Design approach for VHDL and FPGA Implementation of Automotive Black Box using CAN Protocol

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Summary
ECU in automotives are becoming more advanced and standardized. These ECUs communicate on standard networked on protocols. The proposed automotive Black Box design intends for storing and retrieving the data of various ECUs on standards CAN protocol frame. The data thus stored and retrieved can be used for introspection of cause of failure or unfortunate miss happening with the vehicle.

Key words:
CAN: Controller Area Network, FPGA: Field Programmable Gate Array, VHDL: Very High Speed Hardware Description Language, ADC: Analogue to Digital Converter, DIP: Dual In line Package.

1. Introduction

Modern automobile units include many microcontrollers and their number is growing continuously. Driver's comfort and safety is of utmost importance in today's heavy competitive world. The expectations from the vehicular manufacturer, researchers led to design and propose new techniques which are economic as well as easy for interlinking with other gazettes is highly in demand.

Communication, Integration and Standardization amongst various controls operated by these several microcontrollers based electronic gadgets is necessary and it is done via several buses. Most commonly used buses are CAN, LIN, MOST, Flex-ray. Automotive networking has developed a great deal over the last two decades. As vehicular networking began to mature, a range of standard practices and architectures began to emerge within major automotive manufacturers using UARTs. These UART based protocols
(UBPs) often shared common characteristics, but were rarely compatible. Many state-of-the-art methodologies in vehicle communication technology exist within vehicles, as well as between vehicles which are referred as Intra-Vehicular communication & Inter-vehicular communication respectively**.**
Networking is very important & crucial factor in vehicle Communication. In-vehicle networking is also known as multiplexing. It is a method for transferring data among distributed electronic modules via a serial/ parallel data bus. Increasing demand for high-end luxury cars contain more than three miles and nearly 200 pounds of wiring. The resulting number of connectors creates a reliability nightmare. Amongst various buses used in intra-vehicular Communication, most widely used and important communication buses are LIN and CAN in which worldwide research is going in. Various researchers are proposing recent protocols called Flex-ray and have proposed multiple designs of these buses still there is much scope for optimization of cores.

A new era is upon us where vehicles will communicate with the world, the devices within them, and with each other, making the next generation of vehicles into communication hubs. This has also made it possible to introduce & integrate new, wide & advanced range of products in vehicles for e.g. Breaking & stability control, anti-collision systems, parking aids, engine injection i.e. advanced safety systems, exhaust & emission management system, body control, entertainment & driver information & navigation system i.e. infotainment.

In this paper, Authors are presenting results of VHDL code of CAN Protocol and have also presented FPGA synthesis results of CAN bus which will be used for designing of proposed Vehicle black box. The proposed Vehicle black box will be lead to simulate the emergency conditions i.e. accident situations the vehicle have encountered.

1.1 Controller Area Network

The Controller Area Network (CAN) is a serial communications protocol which efficiently supports distributed real time control with a very high level of security. Its domain of application ranges from high speed networks to low cost multiplex wiring. In automotive electronics, engine control units, sensors are connected using CAN with bit rate up to 1M bit/s. At the same time it is cost effective to build into vehicle body electronics, e.g. lamp clusters electric windows etc. to replace the wiring harness required. The intention of this specification is to achieve compatibility between any two CAN implementations. Compatibility however has different

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aspects regarding e.g. electrical features and the interpretation of data to be transferred. Nowadays, there are FPGA-based integrated solutions where programmable logic is included in addition to general purpose processors, allowing dedicated hardware to be synthesized according to the application needs. Besides re-configurability features, low turnaround time of rapid prototyping using FPGA devices is an attractive alternative of system validation, specially when fast time-to-market is required. Equally important, FPGA technology is being largely used in final products when total demand is restricted to few units because of the high cost associated to ASIC fabrication Not only HDL developers but also the IP industry as a whole are aware of all those benefits.

1.2 Standard CAN Frame

Standard CAN frame is as shown in figure 1

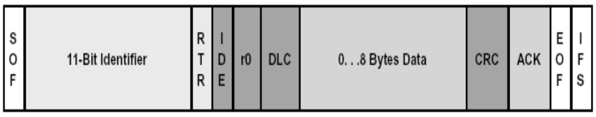


Figure 1 Standard CAN: 11-Bit Identifier

SOF-bit marks the start of a message.

Identifier- establishes the priority of the message.

RTR—remote transmission request (RTR) bit is dominant when information is enquired from another node.

IDE- identifier extension (IDE) bit means that a standard CAN identifier with no extension is being transmitted.

r0—Reserved bit

DLC—The 4-bit data length code (DLC) contains the number of bytes of data being transmitted.

Data—Up to 64 bits of application data may be transmitted.

CRC—The 16-bit (15 bits plus delimiter) cyclic redundancy check (CRC) on the checksum of the preceding application data for error detection.

ACK—indicating an error-free message has been sent.

EOF—end-of-frame (EOF) 7-bit field marks the end of a CAN frame (message) .

IFS—This 7-bit inter-frame space (IFS) contains the amount of time required by the controller to move a correctly received frame to its proper position in a message buffer area.

2. Methodology

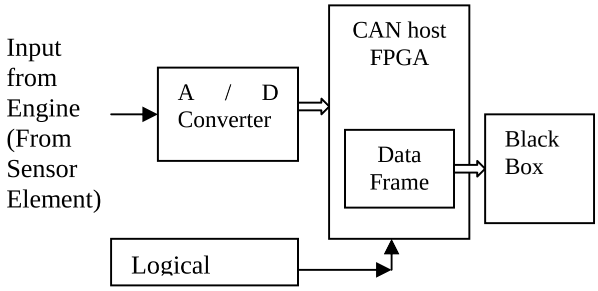


Figure 2 Block diagram of design methodology

Automotive black box will be installed in vehicle and will be used to store the data supplied by CAN host downloaded on FPGA. The data thus stored in Black box can be retrieved and can be used for simulating any external or internal emergency situation which has lead to cause of accident. In the implementation Authors have assumed the simulated emergency situation with the help of Analogue to Digital Converter. The design methodology is shown in Figure 2. The digital signal thus derived from output of ADC is given as input to CAN host FPGA which holds Data frame and directs it to Black box. The black box will store the frame and will make available as and when required. The 8-bit input from the analog to digital converter is used to form the complete data frame by the CAN Host which will be transmitted to the black box. All the fields of the data frame will be decided according to the input from the analog to digital converter. As the input to the CAN-Host is digital data of 8-bit, it can range from 00000000 to 11111111 in binary digital logic where 0 represents a ground voltage and 1 represents a +Vcc (Typically 5 volts).

The operation of system is as shown in the flow chart of Fig.3. Thus after reading these 8 bits first task is to decide the dependency of all the fields of the data frame on the combination of these data bits. The data frame that is to be transmitted by the CAN-Host will consist of the following fields: Identifier field, control field, data field and CRC field. Obviously all of these fields will vary according to the system. The emergency situation in Vehicle i.e. output of sensor element from the Engine of a car can be simulated using ADC converter in which the Analog input is varied by potentiometer or the same can be simulated by operating DIP switches on XILINX FPGA Board. Then according to the input from the sensor the output of the ADC is needed to be interpreted or calibrated. This digital signal is given as input to CAN host FPGA which is employed to operate specific application in the vehicle. The instantaneous CAN Frame of that particular application is hold of and is stored in memory of intelligent vehicle black box.

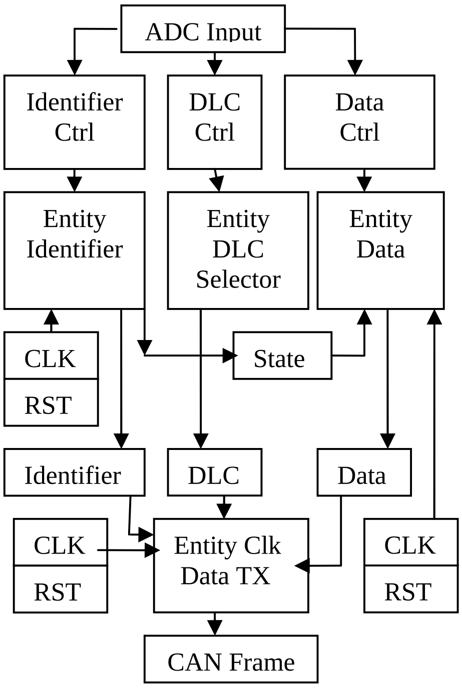


Figure 3 Operational Flow chart

3. VHDL Simulation and FPGA Synthesis Results

The design is implemented in VHDL and is tested for simulation and FPGA synthesis on XILINX MODEL SIM tool. The results presented in this section are simulation results and FPGA route map of Synthesis of various sections of design.

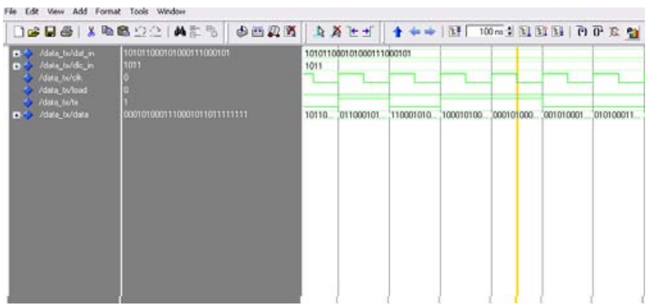


Figure4. Data TX

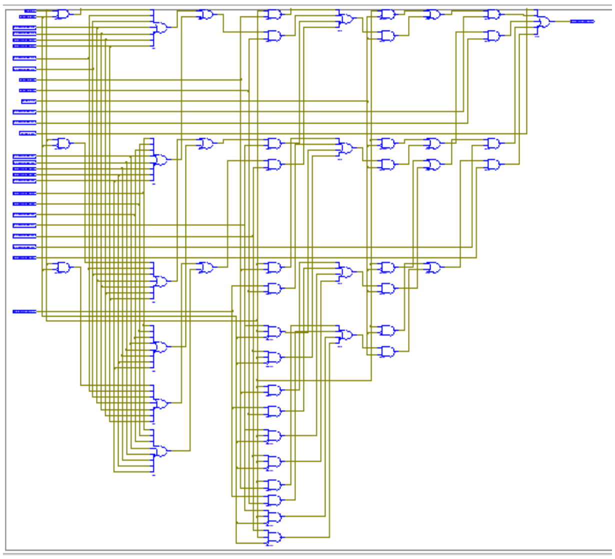


Figure5. DATA

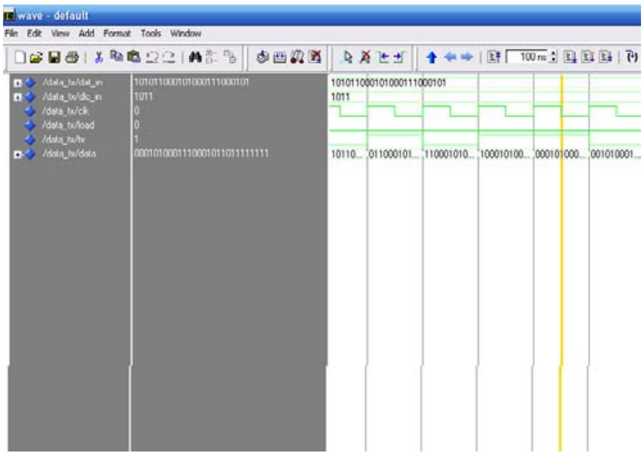


Figure6. DLC SELECTOR

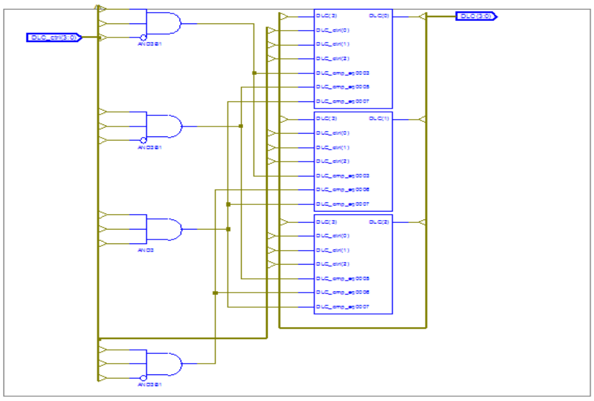


Figure7. DLC 1

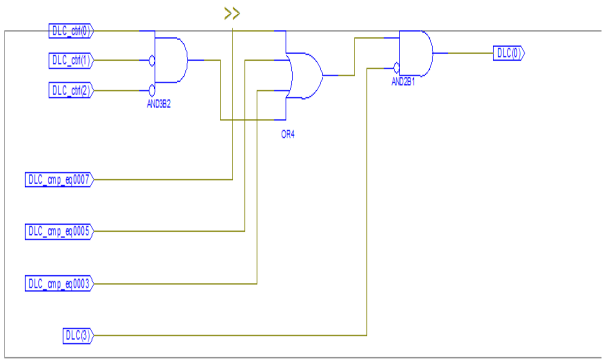


Figure8. DLC2

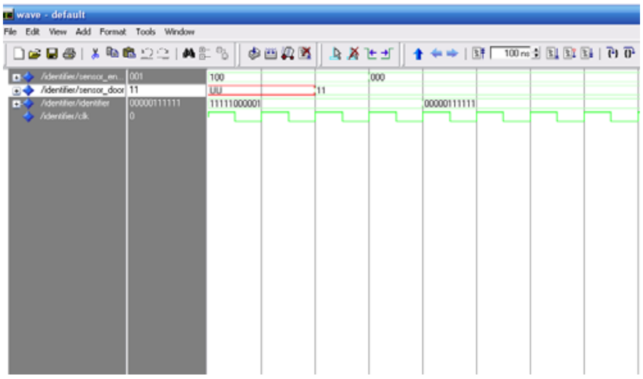


Figure9. IDENTIFIER

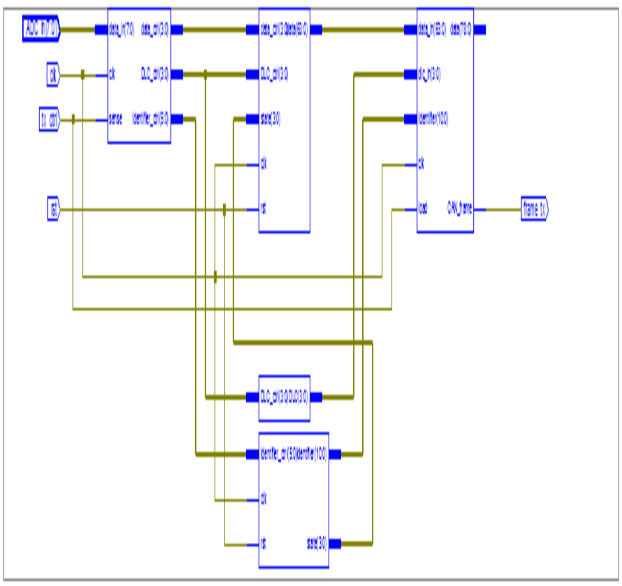


Figure10. CAN

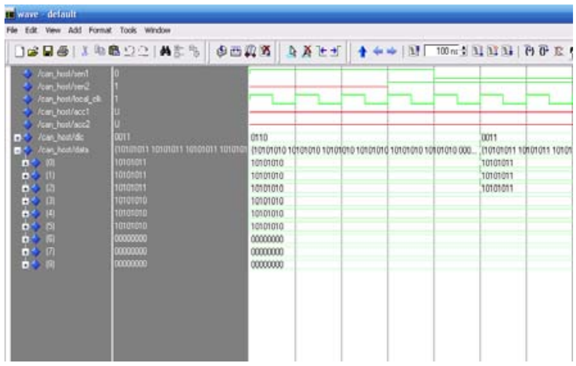


Figure11. CAN HOST

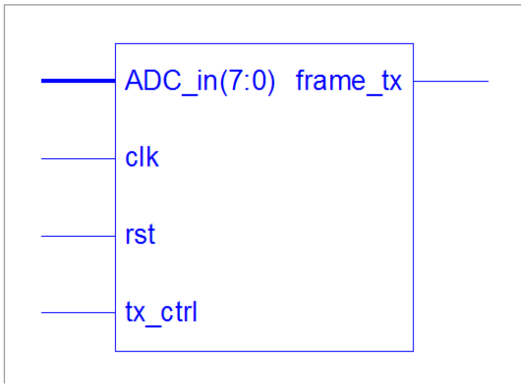


Figure12. CAN host

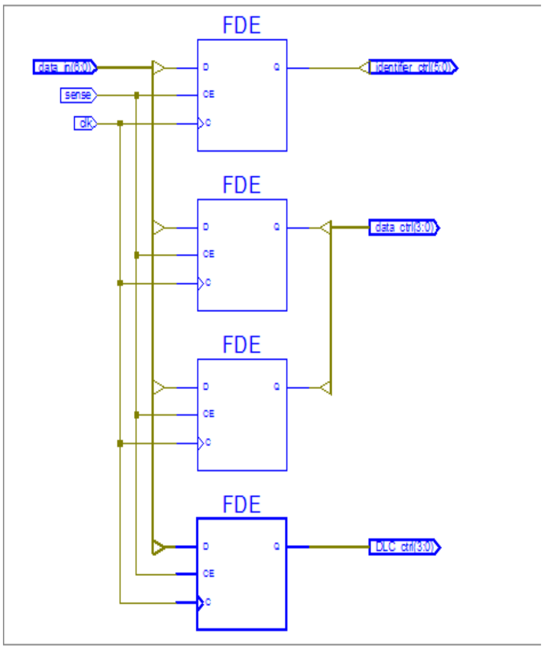
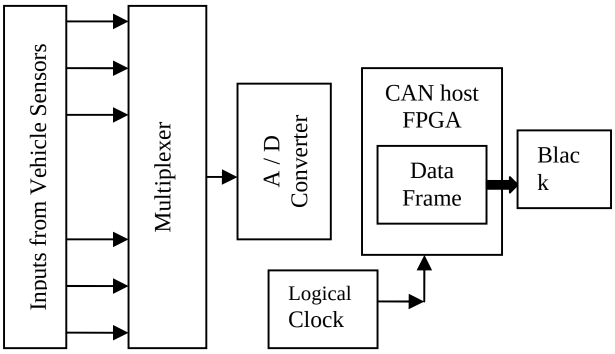


Figure13. CAN HOST COMPLETE DIAGRAM.

4. Future Scope

We have presented design approach for automotive black box using CAN protocol. The design is implemented in VHDL. VHDL code is simulated and is downloaded to FPGA platform to host CAN controller. The signal from sensors of automotive is simulated using A/D converter. As the analog signal form ADC deviates from threshold boundaries the FPGA CAN host responsible for that automotive application is supplying the data, which can be stored in black box.

As in figure 14, the design can be extended for more signals of automotive accounting under Controller Area Network. The multiplexer is used to route one signal at a time to CAN host. With this data related with all the applications under CAN umbrella can be stored in an automotive black box.



5. Conclusion

Ground vehicles are more accident prone which necessitates the implementing of black box for them. The proposed Black Box is to be designed with standard Intra vehicular communication networking protocols (like LIN, CAN, Flex-ray) for its universal acceptance and wide area applications. The Data from vehicle sensors can thus be utilized for introspecting cause of the unfortunate incidence if any.

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