

# High Reliability LED Technology in R<sup>2</sup>Coupler™ Optocouplers for High Temperature Applications in HEVs and EVs



## White Paper

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### Introduction

Avago Technologies R<sup>2</sup>Coupler optocouplers employ Avago's high reliability LEDs to provide isolated signal transmission. Avago automotive-grade LEDs do not degrade across the typical mission profile of automotive vehicles.

LED technology is a mature technology. Avago R<sup>2</sup>Coupler optocouplers use advanced and sophisticated methods for manufacturing LEDs that have been improved and refined over 35 years. Avago Technology optocouplers have been used in all types of applications, including industrial and those requiring ultra-high, mission critical reliability, such as for super express trains, aerospace and military applications.

Optocouplers were first proven in the first commercial hybrid electrical vehicle (HEV) in the Toyota® Prius. Currently, Avago Technologies R<sup>2</sup>Coupler optocouplers are being used in recently released models of HEV and EV from Japan, Korea, China, Europe and the United States. In addition, more than 40 automotive companies, including car manufacturers and tier one suppliers, are using or evaluating R<sup>2</sup>Coupler isolation products.

There is widespread misconception that LEDs are not suited to automotive applications. This perception has arisen because commercial grade LEDs—that are only suitable for consumer applications—have occasionally been applied in automotive environments that should only be served by LEDs designed and manufactured with a high quality testing and control process. This misconception has also been advanced by suppliers of non-optical isolation technologies without supporting evidence.

### Superior LED Design and Manufacturing for extended operating temperatures

Light emitting diodes used in R<sup>2</sup>Coupler optocouplers are manufactured by Avago with advanced, specially-designed semiconductor and manufacturing processes that meet stringent automotive quality standards. Our state-of-art epitaxial and wafer fabrication sites are certified according to the TS16949 automotive quality standard.

R<sup>2</sup>Coupler optocouplers also use specialized tooling, handling practices and manufacturing controls for superior product quality. These tooling, practices and controls have been proven over a 35 year history of successful optocoupler manufacturing.

In addition, product specifications are well-characterized and take into account device parameter variation across operating temperature and product lifetime.

### Stringent Qualification to Automotive Standards

R<sup>2</sup>Coupler optocouplers meet the stringent AEC-Q100 qualification test guidelines set by the Automotive Electronics Council.

Table 1 shows a sample of AEC-Q100 stress-test qualifications performed on R<sup>2</sup>Coupler optocouplers. Other AEC-Q100 stress tests performed include autoclave, high temperature storage life and ESD.

**Table 1. Sample of AEC-Q100 stress test qualifications performed on R<sup>2</sup>Coupler optocouplers**

Stress Test	Conditions	Sample Size	Release Point
High Temperature Operating Life (HTOL)	150° C, LED drive current = 20 mA	77 units x 3 lots	408 hours
Biased Highly Accelerated Stress Test (HAST)	130° C / 85% RH	77 units x 3 lots	96 hours
Temperature Cycle	-65° C to 150° C	77 units x 3 lots	500 cycles

The AEC-Q100 HTOL stress test shown in Table 1 stresses to more than three times the typical operating life.

### Typical Automotive Application Mission Profile

Table 2 shows a typical operating life mission profile of an inverter in an automotive vehicle. Using Black’s model ( $E_a = 0.43 \text{ eV}$ ,  $N = 2$ ) to calculate the acceleration factor (assuming an average of 10 mA LED drive current at 50% duty cycle), the equivalent operating hours of 150°C HTOL stress is approximately 123 hours.

**Table 2. Typical inverter operating mission profile in an automotive vehicle**

Temp Range (°C)	Operating Hours
-20 - 0	10650
0 - 10	1497
10 - 20	19879
20 - 30	6541
30 - 40	17311
40 - 50	5759
50 - 60	3684
60 - 70	2678
70 - 80	2796
80 - 90	2245
90 - 100	1031
100 - 110	812
Total	74883 (8.5 yrs)

Table 3 shows the non-operating mission profile of an inverter in an automotive vehicle.

**Table 3. Typical inverter non-operating mission profile in an automotive vehicle**

Temp Range (°C)	Non-Operating Hours
-20 - 0	11304
0 - 25	28260
25 - 40	19879
Total	59443 (6.7 yrs)

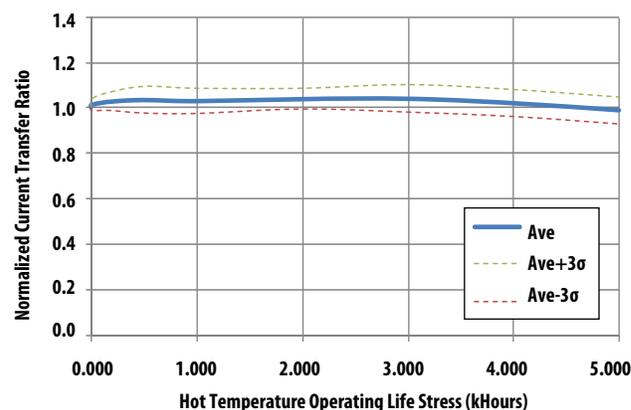
### Reliability Testing Beyond AEC-Q100

Light emitting diodes in R<sup>2</sup>Coupler optocouplers have also been subjected to extended stress above that required by AEC-Q100 guidelines.

**Table 4. Extended stress tests**

Stress Test	AEC-Q100 Release Point	Extended Stress	Result
High Temperature Operating Life (HTOL)	408 hr	5000 hr	All units fully functional and within datasheet specifications
Biased Highly Accelerated Stress Test (HAST)	96 hr	168 hr	
Temperature Cycle	500 cycles	1000 cycles	

The superior LED performance of Avago automotive grade LEDs is demonstrated in Figure 1. Avago automotive grade LEDs showed excellent performance even after 5000 hours of 150°C stress. In addition, R<sup>2</sup>Coupler optocouplers have undergone up to 10000 hour stress and remained fully functional and met datasheet specifications.



**Figure 1. High performance of LED after 5000 hours of 150° C stress**

The results of the extended HAST (Highly Accelerated Stress Test) stress test demonstrates that Avago R<sup>2</sup>Coupler optocouplers will withstand high temperature and high humidity environments.

The extended temperature range cycling stress test also demonstrates the performance of R<sup>2</sup>Coupler optocouplers in extreme temperature conditions.

## Extended Operating Life for Automotive Applications

R<sup>2</sup>Coupler optocouplers provide extended operating life for all automotive applications. Table 5 shows the continuous operating life in various automotive applications. For most applications, the time the LED spends in operation is less than half of the overall product life.

**Table 5. Operating life in various automotive applications**

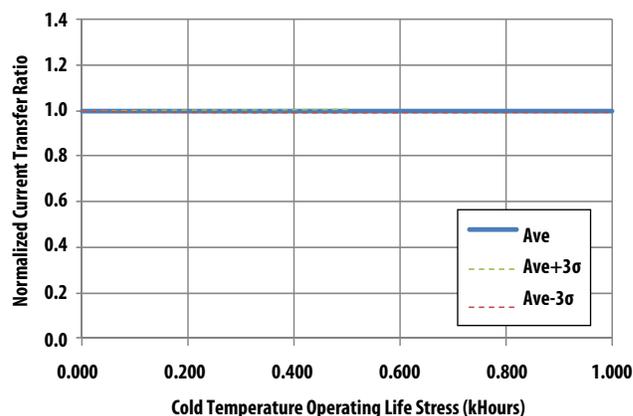
Application	Operating Conditions	Equivalent Continuous Operating Life*	Estimated Product Life**
Charger, HVAC, DC/DC, Oil Pump	Max 125° C, Ave 105° C If = 10 mA @ 50% duty cycle	> 37 years	> 100 years
Inverter	Max 125° C, Ave 110° C If = 10 mA @ 50% duty cycle	> 30 years	> 100 years
BMS	Max 105° C, Ave 85° C If = 5 mA @ 50% duty cycle	> 100 years	> 100 years

\* Based on 5000 hours, 150° C HTOL

\*\* Parts still fully functional after 10000 hours continuous stress, estimate includes non-operating life

## Operating Life at Low Temperatures (-40° C)

In addition to hot temperature stress, low temperature stress at -40° C has also been performed on Avago R<sup>2</sup>Coupler optocouplers. As shown in Figure 2, Avago light emitting diodes showed no degradation in current transfer ratio after low temperature stress. Current transfer ratio is a measure of LED light output.



**Figure 2. High performance of LED after 1000 hrs of -40° C low temperature stress**

## Conclusion

The Avago Technologies R<sup>2</sup>Coupler optocouplers use automotive grade LEDs that are specially designed and manufactured by Avago for long operating life in automotive applications which must operate reliably over a temperature range of -40° C to 125° C.

R<sup>2</sup>Coupler optocoupler technology is designed to exceed automotive user requirements.

For product information and a complete list of distributors, please go to our web site: [www.avagotech.com](http://www.avagotech.com)

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