Fusion Engineering and Design 96–97 (2015) 64–69

Contents lists available at ScienceDirect

Fusion Engineering and Design

journal homepage: www.elsevier.com/locate/fusengdes

Data acquisition remote node powered over the communications optical fiber

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A R T I C L E   I N F O

Article history:
Received 18 September 2014
Received in revised form 21 May 2015
Accepted 10 June 2015
Available online 21 June 2015

Keywords:
Power-over-fiber
Galvanic isolation
Remote data acquisition
Synchronous data acquisition
Nuclear fusion
High energy physics

A B S T R A C T

Large nuclear fusion reactors, like ITER, will have harsh electromagnetic environments nearby the machine. Foreseeing the necessity for special data acquisition remote nodes, on difficult access locations and as close as possible to the experimental devices, motivated the system design. The architecture is based on the power-over-fiber technology recent advancements and respective implementation aim is to attain a proof of concept for the fusion technology field and others, e.g., high energy physics, industry, etc. The design intends the replacement of traditional copper cables and power supplies, vulnerable to electromagnetic interference, by the communications optical fiber of the data acquisition remote node. Optical fibers provide galvanic isolation, immunity to noisy electromagnetic environments and simultaneously can supply power to the remote node electronics. System architecture uses a laser power converter (array of photovoltaic cells) to convert the laser light, from the optical fiber, into electricity. The generated electrical power is enough for powering the remote node electronics and optoelectronics, such as an ADC, a low power FPGA and an optical transmitter. The laser power converter is also used as the communications receiver and from which the acquisition clock is recovered, providing synchronism between remote data acquisition nodes. Descriptions of the system architecture, tested implementations and future improvements are presented.

1. Introduction

Commercial power-over-fiber (PoF) applications have started to be used mainly for remote monitoring of high voltage power networks [1]. PoF has evolved continuously through the last decades and the main components of such technology are Laser Power Converters (LPC), optical fibers and Vertical Cavity Surface Emitting Laser (VCSEL) diodes.

State of the art LPCs [2] have optical to electrical power conversion efficiencies around 50% and are starting to have an affordable cost. This can lead to the LPCs usage in nuclear fusion or high energy physics.

Unlike copper cables, optical fibers provide high voltage galvanic isolation, are immune to Electro-Magnetic Interference (EMI), provide high speed high distance communications and last, but not the least, optical fibers can carry energy. This mix of characteristics allows the implementation of remote data acquisition systems powered by laser light, avoiding the use of galvanic isolated power supplies normally vulnerable to the high magnetic fields of larger tokamaks.

Nowadays small laser diodes can generate enough photonic power to illuminate a LPC over long optical fibers. Also several laser diodes can be accommodated on printed circuit boards, with generous dimensions, as the ones of advanced instrumentation standards such as ATCA [3], MTCA.4 [4] or AXIe [5].

One possible application example, in the nuclear fusion arena, is data acquisition for the magnetics diagnostic of machines with long operation, like ITER. Magnetics diagnostics in larger tokamaks are normally connected to the data acquisition system by several copper cables and connectors across a long distance, which increases signal noise due to EMI and generates small signal offset voltages due to the metal junctions of cables and connectors. The metals junction voltage is temperature dependent (thermoelectric effect) and represents a serious problem on ITER, since magnetics diagnostic signals need to be integrated during the long operation time of the tokamak. The integration result will be affected by a huge error usually called drift [6].

Another problem is the necessity of galvanic isolation between signals normally accomplished using digital isolators and isolated DC–DC converters, as the ones used in the ATCA data acquisition boards at JET [7] or in the ATCA/AXIe boards for the ITER Fast Plant

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http://dx.doi.org/10.1016/j.fusengdes.2015.06.048
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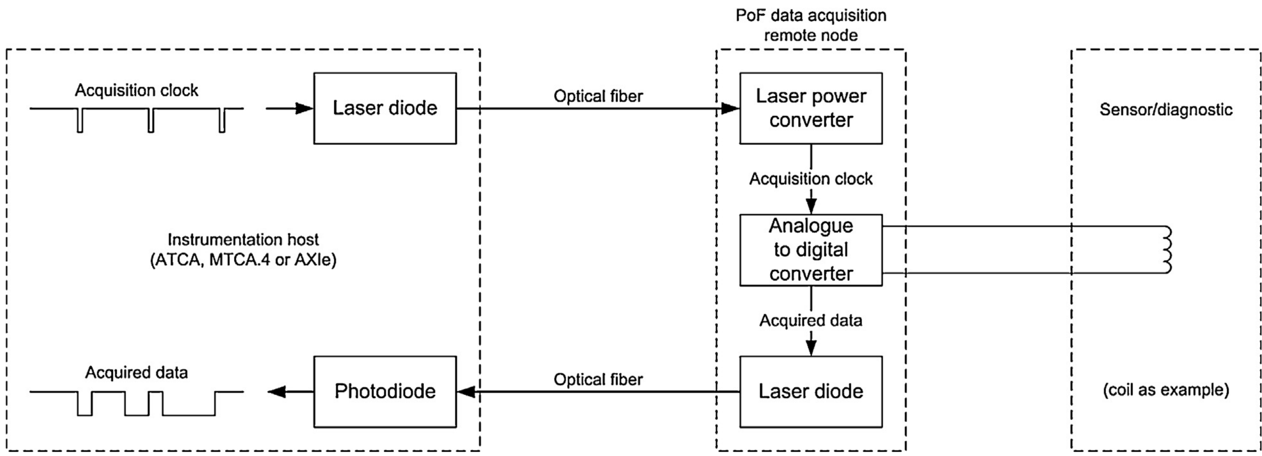

Fig. 1. Simplified system architecture.

System Controller (FPSC) prototype [8]. Typical isolated DC–DC converters used in data acquisition systems are vulnerable to magnetic fields above ~10 mT, starting to fail and not providing the needed reliability.

The above mentioned problems can be diminished if a PoF data acquisition remote node is used, since copper cables distances and connectors number are significantly reduced between the system and the magnetic coils of the diagnostic. Also isolated DC–DC converters are not needed anymore and the system can be built with non-magnetic components and hard radiation ICs.

The system prototype architecture, tests and future improvements are described in Sections 2–4, respectively.

2. System architecture

Conceptually the system architecture is very simple and is depicted on Fig. 1, the real implementation is slightly more complex and is explained in Section 3.

Essentially a laser sends light through a fiber optic to a LPC where is converted into electricity for powering the PoF remote acquisition node. The laser light is pulse modulated with a system clock, which is recovered from the LPC as the acquisition clock for the Analog to Digital Converter (ADC) of the remote node. The analog signal from the sensor/diagnostic is digitized by the ADC and sent to the host system. All PoF remote acquisition nodes are synchronous with the system clock.

3. Tested system implementations

Data acquisition systems in harsh environments, where temperature, EMI and radiation are high, need to be as simple as possible to be reliable. The balance between functionality and reliability depends on the application. To verify the system architecture feasibility three different implementations (Fig. 2), with increasing complexity, were tested and are described, respectively, in Sections 3.2–3.4. Section 3.1 explains the LPC power and clock recovery circuit.

3.1. LPC power and clock recovery circuit

To synchronize the data acquisition of all PoF remote nodes a system clock is sent to the LPC by laser pulse modulation (estimated clock frequencies up to ~5 MHz, LPC and modulation technique dependent). The chosen ADC (ADS7945) is a low power device with 2 MSPS, 14 bits resolution and serial interface. The ADC needs a 2 MHz clock for pacing the acquisition and a 40 MHz clock to generate the serial data. On all three different PoF remote node implementations the 40 MHz clock was generated from the 2 MHz acquisition clock recovered from the LPC.

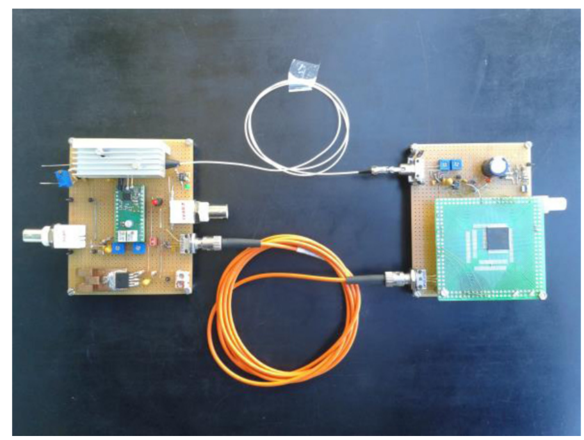

Fig. 2. Prototype for testing different implementations.

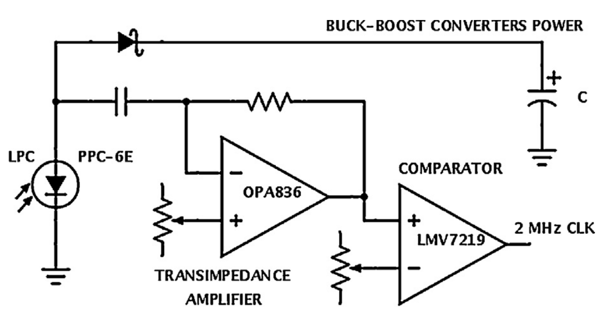

Fig. 3. Circuit to recover the 2 MHz acquisition clock and power generation for the buck-boost converters.

The circuit to recover the 2 MHz acquisition clock is shown on Fig. 3. A transimpedance amplifier based on the low power operational amplifier OPA836 combined with the low power comparator LMV7219, constitute a simple and efficient circuit to retrieve the clock from the LPC.

The LPC (PPC-6E) can produce up to 500 mW of power and above 6 V of output voltage. To generate the required power rails for the Integrated Circuits (IC), of the PoF remote acquisition node, buck-boost converters TPS63000 and TPS63060 have been utilized.

Buck-boost converters have high efficiencies and allow the automatic generation of defined output voltages from higher or lower