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Power over POF – A Short Overview

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Summary:

There are various applications in high voltage, explosive or high electromagnetic interfered environments that require sensors with an electrical isolation from other components of a system. The basics of possible solution, based on optically powered sensor links, were shown previously [1]. Because of different requirements for the applications, a variety of system approaches has been developed (available power for sensor purposes; length between the control node and the sensor; speed of transmitted data etc.). Key requirements and the current approaches will be discussed below.

Keywords: remotely powered sensors, galvanic isolation, sensor networks, polymer optical fiber, power over fiber

Introduction

Due to their application in automotive and consumer market, electronic sensors are versatile, mature, cost-efficient and can measure several parameters. However, many applications make it important to electrical isolate the sensors from other parts of the connected system. This is often necessary in high voltage or in high electromagnetic interfered environments, like for monitoring high-power semiconductors, monitoring systems in magnetic resonance imaging or controlling electric motors.

The needed full electric isolation can be achieved by remote optical powering (Power over Fiber). A simple and cost-effective version of power over fiber is using a Polymer Optical Fiber (POF) as light guide in comparison to the usually used Glass Optical Fiber (GOF). GOF always requires laser diodes as power source. The backward data link is built by specific transmitters and receivers using a second fiber or splitters. POF enables the use of LED as power and data sources. A unique feature of LED is the capability of light-to-electrical current conversion with a reasonable speed and efficiency [1]. Therefore, an extremely simple and economic sensor connection can be set up with two identical LED and one POF.

The two different concepts for a Power over Fiber with POF system including a data transmission from the sensor to the remaining system are shown in Fig. 1.

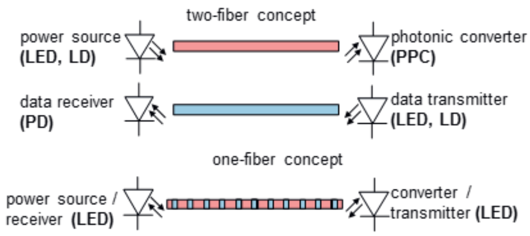

Fig. 1. Different concepts for power over POF systems.

One-fiber system

The one-fiber concept is based on a standard high power LED as power source and an identical LED as photonic power converter (PPC) (and as data transmitter and receiver in the backward direction). If the LED size matches to the fibers diameter, we can achieve efficient coupling into and out of the fiber. LED with different wavelengths can be used. These are red LEDs (usually based on gallium arsenide or gallium phosphide) or blue LEDs, based on gallium nitride.

The benefit using red LEDs is the higher mutual responsivity of around 0.1 A/W. However, due to the lower open circuit voltage (V_{OC}), of around 1.7 V, it is necessary to use some kind of voltage conversion system, like a step-up converter or an energy harvester. This results in an, even if more power efficient, more complex and therefore more expensive system. The wakeup time when powering after some shut down time might be long (seconds, up to minutes) dependent on the charge time for the used capacitors.

On the other hand, using a blue LED enables the possibility to direct start a microcontroller (in a few microseconds), since the open circuit voltage is substantially higher (usually about 2.4 V), which allows an operation without the risk of brownouts. Nevertheless, a capacitance and a step-up converter, at least behind the microcontroller, is still necessary. It stores the energy and rises the voltage high enough to use the converter LED as transmitter for the data transmission. However, the system is still much less complex regarding the components and the microcontroller can start-up directly, enabling the design of an all-in high responsive system.

Demonstration setups for one-fiber system

Our first system was designed for a few mW per sensor to be usable with several standard sensors over medium distances (see Fig. 2). To achieve this a special energy-harvesting component with a large capacitor is used. It uses a red high power LED as power source / Rx and an identical LED as PPC / Tx. The available power on the sensor decreases with the POF length (by about 0.2 dB per meter). Furthermore, it dependents on the duration necessary for data back-transmission with power supply offline. If no down time of the power supply for data transmission is considered, the maximal electrical power input is 9.5 mW (up to one meter fiber length). The drawback of this system is a long charge time of the capacitance of a couple of minutes as well as long measurement cycles due to the energy harvesting circuit.

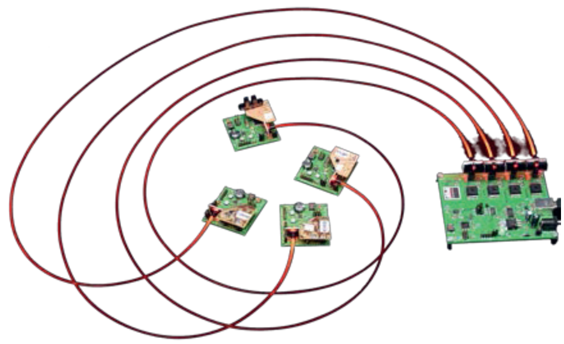

Fig. 2. One-fiber “Power over POF” demonstrator

A second system is optimized for high-speed measurements. It is based on a blue high power LED, which enables a concept with a fast starting microcontroller. It performs temperature measurements with a sampling frequency of 125 Hz. The controller is directly connected to the converter LED and a Step-Up Converter is used to provide the necessary voltage for the LED as transmitter. The drawback of this system is the limited energy available for a connected sensor system and in this very concretely setup, the limitation for an analog sensor.

Two-fiber system

The two-fiber concept consists of a light source and PPC with one fiber for energy transmission and a transmitter and receiver with a second fiber for the data transmission from the sensor to the central node. The benefit of this system is the constant power supply of the sensor board even during the data transmission. In addition, it is possible to use optimized components for data transmission. As power sources, high power LEDs with different wavelength, depending on the photonic converter on the sensor board, can be used. In addition, VCSEL or laser diodes can be used, if the PPC is IR sensitive, like a stacked converter. The benefit in this case is a much higher achievable voltage (up to 5 V).

Demonstration setups for two-fiber system

A realized example for a two-fiber system is a level sensor using a blue LED as power source and an InGaP photo diode (InGaP-PD), which was originally designed for multilayer solar cells, as PPC. For the data transmission, commercial 1 Mbd optical data communication components are used. The high efficiency of the PPC allows the system to function with a LED with only 20 mA current as power source. The drawback however is the high cost of the InGaP-PD.

Another investigated system is using two high red power LEDs as power source and converter. For data communication, due to simplicity, identical red LEDs were used. The system is designed to realize a fast, low cost temperature measurement with a sampling frequency of 1 kHz. The drawback of this system is the use of a special energy-harvesting chip, which results in a complex and expensive design. Other various systems contain e.g. Step-Up converter instead of the energy harvesting chip and bidirectional data communication between the sensor board and the central node, using red LED for power and data communication.

The newest developments are based around two-fiber systems using blue LED for power supply and commercial data communication components with red LEDs. This would allow systems without any voltage conversion. Furthermore, these systems should allow long fibers or sensor networks using only one board with, in this case, up to eight strain gauges.

References

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