CAN&CANFD Network Communication Specification

CAN&CANFD 网络通信规范要求

SOR-Appendix T8

Revision history/修改历史

Date Y/M/D 年/月/日	Edition Change 版本更改	Paragraph Number 段落编号	Change Content 变更内容	Reviser 修订人
2021/10/30	V1.0		初始版本	邢磊 焦根生
2021/11/26	V1.1	5.1.1 章节	增加总线错误处理部分故障恢复的时间	曹晓政
		2.2.2 章节	增加支线终端、非支线终端电阻和单一节点的终端值内容的描述	曹晓政
		5.2 章节	更新节点超时故障的记录时间要求	曹晓政
		6.0 章节	增加第六部分 ECU 启动章节，非 Autosar 网络管理节点启动时刻的时间参数,更改 Autosar 节点引用规范	曹晓政
2022/2/09	V1.2	7.0 章节	增加第七章节 CAN 网关部分的内容	曹晓政 焦根生
		5.2 章节	ECU 故障码记录条件由上电调整为在 ACC 或者 RUN 的状态	曹晓政 焦根生
		8.0 章节	增加第八章 E2E 部分的内容;	曹晓政 焦根生
2022/2/28	V2.0	2.1 章节	增加对于线束和双绞线部分内容的描述	曹晓政 焦根生
		2.4 章节	更新总线电压的描述	曹晓政 焦根生
		3.4 章节	更改收发器应用范围的描述，增加收发器的型号	曹晓政 焦根生
		5.3 章节	添加 5.3 章节。描述通信诊断部分电压和时间的要求	曹晓政 焦根生
		5.1.3 章节	完善 5.1.3 章节关于 Bus off DTC 的描述	
		8.2 章节	优化和增加 E2E 部分算法示例	曹晓政 焦根生
		5.2 章节	修改节点超时诊断使能情况的描述	曹晓政 焦根生
		8.1 章节	删除 8.1 章节信号排布部分的描述	曹晓政 焦根生
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2022/7/29	V2.1	2.2.2 章节	删除支线节点，增加对网段等效电阻的要求	邢磊 焦根生
		2.2.3 章节	修正标题笔误	焦根生
		2.5 章节	表 7 2Mbps 上升沿和下降沿的最大时间改为 150ns	焦根生 邢磊
		3.2.2 章节	1、更新采样点和二次采样点要求 2、增加对于仲裁场和数据场的位定时要求	焦根生 曹晓政
		4.7 章节	增加 4.7 章节	焦根生 曹晓政
		5.2 章节	表 15 增加节点超时时间容差说明	曹晓政 焦根生
		5.3 章节	笔误修正：欠电压或者过电压停止通信后，改为欠电压或者过电压恢复到要求的范围后	焦根生 曹晓政
		7.1.3 章节	增加对路由信号超时处理的要求	曹晓政 焦根生
2022/8/31	V2.2	2.2.2 章节	变更表 2 终端节点和非终端节点电阻的要求 变更网段部分终端电阻的描述	邢磊 曹晓政
		4.3 章节	变更接收到不同长度 CAN 报文的处理策略	邢磊 曹晓政
2022/11/07	V2.3	5.2 章节	变更节点超时诊断记录条件；	曹晓政

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	V2.3	7.2.3 章节	删除网关诊断报文得描述	曹晓政
	V2.3	3.2.2 章节	细化 CANFD 部分采样点的配置参数	曹晓政

目录

1 简介 Introduction

1.1 文档简述 Document description

本标准旨在指导和规范 CAN&CANFD 节点网络通信的设计工作。

This standard is intended to guide and standardize the design of CAN&CANFD network communication

1.2 适用范围 Scope of application

本标准规定了小米汽车 CAN&CANFD 节点的通信要求，适用于本司所有 CAN&CANFD 网络节点，任何偏离都需要得到小米网络工程师的书面认可。

This standard specifies generic CAN implementation requirements for the CAN-interfaced ECU which is connected on CAN/CANFD network. Any deviations from any part of this technical standard must be approved by the responsible Xiaomi network engineer.

1.3 规范性引用文件 Normative references

下列引用文档对于本文档的应用是必不可少的。标注日期的引用文件，仅标注日期的版本适用。未标注日期的引用文件，其最新版本（包括所有的修正项）适用于本标准。

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

标号	标题	版本/修改日期
Ref.1	ISO11898-1-2015: Data link layer and physical signaling	2015
Ref.2	ISO11898-2-2016: High-speed medium access unit	2016
Ref.3	SAE J2284-4-2016 High Speed CAN(HSC) for Vehicle Applications at 500kbps with CAN FD Data at 2Mbps	2016
Ref.4	AUTOSAR Specification of Communication V4.3	
Ref.5	ISO11898-1-2015：数据链路层和物理层信号	2015
Ref.6	ISO11898-2-2016：高速媒体访问单元，2016	2016
Ref.7	SAE J2284-4-2016：车辆应用高速 CAN 500kbps CAN FD 数据速率 2Mbps	2016
Ref.8	AUTOSAR 通信标准 V4.3	
Ref.9	Appendix T8_CAN&CANFD 网络通信规范要求	

1.4 术语及缩写的解释 Terms and abbreviations

Abbr.缩略语	Description 描述
ACK	Acknowledge 应答
CAN	Controller Area Network 控制器局域网

CAN_H	CAN High CAN 高
CAN_L	CAN Low CAN 底
CMC	Common Mode Choke 共模扼流圈
DTC	Diagnostic Trouble Code 诊断故障码
DLC	Data Length code 数据长度码
ECU	Electronic Control Unit 电子控制单元
EMC	Electromagnetic Compatibility 电磁兼容性
ESD	Electro Static discharge 静电放电
SJW	Synchronization Jump Width 同步跳转宽度
PCB	Printed Circuit Board 印刷电路板
REC	Receiver Error Counter 接收错误计数器
TEC	Transmit Error Counter 发送错误计数器

2 物理层 Physical Layer

2.1 总线介质 Bus Interface

图 1 展示了典型 CAN 网络的拓扑结构，ECU1 和 ECU2 应该内部安装终端电阻，并且需要布置在总线最长距离的两端。

Figure 1 shows the typical bus topology of CAN network, ECU1 and ECU2 at the end of the bus topology shall have an internal bus termination. ECU1 and ECU2 are typically located at the largest bus cable distance from each other.

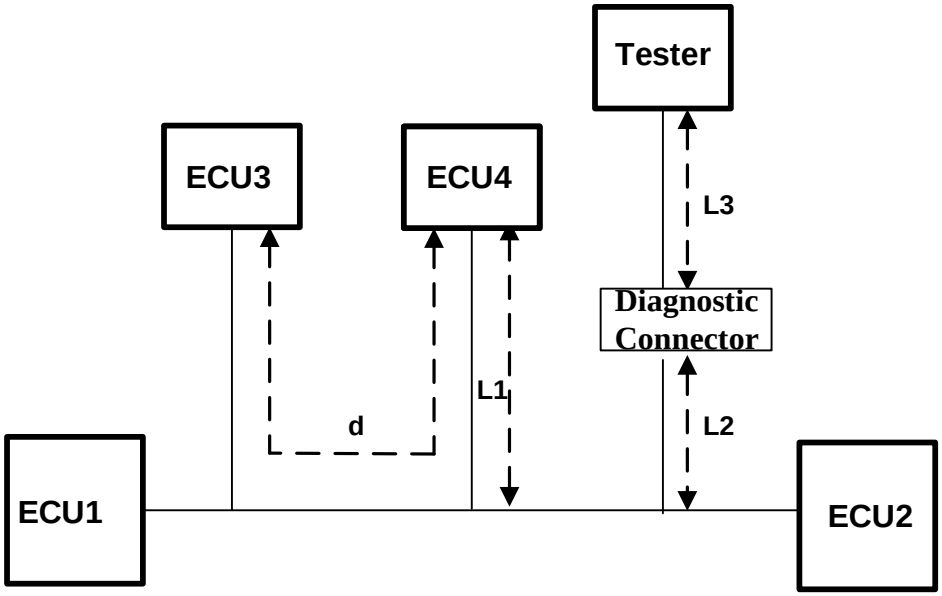

图1典型CAN网络拓扑连接 Figure 1 Typical Bus Topology

其中对于各段线束长度的要求见表 1:

Table 1 shows the length of each wiring harness:

表1 线束长度要求Table 1 wiring length requirement

参数 Parameter	符号 Symbol	最小值 Min	标称值 Nom	最大值 Max	单位 Unit
总线长度 Bus Length	L_{Σ}	0.1	—	40	M
节点间距 ECU Distance	d	0.1	—	30	M
支线长度 ECU Cable Stub Length	L_1	0	—	1	M
诊断设备车内支线长度 Cable Stub Length off-board tool	L_2	0	—	1	M
诊断设备车外支线长度 stub length off-board tool	L_3	0	—	5	M

为了减少驻波，ECU 在总线上不应等距放置且线缆的支线长度也不应相同。布线的线路延迟应小于或等于 5ns/m。CAN/CANFD 线束应使用非屏蔽双绞线，在连接器或支线连接器上未双绞的长度应小于 10cm,在 ECU 内部应避免使用柔性线路或扁线电缆。CAN/CANFD 线束的特性阻抗最大应为 175 mΩ/m。CAN/CANFD 电缆的每米绞数最少为 33 次，推荐使用 40-50 次，导截面积为 0.35-0.5mm^2,各网段应相同，避免反射。

In order to reduce the standing wave, the ECU should not be placed equidistantly on the bus, and the branch length of the cable should not be the same. The line delay of wiring shall be less

than or equal to 5ns / m. Unshielded twisted pair shall be used for CAN/CANFD harness. The length of non twisted pair on connector or branch connector shall be less than 10cm. Flexible line or flat cable shall be avoided in ECU. The maximum characteristic impedance of CAN/CANFD harness shall be 175 m Ω / m. The CAN/CANFD cable shall be twisted at least 33 times per meter. It is recommended to use 40-50 times. The conductive cross-sectional area is 0.35-0.5mm^2. Each network segment shall be the same to avoid reflection

2.2 外围接口电路 Physical Layer circuit

图 2 给出了建议的 CAN 外围接口电路。所有供应商都需要将电路原理图，PCB 布置以及元器件清单提交给小米网络工程师。

The figure 2 shows the recommended CAN peripheral circuit. All suppliers should provide the design of CAN circuit including schematic, layout and BOM to Xiaomi network engineer.

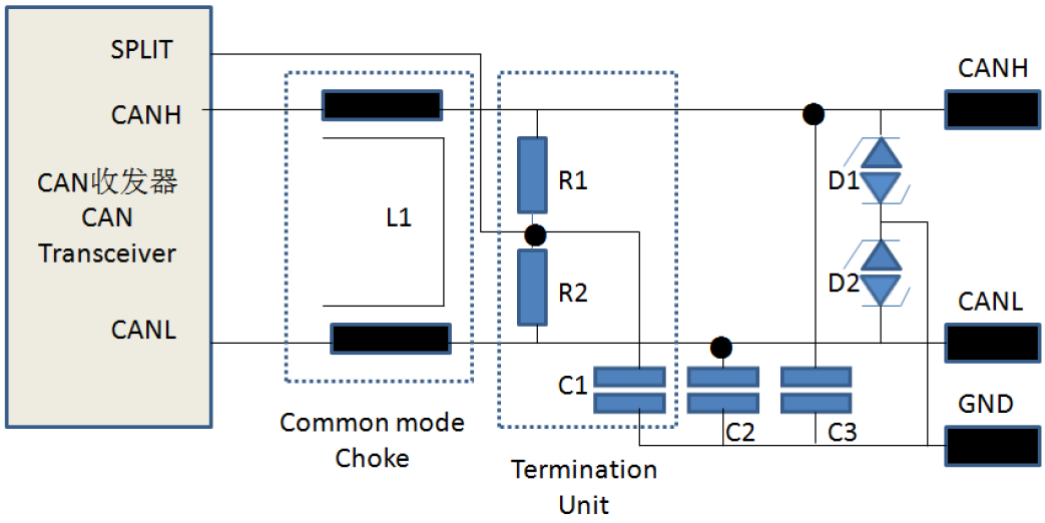

图 2 外围 CAN 接口电路 Figure 2 CAN Peripheral circuit

2.2.1 CAN 共模电感 CAN Common mode inductance

为增强 EMC 可靠性，降低噪声辐射，须在 CAN 双绞线上安装共模电感。如果 ECU 满足小米的 EMC 实验要求，可以不安装共模电感，但是必须得到小米工程师的认可。CAN 共模电感推荐值为: L = 51μH，最大不能超过 70μH。

In order to increase EMC reliability and to stay within the noise emission limits, a common mode inductance that is used in connection with twisted pair CAN wiring in the vehicle is recommended to be used. With the approval of Xiaomi network engineer, it is also accepted that the ECU doesn’t install common mode inductance but it must satisfy the EMC requirement.

The recommended inductance value is L = 51μH (maximum 70μH).

2.2.2 终端电阻 Termination

每条 CAN 网络的等效终端电阻为 50-65Ω（标称值为 60Ω）。一个网络中需要有 2 个终端节点，具体终端电阻方案由小米确认。

对于终端节点，其终端电阻放置在节点内，终端电阻值详细参数要求见表 2。

The equivalent terminal resistance of each can network is 50-65 Ω (nominal value is 60 Ω). In a CAN network, there are 2 Regular termination in a network, detailed termination concept should be confirmed by Xiaomi.

For the terminal node, its terminal resistance is placed in the node. See Table 2 for detailed parameter requirements.

表 2 电阻和电容相关参数 Table 2 Resistance and capacitor parameters

参数 Parameter	最小值 Minimum	标称值 Nominal	最大值 Maximum	单位 Unit
R1	58	60	64	Ω
R2	58	60	64	Ω
C1	4.7	4.7	100	nF

对于非终端节点，必须预留分裂终端电阻的安装位置，要求电阻值为 2×1.3kΩ-2×4.64 KΩ,即 R1 和 R2 分别在 1.3kΩ-4.64 kΩ，考虑到收发器内阻并联等因素，节点 CAN H 和 CANL 两端等效电阻值应在 2.3kΩ-9.28kΩ。

For non terminal nodes, the installation position of split terminal resistance must be reserved, and the required resistance value is 2 × 1.3kΩ-2 × 4.64 kΩ.I.e. both of R1 and R2 are 1.3kΩ-2 × 4.64 kΩ, and the equivalent resistance at both ends of CAN H and CAN L shall be 2.3 kΩ - 9.28 kΩ.

对于只有一个节点的网段，要求终端电阻只安装在该节点内，阻值为 60Ω。

For a network segment with only one node, the terminal resistance is required to be installed only in the node, and the resistance value is 60 Ω

2.2.3 EMC 电容 EMC Capacitor

为了改善 EMC 特性，可以安装 EMC 电容，EMC 电容为选装器件，供应商在设计 PCB 时需要预留该器件的安装位置，详细的电容设计参数要求如下：

In order to improve EMC characteristics, EMC capacitor can be installed. EMC capacitor is an optional device. Supplier needs to reserve the installation position of the device when designing PCB. The detailed capacitor design parameters are as follows:

表 3 EMC 电容相关参数 Table 3 EMC capacitor parameter

参数 Parameter	最小值 Minimum	标称值 Nominal	最大值 Maximum	单位 Unit
C2	0	47	130	pF
C3	0	47	130	pF
备注：C2 和 C3 的容差不能超过 10% Note:The tolerance of C2 and C3 shall not exceed 10%.				

2.2.4 静电放电保护 ESD protection

PCB 设计必须考虑 ESD 及过电压保护。

ESD/Over-voltage protection must be considered for its PCB installation.

2.3 通信电压范围 Communication Voltage Range

所有 ECU 必须最少保证在如下电压范围内维持正常通信，详细要求见表 4.

All ECUs shall minimally guarantee proper CAN communication within a battery supply voltage, as shown in Table 4.

表 4 通信电压范围要求 Table 4 Communication Voltage Range

参数 Parameter	单位 Unit	最小 Min	标称值 Nom	最大 Max	备注 Note
通信电压 Communication Voltage	V	7	-	18	1)
备注 1：在上述通信电压范围之外 ECU 仍可以维持正常通信，上述仅为最小要求。 Note1: it certainly accepted that ECU can communicate below or above this range, .					

为了保证在过压或欠压的情况下仍旧能保持正常的通信，所有的 CAN 节点即使电压超出了其正常工作范围，都不能干扰总线通信。

In order to guarantee proper CAN communication at specified under and over voltages, it is required that none of the CAN ECUs shall disrupt the bus communication even if the battery voltage is outside its operating range.

2.4 总线电压 Bus Level

总线共有两种状态：隐性和显性。详细参数要求见表 5 与表 6。

The bus has two logical states: recessive or dominant. And the detailed bus voltage parameter required, please see table 5 and table 6.

表5隐性位总线电压要求 Table 5 the Bus voltage Parameters of Recessive State

参数 Parameter	电压 Voltage	单位 Unit	最小值 Min	标称值 Nom	最大值 Max
总线电压要求 Common Mode Bus Voltage	V[CAN_H]	V	2.0	2.5	3.0
	V[CAN_L]	V	2.0	2.5	3.0
差分电压要求 Differential Bus Voltage	V[Diff]	V	-0.5	0	0.05

表6显性位总线电压要求 Table 6 Bus Voltage Parameters of Dominant State

参数 Parameter	电压 Voltage	单位 Unit	最小值 Min	标称值 Nom	Max 最大值
总线电压要求 Common Mode Bus Voltage	V[CAN_H]	V	2.75	3.5	4.5
	V[CAN_L]	V	0.5	1.5	2.25
Differential Bus Voltage 差分电压要求	V[Diff]	V	1.5	2.0	3.0

2.5 上升沿和下降沿时间 Rising edge and falling edge time

上升沿和下降沿跳变时间需要在一定的时间范围内，详细要求见图 3 和表 7：

The time of rising edge and falling edge should be within a threshold, see figure 3 and table 7:

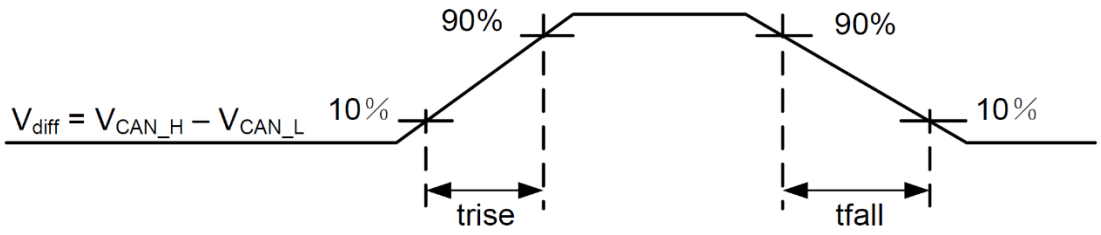

图3 跳变沿时间测量方法 Figure 3 edge time measure

表 7 上升沿与下降沿时间要求 Table 7 rising edge and falling edge time

波特率 Baud rate	参数 Parameter	最小值 Minimum	标称值 Nom	最大值 Maximum	单位 Unit
500kbps	上升沿时间 Rising edge time	0	--	200	ns
	下降沿时间 Falling edge time	0	--	200	ns
2Mbps	上升沿时间 Rising edge time	0	--	150	ns
	下降沿时间 Falling edge time	0	--	150	ns
Note1：Rising edge time 上升沿时间 = |t@90% - t@10%|; Note2：Falling edge time 下降沿时间 = |t@10% - t@90%|.					

2.6 地偏移 Ground offset

为了保证 CAN 网络上不同节点之间的正常通信，ECU 之间的地电压偏移必须在表 8 定义的范围之间。

In order to ensure the proper communication between different nodes on the CAN network, the ground voltage offset between ECUs must be within the range defined in table 8.

表 8 地偏移电压范围 Table 8 Ground offset range

参数 Parameter	最小值 Minimum	标称值 Nominal	最大值 Maximum	单位 Unit
地偏移 Ground offset	-1.5	--	1.5	V

2.7 总线错误处理 Bus Failure Management

总线发生短路、断路故障时，通信通常会受到干扰，详见表 9。但故障移除后，对于停止通信的 ECU 应能够在 1000+10%ms 内自动恢复正常工作。

Normally, bus failure shall disturb the CAN communication, see table 9. When the failure is repaired, all communication shall resume.

表 9 总线错误处理 Table 9 Bus Failures Management

编号 No.	总线错误 Bus Failure	网络行为要求 Behavior of network
1	CAN_L 断开 CAN_L disconnect	不要求进行通信 Communication is not required
2	CAN_H 断开 CAN_H disconnect	不要求进行通信 Communication is not required
3	CAN_H 与 CAN_L 同时断开 CAN_H and CAN_L disconnect	不要求进行通信 Communication is not required
4	CAN_H 短路到 CAN_L CAN_H short to CAN_L	Communication is not required 不要求进行通信
5	CAN_H shorted to battery voltage CAN_H 短路到电源	通信可以进行，但信噪比降低 Communication may be possible with reduced signal to noise ratio
6	CAN_H shorted to ground CAN_H 短路到地	不要求进行通信 Communication is not required
7	CAN_L 短路到电源 CAN_L shorted to battery voltage	不要求进行通信 Communication is not required
8	CAN_L 短路到地 CAN_L shorted to ground	通信可以进行，但信噪比降低 Communication may be possible with reduced signal to noise ratio
9	非终端电阻节点断开连接 One non-terminal ECU becomes disconnected from the bus	剩余 ECU 需要继续正常通信 The remaining ECUs shall continue communication.
10	终端电阻节点断开连接 One terminal ECU becomes disconnected from the bus	通信可以进行，但信噪比降低 Communication may be possible with reduced signal to noise ratio.

3 数据链路层 Data Link Layer

3.1 一般要求 General

CAN 网络通信需要严格遵守 ISO11898 和 CAN2.0B 标准，并且为了保证 CAN 位定时的准确性，不推荐使用锁相环作为 CAN 定时的时钟，CAN 一致性测试需要满足 ISO16845。

Controller Area Network (CAN) should be in accordance with ISO11898 and CAN V2.0B.

It is not recommended to feed CAN controller with a PLL-generated clock signal.

The conformance to the standard ISO11898 shall be checked and tested according to ISO16845.

3.2 波特率和位定时 Baud Rate and Bit Timing

图 4 显示的为 CAN 数据帧的一个位时间，每个位时间被分为四个时间段，其中：

同步段（SYNC），连续两个位时间之间产生的边沿跳变，用于时间同步。

传播段(propagation Segment)，用于补偿报文在总线和节点上传输时所产生的时间延迟；

相位缓冲段 1(Phase Buffer Segment1)和相位缓冲段 2(Phase Buffer Segment2)，用于补偿节点的晶振误差；

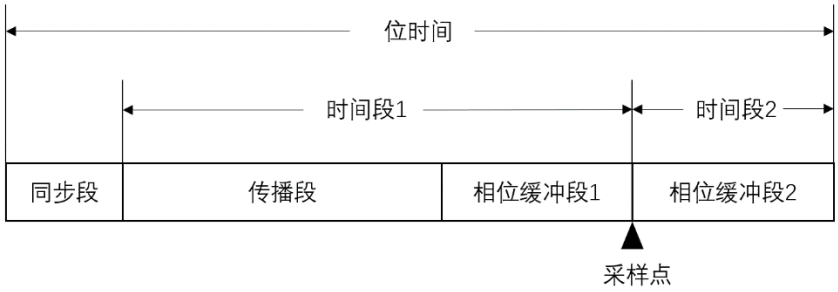

图 4 位定时与采样点 **Figure 4** Bit time and sample point

3.2.1 经典 CAN 网络 Classic CAN Network

经典 CAN 网络的波特率设定为 500kpbs(±0.15%)，采样点需设定在 75%-82%之间，单次采样，具体设计要求如表 10 所示：

The Classic CAN communication controllers used by all ECUs within classic CAN network shall support Classic CAN format communication with 500kbps(±0.15%), and 75%-82% Single Sample point.

表 10 经典 CAN 位定时和采样点设置要求 Table 10 Classic CAN BaudRate and sample point

Parameter 参数	Minimum 最小值	Nominal 标称值	Maximum 最大值	Unit 单位
Bit timing 位定时	1997	2000	2003	ns
Number of tQ tQ 的数量	8	16	25	tQ
Sample Spoint 采样点	75	80	82	%
SJW 同步跳转宽度	1	2	4	tQ
Sample 采样数量	-	1	-	

3.2.2 CANFD 网络 CAN FD Network

CANFD 网络节点硬件需要支持仲裁段 500kbps 和数据段最高 5Mbps 的标准 CANFD 通信，在小米网络拓扑结构中，我们使用 2Mbps 作为 CANFD 数据段的通信速率。具体要求见表 11：

The CAN-FD communication controller used by all ECUs within CAN-FD network shall support CAN-FD format communication with a 500kbps arbitration rate and a maximum 5 Mbps baud rate. In Xiaomi Network architecture, we use 2Mbps for CANFD communication.

表 11 CANFD 网络位定时和采样点设置要求 Table 11 CANFD Network BaudRate and BitTiming

参数 Parameter	Requirement 要求
仲裁段波特率 Arbitration Phase buad rate	500 kbps (±0.15%)
数据段波特率 Data Phase baud rate	2Mbps (±0.15%)
仲裁场位定时 Arbitration Bit timing	2000ns (±0.15%)
数据场位定时 Data Bit timing	500ns (±0.4%)
Number of tQ　tQ 的数量	10 - 80
采样点 Sample Point	75% - 82%
二次采样点 Secondary Sample Point	78% - 82%
发送补偿延时 Transceiver Delay Compensation	使能 Enabled

3.3 CAN 帧类型 CAN Frame type

3.3.1 数据帧 Data Frame

CAN 总线上传输的数据帧格式应符合 ISO 11898-1。

ECU 只允许发送具有 11 位 CAN Identifier 的报文，29 位 CAN Identifier 报文不允许发送到总线。ECU 不允许发送 matrix 文件中没有定义的报文。

The format of data frames transmitted on CAN bus shall follow ISO 11898-1.

Only 11-bit CAN Identifier is allowed to be sent by ECU and 29-bit CAN Identifier shall not appear on the CAN bus. ECUs on CAN bus shall not send any frames of undefined CAN Identifier in matrix file.

3.3.2 远程帧 Remote Frame

ECU 不应发送远程帧到总线上。如果 ECU 收到远程帧，应忽略并不受其干扰。

Remote frame shall not be sent by ECU on the CAN bus. ECU shall ignore the received remote frame and shall keep working without any disturbance.

3.4 CAN 收发器 CAN Tranceiver

CAN 收发器需要满足 ISO11898-2/5 的标准要求，推荐的收发器芯片型号见表 12，若供应商选用其他型号的收发器，则需要得到小米的认可。

The transceiver and ASIC must follow ISO11898-2/5 standard. Only the below listed transceiver types can be used. Other transceiver types can be used only after the permission of Xiaomi.

表 12 认可的 CAN 收发器列表 Table 12 Approved CAN Transceiver

编号	Transceiver type	Manufacture	Wakeup Support	Note
1	TLE6251DS	Infineon	Yes	该收发器仅适用于 500Kbps CAN 网段
2	TLE6251-2G	Infineon	Yes	
3	TLE6251-3G	Infineon	Yes	
4	TLE9251	Infineon	Yes	该收发器仅适用于 2Mbps 及以下 CANFD 网段
5	TJA1042	NXP	Yes	
6	TJA1043	NXP	Yes	
7	TCAN1044	TI	Yes	
8	TJA1145	NXP	Yes	
9	TJA1044T	NXP	Yes	
10	TJA1463	NXP	Yes	该收发器适用于 5Mbps CANFD 网段
11	TJA1462	NXP	Yes	

4 交互层 Interaction Layer

4.1 发送模式 Transmission Mode

报文发送模式应该符合 AUTOSAR COM 规范，该规范基于 OSEK/VDK 通信标准。

Message transmission mode shall be in accordance with AUTOSAR_SWS_COM which is based on OSEK/VDK Communication.

4.1.1 直接发送模式 Direct Transmission Mode

如果报文支持直接发送模式，那么触发传输属性的信号发送更新请求应该触发报文发送。信号交互层应立即向下层发起报文发送请求。

Transmission of an message with Direct Transmission Mode is caused by the transfer of any signals assigned to the message with Triggered Transfer Property. The transfer is immediately followed by a transmission request from the IL (Interaction Layer) to the underlying layer.

两帧报文之间应该有最小时间间隔，如果在最小时间间隔达到前收到应用层的发送请求，信号交互层应推迟到最小时间间隔超时后再向下层发起报文发送请求。

A MDT (minimum delay time) between transmissions (greater than or equal to zero) shall be configured per message. If a transmission is requested before MDT expires, the next transmission is postponed until the delay time expires. See the following figure for this requirement.

最小时间间隔起点为上一帧报文发送成功的时刻。此外信号交互层应支持在应用层触发一次发送请求后，按照 matrix 文件中定义的发送次数，向下层触发一定次数的报文发送请求。

The MDT for the next transmission starts the moment the previous transmission is confirmed. Besdes, IL shall be able to trigger n-times message transmission request to underlying layer by one-time signal update request from application layer and the value of n-times shall refer to the matrix file.

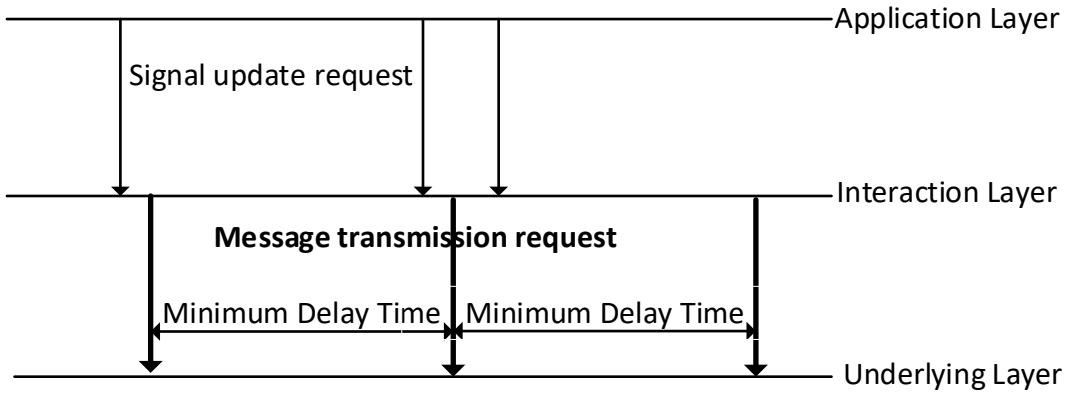

图 5 直接发送模式 Figure 5 Direct Transmission Mode

4.1.2 周期发送模式 Periodic Transmission Mode

在周期发送模式中，信号交互层向下层周期性的发起报文发送请求。应用层的信号更新请求仅更新信号交互层中的缓存值。

In Periodic Transmission Mode the IL (Interaction Layer) issues periodic transmission requests for an message to the underlying layer. Signal value update request from application layer only updates the buffer stored in interaction layer. See figure for this requirement.

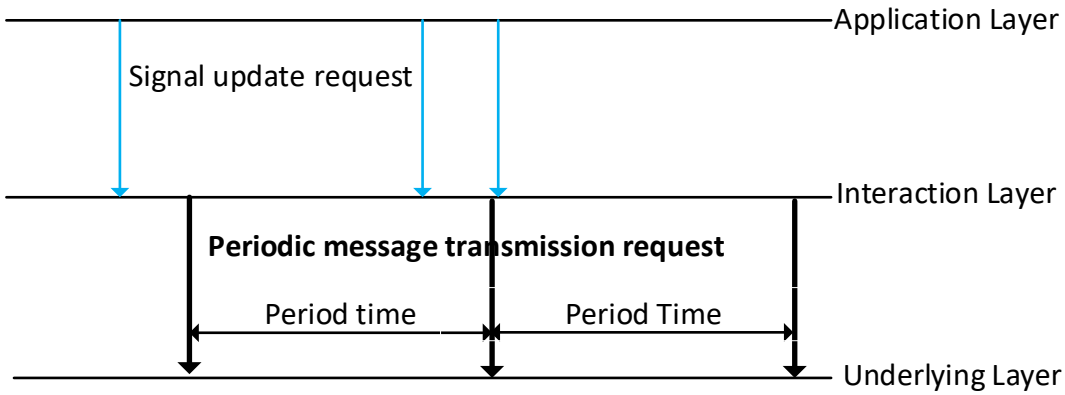

图 6 周期发送模式 Figure 6 Periodic Transmission Mode

4.1.3 混合发送模式 Mixed Transmission Mode

混合发送模式结合了直接发送模式和周期发送模式。

此模式下，信号交互层通过向下周重复调用相关服务实现报文发送。

周期发送报文之间可以插入报文，由具有触发发送属性的信号触发。之后信号交互层立刻向下层发出报文发送请求。此情况下，因为下一帧周期发送请求和上一帧中间插入报文的间隔经过了最小延迟时间，所以周期发送报文的周期保持不变。

两帧报文之间需要支持配置最小延迟时间（大于或等于 0）。如果在最小延迟时间到期前收到发送请求，应推迟到最小延迟时间到期再发出报文。

Mixed Transmission Mode is a combination of the Direct and the Periodic Transmission Modes.

The transmission is performed by repeatedly calling the appropriate service in the underlying layer with a period.

Intermediate transmission of message is caused by the transfer of any signal with Triggered Transfer Property assigned to this message. The transfer is immediately followed by a transmission request from the IL to the underlying layer. These intermediate transmissions do not modify the base cycle because next periodic transmission request shall be triggered after MDT (Minimum Delay Time, greater than or equal to zero) expires since last intermediate transmission request is triggered.

A MDT between transmissions shall be configured. If transmissions are requested before MDT expires, the next transmission is postponed until the delay time expires. See figure for this requirement.

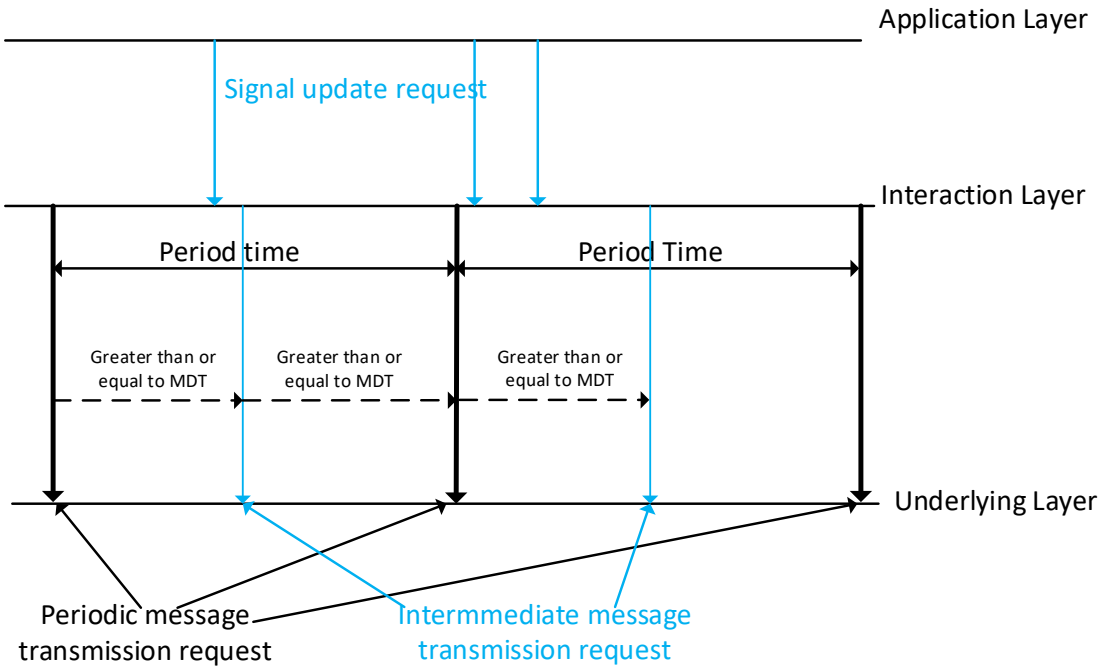

图7 混合发送模式（简单情况） Figure 7 Mixed transmission mode (simple case)

如果中间插入报文请求和最近一次周期报文请求间隔小于最小延迟时间，最近一次周期报文请求会被推迟发送，之后的其他周期报文请求也可能被推迟，参考图 8。

An intermediate transmission request less than MDT before the next periodic transmission request delays this periodic transmission request and possibly also subsequent periodic transmission request, as shown in figure below.

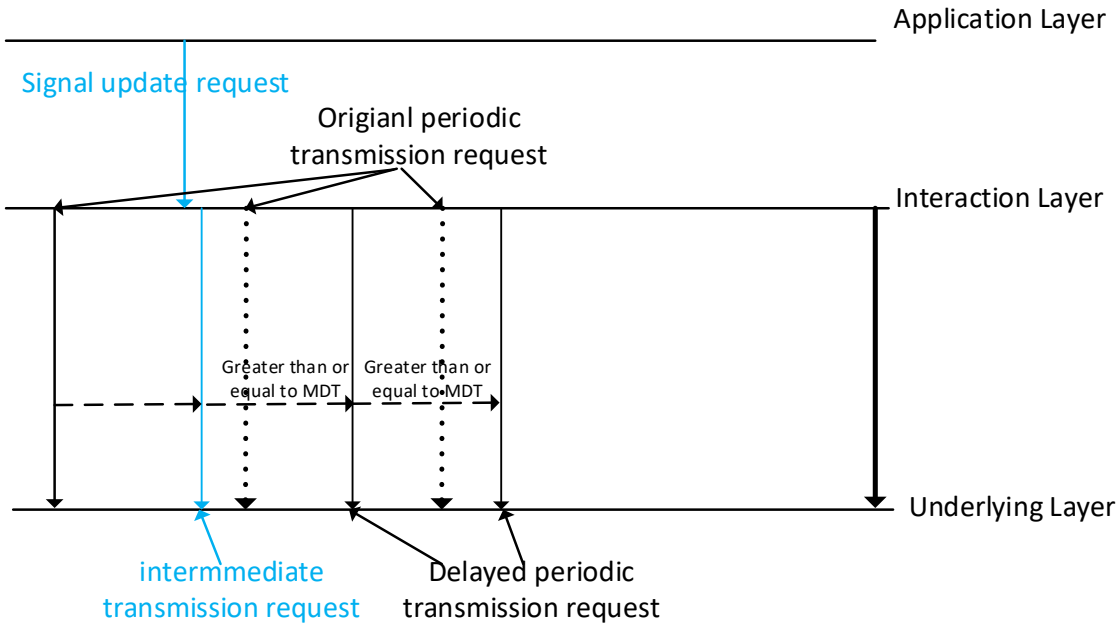

图8 延迟的混合发送模式 Figure 8 Mixed transmission mode with minimum delay time

4.2 字节顺序 Byte Order

CAN 和 CANFD 报文都采用摩托罗拉编码方式。

The Motorola byte order shall be used for CAN message and CANFD message.

4.3 报文长度 Message Length

所有的 CAN/CANFD 报文都有一个确定的长度，该长度定义在网络通信矩阵中，接收节点需要针对接收到的 CAN/CANFD 报文的长度进行监测。

All CAN/CANFD frames have a fix and static message length defined in the communication matrix. The DLC of a received CAN/CANFD message has to be evaluated by the receiver.

CAN 和 CANFD 网络报文的长度应该为 8，12，16，20，24，32，48，64.当接收到的应用报文长度小于通信矩阵中定义的长度时，接收节点应该忽略该报文。如果接收到的报文长度大于等于通信矩阵中定义的长度时，接收节点应该接收该报文，并且应该忽略额外多出的字节。

The DLC for CAN/CANFD network could be 8,12,16,20,24,32,48,64. If the DLC of a received APP CAN message is smaller than that indicated in the communication matrix, then this message should be rejected. If the DLC of a received CAN message is equal to or larger than that indicated in the communication matrix, then this message should be accepted. The ECU shall ignore the data in the extra byte.

表 13 DLC 长度定义 Table 13 definition of DLC

Frames	Data length code				Number of data bytes
	DLC3	DLC2	DLC1	DLC0	
Classical Frames and FD Frames	0	0	0	0	0
	0	0	0	1	1
	0	0	1	0	2
	0	0	1	1	3
	0	1	0	0	4
	0	1	0	1	5
	0	1	1	0	6
	0	1	1	1	7
	1	0	0	0	8
Classical Frames	1	0 or 1	0 or 1	0 or 1	8
FD Frames	1	0	0	1	12
	1	0	1	0	16
	1	0	1	1	20
	1	1	0	0	24
	1	1	0	1	32
	1	1	1	0	48
	1	1	1	1	64

4.4 未使用的位和字节 Unused bits and bytes

对于发送方，所有未使用的位和字节，都应该设置为 0。接收方应该忽略所有未使用的区间。

All unused bits and bytes shall be set to zero by the sender. The receiver shall ignore all unused fields.

4.5 发送初始值 Initial value for transmitter

如果发送方在首次发送时需要更多时间计算信号的值，那么在计算完成之前应该使用信号初始值进行发送。信号初始值在网络通信矩阵中进行定义。

In case the sender need more time to calculate the signal value for a specific signal before the first transmission, and the initial value shall be sent.

The initial value shall be specified in the communication matrix.

4.6 接收方超时处理 Receiver time-out Handling

接收方在接收到对应的报文之前，应该使用默认值。除此之外，接收方也应该监测周期应用报文，当发生超时，应该使用错误替代值。

The receiver has to use the default value before receiving this message.

Besides, the receiver should monitor the time-out of any periodic application message. The error substitute value shall be used by the receiver if time-out occured.

4.7 报文周期偏差要求 Requirements for cycle tolerance

周期报文及混合发送报文中的周期部分应符合如下要求：

a) 周期小于 10ms 报文实际周期应在±50%容差范围内
b) 周期等于 10ms 报文实际周期应该±20%容差范围内
c) 周期大于 10ms 报文实际周期应该±10%容差范围内

The periodic messages and periodic part of the mixed transmission mode messages shall fulfill the below requirements:

a) The actual period of messages with a period of less than 10ms should be within the ±50% tolerance
b) The actual period of messages with a period of 10ms should be within the ±20% tolerance
c) The actual period of messages with a period of more than 10ms should be within the ±10% tolerance

5 错误处理 Failure mode

当节点监测到网络故障时，应该记录相应的网络故障 DTC，通常每一个 ECU 都应该诊断如下故障：

- CAN Bus off 故障
- 节点超时故障
- 过压/欠压故障

When the node detects network fault, a network fault DTC should be recorded. Normally each ECU shall diagnose the following faults:

- CAN Bus off
- Node timeout
- Under/Over voltage

5.1 Bus off 处理 Bus off handling

5.1.1 Bus off 描述 Bus off description

Bus off 状态是指 CAN 控制器的发送错误计数器达到了 255。Bus off 被触发后，周期和事件报文都会停止发送，所有缓存在发送缓冲区里的报文都需要被清空。经过一段恢复等待时间，软件会对 CAN 控制器进行重新初始化，此时，发送错误计数器和接收错误计数器将会被复位，ECU 重新开始尝试正常通信。

A “Bus off state” refers to a CAN controller that the transmit error counter exceeds 255. After Bus-off is triggered, the periodic and event frame shall not be transmitted on the CAN bus. Any remaining frames waiting in the Tx buffer shall be cleared by ECU application. After recovery time, the software program promptly conducts re-initialization on CAN. At this moment, “sending error register” and “receiving error register” shall be reset. And ECU tries to send messages to conduct a normal communication.

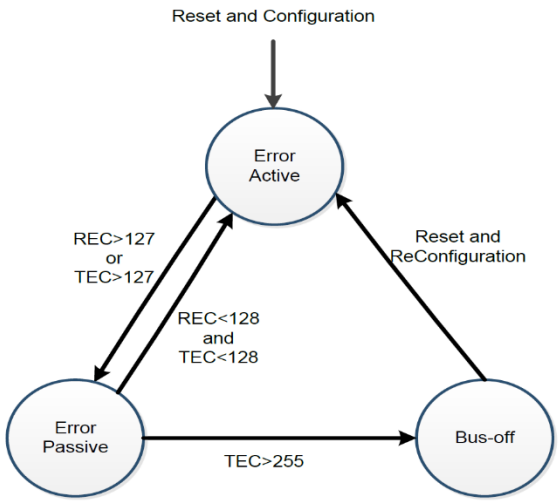

图 9 CAN 节点错误状态 Figure 9 CAN node error state

5.1.2 Bus off 错误处理 Bus off handling

当一个节点进入 Bus off 状态后，不允许它进行 CAN 控制器的自动复位，而需要使用快慢速恢复策略，详细恢复策略要求如下图所示：

When the node enter Bus off state, CAN controller automatic reset is not allowed, and instead a fast and slow recovery strategy shall be used, see below details.

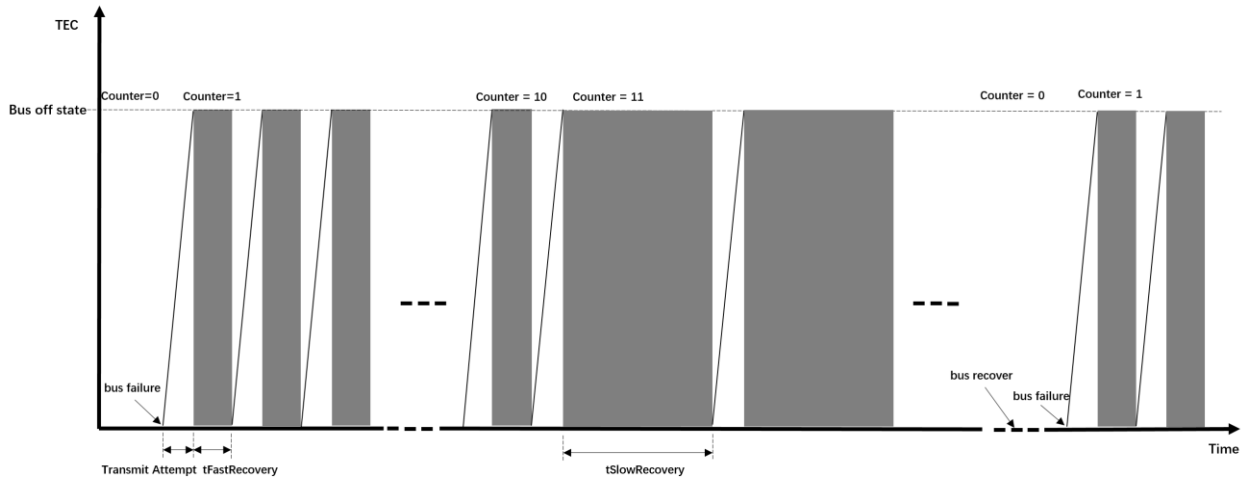

图 10 快慢恢复策略 Figure 10 Fast and slow recovery strategy

Bus off 恢复策略的时间要求见表 14：

The parameters of Bus off recovery are described in table 14:

表 14 CAN Bus off 恢复参数要求 Table 14 CAN Bus off recovery parameter

符号 Symbol	描述 Description	标称 Nominal	单位 Unit	容差 Tolerance
tFastRecovery	在快恢复阶段的总线恢复时间延时 The duration of bus recovery time in fast recovery stage.	100	ms	10%
tSlowRecovery	在慢恢复阶段的总线恢复时间延时 The duration of bus recovery time in slow recovery stage.	1000	ms	10%
Counter	快恢复的最大次数，而后转变为慢恢复 The counter of bus-offs of fast recovery, then change to slow recovery stage.	10	-	-

5.1.3 Bus off 故障 Bus off DTC

Bus off 故障需要在如下条件下被记录到 ECU 非易失性存储器中：

a) Bus off 次数连续达到了 10 次；

b) ECU 供电电压在网络诊断电压范围内；

当报文被成功发送后，Bus off 当前故障应立即被修复，而转变为历史故障。

Bus off DTC shall be recorded in ECU non-volatile memory under such conditions:

a) The Bus off counter reaches 10.

b) Voltage supply of the ECU is in the range of network diagnosis voltage range.

When message can be transmitted successfully, the current fault shall be cleared immediately and turn to a history DTC.

5.2 节点超时诊断 Node timeout monitor

参与 CAN 通信的所有控制器都需要实时监测接收的周期性报文，通过监测总线中各相关 ECU 的关键报文来判断相关 ECU 是否超时，关键报文为相关 ECU 发送的周期报文中具有最高优先级（CAN ID 最小）的一条报文。CAN 节点超时诊断需要在如下条件下进行：

a) ECU 未处于 Bus off 状态，或者距上次 Bus off 修复已超过 1 秒；

b) ECU 在 ACC 或者 RUN 状态或者 Awake 状态（Awake 根据具体功能可选）；

c) ECU 的供电电压在网络诊断电压范围之间。

节点监测报文超时时间参数需要按照下表执行：

Node timeout should be monitored for all nodes connected to CAN bus. It is determined by monitoring one critical message from the relevant ECU. The critical message is a message with the highest priority among the periodic messages sent by the relevant ECU (with the minimum CANID). Node timeout shall be monitored under such conditions:

a) No Bus off detected or 1 second after last Bus off recovery;

b) ECU in ACC or RUN status or Awake status(ECU can be selected according to specific functions in Awake status);

c) The supply voltage of ECU is between the network diagnosis voltage range.

Below table shows the parameter of timeout monitor time:

表 15 节点超时监测时间参数要求 Table 15 Node timeout monitor time parameter

参数 Parameter	标称值 Nominal	容差	单位 Unit
≤20	200	±10%	ms
20<cycle[(1)]≤500	5*cycle	±10%	ms
>500	5000	±10%	ms
	注：（1）cycle 为报文发送周期 (1) Cycle is the message sending cycle		

当收到该关键报文后，相应的节点超时当前故障应立即被修复而转变为历史故障。

When the critical message can be received successfully, the current fault shall be cleared immediately and turn to a history DTC.

5.3 网络诊断条件 Network diagnostic conditions

本节定义了记录网络相关故障码的电压范围和时间要求，如果 ECU 的特定规范与此冲突，以 ECU 特定规范定义为准。ECU 进入 ACC 或者 RUN 状态需经过 tDiagStart 时间，才能开启网络相关诊断功能。欠电压或者过电压恢复到要求的范围（参考图 11）后，应在 tDiagStart*的时间后开启网络诊断功能。具体时间要求如下：

This section defines the voltage range and time requirements for recording network related fault codes. If the specific specification of ECU conflicts with this, the specific specification of ECU shall prevail. When ECU enters acc or run status, tDiagStart time must pass before network

related diagnostic functions can be started. The network diagnosis function shall be started after tDiagStart* since the undervoltage or overvoltage returns to the required range (As depicted in Figure 11). The specific time requirements are as follows:

表 16 诊断初始化时间要求 Table 16 Diagnostic initialization time requirements

参数 Parameter	最小值（ms） Min	标称值（ms） Nominal	最大值（ms） Max
tDiagStart[1]	2500	3000	3500
tDiagStart*[2]	800	1000	1200

注：1 ACC 或者 RUN 状态 tDiagStart 后，开始网络相关诊断功能；
2 欠电压或者过电压恢复后的 tDiagStart*后，开始网络相关诊断功能。
1 After ACC or RUN status tDiagStart, start network related diagnostic functions;
2 After tDiagStart* after undervoltage or overvoltage recovery, start the network related diagnosis function.

网络相关故障码的电压范围和运行条件，见表 17 和图 11：

See Table 17 and Figure 11 for the voltage range and operating conditions of network related fault codes

表 17 网络相关诊断过/欠电压要求 Table 17 Network diagnosis voltage requirements

参数 Parameter	最小值（V）	标称值（V）	最大值（V）
VLon	9.5	10	10.5
VLoff	8.5	9	9.5
VHon	14.5	15	15.5
VHoff	15.5	16	16.5

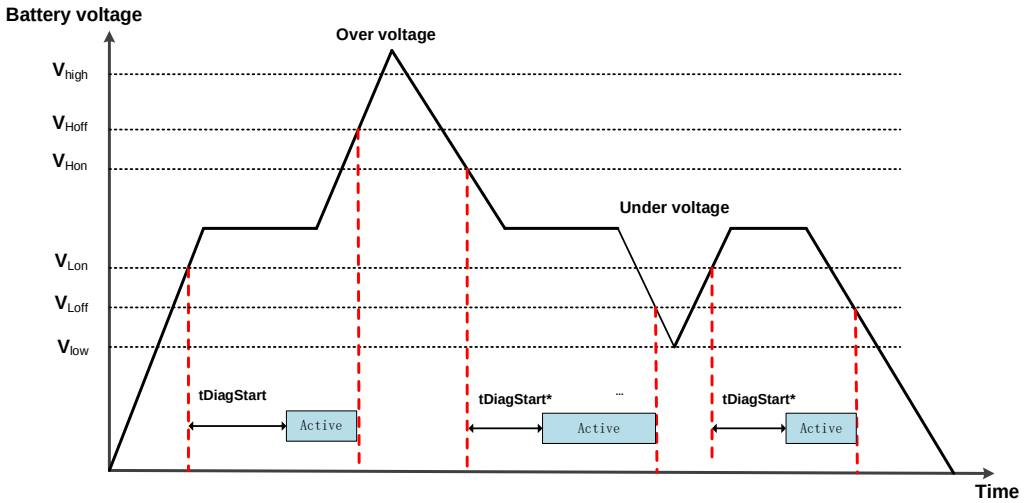

图 11 网络相关诊断时间要求 Figure 11 Network related diagnosis time requirements

6 ECU 启动和睡眠 ECU Startup and Sleep

对于 Autosar 网络管理的节点，启动时刻发送报文的时间要求，参照 Appendix T10_CAN&CANFD Network Management RequirementCAN&CANFD 网络管理规范要求的定义。其余节点的启动和睡眠时间要求如下：

Table 18 Timing Parameter value 表18 时间参数值

参数 Parameter name	数值(毫秒) Value (ms)	容差 Tolerance	描述 Description
T_ack	150	+10%	唤醒事件到 ECU 接收第一帧报文给出应答的最大时间 Max time between wakeup event and the first PDU received and give ack
T_Startappmsg	200	+10%	唤醒事件到 ECU 发出第一帧报文的最大时间 Max time between wakeup event and the first PDU sent out
T_networkStart	100	+10%	ECU 唤醒后在发出第一帧应用报文后，到将所有周期性报文至少发送一次的最大时间 Max time to send all APP cyclic messages for at least once since the first APP memssage is sent after wakeup.
T_shutdown	1000	+10%	ECU 睡眠条件满足，ECU 停发报文的时间 When the ECU sleep conditions are met, the ECU stops sending messages

7 CAN 网关 CAN Gateway

本章节主要针对具有 CAN（CANFD）报文路由能力的域控制器 ，以下统一简称网关。跨网段传输 CAN（CANFD）信号和报文，需要通过网关控制器进行路由传输。若供应商在开发过程中与本规范有偏离项，需与小米网络工程师确认。

网关能够正确路由网关路由表中定义的报文，报文在转发前后，报文 ID 要与路由表中的定义保持一致。网关不应路由未在路由表或整车通信矩阵中定义的报文。

This chapter is mainly for domain controllers with CAN (CANFD) message routing capability, which is uniformly referred to as gateway. Can (CANFD) signals and messages transmitted across network segments need to be routed through gateway controller. If the supplier deviates from this specification during development, it shall confirm with Xiaomi network engineer.

The gateway can correctly route the message defined in the gateway routing table. Before and after forwarding the message, the message ID shall be consistent with the definition in the routing table. The gateway shall not route messages not defined in the routing table or vehicle communication matrix.

7.1 路由准则 Routing rules

7.1.1 直接报文路由 Direct message routing

直接报文路由是源网段的报文和目标网段的报文完全一致的路由方式，即源网段收到报文后不进行处理直接进行转发。不论何种类型（直接发送型、周期发送型、混合发送型）的报文发送到源网段，网关只要在源网段收到需要路由的报文，应立即转发到目标网段。

Direct message routing is a routing method in which the message of the source network segment is completely consistent with the message of the target network segment, that is, the source network segment forwards the message without processing after receiving it. No matter what type of message (direct sending, periodic sending and mixed sending) is sent to the source network segment, as long as the gateway receives the message to be routed in the source network segment, it shall immediately forward it to the target network segment.

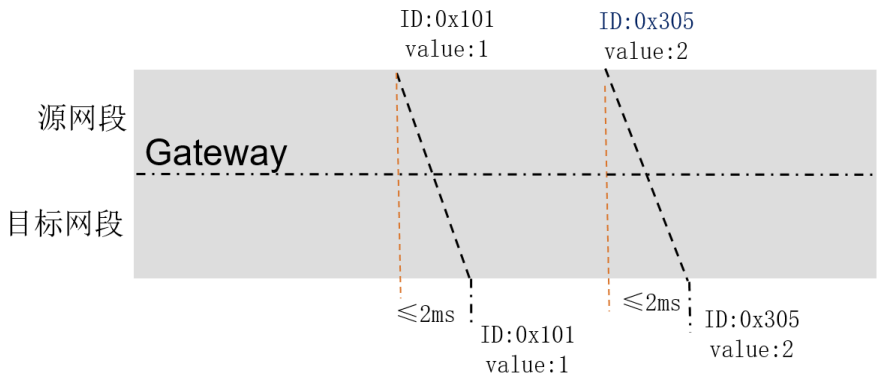

图 12 直接报文路由 Figure 12 Direct message routing

如上图所示，直接报文路由应具有以下的特征：

a) 对报文的 ID、长度、周期等内容不进行处理，直接进行整包的转发；

b) 源网段接收到路由的报文，应立即进行转发，源网段路由的报文停止发送，网关应停止转发；

c) 直接报文路由的延迟时间,即源网段接收到该报文到目标网段接收到该报文的时间应≤3ms。

As shown in the figure above, direct message routing shall have the following characteristics:

a) The ID, length, period and other contents of the message are not processed, and the whole packet is directly forwarded;

b) When the source network segment receives the routed message, it shall forward it immediately. If the source network segment stops sending the routed message, it shall stop forwarding;

c) The delay time of direct message routing, that is, the time from the source network segment receiving the message to the target network segment receiving the message shall be ≤ 3ms.

7.1.2 周期报文路由 Periodic message routing

周期报文路由是指网关被唤醒后需要周期性地向目标网段转发报文的路由方式。网关从源网段收到需要路由的报文，需要将收到的最新信号值路由到目标网段。源网段的节点在报文丢失后，目标网段仍然需要按照定义的报文周期路由。

目标网段周期和源网段报文周期可以不同，但不允许以更快的周期转发报文。例如，在源网段周期 50ms，目标网段的发送周期可以是 100ms，反之则不允许。示例如下：

Periodic message routing refers to the routing mode in which the gateway needs to periodically forward messages to the target network segment after being awakened. The gateway receives the message to be routed from the source network segment and needs to route the received latest signal value to the target network segment. After the node of the source network segment loses the message, the target network segment still needs to route according to the defined message cycle.

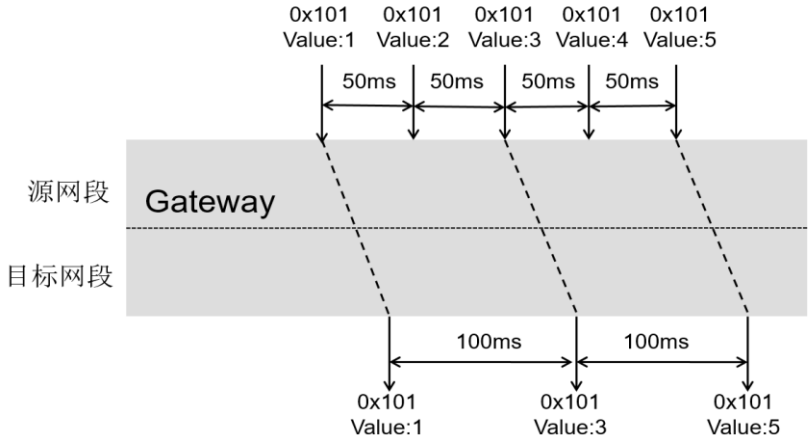

图 13 周期报文路由 Figure 13 Periodic message routing

7.1.3 周期信号路由 Periodic signal routing

网关被唤醒后将源网段中的来源于不同报文的信号打包，形成新的报文，按照具体要求的周期发送到目标网段。对于需要路由的信号来源于不同报文的场景，则使用周期信号路由方式。

After being awakened, the gateway packs the signals of different messages in the source network segment to form a new message, which is sent to the target network segment according to the specific required cycle. When the signals to be routed come from different messages, the periodic signal routing method is used.

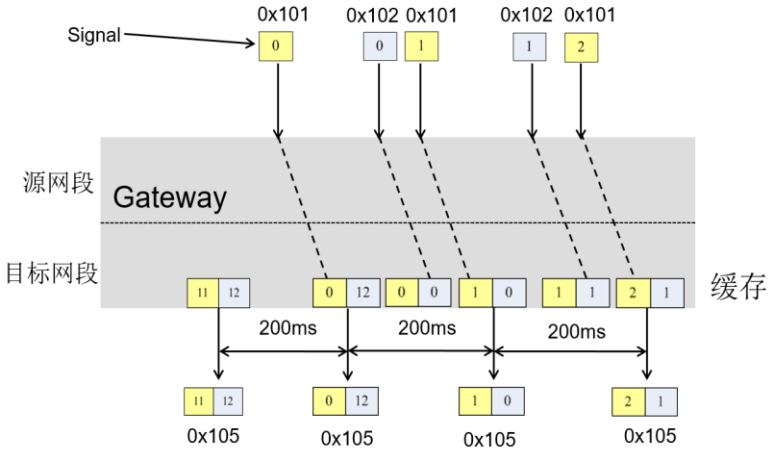

图 14 周期信号路由 Figure 14 Periodic signal routing

如上图示例，周期信号路由具有以下的特征：

a) 周期信号路由在目标网段的信号值应与源网段的最新信号值保持一致；

b) 网关按照目标网段的报文周期发送，但应确保目标网段的报文不丢失；

c) 需要路由的信号可以来自于不同的报文，在目标网段打包成新的报文，周期发送；

d) 在收到源网段的信号值之前，发送初始值，如无初始值则发送无效值。在收到源网段的信号值之后更新发送的信号值。

e) 在超时时间溢出之前发信号的上次值，溢出之后将发送信号的超时值（如无超时值，发送无效值或者初始值）。默认的，对于源网段周期 10ms 及小于 10ms 报文中的信号，需要以 10 倍报文周期（±10%）作为超时时间；对于源网段周期大于 10ms 报文中的信号，需要以 5 倍报文周期（±10%）作为超时时间。特别的，如果应用层对信号路由超时时间及超时值有特殊要求，以应用层要求为准。

As shown in the example above, periodic signal routing has the following characteristics:

a) The signal value of periodic signal routing in the target network segment shall be consistent with the latest signal value of the source network segment;

b) The gateway shall send the message according to the message cycle of the target network segment, but it shall ensure that the message of the target network segment is not lost;

c) The signals to be routed can come from different messages, which are packaged into new messages in the target network segment and sent periodically;

d) Before receiving the signal value of the source network segment, send the initial value. If there is no initial value, send the invalid value. Update the transmitted signal value

after receiving the signal value of the source network segment.

e) The destination signal shall use the last value before the source signal times out and shall use the signal timeout value (invalid value or initial value can be used if there is no timeout value) after the source signal times out. By default, for signals in source messages with a period of 10 ms and less than 10 ms, 10 times of the message period（±10%） needs to be used as the timeout time; for signals in source messages with a period of greater than 10 ms, 5 times of the message period（±10%） needs to be used as the timeout time. In particular, if the application layer has special requirements for the signal routing timeout time and timeout value, the application layer requirements shall prevail this requirement.

7.2 其它要求 Other requirements

7.2.1 网络管理 Network management

对于 Autosar 网络管理的网段，应满足 Appendix T10_CAN&CANFD Network Management Requirement CAN&CANFD 网络管理规范的要求。其它网段的睡眠唤醒策略参考本规范第 6 章节。

For the network segment managed by Autosar network, it shall meet the requirements of Appendix T10_CAN&CANFD Network Management Requirement CAN&CANFD 网络管理规范.

7.2.2 容错 Fault-tolerant

网关对于错误帧、DLC 长度不同的报文、Bus off 的处理机制如下：

a) 当网关的某网段出现错误帧时，不能路由错误帧到其他网段，且路由功能正常；

b) 当网关接收到 DLC 小于网关路由表定义的报文时不进行转发，接收到 DLC 大于网关路由表定义的报文时正常转发；

c) 当网关的源网段发生 Bus off 错误时，应遵循本通信需求规范中定义的 Bus off 恢复策略。某网段发生总线错误进入 Bus off 后，不能影响其它网段的通信及路由功能。例如：网络中的某一网段由于总线错误进入了 Bus off，此时该网段不能发送出任何报文。同时不能向其他网段路由任何错误帧，且其他网段间的路由功能正常。由于 Bus off 而导致的信号超时处理应遵循本规范 5.2 章节的定义。

The processing mechanism of the gateway for error frames, DLC messages and Bus off is as follows:

a) When an error frame occurs in a network segment of the gateway, the error frame cannot be routed to other network segments, and the routing function is normal;

b) When the gateway receives a message with a DLC less than the definition, it will not forward it. When it receives a message with a DLC greater than the definition, it will forward it normally;

c) When a Bus off error occurs in the source network segment, the Bus off recovery strategy defined in this communication requirements specification shall be followed. After a bus

error occurs in a network segment and enters Bus off, the communication and routing functions of other network segments cannot be affected. For example, a network segment in the network enters Bus off due to bus error, and the network segment cannot send any message. At the same time, no error frames can be routed to other network segments, and the routing function between other network segments is normal. The signal timeout processing caused by Bus off shall follow the definition in Section 5.2 of this specification

7.2.3 诊断 Diagnosis

当使用网关进行诊断路由时，采用直接报文路由方式，具体要求参见 7.1.1 章节。例如：当接收到停止通信（28 服务，见 UDS 诊断需求规范）的诊断指令时，网关需停止所有网段上常规报文的路由。对于实现诊断报文路由功能的网关，停止通信诊断命令不影响诊断报文的路由。

When the gateway is used for diagnostic routing, the direct message routing method is adopted. See Chapter 7.1.1 for specific requirements. For example: when receiving the diagnostic instruction to stop communication (28 service, see UDS diagnostic requirements specification), the gateway needs to stop the routing of messages on all network segments. For the gateway realizing the routing function of diagnostic message, the stop communication diagnostic command does not affect the routing of diagnostic message.

8 E2E 通信保护 E2E Communication protection

本章节规定通信的保护方式为 E2E 保护机制，E2E Protection 即端到端保护机制的简称。在该机制中，发送端和接收端之间的信息受到保护，且对传输的信息进行一致性和完整性的校验，不受信息传递过程中协议转换或者路由情况的影响。

This chapter specifies that the protection mode of communication is E2E protection mechanism, which is the abbreviation of end-to-end protection mechanism. In this mechanism, the information between the sender and the receiver is protected, and the consistency and integrity of the transmitted information are verified, which is not affected by the protocol conversion or routing in the process of information transmission.

8.1 CAN/CANFD 适用算法 CAN/CANFD Applicable Algorithm

针对 CAN/CANFD 总线通信，本规范仅采用 AUTOSAR 规范中 Profile 1A 算法，并对该算法的实现进行约束。Profile 1A 算法包含 CRC，Counter，Data ID 的安全元素，其中 CRC 和 Counter 随数据进行传输。通过安全元素的组合，系统可以识别出信号组传输过程中可能发生的下列通信错误，如下图所示：

For CAN / CANFD bus communication, this specification only adopts the Profile 1A algorithm in AUTOSAR specification, and restricts the implementation of this algorithm. Profile 1A algorithm contains security elements of CRC, counter and data ID, where CRC and counter are transmitted with data. Through the combination of safety elements, the system can identify the following communication errors that may occur during signal group transmission, as shown in Table 19:

Table 19 Communication error 表19 通信错误

E2E 机制	可检测到的通信错误
Counter	信息重复，信息丢失，通道延迟，额外信息插入，信息顺序错误
Data ID + CRC	信息伪造，信息来源错误，额外信息插入
CRC	数据损坏，从发送方到接收方的信息不对称

各安全元素的含义如下：

Counter： Counter 的初始化、累加及校验等由 E2E 模块完成，Counter 的长度为 4 bits。对于发送端，初始化完成后第一次发出的 Counter 值应为 0x0，对于每个后续的发送请求，计数器应增加 1。当 Counter 值增加到 0xE 后，下一次发送的 Counter 值从 0x0 重新开始循环（0xF 将会被跳过）。对于接收端，则可以从接收到的计数值，判断出信息丢失、信息重复、信息顺序错误等内容；

Counter: The initialization, accumulation and verification of counter are completed by E2E module. The length of counter is 4 bits. For the sender, the counter value sent for the first time after initialization should be 0x0. For each subsequent transmission request, the counter should be increased by 1. When the counter value increases to 0xE, the next sent counter value will restart the cycle from 0x0 (0xF will be skipped). For the receiving end, the information loss, information duplication, information sequence error and other contents can be judged from the received count

value;

DATA ID: E2E 保护的信号组都有一个特定的 ID，即 Data ID。Data ID 的取值在系统内唯一,Data ID 的长度为 16 bits。本规范要求使用的 E2E 算法为 Profile 1A。该算法中，Data ID 的两个字节均需包含在 CRC 计算的数据流中。计算顺序为：Data ID 的低字节，然后 Data ID 的高字节；

Data ID: each signal group protected by E2E has a specific ID, that is, data ID. The value of data ID is unique in the system. The length of data ID is 16 bits. The E2E algorithm required in this specification is profile 1A. In this algorithm, both bytes of data ID need to be included in the data stream of CRC calculation. The calculation order is: the low byte of data ID, and then the high byte of data ID;

CRC: 即循环冗余校验。Profile 1A 的 CRC 算法采用 CRC-8-SAE J1850 算法的多项式，即多项式值为 0x1D(x8+x4+x3+x2+1)，但采用与 CRC-8-SAE J1850 不同的起始值和异或值，即起始值和异或值均设为 0x00。具体参数设置如下表。

CRC: The CRC algorithm of profile 1A adopts the polynomial of CRC-8-SAE J1850 algorithm, that is, the polynomial value is 0x1D (x8+x4+x3+x2+1). However, the starting value and xor value different from CRC-8-SAE J1850 are adopted, that is, the starting value and XOR value are set to 0x00. The specific parameter settings are shown in the table below.

Table 20 Communication error 表 20 CRC-8 算法中各元素取值

CRC 算法元素	CRC 算法取值
CRC result width:	8 bits
Polynomial:	0x1D
Initial value:	0x00
Input data reflected:	No
Result data reflected:	No
XOR value:	0x00
Check[Note1]:	0xB7
Note1: Check 的值为对数据流“0x21 0x22 0x23 0x24 0x25 0x26 0x27 0x28 0x29”进行 CRC 校验所得结果	

Profile 1A 要求遵循严格的信号排布方式。对一个 E2E 信号组，有如下排布要求：

a) CRC 必须处于被保护信号组的首字节， Counter 位于信号组第二个字节的低四位，CRC 和 Counter 都不允许跨字节排布；

b) 用于排布信号组的数据场连续字节中，不允许排布其他信号。

Profile 1A 在进行 CRC 计算时，先计算 Data ID 的低字节，然后计算 Data ID 高字节，接下来计算 User Data（Counter 包含在内）。

Profile 1A requires strict signal layout. For an E2E signal group, there are the following layout requirements:

a) CRC must be in the first byte of the protected signal group, counter is in the lower four bits of the second byte of the signal group, and CRC and counter are not allowed to be arranged across bytes;

b) In the continuous bytes of the data field used to arrange the signal group, it is not allowed to arrange other signals.

8.2 CAN/CANFD 算法示例 CAN / CANFD algorithm example

本章节通过一个详细的例子来说明算法的计算流程。该算例中，包括受保护的信号组、校验和 Checksum、计数器 Counter 和 DATA ID。CRC、Counter 及具体信号的 Layout 如下图所示：

This chapter illustrates the calculation flow of the algorithm through a detailed example. In this example, the protected signal group, checksum, counter and data ID are included. The layout of CRC, counter and specific signals is shown in the figure below:

<table>
<tr><td>Data</td><td>Bit7</td><td>Bit6</td><td>Bit5</td><td>Bit4</td><td>Bit3</td><td>Bit2</td><td>Bit1</td><td>Bit0</td></tr>
<tr><td>Byte2</td><td colspan="8">CRC</td></tr>
<tr><td>Byte3</td><td>0</td><td colspan="3">Signal 1</td><td colspan="4">Counter</td></tr>
<tr><td>Byte4</td><td colspan="4"></td><td colspan="4">Signal 2</td></tr>
<tr><td>Byte5</td><td colspan="5">Signal 3</td><td>0</td><td colspan="2">Signa 4</td></tr>
<tr><td>Byte6</td><td colspan="8">Signa 4</td></tr>
<tr><td>Byte7</td><td colspan="8">Signal 5</td></tr>
</table>

图 15 E2E 示例排布 Figure 15 E2E Example Layout

假设某次传输中，数据内容赋值如下：

E2E Counter 为 0x6；

Signal 1 取值：0x1；

Signal 2 取值：0x7；

Signal 3 取值：0x18；

Signal 4 取值：0x2A5；

Signal 5 取值：0xC3，即：

Byte	2	3		4	5	6	7
Data	0xD9	0x1	0x6	0x07	0XC2	0xA5	0XC3
Field	*CRC*	*User Data*	*Counter*	*User Data*	*User Data*	*User Data*	*User Data*

其中 E2E Data ID 为 0x123，Counter 为 0x6,没有信号填充的部分以 0x00 代替。在该示例中，受保护的数据流为 Byte3 至 Byte7 之间的数据。参与 CRC 计算的数据流顺序应按照排布顺序依次进行，该数据流为：0x23 01 16 07 C2 A5 C3,E2E CRC 计算结果为 0xD9。

Where E2E data ID is 0x123, counter is 0x6, and the part without signal filling is replaced by 0x00. In this example, the protected data stream is data between byte3 and byte7. The data flow involved in CRC calculation shall be arranged in sequence. The data flow is: 0x23 01 16 07 C2 A5 C3, E2E CRC calculation result is 0xD9.