Peripheral Sensor Interface for Automotive Applications

Substandard Chassis and Safety

Contents

1 Introduction

The substandard Chassis and Safety is effective with the PSI5 Base Specification Standard V2.2 and is valid for all sensors and transceivers used in chassis and safety applications. It substantiates the base standard with application specific operation modes and frame formats.
As chassis and safety application, all systems measuring and controlling the motion of the vehicle (e.g. wheel speed sensors, inertial sensors for dynamic and crash vehicle motion detection, damper level sensors) including the devices for driver input (e.g. example brake pedal sensors, steering angle sensors) should be developed after this substandard. The sensor signals are classically transmitted to receivers in separated control units (e.g. brake control unit, power steering unit) or centralized control units (i.e. vehicle motion observer unit, airbag unit, integrated safety unit).
Compared to the former PSI5 v1.3 specification, this substandard extends the frames format from 10bit to 20bit frames with CRC to address the higher precision requirements for several chassis and safety applications. A dedicated status bit ensures the signal transmission also during a sensor failure allowing a possible usage of the signal for non safety related function. Separate frame control bits allow the transmission of different signals within the dedicated time slots or within asynchronous mode. A special frame mode allows the transmission of normal 10bit data (highly packed) as for several airbag sensors.
For standard airbag systems the PSI5 substandard Airbag is still to be used. For future systems merging airbag and other vehicle dynamic functions, it is advisable that all airbag sensors support additionally the Chassis and Safety substandard.

Please be aware, that not every feature can be combined among one other. Hence it is in responsibility of the system vendor to evaluate which feature is necessary to fulfill the system requirements and assure that the combination of features is compatible.

The document is structured similar to the PSI5 V2.2 Base Specification Standard: Chapter 2 gives recommended operation modes, whereas Chapter 3 and 4 define details of the Sensor to ECU, or the ECU to sensor communication, respectively. Chapter 5 describes Application Layer Implementations and in Chapter 6 specific system parameters and timings for VDC applications are given.

2 System Setup & Operation Modes

The substandard Chassis and Safety limits the possible frame length to fixed 20bit to allow a cost efficient implementation with low variations of the communication interface. There are two asynchronous transmission modes and 4 synchronous modes with a standard 500us sync period whereof two of them require a tighter sensor clock tolerance to allow a higher data rate.

Asynchronous Operation		
Mode	Sensor Data	Description
A20CRC	300/1L	min. 1 value each 300µs (incl. tolerances)
A20CRC	200/1H	min. 1 value each 200µs (incl. tolerances)
Synchronous Operation		
Bus Mode	Sensor Data	Description
P20CRC	500/1L	One message slot parallel bus / 500µs data rate
P20CRC	500/2L*	Two message slot parallel bus / 500µs data rate
P20CRC	500/2H	Two message slot parallel bus / 500µs data rate
P20CRC	500/3H*	Three message slot parallel bus / 500µs data rate

*) This mode requires a tighter sensor clock tolerance as typically assumed (<5%) or dependent sensors within each time slot (so that sync detection variations and clock tolerances do not add up).

3 Sensor to ECU Communication

Recommended data word length is a 20bit data word with two start bits and three CRC bits for error detection. There are two frame modes defined; one with 16bit data one status flag and 3 frame control bits. This format should be used as standard for all sensors requiring a higher precision. For mixed systems including chassis and airbag systems, there is a frame format including two 10bit data words for low precision airbag signals allowing a constant 20bit frame format and a high data rate by packing two signals into one PSI5 frame,.

High precision data frame mode:

Bits	Function	Number of bits
F[0] … F[2]	Frame control	3
E[0]	Status	1
A[0] … A[15]	Data Region	16

It is recommended to use the status bit E[0] to communicate sensor failures. Using the reserved data range of A[0…15], to communicate sensor failures, should be avoided since then signal data, which could for instance be used for safety uncritical functions, would be lost. It is recommended to use the status bit E[0] to communicate sensor failures instead of transmitting status and error messages from data range 2. In that case the signal data can still be transmitted and for instance be used for safety uncritical functions. The three frame control bits can be used to identify the signal data if different signals are sent asynchronous or signals within one time slot of a synchronous application vary from one sync period to another (time multiplexing within different sync periods).

Low precision data frame mode
(i.e airbag sensors)

Bits	function	Number of bits
B[0] … B[9]	Data Region B	10
A[0] … A[9]	Data Region A	10

Data region A[0..9] as well as region B[0..9] can be used to transmit two different sensor signals. Coding for each signal (including error coding and initialisation data) should be the same as defined for the standard payload region A with 10bits within the base standard. Note that this frame format cannot be used in asynchronous operation combined with the high precision data range since no frame control bits exist. Using it in synchronous operation, the time slot with this data format cannot be mixed with other high precision data frame formats and signals cannot be time multiplexed due to the same reason. Mixing low precision data frame and high precision data frames within different time slots of a synchronous transmission is well feasible.

4 ECU to Sensor Communication

ECU to Sensor communication is executed with the Tooth Gap method as defined in the base standard. Sensor response during bidirectional communication is carried out in Data range codes RC, RD1 and RD2. Optionally, for XLong Frames the FC, RAdr and Data Fields can be used otherwise than specified in the Base Standard, i.e. all existing function codes may be applied, followed by the RAdr and Data Field free to use for 16 bit data. Sensor response still has to be executed during the following three sync periods, other response codes as RC, RD1 or RD2 are allowed.

5 Application Layer Implementations

5.1 Sensor start up and Initialization

Sensor identification data is sent via Data Range Initialization. The initialization phase is divided into three phases and the data message repetition count k typically has a value of 4.

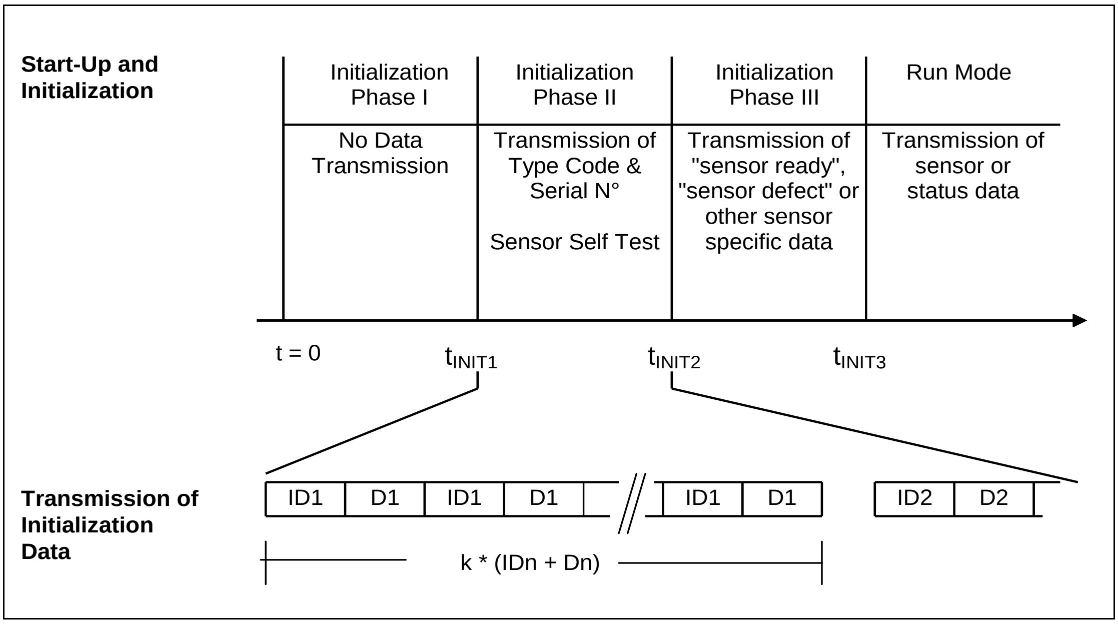

Figure 1 Initialization of the sensor

	Initialisation Phase I	Initialisation Phase III
Duration of initialization phases	t = 50…200 ms Typical: 100 ms	Minimum: 2 messages Maximum: 200 ms Typical: 10 values

Initialization Data Content:

The following definitions are made in addition to the Base Specification.

Recommended definitions:

	Application specific						
Data field	F6						
Data nibble	D10	D11	D12	D13	D14	D15	D16
	sensor specific						

6 Physical Layer - Parameter Specification

All voltage and current values are measured at the sensor's connector pins unless otherwise noted. All parameters are valid under all operating conditions including temperature range and life time.

6.1 System Parameters

This section reduces the possible options on the physical side for the ease of implementation. VDC systems are implemented in “Common Mode” as defined in the Base Specification document with the following parameter selection.

PSI5 Common Mode

- Supply Voltage (standard voltage); $V_{CE, min}$ = 5.5V; $V_{SS, min}$ = 5.0V
- Supply voltage (low voltage); $V_{CE, min}$ = 4,2V; $V_{SS, min}$ = 4,0V
- Sync signal sustain voltage V_{t2} = 3.5V
- Internal ECU Resistance $R_{E, max}$ = 12.5Ω

With this selection the optional given system parameters N° 7, 9 and 11 of the “common mode” table in the PSI5 V2.2 Base Specification Standard are excluded for VDC applications.

6.2 Sensor Power-on Characteristics

6.2.1 Sensor Bus Configuration

As specified in Base Standard.

6.2.2 Extended Settling Time for Single Sensor Configuration

For single sensor configurations an extended stabilization time t_{SET2} is defined, where the current may fluctuate within the specified tolerance band for I_{LOW} before it reaches its steady state value.

N°	Parameter	Symbol/Remark	Min	Typ	Max	Unit
3*	stabilization time for quiescent current I_{LOW}	t_{SET2}			25	ms

3*) Fluctuations between I_{LOW_min} and I_{LOW_max} are allowed; the receiver might indicate communication error for t < t_{SET2}. Final value settles to I_{LOW} with the defined signal noise limits ΔI_{LOW} (Parameter N°21 in Ch.6.1.2 PSI5 V.2.2 Base Specification Standard).

6.3 Undervoltage Reset and Microcut Rejection

The sensor must perform an internal reset if the supply voltage drops below a certain threshold for a specified time. By applying such a voltage drop, the ECU is able to initiate a safe reset of all attached sensors.

Microcuts might be caused by lose wires or connectors. Microcuts within the specified limits shall not lead to a malfunction or degraded performance of the sensor.

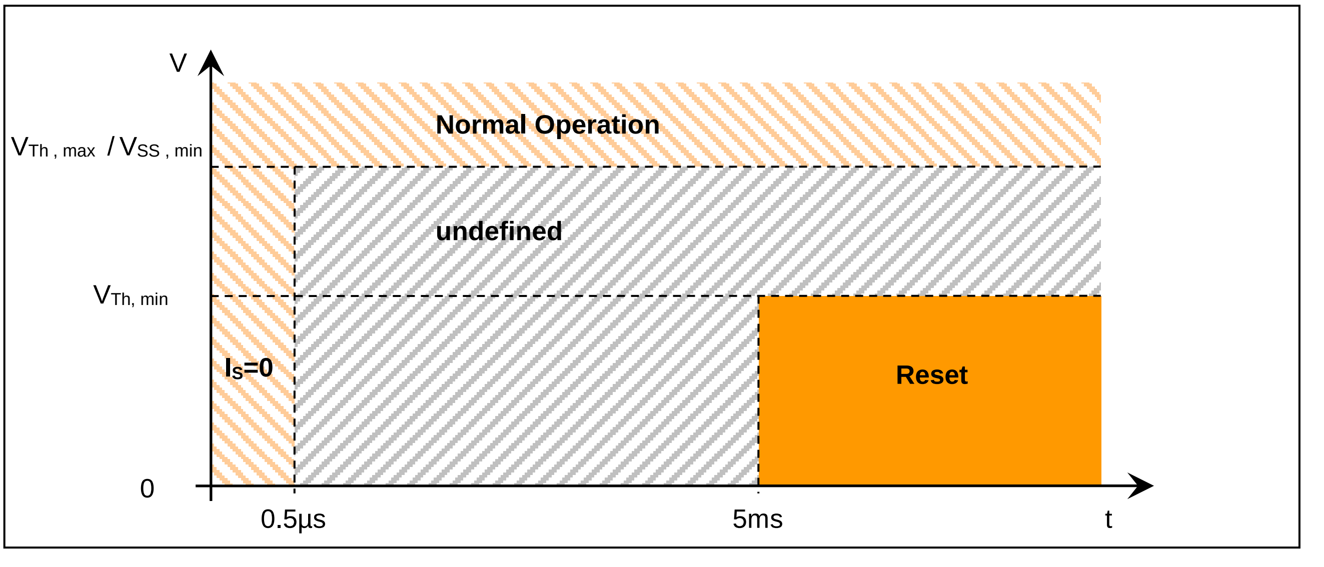

Figure 2 Undervoltage reset behaviour

N°	Parameter	Symbol/Remark	Min	Typ	Max	Unit
1	Undervoltage reset threshold ($V_{Th, min}$ = must reset; $V_{Th, max}$ = $V_{SS, min}$)	V_{Th} - standard voltage mode	3		5	V
		V_{Th} - low voltage mode	3		4	V
2	Time below threshold for the sensor to initiate a reset	t_{Th}			5	ms
3	Microcut rejection time (no sensor reset allowed) : standard	I_S=0	0.5			µs

Table 1 Undervoltage reset specification

The voltage V_{Th} is at the pins of the sensors. In case of microcuts (I_S=0) to a maximum duration of 0.5µs the sensor must not perform a reset. If the voltage at the pins of the sensor remains above V_{Th} the sensor must not perform a reset. If the voltage at the pins of the sensor falls below 3V for more than 5ms the sensor has to perform a reset.

Different definitions may apply for Universal Bus and Daisy Chain Bus.

6.4 Data Transmission Parameters

N°	Parameter	Symbol/Remark	Min	Typ	Max	Unit
3*	Sensor clock deviation during data frame				1	%

Table 2 Data transmission parameters for Chassis and Safety applications

3*) @ maximum temperature gradient and maximum frame length

6.5 Timings

6.5.1 Timing example for PSI5-P20CRC-500/1L Mode

This example is calculated with a standard sensor clock tolerance of 5%.

N°	Parameter	Symbol	Remark	min	nom	max	Unit
1	Sync signal period Maximum tolerance of sync signal period +/-1	T_{Sync}		495		505	µs
				t^N_{Ex}	t^N_{Nx}	t^N_{Lx}	
2	Slot 1 start time	t^1_{xS}	Related to t_0	44	46,5	59	µs
3	Slot 1 end time	t^1_{xE}	Related to t_0	234	246,5	269	µs

The timings also apply for universal bus mode and daisy chain bus mode.
The timings for earliest start and latest end reflect the time span for a maximum time window (“receiver view”); Sensors should be programmed with nominal start times (“sensor view”).

6.5.2 Timing example for PSI5-P20CRC-500/2L Mode

This example calculates the slot timings for two independent sensors within one sync period, a sensor clock tolerance of 1.8% and a time discretization of 0.5us.

N°	Parameter	Symbol	Remark	min	nom	max	Unit
1	Sync signal period Maximum tolerance of sync signal period +/-1 %	T_{Sync}		495		505	µs
				t^N_{Ex}	t^N_{Nx}	t^N_{Lx}	
2	Slot 1 start time	t^1_{xS}	Related to t_0	44	45	56	µs
3	Slot 1 end time	t^1_{xE}	Related to t_0	240	245	259,5	µs
4	Slot 2 start time	t^2_{xS}	Related to t_0	267,5	273	288	µs
5	Slot 2 end time	t^2_{xE}	Related to t_0	464	473	492	µs

The timings also apply for universal bus mode and daisy chain bus mode.

The timings for earliest start and latest end reflect the time span for a maximum time window ("receiver view"); Sensors should be programmed with nominal start times ("sensor view").

6.5.3 Timing example for PSI5-P20CRC-500/2H Mode

This example is calculated with standard sensor clock tolerance of 5% for two independent sensors within one sync slot. Start time discretization is 0.5us.

N°	Parameter	Symbol	Remark	min	nom	max	Unit
1	Sync signal period Maximum tolerance of sync signal period +/-1 %	T_{Sync}		495		505	µs
				t^N_{Ex}	t^N_{Nx}	t^N_{Lx}	
2	Slot 1 start time	t^1_{xS}	Related to t_0	44	46,5	59	µs
3	Slot 1 end time	t^1_{xE}	Related to t_0	169,5	179	198	µs
4	Slot 2 start time	t^2_{xS}	Related to t_0	203,5	214,5	235,5	µs
5	Slot 2 end time	t^2_{xE}	Related to t_0	329	347	374,5	µs

The timings also apply for universal bus mode and daisy chain bus mode.
The timings for earliest start and latest end reflect the time span for a maximum time window ("receiver view"); Sensors should be programmed with nominal start times ("sensor view").

6.5.4 Timing example for PSI5-P20CRC-500/3H Mode

This example is calculated with enhanced sensor clock tolerance of 1.5% with the first two time slots provided by one sensor (equal and correlated clock and sync detection tolerance). Start time discretization is 0.5us.

N°	Parameter		Symbol	Remark	min	nom	max	Unit
1	Sync signal period Maximum tolerance of sync signal period +/-1 %		T_{Sync}		495		505	µs
					t^N_{Ex}	t^N_{Nx}	t^N_{Lx}	
2	Slot 1 start time	data from one sensor	t^1_{xS}	Related to t_0	44	45	56	µs
3	Slot 1 end time		t^1_{xE}	Related to t_0	174,5	177,5	190,5	µs
4	Slot 2 start time		t^2_{xS}	Related to t_0	180	183,5	196,5	µs
5	Slot 2 end time		t^2_{xE}	Related to t_0	310,5	316	331	µs
6	Slot 3 start time	data from another sensor	t^3_{xS}	Related to t_0	336	341,5	357	µs
7	Slot 3 end time		t^3_{xE}	Related to t_0	466,5	474	491,5	µs

The timings also apply for universal bus mode and daisy chain bus mode.
The timings for earliest start and latest end reflect the time span for a maximum time window ("receiver view"); Sensors should be programmed with nominal start times ("sensor view").

Note, that the slot timings of slot 1 and slot two overlap (i.e. $t^1_{LE} > t^2_{ES}$). Although the slots overlap, it is ensured that the real sensor data itself will never overlap and will always be separated by at least T_{GAP}. This is possible since both slots are used by the same sensor. A slow sensor (“A”) may sent both datagrams at a later time than a fast sensor (“B”). Figure 2 depicts both situations exemplarily. Message timing for situation “A” and “B” is possible and both are fulfilling the specification.

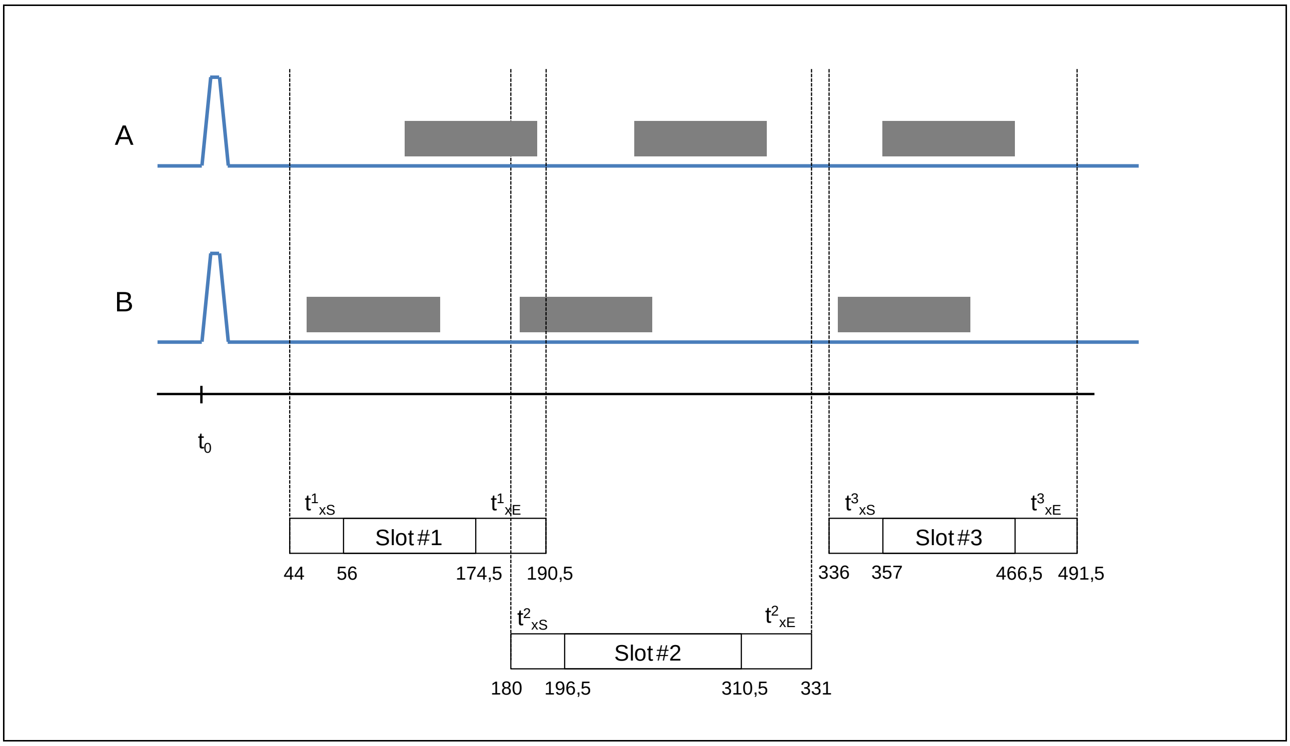

Figure 3 Possible message timing for overlapping slot timings

7 Document History & Modifications

Rev.N°	Chapter	Description / Changes	Date
2.0	all	First Release of VDC Substandard; Revision Number of corresponding PSI5 Base Document adopted	06/2011
2.1	all	Changed name of substandard from “Vehicle Dynamic Control” to “Chassis and Safety”	10/2012
	1	(editorial) rework introduction with further explanations	
	2	(editorial) added verbal description	
	3	(editorial) added verbal description	
	5.1	Application specific definitons removed and shortend Defined responibilities for sensor type / parameter definiton (editorial) added description for sensor type and sensor paramters	
	5.6	(editorial) added verbal description and further explanations	
	div.	Final document completed after full revision	
2.2	5.1	Mandatory definitions of Initialization Data Content (i.e. data nibbles D1 to D9) shifted to base specification	04/2016
	6.2.2	New chapter 6.2.2 “Extended Settling Time for Single Sensor Configuration”	
	6.5	Chapter moved. Previous numbering was 6.3	