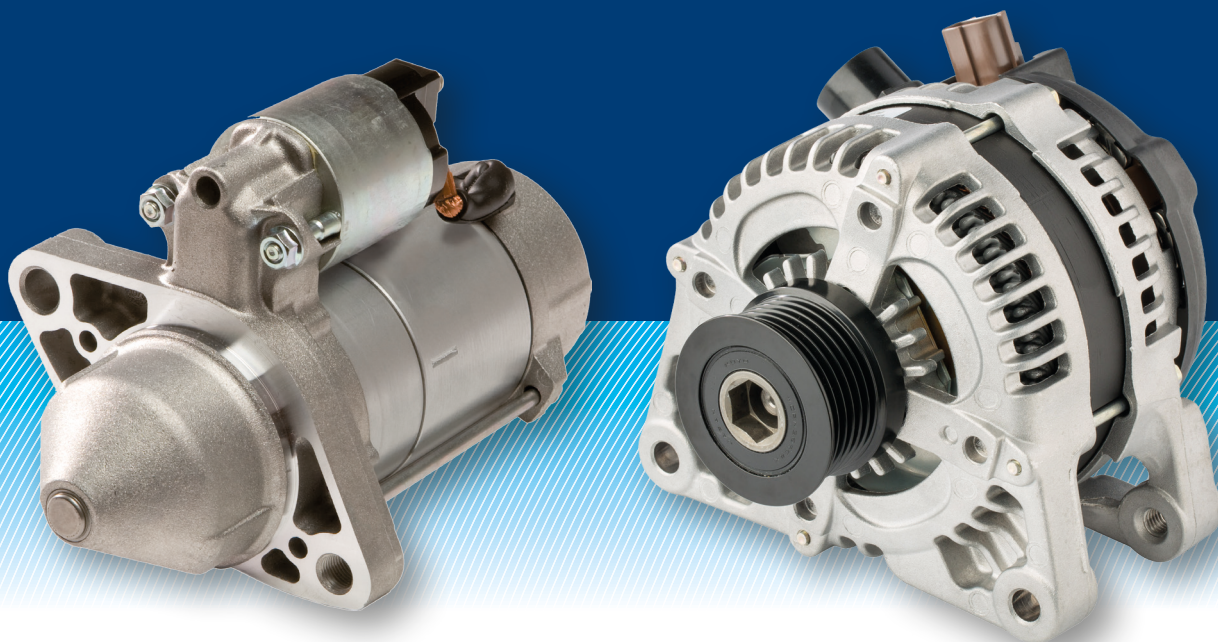


DENSO

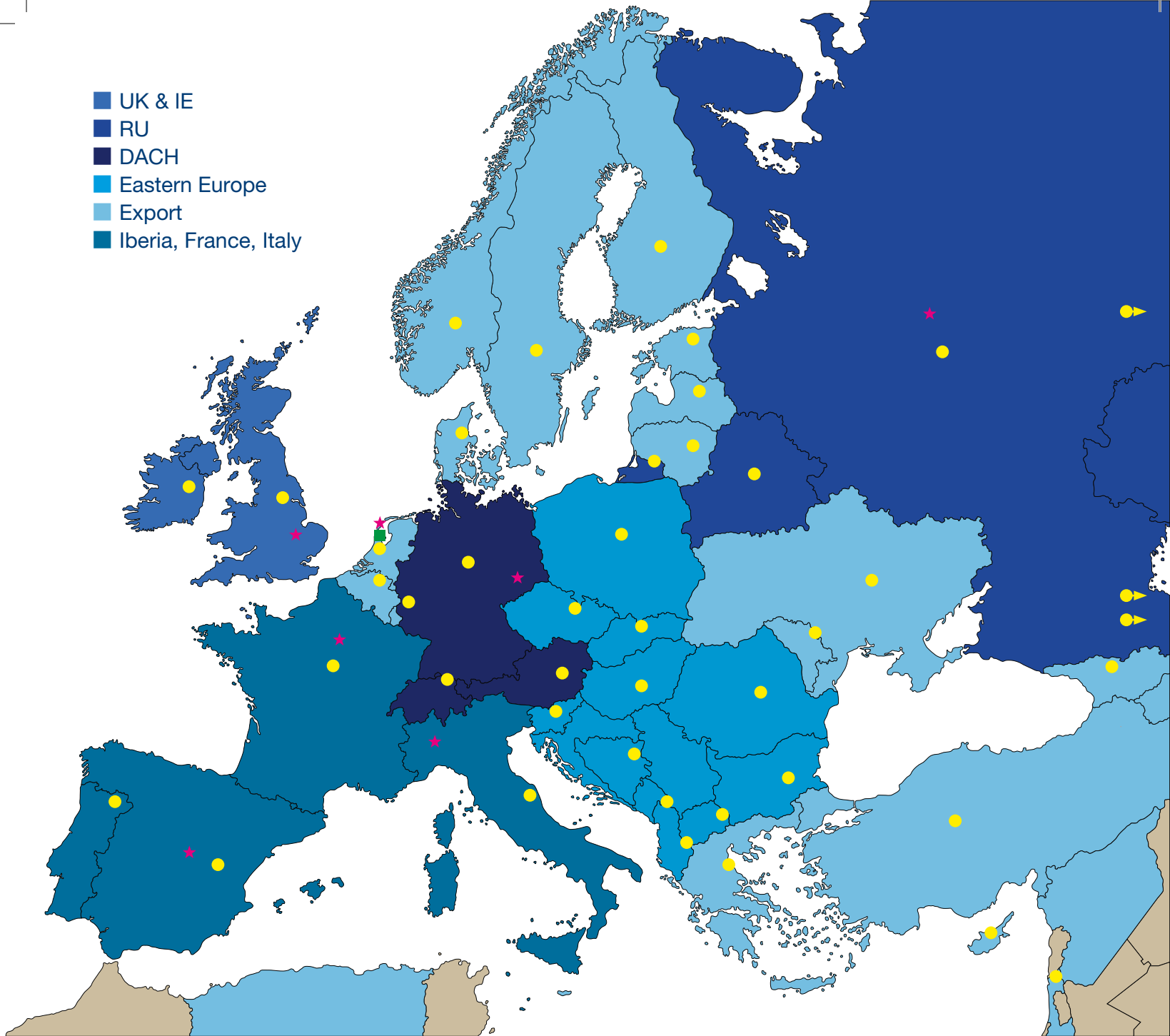
Starters & Alternators

| Technical Manual



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DENSO Starters & Alternators

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DENSO in Europe > The Aftermarket Originals

DENSO Aftermarket Europe is part of DENSO Corporation, one of the world's top 3 manufacturers of advanced automotive technology, systems and components.

Founded in 1949 DENSO is a pioneer of quality products for the automotive industry, supplying a huge range of original equipment to every major vehicle manufacturer in the world.

In fact, you'll find original DENSO parts in nine out of ten cars on the road. We are also proud to bring that unique expertise to the European independent aftermarket. Our technologically advanced programmes feature only OE specification products specially selected for distributor and end-user customers. We manage that supply directly through DENSO Aftermarket Europe, supported by a growing network of local aftermarket sales offices.



Introduction > About This Publication

This Starters & Alternators Manual from DENSO Aftermarket Europe aims to provide distributors, wholesalers and end-users with everything you need to know about our unique, OE specification

rotating units. From system data to case studies and visuals showing each type, this handy manual will provide all the technical information required.

Introduction

> Product Range



True pioneers of Starter and Alternator technology for modern cars, motorcycles and commercial vehicles, DENSO has become the world's largest OE rotating parts manufacturer, with a 20 percent market share. As a result, our replacement Starters and Alternators are the world's smallest and lightest rotating machines for their output, delivering unrivalled efficiency, wear resistance and powerful performance.

DENSO Alternators

DENSO has pioneered new alternator designs capable of producing more electrical power more efficiently, yet in a smaller, lighter unit. In 2000, for example, DENSO introduced the world's first SC (Segment Conductor) alternator using a rectangular conductor for

its stator coil.

DENSO Starters

Since introducing its first commercial automotive Starters in the early 1960s, DENSO has poured its world-leading engineering expertise into developing smaller, lighter units that can maintain the highest possible output. In 2001, for example, DENSO introduced the world's first Planetary Reduction Segment Conductor Motor (PS) Starter featuring a square conductor in the armature coil.

Key Facts

- Completely new, boxed item (no reman) & no core surcharge
- Starter Range include Pinion Shift Starter (GA type); Reduction Starters (R and RA types); Planetary Starters (P, PA, PS and PSW types); and Stop-Start System Starters (AE, TS and PE types)
- Alternator Range include Conventional, Type III (alternator with small internal fan) and SC (Segment Conductor) Types
- Maximum efficiency by offering small size & light weight units while delivering the highest outputs
- 2000 – World's first Segment Conductor (SC) alternator
- 2001 – World's first planetary-reduction segment conductor (PS) starter
- 2005 – World's smallest and lightest high-output SC alternators
- 2011 – Introduction of DENSO Tandem Solenoid (TS) Starter
- DENSO technologies for stop/start systems

The DENSO logo is displayed in white, italicized, sans-serif font on a red rectangular background. The background of the entire advertisement is a detailed, close-up photograph of an engine's internal components, including a belt drive system and a DENSO alternator, illuminated with a blue and orange glow.

Get inside

- 100% OE specification
- All 'new in box'
- No re-manufactured units and no core surcharge or returns policy
- Maximum efficiency
- Extensive applications list
- Market leading

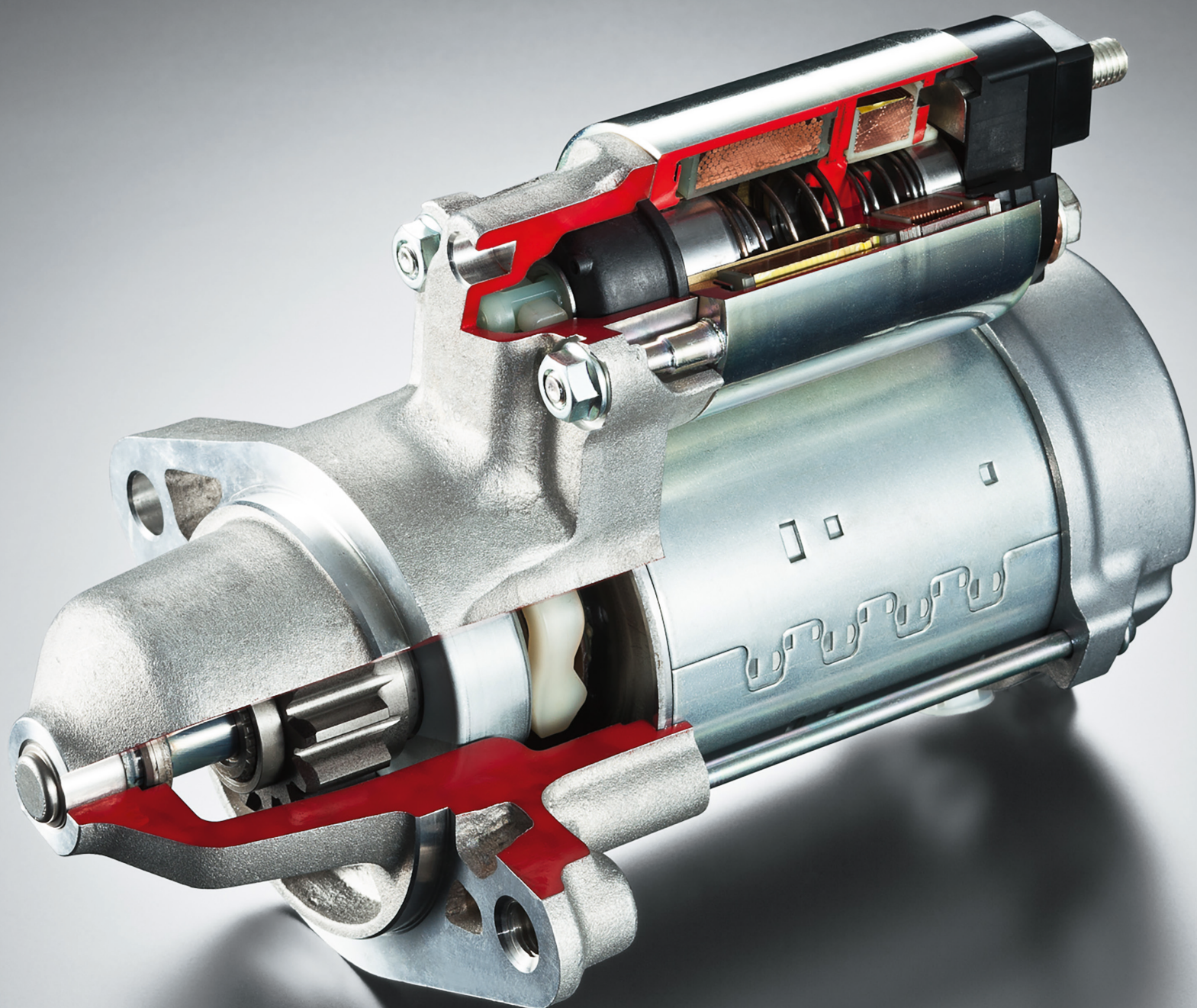
As one of the world's largest automotive component suppliers, DENSO is a global leader in developing and manufacturing rotating machines. Our unwavering commitment to outstanding quality, design and innovation mean that our Starters and Alternators are selected as original equipment by carmakers worldwide – winning many supplier and international quality awards along the way. As well as delivering unique, OE coverage of Toyota and a wide range of European marques such as Fiat, Opel, PSA, BMW, Ford, Volvo and Land Rover, the programme is continually being updated and expanding.

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PART 1

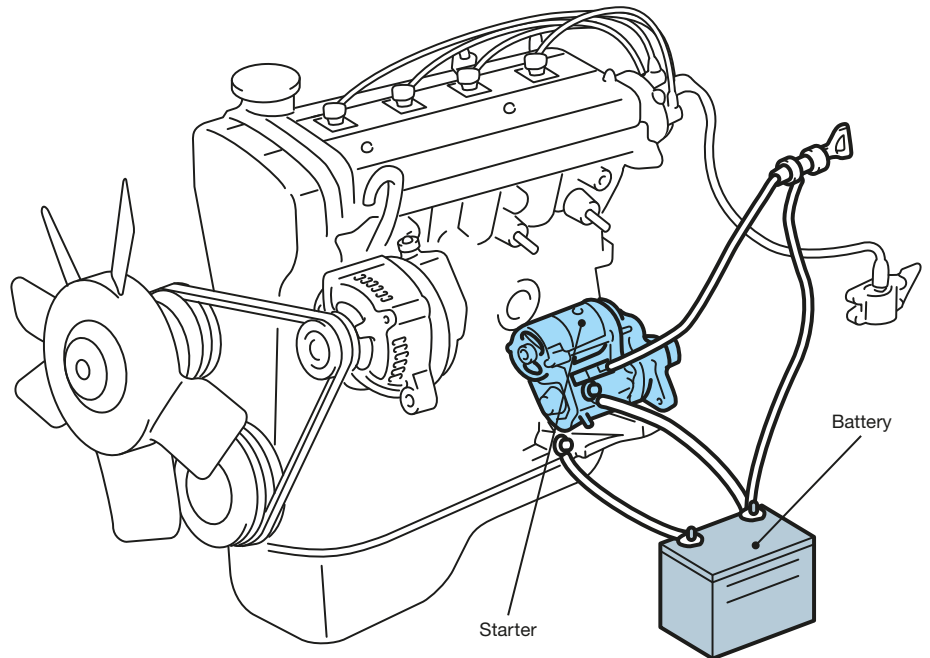
DENSO Starters



DENSO Starters | Characteristics

> System outline

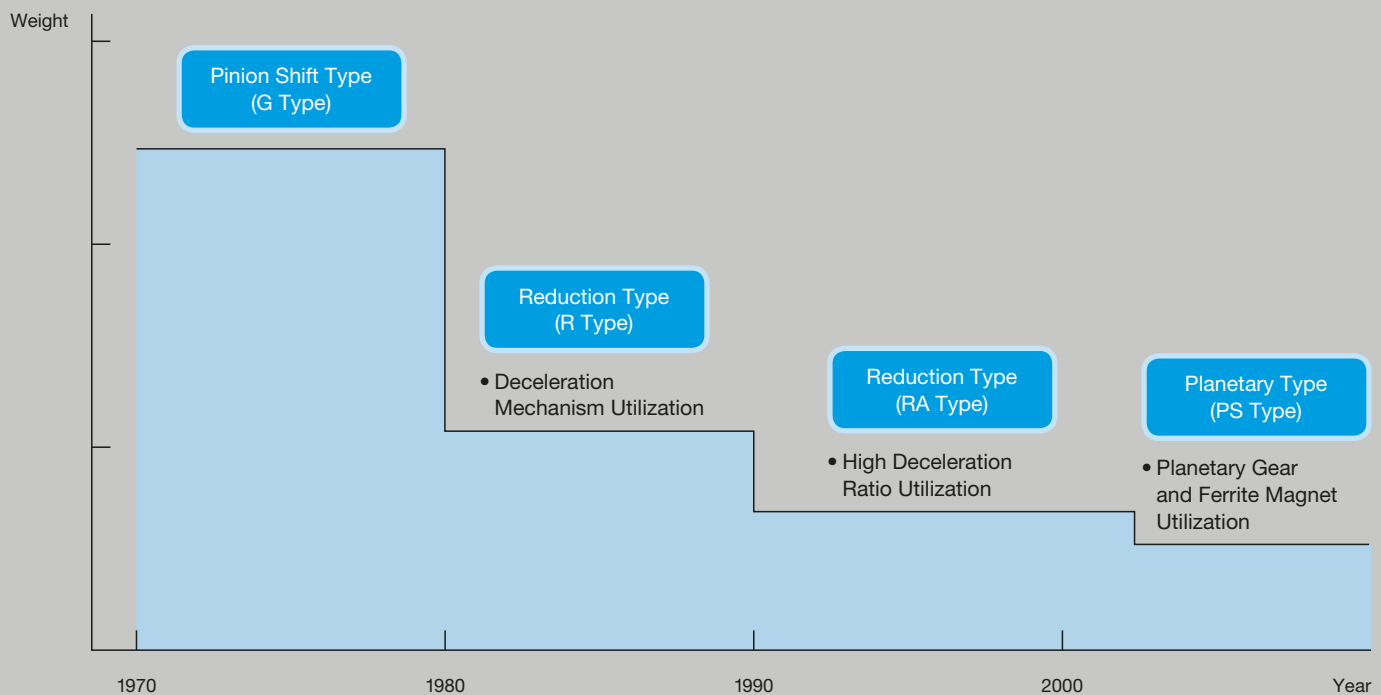
A starter is a device that initiates engine operation. Since a vehicle engine cannot start unaided, an external force is required to provide rotational speed at or above a set value. The starter drives a built-in motor using the vehicle battery as a power source to create power and start the engine. Unlike normal DC motors, the starter is only used for a short time (rated at 30 seconds). Thus, the starter is designed to be very small despite producing a large output.



Transition to compact and lightweight starter

The starter has progressed along with the automobile into a “compact, lightweight, high-performance” device. The 1970s saw the introduction of the pinion shift type starter, followed in the 1980s by the development of the reduction type starter that incorporated a deceleration mechanism. By the 1990s, the reduction type starter

utilized a high deceleration ratio to create an even more compact and lightweight device. Making further reductions in size and weight, the planetary type starter was developed in the first decade of the 21st century, incorporating a planetary gear and ferrite magnets.

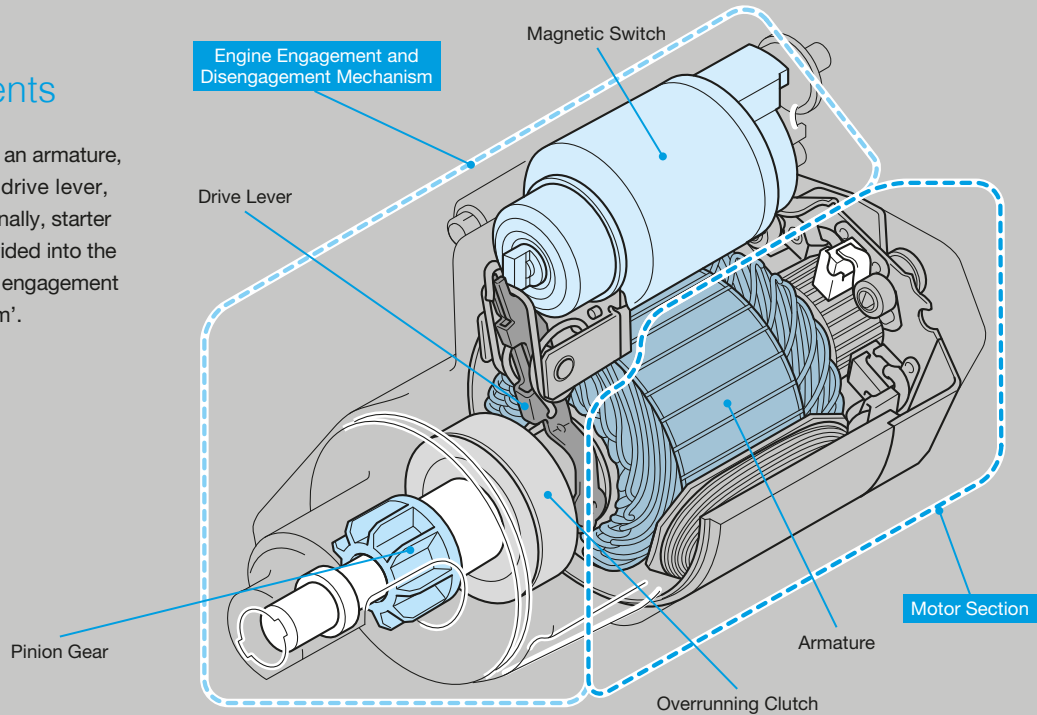


DENSO Starters | Characteristics

> How Starters work

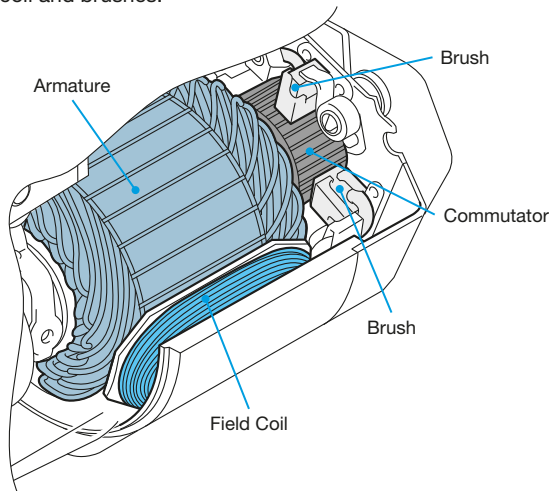
Primary Components

The starter primarily consists of an armature, pinion gear, magnetic switch, drive lever, and overrunning clutch. Additionally, starter construction can be broadly divided into the 'motor section' and the 'engine engagement and disengagement mechanism'.



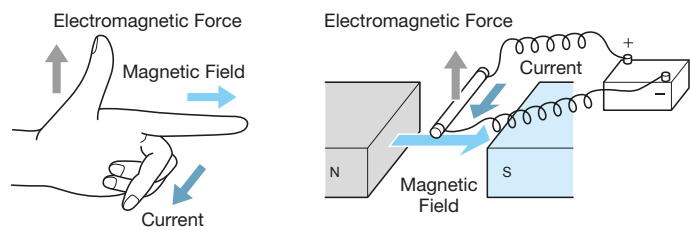
Motor Section

The motor section primarily consists of an armature, field coil and brushes.



Principles of the motor section

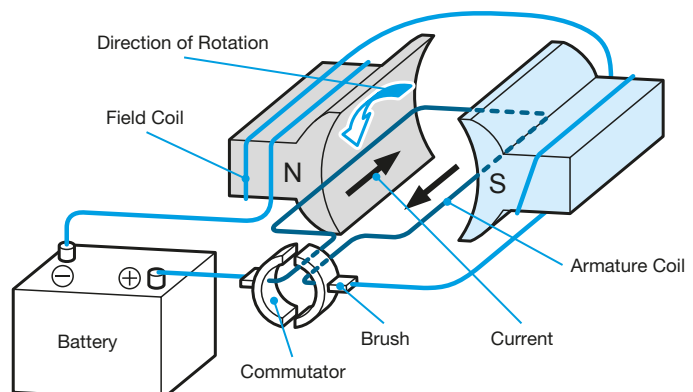
Motor principles are explained using Fleming's Left-Hand Rule*. The size of the electromagnetic force is proportional to the strength of the magnetic field, size of the current, and length of the conductor.



*According to Fleming's Left-Hand Rule, three fingers on the left hand can be used to represent the following phenomenon; pointer finger: direction of the magnetic field (North to South), middle finger: direction of current (positive to negative), thumb: direction of electromagnetic force.

Operations of the motor section

For the starter to operate as a motor, the electromagnetic force must be continuous and work in a fixed direction. Therefore, the motor is equipped with a commutator and brushes so that current always flows in a fixed direction to the North pole side or South pole side of the armature. As a result, the coil generates a force that works in a fixed direction so that the motor can rotate continuously. An actual starter combines multiple armature coils with the commutator.



DENSO Starters | Characteristics

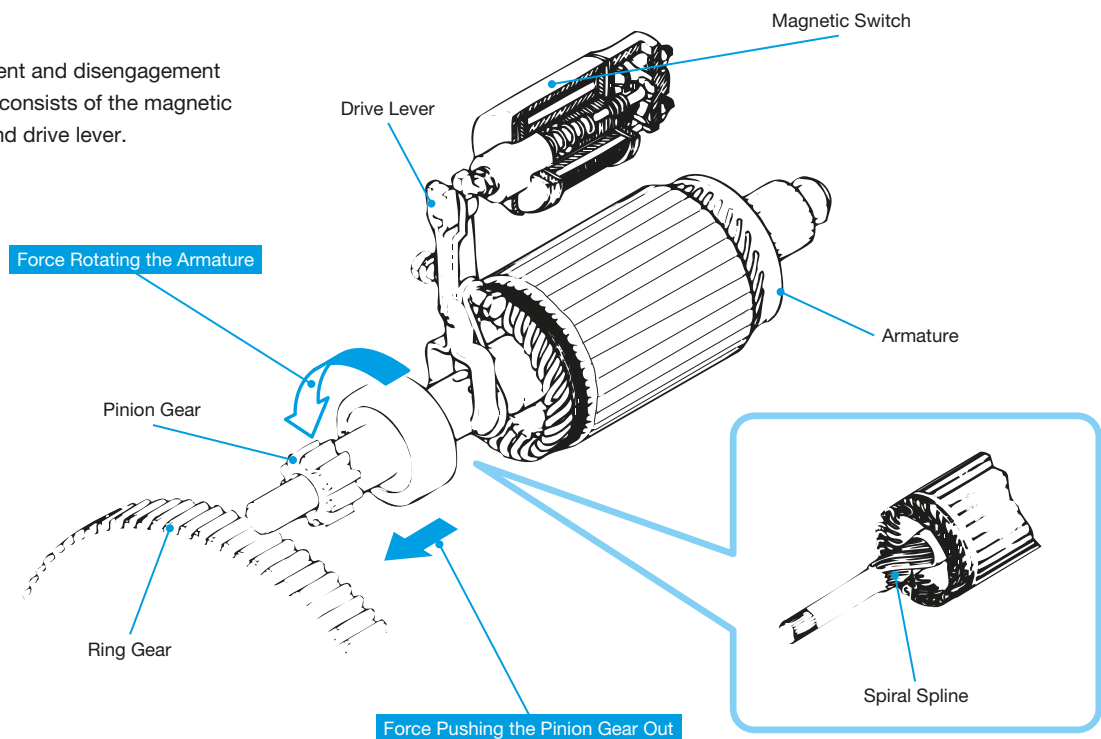
> How Starters Work

Engine engagement and disengagement mechanism

The starter rotates the engine by engaging the starter pinion gear with the engine ring gear. If the pinion gear and ring gear remain engaged after the engine is started, the pinion gear will be rotated by the engine at high speeds, causing starter breakage. Therefore, the pinion gear must smoothly engage the ring gear only when the starter is operating, and must disengage immediately after the engine has started.

Primary Components

The engine engagement and disengagement mechanism primarily consists of the magnetic switch, pinion gear and drive lever.



Engagement

When the starter is operated, the armature begins to rotate, and the drive lever pushes the pinion gear out to engage the ring gear.

However, there are instances when the pinion gear and ring gear collide. In such cases, the force pushing the pinion gear out, and the force rotating the armature work to assuredly engage the two gears. The effect of the two previously mentioned forces combined with the spiral spline make the pinion gear slip onto the ring gear, enabling assured gear engagement.

Role of the spiral spline

The spiral spline is engraved into the armature shaft (engraved into the drive shaft for reduction type, and planetary type starters) to push the pinion gear out. Even when the pinion gear only slightly engages the ring gear, the spiral spline allows the pinion gear to be pushed out to ensure complete engagement using the force rotating the armature.

Disengagement

Once the engine has started and the starter has been stopped, the pinion gear is drawn back and disengages from the ring gear. Simultaneously, the armature stops rotating.

DENSO Starters | Types

> Pinion Shift Type

Outline

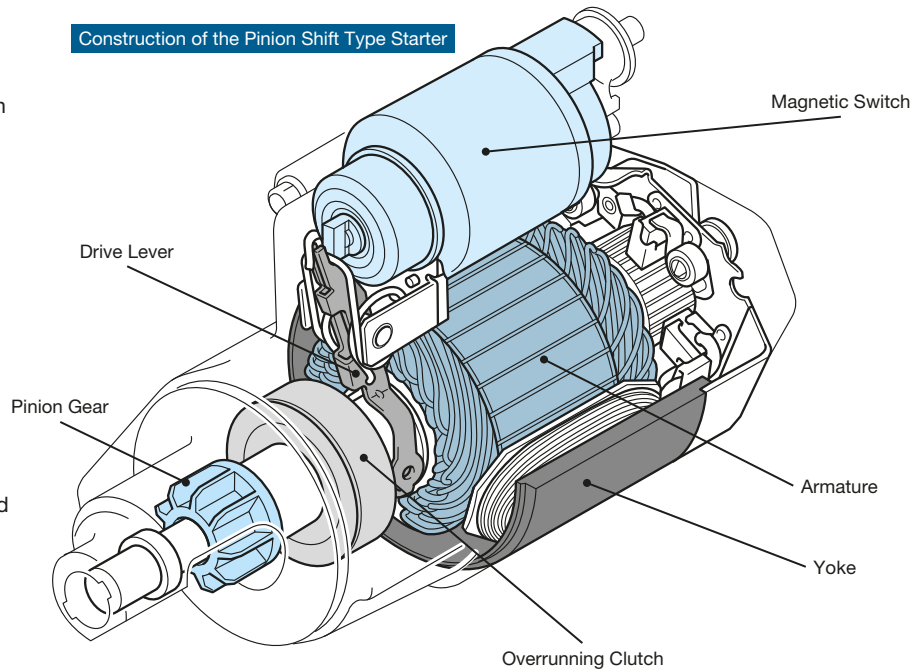
In the pinion shift type starter, magnetic switch force is transmitted via the drive lever to push the pinion gear (located above the armature shaft) out and engage the engine ring gear.

As such, the pinion shift type is a system that transmits force from the motor directly to the ring gear (G and GA types).

Features and benefits

- > Unique structure with the pinion gear pushed through the drive lever
- > Spiral brush spring
- > Aluminium end frame

Construction of the Pinion Shift Type Starter

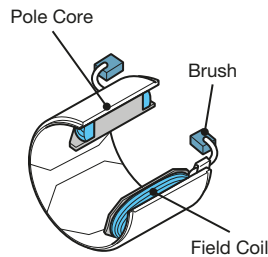


Characteristics

Primary components

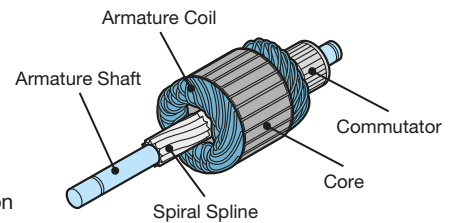
Yoke

The yoke creates the magnetic field necessary to rotate the motor, and consists of field coils, pole cores, and brushes. The field coils are directly wound around the pole cores and secured with resin to improve heat resistance and vibration resistance.



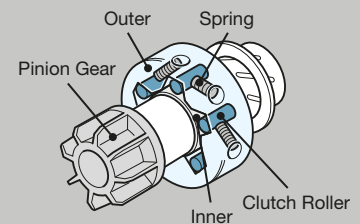
Armature

The armature generates motor rotational power, and consists of a core, armature shaft, armature coil, and commutator. The entire armature coil is secured with resin to improve heat and vibration resistance. In addition, a spiral spline is engraved into the armature shaft for connection to the overrunning clutch.



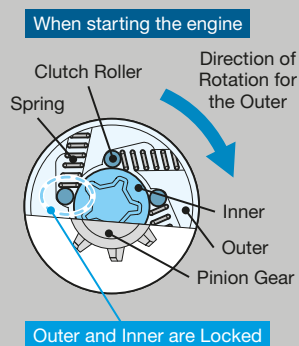
Overrunning clutch

The overrunning clutch prevents starter damage due to armature overrun* by providing a means to smoothly separate the pinion gear from the ring gear. The overrunning clutch consists of an inner, outer, clutch rollers and springs.



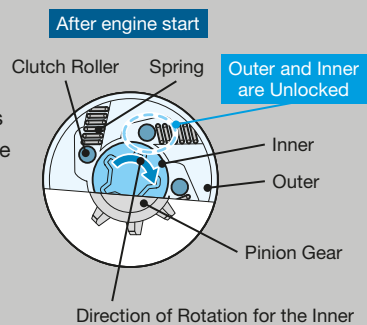
(1) When starting the engine

When the armature rotates, force is first transmitted to the outer (a component in contact with the armature shaft), followed by the clutch rollers, then finally to the inner (a component integrated with the pinion gear). The clutch rollers are pushed by the springs to the narrower side of the indentations in the outer and the gap in the inner, thereby locking the outer and inner together. As a result, the armature torque is transmitted via the inner to the pinion gear, causing the gear to rotate.



(2) After engine start

When the ring gear rotates the pinion gear, the rotational speed of the inner is higher than that of the outer. However, since the clutch rollers move in a direction such that the springs are compressed, the inner and outer are unlocked. Therefore, the pinion gear rotates idly, and the rotational force of the pinion gear is not transmitted to the armature. As such, armature overrun is prevented.



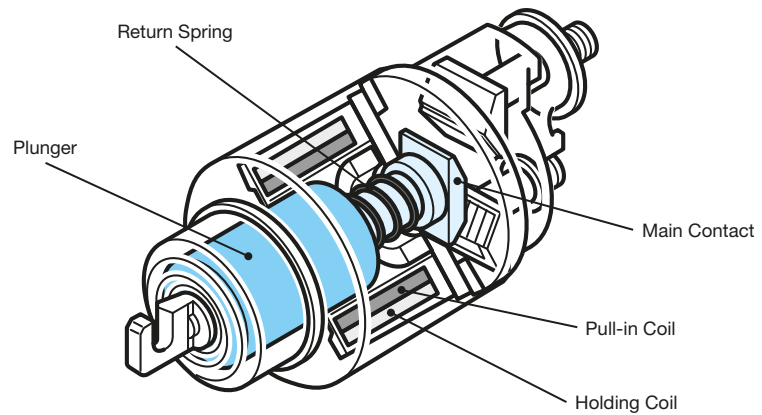
*Overrun is when the pinion gear fails to disengage from the ring gear after the engine starts, and the engine rotates the armature at high speed.

DENSO Starters | Types > Pinion Shift Type

Characteristics

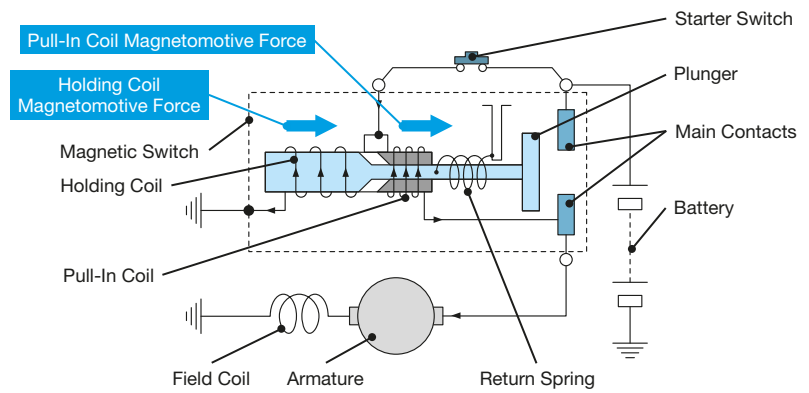
Magnetic switch

The magnetic switch serves to push the pinion gear out, disengages the pinion gear, and turn the motor power supply ON and OFF. The magnetic switch primarily consists of a pull-in coil, holding coil, return spring and plunger. Both the pull-in coil and holding coil have the same number of copper windings; however, each coil is wound in the opposite direction. Magnetic switch operation can be broadly divided into “pull-in”, “holding”, and “return”.



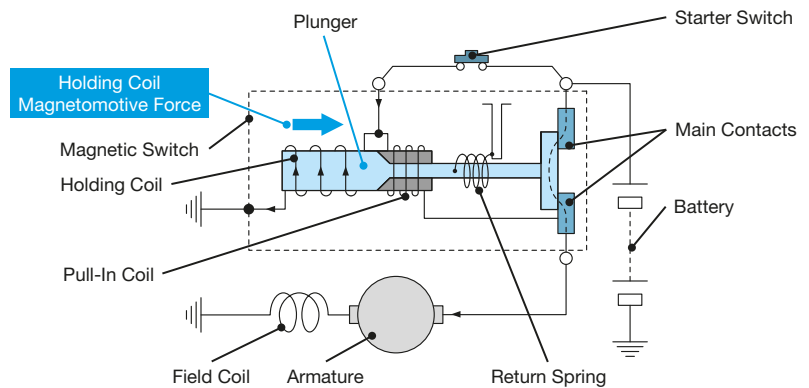
(1) Pull-in

When the starter switch is closed, current flows through the pull-in coil and the holding coil. The magnetomotive force from both coils is applied to the plunger, overcoming the return spring force. As a result, the plunger is pulled in, and the main contacts close.



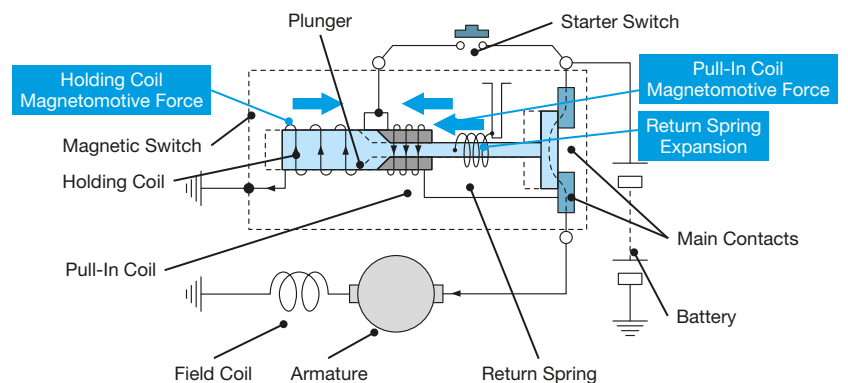
(2) Holding

When the main contacts close, the pull-in coil is placed in a short circuit condition, thereby stopping the flow of current through the coil. As a result, the plunger is pulled in by only the magnetomotive force of the holding coil, placing the starter in a holding status.



(3) Return

When the starter switch is opened with the main contacts closed, current flows through both the pull-in coil and the holding coil. Since both coils are reverse-wound with the same number of copper windings, the direction of the magnetomotive force for the pull-in coil becomes the opposite of that during pull-in. Therefore, the holding coil magnetomotive force cancels out that of the pull-in coil, resulting in the plunger returning to the original position due to return spring expansion, and the main contacts opening.



DENSO Starters | Types

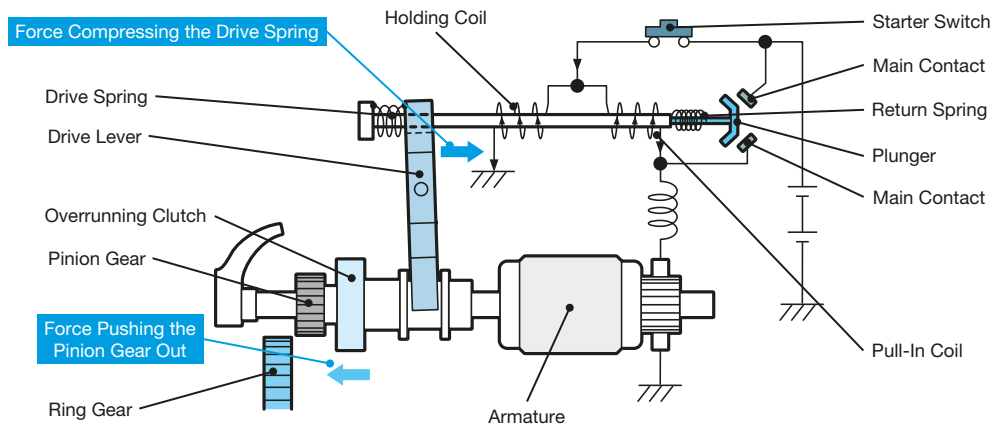
> Pinion Shift Type

Operation

When Starting the Engine

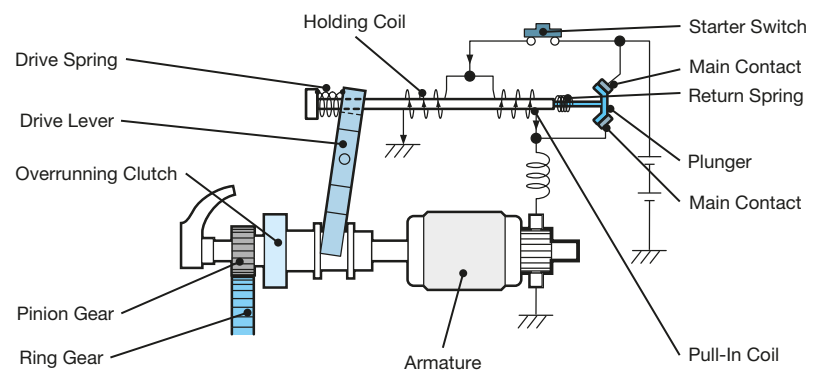
- > When the starter switch closes, the pinion gear is pushed out in the direction of the arrow below by the drive lever, causing the magnetic switch to apply current to the armature.
- > The armature rotates, and pushes the pinion gear out via the armature spiral spline.
- > The pinion gear then engages the ring gear and starts the engine.

However, when the teeth on the pinion gear and ring gear come into contact, the pinion gear is pushed forward and collides with the ring gear without engaging. To ensure that the teeth engage, the compression strength of the drive spring mitigates the force of the armature spiral spline pushing the pinion gear out. Simultaneously, the drive spring acts to displace the position of the pinion gear teeth. As a result, the pinion gear engages the ring gear to start the engine.



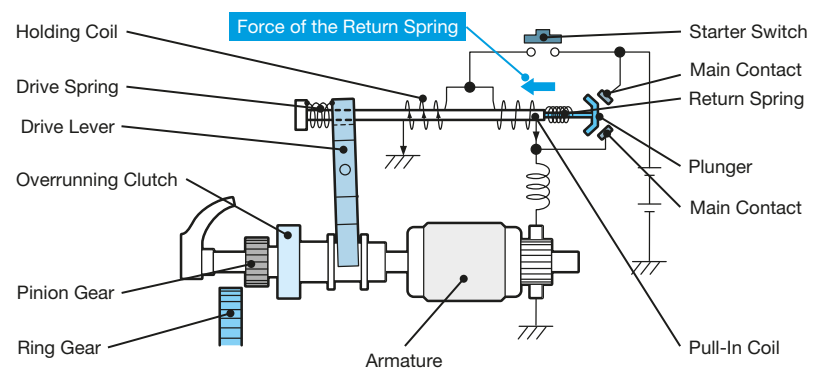
Engine Start

- > When the magnetic switch applies current to the armature, the drive lever holds the drive spring in place.
- > To prevent armature overrun when the ring gear rotates the pinion gear, the overrunning clutch operates such that the pinion gear rotates idly.



After Engine Start

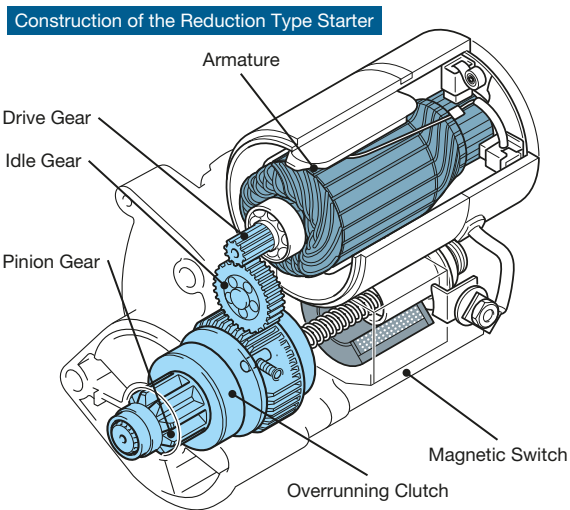
- > When the starter switch opens, the magnetic switch is no longer held, and the plunger returns to the original position due to the return spring, causing the main contacts to open.
- > As a result, the armature stops rotating, and the drive lever separates the pinion gear from the ring gear to stop the starter.



DENSO Starters | Types > Reduction Type

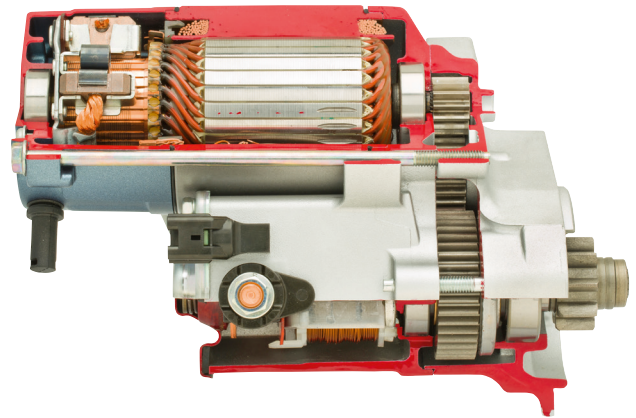
Outline

- > The reduction type starter (R and RA type for example) uses a deceleration mechanism.
- > In the pinion shift type starter, since motor power is transmitted directly to the ring gear, motor size is proportional to starter output, and therefore the motor is very large.
- > However, since the reduction type starter uses the deceleration mechanism, a large output can be generated from a small motor. As such, the reduction type starter is more compact and lightweight than a pinion shift type starter.



RA Starter features and benefits

- > High-speed motor with an improved deceleration ratio and a heat-resistant electric wire reduces the size and weight of the motor.
- > Improved anti-dust and waterproof capabilities.
- > Minimized friction and wear of the bearings.



Characteristics

Primary Components

Armature

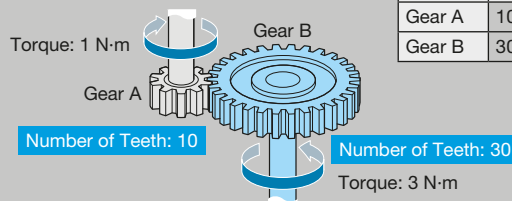
- > The armature in the reduction type starter rotates at higher speeds than in the pinion shift type starter.
- > Ball bearings are used as the armature shaft bearings.
- > These generate less friction, allowing the armature to rotate smoothly.

Deceleration mechanism

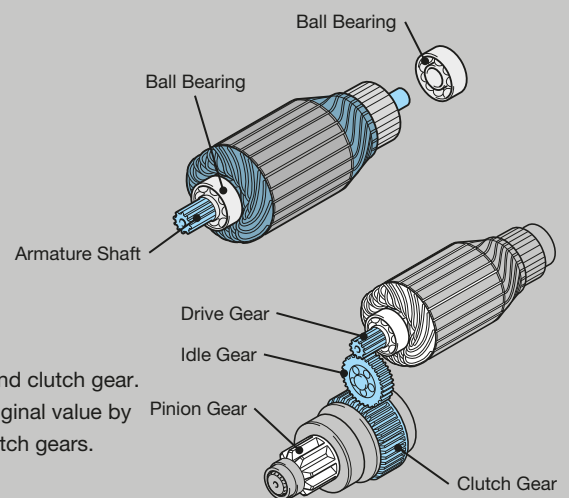
- > The deceleration mechanism comprises of an armature drive gear, idle gear and clutch gear.
- > The deceleration mechanism reduces speed to between 1/3 and 1/4 of the original value by transmitting armature rotational speed in order through the drive, idle, and clutch gears.
- > As a result, the torque transmitted to the pinion gear increases.

Deceleration mechanism theory

- > The following diagram uses a deceleration mechanism consisting of two gears.
- > When gear "A" has 10 teeth, and gear "B" has 30 teeth, gear "B" rotates only once for every three rotations of gear "A".
- > In this situation, if the torque of gear "A" is 1, the torque of gear "B" is three times that of gear "A". The deceleration mechanism rotates a small gear at high speeds to generate a large torque, enabling a more compact, and lightweight motor to be used.



	Number of Teeth	Rotational Speed Ratio	Torque Ratio
Gear A	10	3	1
Gear B	30	1	3



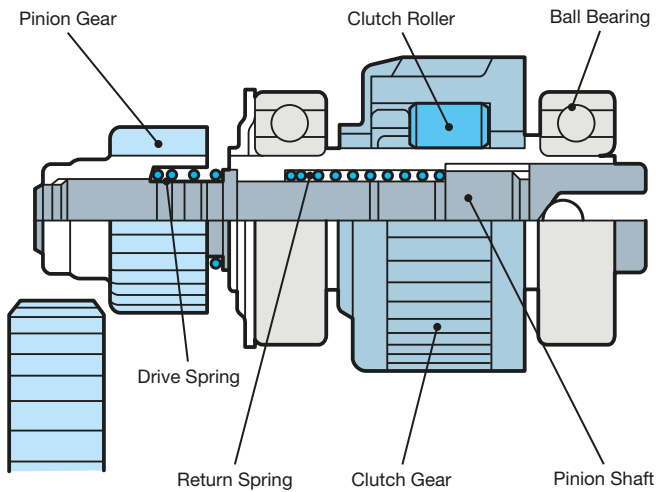
DENSO Starters | Types > Reduction Type

Overrunning Clutch and Magnetic Switch

- > In the pinion shift type starter, where the overrunning clutch and magnetic switch are not arranged coaxially, force from these two components is transmitted through the drive lever.
- > However, in the reduction type starter, the overrunning clutch and magnetic switch are arranged coaxially.

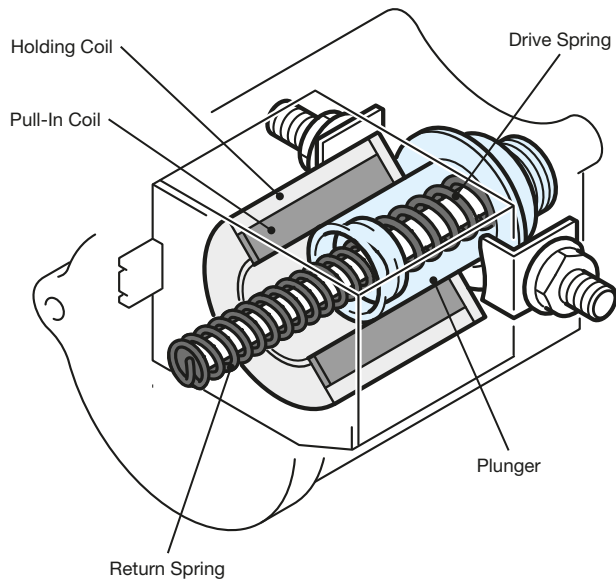
(1) Overrunning clutch construction

- > The overrunning clutch primarily comprises of the pinion gear, clutch roller, pinion shaft, clutch gear, drive spring, and return spring.
- > The rotational force of the armature transmitted to the overrunning clutch is conveyed in order from the armature drive gear to the clutch gear via the idle gear, then through the clutch roller and the pinion shaft to the pinion gear.



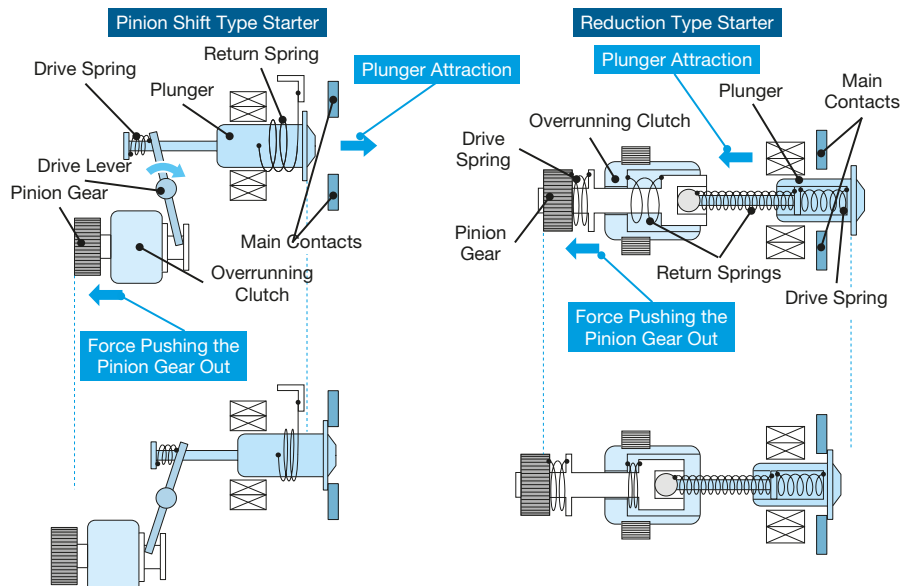
(2) Magnetic switch construction

- > The magnetic switch is made up of a holding coil, pull-in coil, return spring, drive spring and plunger.
- > In the magnetic switch starter switch operation causes current to flow to the pull-in coil and holding coil.
- > The resulting magnetic force and spring force cause the plunger to pull-in, hold or return.



(3) Overrunning clutch and magnetic switch operation

- > Overrunning clutch and magnetic switch operations differ between the pinion shift type starter and reduction type starter.
- > In the pinion shift type starter, when the starter switch is closed, current flows to the magnetic switch, and the plunger is pulled in. Plunger movement is transmitted to the overrunning clutch via the driver lever that connects the two devices, thereby pushing the pinion gear out.
- > In the reduction type starter, when the starter switch is closed, current flows to the magnetic switch. The plunger is pushed out in the direction of the pinion gear, pushing out the pinion gear.



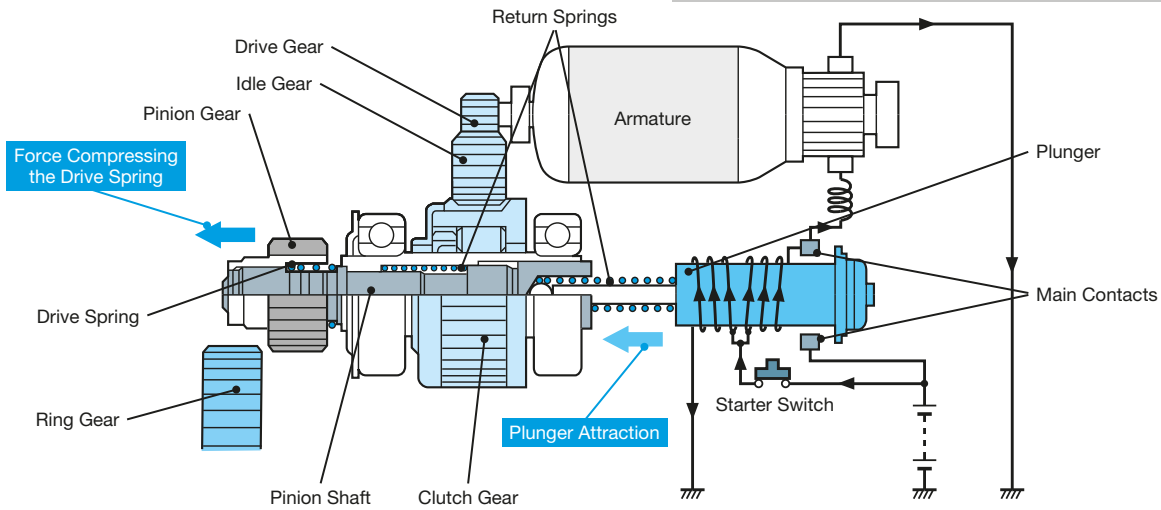
DENSO Starters | Types > Reduction Type

Operation

When Starting the Engine

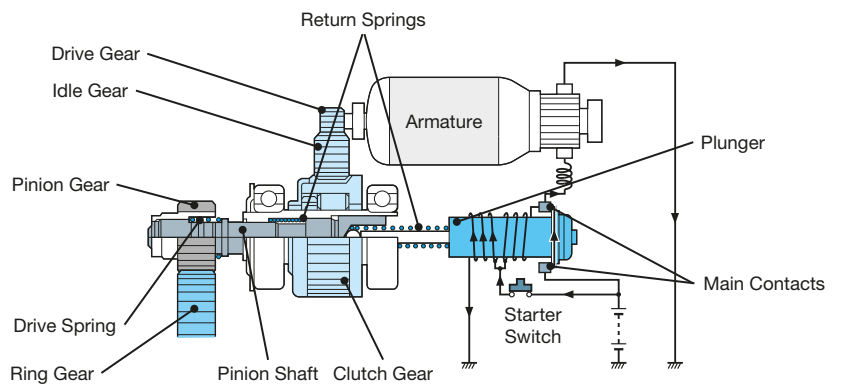
- > When the pinion gear engages the ring gear, the main contacts close, the armature is energised, and the starter begins to rotate.
- > The rotational speed of the armature is first decreased by the drive gear and idle gear, then transmitted to the pinion gear, resulting in pinion gear rotation and engine start.

However, when the teeth on the pinion gear and ring gear come into contact, the pinion gear is pushed forward and collides with the ring gear. To ensure that the teeth engage, the compression strength of the drive spring softens the force of the pinion shaft spiral spline, pushing the pinion gear out. Simultaneously, the drive spring acts to displace the position of the pinion gear teeth. As a result, the pinion gear engages the ring gear to start the engine.



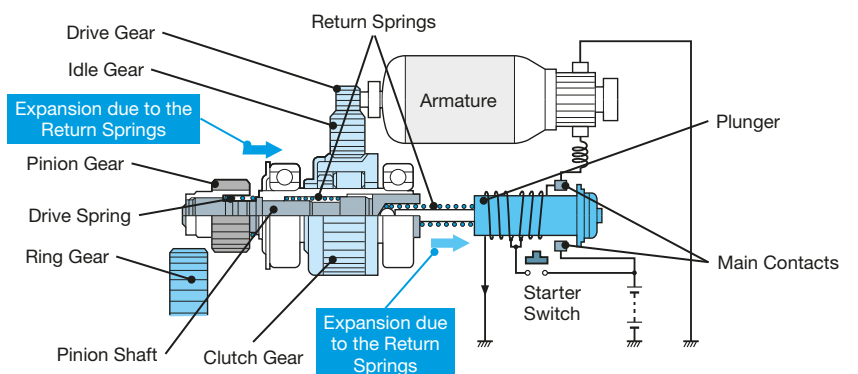
Engine Start

- > When the magnetic switch applies current to the armature, the magnetic switch is held in place.
- > To prevent armature overrun when the ring gear rotates the pinion gear, the overrunning clutch operates such that the pinion gear rotates idly.



After Engine Start

- > When the starter switch opens, the magnetic switch is no longer held, and the plunger returns to the original position due to return spring expansion, causing the main contacts to open.
- > The armature will stop rotating, and the pinion gear separates from the ring gear to stop the starter.



DENSO Starters | Types

> Planetary Type

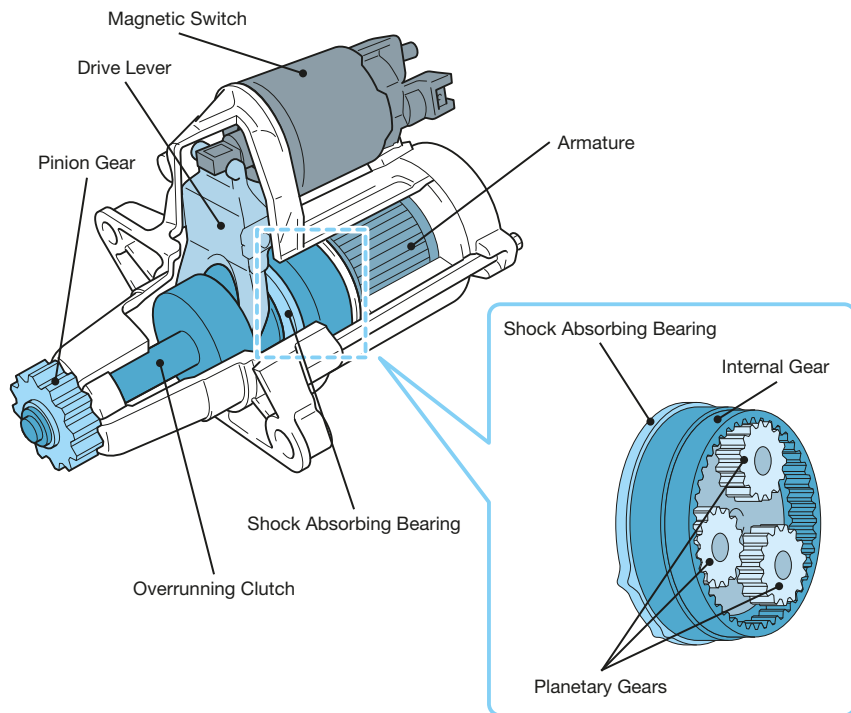
Outline

Similar to the pinion shift type starter, the planetary type starter (P, PA, PS and PSW type for example), transmits magnetic switch force via the drive lever to push the pinion gear (integrated with the overrunning clutch) out, and engage the engine ring gear. Motor rotational power is then transmitted to the ring gear. The planetary type starter utilises both a deceleration mechanism with planetary gears, and a shock absorber bearing.

The planetary type starter uses planetary gears between the overrunning clutch and armature as a deceleration mechanism. Much like the reduction type starter, this system generates a large torque for a small motor, but is comparatively more compact and lightweight than a standard pinion shift type starter.

Additionally, if the starter engages the ring gear when the engine is rotating in reverse, the shock absorber bearing acts to soften the shock of reverse rotation from the engine side, and protect the internal gear.

Construction of the Planetary Type Starter

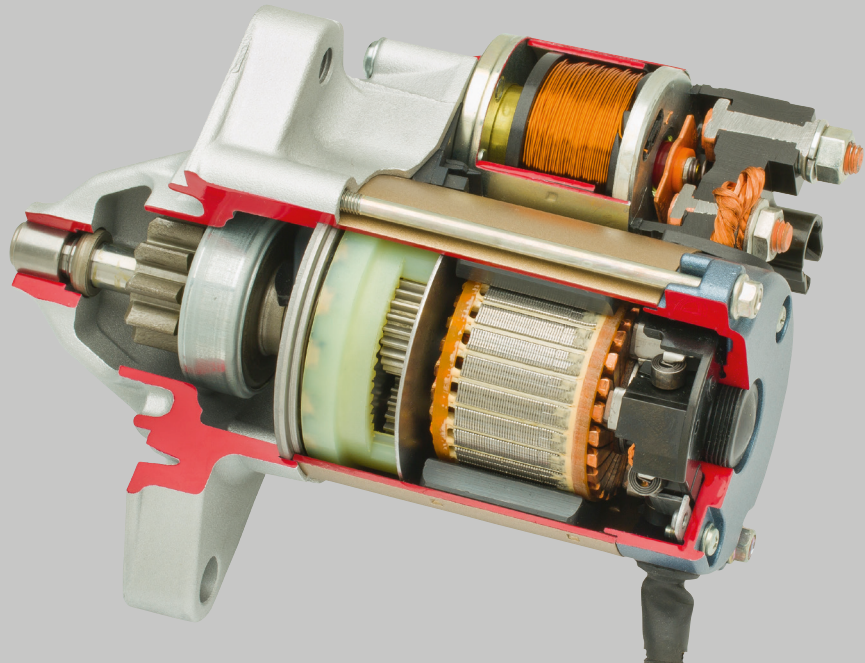


PS Starter (PS: Planetary Reduction Segment Conductor Motor)

The PS starter, developed by DENSO in 2001, is 22 percent lighter and 14 percent smaller than the RA starter, resulting in improved fuel consumption and excellent mountability in the vehicle. DENSO's technological innovation has allowed a smaller and lighter starter; through improving the yoke, employing a segment conductor (rectangular conductor) in the armature coil and improving the armature commutator shape.

Features and benefits

- > Small size, light weight, easy mountability and low cranking noise.
- > Placing a magnet between the yoke main poles increases the total magnetic flux.
- > Rectangular conductor used with the armature coil improves the winding density (space factor).
- > Newly developed surface commutator, placed on the end surface of the armature, reduces the total length of the armature.
- > The deceleration ratio was increased from 4.4 to 7.9, resulting in further reduced size of the motor.
- > Shock absorber is used to absorb the shock of the deceleration device caused by the increased deceleration ratio. The PS starter uses the planetary gear as the deceleration device.



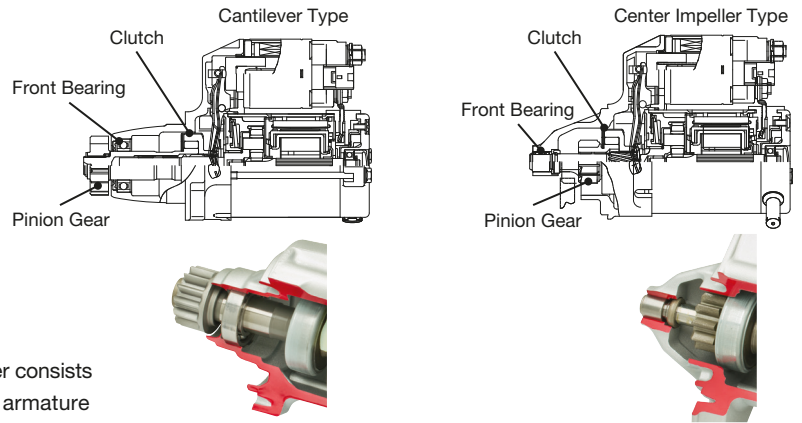
DENSO Starters | Types > Planetary Type

Characteristics

Primary Components

Overrunning clutch

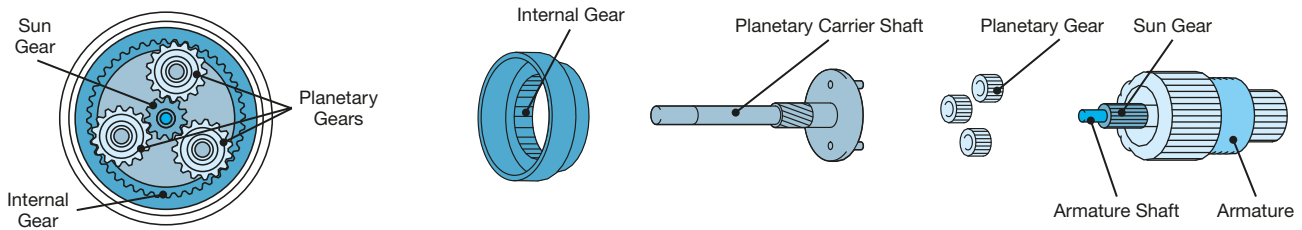
There are two types of clutches depending on the shape and the pinion gear position; a center impeller type and a cantilever type.



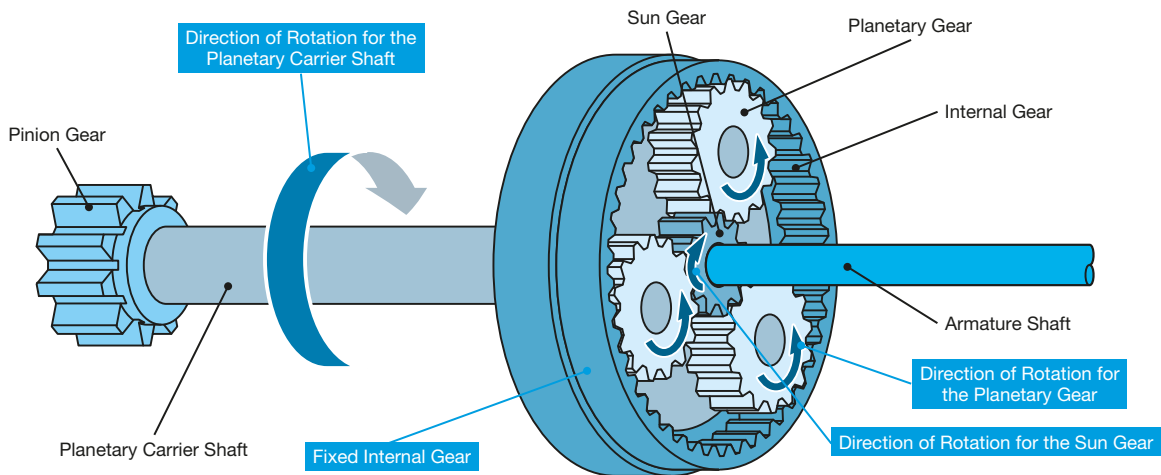
Deceleration Mechanism

The deceleration mechanism in the planetary type starter consists of three planetary gears, a sun gear connected to the armature shaft and an internal gear that surrounds the entire assembly.

The deceleration mechanism reduces speed to between 1/5 and 1/8 of the original value by transmitting armature rotational speed in order through the sun gear, planetary gears and planetary carrier shaft. The torque is transmitted to the planetary carrier shaft, and then the pinion gear increases.



When the armature rotates, the sun gear attached to the armature shaft also rotates. In turn, the three planetary gears engaging the sun gear rotate. As a result, the planetary gears move about the sun gear (in the same direction as the sun gear) along the inner circumference of the fixed internal gear. Since the planetary gears are connected to the planetary carrier shaft, the shaft also rotates when the planetary gears orbit.



Since the internal gear is fixed in place, the deceleration ratio of the planetary type starter deceleration mechanism is determined by the number of teeth on the sun gear and the internal gear. The deceleration ratio is calculated using the equation below.

For example, according to the deceleration ratio equation, if the sun gear has 11 teeth and the internal gear has 45 teeth, the armature rotational speed is reduced to 1/5 of the original value.

Equation for Calculating the Deceleration Ratio of the Planetary Type Starter Deceleration Mechanism

$$\text{Deceleration Ratio} = \frac{\text{Number of Sun Gear Teeth}}{\text{Number of Sun Gear Teeth} + \text{Number of Internal Gear Teeth}}$$

Ex. Number of sun gear teeth: 11
Number of internal gear teeth: 45

$$\text{Deceleration Ratio} = \frac{11}{11+45} = \frac{11}{56} = \frac{11}{5,090} \approx \frac{1}{5}$$

DENSO Starters | Types > Planetary Type

Shock Absorber Bearing

When the shock of reverse rotation from the engine side is added to the internal gear, the shock absorber bearing performs the following functions: 1) mitigation of a portion of the shock, 2) suppression of the shock placed on the sun gear and internal gear to below a set value, and 3) protection of the internal gear from damage and deformation.

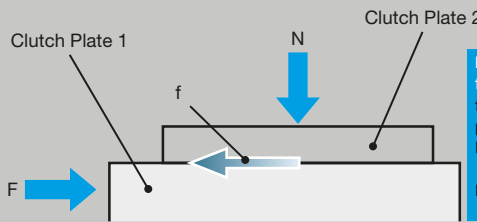
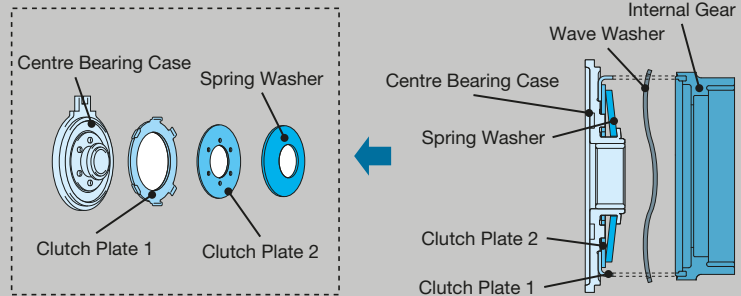
(1) Shock absorber bearing construction

The shock absorber bearing consists of a centre bearing case, two clutch plates and a spring washer. The shock absorber bearing and internal gear are connected by a wave washer sandwiched between the two components.

(2) Shock absorber bearing operation

Clutch plate 1 inside the shock absorber bearing connects with the internal gear. Spring washer force pushes clutch plate 2 against clutch plate 1 to generate frictional force, thereby keeping the clutch plates still. When a shock from reverse rotation of the engine is added to the shock absorber bearing, and the force of the shock exceeds the clutch plate frictional force, clutch plate 1 rotates and mitigates a portion of the shock. As a result, the shock placed on the internal gear is suppressed below a set value.

Construction of the Shock Absorber Bearing



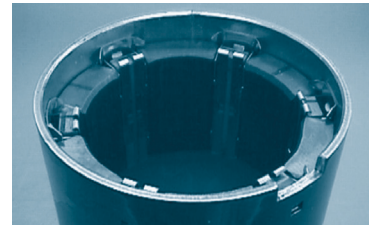
Equation Representing Frictional Force
 $f = \mu N$
 f: Frictional force
 μ : Static friction coefficient
 N: Force of the spring washer holding down clutch plate 2
 F: Shock of reverse rotation from the engine side

Clutch Plate 1
 $f > F$: No clutch plate movement ∇ Shock absorber bearing remains still.
 $f < F$: Clutch plate movement ∇ Shock absorber bearing mitigates a portion of the shock.

Yoke

A portion of P and PA type starters use field coils in the yoke. In addition, some PA type starters, as well as PS and PSW type starters, use ferrite magnets. Yokes that use the ferrite magnets achieve the same quantity of magnetic flux as yokes that use field coils, yet have a shorter motor shaft length and more compact motor.

Yoke Using Ferrite Magnets

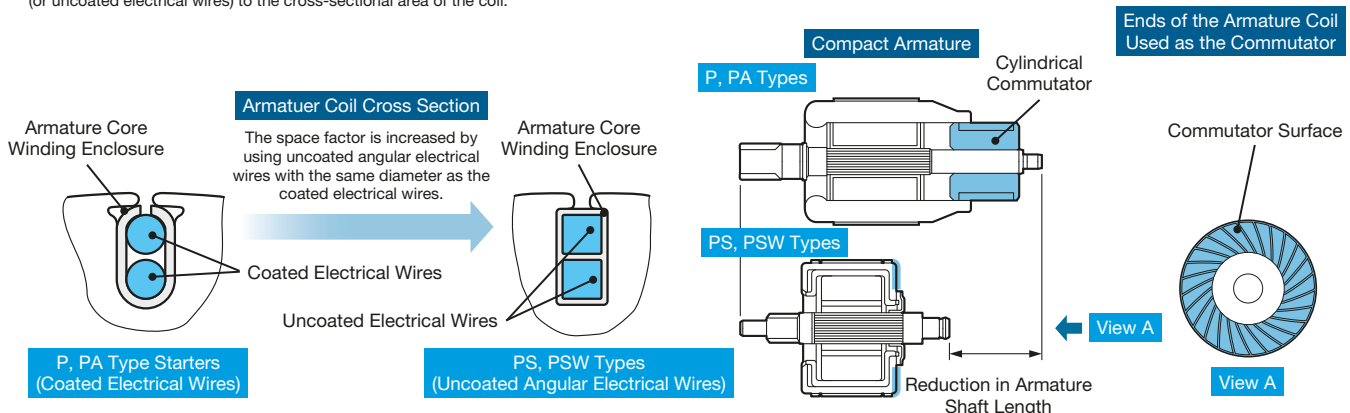


Armature

P and PA type starters use coated electrical wires with circular cross sections for the armature coil. However, PS and PSW type starters use uncoated angular electrical wires. As a result, the space factor* in PS and PSW type starters is improved and torque is increased due to less coil resistance and heat generation.

P and PA type starters use a cylindrical commutator. However, PS and PSW type starters use uncoated angular electrical wires as the commutator; creating the commutator surface from the end of the armature. As a result, armature shaft length is shorter, and the armature itself is more compact.

*Space factor: A ratio of the cross-sectional area of coated electrical wires (or uncoated electrical wires) to the cross-sectional area of the coil.

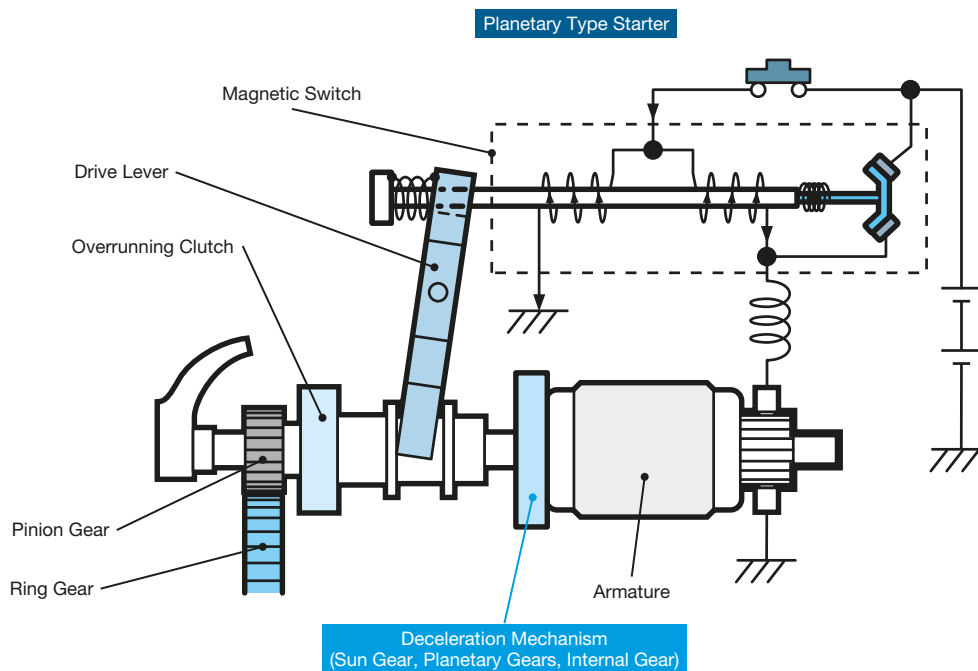
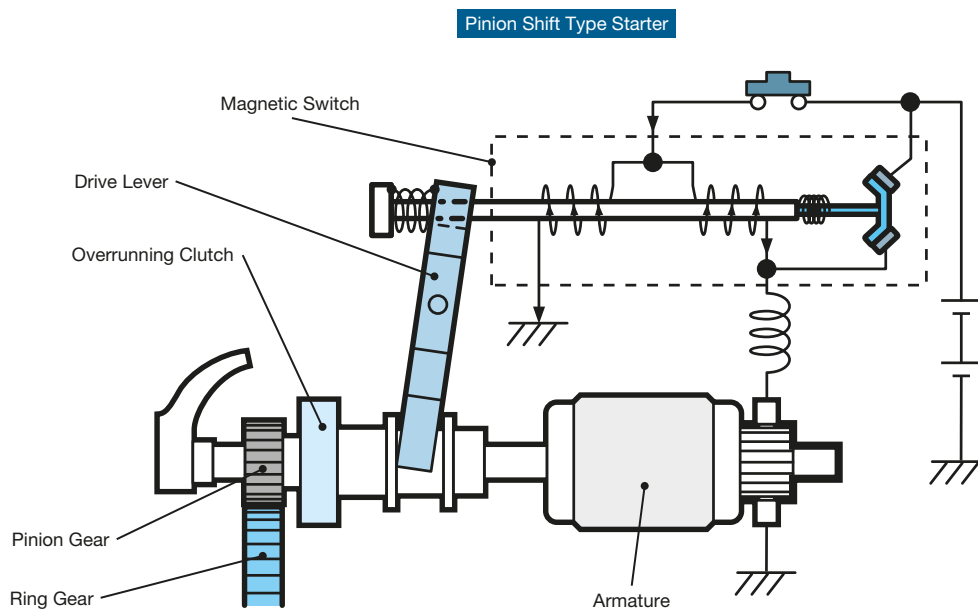


DENSO Starters | Types > Planetary Type

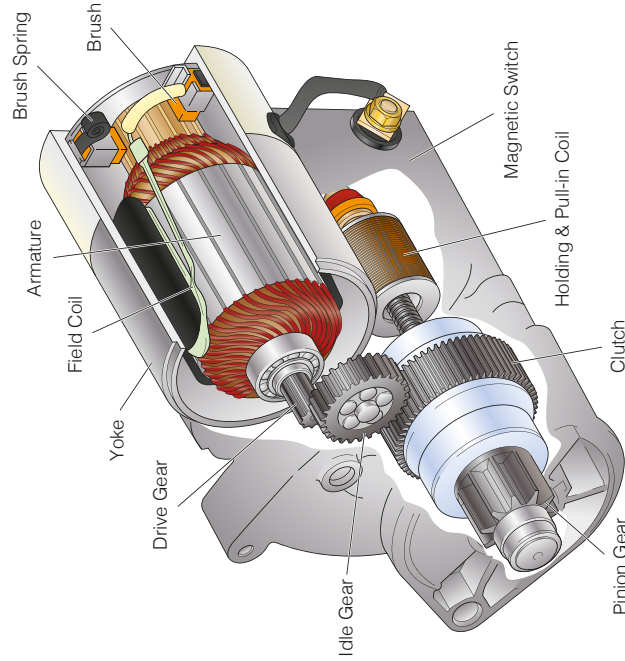
Operation

Similar to the pinion shift type starter operation, in the planetary type starter, magnetic switch force is transmitted via the drive lever to push the pinion gear (integrated with the overrunning clutch) out and engage the engine ring gear. As a result, motor rotational force is transmitted to the ring gear.

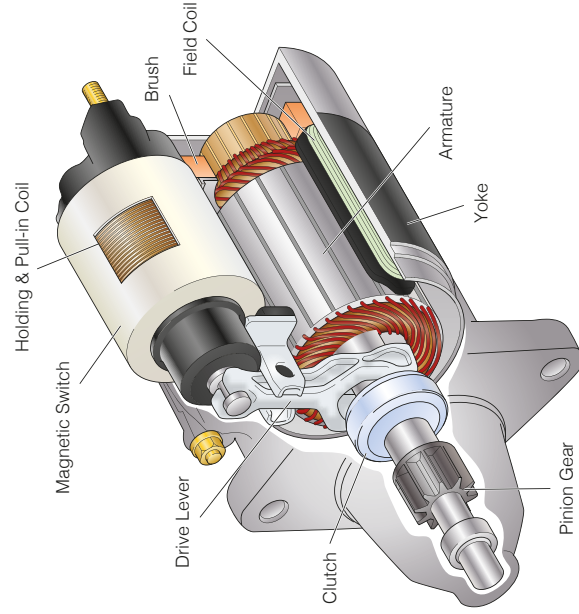
In the pinion shift type starter, armature rotational power is transmitted directly to the ring gear. In the planetary type start, however, armature rotational power is transmitted to the pinion gear after the rotational speed of the armature is decelerated by the sun gear, planetary gear, and internal gear.



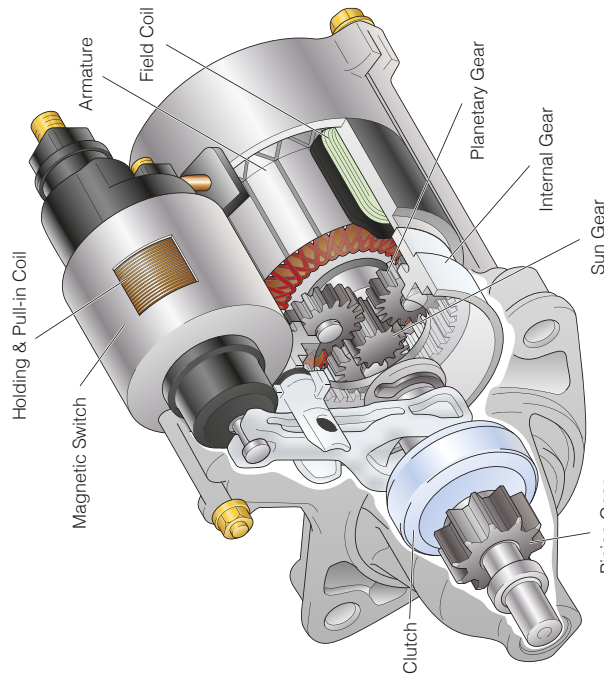
R, RA Types Starter



GA Type Starter

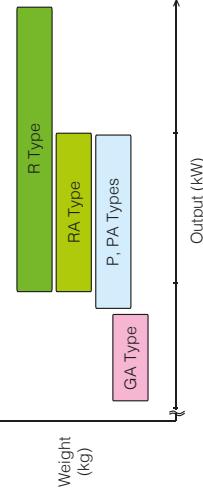


P, PA Types Starter



Starter Type	Product Outline
R, RA Types (Reduction Method)	The R and RA type starters use a compact high-speed motor that is decelerate by 1/3 to 1/4 to drive the pinion gear.
GA Type (Pinion Shift Method)	In the GA type starter, the force of the magnetic switch (via the drive lever) pushes the pinion gear outwards to engage the engine ring gear.
P, PA Types (Planetary Method)	The P and PA type starters use the same type of compact high-speed motor as the reduction type, but use a planetary gear as the deceleration mechanism.

Feature of the product



DENSO Starters | Stop & Start Technology

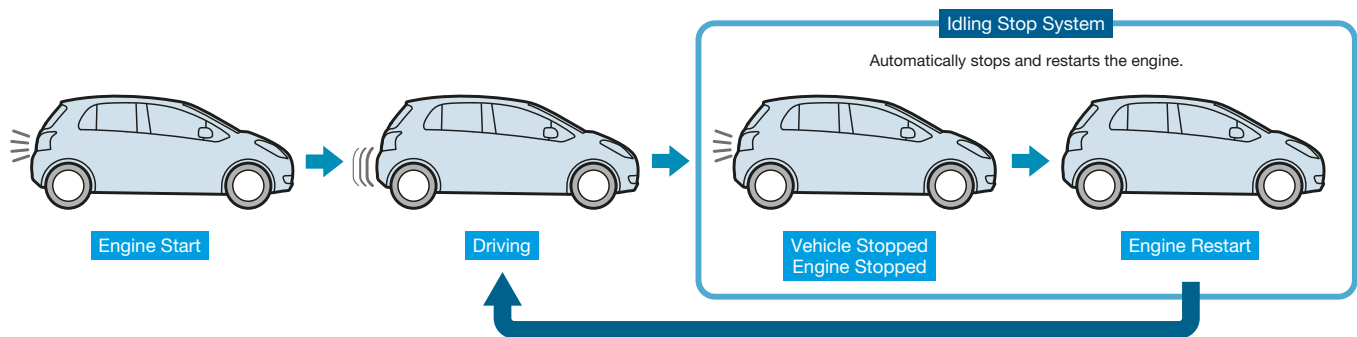
> Idling Stop System (ISS)

Outline

The number of vehicles equipped with idling stop system (ISS) is on the rise due to increased public awareness of environmental issues, and stricter CO₂ exhaust gas regulations. The ISS automatically stops the engine* when the vehicle is not moving, and restarts the engine when accelerator depression is detected. Therefore, the amount of engine idle time decreases, and both the fuel consumption and CO₂ exhaust gas quantities are reduced.

However, the ISS frequently operates the starter, leading to engine vibration and noise. To reduce these undesirable effects, a starting mechanism was required that could quickly and smoothly start and stop the engine.

*Several conditions must be met to stop the engine. These conditions vary according to the vehicle



Functionally, ISS continues to evolve towards further fuel consumption rate improvements such as vehicles equipped with expanded idling stop (engine stops during deceleration) and high-output regenerative braking. These improvements point towards full-scale popularization of idling stop devices. Depending on vehicle manufacturer specifications, the ISS can help improve fuel efficiency by approximately 3 to 5 percent. DENSO has developed ISS technology that can improve fuel efficiency over 7 percent depending on the vehicle manufacturer's overall systems approach.

DENSO has been working on ISS technology since the 1980s. This experience, paired with our in-depth knowledge of powertrain and thermal management systems, gives us a unique advantage to provide car manufacturers with a complete systems approach. The company understands how to seamlessly integrate ISS components into the vehicle and can offer superior technical support that comes from decades of integration experience. DENSO can also provide car manufacturers with different technology solutions depending on their specific needs and requirements.

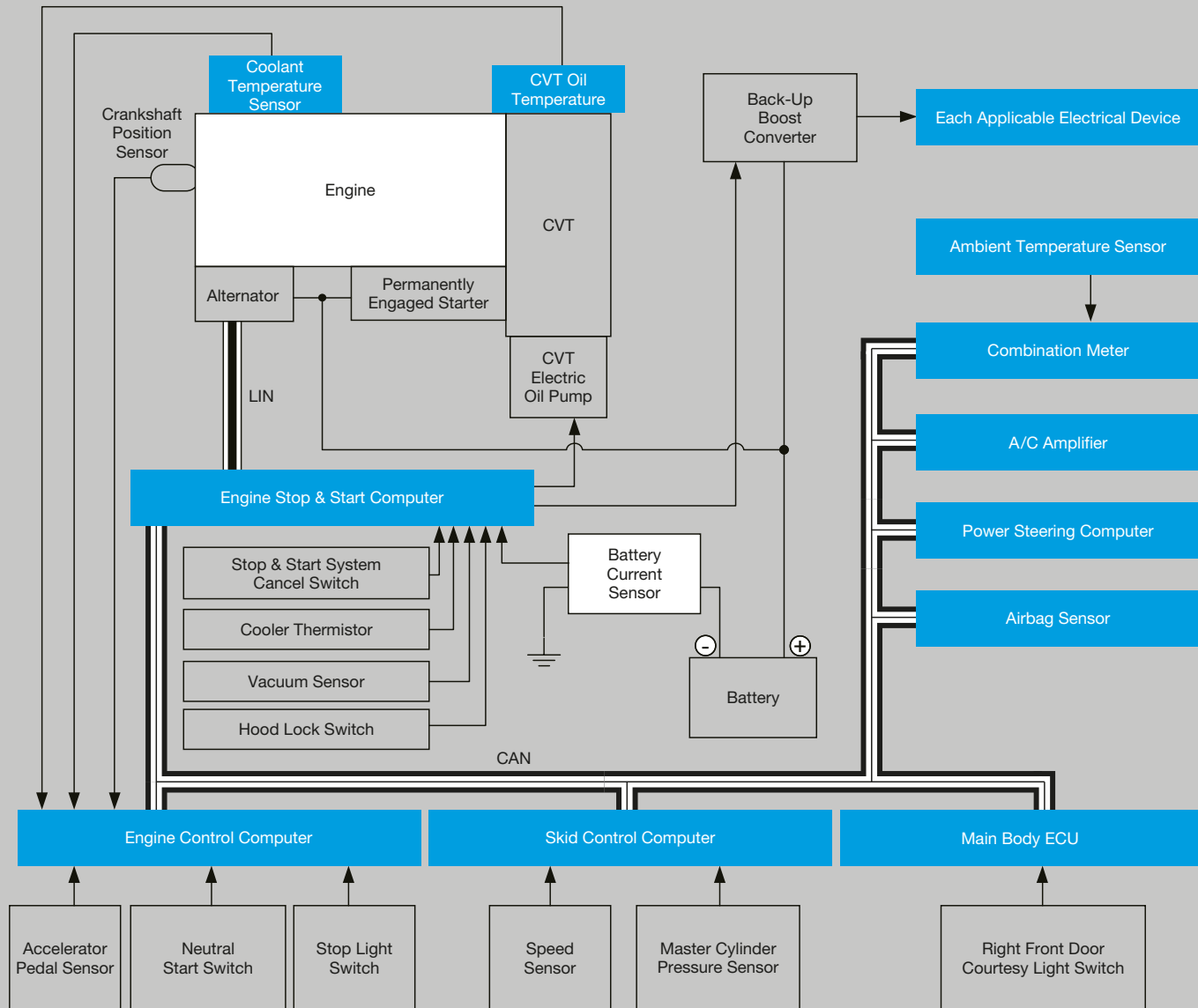
ISS Key Features

- > Compared to vehicles not equipped with ISS, ISS-equipped vehicles undergo at least 10 times the number of engine start-ups. Since frequent engine start-ups not only place load on the starting system, but also on the battery due to a constant need for a power supply, a more robust starting system and battery are required.
- > ISS-equipped vehicles use a charging control system that repeats battery charging and discharging to improve fuel economy. Since repeated charging and discharging places a load on the battery, a high-performance, long-life battery specifically for ISS-equipped vehicles is required. Using a battery other than the aforementioned specialized battery may lead to early battery deterioration and ISS malfunctions.
- > When restarting the engine, the battery voltage will decrease due to power from the battery being used to drive the starter. When driving the starter, the supply of voltage to electrical equipment may be boosted by a device such as a DC-DC converter.
- > Depending on the vehicle, idling stops may be suspended when the number of starter operations reaches a specified value.

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> Idling Stop System (ISS)

Example of ISS configuration & its components



Example of ISS Operating Conditions

ISS primarily operates according to the example conditions as shown in the table. The operating conditions differ according to the car manufacturer and car model.

Item	Example Operating Conditions (Idling stop occurs when all of the following conditions are satisfied)
Engine Coolant Temperature	After Warm-Up
Driver-Side Door	Closed
Engine Hood	Closed
Road Surface Gradient	Approximately 10° or less
Vehicle Speed	0 km/h
Accelerator Pedal	Released
Brake Pedal	Pressed
Shift Position	"D" range
Vehicle Speeds History	After and engine start-up and when speed is input
Idling Stop Button	ON

DENSO Starters | Stop & Start Technology > Idling Stop System (ISS)

DENSO ISS Starters Overview

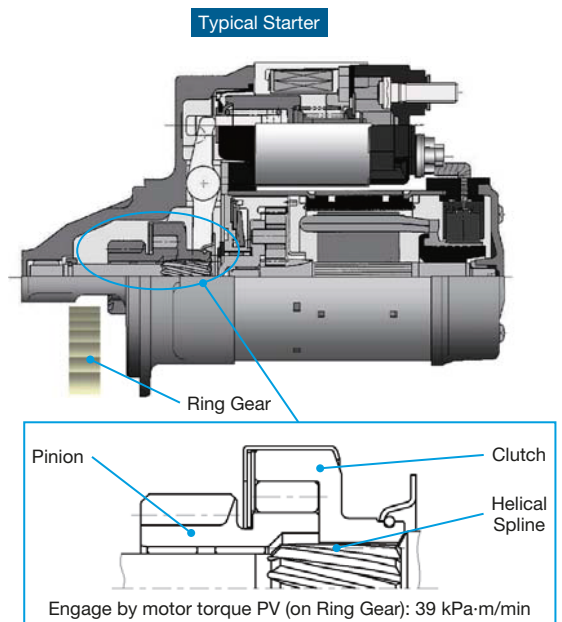
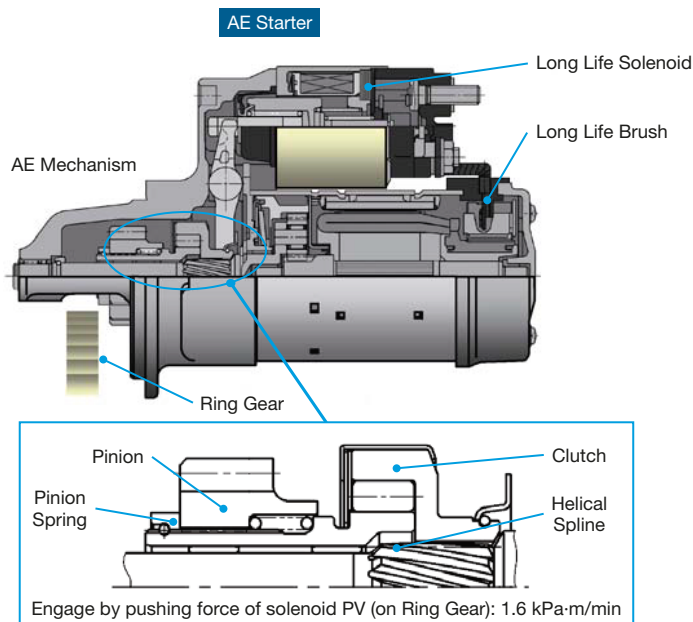
Advanced Engagement (AE) Starter

The Advanced Engagement (AE) Starter works like a typical planetary starter but has 10 times the durability. When it's energized, the pinion shifts forward, engages with the flywheel and immediately spins. As a starter motor-based solution for ISS, the AE starter is the easiest to integrate with the engine - requiring no unique controls, software or engine modifications. The AE starter helps car manufacturers achieve fuel savings of approximately 3-5 percent depending on engine size, and allows easy mountability for the customer, being about the same size as a conventional starter.

With an AE starter, once the vehicle comes to a stop, the fuel will be cut and the engine will stop. However, the engine must reach zero rpm to shut down. At any point after the engine is at zero rpm, the starter can be re-energized to restart the engine. The benefits and convenience of the AE Starter means that it is used by a wide range of manufacturers including Toyota, Hyundai, Honda, Fiat, Volkswagen, Audi, BMW and Mercedes-Benz.

The AE Starter's key design features include dual layer, long-life electrical brushes which have six to ten times durability compared to

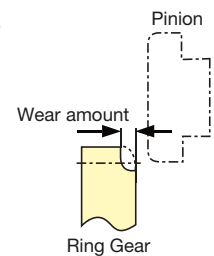
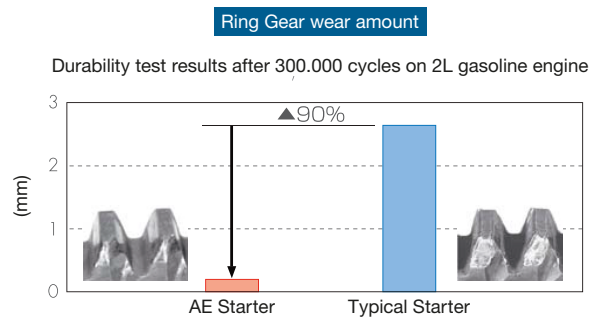
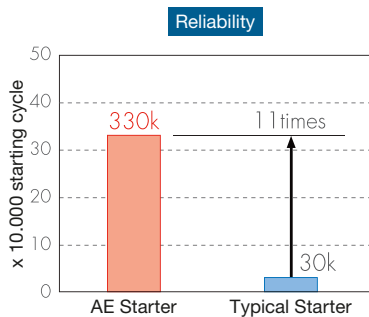
the brushes used for conventional starters, as well as unique structure and pinion spring mechanism (AE mechanism). AE mechanism construction features a pinion gear that is separated from the inner clutch and the addition of a pinion spring. When the pinion gear collides with the ring gear, pinion spring deflection and the effect of the spiral spline produce a smooth gear engagement. Since only the force used to push out the pinion gear is applied to the edges of the pinion gear and ring gear, wear on the gear tips is suppressed, thereby improving the durability of both gears by 90 percent.



Engineering Key Point

Separate pinion from clutch and add pinion spring between pinion and clutch. Complete meshing before motor rotation by spring compression and helical spline.

Benefit



DENSO Starters | Stop & Start Technology

> Idling Stop System (ISS)

“Change of Mind” Starters

Engine restart times are critical for stop and start engines. A unique starting system is required to restart an engine after fuel supply is cut and before a vehicle comes to a full stop. DENSO has developed two different starters, the PE Starter and the

TS Starter, which have the capability of restarting before the engine reaches zero rpm. That means it doesn't need to wait for the engine to completely drop from idle speed to zero rpm, like the AE starter. This is what we call a “Change of Mind” capable

starter that allows the engine to restart with no noticeable lag time. DENSO's PE or TS Starter, paired with a high-efficient alternator and battery, and deceleration regeneration system can improve fuel efficiency by more than 7 percent.

Tandem Solenoid (TS) Starter

DENSO's new starter, Tandem Solenoid (TS) starter, shaves up to 1.5 seconds off the restart time when restarting the engine, compared to the DENSO's previous ISS starter. The TS Starter is designed specifically for ISS. It adopts a co-axial dual solenoid in the magnetic switch to allow for independent control of the starter's pinion gear shifting mechanism, and motor rotation. This enables the engine to restart while it is still rotating. Special software is required to control the timing and synchronize the pinion

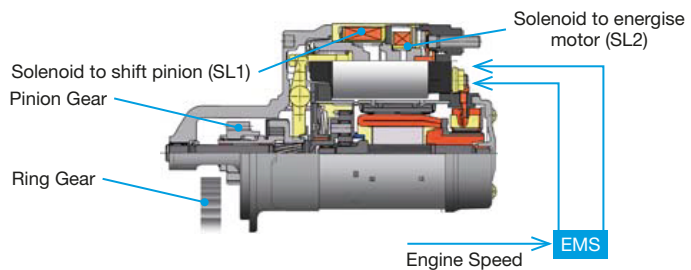
gear into the spinning flywheel ring gear. Aside from the dual solenoid design, TS Starter is equipped with all the same long-life features of the AE Starter. Additionally, the basic construction is identical to a planetary starter and it can fit in the same space as a conventional starter. The TS Starter has already been launched and adopted by many Asian car manufacturers. Various European car manufacturers such as Jaguar and Land Rover also use a TS Starter for new ISS-equipped vehicle models.



To start the engine, starters shift the pinion gear forward to mesh with the engine ring gear, which transmits the rotational force of the starter motor through the pinion gear. The conventional ISS starter has a mechanism that conjunctionally shifts the pinion gear and energises the motor for rotation. This means it is not capable of restarting when the engine is rotating – or while the engine is coasting after the vehicle is stopped. With the TS starter, if the engine is rotating fast, the motor is first energised to increase the pinion gear speed and then the pinion gear is shifted forward when the rotation of the ring gear and pinion gear are close. When the engine is turning slowly enough for the two gears to be connected, the pinion gear is first moved forward and then the motor is powered. This allows the engine to be re-engaged (and re-started) by the starter motor during the 0.5 to 1.5 seconds of dead time that the engine rpm is simply falling from idle (~600 rpm) to zero rpm. Therefore, depending on the engine, up to 1.5 seconds can be shaved off from restarts.

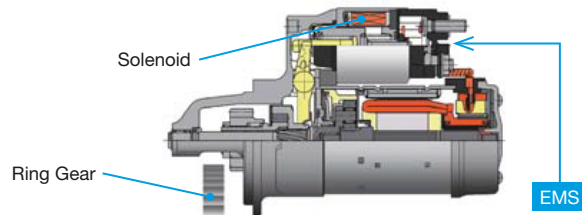
TS Starter

Independent control of pinion gear shift and motor energization by two solenoids



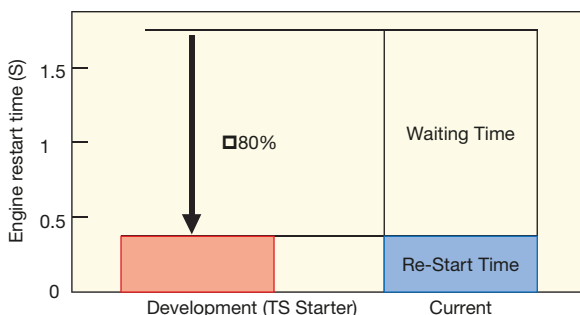
AE Starter

Conjunctional control of pinion gear shift and motor energisation by one solenoid

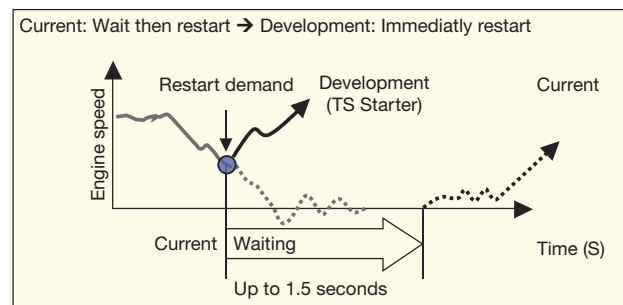


EMS: Engine Management System

Re-start time during engine run down



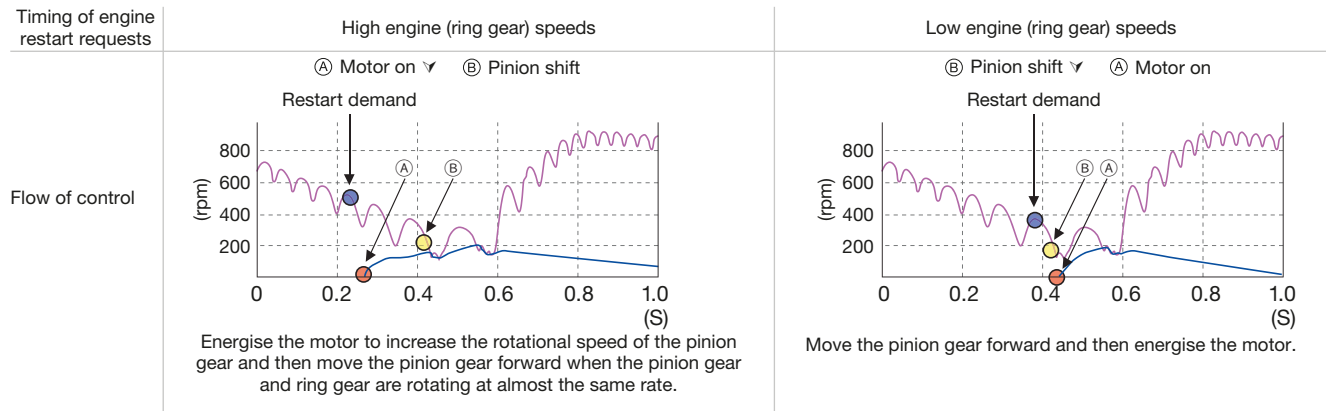
Re-start during engine run down



DENSO Starters | Stop & Start Technology > Idling Stop System (ISS)

TS Starter Engineering Key Point

Separately control pinion gear forward movement and motor energisation according to engine speed



Engine restart requests: The driver's actions identified as requests to restart the engine, such as releasing the brake pedal

Permanently Engaged (PE) Starter

DENSO's Permanently Engaged (PE) Starter eliminates the starter's pinion gear shifting mechanism and mounts to the engine so that the starter is permanently engaged with the flywheel.

The PE Starter is "Change of Mind" capable and delivers the quickest and quietest restart times of all starter motor-based systems, while improving the overall fuel-saving potential depending on the overall system approach.

Conventional ISS starters have to shift the starter motor pinion forward, mesh it into the ring gear, and then disengage the two gears after the engine starts - all of which can result in restart delays and

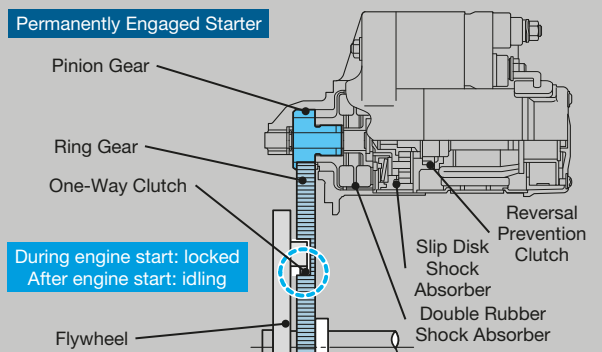
noise.

However, the PE Starter does not need time to engage the mating gears. It has a new mechanism that enables the pinion gear to be constantly meshed with the engine ring gear. When a restart is needed, the motor is energised, and immediately re- cranks the engine. The PE Starter also achieves a compact and lightweight design by using a compact high-speed motor and planetary gears.

The PE Starter is jointly developed with Toyota Motor Corp and is primarily used in Toyota models equipped with ISS, such as the Auris and Yaris models sold in Europe since 2009.

Features

- > **Double Rubber Shock Absorber:** Shock absorption at engine start and starting noise reduction.
- > **Slip Disk Shock Absorber:** Flywheel with built-in one-way clutch protection.
- > **Reversal Prevention Clutch:** Engine oscillation reduction at engine stop and prevention from turning in the wrong direction.
- > **Flywheel with built-in one-way clutch:** The flywheel requires a special clutching mechanism to disengage ring gear from engine after engine restart.



PE Starter Engineering Key Points

- > At engine start: starting noise reduction by the double rubber shock absorber and starting time reduction by the permanently engaged system.
- > At engine stop: vibration reduction by the reversal prevention clutch.

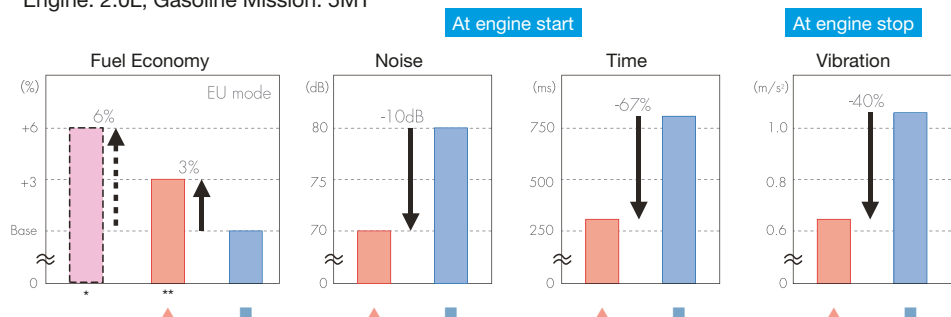
*Fuel cut before vehicle stop

**Fuel cut after vehicle stop

▲ Development
■ Conventional

Benefits

Engine: 2.0L, Gasoline Mission: 5MT



DENSO Starters | Stop & Start Technology

> Idling Stop System (ISS)

Further ISS Approach

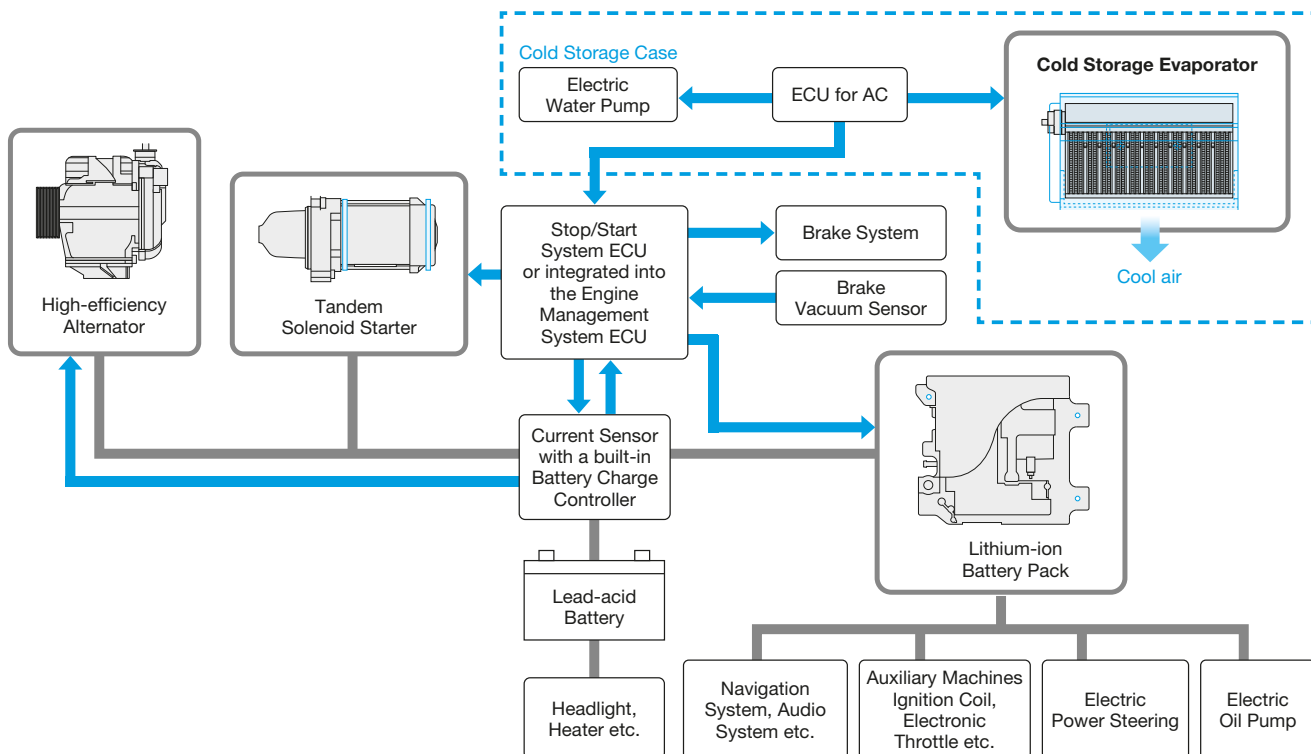
An ISS approach is more than just starter technology. There are many additional products and components that can be added to any ISS approach to enhance comfort and convenience and improve powertrain performance. Many of these products better manage energy in a vehicle, which also translates into fuel efficiency.

Key Points

- > Using a TS (Tandem Solenoid) starter helps the engine to restart quickly and seamlessly after it shuts down.
- > In-rush Current Reduction (ICR) Relay – sometimes when the engine is restarted, there can be a “dimming” of lights, or a reset of some devices due to the large electrical demand placed on the system by the starter motor. An ICR Relay located between the battery and starter motor reduces the system voltage dip that happens every time the starter cranks the engine.
- > A high efficiency alternator recovers the energy wasted while the car is slowing down and transforms it into electric power.
- > DENSO’s lithium-ion battery pack stores regenerated power and supplied it to electric and electronic components, reducing the power generation needed by the alternator.
- > DENSO’s cold storage system helps maintain the cabin’s temperature when a vehicle with ISS is at a stop and air conditioning is no longer powered.
- > DENSO’s brushless electric water pump will help maintain a vehicle’s temperature when a vehicle with ISS is at a stop and the heater is on. The electric water pump is smaller yet more energy efficient because it uses less power.

System Structure

Idle Stop System



DENSO Starters | Replacement Guide

The following general information has been established as a common instruction for starter removal and installation. Refer to the appropriate Vehicle Manufacturer's Service Manual for specific information corresponding to starter removal and installation procedures and safety precautions for the vehicle.

Always disconnect the cable from negative (-) battery terminal before replacement and wait at least 90 seconds after disconnecting the cable to prevent any type of activation. After replacement, connect the cable to negative (-) battery terminal.

Personal injury or damage to the equipment and its components may occur if this step is not performed.

Removal

1. Identify each wire connection, and note the location of each on the starter.
2. Disconnect and remove the battery cable from the starter.
3. Disconnect and remove all other wires from the starter.
4. Loosen the starter mounting bolts. Do not remove the bolts yet.
5. Support the starter and remove the bolts holding the starter in place. Set the bolts and starter aside. Be sure to note fastener size and location before removing the starter.
6. Inspect the flywheel or flexplate ring gear through the starter-mounting port for tooth damage. Replace as necessary.

Installation

1. Physically compare the replacement starter to the original starter. Compare the wire connector locations, front housing clocking, adjusting hole locations and drain hole position to the original starter.
2. Support the starter and fasten it into position. Torque the mounting bolts to the vehicle manufacturer's recommended specifications.
3. Re-connect the previously removed wires to their proper location on the starter. Be sure that there is no interference between the wire harness and other components. Torque all threaded fasteners to the vehicle manufacturer's recommended specifications.
4. Re-connect the battery cable to its proper location on the starter. Do not over tighten battery cable retaining nut. See the vehicle manufacturer's recommended specifications for correct torque value.
5. Re-connect the negative battery cable to the battery. Do not over tighten negative battery cable. See the vehicle manufacturer's recommended specifications for correct torque value.
6. Check the starter for proper operation.

DENSO Starters | Troubleshooting

> Diagnostic Chart

Starting System Diagnostic Chart

Starting problems are not always easy to identify and can cause unnecessary starter replacement. In troubleshooting, it is important to study closely the trouble symptom, thereby narrowing possible causes down to one or two. Most common problem symptoms, related possible causes and corresponding corrective actions are listed in the chart below.

Symptom	Possible Cause	Corrective Action
Engine does not crank	<ol style="list-style-type: none"> 1. Dead or defective battery. 2. Melted fuse/fusible link. 3. Loose connections. 4. Ignition switch or relay, neutral start switch, clutch start switch contacts in poor condition. 5. Magnetic switch contacts worn away. 6. Malfunction of the magnetic switch (pull-in coil or plunger). 7. Malfunction of starter motor assembly (layer short, brush wear). 8. Mechanical problem in engine. 	<ol style="list-style-type: none"> 1. Check battery state of charge. Recharge if possible. Replace if necessary. 2. Replace as necessary. 3. Clean and tighten connections. 4. Replace components as necessary. 5. Replace starter. 6. Replace starter. 7. Replace starter. 8. Check engine.
Engine cranks too slowly to start	<ol style="list-style-type: none"> 1. Weak battery. 2. Loose or corroded connections. 3. Poor magnetic switch contact. 4. Starter motor assembly malfunction (layer short, brush wear). 	<ol style="list-style-type: none"> 1. Check battery state of charge. Recharge if possible. Replace if necessary. 2. Clean and tighten connections. 3. Replace starter. 4. Replace starter.
The starter rotates, but cannot crank the engine	<ol style="list-style-type: none"> 1. Damaged or worn starter pinion gear or engine ring gear. 2. Defective over-running clutch. 	<ol style="list-style-type: none"> 1. Check gears for damage or wear. Replace starter or ring gear. 2. Replace starter.
The starter does not stop rotating	<ol style="list-style-type: none"> 1. Damaged or worn starter pinion gear or engine ring gear. 2. Defective magnetic switch. 3. Defective ignition switch or control circuit. 4. Binding ignition key. 	<ol style="list-style-type: none"> 1. Check gears for damage or wear. Replace starter or ring gear. 2. Replace starter. 3. Replace defective components as necessary. 4. Check key for damage.
Abnormal starter noise	<ol style="list-style-type: none"> 1. Abnormal bushing wear. 2. Wear on the starter pinion gear or engine ring gear tooth tips. 3. Starter pinion gear sliding failure. 	<ol style="list-style-type: none"> 1. Check and replace the starter if necessary. 2. Check gear tooth tips for damage or wear. Replace starter or ring gear. 3. Replace starter.

DENSO Starters | Troubleshooting

> Inspection

Inspection

Visual Inspection

Begin with a thorough visual inspection of system and components.

System Cables & Wires

- > Make sure all connections are intact, tight, clean and corrosion free.
- > Check wires for wear, insulation damage and other physical damage.

Starter Physical Condition

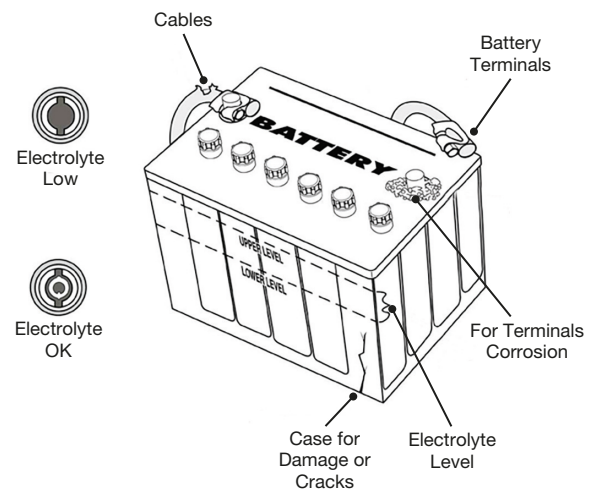
- > Check for oil, dust, water contamination due to usage in severe environmental conditions.
- > Check for damaged holes, terminals, thread due to incorrect tightening or fixing.
- > Check for overheated/deformed label, discolored terminals due to abnormal starter usage such as prolonged cranking.
- > Check for teeth wear, discoloration, hard pinion rotation due to abnormal starter usage such as prolonged cranking.

Electrical Tests

On-Vehicle Inspections

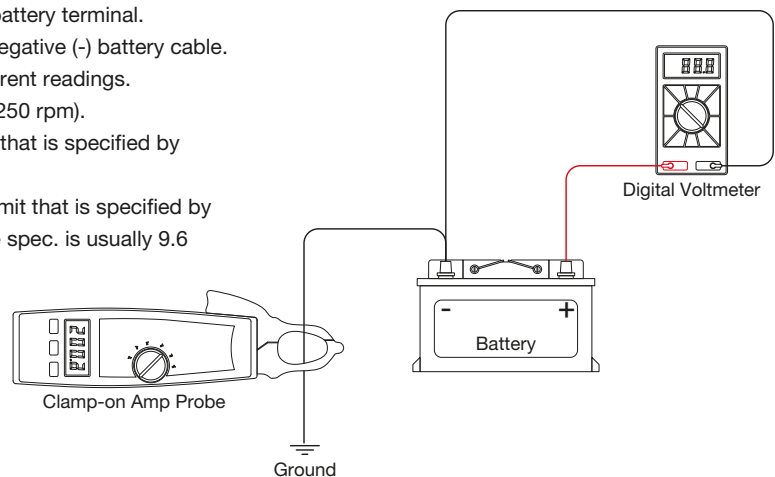
Battery inspection

- > Before performing any electrical system diagnosis or repair, make sure the battery has been visually inspected, performance tested and is fully charged.
- > Battery, battery cables, battery terminals condition affect the ability of the battery to provide sufficient power.
- > Charge the battery and check the open circuit voltage.
- > If 12.6 Volts (full charge) or above is not measured, replace the battery and continue to evaluate the charging system.
- > If the open circuit voltage is 12.6 Volts or above, perform battery load-test.
- > A load-test measures the battery's ability to deliver power.
- > Also, if the battery can not be recharged, there may be a charging problem that causes starting system problems. In this case, inspect the charging system and its components.



Starting system current draw test

- > Connect voltmeter positive (+) lead to positive (+) battery terminal.
- > Connect voltmeter negative (-) lead to the negative (-) battery terminal.
- > Connect the clamp-on amp probe pickup around the negative (-) battery cable.
- > While cranking the engine, observe the voltage and current readings.
- > Cranking speed should be normal (approximately 200-250 rpm).
- > Current draw should be at or below the maximum limit that is specified by vehicle manufacturer's repair manual.
- > Cranking voltage should be at or above the minimum limit that is specified by vehicle manufacturer's repair manual. Cranking voltage spec. is usually 9.6 Volts approximately at 20-25°C.



Note: Test can be performed with:

- > Electronic tester
- > Carbon pile load tester
- > Cranking the engine. If cranking the engine,
 1. Disable the fuel or ignition system to keep the engine from starting during the test.
 2. DO NOT crank the engine for longer than 10 seconds at a time.
 3. Wait a minimum of 60 seconds before cranking engine again to cool the starter.

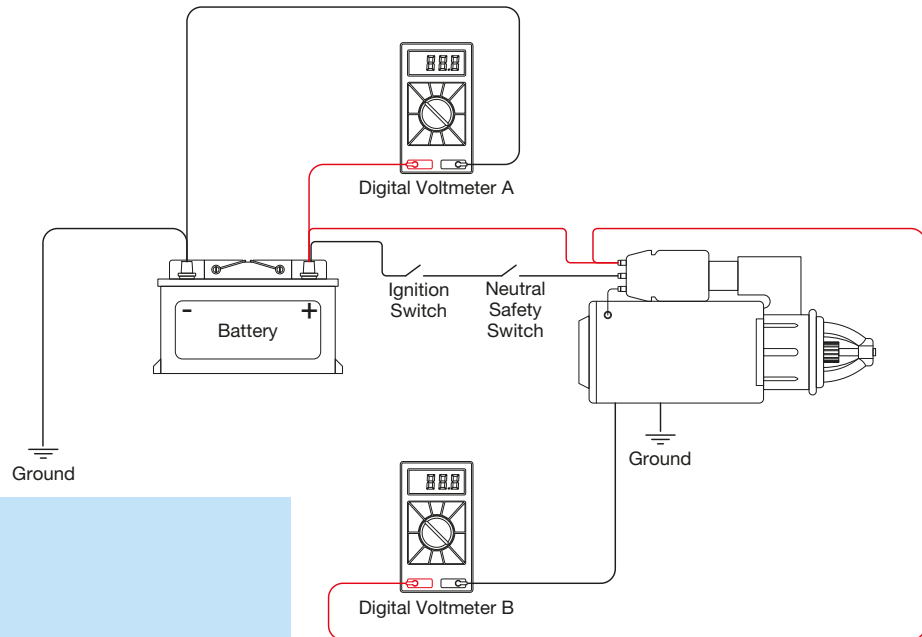
High current draw and low cranking speed usually indicate a defective starter. This can be caused by starter motor layer short, worn brushes or bushings, mechanical blockage. High current draw may also be caused by engine problems. A low cranking speed with low current draw, but high cranking voltage, usually indicates excessive resistance in the starter circuit.

DENSO Starters | Troubleshooting

> Inspection

Starting system voltage drop test

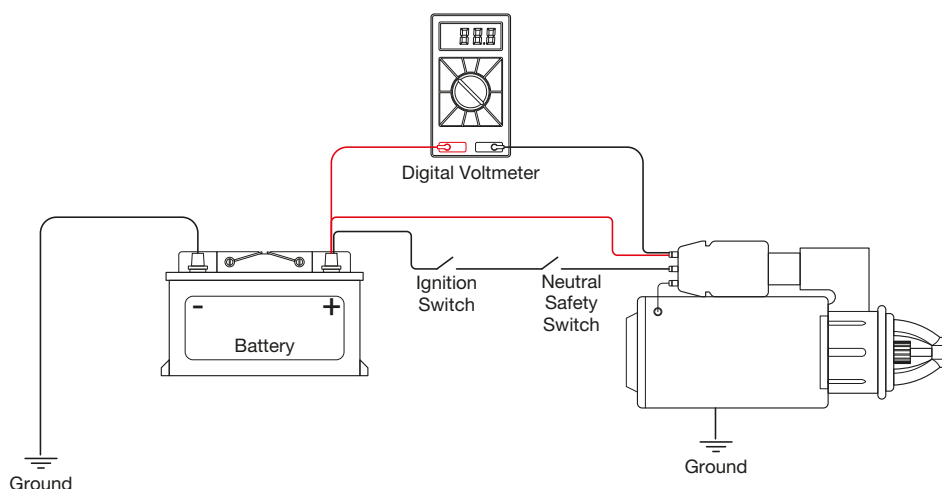
- > Connect the voltmeters according to the illustration. While cranking the engine, observe voltage readings.
- > Calculate voltage drop on the starting circuit by subtracting (-) Voltmeter B from Voltmeter A. Voltage loss should not exceed 0.5 Volt.
- > If total loss exceeds 0.5 Volt, there is excessive voltage drop somewhere in the circuit, proceed with starter positive and negative side voltage drop tests and control circuit voltage drop tests to isolate the cause and repair the fault.



Note: Test can be performed with:

- > Electronic tester
- > Carbon pile load tester
- > Cranking the engine. If cranking the engine,
 1. Disable the fuel or ignition system to keep the engine from starting during the test.
 2. DO NOT crank the engine for longer than 10 seconds at a time.
 3. Wait a minimum of 60 seconds before cranking engine again to cool the starter.

High resistance in starter positive or negative side reduces current to the starter motor and causes slow cranking speed or hard cranking. High resistance in starter control circuit reduces current to the magnetic switch and causes improper operation or no operation at all. Every wire, cable and terminal connection has the potential to create excessive voltage loss that can affect starter performance. Checking the voltage drops provide helpful tips to find hidden problems that can cause a starting system problem. Voltage always flow through the path with the lowest resistance. Therefore, if there is a high resistance somewhere in the circuit, some of the voltage flow through the meter and creates a voltage value on meter's display.



Positive side voltage drop test

- > Connect voltmeter positive (+) lead to positive (+) battery terminal, and the voltmeter negative (-) lead to the battery terminal on the starter. While cranking the engine, observe the voltage reading on voltmeter.
- > If voltage drop is 0.5 Volts or less, the resistance at positive side is acceptable.
- > If voltage drop is more than 0.5 Volts, there is excessive resistance.

Note: Test can be performed with:

- > Electronic tester
- > Carbon pile load tester
- > Cranking the engine. If cranking the engine,
 1. Disable the fuel or ignition system to keep the engine from starting during the test.
 2. DO NOT crank the engine for longer than 10 seconds at a time.
 3. Wait a minimum of 60 seconds before cranking engine again to cool the starter.

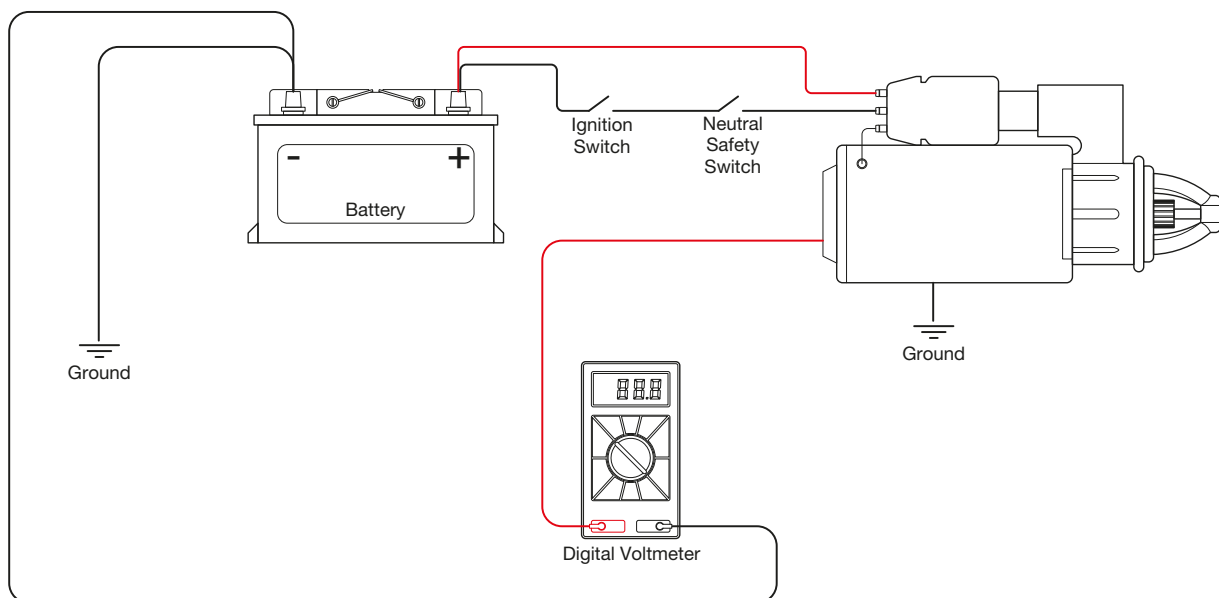
DENSO Starters | Troubleshooting

> Inspection

- > Excessive resistance could be caused by a damaged battery cable, poor connection at battery or starter terminal, or a defective magnetic switch.
- > Clean and tighten the battery terminals and perform the following voltage drop tests to isolate the cause and repair the fault.
- > While cranking the engine, check the voltage drop between positive (+) battery terminal and cable connection. Connect the voltmeter positive (+) lead to the positive (+) battery terminal and the voltmeter negative lead (-) to the battery cable clamp. Acceptable cable connection voltage drop should be zero Volt.
- > While cranking the engine, check the voltage drop of positive (+) battery cable. Connect the voltmeter positive (+) lead to the clamp on the positive (+) battery cable and the voltmeter negative (-) lead to the end of the cable at the starter. Acceptable battery cable voltage drop should be 0.2 Volts or less.
- > While cranking the engine, check the voltage drop across the magnetic switch. Connect the voltmeter positive (+) lead to positive (+) battery terminal on the starter, and the voltmeter negative (-) lead to the starter motor terminal. Acceptable voltage drop across the magnetic switch should be 0.3 Volts or less.

Negative side voltage drop test

- > Connect voltmeter positive (+) lead to a clean spot on starter motor housing, and the voltmeter negative (-) lead to the negative (-) battery terminal. While cranking the engine, observe the voltage reading on voltmeter.
- > If voltage drop is 0.2 Volts or less, the resistance at negative side is acceptable.
- > If voltage drop is more than 0.2 Volts, there is excessive resistance.



Note: Test can be performed with:

- > Electronic tester
- > Carbon pile load tester
- > Cranking the engine. If cranking the engine,
 1. Disable the fuel or ignition system to keep the engine from starting during the test.
 2. DO NOT crank the engine for longer than 10 seconds at a time.
 3. Wait a minimum of 60 seconds before cranking engine again to cool the starter.

- > Excessive resistance could be caused by poor starter mount on vehicle, poor battery ground or a loose connection.
- > Check if the starter is properly installed.
- > Make sure all the ground points/straps between the engine and chassis are secured.
- > Clean and tighten the battery terminals and perform the following voltage drop tests to isolate the cause and repair the fault such as similar to the positive side.
- > While cranking the engine, check the voltage drop between negative (-) battery terminal and cable connection. Should be zero Volt.
- > While cranking the engine, check the voltage drop of negative (-) battery cable from the battery to the engine block. Should be 0.2 Volts or less.
- > While cranking the engine, check the voltage drop between the starter housing and the engine block. Should be 0.2 Volts or less.

DENSO Starters | Troubleshooting

> Inspection

Starting system control circuit voltage drop test

- > If the battery is in good condition but starter does not crank the engine, the problem could be a poor ignition switch connection or excessive resistance in the starter control circuit that can reduce the voltage available to the magnetic switch. Symptoms of this problem will be pinion gear does not engage or engage improperly.
- > Excessive resistance could occur at ignition switch contacts, park/neutral start switch or clutch start switch, or circuit wiring and connections. Perform the following voltage drop tests to isolate the cause and repair the fault.
- > Connect the voltmeter positive (+) lead to the positive (+) battery terminal and the voltmeter negative (-) lead to the magnetic switch terminal on starter.
- > Put the gear shift selector in park or neutral for vehicles with automatic transmission, depress the clutch pedal for the vehicles with manual transmission. Crank the engine and observe the voltage reading on voltmeter.
- > Also, check the voltage drop across the ignition switch and neutral start switch or clutch start switch.
- > Check whether voltage readings are within appropriate vehicle manufacturer's specs. or not. Adjust or replace the defective switches as necessary.

Note: If cranking the engine:

1. Disable the fuel or ignition system to keep the engine from starting during the test.
2. DO NOT crank the engine for longer than 10 seconds at a time.
3. Wait a minimum of 60 seconds before cranking engine again to cool the starter.

Starter Relay

One of the possible causes of the starting system problems could be a defective starter relay (if equipped). Perform continuity test to identify whether the relay is defective or not. Check for continuity with the relay de-energised and energised. If any of these tests do not match the vehicle manufacturer's specified results, replace the starter relay.

An alternative voltage drop method

Checking the voltage drop across each component of the starting circuit is an alternative method to locate the cause of excessive voltage drop. Leave the voltmeter positive (+) lead connected to the positive (+) battery terminal and move the voltmeter negative (-) lead back through the circuit toward the battery. Continue to test each connection while cranking the engine until a noticeable decrease in voltage drop is detected. The cause of the excessive voltage drop will be located between that point and the preceding point.

DENSO Starters | Troubleshooting > Inspection

ISS Troubleshooting Outline

- > A scan tool is necessary for vehicles with ISS system to isolate the cause and repair the fault of ISS system or its components.
- > As an example, the active test and work support are required for starter inspection on the vehicle and removal/installation checks.
- > The test monitor function is useful for dividing up the system for troubleshooting.
- > The number of times that the starter is operated is much greater in vehicles equipped with ISS. As an example, the number of starter operations is counted in Toyota vehicle applications equipped with PE starters. When the number reaches a determined value, a warning light illuminates to urge starter replacement.
- > When parts related to ISS are replaced, it is necessary to register or reset the relevant parts on scan tool to instruct engine ECU.
- > In most vehicles, when the battery terminals are disconnected or connected, the vehicle must be driven for a certain amount of time such as 15 to 40 minutes until ISS system operates. If the vehicle is not driven, ISS system will be prohibited for the specified amount of time.

For Starter Inspection, Removal and Installation

Active Test Forces Drive, Starter Inspection

Work Support Reset Number of Starter Operations

Data Monitor, Separation of Malfunctioning Systems and Components

項目	値	単位
バッテリー電圧	13.5	V
バッテリー電流	2.3	A
バッテリー液温	41.9	°C
オルタ発電量デューティ比	25.0	%
オルタ発電電圧指示	13.80	V
ダイアグノースト	0	個
充電制御	00:02:30	
駆動中[00:00:05]		
総電要求電圧	12.5V	

Active Test, Forces Drive, Separate into System Malfunction or Alternator Malfunction

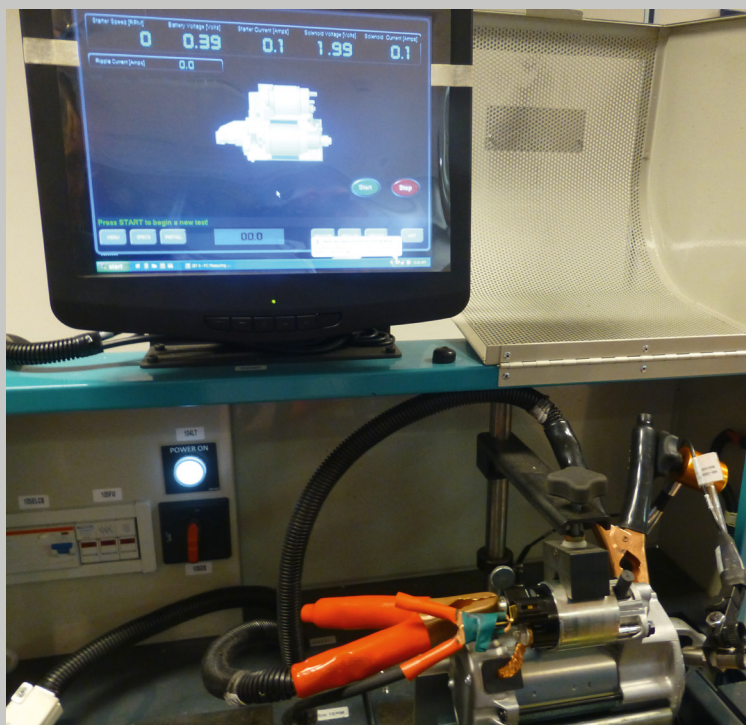
スター作動回数クリア

ステップ1/2

スタータ作動回数の初期化を開始します。

Aキーを押してください。

B:戻る A:開始



Starter Test bench inspection

If a starter will be tested on a test bench, follow the procedures found in the test bench instruction manual to conduct a starter performance test. This test will determine if the starter output is within its performance specification, preventing unnecessary starter replacement.

If the test bench results indicate the starter output to be out of specification, replace the starter.

If the starter output is within specification during bench testing, resolve problems in the remainder of the vehicle's starting circuit and other electrical circuits that may affect starting system performance. Refer to the vehicle manufacturer's service manual for the procedures necessary to identify and correct additional starting circuit problems.

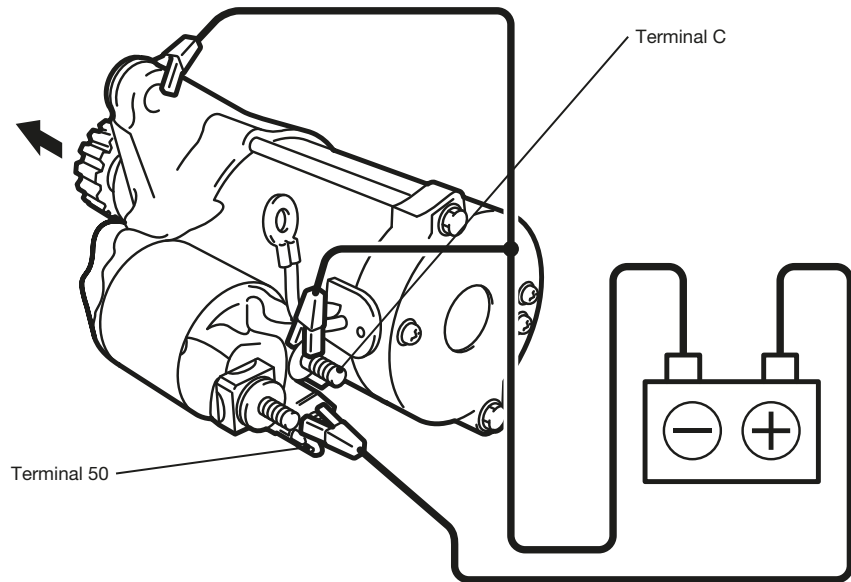
Function Tests

Perform each test in a short period of time (three to five seconds).

1. Pull-in test

- 1) Remove the nut and the lead wire from terminal C.
- 2) When connected as per the figure:
 Battery (+) 1 ⊞ Terminal 50
 Battery (-) 1 ⊞ Body and Terminal C

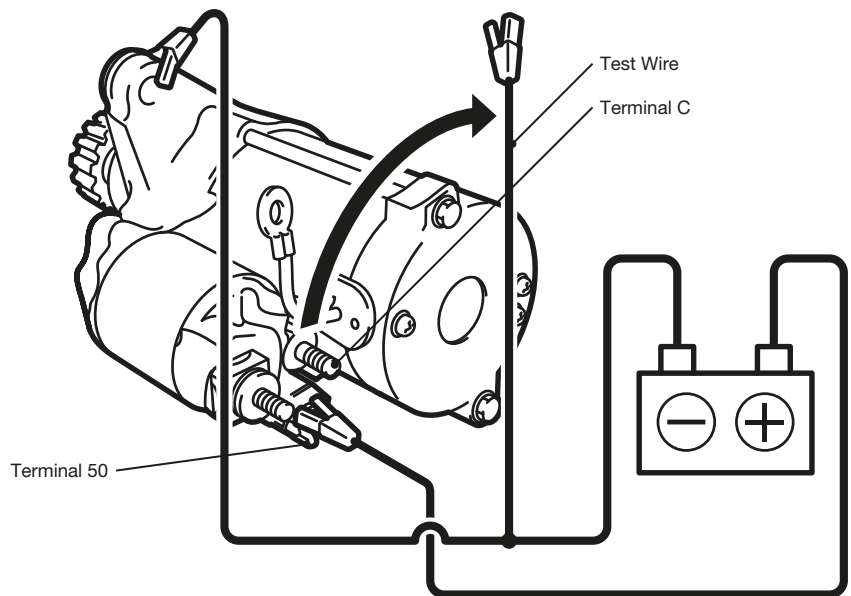
> Verify that pinion gear springs out.



2. Holding test

- 1) From the pull-in test conditions, check the pinion gear remains out even after the test wire is disconnected from terminal C.
- 2) Remove the ground wire.

> Verify that pinion gear returns.



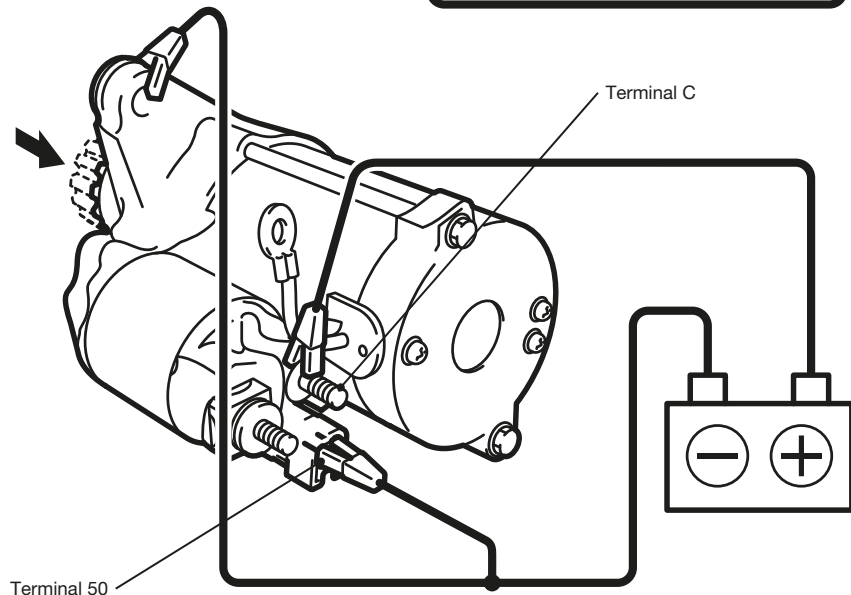
3. Return test

- When connected as per the figure:
- Battery (+) ⊞ Terminal C
 - Battery (-) ⊞ Body and Terminal 50

> Verify that pinion gear springs out.

If terminal 50 is removed during this state, the magnetomotive forces of both coils will balance out.

> Verify that the pinion gear instantly returns.



DENSO Starters | Troubleshooting

> Inspection

Performance Tests

Test Item	Outline
No-load test	Observe the maximum rotation speed and current when there is no load.
Load test	Observe the required current to generate the specified torque, and the rotation speed at that time.
Lock torque test	Observe the torque and current when the rotation speed is 0 under excessive load.

Caution:

- > Starter torque and rotational speed varies greatly according to the battery capacity. Conduct tests when the battery is properly charged.
- > A large amount of current flows, so perform the tests quickly.

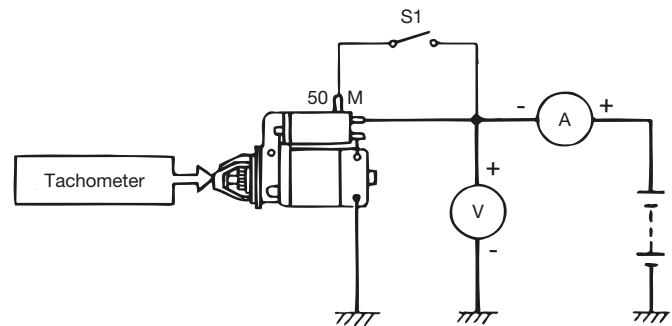
1. No-load test

Purpose

To verify the assembly and main contacts condition.

Method

- > Connect as shown in the figure, and close S1 to startup the starter.
- > Measure the rotational speed, voltage, and current when the starter rotation stabilizes.
- > Check if the results are within the manufacturer's specs or not.



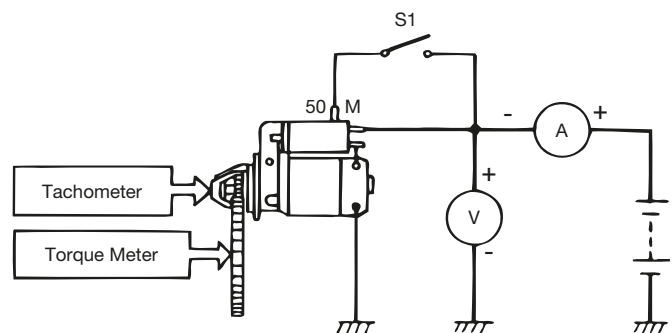
2. Load test

Purpose

To verify starter output under the regulated load.

Method

- > Connect as shown in the figure, and close S1 to startup the starter.
- > Apply the brake to the ring gear and adjust until the current matches the test standards.
- > Measure the voltage, torque and rotational speed.
- > Check if the results are within the manufacturer's specs or not.



3. Lock torque test

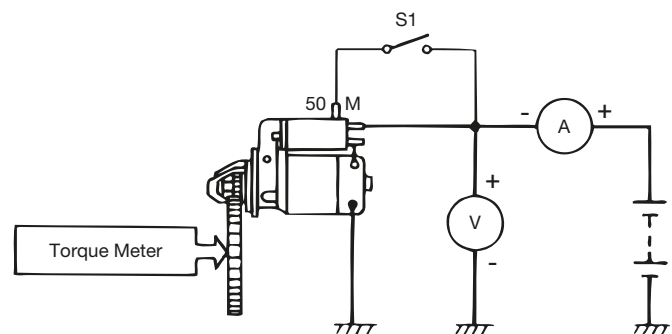
Purpose

To verify that the specified torque is output.

(Also observe the clutch sliding.)

Method

- > Connect as shown in the figure, and close S1 to startup the starter.
- > Lock the ring gear with the brake.
- > Measure the voltage, current, and torque while the ring gear is locked.
- > Check if the results are within the manufacturer's specs or not.



DENSO Starters | Troubleshooting

> Q&A

Q&A Section

Does the starter turn the engine too slowly?

- > The battery must be fully charged (12.6 Volts) and the battery cables, terminals and case in good, clean condition. This includes the frame and body ground connections and connections at the starter motor and magnetic switch.
- > Excessive engine oil viscosity, particularly in cold weather environments, will reduce the ability of the engine to rotate. This increase in engine drag will be transmitted to the starter during starter engagement, reducing its performance capability.
- > Engine modifications change the operating characteristics of the engine. If modifications are performed, a chance of additional forces acting against the starter will be introduced. The starter should be replaced with one matched to the new operating characteristics of the engine.

Does the starter fail to crank the engine?

- > The starter is designed to turn at a specified rotational speed to crank the engine. If there is a high resistance somewhere in the starting control circuit, or the battery connections or cables are corroded or dirty, this will cause the starter to turn slower than the specified rotational speed. Be sure that all the circuit connections and contacts, battery connections and cables are clean and secured properly. This includes the frame and body ground connections and connections at the starter motor and magnetic switch.

Does the starter rotate without rotating the engine?

- > The flywheel or flexplate transfers the rotational energy of the starter to the engine. If the starter is rotating but not the engine, check all teeth on the flywheel or flexplate ring gear to see if they are excessively worn, damaged or missing. Inspecting the flywheel or flexplate ring gear teeth can be performed through the starter mounting port if an inspection plate on the bell housing is not available.
- > A defective starter drive assembly could cause similar symptoms as a damaged flywheel or flexplate. If the starter pinion gear meshes properly with the flywheel or flexplate ring gear and does not rotate, the starter should be inspected for mechanical wear or damage.

Does the magnetic switch make operating noise when activated?

- > If clicking is heard when activating the starter control circuit and the starter does not rotate, the magnetic switch may not be receiving the voltage necessary to be fully activated. Check the starter control circuit for failed or damaged components and wiring, and loose, dirty or corroded connections.
- > If the magnetic switch is receiving proper voltage, the magnetic switch may have burnt contacts. Follow the vehicle manufacturer's procedures and safety precautions to inspect the starter.
- > If magnetic switch does not make any operating noise when activated and the starter does not rotate, the magnetic switch may be defective due to malfunction of pull-in coil or plunger. Follow the vehicle manufacturer's procedures and safety precautions to inspect the starter.

Is there audible noise when trying to start the engine?

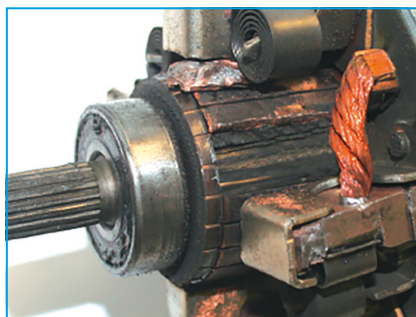
- > Audible noise may be associated with physical damage to the flywheel or flexplate. Inspect the flywheel or flexplate completely for cracks, dents, roundness balance, etc.
- > An inoperable starter magnetic switch or a damaged starter may also cause audible noise. Follow the vehicle manufacturer's procedures and safety precautions to inspect the starter.

What does continuous or prolonged cranking cause?

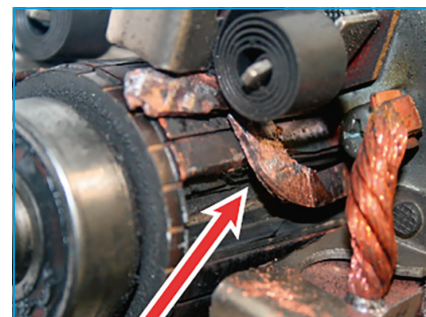
- > Low battery voltage results in excessive current flow to the starter motor.
- > Starter motor commutator is overheated, bars on commutator lift from insulator.
- > Damage to brushes and/or brush holder assembly occurs.



Commutator surface is glazed.
Commutator segment bars bent.



Commutator surface is burned.
Commutator segment bars missing.



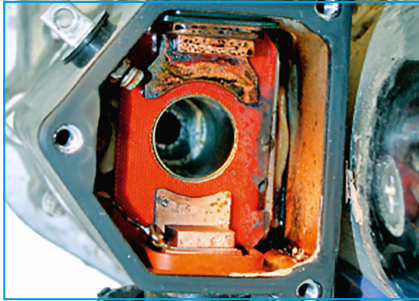
Commutator segment bar has separated,
raised and bent (distorted).

DENSO Starters | Troubleshooting

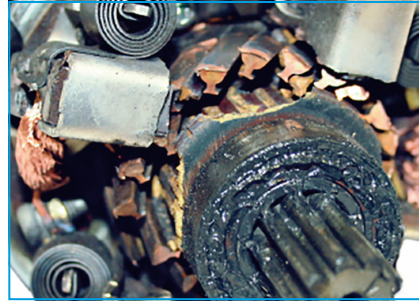
> Q&A

What does occur if the ignition key is excessively held in start position?

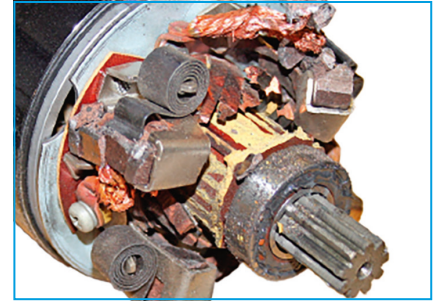
- > Starting control circuit stays closed and causing burnt magnetic switch main contacts.
- > Starter pinion gear rotates at flywheel speed (engine speed) and causing overrunning.
- > Commutator bars separate and causing damage to brushes, brush holder assembly and commutator.



Melted wire coating and case discoloration. Burnt odour.



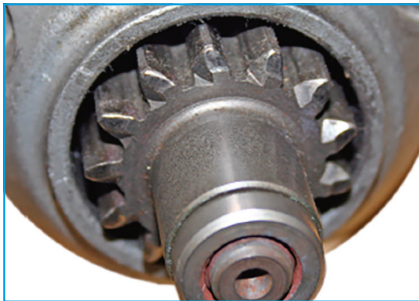
Separated commutator segments.



Damage to commutator, brushes and brush holder assembly.

What are the causes of pinion gear teeth damage and meshing problems?

- > New starter is fitted to the original flywheel which has damaged or worn ring gear teeth (or just the opposite).
- > Driver fault (engagement of the ignition key while the engine is operating).
- > Mechanical problem (ignition switch or starter magnetic switch main contacts stuck closed).



Minor case of re-engagement (will cause flywheel damage and have difficulty engaging into flywheel).



Moderate case of pinion re-engagement.



Extreme case of pinion re-engagement.

What are the signs of starter abuse and mishandling?



Solenoid cover has been struck repeatedly with a hammer or some other foreign object.



Damage to the terminal could cause ground contact with housing.



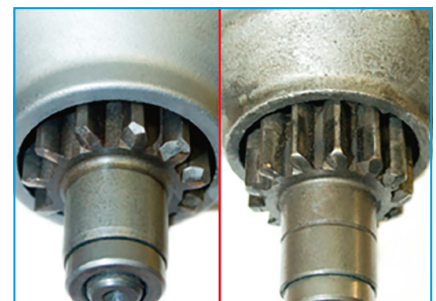
Starter to engine mounting bolt hole broken off due to mishandling, improper installation or over-torquing of the engine bolt.



ID tag has been overheated and has shrunk. This is a sign of excessive heat.



Melted insulation on the starter end housing thru bolts. This is a sign of starter abuse (overheated).



Normal starter (left), pinion gear fully retracted. Overheated (right), pinion gear not fully retracted. Overheating affects tension in the return spring.

DENSO Starters | Troubleshooting

> Q&A

What are the key aspects when selecting an aftermarket starter?

A replacement starter does not have to look like the original one, but it has to function the same and also match the fitting interface dimensions. There are numerous OE part numbers that are used by vehicle manufacturers, hence why aftermarket suppliers consolidate OE part numbers as much as possible. The most important features are:

- > Long lifetime and maintenance-free
- > Fitting interface dimensions such as fixing hole locations, diameters, thread sizes, terminal locations, etc
- > Number of pinion teeth, direction of rotation
- > Power output capacity should meet the vehicle's requirements

Caution: Never use a starter with lower power output capacity for a vehicle that requires a starter with higher power output capacity. For example, do not use a 1.4 kW rated starter for a vehicle that requires a 2.0 kW rated starter. Excessive current flow will cause premature starter failures.

Is it possible to use an Idling Stop System (ISS) starter instead of a conventional starter for the same car model or engine application?

If the ISS starter's overall construction and main dimensions (as shown in the illustration) are equivalent or smaller compared to a conventional starter, ISS starter may replace it. If the dimensions are very close or a little bigger, it is best to perform an installation check for fitting verification.

Also, replacing the conventional starter with an ISS type should not require unique controls, software or engine modifications such as DENSO Advanced Engagement (AE) Starter. It works like a conventional planetary starter but includes key design features like dual layer, long-life electrical brushes as well as a unique structure and pinion spring mechanism (AE mechanism).

Indeed ISS starters are built with high durability and performance features to ensure extended lifetime for increased number of starting cycles even under severe environmental conditions. Replacing with an ISS starter should therefore be considered as an upgrade though it may be costly.

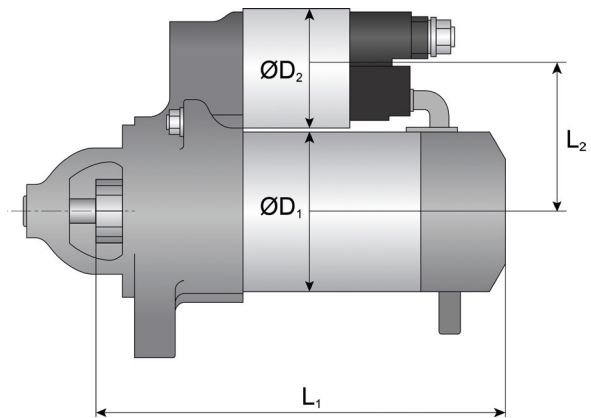
What are the latest developments in starting systems?

With the rise of electrification to save fuel and reduce emissions towards achieving the stringent emission legislation in 2020, advanced developments have been implemented to starting systems.

In comparison to the various hybrid concepts, emerging start-stop technologies for combustion engines have already changed the manufacturing landscape. A unique starting system with robust starter motor is required for vehicles with expanded idling stop-start features such as DENSO's "Change of Mind" starter motors which have the capability of restarting before the engine reaches zero rpm.

When it comes to Hybrid Electric Vehicle's (HEV's), rotating electric machine technology Integrated Starter Generator (ISG) replaces the alternator and starter motor for light electrification system architectures such as belt-driven ISG for micro/mild HEV's with low voltage systems.

- > ISG allows the HEV's engine to instantly and quietly restart (via the belt drive system) after the idle stop, so functions as a starter.
- > Like a conventional alternator, the ISG produces electric power when the vehicle is running, which is used to supply electric devices and/or to charge the battery.
- > The ISG can help to decelerate the vehicle by generating electric power, which is called regenerative braking. The electric power generated charges the battery, reducing fuel consumption.
- > If a clutch disconnects the ISG and the compressor from the engine during the idle stop, the ISG can drive the air-conditioning compressor via a belt.



DENSO is a major developer of small, long life ISGs with diverse OEMs.



Key benefits

- > Instant and quiet restarting
- > Generates electric power
- > Reduced fuel consumption

The DENSO logo is displayed in white, italicized, sans-serif capital letters on a red rectangular background.

Get inside

- 100% OE specification
- All 'new in box'
- No re-manufactured units and no core surcharge or returns policy
- Maximum efficiency
- Extensive applications list
- Market leading

As one of the world's largest automotive component suppliers, DENSO is a global leader in developing and manufacturing rotating machines. Our unwavering commitment to outstanding quality, design and innovation mean that our Starters and Alternators are selected as original equipment by carmakers worldwide – winning many supplier and international quality awards along the way. As well as delivering unique,

OE coverage of Toyota and a wide range of European marques such as Fiat, Opel, PSA, BMW, Ford, Volvo and Land Rover, the programme is continually being updated and expanding.

www.denso-am.eu

Driven by
Quality

PART 2

DENSO Alternators



DENSO Alternators | Characteristics

> System outline

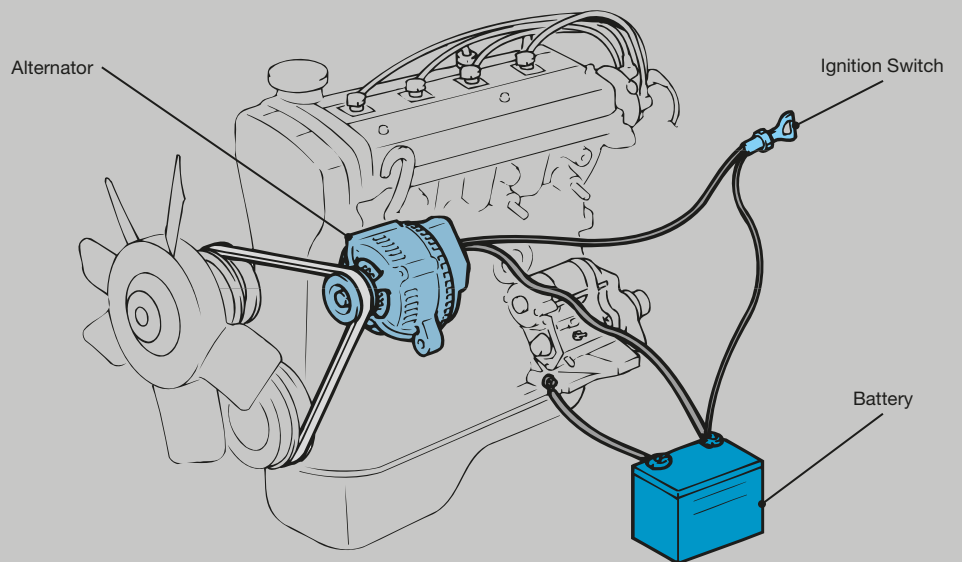
The alternator is driven by the engine, via the belt. It converts mechanical energy into electrical energy and supplies the required power to the various electrical loads. When power supplied by the alternator does not match the required electrical load (when all

the electrical equipment is in use, or when the engine speed is low during idling etc.), the battery temporarily supplies extra power to the electrical equipment. However, during normal driving the alternator re-charges the battery to the original strength.

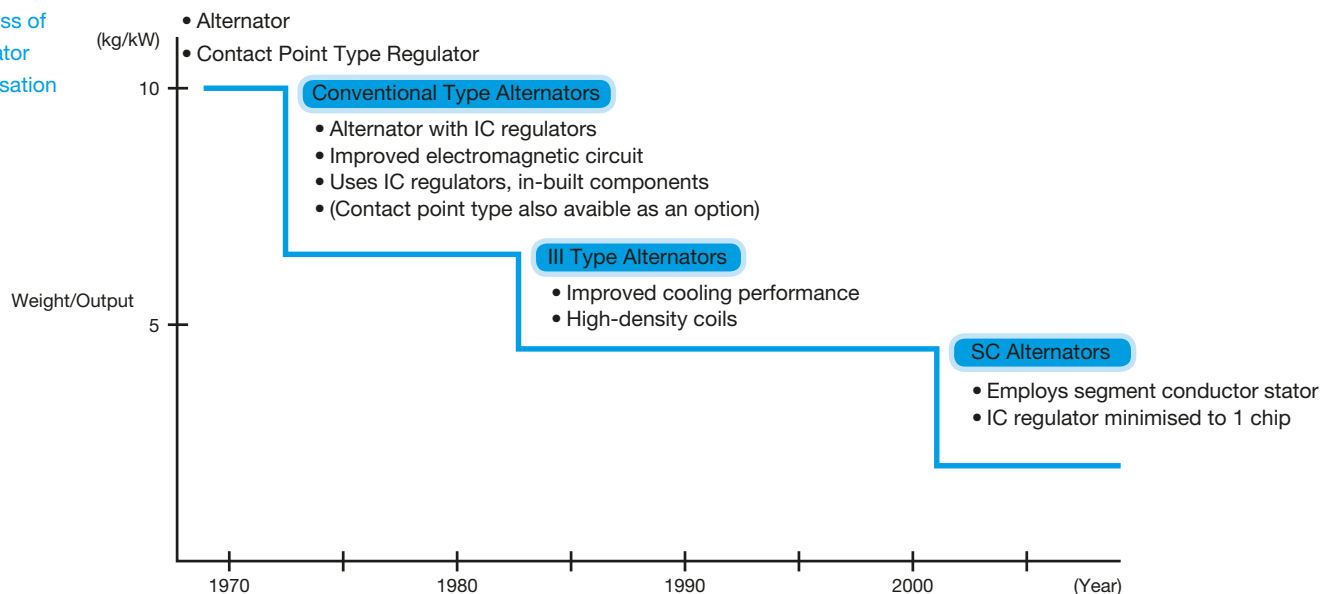
The engine speed changes constantly according to the driving conditions. This means that the alternator speed also changes, with the generated voltage changing in tandem. It is the role of the regulator to control the generated voltage of the alternator, supplying the various electrical loads with the appropriate voltage. The regulator also ensures that the battery is charged appropriately.



Charging Mechanism



Progress of Alternator Minimisation

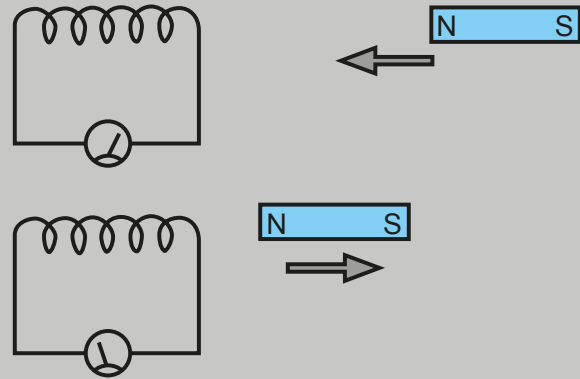


DENSO Alternators | Characteristics

> How Alternators work

Basic Principles of Electricity Generation

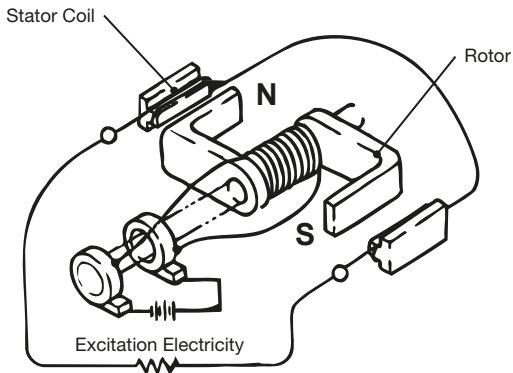
When a magnet is moved in the vicinity of a coil, a voltage is generated. The stronger the magnet, the larger the voltage generated and the faster the magnet is moved, the larger the voltage. Also, the greater the number of windings in the coil, the larger the voltage.



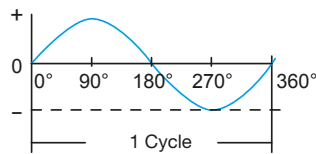
Basic Principles of Electricity Generation

Generating an Alternating Current

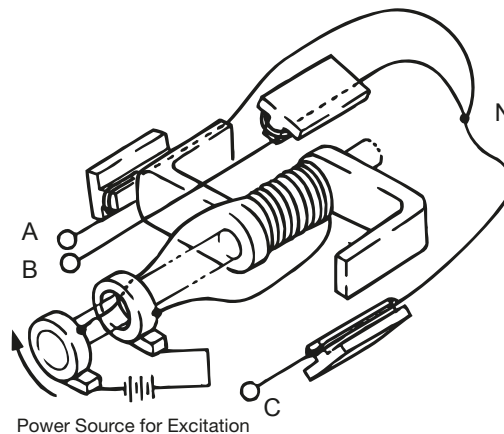
Basic Principles of the Alternator



In an actual alternator, a rotor fulfils the role of the magnet in the above figure, while a stator coil fulfils the role of the coil. The rotor does not move in and out from the stator; instead, it rotates within the stator itself. As the rotor rotates the N pole or the S pole of the rotor alternately approach the stator coil, and a current is generated in the stator coil.



Alternator With 3-Phase Coil

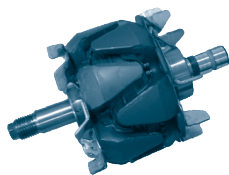


The alternator generates 3-phase alternating current, which offers significant advantages when compared with a single phase alternating current. Taking the example of a simple bipolar alternator, in a single phase, current is received from a generator with one coil. In a 2-phase current, the generator has two coils placed at an interval of 90°, while in a 3-phase current there are 3 coils placed at an interval of 120°.

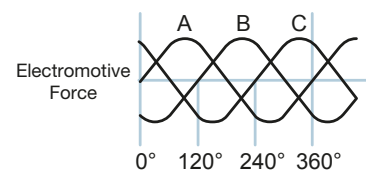
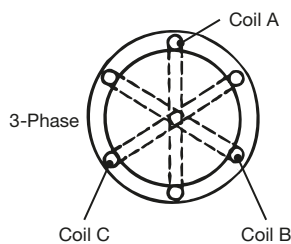
A stator and rotor such as those below are installed in actual alternators.



Stator



Rotor



DENSO Alternators | Characteristics

> How Alternators work

Rectification

One objective of the alternator is to charge the battery, so the alternating current cannot be used unchanged. A diode (solid state rectifier) is used to perform rectification by converting the alternating current into direct current.

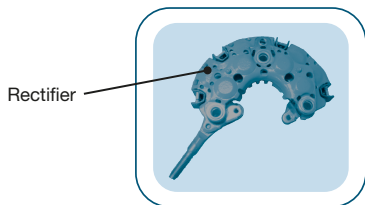
An actual alternator has 3-phase alternating current, so 6 diodes are used for 3-phase full wave rectification.

In (a), a large voltage is generated between phases I and II, and the current flows to the load through diode 1 and flows back from diode 5.

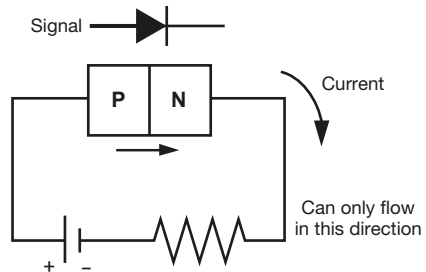
In the next process as shown in (b), the voltage becomes higher between phases I and III, and current leaves through diode 1 and comes back through diode 6.

Following on in sequence to (c), (d), (e) and (f), the current size and direction flowing to each phase and wire is varied, however the current is always delivered to the load in a constant direction.

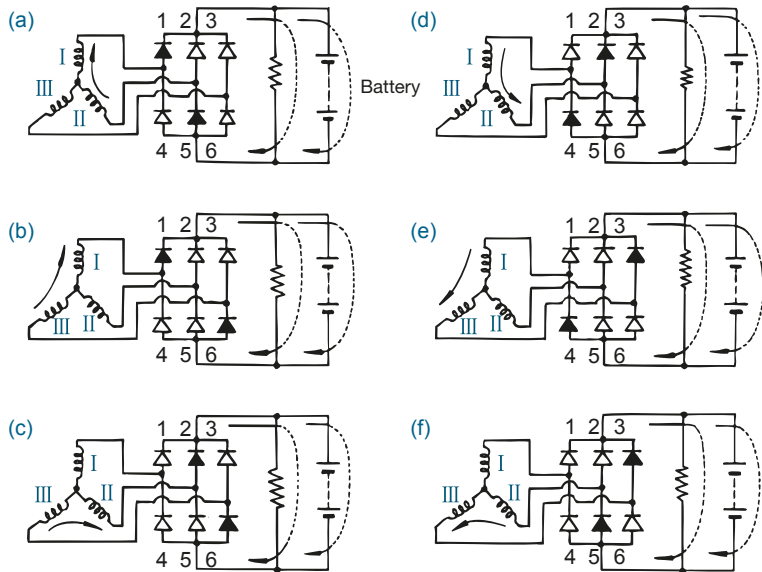
This rectification action is performed by a rectifier.



Rectification Action of the Diode



Schematic Diagram of 3-Phase Full Wave Rectification



Generated Voltage Control

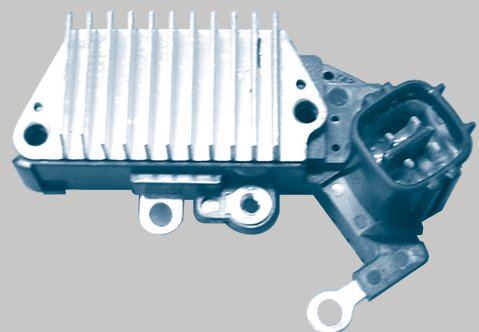
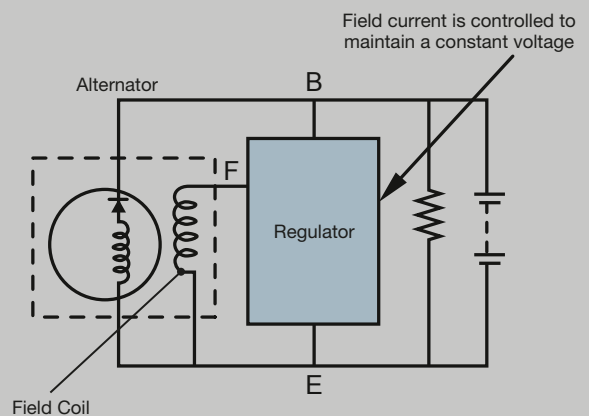
The voltage generated in the alternator increases as the rotating speed of the rotor increases. If the generated voltage is then directly supplied to an electrical load such as a battery or light, increases in alternator speed can result in electrical equipment failure (excessive charging, blown lights, etc.).

Therefore, a constant output must be maintained. The alternator controls this by varying the current flowing to the field coil.

When the rotational speed is high or the load is light and the output voltage seems ready to exceed the specified value, the current flowing to the field coil is reduced. This ensures that the output voltage is always within the specified value range.

The component that performs this control is called the regulator.

The IC regulator is currently the most common type.



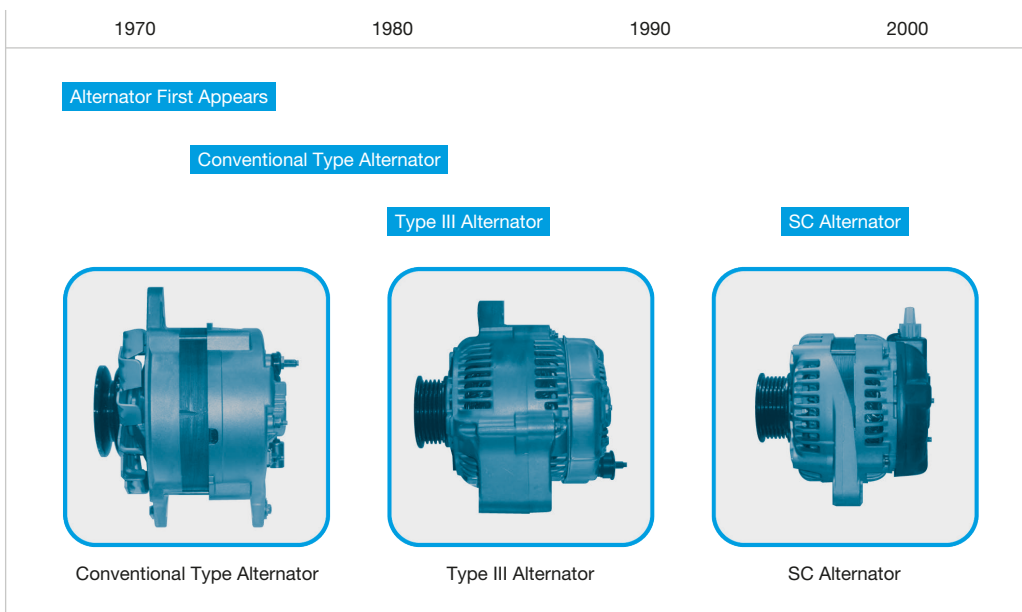
DENSO Alternators | Types

> Conventional Type

In recent years vehicle power consumption has increased with the emergence of information and communication products, such as navigation systems and electronic control products, which are designed to improve comfort and safety and make vehicles environmentally friendly. To meet the demand for additional power, alternators must produce electric power more efficiently whilst being smaller in size and lighter in weight. DENSO has been developing a variety of alternators that meet those requirements for a variety of vehicles.

Most of the alternators produced by DENSO can be broadly classified as follows in terms of construction and features.

History of the Alternator

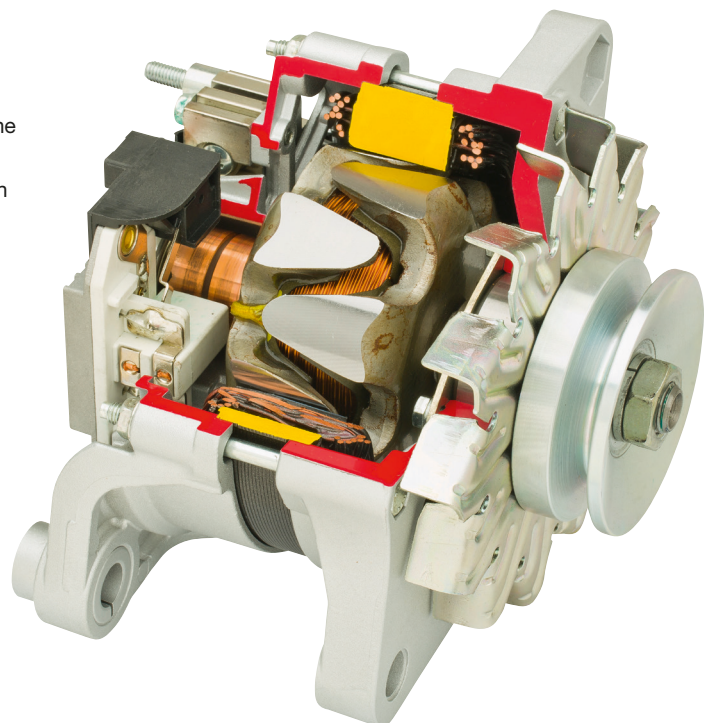


Conventional Type

The alternator pulley is integrated with the rotor and is driven by the engine crankshaft pulley via a belt. The conventional alternator also uses an external cooling fan. The engine thus drives the rotor, generating AC in the stator coil, while the rectifier converts this AC into DC.

Features and benefits

- > Produced higher output by using a cold forged rotor core to improve magnetic circuit.
- > Reduced size and weight by using internal built-in IC regulator.

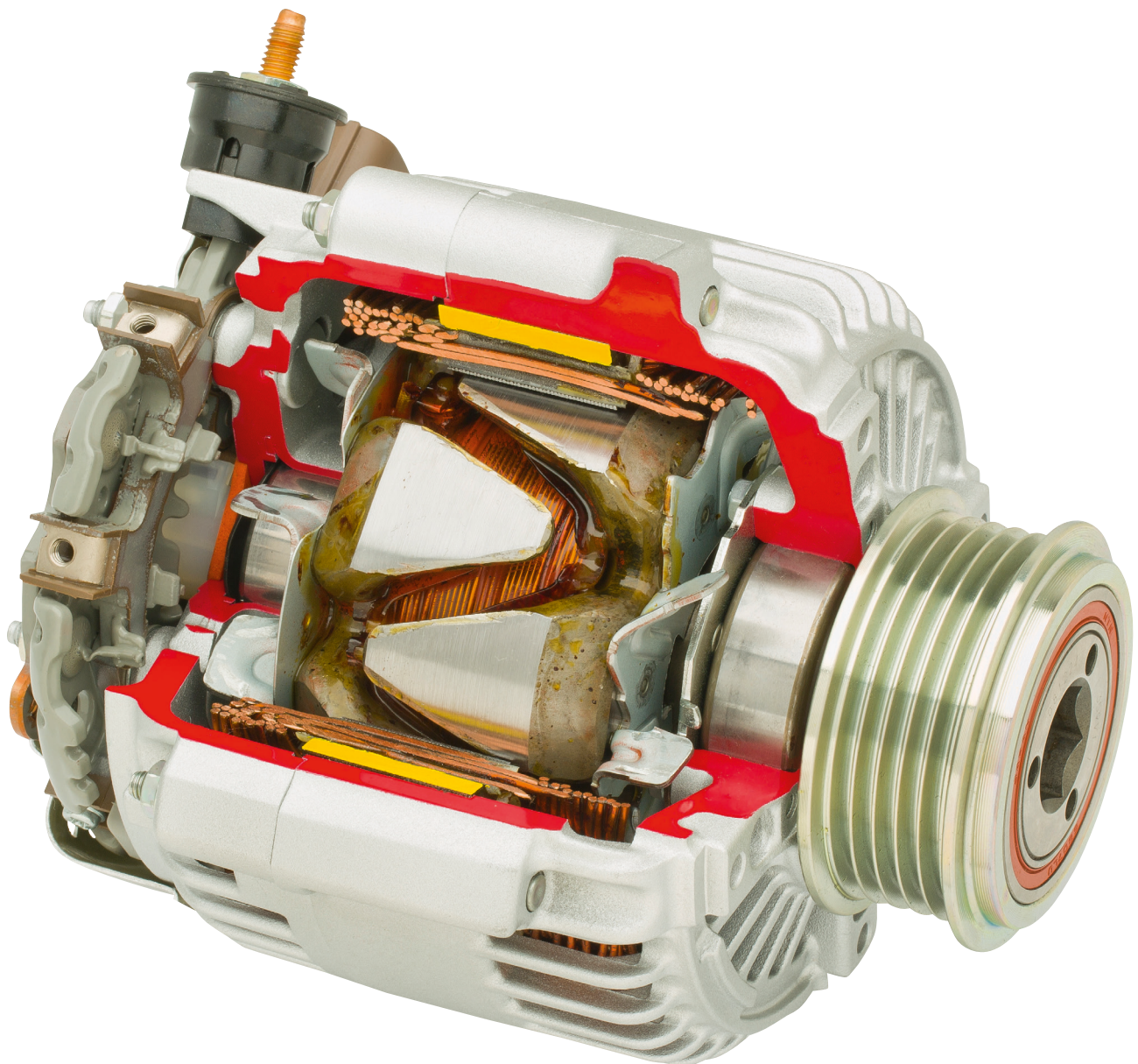


DENSO Alternators | Types > Type III

This is an alternator with small internal fan. Instead of the large exterior fan used in conventional alternator, two compact built-in fan blades are used. This creates an AC generator with faster speed and lower noise. The high-density coils and improved cooling produce a compact and lightweight alternator with high output.

Features and benefits

- > Increased output by optimising stator and rotor sizes to improve the magnetic circuit and decreasing the pulley diameter for a faster rotor.
- > Two fan blades integrated with the rotor reduce alternator size, weight and fan noise.



DENSO Alternators | Types

> SC Type

In 2000, DENSO introduced the world's first SC (Segment Conductor) alternator using a rectangular segment conductor (angular copper wires) for its stator coil.

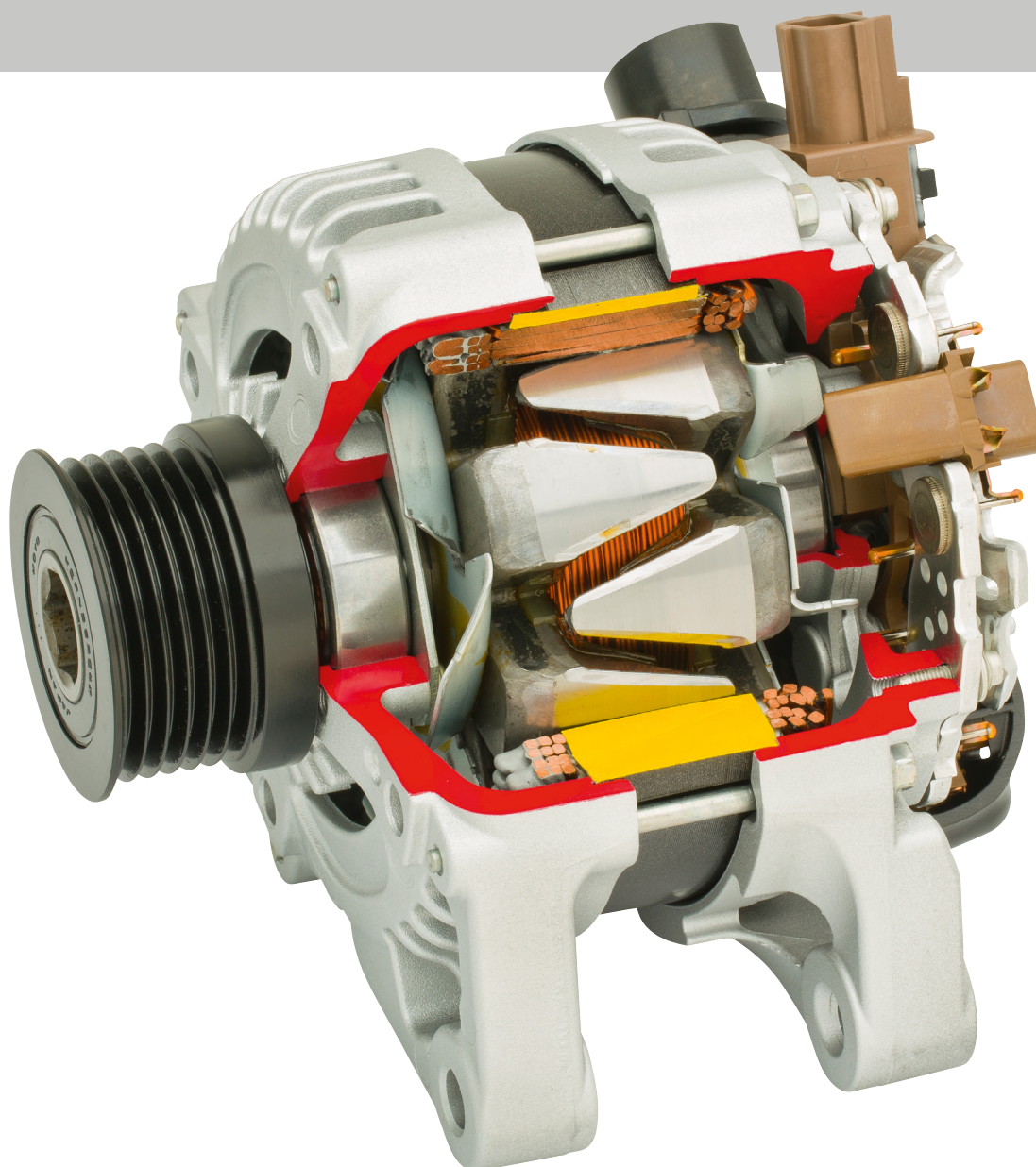
Compared to the conventional type, the SC alternator reduces coil resistance and thermal losses by 50 percent, and raises the winding density (space factor) from 45 percent to 70 percent. Thus, DENSO

made the SC alternator 20 percent lighter and increased the output 50 percent higher than a conventional type.

In addition, the regulator is a miniaturized single-chip IC type, resulting in a compact and lightweight alternator with both high efficiency and output.

Features and benefits

- > Compact, lightweight, high output and high efficiency. The winding density of the stator coil is increased by using an innovative winding method and a rectangular segment conductor. Low magnetic noise. Magnetic pulsation (the main component of magnetic noise in the alternator) is reduced 90 percent due to use of both dual and staggered windings.
- > Small and multifunctional IC regulator.



DENSO Alternators | Types > SC Type

Segment Conductor Stator

Features and Benefits

Lower Electrical Resistance

Vertical segment insertion

High Slot-fill using square section wire

Improved air flow

Smooth Air Flow through formed windings

Suppression of EMF* Fluctuation

Armature Reaction Force

Time

30:degree

Dual circuit Stator & Rectifier cancels Armature Reaction Force

* Electro Magnetic Force

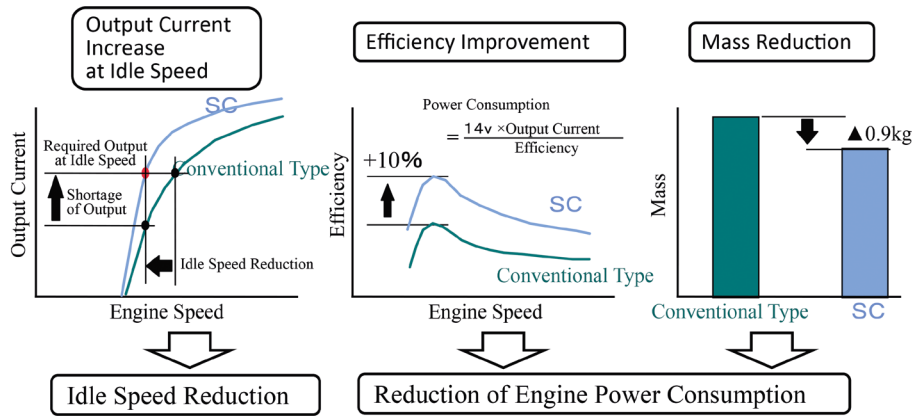
Small Package Size

Low Inertia Rotor

New Outline

Current Outline

1 Chip Regulator



Fuel economy improvement

Conventional

Total Power 100%

Approx. 60% Output

Approx. 40% Loss

Output

- Head light
- Air Condition
- Audio
- Wiper

Analysis of loss

SC

Approx. 70% Output

Approx. 30% Loss

Efficiency 10% increase

- Lower Electrical Resistance
- Higher Slot-Fill factor by Segment conductor

Fuel Economy Improvement

Engine 2.4L Petrol

Electrical Load (A)

30 60 90

+1.5%

+2.7%

DENSO Alternators | Types

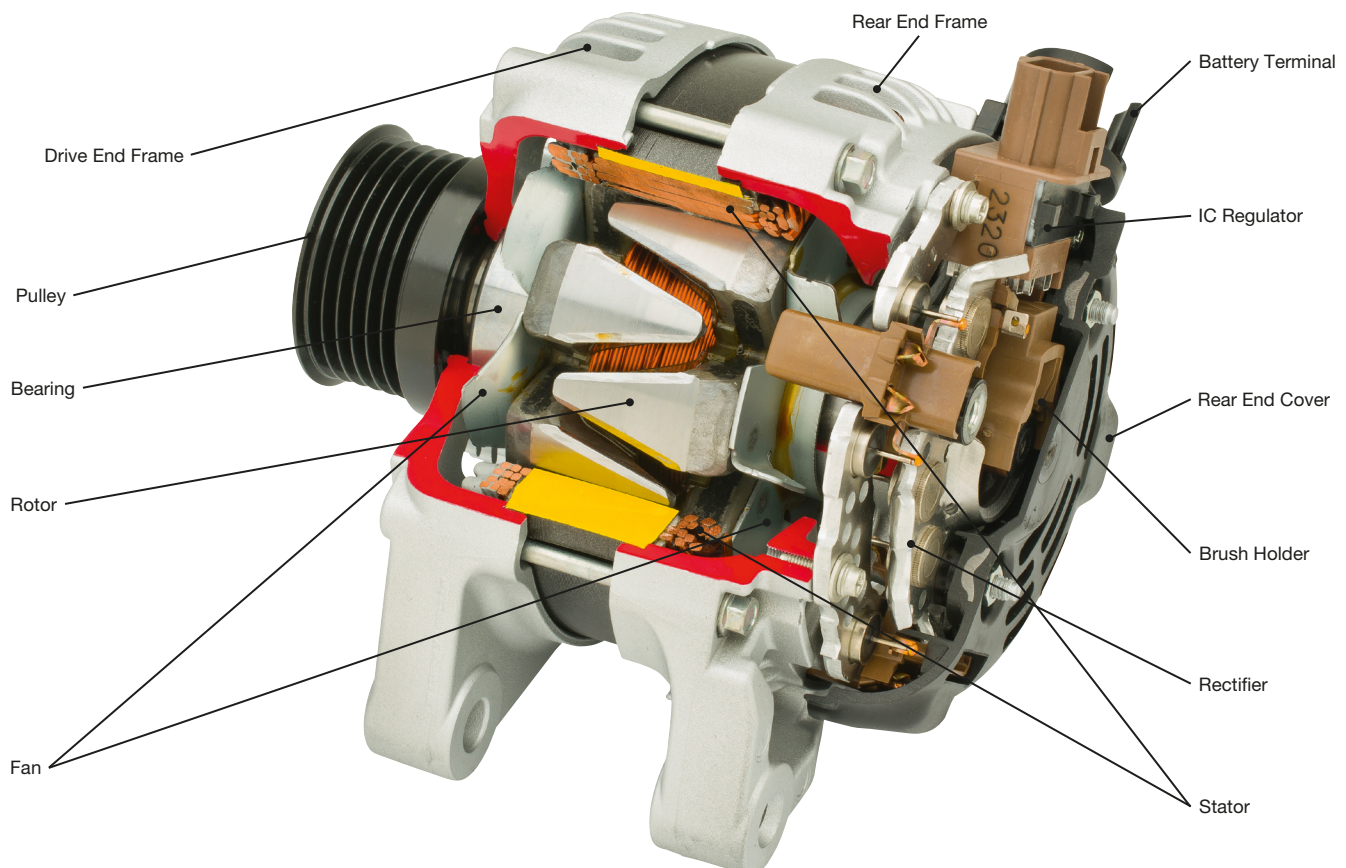
> SC Type

DENSO Excellence



- > DENSO has developed the high output SC alternators that provide rated output currents of 165, 180, 200, 220 and 240 amps; higher than well-known typical SC alternators rated up to 150 amps.
- > DENSO alternators are the smallest and lightest in the world for their output.
- > Vehicles, especially luxury models and large vehicles, now require higher output alternators, as vehicle power consumption increases, and engine revolution at idle is lowered to reduce fuel consumption. To meet these requirements, DENSO developed the high output SC alternators.
- > DENSO's high output alternators, the world's first air-cooled type with output level up to 240A, enables a large vehicle, which traditionally requires a larger, more expensive water-cooled alternator or two air-cooled alternators, to have only one compact air-cooled alternator.
- > In 2000, DENSO developed the world's first SC (segment conductor) alternator using a rectangular segment conductor for its stator coil, reducing coil resistance by 50 percent.
- > The DENSO SC alternator adopted dual windings and rectifiers, achieving smaller size, lighter weight, higher efficiency and lower noise.
- > DENSO further improved the stator coil connection method of the SC alternator to develop the compact and high output SC alternators.
- > To counteract higher heat production due to higher output, DENSO increased the surface area of the rectifier cooling fins to nearly twice the size of conventional fins, improving the cooling ability of the rectifiers.

DENSO's SC Alternator Characteristics



DENSO Alternators | Types

> SC Type

Rotor

The rotor functions to create a magnetic field and rotates in conjunction with the shaft. The rotor primarily consists of a pole core (magnetic pole), field coil, slip rings and shaft.

The pole core is shaped into claws and encloses the field coil. When current flows through the field coil, one side of the pole core fully magnetizes to become a North (N) pole, and the other side becomes the South (S) pole. The claw pole type enables all the poles to be magnetised using the one field coil.

Fan

An integrated cooling fan is installed on both sides of the rotor to blow air to the front, rear and interior for cooling. When current flows through the coils and diodes, the temperature of the parts increases and can cause damage to the system. Cooling via the fan is therefore necessary.

Brush Holder

Components are brushes, springs, brush holder. Two brushes slide around the circumference of the slip rings to supply current to the rotor (field) coil so that a magnetic field can be created.

Battery Terminal

The alternator output terminal that supplies current to the car's battery.

Drive and Rear End Frames

The end frames have heat release holes and fins to improve cooling. The drive (front) side end frame is press fit to the stator and helps improve stator cooling. The rectifier, brush holder and IC regulator are attached to the exterior of the rear side end frame to improve serviceability.

Rear End Cover

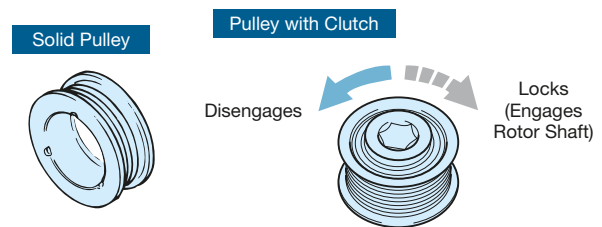
Covering and protecting the rectifier, brush holder and IC regulator, all of which are mounted on the rear end frame.

Bearing

Bearings are used to support the rotor assembly. Rear bearing is mounted on rotor shaft and the front bearing is mounted to the drive end frame.

Pulley

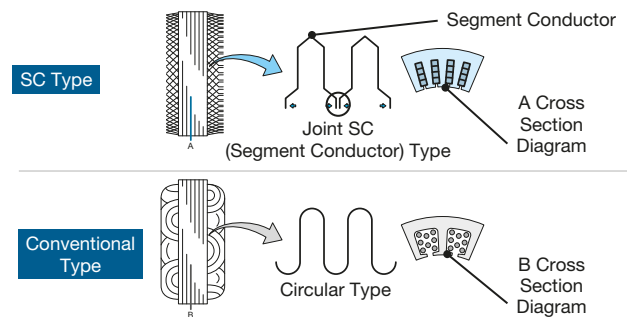
Two types of pulley are used: a solid pulley and a pulley with clutch (One-Way Clutch or Decoupler). The solid pulley has a large contact surface with a belt and does not slip easily, so it can provide a large pulley ratio. The pulley with clutch is used in engines (diesel etc.) with relatively large torque fluctuations. It only engages with the rotor shaft in a forward direction and the belt rotates the rotor via the pulley. In the reverse direction, the clutch function disengages the pulley and rotor, thus functioning to release the engine torque fluctuation.



Stator

The stator consists of a stator core and stator coil, and is supported by front and rear end frames. The stator core is a magnetic flux passage that enables the effective interaction of magnetic flux from the rotor pole cores in the stator coils.

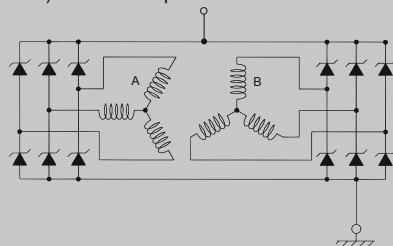
Conventional stator cores use a system where circular wires are wound together, leaving many gaps between them. The SC type uses a segment conductor system in which square-shaped angular copper wires are inserted and joined tightly, in place of a stator with a winding system. The SC system increases the copper wire space factor (the space ratio between the winding gap and the winding in cross section) of the stator core. As a result, stator resistance is half that of the conventional type and heat generation is reduced, thereby dramatically improving power output and efficiency in a compact configuration.



Stator connections

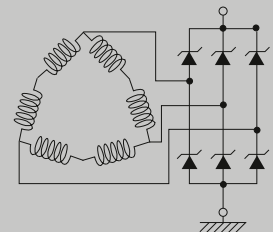
Y Connection (Dual Winding Type)

The Y connection features a dual winding system with two sets of three-phase windings (A and B). These are provided to cancel out each other's magnetic fluctuations that are created at the stator. As a result, the magnetic noise that is generated by the alternator is dramatically reduced.



Delta Connection (Staggered Winding Type)

In the delta connection, an additional winding is connected in series with each of the conventional windings, and the phases are staggered. This suppresses magnetic fluctuation generated by the stator, and reduces the amount of magnetic noise generated by the alternator. This is mainly used in SE alternators (a simple and compact form of SC Type).

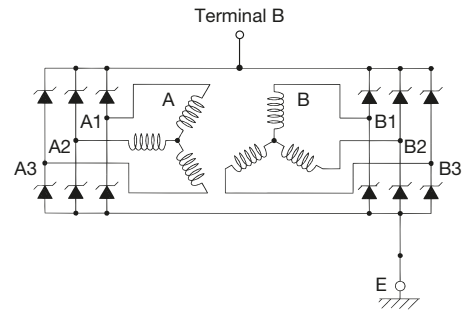
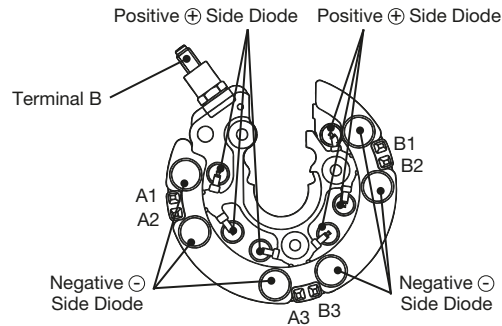


DENSO Alternators | Types > SC Type

Rectifier

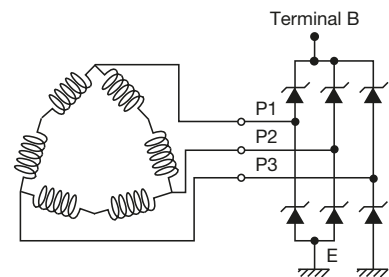
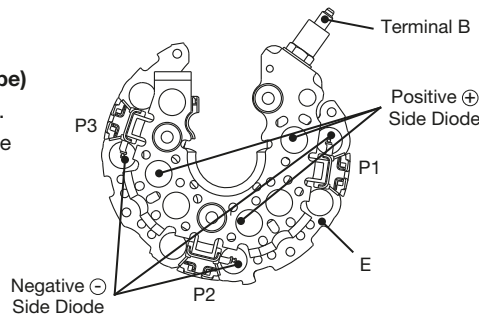
Y Connection (Dual Winding Type)

As the stator contains two sets of three-phase windings, the number of diodes has been increased from six to twelve (Zener diodes). The rectifier works in the same way as the conventional type to rectify the three-phase AC generated in the coil into DC. Stator coils A and B are connected to the rectifier as shown in the figure.



Delta connection (Staggered Winding Type)

Rectifier uses one set of six silicon diodes. This is mainly used in SE alternators (a simple and compact form of SC Type).



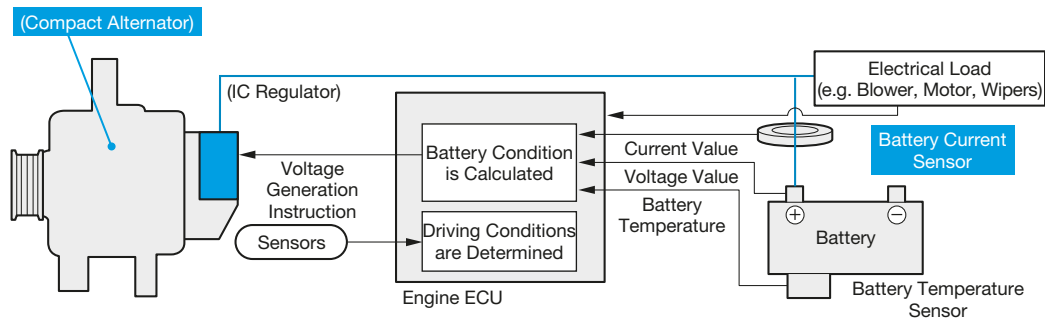
IC Regulator

In contrast to the conventional IC regulator in which the regulator circuit is formed on a ceramic board, a miniaturised multifunctional IC regulator that integrates the circuit into a single-chip is used in an SC alternator resulting in a compact and lightweight configuration.

The basic function and operation of the regulator is very similar to conventional IC regulators. However, some types of the single-chip IC regulator enable communication between alternator and engine ECU to finely control alternator voltage regulation.

Outline of New Charging Control Systems

The New Charging Control System control alternator voltage generation in accordance with various driving conditions through the communication between alternator IC regulator and engine ECU, thus reduce the vehicle's fuel consumption.



The engine load caused by the generation of voltage in the alternator is lessened by reducing the generated voltage during acceleration and by increasing it during deceleration. This improves the engine's fuel efficiency. During idling and constant speed driving, the generated voltage is adjusted to meet the target value for which is determined depend on battery and driving conditions.

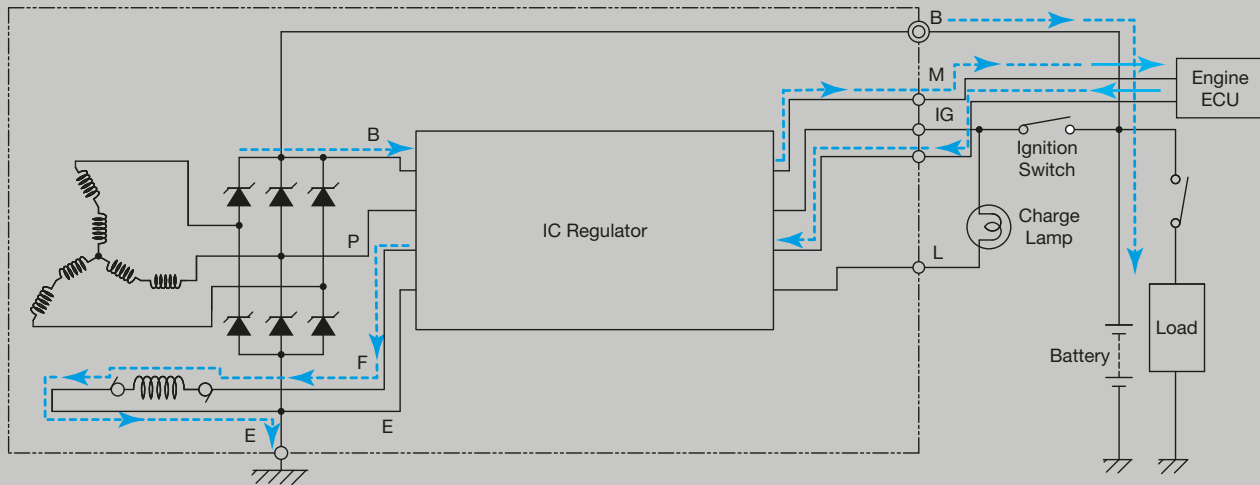
Driving Conditions	Acceleration	Consant Speed/Idling	Deceleration
Circuit Diagram			
Charging Condition	Battery Discharge at Low Voltage	Open Voltage	Battery Charge at High Voltage

DENSO Alternators | Types > SC Type

Example: Operation of an IC regulator with communication function

- A duty ratio (on/off ratio) signal is sent from the M (Monitor) terminal of the IC regulator to the engine ECU. This informs the engine ECU corresponding to the alternator's generating condition.
- The engine ECU calculates the optimum voltage to generate based on the driving conditions, electrical load and the battery condition. The ECU issues instructions for generating this optimum voltage by sending a duty ratio (on/off ratio) signal to the IC regulator.
- The IC regulator uses the engine ECU's instructions to control voltage generation in the alternator.

Example: IC Regulator Circuit Diagram

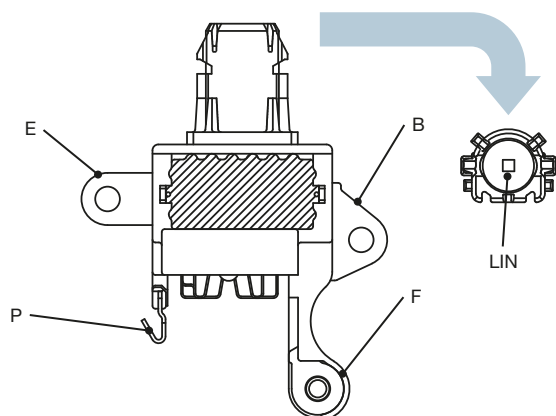


LIN Communication- Compatible IC regulator

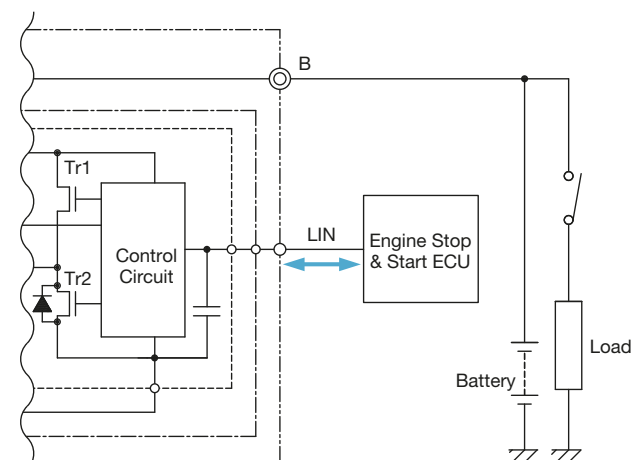
Nowadays, LIN (Local Interconnect Network) communication-compatible IC regulators are used in the charging control systems of new vehicle models that are commonly equipped with the Stop & Start System. Bidirectional, multiplex communication via the LIN is used between the engine ECU and the IC regulator to precisely control alternator voltage regulation. LIN uses single-wire communication lines to transmit digital signals based on special protocols (communication regulations) at 9.6 kbps or 19.2 kbps.

Signals for the gradual excitation power generation function, regulating voltage and excitation current command value are received from the engine ECU by the LIN terminal to adjust voltage and generate power. The signals for each value detected (i.e. power generation status, communication status, etc.) by the control circuit are transmitted to the engine ECU from the LIN terminal.

LIN Type IC Regulator for the SC Alternator



LIN Type IC Regulator Circuit Diagram

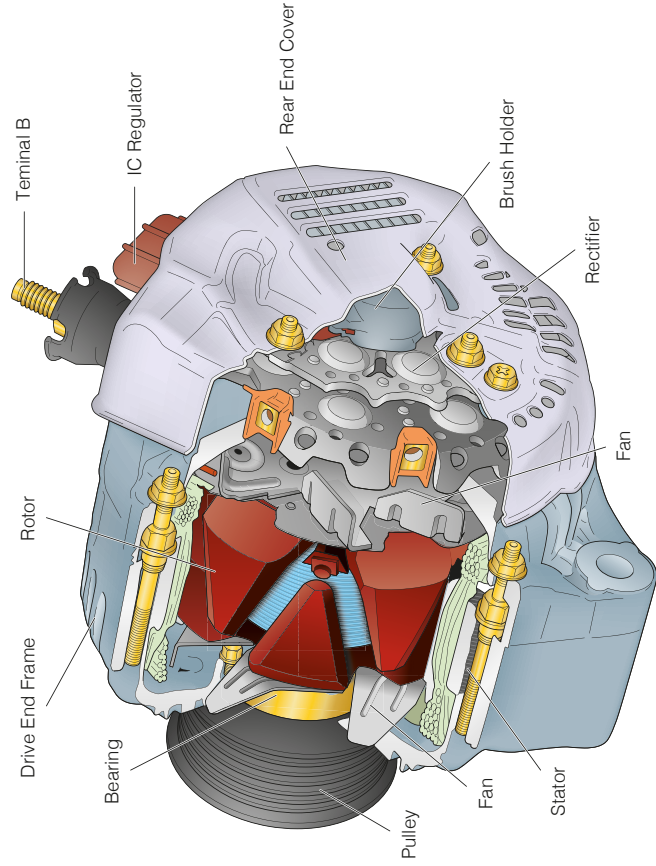




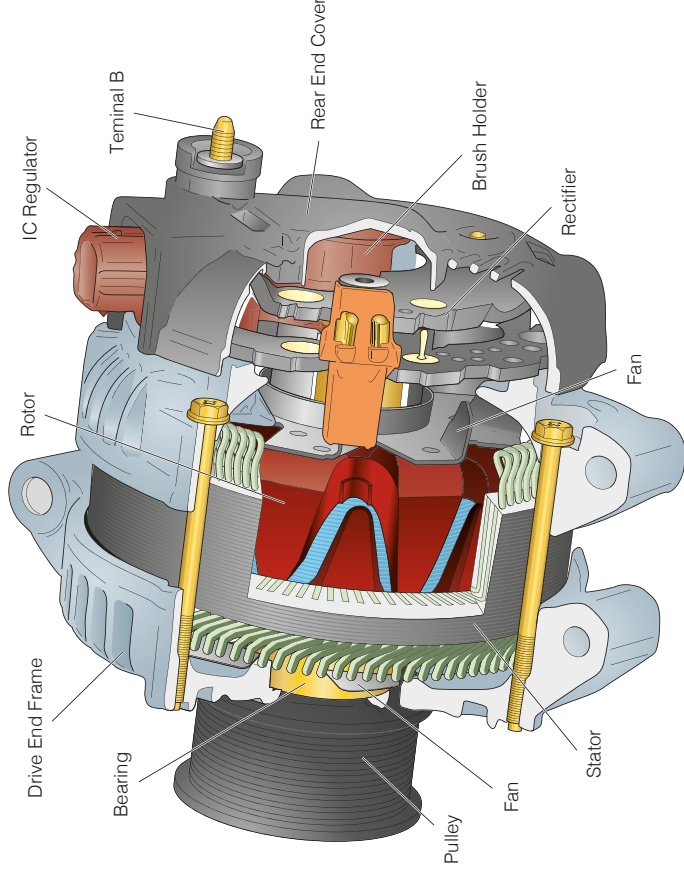
TecÚical Overview DENSO Alternator

Discovering DENSO TecÚology

Type III Alternator

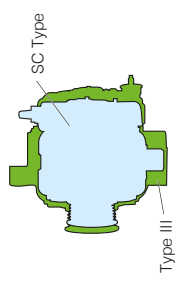


SC, SE Alternator

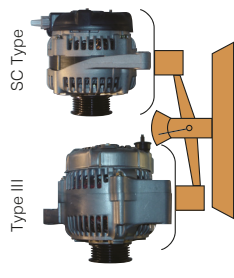


SE Alternator: Has a simple construction based on the SC alternator in a compact configuration

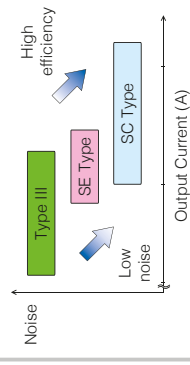
Volume



Weight



Feature of the product



DENSO Alternators | Replacement Guide

The following general information has been established as a common instruction for alternator removal and installation. Refer to the appropriate Vehicle Manufacturer's Service Manual for specific information corresponding to alternator removal and installation procedures and safety precautions for the vehicle.

Always disconnect the cable from negative (-) battery terminal before replacement and wait at least 90 seconds after disconnecting the cable to prevent any type of activation. After replacement, connect the cable to negative (-) battery terminal.

Never disconnect a battery cable while the engine is running. Doing so can damage the alternator as well as other electronic components of the vehicle.

Removal

1. Identify each wire connection and note the location of each on the alternator.
2. Disconnect the wires from the alternator.
3. Loosen the alternator pivot bolt but do not remove the bolt yet.
4. Loosen the tension assembly's lock nut or bolt and turn the adjustment bolt so that drive belt tension is reduced far enough to allow belt removal. Some vehicles may be equipped with an automatic, spring-loaded tensioner. Rotate the spring-loaded tensioner using the appropriate tool far enough to allow drive belt removal.
5. Remove the drive belt from the alternator.
6. Support the alternator and remove the bolts holding the alternator in place. Set the bolts and alternator aside. Be sure to note bracket orientation and fastener length/location before removing the alternator.
7. Inspect the condition of the wiring and connectors. Inspect for worn wire ends, continuity, loose or broken connectors, corrosion and pliability. Repair or replace as necessary.

Installation

1. Physically compare the new alternator to the original. Compare the housing and pulley offsets, pulley size and type, pivot and adjustment hole locations, wire connector locations and terminal configurations with the original alternator.
 2. Install the mounting bracket(s) but do not completely tighten the bolts yet.
 3. Support the alternator and fasten it into position but do not completely tighten the bolts yet.
 4. Install the drive belt. If the drive belt was found to be worn, stretched, cracked, oily or glazed during the charging system inspection, replace the belt.
 5. Set the belt tension while tightening the mounting and adjusting bolts. Be sure to set the belt tension and torque the mounting bolts to the vehicle manufacturer's recommended specifications.
- CAUTION: Do not pry or hit the alternator housing to adjust the belt tension.**
6. Check the drive belt alignment between the alternator pulley and other drive pulleys. Be sure there is no interference between the drive belt and other components.
 7. Re-connect the wire connector to its proper location on the alternator. Be sure there is no interference between the wire harness and other components.
 8. Re-inspect all components are correctly installed, all threaded fasteners properly torqued and there is no interference between components.
 9. Re-connect the battery negative cable.
 10. Start the engine and be sure there is no interference between components. Let the engine idle for 5 minutes to accustom the drive belt.
 11. Turn the engine off and re-adjust the drive belt if necessary. Re-inspect all components are correctly installed, all fasteners properly torqued and there is no interference between components.
 12. Re-test the charging system to verify that it is performing according to the vehicle manufacturer's specifications.

DENSO Alternator | Troubleshooting

> Diagnostic Chart

Charging System Diagnostic Chart

A defective charging system may cause various problems. In troubleshooting, it is essential to start identifying symptoms related to these problems in order to narrow possible causes down to one or two. Most common problem symptoms, related possible causes and corresponding corrective actions are listed in the chart below.

Symptom	Possible Cause	Corrective Action
Charging System/ Battery warning lamp is not ON with key switch ON and engine at stop condition	<ol style="list-style-type: none"> 1. Blown fuse. 2. Lamp burned out. 3. Wiring connections loose. 4. Defective relay. 5. Defective regulator. 	<ol style="list-style-type: none"> 1. Check charging, ignition and engine fuses, replace as needed. 2. Replace lamp. 3. Tighten loose connections. 4. Check relays, if used, for continuity and proper operation. 5. Replace alternator.
NO charge	<ol style="list-style-type: none"> 1. Defective battery or battery connections. 2. Blown fuse or fusible link. 3. Defective wiring. 4. Defective alternator. 5. Excessive electrical load due to additional electrical accessories such as off-road lighting, etc. 	<ol style="list-style-type: none"> 1. Check battery and battery terminal connections Replace as needed. 2. Check fuse and fusible link Replace as needed. 3. Check voltage drop. 4. Replace alternator. 5. Replace alternator with upgraded one.
Constantly overcharging	<ol style="list-style-type: none"> 1. Defective battery. 2. Poor contact at voltage detection pin/terminal of alternator. 3. Defective regulator. 	<ol style="list-style-type: none"> 1. Replace battery. 2. Make sure the contact area is clean and corrosion free. 3. Replace alternator.
Intermittent charging	<ol style="list-style-type: none"> 1. Insufficient belt tension. 2. Poor contact at battery connections. 3. Poor alternator ground. 4. Open or shorted diodes. 5. Open or shorted stator windings. 6. Defective regulator. 	<ol style="list-style-type: none"> 1. Adjust tension or replace. 2. Make sure the battery connections are clean and corrosion free. 3. Make sure alternator is properly grounded. 4. Replace alternator. 5. Replace alternator. 6. Replace alternator.
Abnormal noise	<ol style="list-style-type: none"> 1. Loose/worn belt due to service life, binding, contamination . 2. Defective/worn bearings due to too tight belt adjustment, water ingress, etc. 3. Defective diode due to severe vibration, improper testing, jump start, reverse polarity, etc. 4. Misalignment due to improper installation. 	<ol style="list-style-type: none"> 1. Adjust tension or replace the belt. 2. Replace alternator. 3. Replace alternator. 4. Inspect and make sure installation is properly done.

DENSO Alternators | Troubleshooting > Inspection

Inspection

Visual Inspection

Begin with a thorough visual inspection of system and components.

Drive belt

- > Belt condition
- > Alignment
- > Proper tension

System cables & wires

- > Make sure all connections are intact, clean and corrosion free.
- > Check wires for wear, insulation damage, and other physical damage.

Alternator Physical Condition

- > Check for oil, dust, water contamination due to usage in severe environmental conditions.
- > Check spark marks on housing that are signs of battery reverse polarity.
- > Check wear on fixing lugs/surfaces on housing that are signs of hammering due to improper installation.
- > Check pulley rotation for audible noise.

Electrical Tests

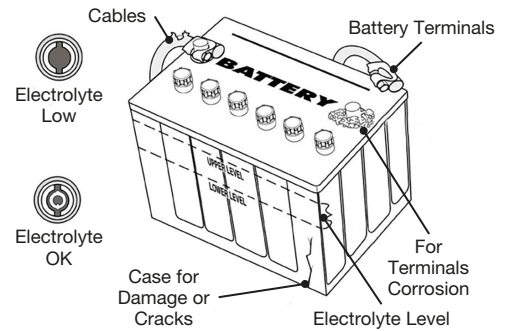
Precautions

- > Do not operate the alternator with its B+ terminal disconnected.
- > Do not disconnect the battery while the alternator is rotating.
- > Never ground the alternator B+ terminal, it has battery voltage at all times.
- > Never expose the alternator to water.

On-Vehicle Inspections

Battery Inspection

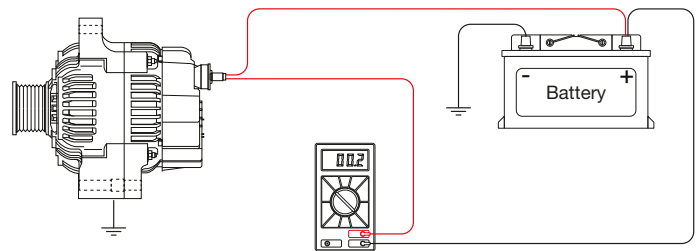
- > Before performing any electrical system diagnosis or repair, make sure the battery has been visually inspected, performance tested and is fully charged.
- > State of battery, battery cables, battery terminals condition affect the ability of the battery to hold the charge.
- > Charge the battery and check the open circuit voltage. If 12.6 Volts (full charge) or above is not measured, replace the battery and continue to evaluate the charging system. If the open circuit voltage is 12.6 Volts or above, recommended to perform battery load-test. A load-test measures the battery's ability to deliver power.



Voltage drop test

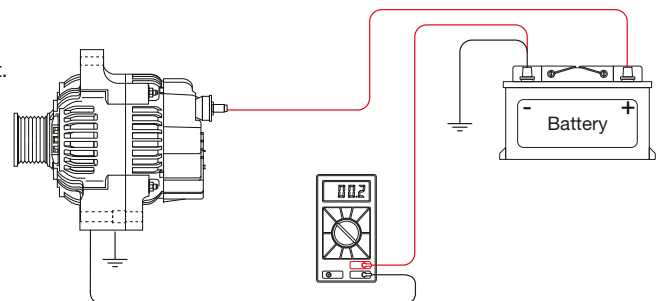
Voltage drop test positive side (output circuit)

- > Attach the meter's positive lead to the alternator output terminal (B+) and meter's negative lead to positive (+) battery post.
- > Run the engine at approximately 2000 rpm with the lights, blower motor and radio on. The reading on meter should be less than 0.2 Volts.



Voltage drop test negative side (ground circuit)

- > Attach the meter's negative lead on the alternator case, or ground strap if equipped, and the positive lead on the negative (-) battery post.
- > Run the engine at approximately 2000 rpm with the lights, blower motor, and radio on. The reading on meter should be 0.2 Volts or less.



DENSO Alternators | Troubleshooting

> Inspection

Checking the voltage drops in positive and negative sides provides helpful tips to find hidden problems that can cause a charging problem. Voltage always flow through the path with the lowest resistance. Therefore, if there is a high resistance somewhere in the positive or negative side, some of the voltage flow through the meter and creates a voltage value on meter's display.

- > If a voltage reading greater than 0.2 Volts is observed at voltage drop test positive side, it indicates there is excessive resistance somewhere in the positive side that causes a voltage drop. Check all the wiring and connector pins/terminals are intact, clean and corrosion free.
- > If a voltage reading greater than 0.2 Volts is observed at voltage drop test negative side, make sure all the ground connections and contact area is clean and corrosion free. Also, make sure that there is no broken, loose or missing ground points/straps between the engine and chassis.
- > If a voltage reading less than 0.2 Volts is observed at voltage drop tests, continue with further electrical tests.

Alternator Output Test

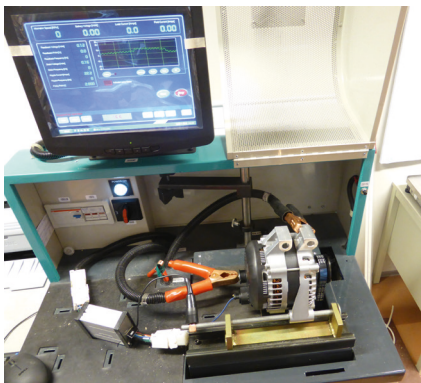
Regulated voltage inspection

Run the engine at approximately 2000 rpm and then check the regulated voltage at alternator output stud (B+) terminal when current output reaches approximately 10 A (Refer to the test standards and values designated by the relevant vehicle manufacturer).

Output current measurement

Turn the headlights to high beam, the blower switch to high, and so on. Then measure the output current at an engine rotational speed of approximately 2000 rpm. Current at this time should be at or above the standard values designated by the relevant vehicle manufacturer.

Caution: The standard values differ according to the vehicle manufacturer. Refer to the appropriate Original Equipment Manufacturer's service manual for specific information corresponding to alternator specifications.



Alternator Test bench inspection

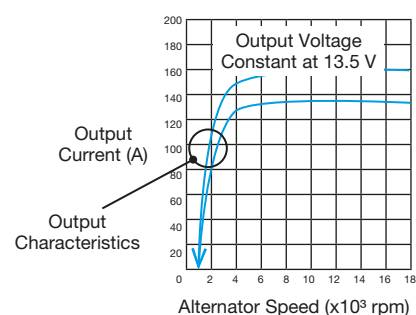
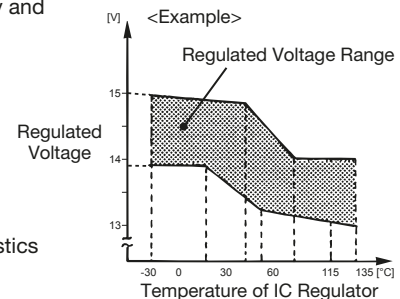
- > If an alternator will be tested on a test bench, follow the procedures found in the test bench instruction manual to conduct an alternator performance test. This test will determine if the alternator output is within its performance specification, preventing unnecessary alternator replacement.
- > If the test bench results indicate the alternator output to be out of specification, replace the alternator.
- > If the alternator output is within specification during bench testing, resolve problems in the remainder of the vehicle's charging circuit and other electrical circuits that may affect charging circuit performance. Refer to the vehicle manufacturer's service manual for the procedures necessary to identify and correct additional charging circuit problems.

Regulated voltage verification

- > Set the alternator on the test bench.
- > Verify that the test bench is set up and that the charge light is ON.
- > Run the alternator, and adjust the rotational speed and load to the standard values.
- > Regulated voltage should be within the standard values at this time.
- > Caution: Perform measurements quickly; the regulated voltage has the temperature characteristics shown in the figure due to the IC regulator specifications.

Output Current test

- > Set the alternator on the test bench.
- > Verify that the test bench is set up and that the charge light is ON.
- > Run the alternator, and adjust the rotational speed and voltage to the standard values.
- > Current should be within the standard values at this time.
- > Caution: Current output gradually decreases while the testing cycle is repeated due to alternator temperature increase.



DENSO Alternators | Troubleshooting

> Q&A

Q&A Section

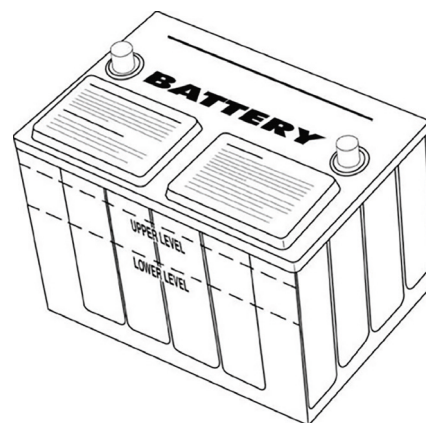
What is the condition of the battery?

This is an electro-chemical device. It converts chemical energy into electrical energy. The battery has three primary functions.

- > Source of electrical energy to start the engine.
- > Act as a voltage stabiliser in the electrical system.
- > Supply current when electrical demand exceeds alternator output.

A visual inspection and a performance test of the battery must always be performed before inspecting the charging system.

The battery must be fully charged (12.6 Volts or above) and the battery cables, terminals and case in good and clean condition.



What is the biggest drain on battery charge?

Electrical consumers can be split into 3 groups: continuous, long-time and short-time.

Thus, the electrical load requirement is not steady. The drain on the battery charge is therefore impacted by usage habits or even the time of year as some systems are seasonal (A/C systems, heated seats).

Engine management system components such as ignition, fuel injection are part of the continuous consumer group and are therefore causing a considerable drain caused by an increased number of sensors and actuators required in modern vehicles.

However the biggest drains on battery at component level will most likely come from long-time and short-time consumers such as headlights, rear window defroster, wiper motors, blower motor.

What are most common problems that cause battery to run down?

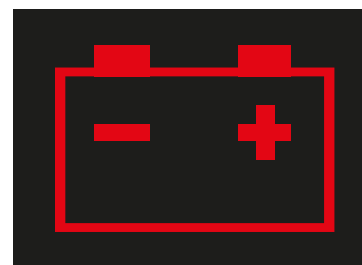
- > Old or service life ended battery that is not able to hold the charge.
- > Charging system problem that is preventing battery to be recharged.
- > A key-off drain due to a stucked switch or relay, computer or electronic modules that are not shut down.

If the battery and alternator are inspected (as previously mentioned) and no issues were found, the root cause of discharged flat battery may come from a key-off drain.

In older cars, key-off drain should not exceed few milliamps. On the other hand, for modern vehicles (fitted with computers and various electronic modules), it can be around 50 to 100 milliamps or even more during a period of time i.e. 15 to 30 minutes after the ignition is switched off in order to keep memory alive. Indeed this is a general assumption, always refer to the vehicle manufacturer's service information corresponding to key-off drain specification if available.

Does a charging system/battery warning light indicate a charging system problem?

- > Ignition switch ON, engine not running
The warning lamp should illuminate.
- > Ignition switch ON, engine running
The warning lamp should illuminate briefly then turn OFF.
- > Weak Battery
A weak battery can cause the warning lamp to illuminate during high amperage draw.
- > Low Idle
A low idle can cause the warning lamp to illuminate dimly.
- > Poor Wiring
Corroded, broken, loose or worn wires/connections could cause the warning lamp to illuminate during idle.
- > Open Warning Lamp
Some charging systems will not properly operate if the warning lamp bulb fails.

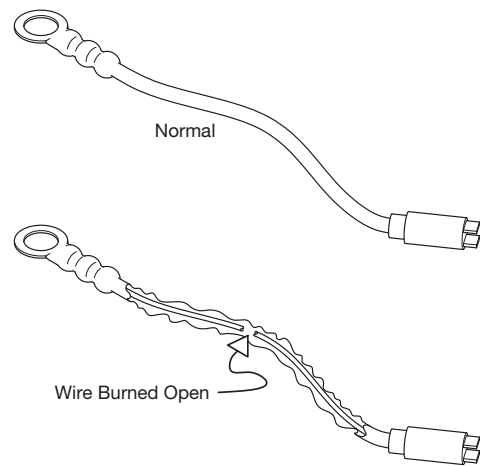
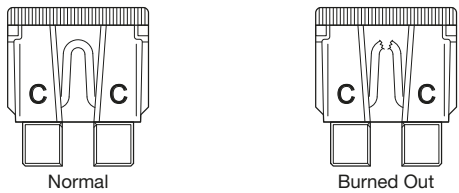


DENSO Alternators | Troubleshooting

> Q&A

Are any fuses open?

Check the fuses in all the fuse box(s). An open fuse indicates circuit problem(s) which may have an affect on the charging circuit. Check the owners manual or the vehicle manufacturer’s service manual for the location of each fuse box.



Is the fusible link(s) open?

There may be several fusible links controlling battery voltage to the vehicle’s electrical circuits. If a fusible link is open, supply voltage will be completely lost to all electrical systems or to the electric circuit(s) that the open fusible link controls. Check the owner’s manual or the vehicle manufacturer’s service manual for the location of each fuseable link.

Is the alternator’s drive belt tension within specification?

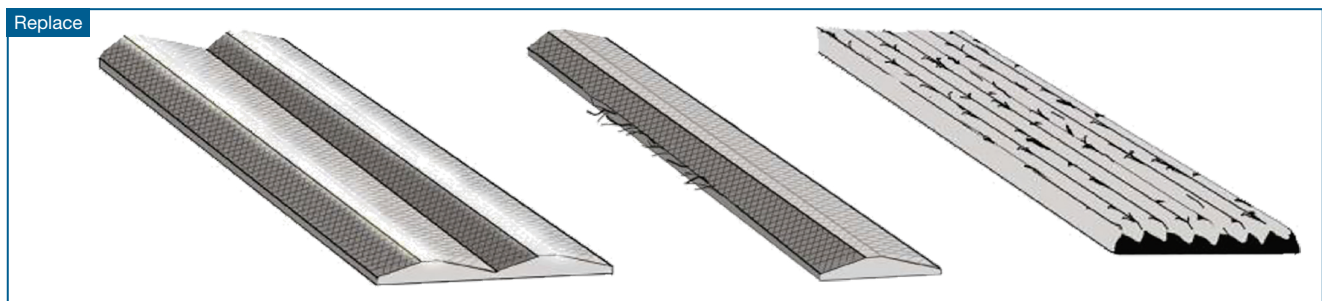
Check the tension and condition of the alternator drive belt.

> Too loose

If the drive belt is too loose, it will slip around the pulley and causing the alternator to charge irregularly or not at all.

> Too tight

If the drive belt is too tight, internal bearing damage will cause premature alternator failure.

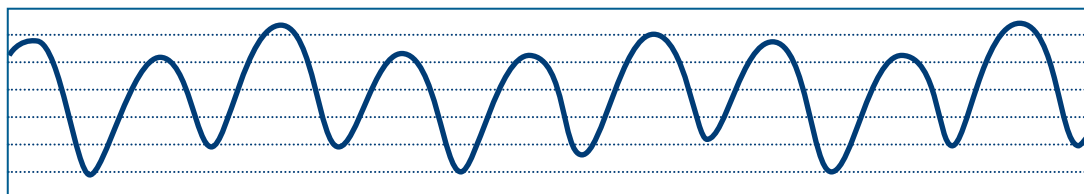


Alternator drive belt condition can affect the transfer of power from the engine crank pulley to the alternator pulley. Old, damaged or worn drive belts can prevent the alternator to charge the battery properly. Service life of a drive belt differs depending on the conditions under which the belt is being used. However, it is recommended to replace the drive belt when replacing the alternator.

Is there an alternative way to check whether alternator works fine or not?

Another way to check the alternator is using a portable/handheld oscilloscope. Observing the “ripple pattern” can identify open or shorted diodes as well as problems in the stator coil. A good ripple pattern should look like the figure below. Any irregularities in the ripple pattern, means that there is open or shorted diode(s) and/or stator winding(s). Most of the modern alternator test benches have the option to check the ripple pattern and to detect defective diode(s).

Ripple Pattern



DENSO Alternators | Troubleshooting

> Q&A

Can an alternator fail because of a poor wiring/ground contact or loose connection?

A poor wiring or ground contact increases resistance and causes a voltage drop in the electrical circuits. In this case, flow of the current through the charging circuit is reduced. Due to this problem, the battery is not able to be fully and properly recharged, causing the alternator to keep charging it at a higher rate than normal. This may cause overheating and premature alternator failure.

Another common problem that causes failure such as in below images is a loose battery cable connection to the alternator. It results in intermittent or no charge alongside a discolored and/or melted alternator output (B+) stud terminal.



What could be the root cause of repeated alternator failures?

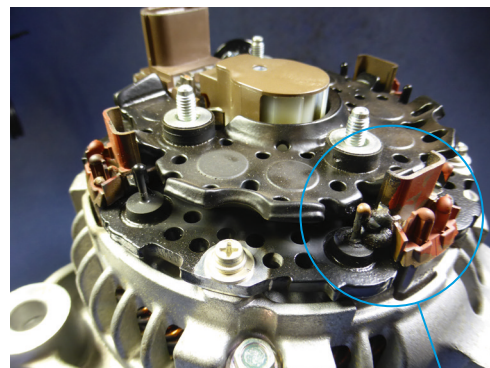
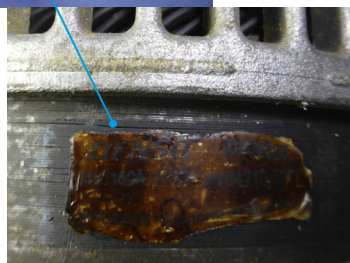
It may be caused by burnt out diode(s) due to an open circuit or a high resistance between the alternator output (B+) and the positive (+) battery connections. In such instances, charging current will flow through the diodes from an alternative route towards the battery. This alternative route will cause excessive current flow through the diode resulting in overheating and failure. Therefore, perform a thorough inspection and voltage drop tests to isolate any problems and avoid repeated alternator failures.

A similar effect may occur when the alternator is forced to charge a discharged battery or when the battery is able to be charged but not able to set up normal resistance. In such cases, the alternator will be instructed to charge the battery to the maximum rate and overloaded for prolonged periods. It will cause the alternator to overheat. As a result, the diodes as well as the stator windings and connections inside the unit can be damaged and failed. Therefore, check the battery carefully and replace if necessary.

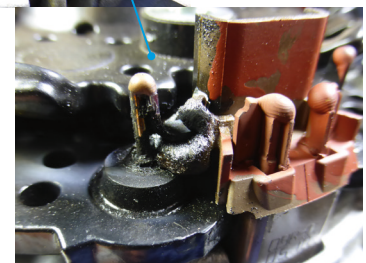
Overheating can also occur if the alternator is located in a space with poor airflow. Especially, when the alternator is working under full load at slow speed in conditions where cooling is insufficient. This may result in premature alternator failures due to overheating.



ID tag has been overheated and has shrunk. This is a sign of excessive heat



Diode has been overheated and failed



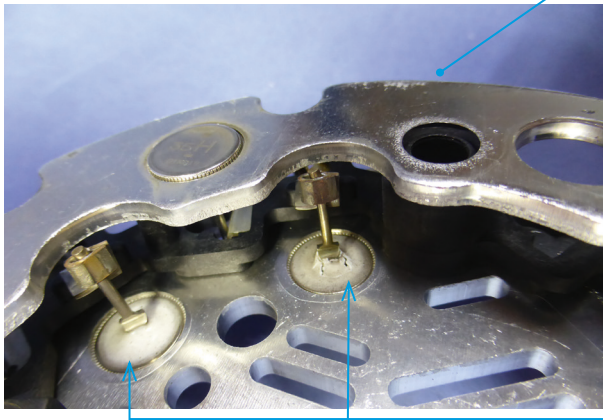
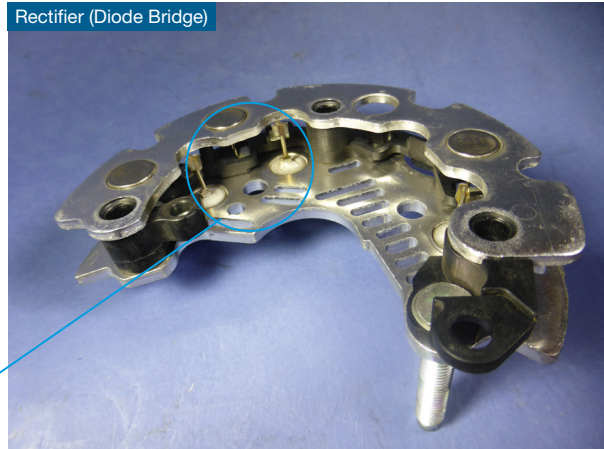
DENSO Alternators | Troubleshooting

> Q&A

What could be the other root causes of alternator failure due to bad diode(s)?

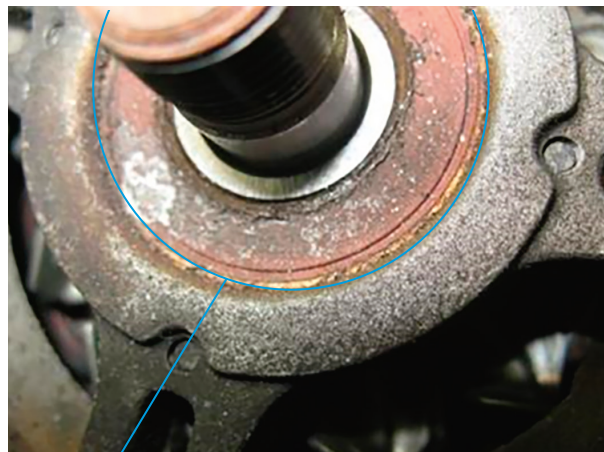
Another most common cause of alternator failure due to one or more bad diode(s) within rectifier is the reverse polarity. Therefore, NEVER apply reverse polarity to the alternator. If the alternator is connected to the battery with a polarity reversal, the diode(s) can explode, melt or be perforated by high current flow and fail. Moreover, all other diodes may have abnormal current leakage.

Besides, the diode(s) can be damaged severely when the battery is disconnected while the engine is running or during a jump start.



Alternator failed because of defective bearing due to water ingress. What could be the root cause of this failure?

Water ingress in bearing causes grease deterioration. Bearing rotation under corrosion and poor lubrication due to grease deterioration causes fatigue and premature failure of the bearing. Although the alternator will be viewed as the main cause of failure, it is most likely related to the location of the alternator in the engine bay or usage in severe environmental conditions exposing the part to excessive water contamination. If the alternator is not shielded sufficiently and continuously exposed to water contamination by tires or if it is located under the windshield draining tube (in line with pulley), water spillage in static condition creates water stagnation and results with water ingress in bearing. Alternator bearings are waterproof due to double lip construction, however they may not withstand prolonged or continuous excessive water contamination.



DENSO Alternators | Troubleshooting

> Q&A

What are the key features of selecting an aftermarket alternator?

A replacement alternator does not have to look like the original one, but it has to provide an equivalent output as well as the same pulley specifications and fitting interface dimensions.

There are numerous OE part numbers for alternators used by vehicle manufacturers, hence why aftermarket suppliers consolidate OE part numbers as much as possible. The most important key features are:

- > Long lifetime and maintenance-free
- > Regulator type is the key feature due to voltage regulation characteristics
- > Pulley type, diameter and number of ribs
- > Fitting interface dimensions such as fixing lug locations, fixing hole diameters, wiring connector, etc.
- > Current output capacity should meet the vehicle's requirements

Caution: Never use an alternator with lower current output capacity for a vehicle that requires an alternator with higher current output capacity. For example, do not use a 80A rated alternator for a vehicle that requires a 120A rated alternator. Overloading an alternator will cause premature alternator failures.

Which in-car technology/features is likely to have the biggest impact on the evolution of alternators?

Developments called Smart or Intelligent Charging allow the alternator's regulator and the engine ECU to communicate and interact with each other improving the reliability and precision of the alternator output control, the electrical power generation and distribution as well as the mechanical power input requirements. Additionally, new features are generated such as boost charging times, enhanced engine performance and idle stability, soft start delay, load response control as well as new diagnostic functions.

Communication between alternator's regulator and ECU is enabled with signals which are Pulse Width Modulated (PWM). Various Smart or Intelligent Charging systems are being used but currently LIN (Local Interconnect Network) based systems are the mainstream and are becoming industry standard. Basically, alternators with LIN regulator use bidirectional, multiplex single-wire LIN Bus communication lines to transmit digital signals based on special LIN protocols.

How will alternator technology change over the next 5-10 years?

EVs are radically changing the manufacturing landscape and are set to play a big part in the future of the automotive industry. This will enable further advances in alternative motor-generator technology. In comparison to the various hybrid concepts, which incur significant costs for return-on-investment through fuel economy, emerging start-stop technology will continue to offer a far more cost-effective solution.

The market is currently dominated by start-stop systems that use enhanced robust starter motor and high-efficiency alternator and will still dominate the market alongside other fuel saving solutions such as high output regenerative braking and boost recuperation. These can make a big contribution toward achieving the stringent emission legislation in 2020 and beyond.

In terms of alternator technology for combustion engines with start-stop system, the main design is unlikely to change radically but more advanced improvements will be introduced to increase efficiency whilst reducing size, weight and noise such as DENSO eSC line high-efficiency alternators achieving up to 80% efficiency in a compact body thanks to reduced rectification loss by use of MOSFETs and reduced iron/copper loss by improved design. Such developments further contribute to the fuel economy and reduce CO₂ emissions.

DENSO Europe B.V.
Hogesweyselaan 165
1382 JL Weesp
The Netherlands

Tel: +31 (0)294 493 493
Fax: +31(0)294 417 122

marketing@denso.nl
www.denso-am.eu

