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
G	Technical	E001/13	1 of 9

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

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

Subject: Basic knowledge on i-ELOOP

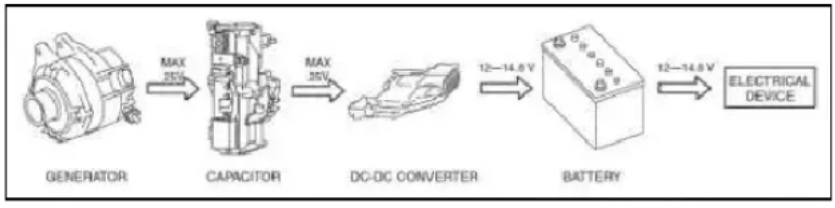
DESCRIPTION

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

1. Summary

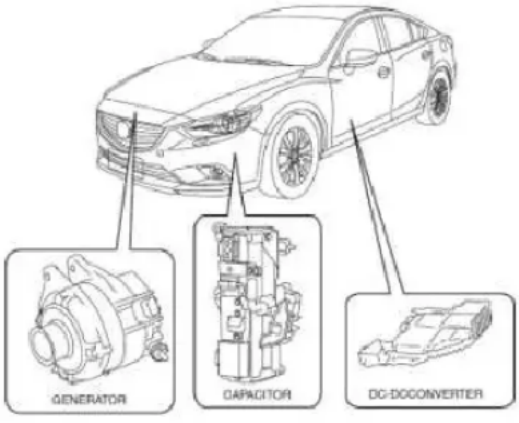
For the purpose of fuel economy improvement, electricity is generated using kinetic energy during deceleration to recover it as electrical energy which reduces amount of fuel that is used for electric supply.
The Mazda-unique regenerative braking system enables us to store, extract and use huge amount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

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

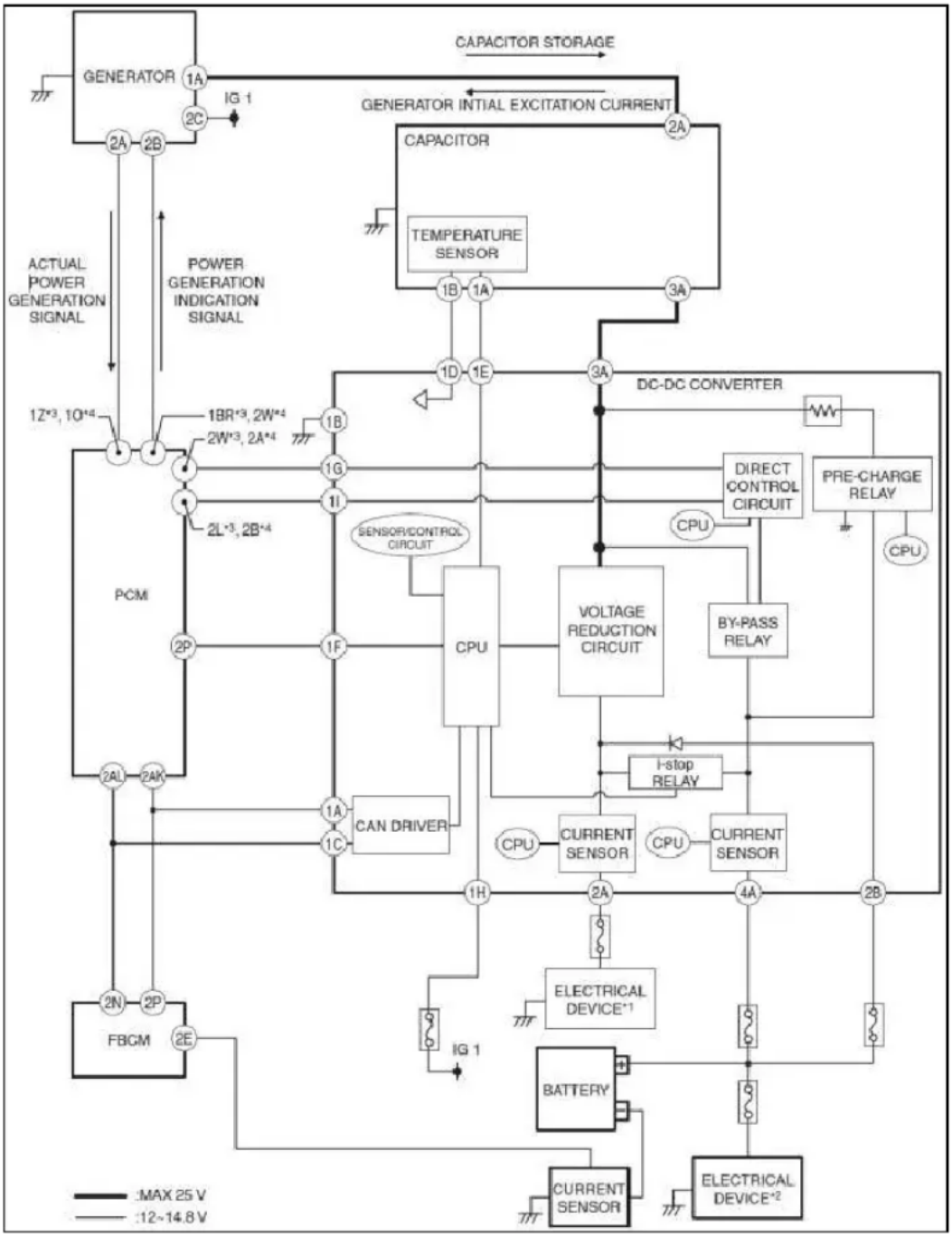


2. Structure

(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

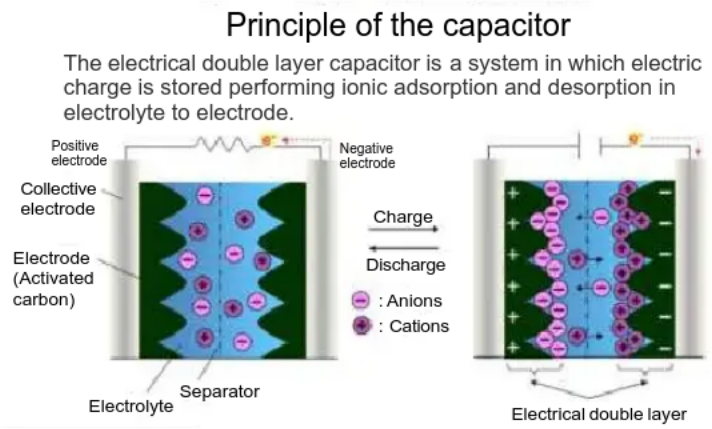
(3) Detail of components

Generator

It is a variable-voltage generator that can generate a voltage of 12-25V during deceleration to charge the capacitor. At normal operation 12 V are generated.
PCM is monitoring the capacitor voltage and electricity is generated when PCM concludes that capacitor voltage decreases.

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.
As ion molecules store electric charge, degradation due to charge/discharge is few.
It can endure about 1 million times of rapid charge/discharge cycles.



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 downstream of DC-DC converter.
Power source for other electrical devices such as starter is supplied from the battery.

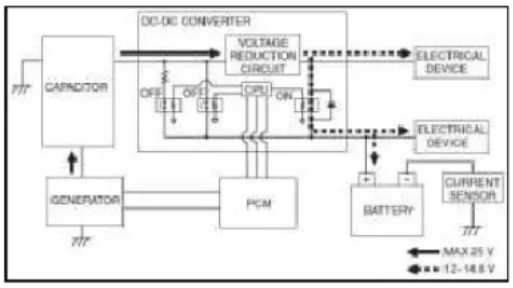
[If consumption current is 50A or more]
If consumption current of vehicle electrical devices exceeds 50A or more, bypass relay is turned on to supply voltage generated by generator (14.8V) to those electrical devices directly.
In this case, movement of i-ELOOP gauge on the combination meter becomes slow,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

3. Operation

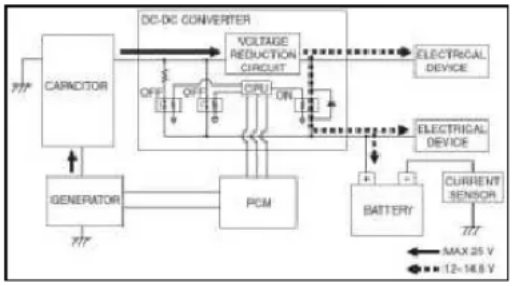
The i-ELOOP operation mode varies depending on the vehicle driving condition and status of electrical devices related to i-ELOOP system.
When the driver lifts his/her foot off the accelerator pedal, variable voltage-type generator generates electricity to store it in the capacitor. It takes only a few 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.

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

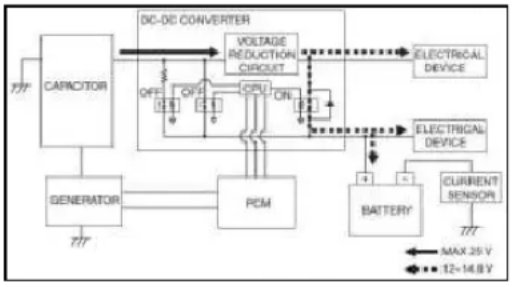
(1) Regenerative braking mode
During fuel-cut by release of accelerator pedal and TCC (Torque Converter Clutch) engagement, generator is activated to store electricity to the capacitor. Voltage stored in the capacitor is reduced at DC-DC converter to for power-supply to each vehicle part.
To prevent deceleration electricity from increasing due to power generation, such power generation is controlled by PCM.



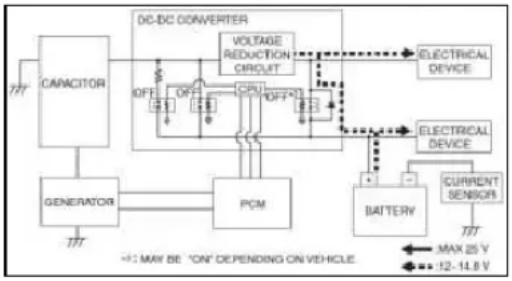
(2) Conventional power generation mode (no regenerative braking)
When battery voltage becomes 14V or less while engine running, generator is activated to store 12 to 25V electricity to the capacitor. Voltage stored in the capacitor is reduced with DC-DC converter for power-supply to each vehicle electrical device.
Generator's output is lower than that of regenerative power generation mode.



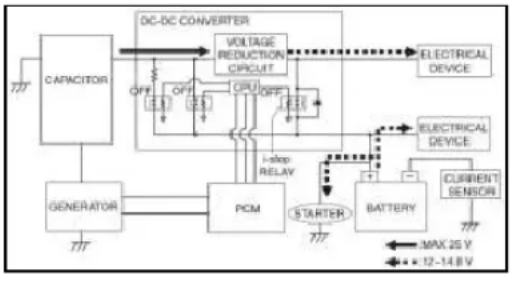
(3) Capacitor (i-ELOOP) power supply mode
If capacitor voltage exceeds battery voltage, voltage stored in the capacitor is reduced with DC-DC converter for applicable power-supply to each electrical device (IG1, IG2 power source) on the vehicle.



(4) Battery power supply mode
In case capacitor voltage falls below the capacitor's designed minimum voltage (14-17.5V *It varies 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 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.
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 electricity generated by generator to vehicle electrical devices directly.
Also, in case DC-DC converter's voltage reduction circuit is failed, or in case it is anticipated that battery voltage cannot guarantee minimum 11V, it is switched to bypass mode.

[Reference]
During the bypass mode, verification is not possible using the instrument cluster indication.

(7) Pre-charge mode

If the vehicle is left for a long time without running the engine or if self-discharge 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 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.)
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.)		(A message won't be displayed when the DC-DC converter supplies the voltage.)
9.5V or more			Not applicable

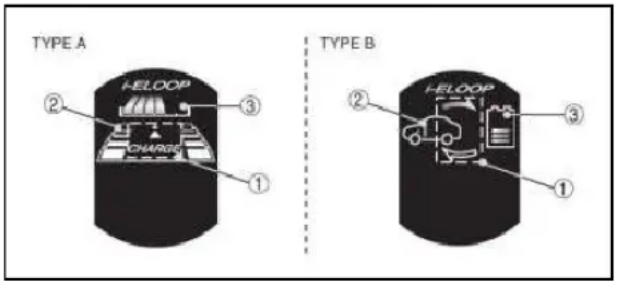
It stops when capacitor voltage is increased with electric voltage delivered from DC-DC converter.

(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.

4. Instrument cluster display

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



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.

5. i-stop operating condition

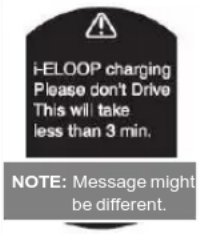
Different or additional i-stop operating conditions compared to other models due to i-ELOOP installation are as follows.

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 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 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 of waiting 3 minutes or more, it indicates a system malfunction, which will turn the master warning lamp on.



NOTE: Message might be different.

When pre-charge mode is activated, you can see 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.

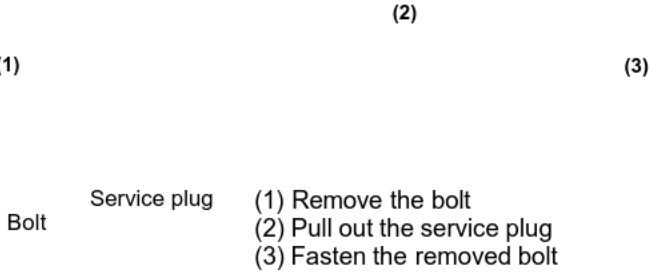
7. How to fix dead battery

If the battery is completely discharged due to lights not being turned off mistakenly and you jump-start the engine with the booster cables, make sure the cables are connected for 3 minutes approximately even after 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 voltage decrease is stored.

8. Things to keep in mind during maintenance work

If terminals of the following i-ELOOP related parts hit the vehicle body with the capacitor service plug installed, it may cause fire or failure of electrical parts. When you separate the following terminals, 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



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

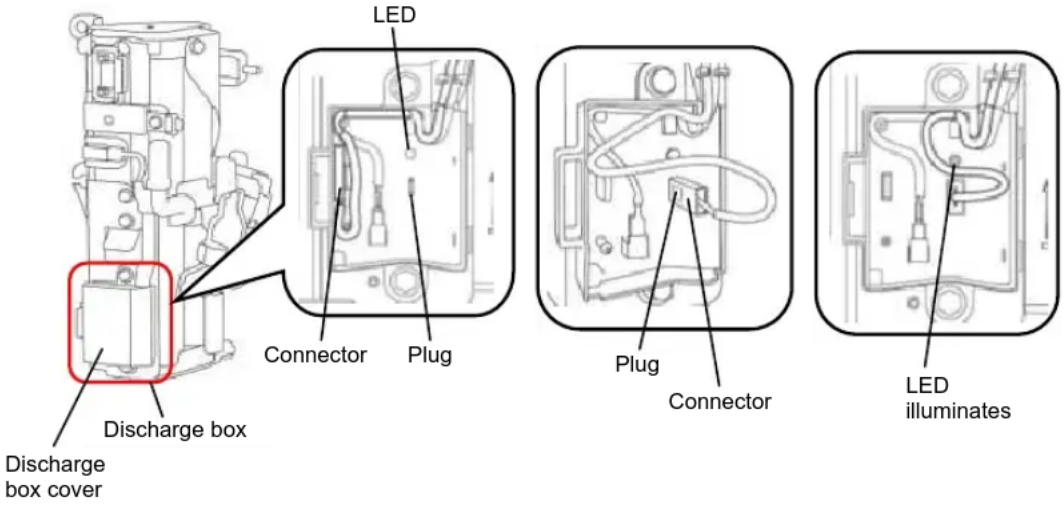
9. Things to keep in mind when storing/transporting capacitor

- 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 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.

Fix the service plug with vinyl tape attached.

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.

Mitsunori Tokunaga
Manager, Technical Information Gr.
Technical Service Dept.
Mazda Motor Corporation