INTEGRATED INTERFACE IC FOR METAL-OXIDE CHEMICAL SENSOR ARRAYS

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Abstract: The design of a mixed-signal integrated interface for the control of the heating resistance and reading of the chemically sensitive resistance of metal oxide chemical sensor arrays is reported. The ASIC contains in a single IC all the analog front-end to operate four MOX sensors while the control logic will be implemented on a microcontroller. Each heater is controlled from a dedicated DAC. Provision has been taken for both polysilicon and Pt heater control. The design has been realized in a standard 0.7um CMOS process.

Keywords: *MOX chemical sensors, sensor electronic interfaces, integrated circuits*

1 Introduction

A mixed-signal integrated circuit containing all of the analog electronics necessary to control and read an array of four metal oxide chemical sensors has been developed. The ASIC is controlled by an AVR microcontroller as shown in figure 1. A metal oxide (MOX) sensor is composed of a chemically sensitive resistance R_s and an underlying microheater R_h, integrated in the sensor structure, responsible to bring the device to the optimum operating temperature [1]. The ASIC then translates the concentration of specific gases in the sensor ambient to a voltage signal by measuring the resistance of the sensitive element. It also provides sensor temperature control through an independent measurement and heating mechanism of the microheater. The chip has been designed for low cost, low power and reduced dimensions and has been realized in a standard 0.7um single poly, double metal CMOS process from AMIS.

As seen in figure 1 the ASIC is divided in two main blocks: i) the heater read and control block and ii) the sensitive resistance measurement block.

2 Heater Control Block

In the heater control block four 8-bit DACs are used to determine the heating voltage on the sensor heater R_h. Each DAC is programmed independently by the AVR to output the appropriate voltage to the respective sensor (fig. 2). The heater temperature is controlled by the AVR by periodically sampling the R_h value and adjusting the DAC outputs accordingly. The current required to drive the sensor heater is of the order of a few tens of mA, thus it cannot be provided by integrated on-chip components. Rather, the DAC output drives an external, off-chip, amplifier connected to the actual heater resistance.

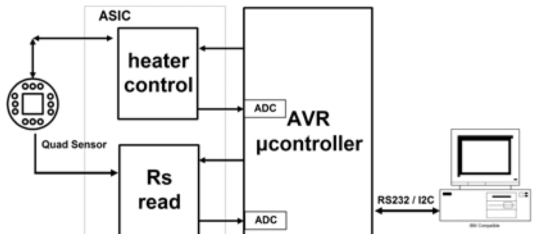

Figure 1. MOX Control and Reading Circuit under development

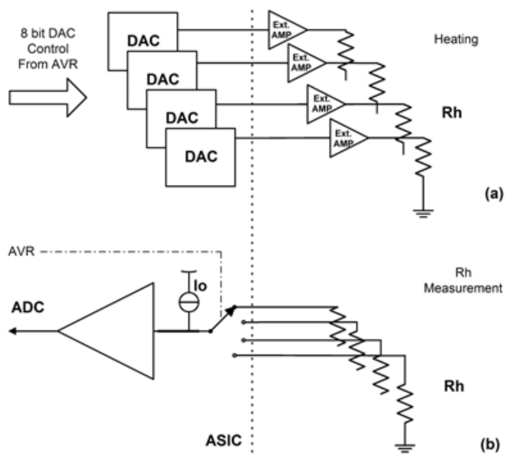

Figure 2. The heater control block consists of the heater driver circuit (a) and the heater resistance measurement circuit (b).

When the resistance of a heater is to be measured, the heater is temporarily disconnected from the DAC output and fed with a reference current I_o. The voltage drop on the heater is then sampled by one of the AVR ADCs. Possible use of different heater materials creates an additional difficulty. Common materials used as heaters are Pt and polysilicon [2] and their use in a practical device results in heater resistances with one order of magnitude difference (around 50 Ohms for Pt and a few kOhms for polysilicon). In order to accommodate this large resistance range, the measured voltage drop has to be amplified before sampling with a variable gain amplifier.

In figure 3 the basic operation of the heater control circuit is simulated. During operation the microcontroller selects the sensor to be heated and the sensor to measure. The operation begins by first programming each DAC to output the appropriate voltage on one of the heater resistors and then monitoring the change in its resistance R_h as temperature rises. A small on chip logic circuit generates the necessary control signals for the measurement cycle. Each time the heater of a sensor is to be measured one of the internal signals MEAS0 to MEAS3 turns on and the reference current is channeled on the corresponding heater. Then the heater resistance is measured by sampling the voltage drop across it (Measured_out in figure 3). At any other time the heaters are driven with their normal operating voltage.

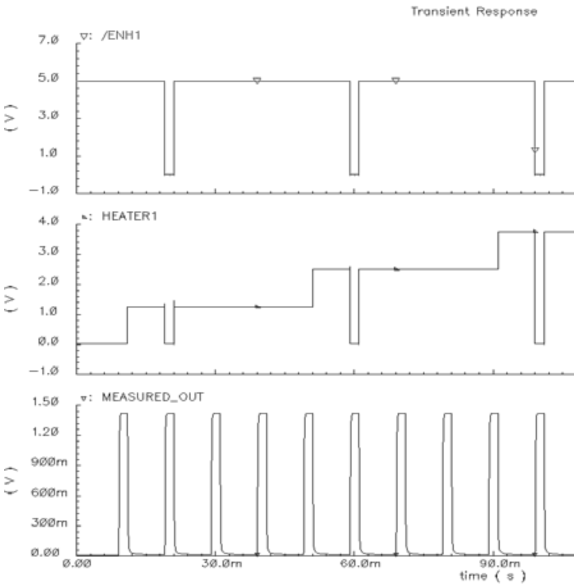

Figure 3. Heater operation. Only heater 1 is depicted for clarity.

3 Sensitive Resistance Read Block

For the measurement of the chemically sensitive resistance each of the four gas sensors is selected and its sensitive element is connected, at one end, to a specific resistor out of a 10-on-chip resistor array. At the same time the resistors are also connected at their other end with a bandgap generated voltage of 1.2V and thus a voltage divider is formed. Changes then of the sensitive resistance may be sensed as a voltage signal at the divider output. The divider output is first filtered and then amplified before being sampled off-chip by one of the 10bit ADCs of the AVR. The AVR is also responsible for the selection of the appropriate range resistor and amplifier gain. Alternatively, an external ADC with higher resolution could be used.

The resistor values at the divider array range from 300 Ohms to 10 MOhms in order to provide a wide dynamic measurement range. Resistor selection takes place after an initial calibration process that calculates the sensitive element resistance. Then, the resistor which forms the voltage-divider with the maximum slope of the V-R curve is selected. This maximizes voltage changes even for very small sensitive element resistance variations. In figure 4, the simulated response of the Rs measuring circuit is depicted for the 10 resistance ranges used.

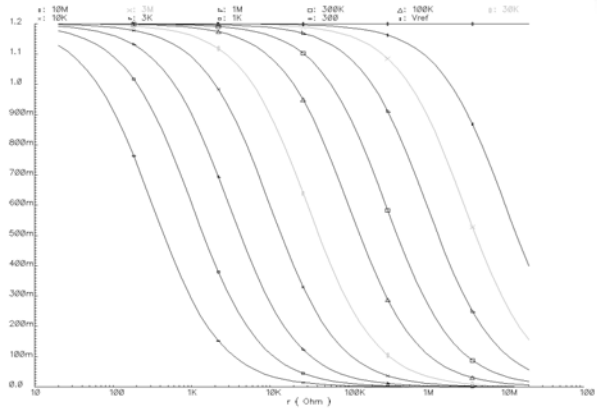

Figure 4. Rs resistance sweep (100 Ohm to 20 MOhm). Each curve represents one of the 10 different range resistors.

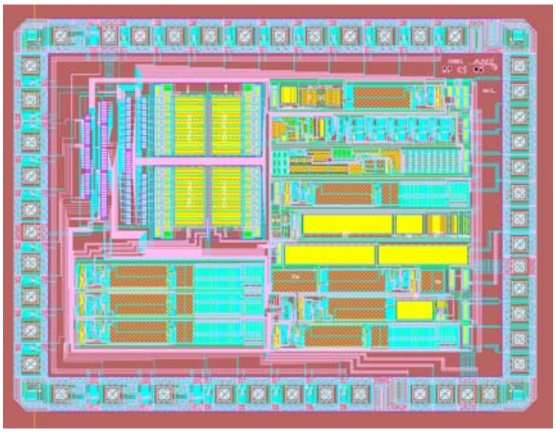

Figure 5. Chip layout

4 References

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