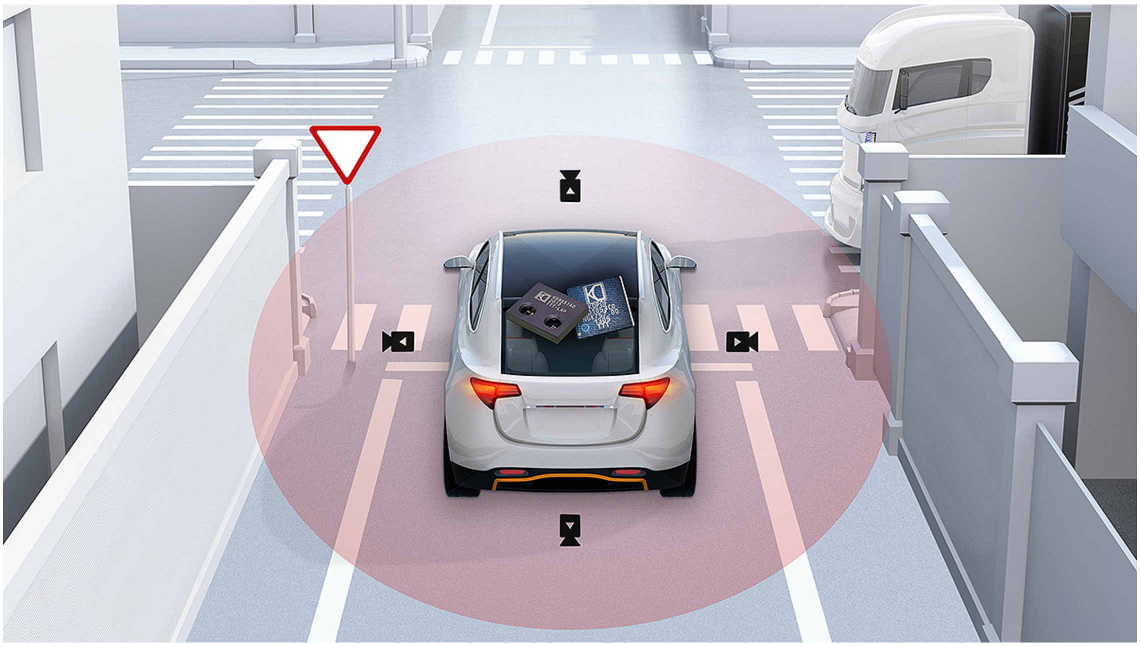
Multi-gigabit Networking Demands Optical Communications System



With technological leaps such as electrical vehicles, automated driving, and V2X interconnection rushing through, automotive applications, utilization, and safety requirements are boosting the necessary network speed. In-vehicle networks are on the brink of speeds from one to multiple gigabits per second. As the auto industry targets the 100 Gb/s*m speed-length threshold, issues such as electromagnetic interference, electromagnetic susceptibility, cost, and weight reduction are becoming more and more serious.

For data transmission rates above 100 Mb/s, commonly used copper links need heavy and expensive modifications to comply with the stringent OEM's EMC specs, resulting in high cost and very difficult engineering. Moreover, the weight of the ever-growing diameter of the required cables plays against the race for increased range in electrical powertrains.

The need to move from copper to optical physical transmission media is becoming evident. The key advantages of the optical solution, among others, are superior

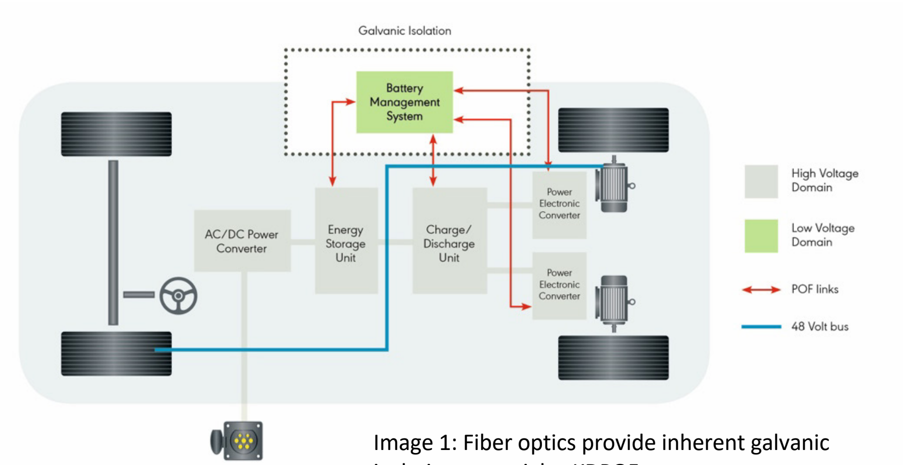


Image 1: Fiber optics provide inherent galvanic isolation, copyright: KDPOF

Electromagnetic Compatibility (EMC) thanks to the inherent galvanic isolation, low weight, and low cost.

The optical cables are absolutely reliable and much more flexible than shielded copper cables. They allow fast, dynamic, and tight bending as well as immersion in dark liquids. Additionally, optical Ethernet generates very low noise and can operate in noisy environments, such as in RF electronic boards. With optical and copper in parallel, the optical network provides ASIL-D safety architecture (ASIL-D = ASIL-B + ASIL-B). It guarantees easy engineering for seamless implementation. Overall, optical is the engineering-wise path for higher data rates.

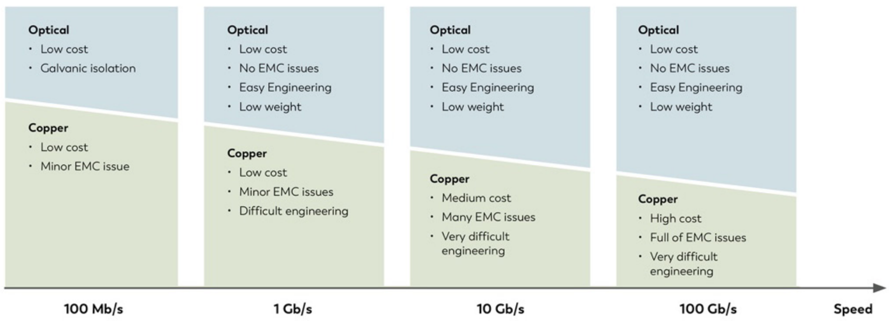


Image 2: Co-existence of optical and copper in automotive networking, copyright: KDPOF

Complete Communications System

Several industry leaders are working on an optical automotive multi-gigabit system that will fulfill the needs of future connected and automated vehicles. Instead of various port components, the upcoming solution provides a single, complete package. The new connector systems are very small, lightweight, and extremely inexpensive compared to the previous ones. With cost-down and consistency in focus, optics, fibers, connectors, and electronics already developed for nGBASE-SR will be reused. Further specifications include 980 nm VCSEL (Vertical-Cavity Surface-Emitting Laser), multimode OM3 fiber, PAM2 receivers, and connectors. Standardization work focuses on the automotive requirements: VCSEL reliability for the operation temperature range, connector development with quality grades, and an adaptive DSP to cope with the large parametric deviation of the VCSEL. Eventually, increasing the yield percentage results in cost reduction.

Complexity stays low with simple modulation. For fiber, the OM3 class is chosen since it is already extensively used by data centers and avionics. Only massive economy-scale light sources will be selected. Two connector grades are defined in order to allow cost-effective implementations. Regarding topology, asymmetric up and down links have been considered from the beginning. The use of the Energy-Efficient-Ethernet (EEE) specification is an appropriate candidate to implement this feature. Cameras, displays, sensors and further asymmetrical use cases have been included as test cases for standardization. An OAM side-channel will be available for dependability and link management. The absence of retransmissions means controlled latency for video distribution. Symmetric links will be added for backbone communications.

The proposed multi-gigabit system wakes up in less than 100 ms. The target BER is better than 10^{-12} with ambient operating temperature ranging from -40 ºC to 105 ºC (AEC-Q100 grade 2) in harsh automotive environments. Meeting OEM reliability requirements, high reliability (15 years operation) and outstanding EMC compliance are also fulfilled. The technology in development is based on advanced digital signal processing, using high-speed DAC and ADC to implement all needed algorithms such as equalization or pre-coding.

VCSEL Operation

A key component for this communication system is the light source. The Vertical-Cavity Surface-Emitting Laser is the device that best fits the high speed and low-cost requirements of the application. The technology of the VCSEL device is well-known, mature and optimized, already heavily used in two killer applications: optical sensors for mobile phones and data center communications. The VCSELs used for the latter application can be leveraged for automotive communications, seizing on its already excellent cost and speed. However, VCSELs used in data centers live a more comfortable life than they will in a car.

Reliable communication must be guaranteed in extreme temperatures ranging from -40 ºC to +105 ºC ambient temperature. Successfully using the VCSEL in automotive conditions means being able to compensate for its impairments at high temperatures. The substrate of the VCSEL will reach an even higher temperature, so to have enough margin, a substrate temperature range of -40 ºC to +125 ºC is favored. The proposed system implementation can support VCSEL operation in this scope, and also take into account the possible technology process variations amongst the different VCSELs manufactured.

Automotive VCSELs are not only required to live in a harsh environment, but they are also required to live longer. The automotive industry sets a very demanding objective for the reliability of electronic components, which can be summarized with a figure: 10 FIT (*Failures In Time*). This means that the failure rate expected for a component is at most 10 failures after one billion device hours, which for example can be expressed saying that no more than 10 out of 1000 devices can fail after one million hours of operation.

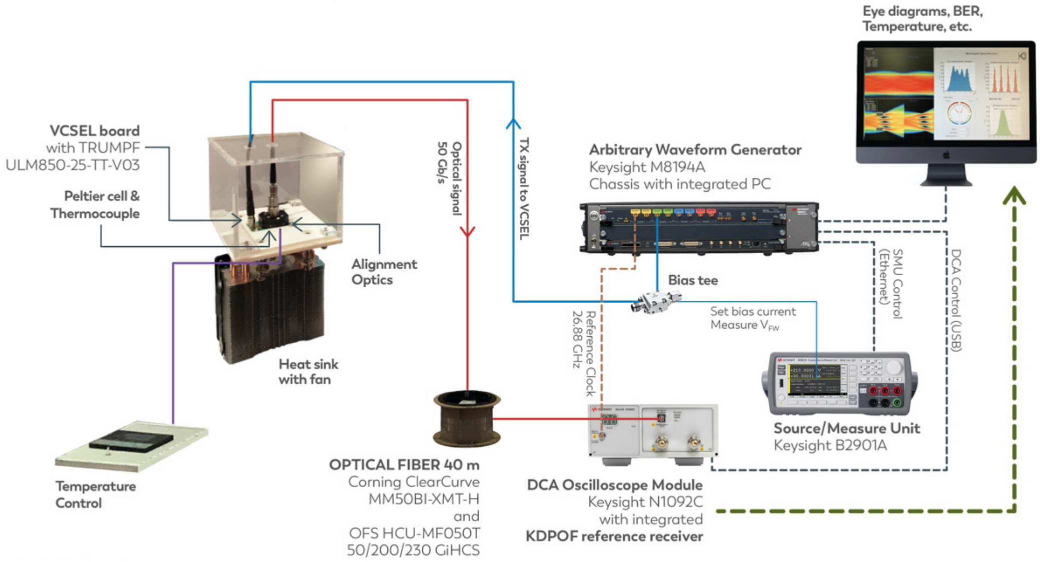


Image 3: Demonstrating 50 Gb/s automotive Ethernet with datacom component leveraging, copyright: KDPOF

Guaranteeing a reliability figure like this makes it necessary to operate the VCSEL in less stressful conditions. There is nothing to do about temperature, but the VCSEL suffers less with a lower current density. The problem is that the optical output power from the laser is proportional to the current, so reducing the current results in less optical power at the receiving end of the communication. On top of that, reducing the current density also results in decreasing the bandwidth of the VCSEL and increasing the Relative Intensity Noise (RIN). Therefore, we need to operate the VCSEL at the right balance of the lowest feasible current.

Outlook

The ecosystem for the proposed optical communications system already exists by leveraging well-proven technologies, such as VCSELs (Vertical-cavity surface-emitting laser), multimode fibers, and photodiodes already developed for the data centers industry. Standardization processes are ongoing with IEEE 802.3 Automotive Ethernet and ISO PWI 24581 in progress. The new optical automotive IVN communication standard IEEE 802.3cz is currently in the task force phase and is targeting data rates of 2.5, 5, 10, 25, and 50 Gb/s. The technology will be scalable in order to enable even higher data rates in the future. It is supported by several industry-leading companies. The robust and reliable system solution thus offers the future-proven path to high speeds.

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Fabless semiconductor supplier KDPOF provides innovative high-speed optical networking for harsh environments. Making gigabit communications over fiber optics a reality, KDPOF technology supplies 1 Gb/s POF links for automotive, industrial, and home networks. Founded in 2010 in Madrid, Spain, KDPOF offers their cost-effective technology as either ASSP or IP (Intellectual Property) to be integrated in SoCs (System-on-Chips). The adaptive and efficient system works with a wide range of optoelectronics and low-cost large core optical fibers, thus delivering carmakers low risk, low cost and short time-to-market.

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