Zurich University
of Applied Sciences

School of
Engineering

InES Institute of
Embedded Systems

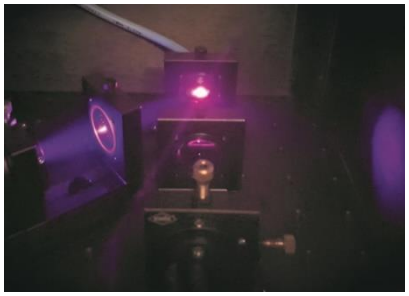
Optical oxygen-measurement device with FPGA

Diplomierende
Sabina Barbara Hafner
Simon Wittwer

Dozierende
Matthias Rosenthal
Francesca Venturini

The measurement of oxygen is essential in many industries, as for example water treatment, wastewater treatment, pharmaceutical industry, food processing, etc. Oxygen sensors must be universal, small, fast and precise.
In this thesis, an oxygen sensor prototype was developed, which is based on the principle of luminescence quenching. The luminescence sample is excited by the light of a LED. The more oxygen comes into contact with the luminescence sample, the less luminescent intensity and the faster luminescence decay can be observed. The reason for this is the luminescence quenching caused by collisions with oxygen molecules. Luminescence quenching refers to the decrease in the intensity and decay time of the luminescence of a luminophore by a quencher molecule. If excited with a sinusoidal signal, the sample emits luminescence light with sinusoidal intensity and with a phase shift with respect to the exciting signal, which depending on the luminescence lifetime. The reflected light is converted with a photodiode into an electric current and amplified analogously. To calculate the amount of oxygen, the phase shift must be measured and algorithmically converted.
The measurement of the phase shift and the conversion to an oxygen value is calculated in a Field Programmable Gate Array (FPGA). The received light signal is filtered by a lock-in amplifier, which generally corresponds to a narrow band bandpass filter. The phase shift is determined precisely by further digital filter methods, such as IIR and average filters.
By using a FPGA, the complete signal generation, filtering and evaluation are written in VHDL, a hardware description language. The signal amplification and conversion are solved in the analogue domain. This allows a flexible software and hardware architecture. This approach allowed to reach a 0.1% accurate oxygen measurement.
The special features of this prototype are the very slim analogue design and the periodic measurement of the reference phase. This periodic measurement of a reference phase can compensate the non-linear phase shift due to the electronics analogue part. The development of this oxygen sensor prototype has clearly demonstrated the versatility of a FPGA for an oxygen sensors. This opens up several new approaches for further development which may exploit the flexibility of FPGA It has lead several new approaches for further developments.

Laboratory setup of the oxygen sensor with the FPGA-board (left) and the optical setup in the black-box (right).



The blue-light is focused on the luminescence sample through the first optical lens (left) and is partially absorbed by the sample, which emits the light in a red color. The red light is focused on the photodiode that produces an electrical current.