S C H O O L

Automotive Industry

CAN FD Communication

Introduction

In the decades since the introduction of the CAN bus the fabric of embedded systems in vehicles has changed profoundly. Arguably the most evident change is quantity: Had there been some hundreds of signals to be communicated at the time CAN was introduced, today the numbers are in thousands.

Consequently the rise in data traffic led to ever higher bus loads on the CAN buses. Aside from the rising demand in bandwidth, an increasing need for deterministic system behavior encouraged the development of new bus systems. New protocols have been developed such as MOST, FlexRay, and LIN.

Introduction

MOST ® (Media Oriented System Transport) is a serial communication system for transmitting audio, video and control data via fiber-optic cables.

MOST bus was created with band widths of up to 150 Mbit/s

FlexRay is a communication bus designed to ensure high data rates.

The deterministic FlexRay bus offers bandwidths of 10Mbit/s suitable for driver assistance functionality

LIN (Local Interconnect Network) is a serial network protocol was introduced as a low cost solution for the systems that requires low speed communication. It is intended to complement the existing CAN network with speed up to 19.2 KHz

CAN Limitation

The limiting factor for the bandwidth of CAN is due to one of its core properties: During specific phases of a message transmission multiple network nodes may be in transmission mode at the same time. This may be the case at the beginning of a transmission during the arbitration phase and is always true in the acknowledge field at the end of a message. This means the transmission time of one bit must not be shorter than it takes its voltage level to propagate from a node on one end of the bus to one on the other — and back again. For example: On a CAN bus of 40 meters in length the maximum transmission rate is about 1 Mbit/s in order to fulfill the required transmission time of one bit.

However during the part between the arbitration phase and the acknowledgement field of a CAN frame only one transmitter is allowed. Hence in this part of the frame there is no restriction on the minimum duration of a bit time. And what would be — so engineers at Bosch thought — if we increased the transmission rate during this portion of a CAN frame? You only would need to toggle between two different transmission rates: A slow one at the beginning and end of a CAN frame and a fast one in the middle. Exactly this is the fundamental idea of CAN FD.

CAN FD Network

CAN FD (Controller Area Network Flexible Data-Rate) is an extension to the original CAN bus protocol that was specified in ISO 11898-1. Developed in 2011 and released in 2012 by Bosch, CAN FD was developed to meet the need to increase the data transfer rate up to 5 times faster and with larger frame /message sizes for use in modern automotive Electronic Control Units.

To make CAN FD work, new CAN FD controllers are needed. These however are downward compatible and are able to handle classical CAN. ECUs on a CAN bus can be replaced with CAN FD capable ones step by step.

CAN FD controllers can send and receive classical CAN frames as well as CAN FD frames. On the other hand, a classical CAN controller will always react with an error frame when receiving a CAN FD frame: A recessive bit in the position of the dominant r-bit in classical CAN is regarded as irregularity.

CAN FD Specifications

In addition to what is defined in classical CAN, the CAN FD Provides:

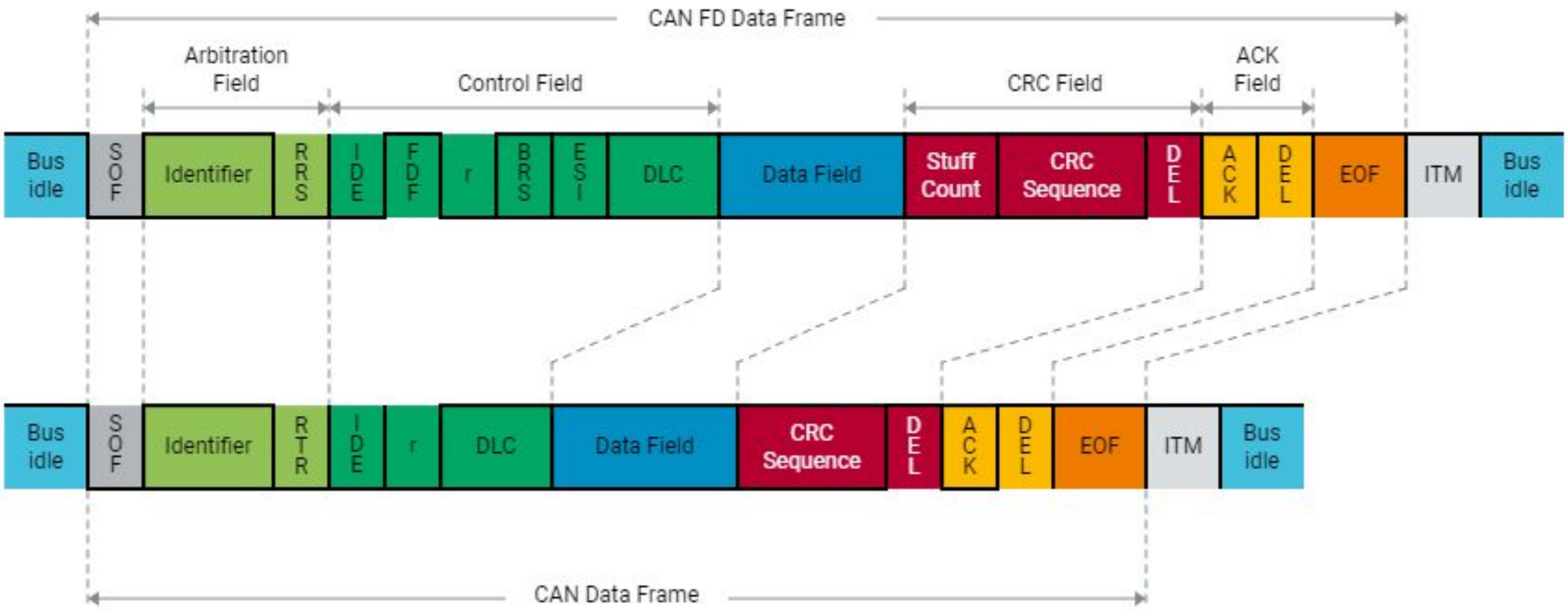
1- Just like traditional CAN also CAN FD knows two types of data frame formats: the standard frame with 11 bit identifier and the extended frame with 29 bit identifier.

2- CAN FD does not define an individual format for Remote Frames.

3- Up to 5 Mbps data bandwidth

4- Up to 64 byte of data in the same data frame

CAN FD Frame



CAN FD Data Frame
Arbitration Field
Control Field
CRC Field
ACK Field
Bus idle
SOF
Identifier
RRS
IDE
FDF
r
BRS
ESI
DLC
Data Field
Stuff Count
CRC Sequence
DEL
ACK
DEL
EOF
ITM
Bus idle
Bus idle
SOF
Identifier
RTR
IDE
r
DLC
Data Field
CRC Sequence
DEL
ACK
DEL
EOF
ITM
Bus idle
CAN Data Frame

CAN FD Frame

Start of Frame (SOF), Identifier and Identifier Extension Bit (IDE) remain unchanged. Also at the end of the CAN FD frame the Acknowledge Bit (ACK), the corresponding Delimiter (DEL), the End of Frame (EOF) as well as the Intermission Field (ITM) remain as in traditional CAN frames.

RTR replaced by RRS

As there are no Remote Frames for CAN FD the RTR bit is not necessary and is substituted by the always dominant Remote Request Substitution bit (RRS).

The reserve bit of the traditional CAN frame now becomes the switch for the CAN FD format. If transferred dominant as 0, it denotes a classical CAN frame. If it contains the recessive value 1, it denotes a CAN FD frame.

FDF

The bit's new name is FDF for Flexible Data Rate Format which establishes the opportunity to transmit a much larger payload. The actual length of the data field and the decision whether to switch to a higher transmission rate or not, follow later in the frame.

CAN FD Frame

Bit Rate Switch

After a reserve bit r for future extensions to CAN FD a bit called Bit Rate Switch (BRS) follows. When dominant, baud rate 2 is equal to baud rate 1, so no accelerated transmission will occur. Baud rate 2 is defined as 5 MBaud which corresponds to 5 Mbit/s,

Error State Indicator

A bit called Error State Indicator (ESI) follows the Bit Rate Switch (BSR). It is dominant, if the ECU is in the Error Active state. If it is recessive it indicates that the ECU is in the state Error Passive. The purpose of this bit is to enable a more transparent way of tracking errors, as well as a simpler network management. The states Error Active and Error Passive of the network nodes are communicated on the entire network.

CAN FD Frame

DLC

The Data Length Code (DLC) had already consisted of four bits under traditional CAN. Now the DLC's remaining seven values 9 through 15 will be used for CAN FD. However the linear correlation between DLC and the number of bytes is abandoned for DLC > 8. The following table displays the different meanings the DLC has for the size of the data field under CAN and CAN FD:

DLC	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Classical CAN	0	1	2	3	4	5	6	7	8	8	8	8	8	8	8	8
CAN FD	0	1	2	3	4	5	6	7	8	12	16	20	24	32	48	64

CAN FD Frame

CRC

The probability of bit errors in a CAN FD frame increases compared to traditional CAN. This is the case because of the shorter bit times of Baud rate 2 on one hand and the much greater number of bits in the data field on the other. This needs to be countered by a larger redundancy in CAN FD frames. Otherwise the probability of errors remaining undetected by the receivers increases. CAN FD frames with data fields with up to 16 bytes will be secured by 17 CRC bits. Even larger data fields will cause the redundancy to have 21 bits.

CAN FD Bit Stuffing

In conventional CAN frames stuff bits are added from the Start of Frame (SOF) through the end of the checksum (CRC). After every five identical bits a complementary bit is inserted. These stuff bits are not calculated into the checksum.

With CAN FD the stuff bits are also added right after the SOF. However, this rule now ends with the data field. The transmitting node calculates the checksum by including the stuff bits that have been added to the frame.

The CRC field itself is stuffed also, but with a higher frequency. Here the following rule applies: The CRC field always starts with a stuff bit complementary to its predecessor. After each four bits which follow, whether they are identical or not, a stuff bit is inserted complementary to its predecessor.

After the CRC no stuff bits are inserted any more as is the case in conventional CAN.

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