Nitrogen oxide measurement using silicon photomultipliers

Graduate

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Introduction: In a research project by the IMES (Institute for Microelectronics, Embedded Systems and Sensor Technology) in collaboration with the company EcoPhysics, the concentration of nitrogen oxides (NOx) is determined by detecting photons produced in a reaction with ozone inside a reaction chamber. The current system uses an expensive vacuum photomultiplier tube (PMT) for this purpose. In the future, cost-effective silicon photomultipliers (SiPMs) are to be used instead. These have only existed for a few years and are still undergoing rapid development. Various manufacturers offer SiPMs, but they are sometimes not fully documented. In this thesis, two SiPM systems developed in preliminary work will be analyzed and evaluated and an optimized system will be developed.

Approach: In the first phase of the project, the existing system was analyzed to identify its signal acquisition and processing performance. Based on these insights, a new system architecture was developed. The redesigned system utilizes a charge amplifier that integrates the charge from incoming pulses over a defined time interval, as shown in Figure 1. All components, from the sensors to the signal processing stage, are integrated on a single PCB. The microcontroller is positioned outside the measurement chamber. The PCB is sealed to prevent external light from interfering with the chemical reaction, as shown in Figure 2. For user interaction and system control, a graphical user interface (GUI) was developed. It allows configuration of the integration time, bias voltage for all sensors, adjustable overvoltage for each channel and provides visualization of the measurement data.

Conclusion: The overall functionality of the system works as intended. The GUI successfully communicates with the hardware, and all user inputs are correctly applied. The charge integration operates as expected, as shown in Figure 3. However, some modifications are still necessary to improve measurement accuracy and to resolve a timing issue affecting the reading of ADC values in the GUI. This issue remains unresolved at the current stage.

Figure 1. Illustration of the signal processing flow from SiPM current pulses to charge integration and output sampling.
Own presentment

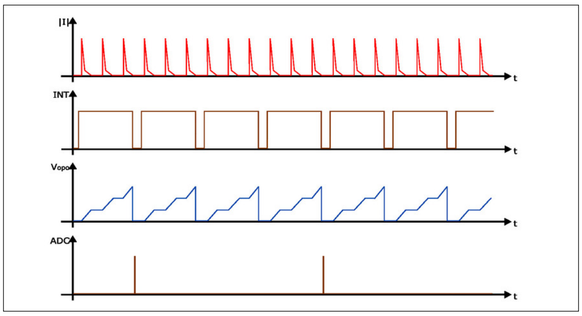


Figure 2. Block diagram showing the data and control flow between the graphical user interface and the hardware system.
Own presentment

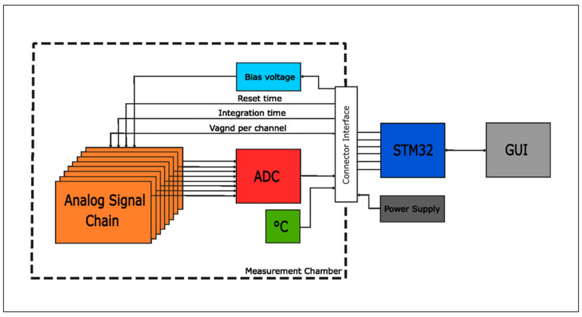
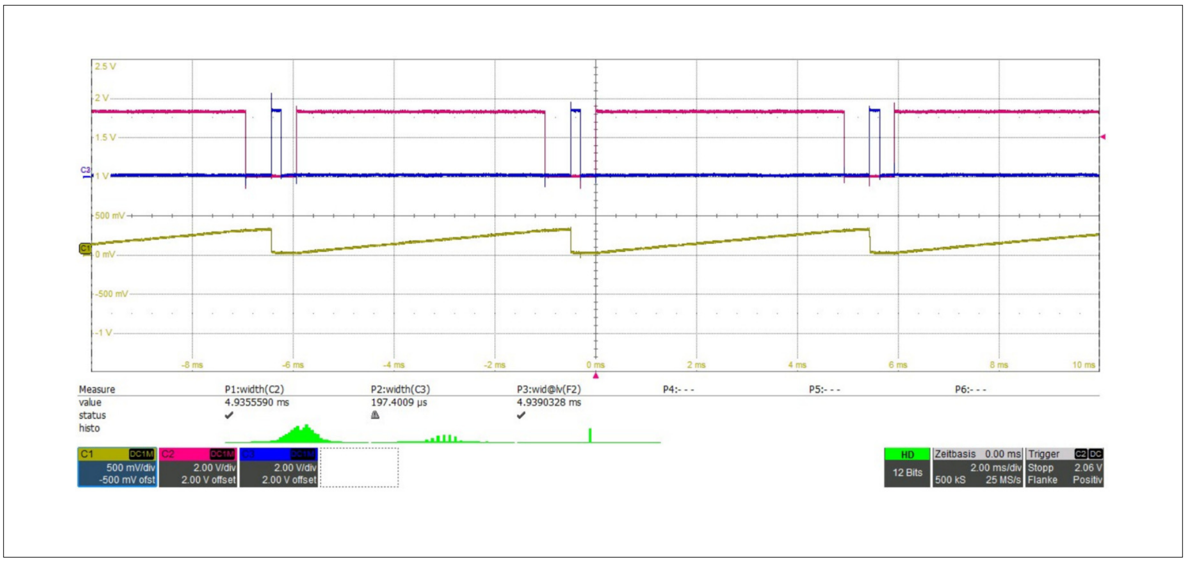


Figure 3. Output of the charge amplifier (C1), integration phase (C2) and reset phase (C3).
Own presentment



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