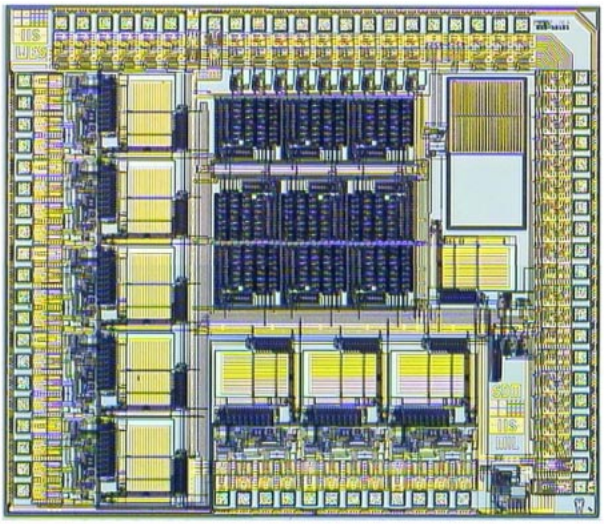
Fraunhofer Institut
Integrierte Schaltungen

Embedded Photosensors in Cost Effective CMOS-Technology



9-channel Opto-ASIC with photodiodes, transimpedance amplifiers, and A/D-converter in 0,6 µm CMOS technology

Main Features

– Wavelength range for optical sensors: 400 nm – 1100 nm
– High dynamic range: 10^6
– sensitivity: 1 pW
– Cost-effective standard CMOS processing
– On-chip integration of analog and digital signal processing
– Availability of standard cell libraries for various applications

Photodiodes in CMOS Technology

Figure 1 below shows a cross section of photosensitive devices after standard CMOS processing. This technology allows for the fabrication of shallow and deep p-n-junctions. Either of these can be used as photodiode, whereas their vertical combination acts as a photosensitive pnp-transistor. In the following, the junction between the p+-diffusion and the n-well will be referred to as the shallow photodiode.

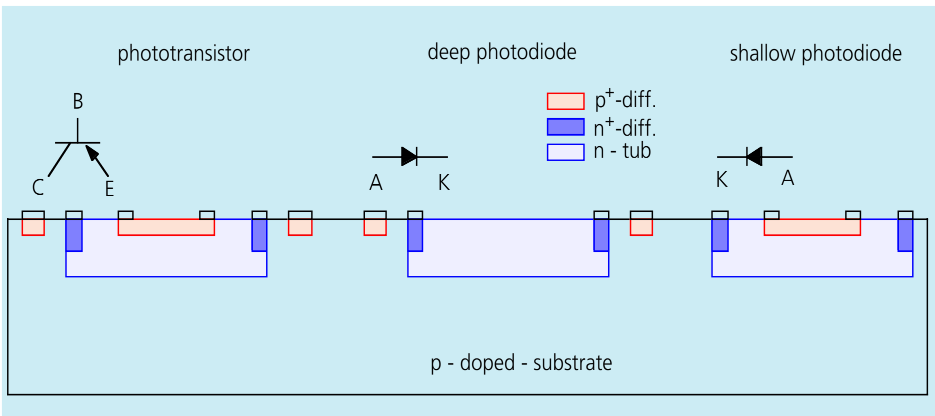


Fig. 1: Cross section of integrated photodiodes in a standard CMOS process

Fraunhofer Institute for Integrated Circuits IIS
Applied Electronics

Director:
Prof. Dr.-Ing. Heinz Gerhäuser

Am Wolfsmantel 33
91058 Erlangen
Germany

Phone +49 (0) 91 31 / 7 76-0
Fax +49 (0) 91 31 / 7 76-9 99
E-mail: info@iis.fraunhofer.de
www.iis.fraunhofer.de

Project Group Optical Communications
Dipl.-Ing. Josef Sauerer
Dr. Norbert Weber

Nordostpark 93
90411 Nürnberg
Germany
Phone +49 (0) 911/58 06-2 10
Fax +49 (0) 911/58 06-2 99
E-mail: ccoc@iis.fraunhofer.de
www.iis.fraunhofer.de/ec/oc

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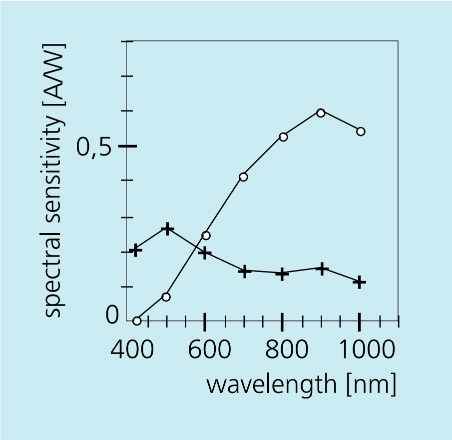

Fig. 2: Spectral Sensitivity of Photodiodes

The p-doped-substrate and the n-well constitute the deep photodiode.
The spectral sensitivities of the photodiodes are shown in figure 2.

Signal Processing Electronics

The devices are manufactured using commercially available standard CMOS processing. This ensures cost-effective production without additional steps and high reproducibility of the integrated sensors. Furthermore, it allows for on-chip integration of analog and digital postprocessing of the monitored signal. Possible features include preamplifiers, filters, analog-to-digital conversion and the provision of serial or parallel interfaces. For various applications, designs can be derived from standard cell libraries at Fraunhofer IIS.

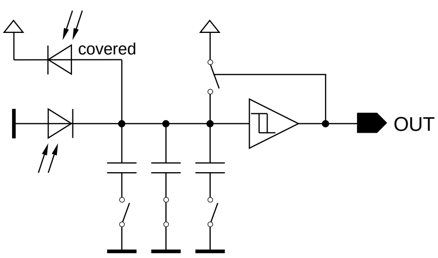

Fig. 3: Block diagram of photosensor front end with dark current compensation

Dark Current Compensation

To achieve a low detection limit we use dark current compensation by placing a metal covered photodiode close to the actual detector and subtracting their currents. A high dynamic range is accomplished by integrating the photocurrent by discharging a capacitor and recharging it via a Schmitt-trigger. In this scheme the frequency of the digital output is only limited by the error current and the maximum toggle frequency of the technology. The single capacitor may be replaced by an array of switchable capacitors in order to be able to calibrate the sensitivity and dynamic range of the circuit. The design as shown in figure 3 can easily be adapted to many application specific needs by customizing the dimensions of the photodiodes and the number and values of the capacitors.

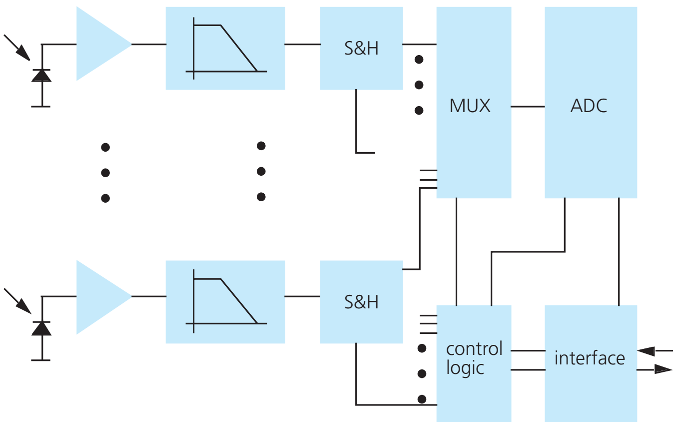

Fig. 4: Photodiodes with transimpedance amplifiers, sample&hold stages and A/D-converter

Applications

- Light intensity measurement (linear and logarithmic)
- Spectroscopy
- Optical position detection
- Light barriers
- Microsystems with on-chip photosensors

An application with analog and digital components is shown in figure 4. The genereated photocurrents are converted to according voltages using transimpedance amplifiers. After filtering the signal, a multiplexed analog to digital converter derives related digital data sets which are transferred to the outside by a serial interface.