# Design Method of CAN BUS Network Communication Structure for Electric Vehicle

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***Abstract*—According to the communication structure of CAN BUS network on EV, this paper works out a SAE J1939 application layer protocol meet the system functional requirements, and designs the software and hardware for the system. First, design the CAN BUS work nod for EV, including the master node, the light node, air conditioning node, doors and instrument node, etc, and the draw the CAN BUS topology diagram. Meanwhile, according to the concrete situation of EV, work out an application layer protocol that consistent with the SAE J1939 protocol, and the information allocation table and message structure chart of CAN BUS network node is also presented. Secondly, design the hardware and software for the CAN BUS communication network. Hardware interface circuit mainly consist of CAN communication controller SJA1000, high-speed opt coupler 6N137 and CAN BUS driver 82C250, and design schematic circuit diagram for CAN bus system hardware. The software designs for CAN BUS network are mainly the design of CAN BUS data communication and exchange between nodes, and communication processing for switch-signal, analog signal. The design of software communication module includes CAN initialization unit, message sending unit, message receiving unit and the interrupt service unit. Finally, the CAN BUS network communication system the paper designed is applied to the new energy bus produced by CENS Energy-Tech Co., Ltd. which is dedicated in the Shanghai World Expo. From the battery voltage data collected when EV are running, we can see that the system is accurate, stable without number lost, frame dropping and transfer error in data communication. The design has practical value promoting the application of new energy vehicles.**

***Keywords- CAN BUS; Communication Structure; SAE J1939***

## I. INTRODUCTION

CAN BUS is a serial data communication protocol invented by German BOSCH Corporation in the early 80s to realize the data exchange between numerous controllers and measuring instruments in modern automobile. It is a multi-master bus, the communication medium can be a double stranded wire, coaxial cable or optical fiber. Communication speed is up to 1MBPS. Bus communication interface integrates the CAN protocol physical level and the data link layer function, and it can complete the framing of the communication of data processing, including the position filled, the block data code, the circulation redundant check, the priority distinguished and other works[1]. CAN communication protocol feature is to encode the data block. Length of the data is up to 8 bytes, which can meet the electric bus control commands, working status and test data requirement. Meanwhile, the 8 bytes will not take the bus for a long time, so it ensures real-time communication. CAN protocol adopts CRC testing and provides the appropriate error processing， ensure that the data communication is reliable. Now, CAN BUS electric bus technology has become a indispensable part of data communication in the bus [2]. According to the CAN BUS communication network structure, this paper developed a SAE J1939 application layer protocol meets the system requirements, and designed the system software and hardware.

## II. CAN BUS COMMUNICATION NETWORK NODE DESIGN

### *A. CAN Bus Electrical Characteristics*

CAN transmission medium formed by the two, One is called high-level transmission line CANH. Another is called low-level transmission line CANL, Ground voltage respectively as VCANH and VCANL. The difference between them is called difference voltage Vdiff.

### *B. Hierarchical structure of CAN BUS*

According to CAN BUS network structure, Classified into the following five levels, as shown in Fig. 1.

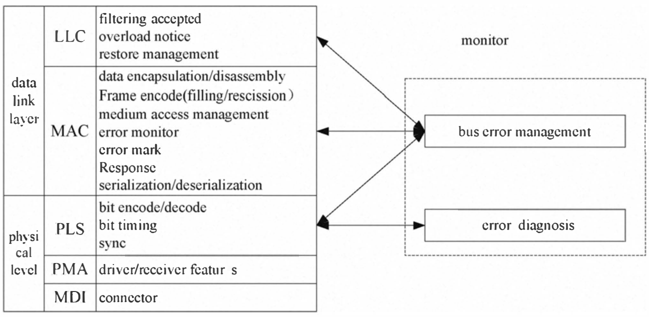


Figure 1. Hierarchical structure of CAN BUS

National 973 Project (2009CB220107), Harbin Science and Technology Innovation Fund (2009RFJGG009)

### C. *CAN Message Transmission and Frame Type*

CAN message use frame as transmission unit. In the CAN 2.0B specification is provided in standard format data frame, Given in two different 2.0B frame format, The difference is the length of different identifiers: Frame with n-bit identifier called the standard frame, the frame contains 29 identifiers is called extended frame. Message transmission has the following four different types of frames: data frame, remote frame, error frame, overload frame.

### D. *CAN BUS Bits Regularly And Node Synchronous Technology*

CAN controller oscillator maximum oscillator tolerance is 1.58%. In the same CAN network, to ensure that each node can communicate properly, the timing of message must be on the corresponding setting. CAN bit rate is divided into four parts, Sync segment, communication segment, Phase buffer segment 1, Phase buffer segment 2. Sync segment used for synchronization bus of different nodes, it was defined as a time range. Communication segment is used for Compensation physical delay time within the network. Phase buffer segment is used to compensate errors for the edge of stage [3].

### E. *CAN BUS Node Design*

CAN BUS system of electric vehicle include master node, lamplight node, air conditioning node, door node, Instrument node and so on. CAN BUS topography of electric vehicle is as shown in Fig. 2. Master node is the central pivot of the body control system, responsible for data communications with all other nodes and handles information, master node mainly from the driver to accept some of the input signal switch. Each child node to detect a variety of quantities such as switch quantity and analog, after process the child node packaged Messages with all the necessary information namely a message sent to the master node, the master node according to the information contained in Messages corresponding processing, including after logic relationship processed then packaged into messages sent to the child node implementation.

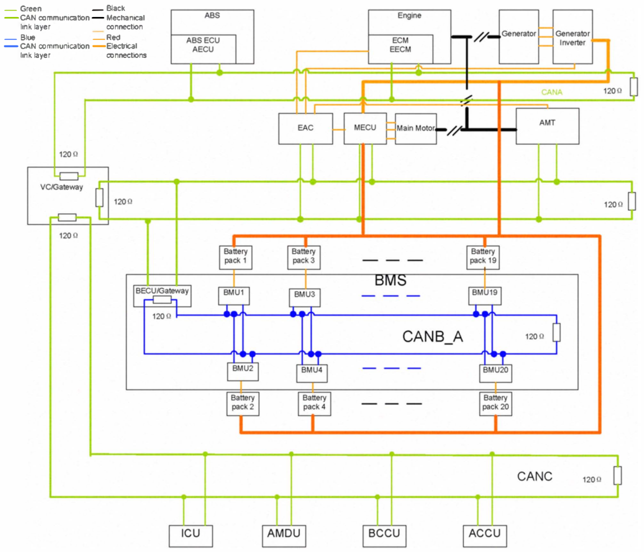


Figure 2. CAN BUS topography of electric vehicle

## III. DESIGN OF SAE J1939 APPLICATION LAYER

### A. *Characters of Application Layer Protocols*

SAEJ1939 communication protocols (J1939, short for SAEJ1939) is developed as a high-level network communication protocol CAN by Control and Communications Network Subcommittee, Society of Automotive Engineer-Trucks and Buses Electrical and Electronics Committee. J1939 protocol defines four layer, the physical layer, data link layer, network layer and application layer. Transfer function of J1939 protocol is a part of data link layer, which has two main functions: information package and restructuring, connection management. In order to send each individual frame to the receiving node to reorganize correctly, the first byte of data field is defined as the package serial number, from 1 to 255. Serial numbers starting from1 until the end of messages are packaged and sent out in order. For targeted news of multiple packages, the maximum time of the transmission nodes between each packet does not exceed delay 200ms. Each packet must include the 7-byte in original message, and the last one contains 8 bytes of data which includes a byte sequence number that at least one byte is a relevant data to the parameter group and the remaining set to FF. Each data packet is transmitted the receiving end in order, arranged by serial number to compose of a long data and sent to the nodes [4].

### B. *Units Design of SAE J1939 application layer protocols*

System bus communication has the speed of 250Kbps. CAN BUS network packet structure diagram is shown in Fig. 3.

| ID Entifier 11 Bits | | | | | | | | | | | SRR | IDE | ID Entifier Extension 18 Bits Table Column Head | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *PRIO-RITY* | | | *R* | *DP* | *PDU FORMAT(PF)* | | | | | | *SRR* | *IDE* | *PF* | | *PDU SPECIFIC(PS)* | | | | | | | | *SOURCE ADDRESS(SA)* | | | | | | | |
| 3 | 2 | 1 | 1 | 1 | 8 | 7 | 6 | 5 | 4 | 3 | | | 2 | 1 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 |
| 28 | 27 | 26 | 25 | 24 | 24 | 22 | 21 | 20 | 19 | 18 | | | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

Figure 3. CAN BUS network message structure

The protocol uses 29 extended frames, and the application layer protocol is developed consistent with SAE J1939 protocol according to the specific circumstances of electric bus, whose CAN BUS network node ID information allocation table is shown in Tab. I.

Among them, the priority level being the three positions, it can have 8 priorities; R generally is fixed at 0; DP is fixed at 0; 8-bit PF is the message code; 8-bit is the destination address or group expansion ;8-bit SA is the source address of sending this message. Data page bit DP is used for selecting data pages. Page 0 contains all the current definitional news, and Page 1 will be used for expansion. DP in this protocol is defined as 0. If the PF domain value is between 0-239 (PDU1), PS field contains the destination address. If the PF domain value is between 240 and 255 (PDU2), PS domain includes the expansion group of PF [5] [6].

TABLE I. CAN BUS NETWORK NODE FUNCTIONAL DESCRIPTION AND SOME ID INFORMATION ALLOCATION TABLE

| Serial number | CAN node name | CAN ID address |
|---|---|---|
| 1 | Stall sign | 0x18FFCE00 Byte 1~6 |
| 2 | Before and after the fog lamp switch symbol | 0x18FECA00 Byte 1~4 |
| 3 | Left and right turn signal sign | 0x18FECA00 Byte 5~8 |
| 4 | Oil warning light symbols | 0x18FEEE00 Byte 1 |
| 5 | Oil Inventory | 0x18FEEE00 Byte 5,6 |
| 6 | Water Temperature | 0x18FEEE00 Byte 1,2 |
| 7 | Oil Pressure Gauge | 0x18FEEF00 Byte 3,4 |
| 8 | Speedometer | 0x18FF83D0 Byte 1,2 |
| 9 | Engine tachometer | 0x0CF00400 Byte 4,5 |

## IV. CAN BUS INTERFACE CIRCUIT MODULE DESIGN

CAN BUS interface circuit which consist of can communication controller sja1000, high -speed photocopiers and CAN BUS driver 82C250. By this operation what read from internal register and write to the internal register, Primary controller can set mode that communication of CAN BUS, it can achieve receive and send data. sja1000 achieve logical encoding and logical decoding when it transmit data, sja1000 improve the capability of the CAN BUS difference send and difference receive data by CAN BUS driver 82C250. Tx and Rx of sja1000 connect with 82C250 after it pass higher-speed photocopiers 6N137 in order to enhance the capability of the node of CAN BUS anti-jamming and void each other crosstalk. By the way, CAN BUS driver use DC/DC with isolated function, it has achieved to make communication to isolate CAN BUS, it enhance reliability of system. CAN BUS hardware of system circuit of principle is showed in the Fig. 4.

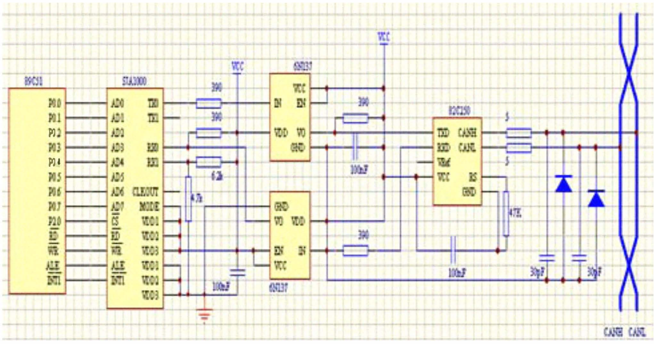

Figure 4. CAN BUS hardware of system circuit of principle

## V. CAN BUS NETWORK SOFTWARE DESIGN

The software part of main program unit is divided into: CAN initialization unit, message sending unit, message receiving unit and interrupt service unit. The communication module is responsible for data communication and exchange between each CAN BUS node all over the vehicle, and it also processes some switch-signal and analog signal communications. How to make the software for communication module stable, reliable and real-time is our top priority.

### A. *CAN Controller Initialization*

CAN controller initialization is mainly some sets for its internal register, such as the digital timer set and the mailbox initialization. When initializing the CAN registers in the single-chip, the system immediately clear the read and write buffer, configurates the clock frequency register, the code receiving-sending register and the interrupt enable register after power-on. After initialization, the single-chip is in normal communication status and is ready to work. The initialization code is as follows:

```
void canCirBufInit(CANCIRBUF *ptCanCirBuf, TCAN_DATA *ptCanFrameBuf, unsigned char ucLength)
{
    ptCanCirBuf->ulWriteIndex= 0; ptCanCirBuf->ulReadIndex= 0;
    ptCanCirBuf->bIsFull= false;
    ptCanCirBuf->ulLength= ucLength;
    ptCanCirBuf->ptCanFramBuf = ptCanFrameBuf;
    for (unsigned int i = 0; i < ucLength; i++)
        {   ptCanCirBuf->ptCanFramBuf[i].isExt = 1;
            ptCanCirBuf->ptCanFramBuf[i].rxRTR = 0;
            ptCanCirBuf->ptCanFramBuf[i].dlc = 0;
            ptCanCirBuf->ptCanFramBuf[i].id = 0;
      for (unsigned int j = 0; j < 8; j++)
            ptCanCirBuf->ptCanFramBuf[i].data[j] = 0;   }
        }
```

### B. *CAN Message Sending*

After initialization, the single-chip is in work mode. The CAN message sending adopts inquiry mode. Every 20ms, it checks the data sending buffer for command packet, if there is no command packet, it will return to main program waiting for the next check, and if there is command packet, the CAN controller sending status is on, it sends data in CAN BUS to buffer, the flow of program design is shown in Fig. 5.

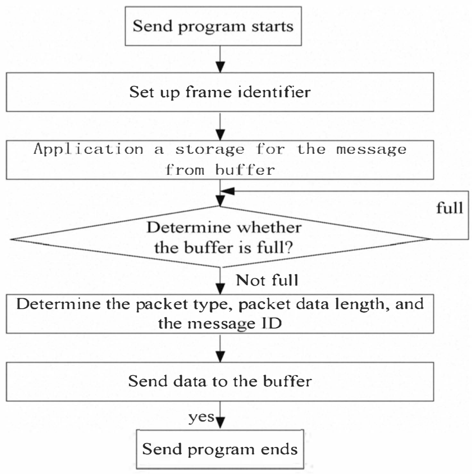


Figure 5. CAN BUS messaging program design process

### *C. CAN Message Receiving*

There are two ways for messages receiving: inquiry mode and interrupt mode. The design adopts the interrupt mode. The single-chip of QY9263K system checks the status register by waiting for interrupting signal. When the interrupt arises, it check the status flag RBS in buffer for new message. When RBS is 0, it means no new message, keeps waiting. When RBS is 1, it means new message received, the single-chip release receiving buffer to read the message. The receiving flowchart is shown in Fig. 6.

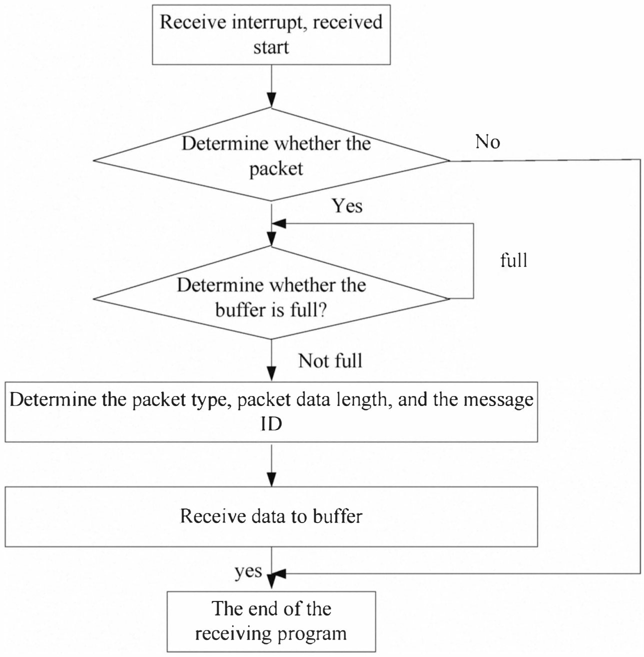


Figure 6. CAN message reception process flow chart design process

## VI. DESIGN VERIFICATION

After design the CAN BUS network, including software and hardware, we should verify stability of system functionality, reliability and data consistency. After the system power, select the battery pack combination, a total of 7 groups, on the body on the electric bus. Record the data that bus instrument receives on the CAN BUS data buffer every 5 minutes. And record the collecting results as follows in Tab. II.

Verified that a large number of real-time packet information sanded from the vehicle CAN node is accurate, stable, and no lost number, frame dropping, the number of strings of communication such as abnormal. Stability of system functionality, reliability and data consistency requirements are complied with.

TABLE II. PART OF BATTERY VOLTAGE DATA (UNIT V)

| Time | Battery pack 01 | Battery pack 02 | Battery pack 03 | Battery pack 04 | Battery pack 05 | Battery pack 06 | Battery pack 07 |
|---|---|---|---|---|---|---|---|
| 00 | 26.61 | 26.596 | 26.62 | 26.609 | 26.602 | 26.624 | 26.611 |
| 05 | 26.602 | 26.596 | 26.616 | 26.607 | 26.605 | 26.62 | 26.603 |
| 10 | 26.59 | 26.588 | 26.6 | 26.595 | 26.59 | 26.612 | 26.587 |
| 15 | 26.566 | 26.572 | 26.584 | 26.575 | 26.574 | 26.592 | 26.579 |
| 20 | 26.546 | 26.536 | 26.552 | 26.553 | 26.539 | 26.572 | 26.554 |
| 25 | 26.546 | 26.536 | 26.556 | 26.554 | 26.546 | 26.556 | 26.554 |
| 30 | 26.508 | 26.502 | 26.518 | 26.52 | 26.506 | 26.531 | 26.518 |
| 35 | 26.479 | 26.47 | 26.49 | 26.476 | 26.47 | 26.495 | 26.485 |
| 40 | 26.439 | 26.441 | 26.464 | 26.448 | 26.445 | 26.464 | 26.447 |
| 45 | 26.41 | 26.401 | 26.42 | 26.408 | 26.405 | 26.422 | 26.415 |
| 50 | 26.363 | 26.363 | 26.386 | 26.366 | 26.362 | 26.385 | 26.37 |

## VII. CONCLUSIONS

Real-time, reliability and flexibility, all these characteristics make CAN BUS an indispensable network communication technology applied in automobile network communication field. This article based on the analysis of the CAN bussing technique, designed CAN BUS working nodes based on which designed the SAE J1939 application layer design. It also gives the basic software and hardware implementations of CAN BUS network. Finally, tests results show that the hardware circuit of the CAN BUS network communication structure is stable and software design is reasonable, achieved the goal of this design.

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