INVESTIGATION OF A FLAME'S DYNAMIC PARAMETERS IN 2 - 3 μM SPECTRAL RANGE

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In order to design, implement and control the flame sensor systems, it is needed information for the electrical signals according the flame's physical parameters. The behaviour of the signals generated by an open-air flame is experimentally investigated using the following circuit. The flame radiation is focused over a PbSe photoresistor, which is sensitive in 2 - 3μm spectral range. The photoresistor is connected to amplification circuit As can be seen on the figure, there are additional amplification stage that is used to increase only the AC component of the signal. Both electrical signals are digitized by ∑-Δ ADC. Personal computer controls the ADC in his turn. The data stored by various flame sources are statistically manipulated using the software package Mathcad. In this paper the methodological steps needed to accomplish experiments for various flame sources are presented in details. The design and implementation of hardware configuration and software code are also considered. To illustrate the dynamic behavior of the signals the presented results are shown in terms of valuation of the autocorrelation function and power spectrum of the measured electrical signals.

Keywords: Flame, PbSe photoresistor, 2 - 3μm spectral range, autocorrelation function, power spectrum.

1. INTRODUCTION

With the advent of digital processing techniques based on monitoring and characterization of combustion flames have developed rapidly in recent years. The physical characteristics of the flame in an industrial furnace, such as geometrical and luminous profiles, temperature distribution and flicker frequency, provide important information on the quality of the flame, and consequently the performance of the combustion process. The recent trend of using low quality fuel and biomass has been reported and the combustion engineers are experiencing a range of combustion problems including poor flame stability, low combustion efficiency and high pollutant emissions. To meet increasingly stringent standards on energy saving and pollutant emissions, advanced technologies for the monitoring and characterization of the flame have become highly desirable [2].

Appearing of flame is connected with emitting the electromagnetic radiation in spectral field dependent on characteristics of burning material. Radiating the energy is changeable quantity in the time and it depends on the conditions in which the flame burns.

In order to design, implement and control the flame sensor systems, information for the electrical signals according the flame's physical parameters is required. The behavior of the signals generated by an open-air flame is experimentally investigated using the following circuit lease comply with these requirements:

2. EXPERIMENTAL SETUP

The flame radiation is focused over a PbSe photoresistor, which is sensitive in 2 - 3μm spectral range. The photoresistor is connected to amplification circuit.

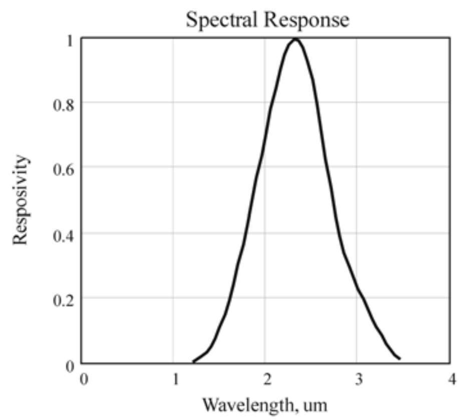

Fig. 1. Spectral response of the used photo resistor

As it can be seen from the figure, there is additional amplification stage that is used to increase only the AC component of the signal. The Σ-Δ ADC digitized both electrical signals. A personal computer controls the ADC performance. The data gathered as a result of conditional operating of various flame sources is statistically proceed using the software package MathCAD.

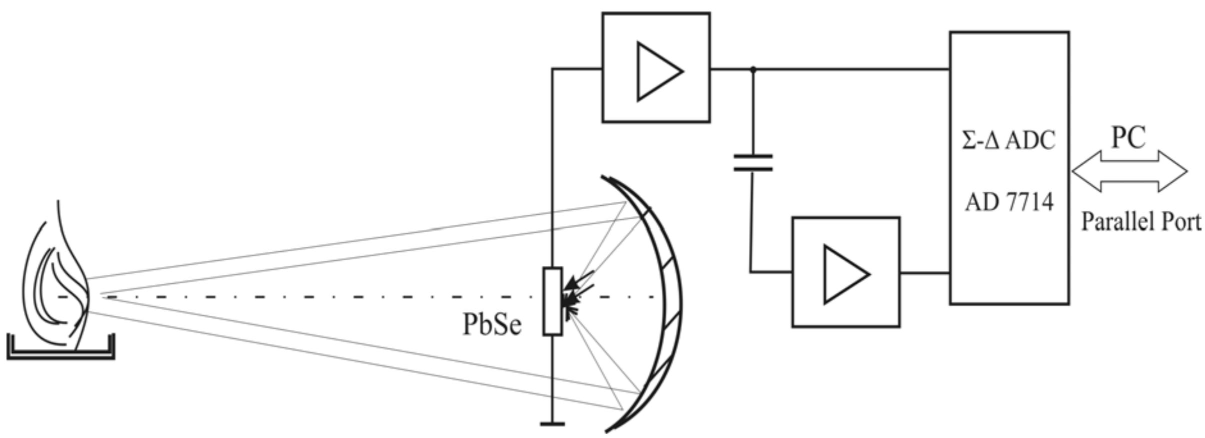

Fig. 2. Experimental setup

3. THE MEASUREMENT MODULE

Architectures incorporating switched-capacitor and sigma-delta technologies have produced low-cost, low-power, and accurate integrated systems ideal for portable and distributed measurement applications. Integrated systems afford the designer the opportunity to place the signal conditioning necessary for direct sensor interface on a chip, which reduces analog circuit design and layout complexity. These systems also offer better control of specifications and error budgets than those made up of discrete components. Sigma-Delta ADC are increasingly widely used in precise sensor systems realization. A series of firms offer schemes with similar architecture and parameters. In our application a measurement module based on sigma-delta ADC AD 7714 is used.

The AD7714 based Data Acquisition Module gives you the ability to amplify and sample low-level signals at various frequencies directly from the sensors. Its analog to digital converter, Analog Devices' AD7714, is a complete analog front end for low-frequency applications providing either, three fully-differential or five pseudo differential input channels. The device accepts low-level signals directly from a transducer and outputs a serial digital word. It employs a sigma delta technique to realize up to 24 bits of no missing codes performance. Included on the measurement module are a +2,5 V ultra high precision reference and digital buffers to buffer signals to and from the edge connectors.

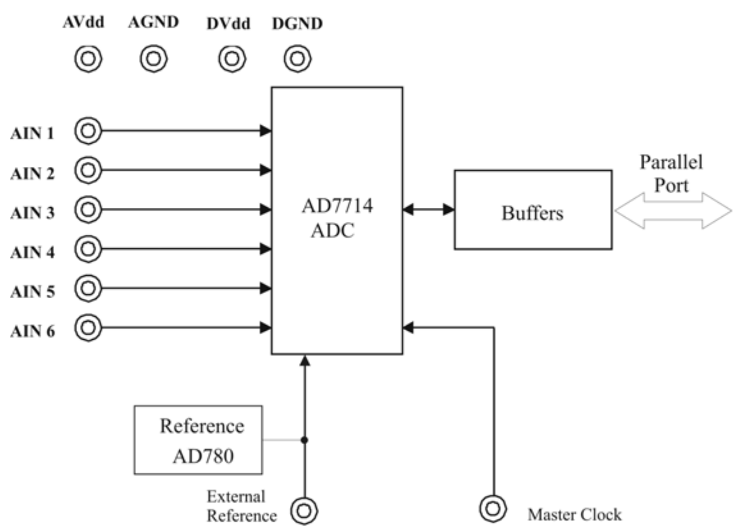

Fig. 3. The measurement module

High-level software routines allow you to initialize, calibrate, configure, and control the measurement. Once commanded to start converting, the analog to digital converter continually samples and converts at a fixed rate. You can read the output once, or store each sequential conversion to a memory buffer. You must sample one channel at a time; changing channels requires restarting the conversion process.

4. EXPERIMENTAL RESULTS

The experiment involves measurements resulted from different types of open flame. The signal output is stored in a file used in mathematical computations based on the mathematical application developed by MathCAD. Final results of the mean and root mean square signal output are shown in the following table:

Table 1. Statistical parameter of measured electrical signals.

Flame	**E_{mean}, mV**	**σ_E, mV**
Paper 100x100mm	27	51
Wood	29	62
Cardboard	10	53
Alcohol	10	80
Absence of a Flame	32	36

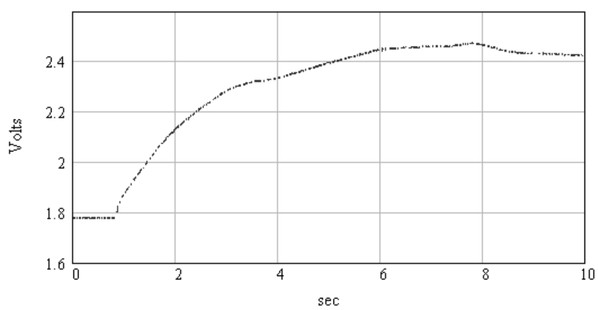

Fig. 4. DC signal of burning paper sheet with dimensions 100x100 mm

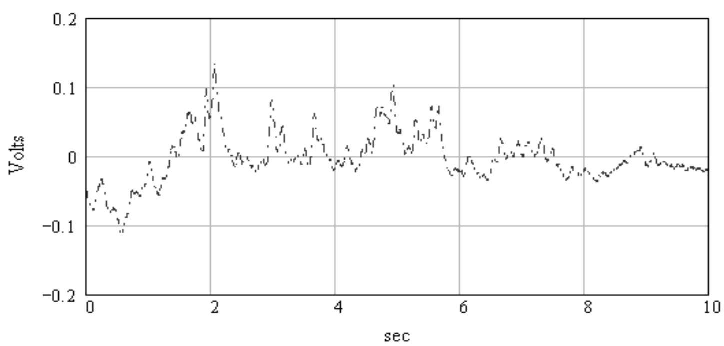

Fig. 5. Signal produced by the flame of burning paper sheet

The experimental results presented in Fig.5 show many times increase of emission received of photoreceiver after appearing the flame. We have two components: DC component and faster changeable component. The calculated power spectral density of the signal in the environment of MatCad shows a concentration of the power for frequencies up to 10Hz (Fig 6).

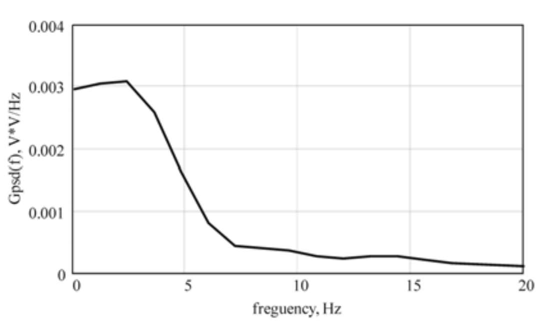

Fig. 6. Power spectral density of a signal generated by the burning paper sheet.

The experimental signals, the mathematically calculated Autocorrelation function, as well as the power spectral density for the flame with different nature are shown in Fig.7 — Fig.10.

The signal of burning wood piece is almost similar with the aforementioned one:

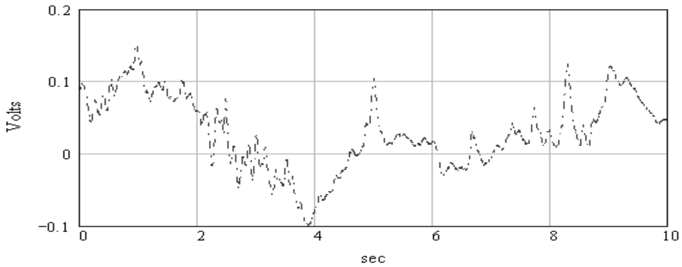

Fig. 7. Signal produced by the flame of burning wood piece

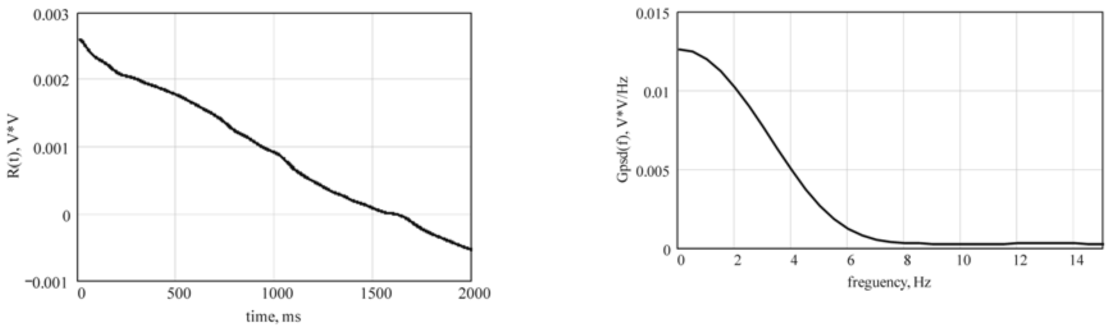

Fig. 8. Autocorrelation function and power spectral density of a signal generated by the burning wood piece.

In case of absence of a flame the graphical function is different and the amplitude is smaller.

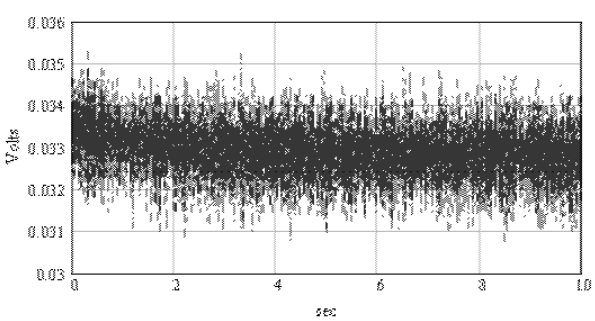

Fig. 9. Signal generated in case when open flame is not presented.

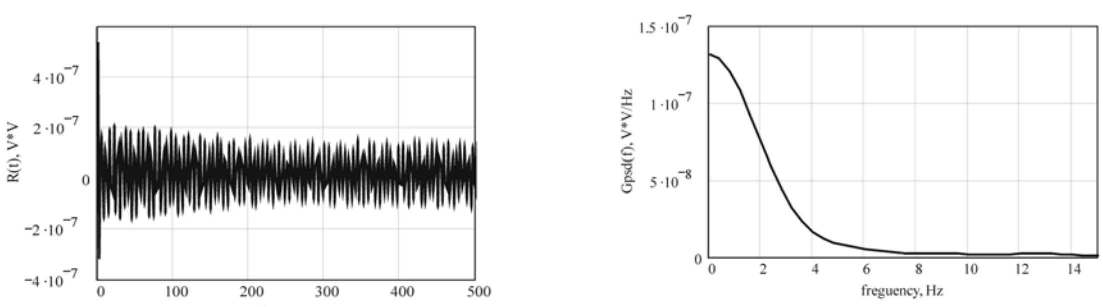

Fig. 10. Autocorrelation function and power spectral density of signal when flame is not presented

5. CONCLUSION

Vision based instrumentation system have been developed for the 2D monitoring and characterization of combustion flames. The system, based on the modern optical sensing and digital image processing techniques, is capable of determining dynamic parameters of a flame. The experimental results demonstrate that the techniques have provided an effective means for monitoring and characterizing the physical parameters of flames on an on-line, continuous basis.

In the experimental set up a PbSe photo resistor with sensitivity in the 2 – 3 mm spectral range is used. The results are used in mathematical computation and represent a significant difference in power spectral density in case of presence or lack of flame. The main part of the energy of the signal is concentrated in the range 8 – 10 Hz.

6. REFERENCES

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