A study of the frequency characteristics of a photovoltaic convertor PPC-4E

Jovan Shikoski,*[1] Rumen Arnaudov,[1] and Tinko Eftimov [2]

[1] *Technical University of Sofia, 8 Kl. Ohridski Blvd, Sofia 1700, Bulgaria*
[2] *Université du Québec en Outaouais, Canada*

Abstract— The paper considers the possibility to use the fiber-compatible photovoltaic converter PPC-4E simultaneously as a detection photodetector for the combined transmission of photonic power and optical communication signals along a single fiber. We have studied the frequency transfer characteristics of the specialized converter PPC-4E designed primarily for photovoltaic conversion.

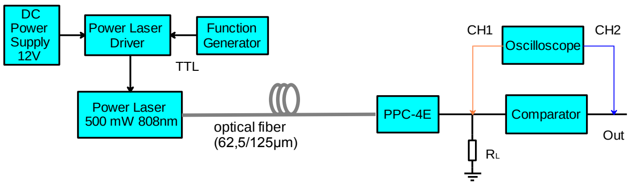

Fig.1. Optical set-up for the study of the frequency characteristics of the PPC-4E photovoltaic converter.

Introduction

It is well known that optical fibers can transfer not only communication data but photonic energy which is converted to electrical at fiber output by means of a fiber-coupled photovoltaic converter [1]. The advantages of photonic energy transmission are the immunity to electromagnetic interference, short-circuiting, sparking [2]. In addition, optical fibers are smaller in size and due to lower losses per unit length can transfer energy over considerable distances [3]. Optical cables are more resistant to humidity and corrosion [4]. The technology is used for systems for remote control, for powering of sensing networks and even for medical applications [5, 6].

In the present paper we present the results for the demodulation detecting characteristics of the fiber-compatible photovoltaic power converter PPC-4E which data is unavailable from the manufacturers [7]. The final objective is to simultaneously transmit both photonic power and communication data over a single fiber. The studies performed showed that the photovoltaic converter can detect signals of up to 3 MHz modulation frequency. This leads to the conclusion that apart from being used as a photovoltaic converter PPC-4E can simultaneously be used as an optical communication data detector.

Basic scheme

The set-up for the simultaneous transmission of photonic energy and communication data along a single fiber to the photovoltaic converter is shown in Fig. 1.

The laser driver is powered by a 12V/1.2A power supply to allow for a 500 mW optical power.

The functional generator provides a series of TTL signals at a given repetition frequency that are applied to the digital input of the laser driver to modulate the high power laser diode emitting at 808 nm. A 62.5 μm multimode optical fiber of 55 m length transmits the 500 mW optical signal to the PPC-4E photovoltaic converter. A load resistance R_L=50Ω is connected to its output. The voltage across the resistance is the output signal from the photovoltaic convertor and is next applied to channel 1 (CH1) of an oscilloscope. An increase in the frequency causes an increase of signal distortion which leads to an increase of the bit error rate (BER). A comparator is then used to regenerate the form of the initial signal that is connected to channel 2 (CH2). The comparison between the signal from the photovoltaic output (CH1) and the regenerated signal (CH2) permits and estimation of its quality.

Measurement results

Distortions of the front shape and the phase of the signal at the photodetector are caused by the processes of generation, diffusion and of the carriers in the semiconductor. The distortions of the output signal from the detector increase with the modulation frequency. In Fig. 2 are shown the output signal from the converter (CH1) and from the output of the comparator (CH2). For the standard frequencies of up to 400 kHz no significant distortions are observed and no bit errors arise. At 460.8 kHz (Fig. 2) weak distortions in the upper front part of the output pulse from the PPC are observed, while that from the comparator remained unchanged. At 1MHz (Fig. 3) the rise time increases which decreases the slope of the rise front of the pulse from the PPC.

[1] E-mail: jovanshiko@abv.bg;
[2] E-mail: ra@tu-sofia.bg
[3] E-mail: tinko.eftimov@uqo.ca

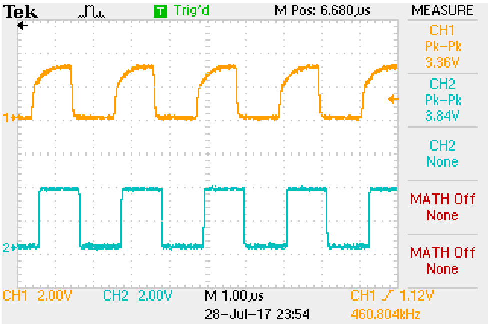

Fig. 2. Output signals from the PPC-4E and the comparator at 460.8kHz

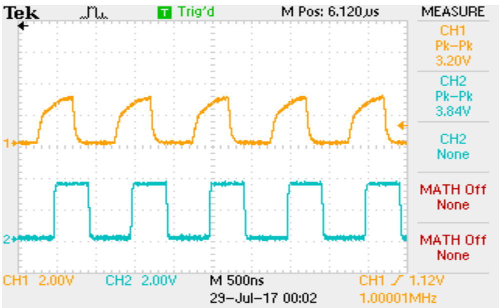

Fig. 3. Output signals from the PPC-and the from the comparator at 1MHz

The signal shape from the comparator remains unchanged, but a phase shift of 45° with respect to the PPC is observed.

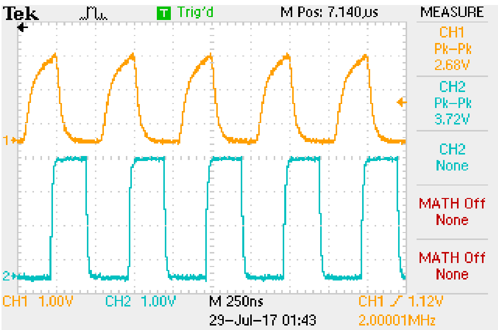

Fig. 4. Output signal from PPC-4E and the comparator at 2MHz.

At a frequency of 2MHz (Fig. 4.) the PPC generates practically triangular pulses but the signal from the comparator maintains a rectangular shape the phase shift being 90°. At a frequency of 3MHz (Fig.5) the distortion of the output signal from the PPC is further increased. Although at this frequency weak distortions of the regenerated signal compared to that from the comparator are observed the pulses ‘1’ and ‘0’ are well defined. The phase difference between both signals are 180°.

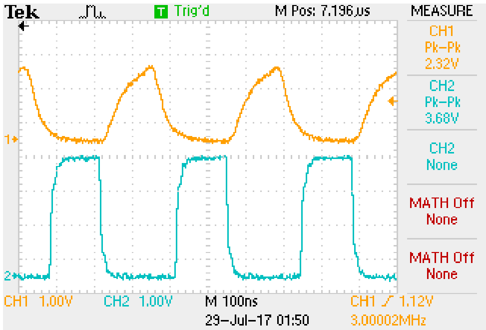

Fig. 5. The output signal from the PPC-4E and from the comparator at 3 MHz.

The results show that for frequencies up to 3 MHz the signals generated by the PPC can successfully be regenerated by the comparator and that the PPC-4E can be used as a photodetector (photoreceiver).

The frequency response f_c at – 3dB can be evaluated from the rise time τ_r from 0.1 to 0.9 level, as $f_c = 0.35/\tau_r$ [9]. From Fig. 2 we can evaluate $\tau_r \approx 0.35$ µs, which yields $f_c \approx 1$ MHz,at which we obtain a 45° phase shift between comparator output and photovoltaic output.

A study of the Bit Error Rate (BER)

An important characteristics of communication system is the probability for bit error (Bit Error Rate – BER) [8].

Fig. 6 shows a scheme of the experimental set-up for a BER measurement of the PPC-4E convertor.

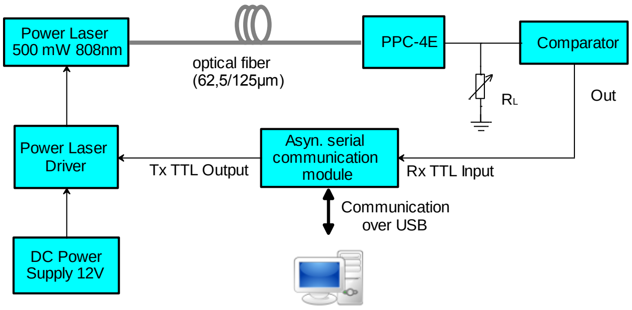

Fig. 6. Experimental set-up for BER measurement.

Using a UART module transmission of data is performed serially and asynchronously along the optical fiber. The UART module is linked via an USB port to a computer to measure the BER. Asynchronous transmission avoids the problems associated with the phase shifts of the signals. The computer transmits through an asynchronous serial communication module a sequence of 10 bits: 0010110101. The letter ‘Z’ is chosen because its ASCII represents a series ‘1’s and ‘0’s combined with a change of signal phase shift of the last four bits with respect to the first four bits. A sequence of

32 MB is transmitted to the input of the driver. The optical signals from the high power laser are transmitted to the PPC-4E module via a multimode fiber. The output signal is picked up from the load resistance R_L of variable value whose shape is regenerated by the comparator. The regenerated signal from the comparator is applied to the receiver of the asynchronous communication module. The computer compares the transmitted to the received bits in every byte in the sequence of 3.2. MB. At the end of transmission of the whole series of bits, the computer after comparison of transmitted and received symbols counts the number of errors.

Table 1. The number of bit error for different loads.

BER for a load R_L	Bit Rate, Kbit/s			
	230.4	460.8	576.0	960.0
R_L=1000Ω	0	0	2 (5.96x10^{-8})	20 (59.6x10^{-8})
R_L=500Ω	0	0	3 (8.94x10^{-8})	10 (29.8x10^{-8})
R_L=100Ω	0	0	2 (5.96x10^{-8})	5 (14.9x10^{-8})
R_L=50Ω	0	0	0	1 (2.98x10^{-8})
R_L=25Ω	0	0	0	3 (8.94x10^{-8})
R_L=10Ω	0	0	58 (172.8x10^{-8})	–

The BER measurements were performed at frequencies standard for microcontrollers: 230.4 kHz, 460.8 kHz, 576 kHz and 960 kHz.

No measurements were performed for frequencies above 960 kHz since the asynchronous serial communication module does not support higher frequencies. The number of bit errors are presented in Table 1. From the results presented it can be concluded that the maximum bit rate at which the photovoltaic converters reliably can receive data at 960 kbit/s for a load of 50Ω

The BER is directly related to the SNR (Signal-to-Noise-Ratio) since the reason for the appearance of bits are noises of various nature. The eye-diagram shows the noise level and the jitter. Fig. 6 presents the eye-diagram of the photovoltaic using MATLAB visualisation for the reception of signals at 960kbit/s. We see that the eye is open at a maximum which implies that the noise level and the time jitter are low.

This shows that PPC-4E can be used as a photodetector for the reception of data of rates up to about 1 Mbit/s.

For a practical proof of the studies a test was performed in which a multiple sequence of the following quotation of Albert Einstein was transmitted: "No amount of experimentation can ever prove me right; a single experiment can prove me wrong“. The text was received and exhibited on the screen without any error at a bit rate of 960kbit/s.

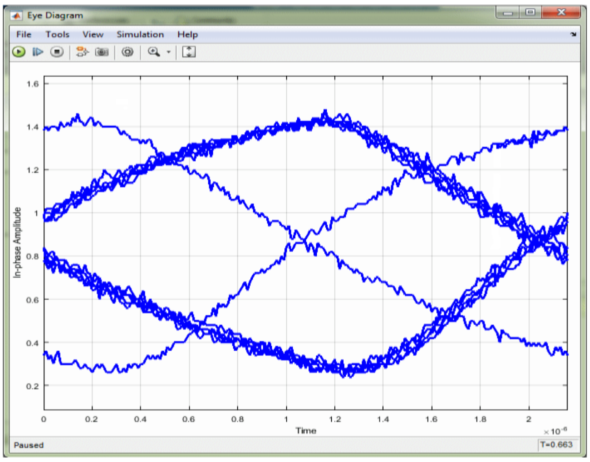

Fig. 6. Eye pattern for a bit rate of 960 kbit/s

Conclusion

The experiments performed allow us to conclude that the photovoltaic converter PPC-4E can detect signals moduated at frequencies of up to 3 MHz for a load of R_L=50 Ω. At this frequency the output signal can be regenerated by a comparator but phase shifted by 180° that must be accounted at the receiver. The measured BER for a variety of bit rates and load resistances shows that the photovoltaic converter PPC-4E can receive data for a load of 50Ω at rates of up to 960 kbit/s, i.e. about 1 Mbit/s. The measured BER is 2.98x10^{-8}.

The studies performed show that the fiber-compatible photovoltaic converter PPC-4E can simultaneously be used to convert photonic into electric energy and detect optical signals at a rate up to 1 Mbit/s along a single optical fiber.

References:

[1] Powering Remote Data Links over Fiber, www.lumentum.com, Lumentum LLC, 2015.
[2] Basanskaya, A.: Electricity over Glass. Spectrum, IEEE, Vol. 40, No. 10, page 18, 2005.
[3] Cohen, M.: Power-over-fibre drives remote data exchange. OPTO and Laser Europe, pages 27-29, 2006.
[4] Yasui, T.; Ohwaki, J.; Mino, M.; Sakai, T.: A Stable 2-W Supply Optical-Powering System. 28th Photovoltaic Specialists Conference, pages 1614-1617, 2000.
[5] Werthen, J.-G.: Powering Next Generation Networks by Laser Light over Fiber. Optical Fiber communication/National Fiber Optic Engineers Conference, pages 1-3, 2008.
[6] Iniewski K., Medical Imaging: Principles, Detectors and Electronics, p. 292, New Jersey, 2009.
[7] Power-Over-Fiber Kit, www.lumentum.com, Lumentum LLC, 2015.
[8] Kartalopoulos, S., Optical Bit Error Rate: An Estimation Methodology (2004) Willey- IEEE Press.
[9] Electronic Devices and Circuits: Discrete and integrated, Chapter 14 Active filters, Denton J. Daily, Prentice Hall, 2001.

