On-chip CMOS Wireless Sensors Interface for Automotive Applications

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Summary: *This paper describes a CMOS interface for short-range wireless sensor networks. The sensor interface is composed by the sensor readout and a transceiver in CMOS 0.18μm process technology and a patch antenna at 5.7 GHz frequency, 50 MHz bandwidth and an efficiency of 18%. Automotive applications are the target of this wireless sensor interface.*

Keywords: *Sensor interface, On-chip antenna, Automotive sensor network*

1 Introduction

Sensors are applied in automobiles. Ever since the introduction of the Manifold Air Pressure sensor for engine control in 1979, followed by airbag sensors in the mid-eighties. Also, microsystems have been increasingly used throughout the vehicle. The demand of new sensing and management applications leads undoubtedly cars to be more intelligent, and the increased need of a networking infrastructure to connect the whole range of sensors and actuators. The system environment of an automobile is becoming more and more complex. While formerly one single supplier delivered all components of an ABS system or all sensors for airbag control, today the networked architecture allows merged sensor systems for different functions. Ambient intelligence, which means an environment of interacting smart devices, is opening up new information sources for the vehicle. With the growing use of bus-systems, building exclusive systems for each function is becoming more and more difficult and too expensive [1]. When looking at electronic stability systems for example, data of the ABS, acceleration and gyroscope sensors is evident the need of a networked infrastructure. The automobiles networks are usually with cables (depending of the model, a car has about 1000-1600 cables) [2]. These networks have serious drawbacks like reliability, maintenance and constraints if the manufacturer plans the addition of new functions. These drawbacks can be overcomed with wireless transmission infrastructures.

This work presents an interface composed by an RF transceiver, an integrated antenna and a signal processing interface for analog sensors used in car applications.

2 System overview

As illustrated in Fig.1, the complete system is divided in four blocks: the sensor, an amplifier, and an AD converter. This eliminates the need of the 4 – 20 mA current loops, commonly used in automotive physical protocols [3].

The operation frequency of the interface is in the 5.7 GHz band, due to the necessity of low dimensions of the integrated antennas, to work with high data-rates, and to reduce the interference [4].

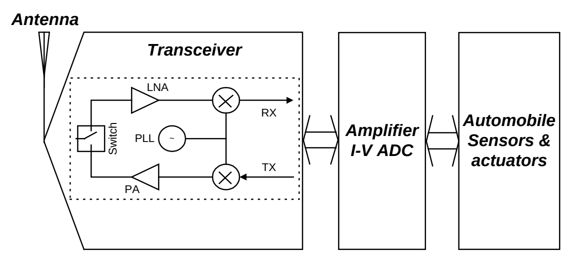

Fig.1: Interface architecture.

2.1 Transceiver design

Transceiver subsystem was projected in UMC 0.18 μm CMOS process to work in the frequency of the 5.7 GHz, in order to be compatible with the antenna. The most common sensing elements presented on vehicles, like temperature and pressure sensors, can be fabricated in conventional CMOS process, achieving a combined integration of the transceiver and the sensor in the same die. The receiving block of the transceiver has a phase locked-loop (PLL) to make the local oscillation of the carrier, in order to make the down-conversion of the signal from the low noise amplifier (LNA), from the 5.7 GHz band to the base-band. The same local generated carrier is used by the transmitting block to up-convert the base-band signal to the 5.7 GHz band. This RF signal enters in a power amplifier (PA) that amplifies it to be transmitted.

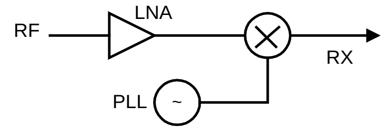

Fig. 2: Receiver block.

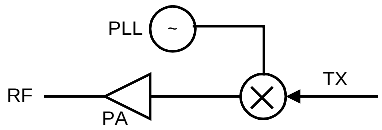

Fig. 3: Transmitter block.

2.2 Antenna design

A planar antenna operating in the 5.7 GHz ISM band and suitable for on-chip integration was designed. From the set of available materials used for IC fabrication, standard silicon was not chosen for use as substrate due to its low resistivity. The option was to use high-resistivity silicon (HRS) together with insulation layers to keep the losses at low as possible [4].

The HRS substrate has a dielectric permittivity of 11.7, conductivity in the range 0.02 – 0.05 S/m, and the wafer thickness of 525 ± 25 μm. The use of HRS is enough to provide considerable loss reduction. Nevertheless, the losses can be reduced even further with the use of a dioxide layer between the silicon wafer and the metal patch. This layer has a permittivity of 3.9 and is an insulator.

The ground and metal patches were made of aluminum, with a thickness of 2 μm. Fig. 4 illustrates the materials and configuration used in the fabrication.

Antenna feeding was carefully designed, in order to provide a correct input impedance (50 Ω) to do the measurements.

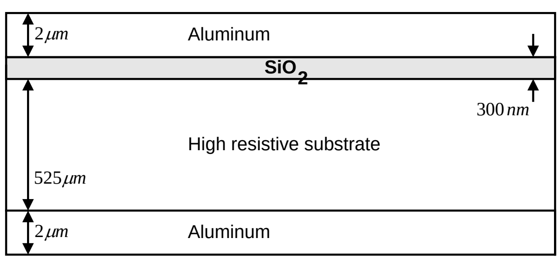

Fig. 4: Cross-section of the patch antenna design.

A photo of the fabricated patch antenna prototype, with 7.7×7.6 mm^2 area dimensions is illustrated in Fig. 5.

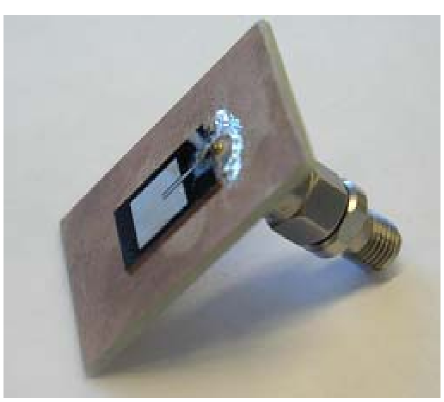

Fig. 5: Patch antenna fabricated on a high resistive silicon substrate, already mounted for measurements.

2.3 Sensor interface design

The majority of the sensing elements used in automobiles have its output in current, on the range 4-20 mA [3]. This current is processed by the sensor interface, which have an amplifier followed by an I-V converter with ΣΔ ADC of 1st order, with a bit stream output with resolution of 14 bits.

3 Results and conclusions

Measurements show a patch antenna, with the central frequency of 5.705 GHz, a bandwidth of 90 MHz at –10 dB, a directive gain of 0.3 dB, with an efficiency of 18%.

The transceiver to be used in our application, in the 5.7 GHz frequency, has internally a PLL that synthesizes a carrier in the range 5.424-5.831 GHz, digitally programmable, using a simplified version of the differential ring oscillator VCO (low area occupancy and low power consumption of 25.3 mW) [5].

The whole interface implements a bus interface at 5.7 GHz operation frequency, reducing the complexity and the weight associated to the wired infrastructures, and increasing the reliability and durability of the sensing system. The automobile wireless sensor interface has the flexibility for changing the design and to add new functions.

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