

An Automated Model Based Design Flow for the Design of Robust FlexRay™ Networks

Thorsten Gerke

Synopsys GmbH

David Bollati

C&S Group/University of Applied Science Wolfenbüttel

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ABSTRACT

The enormous increase of vehicle functions realized through electronic components significantly impacts the communication within the vehicle network. More functions are requesting higher bandwidth; safety applications require a deterministic communication scheme to ensure reliable system performance even under harsh real world conditions. The new FlexRay vehicle communication standard addresses these requirements, with production networks already on the road. The high transmission rate introduces new challenges for network developers dealing with the implementation of the electrical physical layer as the dynamic behavior of the system cannot be predicted using manual calculations. The FlexRay physical layer working group has therefore established a simulation task force dealing with issues related to FlexRay's physical layer implementation. This task force has developed a virtual prototype based methodology to give network developers early verification of FlexRay physical layer implementations. Topology variants that depend on equipment in the vehicle can be investigated quickly with regard to their robustness under nominal and even worst case conditions. This paper introduces an automated, simulation-based methodology based on the guidelines and criteria defined in the FlexRay physical layer specification. In addition, this paper shows how close OEMs, IC vendors, conformance testers and software tool vendors must work together to define and realize a robust design methodology that is based on a virtual prototype implementation of the FlexRay network.

BASICS OF FLEXRAY COMMUNICATION SYSTEMS

When developers are dealing with In-Vehicle network implementations they have to ensure that both the software part as well as the electrical physical layer implementations is robust. The design and verification of both parts is usually very time-consuming. Sufficient testing is not possible using vehicle hardware prototypes

since these are usually not available in the very early design stage when network concepts need to be evaluated in terms of their robustness. This paper shows how to design and verify the physical layer implementation of FlexRay systems through an automated and robust simulation based engineering method. The focus of this paper is on the verification methodology. Details about the FlexRay protocol and how to model them are comprehensively described in [4]. The FlexRay protocol and its electrical physical layer are specified in the FlexRay protocol and the Electrical Physical Layer (EPL) specification. These activities are standardized through the FlexRay consortium which is a society of all major automotive OEMs and their suppliers. Unlike the most popular CAN communication protocol, FlexRay is a time triggered communication protocol with a maximum transmission rate of 10 MBit/s. This is 10x higher than the theoretical transmission rate of CAN

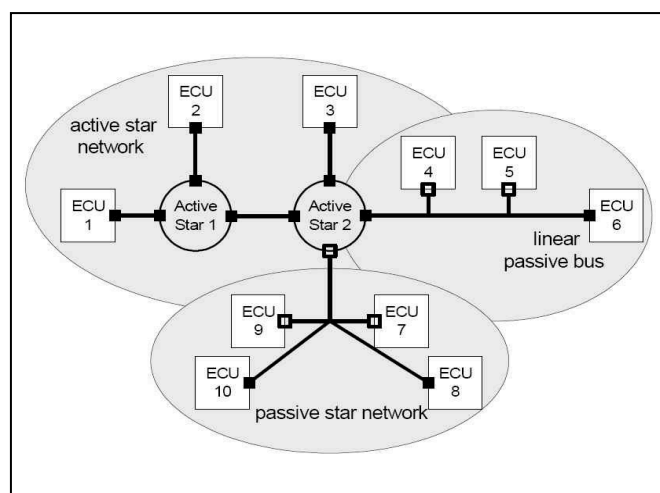


Figure 1: FlexRay topology (source FlexRay EPL)

which is 1 MBit/s (in practical applications the transmission rate of CAN is usually below 1 MBit/s to ensure enough robustness). FlexRay allows arbitrary topology types like linear, star or even hybrid as shown in figure 1. Figure 2 shows a possible future vehicle

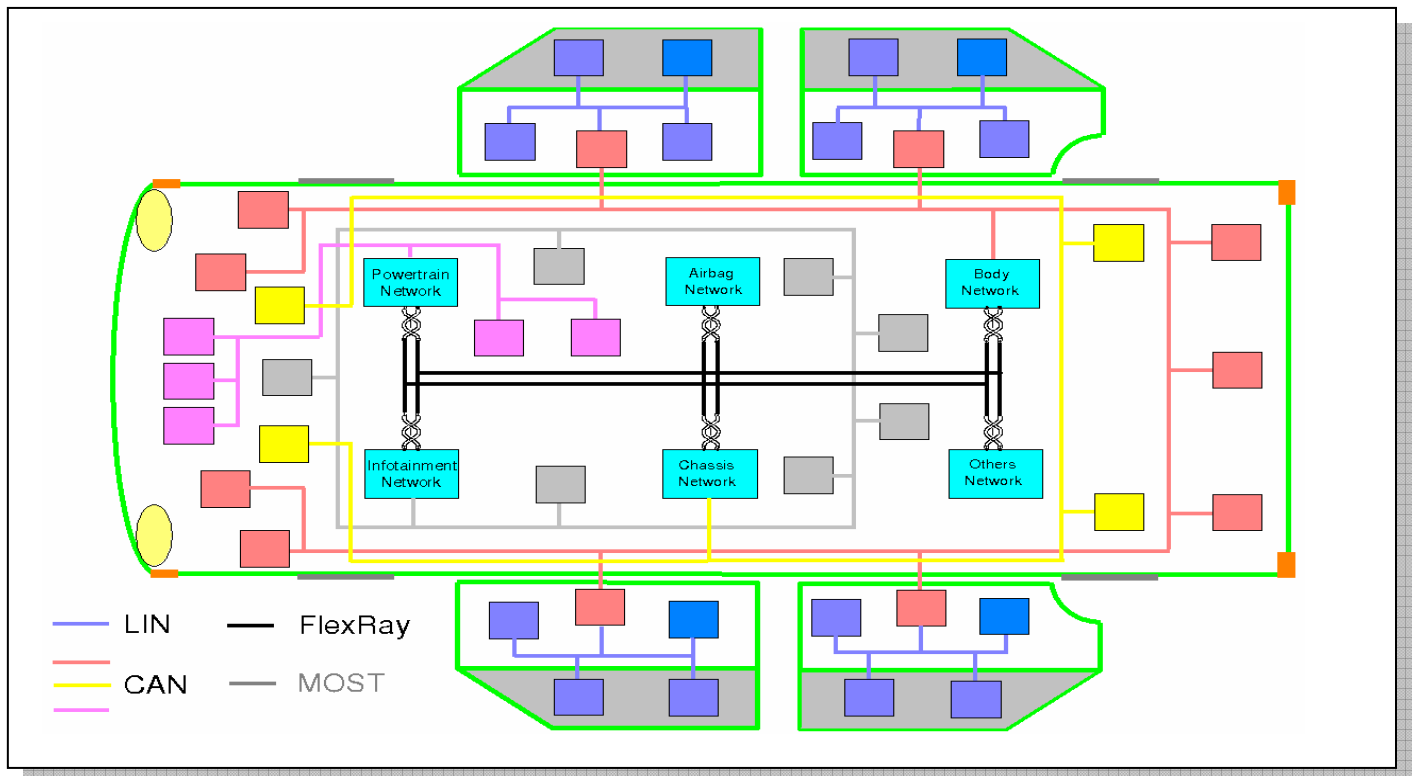


Figure 2: Possible future In-Vehicle Network topology using FlexRay

network implementation which uses FlexRay as a backbone communication channel to interconnect several networks together. One of the challenges while developing the implementation of FlexRay topologies is the signal integrity. The network developer dealing with the physical layer implementation of the vehicle network topology has to ensure a reliable implementation in terms of the signal integrity over the complete lifecycle of the vehicle. Furthermore, the reliability of the network implementation against component variations due to manufacturing tolerances or environmental impact must also be ensured. This is an enormous challenge for the network developer, considering that this verification needs to be done for all vehicle platforms. This cannot be done through vehicle prototype testing since not all vehicle platforms are available before Start of Production (SOP). Even if they were available the developer could not perform tests across all variants since it would be too time consuming due to the time-to-market pressure. The FlexRay EPL specification gives guidelines for the implementation of the vehicle topology but does not prescribe any specific components. In addition, the specification does not ensure that the implementation will function even if the guidelines have been followed. The major problem related to the verification of these systems is the dynamics. The high dynamic behavior makes any manual calculation of the signal integrity impossible. Thus simulation is the only choice to evaluate the reliability and robustness of the FlexRay physical layer implementation before a vehicle prototype is built. This helps developers discover and fix problems very early in the design process before the hardware is assembled.

EVALUATION CRITERIA FOR THE SIGNAL INTEGRITY OF FLEXRAY NETWORKS

The FlexRay EPL specification defines valid ranges for system aspects related to signal integrity. This ensures interoperability of the system from an electrical perspective. The major items are:

- Asymmetric Delay
- Propagation Delay
- Truncation of the Transmission Start Sequence
- Bit deformation due to ringing and reflections
- Message frame stretching due to ringing after transition from active to idle

These items must be evaluated to prove the robustness of the electrical physical layer implementation. This paper focuses on evaluation of the asymmetric and propagation delays as well as on the bit deformation. In addition, a methodology will be presented showing how to automate the evaluation process. All items listed above are heavily dependent on the specific implementation of the topology which includes:

- Topology architecture (Linear, Star,...)
- Wire lengths

- EMC and HF circuitries
- Transceiver type

These aspects are explained in detail in [4] and will be explained in a compressed form in this paper.

Although FlexRay is a digital communication protocol the behavior of the signal along the path between different Electronic Control Units (ECU) is highly analog. Figure 3 shows this fact in detail. ECU 1 sends out a digital bit stream across the network to the other ECUs. Unlike the ideal edges of the transmitted frame, the bits appear in a corrupted form on the bus. This is caused

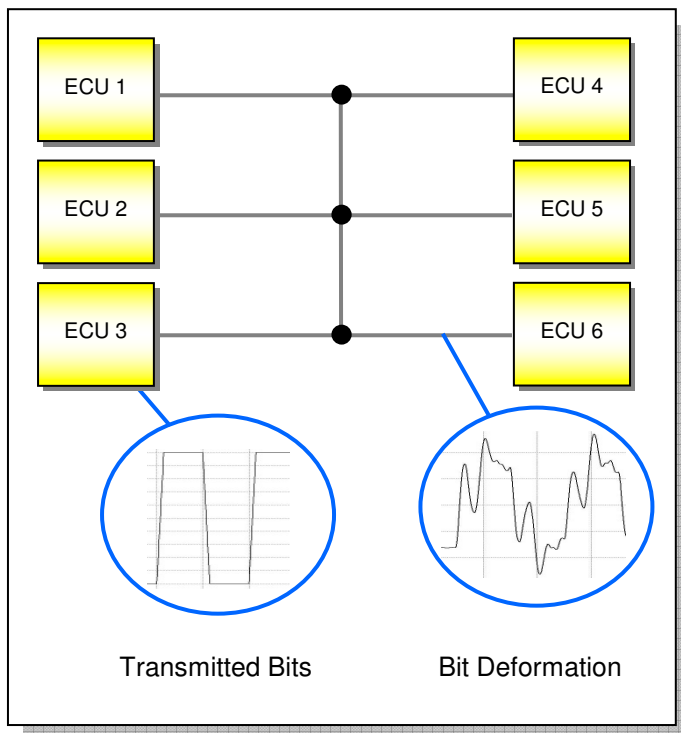


Figure 3: Bit deformation during transmission

by circuit ringing, reflections, and other parasitic effects. FlexRay provides very robust mechanisms, such as majority voting, to ensure glitches caused by bit deformation or RF injection issues are covered. But it is also the responsibility of the network developer to ensure that bit deformation due to the topology does not inhibit communication among the ECUs.

Since behavior of the transceiver and other network components is never ideal, the falling and rising edges of the bits are associated with different slew rates. In addition, the transmission delay through the transceiver for the two logical levels (0 and 1) is different. Furthermore, the threshold levels of the transceiver may vary within a valid tolerance band which is defined in the FlexRay EPL specification. All these items have an impact on the length of the bit that actually arrives at the receiving node. This means a transmitted bit can be longer or shorter than the original signal. The amount of

change with respect to the original bit length or duration is called asymmetric delay. This delay has a significant impact on the correct sampling of the bit values.

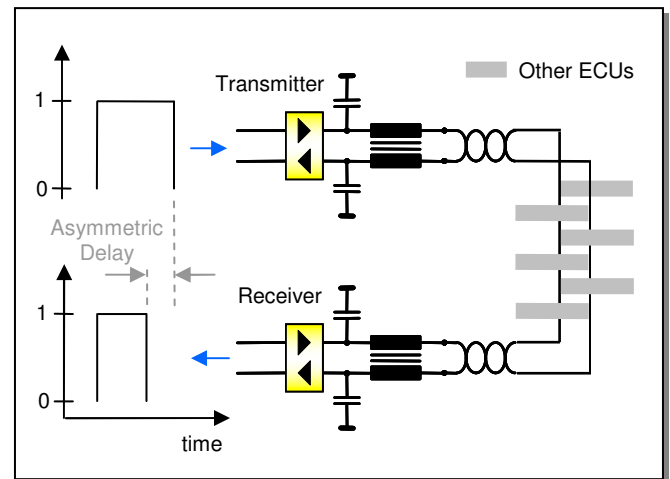


Figure 4: Asymmetric Delay

Therefore the FlexRay EPL specification defines limits for the allowed asymmetric delay to ensure that the topology implementation satisfies the timing requirements.

In addition, the propagation delay needs to be evaluated since it has an impact on the precision of the overall clock synchronization. The propagation delay describes the time lapse between the point in time when the bit was sent out by the transmitting ECU and when it arrives at

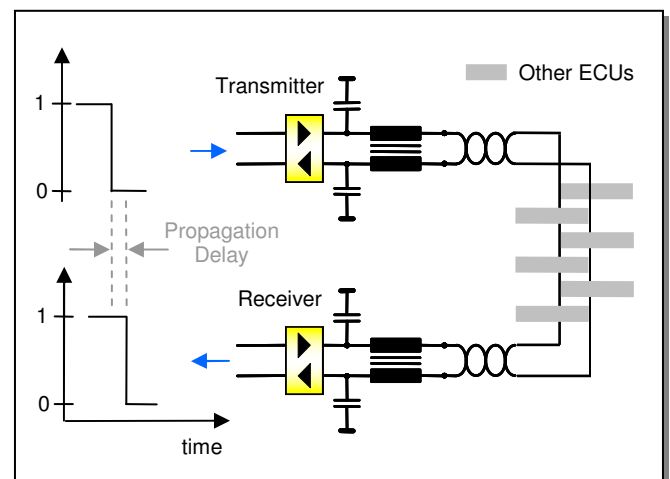


Figure 5: Propagation Delay

the receiving ECU. Figure 5 explains the propagation delay for a FlexRay network example. The propagation delay must be evaluated for all possible signal paths of the topology.