Versatile Hardware Platform for Polymer Fibre Sensors

Bernd Offenbeck [1*], Hans Kragl [2]

1 OBTIS GmbH, Rossbachstr. 5, D-93057 Regensburg, Germany
2 DieMount GmbH, Giesserweg 3, D-38855 Wernigerode, Germany
*Corresponding author: bernd.offenbeck@obtis.de

Abstract: This document shows the development of a versatile, processor controlled hardware platform for polymer fibre based sensors named "POF LINK ANALYZER". The hardware is capable of driving up to 3 LEDs and offers 2 receiver channels with a high dynamic range and fast acquisition rate. The receivers are locked to the modulated signals of the LEDs to suppress ambient light. Depending on the application different LEDs and receivers can be installed. The integration of low crosstalk splitters allows transmitting and receiving on a single fibre, making unique sensor applications possible. This allows the development of various, all optical POF based sensors.

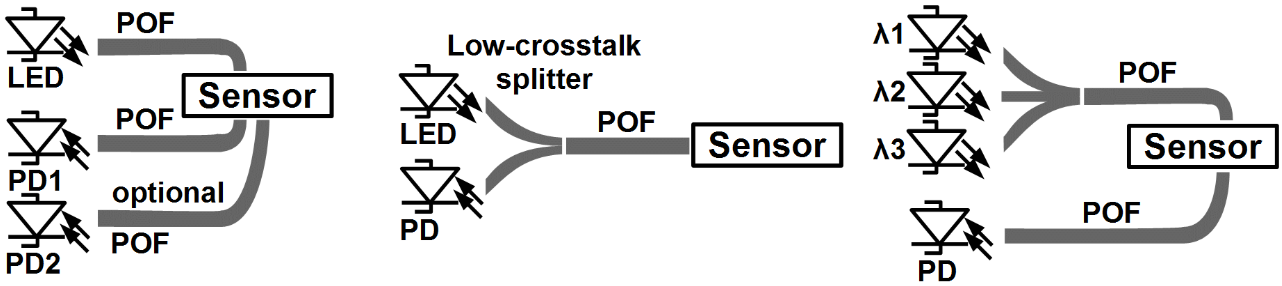
1. Introduction

Many interesting 1 mm PMMA-POF based sensor projects fail, due to lack of the necessary measurement system. Out of this necessity a flexible hardware platform was developed, that is adaptable for most scenarios.

Goal was to cover applications with a sensor in a fibre loop, optional with a second photodiode - as well as sensors working in reflective mode over a single fibre with the use of low-crosstalk splitters.

In addition multi wavelength configurations with up to three LEDs should be covered.

This enables the use in most sensor systems, like mechanical sensors for shock and vibration as well as bio- and chemical sensors working on multiple wavelengths.



left: sensor device in POF loop   middle: single fibre sensor with splitter   right: multi wavelength sensor
Figure 1. Typical application scenarios

In addition the measurement device should provide a fast measure rate of 10 msec, a high dynamic range to deal with fibre and sensor attenuation, low noise floor, suppression of ambient light and the possibility to interface it with a PC or process control system.

2. Measurement system

The only option to satisfy all these demands was a modular, microprocessor controlled platform.

It consists of a microcontroller, that is running code for generating the LED modulation at typically 5 kHz, a synchronized digital lock-in amplifier with good noise performance and high DC suppression to eliminate ambient light, as well as control options for the receiver blocks and digital interfaces for the user section.

The two receiver blocks feature specially designed variable gain transimpedance-amplifier (TIA) with a controllable gain from typically 3 kΩ to 4.8 MΩ, optional changeable up to 300 kΩ to 480 MΩ (low-noise configuration). The amplifiers use a DC cancellation technique that allows suppression of a huge part of the ambient light, before feeding the signal to a high resolution ADC and the digital lock-in amplifier. Inside the microcontroller an individual ADC and lock-in block is present for each photodiode. Both large-area photodiodes measure simultaneously, allowing sensor systems with two optical paths. The gain setting is so fast, that within one period of the 5 kHz modulation signal (200 µsec) the gain can be switched from 3 kΩ to 4.8 MΩ (full scale) with an accuracy of typically better 1%. Within a single 10 msec measurement block the microprocessor adopts the gain various times to give the best performance regarding noise, linearity and ambient light suppression using a special algorithm.

An additional fixed gain input can be used as monitor to supervise the LED operation.

Finally up to three LEDs can be installed on current drivers, capable of driving a modulation of 0.5 to 30 mA, even for devices with higher forward voltage as blue and UV LEDs. With some increase in noise the system is fast enough to switch and measure all three LEDs in one 10 msec timeslot, allowing multi spectral sensing.

A temperature sensor close the LEDs allows compensation of power drift as well as future use for digital compensation of the spectral change over temperature.

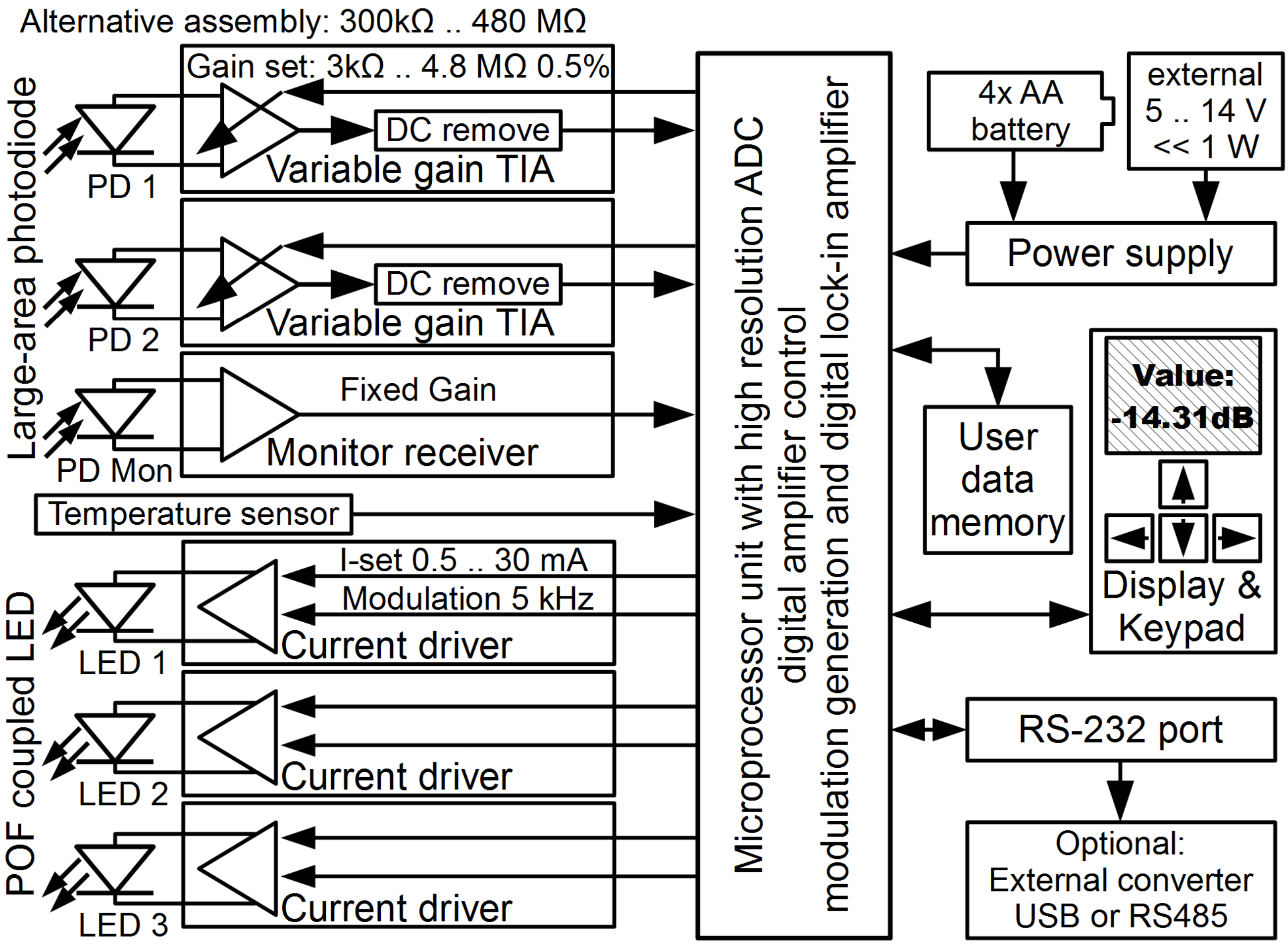


Figure 2. Block diagram of the measurement system in maximal configuration

On user side the system can be configured over a large-area display and keyboard. In addition an RS-232 port allows interfacing the device to a PC, e.g. by a USB converter or to a process control system, e.g. by a RS-485 converter. The configuration data is stored inside a device internal memory.

The software can be updated and changed by a bootloader, e.g. to a special firmware for custom applications.

Power supply runs from either 4 AA batteries or an external power supply from 5 to 14V. The power consumption is far below 1 W, even with all three LEDs installed at maximum current and display backlight. In normal configuration with one LED the typical power consumption is only ~250 mW including display.

3. System performance

The left diagram of figure 3 shows the maximum RMS noise in dB of the standard TIA assembly, reading one LED with 10 msec measurement rate. It is referenced to the average optical input signal in dBm. An optical attenuator was used to reduce the optical power of the LED. The noise floor is very flat with an increase below -50 dBm. If a lower measure rate as 10 msec is acceptable, the system can be used even beyond -60 dBm. Saturation of this receiver type is about +2 dBm. The optional low-noise receiver is 20 dB more sensitive with a little higher noise and saturation at -20 dBm.

The right diagram shows the immunity to ambient light, coupled in by a splitter in the fibre loop. Even with 10000x more external light than signal (-10 vs. -50 dBm) the influence on the measurement is near zero.

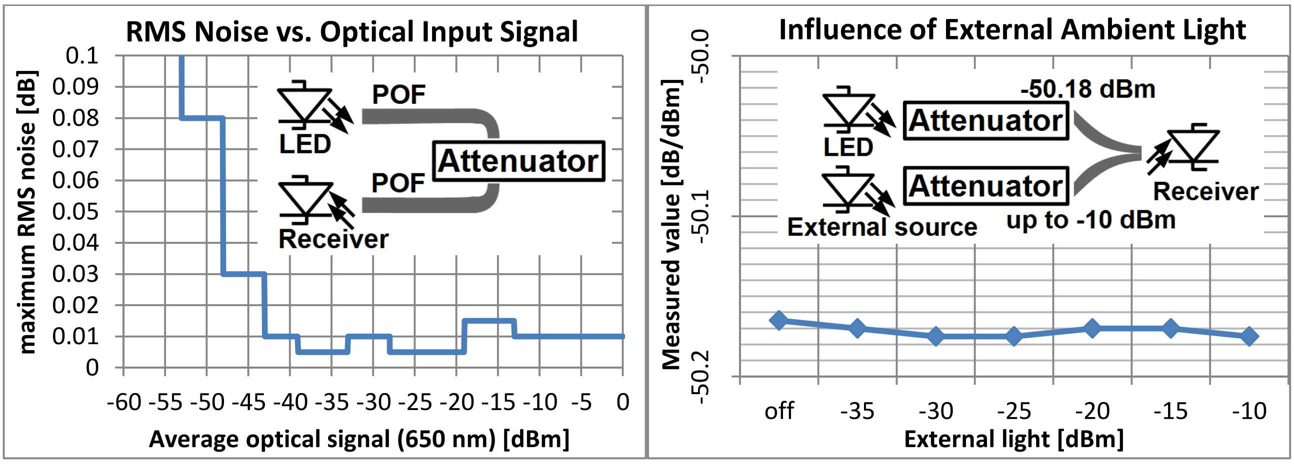


Figure 3. Left: Maximum RMS noise vs. optical input signal   Right: Influence of external light on the measurement

4. Example Applications:

4.1 POF Installation Tester

A very common problem we encountered was the measurement of POF cables itself. The specialized “POF Installation Tester” uses a 650 nm LED, running at absolute eye-safe 200 µW optical power. With a 300 msec measurement rate it allows to measure link attenuations up to -45 dB and external light up to -25 dBm with high accuracy. In addition it features the option to log and document measurements.

Figure 4. POF Link Analyzer in configuration as “POF Installation Tester” with USB cable and protective cover

4.2 Simplex Fibre System (Reflectometer) with low-crosstalk splitters

During the POF 2015 conference in Nuremberg we presented the paper "Polymer optical fiber (POF) based sensors for the measurement of elongation via a single fiber", evaluating mechanical movement and vibration.

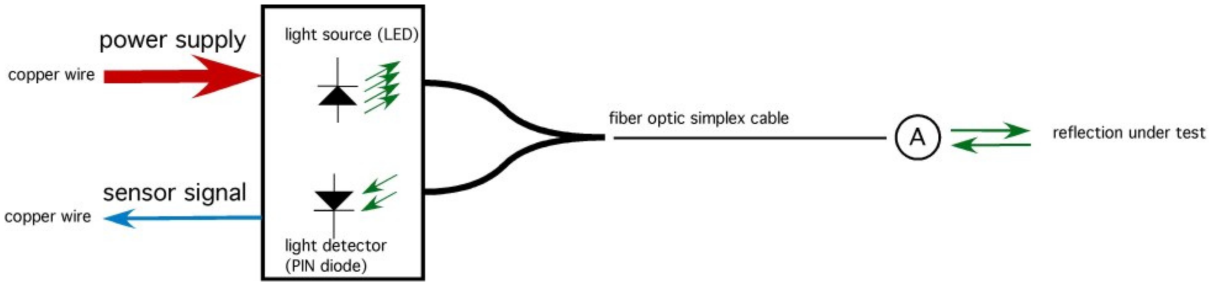


Figure 5. Simplex fibre optical sensor system

The new hardware platform is perfectly suited for this application, as it offers the possibility to further reduce crosstalk electronically as well as the use multiple LEDs and photodiodes.

Currently we are developing the option to measure the attenuation of a single POF from only one side, using a reflector on the fibre end, to save lots of time for qualification of POF data networks.

4.3 Multi LED configuration for wavelength depending sensor principles

With up to three LEDs and two optionally colour filtered photodiodes the POF Link Analyzer allows sensor principles using spectral effects and colour changes. These are for example colour measurement, chemical and biological analysis or even splitting the light and using multiple single wavelength sensors in one fibre loop.

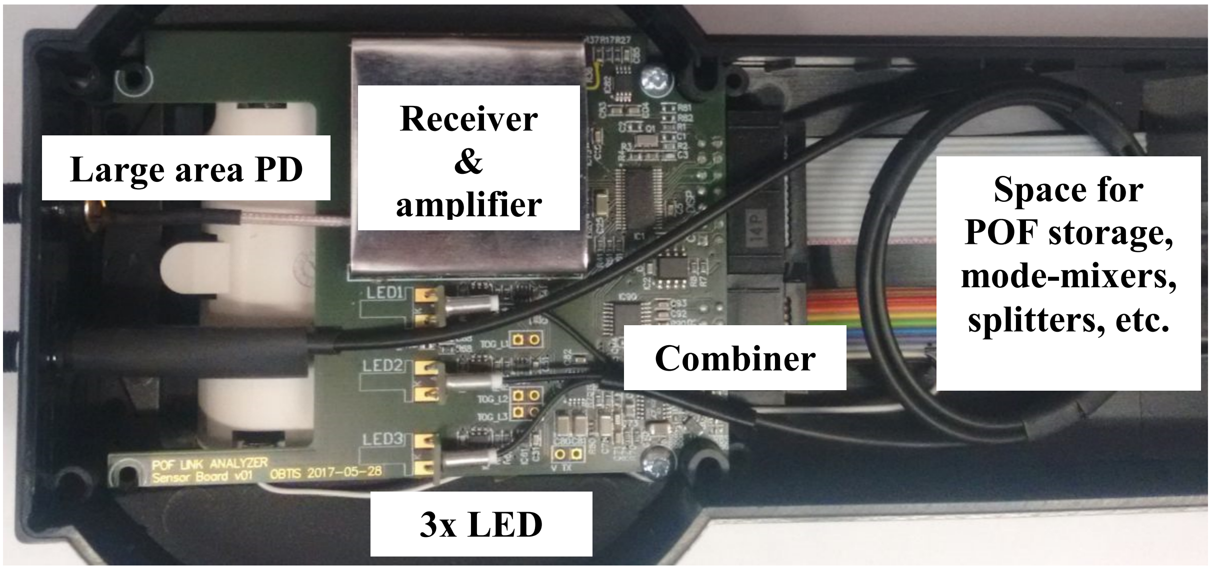


Figure 6. Hardware assembly of a three LED setup with red, green and blue LED and a combiner

One example of an all-optical temperature measurement was presented by Dr. Wolfgang Wildner in his paper "A Fiber Optic Temperature Sensor Based on the Combination of Epoxy and Glass Particles With Different Thermo-Optic Coefficients" [PHOTONIC SENSORS / Vol. 6, No. 4, 2016: 295–302].

5. Conclusion & Outlook

The presented measurement system "POF Link Analyzer" allows a very wide range of configurations for various applications. For example we are investigating the option to use a splitter and two receivers with different gains to boost the dynamic range over 80 dB while keeping the measurement performance.

With our partners we hope to be able to present even more challenging sensor applications in the future.