Physical Layer Design for ECU Nodes in FlexRay-based Automotive Communication Systems

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***Abstract* – This paper presents the physical layer design comprising the Bus Guardian (BG) and Bus Driver (BD) used in an in-vehicle network compliant with FlexRay standards. FlexRay is a new standard for data/signal communication among electronic devices installed in a vehicle. The Bus Guardian is one of the most important components in charge of security and safety for the FlexRay standards. The Bus Guardian proposed in this work is implemented by hardware description language (HDL) and co-verified with our prior FlexRay transceiver using a typical 0.18 um mixed-signal CMOS process.**

Key word: FlexRay, Bus Guardian, physical layer, transceiver, automobile electronics, in-vehicle networking

I. INTRODUCTION

Car electronic has been deemed as the 4th "C" right after Computer, Communication and Consumer electronics. Many novel electronic devices have been introduced and installed in recently publicized cars. Therefore, an in-vehicle network has been proposed to control and supervise all of the automobile electronics. FlexRay is designed for an in-vehicle network to provide message and data exchange among electronic devices. FlexRay will not replace the existing network. By contrast, it can integrate and co-exist with existing network systems, including CAN (Controller Area Network), LIN (Local Interconnection Network), MOST (Media Oriented System Transport) and J1850 protocol etc.

FlexRay requires 10 Mbps data rate in either one of the two channels of an ECU (Electronic Control Unit) [1]. If a single channel is used alone, the speed of the total data rate is expected to reach 20 Mbps. Therefore, even the video signals, multimedia and control signals can communicate via the FlexRay system by such a high bandwidth. The ultimate goal is that the automobile is X-by-wire (X = steer, break, accelerate, A/V, safety, etc.). Fig. 1 shows the features of FlexRay (X-by-wire). Fig. 2 depicts the block diagram of the ECU composed of Hosts, a Communication Controller (CC), Bus Drivers (BD) and a Bus Guardian (BG).

II. BUS GUARDIAN DESIGN FOR FLEXRAY SYSTEMS

The proposed Bus Guardian is in charge of security and safety for FlexRay communication systems. It protects a channel from interference caused by any message that is not aligned with the communication schedule. To meet the requirements of the FlexRay specification, the Bus Guardian is composed of the following function blocks.

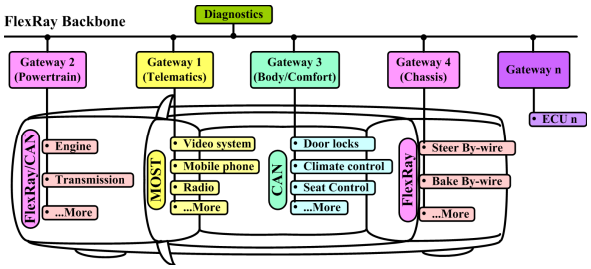

Fig. 1. The feature of FlexRay is used (X-by-wire).

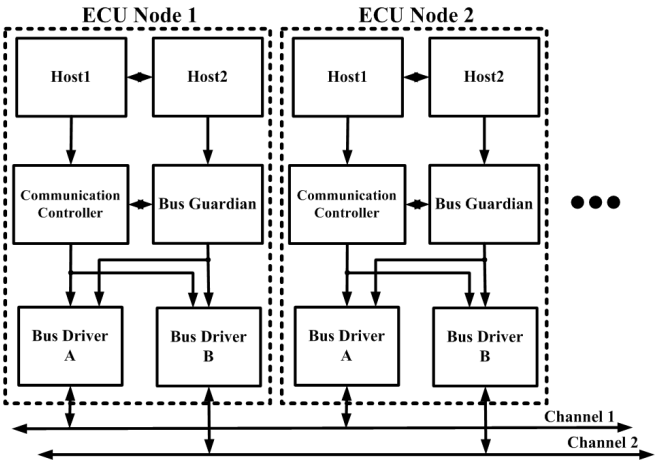

Fig. 2. Block diagram of ECU nodes in a FlexRay system.

- **BG POC:** Bus Guardian protocol operation control (BG POC) is the overall control state machine within the BG. The BG POC has a similar functionality as the POC in the CC.
- **Communication controller based functionality:** The BG has an independent clock synchronization mechanism, including rate and offset correction and macrotick generation, from the local CC. The BG utilizes the same core mechanism as a Communication Controller (Decoder, MAC, FSP (Frame and Symbol Processing) and CSP (Clock Synchronization Process)).
- **CC Supervision (CCS):** This block supervises the slot scheduling of the local CC during wakeup, startup and normal operations and generates the BGE signal to enable and disable access for the local CC to the communication medium. If the local CC attempts to access the communication medium when it is not allowed, the BG generates an error message to the Host. The BG disables access to the communication medium depending on the detected error.

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The infrastructure of this Bus Guardian specification distinguishes the BG POC operation from the CC supervision process. The BG POC includes all functionalities to integrate the Bus Guardian device into a cluster as an integrating node (configuration, integration…). The CC supervision (CCS) process performs the supervision of the CC. In order to reduce the power and area consumption, we integrate the Communication-Controller-based functionality block and BG POC block into Communication Controller as depicted in Fig. 3. Fig. 4 depicts the signals among all of the processes and the interface to the Bus Guardian required to supervise the communication controller during different protocol operating modes, including wakeup, communication startup, and synchronized operations. The TxEN signal is a transmission enable signal issued by Communication Controller. If the TxEN signal is enabled out of the communication schedule, the scheduler denies the bus access and the BGE (Bus Guardian enable) signal is not enabled to stop the signal transmitting to the bus.

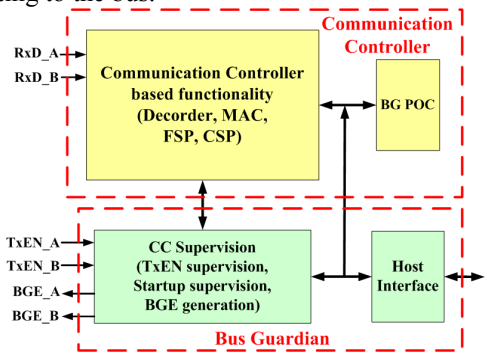

Fig. 3. The block diagram of Bus Guardian.

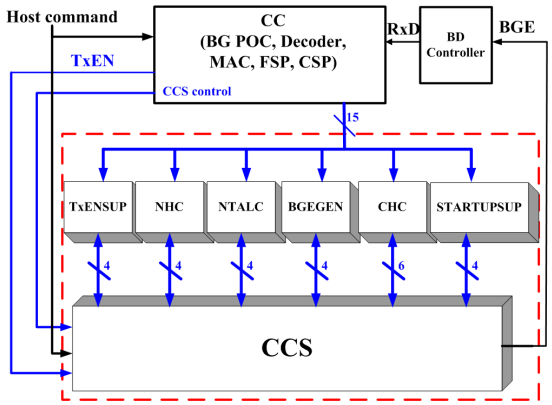

Fig. 4. CCS process signal interface.

III. Implementation and Simulation Result

The proposed design is carried out by a typical 0.18 um single-poly six-metal CMOS technology. Fig. 5 shows the layout of the proposed Bus Guardian and Bus Driver design. The post-layout simulations of the proposed design are shown in Fig. 6, the throughput of the transmitter and the data rate of the receiver can reach 40 Mbps in a single channel. The system clock is 80 MHz and the average power consumption of the proposed Bus Guardian is 3.22 mW. Table I gives a comparison with the prior work [2]. The Bus Driver proposed in our prior work [3] and the proposed BG implemented on a FlexRay development board are used to set up a FlexRay system test environment as shown in Fig. 7 to justify the performance of the entire physical layer design.

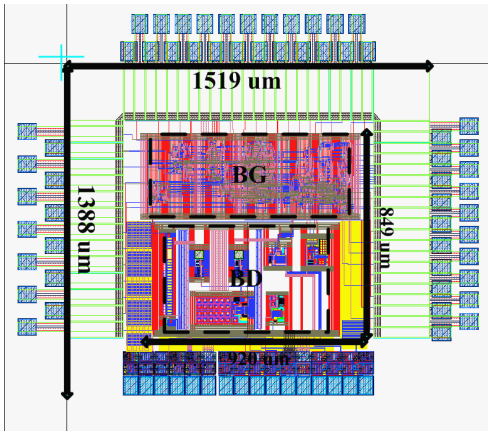

Fig. 5. The layout view of proposed design.

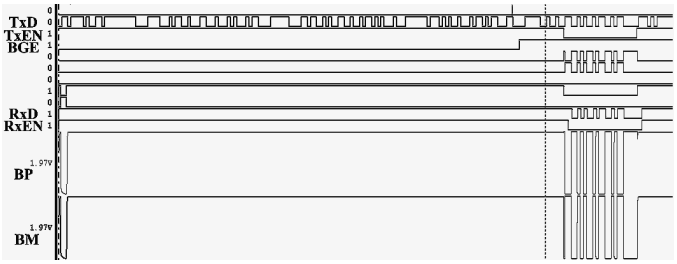

Fig. 6. The post-layout simulation result.

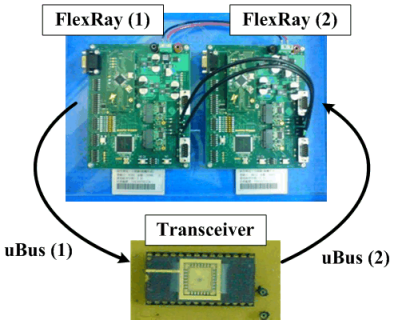

Fig. 7. Test environment of FlexRay system.

TABLE I
COMPARISON IN CATE COUNT AND CLOCK RATE

	Gate Count	Main Clock
[2]	60,000	47 MHz
ours	4,550	80 MHz

References

[1] FlexRay Communication System Electrical Physical Layer Specification V2.1 (http://www.flexray.com), 2005.

[2] P. M. Szecowka, and M. A. Swiderski, " On hardware implementation of FlexRay bus guardian module," *International Conference on Mixed Design of Integrated Circuits and Systems 2007*, pp. 309-312, June 2007.

[3] C.-C. Wang, G.-N. Sung and P.-C. Chen, "A transceiver design for ECU nodes in FlexRay-based automotive communication systems," *International Conference on Consumer Electronics*, pp. 311-312, Jan. 2008.