

# Analysis of a SENT (Single Edge Nibble Transmission) Signal using an oscilloscope

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## Introduction

SENT is a recently developed serial protocol used for sensors in the automotive industry. SENT exhibits several advantages over older serial links. The sensors have a high resolution, are very reliable, immune to Electro Magnetic Perturbations and cost effective. This document explains how to use an oscilloscope to examine several aspects of the SENT bus.

The advantage of using the oscilloscope resides in the fact that the instrument shows the physical transmission layers, the digital encoding, as well as the interpretation of the data embedded in the serial data all at the same time.

In its first section this article explains the SENT protocol using images created with a LeCroy oscilloscope and it's SENT decoder. In its second part, the focus is on monitoring the fast channels used for measuring Pressure and Temperature of the sensor, in this case the MLX90809 built by Melexis.

## The SENT specification

SENT is formally specified by the Society of Automotive Engineers (SAE) under the denomination of J2716 JAN2010. The current specification is available through [www.sae.org](http://www.sae.org) and describes the inner workings of the Fast and Slow channels in detail, with various examples of applications with different parameters.

## SENT Hardware used

In the configuration used for this document, the Melexis 90809 Sensor measures relative Pressure as well as Temperature ([www.melexis.com](http://www.melexis.com)), both with a 12 bit resolution. Other configurations of the same sensor can transmit Pressure and its inverse, or Pressure and a running counter. It is a fully integrated IC, comprising MEMS, analog front end circuitry, 16 bit microcontroller, analog back end circuitry and voltage regulators.

The pressure sensing element consists of a square diaphragm realized in the silicon chip by backside etching. The diaphragm reacts to a pressure difference between its top and bottom with an internal strain increase, in particular at its border. The piezo-resistive elements have been implanted into the silicon diaphragm, acting as a transducer

This sensor has automotive applications such as vacuum measurement, clogged filter detection, industrial applications such as process monitoring, fluid pressure or Consumer/Home appliance applications like filter monitoring or dispensing/metering systems.

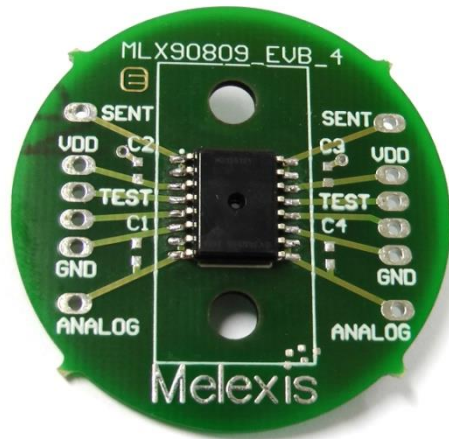


Figure 1: The MLX 90809 on its evaluation board

## The SENT protocol structure

SENT is a point to point protocol, operating between a sensor and an Electronic Control Unit (ECU). The sensor emits data continuously over the link while the ECU receives and processes the data. The following image conveys the overall aspect of a few SENT messages (3  $\mu$ s TickTime), when observed with an oscilloscope. It is hard to believe that the key information resides in pulses length differences of a few millionth of a second emitted by the sensor.

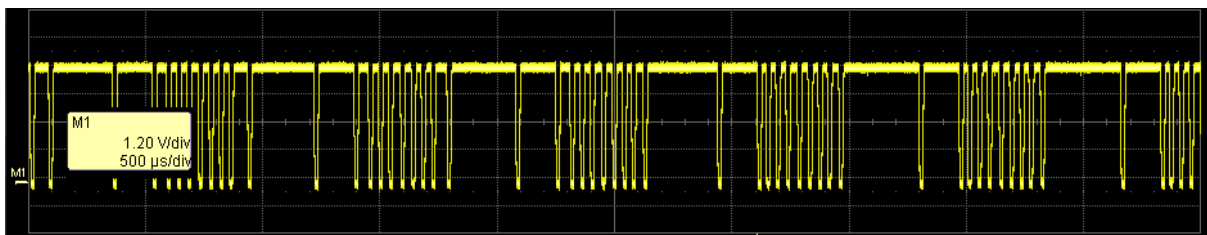


Figure 2: Raw SENT signal observed over 5 milliseconds

When looking closer at the image above, one notices the SENT messages, here 10 negative pulses, separated by a Pause Pulse and started by a SYNC Pulse. (also called CAL Pulse). The information contents of SENT lies in the width of the pulses. Every pulse represents a 4 bit value, called a nibble. This explains the very name of the protocol. A “Single Edge” is needed for the “Nibble Transmission”, assuming a previous edge exists. Philosophically, one could argue that it takes two edges to transmit a nibble, and therefore the protocol should have been called DENT, however, once the first pulse has been emitted, each additional pulse expresses the value of a nibble. Fig 3 below unveils the macro structure of the transmission.

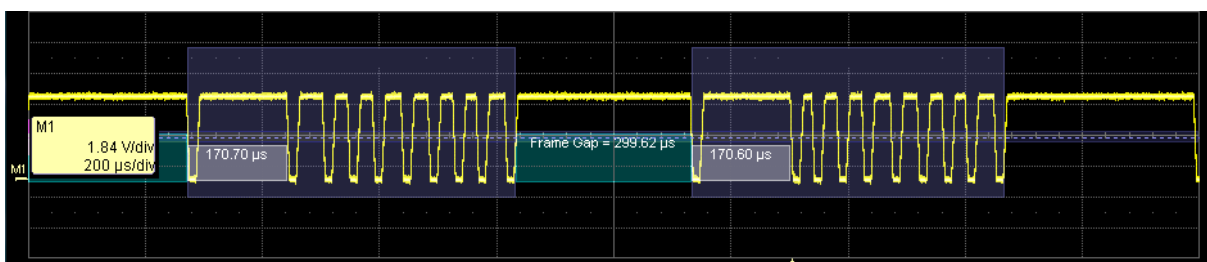


Figure 3: Sequence of messages, started with a SYNC, separated by Pause Pulses

The first key information of a SENT message is the length of the SYNC pulse, annotated in grey in the images. The SYNC always represents 56 Tick Times (TT). The TTs are needed to interpret the subsequent nibbles of the message. In the example shown, a SYNC pulse with a value of 170.70  $\mu\text{s}$  represents 56 TTs and yields a value of 3.0482  $\mu\text{s}$  for the TT. According to the specification, the TT can vary by an amount of 25 % from the nominal value, requiring the receiver to cope with this variability. The TT varies for the same sensor over time, but also varies greatly from one IC to the other.

Once the Tick Time value is known, the decoding of the subsequent nibbles of the message can occur. Fig 4 shows the decoding of one nibble in detail.

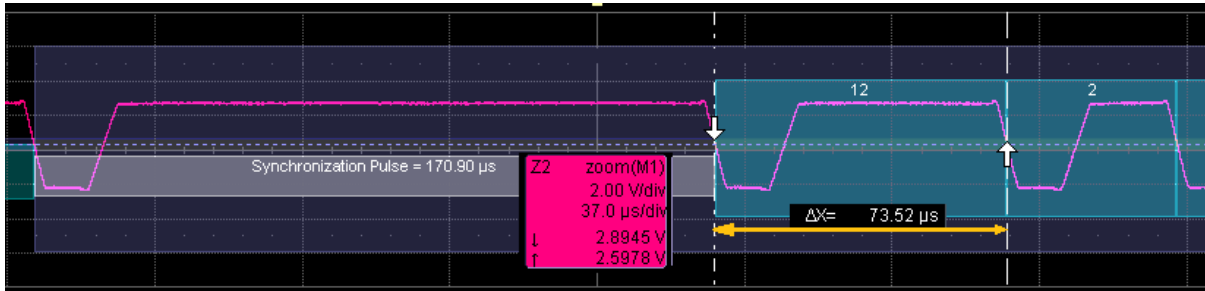


Figure 4: Decoding of First Nibble

Based on the TT of 3.0482  $\mu\text{s}$  determined previously, the first nibble is processed. Its length is 73.52  $\mu\text{s}$ , as measured in the Fig 4 above. This value divided by the TT yields a value of 24.119 Ticks that can be rounded to 24 Ticks. Given the convention that a value of 0 corresponds to 12 Ticks, 12 is subtracted from 24 to obtain the value of 12, also visible above the pulse. The subsequent nibbles of the message are interpreted in the same way. In other words, the difference of pulse width between the nibble with value 5 and the nibble with value 6 would be +3.0482  $\mu\text{s}$ .

Unlike protocols based on NRZ or Manchester encoding, the individual bit values (within a nibble) cannot be associated to a bit time. However, for the sake of readability the SENT annotator decomposes the Status nibble into equally spaced bits.

The last step in decoding the SENT message consists in grouping the nibbles into meaningful values representing temperature and pressure for the MLX 90809.

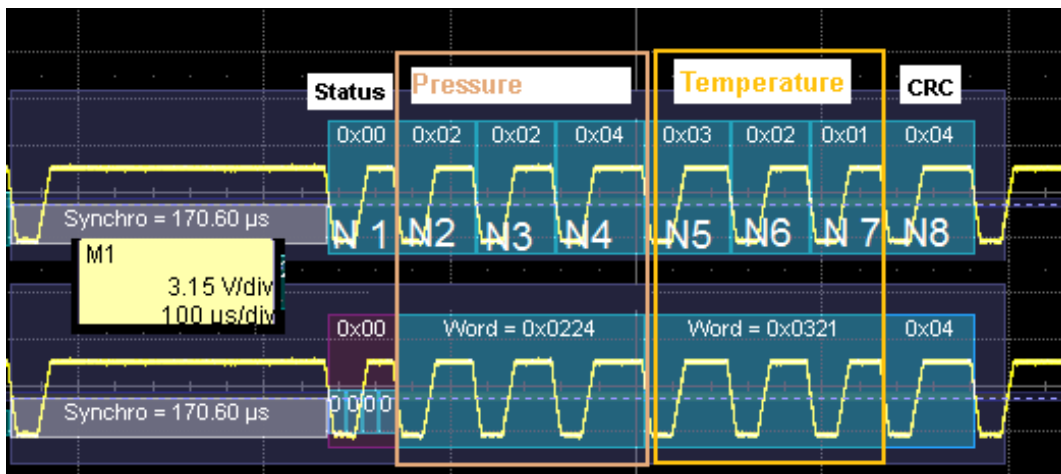


Figure 5: Grouping of Nibbles into raw Pressure and Temperature values.

As shown in Fig 5, nibbles N2-N3-N4 are grouped MSN first into a value of 0x224 representing the raw pressure, and the following 3 nibbles (N5 N6 N7) into a value of 0x321 representing the raw temperature. The first nibble of the message (N 1) is called Status and Communication, while the

last nibble of the message (N 8) represents a 4 bit CRC value warranting the consistency of the data over the previous nibbles (N1 through N7). The number of nibbles used in the transmission varies depending on the sensors and the manufacturers. As more and more SENT sensors appear on the market, more or less nibbles are being used.

## Monitoring Pressure and Temperature Data

The setup required to produce a graph of the pressure is a **3 step processing chain** shown in Fig.6. Each of the components of the chain feeds its results into the next component. The MessageToValue function belongs to the option ProtoBusMag, which can convert results of a decoder into an array of numbers.



Figure 6: 3 Step processing chain of the oscilloscope, from Raw Data on the Channel to the Graph

When the processing is engaged, every acquisition will yield an image of the SENT stream, along with the graph of the pressure (or any other parameter) transmitted in every message. Thanks to the long memories of the oscilloscope, recordings can last seconds. Fig 7 shows a pressure recording over 2 seconds (200 ms/division).

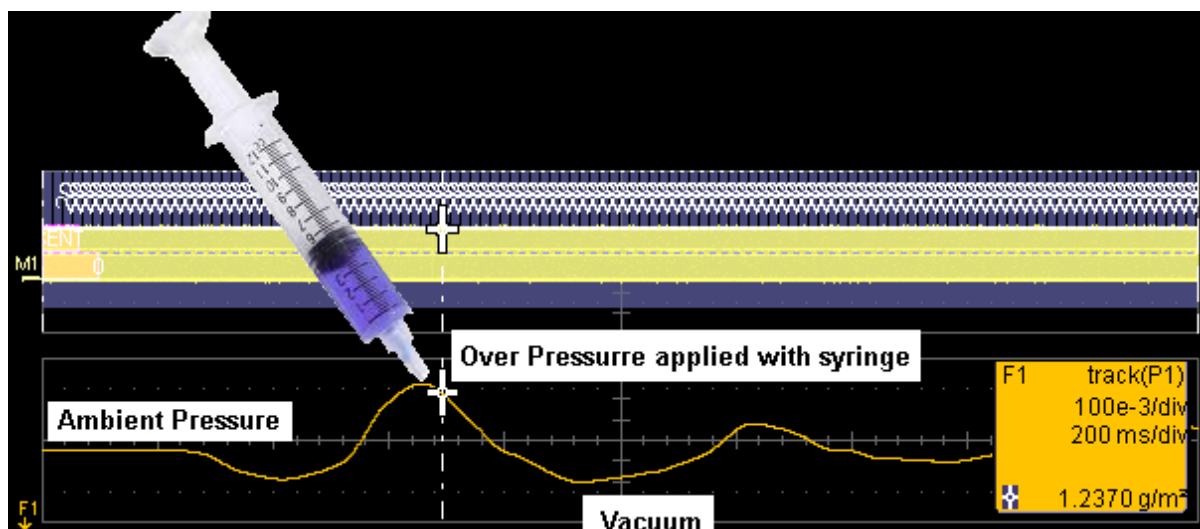


Figure 7: Track of Pressure applied to the sensor over 2 seconds

During the time span of the recording, the relative pressure starts at ambient pressure, and then is changed with the syringe, hence creating cycles of over-pressure and vacuum. The pressure graph can be expressed in raw values, as read out by the decoder or converted to pressure in bars or g/m<sup>2</sup> using a controllable linear conversion in the MessageToValue component.

## Conclusions

Using a modern oscilloscope fitted with a SENT decoder and the Graphing option allows the monitoring of the sensor's output data. The complex signal is decoded, interpreted and graphed easily, in real time. These tools help the sensors designers, as well as users developing sub-systems and integrators, testers, and quality departments, and later for maintenance tasks.

## Thanks

The author thanks Karel Claesen at Melexis, who provided the sensors and associated documentation and explanations. Many thanks as well to Urs Schroffenegger at Teledyne LeCroy for the collaboration, insights and exchanges on the ProtoBusMAG module embedded in the LeCroy oscilloscopes.

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