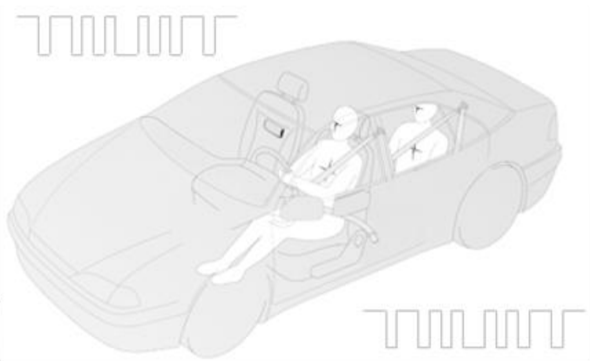
Peripheral Sensor Interface
for Automotive Applications

Substandard Airbag



Contents

1 Introduction

The substandard Airbag is effective with the PSI5 Base Standard V2.3 and is valid for all airbag components. It is in full compliance to the previous PSI5 standard PSI5 V1.3. It substantiates the Base Standard with the proposed operation modes and frames formats for all sensors and transceivers used in Airbag applications. 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 V2.3 Base Standard.

2 Definition of Terms

8 See chapter 2 of PSI-5 V2.3 Base Standard.

3 Data Link Layer

3.1 Sensor to ECU Communication

Chapter 3.1 of PSI-5 V2.3 Base Standard is fully applicable for airbag application.

In addition, the recommended data frame for airbag application is a 10bits payload with two start bits and one parity bit for error detection. An alternative option for airbag sensors is to use a 16 bits payload frame with two start bits and three bits CRC for error detection.

3.2 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.

4 Physical Layer

4.1 General

See chapter 4.1 of PSI-5 V2.3 Base Standard.

4.2 Supply Line Model

See chapter 4.2 of PSI-5 V2.3 Base Standard.

4.3 Single Sensor, Point to Point Topologies

See chapter 4.3 of PSI-5 V2.3 Base Standard.

4.4 Multi Sensor, Bus Topologies

See chapter 4.4 of PSI-5 V2.3 Base Standard.

4.5 Sensor to ECU Communication

All parameters defined in Section 4.5 of the Base Standard are valid for Airbag Applications with the following exception:

Table 1: Data transmission parameters for airbag applications

N°	Parameter	Symbol	Conditions/Remark	Min	Typ	Max	Unit
4*	Sensor clock deviation during data frame (see Substandard)	CD_S	Standard			1	%
5*			Legacy			0.1	%

4-5*) @ maximum temperature gradient and maximum frame length.

5*) It is recommended that sensor complies with limited value to 0.1% for compliance with legacy receiver and reduction of signal to noise ratio

4.6 ECU to Sensor Communication

ECU to Sensor preferred communication (for legacy reasons) is executed in Tooth gap mode as defined in the Base Standard. Sensor response during bidirectional communication is carried out in Data range codes RC, RD1 and RD2.

4.7 General Parameters

4.7.1 Supply and Communication Parameters Definitions

See chapter 4.7.1 of PSI-5 V2.3 Base Standard.

4.7.2 Absolute Maximum Ratings

See chapter 4.7.2 of PSI-5 V2.3 Base Standard.

4.7.3 Configuration Modes & Options

For Airbag systems, it is recommended to use the “Common Mode” with the following selected parameters.

PSI5 Common Mode

- Supply Voltage (standard mode); $V_{CE,\,min}$ = 5.5V; $V_{SS,\,min}$ = 5.0V for bus mode topology
- Supply Voltage (increased mode); $V_{CE,\,min}$ = 6.5V; $V_{SS,\,min}$ = 5.0V for daisy chain bus mode
- Sink Current ΔI_S = 30 mA
- Sync signal sustain voltage V_{t2} = 3.5V
- Internal ECU Resistance $R_{E,\,max}$ = 12.5Ω

4.8 Dynamic Bus Behavior

See chapter 4.8 of PSI-5 V2.3 Base Standard.

4.9 Synchronization Signal

See chapter 4.9 of PSI-5 V2.3 Base Standard.

4.10 Timing Definitions for Synchronous Operation Modes

4.10.1 Generic Time Slot Calculation

Please note that due to backward compatibility the values given below are adopted from PSI5 V1.3. Derivations to calculated timeslots according to Ch. 6.6 in the PSI5 V2.0 Base Standard are possible.

4.10.1.1 *PSI5-P10P-500/3L Mode*

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

Table 2: PSI5-P10P-500/3L timeslots specification

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			µs
3	Slot 1 end time	t^1_{xE}	Related to t_0				µs
4	Slot 2 start time	t^2_{xS}	Related to t_0	181.3			µs
5	Slot 2 end time	t^2_{xE}	Related to t_0				µs
6	Slot 3 start time	t^3_{xS}	Related to t_0	328.9			µs
7	Slot 3 end time	t^3_{xE}	Related to t_0			492	µs

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

4.10.1.2 *PSI5-P10P-500/3L Mode*

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

Table 3: PSI5-P10P-500/4H timeslots specification

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			µs
3	Slot 1 end time	t^1_{xE}	Related to t_0				µs
4	Slot 2 start time	t^2_{xS}	Related to t_0	139.5			µs
5	Slot 2 end time	t^2_{xE}	Related to t_0				µs
6	Slot 3 start time	t^3_{xS}	Related to t_0	245.5			µs
7	Slot 3 end time	t^3_{xE}	Related to t_0				µs
8	Slot 4 start time	t^4_{xS}	Related to t_0	362.5			µs
9	Slot 4 end time	t^4_{xE}	Related to t_0			492	µs

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

4.11 Sensor Power-on Characteristics

4.11.1 Sensor Bus Configuration

To ensure a proper startup of the system, the maximum startup time t_{SET1} is specified. During this time, the ECU must provide a minimum current to load capacitances in sensors and wires. After this time, the sensor must sink to quiescent current within the specified tolerance band.

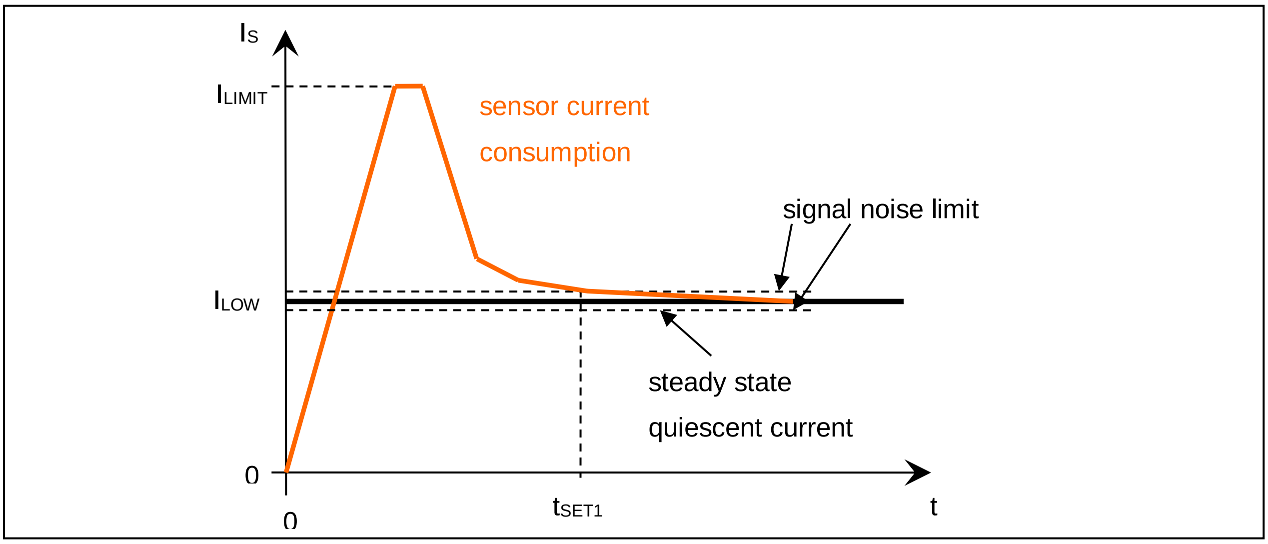


Figure 1: Current consumption during start up

Table 4:

N°	Parameter	Symbol/Remark	Min	Typ	Max	Unit
1	Settling time for quiescent current I_{LOW}	t_{SET1}			5.0	ms
2*	Settling time for quiescent current I_{LOW} (Daisy Chain Bus)	$t_{SET,\ Daisy\ Chain\ Bus}$			10.0	ms

1*) Final value settles to □ILow. = +/-2mA (common mode) with respect to ILOW according to the defined signal noise limit

2*) Mandatory settling time for quiescent current in Daisy Chain Bus. The Bus does not sink a current over ILIMIT,dynamic at any time.

4.11.2 Extended Settling Time for Single Sensor Configuration

An extended settling time t_{SET2} is not allowed.

4.12 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.

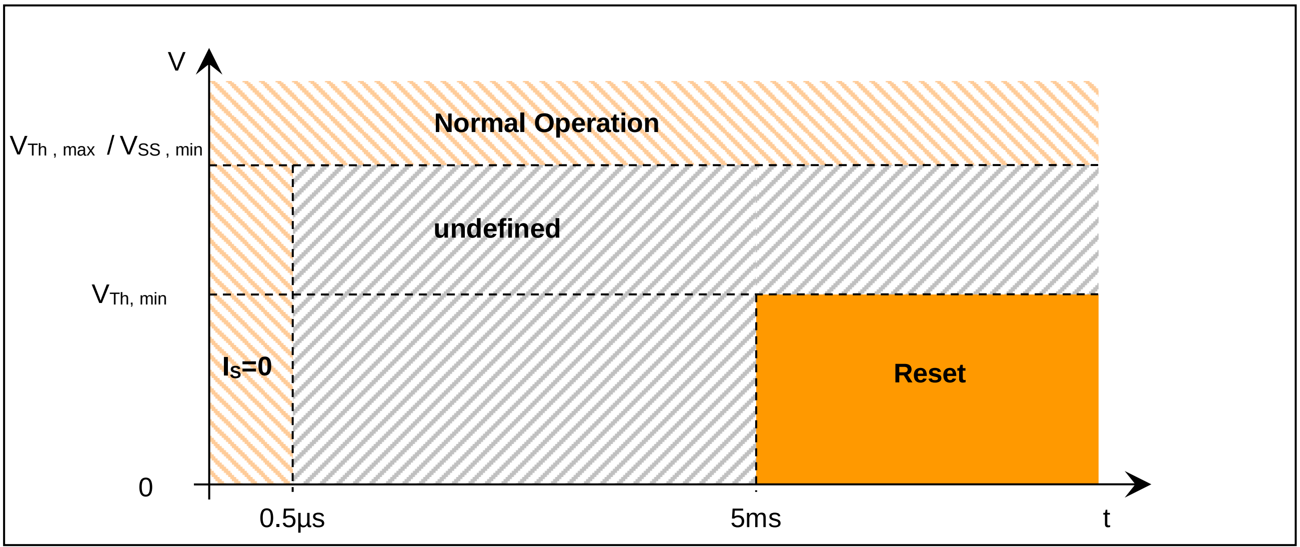


Figure 2: Undervoltage reset behaviour

Table 5: Undervoltage reset specification

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
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
4*	Microcut rejection time (no sensor reset allowed) : optional	$I_S=0$ Applicable test conditions for this specification : micro-cuts of 10 µs, applied every 1 ms for a total duration of 4 s	10			µs

4*) Note: as the micro-cut duration of 10 µs exceeds the transmission bit time, data frame [or sync pulse] corruption might occur when the micro-cut is applied. So it cannot be guaranteed that all data frames are successfully transmitted, but a reset of the sensor (with a complete initialization sequence sent out) is not allowed.

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 (Optional 10 µs) 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.

5 Application Layer

5.1 Data Range

Basically the full data range as specified within the Base Standard can be applied too.

Recommended Data word length is a 10 bit data word (payload) with two start bits and one Parity bit for error detection.

For sensors with a data word length of more than 10 bit, the data range scales as described in the PSI5 V2.0 Base Standard. Furthermore, the following definition is effective: status and initialization data words of range 2 and 3 are filled up with the value of the bit corresponding to the “D0” bit in the 10 Bit data word (possibility to check for stuck bits in the receiver).

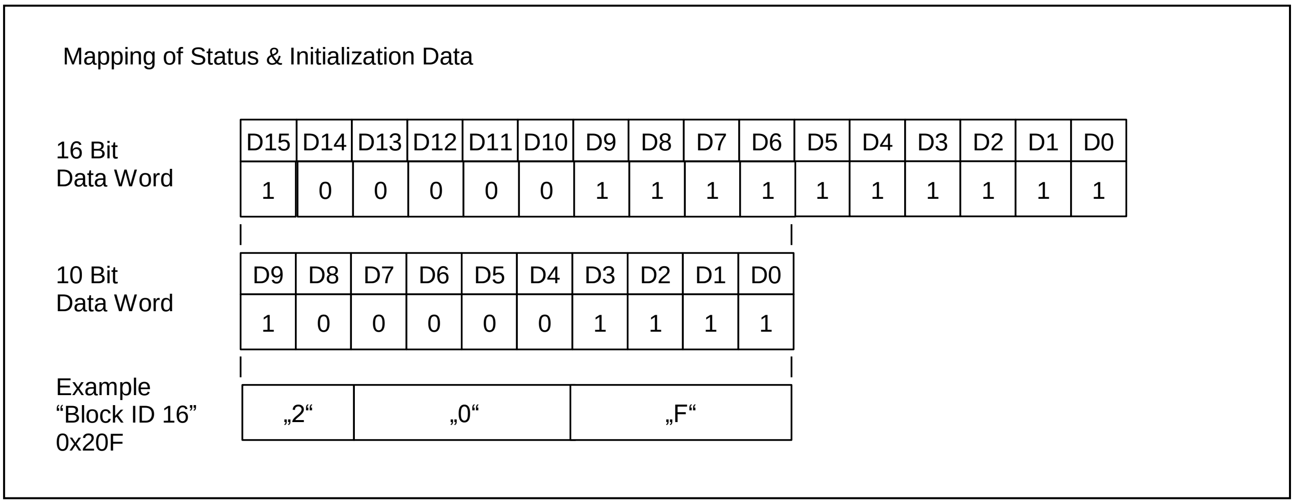


Figure 3: Mapping of status and initialization data into a data word

Table 6: Scaling example: Data Range for a 16 Bit data frame

value		Signification	Range	
Dec	Hex			
32767	0x7FFF	Reserved (ECU internal use)	Status & Error Messages	2
+31231	0x79FF	Sensor Ready		
:	:			
+30720	0x7800	Maximum Sensor Data Value	Sensor Output Signal	1
:	:	:		
0	0x0000			
:	:	:		
-30720	0x8800	Minimum Sensor Data Value		
-30721	0x87FF	Status Data 1111	Block ID's and Data for Initialisation	3
:	:	:		
-31744	0x8400	Status Data 0000		
-31745	0x83FF	Block ID 16		
:	:	:		
-32768	0x8000	Block ID 1		

5.2 Sensor Initialization / Identification

5.2.1 Frame Format - Data Range Initialization

The initialization phase is divided into three phases:

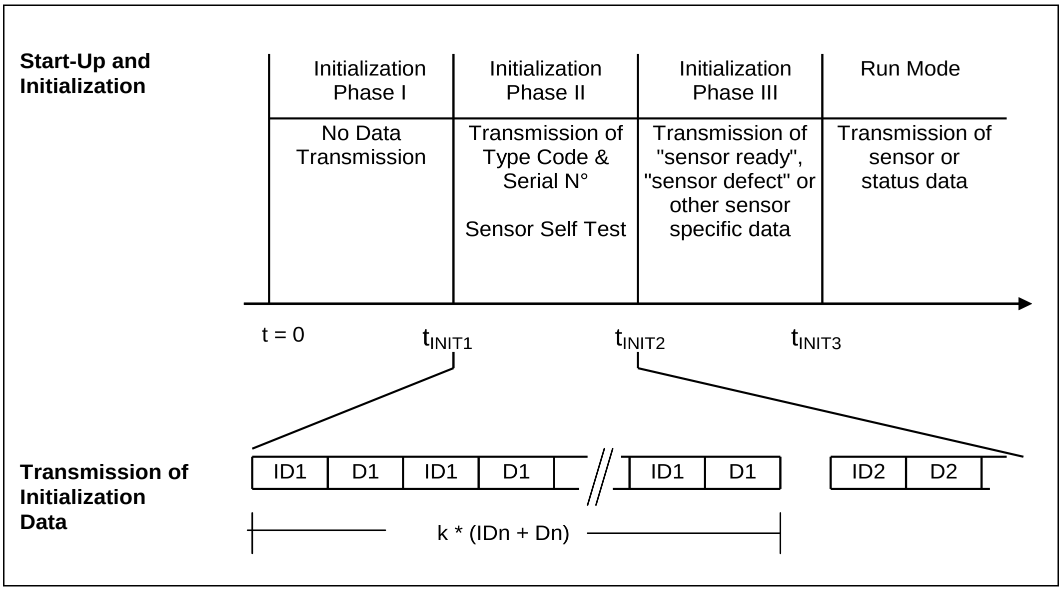


Figure 4: Initialization phases of the sensor

Table 7: Duration of the initialization phases

	Initialisation Phase I	Initialization Phase II	Initialisation Phase III
Duration of initialization phases	t = 50…150 ms Typical: 100 ms	Minimum: see Section 5.2.2.1 Maximum: see Note 3	Minimum: 2 messages Maximum: 200 ms Typical: 10 values

Note 1: During Initialization Phase I, there is no data transmission, but sync pulses may be sent or not. Sensor shall be compliant with Sync pulses in phase I.

Note 2: During Initialization phase II, Sensor identification data is sent via Data Range 3 and the data message repetition count k has typically a value of 4. In case of exception or failure mode, information coded in data range 2 may be sent in place of sensor identification.

Note 3: If at the end of Initialization Phase II, the sensor has not finished its internal self-test, Initialization Phase II is extended and sensor can send "SENSOR_BUSY" (Initialization Phase IIb)

5.2.2 Data Content - Data Range Initialization

5.2.2.1 *Initialization Data Content in Phase II:*

The section 5.2.2 of the Base Standard defined the mandatory Initialization Data Content and definitions.

<u>Note</u> : For compatibility reasons with legacy airbag applications, the field F1 (D1) should refer to PSI5 ver 1.3, value = ‘0100’. For upcoming sensors - compliant with PSI5 ver 2.x - it is recommended to have the F1 (D1) value configurable to either ‘0110’ or ‘0100’ depending on application needs.

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

Table 8: Recommended definitions

	Application specific											
Data field	F6		F7			F8				F9		
Data nibble	D10	D11	D12	D13	D14	D15	D16	D17	D18	D19	**...**	D32
	Sensor manuf.		Sensor application			Sensor production date				Sensor trace inf.		

Table 9: Initialization data content in Phase II

Field	Name	Parameter definition	Value
F6 (D10,D11)	Sensor Code (Sensor manufacturer) Definition of sensor specific parameters or additional information.	To be specified by the sensor manufacturer.	Sensor specific definition
F7 (D12-D14)	Sensor Code (Sensor application)	Usage e.g. for product revision information.	Sensor specific definition
F8 (D15-D18)	Sensor Production Date Production date of the sensor.	Binary coded julian date: Year: 00-99 (7 bit value) Month: 01-12 (4 bit value) Day: 01-31 (5 bit value)	Example: 2006: 0000110 March: 0011 30: 11110
F9 (D19-D32)	Sensor Trace information E.g. production lot / line / serial number	To be specified by the sensor manufacturer	Sensor specific definition

5.2.2.2 *Initialization Data Content in Phase III:*

The purpose of the following recommendations is twofold:

1. To narrow down the number of different - or not compatible - implementations that could have become available through the various sensors provided by different vendors.
2. To ensure that the different implementations are “fairly similar”, in order to allow application teams to integrate and/or substitute the different PSI5 devices into their systems with a reasonable amount of design and validation effort.

The existing solutions vary significantly with respect of the sensor type, as can be seen in the below given description.

a) Acceleration sensors
   Existing Implementations are all working after the same principle:
   Sending “sensor ready” in various repetitions under standard conditions, whereas in case of an error a sequence of various numbers of “sensor defect” is sent followed by an endless repetition of “sensor defect” and the corresponding error code until the power supply is switched off.

b) Pressure sensors

Pressure Sensors not only send “sensor ready” or “sensor defect” + error code during initialization phase III, but also specific sensor status data, as e.g. absolute pressure, or temperature. (All status data from data range 2 or 3,)

The existing solutions cannot be narrowed down to a common minimum principle, which makes integration of different devices complicated. Hence, it is recommended that future implementations for pressure sensors comply with the minimum definition outlined below.

- At minimum one “SENSOR READY” (or “SENSOR DEFECT”) is sent at the beginning of Initialization Phase III.
- Several informations may be sent during Initialization Phase III such as "Absolute pressure", "Sensor temp" or "sensor self diag". These informations are coded in data range 2 and 3

Phase 3		Phase 3 message sequence standard conditions	
time (ms)	#		
0,5	1	Start	sensor ready
1	2	.	.
1,5	3	.	.
2	4	.	.
.	.	.	.
.	.	.	.
.	.	.	.
N	n		sensor ready
.	.	.	.
.	.	.	.
max 200	max 400	End	.
		End of Phase 3	
200,5	1	Start of normal operation	Sensor output signal (Data range 1)

- Initialization Phase III ends with the first sensor measurement data word sent out of data range 1.

In error state an endless repetition of “sensor defect” and the corresponding error code follows the first status message(s) until the power supply is switched off.

Phase 3		Phase 3 message sequence error conditions	
time (ms)	#	continuosly	
0,5	1	Start	sensor defect
1	2		sensor defect
1,5	3		.
2	4		.
.	.		sensor defect
.	.		err code
.	.		sensor defect
.	.		err code
.	.		sensor defect
.	.		err code
.	.	End	... till power down

5.3 Bidirectional Communication

5.3.1 Sensor Addresses

Accordingly of sections 3.2 and 5.3 of the Base Standard, the instruction codes to be used in case of Daisy Chain implementation are:

ECU to sensor (short instructions) :

[@1] = 0x28CE Set address #1
[@2] = 0x28AF Set address #2
[@3] = 0x28E8 Set address #3
[@4] = 0x289A Set address #4
[R] = 0x2F8F Run

Sensor to ECU :

Err_no@ : Sensor error code when address assignment was not successful
Sensor address = RD1 = encoded values from data range 3 (e.g. @1 = 0x211, @2 = 0x212, @3 = 0x213, @4 = 0x214)

Note : following messages are used in the drawings, but are not specific to daisy chain applications
Ack = RC = 0x1E1 (or Err = 0x1E2)
OK = 0x1E7

6 System Setup & Operation Modes

6.1 System Setup

See chapter 6.1 of PSI-5 V2.3 Base Standard.

6.2 PSI5 Operation Modes

Table 10: Recommended operation modes for airbag applications

Asynchronous Operation		
Mode	Sensor Data	Description
A10P	250/1L	min. 1 value each 250µs (incl. tolerances)
A16CRC	500/1L	min. 1 value each 500µs (incl. tolerances)
Synchronous Operation		
Bus Mode	Sensor Data	Description
P10P	250/1L	Single sensor 4kHz data transmission
P10P	500/2L	Two message slot parallel bus / 500µs data rate
P10P	500/3L	Three message slot parallel bus / 500µs data rate
P10P	500/4H	Four message slot parallel bus / 500µs data rate
P16CRC	500/2L	Two high resolution sensors parallel bus / 500µs data rate
D10P	500/3L	Three message slot Daisy Chain bus / 500µs data rate
D10P	500/4H	Four message slot Daisy Chain bus / 500µs data rate

6.3 Synchronous Operation

6.3.1 Bus Operation Principle

In addition to the PSI5 Base Standard description, the purpose of the following recommendations is twofold:

1. To narrow down the number of different - or not compatible - Daisy-Chain implementations that could have become available through the various devices (transceivers or sensors) provided by the IC vendors.
2. To ensure that the different implementations are "fairly similar", in order to allow application teams to integrate and/or substitute the different Daisy Chain devices into their systems with a reasonable amount of design and validation effort.

The different Daisy-Chain solutions can essentially be distinguished by their principle of operation - initialization sequence sent "in parallel" or sent "in series" – as well as by :

- Their capability to support one (or several) of the following communication bit rate(s) :
  - D10P-500/3L : 125 kb/s, 3 time slots maximum
  - D10P-500/4H : 189 kb/s, 4 time slots maximum
- The address encoding scheme used for the sensor response (acknowledgement for a successful address setting)
- The handling of the line switch closure by the sensor :
  - automatic switch closure along with the address setting (upon first sync pulse after completion of address setting) or

- switch closure through dedicated bi-directional instruction (optional).

It is therefore recommended that future Daisy-Chain implementations comply with one of the operation modes outlined in the next 2 sub sections.

6.3.1.1 *Preferred Daisy-Chain Mode: Parallel Initialization Phase*

In this operation mode, each sensor sends out the initialization sequence over the previously assigned sensor time slot. The timeslot is assigned by an address setting instruction. The ECU shall assign the addresses in reverse order, i.e. that timeslot TS1 is the last one receiving its address. Furthermore, timeslot TS1 is defined as being the default timeslot for sensor error reporting in case of an unsuccessful address assignment.

Principle of operation

1. ECU applies supply voltage to PSI5 Interface (power on)
2. Wait for supply settling time
3. ECU assigns sensor address for time slot “TSi” to the next sensor that has not yet received its configuration
4. Addressed sensor responds by sending its internal status (acknowledge or error) message and address confirmation. Sensor closes daisy-chain switch to supply next sensor.
5. Repeat steps 2, 3 and 4 until all sensor addresses have been successfully assigned (From TSn down to TS1)
6. ECU to send RUN broadcast instruction to start runtime mode
7. All sensors to send out their initialization data within their assigned timeslot
8. All sensors to send out “sensor_OK“ messages
9. All sensors to send out their sensor data

Bus configuration (Example with 4 time slots) :

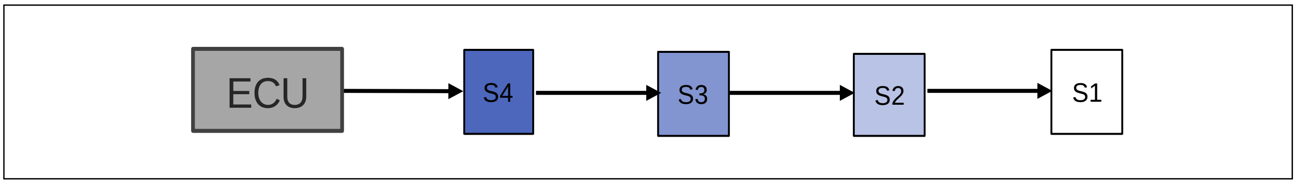


Figure 5: Bus configuration for operation mode #1

Bus timing for daisy chain mode #1 :

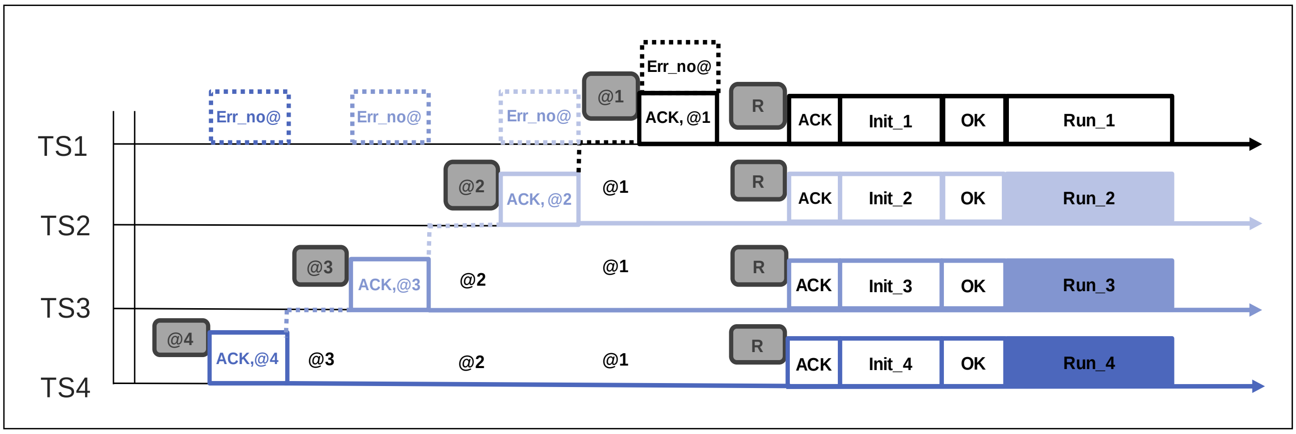


Figure 6: Bus timing for operation mode #1

6.3.1.2 *Alternative implementation : Serial Initialization-phase*

In this operation mode,, each sensor sends out the initialization sequence over the default sensor time slot, right after it is powered on. The timeslot is assigned by an address setting instruction that is sent only once the initialization sequence is over.

Principle of operation

1. ECU applies supply voltage to PSI5 Interface (power on)
2. Sensor sends out initialization sequence and “sensor_OK” messages
3. ECU reads out complete initialization sequence and then assigns sensor address for timeslot “TSi”
4. Sensor responds by internal status (acknowledge or error) message and address confirmation. Sensor closes daisy-chain switch to supply next sensor.
5. Repeat steps 2 to 5 until all sensor addresses have been successfully assigned.
6. ECU to send RUN broadcast instruction
7. All sensors to send out their Ack
8. All sensors to send out their sensor data

Bus configuration (Example with 3 time slots) :

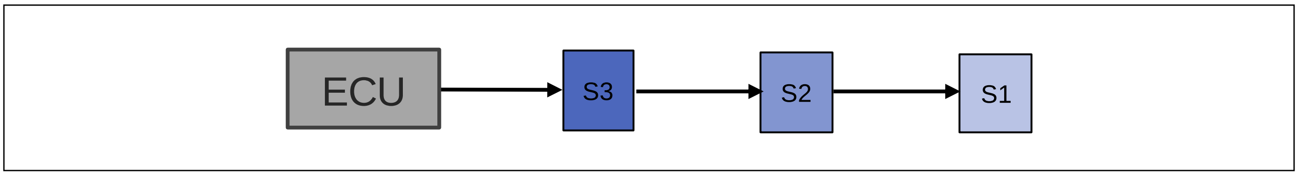


Figure 7: Bus configuration for operation mode #2

Bus timing for daisy chain mode #2 :

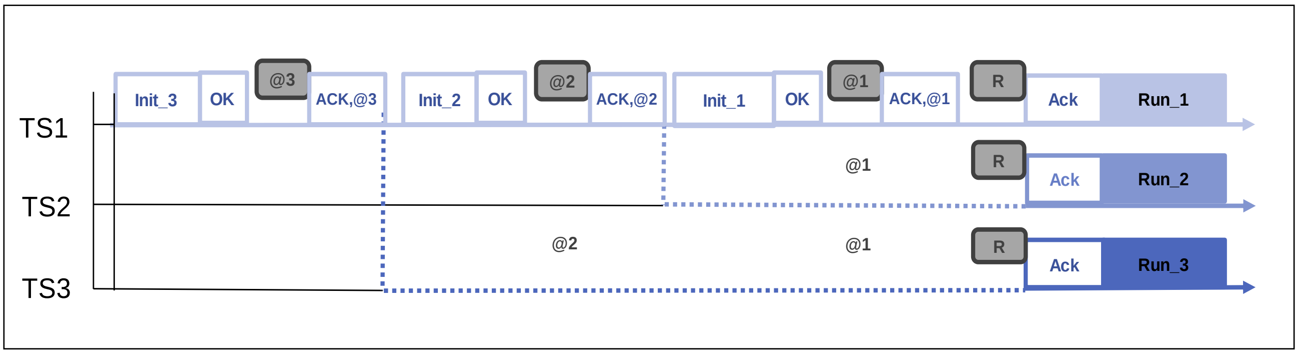


Figure 8: Bus timing for operation mode #2

6.3.1.3 *Recommendations for Daisy-Chain application*

- Daisy-Chain mode #1 (Section 8.1) is the preferred PSI5 solution and is recommended for all future circuit designs. It has some significant advantages like a shorter overall initialization duration and the possibility to assess the quality of the communication channel in the assigned slot over the whole initialization sequence (i.e. increased safety for airbag system).
- Daisy-Chain mode #2 (Section 8.2) is included here because it has already been designed into several PSI5 sensors and might therefore be used as well in some applications.

Any further operation mode should - in principle - be avoided in order to avoid unnecessary diversity.

7 Interoperability Requirements

See chapter 7 of PSI-5 V2.3 Base Standard.

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8 Document History & Modifications

Rev.N°	Chapter	Description / Changes	Date
2.0	all	First Release of Airbag Substandard; Revision Number of corresponding PSI5 Base Standard adopted	01.06.2011
2.1	2	Add Daisy Chain modes in table of section 2 (Recommended operation modes) Add chapter 2.1, on guidelines for implementation of daisy chain operation modes	22.08.2012
2.1	1	Editorial Changes	11.09.2012
	3	Single decimal codes in table 1 corrected	
	5.1	new	
	6.3	new	
2.1	2.1	Add switch closure time (1st sync pulse after address setting) switch closure through dedicated bi-directional instruction => optional	18.09.2012
2.1	all	Some minor changes : add captions for figures and tables	02.10.2012
	3.1	Signal amplitude “0” => If symmetrical sensor scale	
	2	A8P mode has been deleted from table 1 . PSI5 covers only 10bit+ data sizes	
	3.1	Removed : Signal amplitude “0” for 0x0000 value in table 2	
	5.1	Add note for clarification of the list of messages from sensor to ECU : ACK & OK not specific to daisy chain mode	
	5.2	Changed ‘ver 2.0’ to ‘ver 2.x’ in footnote of table 3, as note is applicable for all upcoming versions	
	6	Add footnote to table 6 for clarification of sensor reset behavior when micro-cuts are applied	
	6.1	Add increased voltage mode for daisy chain applications : V_{CE} min = 6.5 V	
	6.4	Add section 6.4 : Data Transmission Parameters Add Sensor clock deviation during data frame : 0.1 % max (Table 7)	
2.2	5.2	Renamed Ch. 5.2 in Sensor start up and Initialization	31.10.2013
	5.2.2	New chapter 5.2.2 Initialization Data Content in Phase III	31.10.2013
	6.2	Sensor Power-on Characteristics added	12.02.2014
	All	Align all sections with Base Standard v2.2 from 10-05-2016	20.06.2016
	Page 1	Update Logos	20.06.2016
	5.1.2	Remove “Mandatory Initialization Data”	20.06.2016
	6.2.1	Add ΔI_{LOW} limits	20.06.2016
	6.2.2	Add a note (Tset2 not allowed)	20.06.2016

	6.4	Add a note to explain the 0.1%	20.06.2016
	5.1.1	Note 1: Remove “in all direction”	13.07.2016
2.3	1st page	Update logo	29-11-2017
	all	All chapters structured similar to PSI5 base standard v2.3	29-11-2017
	1	Refer to base std v2.3	29-11-2017
	3.1	Add description of data frame recommended in airbag applications	29-11-2017
	4.5	Add to clarify usage of sensor clock drfit during message	29-11-2017
	4.7	Clarify usage of standard and extended voltage mode	29-11-2017