

# ENGINE ELECTRICAL

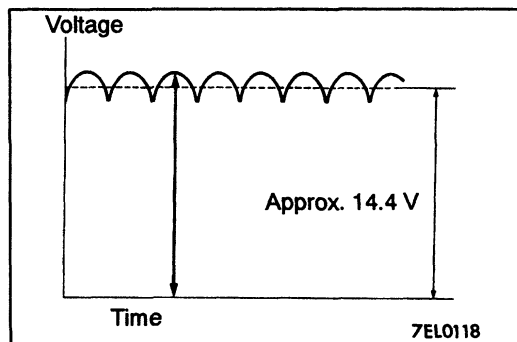
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# CHARGING SYSTEM

## GENERAL INFORMATION

The charging system uses the alternator output to keep the battery charged at a constant level under various electrical loads.



## OPERATION

Rotation of the excited field coil generates AC voltage in the stator.

This alternating current is rectified through diodes to DC voltage having a waveform shown in the illustration at left. The average output voltage fluctuates slightly with the alternator load condition.

When the ignition switch is turned on, current flows in the field coil and initial excitation of the field coil occurs.

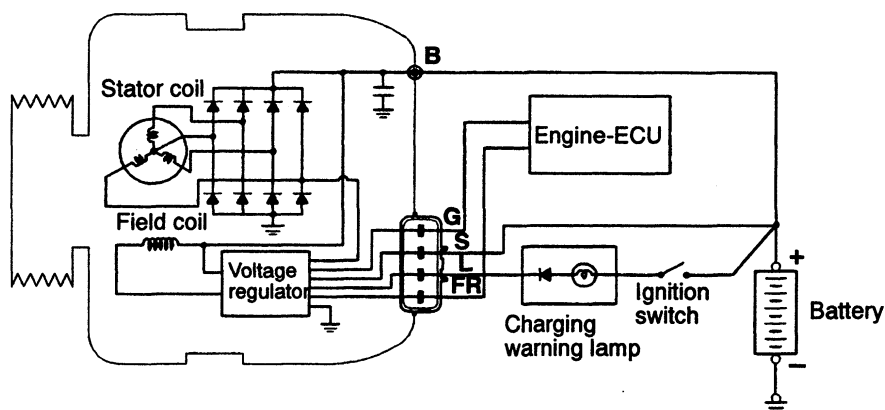
When the stator coil begins to generate power after the engine is started, the field coil is excited by the output current of the stator coil.

The alternator output voltage rises as the field current increases and it falls as the field current decreases. When the battery voltage (alternator S terminal voltage) reaches a regulated voltage

of approx. 14.4 V, the field current is cut off. When the battery voltage drops below the regulated voltage, the voltage regulator regulates the output voltage to a constant level by controlling the field current.

In addition, when the field current is constant, the alternator output voltage rises as the engine speed increases.

## SYSTEM DIAGRAM



9EN0870

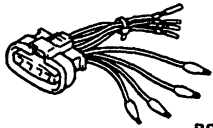
## ALTERNATOR SPECIFICATIONS

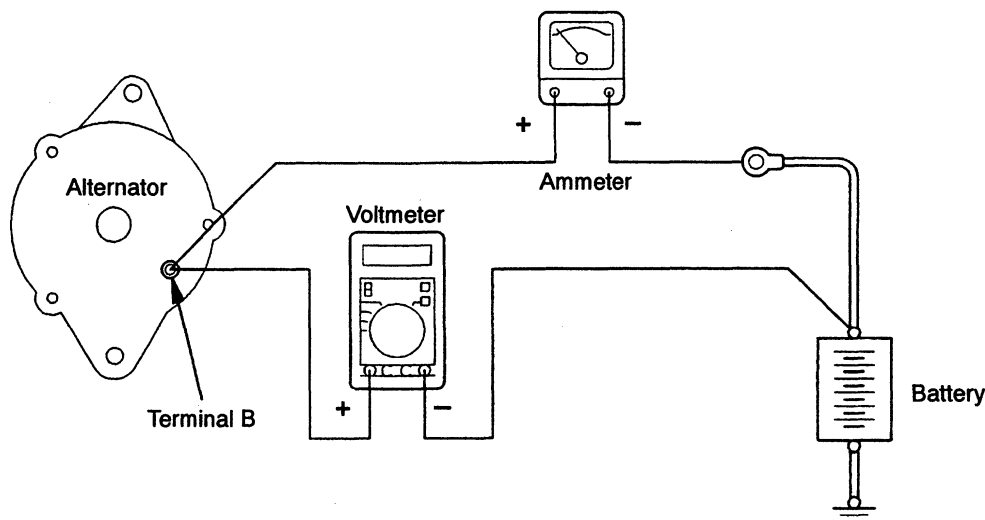
Items	4G9
Type	Battery voltage sensing
Rated output V/A	12/100
Voltage regulator	Electronic built-in type

## SERVICE SPECIFICATIONS

Items	Standard value	Limit
Alternator output line voltage drop (at 30A) V	–	max. 0.3
Regulated voltage ambient temp. at voltage regulator V	–20°C	14.2–15.4
	20°C	13.9–14.9
	60°C	13.4–14.6
	80°C	13.1–14.5
Output current	–	70% of normal output current
Rotor coil resistance $\Omega$	Approx. 2 – 5	–

## SPECIAL TOOL

Tool	Number	Name	Use
 B991519	MB991519	Alternator test harness	Checking the alternator (S terminal voltage)

**ON-VEHICLE SERVICE****ALTERNATOR OUTPUT LINE VOLTAGE DROP TEST**

9EN0468

This test determines whether the wiring from the alternator "B" terminal to the battery (+) terminal (including the fusible line) is in a good condition or not.

- (1) Always be sure to check the following before the test.
  - Alternator installation
  - Alternator drive belt tension (Refer to GROUP 11A – On-vehicle Service.)
  - Fusible link
  - Abnormal noise from the alternator while the engine is running
- (2) Turn the ignition switch off.
- (3) Disconnect the negative battery cable.
- (4) Disconnect the alternator output wire from the alternator "B" terminal and connect a DC test ammeter with a range of 0–100 A in series between the "B" terminal and the disconnected

output wire. (Connect the (+) lead of the ammeter to the "B" terminal, and then connect the (–) lead of the ammeter to the disconnected output wire.)

**NOTE**

An inductive-type ammeter which enables measurements to be taken without disconnecting the alternator output wire should be recommended. Using this equipment will lessen the possibility of a voltage drop caused by a loose "B" terminal connection.

- (5) Connect a digital-type voltmeter between the alternator "B" terminal and the battery (+) terminal. (Connect the (+) lead of the voltmeter to the "B" terminal and the connect the (–) lead of the voltmeter to the battery (+) cable.)

- (6) Reconnect the negative battery cable.
- (7) Connect a tachometer or the MUT-II. (Refer to GROUP 11A – On-vehicle Service.)
- (8) Leave the hood open.
- (9) Start the engine.
- (10) With the engine running at 2,500 r/min, turn the headlamps and other lamps on and off to adjust the alternator load so that the value displayed on the ammeter is slightly above 30 A.  
Adjust the engine speed by gradually decreasing it until the value displayed on the ammeter is 30 A. Take a reading of the value displayed on the voltmeter at this time.

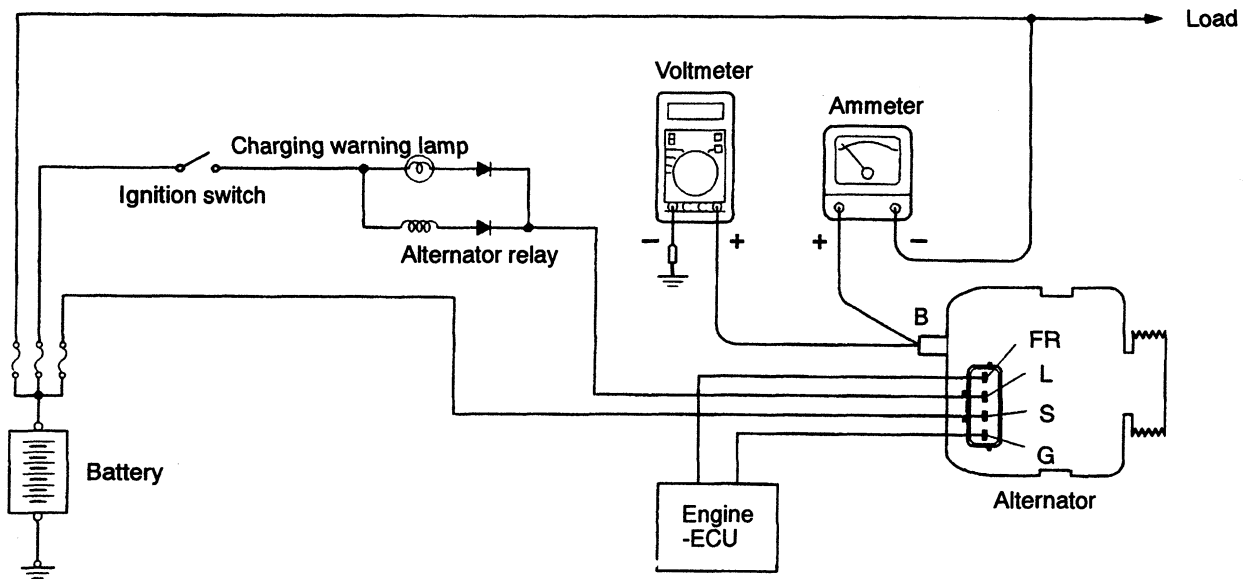
**Limit: max. 0.3 V**

**NOTE**

When the alternator output is high and the value displayed on the ammeter does not decrease until 30 A, set the value to 40 A. Read the value displayed on the voltmeter at this time. When the value range is 40 A, the limit is max. 0.4 V.

- (11) If the value displayed on the voltmeter is above the limit value, there is probably a malfunction in the alternator output wire, so check the wiring between the alternator "B" terminal and the battery (+) terminal (including fusible link). If a terminal is not sufficiently tight or if the harness has become discolored due to overheating, repair and then test again.
- (12) After the test, run the engine at idle.
- (13) Turn off all lamps and the ignition switch.
- (14) Remove the tachometer or the MUT-II.
- (15) Disconnect the negative battery cable.
- (16) Disconnect the ammeter and voltmeter.
- (17) Connect the alternator output wire to the alternator "B" terminal.
- (18) Connect the negative battery cable.

**OUTPUT CURRENT TEST**



6EN1162

This test determines whether the alternator output current is normal.

- (1) Before the test, always be sure to check the following.

- Alternator installation
- Battery

**NOTE**

The battery should be slightly discharged. The load needed by a fully-charged battery is insufficient for an accurate test.

- Alternator drive belt tension (Refer to GROUP 11A – On-vehicle Service.)
- Fusible link
- Abnormal noise from the alternator while the engine is running.

- (2) Turn the ignition switch off.  
 (3) Disconnect the negative battery cable.  
 (4) Disconnect the alternator output wire from the alternator "B" terminal. Connect a DC test ammeter with a range of 0–100 A in series between the "B" terminal and the disconnected output wire. (Connect the (+) lead of the ammeter to the "B" terminal. Connect the (–) lead of the ammeter to the disconnected output wire.)

**Caution**

**Never use clips but tighten bolts and nuts to connect the line. Otherwise loose connections (e.g. using clips) will lead to a serious accident because of high current.**

**NOTE**

An inductive-type ammeter which enables measurements to be taken without disconnecting the alternator output wire should be recommended.

- (5) Connect a voltmeter with a range of 0–20 V between the alternator "B" terminal and the earth. (Connect the (+) lead of the voltmeter to the "B" terminal, and then connect the (–) lead of the voltmeter to the earth.)  
 (6) Connect the negative battery cable.  
 (7) Connect a tachometer or the MUT-II. (Refer to GROUP 11A – On-vehicle Service.)  
 (8) Leave the hood open.  
 (9) Check that the reading on the voltmeter is equal to the battery voltage.

**NOTE**

If the voltage is 0 V, the cause is probably an open circuit in the wire or fusible link between the alternator "B" terminal and the battery (+) terminal.

- (10) Turn the light switch on to turn on headlamps and then start the engine.  
 (11) Immediately after setting the headlamps to high beam and turning the heater blower switch to the high revolution position, increase the engine speed to 2,500 r/min and read the maximum current output value displayed on the ammeter.

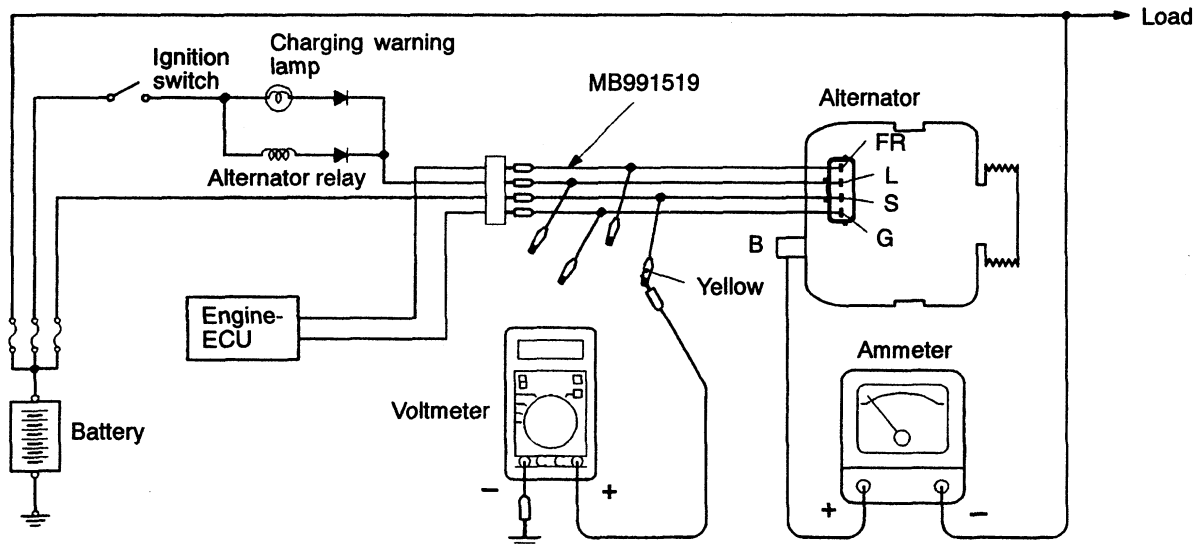
**Limit: 70% of normal current output**

**NOTE**

- For the nominal current output, refer to the Alternator Specifications.
- Because the current from the battery will soon drop after the engine is started, the above step should be carried out as quickly as possible in order to obtain the maximum current output value.
- The current output value will depend on the electrical load and the temperature of the alternator body.
- If the electrical load is small while testing, the specified level of current may not be output even though the alternator is normal. In such cases, increase the electrical load by leaving the headlamps turned on for some time to discharge the battery or by using the lighting system in another vehicle, and then test again.
- The specified level of current also may not be output if the temperature of the alternator body or the ambient temperature is too high. In such cases, cool the alternator and then test again.

- (12) The reading on the ammeter should be above the limit value. If the reading is below the limit value and the alternator output wire is normal, remove the alternator from the engine and check the alternator.  
 (13) Run the engine at idle after the test.  
 (14) Turn the ignition switch off.  
 (15) Remove the tachometer or the MUT-II.  
 (16) Disconnect the negative battery cable.  
 (17) Disconnect the ammeter and voltmeter.  
 (18) Connect the alternator output wire to the alternator "B" terminal.  
 (19) Connect the negative battery cable.

## REGULATED VOLTAGE TEST



9EN0871

This test determines whether the voltage regulator is correctly controlling the alternator output voltage.

- (1) Always be sure to check the following before the test.
  - Alternator installation
  - Check that the battery installed in the vehicle is fully charged.
  - Alternator drive belt tension (Refer to GROUP 11A – On-vehicle Service.)
  - Fusible link
  - Abnormal noise from the alternator while the engine is running
- (2) Turn the ignition switch to the OFF position.
- (3) Disconnect the negative battery cable.
- (4) Use the special tool (Alternator test harness: MB991519) to connect a digital voltmeter between the alternator S terminal and earth. (Connect the (+) lead of the voltmeter to the "S" terminal, and then connect the (-) lead of the voltmeter to a secure earth or to the battery (-) terminal.)
- (5) Disconnect the alternator output wire from the alternator "B" terminal.

- (6) Connect a DC test ammeter with a range of 0–100 A in series between the "B" terminal and the disconnected output wire. (Connect the (+) lead of the ammeter to the "B" terminal. Connect the (-) lead of the ammeter to the disconnected output wire.)
- (7) Reconnect the negative battery cable.
- (8) Connect a tachometer or the MUT-II. (Refer to GROUP 11A – On-vehicle Service.)
- (9) Turn the ignition switch to the ON position and check that the reading on the voltmeter is equal to the battery voltage.

### NOTE

If the voltage is 0 V, the cause is probably an open circuit in the wire or fusible link between the alternator "S" terminal and the battery (+) terminal.

- (10) Turn all lamps and accessories off.
- (11) Start the engine.
- (12) Increase the engine speed to 2,500 r/min.
- (13) Read the value displayed on the voltmeter when the alternator output current alternator becomes 10 A or less.



(14) If the voltage reading conforms to the value in the voltage regulation, then the voltage regulator is operating normally.

If the voltage is not within the standard value, there is a malfunction of the voltage regulator or of the alternator.

(15) After the test, lower the engine speed to the idle speed.

(16) Turn the ignition switch off.

(17) Remove the tachometer or the MUT-II.

(18) Disconnect the negative battery cable.

(19) Disconnect the ammeter and voltmeter.

(20) Connect the alternator output wire to the alternator "B" terminal.

(21) Remove the special tool, and return the connector to the original condition.

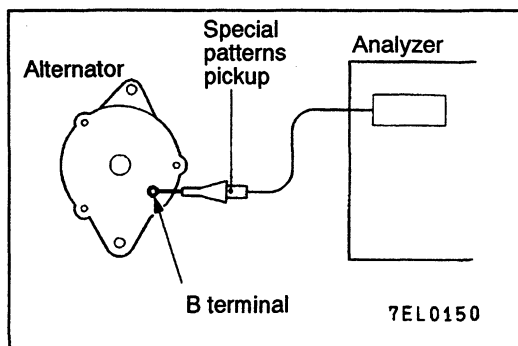
(22) Connect the negative battery cable.

### Voltage Regulation Table

#### Standard value:

Inspection terminal	Voltage regulator ambient temperature °C	Voltage V
Terminal "S"	-20	14.2-15.4
	20	13.9-14.9
	60	13.4-14.6
	80	13.1-14.5





## WAVEFORM CHECK USING AN ANALYZER

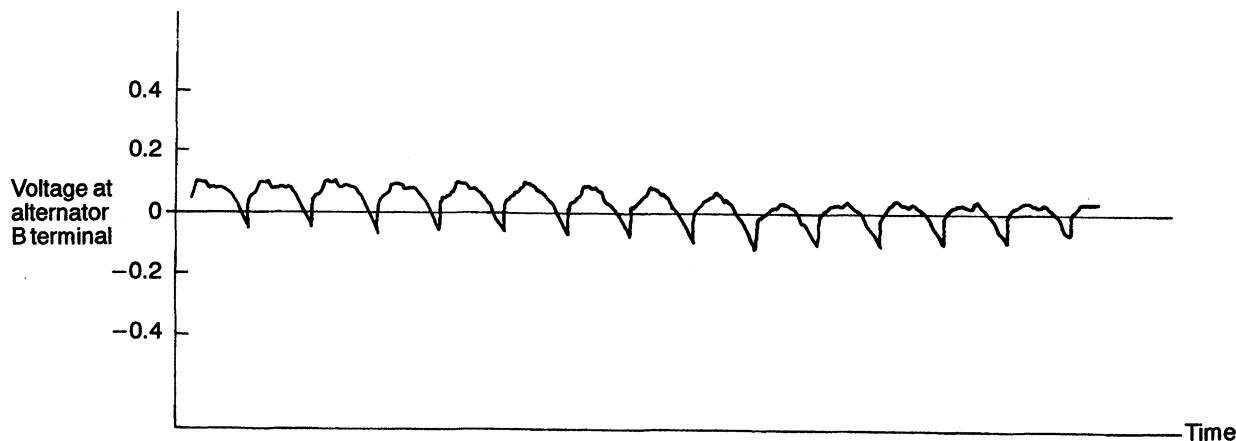
### MEASUREMENT METHOD

Connect the analyzer special patterns pick-up to the alternator B terminal.

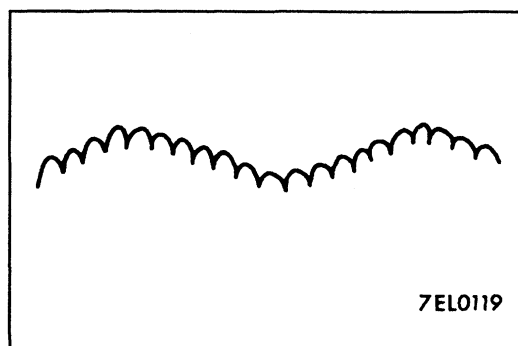
## STANDARD WAVEFORM

### Observation Conditions

FUNCTION	SPECIAL PATTERNS
PATTERN HEIGHT	VARIABLE
VARIABLE knob	Adjust while viewing the waveform.
PATTERN SELECTOR	RASTER
Engine speed	Curb idle speed



7EL0115



### NOTE



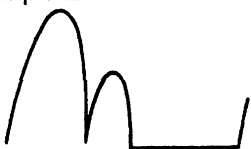


The voltage waveform of the alternator B terminal can undulate as shown at left. This waveform is produced when the regulator operates according to fluctuations in the alternator load (current), and is normal for the alternator.

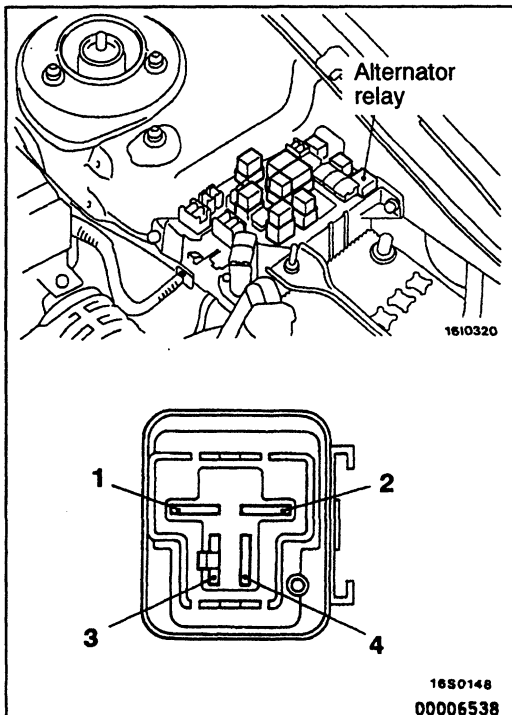
In addition, when the voltage waveform reaches an excessively high value (approx. 2 V or higher at idle), it often indicates an open circuit due to a blown fuse between alternator B terminal and battery, but not a defective alternator.

## EXAMPLES OF ABNORMAL WAVEFORMS

## NOTE

1. The size of the waveform patterns differs largely, depending on the adjustment of the variable knob on the analyzer.
2. Identification of abnormal waveforms is easier when there is a large output current (regulator is not operating). (Waveforms can be observed when the headlamps are illuminated.)
3. Check the conditions of the charging warning lamp (illuminated/not illuminated). Also, check the charging system totally.

Abnormal waveforms	Problem cause	Abnormal waveforms	Problem cause
<b>Example 1</b>  A7EL0120	<ul style="list-style-type: none"> <li>• Open diode</li> </ul>	<b>Example 4</b>  A7EL0123	<ul style="list-style-type: none"> <li>• Short in stator coil</li> </ul>
<b>Example 2</b>  A7EL0121	<ul style="list-style-type: none"> <li>• Short in diode</li> </ul>	<b>Example 5</b>  A7EL0124	<ul style="list-style-type: none"> <li>• Open supplementary diode</li> </ul>
<b>Example 3</b>  A7EL0122	<ul style="list-style-type: none"> <li>• Broken wire in stator coil</li> </ul>	At this time, the charging warning lamp is illuminated.	



## ALTERNATOR RELAY CONTINUITY CHECK

1. Remove the alternator relay from the relay box inside the engine compartment.
2. Set the analogue-type circuit tester to the  $\Omega$  range and check that there is continuity when the (+) terminal of the tester is connected to terminal 2 of the alternator relay and the (-) terminal is connected to terminal 4.
3. Next, check that there is no continuity when the (+) terminal is connected to terminal 4 and the (-) terminal is connected to terminal 2.
4. If the continuity checks in steps 2 and 3 show a defect, replace the alternator relay.

# STARTING SYSTEM

## GENERAL INFORMATION

If the ignition switch is turned to the "START" position, current flows in the pull-in and holding coils provided inside magnetic switch, attracting the plunger. When the plunger is attracted, the lever connected to the plunger is actuated to engage the starter clutch.

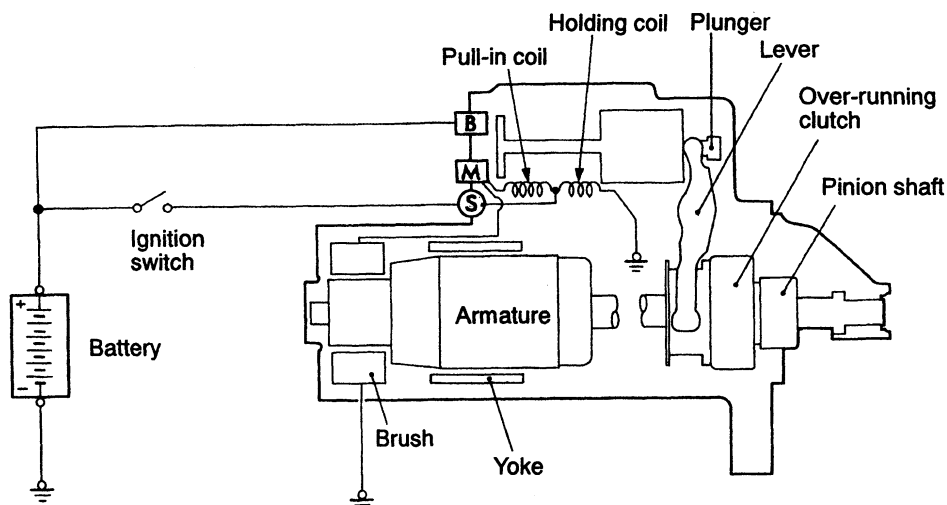
On the other hand, attracting the plunger will turn on the magnetic switch, allowing the B terminal

and M terminal to conduct. Thus, current flows to engage the starter motor.

When the ignition switch is returned to the "ON" position after starting the engine, the starter clutch is disengaged from the ring gear.

An overrunning clutch is provided between the pinion and the armature shaft, to prevent damage to the starter.

## SYSTEM DIAGRAM



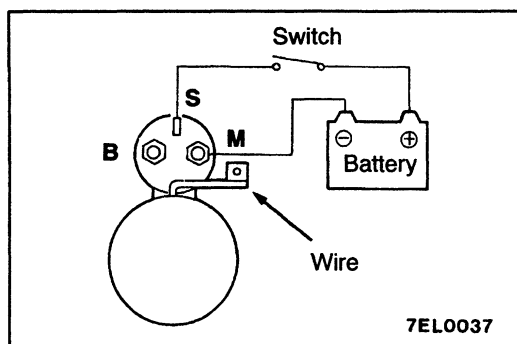
6EN0939

## STARTER MOTOR SPECIFICATIONS

Items	4G9
Type	Reduction drive with planetary gear
Rated output kW/V	1.0/12
No. of pinion teeth	8

## SERVICE SPECIFICATIONS

Items	Standard value	Limit
Pinion gap mm	0.5–2.0	–
Commutator outer diameter mm	29.4	28.8
Commutator runout mm	–	0.05
Commutator undercut mm	0.5	0.2



## STARTER MOTOR

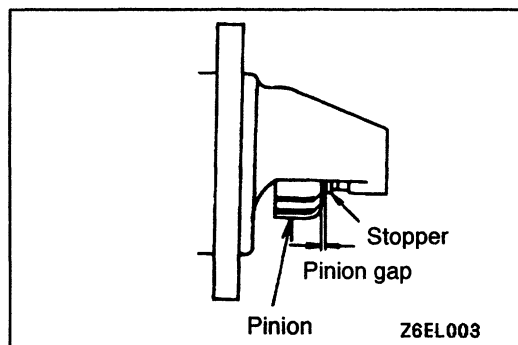
### INSPECTION

#### PINION GAP ADJUSTMENT

1. Disconnect field coil wire from M-terminal of magnetic switch.
2. Connect a 12V battery between S-terminal and M-terminal.
3. Set switch to "ON", and pinion will move out.

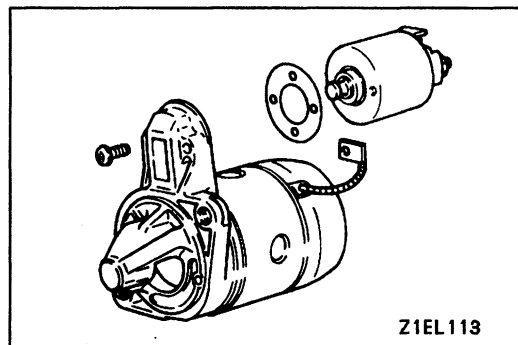
#### Caution

This test must be performed quickly (in less than 10 seconds) to prevent coil from burning.

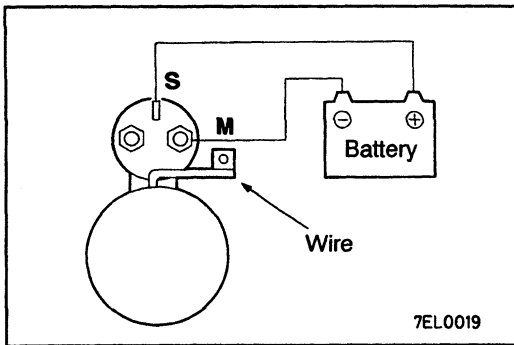


4. Check pinion to stopper clearance (pinion gap) with a thickness gauge.

**Pinion gap: 0.5–2.0 mm**



5. If pinion gap is out of specification, adjust by adding or removing gaskets between magnetic switch and front bracket.



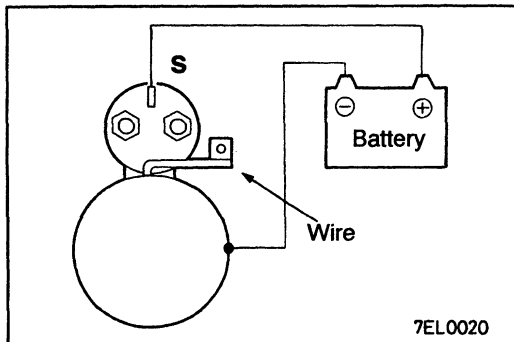
#### MAGNETIC SWITCH PULL-IN TEST

1. Disconnect field coil wire from M-terminal of magnetic switch.
2. Connect a 12V battery between S-terminal and M-terminal.

##### Caution

**This test must be performed quickly (in less than 10 seconds) to prevent coil from burning.**

3. If pinion moves out, then pull-in coil is good. If it doesn't, replace magnetic switch.



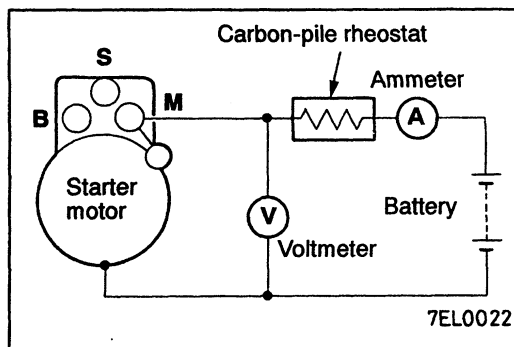
#### MAGNETIC SWITCH HOLD-IN TEST

1. Disconnect field coil wire from M-terminal of magnetic switch.
2. Connect a 12V battery between S-terminal and body.

##### Caution

**This test must be performed quickly (in less than 10 seconds) to prevent coil from burning.**

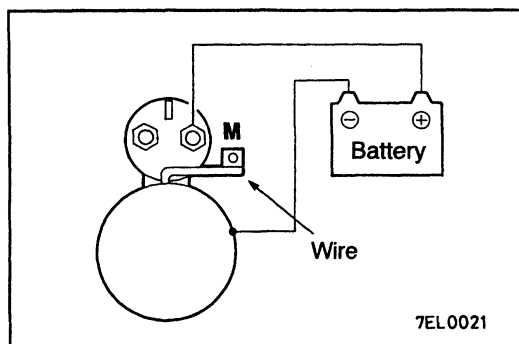
3. Manually pull out the pinion as far as the pinion stopper position.
4. If pinion remains out, everything is in order. If pinion moves in, hold-in circuit is open. Replace magnetic switch.



#### FREE RUNNING TEST

1. Place starter motor in a vise equipped with soft jaws and connect a fully-charged 12-volt battery to starter motor as follows:
2. Connect a test ammeter (100-ampere scale) and carbon pile rheostat in series with battery positive post and starter motor terminal.
3. Connect a voltmeter (15-volt scale) across starter motor.
4. Rotate carbon pile to full-resistance position.
5. Connect battery cable from battery negative post to starter motor body.
6. Adjust the rheostat until the battery voltage shown by the voltmeter is 11 V.
7. Confirm that the maximum amperage is within the specifications and that the starter motor turns smoothly and freely.

**Current: max. 90 Amps**

**MAGNETIC SWITCH RETURN TEST**

1. Disconnect field coil wire from M-terminal of magnetic switch.
2. Connect a 12V battery between M-terminal and body.

**Caution**

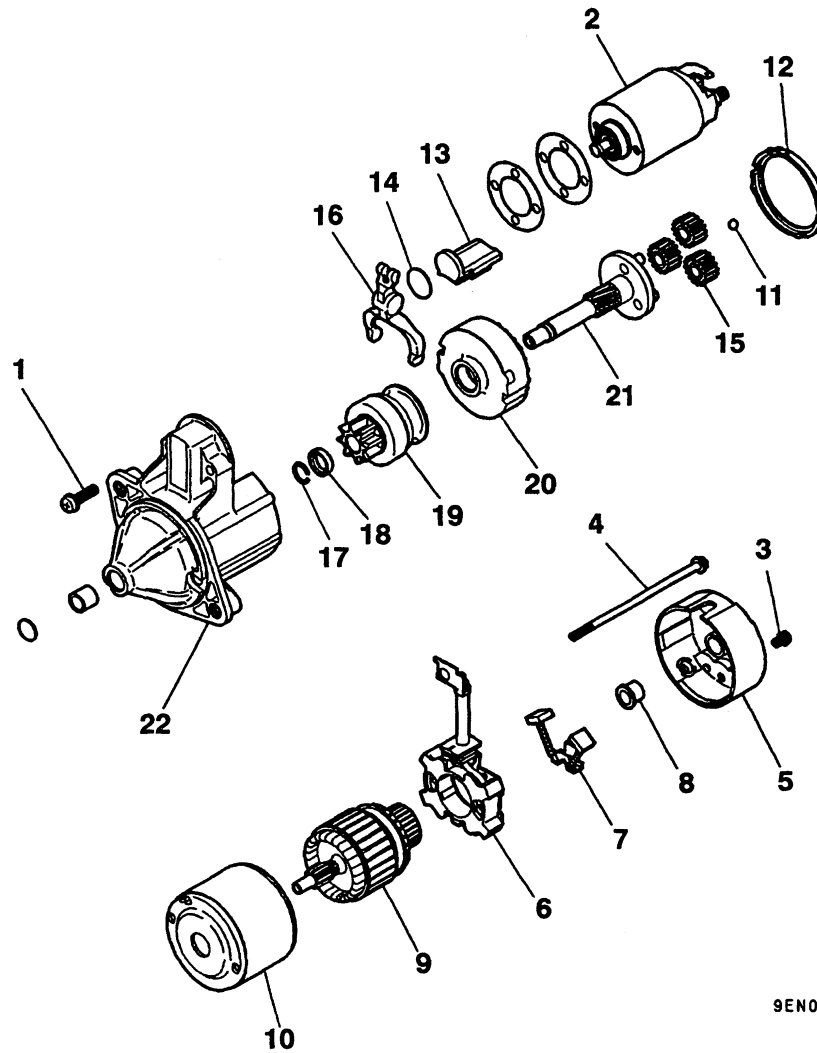
**This test must be performed quickly (in less than 10 seconds) to prevent coil from burning.**

3. Pull pinion out and release. If pinion quickly returns to its original position, everything is in order. If it doesn't, replace magnetic switch.

**Caution**

**Be careful not to get your fingers caught when pulling out the pinion.**

## DISASSEMBLY AND REASSEMBLY



9EN0541

### Disassembly steps

◀A▶

1. Screw
2. Magnetic switch
3. Screw
4. Screw
5. Rear bracket
6. Brush holder
7. Brush
8. Rear bearing
9. Armature
10. Yoke assembly
11. Ball

◀B▶

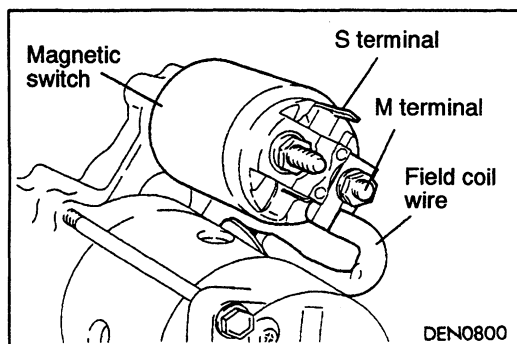
◀B▶

◀C▶  
◀C▶

▶A▶  
▶A▶

12. Packing A
13. Packing B
14. Plate
15. Planetary gear
16. Lever
17. Snap ring
18. Stop ring
19. Overrunning clutch
20. Internal gear
21. Planetary gear holder
22. Front bracket





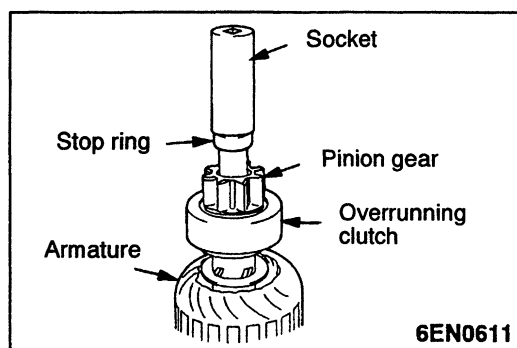
## DISASSEMBLY SERVICE POINTS

### ◀A▶ MAGNETIC SWITCH REMOVAL

Disconnect the field coil wire from terminal M of the magnetic switch.

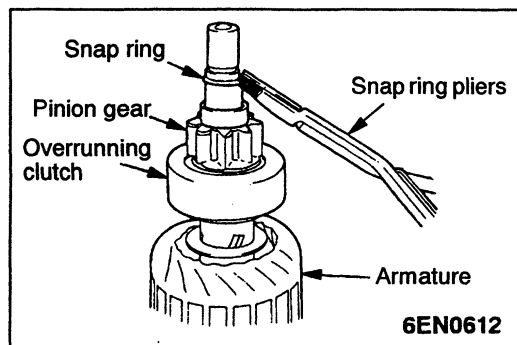
### ◀B▶ ARMATURE AND BALL REMOVAL

When removing the armature, do not lose the ball placed at the end as a bearing.



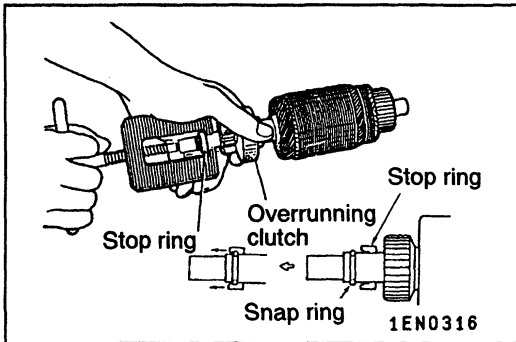
### ◀C▶ SNAP RING/STOP RING REMOVAL

1. Using an appropriate wrench socket, push the stop ring toward the overrunning clutch.
2. Remove the snap ring with snap ring pliers and then remove the stop ring and overrunning clutch.



## STARTER MOTOR PARTS CLEANING

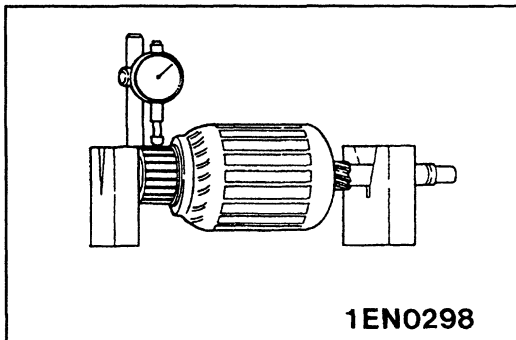
1. Do not immerse the parts in cleaning solvent. Immersing the yoke and field coil assembly and/or armature will damage insulation. Wipe these parts with a cloth only.
2. Do not immerse the drive unit in cleaning solvent. The overrunning clutch is pre-lubricated at the factory and solvent will wash lubrication from clutch.
3. The drive unit may be cleaned with a brush moistened with cleaning solvent and wiped dry with a cloth.



## REASSEMBLY SERVICE POINTS

### ►A◄ STOP RING/SNAP RING INSTALLATION

Using an appropriate tool, pull the stop ring over the snap ring.



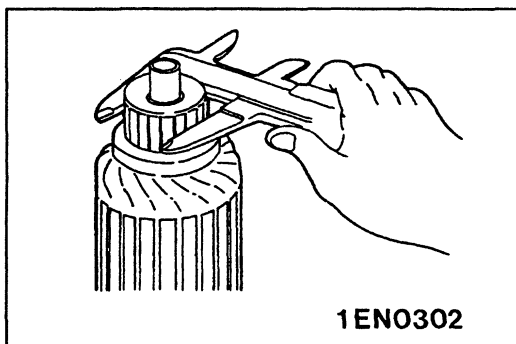
## INSPECTION

### COMMUTATOR

1. Place the armature in a pair of "V" blocks and check the runout with a dial indicator.

**Standard value: 0.05 mm**

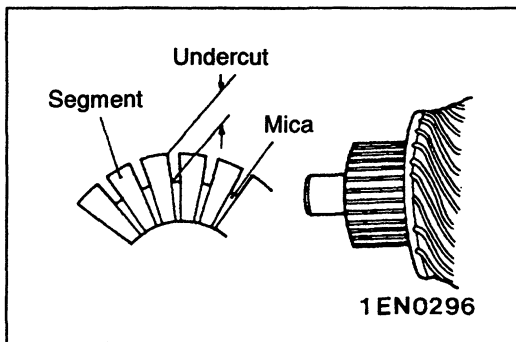
**Limit: 0.1 mm**



2. Measure the commutator outer diameter.

**Standard value: 29.4 mm**

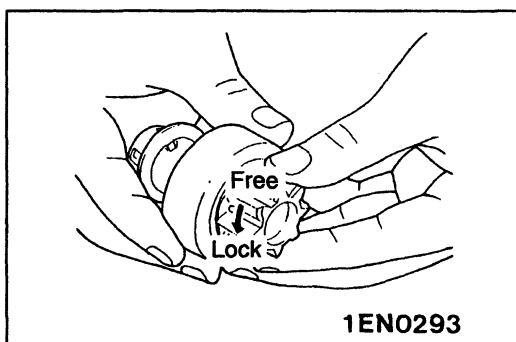
**Limit: 28.4 mm**



3. Check the undercut depth between segments.

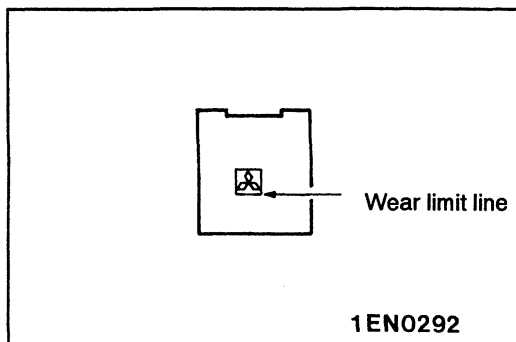
**Standard value: 0.5 mm**

**Limit: 0.2 mm**



### OVERRUNNING CLUTCH

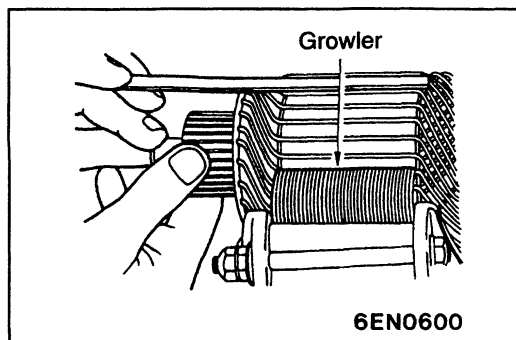
1. Check that the pinion locks when it is turned counterclockwise and moves smoothly when it is turned clockwise.
2. Check the pinion for wear or damage.

**BRUSH**

1. Check the brush for roughness of the surface that contacts the commutator and check the brush length.

**Limit: Wear limit line**

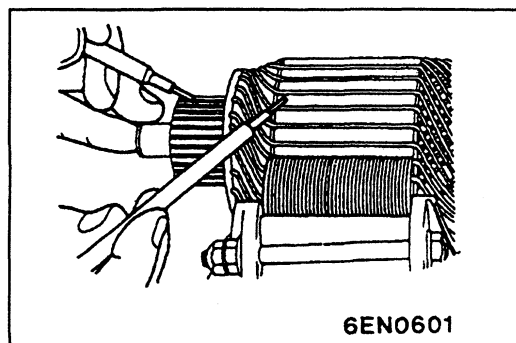
2. In case the contacting surface has been corrected or the brush has been replaced, correct the contacting surface by winding sandpaper around the commutator.

**ARMATURE COIL SHORT-CIRCUIT TEST**

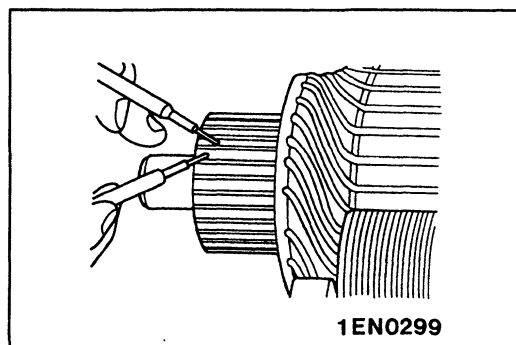
1. Place armature in a growler.
2. Hold a thin steel blade parallel and just above while rotating armature slowly in growler. A shorted armature will cause blade to vibrate and be attracted to the core. Replace shorted armature.

**Caution**

**Clean the armature surface thoroughly before checking.**



3. Check the insulation between each commutator segment and armature coil core. If there is no continuity, the insulation is in order.

**ARMATURE COIL OPEN-CIRCUIT INSPECTION**

Check the continuity between segments. If there is continuity, the coil is in order.

# IGNITION SYSTEM

## GENERAL INFORMATION

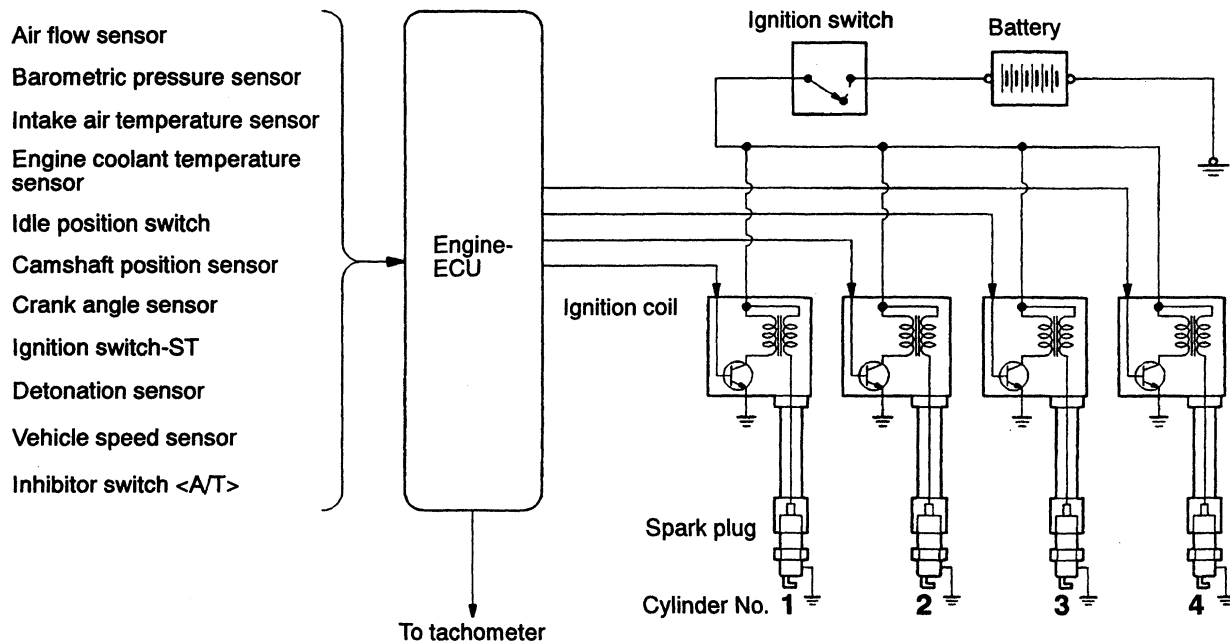
This system is equipped with four ignition coils with built-in power transistors for each of the cylinders. Interruption of the primary current flowing in the primary side of an ignition coil generates a high voltage in the secondary side of the ignition coil. The high voltage thus generated is applied to the spark plugs to generate sparks.

The engine-ECU turns the power transistors inside the ignition coils alternately on and off. This causes the primary currents in the ignition coils to be alternately interrupted and allowed to flow to fire the cylinders in the order 1 – 3 – 4 – 2.

The engine-ECU determines which ignition coil should be controlled by means of the signals from the camshaft position sensor and the crank angle sensor. It also detects the crankshaft position, in order to provide ignition at the most appropriate timing in response to the engine operation conditions.

When the engine is cold or running at high altitudes, the ignition timing is slightly advanced to provide optimum performance. Furthermore, if knocking occurs, the ignition timing is gradually retarded until knocking ceases.

## SYSTEM DIAGRAM



9FU0839

## IGNITION COIL SPECIFICATION

Items	Specification
Type	Molded 4-coil

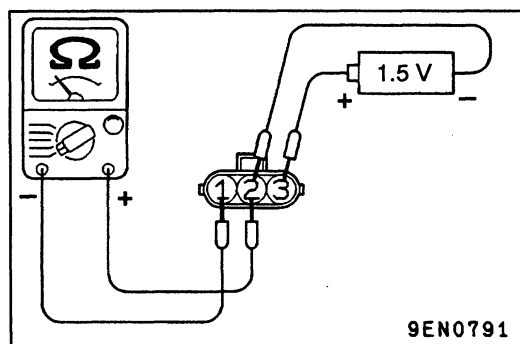
## SPARK PLUG SPECIFICATION

Items	Specification
NGK	PZFR6B

## SERVICE SPECIFICATIONS

### SPARK PLUG

Items	Standard value	Limit
Spark plug gap mm	0.5 – 0.6	0.75
Spark plug insulation resistance M $\Omega$	–	1



## ON-VEHICLE SERVICE

### POWER TRANSISTOR CONTINUITY CHECK

#### NOTE

1. An analogue-type circuit tester should be used.
2. Connect the negative (–) probe of the circuit tester to terminal 1.

#### Caution

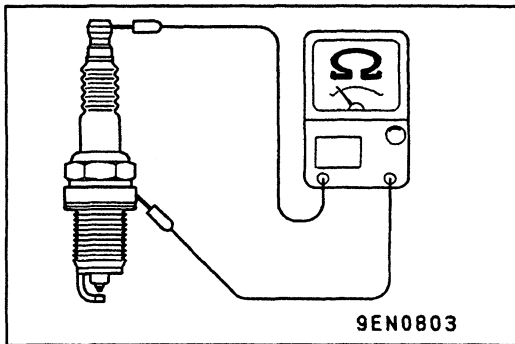
This test must be performed quickly (in less than 10 seconds) to prevent coil from burning and power transistor from breakage.

Voltage: 1.5V	Terminal No.		
	1	2	3
When current is flowing	○	⊖	⊕
When current is not flowing			

## SPARK PLUG CHECK AND CLEANING

#### Caution

1. The spark plug gap for platinum plugs should not be adjusted.
2. Cleaning platinum plugs may result in damage to the platinum tip. Therefore, if cleaning is necessary because the plug is sooty, use a plug cleaner, and do not clean the plug for more than 20 seconds in order to preserve the electrodes. A wire brush should never be used.
3. The spark plugs in GDI engines are special platinum plugs in which the electrodes can become black even when the plugs are working normally. Carbon which may become deposited on these plugs burns off more readily than with conventional plugs, and so should not cause any problems with spark plug performance. Judgement of whether a spark plug is operating normally or not should be made by checking the insulation resistance.



1. Remove the ignition coils.
2. Remove the spark plugs.
3. Check the spark plug gap. Replace the spark plug if the gap exceeds the limit.

**Limit: 0.75 mm**

**Standard value: 0.5 – 0.6 mm**

4. Measure the spark plug insulation resistance. Replace the spark plug if the measured value is lower than the limit value.

**Limit: 1 MΩ**

5. Clean the spark plug holes.
6. Install the spark plugs.
7. Install the ignition coils.

### **CAMSHAFT POSITION SENSOR CHECK**

Refer to GROUP 13J – Troubleshooting.

### **CRANK ANGLE SENSOR CHECK**

Refer to GROUP 13J – Troubleshooting.

### **DETONATION SENSOR CHECK**

Check the detonation sensor circuit if self-diagnosis code, No. 31 is shown.

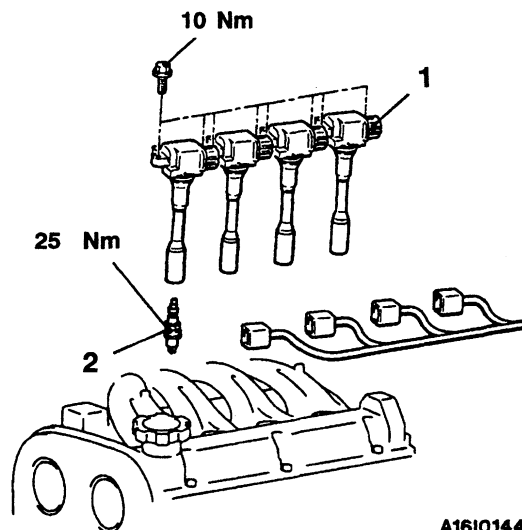
#### **NOTE**

For information concerning the self-diagnosis codes, refer to GROUP 13J – Troubleshooting.

## IGNITION COIL

### REMOVAL AND INSTALLATION

Pre-removal and Post-installation Operation  
Engine Cover Removal and Installation

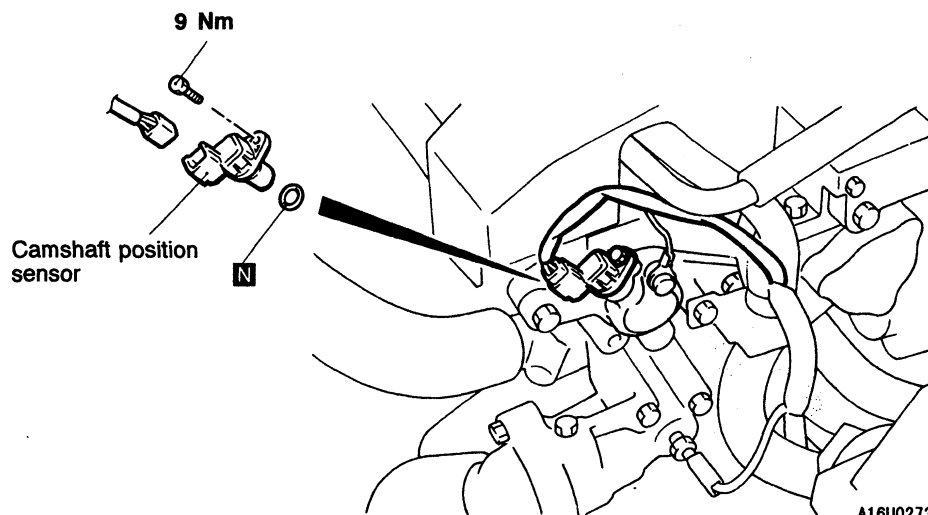


A16IO144

#### Removal steps

1. Ignition coil assembly
2. Spark plug

## CAMSHAFT POSITION SENSOR



A16U0273