OPTIMA’S PARALLEL HYBRID SYSTEM

The Optima Hybrid is a parallel hybrid system. That means it can power the vehicle via the:

- Internal combustion (gasoline) engine only
- Electric motor only
- Combination of both

HYBRID DEFINITION

- A vehicle that uses two or more distinct power sources to move the vehicle
- Currently the most common hybrid vehicles use a traditional internal combustion engine and an electric motor

INTERNAL COMBUSTION (IC) ENGINE

2.4L THETA II MPI 4-CYLINDER

<table>
<thead>
<tr>
<th>SPECIFICATIONS/CHARACTERISTICS</th>
<th>ROLES</th>
</tr>
</thead>
<tbody>
<tr>
<td>• 166 hp @ 6,000 rpm</td>
<td>• Send power to the wheels when needed</td>
</tr>
<tr>
<td>- Total hp (IC engine + EV motor) = 206 hp</td>
<td>• Charge up the battery when needed through the Electric (EV) Motor or Hybrid Starter Generator (HSG)</td>
</tr>
<tr>
<td>• 154 lb. ft. @ 4,250 rpm</td>
<td>• Shut off when not needed. This can occur when the vehicle is stopped, decelerating/braking, or when the vehicle is being powered by the electric motor</td>
</tr>
<tr>
<td>- Total torque (IC engine + EV motor) = 195 lb.-ft.</td>
<td>• A clutch disengages the engine from the drivetrain; it allows the engine to shut off/start up as needed</td>
</tr>
<tr>
<td>• Dual CVVT</td>
<td>- Clutch must be engaged to send power from the engine</td>
</tr>
<tr>
<td>• Atkinson combustion cycle</td>
<td></td>
</tr>
<tr>
<td>• Multi-port fuel injection</td>
<td></td>
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</tbody>
</table>

Graphics of components are arranged to enhance understanding. They do not reflect the actual location of the components in the vehicle.
**HYBRID TECHNOLOGY OVERVIEW**

**HOW THE ATKINSON CYCLE WORKS**

**GASOLINE ENGINE COMBUSTION BASICS:**

- Power comes from compressing a mixture and then igniting it
- Gasoline achieves maximum efficiency when its combustion exceeds the degree it’s compressed
- The Atkinson cycle makes this possible by using valve timing to shorten the engine’s compression stroke in relation to its power (expansion) stroke

![Diagram](image)

The intake valve is open as the piston moves down the cylinder, drawing in the air/fuel mixture.

Instead of closing the intake valve at the bottom of the intake stroke, the intake valve continues to stay open.

The intake valve stays open as the piston makes it way up the cylinder during the compression stroke.

The intake valve closes part way up the cylinder. At this point, technically, the compression stroke begins.

In the sequence above, the compression stroke shortens, yet the power (expansion) stroke will remain the same length — the full length of the cylinder. The result: a shorter compression stroke in relation to the power stroke. Mission accomplished!
HYBRID TECHNOLOGY OVERVIEW

HOW THE ATKINSON CYCLE WORKS (CONT’D)

ATKINSON CYCLE DRAWBACKS

- The engine sacrifices top-end power because the maximum amount of fuel it can burn per cycle is smaller than what is possible in an Otto-cycle engine
- This limit on fuel also makes the engine far less powerful at the low end of its rpm range
- An Atkinson cycle needs to run in a narrow rpm band in order to make the best use of its capabilities
- That’s where the electric motor comes — it provides the low-end torque needed during acceleration and passing, allowing the engine to remain in the range where it functions best
- This combo — an Atkinson cycle engine teamed with an electric motor — is featured on most hybrid configurations

ATKINSON CYCLE BOTTOM LINE

Here are the key messages to communicate to customers:

- The Atkinson cycle enables the engine to achieve greater degrees of efficiency than a conventional combustion cycle, but it needs to operate within a narrow rpm band
- The electric motor kicks whenever high torque is required — during acceleration and passing

ELECTRIC MOTOR + ATKINSON CYCLE = MAXIMUM POWER AND EFFICIENCY
HYBRID TECHNOLOGY OVERVIEW

ELECTRIC (EV) MOTOR

CHARGING MODES:
1. Whenever the vehicle is decelerating, regenerative braking comes into play
   - The IC engine shuts off
   - The wheels — through the driveline and transmission — turn the electric motor, which creates electricity that charges up the high-voltage battery
2. The electric motor can also be switched to “charge” whenever the vehicle is under power by the IC engine
   - Here the engine is powering the driveline
   - The driveline in turn is forcing the electric motor to turn

REGENERATIVE BRAKING NOTES:
• Besides creating electricity, it actually enhances braking
• The turning EV motor creates resistance which takes some load off the actual brakes
• A slight noise can be heard during braking — it's the EV motor turning — and is perfectly normal

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<tbody>
<tr>
<td>• 40.2 hp @ 1,400-6,000 rpm</td>
<td>• Send power to the wheels — either by itself or along with the gas engine</td>
</tr>
<tr>
<td>- Total hp (IC engine + EV motor) = 206 hp</td>
<td>• Charge up the high-voltage battery</td>
</tr>
<tr>
<td>• 151.2 lb.-ft @ 0-1,400 rpm</td>
<td></td>
</tr>
<tr>
<td>- Total torque (IC engine + EV motor) = 195 lb.-ft.</td>
<td></td>
</tr>
<tr>
<td>• Permanent Magnet Synchronous Motor</td>
<td></td>
</tr>
<tr>
<td>- Assists up to 62 mph</td>
<td></td>
</tr>
<tr>
<td>• Maximum 270V DC (nominal)</td>
<td></td>
</tr>
<tr>
<td>• Max Speed: 62 mph</td>
<td></td>
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</tbody>
</table>

6-SPEED AUTOMATIC TRANSMISSION
• Modified version of the 6-speed transmission used across the Optima lineup
• 6 forward gears for improved response and smooth power delivery
• Electric motor is permanently affixed to the transmission, replacing the torque converter
• Power inputs:
  - When the clutch is engaged, receives power from the IC engine
  - Receives power from the Electric Motor when motor is in “propulsion” mode
HYBRID TECHNOLOGY OVERVIEW

HIGH-VOLTAGE BATTERY
• Power output: 30 kW
• Type: Lithium polymer
• Voltage: 270V
• Weight: 95.9 lbs
• Capacity: 5.3 Amp-hour

NOTES:
• Advanced lithium polymer is more efficient and compact compared to the nickel-metal hydride battery packs in competitors like the Fusion Hybrid and the Camry Hybrid.
• The high-voltage battery stores power to drive the electric motor and power the Hybrid Starter Generator (HSG). When these components are switched to “generator” mode, they can recharge the high-voltage battery.
  - Additionally, the high-voltage battery powers the AC compressor. The 12-volt battery (located in trunk) powers vehicle accessories such as the lights and radio.

HYBRID STARTER GENERATOR (HSG)
TO START THE ENGINE
• A belt connects a pulley on the HSG to a pulley connected to the engine crankshaft
• The crankshaft is connected to all the pistons
• To start the engine, the starter motor turns the crankshaft
• At the same time, the controller opens the throttle, and spark and fuel are provided to the point that the engine starts
• The HSG can start the engine during a standstill and when the vehicle is in motion
• When in motion, the heavy-duty, 5.6 kW starter motor seamlessly brings the engine up to speed...“syncs” it with the vehicle speed. The clutch then engages, enabling a seamless power transfer to the wheels.
HYBRID TECHNOLOGY OVERVIEW

HYBRID STARTER GENERATOR (HSG) (CONT’D)

TO RECHARGE THE HIGH-VOLTAGE BATTERY

• System switches HSG to charge mode
• IC engine turns HSG
• HSG sends power to battery, charging it up

HSG CHARGE SCENARIOS

The HSG can charge up the battery in several situations (note: the Hybrid system will have to determine that a HSG charge is needed for the following to occur):

• **Vehicle at a stop**: the system will start up the IC engine; the engine will power the HSG
• **Vehicle under EV motor power**: if the EV motor is powering the vehicle, the system can use the IC engine to power the HSG
• **Vehicle under IC-engine power**: whenever the engine is powering the vehicle, the HSG can charge the high-voltage battery
• **Braking/deceleration**: if an additional charge is needed (more than what can be delivered through regenerative braking alone), the IC engine will remain on and power the HSG

BENEFITS OF UTILIZING EXISTING COMPONENTS IN OPTIMA HYBRID’S POWERTRAIN DESIGN:

• Utilizing the 6-speed automatic transmission and a 2.4L 4-cylinder engine design simplified the design of the vehicle
  - Reduced the number of all-new components to be introduced to the new Optima chassis and helped maintain component consistency across the Optima lineup
• Less components to design from scratch and integrate into Optima’s new chassis means more efficiencies gained in development of the vehicle