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Low Power High Speed CMOS Interface for MOS Gas Sensors

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Abstract

A universal CMOS integrated MOS gas sensor interface for application development and sensor research is presented. Three different integrated heater sources with a maximum output range of 20 V and 40 mA and the possibility to operate an external transistor as current source with an output range of several hundred mA allow the operation of nearly all kinds of hotplates. Two different readout electronics for the sensor's resistance work within a range of 1 kΩ up to 10 MΩ with a constant voltage or constant current sensor bias. All measurements are digitized with two free configurable high speed low noise analog channels which allow fast and low power measurements. The configuration of the chip and the readout of the measurements are done with a register based SPI interface.

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Keywords: MOS gas sensor interface, hotplate interface, temperature-modulation

1. Introduction

Nowadays, a lot of work is being done on the further development of MOS gas sensors. As far as the sensor itself is concerned, the focus is primarily on the sensor layers. Sensitivity has been increased and aging effects have been reduced, thanks to the latest developments in layer compositions and nanowires [1, 2]. Concerning the heater, the power consumption has been reduced by using new micro hotplate structures [3]. The sensor electronics is often neglected, although it has a considerable influence on the sensor performance and power dissipation.

Within the FP7 project MSP a CMOS integrated circuit for MOS gas sensors has been developed. This allows fast and low power heater control modes, as well as a new readout mode for the sensor's resistance to improve its long term stability.

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To enable a high flexibility towards different MOS gas sensors, different power ranges can be selected. The current range can be set between 5 and 40 mA in 5 mA steps. The voltage range can be set to 5 V or 20 V. Additionally, it is possible to control an external transistor with a shunt to reach higher heater currents up to several hundred mA.

The senor's resistance in the range of 1 kΩ up to 10 MΩ can be measured with two different interfaces using a constant voltage source or constant current source. By using the constant voltage mode with a typical bias of 100 mV, the DC-field-induced migration of ions, the main reason for the sensor aging [2], can be reduced.

At a constant temperature, which is depending on the detectable gas and sensor layer, MOS gas sensors have a high sensitivity but only low selectivity. With temperature-modulated sensor operation modes the selectivity can be increased [4]. These temperature modulations need fast measurements which could be done with two fast analog channels and a special Serial Peripheral Interface SPI interface.

By using the platform chip it is not only possible to do high speed measurement but also to use low power modes to enable battery powered applications.

2. Low Power Heater Interface

A basic heater source requirement is an accurate temperature control. This can be achieved by a measurement of the heater resistance in combination with a microcontroller using a current source to operate the heater. Fig. 1. shows the basic principle of the heater interface.

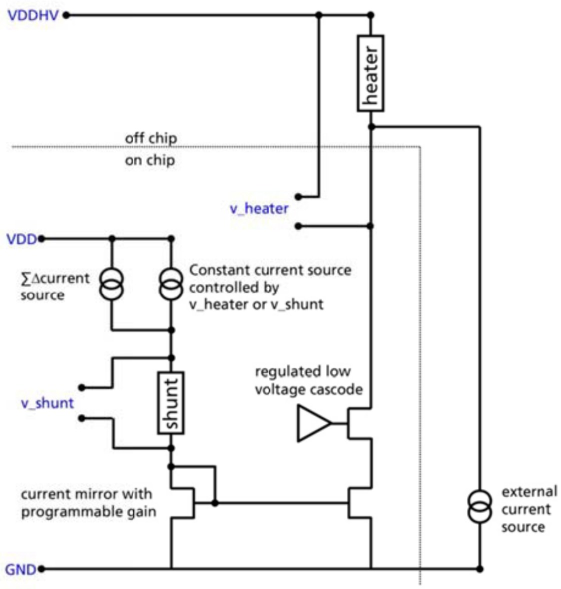

Fig. 1. Basic principle of the low power heater interface.

By changing the gain of the current mirror the range of the heater current can be adjusted between 5 mA and 40 mA in 5 mA steps. The maximum heater voltage is 20 V. For low power consumption, the output stage uses a regulated low voltage cascode, so the voltage drop across the heater source can go down to 0.5 V. Additionally the supply voltage of the heater has to be as low as possible.

By the use of an external transistor and a shunt an external current source can be achieved which can go up to several hundred mA.

To evaluate the influence of different heater sources on the sensor it is possible to switch among them, even during measurements. The following sources are implemented on the platform chip:

- IDC: constant current source
- VDC: constant voltage source
- ISD: sigma delta modulated current source (4 bit base current, up to 8 MHz modulation frequency)
- IExt: external constant current source implemented with an external transistor and a shunt

The current sources IDC, VDC and IExt have a resolution of 10 bit, ISD has a resolution up to 16 bit.

By measuring the heater voltage v_heater and heater current, which is transformed with a shunt into the voltage v_shunt, the heater resistance can be calculated. For most heaters the heater resistance can be used for sensing its temperature. If this is not possible, a separate temperature sensor can be connected to the platform chip.

The heater interface has its own analog channel to allow fast temperature modulations. It includes a first order $\Sigma\Delta$-ADC with 4 bit feedback, working at 8 MHz clock frequency. Depending on the programmable oversampling rate (OSR) the heater control can be operated at different maximum frequencies, for example:

- Resolution 10 bit: OSR 26 => 125.00 kHz = 8 MHz/26
- Resolution 16 bit: OSR 212 => 1.95 kHz = 8 MHz/212

3. Low Leakage Anti-Aging Sensor Readout

The platform chip has two possibilities to measure the resistance of the gas sensor: either using a constant voltage or a constant current biasing. In constant current mode, a current between 10 nA and 150 µA is driven through the senor and the voltage across the sensor is measured. In constant voltage mode a bias voltage in the range of 0 V up to 1 V can be applied, using two integrated voltage sources. The resulting current through the sensor can then be measured with the integrated shunt, as shown in Fig. 2. With a typical sensor voltage of 100 mV (VN = 0.8 V, VP = 0.9 V) it is possible to measure a sensor's resistance in the range of 1 kΩ up to 10 MΩ. This is possible, because the small shunt voltage can be amplified with a programmable gain between 1 and 4096. Referring to [1] the DC-field-induced migration of ions is the main reason for the sensor aging. With only 100 mV sensor bias voltage the sensor aging can obviously be reduced.

Inevitable problems using high sensor resistances are leakage currents, for example of the ESD structures. Without countermeasures, these currents can be as large as the sensor's current itself and thus prevent accurate measurements. The new interface includes a low leakage measurement scheme which allows measurement of high resistances beyond the limits due to leakage currents. This works in three steps:

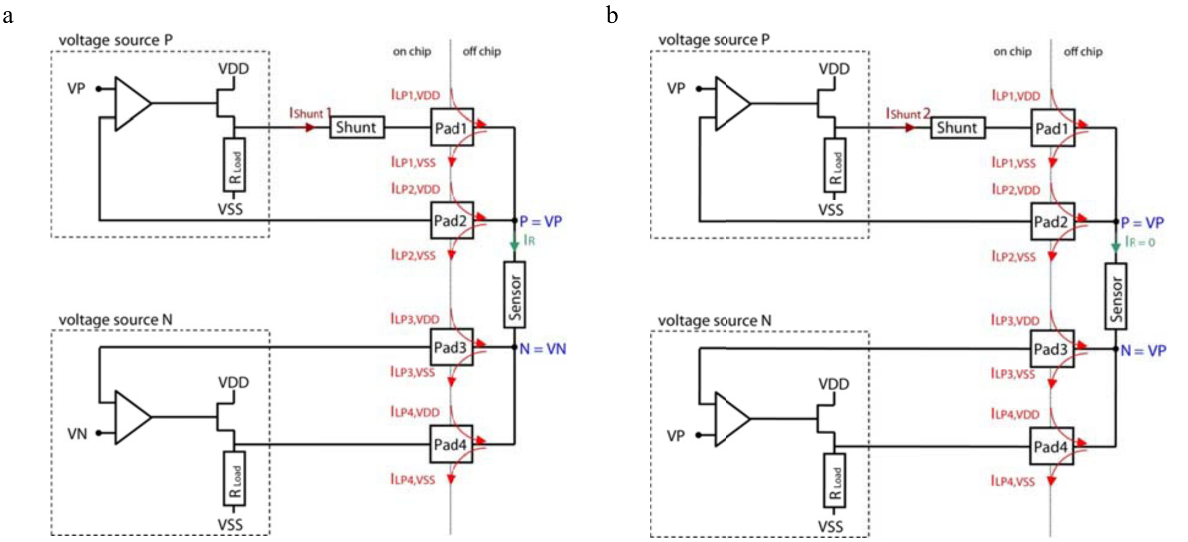

Fig. 2. (a) Low leakage measurement first step; (b) Low leakage measurement second step

In a first measurement step the current through the shunt is measured including the current through the sensor as well as the leakage currents, as shown in Fig. 2, left side.

In a second measurement step the voltage over the sensor is set to 0 V by setting N to VP. Independent of the sensor's resistance the current trough the sensor will be 0 A. By not changing the potential of node P the relevant leakage currents are the same as in the first measurement and can thus be measured, as shown in Fig. 2, right side.

By subtracting the second measurement from the first one the leakage current free sensor current can be calculated which can be used to calculate the sensor's resistance.

4. Measurements with the Platform Chip

The SPI interface allows a fast and simple communication with the platform chip. After power-on the platform chip has to be configured once. Then it is possible to read out the measurement values. If, for example, the heater is biased with 10 mA and the senor's resistance is measured with 100 mV it is possible to read out the voltage across the heater and the current through the sensor at once. Then the microcontroller can calculate the heater's resistance and temperature as well as the sensor's resistance. For temperature-modulations, a control loop has to calculate the new heater current which is set via SPI interface. For fast measurements the new configuration and the measured values can be read out even during measurements. Fig. 3. shows a measured temperature loop.

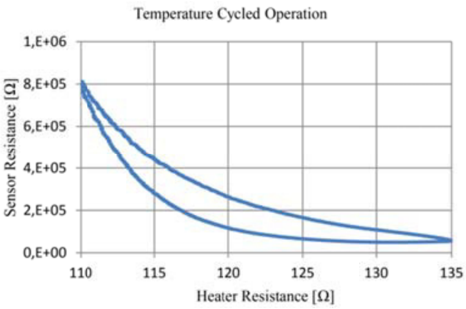

Fig. 3. Measured temperature cycle of a MOS gas sensor in ambient air

5. Conclusions

The presented CMOS integrated MOS gas sensor interface allows a fast temperature-modulated operation of gas sensors as well as low power operating modes with all kinds of MOS gas sensors. Additionally, it is possible to realize different kinds of operation modes which make the platform chip a perfect one for sensor and application development.

Acknowledgements

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References

[1] D. Zappa, et al., Tungsten oxide nanowires for chemical detection. Anal. Methods 7, 2015, 2203-2209

[2] C. Huan, et al., Analysis of the aging characteristics of SnO2 gas sensors, Sensors and Actuators B: Chemical, Volume 156, Issue 2, 2011, 912-917

[3] M. Siegele, et. al., Optimized integrated micro-hotplates in CMOS technology. New Circuits and Systems Conference (NEWCAS), 2013 IEEE 11th International, 1-4

[4] M. Leidinger, et al., Selective detection of hazardous VOCs for indoor air quality applications using a virtual gas sensor array, J. Sens. Sens. Syst., 3, 2014, 253-263