unit also controls the mechanical transmission lock.



Transmission control components

Planetary reducer

The control unit of the hybrid system collects information from the control units of other components, processes it and uses it to control the system. According to the control algorithm of the hybrid system, MG1, MG2 and the distribution of the internal combustion engine's energy to the drive wheels are coordinated with each other using a planetary gearbox. The control electronics coordinate and distribute the power transmission to the drive wheels in such a way that the car drives according to the given conditions using the least amount of energy. If favorable conditions arise during driving (rolling from inertia, braking), the energy is used to charge the batteries (to store renewable energy).



Use of planetary reducer

The internal combustion engine is connected to the drive of the planetary reducer, on which the satellite gears are mounted. MG1 is connected to the central gear of the planetary reducer. MG2 is connected to the outer gear of the planetary reducer and the drive wheel differential. By coordinating the rotation of these three motors, the speed and direction of the car is regulated.

Air conditioner inverter

Converts high-voltage battery DC power to AC power without changing the voltage level. Used to power the car's air conditioner pump.

Electric-only driving

If the driver presses the EV button in the cabin, the hybrid system control unit activates only the MG2 electric motor to drive the car. The internal combustion engine does not start. Driving using only electric energy is only possible under certain conditions (speed, load).

Circuit breaker

In the event of a traffic accident, the airbag control unit sends a signal to the hybrid system control unit. This de-energizes the control relays of the high voltage circuit thus interrupting the power supply. The power supply will also be disconnected if a high voltage circuit fault is detected.

Recording of system malfunctions

The driver is informed about the state of the system and malfunctions by means of various light indications. The control unit of the hybrid system captures and remembers the conditions under which a malfunction occurred in the system. When a failure is detected, the control unit of the hybrid system stops the work of the system, or controls the execution mechanisms and other control units as provided by the control program recorded in the system memory.

4.2. An internal combustion engine

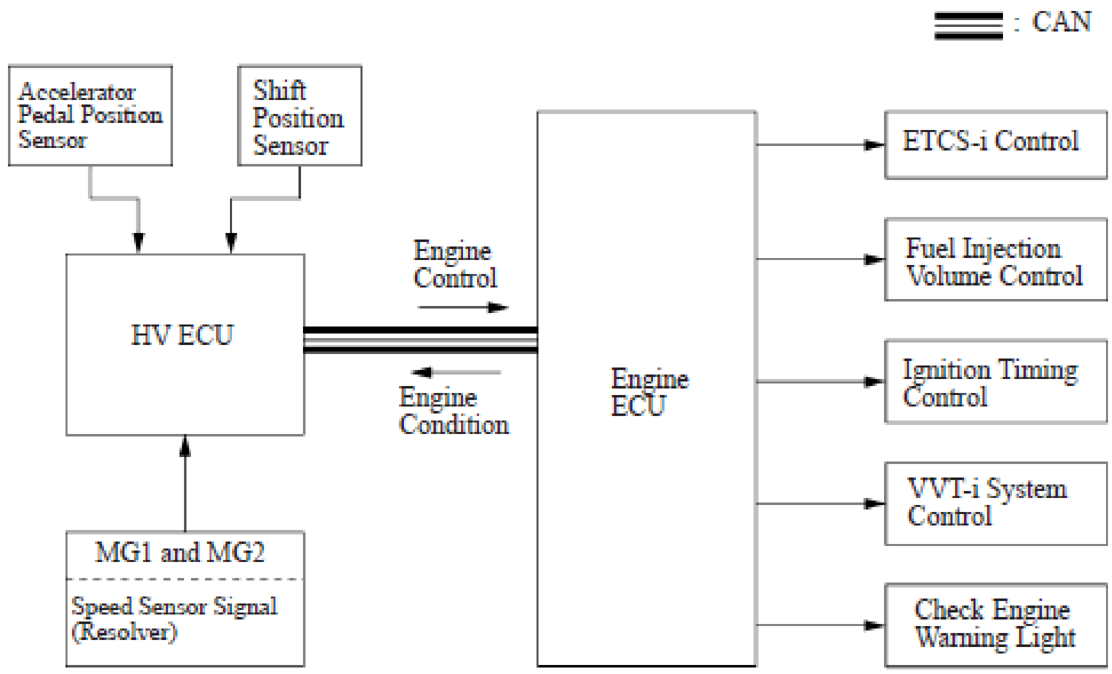
Hybrid system control unit

The control unit of the hybrid system collects information from various sensors, the engine control unit, the high-voltage battery control unit, the braking and traction control system, and the electric motor control unit. Based on the collected data, the control unit of the hybrid system calculates the required torque and output power. The results of the calculations are sent by the control unit of the hybrid system to the engine control, high-voltage battery, brake and traction control control units, and the inverter.

Engine control unit

The internal combustion engine control unit controls and controls the throttle module based on the internal combustion engine crankshaft rotation frequency and the power demand request from the hybrid system control unit. Also, the engine control unit controls the time of fuel injection, the ignition moment of the combustible mixture, and the control of the gas distribution phase process.

The engine control unit sends information to the hybrid system control unit about the operation of the internal combustion engine. According to the command of the hybrid system control unit, the engine control unit turns off the internal combustion engine. In the event of any system malfunctions, the engine control unit activates the malfunction warning light as instructed by the hybrid system.



Internal combustion engine control structure

The arrangement of the contacts of the internal combustion engine control unit connector and the voltage values in the contacts are presented in Appendix No. 1.

Ignition coil

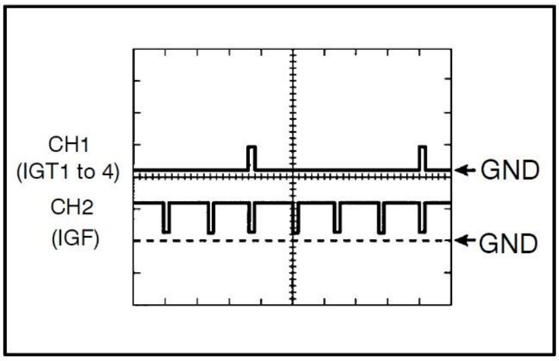
The purpose of the ignition system is to ignite the air-fuel mixture at the right moment in any operating mode. The ignition advance angle, spark energy and duration are combined to achieve this goal. In the electronic ignition system, a separate control signal is generated for each cylinder. Each cylinder requires a separate ignition coil.

The ignition coil, an element of the inductive ignition system, generates a high voltage from the low voltage of the battery pack. A high voltage is required for a spark to appear in the spark plug. The principle of operation of the ignition coil is based on electromagnetic induction, when the energy accumulated in the magnetic field of the primary winding is transferred to the secondary winding of the ignition coil by magnetic induction. Due to this process, a high voltage is induced in the secondary winding, which is able to break the air gap between the spark plug electrodes. Energy is stored even before the spark dances. The ignition coil is both a transformer and an energy accumulator. It stores magnetic energy in the magnetic field created by the primary current, and releases this energy when the primary current is turned off at the moment of ignition. The ignition coil is precisely matched to the rest of the ignition system components: the ignition rear stage and the spark plug. The most important indicators are:

- the stored spark energy is transferred to the spark plug
- a spark current is created in the candle at the moment of the spark break
- spark duration
- high ignition voltage under all operating conditions

The ignition coil has two windings placed on a common ferromagnetic core. The primary winding consists of a small number of turns of thick wire. The voltage flowing in these windings is controlled by the electronics unit. The secondary winding consists of a large number of turns of thin wire. The transformation ratio is between 1:50 and 1:150. A controlled current in the primary winding creates a magnetic field. This field affects the secondary winding and an electromotive force is induced in it. When the current in the primary circuit is interrupted, the changing magnetic field in the secondary winding induces a secondary voltage. The secondary voltage can reach 30000 V. This secondary voltage must be high enough to break the gap between the spark plug electrodes. In the engine control program, at the appropriate moment, the control unit activates the current in the primary winding of the ignition coil through the final stages. The resulting current creates a magnetic field in the ignition coil. The energy required for ignition is stored in this magnetic field.

When the engine control unit turns off the current flow in the primary circuit of the coil, the electronics in the coil sends an ignition confirmation signal (IGF) to the control unit.



Ignition coil primary and confirmation signals

Using a two-channel oscilloscope, it is possible to check the primary control and ignition confirmation signals of the ignition coils (CH1 first oscilloscope channel, IGT 1 - 4 - ignition coil control signal; CH2 second oscilloscope channel, IGF ignition coil confirmation signal).

The primary coil control signals are sent through the corresponding connectors (IGT1, IGT2, IGT3, IGT4) from the engine control unit. When the engine is running, there should be a voltage of 0.1 - 4.5 V between the IGT (1 - 4) (pins 8, 9, 10, 11) and E1 (pin 28) contacts if the ignition coils are not disconnected. If the ignition coil is disconnected, then with the engine running, there should be more than 4.5 V between IGT (1 - 4) pins 8 (9, 10, 11) and E1 (pin 28).

Checking the ignition confirmation signal circuit for an open circuit is checked between pin 2 of the coil and pin 23 of the control unit. When measured with a multimeter, the resistance should be less than 1 Ω. All four ignition coils (IGN 1 - 4) are checked.

Checking the ignition confirmation signal circuit for a short circuit is checked between coil pin 2 or control unit pin 23 and vehicle body ground. When measured with a multimeter, the resistance should be 10 kΩ or more.

Checking the coil control signal circuit for an open circuit is checked between pin 3 of the coil and pin 8 (9, 10, 11) of the corresponding control unit. When measured with a multimeter, the resistance should be less than 1 Ω. All four ignition coils (IGN 1 - 4) are checked.

Checking the coil control signal circuit for a short circuit is checked between contact 3 of the coil or contact 8 (9, 10, 11) of the corresponding control unit and the vehicle body ground. When measured with a multimeter, the resistance should be 10 kΩ or more.

Sprayer

Injectors are designed to supply and precisely dose compressed fuel into the intake manifold. The required amount of fuel is dosed with injectors. The injectors are controlled by the integrated rear stages of the engine control unit.

The injector consists of a body with electrical and hydraulic connections, an electromagnet coil, an injector needle with an anchor and a valve ball, a valve seat with an injection hole plate, a spring.

In order to ensure that the injector works without problems, the elements of the injector through which the fuel flows are made of corrosion-resistant steel. The filter screen in the fuel inlet channel protects against mechanical contamination. In injectors, fuel is fed axially towards the valve from top to bottom. The injector is connected to the fuel distribution pipe with the help of a hydraulic connection. The electrical connector connects to the engine control unit.

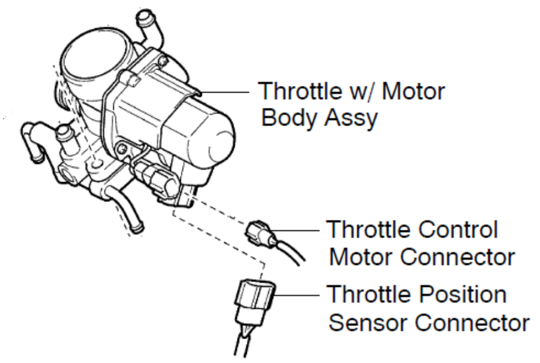
When the injector coil is de-energized, the combined force of the spring and fuel pressure pushes the needle with the valve ball against the poppet valve seat. This seals the fuel supply system from the intake pipe. When current begins to flow through the coil, an electromagnetic field is generated that engages the needle armature. The valve ball rises from the seat and fuel is injected. When the excitation current is turned off, the spring force closes the valve again.

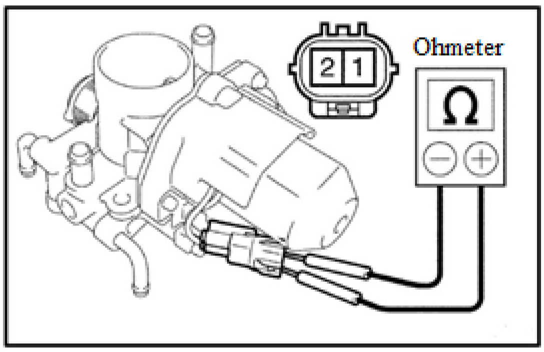
The fuel is finely sprayed through the spray hole plate, which has one or several holes. Stamped injection holes provide high consistency of the amount of fuel injected. This spray plate is also insensitive to pollutants released from the fuel. The pattern of the injected fuel flow depends on the number and placement of the injection holes. Good tightness is guaranteed by the cone-ball sealing principle in the valve seat area. The sprayer is inserted into a dedicated slot in the intake pipe. Fuel injection time 1 - 3 ms. Engine idle time varies.

Fuel injector winding resistance 13.45 - 14.15 Ω at 21 °C.
Fuel injection time 0 - 32.64 ms.

Throttle motor

The throttle module is mounted in the intake manifold behind the air filter. The throttle valve regulates the amount of air entering the cylinders. The throttle valve module consists of a valve, a valve drive mechanism, and a direct current electric motor.





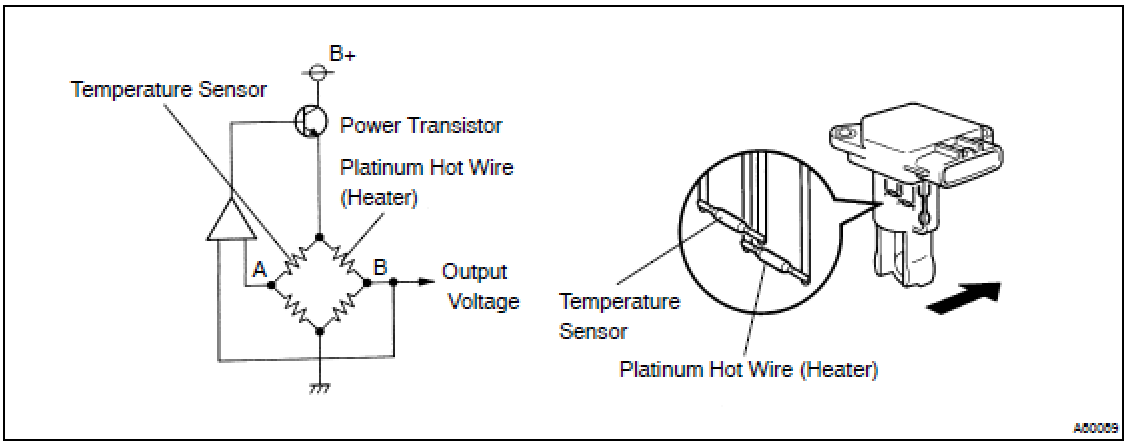
Throttle module and electric motor check

The throttle valve is controlled by the principle of pulse width modulation. An oscillograph is used to test the power supply signal. The fill factor of the electric motor control signal varies between 0 and 100%. The valve is opened and closed by changing the polarity of the voltage. The amount of current supplied to the motor ranges from 0 to 20 A. When the engine is idling, the amount of current consumed is 0 - 3 A.

Throttle motor resistance between pins 1 and 2 - 0.3 - 100 Ω at 20 °C.

Air mass meter

Air mass meter, measures the amount of air passing through the meter itself. This information is used by the engine control unit to calculate the opening time of the sprinklers and adjust the composition of the combustible mixture. Inside the air mass meter, a heated platinum wire is installed in the air flow channel. By passing a current of the appropriate magnitude through this wire, the wire heats up to a set temperature. The incoming air flow cools this wire and the adjacent thermistors. The resistance of the thermistors changes due to the cooling effect. While maintaining the same amount of current, the motor control unit changes the value of the supply voltage. The voltage value is proportional to the airflow through the sensor. According to the change in this voltage, the engine control unit calculates the amount of air entering the engine. The circuit is designed so that the platinum hot wire and the temperature sensor form a bridge. The power transistor is controlled so that the potential difference between points A and B remains the same while maintaining the set temperature.



Air mass meter measuring circuit

Checking the air mass meter.

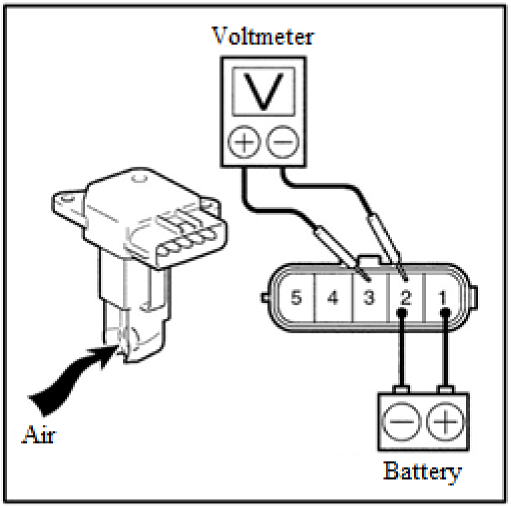
Sensor supply voltage control. When the ignition is switched on, there must be a voltage of 9 - 14 V between the engine control unit +B and the ground of the car.

When the engine is running, there should be a voltage of 0.5 - 3 V between the VG (33) and EVG (32) contacts.

There must be 10 kΩ or more between VG (33) and car ground.

There must be less than 1Ω between the ECG (32) and the car ground.

When checking the disassembled sensor, it is possible to connect a battery pack to the contacts 1 (+) and 2 (-) of its connector. A voltmeter is connected to pins 2 and 3. As air is blown into the sensor, the voltmeter reading should fluctuate.

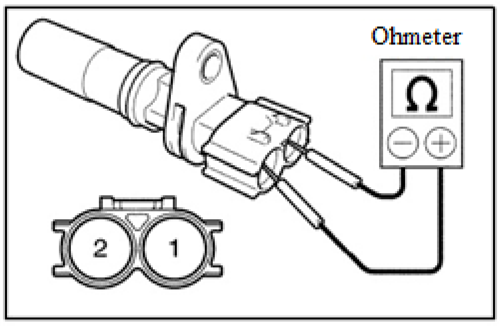


Checking the air mass meter

Crankshaft position sensor

Engine crankshaft speed sensors are used to measure crankshaft speed and record crankshaft position (piston position). The speed is calculated from the time interval of the speed sensor signals. The sensor is installed in front of the ferromagnetic pulse wheel. They are separated by an air gap. The sensor has a ferromagnetic core surrounded by a winding. The pole rod is connected to a permanent magnet. The magnetic field propagates through the pole rod to the pulse wheel. The magnitude of the magnetic field crossing the coil depends on what is in front of the sensor - the pulse wheel gap or tooth. The tooth concentrates the flux emitted by the magnet and strengthens the magnetic field crossing the coil. Space, on the contrary, weakens. These changes in the magnetic field in the coil induce a near-sinusoidal output voltage proportional to the rate of change of the magnetic field, i.e. the speed of rotation. The amplitude of the alternating voltage increases with increasing speed. The magnitude of the voltage generated by the sensor also depends on the distance between the sensor and the pulse wheel. The greater this distance, the lower the generated voltage when the revolutions are constant. This is an inductive speed sensor. A toothed disk has 60 – 2 = 58 teeth. Two teeth are ground from this disc to allow the position of the rotating disc to correspond to the top end point (VGT) position of the first cylinder piston at the end of the compression stroke.

The engine control unit, seeing the sensor signal, calculates the revolutions of the engine crankshaft and determines the position of the piston. Based on this information, the fuel injection start moment and the ignition acceleration angle of the mixture are calculated and selected. The absence of two gears is visible in the oscillogram as a signal change that marks the position of the first piston at the end of the compression stroke at the upper end point.

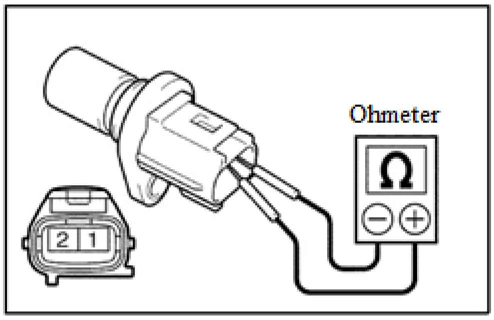


Checking the crankshaft speed sensor

Resistance between pins 1 and 2 985 - 1600 Ω for sensor temperature -10 - 50 °C and 1265 - 1890 Ω for sensor temperature - 50 - 100 °C.

Camshaft position sensor

The structure and principle of operation of the sensor is analogous to the crankshaft rotation frequency sensor.

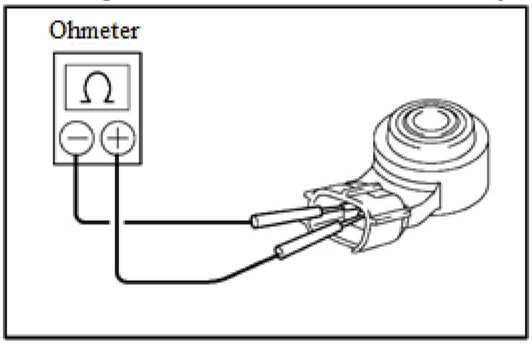


Checking the camshaft speed sensor

Resistance between pins 1 and 2 2065 - 3225 Ω at sensor temperature -50 - 100 °C and 1630 - 2740 Ω at sensor temperature -10 - 50 °C.

Detonation sensor

Detonation sensors are vibration sensors suitable for recording acoustic vibrations. The detonation sensor is designed to detect the detonation of the fuel mixture in the engine cylinders. Detonation is the spontaneous ignition and combustion of a fuel mixture without an external flame source due to high ambient pressure and high temperature. The combustion speed of the gasoline mixture during detonation is 1500 - 2500 m/s (normal combustion speed of the gasoline mixture is 20 - 40 m/s). Detonation is harmful to engine parts and is comparable to an explosion. When protecting the engine from damage, it is necessary to record the incipient detonation and take measures to prevent it. Engine manufacturers typically install one knock sensor for an in-line 4-cylinder engine, two sensors for a V-engine, or one sensor for a twin-cylinder engine.



Checking the detonation sensor

The detonation sensor has a piezo element (piezoceramic ring) mounted in the sensor housing and bolted to the engine block. The sensor is also equipped with a seismic mass, which, due to its inertia, presses the piezo element with the rhythm of the oscillations. Due to this seismic mass force, charges are displaced in the piezo element and an electrical voltage is created between the top and bottom ceramic parts of the element. This voltage is transmitted via slip rings and contacts to the engine control unit for further evaluation and processing.

The detonation sensor is attached to the engine block in such a way as to reliably detect detonation in each cylinder. Most often, the sensor is attached to the wide side of the engine block. The resulting signals from the measurement site must be transmitted without resonance, so a rigid screw connection is required.

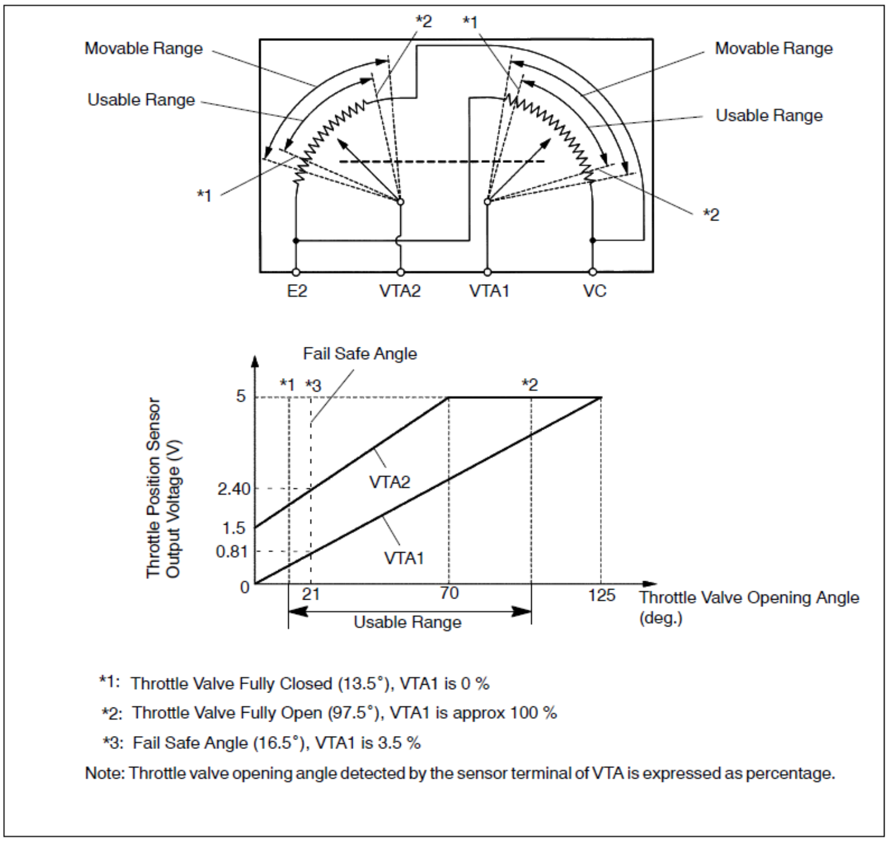
Detonation sensor resistance 120 - 280 kΩ at 20 °C.

The sensor supply voltage between KNK1 (+) and EKNK (-) contacts should be 4.5 - 5.5 V.

Throttle position sensor

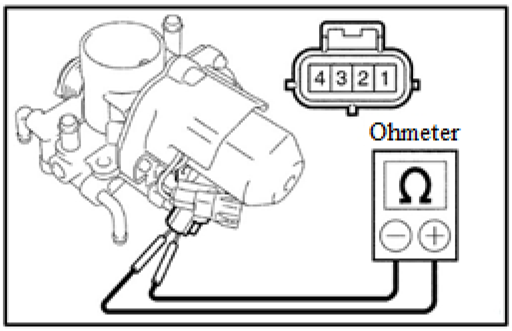
A potentiometer is a variable resistance device in which the resistance between the fixed contacts is always the same, and the resistance between one of the fixed contacts and the rotating contact changes depending on the position of this rotating contact. By changing the position of the rotating contact, the resistance between it and one of the fixed contacts decreases and between it and the other fixed contact increases. however, the sum of these two resistances remains constant and equal to the resistance between the stationary contacts.

Throttle position sensors (2 units) are installed in the throttle module. Two sensors are installed so that the engine control unit can know exactly the position of the throttle and can identify the failure of this module. The voltage at the VTA1 and VTA2 contacts can vary between 0 and 5 V. The VTA1 contact signal is used by the engine control unit to estimate the throttle position and control the internal combustion engine accordingly. The VTA2 contact signal is used for throttle position and fault detection. The engine control unit, using information from the throttle position sensors, controls and adjusts the throttle position accordingly to properly match the engine operating mode to the current conditions. If a fault is detected in the throttle module, the throttle is set to a certain position. Its electrical adjustment is no longer carried out until the fault is eliminated and the car is restarted.



Setting the position of the throttle valve with potentiometers

Throttle position: 0 - 100%. Damper fully closed 8 - 24%, damper fully open 64 - 96%.
Sensor supply voltage 4.5 - 5.5 V is measured between contacts VC and E2.



Checking the throttle position sensor

Damper position sensor 1 measurement signal value: 0 - 5 V. Damper fully closed - 0.5 - 1.2 V, damper fully open - 3.2 - 4.8 V.

Damper position sensor 2 measurement signal value: 0 - 5 V. Damper fully closed - 1.5 - 2.9 V, damper fully open - 3.5 - 5.5 V.

Damper position sensor resistance between pins 1 (VC) and 4 (E2) - 1.2 - 3.2 kΩ at 20 °C.

Sensor VTA1 resistance, measured between pin 2 (VTA1) and pin 4 (E2) - 1.8 - 10.5 kΩ at 20 °C.

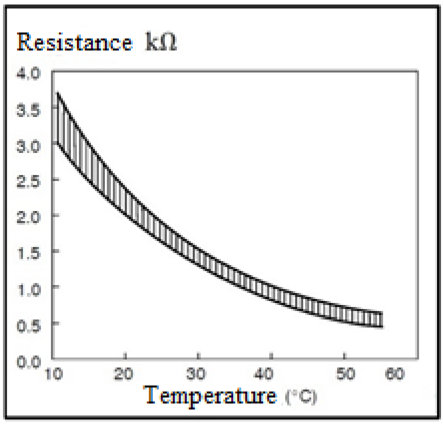
Resistance of sensor VTA2, measured between pin 3 (VTA2) and pin 4 (E2) - 1.8 - 10.5 kΩ at 20 °C.

Outdoor temperature sensor

The outdoor temperature sensor is a resistive element whose resistance value depends on the ambient temperature. As the temperature decreases, the resistance of the sensor increases and vice versa, as the temperature increases, the resistance value decreases. The engine control unit supplies this temperature sensor with a constant voltage of 5V. The control unit evaluates the voltage change in the sensor, and accordingly determines the current ambient temperature.

If there is a short circuit in the outdoor temperature sensor, a temperature of 140 °C is displayed. If the circuit is broken, a temperature value of -40 °C is displayed.

When measured between pins 21 and 28 of the engine control unit, with the car ignition on and an ambient temperature of 25 °C, there will be a voltage of 1.8 - 2.2 V. When the temperature is 40 °C, the voltmeter scale will show 1.2 - 1.6 V.



Sensor resistance dependence on ambient temperature

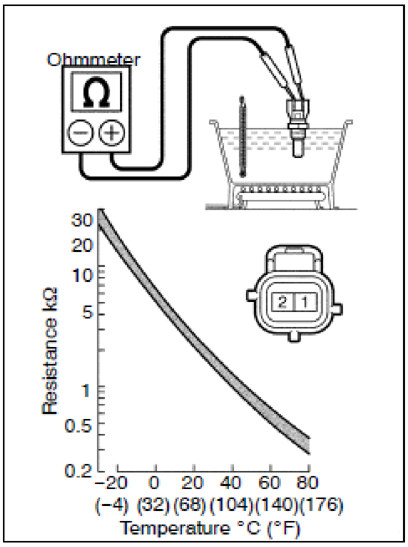
The temperature dependence of the resistance of the sensor is checked between the first and second contacts of the sensor. As the temperature increases, the resistance value decreases.

Temperature, °C	Specific resistance value, kΩ
10	3 - 3.75
15	2.45 - 2.88
20	1.95 - 2.3
25	1.6 - 1.8
30	1.28 - 1.47
35	1 - 1.22
40	0.8 - 1
45	0.65 - 0.85
50	0.5 - 0.7
55	0.44 - 0.6
60	0.36 - 0.5

Coolant temperature sensor

A thermistor sensor, the resistance of which depends on the temperature of the environment acting on it. Its structure is the same as the intake air temperature sensor.

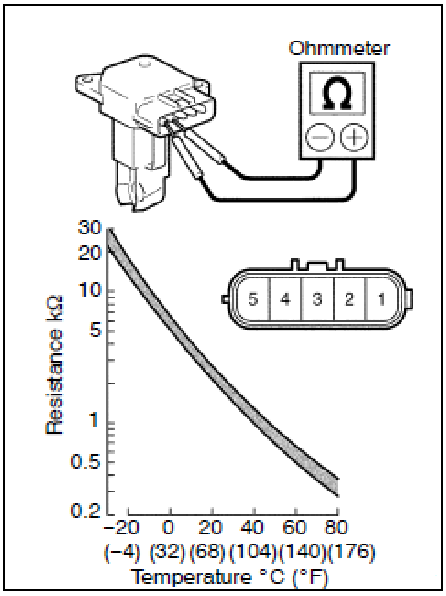
A coolant temperature value of -40 °C indicates that the sensor circuit is broken. If a temperature of 140 °C is displayed, there is a short circuit in the sensor circuit.



Dependence of sensor resistance on ambient temperature and testing methodology

Intake air temperature sensor

The intake air temperature sensor is integrated into the air mass meter. The sensor measures the intake air temperature. The sensor consists of a thermistor whose resistance depends on the temperature. When the temperature is low, the resistance of the sensor increases, when the temperature rises, the resistance decreases. The engine control unit supplies this temperature sensor with a constant voltage of 5V. The control unit evaluates the voltage change in the sensor, and accordingly determines the intake air temperature.

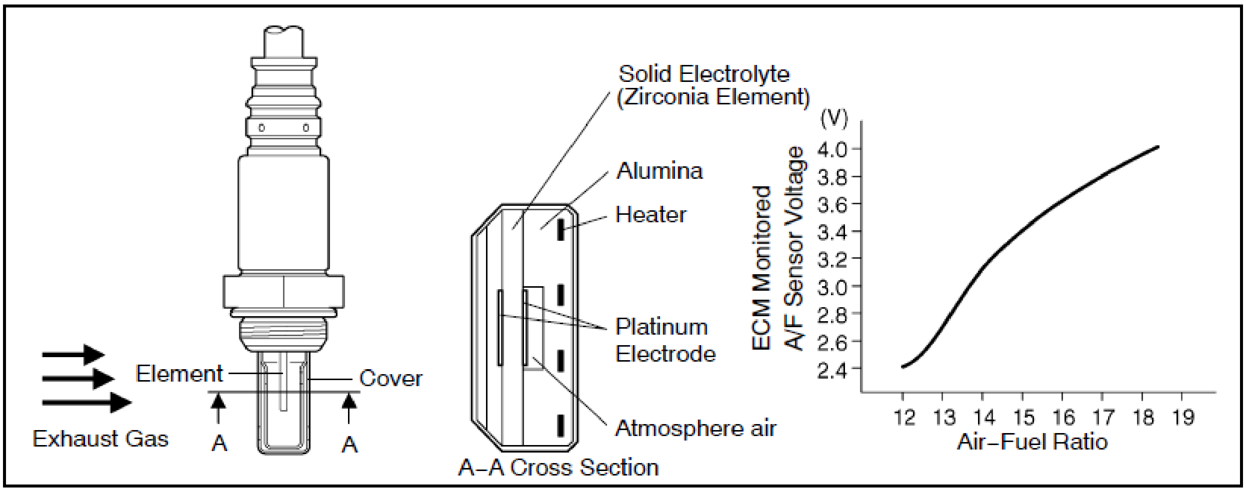


Dependence of sensor resistance on ambient temperature and verification

Intake air temperature value of -40 °C indicates that the sensor circuit is broken. If a temperature of 140 °C is displayed, there is a short circuit in the sensor circuit.

Mixture composition sensor

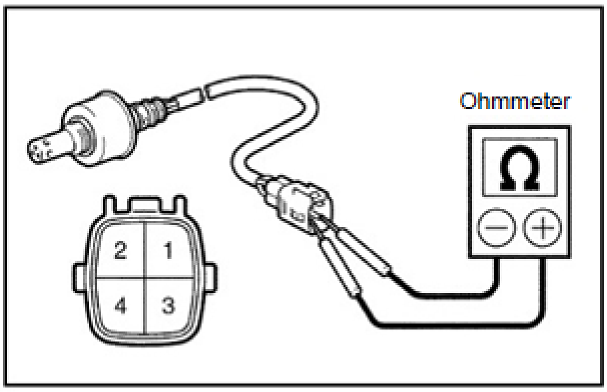
The mixture composition sensor is a planar type. Compared to glove-type sensors, in a planar-type sensor, the measurement elements from heating are closer to each other. Since the heat from the heating element reaches the measuring cage with a noble metal layer faster, such a sensor can perform measurements faster.



Mixture composition sensor

If the sensor signal voltage is less than 3V, it indicates that the air fuel mixture is oily. If the sensor signal voltage is greater than 3.35V, it indicates that the air-fuel mixture is lean.

Resistances of the mixture composition sensor between contacts 1 (HT) and 2 (+B): - 1.8 - 3.4 Ω at 20 °C, between contacts 2 (+B) and 4 (AF-) 10 kΩ and more.



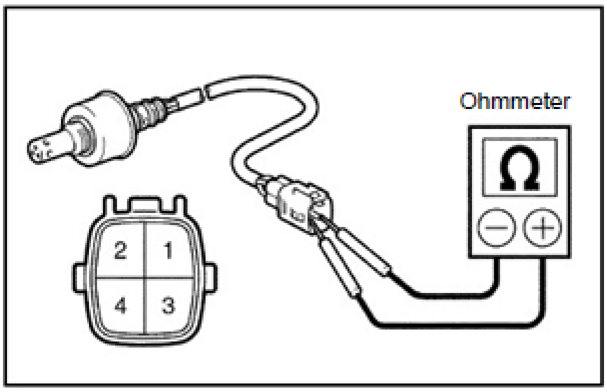
Checking the mixture composition sensor

The supply voltage of the sensor heating element, when the sensor is cold, when the ignition is switched on, between HA1A and E04 contacts 9 - 14 V. When the sensor is warm and the engine is running, between HA1A and E04 contacts - less than 3 V.

Sensor signal voltage between A1A+ and E1 contacts 3 - 3.6 V, between A1A- and E1 contacts - 2.7 - 3.3 V.

Oxygen sensor

If the sensor signal voltage is greater than 0.55V, it indicates that the air-fuel mixture is oily. If the sensor signal voltage is less than 0.4V, it indicates that the air fuel mixture is lean.



Checking the oxygen sensor

Oxygen sensor resistances between pins 1 (HT) and 2 (+B): 11 - 16 Ω at 20 °C, between pins 1 (HT) and 4 (E1) 10 kΩ and more.

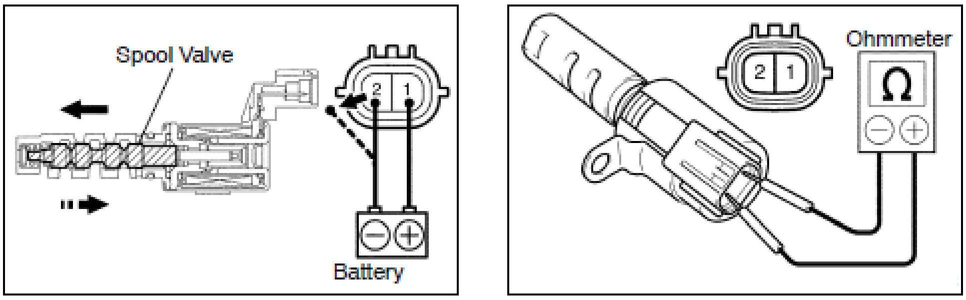
The supply voltage of the sensor heating element when the sensor is cold with the ignition on between the HT1B and E03 contacts is 9 - 14 V. When the sensor is warm and the engine is running, less than 3 V between the HT1B and E03 contacts.

The voltage of the sensor signal between the OX1B and E2 contacts is variable (non-constant). The measurement can be performed only after warming up the sensor by increasing the engine crankshaft speed to 2500 min $^{-1}$ for at least 2 min.

Oil control valve

Hydraulic oil pressure is used to change gas distribution phases, which is controlled by an electromagnetic oil control valve. By changing the phases of the gas distribution, it is possible to obtain a higher torque of the internal combustion engine at lower crankshaft revolutions.

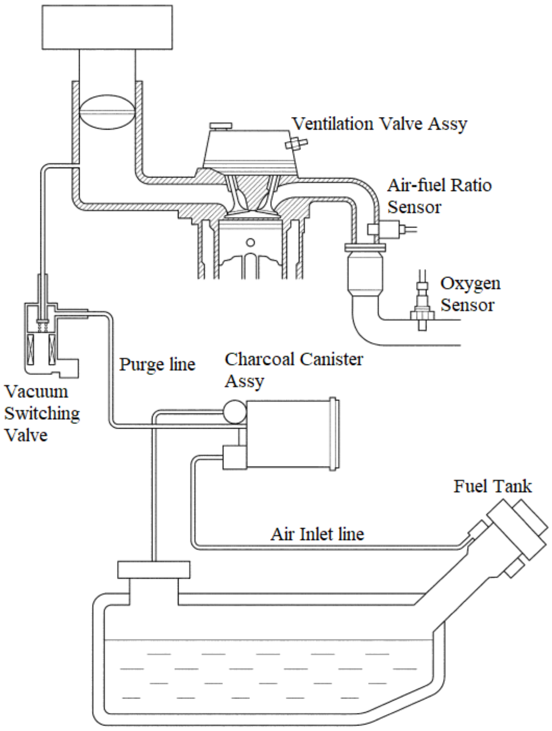
The solenoid valve consists of an electromagnet and a hydraulic distributor. The electromagnet is controlled by a voltage of 12 V. The winding resistance of the electromagnet coil is measured between contacts 1 (+) and 2 (-) and should be 6.9 - 7.9 Ω at 20 °C. It can be connected to a battery of 12V batteries to check the operation of the valve. When the valve is activated, the latch moves in the distributor.



Checking the valve

Gasoline vapor filter cleaning valve

Cars with Oto engines are equipped with a fuel evaporation reduction system to prevent fuel evaporating from the fuel tank into the environment. Fuel vapors from the tank enter the activated carbon filter through a tube, where they are absorbed. The filter fills up over time and needs to be emptied. For this, the filter is connected by a tube to the engine air intake manifold. Since there is a rarefaction (vacuum) in the intake manifold, the pressure in the scavenge pipe decreases when the filter cleaning regeneration valve is opened. This causes air to be drawn through the air intake pipe. As the air flows through the filter, it picks up the absorbed fuel and carries it to the intake manifold. From there, the fuel enters the combustion chamber. By adjusting the composition of the mixture, depending on the amount of fuel taken from the filter, the main amount of injected fuel is reduced. In this way, the required composition of the combustible mixture is maintained. The amount of fuel flowing through the filter cleaning valve is limited to ensure the stability of the engine. The greater the proportion of fuel delivered through the valve, the faster the main dose of injected fuel needs to be adjusted.



Gasoline vapor collection and disposal

The resistance of the filter cleaning valve solenoid coil winding is measured between pins 1 and 2 and should be 26 - 30 Ω at 20 °C.

5. OPERATING PRINCIPLE OF TOYOTA PRIUS HYBRID SYSTEM - II (THS).

Atkinson cycle

in 1886 English engineer James Atkinson proposed to modify the working process of the Otto engine. The main idea of the modification was to increase the duration of the working stroke, that is, to use the combustion gas pressure more efficiently for the rotation of the crankshaft. However, due to complex engineering solutions, engines of this design did not spread in the 19th century.

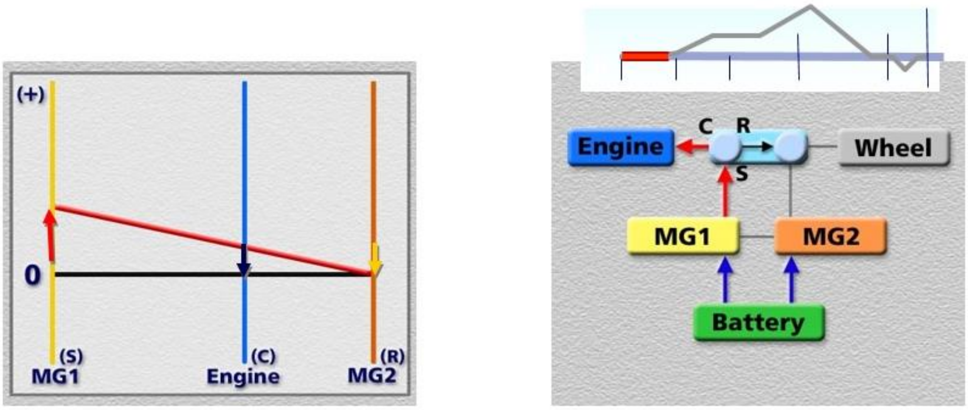
The use of the Atkinson cycle in the engine made it possible to reduce fuel consumption and noise during operation. In such engines, a system for reducing the speed of rotation of the gas distribution shaft is not required. The crankshaft rotates 2 times faster than in engines working according to the Otto principle. Atkinson cycle engines had a complicated throttle control, low torque. Compared to Otto engines, Atkinson cycle engines reduce intake losses due to later closing of the intake valve. Engine cylinders are better filled with fresh air. Due to the subsequent closing of the intake valve, the compression pressure in the cylinder changes, reducing the possibility of detonating fuel mixture combustion. An Atkinson cycle engine operates with an increased expansion ratio cycle that uses exhaust gas energy for a longer period of time. This increases the efficiency of the engine. In Otto engines, all four strokes (intake, compression, power stroke and exhaust) are of equal duration. In the Atkinson cycle engine, due to the more complex design of the crank mechanism, the first working strokes were shortened, and the next 2 strokes were lengthened. This made it possible to increase the efficiency of the engine by about 10%. However, precisely because of the complex design of the crankshaft mechanism, these engines did not spread.

Hybrid cars use Atkinson cycle internal combustion engines. These engines have a compression ratio of 13:1, but with proper control of the intake valves, intake and compression losses of the combustible mixture are reduced. During the work stroke, the energy of the expanding gas is used for a relatively longer time. Atkinson cycle engines can be used in hybrid vehicles because internal combustion engines in these vehicles operate in low speed and load ranges. Electric motors are used for the acceleration of hybrid cars, which provide the necessary power in a wide range of revolutions.

Hybrid drive technology

The MG1 electric motor and energy from the high-voltage battery are used to start the internal combustion engine (ICE). The crankshaft of the VDV is connected to the drive of the planetary reducer, on the axes of which the satellite (satellite) gears rotate. If the car is stationary, the ring gear of the planetary gearbox is also stationary. When the MG1 motor operates in this way, it causes the satellite gears to rotate through the sun gear, which rotates the driver and the VDV at the same time. The gear ratio of this part (when the ring gear is stationary) is 1/3.6.

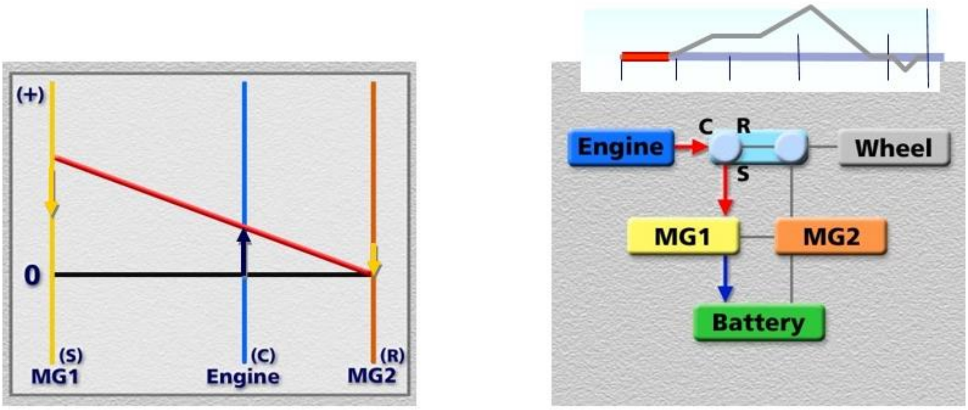
Starting the internal combustion engine takes place according to the following methodology: MG1 turns the VDV up to 1000 min $^{-1}$ and only then starts supplying fuel and ignition spark to the candles. This start-up is much smoother and quieter compared to the traditional starter start-up. The power of the MG1 engine is several times higher than that of a traditional starter. VDV rotation up to 1000 rpm ^{occurs} in less than 1 second. MG1 VDV rotates itself at a speed of 3600 min $^{-1}$ during starting . The engine starts quietly and smoothly, without any extraneous sounds and vibrations. In addition, 1000 min $^{-1}$ VDV is the speed required to overcome internal friction losses. Such a VDV start reduces wear on this engine.



Starting the internal combustion engine

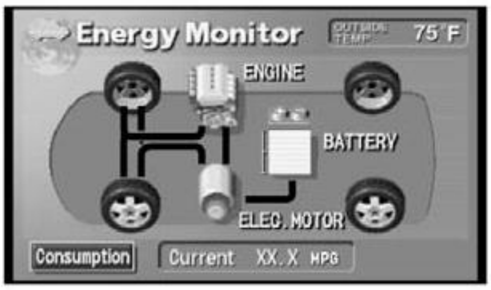
As soon as the VDV is started, the car's control computer calculates the amount of energy required and adjusts the crankshaft revolutions accordingly. Engine warm-up in progress. At this time, the MG1 engine is switched to generator mode. The produced energy is used to charge the batteries. When the energy demand is reduced, the engine crankshaft speed is reduced, or the engine is completely switched off.

During engine warm-up, the crankshaft revolutions reach 1300 min $^{-1}$. The engine is heated to operating temperature. It is important that the catalytic converter, which is responsible for the fuel emission indicators, heats up properly. The heating phase lasts a few minutes.



The internal combustion engine is running

After starting a warm engine, it will run for a very short time and then shut off. Idle revolutions are lower than 1000 min $^{-1}$. The work of VDV cannot be controlled. If the ignition is on, but the car is not running. VDV can be started automatically to maintain the correct battery charge level of the batteries.



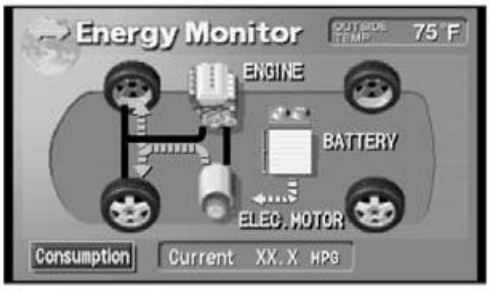
The car is ready

VDV torque depends on crankshaft revolutions. When the car is moving, the torque is distributed according to the external load. The maximum value of the torque of the rotors of electric motors is at the lowest revolutions. With the MG2 electric motor, the torque is matched to the load. The MG2 motor is coupled to a ring gear.

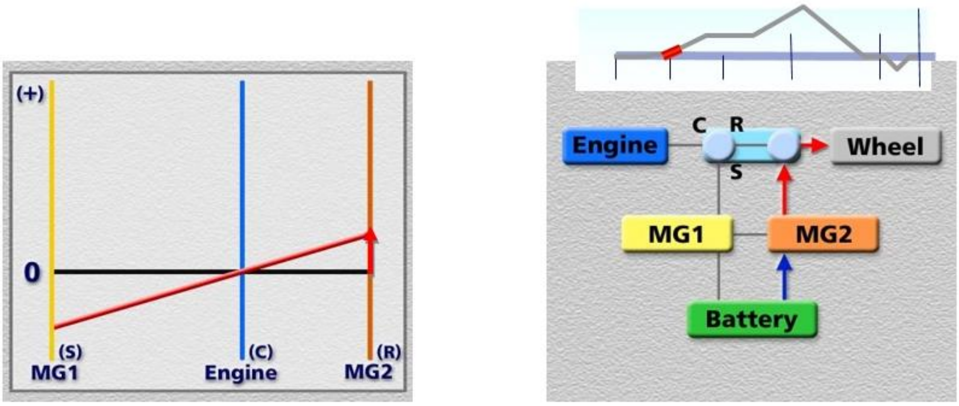
When the car is parked with the VDV working, the MG1 is in generator mode. The generated electricity is transferred to charge the batteries or to the MG2 engine. When the MG2 rotor starts to rotate, the ring gear starts to rotate. Due to the rotation of the ring gear, the speed of rotation of the guide is reduced. To maintain a constant VDV speed, the engine control unit opens the throttle more. When MG1 produces electricity, it opposes the rotation, the speed decreases, the rotation speed of the conductor is controlled by the motor control unit. The ring gear is rotated by the MG2 motor and power comes from the VDV. This creates a force that causes the ring gear to turn and the car to move.

VDV torque is transmitted to sun and ring gears. As long as the accelerator pedal is not depressed, the torque generated by the VDV is small and is transmitted only to the MG1 generator. When the accelerator pedal is pressed, 28% of the torque goes to spin the MG1 generator. 72% of the torque is transmitted to the ring gear and at the same time to the driving wheels of the car. The control unit adjusts the throttle opening so that the required torque is supplied to the drive wheels.

When the car starts moving and reaches a certain speed, the rotation speed of the MG1 generator increases. Power drops. The engine control unit opens the throttle more, increasing VDV torque. A greater part of the torque must also pass through the ring gear. Because of the higher VDV torque, the MG1 generator can maintain a constant output. The decrease in the rotation speed of the MG1 rotor is compensated by the increased torque.

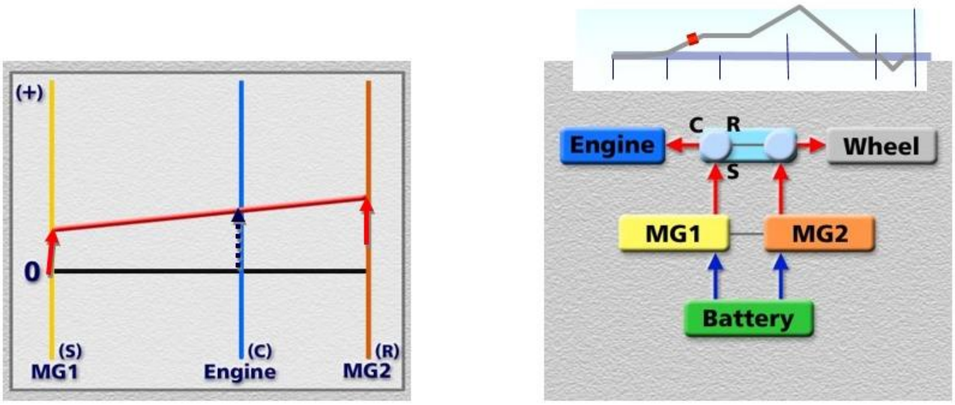


The start of the car drive



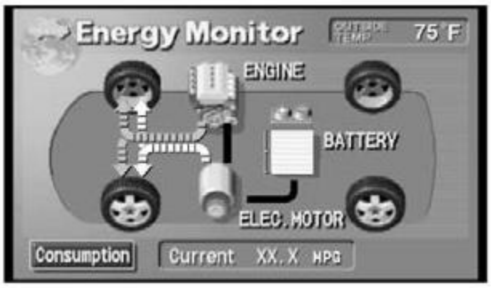
Starting the drive using only electric power

The car is started with only one MG2 engine running. If the power demand is higher or the driving speed is higher, the VDV is also activated.



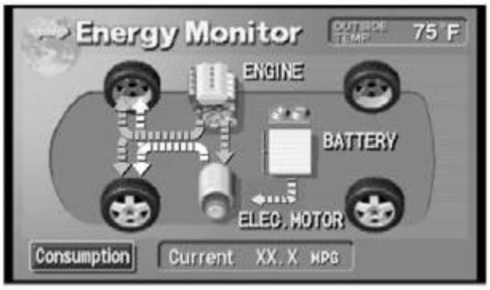
The start of driving using energy from the internal combustion engine and the battery pack

The MG2 engine gets a large part of its power from the battery pack. The VDV can't spin very fast when the car is going slow because it would damage the MG1 motor/alternator. Frequent VDV connection would not be a good solution. This creates inconvenience for car users. The more the accelerator pedal is pressed, the more energy is required from the VDV and at the same time from the battery pack. Up to a speed of about 40 km/h, about 40% of the energy comes from the battery pack and 60% from VDV. When the speed is further increased to 100 km/h, 75% of the energy is supplied from VDV. Another part of the energy is used to rotate the MG1 generator. The generated electricity is fed to the MG2 engine. At speeds above 100 km/h, the MG2 engine produces more torque to the drive wheels than is supplied to the planetary gearbox from the VDV. Part of the electricity for the MG2 motor is supplied by the MG1 generator, indirectly from the VDV.

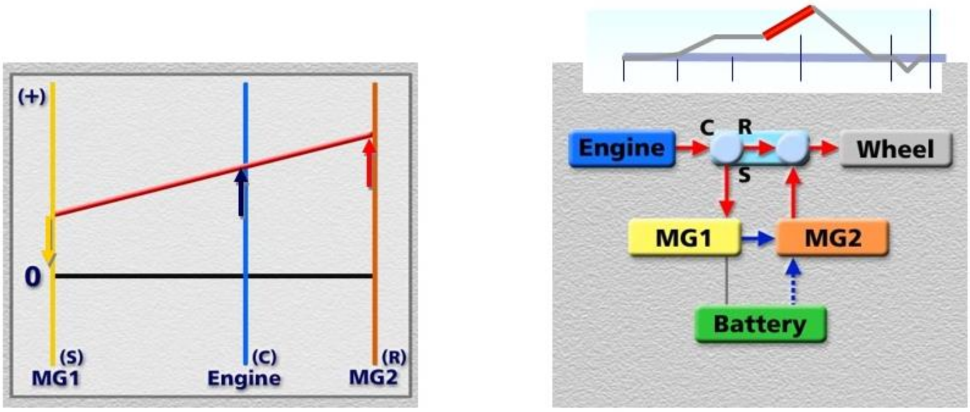


Steady-state driving mode using internal combustion engine energy

During the acceleration of the car, the energy demand is the highest. The system is coordinated in such a way that the power to the driving wheels is supplied by a combination of VDV and MG2 power plants. As the car speeds up, the MG2's output is reduced and only comes into use when the power demand reaches 33 kW. The faster the MG2 rotates, the less torque it produces. Without limiting the power at the start of the MG2 spin, we would have maximum torque spinning the drive wheels. In a conventional car with a manual gearbox, as speed increases, the torque is reduced by the gearbox, and the VDV can operate in the normal range of crankshaft revolutions. A hybrid car does not have a manual gearbox to change the power transmission.



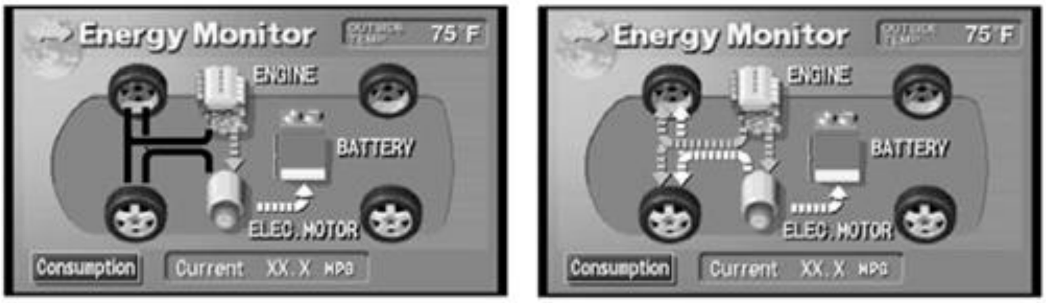
Driving using internal combustion engine and electric power



Maximum acceleration

In summary, the VDV rotates the planetary gearbox driver. 72% of the energy is transmitted mechanically through the ring gear to the drive wheels. 28% of the energy is transferred to the MG1 generator and electricity is produced. This electricity is used to power the MG2 motor.

The harder the accelerator pedal is pressed, the more torque is generated in the VDV. This increases the torque on the ring gear, MG1 generator. The energy produced is used in the MG2 engine and the torque created to drive the car. Depending on environmental factors: battery charge level, road conditions, accelerator pedal pressure, the battery can provide additional energy to the MG2 engine to meet the resulting energy consumption level. So, even with a small 76 Ag engine, it is possible to obtain such acceleration characteristics of the car, which are characterized only by cars with significantly higher VDV power. When the power demand is not high, the MG1's electricity is used to charge the batteries. The VDV transmits mechanical energy to the drive wheels and MG1. How mechanical and electrical energy circulates depends on many factors.



High voltage battery charging

At steady steady speed, the engine must deliver only the power required to overcome aerodynamic drag and frictional forces with the road surface. This is much less power that is needed when accelerating or climbing a hill. By increasing the efficiency of the VDV operation, the crankshaft revolutions are reduced. When increasing the speed of the car, a limit is reached, when we can no longer increase the revolutions of the VDV crankshaft. MG1 then starts to rotate in the opposite direction. Due to the opposite direction of rotation of the MG1, the sun gear causes the satellite gears to rotate faster (the driver speed remains constant or is reduced (the VDV crankshaft revolutions are reduced), which increase the ring gear rotation speed and at the same time the car's driving speed. Changing the direction of rotation of the MG1 also changes its functional purpose: the generator turns into an electric motor. For this, in order to maintain a constant torque, energy is supplied from the battery through the inverter. However, it cannot continue for a long time. In this case, the energy of the battery will be fully used up. So at some point when MG1 starts working as electric motor, MG2 must switch to generator operating mode.

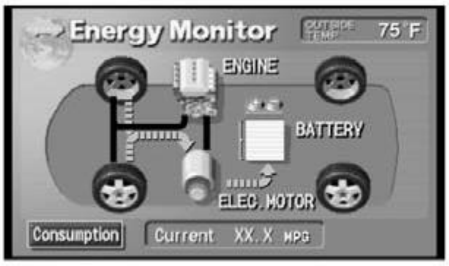
When the accelerator pedal is released, conditions are created as if the car is braked by the engine. The engine does not transmit traction to the drive wheels and the car's speed gradually decreases due to air and road surface resistance. The engine braking effect of the car is due to the MG2 being switched to operate in generator mode. This energy is used to charge the batteries.

When the car does not need energy (it rolls from inertia), the VDV is turned off. The guide stops rotating. The ring gear is rotated from the wheels and at the same time the MG2 generator is rotated. Through the planetary gearbox, MG1 is rotated in the opposite direction, but the energy balance is zero.

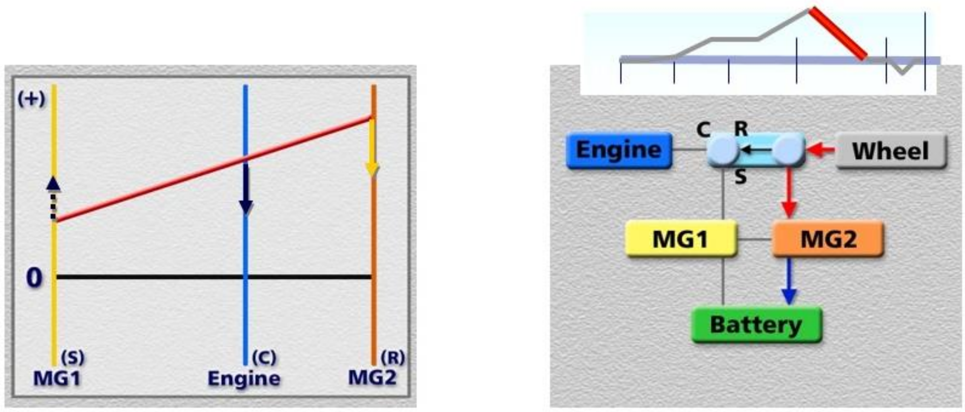
The rotation speed of the MG1 is 2.6 times faster than the ring gear through the planetary gear ratio. Therefore, when driving at high speed, the rotation speed of MG1 can exceed 6500 min $^{-1}$. This speed of rotation can damage the electric motor. For this reason, the control computer switches MG1 to work in generator mode and produce electricity to charge the batteries. However, this does not reduce the revs. In order to reduce the rotation speed of MG1, VDV is started. It rotates the guide at a speed of at least 1000 min $^{-1}$ while reducing the rotation speed of MG1. If the car's driving speed is more than 100 km/h, the VDV rotates correspondingly faster to reduce the rotation speed of the MG1 and protect it from damage.

When braking a normal car, the force from the brake pedal is transmitted hydraulically to the brake pads and discs. The energy of motion is converted into heat. The hybrid car features an energy regeneration system that, when the brake pedal is pressed, increases the output of the MG2 generator, thereby creating a greater torque of resistance to rotation. As a result, the car decelerates more intensively. Braking energy is used to charge the batteries. The engine control unit calculates how much regenerative braking will reduce the car's deceleration, the less force it transfers to the hydraulic brake system drive.

When the car is going downhill, the drive lever can be switched to the "B" position. The control computer then cuts off the fuel supply to the engine and practically closes the throttle completely. The moment of engine resistance to rotation increases, and at the same time, the braking moment on the driving wheels is also increased. By combining the loads of MG1 and MG2, the braking intensity is controlled.



Energy regeneration

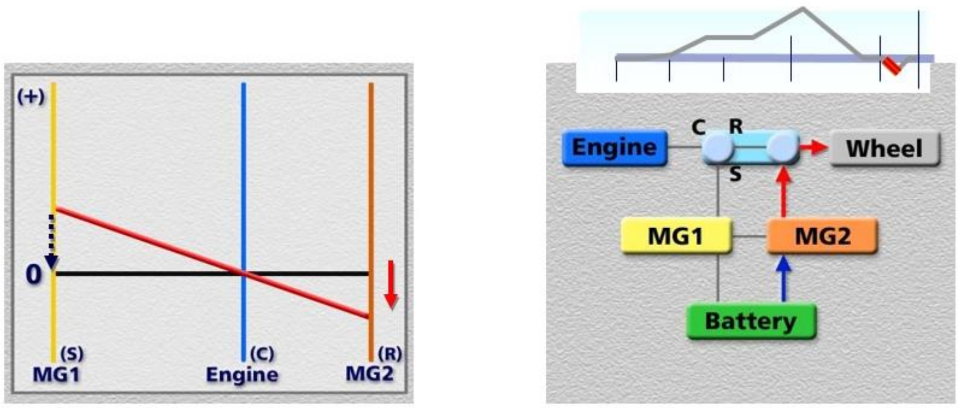


Energy regeneration

Conventional cars with automatic transmissions start to move forward when the brake pedal is released. This is the parasitic energy transfer of the mechanical part. A hybrid car has the same effect. Here, when the brake pedal is released, the car starts to move forward. A small amount of power is supplied to that MG2 motor from the battery pack.

Depressing the accelerator pedal when the car is stationary starts supplying power to the MG2 engine. Since this engine is powerful enough and has a high torque, the car starts from a standstill. If the accelerator pedal is pressed hard, it means the power demand is high, VDV is started. When driving in the city at low speed, only the energy stored in the batteries and the MG2 engine are used. After reaching the desired movement speed until the VDV of the car is activated, it is possible to continue driving using only electric energy. During acceleration, if the power demand is high, VDV is activated, when the desired speed is reached and the driving mode is stabilized, VDV can be switched off again. Further driving is carried out again only with the help of electricity. When VDV will start depends on many factors and the battery charge level.

The car does not have a reverse gear. Reversing the car is created by turning MG2 in the opposite direction. There is no way VDV can increase power or torque here. Shifting the drive selector to the "R" position turns off the VDV. The planetary reducer rotates backwards. Because of the stationary conductor, the MG1 rotates forward, but does not consume or generate any electricity. The computer controls the maximum rotation speed to protect the MG1 from damage.

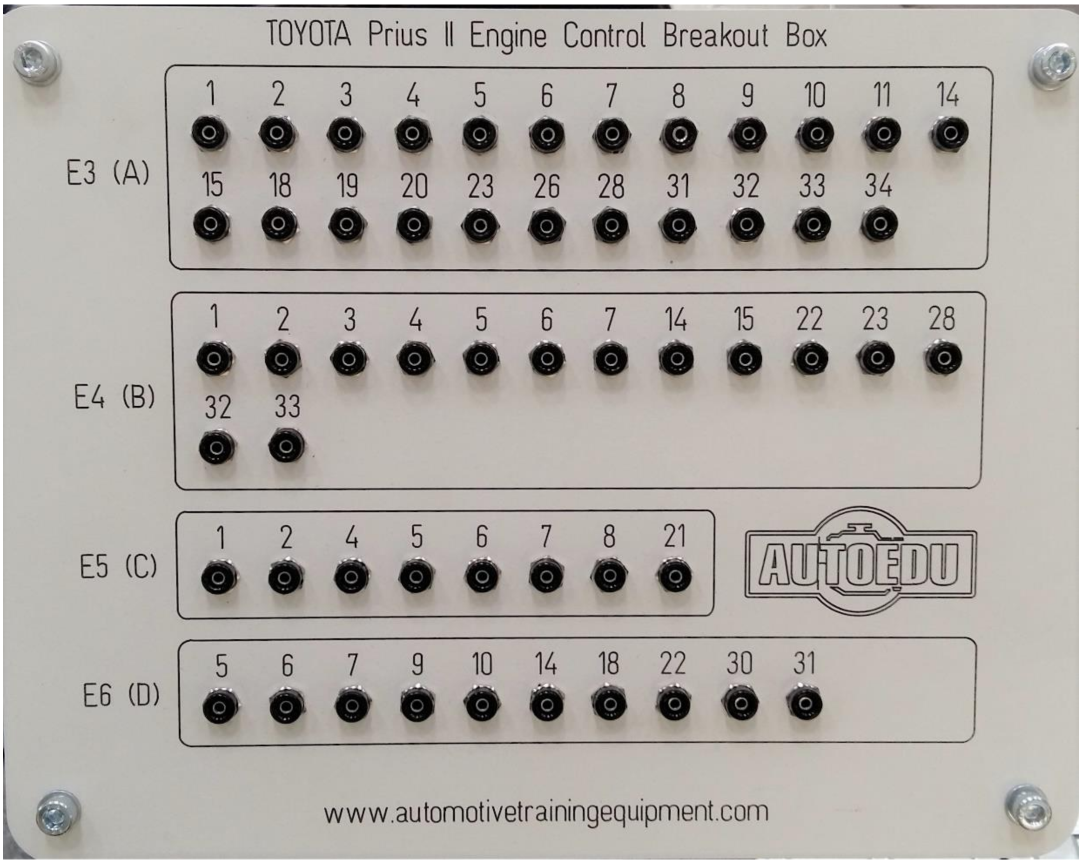


Driving in reverse

6. SIGNAL OUTPUT PANEL , FAILURE SIMULATION

6.1. Signal output panel

The signal output panel is installed in the place of the front passenger seat of the car. Here are prepared for the output of the contacts A, B, C and D of the internal combustion engine (ECM) control unit connectors for various measurements. The contacts are marked according to the same coding methodology as it is implemented in the electrical diagrams of the control units.



Signal output panel

6.2. Failure simulation

The failure simulator is installed in the storage compartment in front of the front passenger seat. When the glove box lid is closed, the crash simulator is not visible. This prevents learners from seeing which switches in the crash simulator are turned off.

Fault simulator switches in the car trunk

The marking of the fault simulator coincides with the contact number of the control unit, whose electrical circuit is interrupted when the switch is turned off.

The crash simulator switches must be turned on if the hybrid car is to function properly. When simulating malfunctions in the hybrid car's systems, the simulator switch is turned off. Errors can be simulated in the control unit of the internal combustion engine system of the hybrid car.

Note:

Depending on the capabilities of the diagnostic equipment used, there may be various options for scanning and removing (erasing) fault codes.

- Fault codes with the diagnostic equipment can be erased immediately after the corresponding switch of the fault simulation has been activated.
- Fault codes with the diagnostic equipment can be erased immediately after the corresponding switch of the fault simulation has been activated. Rechecking the memory of the control unit with the diagnostic equipment shows the fault codes again. These codes disappear from the memory of the control unit only after the car is completely turned off and on.
- Fault codes with the diagnostic equipment can be erased immediately after the corresponding switch of the fault simulation has been activated. When repeatedly checking the memory of the control unit with diagnostic equipment, no fault codes are displayed, but the display of the actual parameter value is restored only after disconnecting and connecting the 12 V battery.

- The measuring contact in the electrical circuit in which the switch simulates a fault is installed between the engine control unit and the switch.
- All switches must be turned on for the system to function smoothly (fault-free). When the switch is turned off, the circuit is broken.

6.3. Simulated fault codes

The numbers of faults simulated in the engine management system and the descriptions of the faults recorded by the diagnostic equipment:

Error simulation

A9
IGT2
Ignition coil 2 control circuit is broken.
Fault code: P0352 Ignition Coil B Primary / Secondary Circuit
Symptoms: CHK ENG light on dashboard comes on, engine stalls, engine stalls

A15
OCV+
The oil control valve circuit is interrupted.
Fault Code: P0010 Camshaft Position A Actuator Circuit (Bank 1)
Symptoms: the CHK ENG light on the instrument panel comes on, the engine stalls, and the crankshaft revs drop.

A19
THW
The coolant temperature circuit is interrupted.
Error Code: P0118 Engine Coolant Temperature Circuit High Input
Symptoms: CHK ENG light on dashboard comes on, engine stalls, coolant radiator fan comes on, engine stalls, starts when accelerator pedal is pressed, but unstable

A20
THA
The intake air temperature circuit is interrupted.
Error code: P0113 Intake Air Temperature Circuit High Input
Symptoms: The CHK ENG light on the instrument panel comes on

A33
NO+
The crankshaft position sensor circuit is broken.
Fault code: P0335 Crankshaft Position Sensor A Circuit
Symptoms: the engine malfunctions, dies, when the accelerator pedal is pressed, it tries to start, but the internal combustion engine does not start

A34
NO- & NO+
We short circuit the crankshaft position sensor
Error Code: P0341 Camshaft Position Sensor A Circuit Range Performance (Bank 1 or Single Sensor)
Symptoms: the engine malfunctions, dies, when the accelerator pedal is pressed, it tries to start, but the internal combustion engine does not start

B6

M+
The throttle motor circuit is broken.
Fault Code: P2102 Throttle Actuator Control Motor Circuit Low
Symptoms: The CHK ENG light on the dashboard comes on, the engine stalls, revs drop and fluctuate, then settles down after a while. It does not respond to pressing the accelerator pedal, but the engine runs. After erasing the error, it is necessary to turn off the ignition to restore the engine.

B7
HA1A
The mixture composition sensor heater circuit is broken.
Trouble Code: P0031 Oxygen (A/F) Sensor Heater Control Circuit Low (Bank 1 Sensor 1)
Symptoms: The CHK ENG light on the instrument panel comes on

B14
EVP1
The gasoline vapor filter cleaning valve circuit is interrupted.
Fault Code: P0443 Evaporative Emission Control System Purge Control Valve Circuit
Symptoms: The CHK ENG light on the instrument panel comes on

D6
HT1B
The oxygen sensor heater circuit is broken.
Error Code: P0037 Oxygen Sensor Heater Control Circuit Low (Bank 1 Sensor 2)
Symptoms: The CHK ENG light on the instrument panel comes on

7 . CONTROL QUESTIONS

1. Safe work with hybrid systems requires:
   a) Tested dielectric safety gloves, mat, face shield, rubber boots
   b) Isolated work tools
   c) Measuring instruments for measuring high voltage

2. A car with a hybrid system drive is:
   a) A car with an internal combustion engine
   b) A car with an electric motor
   c) A car with an internal combustion and electric engine

3. The internal combustion engine control unit controls:
   a) Hybrid system work
   b) Internal combustion engine operation
   c) The work of internal combustion and electric engines

4. The accelerator pedal is connected to:
   a) Hybrid system control unit
   b) Transmission control unit
   c) Internal combustion engine control unit

5. In the hybrid system, the energy generated by the internal combustion engine is transmitted to the wheels:
   a) Only mechanically
   b) Electrical assistance only
   c) Combined with mechanical and electrical assistance

6. High Voltage Battery Battery Relays:
   a) Reduces high voltage to 12V
   b) Disconnects the battery when the car is turned off
   c) Increases voltage from 201V to 500V

7. In an active hybrid system, the internal combustion engine can be started:
   a) Only when driving
   b) When driving in reverse
   c) At any time if energy is needed

8. To start the internal combustion engine:
   a) 12 V starter
   b) MG1
   c) MG2

9. After removing the maintenance connector from the socket, it is possible to work with high-voltage electrical circuits:
   a) Immediately
   b) After 10 minutes
   c) After 1 hour

10. The hybrid drive system is equipped with:
    a) Mechanic gearbox

b) Automatic transmission
c) Planetary reducer

11. The kinetic energy of a hybrid car is used:
a) For charging batteries
b) To discharge the battery
c) Heat is generated in the brake system

12. 12 V battery pack:
a) Required to start a hybrid car
b) For energizing high voltage battery battery relays
c) For all car low voltage users

13. Circuit Breaker Sensor:
a) Allows you to deactivate the hybrid system outside the car
b) Turns off the hybrid system after a set time
c) Disables the hybrid system in the event of an accident or damage to the high-voltage wires

14. For driving in reverse, use:
a) MG2 engine
b) MG1 engine
c) An internal combustion engine

15. The "READY" light on the instrument panel means
a) The internal combustion engine can be started at any moment
b) The high voltage battery is fully charged
c) The 12 V battery is fully charged

16. DC/DC converter:
a) Powers all 12V consumers when the hybrid system is off
b) Converts 12V to 200V
c) Converts 200V to 12V

17. :MG1:
a) Always works as a generator only
b) Always works as an engine only
c) Works in both generator and engine mode

18. Step-up converter:
a) Increases voltage from 201 to 500 V
b) Reduces voltage from 500 to 201 V
c) Increases the power of the internal combustion engine

19. The outer gear of the planetary reducer is connected to:
a) Internal combustion engine
b) MG1
c) MG2

20. Hybrid system high voltage battery pack:
a) Charging while the hybrid system is running
b) Charging when connected to the household electricity network

c) Using the kinetic energy of movement

Answers to the questions:

There may be several correct answers.

1. a, b, c
2. c
3. b
4. a
5. c
6. b
7. c
8. b
9. b
10. c
11. a
12. b, c
13. c
14. b
15. a
16. c
17. c
18. a, b
19. c
20. a, c

8 . WARRANTY CONDITIONS

Educational equipment is a complex engineering product that meets the high standards of modern technology. The equipment is made of high quality, using modern materials and technologies.

Educational equipment is granted 13 months. warranty, unless otherwise stipulated in the sales contract. The guarantee starts counting from the day the invoice is issued.

The warranty for educational equipment is canceled if:

- Non-original parts are used;
- Low-quality fuel is used;
- The wrong power source is used;
- When connecting the power source, the polarity was mixed;
- Technical fluids of the wrong quality are used and/or there are not enough of them;
- The design of the equipment has been changed;
- Equipment damaged during transportation or improper storage;
- The equipment was damaged due to illegal actions of individuals (vandalism, hooliganism, theft);
- Safe work instructions were not followed during work;
- Failures of household electrical networks, voltage fluctuations;
- Aggressive chemical cleaning agents were used to clean the equipment;
- Any equipment damage or loss occurred, defined as a case of *Force* Majeure ;
- Educational equipment is broken or otherwise damaged;
- If foreign objects or liquid get into the educational equipment;
- Using incomplete equipment.

The warranty does not apply to equipment wearing parts, fuses, operating fluids, fuel, seals, filters, liners, belts, bearings, etc.

Warranty repairs are carried out at technical service companies authorized by the manufacturer. Defective equipment units are repaired or replaced with new ones free of charge during the warranty period. The decision on the replacement or repair of parts is made by technicians of authorized companies. Replaced parts become the property of the service point.

After warranty repair, the warranty period is not extended and remains valid until the end of the scheduled period.

The costs related to the disassembly, disassembly, packaging and transportation of the equipment to the authorized warranty service company are not reimbursed to the Customer.

The Customer must cover all expenses incurred by technicians coming to the Customer (transportation, accommodation, etc.) to carry out warranty maintenance work on the educational equipment, when the warranty period of the equipment has not yet expired, but at least one case has been identified that voids the warranty for the educational equipment.

The manufacturer reserves the right to change the design, appearance and equipment of the training equipment.

The warranty conditions are valid only when the educational equipment is used according to the purpose specified in the instructions and in compliance with all work safety instructions.

When applying for a guarantee, the customer must have all the documents for the purchase of the educational equipment: purchase receipt, invoice - receipt, acceptance - transfer deed.

Attention:

If the educational equipment breaks down, a "Warranty maintenance voucher" is filled out. The completed document is sent to the manufacturer of the educational equipment.

Warranty service voucher

Name of educational equipment	___________________________
Product number	
Date of sale	
Owner of educational equipment	___________________________
Trade partner/representative	___________________________

Description of performed works

Date	Description of the failure and its elimination process	Technician / Signature

FOR NOTES

ATTACHMENTS

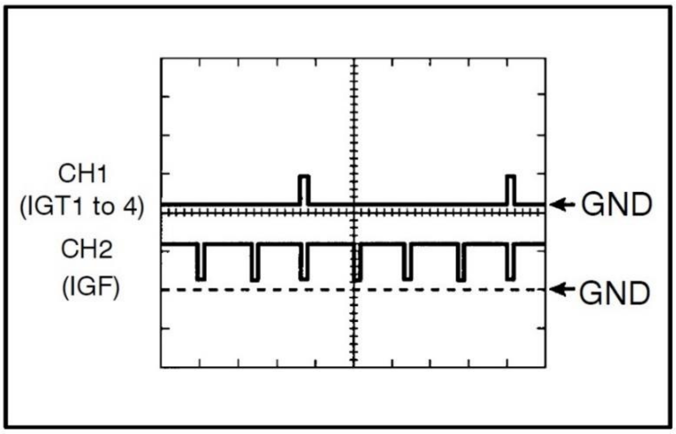
Appendix No. 1

Pin layout and values in the internal combustion engine control unit connector

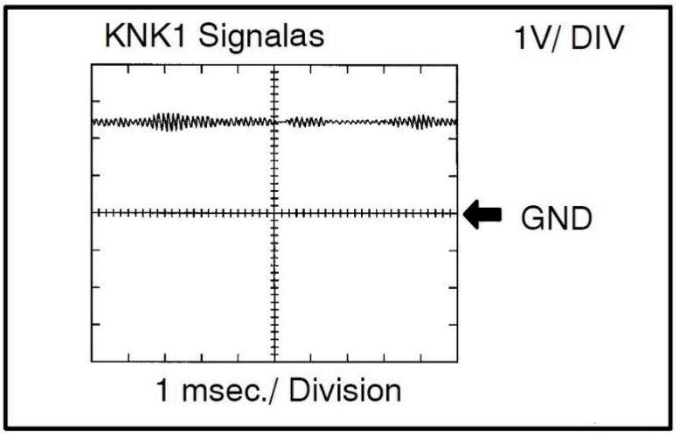
No.	Conclusion	Description	Condition	Value (V)
1	Battery pack (C-6)-E1(B-28)	Battery pack	Permanent	9 - 14
2	+B (C-4)-E1 (B-28)	Engine control unit power supply	When the ignition is turned ON	9 - 14
3	+BM (C-5)-E1 (B-28)	Electronic throttle control	Permanent	9 - 14
4	IGSW (D-9)-E1 (B-28)	Ignition on signal	When the ignition is turned ON	9 - 14
5	MREL (C-7)-E1(B-28)	Switching on the main relay	When the ignition is turned ON	9 - 14
6	VC (A-18)-E2 (A-28)	Sensor supply voltage	When the ignition is turned ON	4.5 - 5.5
7	NO+ (A-33)-NO-(A-34)	Crankshaft position sensor	With the engine idling	Impulse signal
8	G2 (A-26)-NE-(A-34)	Throttle position sensor	With the engine idling	Impulse signal
9	VTA (A-32)-E2 (A-28)	Throttle position sensor	The ignition is on, the shutter is closed	0.5 - 1.2
10	VTA (A-32)-E2 (A-28)	Throttle position sensor	The ignition is on, the shutter is open during the activation test	3.2 - 4.8
11	VTA2 (A-31)-E2 (A-28)	Throttle position sensor	Ignition on, accelerator. the pedal is released	1.5 - 2.9
12	VTA2 (A-31)-E2 (A-28)	Throttle position sensor	The ignition is on, the shutter is open during the activation test	3.5 - 5.5
13	VG (B-33)-EVG (B-32)	Air mass meter	With the engine idling, cond. off	1 - 1.5
14	THA (A-20)-E2 (A-28)	Intake air temp. sensor	With the engine running, when the air temp. 20 °C.	0.5 - 3.4
15	THW (A-19)-E2 (A-28)	Coolant temp. sensor	With the engine running, liquid temp. 80 °C	0.2 - 1
16	#10 (A-2)-E01 (A-7)	Sprayer	When the ignition is turned ON	9 - 14
17	#20 (A-3)-E01 (A-7)	Sprayer	When the ignition is turned ON	9 - 14
18	#30 (A-4)-E01 (A-7)	Sprayer	When the ignition is turned ON	9 - 14
19	#40 (A-5)-E01 (A-7)	Sprayer	When the ignition is turned ON	9 - 14
20	IGT1 (A-8)-E1 (B-28)	1 ignition coil	With the engine running	Diagram 1

21	IGT2 (A-9)-E1 (B-28)	2 ignition coil	With the engine running	Diagram 1
22	IGT3 (A-10)-E1 (B-28)	3 ignition coil	With the engine running	Diagram 1
23	IGT4 (A-11)-E1 (B-28)	4 ignition coil	With the engine running	Diagram 1
24	KNK1 (B-1)-EKNK (B-2)	Detonation sensor	With the engine running	Diagram 2
25	IGF (A-23)-E1 (B-28)	Ignition confirmation signal	With the engine running	Diagram 1
26	A1A+ (B-23)-E1 (B-28)	Mixture composition sensor	When the ignition is turned ON	3 - 3.6
27	A1A-(B-22)-E1 (B-28)	Mixture composition sensor	When the ignition is turned ON	2.7 - 3.3
28	OX1B (D-22)-E2 (A-28)	Oxygen sensor	After 2 min of engine operation at 2500 min $^{-1}$	Impulse signal
29	HA1A (B-7)-E2 (A-1)	Mixture sensor heater	With the engine running	Less than 3
30	HA1A (B-7)-E2 (A-1)	Mixture sensor heater	When the ignition is turned ON	9 - 14
31	HT1B (D-6)-E03 (D-7)	Oxygen sensor heater	With the engine running	Less than 3
32	HT1B (D-6)-E03 (D-7)	Oxygen sensor heater	When the ignition is turned ON	9 - 14
33	EVP1 (B-14)-E1 (B-28)	Gasoline vapor filter cleaning valve	When the ignition is turned ON	9 - 14
34	M+ (B-6)-E1 (B-28)	Throttle control motor	With the engine running	Impulse signal
35	M-(B-5)-E1 (B-28)	Throttle control motor	With the engine running	Impulse signal
36	OCV+ (A-15)-OCV- (A-14)	Oil control valve	When the ignition is turned ON	Diagram 3
37	TAM (C-21)-E2 (A-28)	Outdoor temperature sensor	Temperature limits -40 – 140 °C	0.8 - 1.3
38	MOPS (B-15)-E1 (B-28)	Engine oil pressure	When the ignition is ON, the engine is not running	9 - 14
39	FAN (C-8)-E1 (B-28)	Fan relay	When the ignition is turned ON, the cooling Liquid temp. less than 94.5 °C	9 - 14
40	W (D-18)-E1 (B-28)	Malfunction indicator lamp	With the engine running	9 - 14
41	W (D-18)-E1 (B-28)	Malfunction indicator lamp	When the ignition is turned ON	Less than 3
42	FC (D-10)-E1 (B-28)	Fuel pump relay	When the ignition is turned ON	9 - 14
43	FC (D-10)-E1 (B-28)	Fuel pump relay	With the engine running	Less than 3
44	TC (D-14)-E1 (B-28)	Diagnostic connector	When the ignition is turned ON	9 - 14

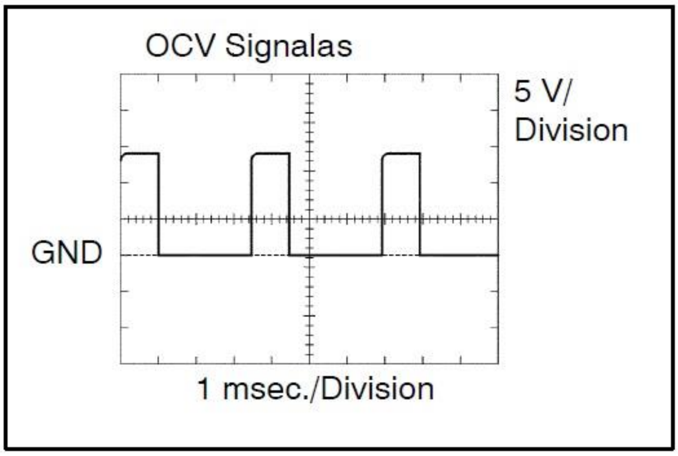
45	NEO (C-1)-E1 (B-28)	Turn signal	With the engine running	Impulse signal
46	GO (C-2)-E1 (B-28)	Turn signal	With the engine running	Impulse signal
47	CANH (D-31)-E1 (B-28)	CAN line	When the ignition is turned ON	Impulse signal
48	CANL (D-30)-E1 (B-28)	CAN line	When the ignition is turned ON	Impulse signal



1 Diagram



2 Diagram



3 Diagram

Annex no. 2

Technical parameters, operating fluids

Vehicle identification		
No. of cylinders	Type:	4/DOHC
Capacity (Fiscal)	cc:	1497
Output	kW (DIN hp) rpm:	57 (78) 5000
Compression ratio	:1:	13
Suitable for unleaded petrol	:	Yes
Minimum octane rating	RON:	95
Ignition system	Make:	Toyota
Ignition system	Type:	TCCS
Ignition system	Description:	Map-DI
Trigger location	:	Cam/Crankshaft
Fuel system	Make:	Toyota
Fuel system	Description:	MFI-s
Air metering	Type:	Mass
Diagnostic socket	:	Yes
Ignition system		
Firing order	:	1-3-4-2
Tuning and emissions		
Ignition timing - basic BTDC	°Engine/rpm:	8-12/1000 Not adjustable
Idle speed	rpm:	1000±50 Not adjustable
Oil temperature for CO test	°C:	80
CO level at idle speed - tailpipe	Vol. % CO:	0,5 Max Not adjustable
HC level at idle speed	ppm:	100
CO2 level at idle speed	Vol. % CO2:	14,5-16
O2 level at idle speed	Vol. % O2:	0,1-0,5
Increased idle speed for CO test	rpm:	1400-1600
CO content at increased idle speed	Vol. %:	0,3
Lambda at increased idle	?:	0,97-1,03
Spark plugs		
Spark plugs	Original equipment:	Denso
Spark plug	Type:	SK16R11
Electrode gap	mm:	1,1
Spark plugs	Make:	NGK
Spark plug	Type:	IFR5A11
Electrode gap	mm:	1,1
Fuel system		
Regulated pressure with vacuum	bar:	3,0-3,4
Crankshaft position (CKP) sensor/engine speed (RPM) sensor	Ohm:	985-1600
Injector	Ohm:	13,4-14,2
Lambda sensor (Oxygen) heater	Ohm:	11-16
Service checks and adjustments		
Valve clearance -INLET	mm:	0,17-0,23 cold
Valve clearance -EXHAUST	mm:	0,27-0,33 cold
Compression pressure	bar:	8,82
Oil pressure	bar/rpm:	1,5-5,5/2250
Radiator cap	bar:	0,74-1,03
Thermostat opens	°C:	80-84
Drive belt tension - AC	mm:	9-12
Lubricants and capacities		
Preferred engine oil		
Ambient temperature range	:	All temperatures
Engine oil grade	SAE:	5W/30
Engine oil classification	API/ACEA:	SL/A1, A3
Engine oil options		
Ambient temperature range	:	-18°C->38°C
Engine oil grade	SAE:	10W/30
Engine oil classification	API/ACEA:	SL/A1, A3
Ambient temperature range	:	-12°C->38°C
Engine oil grade	SAE:	15W/40
Engine oil classification	API/ACEA:	SL/A3
Ambient temperature range	:	-7°C->38°C
Engine oil grade	SAE:	20W/50
Engine oil classification	API/ACEA:	SL/A2
Engine with filter(s)	litres:	3,7
Other lubricants and capacities		
Automatic transmission fluid	Type:	ATF WS
Automatic transmission (drain & refill)	litres:	3,8
Cooling system	litres:	5,3
Brake fluid	Type:	DOT 3
Air conditioning		
No. of AC service connectors	:	2
Air conditioning restrictor type	:	EV
Air conditioning refrigerant	Type:	R134a
Air conditioning refrigerant quantity	grams:	450±30
Air conditioning oil	Type:	Dens Oil 11

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