Service Information

Mazda Motor Corporation
3-1, Shinchi, Fuchu-cho, Aki-gun
Hiroshima 730-8670, Japan
TEL : 81(82)287-5323
FAX : 81(82)287-5220

Category		Ref. No.	Page
T	**Technical**	E001/13A	1 of 13

Coverage	Date Issued
☐ Distributor only ■ Please inform your dealers	February 1, 2013
Please convey this information to your ☐ Director ■ General Manager ■ Warranty Dept. ■ Parts Dept. ■ Training Dept. ■ Field Rep.	Date Revised July 23, 2013

Applicable Model	Applicable Countries or Specifications
Mazda6 (GJ) with i-ELOOP	Worldwide

[Revised]
Description has been revised and some information has been added for improved understanding.

Subject: Basic knowledge on i-ELOOP

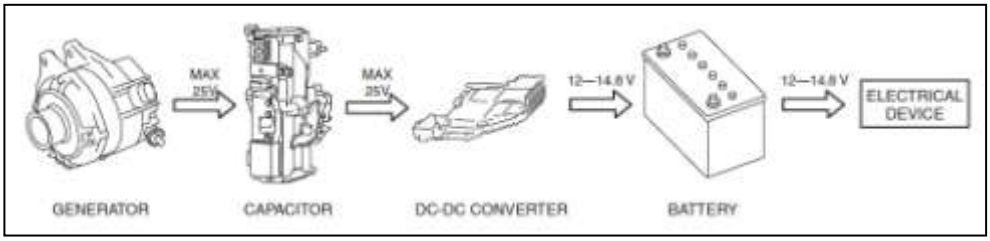
DESCRIPTION

This is to inform you of the basic knowledge and maintenance on newly-adopted i-ELOOP system.

1. Summary

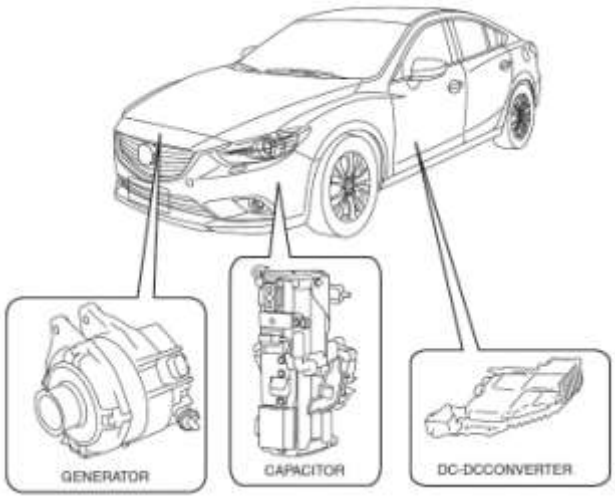
For the purpose of fuel economy improvement, electricity is generated using kinetic energy during deceleration to recover it as electrical energy which reduces amount of fuel that is used for electric supply.
The Mazda-unique regenerative braking system enables to instantly store, extract and use huge amount of energy during deceleration by using a capacitor. Through efficient energy regeneration, storage, and usage, fuel economy improvement is expected during actual driving.

[Reference]
Typically, engine consumes about ~~5-15%~~ 10% fuel for electrical generation. ~~Deceleration regeneration~~ The regenerative braking system uses kinetic energy that has been emitted in vain during deceleration and generates electricity without consuming fuel to contribute to fuel economy improvement.

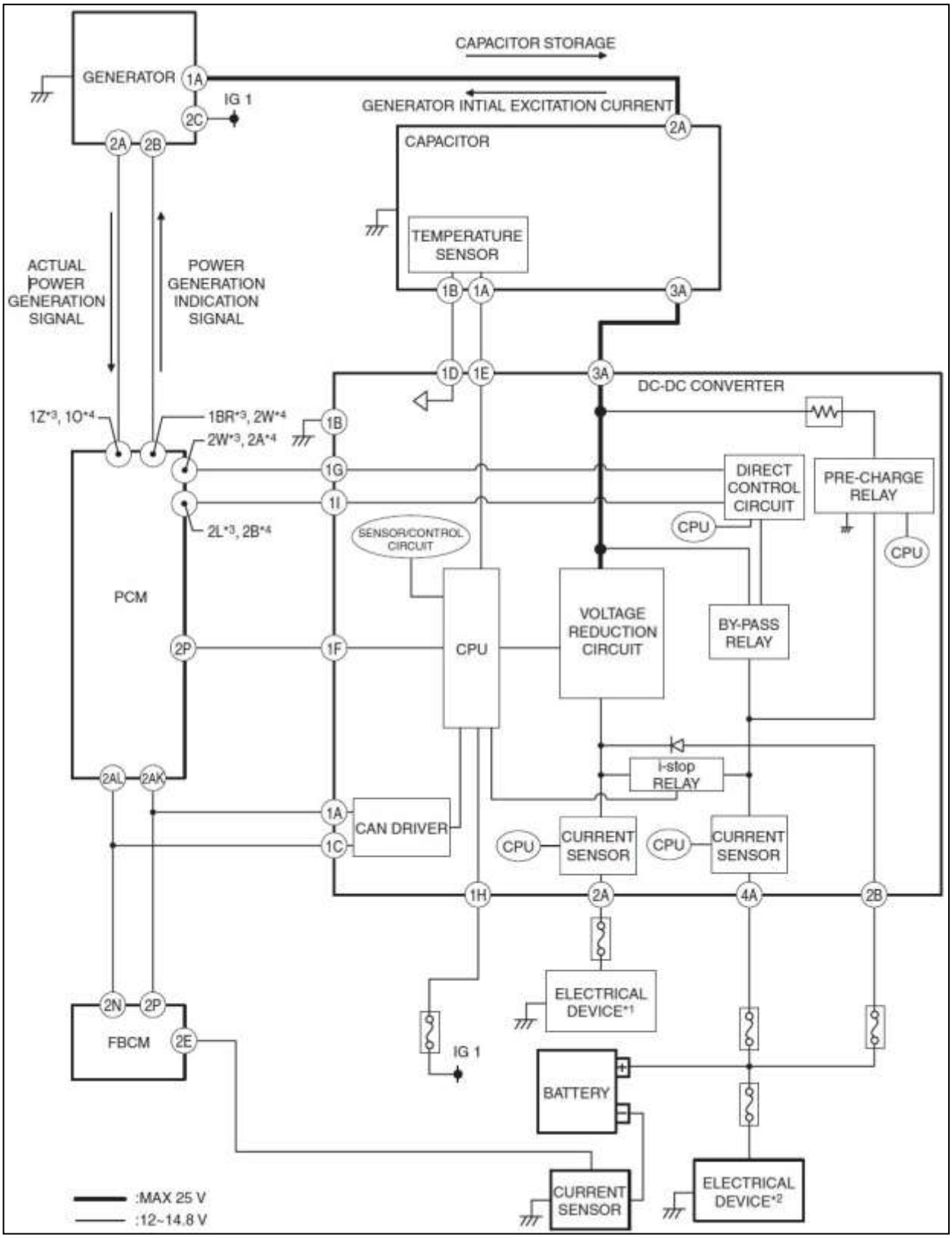


2. Structure

(1) Structural view



(2) System wiring diagram



*1: Audio amplifier, Bluetooth unit (vehicle with Bluetooth system), audio unit, climate control unit (vehicle with auto A/C), parking sensor control module (vehicle with parking sensor system), instrument cluster, rear mount camera, clock (vehicle with manual A/C)
*2: Electrical devices other than electrical device *1
*3: SKYACTIV-G 2.0, SKYACTIV-G 2.5
*4: SKYACTIV-D 2.2

(3) Detail of components

Generator

It is a variable-voltage type generator that can generate a voltage of 25V at the maximum.
During normal operation 12 V are generated.
During deceleration, 12-25 V are generated to charge the capacitor.
~~PCM is monitoring the capacitor voltage and electricity is generated when PCM concludes that capacitor voltage decreases.~~
It generates electricity of 12-25 V using kinetic energy during deceleration (at more than 40Km/h with the accelerator pedal OFF). It doesn't generate electricity during engine idling or acceleration. However, when the capacitor and/or the battery voltage drop, it generates necessary amount of electricity by using fuel.

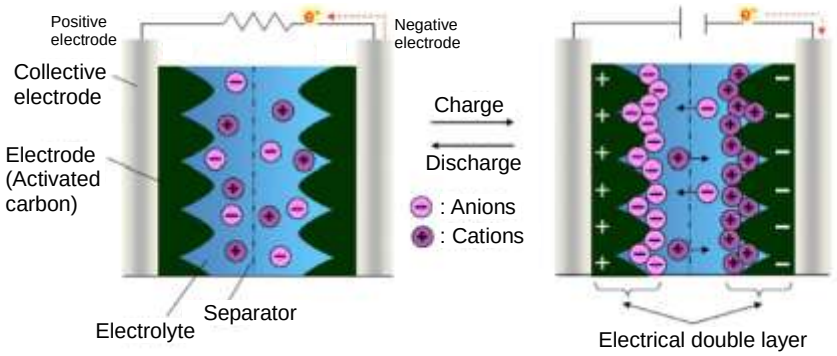
Capacitor

10 electrical accumulators (electrical double-layer capacitor) that can charge/discharge high current instantly are connected in series. 25V charge can be physically stored.
Degradation due to charge/discharge is few and it can endure about 1 million times of rapid charge/discharge cycles.

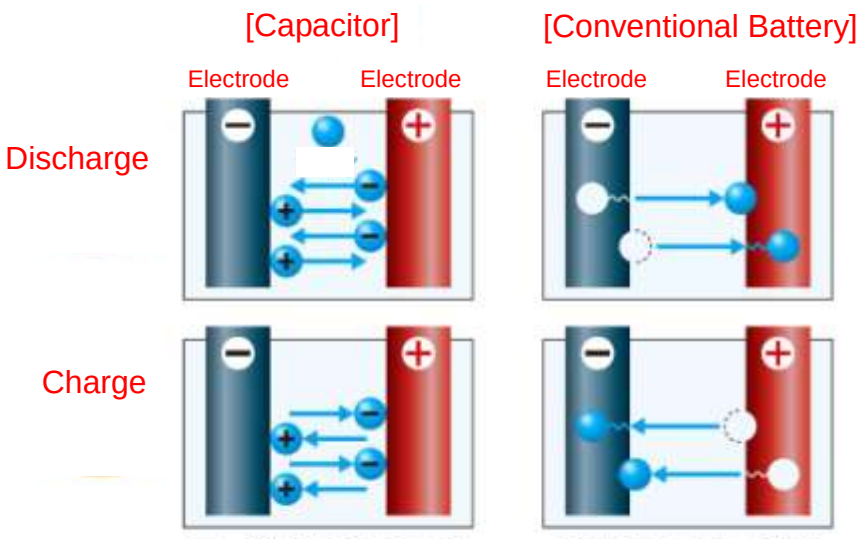
Charge characteristic

It is an electricity storage device like a large condenser and it stores electricity by using the principle of electric double-layer.

Charge/Discharge action of the capacitor



Differences from conventional battery



Ions move up to the surface of electrodes only. Ions are physically tossed back and forth between two electrodes, so it will less deteriorate and can achieve long life.

Ions move up to inside the electrodes. Ions move in and out by melting the electrodes with chemical reaction, and so it accelerates deterioration.

Characteristics comparison between Capacitor and Lithium Ion Battery/ Zinc Battery

	Capacitor	Lithium Ion Battery	Battery (Zinc Battery)	Merit of Capacitor
Charging Time	◎	△ In comparison to Capacitor, it takes 3 times as more time.	× In comparison to Capacitor, it takes 8 times as more time.	It can store large quantities of electricity instantly.
Charging ability (Amount of electricity store-able at a time)	◎ No influence to life	△ Influence to battery life (1/3 in comparison to Capacitor)	△ Influence to battery life (1/8 in comparison to Capacitor)	
Heavy metal (Environmental impact)	◎ Not used	× Used	× Used	Harmless activated charcoal is used.
Safety	◎ Less smoke evolution and ignitible	× Smoke-able and ignitible	× Diluted sulfuric acid is used.	
Charge/ discharge cycle	◎ More than million times	× 30,000 – 70,000 times	× 30,000 – 50,000 times	It will not deteriorate for long period of use.
Operating ambient temperature	◎ -40 ~ 85℃	○ -10 ~ 60℃	× 0 ~ 40℃	
Capacity	×	◎	○	
Power density (Amount of electricity discharge-able at a time)	◎	○	×	It can supply large quantities of electricity instantly.

DC-DC converter
When the generator produces the maximum voltage (25V), it is reduced to 12V with DC-DC converter so that applicable voltage can be supplied to electrical devices.

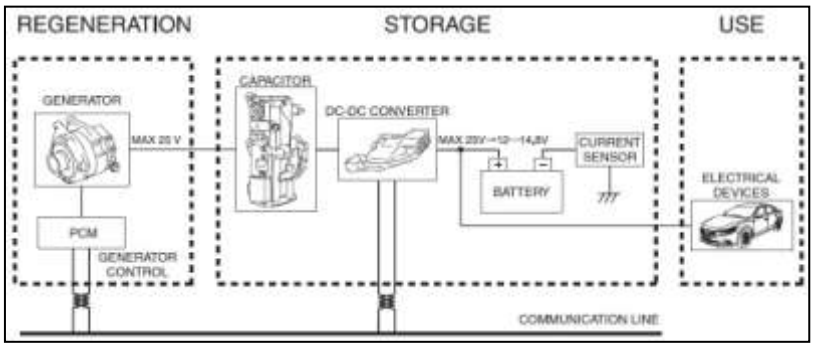
[During regeneration]
14-25V voltage stored in the capacitor is converted through DC-DC converter.

[During i-stop]
During i-stop, capacitor voltage is converted to 11.5 to 12.5V by DC-DC converter.
When restarting the engine, i-stop relay is turned off to retain source voltage of meter/audio systems ~~that lie~~ located in a downstream of the DC-DC converter.
Power source for other electrical devices such as starter is supplied from the battery.

[If consumption current is 50A or more]
If consumption current of vehicle electric devices exceeds 50A or more, bypass relay is turned on to supply voltage generated by generator (14.8V) to those electrical devices directly.
In this case, movement of i-ELOOP gauge on the combination meter becomes slow, but this is not a failure.

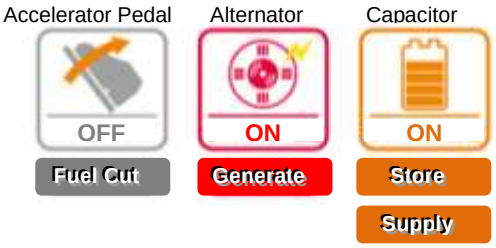
3. Operation

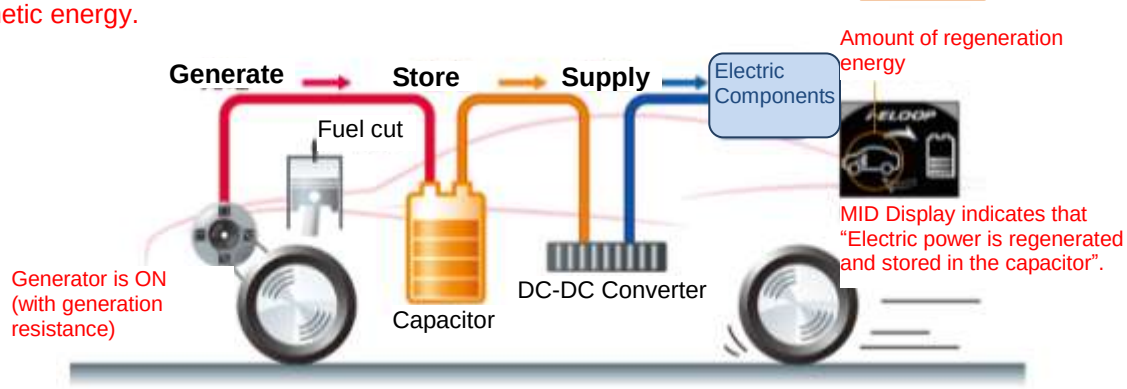
The i-ELOOP operation mode varies depending on the vehicle driving condition and status of electrical devices related to i-ELOOP system.
When the driver lifts his/her foot off the accelerator pedal, variable voltage-type generator generates electricity to store it in the capacitor. It takes only a few seconds to charge the capacitor to the full. Voltage of electricity stored in the capacitor is reduced to 12V with DC/DC converter for power supply to various electric devices.



During Regeneration

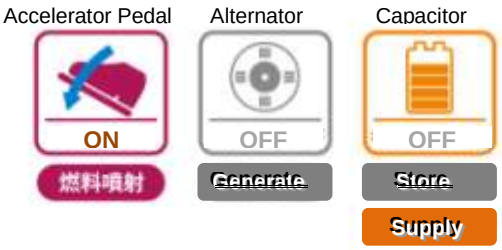
[Electricity is generated without using fuel]
When a vehicle is running with the accelerator pedal OFF at deceleration or downhill, electricity is generated using kinetic energy.

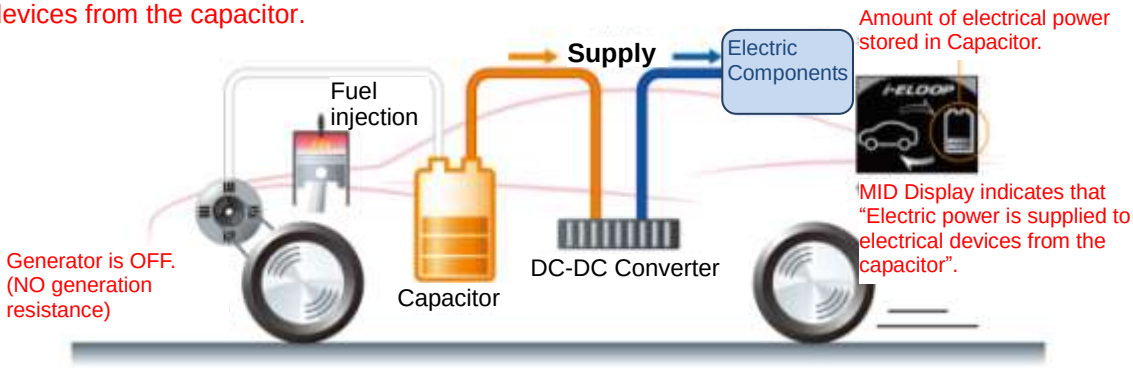




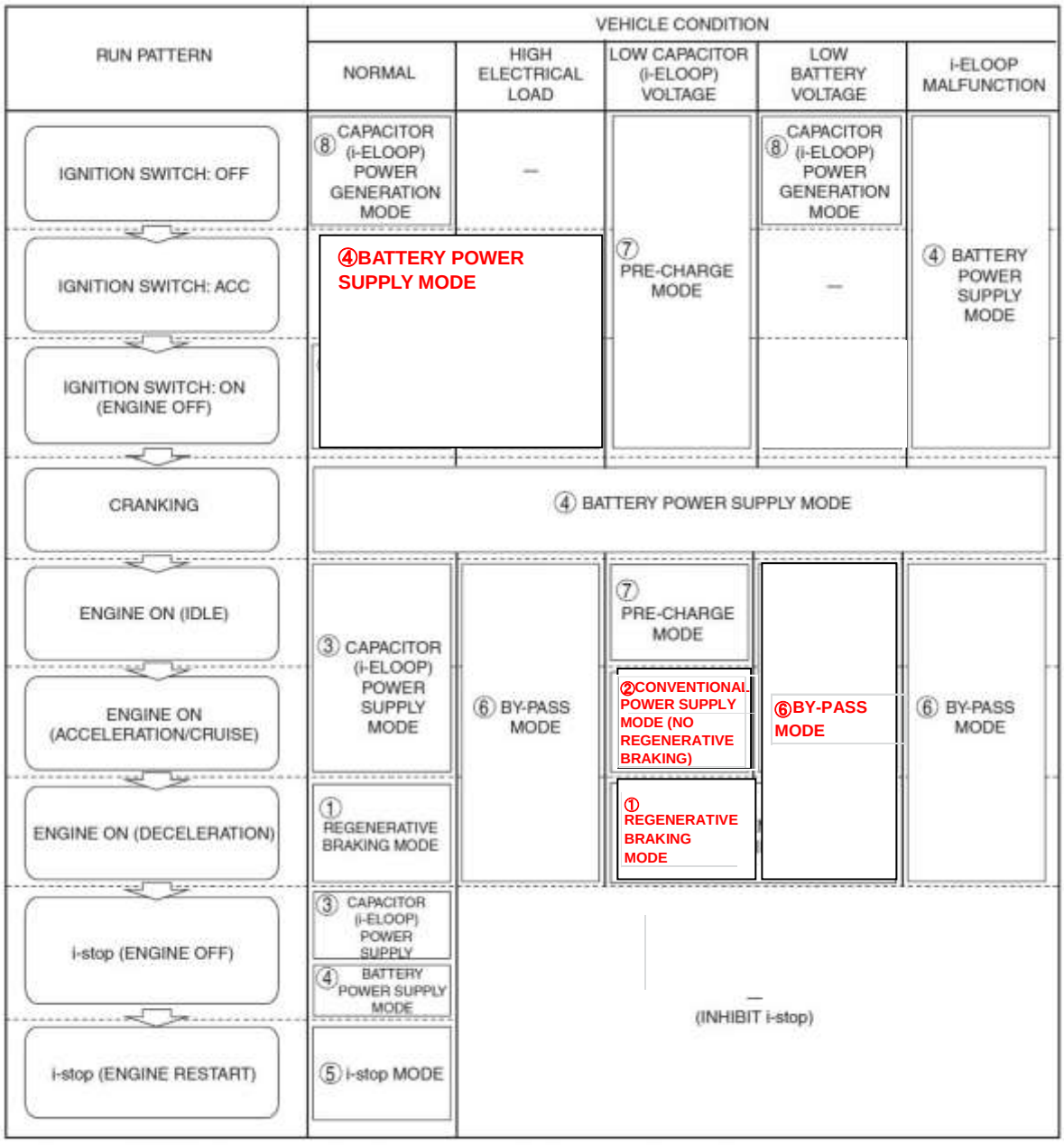
During Normal Driving

[Deduction of load applied to engine]
When a vehicle is normal running with the accelerator pedal ON, operation of the generator is stopped to reduce generation resistance and to improve fuel economy. Electric power is supplied to electrical devices from the capacitor.





The following are examples of i-ELOOP operation in each mode.

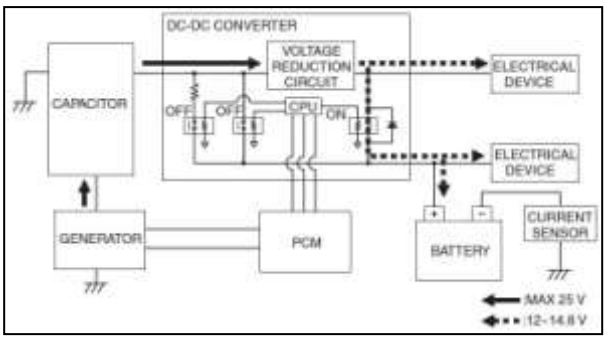


* : ONLY WHEN VOLTAGE REDUCTION OPERATION INDICATION IS OUTPUT FROM PCM

(1) Regenerative braking mode

During fuel-cut by release of accelerator pedal and TCC engagement, the generator is activated to provide electricity to the capacitor. ~~Voltage~~ Electricity stored in the capacitor is ~~reduced~~ regulated ~~at~~ by the DC-DC converter for and, is supplied to each vehicle electrical ~~part~~ device.

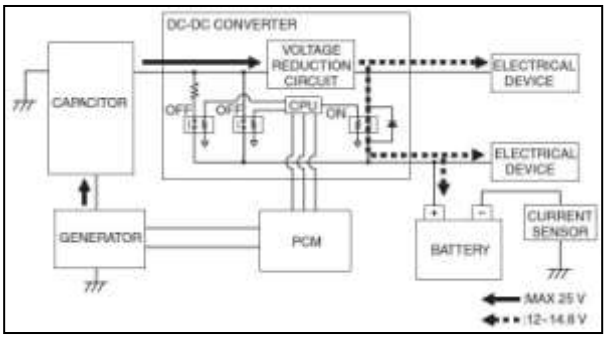
~~To prevent deceleration electricity from increasing due to power generation, such power generation is controlled by PCM.~~



(2) Conventional power generation mode (no regenerative braking)

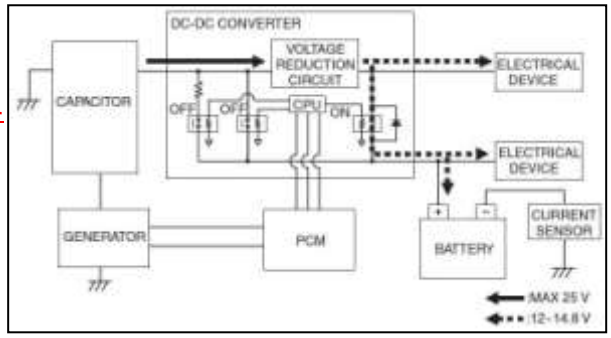
When battery voltage becomes 14V or less while engine running, the generator is activated to ~~store~~ provide 12 to 25V electricity to the capacitor. ~~Voltage~~ Electricity stored in the capacitor is ~~reduced~~ with DC-DC converter for power-supply to each vehicle electrical device.

Generator's output is lower than that of the regenerative power generation mode.



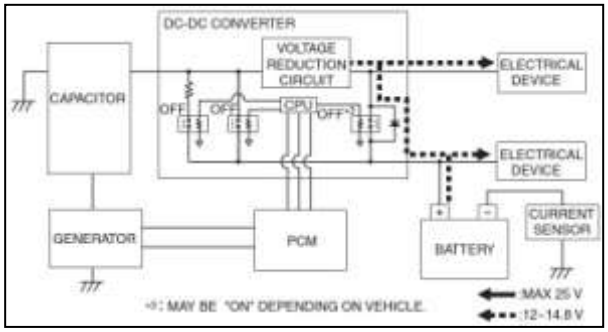
(3) Capacitor (i-ELOOP) power supply mode

If capacitor voltage exceeds battery voltage, ~~voltage~~ electricity stored in the capacitor is ~~reduced~~ regulated ~~with~~ by DC-DC converter ~~for applicable power-supply~~ and is supplied to each electrical device (IG1, IG2 power source) on the vehicle.



(4) Battery power supply mode

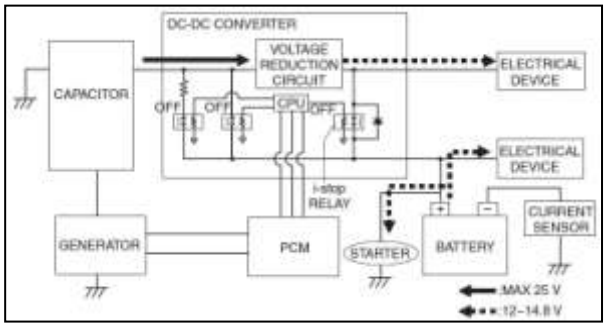
In case capacitor voltage falls below the ~~capacitor's designed minimum voltage~~ certain threshold (which varies 14-17.5V depending on the capacitor's degradation condition) during i-stop operation, or in case of cranking, electrical power is supplied from the battery to each electrical device on the vehicle.



(5) i-stop mode (Engine restart)

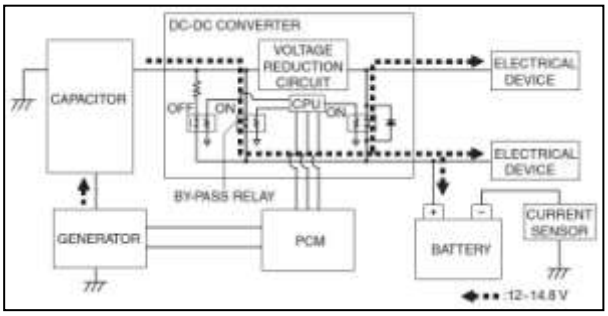
The i-stop relay in the DC-DC converter is shut off during engine restart to avoid ~~supply of electrical power from the capacitor to the battery, as battery voltage has been reduced due to cranking~~ the capacitor supplies electricity to the voltage-lowered battery due to cranking.

Electrical power source is split into battery and capacitor to ensure electrical power is supplied to meter/audio system etc.



(6) By-pass mode

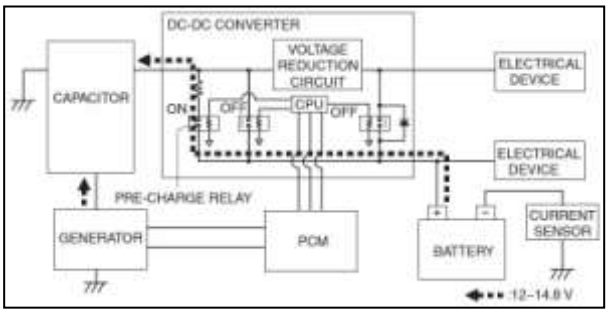
When vehicle electrical load (consumption current) exceeds 50A or more, bypass relay within DC-DC converter is turned on ~~for supplying~~ to supply electricity generated by the generator to each electrical devices directly.
In case the voltage reduction circuit on the DC-DC convertor is failed, or in case ~~it is~~ the CPU anticipates the battery voltage ~~cannot guarantee minimum~~ drops below 11V, ~~it is switched to bypass mode~~. the bypass mode is activated.



[Reference]
During the bypass mode, verification is not possible using the instrument cluster indication.
Only as a guide, the amount of electricity generated will be “Level 3” and the amount of electricity stored in the capacitor will be “Level 1”.

(7) Pre-charge mode

If the vehicle is left for a long time without running the engine, or if the capacitor is self-discharged ~~of capacitor~~, such as excessive dark current is continued, capacitor’s voltage decreases. In such case, electrical power is supplied from the battery or the generator to the capacitor due to the following reasons.



1) To secure generator’s initial excitation current that is supplied from the capacitor.
2) In order to supply electrical power source from the capacitor, capacitor’s electric potential needs to be higher than that of the battery.

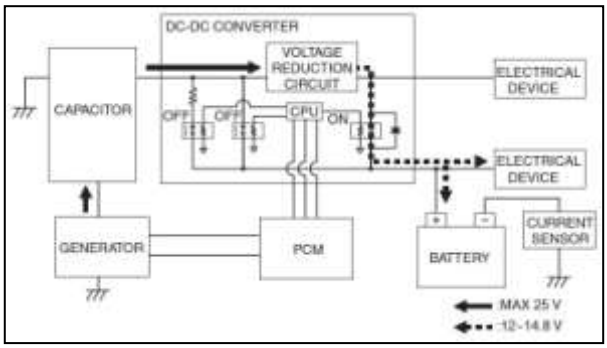
Operation is different depending on the condition.

Capacitor voltage	Ignition switch: ON → OFF (Engine ON or OFF)	Ignition switch: ON (Engine ON or OFF)	Instrument cluster display
3.5V or less (Due to ensuring initial exciting voltage of the generator.)	The capacitor is charged up to 3.5V from the battery by control of the DC-DC converter.	The capacitor is charged up to 4.5V from the battery by control of the PCM.	~~Applicable~~ · A message is displayed when the voltage of the capacitor is 9.5V or less and the engine is started. · A message won’t be displayed when the DC-DC converter supplies the voltage. · A message is displayed for 3 seconds as the minimum.
3.5V – 9.5V (Due to outputting the current from DC-DC converter.)	The capacitor isn’t charged from the battery. (Because the generator can be operating when the engine on.)		
9.5V or more			Not applicable

It stops when capacitor voltage is increased with electric voltage delivered from DC-DC converter.

(8) Capacitor (i-ELOOP) power generation mode

When capacitor voltage exceeds 20V or more (16V or more if battery output is decreased) with engine switch OFF + bonnet closed, extra voltage owned by the capacitor is charged to the battery.



(9) Fail-safe Mode

When i-ELOOP system is failed, it is switched to the By-pass Mode. However, depending on the failed condition, there is a possibility that electric power generated by the generator is not supplied to the battery and vehicle electrical devices. In this case, electric power is supplied only from the battery and so the engine may stall if the battery power drops.

When a vehicle, with a message "Charging System Inspection Required" message on TFT-LCD or “charging system warning light illumination” for the vehicle without TFT-LCD, is brought into workshop, troubleshoot the applicable DTC following the instructions in the Workshop Manual. If the specific gravity of battery is found to be less than specification, charge the battery according to the instructions in Service Information E039/12A and/or the Workshop Manual.

(10) How to confirm i-ELOOP operation mode by using M-MDS

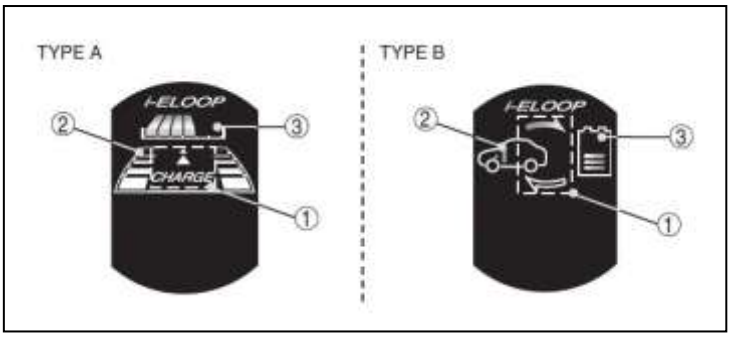
i-ELOOP operation mode can be confirmed by verifying PIDs value.

(1) Select “DataLogger”.
(2) Select “Modules”.
(3) Select “DCDC”.
(4) Select the PIDs in the following table from the PID table.

PID / MODE	BYPS_STAT State of Bypass circuit within DC-DC Converter (i-ELOOP)	DCDC_IN_V DCDC Input Voltage (Input Terminal Voltage)	CONV_STAT State of Converter circuit within DC-DC Converter (i-ELOOP)	IR_SW_STAT State of IR circuit within DC-DC Converter (i-ELOOP)	IR_LOAD_I Output Current to compensating load at IR	CONV_OUT_V Converter circuit Output Voltage	DCDC_OUT_I DC-DC converter (i-ELOOP) output current	DCDC_OUT_V DC-DC converter (i-ELOOP) output voltage
Regenerative Braking Mode	Bypass-Off	Voltage increase from more than approx. 14.5V.	Power Output (Normal)	Connect (ON)	Output	Output (approx. 14V)	Output	Output (approx. 14V)
Capacitor Power Supply Mode	Bypass-Off	Voltage decrease from more than approx. 14.5V.	Power Output (Normal)	Connect (ON)	Output	Output (approx. 14V)	Output	Output (approx. 14V)
Conventional Power Generation Mode (no regenerative braking)	Bypass-Off	Voltage is constant for approx. 14~15V	Power Output (Normal)	Connect (ON)	Output	Output (approx. 14V)	Output	Output (approx. 14V)
Battery Power Supply Mode	Bypass-Off	During i-Stop: approx.14V Other than i-Stop: Input	Power Output (Stop)	Disconnect (OFF)	Output	Output (Battery voltage)	0A	Output (Battery voltage)
i-stop Mode (Engine restart)	Bypass-Off	Input (More than approx. 14V)	Power Output (Normal)	Disconnect (OFF)	Output	Output (approx. 13V)	Output	Output (Battery voltage)
By-pass Mode	Bypass-On	Voltage is constant for approx. 14~15V	Just before By-pass Mode: Power Output (Limit) During By-pass Mode: Power Output (Stop)	Connect (ON)	Output	Output (approx. 14V)	Output	Output (approx. 14V)
Pre-charge Mode	Bypass-Off	Voltage gradually increase from less than 9.5V.	Power Output (Stopl)	Disconnect (OFF)	Output	Output (Battery voltage)	0A	Output (Battery voltage)
Capacitor (i-ELOOP) Power Generation Mode	The status cannot be monitored by using M-MDS because the mode operates after the ignition switch is turned off.							

4. Instrument cluster display

PCM sends ~~a signal~~ to the combination meter ~~in terms~~ a signal of Regenerative power generation condition through i-ELOOP /Output of regenerative power generation/ Capacitor ~~storage. Then information related~~ to display i-ELOOP information. ~~is indicated on the liquid crystal screen.~~



No.	Name	Condition
①	Regenerative braking power generation condition gauge	Displays the direction in which power is moving from the regenerative braking power generation.
②	Regenerative braking power generation amount gauge	Displays the amount of power generated by regenerative braking.
③	Capacitor accumulation amount gauge	Displays the amount of electrical power stored in the capacitor.

To indicate capacitor storage, amount of electric energy stored in the capacitor is calculated based on DC-DC converter input terminal voltage and electric current sensor within DC-DC converter etc.

I-ELOOP display may be fixed depending on situation like during By-pass mode.

Display	Reasons
Capacitor accumulation amount gauge indicates “Level1 (1 bar)”. (The amount of electrical power stored in the capacitor doesn’t increase.)	When consumption current by vehicle electric devices is large, regenerative braking power is directly used for them and so it comes into a state that the amount of electrical power stored in the capacitor will not increase.
Regenerative braking power generation amount gauge doesn’t indicates “Level 5 (5 bar)”but indicates “Level 3 (3 bar)”.	When consumption current is large (when it is hard to store regenerative braking power in the capacitor) or depending on the battery condition, regenerative braking power generation amount gauge indicates lower level.
Movement of Capacitor accumulation amount gauge is slow. (When consumption current is large.)	When consumption current by vehicle electric devices is large, regenerative braking power is directly used for them and so it comes slow to store regenerative braking power in the capacitor.
Movement of Capacitor accumulation amount gauge is slow. (At low engine coolant/oil temperatures/low vehicle speeds)	At low engine coolant/oil temperatures or low vehicle speeds, deceleration feeling by engine braking increases. To compensate this condition, regenerative braking power is controlled to reduce and so movement of Capacitor accumulation amount gauge becomes slow.

5. i-stop operating condition

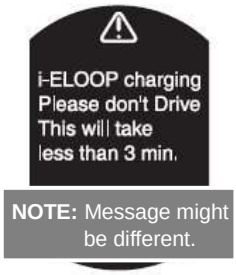
Different or additional i-stop operating conditions compared to other models due to i-ELOOP installation are as follows.

DC-DC converter (i-ELOOP) PWR3 output current	25 A or less
i-ELOOP bypass mode operational condition	Not DC-DC converter overheats condition. （If it's overheat condition, bypass mode is activated.）
Capacitor voltage	Capacitor voltage has to be more than the capacitor's designed minimum voltage(14～17.5V).

6. In case vehicle isn't driven for a long time (about 1 month), ~~and~~ or in case of capacitor replacement

In case capacitor self-discharge is continued (vehicle left for a long time without running the engine)/dark current is excessive, voltage stored in the capacitor decreases. In order to supply electrical power from the capacitor, capacitor's electric ~~charge~~ voltage needs to be higher than that of the battery. Therefore, pre-charge mode starts to charge the capacitor as described the above.

During pre-charge mode, the message shown on liquid crystal screen in the meter is changed as shown on the right.
It takes several to 30 seconds to complete charging. During charging (until the message on screen disappears), electric power is supplied only from the battery. Then, you may feel the electric power steering operation is heavy depending on the battery condition. That's why we recommend users not to drive the vehicle during charging period. If you drive the vehicle, you will hear warning tone. Also, if message on the liquid screen isn't turned off ~~regardless~~ despite of waiting 3 minutes or more, it indicates a system malfunction, and turn the master warning lamp on.



NOTE: Message might be different.

When pre-charge mode is activated, you can ~~see~~ read the mileage as of pre-charge occurrence by monitoring PCM data "PRE_CHG_DIS" with M-MDS.
When capacitor is replaced, pre-charge mode is activated because voltage in the capacitor is low.

If you use the vehicle as demonstration car, be sure to charge the battery regularly as usual. Capacitor is charged only through supply from the generator. If you want to prevent the vehicle from going into the pre-charge mode, start the engine once per two weeks and push the accelerator pedal several times to charge the capacitor.

7. How to fix dead battery

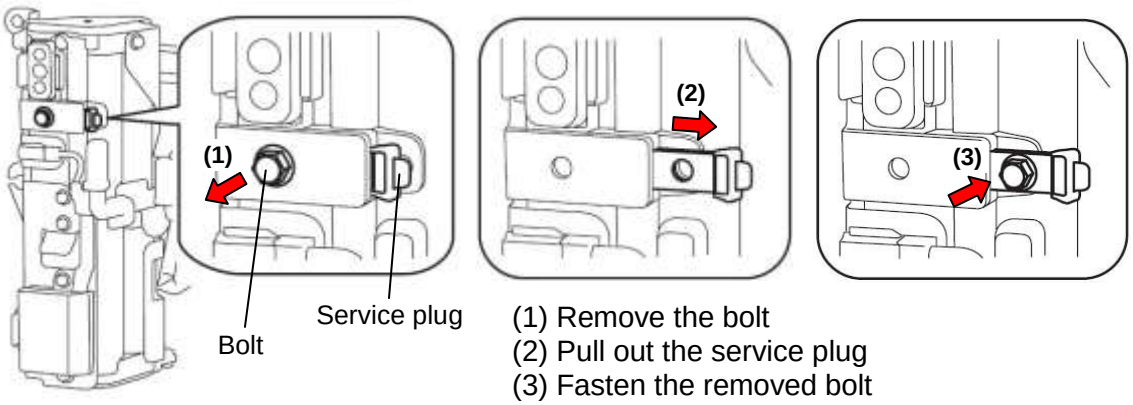
If the battery is completely discharged due to lights not being turned off mistakenly etc. and you jump-start the engine with the booster cables, make sure the cables are connected for 3 minutes approximately even after the engine starts, ~~in order to wait~~ until the battery voltage is raised. If you start the engine, remove the booster cables and drive the car immediately while battery voltage is still low, DTC ~~showing~~ related to voltage decrease, is stored.

Note: After the engine is started, DO NOT leave the engine at idling for more than 30 minutes for charging the battery. Gas may generate and the battery fluid may spill out caused by the gas generation. ~~causing paint damage.~~

8. Things to keep in mind during maintenance work

If terminals of the following i-ELOOP related parts ~~hit~~ touch with the vehicle body or something with the capacitor service plug installed, it may cause fire or failure of electrical parts. When you separate the ~~as shown in below~~ terminals detailed below, be sure to remove the capacitor's service plug before the separation.

- Capacitor's battery cable terminal
- Capacitor's engine harness terminal
- DC-DC converter's battery cable terminal
- Generator B terminal

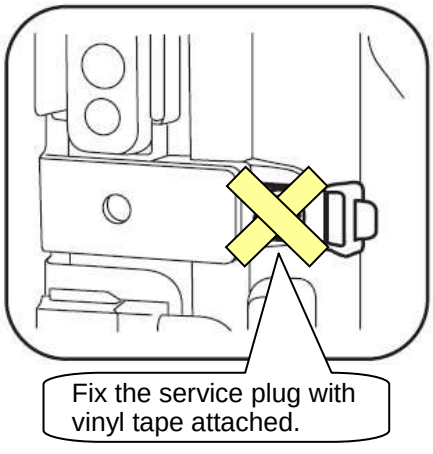


(1) Remove the bolt
(2) Pull out the service plug
(3) Fasten the removed bolt

When you ~~cause~~ made a short circuit by mistake, replace the fuse on top of the service plug because ~~such~~ the fuse is melted.

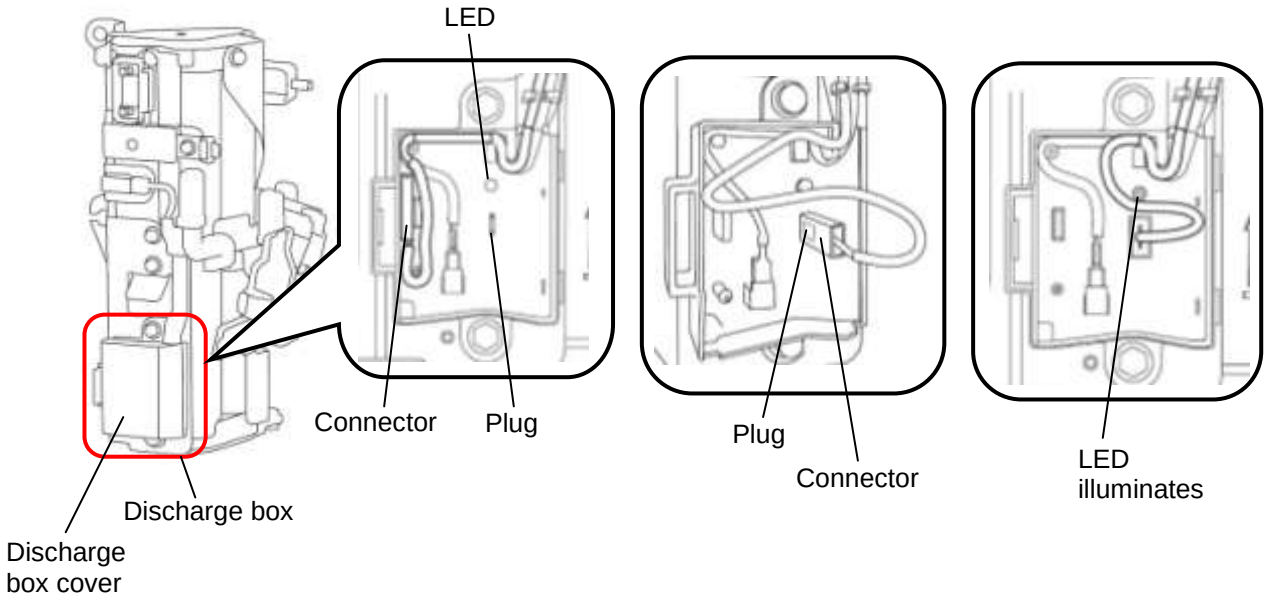
9. Things to keep in mind when storing/transporting capacitor

- If the capacitor is stored as a part (new part, replacement part for claim), please follow the precautions described on the packaging box. If it's stored in laterally-facing or downward-facing directions, electrolyte solution in the capacitor may flow into pressure regulation valve, which may cause valve seizure.
- Avoid agitation of parts
  If part is dropped and seems to have breakage or deformation on the surface, replace it.
- Service parts are delivered with short wiring harness attached to prevent a static electrification.
  Remove the short wiring harness after the part is installed on the vehicle.
- If it is kept and sent as warranty claim parts, remove the service plug, fix it with the removed bolt, fasten the area around bolt with vinyl tape etc., and store it in the original packaging., because the installation bolt may be removed during transportation, which may make the service plug to go back to the original position.
- Capacitor that is stocked as repair part must be used within 2 years after production date.
  Production date is indicated on the outer case of the repair part.



10. Capacitor disposal

Capacitor reserves electric charge as the battery does.
If the vehicle or the part is discarded (disassembled) while the capacitor (i-ELOOP) is still charged with electricity, spark or fire may occur due to electricity stored in the capacitor. When you dispose the vehicle or the part, be sure to conduct the forcible discharge of the capacitor as follows before disposal.



(1) Remove the discharge box cover.
(2) Connect the connector in the discharge box to the plug.
(3) Verify that the LED which displays during discharging is displayed.
(4) Verify that the LED turns off.
(5) Dispose the capacitor.

Ryu Shimizugawa
Manager, Technical Information Gr.
Technical Service Dept.
Mazda Motor Corporation