International Journal of Emerging Technology in Computer Science & Electronics (IJETCSE)
ISSN: 0976-1353 Volume 8 Issue 1 –APRIL 2014.

LOW POWER CONTROL ARCHITECTURE FOR AUTOMOBILE FUNCTIONS

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***Abstract— Automobiles* were born to enhance human mobile performance. The importance of electronic systems in an automotive has been dramatically rising. Managing the increasing complexity and number of Electronic Control Units (ECUs) in a vehicle has become a key challenge for its manufacturers. As the number of ECUs increases, power and efficiency become more important in modern vehicles. This leads to a strong demand for reducing the number of ECUs in cars by combining different application functions. Hence, consolidation of more and more functionalities into a single ECU is very important. Here, an integrated approach of functions of an automobile has been proposed. This approach is beneficial in the sense that there is only a marginal increase of maximum 3mW power in the integrated approach when compared to a single functionality. The power values for individual units are 34, 36, 37mW while for integrated approach, it is 38mw.**

***Index Terms*— ECU, ECU architecture, in-vehicle functionalities, safety critical and non-safety critical function, power consumption.**

I. INTRODUCTION

Over the past decades, there has been a rapid growth in performance and reliability of electronic embedded systems. This has enabled vehicle manufacturers to implement complicated automotive control systems through the use of sophisticatedly integrated mechanical and electronic devices. The stepping stone towards such systems for automobiles were the introduction of digitally controlled combustion engines with fuel injection in 1979 and digitally controlled antilock brake systems in 1978 [5]. In-vehicle electronics mainly consists of functional units and various communication networks interconnecting these functionalities. Vehicles are equipped with a large variety of devices performing different functions and mostly transferring signals via electrical wiring. Most of the automobile functions are enabled by the use of distributed electronic systems including sensors, switches, actuators and electronic control units. In today's premium automobiles, there can be a hundred ECUs (Electronic Control Units) communicating over data networks. Hence, vehicles incorporate a significant amount of computation, because of the fast increase in the number of functionalities [7].

Non safety critical and safety critical functions are the two main categories in which functionalities fall in to. The spectrum starts from non-critical control of electric windows, through critical drive-by-wire systems, to entertainment applications. More the automation of such systems more is the number and variety. Currently, vehicles use embedded system architectures that consist of up to hundred ECUs with several heterogeneous buses that are interconnected by one or more gateways. The complexity is still on its rise as new functionality is often introduced by adding separate devices. While the federated approach has been feasible in the recent years, it is reaching its limits with the growing complexity of in-vehicle networks and the lack of installation space. Hence it is high time that sophisticated methodologies that utilize lesser power and area are to be adopted.

This paper is organized as follows: Section II describes the basic operation of in-vehicle functionalities. Section III gives a brief description about ECU architecture. Section IV introduces the proposed ECU architecture methodology. Simulation results have been shown in section V. The performance analysis is included in Section VI and finally Section VII concludes the paper.

II. IN-VEHICLE FUNCTIONALITIES

Vehicles presently incorporate large number of ECUs, which control and coordinate both critical and non-critical functions. Non safety-critical systems usually include user-oriented features like multimedia, telematics and so on, which do not affect the safety of the driver or passenger. Safety-critical systems like drive-by-wire, Anti-Lock braking or occupant safety systems are the ones which ensure safety of the vehicle and human. They require high levels of determinism and isolation. Most of the automobile systems, both safety-critical and non-safety-critical, operate in a control loop anatomy. A passenger car is an aggregation of various control systems that interact with each other in complex ways. Each control system is made up of a plant, sensors, actuators and ECU. Fig. 1 shown below illustrates a control system for a typical automobile functionality.

A number of sensors measure controlled variables as input signals for ECUs as shown in Fig. 1. The input signals can be analog like voltage signals from sensors, digital such as switch positions, or modulated like Pulse Width Modulation (PWM) signals. With these input signals, ECUs calculate required parameters to adjust controlling devices such as actuators. The ECU makes all the decisions based on all the information it gets from the sensors. Accordingly to the processed data, the ECU provides necessary commands to the actuators.

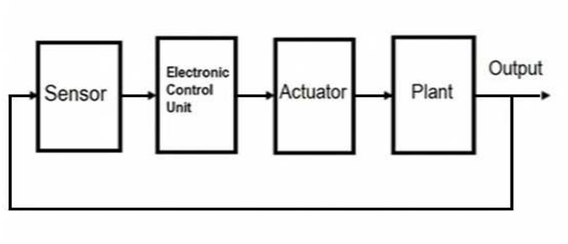

Fig. 1: Control System for a typical automobile application

III. ECU ARCHITECTURE

Fig.2 shows architecture of an Electronic Control Unit. The primary function represents the functional implementation of an automotive algorithm in either software or hardware. Communication to the sensors and other ECUs over the FlexRay bus is controlled by the FlexRay communication controller and the bus driver module [11].

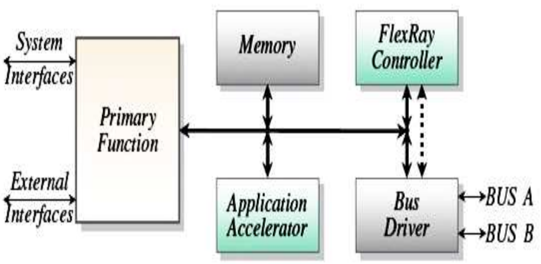

Fig. 2: ECU architecture

The usage of so many numbers of such ECUs increases the complexity, power and installation space. Each functional unit requires one such ECU and adding each functionality means an addition of ECU.

IV. PROPOSED ECU ARCHITECTURE

In this paper, an integration approach of functionalities is proposed. Leaving behind the one-to-one methodology of single functionality – single ECU approach, it is proposed that multiple functionalities can be aggregated on a single ECU unit. It is possible to create optimized nodes that integrate different functionalities of an automobile into a single ECU, thus resulting in reduction of the total number of on-board ECUs. An illustrative figure of the above proposed system is shown below in Fig. 3.

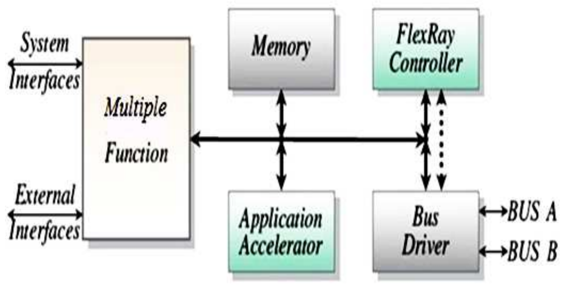

Fig. 3: ECU architecture with multiple functions

This methodology reduces the number of ECU modules, bus drivers, and the associated wiring, all contributing towards a better in-vehicle system. If two or more functions can be implemented in the ECU unit instead of a single function, this can highly decrease the number of ECUs that has to be used. Here, three main safety-critical functionalities of an automobile namely, Tire-Pressure Monitoring, Collision Avoidance System and Airbag Control functionalities have been integrated in to a single functionality.

V. SIMULATION RESULTS

The entire simulations have been done in VHDL using Xilinx 9.1i and ModelSim 6.3. Some of the major safety-critical functionalities namely Tire – Pressure Monitoring, Airbag Control, and Collision Avoidance system of the automobile have been simulated based on their operation as a control system. The sensor outputs are the input signals to each of the functionality and outputs of functional units are connected to the actuators which in turn perform the functions. These individual functionality units are then aggregated to a single unit in the integrated approach. The various simulation results of the functionalities and the device utilization summary are shown below:

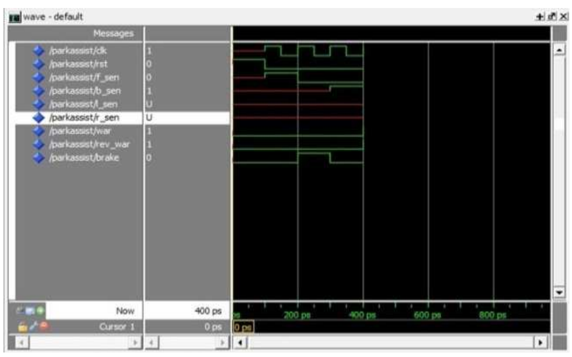

Fig. 4: Simulation output of Collision Avoidance functionality

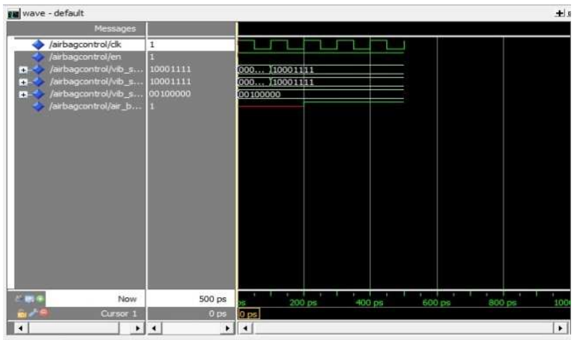

Fig. 5: Simulation Output of Airbag Control function

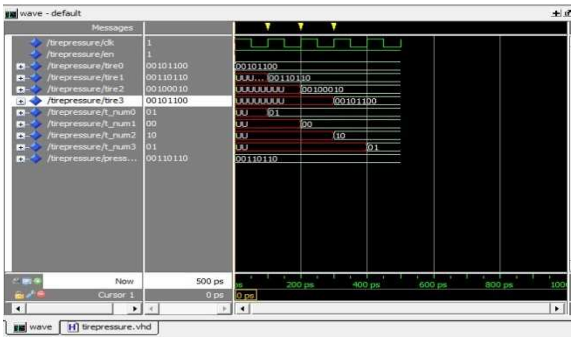

Fig. 6: Simulation Output of Tire-Pressure Monitoring Unit

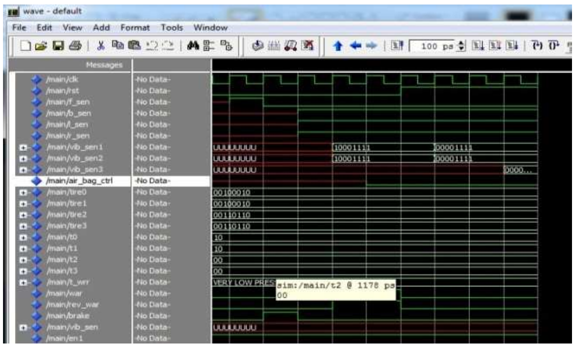

Fig. 7: Simulation Output of integrated ECU

VI. Performance Analysis

The power consumption results obtained for each individual function and the integrated functionality approach is shown below. The power values clearly indicate that there is only a marginal increase in power consumption when all the three functionalities are integrated. Individual units alone when taken, consume power in this range, hence three separate functions increases the total power consumed by three times. Therefore, this integrated approach in advantageous wherein it consumes only more or less the same power as consumed by an individual function.

TABLE I: COMPARISON TABLE FOR POWER CONSUMPTION OF INDIVIDUAL FUNCTIONALITIES AND INTEGRATED APPROACH

Function	Power Consumption
Airbag control	34 mW
Collision Avoidance	36 mW
Tire Pressure monitoring	37 mW
Integrated functionality	38 mW

VII. Conclusion

Complex functions are being added to in-vehicle systems to enhance human machine interaction and performance. User-oriented applications like multimedia require high computational throughput. As the number of ECUs increases, power and efficiency become more important in modern vehicles. The total number of ECUs in a car is on one hand limited by the complexity of the networked system and on the other hand by the power consumption of the whole electrics system including mechatronic devices like sensors and actuators. This leads to a strong demand for reducing the number of ECUs in future cars. Aggregation of multiple functions onto a single ECU can highly reduce the number of ECUs required by overcoming the one-to-one methodology of function-ECU relationship.

In future, this work can be extended in analyzing the interfacing between aggregated functionalities and peripheral components (like communication controllers, memory, and so on). Also interfacing this ECU to other ECUs without affecting the accurate operation and reliability factor should be properly scrutinized. Various functionalities require different communication networks based on bandwidth, high volume of data transfer required, determinism etc. Sharing the interface between the multiple functions can be inspected.

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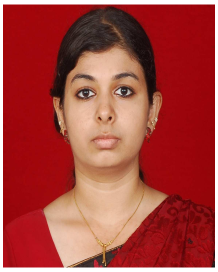

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