

PSI5 in Powertrain

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ABSTRACT

Among the currently available sensor interfaces for automotive applications, only the PSI5 interface - as standardized in the new 2001 PSI5 V2.0 - meets the rising system requirements, the increased requirements of the new environmental regulations, and the requirements of current functional safety standards.

PSI5 not only features the capability to transmit highly accurate sensor data, high EMC robustness, bus capability, and bidirectional communication, but also offers savings in the cable harness and a reduced number of connector pins by using just two wires. It therefore offers enhanced technical functionality at a reasonable cost.

To improve the environmental friendliness and sustainable operation of drive concepts, Bosch is also employing sophisticated and cross-linked sensors, actuators and control units. In addition, there is also the need to optimize system functions, weight, construction space and costs.

The new version PSI5 V2.0 is a universal standard for automotive applications from the airbag, chassis and powertrain domains. In particular, the new standard satisfies the specific powertrain requirements: lower supply voltage, fast initialization, new flexible data frame format and protocol. PSI5 fulfills the future requirements for OBD legislation and manipulation detection, improves sensor signal accuracy, and features detailed and reliable error and status indication for diagnostic purposes at the ECU.

In future, the first advantageous application of PSI5 will be realized at the digital rail pressure sensor for Common Rail injection systems and its connected control unit. Further applications with transmission of several sensor signals on 2 wires and the connection of sensors to one sensor bus are planned.

The next generation of automotive microcontrollers in powertrain control units of Bosch MDG1, with series production planned for 2014, fully supports PSI5.

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INTRODUCTION

Trends in Powertrain

Stricter legislation concerning exhaust emission and CO₂ or fuel consumption leads to electrification and hybridization of the powertrain, to downsizing concepts for combustion engines with turbocharging and high pressure direct injection, and to the use of alternative fuels.

At the same time, the objective must be to further reduce the Total Cost of Ownership. Space requirements and weight, especially of mechatronic vehicle components, follow the trend toward increased functional density.

In order to achieve exhaust emission and fuel consumption targets, a further increase of injection pressure and a higher level of injection accuracy of Common Rail injection systems with multiple injections are of great

importance. The rail-pressure sensor, which is the central component of the storage injection systems for high-pressure control, plays a very important role in terms of accuracy and diagnosis and the detection of signal distortion.

Requirements for Sensor Interfaces in the Vehicle

Compared to applications in the consumer and multimedia industry, requirements concerning electronic sensor interfaces intended for use in vehicles are stringent. If the interfaces are used in safety-critical systems, preservation of data integrity and especially the availability of data play a decisive role. A lack of sensor data - if only for milliseconds - may cause delayed activation of the airbag, functional impairment of braking interventions by the ESP system, or a malfunction of the engine. As a rule, data transmission rates

and bandwidths must remain constant and must be guaranteed under all operating conditions.

The large number of electronic systems in today's vehicle and the possibility of external interference require very high EMC robustness. On the other hand, the level of electrical emission must remain below the relevant legal limits even if the cable harness from the ECU to the sensors runs through the entire vehicle and remedies such as shielded cables cannot be implemented due to cost considerations. In general, in many applications the costs for interface and wiring are to a large extent already determined by the reusability of a particular interface or sensor solution and the associated overall comfort or safety function. Minimum costs for implementation in the sensor and electronic control unit (ECU), as well as applicability in the vehicle (cable, connectors) are the key requirement for a universal interface for sensors in the vehicle.

In summary:

Costs	Implementation in components, wiring
Functionality	e.g., data rates, sensor configurations
Robust transmission	Low bit error rates, data availability
Availability	Components, standardization
EMC	Low emission, high interference immunity

DIGITAL INTERFACES IN THE VEHICLE

As regards multimedia applications in the vehicle, the wireless bluetooth interface for mobile communication is currently among the most widely used. The MOST bus (MOST = Media Oriented System Transport) is based on optical or electric cables and will be used in future for the transmission of audio and video signals with very high data transmission rates of up to approx. 23MBaud. For the networking of electronic systems and connection of sensors, various CAN dialogues (Controller Area Network) are available in the upper vehicle segment, in future together with the Flexray bus system as a promising standard for high data rates and complex systems. LIN (Local Interconnect Network) is positioned in the lower segment and widely used in local, non-safety-critical subsystems. Typical applications are in the comfort sector of body electronics, for instance in air conditioning systems, sun-roofs, doors, and seats. Due to its limitation to approx. 20 kbps, LIN is too slow for many sensor applications. The SENT interface (Single Edge Nibble Transmission), as standardized in SAE J2716 JAN2010, is a three-wire voltage interface for unidirectional, point-to-point sensor-to-ECU connections. Data rates are typically about 40

Kbit/s with message rates of 1.2 ksamples/s. In the powertrain and chassis domains SENT is now being widely-used as an upgrade replacement for analog interfaces.

A common feature of all hitherto described interfaces is that the physical transmission layer is exclusively used for data transmission and that it can be optimized for that purpose. If power supply to connected sensors is required it is done via additional, external lines. In the case of "genuine" dual-wire interfaces, data and power are both transmitted via only two lines. The primary advantage is the reduced cost for cable and connectors. Dual-wire interfaces have become mainly established in applications where cost pressure is high, such as airbag systems in which several sensors are connected to a central control unit. The initial trigger for the development of different proprietary and application-specific dual-wire interfaces was the introduction of external acceleration sensors for side airbag applications. Among these are, to name a few, "PAS" (Bosch), "RSU" (Autoliv), "MRSA" (Continental), "PEGASUS" (Siemens VDO), "MERAS" (TRW), and "DSI" (TRW, Freescale). A particular role is played by "Safe-by-Wire Plus", which is the result of the merger of two initially separate standardization efforts by "BST" (Bosch, Siemens, Temic) und "ASRB" (Advanced Safety Restraint Bus).

With the objective of an open standard in mind, PSI5 emerged from existing, proprietary developments of Autoliv, Bosch und Continental. A first joint publication of the cooperation partners was issued during the "Sensor" Trade Fair in Nuremberg in May 2005. Since summer 2006, standardization is also supported by Siemens VDO. The main characteristics of PSI5 are the use of a dual-wire current interface, a Manchester coded data transmission with 8, 10, 16, 20, or 24 data bits, a data transmission rate of 125 or 189kbps, and a variable standby current of the sensors of 4 - 35mA. It supports asynchronous and synchronous operation modes in point-to-point connections as well as parallel or serial bus configurations.

Figure 1 shows a classification of standardized interfaces regarding the data transmission rate and relative implementation costs per node. With increasing data transmission rates one can generally expect higher costs.

Classification PSI5

PSI5 (Peripheral Sensor Interface 5) is a digital bus interface to connect control units and sensors. On the list of digital sensor interfaces (LIN, SENT, CAN, FLEXRAY), PSI5 fills the gap between SENT and CAN, as illustrated in Figure 2.

Trends in Sensor Technology and Signal Processing

As a result of the rapid spread of electronic systems for safety, comfort and reliability in the vehicle, the number of sensors acting as essential signal transmitters for operational, environmental and system parameters has dramatically

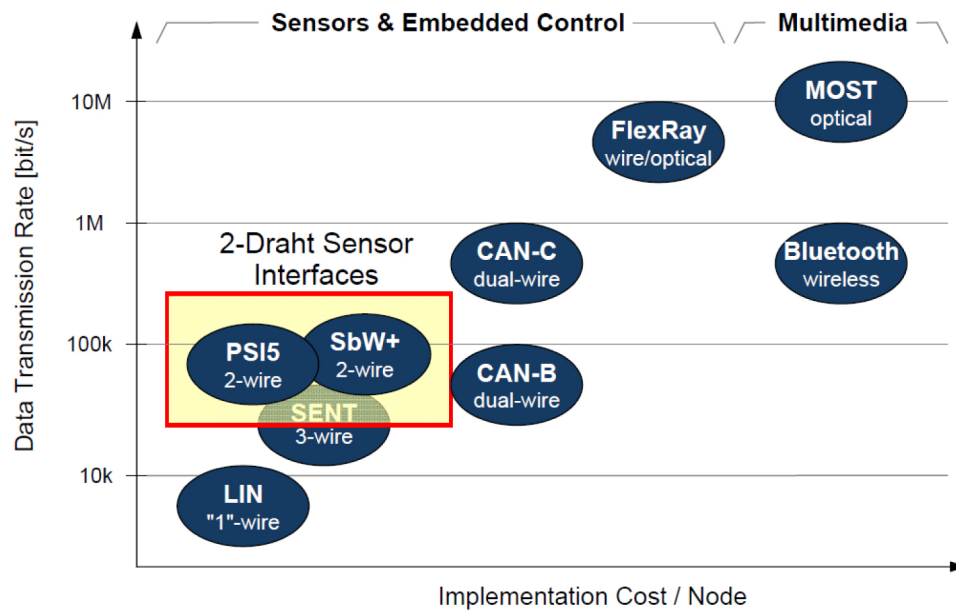


Figure 1. Overview of digital interfaces in the vehicle.

	SENT Single Edge Nibble Transmission SAE J2716	PSI5 Peripheral Sensor Interface PSI5 V2.0	CAN Controller Area Network ISO 11898
Modulation	Voltage	Current	Voltage
Wires, pins	3	2	4
Data transmission	Sensor-to-ECU	Bidirectional, asymmetric rates	Bidirectional, symmetric rates
Bus subscribers	---	max. 3	max. 30
Data rate, asynchronous to ECU	39 kbit/s	98.1 kbit/s (88.6 kbit/s)	140.8 kbit/s (236 kbit/s)
Message („sample“) rate, asynchronous	1.22 ksamples/s	4.0 ksamples/s (5.52 ksamples/s)	5.8 ksamples/s (3.7 ksamples/s)
Data rate, synchronous to ECU	-	78.2 kbit/s (69.0 kbit/s)	112 kbit/s
Message („sample“) rate, synchronous	-	3.26 ksamples/s (4.3 ksamples/s)	4.6 ksamples/s
	24-bit (+ 4-bit messaging)	24-bit frame (16-bit frame), CRC	3 data bytes, 500 kbaud mode (8 data bytes)

Figure 2. Comparison of SENT, PSI5 and CAN for sensor applications with 2×12 -bit measurement data

increased. Wherever possible, acquisition of the signals required for the various systems is directly integrated in the evaluation electronics. However, many applications rely on parameters whose signal quality is only sufficiently available in very restricted areas in the vehicle - thus requiring the use of external sensors and a suitable interface for data transmission.

Today, analog sensor-to-ECU communication is common in the powertrain. Analog ratiometric signals are transmitted by the sensor. The analog-to-digital conversion is performed on the ECU-side. The examples in Figure 3 explain the

structure of an all-analog sensor and of a sensor with digital signal processing but with an analog sensor interface. Many of today's sensors with advanced digital signal processing have analog interfaces.

Whereas in the past, analog signal acquisition and transmission dominated the market and still play a surprisingly large role today, the trend towards fully digital systems is unstoppable. Due to the progress in semiconductor technology, digital signal processing in the sensor replaces monolithic mixed signal sensor integrated circuits. Modern sensors quantify the electrical representation of physical

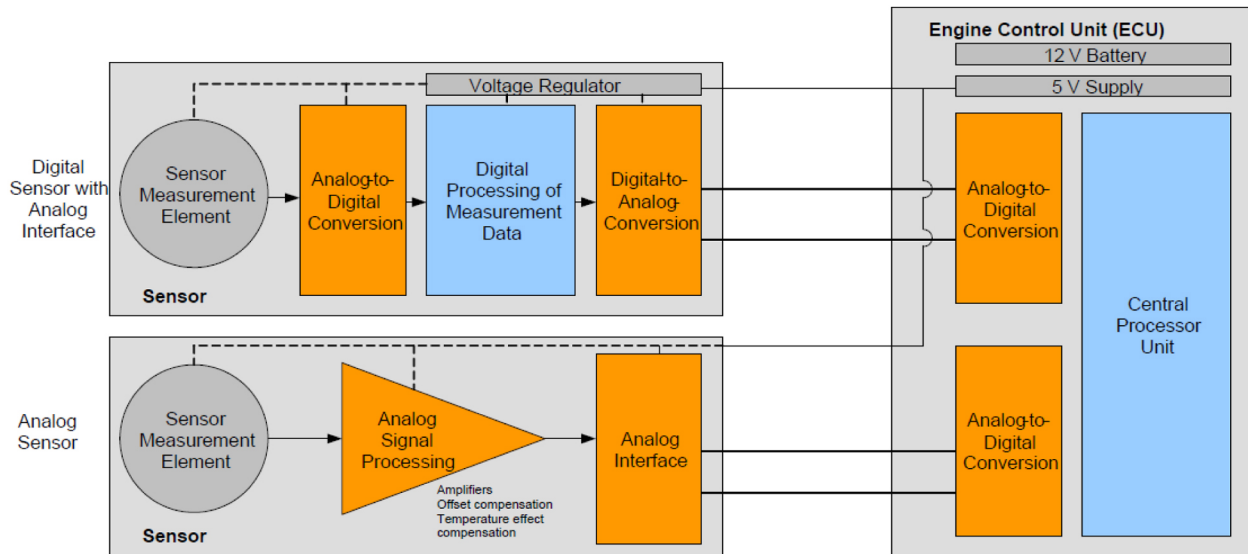


Figure 3. Analog automotive sensor-to-ECU interfaces

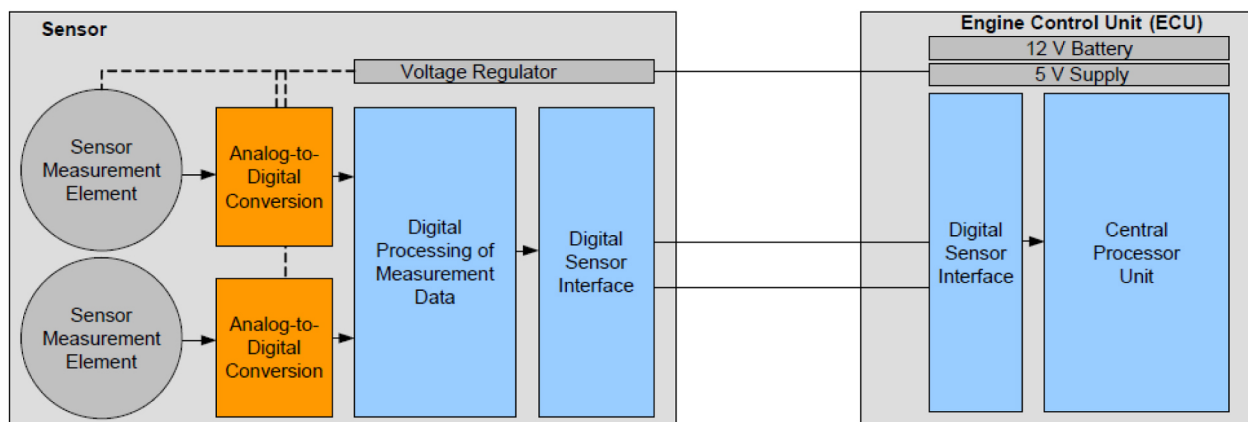


Figure 4. Sensor with multiple measurement signals and digital sensor-to-ECU interface

parameters by analog-to-digital converters. In this way it is possible to obtain digitized measurement input data with high resolution and accuracy. The remaining signal path including filtering and data processing is completely digital. The transmission of high-resolution measurement signals over an analog interface can result in a loss of measurement resolution or bandwidth (dynamics), since the analog transmission channel is limited by the product of resolution and bandwidth of the measurement signal.

On the other hand, a digital interface has a bitwidth and message rate specified by the particular interface standard. This allows the transmission of the sensor measurement signal with the accuracy and resolution determined by the sensor's ADC (assuming the bitwidth of the digital interface is sufficiently large). The dynamics of the measurement signal can be transmitted up to the message rate (samples/second) of the particular digital interface.

Figure 4 shows an example of a sensor with a digital sensor-to-ECU interface. With the trend toward ever lower supply voltages in micro controllers, analog signal processing is becoming less and less important in the ECU.

A digital sensor interface combines numerous inherent advantages: Digital data transmission is robust and provides error detection (e.g. by CRC checksum). In contrast to analog transmission, the measurement signal is not distorted by additive noise coupled into the cables (e.g. EMI). Moreover, digital interfaces permit to multiplex multiple measurement signals onto one sensor-to-ECU connection and can carry messaging channels for sensor status indicators and sensor-specific information.

Rapid replacement of analog interfaces by new digital interfaces has just started in the powertrain sensor-to-ECU communication. Numerous vehicles from various OEMs going into serial production in 2014 will use up to a dozen