Reliable LEDs for Automotive Grade Optocouplers

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White Paper

Abstract

One of the key enablers for optocouplers to handle automotive grade 1 applications is the use of very high performance LEDs. The LED light output dropping by less than 0.2%/°C, aids in achieving high temperature specifications and the improvements in LED design and fabrication. Coupled with package design, this has demonstrated very reliable performance. Based on the mission profiles of some automobiles 15 years old, this translated to about 2000 hrs under highly accelerated continuous operating life stress conditions. With current transfer ratio drop of less than 10% after 5000 hrs of stress, system designers can accommodate such variations to cover more than 35 years of the automobile's life.

Introduction

The rapid rise of oil prices has pushed the growth of fuel-efficient hybrid electric vehicles (HEVs) to take center-stage in the automotive industry. The high voltage batteries used in the HEVs brought about a need for insulation and isolation. Optocouplers have been chosen for this task in the current hybrids design. Figure 1 shows an example of where optocouplers are located in the electric motor drive system of the HEV.

Although Avago Technologies' automotive optocouplers are recent additions to the isolation products portfolio, Avago optocouplers have been successfully used in hybrid automotive projects for nearly ten years, albeit in the form of industrial grade products. In today's market, it is no longer sufficient to address all emerging automotive isolation applications, particularly in applications requiring reliable long term operation at high ambient temperatures up to 125°C.

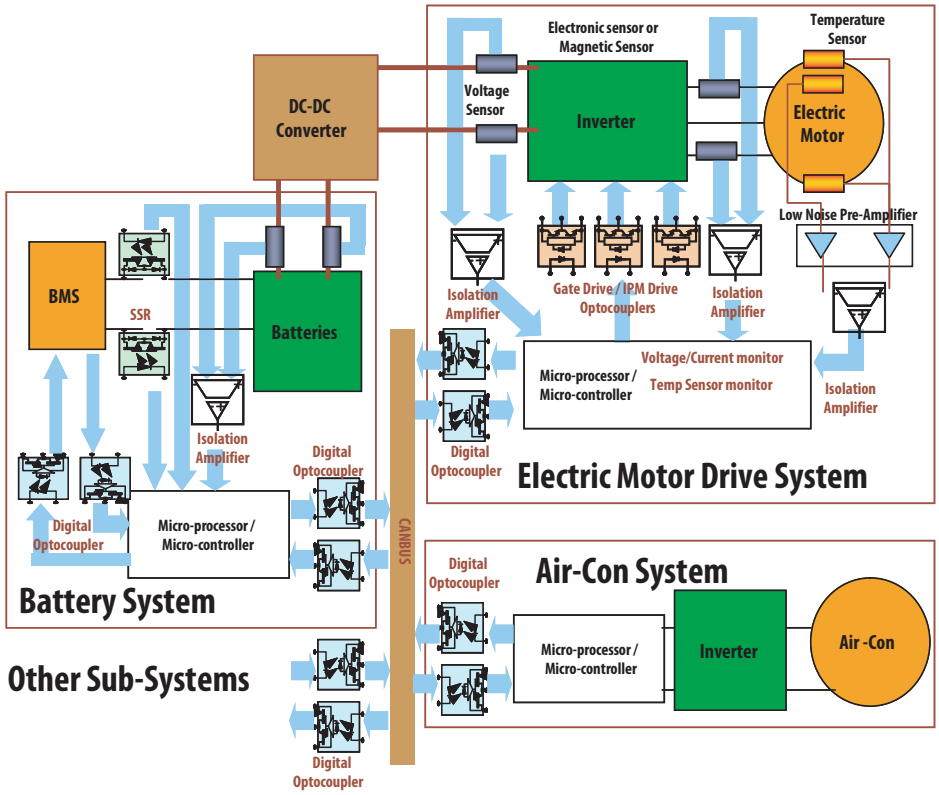

Figure 1. Optocouplers in the Electric Motor Drive System

LED Improvements

The primary piece parts of an optocoupler consist of a photodetector IC and an LED. In practice, the photodetector can sometimes be re-qualified for high temperature automotive use with little or no design changes. The LED, however, requires more careful consideration. Some competitors or even customers might express concern or prejudice against the use of LEDs at such high ambient temperatures. Some of this opinion has some grounding from the potential that an LED can suffer from significant light output degradation after prolonged use at high ambient temperatures. The key operative word here is: potential. Since the advent of the LED, continuous and rapid developments in LED design and processing have resulted in a massive divergence in the intrinsic aging performance of LEDs. Providing customers with an LED of exceptional lifetime performance is no longer a fundamental technological problem.

LED reliability has seen significant advancements in various areas, as summarized in Figure 2. Higher LED internal quantum efficiency, better LED light extraction and improvements in optical channel efficiency, have enabled the reduction of the input driving current (I_F) requirement. By designing low forward voltage (V_F) LEDs, Avago can lower the input power (I_F x V_F) to reduce heat generated in the LED. Good current-spreading LED designs will improve current distribution within the LED, further improving the intrinsic lifetimes.

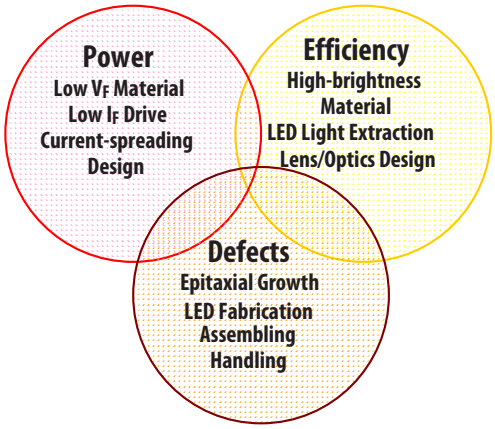

Figure 2. Summary of Improvements of Light Emitting Diodes

Elimination of LED fabrication defects has been achieved through better equipment and continuous process optimizations. These improvement efforts have been ongoing for more than 35 years since the introduction of Avago's optocouplers.

Temperature Coefficient of LED Light Output

LEDs brightness has a negative coefficient with temperature. To be able to handle ambient temperatures beyond +105°C (Automotive Grade 1 and 2), a low temperature drift has a significant advantage in minimizing parametric temperature drifts.

The LEDs used for Avago's Automotive Grade optocouplers typically drops by <20% at +125°C, whereas commercially available (consumer grade and general purpose industrial) infrared LEDs typically experience a drop of up to 60% at +125°C (Figure 3). As this is beyond the recommended temperature range for commercially available LEDs, it does highlight the importance that only specially designed LEDs for high temperature operation can be used for automotive grade optocouplers.

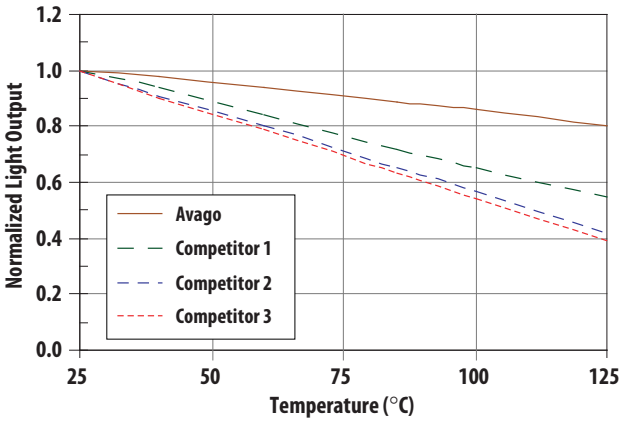

Figure 3. Normalized Light Output of LEDs at High Ambient Temperature

With a low drift in light output, this is somewhat mitigated by the negative temperature coefficient of the LED forward voltage. For example, in a 3.3V system, this will have a 10% compensation effect, resulting in an overall drift of <10%.

Assembly Packaging

The LED is covered with silicone to reduce the package stress on the LED, preventing mechanical stress related failures. Avago optocouplers are qualified to moisture sensitivity level 1 (MSL1), which plays a significant role in reducing moisture-induced failures. The package construction shown in Figure 4 (page 3) indicates the various construction components.

Thermal dissipation enhancements were taken into account during the product design as well. Leadframe material and design are used to improve heat dissipation from the product to reduce the junction to ambient thermal resistance (θ_{JA}), thereby preventing localized heating on the LED.

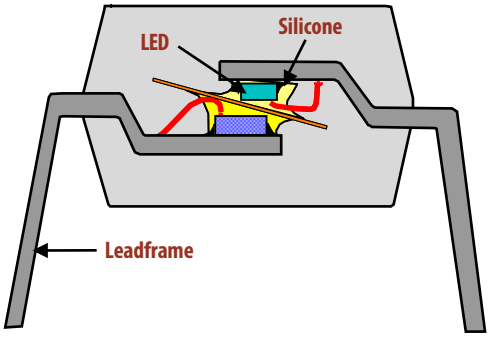

Figure 4. Cross-section of Construction of Avago Technologies' Automotive Optocoupler

Automotive Optocoupler Operating Lifetime

The results of the process and design improvements can be observed in the high temperature operating life stress of Avago's ACPL-M43T in Figure 5. Consumer grade LEDs were put into the same package for comparison with Avago's automotive grade LEDs. The results yielded vast differences in reliability performance between consumer grade LEDs from other suppliers versus Avago's automotive grade LEDs. Consumer grade LEDs do not handle high temperatures well, not surprising as their end applications do not require them to do so. The consumer grade LEDs degrade quickly and exhibit wide variations over time. The next important point worth highlighting is that this data was obtained from LEDs manufactured from a range of wafer lots, so this extremely tight distribution is indicative of a very well controlled manufacturing process for Avago's automotive grade LEDs.

Automotive designers use mission profiles to establish the suitability of a component for automotive use. Mission profile is the time which the component or system is in use, taking into account the temperatures at which the application is operating. Based on some of the mission profiles provided to Avago for assessment, 15 years of field life was translated to 2000 hrs of continuous component stress under high temperature conditions. Current transfer ratio (CTR), which is the key indicator of coupling efficiency in the optocouplers, demonstrated variation of less than 10% after 5000 hrs continuous stress, and can be easily budgeted in to enable robust designs in excess of 35 years of field life.

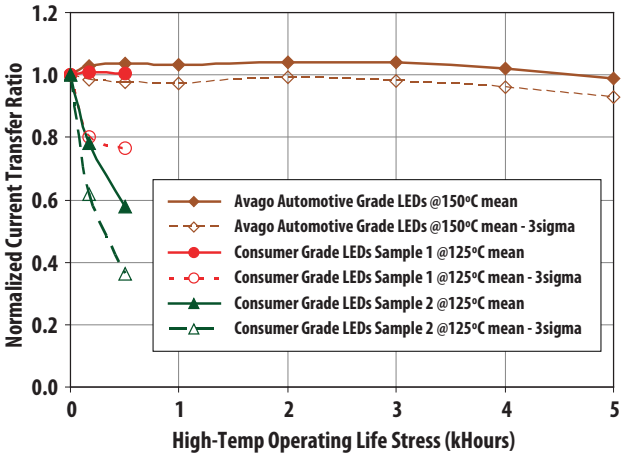

Figure 5. Normalized CTR of Single Transistor Optocoupler up to 5k Hrs

Conclusion

Avago's hermetic optocouplers have demonstrated high reliability and high temperature robustness (-55°C to +125°C) in the military and space applications. Avago has now upgraded its plastic optocoupler portfolio to handle the extended temperatures and to meet the price demands of the automotive industry. Plastic optocouplers have already been proven in use by hybrid car manufacturers in high volume HEV applications at the industrial temperature range. The introduction of the full temperature range up to +125°C facilitates the use of AECQ100-qualified plastic optocouplers in all automotive applications.

For product information and a complete list of distributors, please go to our web site: **www.avagotech.com**

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