PETROL / ELECTRIC HYBRID WORKING ENGINE TOYOTA PRIUS II

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2022 Kaunas Lithuania

CONTENTS

1. SAFETY REQUIREMENTS

1.1. General safety requirements

Attention:

Before using the training board, take a look at the user manual.

Training equipment may only be used for the training purposes specified in the instructions.

The staff conducting the training (lecturer, teacher, instructor and others) must be familiar with the instructions for the training equipment, know the methods and principles of use, settings, control of the equipment, be able to switch off (stop) the training equipment in an emergency.

The training staff (lecturer, teacher, instructor and others) acquaint those working and learning with the training equipment with the work safety requirements.

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

It is forbidden to work with educational equipment for children, unqualified staff.

It is forbidden to work with training equipment for persons under the influence of alcohol or other psychotropic substances.

It is forbidden for people who do not have the appropriate qualifications to open the electrical input boxes, connect or change anything there.

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

Do not ignore the information on possible dangers provided by the warning signs on the training equipment. Beware of the hazards indicated on the warning signs.

The training equipment must be switched off completely during cleaning work.

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

It is forbidden to clean the electronic components of the training equipment with damp cloths.

The equipment must be completely switched off during maintenance and repair work on the training equipment.

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

Before working with training equipment, check that:

- Equipment is not mechanically damaged, broken;
- All protective shields are assembled;
- All heated, rotating parts (e.g., heating plugs, pulleys, gears, etc.) are covered;
- All components (e.g., wires, jumpers, fuses, handles, etc.) are available;
- Sufficient technical fluids (e.g., brake fluid, oil, coolant, etc.);
- Liquids do not leak through the joints;
- The equipment components are free of foreign bodies;
- Undamaged power cords;
- Neat power supplies (battery or stand power supply);
- Power supplies are properly connected (e.g., battery terminals are screwed on, polarity is not mixed, proper power supply is used according to local electrical installation standards);
- The use of training equipment with internal combustion engines ensures the removal of burns from the auditorium;
- The training equipment is properly constructed and locked (e.g., the equipment is placed on a sufficiently solid base, the transport wheels are locked);
- During operation, the equipment will not pose any danger to those working with it and the surrounding staff;
- There are other factors not specified in the instructions that may endanger the health of personnel working with the equipment and others.

Observe during work with the equipment:

- The removal of incinerators from the auditorium is smooth and uninterrupted;
- The noise emitted by the equipment is characteristic of such a work process (no extraneous sounds);
- No leakage of liquids from the equipment;
- The exhaust gas extraction system is working properly;
- Sufficient quantity of technical fluids;
- Odour of glowing, burning objects;
- Power supplies are working properly;
- There are no factors or processes other than those specified in the instructions that could endanger the health of personnel working with the equipment or other persons.

1.2. Safety requirements for working with electric and hybrid cars

Employees, lecturers, students, support and service personnel must be familiar with the requirements of the work instructions for work with electrical devices after listening to the instructions and must sign the work safety logs. Instruction 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). The "Safety Regulations for the Operation of Electrical Equipment" are followed.

Only persons with appropriate qualifications may work with high-voltage components and circuits of electric vehicles.

Elements marked in orange (wires, connectors, control units, voltage converters, etc.) are constantly or periodically exposed to high voltages.

Follow the rules for safe work when operating cars.

The high voltage system can turn on automatically. Before starting work on the stand, it is necessary to make sure that the air conditioning control timer is not set.

Warning:

• Before inspecting or servicing the circuits and components of the high voltage system, be sure to remove the maintenance connector (fuse) from the socket in the battery box of the high voltage battery. This will turn off the high voltage circuit.

• Place the maintenance connection (fuse) safely out of the reach of other persons to prevent it from being accidentally connected by another person during maintenance and service work.

• Before working on high voltage components, take care of personal protective equipment and equipment: gloves, shoes, face shield, rubber mat, earthing circuit, etc.

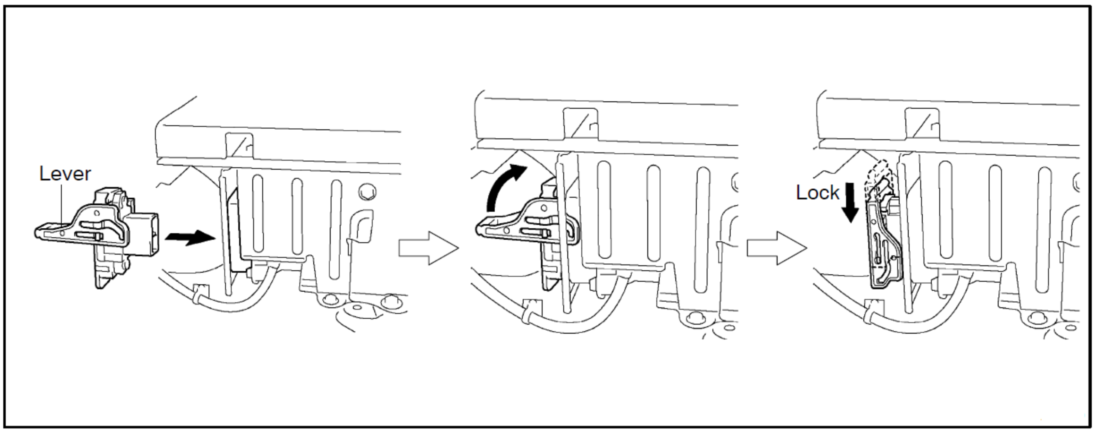
• Take care of the safety of the work area around the high-voltage battery: the work area must be marked, a responsible employee must be appointed, and the work area must be fenced. When work is not in progress, high-voltage parts and components must be covered with insulating covers or shields to prevent them from touching them.

Service plug

When carrying out any work on a high-voltage (~ 200 V) electrical circuit, it is necessary to remove the service plug.

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

After removing the service plug, only after 10 minutes. it is possible to start work with high voltage electrical circuits. This time is required for the discharge of high voltage capacitors



Service plug

Removal of the service plug is performed in the opposite direction to installation.

CAUTION: HIGH VOLTAGE. DO NOT TOUCH DURING OPERATION.

To draw the attention of other employees, set up an information warning sign.

CAUTION:

HIGH VOLTAGE. DO NOT TOUCH DURING OPERATION

CAUTION:

HIGH VOLTAGE. DO NOT TOUCH DURING OPERATION

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

Hybrid cars may not make any noise. The absence of noise does not mean that the car is switched off.

Always disconnect the negative terminal of the 12 V battery if necessary.

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

The high voltage battery is protected by a fuse. Voltage switching on and off is control

Attention:

There may be residual voltage in the high voltage circuit after it has been switched off. Therefore, wait at least 10 minutes after switching off the system. During this time, it is forbidden to touch, disconnect, repair or inspect high-voltage wires.

Both positive and negative high voltage wires are separated from the car body. Therefore, there is no possibility of electric shock when touching the metal parts of the car.

The high voltage battery is disconnected as soon as the SRS (Supplemental Restraint System) is activated in the event of a car accident. This prevents high voltage leakage into the car body.

When working with high voltage components, the battery must use protective equipment:

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

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

When preparing to work with a hybrid 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, goggles, mats, etc.) disconnect the high voltage service connector (fuse): unlock the lever lock, lift the lever up and pull the entire service connector out of the socket.

When disconnecting high-voltage wires or other electrical connections, it is mandatory to insulate the open contacts with insulating materials.

After disconnecting the electrical components, make sure that there is no residual voltage.

Protective equipment must be used when working with high voltage circuits. Measure the voltage inside the electrical components before working on them. The devices must display 0 V. It is only possible to work with high-voltage circuit elements at least 10 minutes after the circuit has been switched off. There are capacitors in the system that need to be discharged (discharged).

The SRS system may still operate 90 seconds after disconnecting the battery. The system must be handled with care to avoid possible injuries due to operation of the SRS system components.

Attention!

Work safety instructions must be observed when working with high voltage circuits. Workers working on high-voltage circuits can be shocked by high-voltage electricity and injured by improper handling of measuring and repair equipment due to sparks. At the beginning of the work, it must be ensured that all repair and maintenance work is carried out only with the high-voltage lines disconnected.

When disconnecting high voltage cables, they must be insulated. This avoids short circuits, self-coupling and human protection. Use only fully insulated tools for this purpose.

It is forbidden to remove the clear plastic covers from the frame holding the high-voltage battery.

Attention:

In hybrid car stands, the internal combustion engine can start independently at any time as long as the POWER switch is on. Engine start is controlled and performed by the car's hybrid system control computer by estimating the charge level of the high-voltage battery. When working with hybrid car stands, it is mandatory to ensure that the flues are properly removed from the room and that there are no working persons or foreign objects near the rotating engine parts before switching on the POWER switch.

2. GENERAL INFORMATION

2.1. Purpose of training equipment

Teaching equipment 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 analysis of various car systems work processes. It is possible to perform various measurements of the system parameters installed in the training equipment, to perform fault simulations, to diagnose. A variety of laboratory tasks can be performed using the training equipment. The equipment is designed and manufactured in order to provide learners with the clearest and most convenient information about the structure of the unit, the composition of the system and the principle of operation.

The training equipment is intended for demonstration, training and learning of the design, construction, principle of operation, settings and adjustments of the Toyota Prius hybrid car.

2.2. Training equipment parameters

Length	1750 mm;
Width	1200 mm;
Height	1450 mm;
Weight	~ 470 kg;
Power supply	12 V battery
	High voltage battery ~ 200 V
	Gasoline A95

Training equipment is made using car elements:

Manufacturer:	Toyota
Model:	Prius
Code:	NHW20
Production Year:	2003 – 209
Engine code:	1NZ-FXE

2.3. Transport and storage conditions

The training equipment is mounted on a dedicated stand, frame, platform or chassis. When transporting equipment with an internal combustion engine or any other technical fluids, it is forbidden to overturn or lay down. During transport, the equipment must be protected from falling, tipping, shocks, humidity, temperature, vibration.

Training equipment with its own chassis must be equipped with locked transport wheels during training and storage (including transport). The wheels can only be unlocked when the training equipment is relocated.

Training equipment without its own stand or chassis must be placed on a suitable, solid base (table, cabinet).

Export or import procedures must take into account the legislation in force 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. Equipment must be covered with protective equipment if the equipment is exposed to direct sunlight.

Unused training equipment is kept completely switched off. The emergency stop button is left on. The training stands are switched off with the control key and by disconnecting the power supply (switching off the power supply and / or disconnecting the 12 V battery).

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

- The 12 V battery must be taken care of and charged regularly.
- The charge level of the high-voltage battery (hybrid cars and electric cars) must be taken into account. It must not be less than the minimum allowable voltage specified (specified) by the

The training equipment must be switched on and operated for at least 20 minutes within a period of 30 days. This is a preventative measure designed to reduce the chances of stalling and getting stuck in various components of the engine or car systems. It is not recommended to leave the training 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. Preparation and use of equipment

Attention:

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

The training equipment is maintained as conventional mechanical, hydraulic, pneumatic, electrical machines and systems. Training equipment requires minimal maintenance and service.

Training equipment - a car, maintained and serviced according to the car manufacturer's recommendations.

It is necessary to constantly monitor the leakage of fluids from the training equipment units.

All components of the training equipment must be controlled and ensured.

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

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

The engine oil and filter are changed once a year using the right quality parts and specifications.

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

On stands - cars, the engine oil level, coolant level, brake fluid level, clutch fluid level, gearbox oil level must be constantly monitored.

The drive element (chain or belt) of the gas distribution mechanism of an internal combustion engine shall be replaced according to the engine manufacturer's recommendations. 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 wheel constantly decreases, leaks must be repaired - sealed.

The charge of the 12 V battery must be checked and monitored regularly. Strong battery discharge (voltage less than 10.5 V) is not permitted. Do not store a discharged battery for more than 10 days (lead acid batteries can cause irreversible sulphation processes that can damage the battery).

The battery charge level of high voltage (hybrid and electric) batteries must be checked regularly. The charge level must not be less than the minimum permissible battery voltage specified by the battery manufacturer. If necessary, the battery must be charged with the appropriate means and equipment.

Training equipment with internal combustion engines or equipment demonstrating the operation of car systems (systems: interior air conditioning, petrol or diesel engine power supply, ignition, etc.) must be switched on and operated for at least 20 minutes within a period of 30 days. This is a preventive measure designed to reduce the chances of stalling and getting stuck in various components of the engine or car systems.

Only technical fluids of the appropriate quality and technical specification (engine, transmission oil, coolant, brake fluid, etc.), high-quality filters and other spare and components must be used for maintenance and service work on the training equipment.

2.5. Energy supply

Mineral fuels

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

Attention:

The use of biofuels or flammable and other liquids of unknown origin in training equipment is prohibited.

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 when working with training equipment that is powered by a 12 V battery. The charger can emit electromagnetic noise that affects the operation of the training equipment and can be recorded by sensitive measuring devices (oscilloscope).

Attention:

When connecting a 12 V battery to the stand, the control key and all other users must be turned off. First connect the "+" battery contact (terminal) and tighten. Then connect the "-" battery contact (terminal) and tighten.

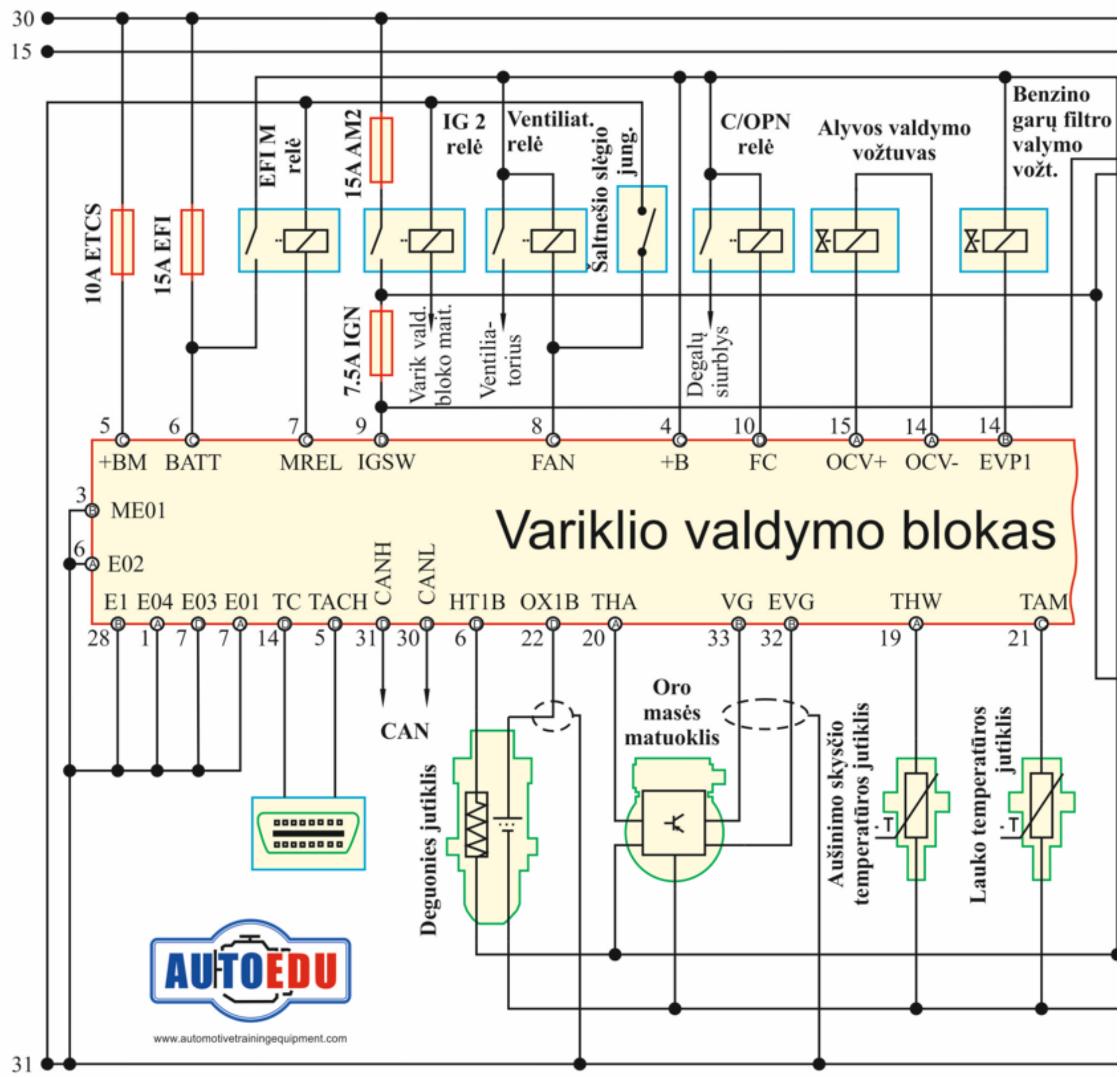
When disconnecting the 12 V battery from the stand, the stand must be turned off. First release and disconnect the "-" battery contact, then release and disconnect the "+" battery contact.

Attention:

Do not confuse the polarity of the wires to the 12 V battery. The "+" (positive) and "-" (negative) contacts (terminals) are marked on the battery and on the cable connections. The cable contact marked with a "+" (positive) sign (cable insulation colour red) is connected to the battery terminal marked with a "+" (positive) sign. The cable contact marked with a “-” (negative) sign (wire insulation colour black) is connected to the battery contact marked with a “-” (negative) sign.

2.6. Symbols and markings

Automotive symbols for marking wiring diagrams and components are used in the training equipment. The figure below shows an example of component marking in a wiring diagram.



Example of wiring diagram and component marking.

Marking of wiring diagrams:

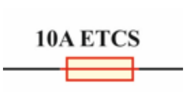
Black line connecting wires;

the wires are connected to each other;

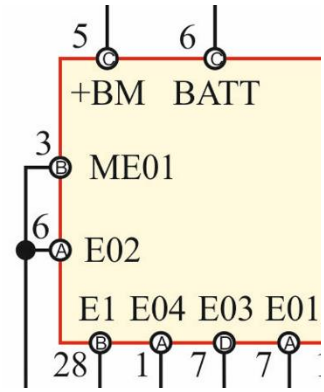
30 a numbered wire is an electrical circuit having a constant voltage of +12 V from a battery;

15 the numbered wire is an electrical circuit in which a +12 V DC voltage is turned on by the ignition key;

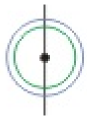
31 is the electrical circuit connected to the car body and the negative terminal of the battery (ground);



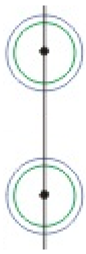
Fuse. Fuse marking symbol.



Vehicle system (unit) control unit (computer) (e.g., engine control unit, airbag control unit, brake ABS control unit or other). The letters in a circle (A, B, C, D) indicate the connector. The numbers denote the contact of the control unit connector. For example: C6 is the sixth contact of connector C. A power cord from the battery is connected to this terminal BATT.



A 4 (2) mm banana was installed in the training equipment and connected to that cable. connector (socket) for connecting measuring equipment or a jumper.



Two banana connectors (sockets) are mounted on the cable for connecting the jumper. A jumper removed from the connectors breaks the circuit of this wire. Electric current cannot flow. The wiring diagram of the stand does not show this disconnection of the cord, because in real cars banana connectors are not installed. These connections are installed in the electrical circuit of the training equipment, enabling measurements to be made and faults to be simulated.

Jumper. 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 to each other.

Attention:

It is recommended to connect measuring wires with 4 (2) mm banana type contacts (plugs) to the training equipment when performing various measurements of electrical parameters.

2.7. Preparation and use of equipment

When preparing training equipment for work, it must be properly constructed and secured. Equipment with a chassis, built on a level and solid floor. The equipment transport wheels are locked by locking the brakes.

Attention:

Equipment with internal combustion engines must be connected to a functioning flue system. The room must be well ventilated, even with the flue system in operation.

A suitable, charged 12 V battery is connected before working with the training equipment.

The technical condition of the equipment, attachment of protective shields, complete set and other things are checked. For more information on safe work requirements, see the section "Occupational safety → Before working with the training equipment, check that:".

The position of the emergency stop switch is checked. If the training equipment has been stopped in an emergency, the emergency stop switch will remain depressed and the equipment will not start. When the emergency stop switch is unlocked, it pops out when its upper part is turned clockwise (the upper part moves to the right).

Emergency stop switch

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

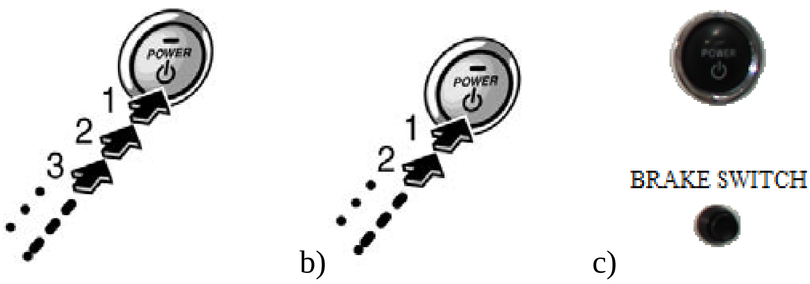
Attention:

The emergency stop switch must be switched off when you have finished working with the training stand. The status of this switch is indicated by a light indication above it. If the indication is lit, the training stand is switched on.

When you have finished working with the training stand, we recommend that you do not leave the ignition key and the maintenance connection on the stand.

In training equipment with an in-car dashboard, all indications of equipment operation are reflected on the dashboard.

Press the “POWER” switch slowly and surely. Quick operation may not activate the desired mode.



a) b) c)

a) Pressing the POWER key when the brake pedal is not depressed:

1. The ACC function is activated when power is supplied to the radio

2. The ignition IGNITION ON is switched on. All car systems are working (interior ventilation, wipers, lights, etc.)

3. Everything is turned off

b) Pressing the POWER key when the brake pedal is depressed b):

1. The ignition IGNITION ON is switched on. All car systems are working (interior ventilation, wipers, lights, etc.) The READY mode is activated. The hybrid system stand is fully engaged.

2. Pressing the POWER key again turns off the entire hybrid system.

c) Pressing the BRAKE SWITSCH button below the POWER key simulates pressing the brake pedal.

Training equipment is made for studying and demonstrating parts, assemblies, systems, engine structure, construction, operation. The systems installed in the training equipment are fully operational.

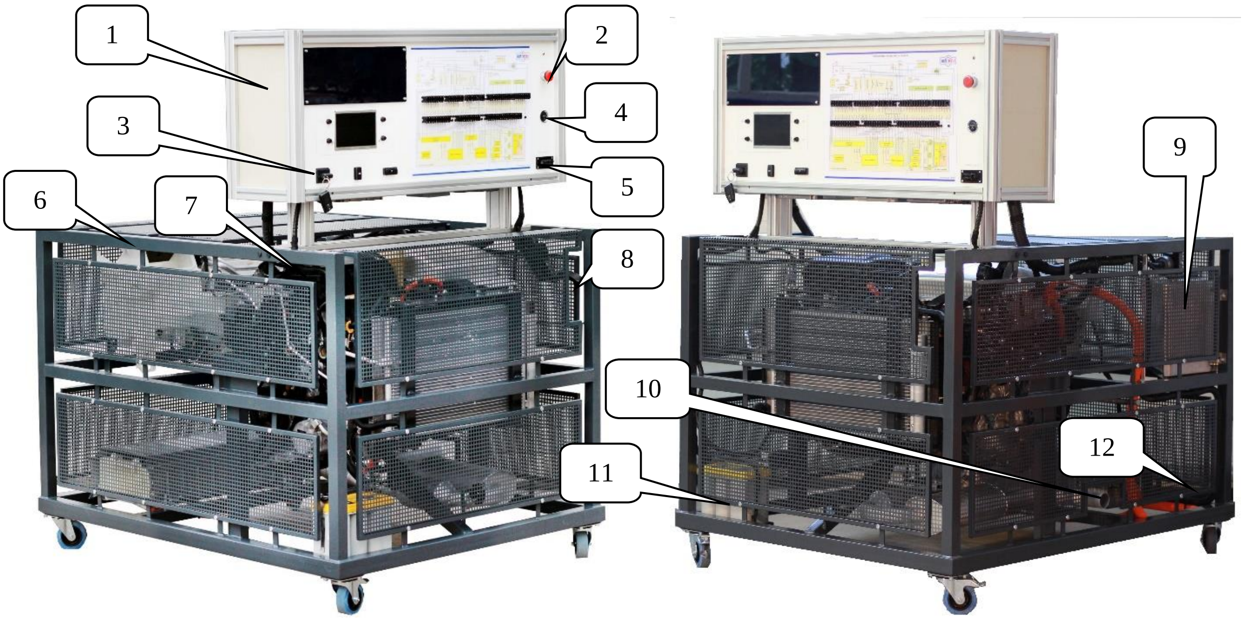
By learning diagnostics, car control computer system scanners (computer diagnostics), it is possible to activate the execution components. This item can be activated depends on the available diagnostic and training equipment.

With the help of system scanners, written fault codes / messages can be found in the car's control computer memory. These codes / messages are stored in the memory when the sensor, the actuator, the wire is broken, the contacts are lost, the jumper is removed from the circuit. All fault codes can be deleted from the car's control computer memory using system scanners. Fault codes are stored in the memory, for example: when the jumper is disconnected when the training equipment is switched on, the signals of the speed sensors do not match, due to voltage fluctuations and other real or simulated malfunctions. As in cars, errors can only be cleared from the control computer's memory when the fault has been physically rectified (e.g., jumper inserted, cable connected, faulty sensor replaced, etc.).

3. TRAINING EQUIPMENT

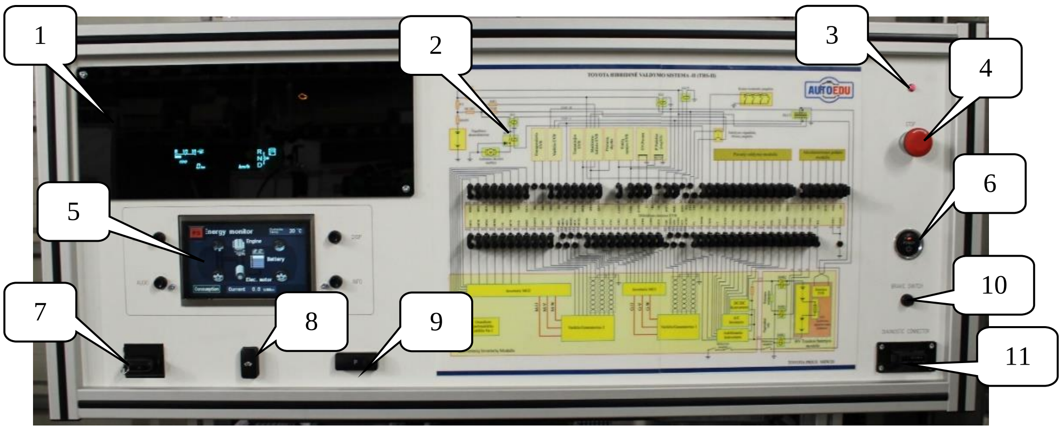
3.1. General overview of training equipment

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



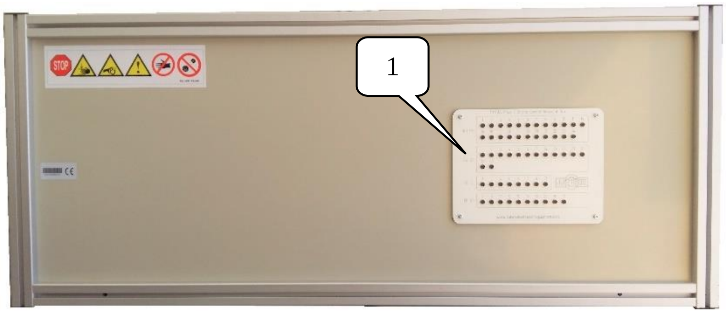
Toyota Prius Hybrid System -II (THS) training bench overview

1. Hybrid system control panel;
2. Emergency stop switch
3. Ignition key
4. POWER switch
5. OBD II diagnostic connector
6. Stand frame with transport wheels and protective shields
7. Hybrid system (internal combustion engine, electric motors, planetary gearbox, high voltage battery)
8. Accelerator pedal
9. Fuel tank
10. Exhaust system
11. 12 V battery
12. High voltage battery and Service Plug



Toyota Prius Hybrid System -II (THS) control panel

1. Dashboard
2. Wiring diagram of the hybrid system, and jumpers
3. Indication of the switched-on 12 V electrical circuit of the stand
4. Emergency stop switch
5. Information screen for control of other systems
6. POWER switch
7. Ignition key
8. EV mode control switch
9. Parking brake control switch
10. Brake pedal switch 11 OBD II diagnostic connector

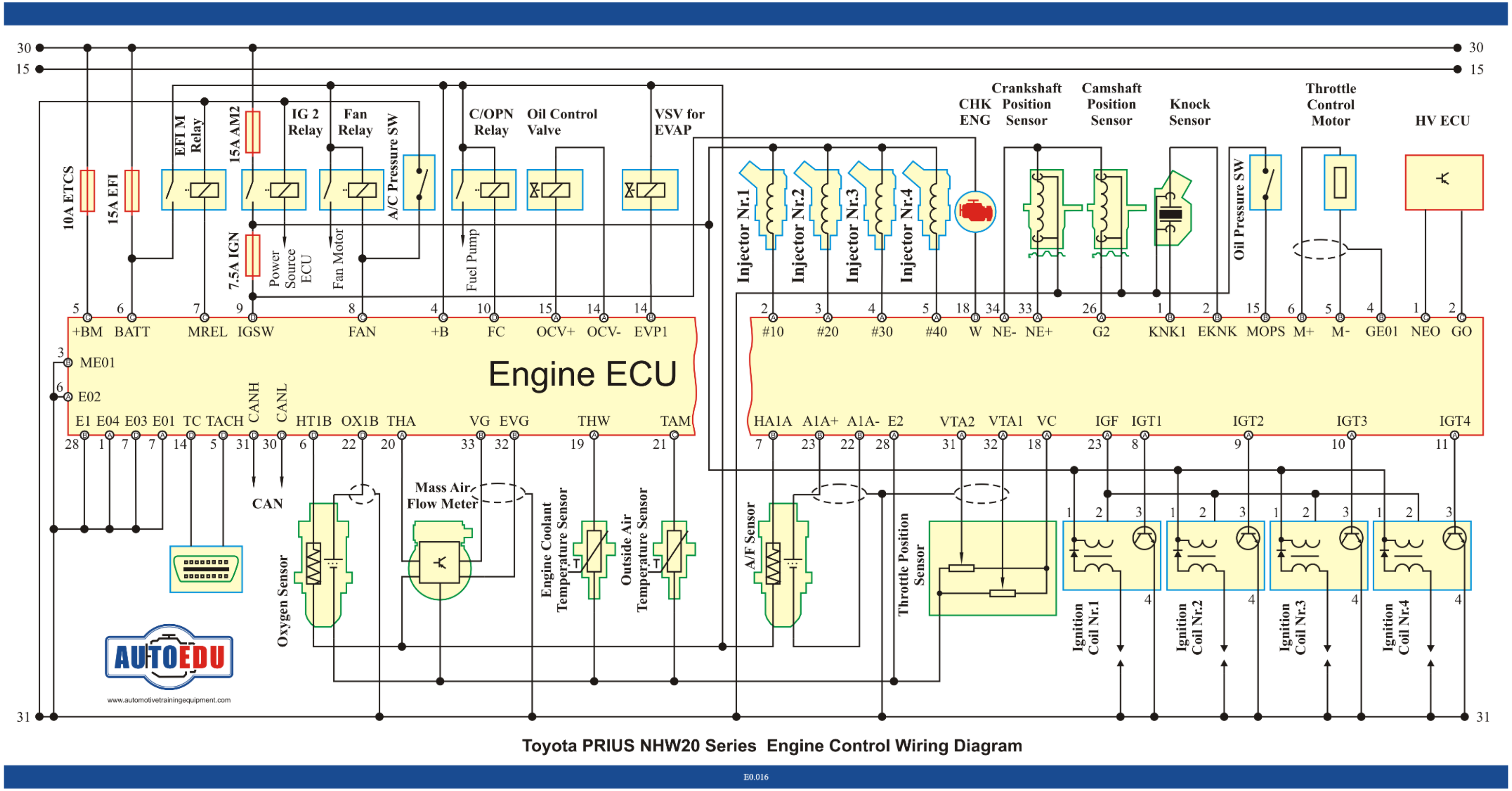


Toyota Prius Hybrid System -II (THS) control panel (second side)

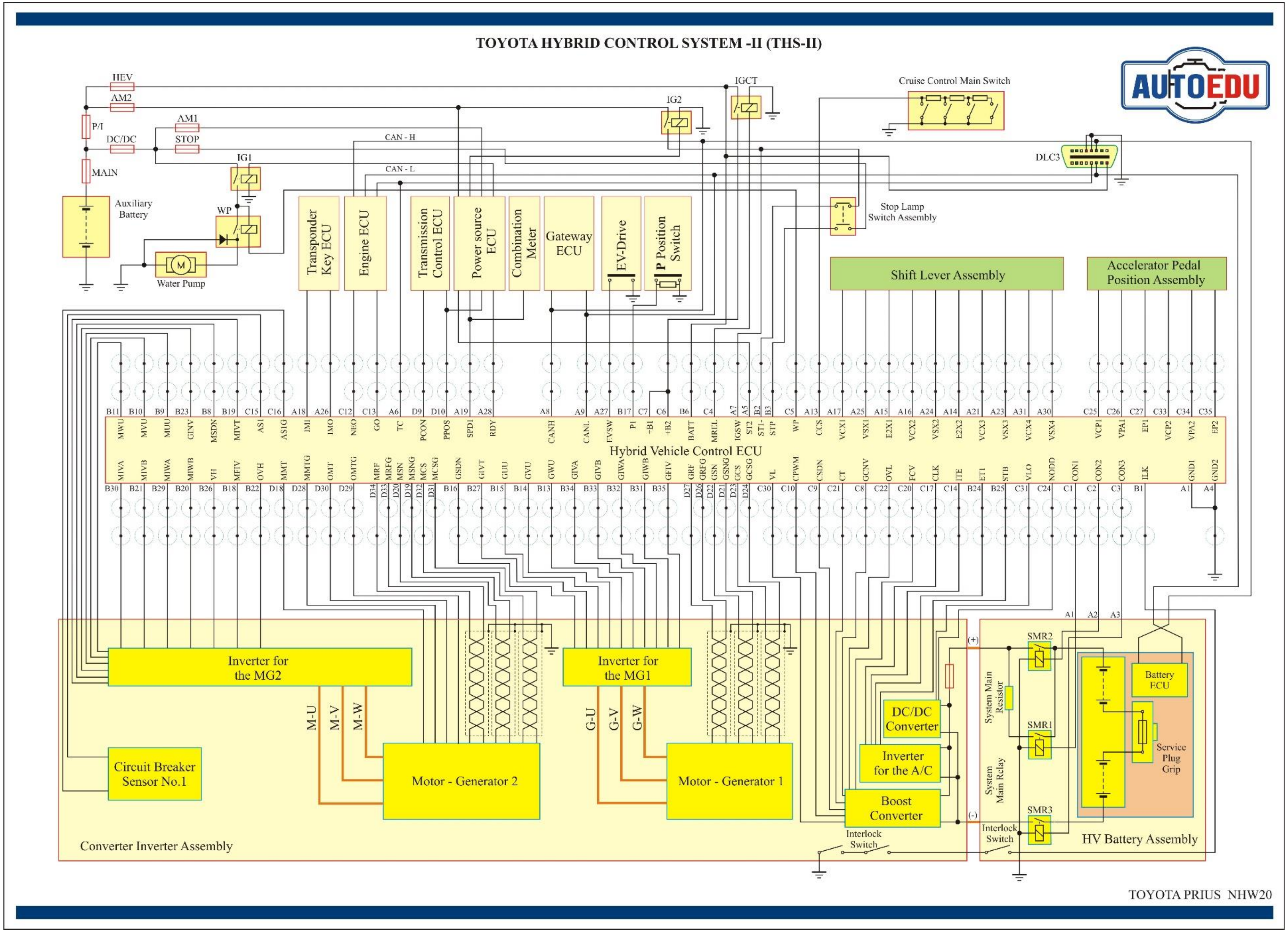
1. Breakout Box

3.2. Electric scheme

The wiring diagram contains all the elements: sensors, actuator components, data transmission lines, diagnostic connection. This diagram shows the connection circuits of the elements, the connection contact numbers, the component numbers, the mounting locations of the jumpers.



Electrical diagram of the internal combustion engine control system



Wiring diagram of the hybrid system

4. HYBRID SISTEM STRUCTURE

4.1. Internal combustion engine

Hybrid vehicle ECU

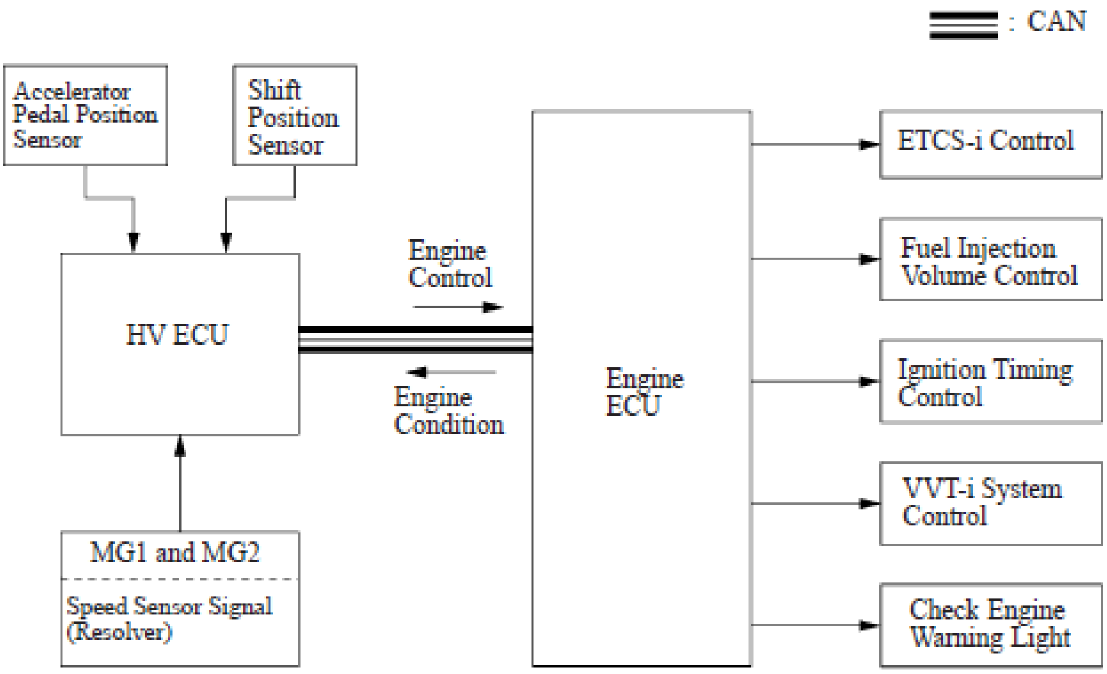
Information from each sensor as well as from the ECU (engine ECU, battery ECU, skid control ECU, and EPS ECU) is received, and based on this the required torque and output power is calculated.

The HV ECU sends the calculated result to the engine ECU, inverter assembly, battery ECU and skid control ECU

Engine ECU

Activates the ETCS-i (Electronic Throttle Control System-intelligent) in accordance with the target engine speed and required engine motive force received from the HV ECU. The engine ECU also controls the fuel injection time, the ignition moment of the combustible mixture and the control of the gas distribution phase process.

The engine control unit sends information to HV ECU about the operation of the internal combustion engine. At the command of HV ECU, the engine ECU shuts off the internal combustion engine. In the event of any system fault, the engine ECU turns on the fault warning lamp as instructed by the hybrid system.



Internal combustion engine control structure

Ignition coil

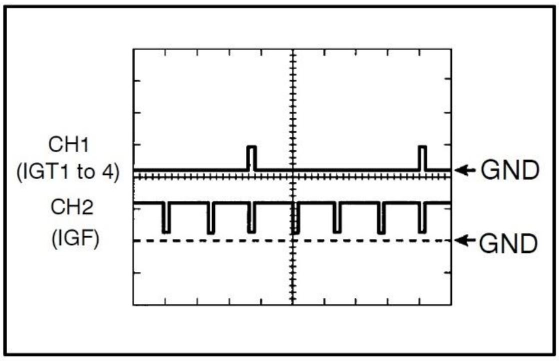
The purpose of the ignition system is to ignite the air - fuel mixture at the appropriate time in any mode of operation. To achieve this goal, the ignition angle, spark energy, and duration are combined. In the electronic ignition system, a separate control signal is generated for each cylinder. A separate ignition coil is required for each cylinder.

The ignition coil, an element of the inductive ignition system, generates high voltage from the low voltage of the battery. High voltage is required for sparks in the spark plug to occur. The principle of operation of the ignition coil is based on electromagnetic induction, when the energy stored in the magnetic field of the primary winding is transferred to the secondary winding of the ignition coil by magnetic induction. As a result of this process, a high voltage is induced in the secondary winding, which is able to break through the air gap between the spark plug electrodes. Energy is stored even before the sparks dance. The ignition coil is both a transformer and an energy storage device. 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 rear ignition stage and the spark plug. The most important indicators are:

- the accumulated spark energy is transmitted to the spark plug
- the spark current generated in the candle at the moment of spark breakage
- spark duration
- high ignition voltage in all operating conditions

The ignition coil has two windings placed on the common ferromagnetic core. The primary winding consists of a small number of thick wire windings. The voltage flowing in these windings is controlled by an electronics unit. The secondary winding consists of a large number of thin wire strands. The transformation coefficient is between 1:50 and 1: 150. The current is controlled in the primary winding, creating a magnetic field. This field acts on the secondary winding and induces an electromotive force in it. When the current supply to the primary circuit is interrupted, an alternating magnetic field in the secondary winding induces a secondary voltage. The secondary voltage can reach 30,000 V. This secondary voltage must be high enough to break the gap between the spark plug electrodes. At the appropriate time in the engine control program, the control unit switches on the current in the primary ignition coil via the end stages. The resulting current creates a magnetic field in the ignition coil. This magnetic field stores the energy needed for ignition.

When the motor control unit shuts off the current in the primary coil circuit, the electronics in the coil send an Ignition confirmation (IGF) signal to the control unit.



Ignition coil primary and confirmation signals

Using a two-channel oscilloscope, the primary control and ignition acknowledgment 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) can be checked.

The primary coil control signals are sent via the respective connections (IGT1, IGT2, IGT3, IGT4) from the motor control unit. With the engine running, there must be a voltage of 0.1 to 4.5 V between the IGT (1 - 4) (contacts 8, 9, 10, 11) and E1 (pin 28) if the ignition coils are not disconnected. If the ignition coil is disconnected, the voltage between terminals 8 (9, 10, 11) and E1 (pin 28) of the IGT (1 - 4) must be greater than 4.5 V while the engine is running.

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 must be less than 1 Ω. All four ignition coils (IGN 1 - 4) are checked.

Checking the ignition confirmation signal circuit for a short circuit in the circuit between the coil contact 2 or the control unit contact 23 and the vehicle body mass. When measured with a multimeter, the resistance must be 10 kΩ or more.

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

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

Injectors

The injectors are designed to supply and accurately dose compressed fuel to the intake manifold. The injectors dispense the required amount of fuel. The injectors are controlled by integrated end stages of the engine control unit.

The injector consists of a housing 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.

To ensure trouble-free operation of the injector, the fuel elements of the injector are made of corrosion-resistant steel. The filter sieve protects the fuel inlet channel from mechanical contamination. In the injectors, fuel is supplied axially toward the valve from top to bottom. The injector is connected to the fuel distribution pipe via a hydraulic connection. The electrical connection is connected to the motor control unit.

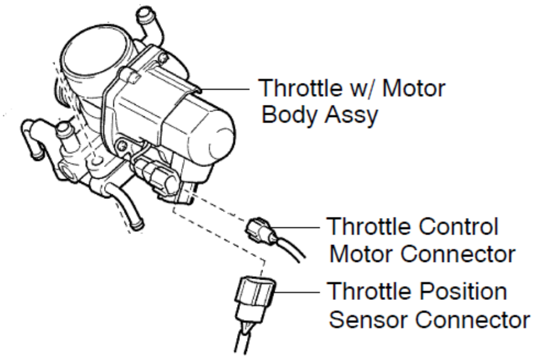
When no current is flowing in the injector coil, the combined force of the spring and fuel pressure presses the needle with the valve ball to the conical valve seat. This separates the fuel supply system from the intake manifold. When a current begins to flow in the coil, an electromagnetic field is generated that enters the anchor of the needle. 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.

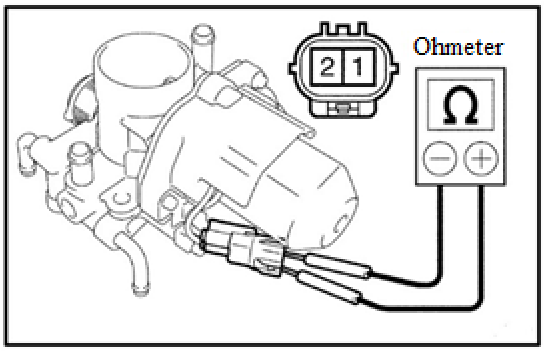
The fuel is finely injected through an injector plate containing one or more holes. Extruded injection holes provide high fuel stability. This injector is also insensitive to fuel emissions. The fuel flow pattern depends on the number and arrangement of the injection holes. Good sealing is guaranteed by the principle of sealing the cone-ball in the valve seat area. The sprayer is inserted into a dedicated socket in the suction pipe. Fuel injection time 1 - 3 ms. The idling 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 regulates the amount of air entering the inside of the cylinders. The throttle valve module consists of a damper, a damper drive mechanism, a DC electric motor.





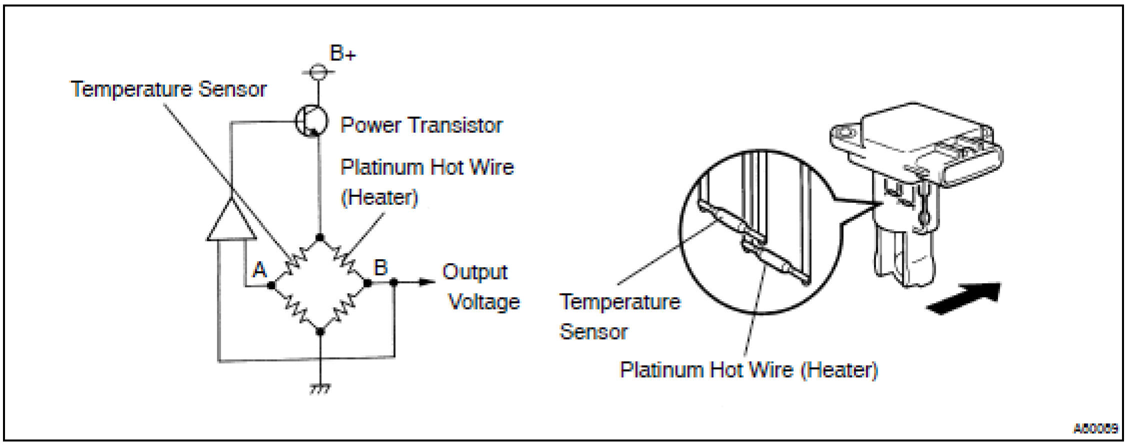
Throttle module and electric motor inspection

The throttle is controlled by the principle of pulse width modulation. An oscilloscope is used to check the power signal. The fill factor of the electric motor control signal varies in the range of 0 - 100%. The opening and closing of the valve are performed by changing the polarity of the voltage. The current supplied to the motor varies between 0 and 20 A. When the motor is idling, the current consumption is 0 - 3 A.

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

Air mass meter

An air mass meter that measures the amount of air flowing through the meter itself. This information is used by the engine control unit to calculate the opening time of the injectors and to adjust the composition of the flammable mixture. Inside the air mass meter, a heating platinum wire is installed in the flowing air duct. By passing an appropriate amount of current through this wire, the wire is heated to the set temperature. The incoming airflow cools this wire and nearby thermistors. The resistance of the thermistors changes due to the cooling effect. Maintaining the same current, the motor control unit changes the value of the supply voltage. The voltage value is proportional to the air flow through the sensor. Based on 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.

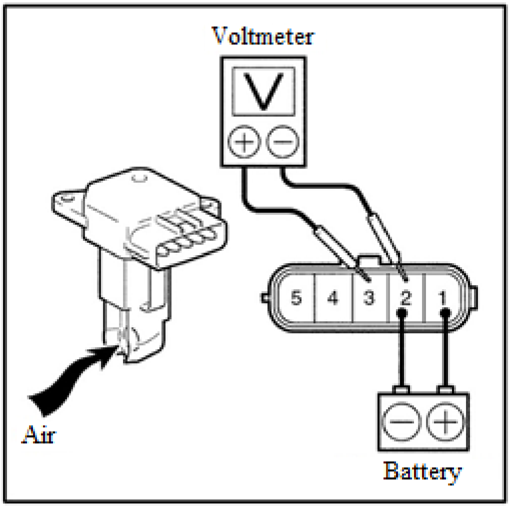
Sensor supply voltage control. The voltage between 9 and 14 V must be between the engine control unit + B and the vehicle's ground when the ignition is switched on.

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

There must be a mass of 10 kΩ or more between VG (33) and the ground.

There must be less than 1Ω between the EVG (32) and the vehicle ground.

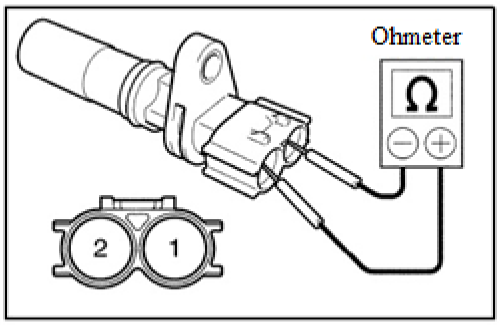
When checking a disassembled sensor, a battery can be connected to its terminal 1 (+) and 2 (-). A voltmeter is connected to pins 2 and 3. When blowing air into the sensor, the voltmeter readings should fluctuate.



Crankshaft position sensor

Engine crankshaft speed sensors are used to measure crankshaft speed and record shaft position (piston position). The speed is calculated from the time interval of the speed sensor signals. The sensor is mounted in front of a ferromagnetic pulse circuit. 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 circle. The size of the magnetic field crossing the coil depends on what is in front of the sensor - the pulse wheel gap or the tooth. The tooth concentrates the flux emitted by the magnet and amplifies the magnetic field crossing the coil. The gap, on the contrary, weakens. These changes in the magnetic field in the coil induce an output voltage close to sinusoidal in proportion to the rate of change of the magnetic field, i.e., the speed. 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 voltage generated when the speed is constant. This is an inductive speed sensor. The toothed disc has 60 - 2 = 58 gears. The two gears are ground from this disc to determine the position of the rotating disc that corresponds to the position of the upper end point (VGT) of the first cylinder piston at the end of the compression stroke.

When the engine control unit sees the sensor signal, it calculates the engine crankshaft speed and determines the position of the piston. Based on this information, the starting moment of fuel injection and the angle of ignition of the mixture are calculated and selected. The absence of two teeth in the oscillogram is seen as a change in signal that indicates the position of the first piston at the end of the compression stroke at the upper end point.

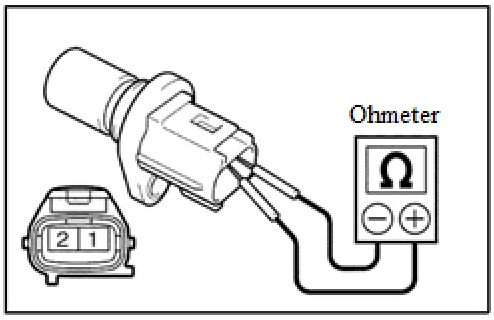


Crankshaft speed sensor check

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

Camshaft position sensor

The design and operation of the sensor is analogous to that of a crankshaft speed sensor.

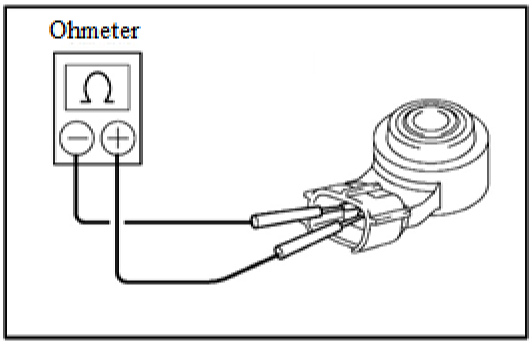


Checking the gas camshaft speed sensor

Resistance between contacts 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 - 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. Burning speed of the petrol mixture during detonation 1500 - 2500 m / s (normal burning speed of the petrol mixture 20 - 40 m / s). Detonation is harmful to engine parts and is considered an explosion. When protecting the engine from damage, the onset of detonation must be recorded and measures taken to prevent it. Engine manufacturers typically install one detonation sensor each for a linear 4-cylinder engine, two sensors for a V-shaped engine, or one sensor for two cylinders.



Detonation sensor test

The detonation sensor has a piezo element (piezoceramic ring) mounted in the sensor housing and screwed to the motor unit. The sensor is also fitted with a seismic mass which, due to its inertia, which excites the rhythm of the oscillations, presses on the piezoelectric element. Due to this seismic mass force, loads are transferred in the piezoelectric element and an electrical voltage is generated between the upper and lower ceramic parts of the element. This voltage is transferred to the motor control unit via contact rings and contacts for further evaluation and processing.

The detonation sensor is attached to the engine block in such a way that the detonation in each cylinder is reliably recognized. The sensor is usually attached to the wide side of the engine block. The resulting signals must be transmitted from the measuring point without resonance, so a rigid screw connection is required.

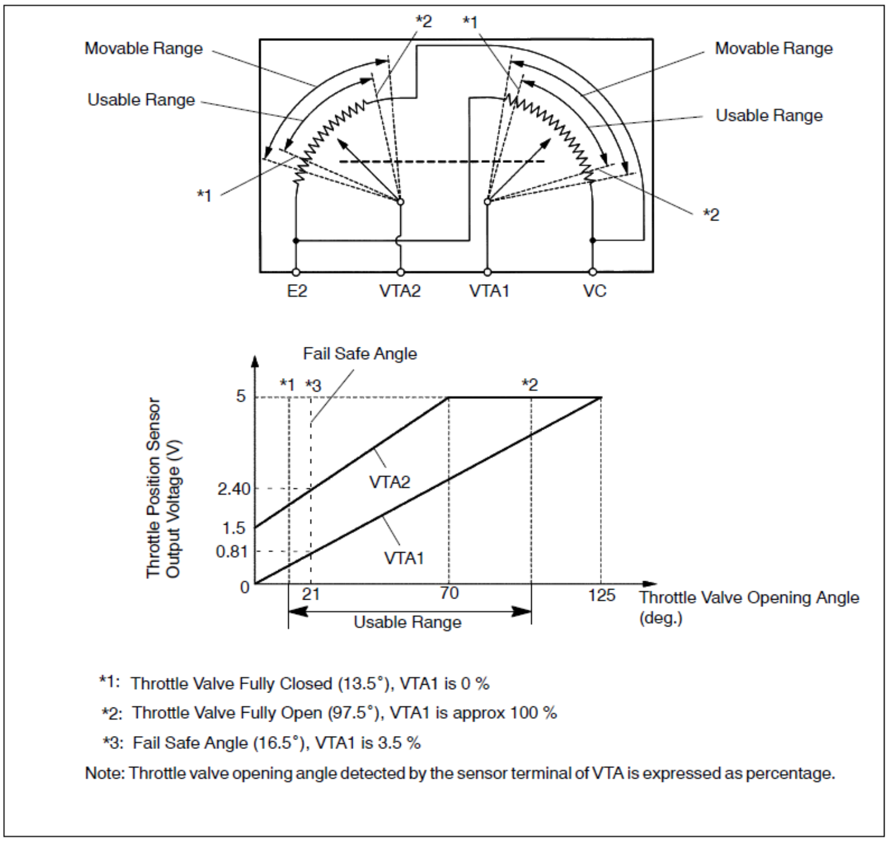
Detonation sensor resistance 120 - 280 kΩ at 20 ° C.

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

Throttle position sensor

A potentiometer is a variable resistance device whose resistance between the fixed contacts is always the same, and the resistance between one of the fixed contacts and the rotating contact varies depending on the position of this rotating contact. As the position of the rotating contact changes, 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 resistances between the fixed contacts.

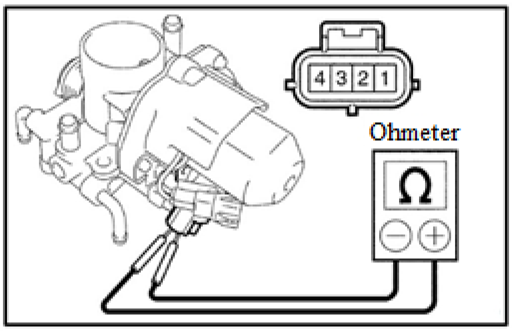
Throttle position sensors (2 pcs.) Are installed in the throttle module. Two sensors are installed so that the motor control unit can know the exact position of the valve and can identify a fault in this module. The voltage at contacts VTA1 and VTA2 can vary between 0 and 5 V. The VTA1 contact signal is used by the engine control unit to evaluate the throttle position and to control the internal combustion engine accordingly. The VTA2 contact signal is used to position the throttle and detect a fault. The engine control unit, using information from the throttle position sensors, controls and adjusts the throttle support accordingly to properly adjust the engine operating mode to the prevailing conditions. If a fault is detected in the throttle module, the valve is set to a certain position. Its electrical adjustment is no longer carried out until the fault has been rectified and the vehicle has been restarted.



Throttle positioning with potentiometers

Throttle position: 0 - 100%. The valve is fully closed 8 - 24%, the valve is fully open 64 - 96%.

The sensor supply voltage 4.5 - 5.5 V is measured between contacts VC and E2.



Checking the throttle position sensor

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

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

The resistance of the valve position sensor between contacts 1 (VC) and 4 (E2) is 1.2 - 3.2 kΩ at 20 ° C.

The resistance of the sensor VTA1, measured between contacts 2 (VTA1) and 4 (E2) - 1.8 - 10.5 kΩ at 20 ° C.

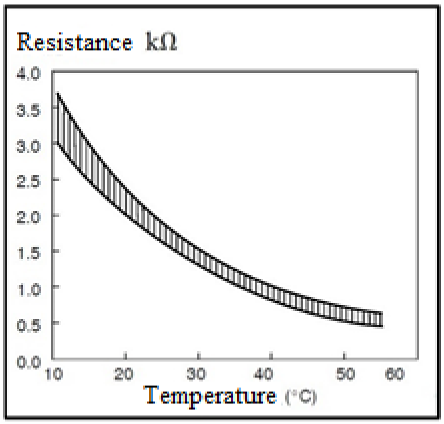
The resistance of the sensor VTA2, measured between contacts 3 (VTA2) and 4 (E2) - 1.8 - 10.5 kΩ at 20 ° C.

Outdoor temperature sensor

The outdoor temperature sensor is a resistive element whose resistance 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 motor control unit supplies this temperature sensor with a constant 5 V voltage. The control unit evaluates the voltage change in the sensor and determines the current ambient temperature accordingly.

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

When measuring between contacts 21 and 28 of the engine control unit when the car's ignition is switched on and the ambient temperature of 25 ° C, the voltage will be 1.8 - 2.2 V. At a temperature of 40 ° C, the voltmeter scale will show 1.2 to 1.6 V.



Dependence of sensor resistance on ambient temperature

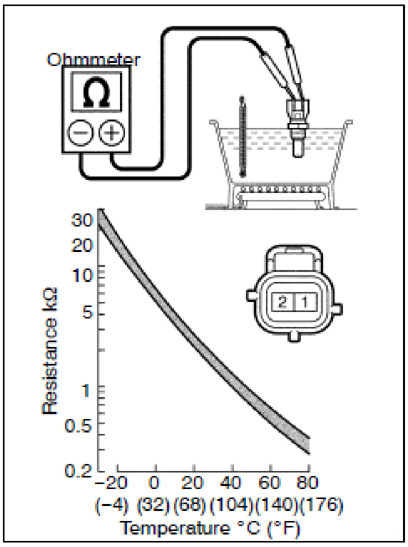
The temperature dependence of the sensor resistance is checked between the first and second contacts of the sensor. As the temperature increases, the resistance value decreases.

Temperature, °C	Resistance, 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 whose resistance depends on the ambient temperature acting on it. It is structured in the same way as the intake air temperature sensor.

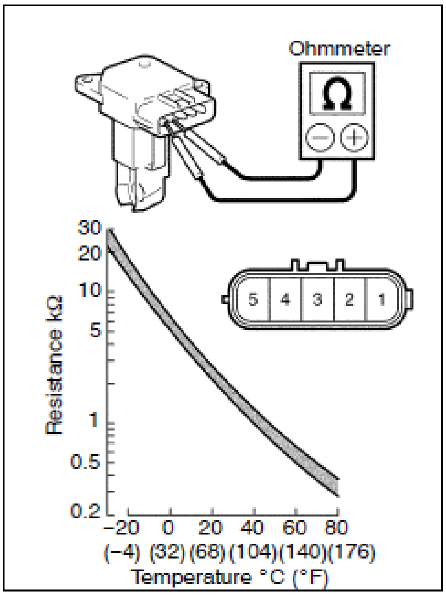
A coolant temperature value of -40 ° C indicates that the sensor circuit is open. If a temperature of 140 ° C is displayed, there is a short circuit in the sensor circuit.



Dependence of sensor resistance on ambient temperature and test methodology

Intake air temperature sensor

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

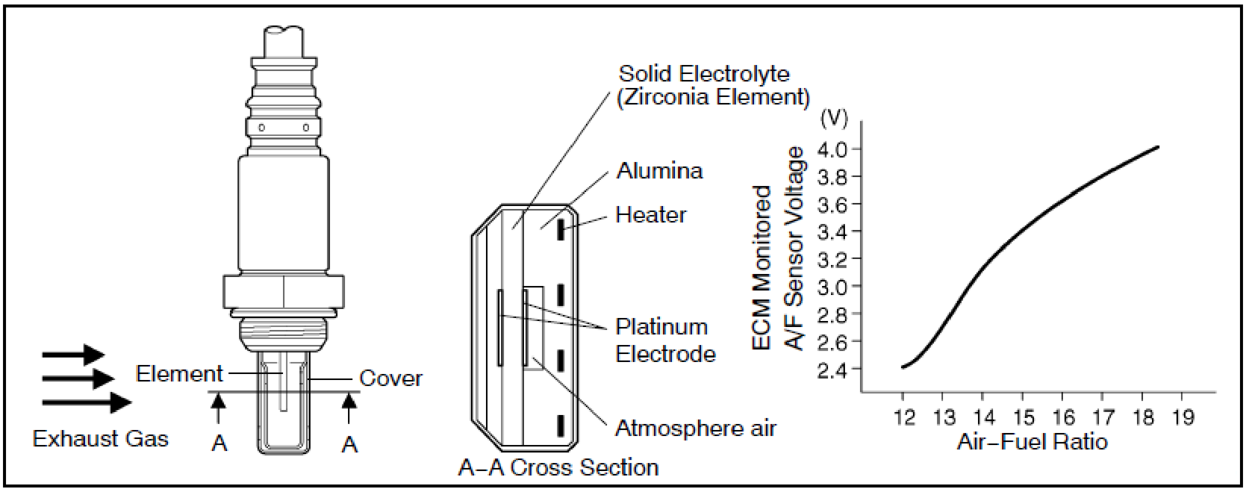


Dependence of sensor resistance on ambient temperature and inspection

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

Air – fuel ratio sensor

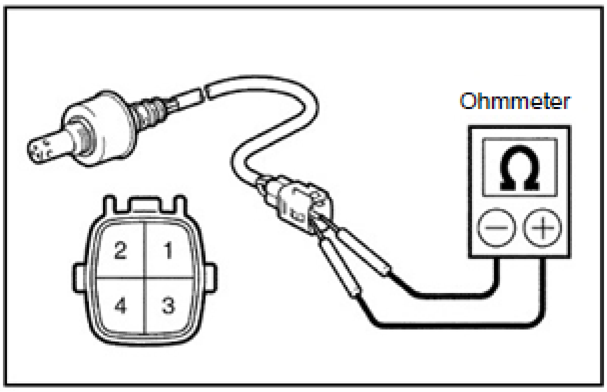
The air – fuel ratio sensor is of the planar type. Compared to glove-type sensors, in a plane-type sensor, the measuring elements from the heating are closer to each other. Because the heat from the heating element reaches the measuring cage with a layer of precious metal faster, such a sensor can perform measurements faster.



Air – fuel ratio sensor

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

Mixture composition sensor resistances 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.



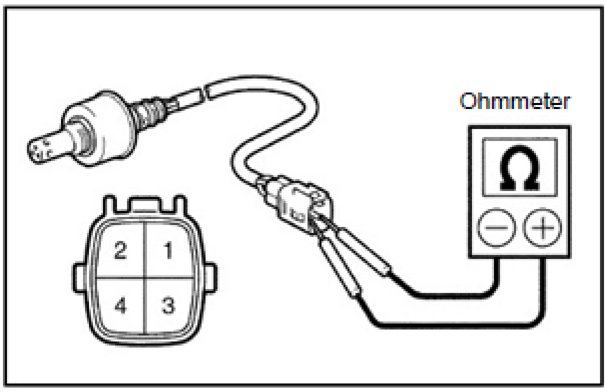
Inspection of air – fuel ratio sensor

Sensor heating element supply voltage when the sensor is cold, with the ignition between the HA1A and E04 contacts 9 - 14 V. When the sensor warms up and the motor runs between the 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.

Lambda sensor

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



Inspection of Lambda sensor

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

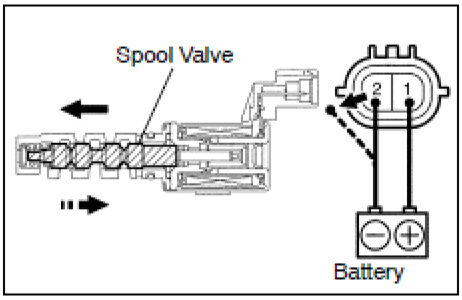
Sensor heating element supply voltage when the sensor is cold, with the ignition between the HT1B and E03 contacts 9 - 14 V. When the sensor warms up and the motor is running between the HT1B and E03 contacts less than 3 V.

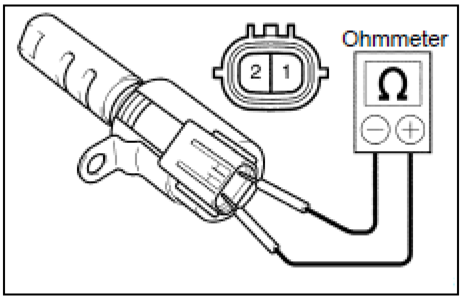
Sensor signal voltage between contacts OX1B and E2 variable (volatile). The measurement can only be performed by warming up the sensor by increasing the engine crankshaft speed to 2500 min-1 for at least 2 min.

Camshaft timing oil control valve

Hydraulic oil pressure is used to change the gas distribution phases, which is controlled by an electromagnetic oil control valve. By changing the gas distribution phases, higher torque of the internal combustion engine can be obtained at lower crankshaft speeds.

The solenoid valve consists of a solenoid and a hydraulic distributor. The electromagnet is controlled by 12 V. The resistance of the solenoid coil is measured between 1 (+) and 2 (-) contacts and must be between 6.9 and 7.9 Ω at 20 ° C. The valve can be connected to a 12 V battery to test its function. When the valve is actuated, the latch moves in the distributor.

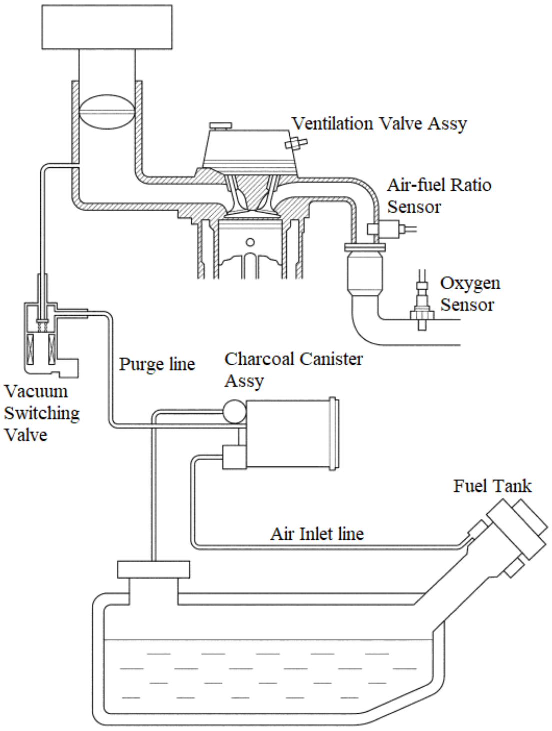




Inspection of control valve

Evaporative emission control system purge control valve

Vehicles with Otto engines are equipped with a fuel evaporation reduction system to prevent fuel evaporating from the fuel tank from entering the environment. Fuel vapor from the tank through the tube enters the activated carbon filter where it is absorbed. The filter fills up over time and needs to be emptied. To do this, the filter is connected by a pipe to the engine air intake manifold. Due to the dilution (vacuum) in the intake manifold, the pressure in the purge pipe decreases when the filter purge regeneration valve is opened. This starts pumping air through the air intake pipe. As the air flows through the filter, it absorbs the absorbed fuel and carries it to the intake manifold. From there, the fuel enters the combustion chamber. Adjusting the composition of the mixture, depending on the amount of fuel taken from the filter, reduces the main amount of fuel injected. This maintains the required composition of the flammable mixture. The amount of fuel flowing through the filter cleaning valve is limited to ensure engine stability. The higher the proportion of fuel delivered through the valve, the faster the basic injection fuel dose needs to be adjusted.



Petrol vapor collection and disposal

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

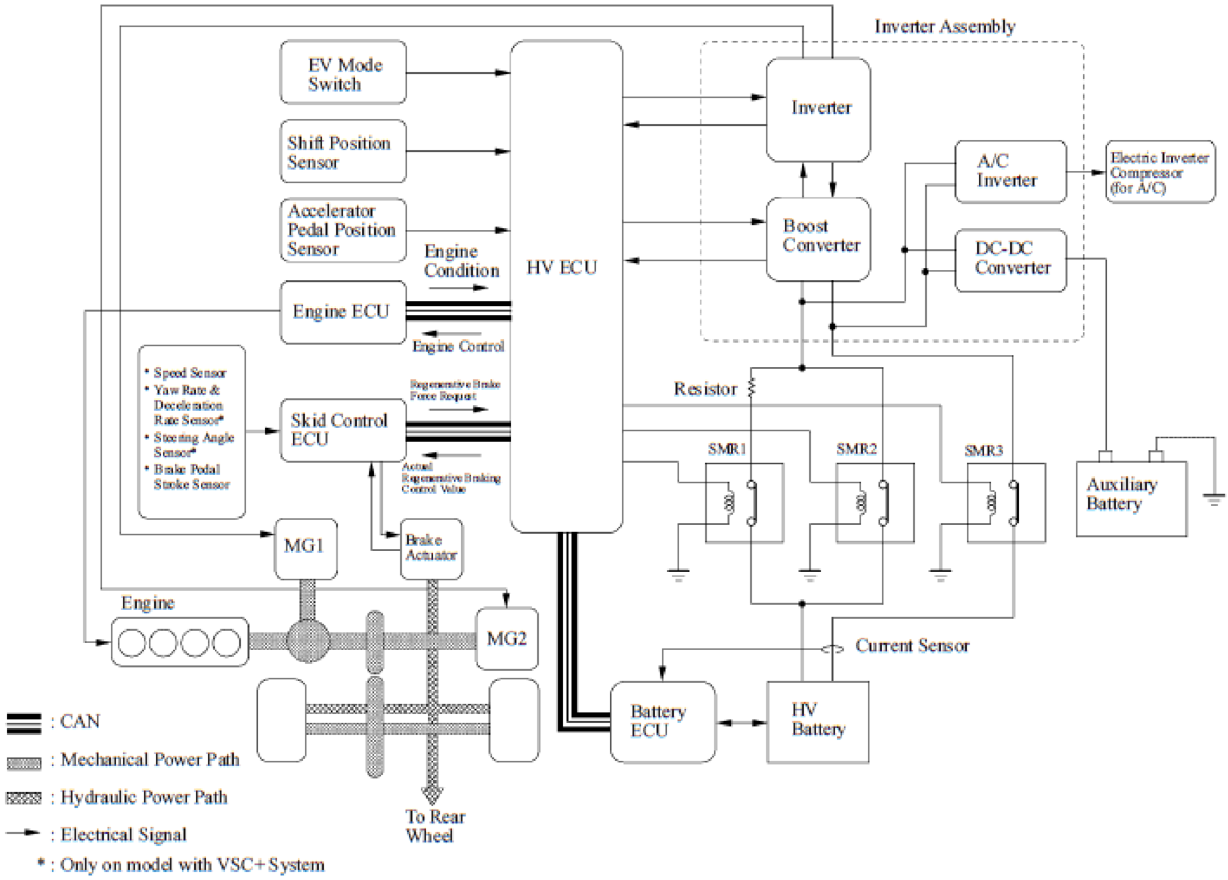
4.2. Hybrid drive

HV ECU

The THS-II system uses the two types of motive forces provided by the engine ang MG2, and uses MG1 as a generator. The system optimally combines these forces in accordance with the various driving conditions.

The HV ECU constantly monitors the SOC condition, the battery temperature, the water temperature, and the electrical load condition. If any one of the monitoring items fails to satisfy requirements when the READY indicator is ON and the shift position is in the "P" position, or the vehicle is driven in reverse, the HV ECU demands to start the engine to drive MG1, and then charges the HV battery.

The THS-II system drives the vehicle by optimally combining the operation of the engine, MG1, and MG2.



System diagram

MG1 and MG2

Both the MG1 (Motor Generator No.1) ant the MG2 (Motor Generator No.2) are compact, lightweight, and highly efficient alternating current permanent magnet synchronous type.

Serving as the source of supplemental motive force that provides power assistance to the engine as needed, the electric motor helps the vehicle achieve excellent dynamic performance, including smooth start-offs and acceleration. When the regenerative brake is activated, MG2 converts the vehicle's kinetic energy into electrical energy, which is the stored in the HV battery.

MG1 recharges the HV battery and supplies electrical power to drive MG2. In addition, by regulating the amount of electrical power generated (thus varying the generator's rpm). MG1 effectively controls the continuously variable transmission function of the transaxle. MG1 also serves as the starter to start the engine.

A cooling system via water pump for the MG1 and MG2 has been added.

Accompanied by enhancing the rotor robustness of MG1, its rpm range for the maximum possible output has been increased from 6500 to 10000 rpm, therefore the charging capability has been enhanced.

Structure of each built-in permanent magnet inside the rotor of MG2 has been optimized by redesigning it to V shaped structure, and improvement of its power output and torque has been realized.

Speed sensor / resolver. This is an extremely reliable and compact sensor that precisely detects the magnetic pole position, which is indispensable for ensuring the efficient control of MG1 and MG2.

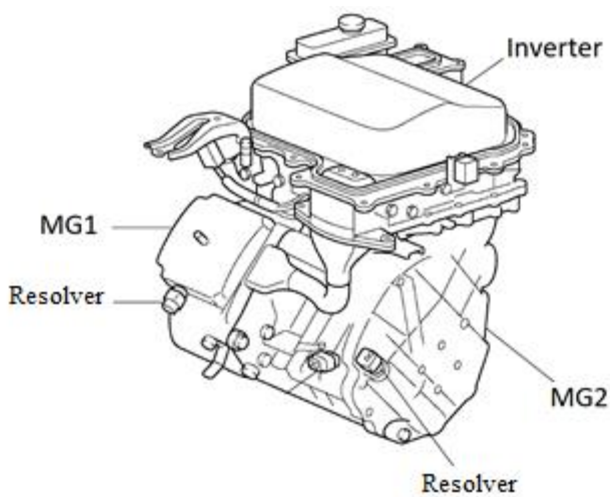
The hybrid drive uses two three-phase, synchronous electric motors with permanent magnets. The rotor is a large magnet without electrical connections.

MG1 - 18 kW. MG2 - 50 kW.

Inverter

The inverter converts the high-voltage direct current of the HV battery into three-phase alternating current for driving MG1 and MG2. The activation of the power transistors is controlled by the HV ECU. In addition, the inverter transmits information that is needed for current control, such as the output amperage or voltage, to the HV ECU. Together with MG1 and MG2, the inverter is cooled by the dedicated radiator of the coolant system that is separate from that of the engine. In the event of a collision involving the vehicle, the circuit breaker sensor, which is installed in the inverter, detects a collision signal in order to stop the system.

HV ECU sends signals to the power transistors of the inverter in such a sequence that the windings U, V and W of the motors MG1 and MG2 are switched on properly.



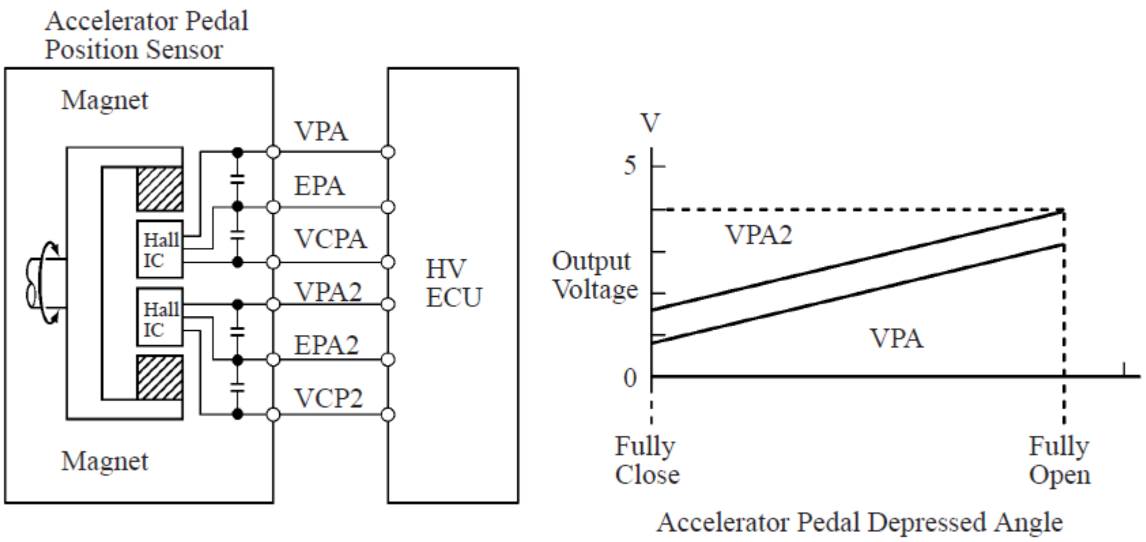
Arrangement of hybrid system components

Boost converter

This boost converter boosts the nominal voltage of DC 201,6 V that is output by the HV battery to the maximum voltage of DC 500 V. The converter consists of the boost IMP (Integrated Power Module) with a built-in IGBT (Insulated Gate Bipolar Transistor) which performs the switching control, and the reactor which stores energy. By using these components, the converter boosts the voltage. When MG1 or MG2 acts as the generator, the inverter converts the alternating current (range of 201,6 to 500 V) generated by either of them into the direct current, and boost converter drops in to DC 201,6 V, thus the HV battery is charged.

Accelerator pedal position sensor

The magnetic yoke that is mounted at the base of the accelerator pedal arm rotates around the Hall IC in accordance with the amount of effort that is applied to the accelerator pedal. The Hall IC converts the changes in the magnetic flux that occur at that time into electrical signals, and outputs them in the form of accelerator pedal effort to the HV ECU.



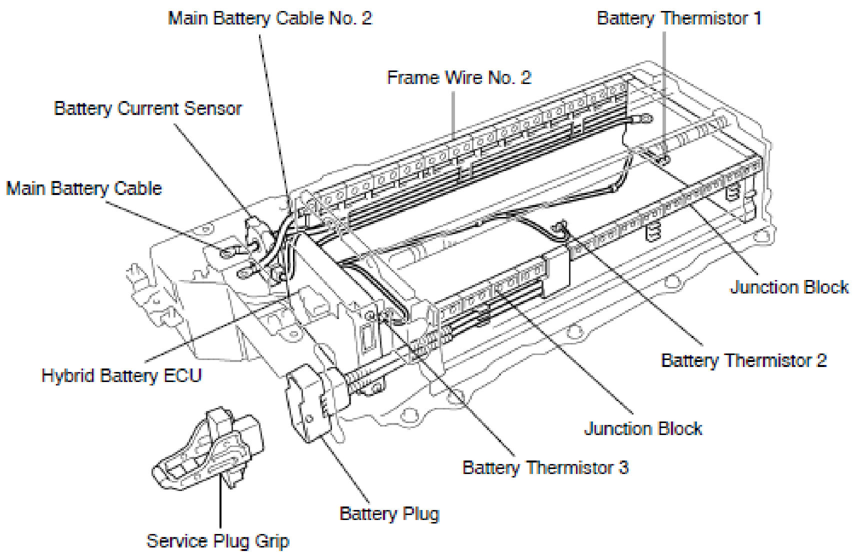
Accelerator pedal sensor and its signal

DC/DC converter

The power source for auxiliary equipment of the vehicle such as the lights, audio system, and the air conditioner system (except A/C compressor), as vell as the ECUs, is based on a DC 12 V system. Because the THS-II generator outputs at nominal voltage DC 201,6 V, the converter is used to transform the voltage from DC 201,6 to DC 12 V in order to recharge the auxiliary battery. The converter is installed on the underside of the inverter.

High voltage battery control unit

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



High voltage battery structure

The high-voltage battery is discharged as the car accelerates and charged at reduced speed. The battery control unit calculates charge / discharge cycles, monitors voltage, current, temperature. The calculation data is provided to the control unit of the hybrid system. Based on this information, the control unit of the hybrid system decides on the need to charge the high-voltage battery.

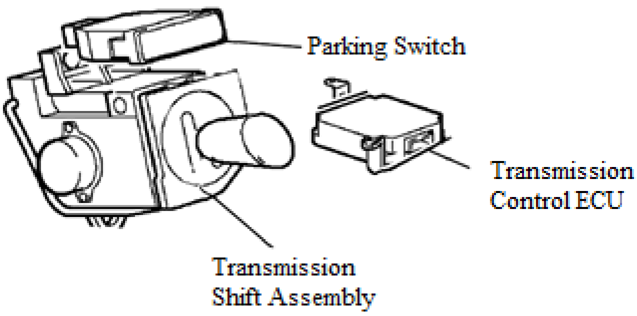
Skid Control ECU control

During braking, the skid control ECU calculates the required regenerative brake force and transmits it to the HV ECU. Upon receiving this signal, the HV ECU transmits actual regenerative brake control value to the skid control ECU. Based on these results, the skid control ECU calculates and executes the required hydraulic pressure brake force.

Shift control

The HV ECU detects the shift position (“R”, “N”, “D”, or “B”) in accordance with the signal provided by the shift position sensor, and controls MG1, MG2, and the engine, in order to create the driving conditions that suit the selected shift position.

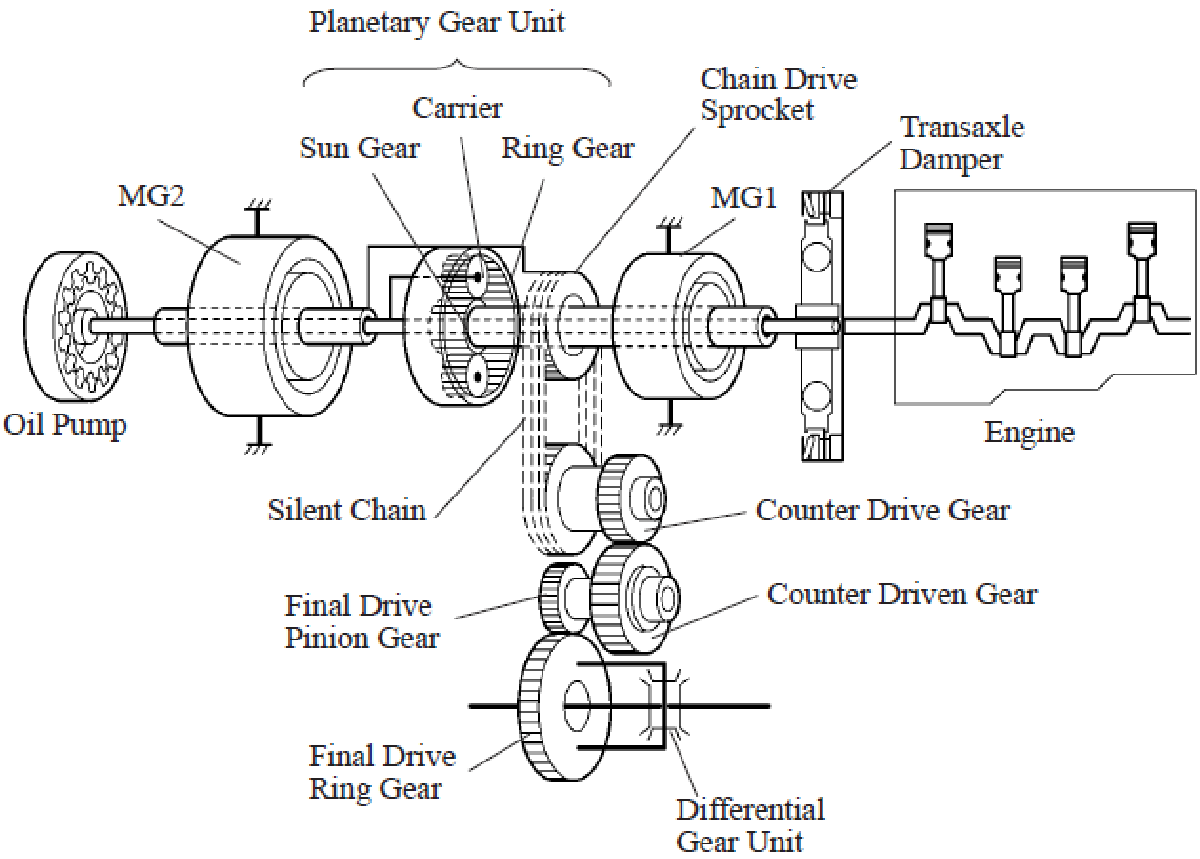
The transmission control ECU detects that the driver has pressed the parking switch through a signal provided by the HV ECU. Then, it operates the shift control actuator in order to mechanically lock the transaxle.



Transmission control components

Planetary gear

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, the energy distribution of the MG1, MG2 and internal combustion engine to the drive wheels is combined using a planetary gearbox. The control electronics coordinate and distribute the power transmission to the drive wheels so that the car travels under the set conditions with the least amount of energy. If favourable conditions are created while driving (rolling out of inertia, braking), the energy is used to charge the batteries (to store renewable energy).



Transmission

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

A/C inverter

An A/C inverter, which supplies power for driving the electric inverter compressor of the A/C system, has been included in the inverter assembly.

This inverter converts the HV battery's nominal voltage of DC 201,6 V into AC 201,6 V and supplies power to operate the compressor of the A/C system.

Driving on electric power only

If the driver presses the EV key in the passenger compartment, the hybrid system control unit only starts the MG2 electric motor for the car's drive. The internal combustion engine does not start. Driving with electricity only is possible under certain conditions (speed, load).

Circuit breaker sensor

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

Recording system malfunctions

Various light indications inform the driver about the condition of the system, faults. The control unit of the hybrid system records and remembers the conditions under which the system fault occurred. When a fault is detected, the control unit of the hybrid system stops the operation of the system, or controls the actuators and other control units as provided in the control program stored in the system memory.

The main functions of the components of the hybrid car

Item		Outline
Hybrid Transaxle	MG1	MG1, which is rotated by the engine, generates high-voltage electricity in order to operate MG2 or charge the HV battery. Also, it functions as a starter to start the engine
	MG2	Driven by electrical power from MG1 or HV battery, and generates motive force for the vehicle
	Planetary Gear Unit	Distributes the engine ‘s drive force as appropriate to directly drive the vehicle as well as the generator
HV Battery		Supplies electric power to the MG2 during start-off, acceleration, and uphill driving recharged during braking or when the accelerator pedal is not depressed
Inverter Assembly		A device that converts the high-voltage DC (HV battery) into AC (MG1 and MG2) and vice versa (Converts AC to DC)
	Boost Converter	Boosts the maximum voltage of the HV battery from DC 201,6 to DC 500 V and vice versa (drops DC 500 V to DC 201,6 V)
	DC-DC Converter	Drops the maximum voltage of the HV battery from DC 201,6 V into DC 12 V in order to supply electricity to body electrical components, as well as to recharge the auxiliary battery (DC 12 V)
	A/C Inverter	Converts the nominal voltage of DC 201,6 V of the HV battery to AC 201,6 V and supplies power to operate the electric inverter compressor of the A/C system
HV ECU		Information from each sensor as well as from the ECU (engine ECU, battery ECU, skid control ECU, and EPS ECU) is received, and based on this the required torque and output power is calculated. The HV ECU sends the calculated result to the engine ECU, inverter assembly, battery ECU and skid control ECU
Engine ECU		Activates the ETCS-i (Electronic Throttle Control System-intelligent) in accordance with the target engine speed and required engine motive force received from the HV ECU
Battery ECU		Monitors the charging condition of the HV battery
Skid Control ECU		Controls the regenerative brake that is affected by the MG2 and the hydraulic brake so that the total braking force equals that of a conventional vehicle that is equipped only with hydraulic brakes. Also, the skid control ECU performs the brake system control (ABS with EBD, Brake Assist) conventionally
Accelerator Pedal Position Sensor		Converts the accelerator angle into an electrical signal and outputs in to the HV ECU
Shift Position Sensor		Converts the shift position into an electrical signal and outputs in to the HV ECU
SMR (System Main Relay)		Connects and disconnects the high-voltage power circuit between battery and inverter assembly, through the use of a signal from the HV ECU
Interlock Switch (for Inverter Cover and Service Plug)		Verifies that the cover of both the inverter and the service plug have been installed
Circuit Breaker Sensor		The high-voltage circuit is intercepted if a vehicle collision has been detected
Service Plug		Shuts off the high-voltage circuit of the HV battery when tis plug is removed for vehicle inspection or maintenance

5. PRINCIPLE OF HYBRID SYSTEM OPERATION

The Atkinson cycles

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 work cycle, a. makes more efficient use of combustion gas pressure to rotate 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 has made it possible to reduce fuel consumption and noise during operation. Such engines do not require a speed reduction system for the camshaft. The crankshaft rotates 2 times faster than Otto engines. Throttle control of Atkinson cycle engines was complicated by low torque. Compared to Otto engines, Atkinson cycle engines reduce intake losses due to the later closing of the intake valve. The engine cylinders are better filled with fresh air. Subsequent closing of the intake valve changes the compression pressure in the cylinder and reduces the possibility of the detonating fuel mixture burning. The Atkinson cycle engine runs on an extended expansion cycle that uses the exhaust energy for a longer period of time. This increases engine efficiency. In Otto engines, all four strokes (intake, compression, stroke, and exhaust) are of equal duration. In the Atkinson cycle engine, due to the more complex design of the crank mechanism, the first strokes were shortened and the other 2 strokes were lengthened. This increased the engine efficiency by about 10%. However, it was precisely due to the complex design of the crankshaft mechanism that these engines did not spread.

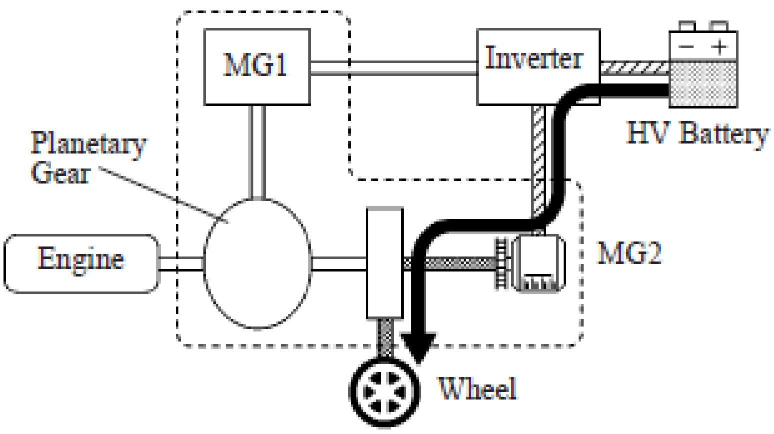
Hybrid cars use Atkinson cycle internal combustion engines. The compression ratio of these engines is 13: 1, but with proper control of the intake valves, the intake and compression losses of the combustible mixture are reduced. During the working stroke, the energy of the expanding gas is used for a relatively longer time. Atkinson cycle engines can be used in hybrid cars because in these vehicles, internal combustion engines operate at low speeds and load ranges. Electric motors are used to accelerate hybrid cars to provide the required power over a wide rev range.

Hybrid drive technology

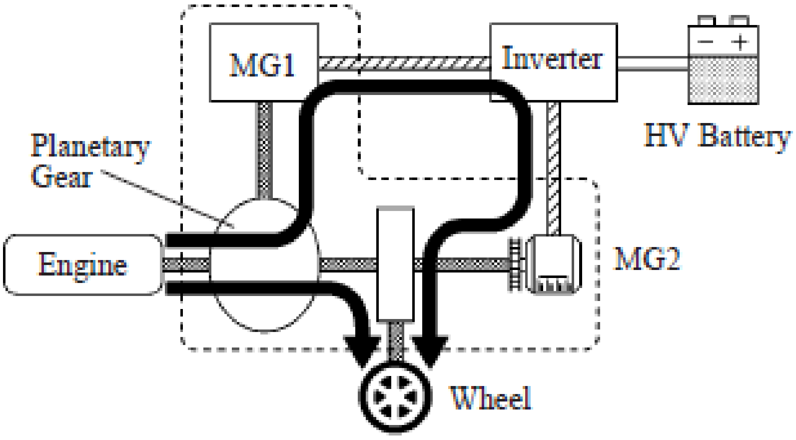
Basic operation

This system controls the following modes in order to achieve the most efficient operations to match the driving conditions:

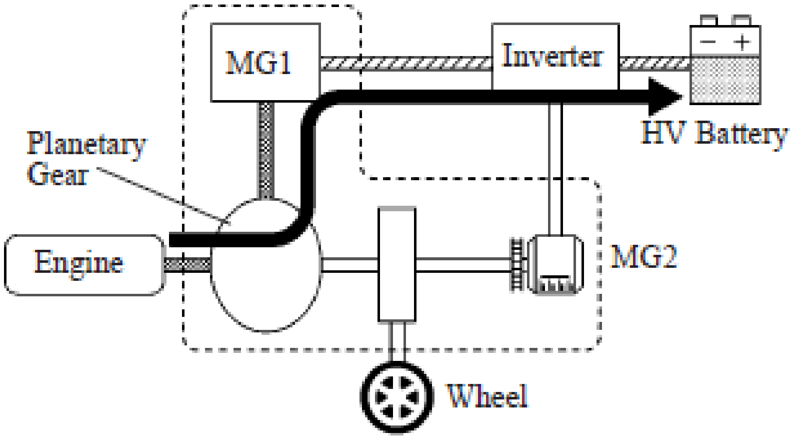
1. Supply of electric power from the HV battery to MG2 provides force to drive the wheels.



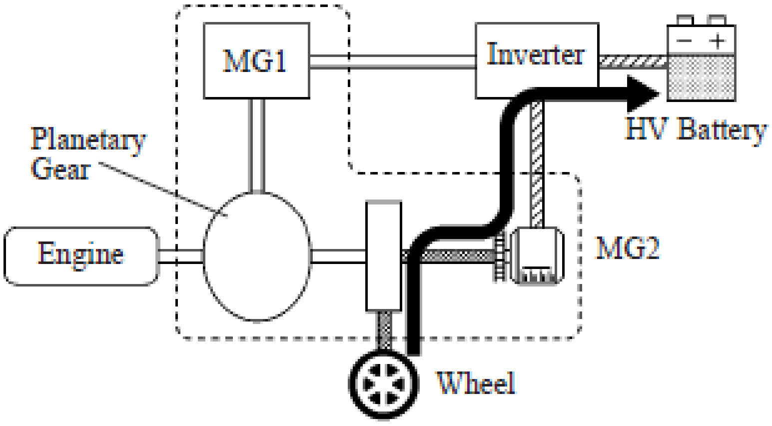
2. While the wheels are being driven by the engine via the planetary gears, MG1 is rotated by the engine via the planetary gears, in order to supply the generated electricity to MG2.



3. MG1 is rotated by the engine via the planetary gears, and order to charge the HV battery.



4. When the vehicle is decelerating, kinetic energy from the wheels is recovered and converted into electrical energy and used to recharge the HV battery by means of MG2.

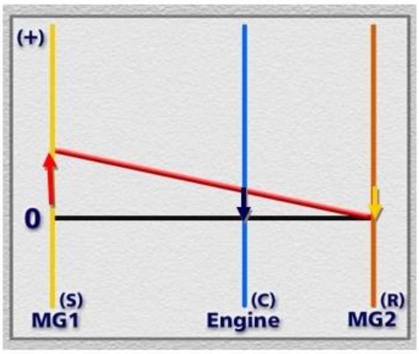


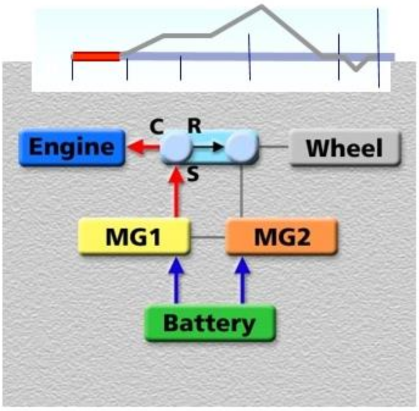
The HV ECU switches between these modes ((1), (2), (3), (1) + (2) + (3), or (4)) according to the driving conditions. However, when the SOC (State of Charge) of the HV battery is low, the HV battery is charged by the engine by turning MG1.

As a result, it achieves far greater fuel economy compared to conventional gasoline engine vehicle, at a reduced level of exhaust gas emissions. Furthermore, this revolutionary power train has eliminated the constraints that are associated with electric vehicle (such as their short cruising range or their reliance on external recharging units).

The MG1 electric motor and energy from the high voltage battery are used for starting up the internal combustion engine (ICE). The crankshaft of the ICE is connected to the planetary carrier of the planetary gear, where axes of the satellite gears rotate. If the car is in a stationary position, the ring gear of the planetary gear is in a stationary position. When the MG1 engine operates in this way, it rotates the satellite gears through the sun gear, and it rotates the planetary carrier and at the same time the ICE. The transmission ratio of this part is 1/3.6.

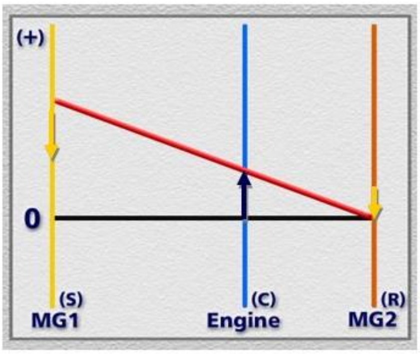
The starting of the internal combustion engine takes place according to the following methodology: MG1 rotates the ICE up to 1000 min^{-1} and only then starts supplying the fuel and sparks for the spark plugs. This start-up is much smoother and quieter compared to conventional start-ups. After all, the power of MG1 is several times greater than that of a starter. Rotation of the ICE up to 1000 min^{-1} occurs faster than in 1 second. The MG1 during the start-up of the ICE rotates at a speed of 3600 min^{-1}. The engine is started quietly and smoothly, without any extraneous sounds and vibrations. Also, the ICE of 1000 min^{-1} are the revolutions, which are necessary for defeating internal friction losses. Such start-up of the ICE reduces the wear of this engine.





The start-up of the internal combustion engine

As soon as the ICE is started, the car's control computer calculates the required amount of energy and thus adjusts the throttle position. The engine is being heated. At present, the MG1 engine is reconfigured to operate in generator mode and starts generating electricity. This energy is used to charge the batteries and restore the energy balance. Part of the energy was used to start the ICE. If the energy demand changes, the control computer controls the opening of the throttle.
During the engine warm-up, the crankshaft speed reaches 1300 min^{-1}. Engine is heated to the operating temperature. It is important that the catalyst that is responsible for the emission indicators of the exhaust gases would be heated properly. The heating phase lasts for a few minutes.



Active ICE

After starting a warm engine, it will work for a very short time and will be turned off. Idle speed is less than 1000 min^{-1}. The work of the ICE cannot be controlled, if the combustion is switched on but you are not going to go anywhere by car. Also, the ICE can be started automatically in order to maintain the correct battery charge level. When braking, the gasoline engine shuts off automatically.

The ICE torque depends on the crankshaft's torque. So, in order to move smoothly, the torque must be distributed evenly according to the external load. The torque value of the electric motors is maximum when the shaft revolutions are the lowest. So, when using the MG2 electric motor, you can ideally adjust the torque to the load. The MG2 engine is integrated with the ring gear and differential of the drive wheels.

When the vehicle is stationary with an active ICE, MG1 operates in generator mode. The generated electricity is transferred to the batteries for loading or to the MG2 engine. When the MG2 starts operating, the ring gear starts rotating. The rotation of the ring gear reduces the rotational speed of the planetary carrier. In order to maintain constant ICE revolutions, the engine control unit opens the throttle valve more. While generating electric power, MG1 resists the rotation, the speed decreases, the rotational speed of the planetary carrier is maintained by the engine control unit. The ring gear is rotated by the MG2 engine and by the force coming from the ICE. In such a way the force appears that causes rotation of the ring gear and forces the car to move.

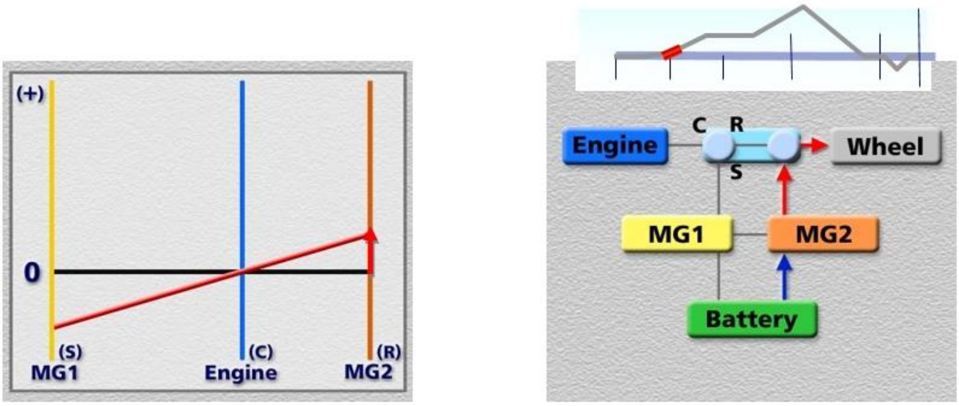
The ICE torque is transmitted to the sun gear and to the ring gears. As long as the accelerator pedal is not pressed, the torque generated by the ICE is small and is transmitted only to the MG1 generator. Having pressed the accelerator pedal, 28% of the torque goes for rotation of the MG1 generator. 72% of the torque is transmitted to the ring gear, and at the same time to the drive wheels of the vehicle. The control unit controls the opening of the throttle valve to provide the drive wheels with the required torque.

When the car starts to move and reaches a certain speed, the speed of the MG1 generator increases and the power decreases. The engine control unit opens the throttle more effectively by increasing the torque of the ICE. A larger part of the torque must go through the ring gear. Due to higher torque of the ICE, the MG1 generator can maintain constant power. Reduced speed of MG1 is compensated by increased torque.

When starting or backing up, etc., the vehicle runs on electric power from the hybrid vehicle battery, because the gasoline engine efficiency is low.

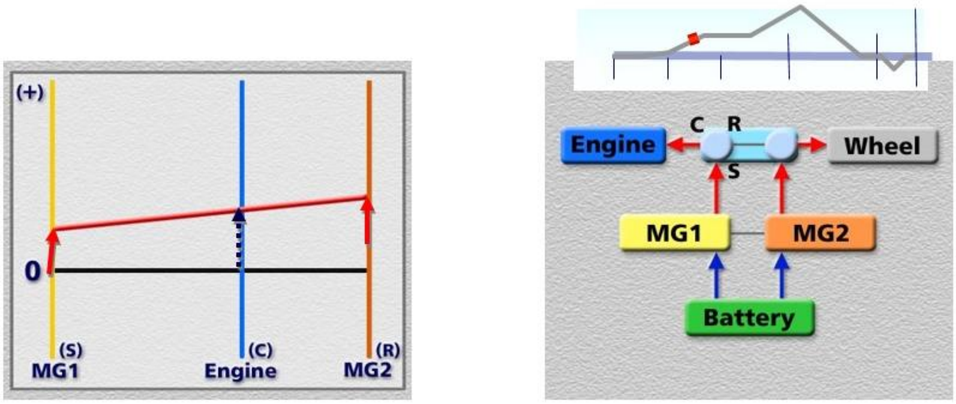
During normal driving, the vehicle runs mainly on gasoline power. However, the electric motor, using electric power generated by the gasoline engine, can supplement the gasoline engine power.

The vehicle controls the optimum ratio of the gasoline and electric power to help use energy more efficiently.



The start of the ride using electric power only

The start of the car ride is carried out by operating only MG 2 motor alone. If the power demand is higher or the travel speed is higher, the ICE also switches on.

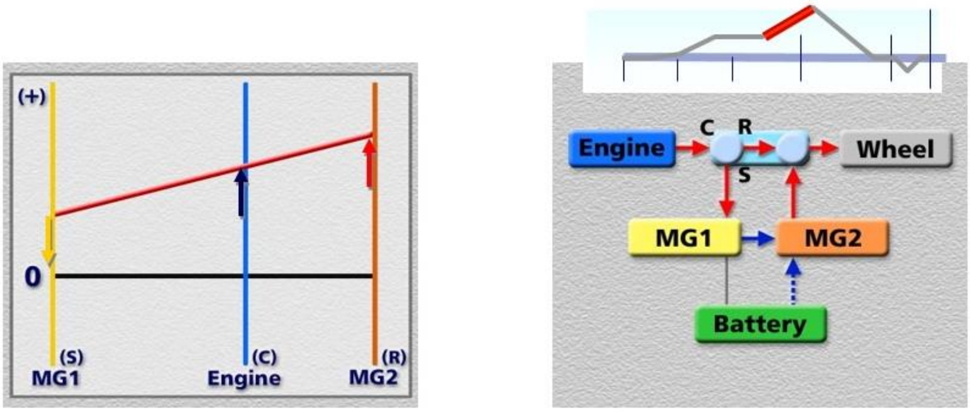


The start of the ride using electric power from the ICE and the battery

MG2 engine consumes a large part of energy from the battery. The ICE cannot rotate very fast when the car rides slowly, as the MG1 engine/generator will be damaged. Frequent switching of the ICE would not be an appropriate solution. This causes inconveniences to the car users. The more the accelerator pedal is pressed, the greater amount of energy is required from the ICE and from the battery as well. At around 40 km/h, about 40% of energy comes from the battery and 60% from the ICE. When the speed is further increased to 100 km/h, 75% of the energy is supplied from the ICE. Another part of energy is used to rotate the MG1 generator. The power generated here is supplied to the MG2 engine. When the driving speed is higher than 100 km/h, the MG2 engine produces a higher torque for the drive wheels, than it is supplied to the planetary gear from the ICE. A large part of the electric power is supplied to the MG2 engine from the MG1 generator, indirectly from the ICE and not from the battery.

At the time of the car's acceleration, energy demand is the highest. The system is adapted to provide power for the drive wheels combined from ICE and MG2 powertrains. As the speed of the car increases, the MG2's power is reduced and only used when the power requirement is 33 kW. The faster MG2 rotates, the less torque it develops. Without limiting the power at the start of rotation of the MG2, the torque that would rotate the drive wheels, would be the highest. In a traditional car with a manual gearbox, when the speed increases, the gearbox reduces the torque while the ICE can operate in the normal range of the crankshaft. The hybrid car does not have a mechanic gearbox allowing to change power transmission.

When driving at full throttle, additional electric power is applied from the hybrid vehicle battery. The performance of the vehicle improves.



Maximum acceleration

The ICE rotates the carrier of the planetary gear. 72% of the torque goes mechanically through the ring gear to the drive wheels. 28% of the torque travels to the MG1 generator where it is converted into electricity. This electric power generates an additional torque in the MG2 engine and in the ring gear.

The stronger the accelerator pedal is pressed, the higher torque is generated by the ICE. This increases torque on the ring gear, MG1 generator. The energy produced here is used to create the torque of the MG2 and to get the car moving. Depending on the environmental factors, such as battery charge level, road conditions, driver's preferences, the battery can additionally supply power to the MG2 engine to meet the level of energy consumption. So, even with a small 76-hp engine, it's possible to get the car's acceleration characteristics, which feature only the vehicles with a significantly higher output of the ICE. When the power demand is not high, the MG1 power is used to charge the battery. ICE transmits mechanical energy to the drive wheels and MG1. The circulation of mechanical and electrical energy depends on a lot of factors.

Charging the battery of the hybrid vehicle

When the power of the hybrid vehicle battery is insufficient, the gasoline engine charges the battery of the hybrid vehicle. The system supplies electricity at a constant level all the time.

Having reached continuous steady speed, the engine must supply only the power required for aerodynamic resistance and for defeating the forces of friction with the road surface. This is a lot less power that is necessary for accelerating or getting uphill. By increasing the efficiency of the ICE, the crankshaft revolutions are reduced. By increasing the speed of the car, the limit is reached when we can no longer increase the revolutions of the ICE crankshaft. Then MG1 starts to turn into the opposite side. Due to the opposite rotational direction of MG1, the sun gear makes it faster to rotate the satellite gears (the speed of the planetary carrier remains constant or is reduced (crankshaft revolutions of the ICE are reduced)) and these increase the speed of the ring gear and, at the same time, the speed of the car. By changing the rotational direction of MG1, its functional purpose also changes - the generator becomes an electric motor. In order to maintain a constant torque, the energy from the battery is supplied through the inverter. However, this cannot continue for so long. After all, the battery would be fully consumed. So, at a certain point, when MG1 starts to act as an electric motor, MG2 must switch to work as a generator.

Having released the accelerator pedal, the conditions are created as if the car is braked by the engine. The engine does not transmit attractive force to the drive wheels and the speed of the car gradually decreases due to the resistance of the air and road surface. The engine braking effect is due to switching the MG2 to generator mode. This energy is used to charge the batteries.

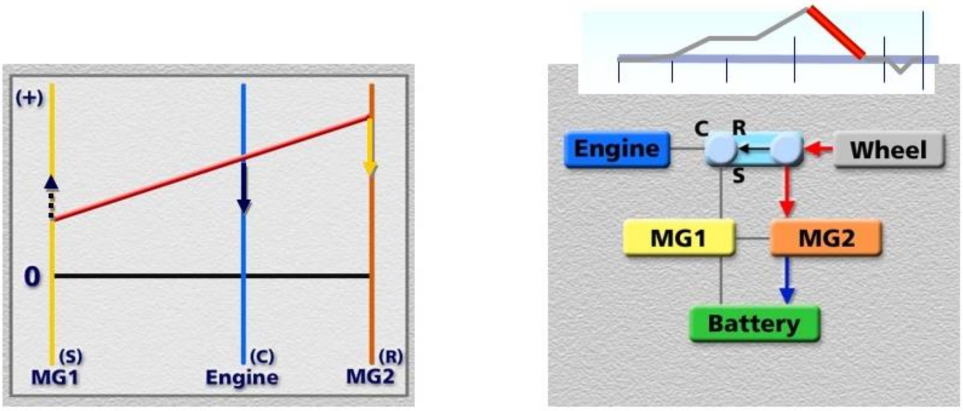
When the car does not need energy (it is driven of inertia), the ICE is switched off. The planetary carrier stops rotating. The ring gear is rotated from the wheels and at the same time the MG2 generator is rotated as well. Through the planetary gear the MG1 is rotated to the opposite side, but the energy balance is zero. The rotational speed of the MG1 according to the transmission ratio of the planetary gear is 2.6 times higher than that of the ring gear. So, driving at high speed, the

MG1 rotational speed can exceed 6500 min^{-1}. Such rotational speed can damage the electric motor. For this reason, the control computer switches the MG1 to operate in generator mode and generates electricity for the battery charging. However, this does not reduce the rotational speed. In order to reduce the speed of MG1, the ICE is started. It rotates the planetary carrier at a speed of at least 1000 min^{-1} and at the same time reduces the speed of MG1. If the speed of the car is more than 100 km/h, the ICE rotates faster in order to reduce the rotational speed of MG1 and prevent it from being damaged.

When breaking a normal vehicle, the brake pedal force is transmitted hydraulically to the brake pads and discs. The energy of movement turns into heat. The hybrid car has the energy regeneration system that increases the power of the MG2 generator, thereby creating a higher resistance moment for rotation by pressing the brake pedal. As a result, the car slows down more intensively. Braking energy is used to charge the batteries, not for the heat, released during braking. The engine control unit calculates how much the car's deceleration will be reduced by regenerative braking, and so much less power will be transmitted to the hydraulic brake actuator.

When driving from the mountain, the *travel knob* is switched to "B" position. Then the control computer terminates the fuel supply to the engine and practically completely closes the throttle. The moment of the motor rotational resistance is increased, and at the same time the braking moment on the driving wheels is also increased. The braking intensity is controlled by combining MG1 and MG2 loads.

When the speed is reduced or the brakes are applied, the wheel turning force makes the electric motor operate as a generator and additional electricity is stored in the battery of the hybrid vehicle (regenerative brake).

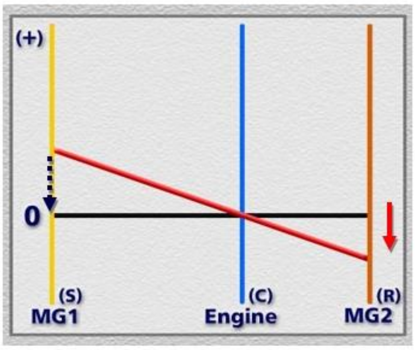


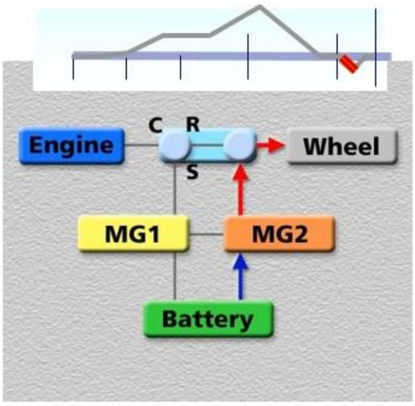
Regeneration of energy

Traditional cars with automatic gearboxes after releasing the brake pedal begin to move forward. This is a mechanical part of the parasitic energy transmission. The same effect has a hybrid car. Here, after releasing the brake pedal, the car starts to move forward. The MG2 is supplied with a small amount of power from the battery.

When the accelerator pedal is pressed and when the vehicle is stationary, energy is supplied to the MG2 engine. As the engine is powerful enough and has a high torque, the car moves out of the place. If the accelerator pedal is pressed firmly, the need for power is high and the ICE is started. When driving in a town at low speed, only energy accumulated in the batteries and the MG2 engine is used. Once the desired speed has been reached, till the vehicle's ICE goes on, it is possible to continue driving using electricity only. When accelerating, if the power demand is higher, ICE can be started but the ICE can be switched off once the desired speed and operating mode have been reached. The journey continues with the help of electricity. When the ICE will be started, depends on many factors and the battery charge level.

The car does not have a reverse gear. The reverse movement of the car is created by turning the MG2 to the opposite side. The ICE cannot increase power or torque in any way. After switching the drive selection lever to "R" position, the ICE is deactivated. The planetary gear is rotated backwards. Due to the stationary planetary carrier, the MG1 is rotated forward, but no power is consumed or produced. The computer controls the maximum rotational speed to protect MG1 from damage.





Reverse driving

7. WARRANTY CONDITIONS

Our products meet modern technical standards. We guarantee that our product is perfectly constructed and manufactured. They operate reliably if used correctly and in accordance with the provided maintenance rules.

Educational training board is used for educational purposes and can be used only with the components and operating fluids that are fitted on the board.

The guarantee of ____ months is provided for the educational training board. The guarantee begins to run from the sale date of the stand.

In order to warrant the setting of the appropriate date of sale, we ask the buyer to save the relevant contract documents: purchase check, invoice, transfer-acceptance act, warranty card with a product name filled correctly and clearly, number, date of sale, store stamp, signature and the signature of the seller.

The warranty is not applied:

- if the user did not comply with the usage, transportation and storage conditions, used not appropriate operating fluids and aggressive cleaning agents;
- if the stand was damaged by the third parties, force majeure (fire, catastrophe etc.) or another side effect;
- for mechanical breakings and other breaches;
- for warn out parts of the stand, fuses and if non-original spare parts are used;
- when the stand is regulated, improved or remade by unauthorized persons who cannot carry out this work;
- for naturally worn parts such as collars, straps and filters;
- in case of the fluid spill;
- when using the incomplete kit;
- if extraneous objects or some water gets into the product;
- when operating incorrectly or plugging into a messy electric network.

Warranty conditions do not cover the costs related with dismantlement of the product and transportation to the authorized warranty service enterprise. Also, it does not cover consultation, actuation and adjustment work costs. If the elements necessary for repairing the board have to be ordered from the supplier, the repair work may be prolonged.

Warranty repair is done at technical service stations authorized by the manufacturer. During the warranty period defective product components are repaired or replaced free of charge. Technical service station has the right to make a decision about the repair or replacement of the components. The elements that are being changed become the property of the service station.

After completion of the warranty repairs, the guarantee is not extended but remains valid until the time limit provided. The manufacturer reserves the right to change the appearance, design and structure of the product. Service center has the right to suspend the guarantee if the stand was used for other purposes.

Warranty maintenance coupon

Name	___
Product number	
Date of sale	
Training equipment owner	___
Trading partner / representative	___

Description of work performed

Data	Description of the fault and its elimination process	Technician / Signature

NOTES

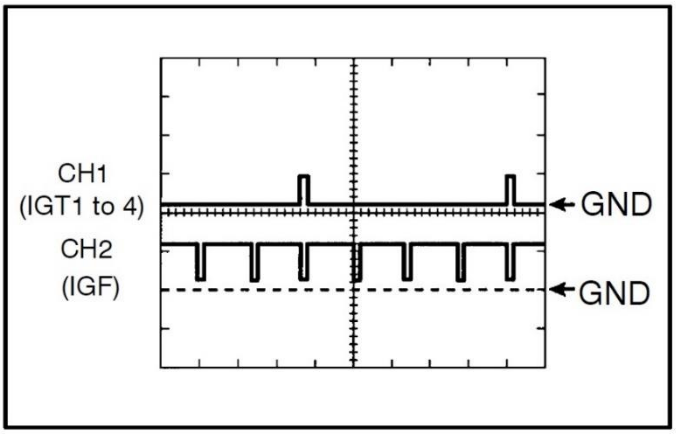
APPENDIX

Terminals of Engine ECU

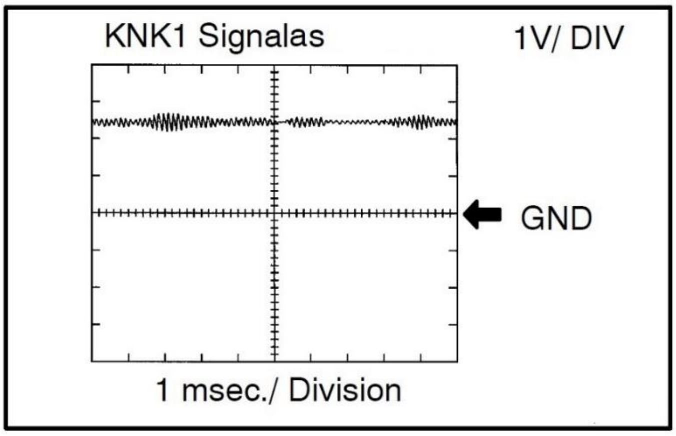
Nr	Terminals	Description	Condition	Value
1	Batt (C-6)-E1(B-28)	Battery	Always	9 – 14
2	+B (C-4)-E1 (B-28)	Power source of ECM	Power switch (ON)	9 – 14
3	+BM (C-5)-E1 (B-28)	Power source of ETCS	Always	9 – 14
4	IGSW (D-9)-E1 (B-28)	Power switch signal	Power switch (ON)	9 – 14
5	MREL (C-7)-E1(B-28)	Main relay control signal	Power switch (ON)	9 – 14
6	VC (A-18)-E2 (A-28)	Power source of sensor	Power switch (ON)	4,5 – 5,5
7	NE+ (A-33)-NE-(A-34)	Crankshaft position sensor	Idling during inspection (Mode)	Pulse generator
8	G2 (A-26)-NE-(A-34)	Camshaft position sensor	Idling during inspection (Mode)	Pulse generator
9	VTA (A-32)-E2 (A-28)	Throttle position sensor	Power switch ON IG, Throttle valve fully closed	0,5 – 1,2
10	VTA (A-32)-E2 (A-28)	Throttle position sensor	HV system ON, During active test to open throttle valve	3,2 – 4,8
11	VTA2 (A-31)-E2 (A-28)	Throttle position sensor	Power switch ON IG, Accelerator pedal released	1,5 – 2,9
12	VTA2 (A-31)-E2 (A-28)	Throttle position sensor	HV system ON, During active test to open throttle valve	3,5 – 5,5
13	VG (B-33)-EVG (B-32)	Mass air flow meter	Idling (during inspection mode), A/C switch OFF	1 – 1,5
14	THA (A-20)-E2 (A-28)	Intake air temperature sensor	Idling (during inspection mode), Intake air temperature at 20 °C.	0,5 – 3,4
15	THW (A-19)-E2 (A-28)	Engine coolant temperature sensor	Idling (during inspection mode), Engine coolant temperature at 80 °C	0,2 – 1
16	#10 (A-2)-E01 (A-7)	Injector	Power switch ON (IG)	9 – 14
17	#20 (A-3)-E01 (A-7)	Injector	Power switch ON (IG)	9 – 14
18	#30 (A-4)-E01 (A-7)	Injector	Power switch ON (IG)	9 – 14
19	#40 (A-5)-E01 (A-7)	Injector	Power switch ON (IG)	9 – 14
20	IGT1 (A-8)-E1 (B-28)	Ignition coil No. 1 (Ignition signal)	Idling during inspection mode	1 Waveform
21	IGT2 (A-9)-E1 (B-28)	Ignition coil No. 2 (Ignition signal)	Idling during inspection mode	1 Waveform

22	IGT3 (A-10)-E1 (B-28)	Ignition coil No. 3 (Ignition signal)	Idling during inspection mode	1 Waveform
23	IGT4 (A-11)-E1 (B-28)	Ignition coil No. 4 (Ignition signal)	Idling during inspection mode	1 Waveform
24	KNK1 (B-1)-EKNK (B-2)	Knock sensor	Idling during inspection mode	2 Waveform
25	IGF (A-23)-E1 (B-28)	Ignition confirmation signal	Idling during inspection mode	1 Waveform
26	A1A+ (B-23)-E1 (B-28)	A/F sensor	Power switch ON (IG)	3 – 3,6
27	A1A- (B-22)-E1 (B-28)	A/F sensor	Power switch ON (IG)	2,7 – 3,3
28	OX1B (D-22)-E2 (A-28)	Heated oxygen sensor	Maintain engine speed at 2500 rpm for 2 minutes after warming up	Pulse generator
29	HA1A (B-7)-E2 (A-1)	A/F sensor heater	Idling during inspection mode	Below 3
30	HA1A (B-7)-E2 (A-1)	A/F sensor heater	Power switch ON (IG)	9 – 14
31	HT1B (D-6)-E03 (D-7)	Heated oxygen sensor heater	Idling during inspection mode	Below 3
32	HT1B (D-6)-E03 (D-7)	Heated oxygen sensor heater	Power switch ON (IG)	9 – 14
33	EVP1 (B-14)-E1 (B-28)	EVAP VSV	Power switch ON (IG)	9 – 14
34	M+ (B-6)-E1 (B-28)	Throttle actuator control motor	Idling during inspection mode	Pulse generator
35	M- (B-5)-E1 (B-28)	Throttle actuator control motor	Idling during inspection mode	Pulse generator
36	OCV+ (A-15)-OCV- (A-14)	Camshaft timing oil control	Power switch ON (IG)	3 Waveform
37	TAM (C-21)-E2 (A-28)	Outside air temperature sensor	Ambient air temperature -40 – 140 °C	0,8 – 1,3
38	MOPS (B-15)-E1 (B-28)	Engine oil pressure	Power switch ON (IG), Not engine running	9 – 14
39	FAN (C-8)-E1 (B-28)	Cooling fan relay	Power switch ON (IG), Engine coolant Temp. less than 94,5 °C	9 – 14
40	W (D-18)-E1 (B-28)	CHK ENG	Idling during inspection mode	9 – 14
41	W (D-18)-E1 (B-28)	CHK ENG	Power switch ON (IG)	Below 3
42	FC (D-10)-E1 (B-28)	Fuel pump control	Power switch ON (IG)	9 – 14
43	FC (D-10)-E1 (B-28)	Fuel pump control	Idling during inspection mode	Below 3
44	TC (D-14)-E1 (B-28)	Terminal TC of DLC3	Power switch ON (IG)	9 – 14
45	NEO (C-1)-E1 (B-28)	Revolution signal	Idling during inspection mode	Pulse generator

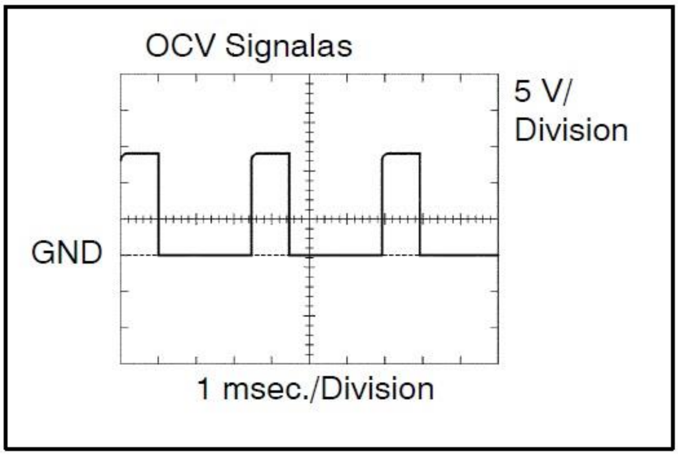
46	GO (C-2)-E1 (B-28)	Revolution signal	Idling during inspection mode	Pulse generator
47	CANH (D-31)-E1 (B-28)	CAN communication line	Power switch ON (IG)	Pulse generator
48	CANL (D-30)-E1 (B-28)	CAN communication line	Power switch ON (IG)	Pulse generator



1 Waveform



2 Waveform



3 Waveform

Terminals of Hybrid Control System ECU

Nr	Terminals	Description	Condition	Value
1	ST2 (A-5) - GND1 (A-1)	Starter signal	Power switch ON (READY)	9 to 14
2	IGSW (A-7) - GND1 (A-1)	IG Signal	Power switch ON (IG)	9 to 14
3	BATT (B-6) - GND1 (A-1)	Auxiliary battery (for measuring the battery voltage and for the HV control ECU memory)	Always	9 to 14
4	+B1 (C-7) - GND1 (A-1)	Power source of HV control ECU	Power switch ON (IG)	9 to 14
5	+B2 (C - 6) - GND1 (A - 1)	Power source of HV control ECU	Power switch OM (IG)	9 to 14
6	MREL (C - 4) - GND1 (A -1)	Main relay	Power switch ON (IG)	9 to 14
7	CANH (A -8) - GND1 (A - 1)	HIGH-level CAN bus line	Power switch ON (IG)	Pulse generation (see waveform 1)
8	CANL (A -9) - GND1 (A - 1)	LOW - level CAN bus line	Power switch ON (IG)	Pulse generation (see waveform 2)
9	NEO (C -12) - GND1 (A - 1)	Engine speed signal	Engine running	Pulse generation (see waveform 3)
10	GO (C -13) - GND1 (A - 1)	G signal	Engine running	Pulse generation (see waveform 4)
11 **	SPDI (A -19) - GND1 (A - 1)	Vehicle speed signal	Driving at approximately 20 km/h (12 mph)	Pulse generation (see waveform 5)
12	VPA1 (C-26) - EP1 (C-27)	Accelerator pedal position sensor (for the HV system)	Power switch ON (IG), accelerator pedal released	0.5 to 1.1
13	VPA1 (C-26) - EP1 (C-27)	Accelerator pedal position sensor (for the HV system)	Power switch ON (IG), engine stopped in P position, accelerator pedal fully depressed	2.6 to 4.5

14	VPA2 (C-34) - EP2 (C-35)	Accelerator pedal position sensor (for the sensor malfunction detection)	Power switch ON (IG), engine stopped in P position, accelerator pedal released	3.4 to 5.3
15	VPA2 (C-34) - EP2 (C-35)	Accelerator pedal position sensor (for the sensor malfunction detection)	Power switch ON (IG), accelerator pedal fully depressed	1.2 to 2.0
16	VCP1 (C-25) - EP1 (C-27)	Power source of accelerator pedal position sensor (for VPA1)	Power switch ON (IG)	4.5 to 5.5
17	VCP2 (C-33) - EP2 (C-35)	Power source of accelerator pedal position sensor (for VPA2)	Power switch ON (IG)	4.5 to 5.5
18	VSX1 (A-25) - E2X1 (A-15)	Shift position sensor (main)	Power switch ON (IG), selector lever home position	2.0 to 3.0
19 **	VSX1 (A-25) - E2X1 (A-15)	Shift position sensor (main)	Power switch ON (IG), selector lever moved to R position	LHD: 4.0 to 4.8
20 **	VSX1 (A-25) - E2X1 (A-15)	Shift position sensor (main)	Power switch ON (IG), selector lever moved to B or D position	LHD: 0.2 to 1.0
21	VSX2 (A-24) - E2X2 (A-14)	Shift position sensor (sub)	Power switch ON (IG), selector lever home position	2.0 to 3.0
22 **	VSX2 (A-24) - E2X2 (A-14)	Shift position sensor (sub)	Power switch ON (IG), selector lever moved to R position	LHD: 4.0 to 4.8
23 **	VSX2 (A-24) - E2X2 (A-14)	Shift position sensor (sub)	Power switch ON (IG), selector lever moved to B or D position	LHD: 0.2 to 1.0
24	VCX1 (A-17) - E2X1 (A-15)	Power source of shift position sensor (for VSX1)	Power switch ON (IG)	4.5 to 5.5
25	VCX2 (A-16) - E2X2 (A-14)	Power source of shift position sensor (for VSX2)	Power switch ON (IG)	4.5 to 5.5
26	VSX3 (A-23) - GND1 (A-1)	Select position sensor (main)	Power switch ON (IG), selector lever home position	LHD: 0.5 to 2.0
27 **	VSX3 (A-23) - GND1 (A-1)	Select position sensor (main)	Power switch ON (IG), selector lever moved to R, N or D position	LHD: 3.0 to 4.85

28	VSX4 (A-30) - GND1 (A-1)	Select position sensor (sub)	Power switch ON (IG), selector lever home position	LHD: 0.5 to 2.0
29 **	VSX4 (A-30) - GND1 (A-1)	Select position sensor (sub)	Power switch ON (IG), selector lever moved to R, N or D position	LHD: 3.0 to 4.85
30	VCX3 (A-21) - GND1 (A-1)	Power source of select position sensor (for VSX3)	Power switch ON (IG)	9 to 14
31	VCX4 (A-31) - GND1 (A-1)	Power source of select position (for VSX4)	Power switch ON (IG)	9 to 14
32	NODD (C-24) - GND1 (A-1)	DC/DC movement monitor or stop request signal	When converter is in normal operation	5 to 7
33	NODD (C-24) - GND1 (A-1)	DC/DC movement monitor or stop request signal	When converter is improper	2 to 4
34	NODD (C-24) - GND1 (A-1)	DC/DC movement monitor or stop request signal	When converter is required to stop	0.1 to 0.5
35	VLO (C-31) - GND1 (A-1)	Two-stage selector signal	Converter switching to 14 V output	13 to 14
36	VLO (C-31) - GND1 (A-1)	Two-stage selector signal	Converter switching to 13.5 V output	Below 0.5
37	TC (A-6) - GND1 (A-1)	Terminal TC of DLC3	Power switch ON (IG)	9 to 14
38	STP (B-3) - GND1 (A-1)	Stop lamp switch	Brake pedal depressed	9 to 14
39	STP (B-3) - GND1 (A-1)	Stop lamp switch	Brake pedal released	2 to 3
40	ABFS (A-20) - GND1 (A-1)	Airbag deployment signal	Power switch ON (READY) (2 seconds after ACC ON)	Pulse generation see waveform 6 to 8)
41	AS1 (C-15) - AS1G (C-16)	Circuit breaker sensor No.1	Satellite signal system normal	2.5 to 2.9
42	ILK (B-1) - GND1 (A-1)	Interlock switch	Power switch ON (IG), inverter cover and service plug grip installed normally	Below 1
43	ILK (B-1) - GND1 (A-1)	Interlock switch	Power switch ON (IG), inverter cover and service plug grip detached	9 to 14
44	CON1 (C-1) - GND1 (A-1)	System main relay No.1	Power switch OFF to ON (READY)	Pulse generation

				(see waveform 9)
45	CON2 (C-2) - GND1 (A-1)	System main relay No.2	Power switch OFF to ON (READY)	Pulse generation (see waveform 9)
46	CON3 (C-3) - GND1 (A-1)	System main relay No.3	Power switch OFF to ON (READY)	Pulse generation (see waveform 9)
47	VH (B-26) - GINV (B-23)	Inverter condenser voltage monitor	Power switch ON (READY)	1.6 to 3.8
48	GUU (B-15) - GINV (B-23)	Generator switch U signal	Power switch ON (IG)	Pulse generation (see waveform 10)
49	GVU (B-14) - GINV (B-23)	Generator switch V signal	Power switch ON (IG)	Pulse generation (see waveform 10)
50	GWU (B-13) - GINV (B-23)	Generator switch W signal	Power switch ON (IG)	Pulse generation (see waveform 10)
51	GIVA (B-34) - GINV (B-23)	Generator V phase current	Power switch ON (IG)	Approximatel y 0
52	GIVB (B-33) - GINV (B-23)	Generator V phase current	Power switch ON (IG)	Approximatel y 0
53	GIWA (B-32) - GINV (B-23)	Generator W phase current	Power switch ON (IG)	Approximatel y 0
54	GIWB (B-31) - GINV (B-23)	Generator W phase current	Power switch ON (IG)	Approximatel y 0
55	GIVT (B-27) - GINV (B-23)	Generator inverter temperature sensor	Power switch ON (IG)	2 to 4.5
56 **	GSDN (B-16) - GINV (B-23)	Generator shutdown signal	Power switch ON (READY), N position	0.2 to 0.7
57	GSDN (B-16) - GINV (B-23)	Generator shutdown signal	Power switch ON (READY), P position	5.1 to 13.6
58	GFIV (B-35) - GINV (B-23)	Generator inverter fail signal	Power switch ON (IG), inverter normal	5.4 to 7.4
59	GFIV (B-35) - GINV (B-23)	Generator inverter fail signal	Power switch ON (IG), inverter abnormal	2 to 3
60	GRF (D-27) - GRFG (D-26)	Generator resolver signal	Generator resolver stopped or rotating	Pulse generation

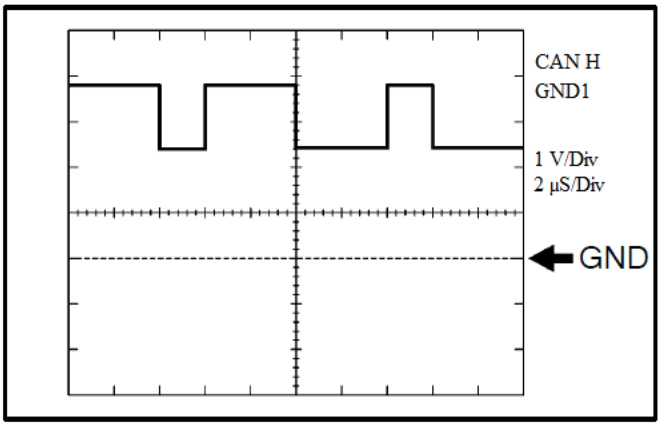
				(see waveform 11, 12)
61	GSN (D-22) - GSNG (D-21)	Generator resolver signal	Generator resolver stopped or rotating	Pulse generation (see waveform 11,12)
62	GCS (D-23) - GCSG (D-24)	Generator resolver signal	Generator resolver stopped or rotating	Pulse generation (see waveform 11, 12)
63	OMT (D-30) - OMTG (D-29)	Motor temperature sensor No.2	Refer to DATA LIST on page 05-262	-
64	MUU (B-9) - GINV (B-23)	Motor switch U signal	Power switch ON (IG)	Pulse generation (see waveform 13)
65	MVU (B-10) - GINV (B-23)	Motor switch V signal	Power switch ON (IG)	Pulse generation (see waveform 13)
66	MWU (B-11) - GINV (B-23)	Motor switch W signal	Power switch ON (IG)	Pulse generation (see waveform 13)
67	MIVA (B-30) - GINV (B-23)	Motor V phase current	Power switch ON (IG)	Approximatel y 0
68	MIVB (B-21) - GINV (B-23)	Motor V phase current	Power switch ON (IG)	Approximatel y 0
69	MIWA (B-29) - GINV (B-23)	Motor W phase current	Power switch ON (IG)	Approximatel y 0
70	MIWB (B-20) - GINV (B-23)	Motor W phase current	Power switch ON (IG)	Approximatel y 0
71	MIVT (B-19) - GINV (B-23)	Motor inverter temperature sensor	Power switch ON (IG)	2 to 4.5
72 **	MSDN (B-8) - GINV (B-23)	Motor shutdown signal	Power switch ON (READY), N position	0.2 to 0.7
73	MSDN (B-8) - GINV (B-23)	Motor shutdown signal	Power switch ON (READY), P position	5.1 to 13.6
74	OVH (B-22) - GINV (B-23)	Motor inverter over voltage signal	Power switch ON (IG), inverter normal	5.3 to 7.3
75	OVH (B-22) - GINV (B-23)	Motor inverter over voltage signal	Power switch ON (IG), inverter abnormal	1.9 to 2.9

76	MFIV (B-18) - GINV (B-23)	Motor inverter fail signal	Power switch ON (IG), inverter normal	5.4 to 7.4
77	MFIV (B-18) - GINV (B-23)	Motor inverter fail signal	Power switch ON (IG), inverter abnormal	2 to 3
78	MRF (D-34) - MRFG (D-33)	Motor resolver signal	Motor resolver stopped or rotating	Pulse generation (see waveform 11, 12)
79	MSN (D-20) - MSNG (D-19)	Motor resolver signal	Motor resolver stopped or rotating	Pulse generation (see waveform 11, 12)
80	MCS (D-32) - MCSG (D-31)	Motor resolver signal	Motor resolver stopped or rotating	Pulse generation (see waveform 11, 12)
81	MMT (D-18) - MMTG (D-28)	Motor temperature sensor No.1	Refer to DATA LIST on page 05-262	-
82	VL (C-30) - GCNV (C-8)	Boost converter input voltage	Power switch ON (READY)	1.9 to 3.4
83	OVL (C-22) - GCNV (C-8)	Boost converter over voltage signal	Power switch ON (IG), boost converter normal	5.3 to 7.7
84	OVL (C-22) - GCNV (C-8)	Boost converter over voltage signal	Power switch ON (IG), boost converter abnormal	1.9 to 3.0
85	FCV (C-20) - GCNV (C-8)	Boost converter fail signal	Power switch ON (IG), boost converter normal	5.3 to 7.7
86	FCV (C-20) - GCNV (C-8)	Boost converter fail signal	Power switch ON (IG), boost converter abnormal	1.9 to 3.0
87	CT (C-21) - GCNV (C-8)	Boost converter temperature sensor	Power switch ON (IG)	2.0 to 4.5
88	CPWM (C-10) - GCNV (C-8)	Boost converter PWM switch signal	Power switch ON (READY), parking brake ON, D position, brake pedal and accelerator pedal depressed	Pulse generation (see waveform 14)
89	CSDN (C-9) - GCNV (C-8)	Boost converter shutdown signal	Power switch ON (IG)	5.6 or higher
90	CSDN (C-9) - GCNV (C-8)	Boost converter	Power switch ON (READY)	Below 0.7

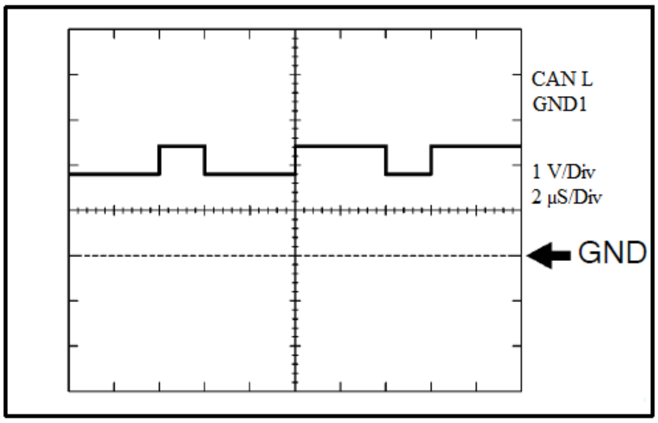
		shutdown signal		
91 **	ST1- (B-2) - GND1 (A-1)	Stop lamp switch (opposite to STP)	Power switch ON (IG) and brake pedal depressed	Below 0.5
92 **	ST1- (B-2) - GND1 (A-1)	Stop lamp switch (opposite to STP)	Power switch ON (IG) and brake pedal released	9to 14
93	CCS (A-13) - GND1 (A-1)	Cruise control switch	Cruise control system - Terminal of ECU - CCS terminal (see page 05-2452)	-
94	EVSW (A-27) - GND1 (A-1)	EV - drive mode switch	Power switch ON (IG), EV-drive mode switches ON	Below 1
95	EVSW (A-27) - GND1 (A-1)	EV-drive mode switch	Power switch ON (IG), EV - drive mode switch OFF	9 to 14
96	IMI (A-18) - GND1 (A-1)	Immobilizer communicatio n	Immobilizer communicating	Pulse generation (see waveform 15)
97	IMO (A-26) - GND1 (A-1)	Immobilizer communicatio n	Immobilizer communicating	Pulse generation (see waveform 15)
98	P1 (B-17) - GND1 (A-1)	P position switch	Power switch ON (IG), P position switch ON	3 to 5
99	P1 (B-17) - GND1 (A-1)	P position switch	Power switch ON (IG), P position switch OFF	7 to 12
100	PCON (D-9) - GND1 (A-1)	P position control signal	Power switch ON (IG)	Pulse generation (see waveform 16)
101	PPOS (D-10) - GND1 (A-1)	P position signal	Power switch ON (IG)	Pulse generation (see waveform 16)
102	RDY (A-28) - GND1 (A-1)	READY control signal	Power switch ON (IG)	Pulse generation (see waveform 17)
103	RDY (A-28) - GND1 (A-1)	READY control signal	Power switch ON (READY)	Pulse generation (see waveform 18)
104	CLK (C-17) - GND1 (A-1)	A/C communicatio n	Power switch ON (IG), A/C operating	Pulse generation (see waveform 19)

105	ITE (C-14) - GND1 (A-1)	A/C communication	Power switch ON (IG), A/C operating	Pulse generation (see waveform 19)
106	ETI (B-24) - GND1 (A-1)	A/C communication	Power switch ON (IG), A/C operating	Pulse generation (see waveform 19)
107	STB (B-25) - GND1 (A-1)	A/C communication	Power switch ON (IG), A/C operating	Pulse generation (see waveform 19)
108	WP (C-5) - GND1(A-1)	Water pump relay control	Power switch ON (IG), A/C operating	Below 2
109	GND1 (A-1) - Body ground	Ground	Always (resistance check)	Below 5 Ω
110	GND2 (A-4) - Body ground	Ground	Always (resistance check)	Below 5 Ω

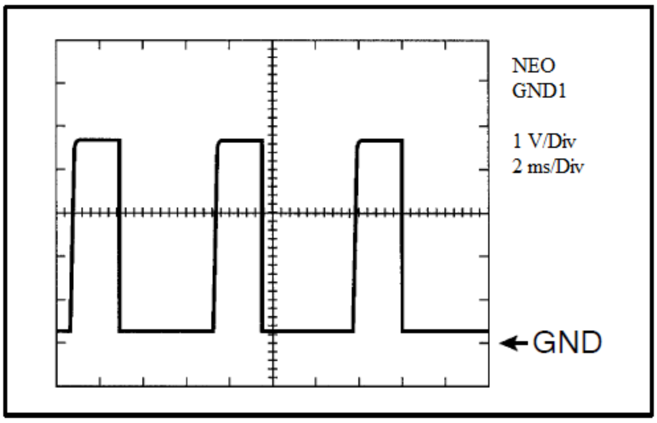
Note:
It is not possible to measure the points marked with ** an asterisk on this stand.



1 Waveform
Note: The waveform varies depending on the contents of communication.

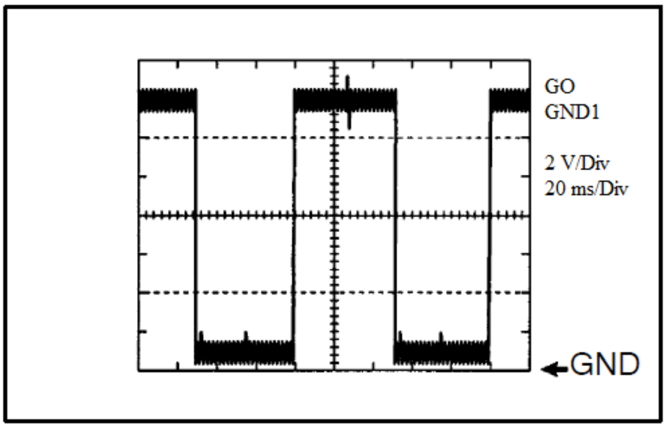


2 Waveform
Note: The waveform varies depending on the contents of communication.

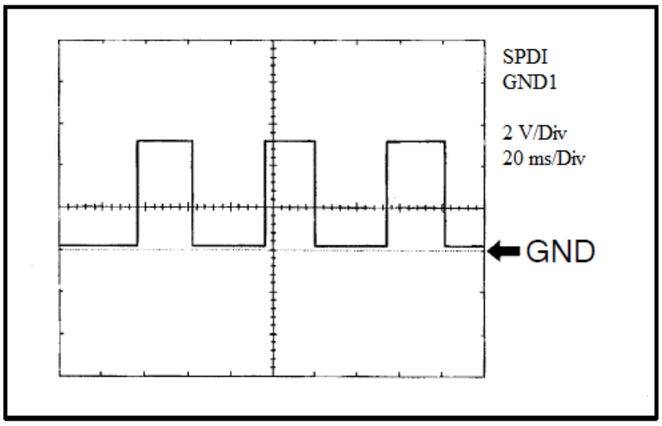


3 Waveform

Note: The pulse cycle becomes shorter as the engine speed increases.

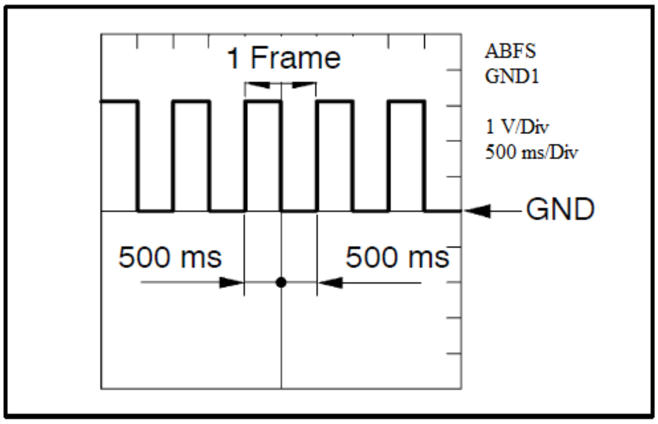


4 Waveform



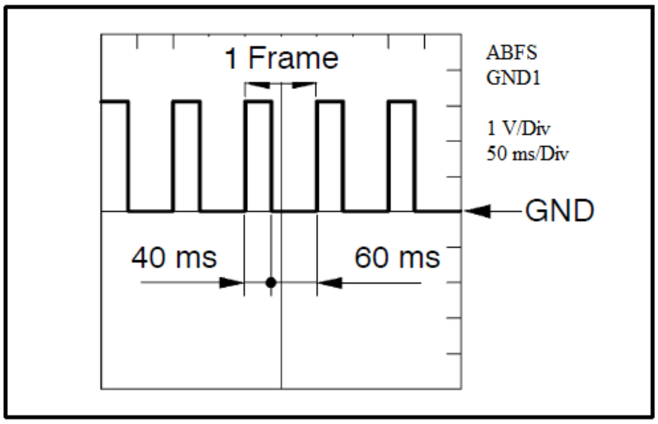
5 Waveform

Note: The higher the vehicle speed, the shorter the cycle and higher voltage.



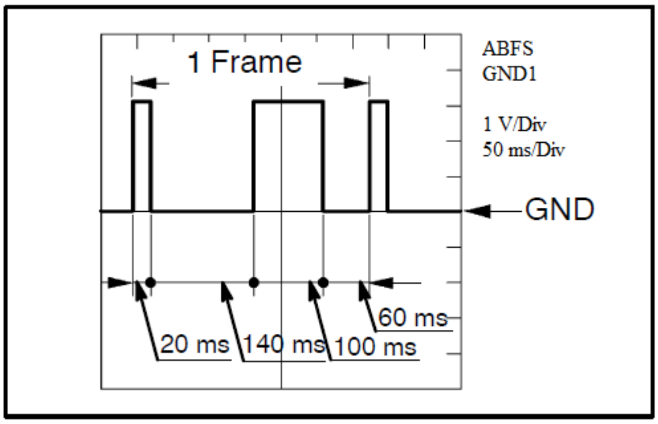
6 Waveform

Note: The waveform on the left is repeated when the airbag system is normal.



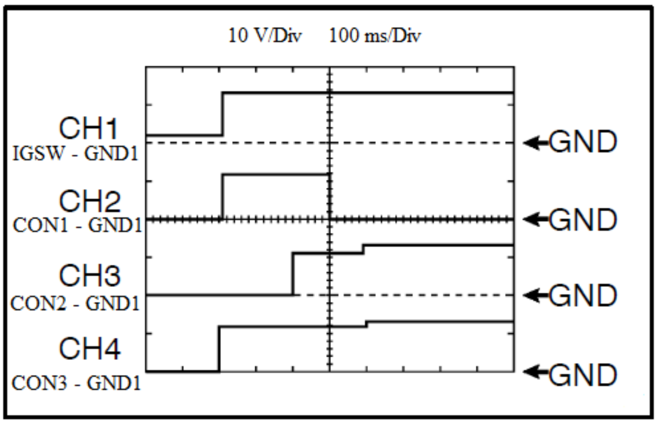
7 Waveform

Note: The waveform on the left is repeated when the airbag system is abnormal.

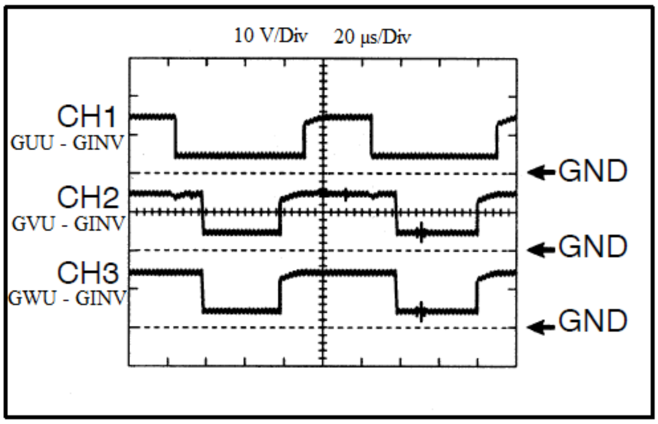


8 Waveform

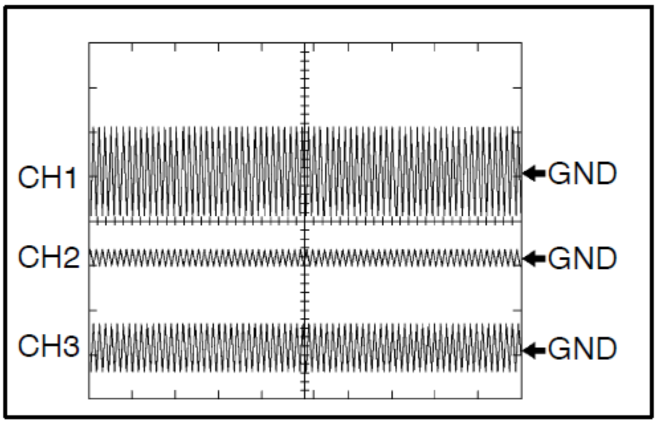
Note: When the airbag system is deployed, after 1 frame of transmission indicating a normal condition is completed, the waveform on the left is repeated for 50 frames. After that, normal transmissions return.



9 Waveform



10 Waveform



11 Waveform

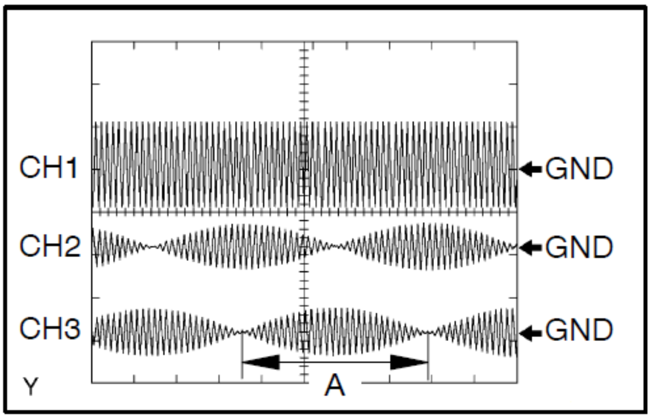
Generator resolver
CH1: GRF – GRFG;
CH2: GSN – GSNG;
CH3: GCS – GCSG

Motor resolver
CH1: MRF – MRFG;
CH2: MSN – MSNG;
CH3: MCS – MCSG

CH1: 10 V/Div, 1 ms/Div
CH2, 3: 5V/Div, 1 ms/Div

Generator and motor stopped

Note: The phases and the waveform height of the GSN and GCS, or the MSN and MCS change depending on the stopped position of rotor.



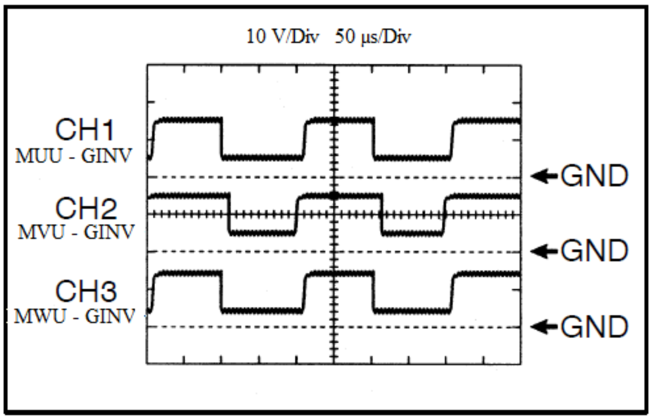
12 Waveform

Generator resolver
CH1: GRF – GRFG;
CH2: GSN – GSNG;
CH3: GCS – GCSG

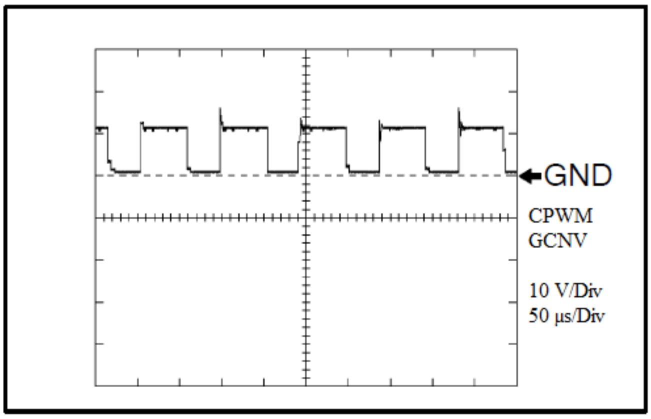
Motor resolver
CH1: MRF – MRFG;
CH2: MSN – MSNG;
CH3: MCS – MCSG

CH1: 10 V/Div, 1 ms/Div
CH2, 3: 5V/Div, 1 ms/Div

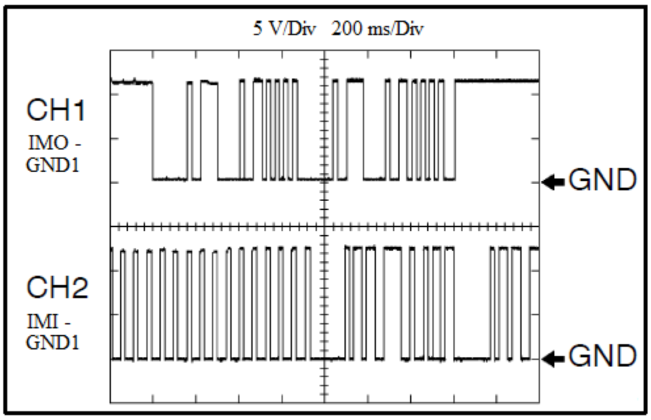
Note: Distance “A” in the diagram becomes shorter as the rotor speed increases.



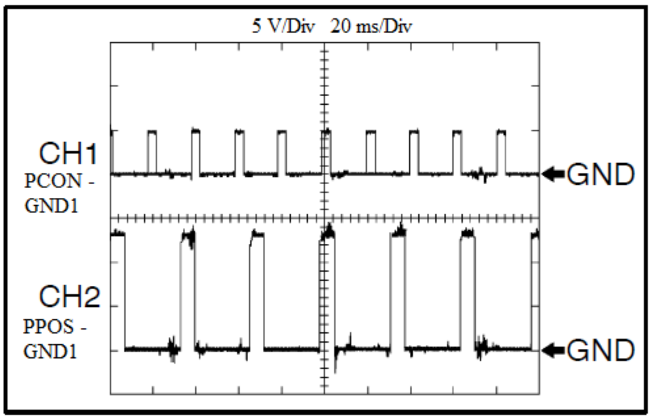
13 Waveform



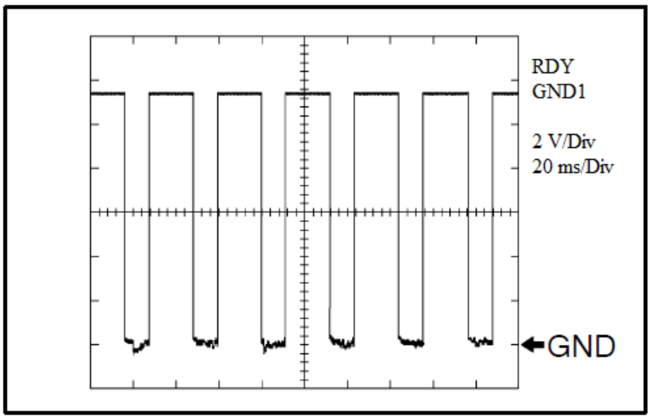
14 Waveform



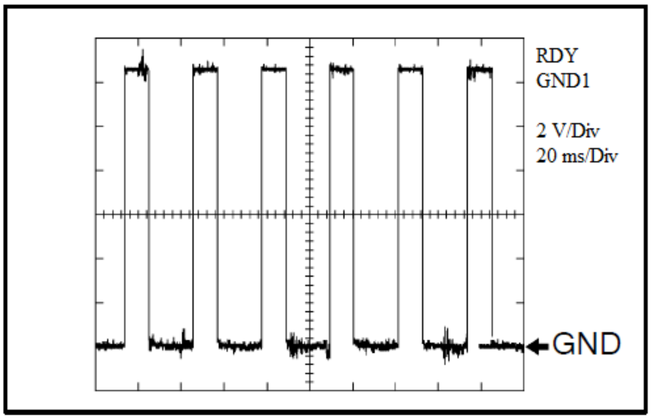
15 Waveform



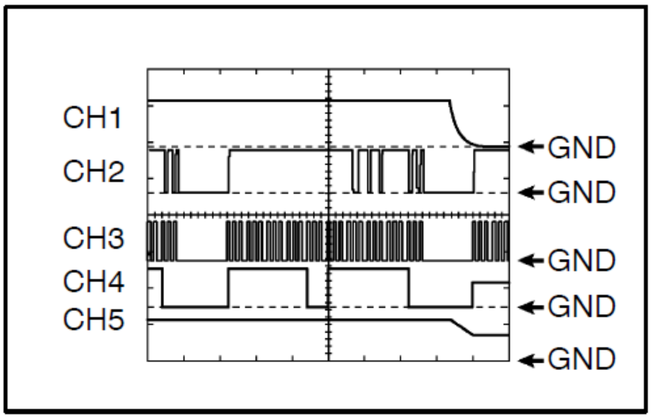
16 Waveform



17 Waveform



18 Waveform



19 Waveform

CH1: IGSW – GND1
CH2: ITE – GND1
CH3: CLK – GND1
CH4: ETI – GND1
CH5: STB – GND1

10 V/Div, 50 ms/Div

Technical data

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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