Executive summary
This white paper outlines how Groupe Renault has broken down headlamp costs and used thermal analysis tools to incrementally optimize headlight designs to achieve a 50 percent cost reduction from 2014 to 2016, and how the company intends to halve it again in the next few years.

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Automotive headlight design is an important part of the Renault brand these days and the “C-shape” headlights are a signature part of the appeal of Renault cars. About 30 percent of the cost of automotive headlight assemblies can be found in the mechanics and 70 percent in the electronics. Hence, any savings that can be made on the electronic side will have a profound influence on the overall cost of these units.

In Generation 1 of full LED headlight assemblies, Renault looked at six of its C- and D-segment vehicles from the Espace to the Koleos. The company first standardized all platforms to one common height sensor, one common static leveler, one common daytime running lamp (DRL)/low beam/high beam driver, one common central connector, and common low- and high-beam modules with two suppliers for each (figure 1). Renault accomplished this in one year by examining the partition of costs and standardized about 60 percent of the headlight components (figure 2). The plastics Renault used accounted for only about 30 percent of the overall assembly price. The volume effect is the main cost factor for a headlamp’s part price as is its supply entry ticket. However, by moving from halogen headlights in 2012 (see figure 3) to LED-based headlights in 2014, the overall costs went up four-fold. This gave the company the impetus to determine whether it could cut costs in Generation 2 of the headlight evolution.
Renault focused its Generation 2 headlamp effort on the popular segment B car, the Renault Clio, which was undergoing a facelift; stylistically the company wanted to move it to the LED-based, C-shape DRL lighting (figure 3). There were four pillars to the Generation 2 strategy:

- Be the first generalist automotive OEM with full LED headlights in this B-segment car
- Reduce by a factor of two the headlight part price between Generations 1 and 2
- Achieve better LED lighting performance than the Clio Initiale (which had Xenon 25W lights)
- Reduce overall headlight assembly depth by 50mm

Renault standardized the Clio on a common LED electronic control unit (ECU), a common height sensor, and a common leveler. The company then focused on the LED low-beam light and reduced its price by 30 percent by reducing the number of LEDs, the size of the heatsink by 30 percent, and improving the optical system. By doing all these things (table 1), Renault improved the LED light flux by 33 percent and reduced the assembly from eight to five LEDs. The company also increased optical efficiency by 25 percent and produced an overall assembly size reduction of 50mm. With the thermal improvements to the LEDs, Renault was able to increase the LED current, increase the maximum junction temperature usage and the flux derating at a lower ambient temperature (table 1). Similarly, with the associated

<table>
<thead>
<tr>
<th>Solution</th>
<th>Current (mA)</th>
<th>Flux/LED</th>
<th>Number of LEDs</th>
<th>Tj @ 23°C T° ambient</th>
<th>Start of derating</th>
</tr>
</thead>
<tbody>
<tr>
<td>LED low-beam Gen1</td>
<td>800 mA</td>
<td>200lm</td>
<td>8</td>
<td>120°C</td>
<td>T° ambient 60°C</td>
</tr>
<tr>
<td>LED low-beam Gen2</td>
<td>1A</td>
<td>270lm</td>
<td>5</td>
<td>130°C</td>
<td>T° ambient 50°C</td>
</tr>
<tr>
<td>LED high-beam Gen1</td>
<td>800 mA</td>
<td>200lm</td>
<td>4</td>
<td>120°C</td>
<td>T° ambient 60°C</td>
</tr>
<tr>
<td>LED high-beam Gen2</td>
<td>1A</td>
<td>270lm</td>
<td>4</td>
<td>130°C</td>
<td>T° ambient 50°C</td>
</tr>
</tbody>
</table>

Table 1: LED solution evolution from Generation 1 to 2 for the Renault Clio headlamp.
heatsink design, the company was able to get better junction temperature management and better derating management through detailed thermal simulations (figure 4).

With respect to the overall headlamp package size, figure 5 shows the 50mm depth saving we were able to achieve between Generation 1 with a halogen headlamp and Generation 2 with a LED headlamp due to a better designed assembly. Figure 6 shows results of a typical CFD simulation for a halogen headlamp using Siemens Digital Industries Software’s CAD-embedded flow simulation software, Simcenter™ FLOEFD™, illustrating the complex air flows and thermal effects to be found on the surfaces in the assembly.

<table>
<thead>
<tr>
<th></th>
<th>Gen 1</th>
<th></th>
<th>Gen 2</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Low beam</td>
<td></td>
<td>309 gr</td>
<td>-30%</td>
<td>198 gr</td>
</tr>
<tr>
<td>High beam</td>
<td></td>
<td>186 gr</td>
<td>-20%</td>
<td>154 gr</td>
</tr>
</tbody>
</table>

Figure 4: Renault Clio headlamp heatsink weight evolution, Generations 1 to 2.

Figure 5: 50mm headlamp package savings between Generation 1 (halogen) and Generation 2 (LED).

Figure 6: Simcenter FLOEFD thermal predictions for a Renault halogen headlamp assembly.
Looking deeper at the general CFD-based thermal analysis approach to headlamp design that typically is used to optimize designs, engineers would normally be interested in predicting lighting performance at 23°C outside the headlamp in ambient air and up to a maximum of 70°C for the outside temperature for the outer boundary of LED reliability. To validate our simulations, Renault therefore carried out some experimental tests where the ambient temperature outside the headlamp was fixed at 23°C and installed eight thermocouples outside the assembly (see figure 7) for a car with its engine on and off.

Figure 8 shows thermocouple time traces for both the engine on and car stationary for 3hr 30mins; then lights switched on for 1hr 30mins with the engine on and stationary, and then the lights on and engine driving for 1hr 30 minutes. It is clear that the temperatures can reach over 50°C inside the headlamp when the engine is idling and the lighting is on for a prolonged period. In addition, headlamp surface temperatures can rise to 65°C in certain idling conditions. Other tests revealed that with just a low beam on for an hour, the temperature inside the headlight went to 20°C and with both low and high beam on for an hour an extra 5°C in temperature was measured.

![Figure 7: Location of the eight thermocouples for the ambient temperature headlamp engine tests.](image)

![Figure 8: Thermocouple temperatures outside the headlamp assembly for various engine on and light on/off scenarios.](image)
A series of tests evaluated the effects of engine idling and lights either on or off by looking at $R_{jth}$ of an Altilon LED with 3K/W and 3 chips @ 1A and for a delta (Tjunction – Tcase) of 20°C. These tests show that for ambient temperatures of 70°C and with both low beam and high beam lights on together with the engine on that the junction temperature of the LEDs comes very close to the worst case scenario of 150°C. Renault concluded that it was not possible to design a LED system that takes into account all the use cases. The OEM must therefore define the best compromise. For example, at 23°C, after one hour engine idling, lighting performance was shown to be at 100 percent, but if the ambient temperature rose to 50°C for the same situation, the lighting performance would go down to 80 percent. In order to respect this specification, Renault concluded that a thermal sensor had to be added to the PCB so that the current could be reduced if the temperature at the LED was greater than a defined threshold. The company could then do a thermal derating and a flux derating of the full LED headlamp.

Going forward, Renault is putting in place an action plan to deal with simulation and testing of lighting in transient drive cycle modes (figure 9). As an OEM, Renault wants to be able to simulate the impact of car speed on its lighting’s thermal performance, and in particular the thermal variation due to speed of each of our engines. This will make thermal CFD software key for lighting engineers in the future.
The company also needs to be able to model the nearby engine bay’s thermal behavior in parallel with the headlight simulation as they affect each other. Renault also sees the need for thermal management inside the headlamp when thermal inductors will be present. In short, Renault believes that the OEM should be responsible for the complete thermal system associated with headlamp design. To do so will make the OEM a market system leader.

The Renault lighting team’s goal with Generation 3 of the project is to increase the LED flux of headlamps from 270lm to 320lm by 2018 – 2020, introduce new LED drivers to deal with higher power, introduce turn indicators and adaptive frontlight system (AFS) functionalities and reduce overall assembly size. Finally, the company is aiming for a height sensor regulation evolution. The eventual target is to reduce the full headlamp assembly price by another 50 percent, bringing it to the levels realized with halogen headlamps five years ago (figure 10).

![Headlamp cost roadmap](image)

**Figure 10**: Renault headlamp cost reduction roadmap to Generation 3 headlighting.
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