A Typical Application of FlexRay Bus in the Vehicle

Yandong Dong and Wanrong Wang

Abstract *Objective*. FlexRay is a new and high-powered bus which is designed to achieve the purpose of "X-by-Wire", may be one day, the CAN bus will be replaced by FlexRay bus. Although this is a high speed and reliable bus, but it is very difficult to apply this bus in the vehicle. The cost is too high, by now on, only a few top grade cars like Audi A8 and BMW X7 use the FlexRay bus. We are doing the research about how to apply the FlexRay in a low cost and feasible way. *Methodology*. FlexRay is a high cost bus: 1. The FlexRay controller and the MCU which support FlexRay communication is very costly. 2. The software design is very difficult, and there are no uniform guidelines to develop the system. Our research focus on the vehicle network's strategy, the uniform FlexRay develop standards as well as the tool chain, the uniform diagnostic strategy and software reprogram strategy. We can use the FlexRay bus as a subnet of the vehicle. The important module like ECM, TCM, ABS module use FlexRay, other module like BCM, SDM, IPC use CAN, there will be a central gateway to transmit the signals between the FlexRay bus and CAN bus. If more and more module suppliers can follow our standards, the cost will be low and the system development will be easy. *Results*. Based on the ISO and FlexRay Union's documents, we have developed some standards for the FlexRay, these standards contains the FlexRay Physical layer standard, the Protocol layer standard, the net management standard, the Communication layer standard and the Diagnostic layer standard. These standards have established main parameter and many other important schemes for the FlexRay bus. The modules which are developed based on these standards can communicate on the same FlexRay bus with no error. We are developing the

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central gateway module which can transmit the signals from CAN bus to FlexRay bus, these signals contain the cycle signals the diagnostic signals and the programming signals. Use the gateway, we can diagnostic and programming the FlexRay modules through the CAN bus. *Limitations of this study*. We are now designing the entire system and the central gateway module, we have not enough FlexRay modules to do the network testing. We have to use the diagnostic equipment to simulate the entire network. What does the paper offer that is new in the field in comparison to other works of the author: Only few vehicles use FlexRay bus. We will develop a low cost and feasible architecture and network strategy to apply the FlexRay bus in the vehicle. *Conclusion*: Although the FlexRay bus is complex bus, we still can find a low cost and feasible way to apply the bus in the vehicle.

Keywords Flexray · Network · Gateway · CAN · UDS

1 Overview

FlexRay is the high-powered bus in the future. It is Time Division Multiple Address (TDMA) to ensure the FlexRay communication precision, compared with CAN, it has much higher speed (more than 10 Mbps), more flexible topology, higher bus load (more than 90 %), and more safety (support two channel redundancy communication).

The technical standard about FlexRay:

- The speed is more than 10 Mbps;
- Dual channel, high speed, deterministic, fault tolerant;
- The bus length can reach 72 m;
- Deterministic communication (Time Division Multiple Address);
- Distributed clock synchronization;
- Flexible topology;

As a new network technology, FlexRay is more complicated, require high qualified communication wire. On the standard of communication, Flexray union has made a detailed definition of physical layer and data link layer, but FlexRay union did not define the communication layer and diagnose layer of FlexRay [1]. Because FlexRay's agreement is far complicated than CAN and it has many communication parameters, every factory has not form the unified and applied agreement standard, which is not good for the promotion of FlexRay.

This article schemes out a more detailed FlexRay agreement standard on basis of the existed FlexRay standards. The article has a much detailed definition of physical layer, data link layer, communication layer, diagnostic and key parameters. The aim of this article is to make FlexRay more convenient for the use of engineering.

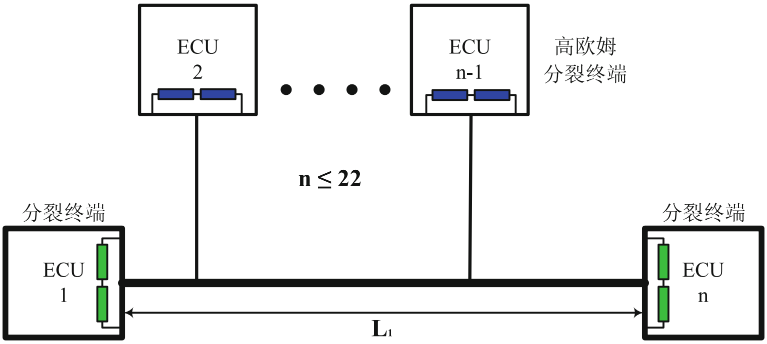


Fig. 1 FlexRay topology

On the basis of this standard, the article puts up with a typical FlexRay scheme, defines the topology. Here this topology needs a central gateway to link CAN and FlexRay. Because the working style and message format of CAN and FlexRay has a big difference, the article puts up with a transition way between CAN and FlexRay. The way can solve the problem of message route, reprogram, network management and diagnostic.

2 The Specifically FlexRay Protocol for the System

2.1 Physical Layer

FlexRay topology is shown in Fig. 1, the parameter is shown in Table 1.

2.2 Data Link Layer

2.2.1 Parameters

All ECU use dual channel, fault tolerant, all ECU baud rate is 10 Mbit/s. When the baud rate is 10 Mbit/s, The global sample clock period gdSampleClockPeriod is 0.0125us [2].

2.2.2 Period

As shown in Fig. 2, except the startup stage, the period is continuous and contain fixed time slot. gMacroPperCycle and gdMacrotick are defined in Table 1; Communication period counts is from 0 to cCycleCountMax = 63 (Table 2).

Table 1 FlexRay topology parameters

Parameter	Symbol	Min	Median	Max	Unit	Comments
Wire length	L_1	0.1	–	24	m	Tow ECU's distance
ECU number	n	0	–	22	Count	The max ECU number

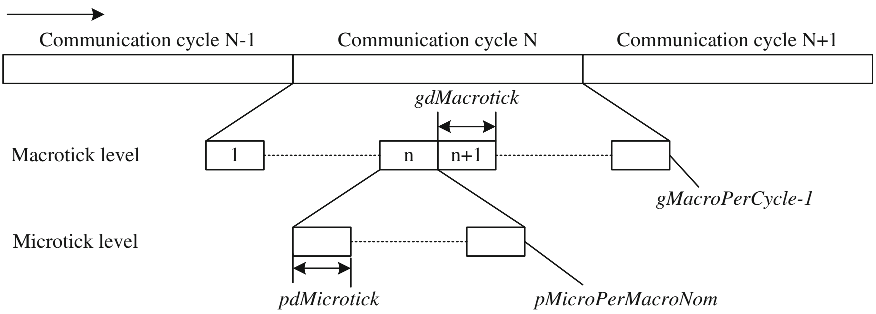


Fig. 2 FlexRay communication cycle

Table 2 The communication cycle parameters

Parameter	Min	Median	Max	Unit	Comment
gdCycle	-	5,000	16,000	us	Cycle time
gMacroPerCycle	-	3,636	16,000	MT	The MT number in a cycle
gdMacrotick	1	1.375	6	us	The general MT time
gdMaxMicrotick	0.0125	0.025	0.1	us	The max time of uT

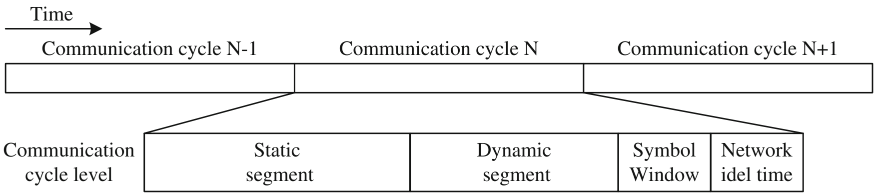


Fig. 3 FlexRay communication cycle structure

The communication cycle contain Static segment, Dynamic segment, Symbol Window, Network idle time (Fig. 3).

2.2.3 Static Segment

In static segment, ECU use static Time Division Multiple Address to adapt to the communication.

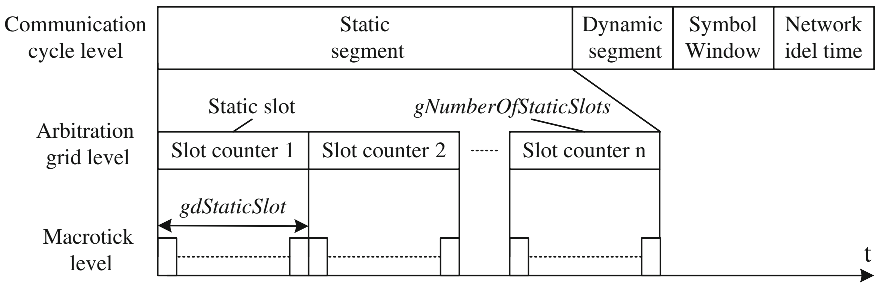


Fig. 4 Static segment

Table 3 Static segment time parameters

Parameters	Min	Median	Max	Unit	Comment
gNumberOfStaticSlots	2	91	1,023	-	The number of static slot in the static segment
gdStaticSlot	4	24	661	MT	The static slot length
gdTSSTransmitter	6	9	15	gbBit	
gdActionPointOffset	1	2	63	MT	

As shown in Fig. 4, all the static slots are equal. Static segment contain some static slots which can be configured. All the static slots can be constituted by some MT [3] (Table 3).

2.2.4 Dynamic Segment

As shown in Fig. 5, dynamic segment is constructed by some mini slots. Each mini slot can be divided into some MT. The number of mini slot in dynamic segment is given the name dNumberOfMinislots, this parameter is a global variable. The parameter gdMiniSlot which shows the length of mini slot, is a global variable, all these parameter should be given the value as Table 4.

2.3 Communication and Diagnostic

2.3.1 Addressing Mode of Diagnostic

The addressing mode show the target address and source address in FlexRay network. The format is shown in Table 5.

The diagnostic message is in dynamic segment, the message ID is target address, the addressing mode in data link layer is shown in Fig. 6.

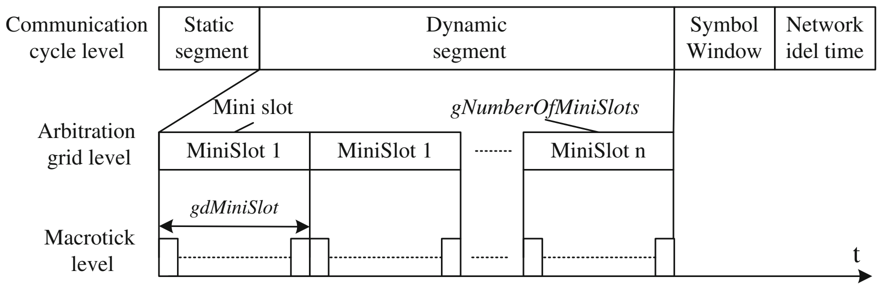


Fig. 5 Dynamic segment

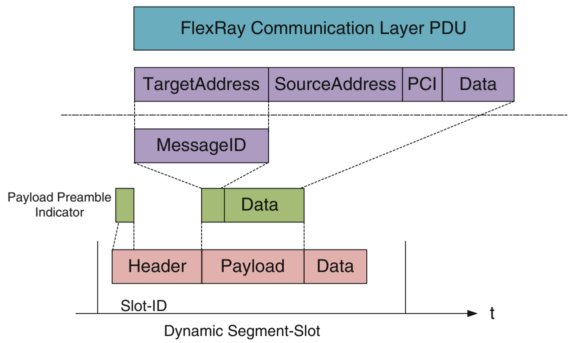
Table 4 Dynamic segment parameters

Parameters	Min	Median	Max	Unit	Comments
gNumberOfMiniSlot	0	289	7,986	-	The number of Mini Slot
gdMiniSlot	2	5	63	MT	The length of Mini Slot

Table 5 The Addressing mode format

Byte1	Byte2	Byte3	Byte4
15	0	15	0
C_TA		C_SA	

Fig. 6 Target address in dynamic segment



All the ECU should support function addressing and physical addressing. Physical addressing is used in the condition that tester diagnose only one ECU (1:1).Function addressing is used in the condition that tester diagnoses many ECUs at the same time (1:n). Function addressing mode can only support single diagnostic frame. All the diagnostic messages should be transmitted in channel A.

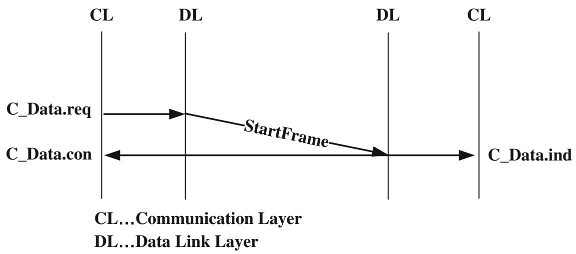


Fig. 7 Un segmented unacknowledged message (known message length)

2.3.2 Communication Layer

The communication layer should follow ISO10681-2 and the standard bellow. OSI transport layer and network layer together constitute the communication layer.

The ECU should support the communication mode as bellow:

1. Un segmented unacknowledged message (known message length), as shown in Fig. 7;
2. Segmented unacknowledged message (known message length), as shown in Fig. 8;

When tester communication with ECU in FlexRay network, the message must be routed by the Gateway, only PCI need to be changed, this must follow the standard bellow:

1. When the data is less than 7 bytes, use single frame to transmit;
2. When the data is more than 7 bytes, use multi frame to transmit, and must follow the standards bellow [4]:

- STF (Start Frame) should transmit 6 payload bytes, FPL is 6;
- CF (Consecutive Frame) should transmit 7 payload bytes, FPL is 7;
- CFEOB (Consecutive Frame EOB) should transmit 7 payload bytes, FPL is 7;
- LF (Last Frame) should transmit less or equal to 7 payload bytes, FPL is less or equal to 7;
- The max length of the multi frame transmission is 4,095 bytes (ML is 4,095 bytes);
- If the number of payload data length is odd, 0×00 must to be used to fill the data to reach even number.

2.3.3 Diagnostic Services

Overview of enhanced diagnostic services shown in Table 6.

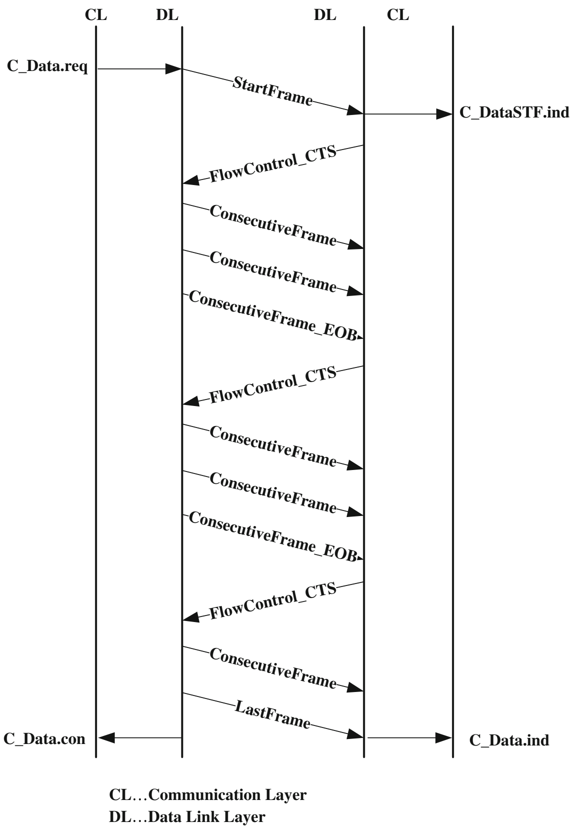


Fig. 8 Segmented unacknowledged message (known message length)

3 FlexRay Typical Application

3.1 FlexRay Architecture Scheme

Now most of vehicles have CAN network, for FlexRay network, the most convenient way is change the existent CAN network into FlexRay network, the communication speed and quality will be improved, the system performance will be improved. As shown in Fig. 9, the architecture contains the Gateway, the diagnostic interface, the Chassis CAN network and the Chassis FlexRay network. The CAN network and the FlexRay network contain the same electronic modules. Only one network can work at the same time, the other is the backup network, vehicle can either use the CAN network or use the FlexRay network. Only upgrade these electronic modules to support FlexRay, the vehicle will use FlexRay to replace CAN.

This Gateway can support 4 CAN network, the Body CAN network, the Chassis CAN network, the Power train CAN network and the diagnostic CAN network.

Table 6 Enhanced diagnostic service [5]

SID (Hex)	Service	Session		Supported		Cvt	Dependence
		Default	Other	Fun	Phy		
Diagnostic and communication management							
0 × 10	DiagnosticSessionControl	0	0	√	√	M	–
0 × 11	ECUReset	0	0	√	√	M	–
0 × 27	SecurityAccess	–	0	–	√	U	–
0 × 28	CommunicationControl	–	0	√	√	U	–
0 × 3E	TesterPresent	0	0	√	√	M	–
0 × 85	ControlDTCSetting	–	0	√	√	U	–
Data transmit							
0 × 22	ReadDataByIndetifier	0	0	√	√	M	–
0 × 23	ReadMemoryByAddress	0	1	–	√	U	–
0 × 2A	ReadDataByPeriodicIdentifier	0	0	–	√	U	–
0 × 2E	WriteDataByIdentifier	–	1	–	√	U	0 × 22
0 × 3D	WriteMemoryByAddress	–	1	–	√	U	0 × 23
DTC							
0 × 14	ClearDiagnosticInformation	0	0	√	√	M	–
0 × 19	ReadDTCInformation	0	0	√	√	M	–
Input output control							
0 × 2F	InputOutputControlByIdentifier	–	1	–	√	U	–
Up load/down load							
0 × 34	RequestDownload	–	1	–	√	U	0 × 36, 0 × 37
0 × 36	TransferData	–	1	–	√	U	0 × 34, 0 × 37
0 × 37	RequestTransferExit	–	1	–	√	U	0 × 34, 0 × 36
RoutineControl							
0 × 31	RoutineControl	–	1	–	√	U	–

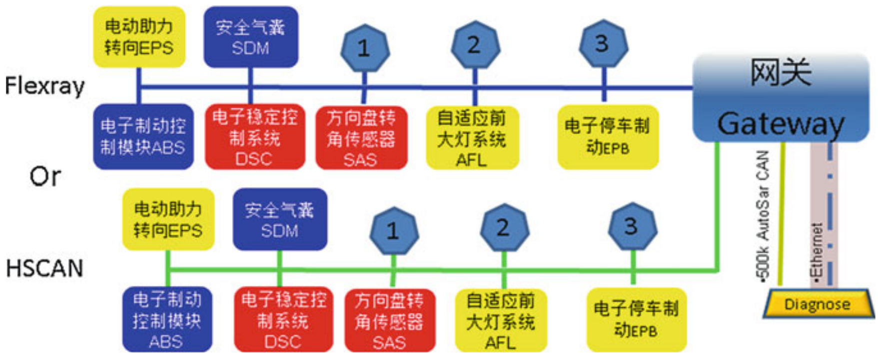


Fig. 9 Architecture

The Gateway can also support 1 FlexRay network which can fulfill the function of the Chassis CAN network.

3.2 FlexRay Protocol and CAN Protocol Exchange

3.2.1 Gateway

The Gateway is the kernel module of the whole network, it can connect 4 CAN network and FlexRay network together, to fulfill the signal routing between different network. The Gateway support not only CAN protocol but also FlexRay protocol, it can route the period message and diagnostic message.

3.2.2 Period Message Routing Between CAN and FlexRay

CAN protocol is simple, each CAN message contain 8 bytes, each CAN message has the only CAN ID, all the CAN ID is different; The FlexRay is different from CAN, FlexRay contain static segment and dynamic segment. The message in static segment is cycle message; the message in dynamic segment is usually diagnostic message. The max data length of FlexRay message is 254 bytes [6].

When route the FlexRay message of static segment to CAN network, there are many ways. If the payload data length is 32, this message can be split into 4 different CAN message, if the payload data length is 80, this message can be split into 10 different CAN message. In static segment, all the message data length should be the same.

When route the cycle CAN message to FlexRay network, if the FlexRay payload data length is 32 bytes, then 4 CAN message should be packed into one FlexRay static message. When the period time of the 4 CAN message is different, the shortest period time should be used as the FlexRay message's period. For this system, the FlexRay static message's payload data length is 16 bytes.

FlexRay is different from CAN, CAN is based on event, FlexRay is based on time, the CAN message period time is not very precise, but the FlexRay message period time is very precise. Use CAN id, each CAN message can be exactly identified, but the FlexRay Frame ID cannot exactly identify the message, now the FlexRay schedule is needed. Based on the schedule, use FlexRay frame ID and FlexRay cycle count, tester can distinguish which module the message is come from. FlexRay cycle count is from 0 to 63, so the static message period time should be the multiple of one cycle time.

In this system the single cycle time is 5 ms, the entire communication cycle time is 5 ms*64 = 320 ms. Thus, the static message period time should be the multiple of 5 ms, such as 5, 10, 20 ms, and so on. If the CAN message period time is 12 ms, when route this message to FlexRay network, the period time should use 10 ms, less than 12 ms.

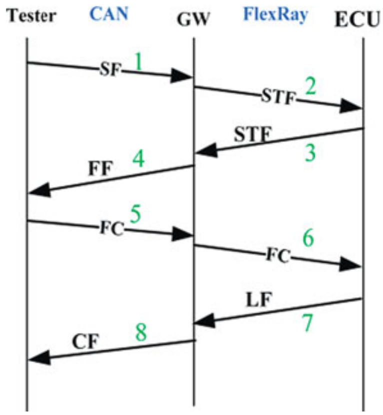


Fig. 10 Communication between Tester and ECU

3.2.3 Diagnostic Message Routing Between CAN and FlexRay

The CAN diagnostic transport protocol should follow ISO15765-2, the application protocol should follow ISO14229-1. The FlexRay diagnostic transport protocol will follow ISO10681-2, the application protocol should follow ISO14229-1.

For this system, tester can only diagnostic the network through CAN bus, the diagnostic message must be routed to the FlexRay bus by Gateway, one CAN diagnostic message versus one FlexRay diagnostic message. The CAN diagnostic message contain 8 bytes data, the FlexRay diagnostic message contain 16 bytes payload data. The following example will show how the CAN diagnostic message converted to the FlexRay diagnostic message by Gateway.

Condition:

Such as UDS $22 service, read PID, tester send the CAN message: 241 03 22 C0 00. ($241 is the ABS module which is on FlexRay bus, $03 is the data length). Response from CAN: 641 10 0A 62 C0 00 00 00 00. Tester send: 241 30 00 00 (flow control). Response from CAN: 641 21 01 03 FF FF 00 00 00 [7, 8].

Process:

$241 is ECU ID, the ECU is on FlexRay bus, $641 is tester ID, the dataflow can be shown in Fig. 10 and Table 7.

- Red data in Table 7: for transport layer, red data is available data
- Blue data in Table 7: transport layer protocol control message
- Black data in Table 7: filling data (follow ISO10681-2)

Message 1 and message 2 are single frame request for PID, $02 41 is ECU address, $06 41 is tester address, $40 is FlexRay STF (Start Frame) communication control message, $03 is the frame payload length (FPL), $00 03 is single frame or multi-frame max data length (ML). Message 2 is single frame transmission.

Message 3 is a multi-frame transmission, this is multi-frame response to tester. $06 41 is tester address, $02 41 is ECU address, $40 is STF, $06 is FPL, $00 0A is ML, the other 6 bytes is payload data.

Table 7 Data flow example

Message ID	Data Flow														
1	03	22	C0	00	00	00	00	00							
2	02	41	06	41	40	03	00	03	22	C0	00	00			
3	06	41	02	41	40	06	00	0A	62	C0	00	05	00	00	
4	10	0A	62	C0	00	05	00	00							
5	30	00	00	00	00	00	00	00							
6	02	41	06	41	83	00	0F	FF							
7	06	41	02	41	90	04	00	0A	01	03	FF	FF			
8	21	01	03	FF	FF	00	00	00							

Message 5 is the flow control message sent by tester, message 6 is the flow control message for FlexRay which is converted from Message 5. $02 41 is ECU address, $06 41 is tester address, $83 is flow control message which means continue to send (CTS), $00 is BC (Bandwidth Control), $0F FF is communication layer buffer which is only used in FlexRay communication layer.

Message 7 is continue frame sent by ECU, $06 41 is tester address, $02 41 is ECU address, $90 is last frame (LF), 04 is payload data length (FPL), $00 0A is max data length (ML), the other 4 bytes is payload data.

4 Conclusions

This article advances the FlexRay standards which have been proved to be all right in simulation test. If more company can unite to use the same standards, the cost will be low, this is very important for the cosmically application of FlexRay.

The scheme that based on the Gateway, use FlexRay to replace the CAN network, is very efficiency for the development of FlexRay. This scheme can save time for developing and is very convenient for the FlexRay generalization.

The conversion scheme between CAN and FlexRay proposed by this article, can realize the CAN protocol transfer to FlexRay protocol with no error. This conversion scheme can resolve the diagnostic problem, the net management problem and the reprogramming problem between CAN and FlexRay.

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