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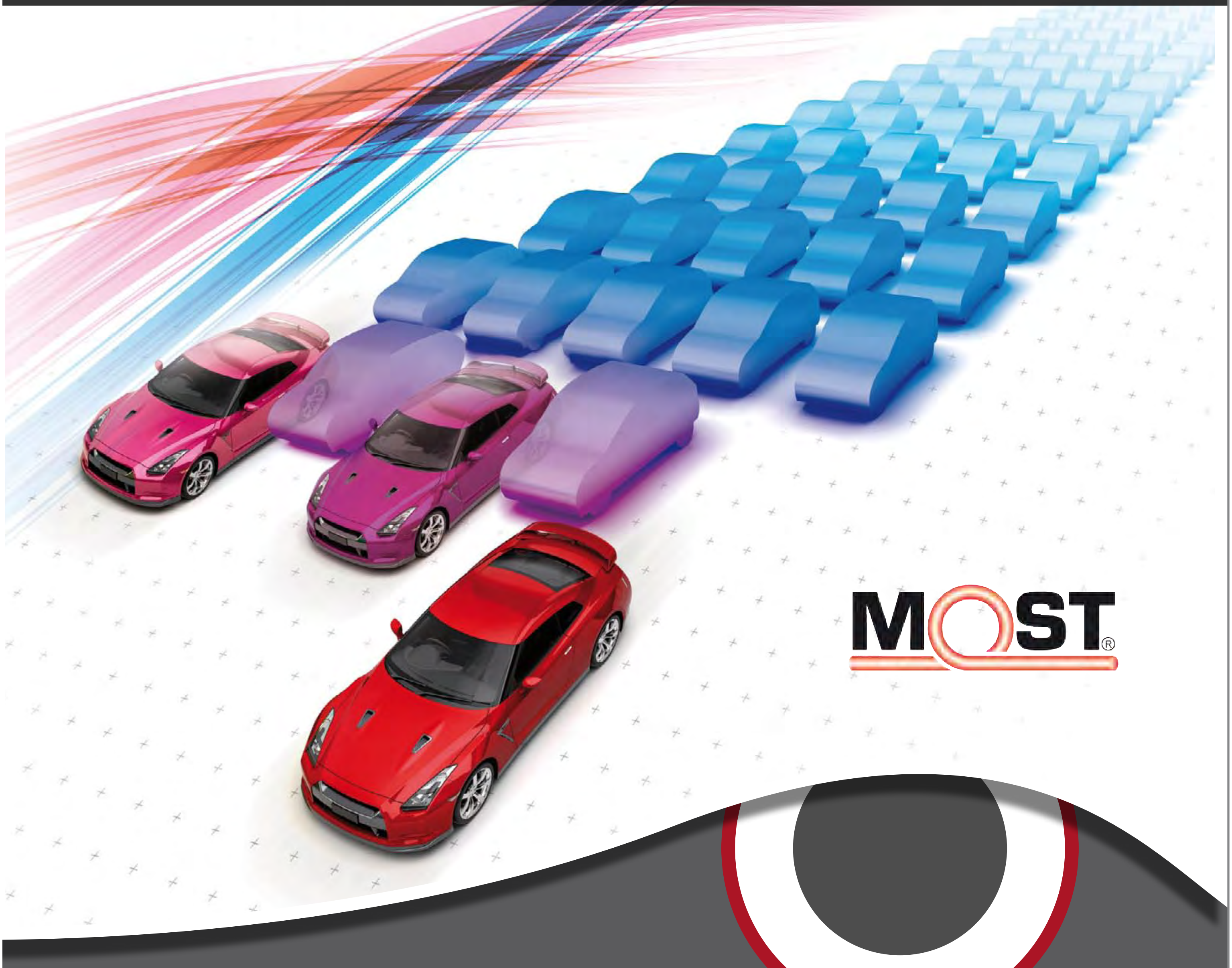

Special Issue MOST

Bus systems:

Pumping Up the Volume

The third generation of the networking standard has recently been introduced to the market with the MOST Specification V3 and MOST150. The rollout has started in the new Audi A3. The first Daimler car model to implement the standard will be the S Class. The technology will roll out successively through other car models. The latest MOST generation provides significant additions like seamless support of digital video transmission through isochronous channels and the MOST Ethernet channel used to transmit IP data independent of and in parallel to the audio and video transmissions.

Developing the latest version of the MOST specifications has been a multi-year undertaking, with contributions from many people and many companies. The degree of backward compatibility was a big topic. The MOST application framework and the MOST specification were fundamentally restructured. New optical and coax physical layers were specified and developed. The stream transmission specification was extended in order to define the handling of the new data channels. The function catalogue exchange format was reworked to cope with the new and changed data type definitions, and the function catalogue editor had to be developed further as well. The compliance testing specifications also had to be refined and adjusted to the new specifications. Implementation in the first car model was very seamless. I would like to use this opportunity to thank all contributors.

The MOST Cooperation has already started to investigate the requirements for the next generation specifications and network to support and combine future infotainment applications and driver assist functions.

What are the requirements for a next generation of the specifications?

- ➜ A complete overhaul and streamlining of the specifications.
- ➜ A flexible and upgradable network that forms a stable, robust backbone, so upcoming and partially yet unknown applications can be integrated seamlessly.
- ➜ The bandwidth will increase to several gigabits for applications like WLAN- or LTE-connected car2X.
- ➜ Common and future common data and stream formats have to be supported with transport mechanisms for new and additional formats.
- ➜ The network concept should be scalable and extendable with respect to speed as well as numbers and characteristics of the data channels.
- ➜ For each protocol and data channel, adequate interfaces should be available to allow glueless or lean interfacing.
- ➜ Whether star, daisy-chain or tree – different topologies and combinations should be able to assemble.
- ➜ For the physical layer, optical and electrical variants will be specified.

Thanks to its protocol multiplex architecture, the MOST architecture is well suited to provide a good answer to those requirements. The network and its specifications will be developed further in an evolutionary step into a next generation in order to make it ready for the future.

W. Bott

Dr. Wolfgang Bott
MOST Cooperation Technical Coordinator

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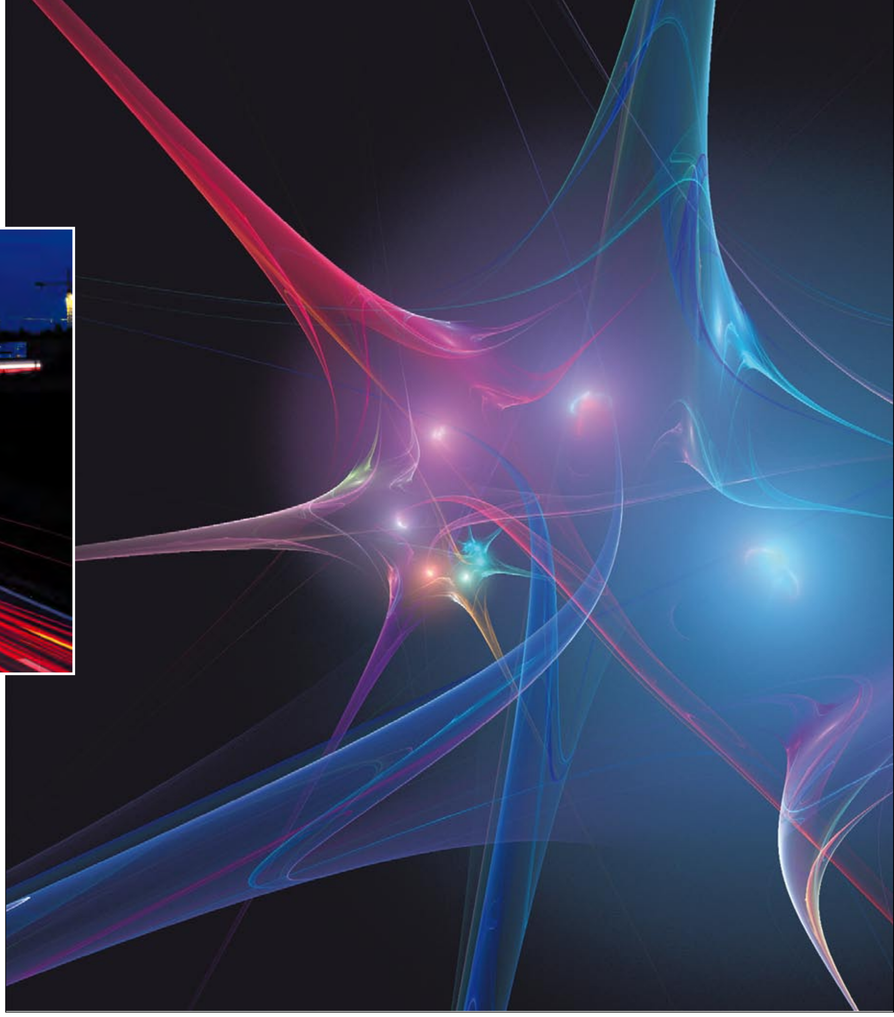

Virtual Prototypes – Evaluation Framework for MOST-based Driver Assistance Systems

An efficient communication network is the backbone of distributed Advanced Driver Assistance Systems (ADAS). Analysing such systems in different scenarios under different system parameters is a complex task. Evaluating essential system parameters in an early design phase for the optimum system behaviour is important. This article discusses an evaluation framework based on a virtual prototype for assessing MOST and its role in ADAS. >> 44

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Interview with Christian Thiel, SMSC:

"We Are Going Forward"

MOST150 has been on the road since mid-2012, marking a significant milestone. However, the technical development of MOST is moving forward. But, how does the future roadmap of MOST technology look like? Christian Thiel, Senior Vice President at SMSC and General Manager of SMSC's Automotive Information Systems product line answers questions not only about MOST in comparison to the "silver bullet" Ethernet and what is coming after MOST150 with MOSTnG but also regarding the influence of SMSC's acquisition by Microchip on MOST.

? In August of 2012, SMSC was acquired by Microchip Technology. What does that mean for MOST?

! Christian Thiel: SMSC's automotive product line is mainly focused on infotainment; quite contrary to Microchip. Its line is mostly active in other areas of the car. SMSC focuses on networking, and Microchip's key area is microcontroller, memory and analog solutions. Therefore, the acquisition is very synergistic with almost no overlap. SMSC's automotive division was just plugged into Microchip as an additional product line. The group is the same, the people are the same and not even the name changed: it continues to be called Automotive Information Systems (AIS). Consequently, MOST will also have continuity. We will continue pushing the roadmap for MOST as planned.

? SMSC committed to an opening of MOST with increasing market size. Nonetheless, some people continue criticising the lack of openness of MOST. Will the acquisition by Microchip change anything?

! Christian Thiel: Back in 2007 and after intensive discussions with different car makers, SMSC and Harman – the other major holder of MOST patents at that time, besides SMSC – committed in a press release to open each generation of MOST in two steps with growing market size. After 10 million nodes sold – a point when the technology has proven to be mature – SMSC would license its design IP of the MOST interface to other semiconductor companies under fair and non-discriminatory conditions. After 50 million nodes sold, SMSC would open the specification of the data link layer of the respective generation of MOST and license the patent IP. For MOST25, both opening steps have been taken. In the past, one company licensed the MOST design IP, but the product has never made it to market. For MOST50, the first step will be due soon. Back in 2007, when SMSC and Harman announced this opening policy, top electronics managers of Audi, BMW and Daimler embraced it in a joint press release. Of course, Microchip will honour SMSC's commitment. In addition, we are ready to re-visit the topic upon request and adjust the opening policy to new requirements. Microchip wants to drive long-term business relationships with the car industry. Microchip is well aware that the industry wants open standards and is willing to support this.

? Will Microchip continue to invest in MOST and a next generation?

! Christian Thiel: Microchip acquired the business in order to accelerate it. Investment in a next generation is mandatory for that. Therefore, we will drive the development as planned. Actually, we already have early prototypes of a next generation of MOST with multi-Gigabit transmission working. But, we continue working on MOST150 as well as to reduce costs and offer additional features.

? There are a lot of discussions in the industry about Ethernet and MOST. Some people say that MOST is dead. Does MOST have a chance against Ethernet?

! Christian Thiel: The car industry has a problem with its long design cycles and development cost compared to the consumer industry. Therefore, it is very understandable that it desires to use consumer standards as much as possible. Ethernet is just one example. However, the car industry also has a long track record of struggling to adopt consumer technology in the car 'as is'. The technologies need to cope with the different environment of the car, especially on the lower layers. Therefore, consumer technologies usually either fail to be adopted or need to be changed significantly and turn into yet another car-specific solution. That is exactly what is happening with Ethernet. The solution under discussion needs a non-standard physical layer transceiver that provides the necessary EMC performance. It is completely different from and incompatible with standard Ethernet physical layer transceivers. In addition, in order to provide quality of service (QoS) for audio and video streams, a protocol like Ethernet AVB needs to be used. Ethernet AVB requires AVB-compatible Ethernet hardware, which means that all sections of a network that are supposed to send or receive AVB streams, need to be updated to AVB compatible hardware. Standard Ethernet components cannot be used. When AVB Ethernet was defined as an IEEE standard, it has not commonly been used by the consumer industry so far. Even AVB as is cannot handle real-time control well and needs to be modified further. In essence, the solution under discussion is yet another car specific solution – just like MOST. But MOST has been designed for the use in the vehicle from the very beginning and, on top of that, it has been optimized for several generations and for more than ten years of series production. It is a mature solution that is ready to be used. Our customers are smart people. While they are investigating all options, they pick the best one. It is our job to continue to make MOST the best solution. The competition by Ethernet – or the car proprietary flavour of it – drives us forward to continue to make MOST the best option for our customers.

? What is the MOST answer to the desire of the car industry to adopt consumer technology quickly?

! Christian Thiel: We absolutely recognize and serve this need. The MOST philosophy is to combine it with the

need for a solution that is optimized for the specific environment of the car. MOST has been developed and optimized by car people for the car environment, from the ground up. The lower layers of MOST are optimized for in-car use. On the higher layers, MOST allows the adoption of consumer software stacks without change. The software stacks are where the real value of a seamless adoption lies, as they require high investment to be developed. Fast software stack adoption means fast time to market with consumer-like applications. What people really need is not Ethernet in the car – they want IP transmission. MOST150 introduces an Ethernet channel that looks and feels for the consumer software stacks like Ethernet. The MOST INIC behaves like an Ethernet controller. This way, the consumer software stacks that use IP for communication can be used on MOST just like on Ethernet without any modifications. The Ethernet channel of MOST is just another technology to transport Ethernet and IP packets – like 802.11 WiFi or other such technologies.
Another aspect to make adoption from the consumer industry seamless is that MOST is a protocol multiplex network. Of course IP transmission is very much in the focus of discussions right now, and MOST provides the Ethernet channel, but infotainment systems will need to support the transmission of other standard consumer protocols as well. MOST supports those by tunneling them natively. For the next generation of MOST, this strength will be enhanced further by adding support for even more protocols.

? How does MOST handle quality of service and real-time control?

! **Christian Thiel:** In infotainment and driver assistance systems, devices usually send and receive multiple audio and video streams in parallel and also exchange real-time control. Packet switched networks like Ethernet – or any automotive-specific variant thereof – transport everything in packets. In the transmitting device the packets need to be packed and addressed. On the receiving side, they need to be unpacked and the content sorted. This involves a lot of overhead and can cause delays. But that is not the worst. In between, all packets are sent sequentially over the network. Therefore, all transmissions are connected – if one packet gets transmitted, another cannot be transmitted simultaneously. One transmission influences all others – the whole transmission system becomes mushed together with cross-influences and timing conditions that are very hard to track and which change with the topology or the current operating condition of the system. In order to give quality of service to certain streams, special mechanisms can be provided, like AVB, which realize priority transmission and scheduling. This might partially address the issue, but the fact remains that all transmissions are dependent on each other and form a very complex timing problem. The partial

Dr. Christian Thiel, Senior Vice President at SMSC and General Manager of SMSC's Automotive Information Systems product line.

solution involves a lot of memory on the network ICs. Giving priority to one packet means storing all others. Memory costs money even in times of continuous miniaturization.
MOST, on the other hand, provides several data channels that are independent from each other. Each of them has its own time slot in the serial data stream. This way, the different transmissions happen in parallel – virtually at the same time. They neither collide nor interact. The various transmissions are completely independent from each other and their timings are not linked. On MOST, the problem of QoS and real-time has already been addressed by design on the lowest possible layer. MOST does not need extensive memory to address the issue, and this keeps the cost of the network controllers low. MOST has the Ethernet channel. Therefore, it is an automotive grade physical layer for Ethernet. If people want, they can use MOST150 as a 150 Mbit/s Ethernet network by using only the Ethernet channel. However, they then have the same issue as Ethernet: linked timings. The MOST solution for the problem is parallel data channels instead of memory. Therefore, MOST offers channels for quality of service audio and video streaming and for real-time control in parallel to the Ethernet channel.

? At home, we have a lot of packet switched networking, for example, Ethernet or WLAN and it works. Is a synchronous network like MOST outdated?

! **Christian Thiel:** The home evolved from office and data networking where packet mechanisms are sufficient. Audio and video streaming is just starting. Usually, not many transmissions happen in parallel. I haven't seen a home so far that offers an infotainment system that has the same level of features and integration as a high-end car today – not even close. In the car, we have a lot more signals that are transported across the network and we strive to have lean devices without much memory. Furthermore, in home applications streams usually come from the internet or from a server, where delays don't matter. In the car, we have requirements like simultaneous transmission to several displays or audio sinks when even small delays cannot be tolerated. Therefore, the car is an environment with much tougher conditions that need to be met. In packet switched networks, synchronization issues can be solved, but that usually involves spending money (for bandwidth and storage) and/or introducing delays. Having a synchronous network helps to keep system cost low and delays small. And, besides audio/video data from the infotainment system, there is an increasing need to transport data from driver assist units like cameras as well. For such applications, synchronicity and minimum latency are even more critical.
And as a matter of fact, the consumer industry is also facing issues. The telecom industry, particularly, is confronted with the need to stream more and more

audio and video content in real-time from the cloud to the users, with high quality of service. In the past, they migrated to a purely packet switched network infrastructure. Now, they are investigating ways to bring back TDMA-based mechanisms. In short: synchronous and channel switched networks like MOST are not outdated at all.

? Before we talk about the next generation, what can be expected of MOST150?

! **Christian Thiel:** The key targets of our development are ease of use and lowering cost. On the one side, we are adding USB as an application interface to our INIC. All MOST channel types are supported via USB. This way, a MOST interface can be hooked up seamlessly to a broad range of microcontrollers. Now small controllers have a fast lane to MOST's control channel. High end multimedia SoCs, as used in today's mobile devices, can additionally access streaming and IP based services. This follows the trend in modern controllers of having USB only to connect to wired networks, as their development and requirements are mainly driven by high volume mobile devices and their needs. Those controllers also don not have interfaces to Ethernet anymore.
On the other side we are integrating transceivers on the INIC that support transmission over coaxial cables. We see the need in the industry for electrical cables and low cost. From our own experience with unshielded cables, we are expecting major issues with driving higher data rates over unshielded cables in an automotive environment and with real world implementations. Coax cables, on the other hand, are the standard medium in the industry to transport high-speed signals. They are shielded but in a low cost way – the second wire is the shield. They can run very high data rates up to multiple Gigabit per second and are therefore future proof. They can even transport power in parallel to data. Coax cables can be assembled cheaply as they are rotation symmetric, which makes automated connector assembly possible. We expect that, compared to today's optical implementations, several dollars can be saved per MOST node by going to a coax physical layer. We also expect that on a system level, the cost is absolutely competitive to unshielded cable solutions. The MOST Cooperation has released a full specification for the coax physical layer. We are sampling the first INIC with a USB application interface and fully integrated coax transceiver now and are showing demonstration systems to customers.

? What do you expect for the next generation of MOST? What will it look like?

! **Christian Thiel:** Together with our customers and partners both inside and outside the MOST Cooperation we are currently refining the requirements for the next generation of MOST. Many things have already been on their way, although not everything has been fully settled. First of all, the next generation of MOST will be an evolution. As mentioned before, we are convinced of the strengths of MOST. We will continue to evolve and complement them. MOSTnG, as we call the next generation, will continue to be a synchronous network. We will emphasize the protocol multiplex nature of MOST by adding support for additional protocols and data channels. One focus area will certainly be the transmission of uncompressed video streams, which calls for very high bandwidth. But it doesn't make sense to run the gigabit super highway to each device. Therefore, MOSTnG will support various speed modes. Different parts of a MOSTnG network can run at different speeds, simultaneously, simplifying backward compatibility to existing generations of MOST. Nonetheless, the parts will be managed as one synchronized network. MOSTnG will support flexible topologies, including ring, star, daisy chain, tree and any mixture of them. Furthermore, MOSTnG will use optical and electrical physical layers. Overall, it will be very flexible. Another focus area will be application connectivity. Having parallelism of several data streams on the network is only half of the solution. The streams also need to be run in parallel and without influencing each other from and to the applications. This will happen over appropriate application interfaces that meet the nature of the application and of the data to be transported. MOSTnG will also support the separation of the data transport of different applications, for example infotainment and driver assist or on-board and off-board traffic over one physical network, which may be essential to prevent any occasional unwanted influence between the applications. This will become even more important in the future because of the clear industry trend of higher functional integration. In that sense we will continue to drive the key feature of MOST, that the INICs include data stream distribution via several specialized and general purpose application interfaces.
eck

Test tips for common serial buses:

Tektronix Announces Online Automotive Resource Centre

Tektronix announced its release of a new dedicated Automotive Resource Centre that provides online tips and guidance on common automotive measurement challenges. It consists of a content rich webpage enabling electronic designers to easily access information to debug and verify the latest embedded designs, so it will speed integration of embedded technologies. Users can view comprehensive tips and insight to ensure their automotive testing is streamlined.

"We offer a vast variety of technical documentation, videos & webinars as well as software downloads for the automotive market with this newly introduced Automotive Resource Centre webpage," said Johann Winterholler, Sales Director for Germany/Austria/Switzerland. "We are focused on providing our customers with best in class measurement solutions and automated tools to help overcome the toughest signal integrity challenges."
eck

New Car Models with MOST Technology


Aston Martin Vanquish


Aston Martin DB9


Aston Martin V12 Zagato


Cadillac SRX


MB G-Class


MB E-Class


Porsche Cayman


Audi A3 Sportback


MB CLA-Class


Lexus LS


Range Rover

(Source: TE Connectivity)

Glass Fiber Connectivity for Automotive Networks

In 2001, the very first car implemented MOST. Since the introduction, more than a hundred vehicle models by several car manufacturers have used this technology for automotive network applications. At these times, the physical layer was started based on plastic optical fiber (POF) with a data rate of 25 Mbit/s. Now, the MOST Cooperation is requesting a physical layer with a data rate capacity of 3 to 5 Gbit/s for the next generation.

By Andreas Engel and Markus Dittmann

At the very first beginning, the physical layer was started with a data rate of 25 Mbit/s. It was enhanced to 50 Mbit/s over unshielded twisted pair (UTP) and later to 150 Mbit/s over coax and POF cables. But, that is not enough. Following the needs of several future use cases in the area of automotive infotainment and driver assistance systems, the MOST Cooperation is requesting a physical layer with a data rate capacity of 3 to 5 Gbit/s for the next generation. At these requested data rates, all glass fiber (AGF) based optical transmission has become attractive, because of its well-known and successful history in the data communication world. Even for consumer IT applications like USB 3.0, optical solutions become apparent. So, the optoelectronic technology has been already in existence and there will be an attractive solution for the upcoming bandwidth need on the horizon – with some adaptations to the automotive requirements on the packaging, cable and connector.

At the beginning of the 1990s, TE Connectivity (TE) started under the brand AMP to investigate the performance of plastic optical fibers and connectors in regards to automotive requirements. In particular, the harsh and severe environment conditions in the vehicle were tested and examined. Besides the temperature, humidity, vibration and mechanical stress, the impact of severe contamination with oil, sealing gel, dust and several chemical substances were also investigated. From the very first beginning, a major challenge was to adopt the optical technology, which was originally developed for telecommunication applications, to the requirements of the automotive industry. The first milestone for the optical physical layer was achieved with the successful implementation of the D2B infotainment network at Daimler AG in 1998. With the launch of the optical MOST networks in 2001, more and more cost efficient, fully automatic processes for pigtail assembly and for fiber termination have been established. The knowledge and experience gathered was a good base to examine future needs for the optical physical layer for automotive applications based on glass optical fiber.

High data rates are possible

Regarding future applications in the car's infotainment and driver assist systems, data rates are expected to come into the range of 3 up to 5 Gbit/s. One bandwidth-consuming application is high resolution, low latency video as needed for real time object recognition. Stringent reliability requirements have to be guaranteed over the car's expected average lifetime of more than 15 years. During that time, the operating environment is anything but pleasant: Vibration, temperatures ranging from −40 up to 105°C while humidity changes from desert dry to foggy. But overall costs for such a robust, reliable high speed data link have to be reasonably low to be acceptable. Besides that, there are additional demanding requirements on the agenda such as light weight and compatibility with cable harness processes and structures.

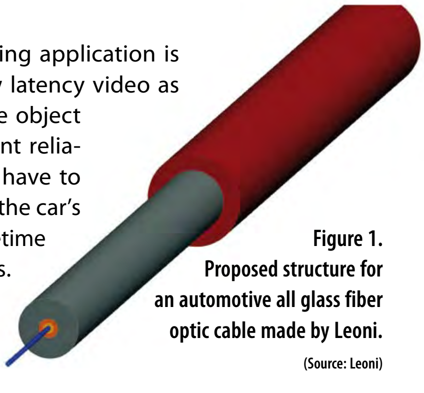

Figure 1. Proposed structure for an automotive all glass fiber optic cable made by Leoni. (Source: Leoni)

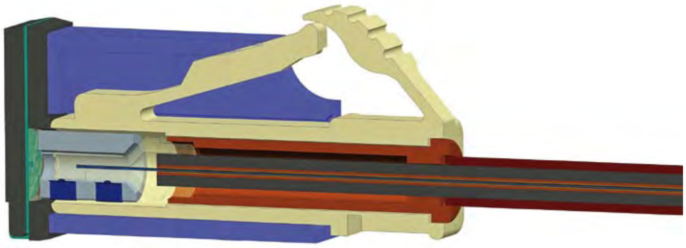

Figure 2. Device connector and plug design with expanded beam coupling and decoupling of the optical axis alignment from harness and connector induced forces. (Source: TE Connectivity)

An optical cable is inherently immune to electro-magnetic interference. Because of this, it is attractive for use in densely packaged, high noise environments like the harness of a car. In comparison to copper based solutions there is no need to shield the cable. So, thinner, lighter and more flexible cables than copper cables are possible for the same application.

The technology used in optical data communication applications is based on 850 nm vertical cavity surface emitting lasers (VCSEL) launched into all glass fibers (AGF) with a graded (refractive) index profile avoiding modal dispersion, as it would ruin the bandwidth in step index fibers like the POF or PCS. This combination allows for data rates >5 Gbit/s over 15 m link length, as currently requested for future cars. These fibers have been used in the data communication industry not only for their high bandwidth on long link length but also for their low power demand and small diameter cable, allowing for better air flow and cooling in the server racks. Server cooling might not be a relevant argument for automotive applications, but light weight, small diameter and bend radius performance will be.

Within TE Connectivity there is profound experience with AGF, VCSEL based transceiver technology to build fiber optic transceivers (FOTs) and connector systems. This provides an ideal portfolio for the development and specification of a reliable future glass fiber based physical layer with adaptations to meet automotive requirements.

Glass fiber and cable concept for automotive application

When calculating the required analogue bandwidth needed for a physical channel using digital on-off-keying data transmission, the rule of thumb

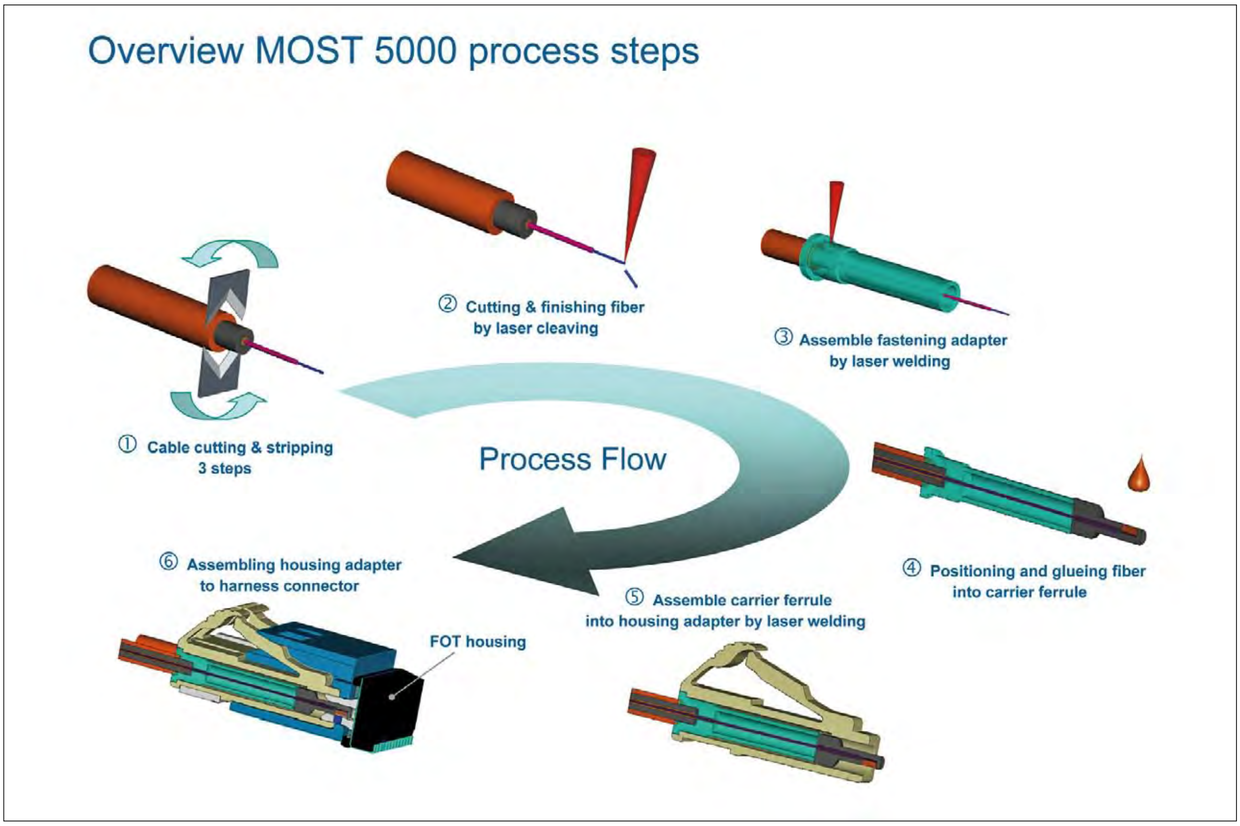

Figure 3. Process flow for stripping, cleaving and terminating the fiber optic cable. (Source: TE Connectivity)

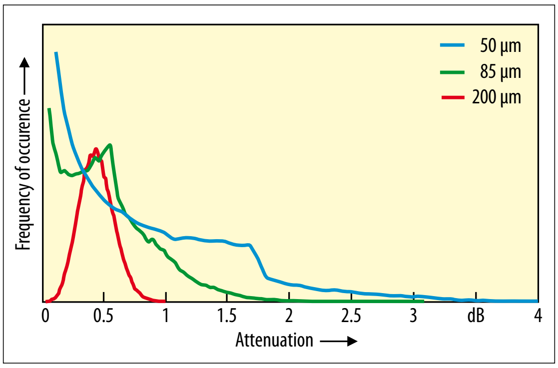

Figure 4. Simulated effect of randomly distributed dust particles on the optical transmission surface of 50 and 85 µm fiber cores and 200 µm expanded beam lens surface.

gives a factor of 0.7 bit/s/Hz. Calculating a bandwidth of 5 Gbit/s, this fact results in a basic corner frequency of 3.5 GHz for the physical channels low pass filter property. Thus, for a link length of 15 m, the fiber must have a bandwidth-length product of at least 52 MHz·km. Giving some more bandwidth and length, the calculation for a 40 m link at 10 Gbit/s would give a result of 280 MHz·km for the minimum bandwidth length product. Standard available modern high bandwidth performance optical fibers have core diameters of 50 µm and 125 µm cladding. These dimensions require axial alignment tolerances in the range of <5 µm. On the other hand, the fibers are available with bandwidth length products of up to 4,700 MHz·km! In order to ease the necessary alignment precision while maintaining a given coupling efficiency, larger core diameters would be beneficial in order to stay within the tight cost frame the automotive market allows for. But, as a drawback, larger core diameter will reduce the achievable bandwidth capability of the optical fiber.

The minimal bending radius allowed for an all glass fiber (AGF) is directly linked to the lifetime probability. The thicker the fiber diameter, the lower the acceptable minimum bend radius to achieve a specified lifetime for the fiber. With that in mind, TE proposes developing a gradient index type of fiber with a core diameter of 85 µm while maintaining the data communication standard glass cladding diameter of 125 µm. These fibers come with a numerical aperture of 0.275. The bandwidth length product for those fibers at 850 nm is >500 MHz·km. For sufficient lifetime reliability, the bend radius for these 125 µm cladding diameter fibers can go down to 7.5 mm in the long term. In order to withstand the mechanical and chemical requirements in an automotive environment, a proper cable design is needed. One of the main challenges is the pull-strength, as the requirement of 60 N is too high for a 125 µm glass fiber. The forces have to be handled within the cable construction to prevent overload on the fiber. On the other hand, the termination should keep cost efficient.

The proposed cable design incorporates several functional layers, as you can see in **Figure 1**. The pure silica optical fiber has an outer cladding diameter of 125 µm. The inner core has a laser launch optimized graded index profile of 85 µm diameter. As a first protecting layer, an acrylate coating is applied. In order to cushion the sensitive fiber, an inner buffer layer of a softer acrylate is wrapped around it. To give the cable high pull-force durability, an additional buffer layer with embedded strength member is necessary. This buffer layer is designed to be laser weldable in order to ease process automation at the fiber/cable termination. An outer protection layer completes the layer stack of the cable design proposal for color coding and marking.

	Expanded beam	Butt coupling (physical contact)
Pro "+"	- Axial tolerance relaxed - Spring loaded not mandatory - Beam diameter enhanced - Dust contamination influence low - Vibration robustness higher - Protection of fiber surface - Automotive processes applicable - LASER-cleaving and welding possible	- Physical contact – low Fresnel loss - No additional light absorption - Simpler ferrule design - Limited number of tolerances
Con "–"	- Fiber to lens position sensitive - Fresnel loss between lens/air - Absorption of light in lens material	- Critical tolerance field axial and radial - Spring loading is standard - Fiber end face preparation critical - Gluing and polishing as standard process - Dust contamination influence high - Vibration robustness open (friction) - No protection of fiber surface

Table 1. Comparison of coupling concepts for optical connectors.

Connector proposal

To be robust enough for automotive environmental conditions, the glass fiber(s) end faces are not in contact with each other within an inline connector. The fiber end is terminated with a plastic molded ferrule including a lens feature to achieve sufficient insertion loss performance while not coming into physical contact. This lens allows for an expanded and collimated (almost parallel) beam characteristic at the coupling interfaces (**Figure 2**). The lenses in this concept are designed and calculated for a collimated beam diameter of approximately 250 µm. With this collimated beam diameter the attenuation risk due to dust particles on the optical interface surfaces is reduced significantly in comparison to a 50/62.5 µm fiber core diameter using butt coupling in the connector. In order to achieve low coupling loss of optical power within a connector, tight control on the alignment of all optical elements within the interface is a key factor.

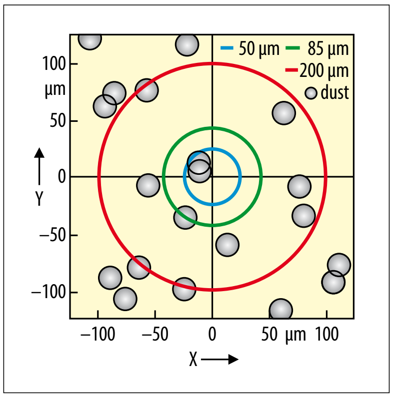

Figure 5. Distribution on the optical transmission surface of 50 and 85 µm fiber cores and 200 µm beam lens: With the 200 µm expanded beam version the dust impact risk can be minimized.

The fiber and cable termination process proposal

The fiber and cable termination process consists of the six process steps outlined in **Figure 3**. Since we can utilize laser welding and laser cleaving processes, experience shows constant and reliable performance will be obtained.

One of the most critical steps will be the positioning and gluing of the fiber in the ferrule.

Concept discussion: Expanded beam versus physical contact

In order to estimate (**Table 1**) the dust attenuation risk, randomly distributed particles of 20 µm diameter are assumed. Simulation of attenuation due to dust particles shows that the number of losses above 1 dB drops to zero for a beam diameter of 200 µm. Whereas for 50 µm or 85 µm beam diameter, losses higher than 2 dB and up to 4 dB occur within the same random dust distribution (**Figure 4**). This shows clearly the reduced probability of dust-induced exceptional attenuation (**Figure 5**).

The attenuation resulting from the simulation shows very clearly that with the 200 µm expanded beam version the dust impact risk can significantly be minimized. With the standard 50 µm fiber much higher worst case impact to the link budget has to expected.

Recommendations

Using a collimated beam coupling for the next generation of the MOST networks is highly recommended. It provides a better performance regarding mechanical and optical stability in the automotive environment.

In combination with proven automotive processes like laser welding and laser cleaving for fiber and cable termination, it would offer a real "automotive solution". *eck*

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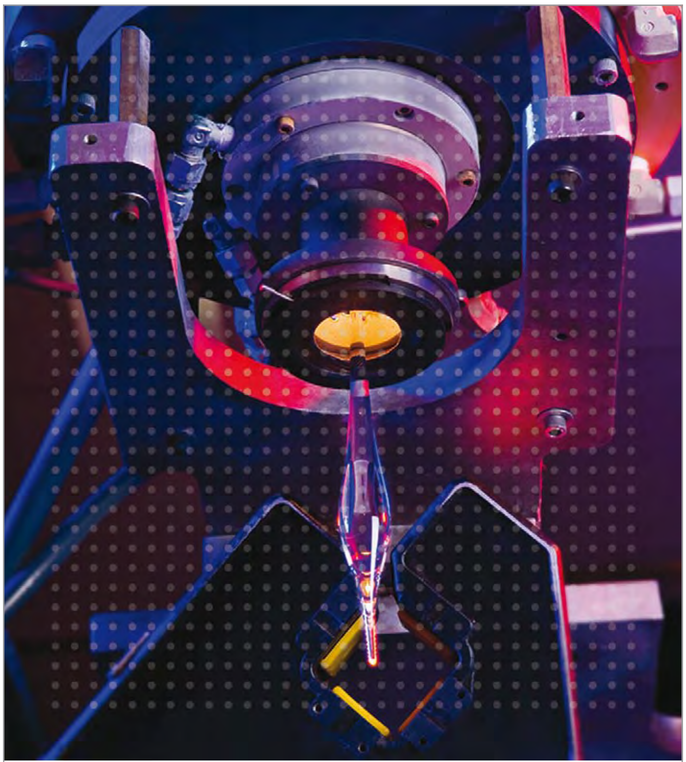


(Source: Gina Sanders, Fotolia)

R&D Approach to 5 Gbit/s Communications Technology for Next Generation MOST Systems

MOST next Generation (MOSTnG) systems require a fast data transmission. In order to achieve a data rate of 5 Gbit/s the physical layer plays a decisive role. The Japanese company Sumitomo expects that in-vehicle all glass fiber (AGF) is suitable for the physical layer in MOSTnG systems and discusses its adequacy in the following article.

By Hayato Yuki, Takashi Fukuoka, Yuji Nakura and Hidetoshi Ishida

Expecting that in-vehicle AGF technology would be suitable for the physical layer in MOSTnG systems, Sumitomo produced prototypes of 1.25 Gbit/s optical and physical layers and operated them to demonstrate their suitability. It was beyond the expectations that 5 Gbit/s communication capabilities would be required for the MOSTnG system. AGF technology will hopefully meet the requirements for the MOST system because an optical harness consisting of AGF cables and connectors has a communication capability of 10 Gbit/s or more. Fiber optical transceivers (FOTs) have to be redesigned for 5 Gbit/s communications. To design 5 Gbit/s FOTs, changing the operating conditions of elements is necessary as well as selecting appropriate vertical cavity surface emitting lasers (VCSELs) and photo diodes (PDs). Because of this, the driver ICs and receiver amplifier that are built into the FOT have to be altered. While redesigning the FOTs, a review of the AGF harness specifications was started. The development approach includes two objectives:

- ➜ Establishing 5 Gbit/s communications based on a system using butt coupling that was proposed last year.
- ➜ Verifying the expanded beam optics (EBO) concept that was determined by the MOST Cooperation.

Sumitomo will apply the AGF technology to an in-vehicle network for the very first time, hoping that it will be one of the achievements of MOST.

Approach to faster communication systems

Significant specification changes are definitely needed for in-vehicle installation, even if the AGF technologies of 10 or 100 Gbit/s public circuit have good performance in their field. The critical attributes in the operating environment are temperature, humidity, vibration, dust, voltage, and noise. The criteria are more demanding than those in base stations of public circuits. To maintain quality communication in vehicles, the total insertion loss under any circumstances has to be kept within a "system power budget". The light source for 5 Gbit/s communications is a laser, not a traditional LED. The safety rules for using laser equipment are defined in IEC 60825-1 and classified according to optical output specifications. The equipment that contains laser optics devices must conform to the "Eye Safety" requirements specified by IEC. The size of PD affects communication speeds and receiving sensitivity. A larger PD has better receiving sensitivity, but it does not support a higher speed of communication. Therefore, the chipsize of PDs will be determined according to the communication system specification. Sumitomo estimated the system power budget of 6.2 dB from TP2 to TP3 by determining the communication speed of 5 Gbit/s for MOSTnG. Then optical performance was assigned that included environmental changes to each component in the communication system.

Figure 1 shows the communication system model on which the trial calculation is based, and the level diagram of the system. A system margin, which is obtained by subtracting insertion loss of the components from the system power budget, is 2.45 dB. The communication system components used for the verification were 50/125 µm-diameter AGF cables and butt-coupling inline connectors that were selected, considering technologies reported in the MOST Forum 2012. The prototype AGF communication system was applied to attempt 5 Gbit/s communications using the standard signals specified by the MOST Cooperation. In this examination, the optical output of the FOT resulted in –5.0 dBm (OMA) at TP2. Optical power at TP3 was –6.5 dBm (OMA) after passing through a 15 m AGF cable and inline connectors at three locations. The “eye open” condition observed at TP4 indicates that 5 Gbit/s communications was established (see **Figure 2**).

The experiment results have demonstrated that jitter at TP4 does not change significantly when two or more optical inline connectors configured with the butt-coupling method are inserted in the transmission line. So, a stable communication is guaranteed. Butt-coupling technology has had a long evolution in public communication and has provided superior performance stability. As mentioned before, the development of 5 Gbit/s in-vehicle FOTs must start with designing VCSELs and PDs. A key point of the development of the FOTs, which are operated in a temperature range of –40 to +105°C: ensuring multiple operating conditions of VCSELs. The operation of a VCSEL, where the changes in ambient temperature significantly affect optical output, depends on the driver IC design. The driver IC design is important while designing in-vehicle FOTs, because a stable optical output is required under a wide temperature range. Needless to say, “eye-safety levels” as specified by IEC must be maintained even in failure mode. The wanted FOT is an optical component that can maintain communication if it is installed in vehicles. The FOT should be able to produce optical output in a stable manner that meets the safety levels. To achieve this goal, both efficient optical coupling technology and stable operation technology have to be implemented. Additionally, a key point to designing an optical communication system is to prove the robustness of the system in response to the acceptance criteria of carmakers. Most Japanese carmakers emphasize the feasibility of a system at its utmost worst-case scenario, in which the total sum is the accumulation of each worst case – this is beyond the framework of probability theory. If the MOSTnG systems undertake automated driving tasks in the future, you will have to consider the worst cases of performance changes in individual components. This means that the system should be designed based on the worst performance of each component.

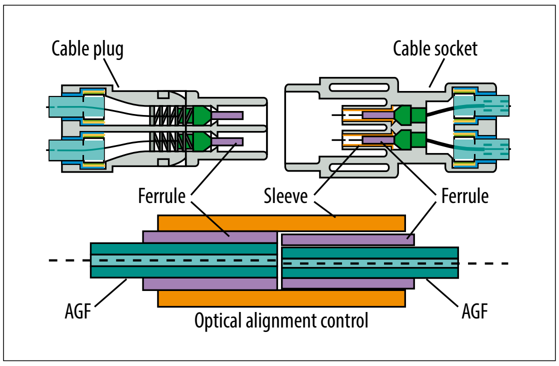


Figure 3. The dimensional accuracy for the connector housing should only be the same as that for traditional in-vehicle connectors.

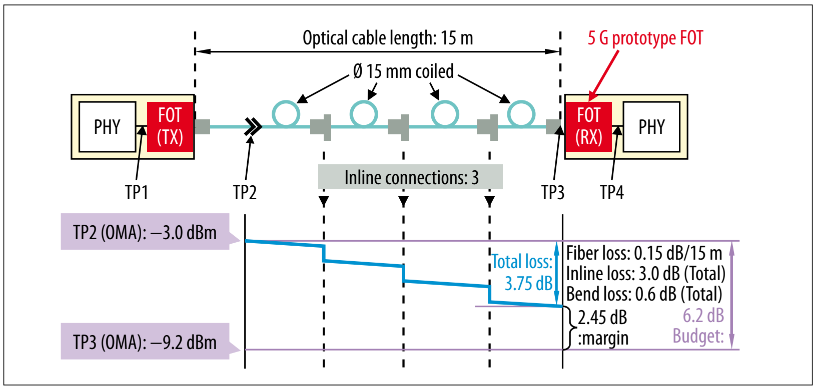


Figure 1. Communication system model on which the trial calculation is based, and the system's level diagram.

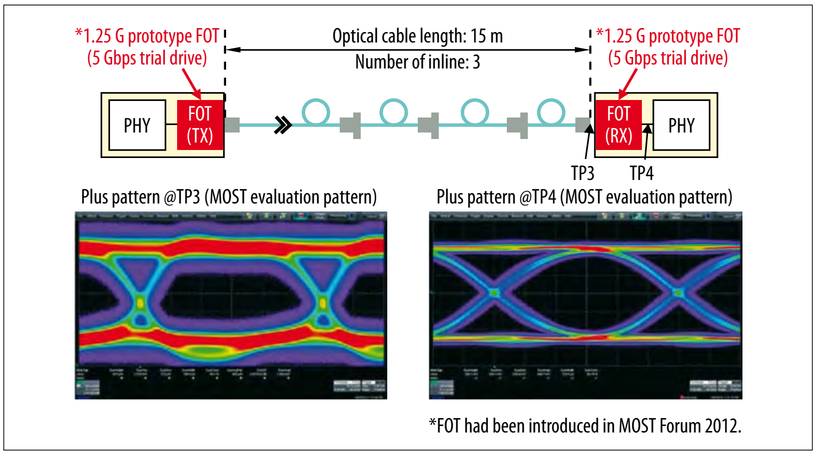
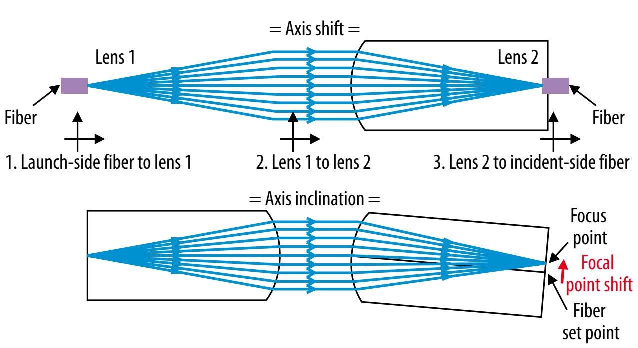


Figure 2. The “eye open” condition observed at TP4 indicates that 5 Gbit/s communications was established.

The butt coupling concept: compliance with in-vehicle installation requirements

The butt coupling technology proposed by Sumitomo uses 50/125 µm-diameter AGF cables as transmission media. This can result in difficulties with the dimensional accuracy of components and dust prevention steps. However, the AGF cable is the only optical fiber that can support communication speeds of 5 Gbit/s or faster. The next logical step is to consider how to treat the AGF cables when they are installed in vehicles. Regarding optical coupling technologies, there are different arguments about the EBO concept discussed below. However, it is important to understand the environmental tolerance



Check item		Range	Probability
1. Launch-side fiber	Axis shift	±10 µm	
↓	Axis inclination	±0.5 deg	
Lens 1 (Ø 1.4 mm)	Gap	±20 µm	
2. Lens 1 (Ø 1.4 mm)	Axis shift	±50 µm	
↓	Axis inclination	±0.5 deg	3σ
Lens 2 (Ø 1.4 mm)	Gap	±50 µm	
3. Lens 2 (Ø 1.4 mm)	Axis shift	±10 µm	
↓	Axis inclination	±0.5 deg	
Incident-side fiber	Gap	±20 µm	

Figure 4. Sumitomo combined these optical beam diameters and AGF cables to carry out four simulations in total.

of butt coupling, which has a simple structure and many results. Sumitomo used butt coupling AGF optical cables/optical connectors and 1.25 Gbit/s FOTs to carry out environmental tolerance testing specified by MOST. The European specifications were reevaluated as they slightly differ from the requirements in the IDB1394 (AMI-C 4001) standards that the company had already evaluated. You can see the results in the **Table**.

There were no problems in any environmental testing, including physical strength and resistance to temperature, humidity, corrosive gases, vibration, shock, or noise. For specifications, which are required for connector housings and PCB fastening, lock strength, Kojiri measures, fiber-end protection were evaluated. All European MOST specifications were met. However, there was a recurring observation: It is difficult to ensure dimensional accuracy at the component design stage as the 50 µm fiber core is very thin. Therefore, the dimensional relationship between the two ferrules and the sleeve in the inline connector were reexamined in terms of tolerance. In this case, slit sleeves are helpful. The ferrules are held by the elastic force of the sleeve when they are inserted. There is almost no gap between the ferrules and sleeve. This behaviour prevents the two ferrules facing each other from being tilted in the sleeve and helps stabilise optical coupling efficiency. This technology has been popular in public communication and enables anyone to procure components easily. There are only two prerequisites for connector housings:

- Meeting requirements for in-vehicle connectors.
- Having a structure that accepts ferrules and a sleeve.

The ferrules and sleeve help with the efficient optical coupling between AGFs. This means that the dimensional accuracy of the connector housing should be the same as of the traditional in-vehicle connectors (see **Figure 3**).

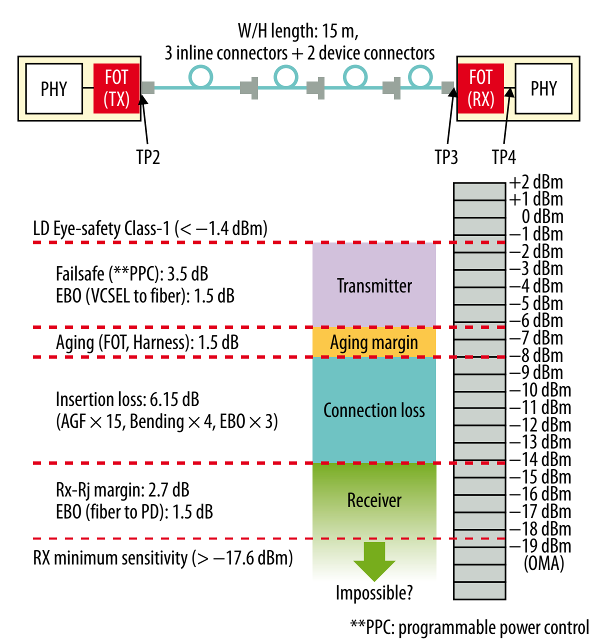


Figure 5. When transmission and bending loss in optical cables, aging deterioration or environmental changes in components, and system margin are counted, the load on the FOT will be increased.

EBO concept: verification of validity

At the MOST Interconnectivity Conference Asia 2012, the MOST Working Group Optical Physical Layer announced the prioritised development of the EBO concept. The purposes of the EBO concept are to make optical inline components as easy to handle as POF and to suppress a sharp increase in coupling loss due to dust adhesion. Sumitomo effectively used simulation technologies to verify the effects of EBO under several conditions. 1,000 µm and 500 µm were selected as optical beam diameters at optical couplings as well as two different AGF cables: 50 µm core/NA=0.24 and 80 µm core/NA=0.29. These optical beam diameters and AGF cables were combined to carry out four simulations in total (see **Figure 4**).

Using dimensional tolerances of EBO components, the simulations centered on the distance between the EBO coupling faces that face each other, and the shift and tilt of optical axes. **Figure 6** summarises the results of the calculated insertion loss of inline connectors that used the EBO concept. Sumitomo used the Monte Carlo methods to calculate the frequency distribution of the insertion loss shown.

The simulation results indicate that the distance between the optical coupling faces does not greatly affect the insertion loss, but the tilt of optic axes significantly contributes to the distribution of the loss values. The maximum coupling loss amounted to 1.8 dB even in the best scenario found in condition 2. This value may be a serious problem when the communication system is designed to take into account the accumulation of the worst performances of individual components. The basic configuration of the MOST system requires a 15 m communication distance and five optical couplings that include three optical inline connections in an optical harness. The total loss of two optical couplings in the equipment and three optical couplings in the optical harness is 9 dB. When transmission,

	GS95 006 – 6 – 3	Criteria	Result	Samples
4.3.1	Thermal pistoning	pistoning?	no pistoning	5
4.4.1	Slant plug angle/Kushiri security	damage?	na damage	design matter
4.5.1	Temperature resistance	loss increase < 1.0 dB	max. 0.09 dB	5
4.5.2	Temperature change	loss increase < 1.0 dB	max. 0.42 dB	5
4.5.3	Temperature stages	loss increase < 1.0 dB	max. 0.42 dB	5
4.5.4	Humidity heat cyclic	loss increase < 1.0 dB	max. 0.11 dB	5
4.5.5	Temperature shock	loss increase < 1.0 dB	max. 0.25 dB	5
4.6.1	Torsion of contacts	loss increase < 1.0 dB	no loss increase	3
4.6.2	Mechanical Shock	loss increase < 1.0 dB	max. 0.01 dB	3
4.6.3	Vibration with temperature overlap	loss increase < 1.0 dB	max. 0.03 dB	3
4.6.4	Impact test	loss increase < 1.0 dB	no loss increase	3
4.6.5	Dust protection	loss increase < 1.0 dB	max. 0.15 dB	3
4.6.8	Plugging frequency	loss increase < 1.0 dB	max. 0.38 dB	5
4.6.9	Plug force and pull force	< 40 N	max. 20.6 N	5
4.6.11	Pull-off force of the housing parts	> 100 N	min. 131.7 N	5
4.6.12	Continuous pull/tension at the fiber	loss increase < 1.0 dB	max. 0.05 dB	2
4.7.1	Resistance against chemical material	loss increase < 1.0 dB	max. 0.06 dB	2
4.7.2	Resistance against noxious gas	loss increase < 1.0 dB	no loss increase	4

Table. Reevaluation of the European specifications as they were slightly different from the requirements in the IDB1394 (AMI-C 4001) standards that Sumitomo had already evaluated.

the bending loss in optical cables, aging deterioration or environmental changes in components and system margin are counted, the load on the FOT will be increased (see **Figure 5**).

To realize the EBO concept, it could be necessary to change the initial conditions in the basic system. The components will be optimised by in-depth simulations when the optical beam diameter optimum for EBO is determined.

The proposed butt coupling system was reevaluated last year, and Sumitomo is certain that this system meets the requirements for in-vehicle installation. The butt coupling technology should be considered as one of the candidates capable of achieving 5 Gbit/s optical communications in vehicles, although there still are some challenges in terms of dust solution.

The handling of the fiber edge etc. is recommended because the AGF core is thin. Countermeasures, auxiliary tools, and operation manuals need to be developed. Sumitomo is convinced that butt coupling is one of the best technologies to support EBO. Therefore, the company will continue the research and development of this technology. The EBO concept the MOST Cooperation decided on is excellent in terms of dust prevention. In order to put the EBO concept into practical use, simulations were carried out and system feasibility was examined. There are few technical problems except some limitations. The various problems with manufacturing methods and prices of EBO technology will be solved successively. *eck*

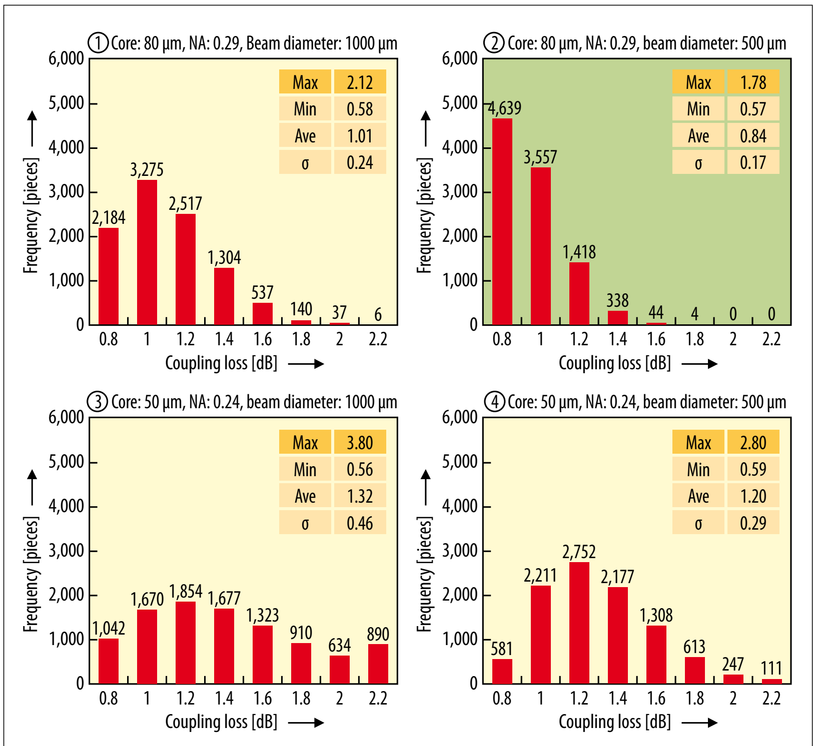


Figure 6. The Monte Carlo method was used to calculate the frequency distribution of the insertion loss.

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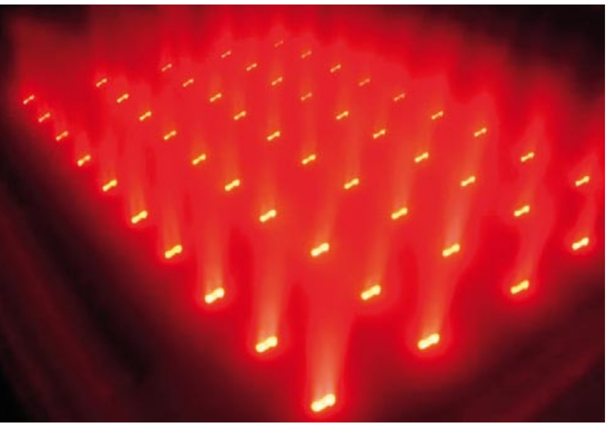


Reliability Assessment of VCSEL Devices for 5 Gbit/s Data Transmission in Automotive Environments

Optical data transmission with data rates of up to 150 Mbit/s in automotive environments is realized today by using LED/RCLED transmitter devices. This article discusses a reliability assessment process for VCSEL semiconductor devices by means of established reliability methods to demonstrate the robustness under the demanding requirements. The assessment is based on the semiconductor device itself without regards to the packaging.

By Jörg Angstenberger and Dr. Viktor Tiederle

Due to the fact that LED/PMMA-based transmission layers have a limited bandwidth of about 100 up to 200 Mbit/s, there is a demand to change some key devices in the optical physical layer to achieve higher data rates. In terms of the transmitter, vertically emitting laser diodes (VCSEL, vertical cavity surface emitting diodes) could be the choice to provide bandwidth in the range of several Gbit/s for future optical automotive networks. VCSEL devices are well established. They are reliable in short-link datacom applications such as Gigabit Ethernet. However, there is no reliable data about the robustness of VCSEL devices in automotive environments.

Description of automotive environmental requirements

First, the environmental requirements and reliability goals of semiconductor devices in automotive applications have to be defined. By knowing the thermal distribution of the compartment area in the car, a temperature model can be developed and the thermal requirements of the VCSEL in the application can be derived. The mission profile is principally defined by the required life time of the device in a specific compartment area of the vehicle. In terms of motor vehicles made by important German manufacturers, this information can be found in the LV124 specification [1] published by Audi, BMW, Daimler, Porsche and Volkswagen. **Figure 1** shows the failure rate of an electronic semiconductor device dependent on life time and the relationship to a defined car mission profile [2].

To assure that the electronic device is able to fulfill the mission profile of the car, the failure rate of the device has to be below the maximum accepted failure rate over the defined car life time. The required car life time is specified with 8,000 h according to LV124. With this consequence, the potentially high failure rates in the early life of the device have to be reduced by a production measure such as burn-in. In addition, the beginning of the wear-out phase has to be far beyond the end of the defined car life time. There is no general definition of a maximum accepted failure rate during the life of a car in the automotive area. Nevertheless, for a less complex automotive semiconductor device, random failure rates of ≤10 FIT are assumed and accepted. Therefore, to demonstrate that a VCSEL device is able to meet the reliability of a standard automotive semiconductor, a test setup is sought that proves this magnitude over the defined car life time with a confidence level of generally 90 percent.

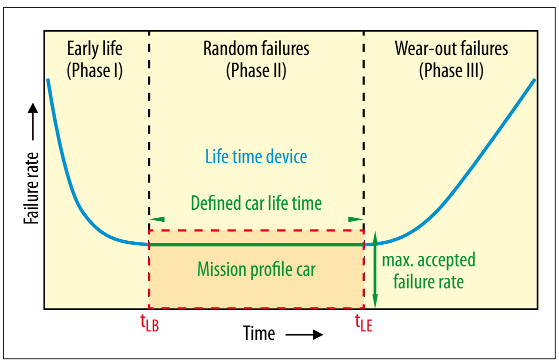


Figure 1. Mission profile of a car and life time chart of an electronic device.

Required temperature conditions

According to LV124 there are certain temperature profiles corresponding to different compartment areas in the car. In the case of MOST applications, only temperature profiles 1 and 2 are relevant. Considering the worst-case application condition, the further study will be focused only on temperature profile 2 (**Table**).

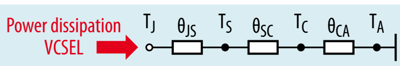
Figure 2 shows the thermal model of a VCSEL device packaged and mounted within an electronic control unit (ECU) in the compartment area. The relevant temperature for the reliability assessment is the same as the junction temperature of the VCSEL device. The junction temperature depends on the ambient temperature – out of the related temperature profile of the compartment area – and the thermal resistance between the ambient temperature and the junction temperature. The resulting thermal resistor is defined by the thermal model of the VCSEL itself; the thermal resistance of the packaging and the temperature increase between the surface of the VCSEL packaging and the ambient temperature of the compartment area.

Temperature Profile 1 in °C	Temperature Profile 2 in °C	Percentage	Operating hours
−40	−40	6	480
23	23	20	1,600
40	50	65	5,200
75	100	8	640
80	105	1	80
Operating hours complete:			8,000 h

Table. Temperature profiles according to LV124.

Derived operating conditions

Because the reliability assessment is performed on the bare VCSEL semiconductor, and the thermal resistance between the substrate of the VCSEL and the ambient temperature has not been known yet, a worst case temperature increase of 5 K between ambient and the substrate of the VCSEL was assumed for temperature profile 2. This results in a substrate temperature profile at the VCSEL with a maximum temperature of 110°C. For this reason, the junction temperature of the VCSEL is dependent on the maximum substrate temperature and the power dissipation of the VCSEL. This is fixed by the individual thermal model of each VCSEL device. The power dissipation is related to the operating current and has an assumed value of about 5 mA (typical).



T_A Ambient temperature (Temperature Profile compartment area)
T_C Temperature of case (surface of the VCSEL package)
T_S Temperature of VCSEL substrate
T_J Junction temperature of VCSEL
θ_{JS} Thermal resistor - junction/substrate (VCSEL)
θ_{SC} Thermal resistor - substrate/case (substrate VCSEL/surface package of device)
θ_{CA} Thermal resistor - case/ambient (surface package of device/compartment area)

Figure 2. Thermal model.

Reliability assessment

In this reliability assessment, there are basically two intentions in performing life time testing:

- To determine the point in time when the wear-out phase of the device begins and
- to predict the random failure rate of the device during the specified car life time.

In this case, the scope of the reliability validation is related to the bare VCSEL chip without packaging and connections. So the life time test is focused only on the failure mechanisms that are activated by thermal stress. Therefore, testing is done by using a high temperature operating life test setup (HTOL). During the test, the VCSEL devices are in an active mode that is comparable with real operation, for instance similar power dissipation.

To ensure that all possible failure mechanisms are addressed by the test setup, the junction temperature of the VCSEL under test conditions has to coincide with the maximum possible junction temperature of the corresponding temperature profile of the compartment area at least. The maximum test temperature is limited by the maximum junction temperature of the VCSEL device and is specified by the thermal model of each individual VCSEL.

Life time testing in order to predict low random failure rates and late wear-out behaviour is very time consuming. Because the life time of an electronic device generally decreases over an increase of operating temperature, there is a possibility of accelerating the test under certain conditions by increasing the junction temperature in addition. This behaviour is described by the modified acceleration model of Arrhenius (**Equation 1**) and by the Telcordia GR-468-CORE [3].

$$A_f = \left(\frac{I_1}{I_2}\right)^N \times e^{-\frac{E_A}{k}\left(\frac{1}{273{,}15\,°C+T_1}-\frac{1}{273{,}15\,°C+T_2}\right)}$$

E_A Activation energy
k Boltzmann constant
A_f Acceleration ractor
I_1 Current at test
I_2 Operating current
T_1 Test temperature (junction temperature T_J)
T_2 Temperature in operating condition (junction temperature T_J)
N Current acceleration exponent

Equation 1. Modified Arrhenius.

Obtaining wear-out and random failure rate information from one single test setup is challenging. On the one hand, a significant acceleration by increasing the temperature and operating current is necessary to achieve an acceptable test time for wear-out. On the other, this high acceleration increases the risk of activating additional random failure mechanisms that increase the random failure rate. Therefore, the life test is divided into two different setups:

- Determining the point of time for wear-out and
- the prediction of random failures.

Test setup for wear-out

Wear-out failures are generated by using a limited number of samples and performing a high-temperature operating life test with a large acceleration factor. Equation 1 demonstrates that a high acceleration factor can be achieved by increasing the test temperature and the test current beyond the maximum specified application conditions. According to Telcordia GR-468-CORE, the current acceleration exponent and the activation energy can be derived empirically out of aging tests. A typical value for wear-out activation energy is 0.7 eV and for the current acceleration exponent N = 2. The intent of this test is to generate a significant number of failures, for example 50 per cent, in a limited time frame.

Figure 3 shows a typical reliability wear-out plot in test conditions for a dummy device. The blue graph is the fitted probability of failure;

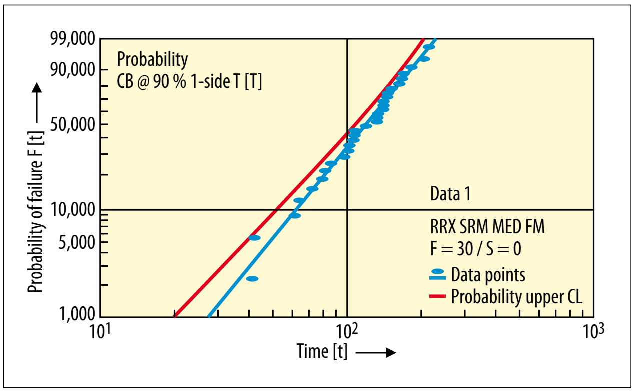


Figure 3. Typical wear-out chart.

the red graph is the lower single-sided 90 per cent confidence level of the test data.

In this case, one per cent of the devices are expected to fail in test conditions by wear-out mechanisms after 20,000 h with a confidence level of 90 per cent. To get a prediction of the wear-out behaviour at the regular application condition (lower temperature and current), the graph can be transformed by using the Model of Arrhenius. This results in a parallel right-shift of the graph on the x-axis.

According to LV124, the required life time of electronic devices should be at least 8,000 h considering the specified temperature profile. Therefore, the test has to prove that the wear-out point with failure rates which are significantly higher than the specified 10 FIT, is far off the 8,000 h.

Test setup random failures

In comparison to the test setup for wear-out failure mechanisms used to generate a significant number of failures in an acceptable time frame, the test setup for random failure mechanisms tends to generate a large number of device hours.

To assure that all inherent failure mechanisms are activated, the test temperature of the junction has at least to coincide with the maximum junction temperature of the real application. In order to avoid the risk of activating additional failure mechanisms that could be addressed by an additional temperature increase over the specified operating conditions, the acceleration factor for random failure testing is kept at a moderate level and depends on the thermal model of each individual VCSEL design.

$$D(T_{JApp}) = nt \times e^{-\frac{E_A}{k}\left(\frac{1}{273{,}15\,°C + T_{JTest}} - \frac{1}{273{,}15\,°C + T_{JApp}}\right)}$$

$D(T_{JApp})$	Device hours at application condition
n	Number of tested devices
t	Number of test hours at test condition T_{JTest}
T_{JTest}	Temperature test condition (junction temperature)
T_{JApp}	Temperature application condition (junction temperature)
E_A	Activation energy
k	Boltzmann constant

Equation 2. Calulation of device hours at application condition.

In **Equation 2** you can see how to calculate the number of device hours within a certain segment of the application temperature profile regarding a number of tested devices and the test duration. The equation is based on the Model of Arrhenius considering a conservative approach according to Telcordia GR-468-CORE; the activation energy is set to 0.35 eV without using an additional current acceleration.

The corresponding random failure rate of a certain application condition

$$\lambda(T_{JApp}) \le \frac{X^2(CL, 2r+2)}{2D(T_{JApp})}$$

$\lambda(T_{JApp})$	approved random failure rate for corresponding application condition
T_{JApp}	Junction temperature (application condition)
$D(T_{JApp})$	Tested device hours at application condition T_{JApp}
CL	Confidence level
r	Number of failures
$X^2(CL, 2r+2)$	Bound of X^2 distribution

Equation 3. Random failure rate.

and a certain confidence level is calculated according to **Equation 3**:

To predict a failure rate not only for a certain temperature but for the complete specified temperature profile according to LV124, the random failure rate is calculated for each temperature segment separately. Afterwards, the failure rate of each temperature segment is weighted by the individual percentage of this segment. Finally, the weighted failure rate of each segment is added to obtain the random failure rate for the complete temperature distribution. According to the defined requirements, the test setup has to be able to prove a random failure rate of about 10 FIT with a confidence level of 90 per cent.

Future perspective

In 2012 a reliability study based on the introduced evaluation method was realized on three VCSEL devices by different manufacturers. The selected devices fulfill the basic functional requirements of a potential further optical MOST Physical Layer. Initial test results furnish proof that the requirement of an 8,000 h life time can be achieved without running into wear-out. There are also some initial test results that demonstrate that a random failure rate of around 10 FIT is realistic and feasible. Some tests are still running and planned to be finished by the middle of 2013.

eck

References

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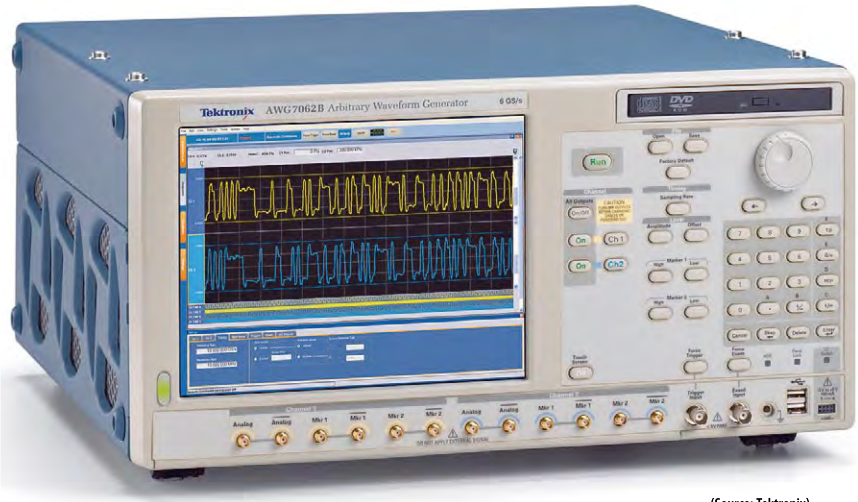
Physical Layer Compliance Test Challenges for MOSTnG

The demand for high data rates in MOST systems is driven by automotive applications like high resolution video entertainment and driver assistance systems with uncompressed video signals. As data rates increase, so does the complexity of the physical challenges. Unfortunately, this increase is not linear. In addition, cost issues limit the characteristics of the transport channel. In order to find a good balance between these different design targets, it is important to determine the right transport method – for example NRZ or PAM4 –, redundancy of the physical layer such as 8 bit/10 bit coding, and equalisation for the transmitter (pre/de-emphasis) and/or receiver (FFE/DFE).

By Venkatesh Avula and Bernd Wessling



(Source: Tektronix)

Repeatability and accuracy of compliance verification methods are important for detecting the limitations of a design and the reliability of the implemented transmission technology. Based on these results, the decision might be made to start with a re-design of the tested components, which certainly has an impact on development cost and time to market for the final product. Therefore, the accuracy of these tests results is critical.

MOST testing challenges

The choice of transmission signaling, such as PAM4 (see **Figure 1**) or NRZ (**Figure 2**), will affect all subsequent components and methods. Various problems need to be considered: How

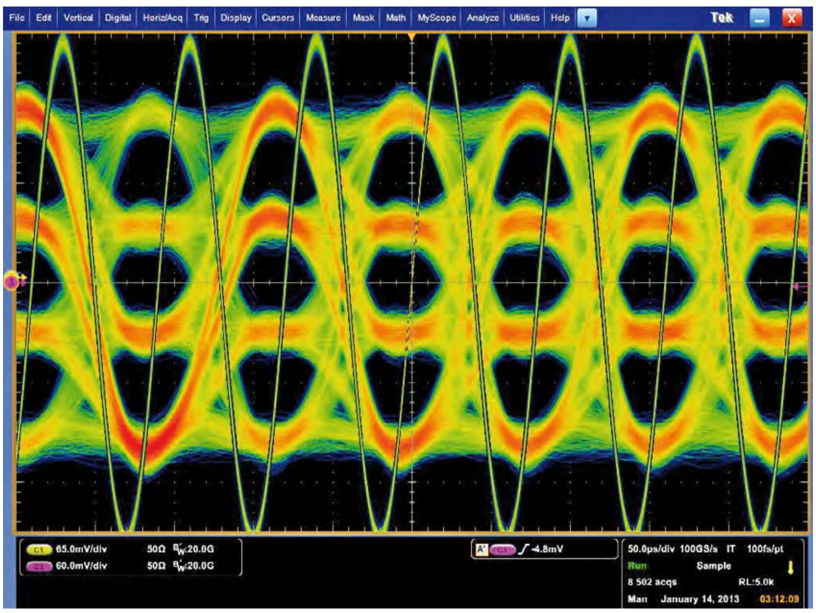


Figure 1. PAM4 eye diagram with reference clock. (Source: Tektronix)

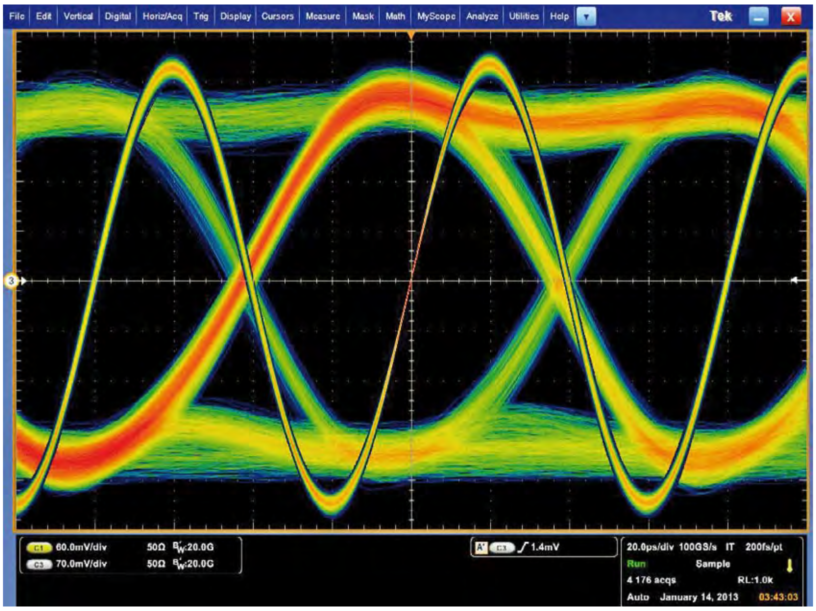


Figure 2. NRZ eye diagram with reference clock. (Source: Tektronix)

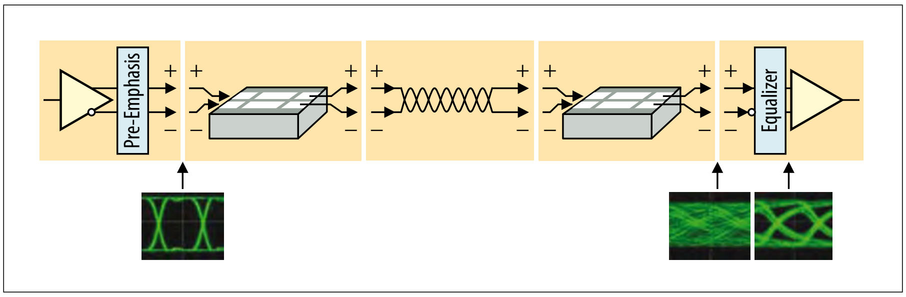


Figure 3. Transmission system: transmitter circuit on PCB, transmission media, receiver circuit on PCB.

is the clock recovered from the signal for eye diagram analysis? Is the test point after equalisation accessible within the receiver section, or which equalisation technology should be used? Is it possible to use just a simple equaliser? This simple equaliser will increase any high frequency losses, but it will also increase noise at the same time. Or should it be a more complex equaliser, like a FFE/DFE (feed forward/decision feedback equaliser) for NRZ-based signals?

For the correct validation of the eye diagram, the same equalisation method has to be used by the test equipment. If the test point after the built-in equaliser section of the receiver is accessible, then the test situation is not very complex. However, if the equaliser is implemented within the receiver chip then the equaliser has to be implemented in the test equipment as well. This could be done with mathematical post-processing after test signal acquisition.

Reliability of the transmission system is a key feature in this technology (**Figure 3**). How much jitter can be added by the transmission medium before the receiver starts to see bit errors? This kind of test could be done with a stress pattern generator. The challenge here is to have a generator with fine amplitude and timing resolution. This allows to add exact amounts of jitter and/or noise in order to find the critical tolerance point.

With high data rates, the impact of test signal probing has an impact which cannot be ignored. Compensating for probing and adaptor losses is necessary with de-embedding.

MOST test strategies

Buying test and measurement equipment is a long term investment. Therefore, the flexibility of the measurement equipment is a key issue. The equipment should be adaptable to a wide range of different signals.

In particular, difficult receiver stress tests like jitter tolerance, robustness against noisy environments and other interference tests can easily and repeatedly be performed by using arbitrary waveform generators (AWGs). AWGs use the principle of Direct Digital Synthesis to enable the creation of physical layer test signals straight from a mathematical description (see **Figures 4 and 5**). Tests with realistic and precisely defined signal impairments can be applied under constant and repeatable conditions using AWGs. The arbitrary waveform generator should feature high signal fidelity and dynamic range as well as a sufficiently high sample rate to simulate different test scenarios and support the trend of ever faster busses.

A wide range of various jitter sources can be added to the test pattern at

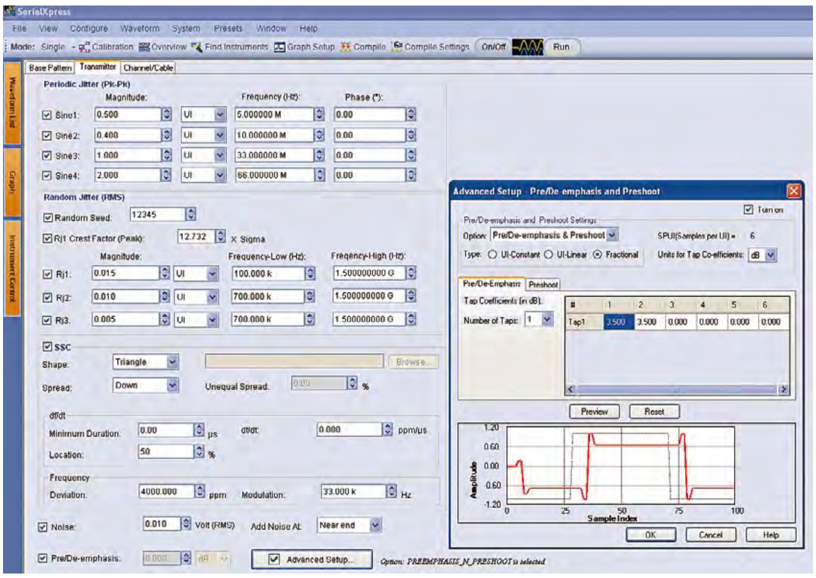


Figure 4. Evaluation of jitter at a transmitter signal test. (Source: Tektronix)

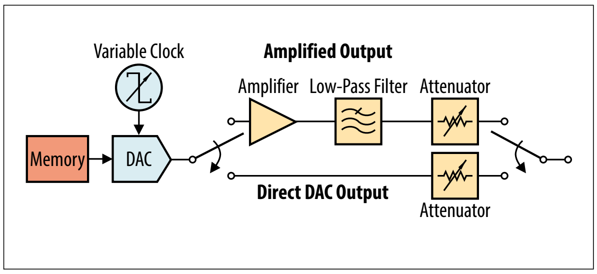


Figure 5. Direct synthesis test pattern signal generation with high resolution digital to analog converter (DAC) technology.

the same time with the mathematical direct synthesis method. 10 bit vertical resolution and small horizontal sample interval give the necessary accuracy to generate the appropriate test pattern. Generation of specific jitter test patterns could be calculated with different tools: Matlab scripts can be used to calculate the test patterns, and then export them into the AWG memory. Or you can use SerialXpress, optional software by Tektronix, which will take the key characteristics of the waveform and generate the required test pattern. It is even possible to embed or de-embed the transmission path characteristics into the test pattern by using S-parameter files. This is very helpful when characterising the quality of connectors as well as interconnect devices and their influence on the eye diagram and jitter analysis results.

In order to test the quality of the receiver and transmission path when handling the different stress patterns, there needs to be a way to compare the transmitted bits with the received data. For instance, the internal loop function of the receiver chip could be used to retransmit the received bits from the Rx to the Tx path. The retransmitted pattern can then be compared with the original signal using the built-in bit error detection function for NRZ-based signals in an instrument such as the Tektronix DSA70000 series oscilloscope.

Another example is that the receiver chip might also have the ability to perform the bit error analysis internally on a predefined bit pattern. *eck*

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Optical TRX to Enable MOST Next Generation at 5 Gbit/s

For more than ten years, MOST technology has been implemented in about 130 car models by 16 car manufacturers. Avago Technologies supports MOST technology with fiber optic transmitters and receivers. After presenting MOST25 fiber optic transceivers (FOTs) in 2001 and MOST150 FOTs in 2009 it is time to take the next step towards TRX for 5 Gbit/s transmission and beyond. The higher data rate is necessary because of application requirements like driver assistance systems, new consumer interfaces e.g. USB3.0 or Thunderbolt, and extended multimedia needs like HD video.

By Thomas Lichtenegger and Nikolaus Schunk

Driver assistance applications might have a huge impact on introducing the new MOST technology. A few years from now, you will see applications such as pre-crash warning, pedestrian warning, collision warning, traffic sign monitor, automated parking, lane departure warning, and lane guidance, and maybe autonomously driven cars as shown by Google. In order to support these applications the protocol has to fulfil safety requirements such as determinism, low latency and real time communication. MOST has already been proven to meet those requirements and MOST150 have already supported certain safety layer concepts.

Current physical layer compared to the proposed new one

MOST25 and MOST150 optical physical layers are based on a 650 nm wavelength and plastic optical fiber (POF) with a diameter of 1 mm. The LED light source, the POF and the silicon photodiode limit the data rate, so it is not possible to reach 5 Gbit/s with this technology. Therefore, three new essential components have been introduced:

- 850 nm Vertical Cavity Surface Emitting Laser (VCSEL)
- Multimode glass fiber
- Gallium arsenide (GaAs) photodiode

For almost 20 years, these components have already been used in the datacom industry. Avago Technologies designs and manufactures both core optical components on its own: VCSEL and GaAs photodiodes. VCSEL and glass fiber are new for the automotive industry and its more stringent requirements. The multimode fiber will have a diameter of either 50 or 80 µm. The advantage of the 50 µm fiber is the higher bandwidth length product and lower costs. However, the 80 µm fiber is much better regarding coupling and reduces the costs of the FOT assembly. Because of the small fiber diameter, butt coupling is most probably not suitable for automotive applications due to dust requirements. Therefore, the later discussion of the VCSEL to fiber coupling takes into account that expanded beam optics (EBO) are preferred for the fiber to fiber coupling. One essential requirement of the VCSEL is its lifetime in an automotive environment.

Stress temperature [°C]	Stress current [mA]	Number of units	Failed units	Cumulative device hours at stress condition	Cumulative device hours at 70 °C operating condition
100	10	3,000	0	16m	59m
100	7	2,500	0	16m	36m
85	7	500	0	3m	4.5m

Table 1. Test matrix for random failure detection.

Light source VCSEL

The chosen light source for a 5 Gbit/s system is an infrared 850 nm VCSEL. The VCSEL is much higher in bandwidth than LED and much more efficient. Today's designs show up to 16 Gbit/s and the roadmaps are even going to 25 Gbit/s for the datacom industry. Therefore, this technology is scalable to higher data rates that will be required in the future. The VCSEL emits in a vertical direction compared to an edge emitter. The vertical beam results in simpler and lower cost transmitter assembly in comparison to these edge emitters. Furthermore, the VCSEL can be processed in wafer processes, which also reduces the costs.

A bathtub curve characterises the reliability consideration of the VCSEL. Therefore, the failures can be grouped in three categories: infant, random and wear-out failures. The infant failures are sorted out at the burn in of the FOT manufacturing process. On account of this, they will not be discussed further in this article. The random and wear-out failures are most interesting for reliability in the car.

VCSEL random failures

The stress matrix in **Table 1** was used to calculate the random failure rate. The VCSEL devices were packaged in TO headers and put into accelerated aging tests with constant current. The devices were removed by the oven periodically for testing. The numbers of units represent the sample sizes at each condition. The duration of these stress cells has exceeded 5,000 h. The Arrhenius model for acceleration is assumed for calculating the reliability at normal operating

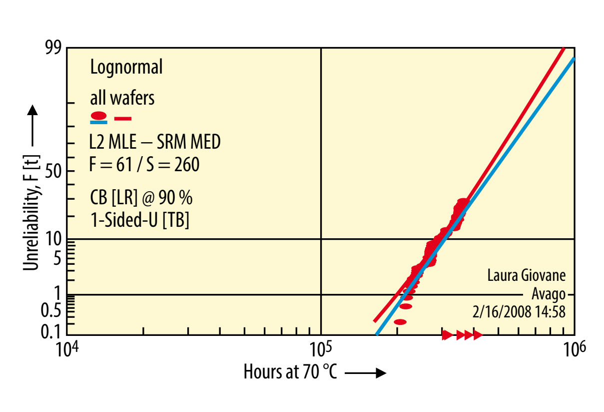

Figure 1. Lognormal distribution of cumulative per cent failure versus time at 70°C, 7 mA for 10 Gbit/s VCSEL. The black line is the maximum likelihood fit to data, the red line is the 90% upper confidence limit [2].

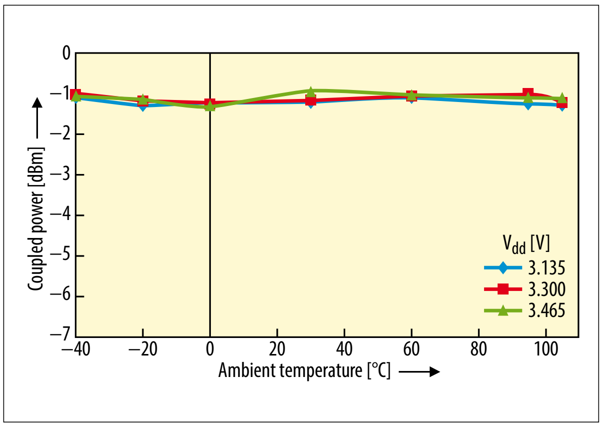

Figure 2. Transmitter optical output power versus ambient temperature range.

conditions by the accelerated aging tests. The activation energy of 0.35 eV was used to determine the acceleration factor to translate between stressed and use conditions for random failures.

There were no random failures in over 99 million device hours. So the random failure rate is too low to be detected experimentally, but an upper limit can be determined statistically. The zero failures and the 99 million device hours result in an upper limit of 9 FIT for 60 per cent confidence level and 23 FIT for 90 per cent confidence level for 70°C ambient temperature. Assuming the automotive temperature profile by Relnetyx [1], a maximum case temperature of 110°C, a current of 4…5 mA and a confidence level of 90 per cent yields to the rate of approximately 10 FIT. This excellent result proves that the VCSEL fulfils the stringent automotive reliability requirements.

VCSEL wear-out failures

VCSEL wear-out failures are generally characterised with gradual degradation and typically follow a lognormal distribution versus time. **Figure 1** shows a cumulative failure rate curve for a typical 10 Gbit/s VCSEL at use temperature of 70°C ambient (7 mA), which follows a lognormal distribution. The curve is derived by the actual accelerated wear-out result at 150°C, 9 mA. The failure criteria is defined as 20 per cent increase in threshold current or 20 per cent decrease in launch power. The extrapolated operating life time for this data set at 7 mA, 70°C is over 24 years for time to one per cent failure, and MTTF of 57 years. With respect to automotive requirements: the wear-out of the VCSEL is less than 1 FIT for an 8,000 h life time. Avago Technologies also implements an extensive reliability monitor program for the VCSEL production line in order to eliminate sudden reliability period swings from undetected process drifts [2].

VCSEL launch power

One Gbit/s data rate transmission has been evaluated using 850 nm VCSEL in a clear mold package, similar to the MOST150 package. A 200 µm core Polymer Cladding Silica fiber (PCS) was used for the transmission fiber. **Figure 2** shows the coupled optical power into the PCS fiber versus the temperature range from –40 to 105°C at different power supply voltage levels of 3.135 V, 3.3 V and 3.465 V. Despite the huge temperature range, the coupled power is nearly constant at around –1 dBm. No monitor photodiode has been used for regulation of the VCSEL output power. The VCSEL driver IC was adapted to the laser so that the threshold shift and the output power drop are perfectly compensated.

The threshold of the VCSEL is in the range of 1…1.5 mA and the slope efficiency temperature variation is –0.4%/°C. These small variations can be compensated by a temperature variable bias current and modulation current, which are implemented in the VCSEL driver IC. The current temperature relationship for the transmitter module is depicted in **Figure 3**. Compared to an LED transmitter the current consumption is one order of magnitude lower for the VCSEL transmitter.

Multimode glass fiber

At 850 nm, a POF is not suited for automotive applications. Graded index glass fibers have to be used. The fiber attenuation across the link distance of 15 m is smaller than 0.1 dB and therefore, it can be neglected in comparison to POF. Multimode glass fibers with 62.5 µm (OM1) and 50 µm (OM2, OM3 and OM4) core diameter are the standard fibers for Gigabit datacom transmission. 50 µm fibers are in very high volume production around the world. They are the fibers with the lowest cost. However, a larger core fiber

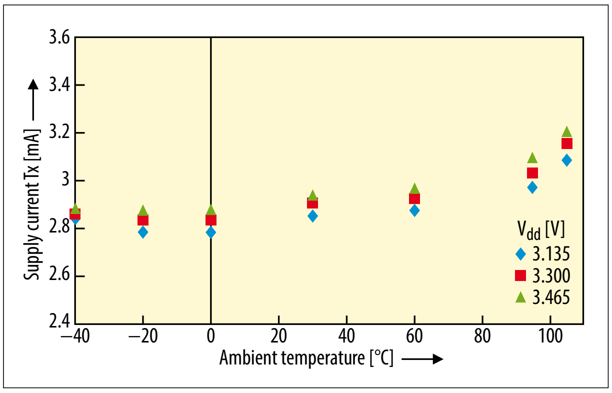

Figure 3. Current consumption of the VCSEL transmitter versus ambient temperature range.

could result in lower system cost because the coupling allows better tolerances for the components. New glass fibers were developed for the consumer industry with a larger diameter of 80 µm. The characteristics of this fiber might fit very well to automotive needs. A strong refractive index drop at the core-cladding interface enables very low bending radii down to 3 mm. The bandwidth length product of 800 MHz*km corresponds to 12 GHz bandwidth for a 15 m link length, which also demonstrates that this fiber is future proven regarding the data rate [3].

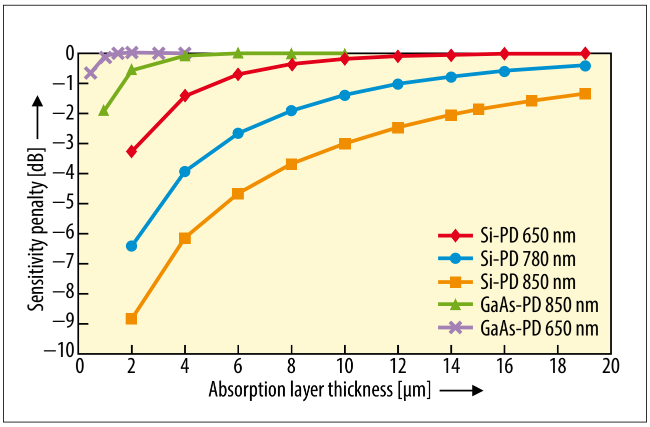

Figure 4. Sensitivity penalty over the absorption layer thickness for silicon and GaAs photodiodes at different wavelengths.

GaAs photodiode

A silicon photodiode is normally used at bit rates up to 1…2 Gbit/s for the optical-electrical conversion in the receiver. The thickness of the absorption layer has to be optimised for maximum conversion efficiency. At 850 nm the absorption coefficient per unit is lower; therefore the layer thickness should be increased. Corresponding with that, the transit time of the generated carrier-hole pairs will increase, reducing the maximum detectable bit rate. Especially at a low 3.3 V power supply; the reverse voltage at the photodiode is low corresponding with a high transit time. GaAs has an absorption coefficient that is one order of magnitude higher than silicon, especially at 850 nm. A very thin absorption layer is sufficient for the highest conversion efficiency and shortest transit time, yielding very high detectable data rates in excess of 16 Gbit/s.

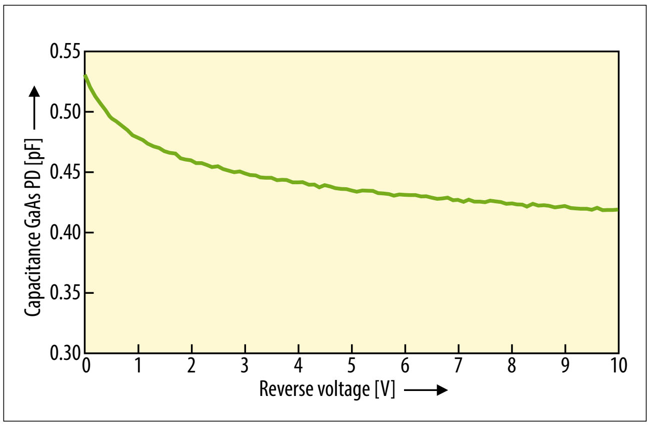

Figure 5. GaAs photodiode capacitance versus the reverse voltage for 85 µm diameter of the active area.

Figure 4 shows the sensitivity penalty over the thickness of the absorption layer for GaAs and silicon material for different wavelengths. The shorter the wavelength, the better the conversion efficiency for silicon photodiodes. At 650 nm, for example, an absorption layer of 10 µm is thick enough for 100 per cent conversion efficiency, whereas at 850 nm wavelength the layer should be thicker than 20 µm in order to reach full conversion. Using GaAs photodiodes, an absorption layer thickness of about 4 µm is sufficient for complete photon absorption at a wavelength of 850 nm. It should be kept in mind that above 860 nm the absorption in GaAs drops dramatically. Therefore the emission wavelength of the VCSEL should be in the range of 830…860 nm. A second bandwidth limiting effect in optical receivers is given by the cut-off frequency of the input stage. For low noise, corresponding with high receiver sensitivity, the input resistor should be as high as possible. On the other hand, the cut-off frequency must be half the bit rate at a minimum. Both conditions could only be fulfilled at a low capacitance of the photodiode. The capacitance is inversely proportional to the absorption thickness. Therefore GaAs photodiodes must have a small active area in order to get a low capacitance. You can see the capacitance of a GaAs photodiode versus the reverse voltage for an active diameter of 85 µm and yield to low losses with the MM GOF in **Figure 5**. The coupling tolerances are not as stringent as they are at the transmitter coupling.

Coupling tolerances

The coupling is much more critical for MOSTnG compared to the current MOST system, because the fiber core is 50 or 80 µm at maximum. The current MOST system also uses the in-line connector for the interconnection of the header connector to the transceiver. This might also be the case in the future. The EBO has been chosen for the in-line connector coupling in order to tolerate dust pollution of the connector optical front side. The EBO principle works as follows: 2 lens stubs inversely transform the divergent fiber far field into a parallel optical beam, e.g. offsets of one fiber with respect to the optical axis are partly compensated for, and small dust particles only slightly reduce the coupling efficiency. Vibrations also have a lower influence on the coupling stability. You can see a schematic arrangement in **Figure 6**. The VCSEL far field is expanded to 0.5 mm with the first lens, for example, and afterwards transformed into a parallel optical beam, which is focused to the fiber core with the second lens. The distance between the top positions of the two lenses is assumed to be 2.6 mm in order to have enough room for protection of the lenses within a connector. This distance might be discussed further towards the specification process. The coupling loss is given for a radial VCSEL-lens 1 displacement and a radial fiber-lens 2 displacement with respect to the common optical axis. The results in Figure 6 demonstrate the coupling losses of a 50 µm fiber and 80 µm fiber. The displacement

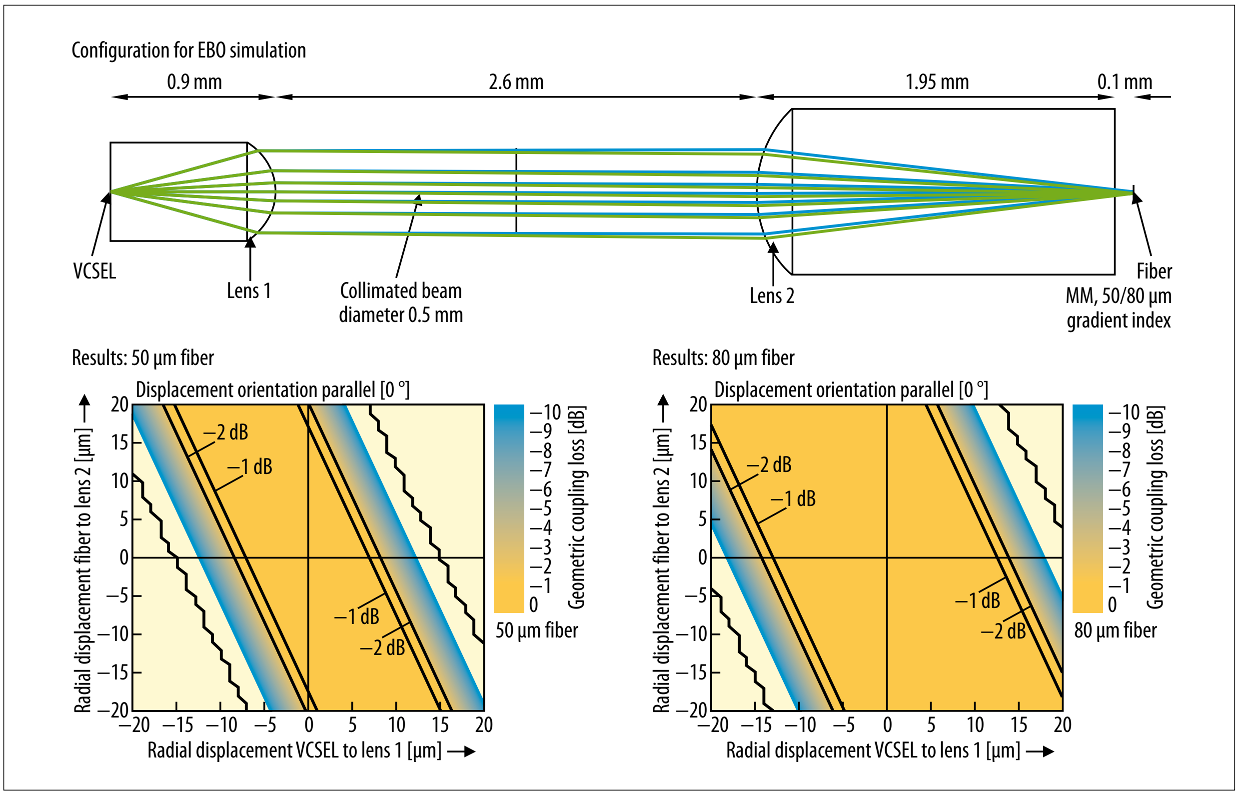

Figure 6. VCSEL - fiber coupling arrangement with EBO coupling.

orientation is parallel of the VCSEL to lens 1 and fiber to lens 2. The results prove that the 2 dB limit for the VCSEL to lens 1 yields to a maximum displacement of ±8 µm for the 50 µm fiber and ±14 µm for the 80 µm fiber. This means that there could be a gain of almost factor 2 for the displacement by taking the 80 µm fiber. However, the displacement tolerances are so small that a very precise alignment process for the VCSEL and the lens is required. Further simulations are necessary to find the optimum setup regarding displacement tolerances.

Power budget

Datacom transceivers usually have a power budget of about 6 dB at 5 Gbit/s. The minimum transmitter OMA is circa –6 dBm and the receiver OMA sensitivity is about –12 dBm. The receiver sensitivity may be very difficult to improve because of the physical limits. If the power budget will be increased there is a chance to improve the optical output power of the transmitter. But, there is an eye safety limit of approximately –1 dBm and there is also a production range needed for the transmitter which should be at least 5 dB for a robust high volume solution without any further measures like a monitor photodiode. Therefore, the eye safety limit presumably cannot be guaranteed if more than a 6 dB power budget is necessary. In order to solve this problem the transmitter could work in a pulsed mode with an average output power below the eye safety limit as long as the transmission line is open. Closing the connection could start the data transmission with the high launched power. This function could be implemented in the bus protocol.

Future perspective

GaAs photodiodes and VCSEL for 5 Gbit/s have already been available and under development for 25 Gbit/s. The implementation of the next optical physical layer supporting 5 Gbit/s will be a huge step for the whole supply chain, but afterwards scalability is given up to 25 Gbit/s. Avago has demonstrated leading edge VCSEL reliability data, robust performance over temperature and key enabling technology to prepare the path for next generation automotive 5 Gbit/s MOST networks and beyond. *eck*

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[1] *Jörg Angstenberger, Dr. Viktor Tiederle*: **Reliability Assessment of VCSEL-Devices for 5Gbit/s Data Transmission in Automotive Environments. MOST Forum (2013)**

[2] *Ji, Chen et al*: **High volume 850nm oxide VCSEL development for high bandwidth optical data link applications. Proceedings of the SPIE, Volume 7229 (2009)**

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Realising an Optical Data Bus with POF and Passive Star Coupler

Electrically powered cars, both pure and hybrid, are gaining market share. But one has to cope with the challenges related with the EMI between power lines and data lines. Optical fibers offer a perfect solution for that in terms of bandwidth, data security and, in the case of using polymer optical fiber (POF), they additionally offer easy handling and outstanding ruggedness. POF bus systems have already proven their reliability within the MOST system and have been used in more than 10 million cars. In 2012 they were upgraded to 150 Mbit/s within the latest MOST generation. Additionally, bus systems covering higher data rates such as FlexRay have entered the market. But, when using a copper-based approach, it has been pointed out that a cost-effective, robust passive star system could not be realised because of problems with reflections in the data lines. Therefore, a passive star system would be desirable in some applications.

By Martin Bloos, Hans Poisel, Olaf Ziemann und Peter Urbanek


(Source: Milos Willing)

Using the recently designed and prototypically fabricated reflective POF star coupler [1], the POF-AC could exemplify an optical FlexRay system with full functions. In principle, this could have been done with any other bus system. Nevertheless, the Polymer Optical Fiber Application Center (POF-AC) presents its latest results concerning the coupler. The application center demonstrates a perspective to progressively offer a future-proof automotive bus system with increased performance.

Optical data buses

With the increasing flood of information that is exchanged in today's modern world, the demand on high performance buses has increased. Depending on the application, these buses have to meet various requirements. In the field of entertainment, for example, a particularly high data rate is achieved. On the other hand, the focus for control and automation is on the real-time capability of the bus. For use in harsh environments especially, the transmission integrity plays a decisive role. Today's bus systems usually meet only one of these requirements. In order to proof its concept the POF-AC used the FlexRay protocol for the demonstrator.

Figure 1. Polymer optical fibers. (Source: POF-AC)

Copper as a physical layer

All current FlexRay clusters [2] use the old proven differential pair cable as a medium. Due to years of experience with CAN on dealing with copper, the decision to use this medium of transmission initially is plausible. The results from the previous operations of FlexRay have demonstrated that the differential transmission at 10 Mbit/s and the extremely harsh environmental conditions have already been close to the technically possible border. Thus, the implementation of FlexRay is represented by multi-stage shielding and complex simulations of the topology, which are expensive and time consuming. Even the smallest changes in topology, such as line length or the number of nodes, can already bring the cluster to a halt and must therefore always be simulated.

POF as a physical layer

The polymer optical fiber is made of transparent plastic [3]. While the light is being guided in the polymethyl methacrylate (PMMA) core, the combination with the optical cladding is used for the total reflection of light. The outermost layer (jacket) prevents the input of light from outside the POF and protects the fiber from mechanical stress (**Figure 1**). Because of advantages such as insensitivity to electromagnetic interference, mechanical robustness and its high transmission capacity, POF has been used in data buses such as MOST or Byteflight in the automotive industry for a long time.

Precisely because of these advantages, and because of the complex problems of copper wires as physical layer, the use of POF would be a logical step for FlexRay.

The most important advantage of optical transmission: data can be transmitted on two fibers as well as on a single fiber. Optical fibers do not need impedance matching in comparison to copper cables. Copper cables need impedance matching to ensure full duplex operation on one pair. On the other hand, a single-core POF connection leads to reduced weight of the wiring harness and decreases the number of connections. With a possible data rate capacity of several Gbit/s, there are not any restrictions for POF with rising data volumes.

Passive optical star topology

Just by using optical connection technology, the design of any topology is significantly simplified. If point to point connections are used, for instance, in the realisation with copper cables, an active element is necessary for connecting the individual nodes. A failure of this component results in the total failure of the network.

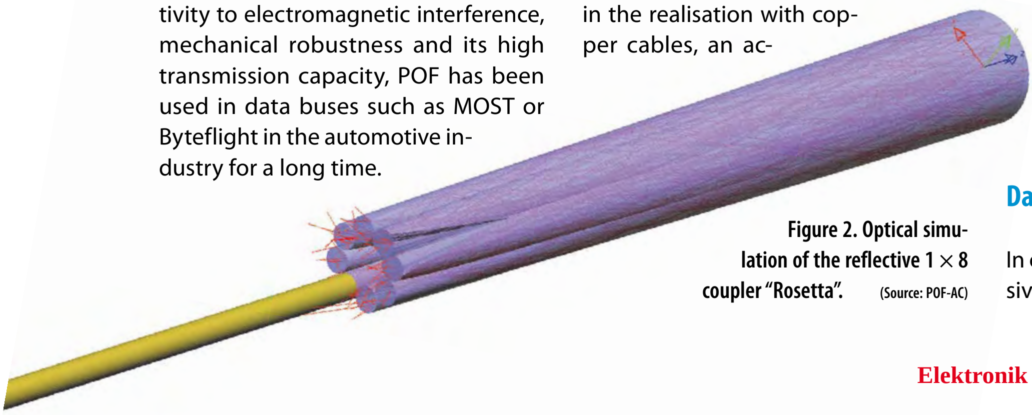

Figure 2. Optical simulation of the reflective 1 × 8 coupler "Rosetta". (Source: POF-AC)

So far, the use of POF for passive multi-point connections failed due to missing components. By building a transmissive star coupler and also a reflective star coupler "Rosetta" (**Figure 2**), this hurdle has been overcome [4], [5]. All conditions of the passive optical star topology for data bus systems in the future have been fulfilled. Each node of the cluster is directly connected to the coupler by a fiber. There is not any need to connect all ports of the coupler, resulting in easy expandability. For coupling of two stars, individual nodes can take on bridge functions (**Figure 3**). Selected packages can be passed from one cluster to another.

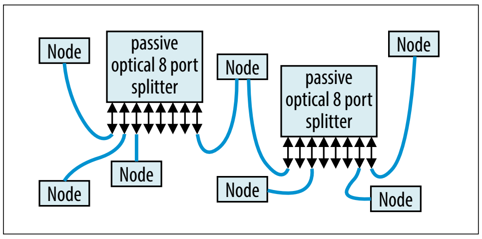

Figure 3. Topology with two connected star networks.

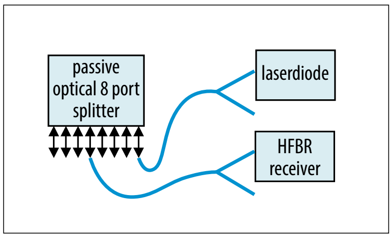

Figure 4. Data transmission experiment setup.

This function is helpful if a particular cluster has specific priorities and should not be burdened with excessive overhead from other nodes. By filtering the data, the load within the individual subclusters can be lowered. By using two channels per node, combined with two passive optical couplers, redundancy can be achieved for better reliability. If both channels are used in parallel, transmission speed is increased.

Data transmission performance

In order to explore the limits of the passive optical star system, the following

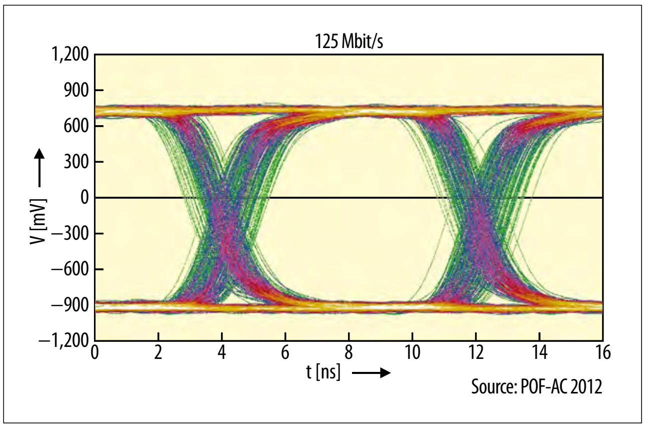

Figure 5. Eye diagram at –28 dBm received optical power (125 Mbit/s).

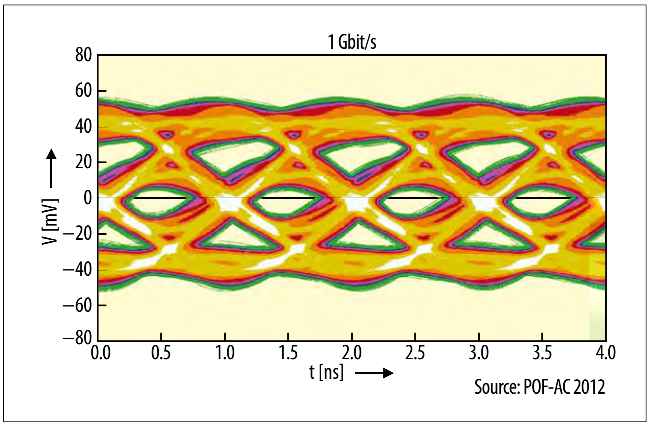

Figure 6. Eye diagram at –16 dBm received optical power (1 Gbit/s).

test setup was used: A red laser diode was connected to one port of the coupler via a Y-coupler. The Y-coupler is usually used to maintain bidirectional data transmission. At a different port, a second Y-coupler was used to connect an Agilent HFBR type receiver (**Figure 4**). With this setup, the POF-AC received the following results at a data rate of 125 Mbit/s. With an optical output power of 6.3 dBm for the laser diode, –14 dBm were received at the output end. By inserting an optical attenuator, the received optical power was lowered down to –28 dBm, as can be seen in **Figure 5**. The eye is clearly wide open, so there is a stable, error free data transmission.

In addition, transmission experiments with a higher data rate of approximately 1 Gbit/s were performed. The setup was the same as described before, but a receiver capable of 1 Gbit/s was used. With an optical output power of 6.4 dBm for the laser diode, a received power of –16 dBm was achieved, as you can see in **Figure 6**. This data transmission was also error free and stable. The power margin at 125 Mbit/s operations is about 14 dB. Even with a limitation of 0 dBm (eye-safe) a remaining 8 dB power margin would be available.

For gigabit operation, the power margin is only a few dB. On the other hand, present developments in miscellaneous applications will offer data transmission components with much higher link budgets, gaining from bandwidth efficient modulation formats like PAM16 and DMT. The use of GaN-based LEDs will expand the temperature range and offer extremely high lifetimes. Gigabit transmission using green LEDs over 50 m of PMMA-POF has been demonstrated recently by POF-AC.

Conclusion

Fiber-optical bus systems benefit from the use of passive optical systems. Elaborate modeling and simulation of the physical layer are no longer necessary; the passive optical systems have high scalability and extensibility. Passive optical couplers and POF in combination affect the design of bus systems for the automotive industry in a sustainable way, thus could make cars safer, more efficient and more comfortable. *eck*

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Reliable Diagnostics of a MOST System

MOST is a proven standard of infotainment systems. A MOST network has high demands regarding performance and stability. Developers of these infotainment systems are aware that in case of a critical failure – ring break in a system where it cannot be diagnosed by the "switch to power" method via MOST, for example – there must be a powerful method for analyzing the network. Ruetz System Solutions, as part of the MOST Compliance Technical Group (MCTG), has developed an efficient test system for the Electrical Control Line. It ensures a constant high quality, so that in case of an error the diagnosis works correctly.

By Dr. Terezia Toth

If failures are not found and not resolved quickly, the car is held up at the car workshop and that means the consumer loses confidence in the quality of the car as a product. To avoid this and fulfill important diagnostic purposes, the MOST Cooperation has introduced the Electrical Control Line (ECL) as a new optional feature for MOST150. ECL is the key element to increase diagnostic capability in a MOST system. It is the way to detect and allocate errors in the MOST system via an additional wire line. This wire line can also be used to generate an electrical wake-up signal.

The ECL protocol provides a variety of functions which can be divided into two separate groups:

- ➜ Triggering a system test
- ➜ Waking up the system by an electrical wake-up signal.

A device connected to the ECL can act in the role of an initiator and/or in the role of a participant. Because of the two separate functions there are two roles for each:

- ➜ System test initiator triggers the test and collects the test results,
- ➜ System test participant report the test results.
- ➜ Electrical wake-up initiator creates the electrical wake-up signal,
- ➜ Electrical wake-up participant is woken up by this signal.

There is exactly one system test initiator, but eventually more than one electrical wake-up initiator in a MOST system.

A system test message has three sequences: start sequence, parameter sequence and result sequence. Each message is initiated by the initiator and starts with the system test start impulse and optional retries, followed by the parameter sequence. The initiator generates five parameter values, which together define one of the four kinds of system test:

- ➜ Ring break diagnosis (00000)
- ➜ Alive (10000)
- ➜ Coding error / threshold (01000)
- ➜ Sudden signal off / critical unlock (11000)

Electrical control line in a MOST network

ECL is limited to MOST systems with a maximum of 20 devices. Each device gets a unique node class in the system. Each node class has a result slot in the test result sequence. Each result slot has two parameters: "En" and "On", where n is the node class. En=1 indicates that the device is not alive or the test is not supported. "On" is the MOST signal result.

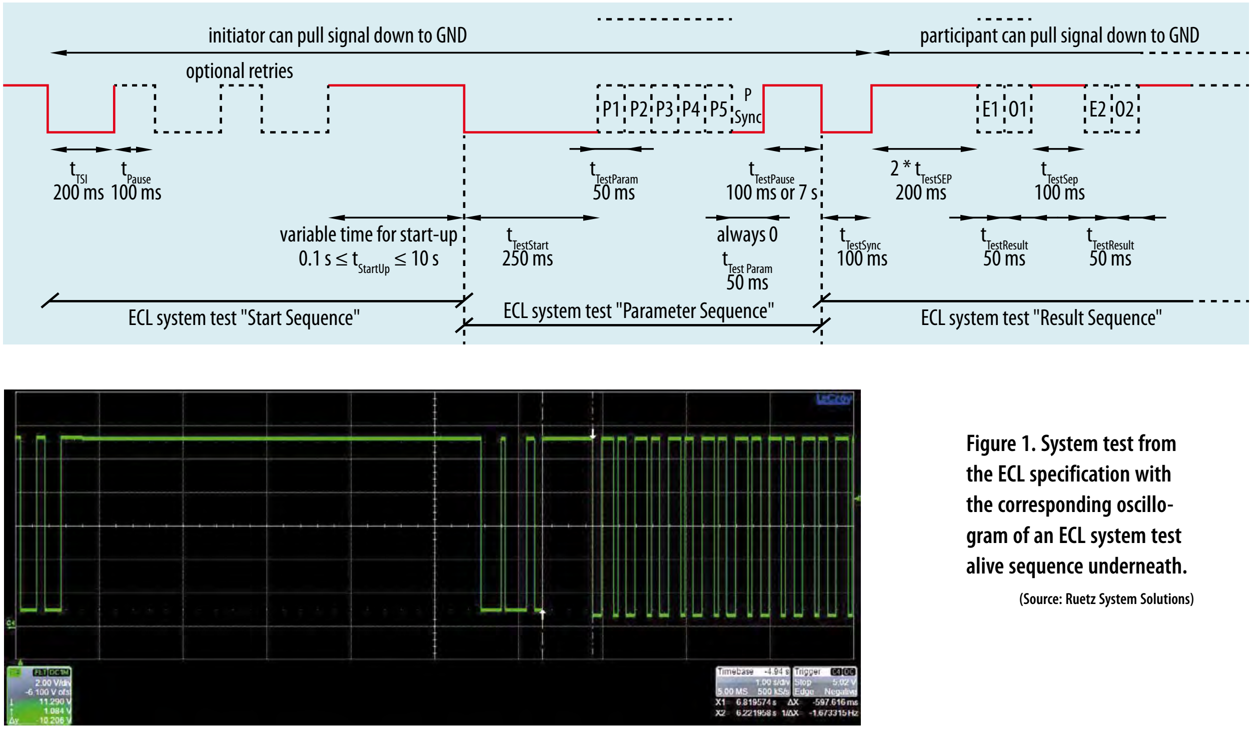

Figure 1. System test from the ECL specification with the corresponding oscillogram of an ECL system test alive sequence underneath.

(Source: Ruetz System Solutions)

An electrical wake-up impulse (EWU) defines the start of an electrical wake-up without a system test. With a single EWU, the wake-up has to be triggered by the falling edge of the first impulse. Electrical wake-up repetitions are called a multiple EWU.

If implemented, the optional ECL feature must be compliant with the ECL Specification [1] of the MOST Cooperation. Compliance with the specifications is one major element for the success of MOST technology. To ensure it, the MOST Cooperation released the "MOST Extended Core Compliance Test Specification: Electrical Control Line" in July 2012 [2]. Depending on the functionality of the device under test (DUT), the corresponding features have to be tested while the other roles have to be simulated. On the one hand the tester has to simulate the ECL sequences of the initiator or the participant, depending on the DUT. On the other hand the tester has to evaluate the received sequences.

The testing process shall be flexible enough to handle this diversity of options and requirements. The challenge is to test not only the good case but also the bad cases with fault injection.

On the one hand the tests have to be reliable, without oversights, mistakes, or other chances of human error. The test specification has to be easily readable and understandable. The execution shall be independent of the area where the test takes place, at a MOST Compliance Test House (MCTH) or at a supplier's in-house test lab. Global consistency regarding test results has to be ensured. On the other hand the effort has to be limited. The test process shall not be costly and time-consuming but provide results fast.

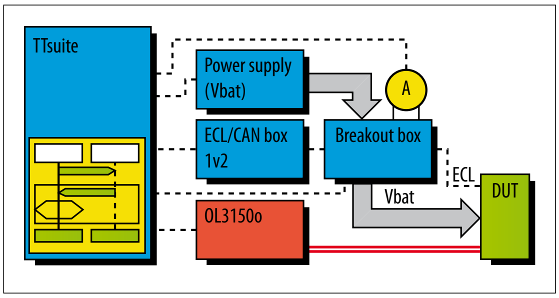

Figure 2. Test setup ECL test automation. (Source: Ruetz System Solutions)

Qualified testing through automation

Automation is generally a significant saving of time and effort compared with manual testing. In this case it is also a strong argument for automation that some of the tests cannot be performed manually because a very short reaction time is needed. Ruetz System Solutions, as a MCTH, has developed an automated ECL compliance test suite. Its fully automated test systems have their own history and evolution. A giant leap forward was the TTsuite. The TTsuite provides users with an easy to use TTCN-3 based platform that allows them to carry out tests and simulations of varying complexity. With TTsuite it is easy to describe and carry out new test scenarios such as the ECL test suite.

The test cases in the "MOST Extended Core Compliance Test Specification: Electrical Control Line" introduced by the MOST Cooperation are written as executable test specifications in the Graphical Format of TTCN-3 (GFT). The ECL test suite is generated from these GFTs by TTsuite. This kind of test development process provides a reliable test specification and eliminates the chance of misinterpretation from the very beginning.

TTsuite is able to handle very different communication protocols via adapters. ECL is similar to the LIN bus, therefore TTsuite has an adapter that translates the ECL pulses into data for testing purposes and codes the data into pulses for the simulation. Tests regarding the reaction of the DUT to ECL protocol violations by changing the pulse width can reliably be performed with TTsuite [3]. Information is transferred via pulse state and pulse width on the ECL as a bidirectional bus line. It has two states: high, logical 1 (supply voltage) and low, logical 0 (ground). The default state is high.

The ECL sequence chart (see **Figure 1**) shows the results of a system test from the ECL specification; below that is a corresponding oscillogram of an ECL system test alive-sequence. It begins with the start sequence with 7 s start up time, followed by the parameter sequence 10000 and the result sequence with results from node classes 4 to 19. An oscilloscope is used only for display purposes, not for the measurements.

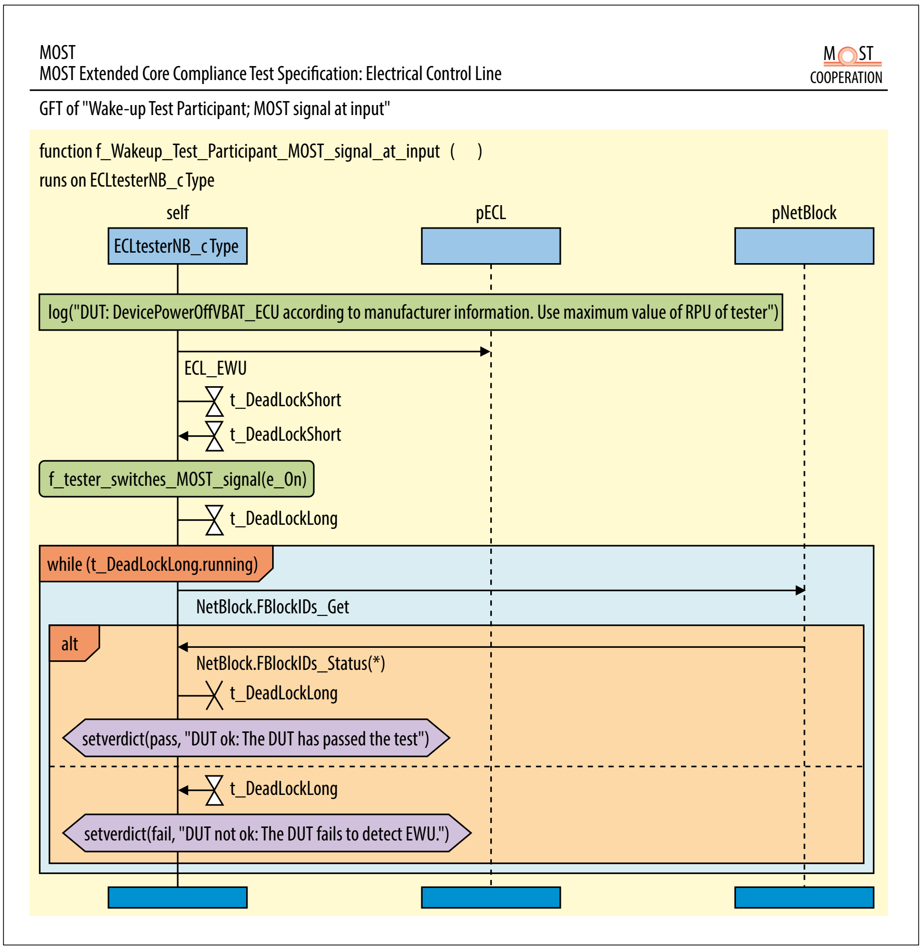

Figure 3. Excerpt from the test case specification, a GFT. (Source: MOST Cooperation)

Efficient test environment for reliable networks

TTsuite is able to control any additional tools needed for the test setup. In this case, TTsuite controls Ruetz System Solutions' ECL/CAN Box and Breakout Box, with OptoLyzer and a power supply (see **Figure 2**). The MOST bus of the test setup is set via the OptoLyzer module. The ECL bus is formed by the ECL/CAN Box. The Breakout Box is a device for configuring the test setup. This hardware interface serves as an expansion of the TTsuite test bench in order to automatically execute the test setup described in the test specification. It is connected to the power supply of the DUT, and to the ECL line of the DUT. The ECL/CAN Box is a device for sending wake-up and test sequences of the ECL and for receiving subsequent replies from the DUT and forwarding them to the TTsuite via the interface. Apart from this, connected control devices can be woken up by CAN messages from the ECL Box.

The documentation of the test results is fundamental in the compliance verification process. It shall include detailed information about the behaviour of the DUT and recommendations for improvement if necessary. TTsuite provides a test report with a chart about the test result, including a statistical overview. The tool also provides a graphical test protocol, which has the same structure and look as the test specification from the MOST Cooperation. So it is very easy to analyze and understand the test protocol and to compare it to the test specification (see **Figure 3**).

This new, fully automated ECL test system ensures global consistency regarding test results. The benefits of using this test system are apparent. Executable test specifications, detailed documentation of test results, easy to analyze test protocols provide transparency and allow unambiguous, clear communication between tester and developer regardless whether the tester sits in a MCTH or in-house with the developer. The devices can be validated using this test system from the beginning of the development via in-house tests. *eck*

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MOST and AVB: Two Candidates for Next Generation Automotive Infotainment Networks

MOST150 is the prevalent networking technology for the coming years in automotive infotainment. Although MOST150 is only at the beginning of mass deployment, pre-development of the next generation has already started. With IEEE 802.1 AVB, another concept has entered the discussion about the successor to MOST150. AVB needs to be considered, appropriately evaluated and compared with current and evolving MOST concepts.

By Günter Dannhäuser, Dr. Walter Franz und Prof. Dr. Wolfgang Rosenstiel


(Source: Daimler AG)

The MOST technology framework is the dominant technology in automotive telematics and infotainment networks, and has been smoothly brought to the road in its third generation with integrating MOST150 in 2012. The MOST Cooperation has proven to be an excellent body, permitting very direct specification and implementation processes for the benefit of both OEMs and suppliers. The close and open cooperation of OEMs and suppliers is the key factor of this success story. MOST150 systems will continue to boom in car models as the dominant infotainment network system until at least 2020.

A succeeding next generation network system for the time after MOST150 needs to meet high expectations, considering the significant increases in bandwidth demands driven by camera, display link and consumer electronics (CE) device based use cases. Flexible topology options and the seamless interconnection of previously separated car domains are further key topics. Aside from that, general requirements apply, such as cost, scalability, future-proof design, efficient supply chains, automotive maturity, ecosystem tools and IT security.

With IEEE 802.1 Audio/Video Bridging standards [1–5], packet-based synchronised streaming has become a competitive alternative in media streaming applications. Ethernet network interfaces supporting AVB have just been launched in consumer products [6] and AVB will conceivably become a common feature in CE devices which commonly use IEEE 802.3 Ethernet and IEEE 802.11 Wi-Fi technologies.

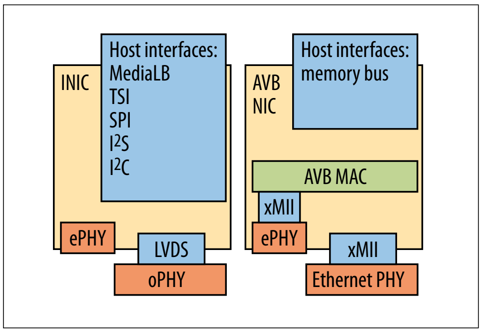

Figure 2. Integration of host and physical layer hardware interfaces in MOST and Ethernet AVB.

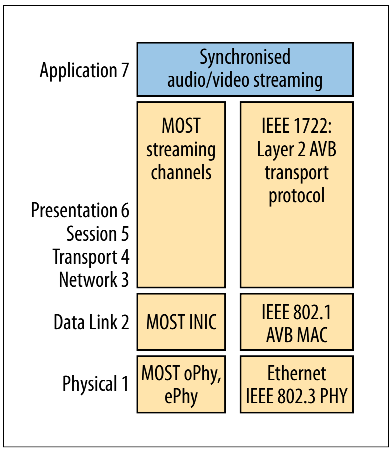

Figure 1. ISO/OSI model layering for synchronised audio/video streaming on MOST and on AVB.

Here, another trend has to be taken into account, as Ethernet is also being evaluated in the automotive industry as a future technology option in automotive domains adjacent to the telematics domain.

Due to these facts and driven by new use cases, cross-domain interoperability is rapidly gaining importance and the applicability of AVB concepts and their interoperability with MOST need to be evaluated.

MOST and AVB in comparison

Both the AVB and the MOST approaches encounter critiques on various technical aspects. These can be answered more or less satisfyingly, as the discussions are about systems-to-be and that kind of critique is mostly based on experience gained from current systems. Concept proposals, on the other hand, are the technical basis for the time being. They are a flexible matter and therefore often deliver only weak arguments for hard technical decisions.

MOST as a synchronous system has the advantage of inherently providing maximum quality of service (QoS), since collisions or priority conflicts principally do not occur. Delay is minimal and, moreover, it is deterministic and predictable, thus enabling application-level synchronisation with simple fixed delay elements. On top of this, MOST150 offers isochronous and packet channels, including a transparently usable Ethernet channel. In the short term, the MOST Multiport INIC concept as presented earlier [7] has already answered the most frequently raised objections against classic MOST systems by enabling flexible, mixed topologies and different speed grades on the same net. A MOST successor, preliminarily called “MOSTnG”, will further improve on this, key points being error detection/correction and bridging between network clusters, which may run at different speed grades over various, even mixed physical layers.

With introducing AVB standards, Ethernet as a packet-switched networking technology responds to the lack of guarantees and determinism with a synchronised network layer, enabling time-synchronised low-latency streaming services. The standards cover precise clock synchronisation, traffic classes with bounded latency, partitioning of bandwidth, stream reservation, traffic prioritisation and data link layer transport protocol. Layering of this synchronised network looks very similar to synchronous MOST (**Figure 1**). However, application level synchronisation is not a question in the scope of AVB standards so far and thus must be taken into account by application developers.

Regarding automotive infotainment systems, a crucial feature is the seamless integration of audio/video (A/V) interfaces in the network interface controllers. A/V streams should be directly transferred to corresponding A/V interfaces, thus unloading the host processor from handling A/V tasks. The MOST150 INIC already integrates various interfaces such as MediaLB, TSI, SPI, I^2C and I^2S, benefitting from its synchronous network layer transport. AVB-enabled Ethernet NICs can, in principle, provide similar interfaces by separating AVB streams from other traffic on the Data Link Layer, taking care that the AV streams do not burden the host processor. However, such functions are not found in today’s NIC implementations (**Figure 2**).

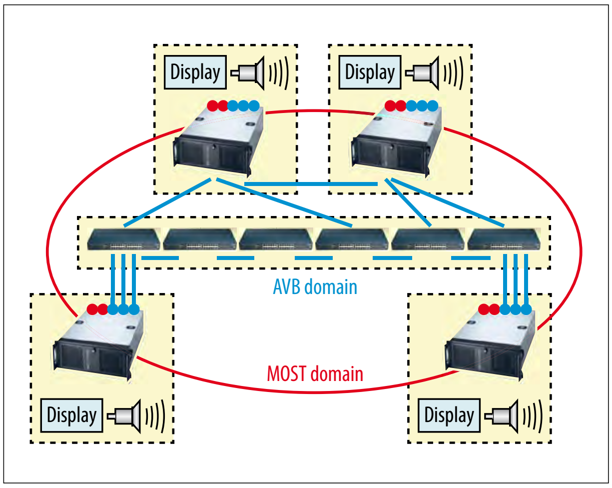

Figure 3. Overview of the MOST and AVB evaluation platform. Standard PCs with NICs of both network domains (blue/red points). Note: MOST domain topology depicted as ring just for illustration purposes.

Differences between both technologies

Both technologies are essentially independent of baseband physical layers. MOST150 INIC interconnects the FOT using LVDS interfaces, whereas Ethernet MACs connect to Ethernet PHY units with Media Independent Interface variants. Otherwise, choice of a physical layer, whether on optical media, electrical over twisted pairs or coax, is to a large extent independent of the approach taken on the data link layer.

Whereas MOST has been designed and developed for automotive use and automotive qualification, for AVB a lot of experience needs to be gained regarding automotive use of the standards and realisation of automotive requirements. This ranges from the API level to service discovery and control mechanisms, wake-up strategies and times to power consumption, just to name a few. AVB generation 2, which is being standardised now, will address some crucial issues, including the handling of high frequency/low volume data such as sensor data and further minimization of latency by preemption of packets [8–10]. AVB standards were written to flexibly support comparatively dynamic networks and to provide interoperability between brands of different manufacturers. The in-car situation is a lot more static, with plenty of opportunities to keep oversizing, redundancy, start-up times and thus power consumption and costs down. Pre-configuration for the startup phase and beginning to reduce complexity right at design time are examples for that. A strip-down of AVB protocols and techniques is imperative for automotive usage. Yet, an appropriate form of cooperation for standardisation of such a tailored AVB automotive profile needs to be found that fits into the landscape of the IEEE and other groups concerned.

Both MOSTnG and AVB can be considered technologically feasible concepts, sufficient to meet the demands of next generation infotainment networks. MOST has a big bonus in confidence and maturity and is better adapted for automotive use. Development of MOSTnG could further on be directly influenced and tailored via the MOST Cooperation, in line with OEM demands, quickly and pragmatically.

There is a great deal of work to do for automotive use of AVB. Although its standardisation enables flexible usage that results in a prolific supplier and market situation, the standardisation processes are challenging, with lots of voices from non-automotive interest groups in manifold international committees and working groups.

With these points in mind, at present it is very difficult to identify clear deci-

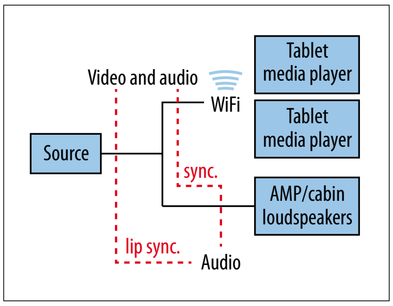

Figure 4. Use case A/V-streaming from a source in the car domain (head unit, tuner, Blu-ray player, etc.) to two tablet computers with user-domain media player, lip-sync with each other and cabin speakers.

sive factors on a technical level for one approach or the other. Regarding market size and heterogeneity on each side, especially in the long term, AVB is an option that needs to be seriously considered, at least. As for automotive usage, primarily in the infotainment domain, AVB needs to be evaluated and its performance needs to be compared to the MOST system.

Evaluating AVB and interoperability

For these reasons, Daimler AG decided to build a system to evaluate both technologies on one single platform. MOST and AVB networking domains are combined by integrating multiple MOST and AVB adapters in standard PCs (**Figure 3**). The idea is to make use of a unified hardware, operating system and system clock environment to be able to correlate timestamps for both networking domains as a base method for evaluation on higher and application level. So it is possible to further explore interoperability scenarios between MOST and AVB, taking into account that Ethernet systems may be deployed in other time-sensitive automotive domains interacting with MOST technology deployed in the infotainment domain.

Daimler aims to evaluate the full scope of AVB standards and will include further AVB building blocks as soon as they are available. Based on the results of these investigations, the company plans to narrow down what will apply to automotive profiles of AVB and interoperation possibilities with other systems. A first step is to create exemplary implementations of scenarios that are typical for automotive infotainment, though yet not common in the consumer market. One scenario for AVB evaluation is application-level synchronisation of multiple media streams on different sinks, including CE devices (**Figure 4**). With AVB providing synchronisation on a network level, Daimler wants to investigate what additional measures have to be implemented to achieve application-level synchronisation and which preconditions have to be met.

As a second step, mapping of a present MOST150 system to AVB on the evaluation system will provide hands-on experience with AVB and allow direct comparison to the functionality and performance that MOST150 delivers. Driving the evaluation system to its limit, there will be an analysis of its behavior regarding factors such as synchronisation accuracy or impact on best effort traffic. Additionally, this will allow engineers to identify optimisation possibilities, for example by using static stream classification, reservation or traffic shaping.

It is also planned to use the evaluation system for research on how to integrate wireless CE devices. Applicability of AVB concepts for Wi-Fi is therefore another topic Daimler will investigate, though Wi-Fi AVB is anything but definite so far.

The main focus of the investigation will be the interoperation of MOST150 and Ethernet/AVB. Synchronisation of time and clocks is the basic property of both, and hence the premise for interoperation. Establishing a cross-system time base reference, therefore, is a key topic to build on for a gateway scenario. Another idea is to investigate possibilities to use or enhance the Ethernet channel of MOST to transparently support AVB. Finally, incorporating the steps mentioned before, the target scenario is cross-system, synchronised video-streaming, integrating wireless CE. *eck*

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(Source: Audi AG)

Building a MOST Infotainment System in a Heterogeneous Networking Environment

The rapid progress of consumer electronics forces car manufacturers to significantly reduce time to market (TTM) when creating a new infotainment system or implementing new features in existing systems. The growing value of software in the automotive industry and the complexity of modern systems both increase the importance of the software development process. TTM can be improved by accelerating this process, but this must not compromise the reliability of the software components. Methodologies that are able to optimize the software development include automation of the process and parallelization of its steps. However, this means that development tools have to support those methodologies.

By Yury Asheshov

The convergence of end-user devices and computing networks is another challenge coming from the consumer electronics world. In this area, the proportion of products that support Internet connectivity, especially when using wireless technologies, is rising sharply. User data is shared between different devices, Internet services and enterprise applications as well. The next step is to provide the customer with the opportunity to keep all the data in the cloud and synchronise the devices with it. The infotainment system in a vehicle will be a part of this environment, of course, with limitations according to automotive safety requirements. A tool that automates the communications between automotive devices and end-user products can simplify and speed up development.

Software development process

Considering the software development process, a project usually starts with an analysis, the creation of a specification and a prototype. Those steps are iterative, and may be repeated. After several iterations, the artifacts such as the requirements, architecture and design document specifications are available. The software implementation based on these artifacts must be tested and verified. It is essential to note that several participants from different companies are usually working on such automotive projects.

In the "analysis" step, a Unified Modeling Language (UML) abstract system model is created, which includes specific requirements, use cases, etc. UML is the widespread modeling language used in software development. The mature UML tools may be a great help in verifying the integrity of the model, so the usage of UML reduces the time needed to create such a model. The UML model, and especially the diagrams that specify the API and dynamic behaviour, are the important parts of the specification.

One of the possible automation methods is code generation. It provides the ability to create ready-to-use program code directly from the UML model or from an exchange format. This generated code works together with a framework and implements a public visible interface of the business logic of the component. It helps to rapidly build a prototype application.

A prototype application is a skeleton with the default (dummy) implementation of the interfaces. Existing software can be integrated into this skeleton. Another possibility is to extend the skeleton with functions that simulate the behaviour of the specified device or component.

Simulation of device behaviour

There are several advantages of having such a simulation. First, the simulation itself is the proof of concept of the UML model and creates the possibility of detecting mismatches between the UML model and the real system. This is one of the main challenges at the early stages of the project. Another challenge is the ability to efficiently roll out modifications to the abstract model at later stages of the project when the software implementation has already been started or even completed. The code generation localizes changes in the abstract model to the integration code between the generated code and the business logic. This means that modifications to the abstract model that break the generated code will be identified at compilation time as syntax errors, and only the integration code needs to be fixed.

Second, the simulation delivered to the project participants integrates their components within the system, because this simulation is a running sample and demonstrates to the developers how the system works.

How do the typical project activities work properly? The developer of one device that communicates with one or several other devices can immediately use the simulation of other devices during the software development instead of waiting for a delivery from other project participants. The tester can directly start to implement device-specific tests against the simulation. In addition, the project group of the car manufacturer can begin to create a set of acceptance and production tests directly after completing work on the simulation.

In addition, if a simulation is built on a tool that virtualises network communications, then all project members can work even if the hardware devices are not stable yet or available at all. In this case, the firmware developers who work on the evaluation boards may use firmware components which are capable of connecting to the virtual networks provided by this tool. At this point, the firmware is capable of communicating with the simulation. It enables the firmware and hardware tests to be developed in parallel. This means that the simulation of the system containing components that communicate with each other over networks is the key to parallelizing work on the project.

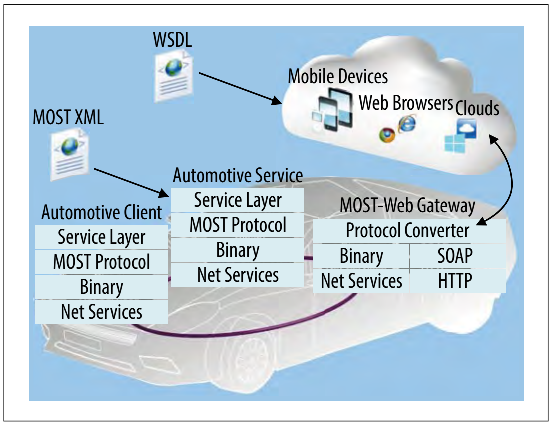

Figure 1. Putting it all together: convergence of automotive and consumer electronics.

In the focus: the Automotive Test System solution

The solution proposed by K2L is the Automotive Test System (ATS), which enables simulation and testing of automotive devices or systems. This is a comprehensive PC development tool, which is built on the .NET framework and works under a Windows operating system. It consists of the following parts:

- the hardware interface,
- the viewer software,
- the Windows service application,
- the framework and
- the code generator.

The hardware, named MOCCA compact, is connected to the PC over USB and provides access to field buses such as MOST, CAN and LIN. The viewer application is a trace tool to display incoming and outgoing messages, to disassemble their data and to show information about the buses. The ATS Windows service application is a communication center that implements the virtual MOST on the PC and connects it to the hardware (if any). The framework is a set of .NET libraries that can be used in customer applications built on ATS. The code generator, called MAG.NET, creates the .NET assemblies from files that describe the network protocol. The generator supports CAN DBC, LIN Description File (LDF) and a MOST XML function catalog. MAG.NET generates .NET classes that represent the messages for the CAN, MOST and LIN protocols. The generated code for the LIN protocol includes the driver configuration as well. The code generated from a MOST XML file also contains the

.NET classes that implement the default behaviour for both sides of the communication: the controller/shadow (client) and the slave/FBlock (server).

Modern techniques which include, for example, parameterized tests, are widely spread in the .NET environment, and can reduce the development efforts for the automated tests.

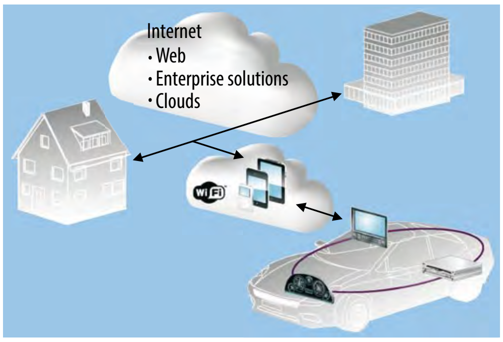

Figure 2. Car of the future.

K2L ATS is well-suited for testing and simulation of the traditional infotainment system as a set of devices that are built into the vehicle and communicate over MOST, CAN and LIN. Some of these devices can have a pair-to-pair connection to the end user devices, for example, over Bluetooth.

Convergence of automotive and consumer electronics

As mentioned before, future infotainment systems require a tool for support of the convergence between automotive and consumer electronics over computer networks. There are several variants of networking topologies regarding how consumer electronic devices such as mobile phones, tablets and laptops and the infotainment system could be connected. The simplest topology: the car has its own mobile broadband Internet connection and its own Wi-Fi hot spot. This provides access to the Internet and remote automotive services. Another topology is an analogy to the Bring Your Own Device (BYOD) concept. Here, the infotainment system has a Wi-Fi network interface and connects to the hot spot provided by the customer mobile device, which has Internet access over a cellular network.

The principal difference between these two topologies: In the first case, the infotainment system communicates with the service endpoints in the Internet directly, whereas in the second case the network address translation (NAT) takes place between the communication partners. Moreover, enterprise systems have even more complex topologies, including firewalls, virtual private networks (VPN), etc. In this situation a greater reach for applications is necessary.

It should be noted that some parts of the infotainment system, such as navigation components, can use Internet services e.g. to update the traffic information on a route. It means that service providers as well as consumers of these services may be deployed on automotive and mobile devices and also on the Internet. Software applications that offer a service or consume it, especially over a network, are called service-oriented applications.

A part of the .NET framework for building service-oriented applications is the Windows Communication Foundation (WCF). The conceptual model that supports the service orientation is called Service Oriented Architecture (SOA). There is a wide range of technologies such as Web services (WS) or Representational State Transfer (REST) that can be used to implement SOA. The WCF supports the most common technologies.

In WCF, a .NET interface defined in the code or generated from a Web Services Description Language (WSDL) file specifies the contract of a service. The class that implements this interface to deploy on the server is called service class. The instance of this class can be hosted in a desktop application, a Web server or in Windows Azure, the Microsoft cloud platform. K2L ATS paves the way for connecting MOST and WCF to simulate the new features provided by the vehicle-Web interconnection.

With the MAG.NET tool, the user can select MOST functions from a function block to create the .NET interface as a service contract. The K2L ATS framework includes the .NET class, which implements the MOST WCF gateway. It receives an incoming message from the MOST function and transforms its data to the parameters of the corresponding method for the specified WCF interface. After this, the gateway-class calls the method of the instance of the service class that implements this WCF interface. This instance can be a client proxy that accesses the service hosted outside the MOST network. It can also be a service implementation available in MOST, as well as on the Internet or in a local area network, for example, over HTTP.

The client or service can be implemented on other platforms. The tool svcutil.exe (part of Windows SDK) can be used to generate the WSDL file from the .NET interface. The WSDL file serves as an input for other tool chains to implement services or to generate client code for other programming languages or platforms such as C++ or JavaScript.

This approach shows that MOST, as the dedicated technology for infotainment networking, already contains the elements that are suited for communication with the services deployed on the Internet. The solid methodology (top-down) used to build a MOST based infotainment system is close to the development process of enterprise Web services. An integration of the best parts of these technologies opens up new and interesting opportunities for MOST applications. *eck*

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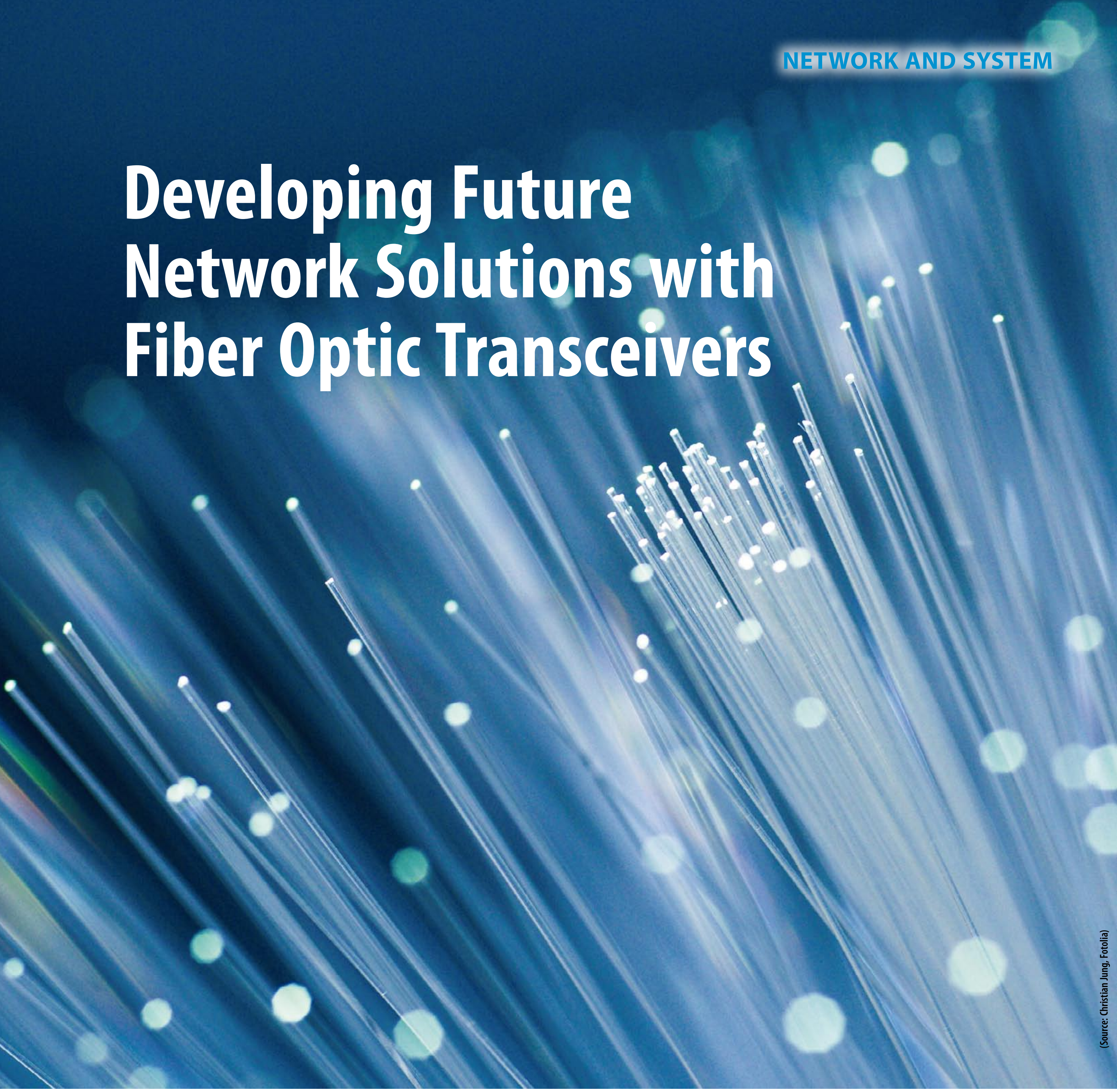
Developing Future Network Solutions with Fiber Optic Transceivers



(Source: Christian Jung, Fotolia)

Fiber optic transceivers (FOTs) are key components of MOST systems, serving as the connection between the optic and electronic data communications. More than ten years ago, Hamamatsu Photonics released its first FOT generation, which was capable of 25 Mbit/s. For MOSTnG, the opto-semiconductor manufacturer is developing a new cost-efficient and highly reliable FOT that is capable of 5 Gbit/s communications.

By Takayuki Suzuki, Kenichi Okajima, Makio Kume and Kota Kiuchi

The 5 V operation type and 3.3 V operation type of the first FOT generation are available for MOST25 and the operating temperature is up to 105°C. At 25 Mbit/s, the next FOT generation can transmit 150 Mbit/s, operates at 3.3 V supply voltage and is now available in Sidelooker and SMD versions. The SMD version has a fiber ferrule guide and is box-shaped, enabling easy push-in and pull-out and good holding force for the ferrules. It also provides more mechanical stability and robustness; the device is easier to handle in automated production processes. There are no manu-

Item	Technology	Speed availability @ 20 m	Cost	Automotive quality	Remark
Detector	GaAs-PD	7 GHz	High	Acceptable	850 nm, 0.6 A/W
	InGaAs-PD	> 10 GHz	Very High	Acceptable	For 1.3, 1.55 µm
	Si-PD	1.5 GHz	Low	Very Good	For 850 nm, 0.3 A/W
Emitter	VCSEL	> 5 GHz	Low	Challenge	
	Edge emitting LD	> 5 GHz	High	No Good	
	RCLED	< 500 MHz	Low	Very Good	
Package	TOSA, ROSA and SFF or XFS	> 10 GHz	High	Good	Module
	SMD	< 1 GHz	Low	Very Good	FOT
	Sidelooker	< 1 GHz ?	Low	Very Good	FOT
	Sub Assembly	> 5 GHz ?	Low	Very Good	FOT

Table 1. Comparison table for devices and packages for gigabit communications.

al handling processes necessary in production because the part is reflow solderable and can easily be handled by automatic pick and place machines. In addition to the SMD version of MOST150, the SMD version of MOST25 has recently been released and shipping of these parts has already started. The Sidelooker package for MOST150 uses a new kind of resin that enables automatic handling in reflow soldering processes.

Hamamatsu Photonics' line-up of opto-semiconductors covers a wide spectrum, such as infrared, visible and ultraviolet regions, X-rays and even high energy particles. These are used in fields like automotive, medical diagnosis, scientific measurements, communications or consumer electronics.

The company produces not only silicon (Si) semiconductor devices but also compound semiconductor devices such as indium gallium arsenide (InGaAs) and gallium arsenide (GaAs). In the MOST market, more than 100 million pieces of FOTs have been produced during the last ten years. These FOTs are highly reliable with a failure rate of less than 1 ppm. Furthermore, the user profits by the in-house support including IC design, package design, infrared LED wafer production and PD wafer production.

Next generation networks

For the next generation of MOST networks, Hamamatsu is developing a new FOT which is capable of 5 Gbit/s communications. The target is a cost-efficient and high reliable FOT suitable for automotive applications. So, Hamamatsu Photonics will outline this idea regarding the use of FOTs for gigabit communications in automotive applications. The basic factors incorporated into the design of the FOT are transmission speed and power budget. This is strongly dependent on the characteristics of the emitter (Tx) as well as the receiver (Rx), and the coupling condition with an optical fiber (**Table 1**). The following factors have been evaluated:

- Optical device
- Receiver
- Package

Evaluation of optical devices

First, the selection of the optical devices has to be considered. The candidates for the light emitter are a semiconductor laser (LD), a vertical cavity surface emitting laser (VCSEL) and a resonant-cavity light emitting diode (RCLED). The RCLED is an effective choice regarding price and reliability. However, the speed of the RCLED is not suitable for high-speed communication up to the gigabit range. Therefore, in the case of using a RCLED, parallel communication like "250 Mbit/s to 500 Mbit/s × n" has to be considered. The parallel method requires multiple parts and the structure becomes complex, so there is no price advantage.

The use of a VCSEL or a LD is necessary for high-speed communication. In the case of those two devices, their speed is sufficient. The reliability has to be considered. Both the VCSEL and LD are used in a wide range of applications. However, in the case of automotive applications, their reliability is unknown. Therefore, their capability for this area has to be checked. From a cost

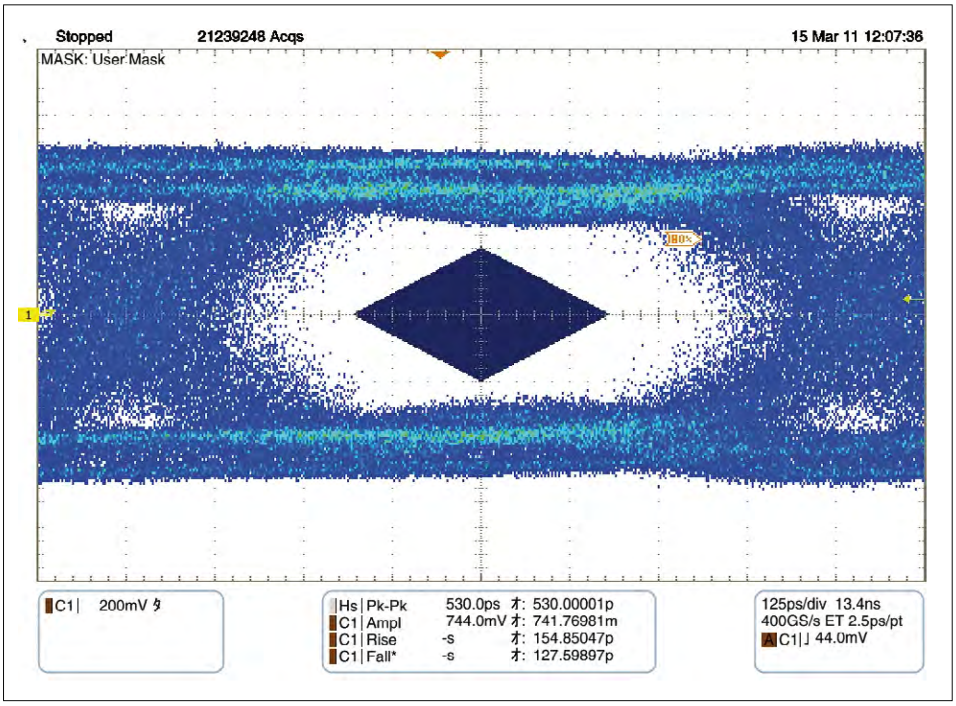


Figure 1. Eye pattern at –20 dBm (850 nm VCSEL), PCF (200 µm diameter), GaAs PD (200 µm diameter).

(Source: Hamamatsu Photonics)

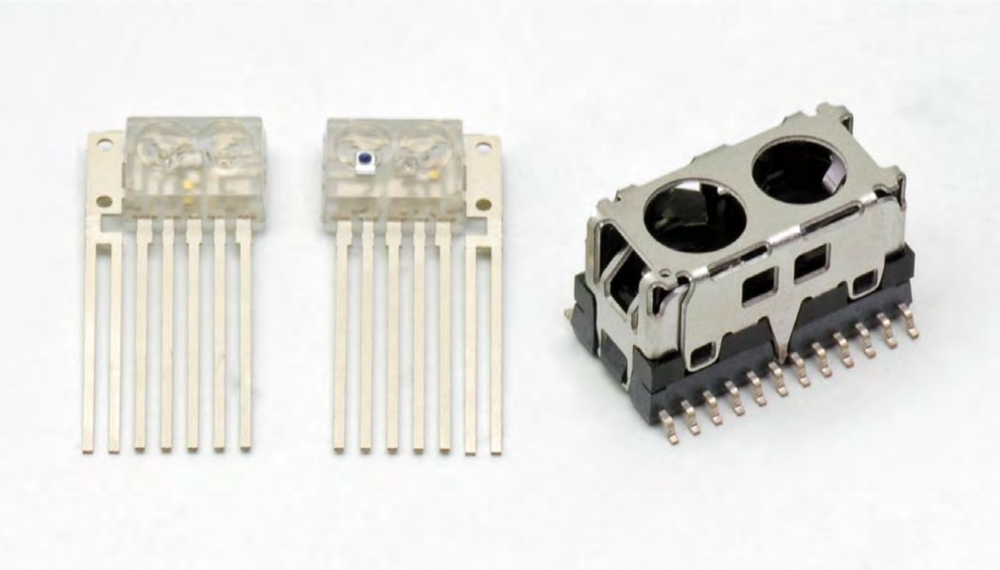


Figure 2. Fiber optic transceiver developed by Hamamatsu Photonics for the use in MOST networks. (Source: Hamamatsu Photonics)

point of view as well as the productivity and the mounting method, a VCSEL is better than a LD. Therefore, Hamamatsu decided to use VCSEL as emitter.

Focusing on the receiver

The next point which has to be evaluated is the receiver. A Si PD has been adopted for existing MOST FOTs. The Si PD is suitable for data rates up to 150 Mbit/s. Additionally, it has a good coupling with the POF. From a material and process point of view, silicon is more cost-efficient in comparison to other materials. However, in the case of gigabit communication, higher communication speed and higher sensitivity at the wavelengths of the emitter side are necessary. For example, optical detectors such as GaAs PDs and InGaAs PDs – the active area size is <100 µm in diameter – can obtain a sensitivity of 0.5 A/W at 850 nm wavelength and a bandwidth of more than 5 GHz.

Evaluation of the package

After evaluating optical devices and the receiver, the package has to be assessed. Due to the higher transmission speed, glass fiber which has a smaller core diameter than a conventional plastic optical fiber (POF), is adopted. Therefore, package technology with a higher accuracy is necessary to maintain the coupling efficiency of the fiber. Also, in the case of gigabit communication speed, the parasitic factor due to the package has to be evaluated.

Often, the Small Form Factor (SFF) which TOSA/ROSA is commonly mounted on, is often too expensive and the SFF is not suitable. Also, the SMD and Sidelooker packages used in existing MOST FOTs are limited with regards to speed and alignment accuracy. To break the limitation, based on experience and technical knowledge in the MOST market, the Hamamatsu proposes a subassembly package including MEMS technology and high accuracy mounting technology.

Prototyping

Hamamatsu Photonics has started trial manufacturing. As mentioned before, the prototype was produced by mounting the optical devices (GaAs PD + 850 nm VCSEL) and the in-house signal processing IC on a Sidelooker package. Regarding the emitter side, in addition to increasing the speed, temperature correction is important. Regarding the receiver side, it is not easy to obtain enough sensitivity because securing S/N is difficult due to the use of broadband amp. You can see the eye pattern at the receiver in **Figure 1**.

Through the feasibility trial manufacturing stage, Hamamatsu Photonics is concentrating on enhancing the FOT sensitivity, increasing speed and improving miscellaneous functions by taking into account the new high-speed IC for next generation MOST networks, based on the experience as an opto-semiconductor manufacturer.

Hamamatsu will propose automotive network architecture with fault tolerance in order to secure a stable power budget in the network. The company is working on the trial manufacturing of the package, including each device and process. The first trial samples will be released this autumn. *eck*

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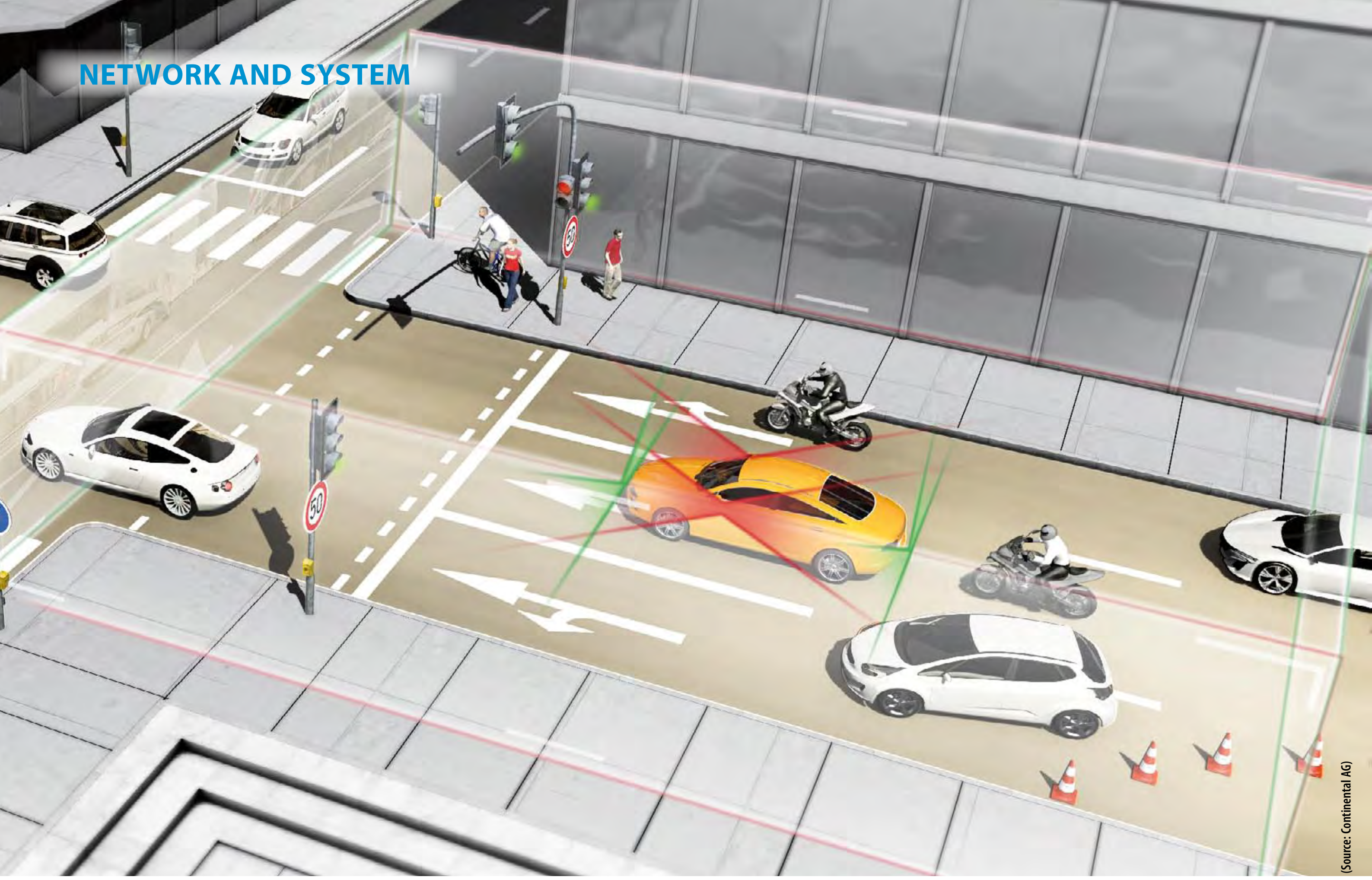

(Source: Continental AG)

Virtual Prototypes – Evaluation Framework for MOST-based Driver Assistance Systems

An efficient communication network is the backbone of distributed Advanced Driver Assistance Systems (ADAS). Analysing such systems in different scenarios under different system parameters is a complex task. Evaluating essential system parameters in an early design phase for the optimum system behaviour is important. This article discusses an evaluation framework based on a virtual prototype for assessing MOST and its role in ADAS.

By Jyoti Joshi, Sebastian Reiter, Alexander Viehl, Oliver Bringmann and Wolfgang Rosenstiel

The number of ADAS in a vehicle is continuously increasing. These systems process the information from multiple sensors such as radar, cameras or the Global Positioning System (GPS). Because these sensors are located all over the vehicle, an efficient data communication network is necessary to share the information between the different ADAS. Additionally, these systems often demand commonly used, complex processing algorithms like fast Fourier transformation or a Hough transformation. It could be beneficial to have dedicated preprocessing nodes for this common task, maybe with optimized hardware architectures. This increases the requirements for the distributed ADAS network. By providing an optimised communication network, the amount of wiring can be reduced. The MOST communication network offers many features that are required for such a task.

The MOST network technology offers a variety of configuration alternatives. They have to be assessed to find the optimal solution, preferably in an early design phase. To support the assessment, an evaluation framework based on virtual prototyping has been developed. It reduces the evaluation complexity of such distributed, network-based applications.

Evaluation Framework – Use Case ADAS

The evaluation framework presented enables the functional and timing verification, performance and reliability analysis and supports design space exploration. Main focuses of the framework are modularity and a generic approach to enable the analysis of a variety of different system alternatives. Therefore, the virtual prototype-based framework is structured in a multitude of basic modules. These modules are aggregated to form the desired system; the ADAS use case scenario, for example, is assembled from around 150 module instances. An extract is shown in **Figure 1**. This allows an easy alteration of the system, such as changing the communication channel – by just replacing or extending the existing system using the appropriate modules. With this approach, it is possible to easily integrate new applications by using already existing IP components. The virtual system is configured using an .xml file, which allows easy assembly and configuration of the modules during runtime.

The distributed ADAS use case consists of two camera devices, a preprocessing module, a circle detection module, a speed sign classification module, a stereo depth map calculation module and a Human Machine Interface (HMI). The system contains two ADAS functions: the Stereo Depth Maps (SDM) and the Traffic Sign Recognition (TSR). The two systems share a common camera device and the image preprocessing module. The communication network has to forward the diverse image streams: the original camera images, the preprocessed images, clippings of the detected circles, the stereo depth map or the classified speed values.

As per the role of a module, the demand on the underlying communication network differs. For instance, the preprocessing model requires a 1-to-n communication association to address multiple receivers. The camera image streams provide a continuous data stream; on the other hand, the clipped traffic signs appear in a burst-like manner. To reveal the impact of the communication technology, the camera streams of the stereo depth map application are analysed in detail.

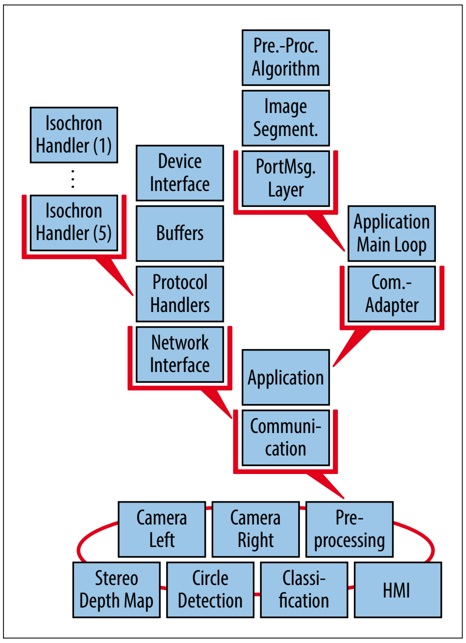

Figure 1. Modular structure of the virtual prototype.

Impact of communication technology on the application

The stereo depth map calculation needs the synchronous delivery of the two preprocessed camera images. If the images are not associated with additional information like a sequence number, it is necessary for the receive buffers to contain continuously synchronised camera images. Therefore, the communication network has to ensure that the left and right camera images are always transmitted in pairs between two subsequent read accesses. Different aspects of the communication network can affect this behaviour. There could be permutations because of e.g. a shared communication channel with non-deterministic access behaviour. Different channel types or channel utilisations could result in varying delays, causing old image instances to be used.

Figure 2 shows a stereo depth map with different displacements between the left and right camera image. The nearby objects appear with warm colours, starting from red, and the distant objects appear in cold colours, like blue. The nearer the object, the warmer its colour is, and vice a versa. In the upper

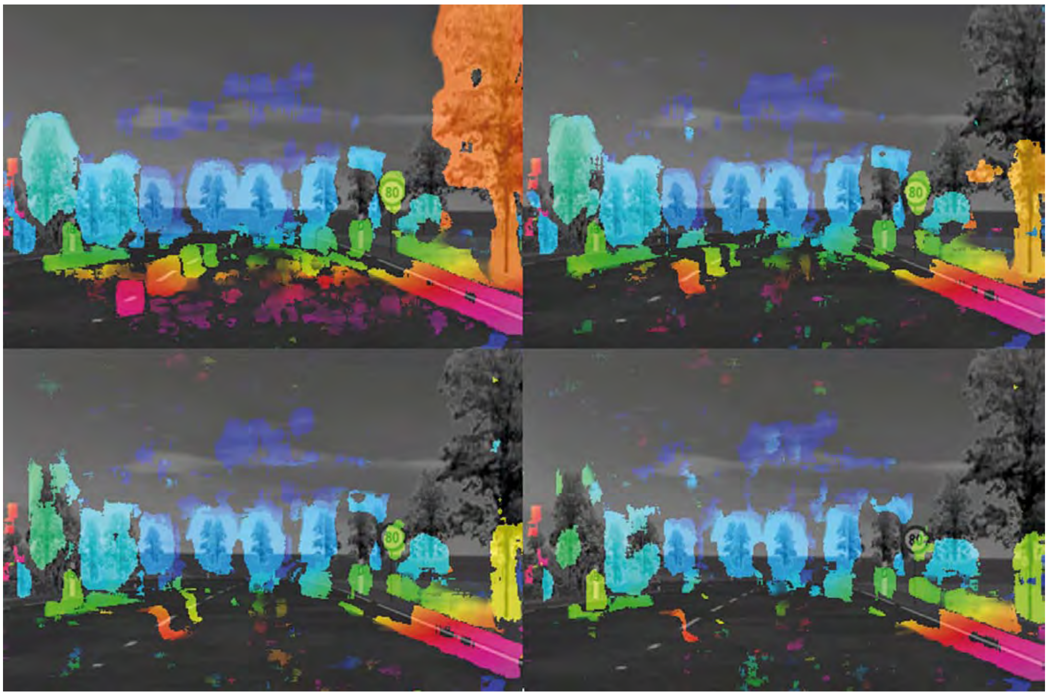

Figure 2. Stereo depth map with different levels of displacement between left and right camera image: (a) no displacement, (b) one frame, (c) two frames, (d) three frames displacement. (Source: FZI)

Figure 3. Evaluation of a TCP/IP and MHP data connection with different tools. (Source: FZI)

left corner, you can see the resulting image with synchronous left and right images. The tree in the front at the right corner of the graphic is well detected. In the top right image, a displacement of one frame between the left and right camera is introduced. The depth information does not cover the complete tree. In the bottom right graphic, a displacement of three frames is inserted. Here, the tree is almost undetected and the information about the distance differs.

The isochronous channel of MOST is the best suited channel for this task. It offers a non-shared channel with a deterministic delay. Because of the continuous image stream, no bandwidth will be allocated unnecessarily. A huge benefit of this channel is that it allows a 1-to-n communication, enabling the reception of the camera image by the preprocessing device and the HMI, which calculates an overlay with depth information.

Optimization of system parameters

Virtual prototyping can be used to determine optimal configuration parameters according to use case scenarios. The key buffers in the ADAS scenario are located between the MOST device and the applications. The buffers are divided into receive and transmit buffers. The receive buffer utilisation is used as an example. The MOST data handler, which models the rudimentary behaviour of the INIC, extracts/writes the data from/to the MOST frame. The data read is stored in the receive buffer every 20.833 µs. On the application side, the buffer is read with the application interrupt rate. These read and write accesses have to be balanced to avoid buffer overflow and subsequent data loss or retransmissions. In virtual prototypes, it is easily possible to monitor the buffer utilisation, e.g. with different application interrupt rates or with various traffic scenarios that influence the frame utilisation.

Evaluation of packet channel sharing applications

A huge potential of virtual prototyping is the analysis of data traffic that depends on a variety of parameters. The evaluation framework allows capturing, monitoring, comparing and analysing the data at the different junctions, for instance, the data sent and received by applications, the data handlers, the different types of buffers or the data on the MOST bus itself. The data access points can easily be defined by the user in the configuration file. This allows the user to analyse the entire system behaviour.

In the following use case, the behaviour of two applications sharing the same packet channel is analysed. In the TSR scenario, the clipped images are

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transferred over the packet channel because no constant bandwidth allocation is necessary. In this scenario the influence of additional connections is evaluated. The first connection is based on the MOST High Protocol (MHP) while the second one is based on TCP/IP over the MOST Ethernet Protocol (MEP). Both protocols are implemented by encapsulating the original protocols – MHP from the NetServices and TCP/IP from the open source lwIP - Lightweight TCP/IP stack.

In **Figure 3** you can see an extract of the generated tracing data for a one sender and one receiver scenario. The bottom graph shows four buffer overflows in the shared receive buffer. The last but two graph shows the buffer utilisation in bytes. The two graphs in the middle show the data sent e.g. by the Circle Detection, (MHPOutNode01) and the data received e.g. by the receiver HMI (MHPInNode00), respectively. The two messages marked with red circles, are lost due to buffer overflow, and MHP retransmits the data at the end of the block. To verify the correctness of the behaviour, MHP traffic trace can additionally be viewed with the OptoLyzer tool suite. MHP sends a MultipleFrameRequest for retransmission of frames 0x02 and 0x09. The top two graphs show the data exchange from the MEP communication. To analyse these communications, the open source packet analyser Wireshark is used. In this use case scenario the TCP/IP retransmission time-out which was triggered by a frame loss due to the third buffer overflow, is long enough to allow the MHP connection to transmit one complete data set. This short example has demonstrated how the evaluation framework can be used to give a detailed insight into system behaviour. With the link to existing analysis tools, a complete integration of the virtual prototyping approach is accomplished.

eck

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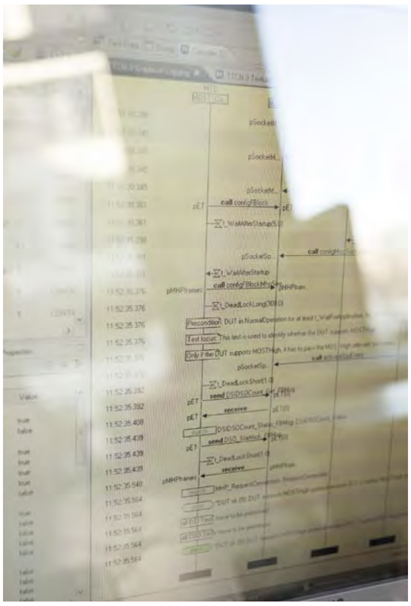
PRODUCT NEWS

Test platform:

Seamless IP-based testing of automotive data communication

Ruetz System Solutions announces the availability of TTsuite 1.3.0, the enhanced version of the well-proven and easy to use test platform. The qualified system integrator for automotive data communication has added several features such as seamless IP protocol-based testing and the creation of test cases out of capture files. In addition, an extended test development kit (TDK) is available.



TTsuite 1.3.0 allows IP-based scenarios to be generated simply by using IP protocol stacks in parallel with the recognised MOST protocol. The user friendly and comfortable test system supports all commonly used IP protocols and description languages. Use cases in the automotive, consumer and telecommunication industries include e.g. Universal Plug and Play (UPnP) and Digital Living Network Alliance (DLNA) requirements.

TTsuite 1.3.0 performs testing of the robust IP protocol stacks using the MOST Ethernet packet (MEP) and MOST data packet (MDP) channels of the in-car network. The latest version offers several plug-ins for commonly used IP protocol support such as TCP, UDP, FTP, HTTP, and SOAP. IP-based test scenarios can easily be created by using these protocol stacks in parallel with the MOST protocol. Moreover, the support of common type description languages like IDL, Protobuf and ASN.1 adds various possibilities for managing complex communication scenarios in a very comfortable way. Since encoding and decoding is completely independent of the data transportation, the protocols can easily be combined and sent over ports such as the MDP or MEP channels in the MOST network.

A new feature of TTsuite 1.3.0 simplifies testing even further by adding an easy to use capture and replay wizard. It is possible to easily create complete test scenarios out of Wireshark pcap (packet capture) capture files. The benefit for users is that no programming skills are required. Multiple capture sources are supported. Test authoring is done quickly and easily. The simulation allows the analysis of real world situations. Users may flexibly create their test configurations out of selected scenarios and decide which communication peers shall be tested or simulated.

Ruetz System Solutions provides an expanded Test Development Kit (TDK) with various opportunities for automation in the areas of physical layer, network, system behaviour, and application for a smooth start to test projects. The added features ease the derivation of tests out of dynamic specifications. Whenever new test cases need to be derived out of message sequence charts (MSC), the Test Development Kit meets this challenge, providing an excellent solution. Performing default routines for error and time-out handling make test specifications purport to be like the original MSC but behave like a tester. With this behaviour being contrary to the ECU's target, the tester provokes a stress scenario for the ECU.

Ruetz System Solutions
www.ruetz-system-solutions.com

Data logger:

MOST streaming data recording with blue PiraT

MOST150 for the transmission of multimedia data in vehicles as well as the MOST50 technology enjoy an increasing demand in the automobile industry. So Telemotive has extended the established blue PiraT data logger family to also cover the ability to record the synchronous part of the MOST50 streaming data. Synchronous data is used for the real-time transmission of audio and video data.

Due to the wide range of vehicle bus interfaces, the blue PiraT 50M5C1SW2L is able to record MOST Status information MPR/SBC/MOST-Lock/Master-Lock, Control messages, Packet data and, as a new addition, synchronous streaming data. The client software provides this data in the common IMG format, using individual user selection possibilities.

The MOST50 streaming functions are available as a license for all blue PiraT MOST50 data loggers. All blue PiraT models offer high flexibility, an automotive qualification, paired with power management, ease-of-use operation, compact product size and various extensions.

The next upcoming highlight for blue PiraT2 data loggers is the ability to record MOST150 streaming data (synchronous and isochronous data), which is currently under development and is going to be available in the second half of 2013.

Telemotive
www.telemotive.de

Data loggers:

Parallel logging of MOST, CAN, LIN and FlexRay messages

Time-synchronous logging of MOST150 data is now possible using data loggers of the GL3000/GL4000 logger families together with the GLA150 accessory. GLA150 is based on the established VN2640 MOST150 interface by Vector and utilises its proven spy function and performance. With GLA150 support, the loggers log the control channel and the asynchronous channel with both MOST Data Packets (MDP) and MOST Ethernet Packets (MEP). The subsequent evaluation is carried out e.g. with the extensive functions of CANoe or CANalyzer.

Data logger GL3100

GLA150
for MOST150 speed grade

This complete solution now permits parallel logging of MOST, CAN, LIN and FlexRay messages. Other inputs enable acquisition of the signal level on the Electrical Control Line (ECL). Users can apply this solution to automate the transfer of data from their vehicle buses to company servers over WLAN or 3G. Test fleet operators, in particular, will appreciate the low quiescent current consumption of the loggers in sleep mode, which preserves car batteries.

The data logging is prepared on a PC with the logger configurator, whose convenient user interface makes it easy to select operating modes e.g. either continuous or triggered logging. You can also activate options to reduce data volumes for long-term recordings there. The ASC, BLF and IMG file formats are directly supported while other formats used in the MOST field can be created by conversion in Vector tools.

Vector Informatik
www.vector.com

MOST150 controller:

Multitalent for multivalent applications

Introducing basic MOST 6161, Goepel electronic has extended the range of communication solutions for MOST150. The new stand-alone module can be integrated in test environments for electronic control units (ECUs) via either USB or Ethernet interface. Both host interfaces are provided in parallel.

Basic MOST 6161 can execute bus master and slave functions within a MOST ring configuration. Furthermore, a so called Spy Mode is provided in which basic MOST 6161 does not simulate active bus participants but records the data traffic on the MOST bus. Control, package and streaming channels are supported in MOST transmission.

In addition to the MOST150 interface, the module provides numerous test resources, such as two communication interfaces to be configured as CAN, LIN or K-Line. They allow for execution of gateway or routing functions, e.g. the transfer of the speed signal from CAN to MOST for speed-independent volume control. According to specification, the Electrical Control Line (ECL) represents an additional line to the MOST bus, designed for status requests or ring break detection.

Furthermore, the signals SPDIF IN/OUT for audio streaming via synchronous and isochronous channels as well as a DVI interface for connecting an external monitor are supported. An optional breakout box can be provided to make the module more robust for lab utilization with frequently changing connectors. The breakout box provides the mentioned signals to connectors with respective mechanical wear resistance.

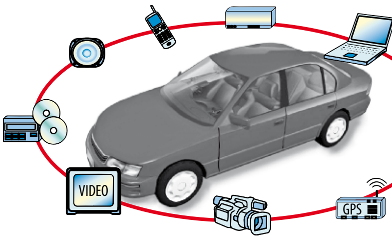
In terms of software, users are supported by a convenient user interface (GOEPEL-API), facilitating the module integration in individual hardware and software projects. User access to the INIC command set is possible without additional net services. An extensive macro library with configurable single test steps is provided for users of Goepel electronic's test sequencer software "Program Generator".

Goepel electronic
www.goepel.com

Fiber optic transceiver:

Taking MOST to the next level

Hamamatsu Photonics has been producing MOST parts for more than ten years. The company has sold about



100 million components of six different FOT models with a failure rate of <0.1 ppm.
Hamamatsu is developing a new FOT for the next generation MOST network which will be capable of transmitting 5 Gbit/s. To achieve such high data rates, a technology change for both transmitter and receiver is necessary. For the receiver, a GaAs photodiode is used instead of a Si component. These receivers have a higher sensitivity and a higher bandwidth than Si diodes. For the transmitter, a vertical cavity surface emitting laser (VCSEL) is evaluated. The coupling efficiency of VCSELs into the fiber is very high and the emitted peak wavelength can be adapted to the receiver. Because of the higher transmission speed, a glass fiber with a smaller core diameter is used instead of a plastic optic fiber. Therefore, the package manufacturing will also be a challenge as it has to be built with a very high accuracy to maintain the coupling efficiency. As a feasibility study, Hamamatsu Photonics has already started trial manufacturing. The first trial samples will be available in autumn of 2013.

Hamamatsu Photonics
www.hamamatsu.de

Fiber optic transceiver:

MLX75605 fully deployed for MOST150

The first cars with a Melexis fiber optic transceiver (FOT) inside will take the road during 2013. The innovative design of the Melexis surface-mount FOT has been proven in development with suppliers to provide high performance at a competitive total cost of ownership.
Melexis' capacity for mass production of the MLX75605 FOT is fully deployed for both the MOST150 and MOST25 surface-mount FOT versions. The customised SOIC24 SMT package and tough specifications represented a significant development challenge in deploying production testing. Hence the transition from pilot production to full volume is a significant milestone.
The MOST150 FOT (MLX75605) is fully compliant with MOST150 oPHY Automotive Physical Layer Sub-Specification Rev. 1.1. It shows an unprecedented sensitivity, hitting the limits of fundamental physical barriers. The maximized optical budget provides the necessary robustness required for years of reliable operation in the field.
MLX75605 also has a MOST25 twin (MLX75608) running on the same production line: the packages and pin out are almost identical. Both devices benefit from more than two decades of Melexis experience in providing automotive quality microelectronics solutions.

Melexis
www.melexis.com

Oscilloscope:

One for all

Agilent Technologies now offers physical layer compliance testing of MOST50 and MOST150 standards. Agilent's N6566A compliance application is compatible with all current Infiniium oscilloscopes. So, jitter measurements, clock recovery and eye measurements can be bundled into the compliance application, eliminating the need to purchase additional add-on oscilloscope applications for testing of MOST Technology. In addition, Agilent's 81160A pulse/pattern generator provides an ideal lower cost alternative for generating test stress patterns.

Agilent Technologies
www.agilent.com

Hardware interface:

Interlink between automotive bus networks and test PCs

The simulation, testing and verification of MOST devices and systems can be a challenging task, especially when the device under test (DUT) needs to be physically built into complex test systems. The best solution for complete test coverage would offer a comprehensive feature set in all aspects of simulation, testing and verification delivered through a single hardware interface.

The new OptoLyzer MOCCA Compact by K2L is a flexible hardware interface which incorporates all the necessary features to act as an interlink between leading-edge automotive bus networks and test PCs. It supports connectivity to CAN (high speed, low speed, single wire), LIN, FlexRay, and MOST (MOST25, MOST50 or MOST150) and offers a convenient connection to a client PC through USB.
In addition to its simulation and verification capabilities, the OptoLyzer MOCCA Compact provides a number of capabilities to support stress testing for all interfaces.
The integrated .NET-based programming interface offers all the benefits of customised or third party software solutions. It also provides full support for K2L's current portfolio of software solutions, including ATS and OptoLyzer Suite.

SMSC
www.smsc-ais.com

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