Application Note

NOVOSENSE

SENT Interface Description Based on NSC9264
AN-12-0039

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ABSTRACT

The NSC9264 is a highly integrated and AEC Q100 qualified ASIC for capacitive sensor conditioning with SENT output.

This document serves as a supplementary instruction to the SENT interface.

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SENT Interface Description Based on NSC9264

1.SENT Interface Overview

The SENT interface is widely used for point-to-point, unidirectional transmission in automotive applications. SENT is short for Single Edge Nibble Transmission. The standard SENT protocol defines the content of the transmitted data by the length of time of adjacent falling edges. The fundamental time unit in transmitter used to construct SENT output signal is defined as a tick.

The encoding scheme consists of a sequence of pulses which is repeatedly sent by the transmitting module. The transmission consists of the following sequence (all times nominal):

- Calibration/Synchronization pulse period 56 clock ticks.
- One 4 bit Status and Serial Communication nibble pulse of 12 to 27 clock ticks.
- A sequence of one up to six 4 bit Data nibble pulses (12 to 27 clock ticks each) representing the values of the signal(s) to be communicated. The number of nibbles will be fixed for each application of the encoding scheme (i.e., throttle position sensors, mass air flow, etc.) but can vary between applications. For example, if two 12 bit values are transmitted, 6 nibbles will be communicated.
- One 4 bit Checksum nibble pulse (defined in 5.2.5) of 12 to 27 clock ticks.
- One optional pause pulse

Figure 1.1 shows an example single message transmission for two 12 bits signals.

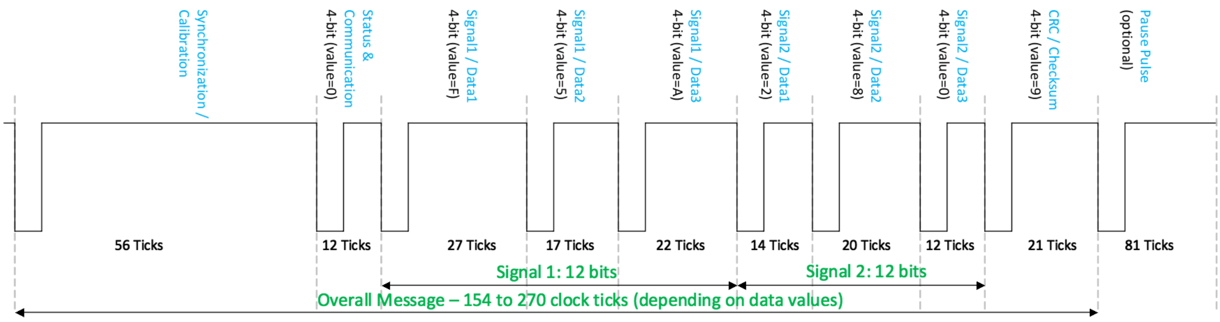

Figure 1.1 Example Encoding Scheme for Two 12 Bit Signals

2.SENT Message Format – Fast Channel

2.1.Pulse Shapes

Figure 2.1 shows the diagram of a calibration and synchronization pulse. The nominal pulse period is 56 clock ticks. The low time is more than 4 clock ticks. All the remaining clock ticks are driven high.

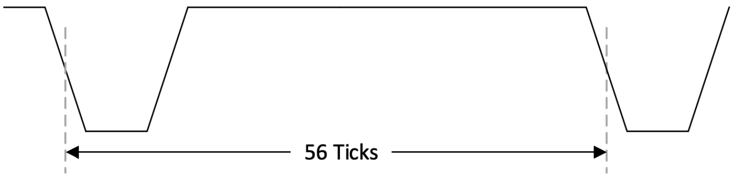

Figure 2.1 Capacitive Sensor Connection Diagram

Figure 2.2 shows an example of two nibble pulses which are defined as data “F” and ”0”. Nominal pulse period is 12~27 clock ticks. The low time is more than 4 clock ticks. All the remaining clock ticks are driven high. The correspondence between the pulse length and the data value is shown in the table 2.1.

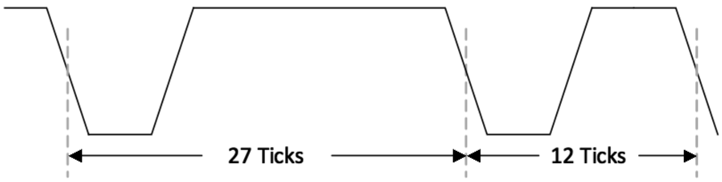

Figure 2.2 Synchronization Pulses

Table 2.1. Values of 4-bit Nibble Pulse

Ticks	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
Hex	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F

2.2.Message Structure

The default SENT frame format of NSC9264 is H.4 which is defined in the SAE J2716-2016 specification.

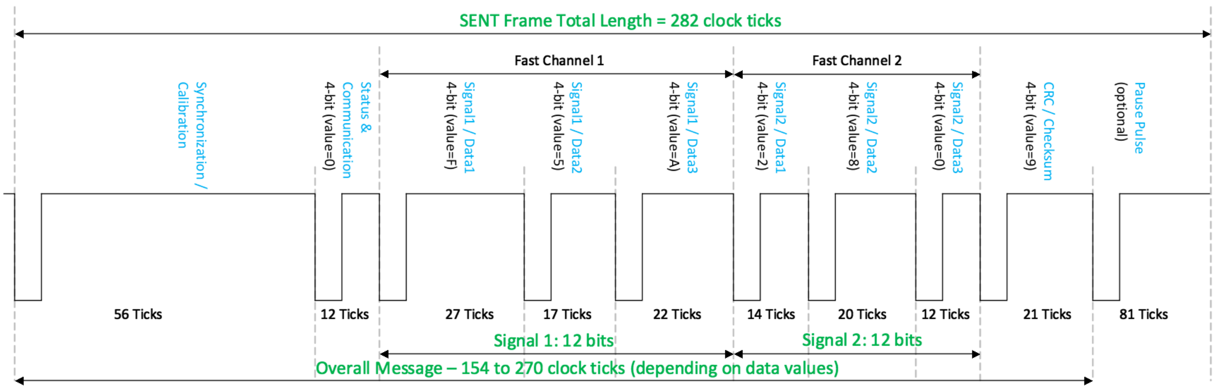

Figure 2.3 Default Frame Format

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As Figure 2.3 shows, the data channels for Pressure Sensor are defined as follows:

Fast Channel 1

Data order

① Data nibble 1: Pressure measurement data MSN

② Data nibble 2: Pressure measurement data MidN

③ Data nibble 3: Pressure measurement data LSN

Fast Channel 2

Data order

① Data nibble 4: Rolling Counter MSN

② Data nibble 5: Rolling Counter LSN

③ Data nibble 6: Inverted Data nibble 1

The checksum nibble is a 4-bit CRC of the data nibbles only. The status and communication nibble is not included in the CRC calculation. The CRC is calculated using polynomial x^4+x^3+x^2+1 with seed value of 4’b0101.

Table 2.2 Component of a SENT Message

Message Part	Pulse	Ticks	Data content
Calibration and synchronization pulses	SYNC pulse	56	Synchronizing pulses as defined above
Status Serial communication	1 Nibble 4 bits	12(=0x0) 27(=0xF)	Bit 0: 0=sensor ok, 1 =fail Bit 1: reserved, default 0 Bit 2: slow serial Ch. See Chapter 2 Bit 3: slow serial Ch. See Chapter 2
Pressure reading	3 Nibble 12 bits	36 (=0x000) 81 (=0xFFF)	Measured value of pressure value.
Rolling Counter	2 Nibble 8 bits	24(=0x00) 54(=0xFF)	Rolling counter 0 to 255 with rollover
Inverted MSN	1 Nibble 4 bits	12(=0x0) 27(=0xF)	Inverted of fast channel data 1
Checksum, CRC	1 Nibble 4 bits	12 (=0x0) 27 (=0xF)	Checksum, 5.4 in SAE J2716
Pause	Pause Pulse	10 130	Pause pulse adds the number of ticks on the constant message length of 282 ticks
Total SENT Message		282	

In addition, NSC9264 supports the other frame formats listed in the table 2.3.

Table 2.3 Fast Channel Frame Format

Setting(0xA2:2-0)	Format	Data 1	Data 2	Data 3	Data 4	Data 5	Data 6
3'b000	H.4 (12bit+Secure Info)	CH1 MSN	CH1 MidN	CH1 LSN	CNT MSN	CNT LSN	INV MSN
3'b001	(12bit+Counter)	CH1 MSN	CH1 MidN	CH1 LSN	CNT MSN	CNT LSN	0
3'b010	H.1 (2*12bit FC)	CH1 MSN	CH1 MidN	CH1 LSN	CH2 MSN	CH2 MidN	CH2 LSN
3'b011	H.5 (12bit+Zero)	CH1 MSN	CH1 MidN	CH1 LSN	0	0	0
3'b100	H.6 (14bit+10bit)	CH1 MSN	CH1 MidMSN	CH1 MidLSN	CH1/CH2 LSN	CH2 MidN	CH2 MSN
3'b101	H.7 (16bit+8bit)	CH1 MSN	CH1 MidMSN	CH1 MidLSN	CH1 LSN	CH2 LSN	CH2 MSN
3'b110	H.2 (1*12bit FC)	CH1 MSN	CH1	CH1 LSN	N/A	N/A	N/A
3'b111	H.3 (High-speed) (1*12bit FC)	Bit 11:9	MidMSN	Bit 5:3	Bit 2:0	N/A	N/A

2.3.Pressure and Temperature

The representation of the physical pressure value in the digital 12-bit data format is according to the SAE J2716 JAN2010. Appendix A.5.3.1.3 / SAE J2716 APR2016. Appendix E.2.4.

This section describes the mapping of pressure data to 12-bit values (numbers). The partition of the address space is defined either with default values Y1, Y2 or with sensor-specific values Y1, Y2 that are transmitted over the optional slow serial channel. The default values Y1 =193, Y2=3896 indicated the beginning and the end of the default pressure range with guaranteed tolerances.

$$P[Pa] = X_1 + \frac{X_2 - X_1}{Y_2 - Y_1}\left(SENTval - Y_1\right)$$

P: physical pressure value.

$SENT_{Val}$: 12-bit unsigned fixed-point integer number (0 - 4095) Fast channel 1.

X_1, X_2: floating-point number (X_i is calculated from $X_i = X_{m,i} * 10^{Xe,i}$[Pa])

Y_1, Y_2: default value (Y_1=193, Y_2 = 3896)

optional: 12-bit unsigned fixed-point integer number (1~4088)

Node-values X1, X2 and Y1, Y2 can be transmitted over the slow channel with specific ID. The pressure indices X1, X2 shall be encoded using a 12-bit data format. The total 12-bit shall be communicated from the sensor to the ECU.
The representation of the pressure indices (in Pascal [Pa]) shall use the following formula

$$Xi[Pa] = \left(X_{m,i} * 10^{X_{e,j}}\right) Pa$$

Mantissa $X_{m,i}$: 9-bit signed
Exponent $X_{e,j}$: 3-bit unsigned

The 12-bit data Xi shall be composed in the following way:

$$Xi = [X_{m,i,8} \cdots X_{m,i,0} X_{e,j,2} \cdots X_{e,j,0}]$$

For example: Xi = [0 0 1 0 1 0 0 0 0 1 0 1] = 0x285 [80 * 105 Pa]

Table 2.4 12-bit representation of the transfer characteristic node value X_i

Data bit	D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0
Encoded pressure value X_i	$X_{m,i,8}$	$X_{m,i,7}$	$X_{m,i,6}$	$X_{m,i,5}$	$X_{m,i,4}$	$X_{m,i,3}$	$X_{m,i,2}$	$X_{m,i,1}$	$X_{m,i,0}$	$X_{j,e,2}$	$X_{j,e,1}$	$X_{j,e,0}$
$X_i = X_{m,i} * 10^{Xe,i}$	Mantissa									Exponent		

This information shall be transmitted through slow channel with specific Message ID.

The pressure sensor should transmit not only pressure signal but also temperature data with specified slow channel. This temperature has a specific characteristic which is also transmitted via SENT slow channel with the characteristic values TX1, TX2, TY1 and TY2. With this characteristic value the transmitted temperature T (12-bit data in Enhanced Serial Message ID23) can be mapped to the SENT standard temperature characteristic (SAE J2716 JAN2010. Appendix A.5.3.2 / SAE J2716 APR2016. Appendix E.2.2.1).
The transfer characteristic nodes (TX1, TY1) and (TX2, TY2) for temperature data shall be translated as follow. It represents the conversion of 12-bit SENT temperature data, Tval into physical temperature values in the unit of [°C].

$$T[℃] = X_1 + \frac{X_2 - X_1}{Y_2 - Y_1}(SENTval - Y_1)$$

X1	Minimum measurement data, 1 (200.125[K], -73.025 [°C])
X2	Maximum measurement data, 4088 (711 [K], 437.85 [°C])
Y1	Minimum SENT data reading, 1.
Y2	Maximum SENT data reading, 4088
$SENT_{VAL}$	SENT reading when the digit is in the address available for temperature signal.
T	Physical temperature value calculated from the measured data.

The above equation can also be simplified as below.

$$T[℃] = (0.125 * SENTval - 73.15)℃$$

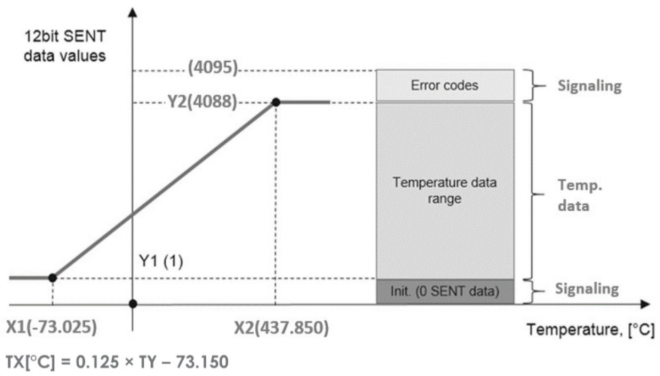

Figure 2.4 Temperature Characteristic Function

3.SENT Message Format – Serial Message Channel

3.1.Serial Message Structure

For the serial message format, the enhanced serial message format is used. Serial data is transmitted in bit #2 and bit #3 of the status and communication nibble. A serial message frame stretches over 18 consecutive SENT data messages from the transmitter as shown in Figure 3.1.

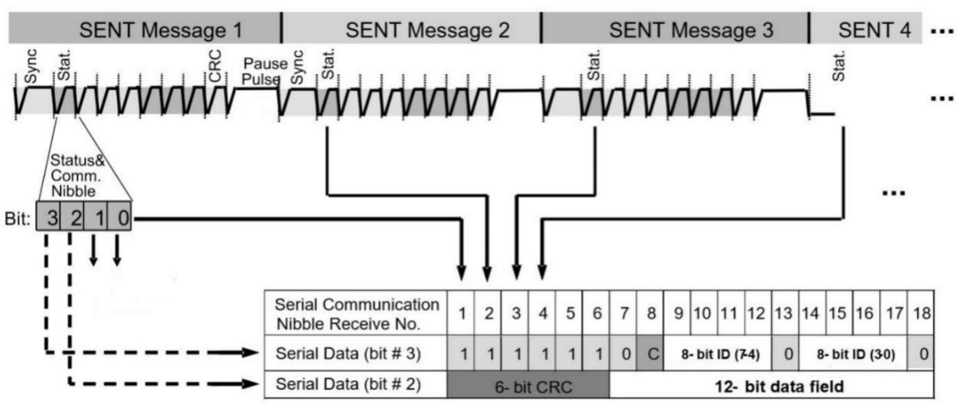

Figure 3.1 Serial Message Structure

- Message-Start: The frame start of a serial message is indicated by the unique pattern "01111110" in bit 3 of the status and communication nibble. The first "1" in a series of six ones (after a "0") indicates the first nibble of a serial message frame.
  Serial data bit #3 of serial communication nibbles 1-6 are set to "1". Serial data bit #3 of serial communication nibble 7, 13 and 18 are set a "0".
- Configuration bit: it should be chosen a "0" in serial data bit #3, serial communication nibble No. 8.
  → 12-bit data and 8-bit message ID (C = "0")
- Message ID bit: the identifier (8bit: ID7 ... ID0) is the location of bit 3 message #9 (MSB) to #12 and #14 to #17.
- Data bit: the data are at the point of bit2 message #7(MSB) to # 18(LSB)
- CRC: the check-sum (6bit: CRC5 ... CRC0) for the full message is at the point of bit 2 message #1 (MSB) to #6(LSB)
- The checksum is a 6-bit CRC of the data only. The CRC is calculated using polynomial $X^6 + X^4 + X^3 + 1$ with seed value of 010101

Serial Communication Nibble Receive No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Serial Data (bit #3)	1	1	1	1	1	1	0	C	8Bit ID(7~4)				0	8Bit ID (3~0)				0
									ID7	ID6	ID5	ID4		ID3	ID2	ID1	ID0	
Serial Data (bit #2)	CRC-6 Bit						12Bit DATA											
	CRC5	CRC4	CRC3	CRC2	CRC1	CRC0	D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0

Read-in order of the 24 message data bits for CRC generation

24-bit message data for CRC generation

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
D11	0	D10	C	D9	ID7	D8	ID6	D7	ID5	D6	ID4	D5	0	D4	ID3	D3	ID2	D2	ID1	D1	ID0	D0	0

25	26	27	28	29	30
0	0	0	0	0	0

Figure 3.2 CRC of Serial Message

3.2.Serial Message Definition

In the standard SAE J2716, the range 0x00 to 0x7F of the message identifier is reserved for the general determination of transmitted values. The range 0x80 – 0xFF is free and can be used application-specific by the OEM or supplier.
The following data/identifiers are sent from the reserved range by the pressure sensor in Table 3.1.
Attention that most of the messages support re-configuration. The NSC9264 owns dedicated communication interface to the NVM inside (e.g. EEPROM). In spite of the default value, most messages can be fully or partly re-configured during communication window. When configuration completed, the communication window will be closed after power-on-reset and standard SENT data flow comes out. Then all the message data will be constant except Status indicator and Temperature.

Table 3.1 Slow-channel Message ID & Value

Message ID (8bit)	Definition	Default Hex Value (12bit)	Comment
0x01	Status Indicator	Refer to “Error Handling”	
0x03	Sensor Type	0x004	
0x04	Configuration-description	0x001	
0x05	Manufacturer Code	0x000	Low 8-bit Configured by Customer
0x06	Protocol standard revision	0x003	
0x07	Fast Channel value X1 of P1 X1 = 100 [kPa]	0x323	Configured by Customer
0x08	Fast Channel value X2 of P1 X2 = 1100 [kPa]	0x374	Configured by Customer
0x09	Fast Channel value Y1 of P1 Y1 = 193 [DEC]	0x0C1	Configured by Customer
0x0A	Fast Channel value Y2 of P1 Y2 = 3896 [DEC]	0xF38	Configured by Customer
0x29	Sensor Serial ID #1	0x000	Configured by Customer
0x2A	Sensor Serial ID #2	0x000	Configured by Customer
0x2B	Sensor Serial ID #3	0x000	Configured by Customer
0x2C	Sensor Serial ID #4	0x000	Configured by Customer
0x90	OEM part number	0x510	
0x91	OEM part number	0x663	
0x92	OEM part number	0x590	
0x93	OEM part number	0x590	
0x94	OEM part number	0x8D0	High 6-bit can be configured.
0x95	OEM part number	0x40E	High 6-bit can be configured. Indicating high 4-bit of version.
0x96	OEM part number	0xD11	Configured by Customer. Low 6-bit indicating low 4-bit of version. High 6-bit indicating high 4-bit of manufactory code.
0x97	OEM part number	0x62E	Configured by Customer. Indicating low 8-bit of manufac-tory code.
0x23	ASIC Internal Temperature	T[11:0]	Temperature data. Refer to chapter 2.3.

Below is the default schedule table. Message ID 0x01 is repeated with every 4th message.

Table 3.2 Schedule table of Slow-channel Message

MSG#	1	2	3	4	5	6	7	8	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
MSG ID	29	2A	2B	01	2C	03	04	01	06	07	01	08	09	0A	01	90	91	92	01	93	94	95	01	96	97	23	01

3.3.Error Handling

The following table lists the diagnostic error codes in descending order of priority (which matters if two different error codes are valid at the same time). When no error occurs, the Message ID01 will be set to 0x000 for Slow Channel transmission.

Table 3.3 Diagnostic Function and Sensor Error Transmission

Error Code					Remark
12-bit Data Value Fast Channel	Slow Channel		Priority	Type	
	ID	Code			
1 - 4088	0x01	0x000	0	NA	No error
1 - 4088	0x01	0x900	1 (Highest)	TEC*	Supply Voltage Under-voltage, VDDHV < 4V
1 - 4088	0x01	0x901	2	TEC	Supply Voltage Over-voltage, VDDHV > 6V When over-voltage happens, the output driver of SENT interface is off until the supply recovers
4090	0x01	0x003	3	PEC*	Initialization Error, includes EEPROM CRC Check Error, EEPROM Loading Error, ROM Check Error and Watchdog Timeout Error
4090	0x01	0xA00	4	PEC	Sensor Connection Check Fail, includes capacitor input pin open and leakage current detected at capacitor input pin
1 - 4088	0x01	0xA01	5	TEC	Thermal Shutdown. When ASIC internal temperature higher than 180°C, the output driver of SENT interface is off until the temperature recovers
4090	0x01	0xA02	6	PEC	AFE raw data out of range
1 or 4088	0x01	0xA03	7	TEC	Pressure data out of range(Related to Clamp)

*Note: TEC means temporary error code; PEC means permanent error code

Attention that all the above sensor errors are considered as Sensor Failure Status. So any of the errors occurring affects the “Status Serial communication” Message Part in Table 2.2. The bit-0 will be set to “1” indicating the sensor is not ok and the irrelevant bit-1 keeps “0”.

4.Revision History

Revision	Description	Author	Date
1.0	Initial Version		15/3/2024

IMPORTANT NOTICE