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ScienceDirect

Procedia Engineering 168 (2016) 1714 – 1716

Procedia Engineering

www.elsevier.com/locate/procedia

30th Eurosensors Conference, EUROSENSORS 2016

Low-Cost Discrete Off-The-Shelf Components 1MHz Analogue Lock-In Amplifier for Fast Detection of Organic Compounds Through Pulsed Lasers

Andrea De Marcellis[a,]*, Elia Palange[a], Nicola Liberatore[b], Sandro Mengali[b]

[a]*University of L'Aquila, Department of Industrial and Information Engineering and Economics, 67100 - L'Aquila, Italy*
[b]*Electro-Optics Research Centre, CREO Consortium, 67100 - L'Aquila, Italy*

Abstract

We report on a low-cost analogue Lock-In Amplifier (LIA) designed to measure amplitude variations of 100ns pulsed signals at operating frequencies f_0 up to 1MHz. The fabricated prototype PCB, implemented through discrete off-the-shelf components, allowed to validate the solution and to perform circuit testing and characterisations. The LIA architecture is simple and based on the classic phase-sensitive synchronous demodulation technique including two different amplification stages together with suitable filtering blocks that allow setting the instrument gain, sensitivity and resolution. With respect to conventional LIAs typically working at lower operating frequencies, the reported solution provides also high-speed DC output of about 1ms. By employing short voltage pulses, the LIA is capable to detect fast and small variations of the signal amplitude envisaging its use in sensor applications to measure reduced variations of chemical and physical phenomena through high-speed systems with very small time constants.

Peer-review under responsibility of the organizing committee of the 30th Eurosensors Conference

Keywords: Analogue Lock-In Amplifier; Fast Detection; Chemical and Organic Compounds; Pulsed Laser System.

1. Introduction

Sensors are able to reveal the presence of organic and inorganic compounds by probing some of their chemical/physical properties and converting them into "electrical" signals whose amplitude can be very small and

* Corresponding author. Tel.: +39 0862 434424; fax: +39 0862 434403.
E-mail address: andrea.demarcellis@univaq.it

Peer-review under responsibility of the organizing committee of the 30th Eurosensors Conference
doi:10.1016/j.proeng.2016.11.497

also buried into noise. In particular, fast detection of dangerous gases and toxic substances is especially important for safety and environmental applications [1-4]. In this regards, the optical sensing of absorbing substances are generally performed by accurate measurement systems based on phase-sensitive synchronous demodulation technique, as LIAs [5-8]. These instruments permit to enhance the detection sensitivity and resolution as well as to improve the Signal-to-Noise Ratio allowing for the measurement of small AC signal amplitudes (and/or their small variations) modulated at an operating frequency f_0 providing, as output signal, a proportional DC voltage level. Only few commercial analogue and digital LIAs are able to work at high operating frequencies (also up to hundreds of MHz) but at very high costs, sizes and weights so resulting not suitable for portable sensor systems. On the other hand, *ad-hoc* solutions reported in literature are generally cheap, compact and lightweight but are mainly designed for low frequency operations with very high response times [9-12].

For these reasons, we propose here a simple, small, low-cost, analogue LIA capable to measure amplitude variations of pulsed signals at operating frequencies f_0 up to 1MHz with a response time of about 1ms.

2. The proposed circuit architecture and its experimental characterisation

In Fig.1 is reported the block scheme of the designed LIA, whose architecture is based on the phase-sensitive synchronous demodulation technique, and Fig. 2 shows the fabricated prototype PCB employing commercial discrete off-the-shelf components powered at ±12V. The circuit includes two different amplification stages that, together with a low-pass filter, allow setting the instrument gain, sensitivity, resolution and response time. The PCB has been employed to validate the proposed LIA solution and to perform the circuit testing and characterisations. In particular, the LIA has been used to detect amplitude variations of short voltage pulses at the operating frequency f_0=1MHz. The electrical characterisation is reported in Fig.3 showing the variation of the output DC signal V_{OUT} as a function of the change of the amplitude of the input pulsed signal V_{IN} provided by an external signal generator. The achieved sensitivity is about 40[V/V] setting a LIA total gain to 36dB and the low-pass filter cut-off frequency to 860Hz providing a LIA response time of about 1ms. The reported results demonstrate the LIA capabilities to be employed in electronic and optoelectronic instrumentations for detecting fast and small variations of signals coming from sensors designed to reveal dynamics of chemical and physical phenomena as well as to measure the presence of substances even at very low molar concentrations.

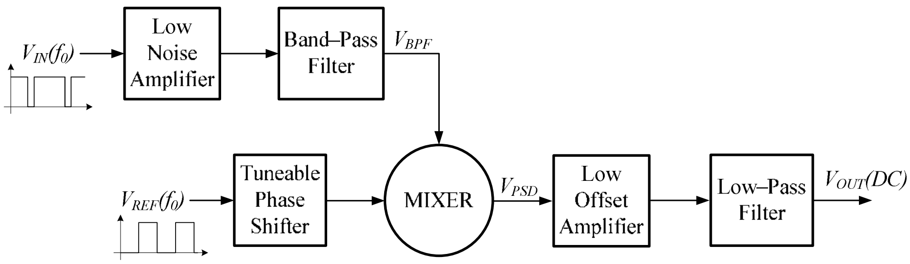

Fig. 1. Block scheme of the proposed LIA.

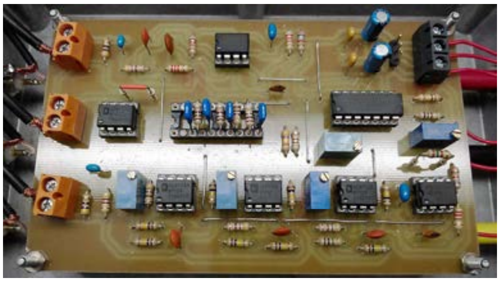

Fig. 2. Prototype PCB fabricated with commercial discrete off-the-shelf components.

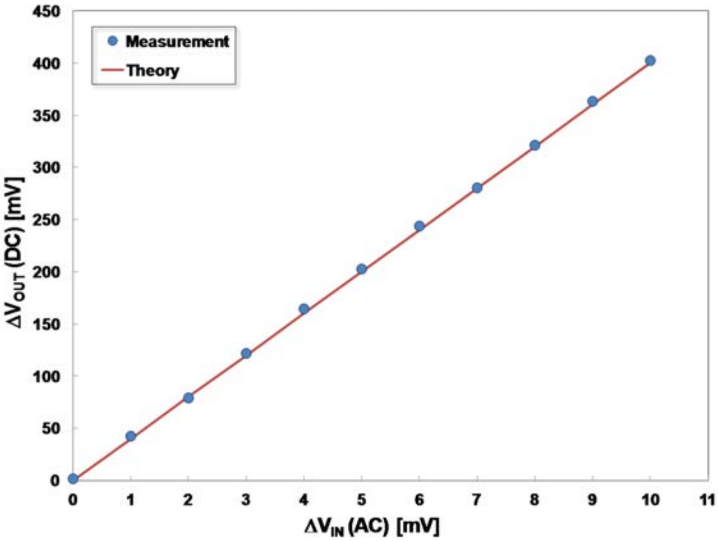

Fig. 3. Measurement of the variation of the output DC signal V_{OUT} as a function of the amplitude change of the input pulsed signal V_{IN}.

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