Application Note

NOVOSENSE

LIN Interface Description Based on NSC9262

AN-12-0028

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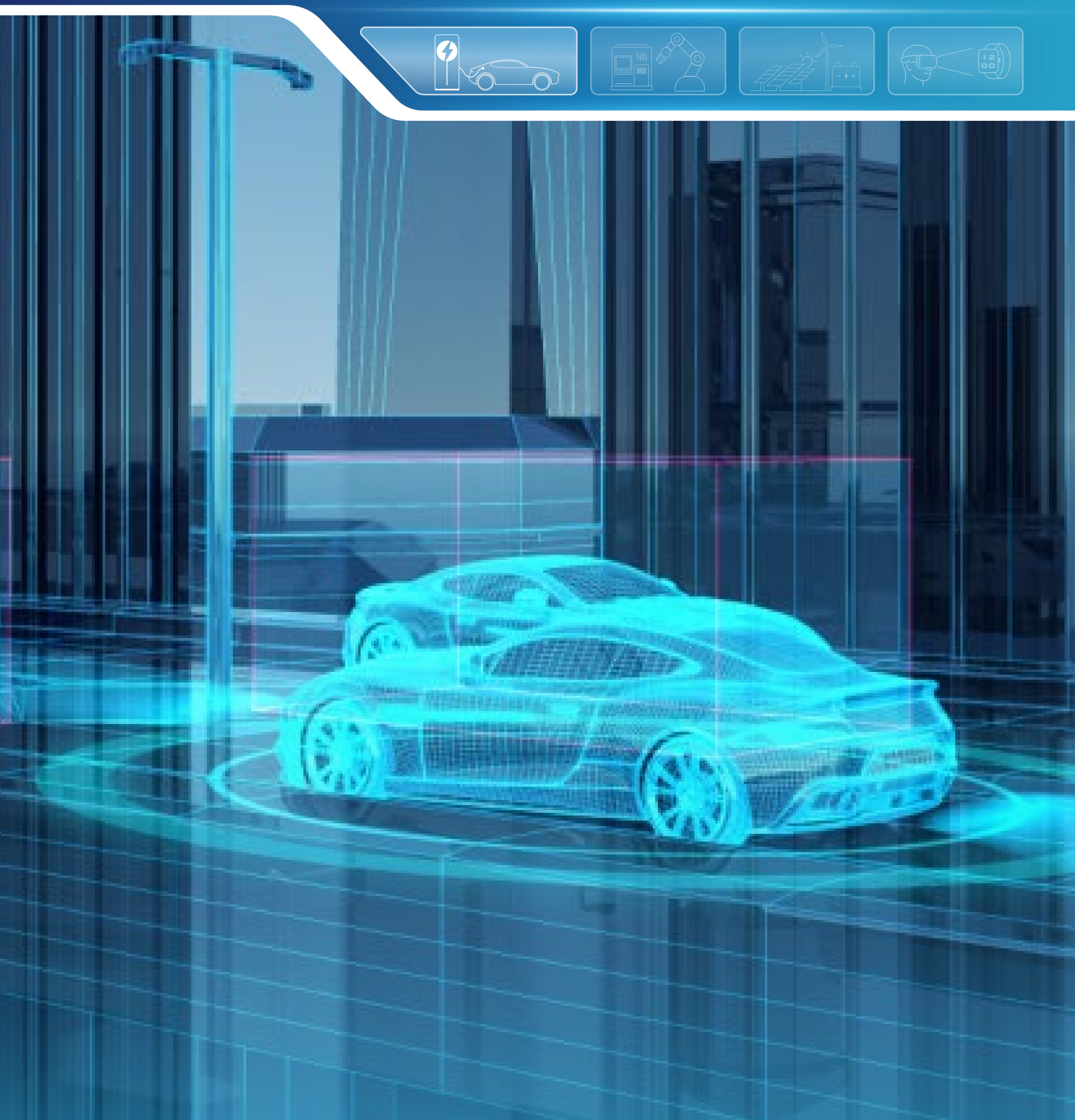

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ABSTRACT

The NSC9262 is a highly integrated and AEC Q100 qualified ASIC for capacitive sensor conditioning with LIN output.
This document serves as a supplementary instruction to the LIN interface.

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1.LIN Interface Overview

The NSC9262 includes a serial digital LIN interface. During normal operation, it provides the read-out of the conditioned sensor signals, including primary signal measurement and the temperature measurement.
The LIN interface implemented in the NSC9262 is based on the LIN Specification Package 2.2A (2010-12-31), Package 2.1 (2006-11-24) and Package 2.0 (2003-09-16). For compatibility reasons, it includes a mode based on LIN Specification Package 1.3 (2002-12-13).
The NSC9262 always works as a LIN slave node.
The LIN interface is conceptually divided into two main parts: the LIN protocol control and the LIN physical transceiver.
The NSC9262 LIN interface supports the following features:

- Single-wire LIN transceiver
- Compatibility with LIN Specification Package 1.3/2.0/2.1/2.2
- Bit rates: 1kbit/s up to 20kbit/s
- Re-configurability
- Transport layer and diagnostic support
- Sleep mode support
- Test mode with pin multiplexing for transceiver conformance test
- Protection against short circuits on the supply and ground
- LIN PIN load dump protection(40V)
- LIN PIN ESD protection

Figure 1.1 shows LIN interface diagram.

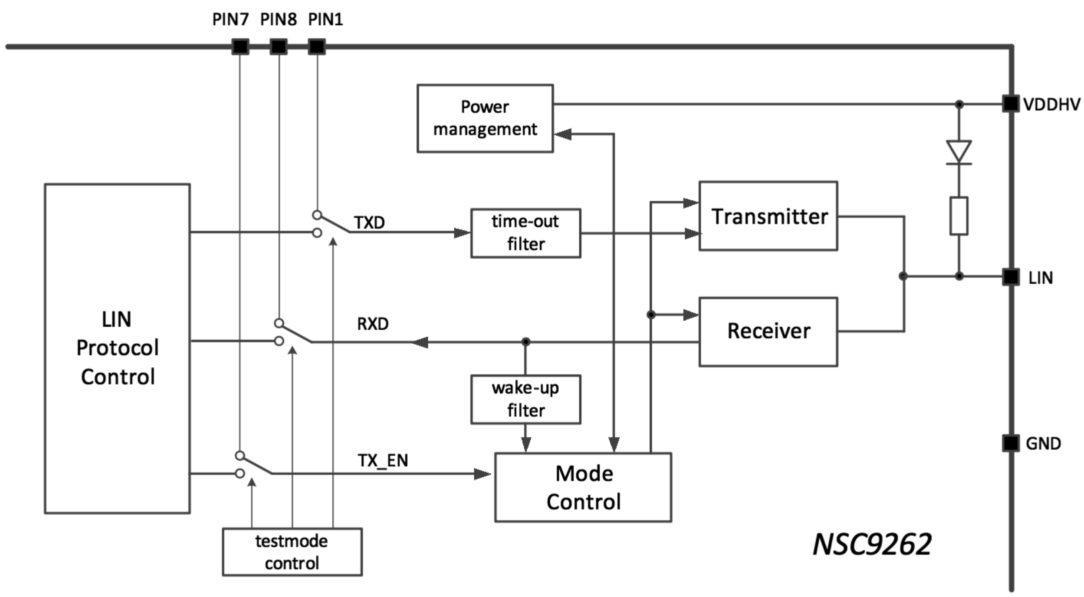

Figure 1.1 Example encoding scheme for two 12 bit signals

Table 1.1 Pin Description

PIN	Symbol	Description
1	RXD	receive data signal to protocol control (can be routed to NSC9262 PIN8)
2	TX_EN	transceiver mode control signal from protocol control TXD mode = high, RXD mode = low (can be routed to NSC9262 PIN7)
3	TXD	transmit data signal from protocol control (can be routed to NSC9262 PIN1)
4	GND	ground
5	LIN	single wire bus input/output
6	VDDHV	supply voltage

2.Characteristics

Table 2.1 Absolute Maximum Ratings

Parameters	Symbol	Min	Typ	Max	Unit	Comments
Supply voltage2	VDDHV	-0.5		40	V	
Withstand voltage to ground (LIN)	VLIN	-40		40	V	
ESD susceptibility	HBM	±1.5			kV	According to AEC-Q100-002 RevE
	CDM	±500			V	
Storage temperature		-60		150	℃	
Operation temperature	TBA_EXT	-40		150	℃	Normal temperature range

Table 2.2 Electrical Characteristics

Parameters Supply and Regulation	Symbol	Min	Typ	Max	Unit	Comments
Supply voltage Range	VDDHV	7	12	18	V	
Operation Current	I_{avdd}		1.9		mA	
Standby Currenti	I_{sleep}		95		μA	25℃
LIN Interface						

Input Low Level Voltage Receiver	V_{RECL}			0.4	VDDHV	
Input High Level Voltage Receiver	V_{RECH}	0.6			VDDHV	
Input Hysteresis Receiver	V_{RECHYS}	0.08		0.12	VDDHV	$V_{RECHYS} = V_{RECH} - V_{RECL}$
Input Center Point Receiver	V_{BUS_CNT}	0.475	0.5	0.525	VDDHV	$V_{BUS\_CNT} = (V_{RECH} + V_{RECL})/2$
Output Low Level Voltage Transmitter	V_{LINL}	0.6	1.2	2.0	V	
Output High Level Voltage Transmitter	V_{LINH}	0.9		1	VDDHV	
Pull Up resistance VDDHV to LIN	R_{LINPU}	20	30	47	Kohm	in series with diode to VDDHV
Output Capacitance LIN	C_{LIN_OUT}			250	pF	
Output Current Limitation LIN Output Driver	I_{LIM}	40	90	200	mA	Sink, driver on, V_{LIN} = VDDHV
Input Current LIN Dominant	$I_{LINPASdom}$	-1			mA	V = 0V, VDDHV = 12V Driver off
Input Current LIN Recessive	$I_{LINPASrec}$		3	20	µA	$V_{LIN} \geq$ VDDHV 7V ≤ V_{LIN} ≤18V 7V ≤ VDDHV ≤18V Driver off
Input Current LIN Lost GND	I_{LIN_NOGND}	-1		1	mA	0V ≤V_{LIN}≤18V VDDHV = 12V Lost GND
Input Current LIN Lost Supply				20	µA	0V ≤V_{LIN}≤18V VDDHV = 0V
Voltage Drop over Pull Up Diode	$V_{SerDiode}$	0.4	0.7	1	V	
TXD Timeout	$t_{TXDTIMEOUT}$	10	19	30	ms	
Slew Rate (Rising and Falling Edges)	SR_{LIN}	0.5	1.3	3	V/µs	Refer to Figure 2.1
Propagation Delay Receiver: LIN low -> RXD low	$t_{RXDLINL}$	2	4	6	µs	Refer to Figure 2.2
Propagation Delay Receiver:LIN high-> RXD high	$t_{RXDLINH}$	2	4	6	µs	Refer to Figure 2.2
Symmetry of Receiver Propagation Delay	$t_{RXDLINSYM}$	-2		2	µs	$t_{RXDLINH} - t_{RXDLINL}$
Symmetry of Transmitter Propagation Delay	$t_{TXDLINSYM}$	-2		2	µs	$t_{TXDLINL} - t_{TXDLINH}$

The following table (Table 2.3) specifies the timing parameters for proper operation at 20kbit/s or 10.4kbit/s. Bus load conditions at LIN are: (C_{BUS} = 1nF; R_{BUS} = 1kohm) or (C_{BUS} = 6.8nF; R_{BUS} = 660ohm) or (C_{BUS} = 10nF; R_{BUS} = 500ohm).

Table 2.3 LIN Bus Output Driver

Parameters	Symbol	Min	Typ	Max	Unit	Comments
LIN bus speed 20kbit/s Duty Cycle 1	D1	0.396				$TH_{Rec(max)}$=0.744*VDDHV; $TH_{Dom(max)}$=0.581*VDDHV; VDDHV=7.0…18V; t_{Bit}=50μs; D1= $t_{Bus\_rec(min)}$ /(2 * t_{Bit}); Refer to Figure 2.3
LIN bus speed 20kbit/s Duty Cycle 2	D2			0.581		$TH_{Rec(min)}$=0.422*VDDHV; $TH_{Dom(min)}$=0.284*VDDHV; VDDHV=7.6…18V; t_{Bit}=50μs; D2= $t_{Bus\_rec(max)}$ /(2 * t_{Bit}); Refer to Figure 2.3
LIN bus speed 10.4kbit/s Duty Cycle 3	D3	0.417				$TH_{Rec(max)}$=0.778*VDDHV; $TH_{Dom(max)}$=0.616*VDDHV; VDDHV=7.0…18V; t_{Bit}=96μs; D3= $t_{Bus\_rec(min)}$ /(2 * t_{Bit}); Refer to Figure 2.3
LIN bus speed 10.4kbit/s Duty Cycle 4	D4			0.590		$TH_{Rec(min)}$=0.389*VDDHV; $TH_{Dom(min)}$=0.251*VDDHV; VDDHV=7.6…18V; t_{Bit}=96μs; D4= $t_{Bus\_rec(max)}$ /(2 * t_{Bit}); Refer to Figure 2.3

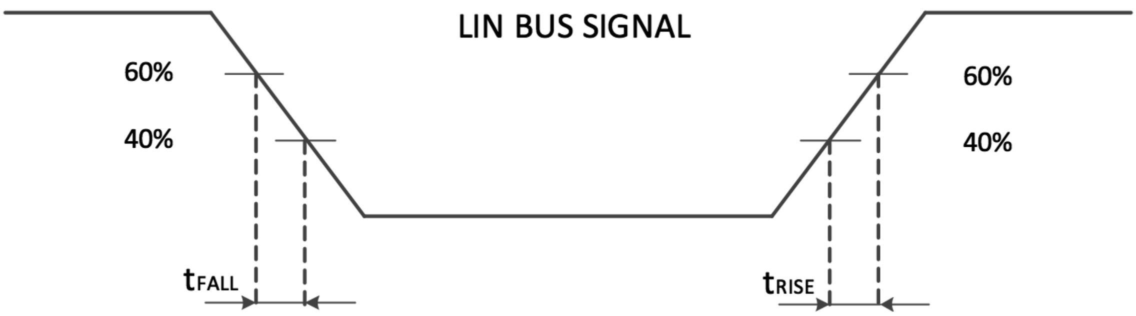

Figure 2.1 t_{FALL} and t_{RISE}

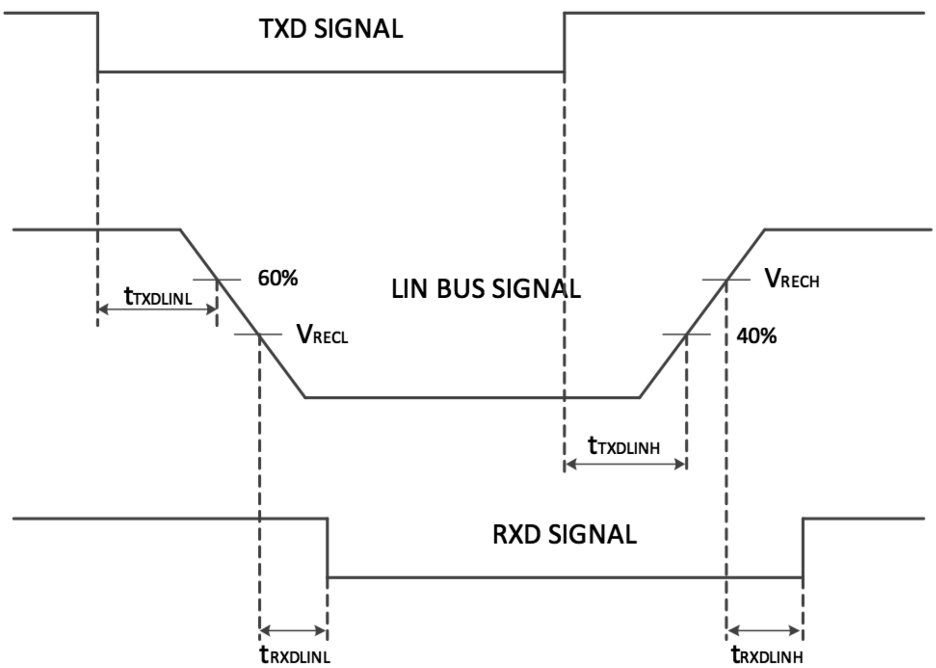

Figure 2.2 $t_{TXDLINSYM}$ and $t_{RXDLINSYM}$

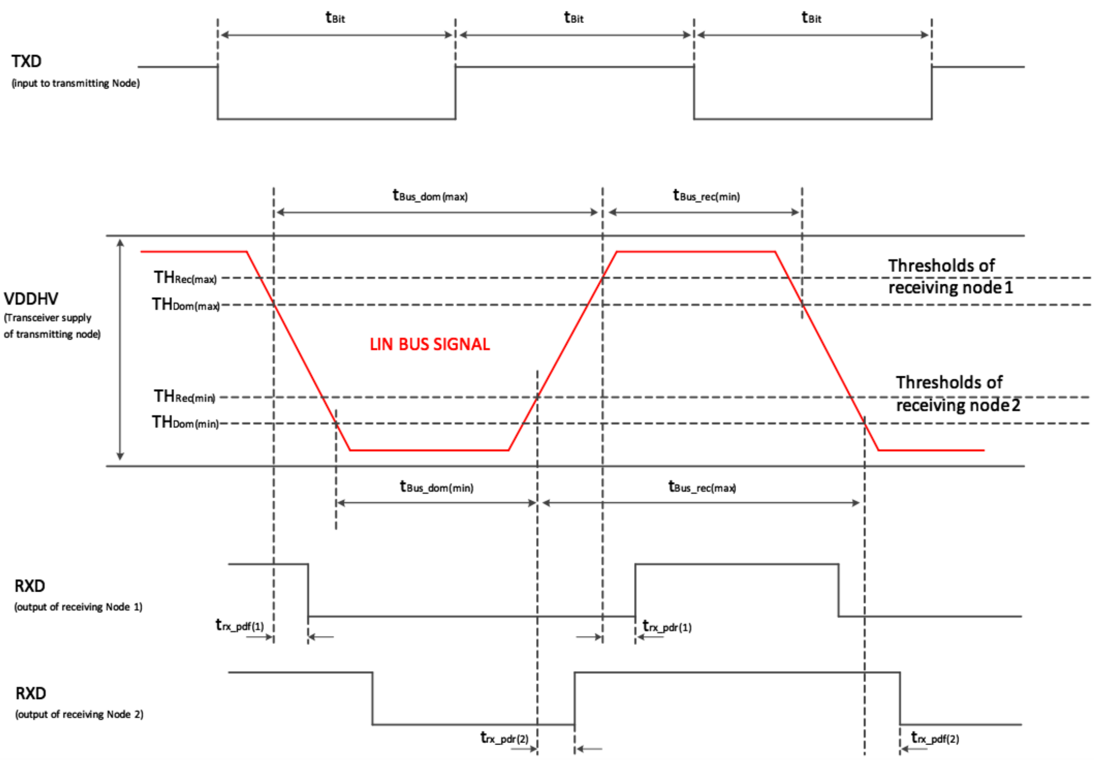

Figure 2.3 LIN Bus Output Driver Characteristics

NSC9262 provides full protection in case of reverse polarity, short circuit and Over-voltage. The specific behavior is shown in Table 2.4.

Table 2.4 Behavior in case of reverse polarity, short circuit and Over-voltage

Condition	NSC9262 Behavior	NSC9262 Function
0V<GND=40V, LIN = GND, VDD = 0V	No AVDD and DVDD supply	No output signal
0V<GND=40V, LIN = 0V, VDD = 0V	LIN driver in high-impedance state	No output signal
GND=0V, LIN = 0V, 3.6V < VDD ≤ 40V	No current flow through the LIN driver	No output signal
GND = 0V, LIN = VDD, 3.6V < VDD ≤ 40V	Activation of a LIN transmission isn't possible	No output signal
GND = 0V, LIN = VDD, 0V < VDD ≤ 3.6V	LIN driver in high-impedance state	NSC9262 in reset condition
GND = 0V, LIN = 0V, 0V < VDD ≤ 3.6V	LIN driver in high-impedance state	NSC9262 in reset condition
GND = VDD, LIN = 0V, 0V < VDD ≤ 40V	Activation of a LIN transmission isn't possible. LIN driver in high-impedance state	No output signal
GND = VDD, LIN = VDD, 0V < VDD ≤ 40V	No AVDD and DVDD supply	No output signal
GND = 0V, 0V < LIN ≤ 40V, VDD = 0V	LIN driver in high-impedance state	No output signal

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3.LIN Protocol

3.1.Frame

The entities that are transferred on the LIN bus are referred to as frames. The NSC9262 always provides the response to the header as the publisher. As shown in Figure 3.1, The NSC9262 publisher frame consists of a break field, a sync byte field, a protected identifier, 4 data bytes and a checksum. This results in a publisher frame with a nominal length of 84 bit-times (t_{Bit}). The break field, sync byte field, and protected identifier are also called the header. The data bytes and checksum are called the response.

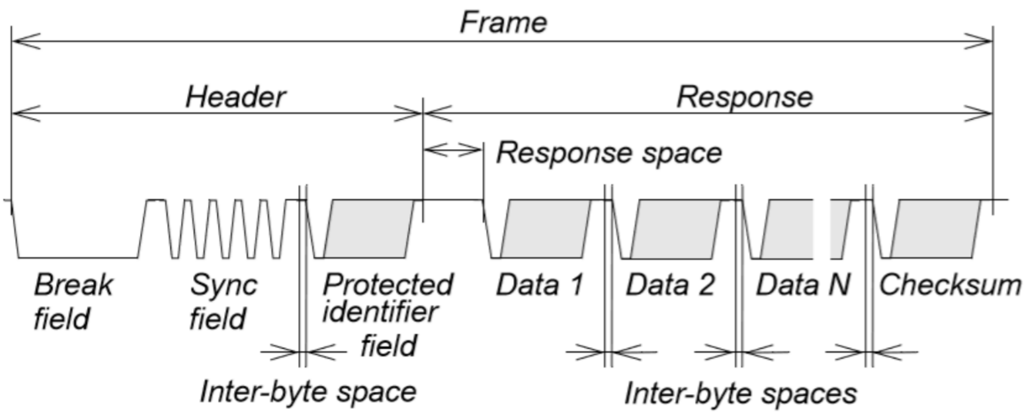

Figure 3.1 Frame Structure (N = 4)

3.2.Bit Rate and Synchronization

The supported LIN bit rate is specified in the range of 1kbit/s to 20kbit/s. The full range adjustable communication bit rate is implemented by the sync byte field of every LIN frame. Synchronization between the slave node and the master node helps the slave one calculate the bit time with accuracy. Based on the accurate bit time, the NSC9262 can capture the protected identifier and trigger each byte of sending data.

3.3.Bit Sampling

A byte field is synchronized at the falling edge of the start bit. There are two possible bit sampling modes, selected via OUTPUT_CONFIG: LIN_sample_point in register map. A bit is evaluated either with 3 samples or with 5 samples within a window between 7/16 and 10/16 of bit time. The default sampling mode is 3 samples per bit. The bit data is determined by the bit sample majority.

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3.4.Protected Identifier (PID)

The protected identifier byte field consists of an identifier (6LSB) and parity bits (2MSB). Different PIDs correspond to different publisher frame. When the PID programmed in EEPROM with 8 bits matches the one captured from LIN bus, NSC9262 starts to transmit 4 data byte fields carrying the primary measurement signal, temperature result values and status information.

NSC9262 owns one unique publisher frame during normal operation and the related PID is PID1<7:0> (0xd7) in register map. The value of PID1 can be modified during normal operation by transport layer communication using reserved 60 (PID 3C) and 61 (PID 7D). On the other hand, PID2<7:0> (0xd8) can only be reserved for internal use with no access to publisher frame.

3.5.Checksum

The checksum is calculated including all data bytes (classic checksum) or including all data bytes and the protected identifier (enhanced checksum). The classic checksum is used for publisher frames according to LIN 1.3 and for transport layer frames. The enhanced checksum is used for publisher frames according to LIN 2.0/2.1/2.2. The checksum type is selected via OUTPUT_CONFIG: LIN_VERSION<1:0> in register map.

Commands received via master request frame are only further processed if a valid checksum is detected.

4.LIN Publisher Frame

There are two kinds of signal formats for publisher frames according to PID1, respectively corresponding to LIN 1.3 and LIN 2.X. The pressure data and temperature data are organized as LSB first as shown in Table 4.1. At most 4-bits status information can be carried in signal data frame. Please refer to the chapter of Diagnostic Status Information for details.

Only 1-bit of Response Error is used for status management of LIN 2.X communication, and the unused bits are reserved as 1's; 1-bit of Checksum Error and 1-bit of Bit Error are used for status management of LIN 1.3 communication.

Table 4.1 PID1 publisher frame

	BIT0 **LSB**			**BIT31** **MSB**	
LIN version	**Data Byte 0**	**Data Byte 1**	**Data Byte 2**	**Data Byte 3**	**Checksum**
LIN1.3	Pressure LSB (11-bit) MSB	Temperature LSB (9-bit) MSB		ID & Information	Classic
LIN2.X (X=0/1/2)	Pressure LSB (11-bit) MSB	Temperature LSB (9-bit) MSB		ID & Information	Enhanced
	RESPONSE				

Pressure Error	Temp Error	Checksum Error	Bit Error	Response Error	Unused Bit

The content of ID & Information for data byte 3 is stored in SPARE4<7:0> (0xd6) in register map, such as Software/Hardware Version, Product ID and so on. For the last checksum byte, the enhanced type is targeted for LIN 2.X and the classic type is targeted for LIN 1.3 as mentioned above.

5.Diagnostic Status Information

Table 5.1 summaries all the status information bits and the relevant diagnostic items. Any of the below error detections has indicated a failure. The failure is annunciated through the status bits in the signal data for alarming.

Table 5.1 Description of Status Information

	VW LIN 1.3 Signal Frame						VW LIN 2.X Signal Frame					
No	Pressure Signal	Temperature Signal	Pressure Error	Temp Error	Checksum Error	Bit Error	Pressure Signal	Temperature Signal	Pressure Error	Response Error	Fault	Description
1	0 - 2045	0 - 509	1	1	0	0	0 - 2045	0 - 509	1	0	Voltage Check	Check Vref
2	0 - 2045	0 - 509	1	1	0	0	0 - 2045	0 - 509	1	0	POR	Power on Reset occurred
3	0 - 2045	0 - 509	1	1	0	0	0 - 2045	0 - 509	1	0	Over Voltage	VDDHV over 35 volts detected
4	0 - 2045	0 - 509	1	0	0	0	0 - 2045	0 - 509	1	0	Connection Check	CINP open or short detected
5	0 or 2045	0 - 509	1	0	0	0	0 or 2045	0 - 509	1	0	AFE	AFE out of range failure (clamped to 0 or 2045)
6	0 - 2045	0 - 509	1	0	0	0	0 - 2045	0 - 509	1	0	Leakage	Leakage current detected at CINP node
7	0 - 2045	511	0	1	0	0	0 - 2045	511	0	0	Tinternal	ASIC Temperature Limit exceeded
8	0-2045	0-509	1	0	0	0	0-2045	0-509	1	0	Thermal ShutDown	Thermal Shutdown occurred. Note: during thermal shutdown no communications occur

9	0 - 2045	0 - 509	1	1	0	0	0 - 2045	0 - 509	1	0	EEPROM	EEPROM failure detected
10	0 - 2045	0 - 509	1	1	0	0	0 - 2045	0 - 509	1	0	ROM	ROM failure detected
11	0 - 2045	0 - 509	1	1	0	0	0 - 2045	0 - 509	1	0	Watchdog	Watchdog timed out, software reset
12	0 - 2045	511	0	1	0	0	0 - 2045	511	0	0	Thermistor	Thermistor pin open or short detected
13	2045	0 - 509	0	0	0	0	2045	0 - 509	0	0	Pressure	Pressure out of range
14	0 - 2045	511	0	1	0	0	0 - 2045	511	0	0	Temp	Temperature out of range (high or low)
15	2046	510	0	0	0	0	2046	510	0	0	Initialize	Device is still initializing after power on or wake up or thermal shutdown
16	N/A	N/A	N/A	N/A	N/A	N/A	0 - 2045	0 - 509	0	1	Lin response error	checksum error OR framing error OR readback error
17	0 - 2045	0 - 509	0	0	1	0	N/A	N/A	N/A	N/A	Checksum error	Checksum error: The DS_ChecksumError bit will be sent in the next VW signal frame after the error is detected
18	0 - 2045	0 - 509	0	0	0	1	N/A	N/A	N/A	N/A	Bit error	Readback error/ Bit error: The DS_BitError bit will be sent in the next VW signal frame after the error is detected

6.LIN Transport Layer

LIN transport layer is used for diagnostic and for configuration of the NSC9262. The NSC9262 supports Diagnostic Class I according to the LIN Specification Package 2.2A.

The transport layer messages issued by a master are called master requests and use the ID 60 (PID 3C). Messages issued by the slave are called slave requests and use the ID 61 (PID 7D).

The NSC9262 transport layer supports only single frames containing the node address byte (NAD); protocol control information byte (PCI); service identifier byte (SID) or response service identifier byte (RSID); 5 additional data bytes; and classical checksum byte. Unused bytes must be filled with 0xFF.

The service identifier (SID) specifies the request that shall be performed by the slave node addressed. The following Table 6.1 shows what SIDs are supported in the NSC9262.

Table 6.1 Supported node configuration and identification services

SID	Service	Reference	Comments
0xB0	Assign NAD	LIN 2.2A Specification	
0xB1	Assign frame identifier	LIN 2.0 Specification	Service is enabled when LIN mode set to LIN2.0
0xB2	Read by identifier	LIN 2.2A Specification	Support the mandatory items of ID0 and ID1
0xB3	Conditional change NAD	LIN 2.2A Specification	
0xB6	Save configuration	LIN 2.2A Specification	Service can be disabled by configuration register
0xB7	Assign frame identifier range	LIN 2.2A Specification	Only PID1 and internal PID2 can be assigned

7.LIN Operating Modes

There are three modes in NSC9262, normal mode, sleep mode (include dormant phase and pre-process phase), standby mode.

7.1. Normal Mode

In normal mode, LIN bus transmitter is enabled, and all LIN requests can be responded normally. Two conditions can switch the NSC9262 into sleep mode:

- LIN bus is consecutively inactive (recessive or dominant level) for 4s or more.
- 'Go-To-Sleep' request from master is received.

7.2. Sleep Mode

In sleep mode, all the NSC9262 configurations are remained but no LIN requests can be responded, and the capacity measuring is also stop. A wake-up signal is issued by forcing the bus to a dominant state for at least 250μs. NSC9262 detects a dominant state longer than 150μs and then starts the measurement cycles again. NSC9262 is not able to generate the wake-up signal by itself. There are two phases when resuming from sleep mode.

7.2.1. Dormant Phase

In dormant phase, only LIN receiver is active which is used for detecting wake up event. NSC9262 will go to pre-process phase after LIN wake up event detected for more than t_{WAKE} (150μs).

7.2.2.Pre-process Phase

In pre-process phase, LIN module is still in sleep mode. Data processing modules are active, Data processing includes Capacity sampling circuits, A/D convertor etc., these modules are working for the pressure measurement of sensor. The pre-processing is independent of LIN module and does not affect the work of LIN module.
The NSC9262 will exit pre-process phase after the rising edge of LIN bus, and switch to Standby MODE. At the same time, RXD is driven low to inform the control logic.

7.3. Standby Mode

The LIN_EN signal will be set to high after RXD is set to low. And then the NSC9262 will switch to normal mode from standby mode.

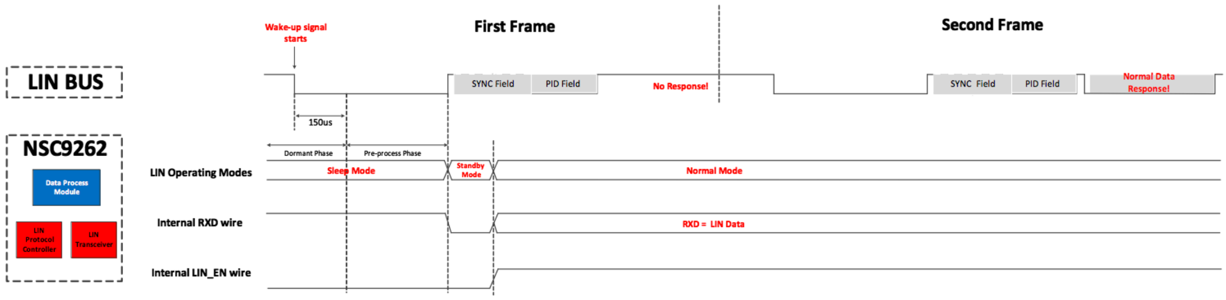

Figure 7.2 LIN Wake Up

8.Revision History

Revision	Description	Author	Date
1.0	Initial version	Feifei Sun	30/8/2023