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# The Advantages and Application Prospects of CAN FD Bus Technology for Vehicle Network Communication

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## Abstract

The fact that the degree of electronic control of automobiles increases rapidly has promoted the research of new vehicle-mounted buses. CAN FD bus, released by Bosch based on CAN bus, is the most promising one.

Its biggest feature is that the data field length is increased to 64 bytes and it has a flexible and variable baud rate. It inherits many advantages of traditional CAN bus and it has made some improvements. Due to these changes, some advantages of CAN FD bus, compared with CAN bus, can be verified. Firstly, the data transmission efficiency and the synchronization of the signal transmission are greatly improved. Secondly, encryption design can be done to improve the security of communication. The CRC-16 check code is stored in the 63rd and 64th bytes. In addition, a CAN node can be compatible with a CAN FD node in the same network by letting the traditional CAN node enter two different working states, sleeping and waking up.

Through experiments, it is found that compared with traditional CAN bus, CAN FD bus greatly reduces the load rate of the bus. Transmitting the same amount of information, as for physical nodes, CAN FD bus can reduce the bus load from 45.64% to 8.19%. Also it can significantly reduce the flash writing time based on the bus when the data field is extended to 64 bytes.

**Keywords:** CAN FD, vehicle communication bus, variable baud rate, 64 bytes data field length, low load rate.

## Nomenclature

*Abbreviation*

| | |
|---|---|
| CAN FD | CAN with Flexible Data Field |
| BMS | Battery Management System |

## 1. Introduction

With the increase of electronic control components of vehicles, especially the development of new energy vehicles and driverless vehicles, the amount of data exchanged on automobiles is increasing. And for some control systems in the car, such as the Autonomous Emergency Braking System (AEB), communication is also required to have high real-time performance. AEB is an important part of the future Advanced Driver Assistance System (ADAS). As an important active safety technology, AEB has been included in the active safety test content in new car evaluation procedures in many countries[1]. The development momentum of new energy vehicles is fierce and the annual average growth rate will be 40% in the next few years. It is predicted that the number of new energy vehicles in the country will reach 5 million in 2020[2]. The electrical and intelligent trend of automotive development puts forward new requirements for the transmission bandwidth and efficiency of the vehicle communication bus.

As a reliable automotive computer network bus, CAN bus has been applied in many automobiles[3]. With reliable performance, the CAN bus is not only widely used in automobiles, but also rapidly extended to industrial control. However, it has been many years since the protocol of communication of CAN bus was released. Its communication bandwidth of up to 1Mbits/s and the existing frame structure of the message are insufficient to meet the new requirements of vehicle communication nodes. Firstly, the amount of communication data is increasing. The limited data field length of the CAN bus results that information often needs to be divided into multiple packets for transmission. Due to the dispersion of data, the probability of error increases and the total transmission time of the information also prolongs. And for associated signals, data packet transmission results in unsynchronized reception, degrading the accuracy of the control. Secondly, the advanced driver assistance system and systems on the driverless car[4] have high requirements for real-time communication and high real-time performance means higher security. Due to limited bandwidth, the CAN bus has limited capabilities to improve real-time performance. The limitations of the CAN bus in the face of new demands have led to the study of new buses.

At present, in addition to the CAN FD bus, buses that are being researched and developed in the automotive field also includes Flexray, Most, Ethernet, LVDS and so on. Although these buses exceed the CAN bus in terms of communication speed, they still need to wait and be further developed because of application cost, market application promotion, communication reliability and fault handling. The CAN FD bus is developed through upgrade improvement based on the existing CAN bus. It retains the various advantages of CAN communication and makes up for the shortcomings of CAN communication. In addition, considering the large number of CAN communication nodes already applied in the market, compatible communication between traditional CAN nodes and new CAN FD communication nodes in the same network can be realized and the communication rate requirements of different nodes can be met. This solves the current demand for vehicle network communication with low application cost and has great significance for the marketing and engineering application of CAN FD bus.

CAN FD was first proposed by Bosch and it has developed rapidly. Many foreign companies have already developed CAN FD related tools and devices. The development of CAN FD has also been supported by many manufacturers. At present, many manufacturers such as Volkswagen, Daimler, General Motors, Infineon and NI have provided opinions for CAN FD standardization promotion.

Based on the comparison of CAN FD and traditional CAN, this paper draws the application advantages of CAN FD bus and studies the compatibility method between CAN FD communication nodes and CAN communication nodes for further analyzing the application prospect of CAN FD.

## 2. Comparison between CAN FD and CAN

### 2.1 Higher communication rate

The communication rate commonly used in the traditional CAN bus is 500 kbit/s and the communication rate is up to 1 Mbit/s (the communication distance is up to 40 m at this time)[5]. CAN FD, with flexible variable data baud rate, can achieve that communication baud rate in the data segment is up to theoretical 15Mbit / s. From the BRS bit in the control field to the ACK field (including CRC delimiter), the rate is variable. The rate of the rest is same as that used by the original CAN bus[6]. The rate test uses a transceiver model of ATA6561 and the CAN FD bus data segment can reach a communication rate of 5 Mb/s, which far exceeds the communication rate of the traditional CAN bus.

### 2.2 Larger data field length

In the early stage of the development of automotive electronic control, due to the small number of electronic control components, the 8-byte data field length of the traditional CAN bus can meet the communication requirements. However, with the substantial increasement in automotive electronic control components, especially in new energy vehicles and driverless vehicles, the amount of data that needs to be exchanged has increased substantially and the real-time requirements are high, making the data field length of the traditional CAN bus unable to meet new communication demands.

#### 2.2.1 Higher data transmission efficiency

As shown in Figure 1, taking a 29-bit ID data frame as an example, in the case where the number of bits in other fields increases little, the number of data field is expanded from up to 64 bits to a maximum of 512 bits. Obviously, the data transmission efficiency is extremely promoted.

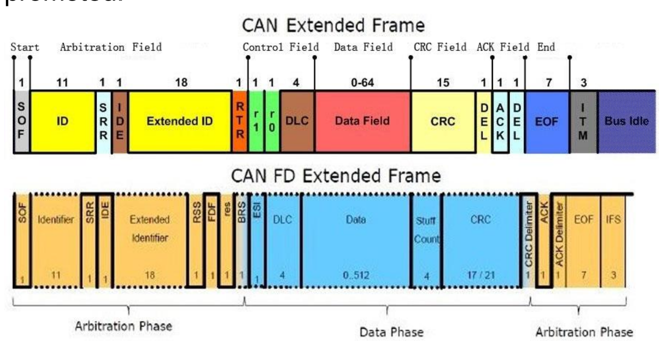


**Figure 1** Comparison of CAN bus and CAN FD bus data extended frame

#### 2.2.2 Better signal synchronization

Since the CAN FD bus increases the data field length to 64 bytes, one frame of message can transmit more information. Taking the battery management system (BMS) of a new energy vehicle as an example, each battery pack used in a new energy vehicle is equipped with a battery management system slave control board and the voltage of each battery cell in the battery pack is represented by two bytes. The battery pack used in the experiment has a total of 15 cells, so the traditional CAN bus needs to send multiple frames to send the voltage of all the cells. The master control performs calculations and control by receiving the single-cell voltages sent by the slaves. Since the voltage data is transmitted in multiple frames, the synchronization of the transmission and reception of different cell voltage information is reduced. The CAN FD bus can transmit the voltage information of all the cells of the battery pack in one frame. Therefore, CAN FD makes the synchronization of the associated signal transmission better.

### 2.2.3 Reduce bus load rate data

The large amount of data to exchange and high real-time requirements put much pressure on the traditional CAN bus, causing a significant increase in bus load rate. As the load rate increases, the risk of message loss is increased, and the delay in sending and receiving messages increases. The CAN FD bus has a lager data field length, which is 8 times that of the conventional CAN data field. When the same amount of data is exchanged, the load rate of the CAN FD bus is much lower.

In order to verify the performance of the CAN FD bus in reducing the load rate, the battery management system (BMS) on the new energy vehicle is adopted as the application scenario. The communication network includes one master and ten slaves. The slave control sends the cell voltage, temperature and other information of the corresponding battery pack to the master through the bus. Traditional CAN bus requires 8 frames of messages to send all the information, while CAN FD message can send all the information in one frame. The software of Canoe is used to simulate the virtual nodes of the network communicating. The scheme is shown in Figure 2. As for CAN bus, the baud rate is set to common 500kbit/s. For CAN FD bus, the baud rate for the data segment is set to 2Mbit/s and the baud rate for the rest is set to 500kbit/s.

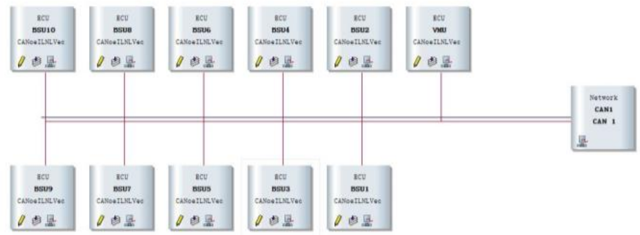


**Figure 2** Communication network architecture

The simulation results are as follows. The load rate of traditional CAN bus is close to 50% while the load rate of CAN FD bus is just over 5%. The load rate is significantly reduced, which is significant for the reliability of the communication and the safety of the vehicle.

CAN Channel: CAN 1 - CAN1

| Statistic | Current ... | Min | Max | Avg |
|---|---|---|---|---|
| Busload [%] | 47.59 | 47.59 | 47.59 | 47.59 |
| Min. Send Dist. [ms] | 0.000 | n/a | n/a | n/a |
| Burst Time [ms] | 23.796 | 23.796 | 23.796 | 23.796 |
| Bursts [total] | 1935 | n/a | n/a | n/a |
| Frames per Burst | 81 | 81 | 81 | 81 |
| Std. Data [fr/s] | 0 | 0 | 0 | 0 |
| Std. Data [total] | 0 | n/a | n/a | n/a |
| Ext. Data [fr/s] | 1620 | 1620 | 1620 | 1620 |
| Ext. Data [total] | 156735 | n/a | n/a | n/a |
| Std. Remote [fr/s] | 0 | 0 | 0 | 0 |
| Std. Remote [total] | 0 | n/a | n/a | n/a |
| Ext. Remote [fr/s] | 0 | 0 | 0 | 0 |
| Ext. Remote [total] | 0 | n/a | n/a | n/a |
| Errorframes [fr/s] | 0 | 0 | 0 | 0 |
| Errorframes [total] | 0 | n/a | n/a | n/a |
| Chip State | Simulated | n/a | n/a | n/a |
| Transmit Error C... | 0 | n/a | 0 | n/a |
| Receive Error Count | 0 | n/a | 0 | n/a |
| Transceiver Errors | 0 | n/a | n/a | n/a |

CAN Channel: CAN 1 - CAN1

| Statistic | Current ... | Min | Max | Avg |
|---|---|---|---|---|
| Busload [%] | 5.76 | 5.76 | 5.76 | 5.76 |
| Min. Send Dist. [ms] | 0.000 | n/a | n/a | n/a |
| Bursts [total] | 829 | n/a | n/a | n/a |
| Burst Time [ms] | 2.879 | 2.879 | 2.879 | 2.879 |
| Frames per Burst | 11 | 11 | 11 | 11 |
| Std. Data [fr/s] | 0 | 0 | 0 | 0 |
| Std. Data [total] | 0 | n/a | n/a | n/a |
| Ext. Data [fr/s] | 220 | 220 | 220 | 220 |
| Ext. Data [total] | 9119 | n/a | n/a | n/a |
| Std. Remote [fr/s] | 0 | 0 | 0 | 0 |
| Std. Remote [total] | 0 | n/a | n/a | n/a |
| Ext. Remote [fr/s] | 0 | 0 | 0 | 0 |
| Ext. Remote [total] | 0 | n/a | n/a | n/a |
| Errorframes [fr/s] | 0 | 0 | 0 | 0 |
| Errorframes [total] | 0 | n/a | n/a | n/a |
| Chip State | Simulated | n/a | n/a | n/a |
| Transmit Error C... | 0 | n/a | 0 | n/a |
| Receive Error Count | 0 | n/a | 0 | n/a |
| Transceiver Errors | 0 | n/a | n/a | n/a |

**Figure 3** Comparison of load rates between CAN bus and CAN FD bus

In order to further verify the performance of CAN FD in reducing the load rate, the actual circuit board is used for the full physical nodes communication test. The single-chip microcomputer used in the experiment is Atmel's ATSAMC21J18A and the circuit board design scheme is shown in Figure 4.

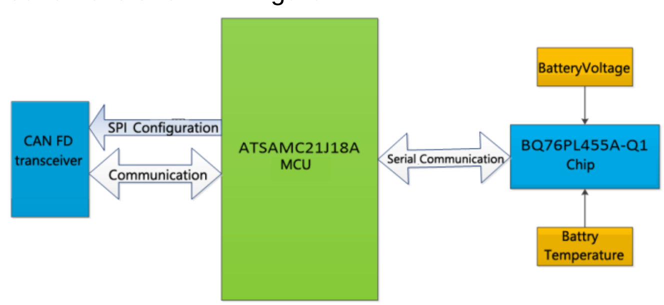


**Figure 4** The scheme of circuit board design

When performing the whole physical nodes test, taking into account the influence of the temperature and voltage acquisition time on the comparison of the bus

CAN Channel: CAN 1 - CAN1

| Statistic | Current ... | Min | Max | Avg |
|---|---|---|---|---|
| Busload [%] | 45.64 | 44.93 | 46.00 | 45.43 |
| Min. Send Dist. [ms] | 0.000 | n/a | n/a | n/a |
| Burst Time [ms] | 15.127 | 0.566 | 15.127 | 5.631 |
| Bursts [total] | 2636 | n/a | n/a | n/a |
| Frames per Burst | 53 | 2 | 53 | 20 |
| Std. Data [fr/s] | 0 | 0 | 0 | 0 |
| Std. Data [total] | 0 | n/a | n/a | n/a |
| Ext. Data [fr/s] | 1600 | 1575 | 1600 | 1590 |
| Ext. Data [total] | 75933 | n/a | n/a | n/a |
| Std. Remote [fr/s] | 0 | 0 | 0 | 0 |
| Std. Remote [total] | 0 | n/a | n/a | n/a |
| Ext. Remote [fr/s] | 0 | 0 | 0 | 0 |
| Ext. Remote [total] | 0 | n/a | n/a | n/a |

CAN Channel: CAN 1

| Statistic | Current ... | Min | Max | Avg |
|---|---|---|---|---|
| Busload [%] | 8.19 | 8.00 | 8.23 | 8.15 |
| Min. Send Dist. [ms] | 0.000 | n/a | n/a | n/a |
| Bursts [total] | 140 | n/a | n/a | n/a |
| Burst Time [ms] | 0.000 | 0.813 | 1.251 | 0.893 |
| Frames per Burst | 0 | 2 | 3 | 2 |
| Std. Data [fr/s] | 0 | 0 | 0 | 0 |
| Std. Data [total] | 0 | n/a | n/a | n/a |
| Ext. Data [fr/s] | 200 | 195 | 200 | 199 |
| Ext. Data [total] | 6458 | n/a | n/a | n/a |
| Std. Remote [fr/s] | 0 | 0 | 0 | 0 |
| Std. Remote [total] | 0 | n/a | n/a | n/a |
| Ext. Remote [fr/s] | 0 | 0 | 0 | 0 |
| Ext. Remote [total] | 0 | n/a | n/a | n/a |

**Figure 5** Comparison of load rates between CAN bus and CAN FD bus in physical test

load rate, the control board sends messages directly to the bus and the master receives it. The test result is shown in Figure 5. It can be seen that the load rate of the CAN FD bus is also significantly reduced during the physical test.

## 2.3 Increased network security design

Whether it is the traditional CAN bus or the CAN FD bus, the CRC field is used to verify the correctness of the data transmission. In order to improve the communication security of the bus network, the CAN FD bus can be added with the following design. The CRC-16 check is performed on the first 62 bytes of the data field and the upper 8 bits and the lower 8 bits of the obtained 16-bit check code are respectively stored in the 63rd and 64th bytes of the data field. The check polynomial is: x^ 16+x^15+x^2+1 and the initial value of the checksum is 0. The CRC-16 check uses the method of looking up table. The figure 6 below shows the code design.

```
Output Window
Chn Identifier Flg   DLC  D0...1...2...3...4...5...6..D7     Time        Dir
0    1800F301 XFB    40   AA  AA  AA  AA  AA  AA  AA  AA   2869.896540 R
                          AA  AA  AA  AA  AA  AA  AA  AA
                          AA  AA  AA  AA  AA  AA  AA  AA
                          AA  AA  AA  AA  AA  AA  AA  AA
                          AA  AA  AA  AA  AA  AA  AA  AA
                          AA  AA  AA  AA  AA  AA  AA  AA
                          AA  AA  AA  AA  AA  AA  AA  AA
                          AA  AA  AA  AA  AA  AA  FE  D5
```

**Figure 6** CRC-16 code design

When transmitting a message, the check code of calculating the first 62 bytes are sent through the 63rd byte and the 64th byte. The check code of the first 62 bytes are also calculated when receiving and compared with the received check code. If the two check codes are the same, the message is received correctly. Otherwise, there are errors already generated and receiving nodes will send error frames. As can be seen from Figure 7, the bus receives the correct message and the last two bytes are the CRC-16 check code of first 62 bytes. This additional verification design, along with CRC field greatly increases the security and reliability of network communication.

```
uint16_t CRC16(uint8_t* dataIn, int length)
{
    uint16_t result  = 0;
    uint16_t tableNo = 0;

    for( i = 0; i < length; i++)
    {
        tableNo = ((result & 0xff) ^ (dataIn[i] & 0xff));
        result  = ((result >> 8) & 0xff) ^ CAN_CRC16Table[tableNo];
    }

    return result;
}
```

**Figure 7** Test Result of bus receiving messages

## 2.4 Higher bus writing rate

For a host factory, the development of a set of its own basic software to refresh software for vehicle verification and re-development can greatly reduce the cost and time of its development[7]. Software refreshing is usually based on the vehicle bus, so the writing rate is important. In order to compare the flash writing rate of CAN bus and CAN FD bus, the hex file of the BMS master program is converted into an hst file by the M script. The messages in the hst file is loaded by the Canking software and then sent out through the bus. The interval between two adjacent messages is 10ms. As can be seen from Figure 8, when the data field is increased to 64 bytes, the flash writing time is greatly reduced. The CAN FD bus significantly increases the flash writing rate and facilitates the upgrading of software based on the vehicle bus.

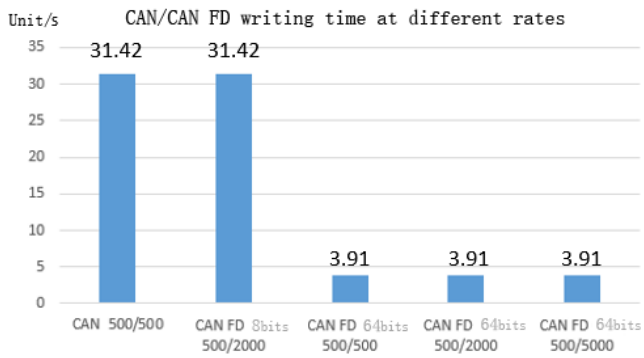


**Figure 8** Writing rate test of CAN and CAN FD bus

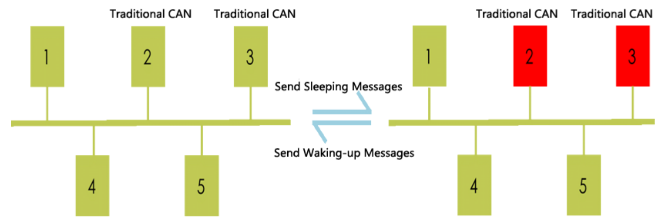


**Figure 9 CAN nodes and CAN FD nodes compatibility**

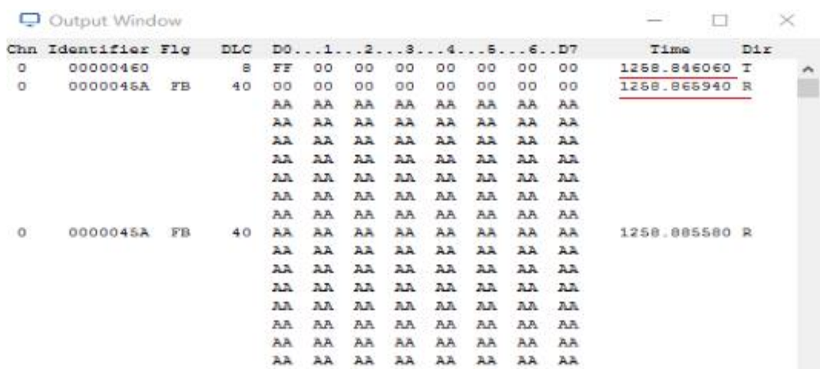


**Figure 10** Sleeping time test

## 3. Compatibility between CAN and CAN FD

At present, there are many CAN bus nodes in vehicles and it is possible to upgrade some CAN nodes into CAN FD nodes and achieve compatible communication between CAN nodes and CAN FD nodes in the same network, which will reduce the cost of upgrading the bus. This has a significant effect on the application prospect of CAN FD bus. The realization of compatibility between CAN FD and CAN is still in the research stage and many schemes are proposed. Since the CAN FD nodes can send and receive CAN messages, but the CAN nodes cannot receive CAN FD messages. The solution adopted in this study is to set all the CAN nodes to sleeping state by sending a message before sending CAN FD messages. After the CAN FD communication is completed, immediately a message is sent to wake up all CAN nodes, as shown in Figure 9.

The sleeping time test is shown in Figure 10. After the sleeping command is transmitted, no more than 20ms, the first frame of CAN FD message is sent from CAN FD nodes. The switching time is very short and the working modes is switched efficiently, which achieves the compatibility between CAN and CAN FD.

## 4. Conclusions

The CAN FD bus has higher communication bandwidth and larger data field length than traditional CAN bus. It can significantly reduce the load rate of bus and improve security and reliability of the communication while inheriting the performance of traditional CAN bus. It enhances signal synchronization and facilitates bus-based software refreshing.

It can realize the compatibility between traditional CAN and CAN FD. In the same bus network, there are both CAN nodes and CAN FD nodes, which takes into account the existing situation of a large number of traditional CAN nodes and some electronic control components have requirements on exchanging large amount of data and high real-time communication. The compatibility reduces the application cost and is essential for the promotion and application of CAN FD bus, which can meet the requirements of current electronic control components for the communication bus.

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