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Simulation for Vehicle Comfort System Based on CAN Bus

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***Abstract*—On the basis of researched on CAN bus and vehicle network, an entire design model of vehicle network was submited in this paper. The function of each node was determined based on the analysis of network protocol. A new simulation tool CANoe was used on off-line simulation and semi-physical simulation of these nodes. This development approach could make the development of car network system more convient and efficient.**

Keywords- CAN bus; vehicle network; CANoe; Simulation system.

I. INTRODUCTION

Currently, computer technology has been widely used in vehicle control systems, and the proportion of vehicle electronics represented by microcontroller continues to increase in vehicle electronic systems. The control system of luxury cars has been converted to intelligent control system based on distributed network. With the increasing complexity of auto motive electronic systems [1], the traditional point-to-point information exchange has been unable to meet the real-time communication requirements in interior distributed control systems. The increasing number of electronic devices, makes a sharp increase in difficulty of wiring, and also lowers the reliability of car electrical system. CAN bus is a serial communication network which effectively supports distributed control and real-time control, has been widely used in the field of automatic control with its high performance and high reliability.

At present, foreign countries for the CAN bus technology research and design of automotive CAN networks have become mature, such as Mercedes-Benz, Volkswagen, BMW, Porsche and other car companies have already realized the network system and developed their own agreement and in accordance with standard CAN communication protocol[2]. CAN bus technology is in development stage interiorly, most of the domestic automotive have not integrated CAN networks. Even the high-end car assembled are mostly of foreign products and technologies, the price is also very high. Therefore, how to get rid of dependence on foreign car company, with the capacity of independent R & D CAN network to achieve in the domestic automotive CAN network structures has become the important issues domestic auto industry is facing.

II. CAN BUS AND AGREEMENT

CAN (Controller Area Network) bus is a data communication protocol which was developed by German company BOSCH in the 1980s to solve the data exchange among numerous control and test equipments in modern vehicles [4]. It's a serial communicational network supports distributed control and real-time control efficiently.

The communications network constructed on CAN bus is designed by hierarchical structure in accordance with the OSI standard. As the relatively small amount of the information transmission of CAN network, the high requirement of realtime features of information transmission and the relatively simple connection mode of the network, so the CAN bus network only uses the lowest two layers of communication model - Physical Layer and Data Link Layer [5]. And the Application Layer at the top only.

In addition, CAN 2.0 is divided into two parts: standard data frame and expanded data frame. The identifier length of CAN standard format is 11 bits, and the identifier length of CAN expanded format is 29 bits. CAN 2.0A version provides that CAN controller must have an identifier with 11 bits. Meanwhile, CAN 2.0B version provides that the identifier length of CAN controller can be 11 bits or 29 bits. CAN controller which keeps to the CAN 2.0B protocol can send and receive standard format message with 11 bits identifier or expanded format message with 29 bits identifier. If it is forbidden to use CAN 2.0B, CAN controller can only send and receive standard format message with 11 bits identifier, and neglect the message structure of expanded format without error. Both physical layer and data link layer of the designed network system keep to the CAN 2.0B protocol.

III. SIMULATION OF COMFORT CAN NETWORK

A. The Overall Design of Comfort CAN

In this part, the comfort CAN network system of the Bora car is studied, a simple comfort CAN network model and a network topology map of more intuitive for the various nodes on the network is designed, as well as communication between the nodes of its own electrical control. The network mainly composed by the central controller and 4 doors' controllers. Controled object includes 4 door electric windows and door locks, mirrors, trunk lock, and also includes a remote control signal of

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receiving and processing, and other anti-theft system controllers.

Network model shown in Fig. 1:

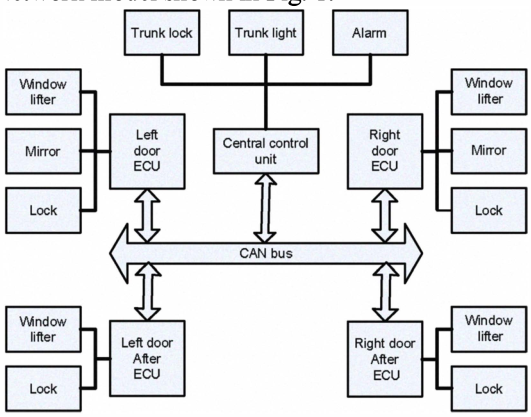

Figure 1. Comfort CAN network model

The ECUs on the 4 doors control their own appliance, such as window lifters, door locks and the mirrors. The left door has a higher level of control, the other three window lifters, car door locks, trunk lock and right-side door mirror can be controlled by it through the CAN message. The right door node control other three car locks and trunk lock through the bus. Left and right rear door nodes do not have permission to control other nodes through the bus, and can be controlled only.

Central controller node is rather special, its main functions are: enable comfortable functions; receive and process the signal from the remote control system; through the CAN messages from other nodes under the control of electrical appliances and electrical switches state for fault monitoring and alarm functions ; separate control trunk lock and four door locks through the bus control.

B. Nodes Off-line Simulation of CANoe

CANoe is a practical and powerful tool for system design and analysis developed by German company Vector. It can realize the link between virtual bus and real physical busthrough Vector's CAN bus interface hardware. With CANoe we can realize the total digital simulation of bus application system based on total virtual nodes, the half-physical simulation of the combination of physical node and virtual node, and can also realize real-time monitoring of the real physical bus communication. CANoe supports the whole process of the bus development from the initial design, simulation and final test analysis, and realizes the seamless integration of the design, simulation and test of the network.

This article take the left door as an example, which is the highest features node, to elaborate the application of simulation with CANoe, and the process of design and develop a network node is discribed.

1) Design Idea.

Simulate the left door nodes in the CANoe simulation platform, design the same physical function of the virtual electrical equipment. In addition to complete control their own appliances, but also enable simulation nodes on the bus, sending packets to other nodes on the bus under the control of electrical equipment, receiving the packet from other nodes in the door to the left door node, the operation of electrical equipment on the left door. In addition to the left door node send or receive control messages, but also send or receive some state information, to monitor the electric equpment on the vehicle.

2) Functional Analysis.

Nodes in the left door electrical equipment can be divided into the following two aspects:

- Control agencies: the car lock button on the left door lock buttons, left, right, left rear, right rear window lift button, rear-view mirror adjustment button;
- The executing agencies: left lock, left window, left rear-view mirror.

3) Simulation Process.

The design by virtue of CANoe simulation tools to simulate nodes in the left door is divided into four parts: CAN database design, the establishment of a virtual model for the left door node, function design and control panel presentation program design. CAN database design is the core issue, the other three parts of the design must be defined with the data in the database is associated, so that share the data in the four-part design, and control the function of the left door node by changing the value of these data. In the following we will take the left window for example to achieve the functions, as well as left-node through the CAN bus control the right door window, to describe the various parts of the specific design:

a) CAN database design:

CAN database needs to complete the name of the node definition, the definition of packet, packet of data definitions, the definition of control equipment (such as: window lift button on the left), the definition of charged devices (example: the left window, left lock). Establish the name Left_door nodes and Right_door nodes in the database. Add the following attributes in the Left_door node: message name control_window, ID 181; the data packet is defined as window_up_left, window_down _left, window_up_right, window_down_right, respectively left windows up, left window down, right window up, right window down, valid value is 1; control equipment button_le_window_up, button_le_window_down, button_ri_window_up, button_ri_window_down, respectively up button and left window down button, right window up button and right window down button, valid value of 1; accused device is defined as the window_le that the left window, it is divided into 16 states to indicate the location of the window of valid values range which is 0-15. Add the charged device window_ri under Right_door node indicated to the right window, the same with left window.

b) Establish the virtual model node in the left door:

Add vitual node in CANoe's simulation founction, add the name of the virtual bus for left_door node and right_door node, set the node name defined in the database the same as in the simulation interface has been designed to introduce a CANdb, in this time with the virtual node interrelated in the database.

c) Functional demo panel design:

In fact, functional demo panel is to design an interactive interface, control program through the data in a database associated, find the virtual interface device and control it. Functional interface design, as shown in Fig. 2:

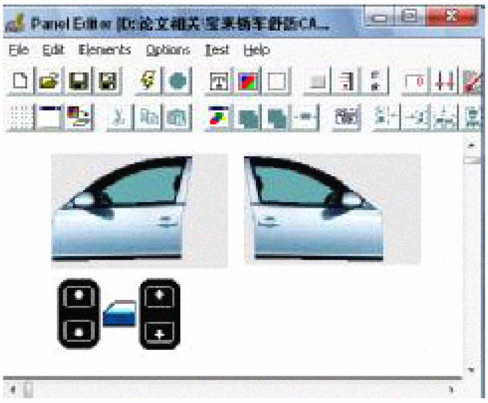

Figure 2. Functional demo panel

d) Control Program Design:

In the CANoe dedicated programming interface CAPL Browser using CAPL programming language for the node. In the control program, the data can be associated in the database to control the movements of the windows. Code is as follows:

```
control_windows_le()
{
a=getvalue(window_le);
// To obtain the current window position
if(a>0&&getvalue(button_le_window_up)==1)
// To determine whether the left window up button is pressed and the window is not at the top in the current state
{a=a-1;}
// Position the windows up a grid
if(a<15&&getvalue(button_le_window_down)==1)
// To determine whether the left window down button is pressed and the window is not in the bottom in current state.
{a=a+1;}
// Position the windows down a grid
putValue(window_le,a);
// Set the current location of the window
}
```

4) Control Strategy.

To take the control of movements of window for example, the left, right, left rear, right rear window lift button are four separate buttons, after anyone of them being operated, Message ID 181 will be sent to the bus, there are control orders with the other three doors' window in ID 181, when the button is lifted the sending stoped. Take into account when the button has been pressed, the virtual node can not occupy the bus resources to send message all the time, neither to reduce the bus load rate and affect the real-timing after push the button. Otherwise, message adopt a 20ms period as sending method. The circle sending is conductive to control the load rate of the bus when the button has been operating, while the proven 20ms time interval can also meet the timeliness requirements. Since sending the operation commands. Therefore, the button should not be lifted immediately when stop sending message, it should be made one more cycle of the current state of the button, and then stop sending message, otherwise the window lifter will remain in the rise or decline.

C. *CANoe Semi-physical Simulation*

Off-line simulation only completed an initial function of the door node simulation and packet simulation, in order to further modify and improve the simulation node to achieve a real node standard, CANoe simulation nodes to be on-line simulated. On-line simulation that CANoe semi-physical simulation is to use CANoe simulation of virtual nodes replace the actual node in real car, with real-time performance has improved real-connected, using a real vehicle to approve a virtual network of nodes is reasonable, with data on-line monitoring and analysis, found unreasonable and wrong problems, could be updated in time. The hardware connections as shown in Fig. 3.

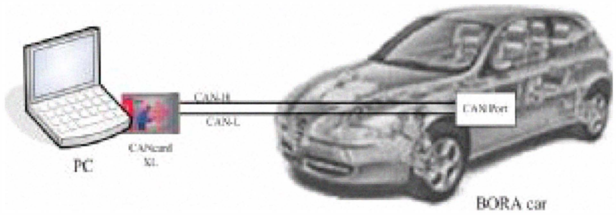

Figure 3. CANoe hardware connection

IV. Test Results and Data Analysis

The left door node will be disconnected with the comfort network, virtual nodes simulated by CANoe connected with the comfort network, data from semi-physical simulation of the vehicle is as shown below:

A. *Data obtained under static conditions*

Interception of data in the static circumstance of any operation nor device connected as shown in Table 1.

TABLE I. Part of Data in Static

Time（S）	ID	DL (byte)	Data				
0.011200	601	1	20				
0.029100	3b5	5	80	00	00	00	00
0.029000	2b1	2	05	00			
0.035400	635	3	00	ff	00		
0.037700	353	8	0b	00	00	47	00
0.037000	271	1	02				
0.039800	293	2	09	01			
0.042500	591	3	07	04	8f		
0.061600	351	8	64	00	00	00	00
0.061100	5c3	2	00	00			
0.062000	621	3	00	00	80		
0.079200	371	1	c0				
0.091500	381	5	80	00	00	00	00
0.092300	281	2	05	00			
0.161700	551	1	00				
0.463800	659	8	17	04	00	3e	01
0.464000	653	6	01	00	00	00	c0
0.465000	651	6	00	03	40	a0	18

The figures above are interception of the data only each packet in a cycle time based on order of appearance time.Through analysis of the data obtained in the static case, within 10 hours, or more packets of data derived from the value of no change, with the original packet data (data measured with real-node), compared with the same conditions, the data value identical, indicating the data rate is 100% correct.

B. Data obtained under dynamic conditions

This paper lists some of the windows packet data for instance, analyse the variation of data , data accuracy and whether the functions of the virtual node is consistent with the original node. In the operation of the window down button, some data of the packet ID 181 send through the CANoe simulation node shown in Table 2.

TABLE II. PART OF DATA FROM ID 181

Time (S)	ID	DL(byte)	Data	
13.560760	181	2	00	02
13.580760	181	2	00	02
13.600760	181	2	00	02
13.620760	181	2	00	02
13.640760	181	2	00	02
13.660760	181	2	00	00
13.680760	181	2	00	00
15.680760	181	2	00	01
15.700760	181	2	00	01
15.720760	181	2	00	01
15.740760	181	2	00	01
15.760760	181	2	00	01
15.780760	181	2	00	01
15.800760	181	2	00	01
15.820760	181	2	00	01
15.840760	181	2	00	01
15.860760	181	2	00	00
15.880760	181	2	00	00

From analyzing the data we can see two packet interval delay is 20ms, meets the protocol requirements on timeliness. When data value changed from 00 00 to 00 02, the right window down; from 00 02 to 00 00, the right window stoped; from 00 00 to 00 01, the right window rised. Design program so that the button could be operated continually, data changes every two seconds, test continuous 10 hours. Data ID 181 on the bus compared with the original data is correct, therefore, the virtual node can control the window down and achieve the desired results.

V. CONCLUSION

The characteristics of vehicle networks are studied in this paper, application of CAN, offline simulation and semi-physical simulation of network nodes are achieved with CANoe on the basis of hardware implementation, and vehicle network system is designed based on CAN Bus with providing convenience for domestic cars with the development of vehicle network. Its significance lies in reducing traditional design of hardware on loss time and costs, in order to avoid the shortcomings of previous design and the black cartridge operation. With facilitating the node in the functional and procedural changes, the design and debugging efficiency is improved, and it is of great significance for self-development of a complete vehicle network.

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