

# A Full-Custom Interface for Ultra-Low Power IoT Sensing Nodes

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## Summary:

We present an interface for conductometric/amperometric sensors (resistors, photodiodes, etc.) and current-driven actuators (LEDs, heaters, etc.) that includes data acquisition and wireless communication capabilities for less than 15  $\mu\text{W}$ , enabling autonomous, self-powered, applications, making it suitable for remote IoT applications with minimal maintenance.

**Keywords:** ASIC, conductometric sensor, Internet of Things (IoT), low power, remote sensing

## Introduction

Following the path of an environmentally friendly society, recent improvements in sensor technology have focused on miniaturized ultra-low power devices [1], opening the door to easily run IoT sensor nodes through batteries for remote sensing applications. A step forward is to optimize the system to the point where it can be powered by energy harvesting to be self-sufficient. This requires not only the sensors to be in the micro-power range, but also the front-end electronics to be equally optimized, which in most cases implies designing a custom Application Specific Integrated Circuit (ASIC).

Here we present a micro-power-optimized ASIC capable of periodically taking sensor measurements and driving the actuators autonomously. It is equipped with two current sources to bias components (e.g. resistive-based sensors) and/or drive the actuators needed for measurement conditioning (e.g. LEDs, heaters, small DC motors). It also includes circuits to precise measurement of voltage, current and resistance, suitable for a wide range of sensors used nowadays. Finally, a wireless module controller is integrated to work with commercial LoRaWAN or Bluetooth Low Energy (BLE) transceivers.

## System Description

The system, fabricated in XFAB 180 nm CMOS technology, presents two main sections (see Fig. 1): an analog block responsible of talking with the sensors and actuators and a digital block that includes controllers for each analog

circuit, processing units and interfaces for the non-volatile data-log memory and wireless modules. It also includes an ultra-low power timer and a Power Management Unit (PMU) to switch-off the unused circuits (power gating) and save power. The analog section is composed by four circuits: (i) a resistance dependent oscillator with a 14-bit Time-to-Digital Converter (TDC), (ii) a 10-bit OPAMP+ADC interrogation circuit that can be externally configured to operate either as a voltage amplifier or as a Trans-Impedance Amplifier (TIA) to measure current, (iii) an 8-bit current DAC used for current driving and (iv) a low current source (nano-ampere range) for biasing resistive sensors or current drive small devices.

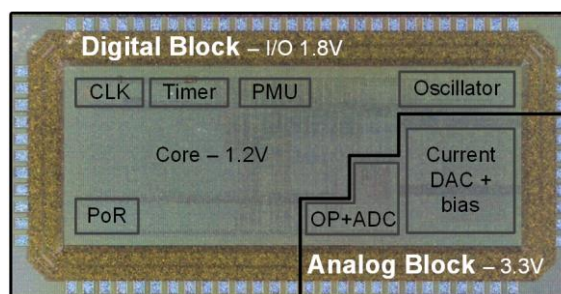


Fig. 1. ASIC Micro-photograph of the ASIC developed. Chip size 1.5 mm x 3 mm.

## Results

All results presented were measured in lab conditions from the fabricated ASIC.

2 shows the measurement of the oscillator circuit with an external parallel capacitance of 1 nF, which sets the desired dynamic range. It

presents high linearity for values above 1 k $\Omega$ , with the measurement saturating for values below this. The TDC incorporates a prescaler to increase the dynamic range but at the cost of resolution.

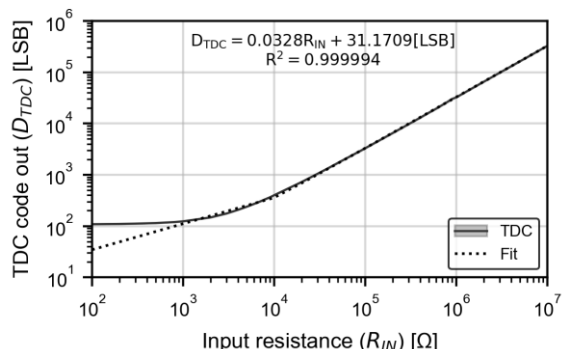


Fig. 2: 14-bit oscillator/TDC transfer function.

Fig. 3 presents current measurements of the OPAMP+ADC in a TIA configuration for multiple gain values. Again, we observed a high linearity of the output with a useful dynamic range going from 10 nA up to at least to 1 mA.

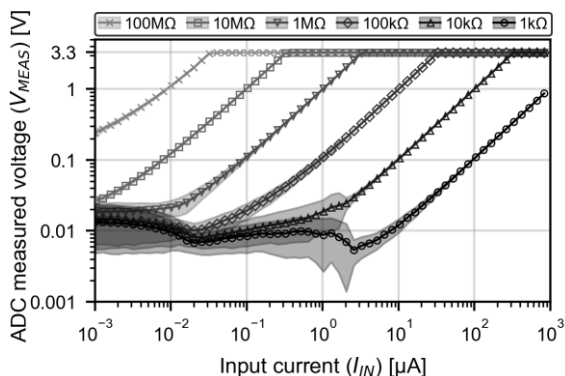


Fig. 3: TIA+ADC transfer function for multiple gains.

The current DAC measurements are presented in Fig. 4. We can select between four LSB steps to suit different sensor ranges and have more resolution at lower currents. The dynamic range goes from 0.0 V up to 3.1 V. The low current source can provide a selectable output of 2.5 nA, 5 nA, 30 nA, 200 nA over the full voltage dynamic range.

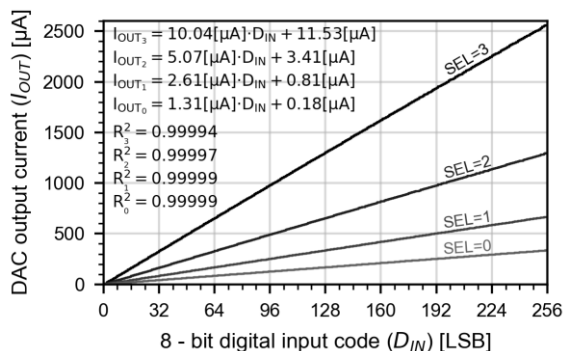


Fig. 4: 8-bit current DAC transfer function.

Finally, Fig. 5 shows the current consumption of the ASIC for a single measurement of a light-

activated gas sensor (LED driven with 100  $\mu$ A and resistance measurement). Table 1 summarizes the power used by the ASIC and the external modules, assuming a sampling period of 1 second and data transmission every 15 minutes (900 samples). The LoRaWAN wireless mode required a total power of 31.05  $\mu$ W (time average), while the BLE mode only added up to 14.05  $\mu$ W.

Table 1: System power consumption summary.

Device	Supply [V]	Power [ $\mu$ W]
ASIC	1.2	1.44
	1.8	10.65
	3.3	1.16
Memory	1.8	0.4
LoRaWAN	1.8	17.4
BLE	1.8	0.4

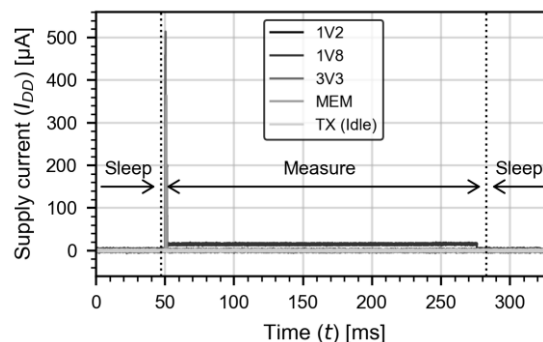


Fig. 5: ASIC current consumption.

## Conclusions

We developed an IoT sensor node that interfaces with conductometric/amperometric sensors and requires less than 15  $\mu$ W to operate with a BLE wireless connection. It is a perfect complement to ultra-low power sensor developments in multiple fields such as gas, chemical, biological or physical sensing.

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