

MOST on Hyper Speed

Robust and low-cost MOST network with a data rate of 1 Gbit/s for automotive applications

The automotive industry is steadily increasing the electronic content of its cars with the addition of sensors, cameras, and displays. These new subsystems will implement both advanced driver assistance systems (ADAS) and high quality infotainment systems.

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In order to keep control over cost and reliability of the system in the face of higher bandwidth demands, the currently used physical media (POF) and optoelectronic devices (LEDs and Photo diodes) should ideally remain in place.

This paper presents the KDPOF technology proposal for POF-based communication systems. KDPOF believes in upgrading the physical layer as the only feasible alternative for the industry. As such, a new simplified physical layer is presented to reach a data rate of 1 Gbit/s.

Video applications demand higher bandwidth

Current MOST versions MOST25 and MOST50 and the newest specification MOST150 provide enough bandwidth for infotainment functions like radio, multiple DVD players/screens or video games. Today, however, new sensors are being added to the cars in the form of cameras and radar, displays to show information to the driver and, on top of all this, ADAS functions that have to deal with a large amount of data. In the near future, HD video will be demanded by users as an extension of their home experience.

The most demanding functionalities in terms of communication bit rates are

the video applications, where cameras send all the video information from their location to displays or ADAS subsystems. In addition to high capacity communications demands, these systems have very low latency requirements: less than 1 ms for user-related sensors, and around 1 μ s for automatic sensors.

POF is the best option for providing the required gigabit links in the car. There are new POF technologies like Graded Index (GI) POF with more bandwidth and attenuation, but with better possibilities for high speed communications. However, GI POF technology is still not mature compared with the current SI POF; it is more expensive, and it has not yet been tested and approved for the automotive industry.

Within this context, the reuse of current stable, robust, and proven LED and SI POF technologies should be the preferable choice. But when

using transceivers similar to the current MOST150 devices for a gigabit solution, the maximum length of the fiber will be a few meters, and communication probably could not be established under real life bending conditions.

Current transceivers are based on Non-Return Zero (NRZ) modulation and Bi-phase Mark Coding (BMC) with a direct decision at the receiver by means of a limiting amplifier. In order to increase the data rate from 150 Mbit/s to 1Gbit/s while keeping the modulation scheme, the symbol rate should be increased almost by a factor of seven. Therefore, the communication system would be demanding almost seven times more bandwidth, strongly limited by the current optoelectronic devices and SI POF.

Clearly a new technological approach is required in the industry to fill this gap.

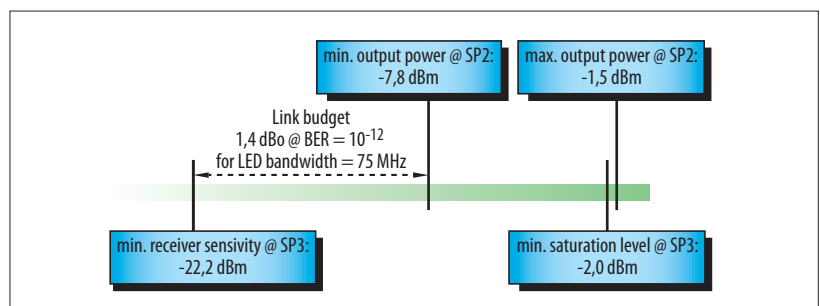


Figure 1. Link budget.

Using advanced tele-communications techniques

KDPOF proposes the use of advanced telecommunication techniques in the POF media. These techniques are widely used in cable and wireless communication systems 10G base-T or Wi-Fi.

KDPOF takes a look at the POF media not as a perfect glass fiber communication system where simple NRZ gives a good trade-off between performance and cost, but as a system closer to copper cable or air, where communication channels are much more complex. KDPOF technology defines four parts of the communication system physical layer:

► **Modulation:** KDPOF implements the multi level Pulse Amplitude Modulation (PAM) technique. The number of levels is defined by the bandwidth, the required bit rate, and the coding. Detailed studies on link power budget maximization show that there exist optimum values for the number of levels and the signal bandwidth in order to provide a robust gigabit link. These

LED bandwidth [MHz]	Link budget [dBo]
75	20.1
100	20.6
350	21.6

Table 1. Link budget.

values have a very small dependency on the launching mode distribution, wavelength width, and the fiber length. This paper shows that a 16-PAM and a bandwidth of about 150 MHz are the best choices to provide 1 Gbit/s with the maximum link power budget.

► **Equalization:** KDPOF technology uses an advanced channel and noise equalization system, allowing accurate channel and noise estimation and compensation. This part cancels the distortion created by the fiber and the optoelectronic devices. Linear and non-linear components of the channel response are compensated. The equalization is based on Tomlinson-Harashima Precoding (THP), where the channel post-cursor response is compensated at the transmitter. The pre-cursor response and noise are equalized at the receiver. The equalization is the most relevant part of the architecture in terms of link budget for MOST in gigabit applications.

► **Channel coding:** This is a challenging part of the communication system. Current state-of-the-art coding, such as LDPC (Low Density Parity Check) and turbo codes, are very expensive in terms of silicon area and power consumption when managing a bit rate of 1 Gbit/s. KDPOF technology implements a low power Multi-Level Coset Code (MLCC), which minimizes the silicon area and power while keeping very good error correction performance operating close to the Shannon limit. The MLCC is based on binary algebraic component codes, ensuring the absence of an error floor, thus enabling the operation of the system with arbitrarily low BER. This part has an important contribution to the link budget, providing a coding gain of 7.2 dB (3.6 dBo) for BER $<10^{-12}$.

► **Frame building:** The encapsulation of the higher layer information in the physical layer requires a flexible and efficient frame building, with preambles of correct size for synchronization and equalization, headers for announcing the basic physical layer parameters and to encapsulate higher layer data, as well as a required CRC to guarantee packet integrity.

Link budget for gigabit MOST

KDPOF's physical layer provides a reliable and feasible gigabit MOST solution in terms of link budget.

For the link power budget calculations, an LED with a wavelength width FWHM (Full Width at Half Maximum) of 20 nm, a numerical aperture FWHM of 0.3 (with launching condition similar to EMD), and a POMA of 0 dBm is considered. Alternatively analog -3 dB electrical bandwidths are considered in order to show how the link budget depends on this parameter. The link budget is calculated for a 20 m SI POF (A4a.2) and POF attenuation is included within the link budget, as it is for MOST150. In other words,

POF response is considered DC normalized, with all modal dispersion and the consequent ISI included within the link power budget evaluation.

A state-of-the-art integrated optical receiver is considered. The response

LED bandwidth [MHz]	Link budget between SP2 and SP3 [dBo]	SP3 sensitivity [dBm]
75	14.4	-22.2
100	14.9	-22.7
350	15.9	-23.7

Table 2. Link budget for MOST with 1000 Mbit/s.

sensitivity is 0.5 A/W at 650 nm and the trans-impedance is adjusted to optimize the noise-bandwidth trade-off as a function of the baud-rate and modulation level.

Figure 1 shows the link budget as a function of the signal baud rate. The link budget has a maximum between 300 and 400 MHz, for LED bandwidths between 75 and 100 MHz, and somewhat more than 400 MHz for 350 MHz. In order to enable longer POF distances and prevent clock synthesis issues, KDPOF has selected 312.5 MHz for the gigabit MOST solution. Therefore, it is based on $f_s = 312.5$ MHz, 16-PAM modulation, providing a spectral efficiency of about 3.3 bits/symbol (6.6 bits/s/Hz).

Based on this sampling frequency, the link power budget referred to the OMA (Optical Modulation Amplitude) = 0 dBm @ SP2 is summarized in table 1.

From the previous values it is easy to extract similar figures of merit comparable with the MOST150 ones. Considering an Extinction Ratio (ER) ≥ 10 dBo and a minimum average power @ SP2 of -7.8 dBm, a minimum

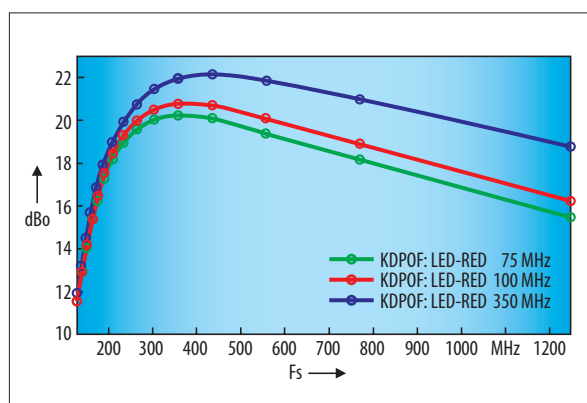


Figure 2: Link budget scheme.

OMA @ SP2 of -5.66 dBm can be seen. From this, one can calculate the receiver sensitivity as well as the link budget as it is calculated for the MOST150 case. The figures are summarized in **table 2**.

As it can be seen, KDPOF is able to provide a link budget between SP2 and SP3 for MOST with 1000 Mbit/s similar to the one currently available for MOST150 based products. The results show the suitability of KDPOF

technology as a reliable and robust physical layer for the next generation MOST with data transmission rate of 1000 Mbit/s. **Figure 2** summarizes the results for KDPOF and an LED bandwidth of 75 MHz. *sj*



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Know-how for study and work

MOST – The automotive multimedia Network

MOST (Media Oriented Systems Transport) is a multimedia network technology developed to enable an efficient transport of streaming, packet and control data in an automobile. It is the communication backbone of an infotainment system in a car. MOST can also be used in other product areas such as driver assistance systems and home applications.

ISBN 978-3-645-65061-8
€ 49,95 UVP

