ISSN 1726-5479

SENSORS & TRANSDUCERS

9/10
vol. 120

TEDS Sensors, IEEE 1451 Standards

International Frequency Sensor Association Publishing

Sensors & Transducers

Volume 120, Issue 9, September 2010

www.sensorsportal.com

ISSN 1726-5479

Contents

Volume 120
Issue 9
September 2010

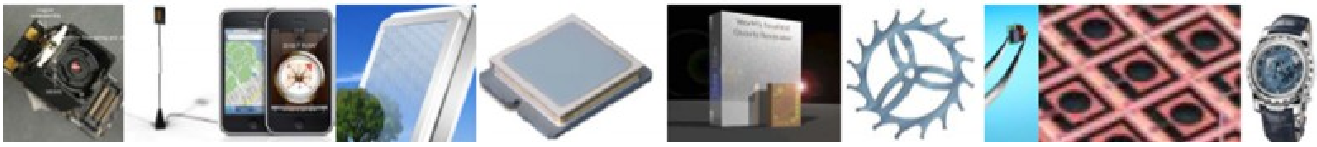
www.sensorsportal.com

ISSN 1726-5479

Research Articles

Authors are encouraged to submit article in MS Word (doc) and Acrobat (pdf) formats by e-mail: editor@sensorsportal.com
Please visit journal's webpage with preparation instructions: http://www.sensorsportal.com/HTML/DIGEST/Submition.htm

International Frequency Sensor Association (IFSA).



Sensors & Transducers Journal, Vol. 120, Issue 9, September 2010, pp. 107-118

www.sensorsportal.com

Sensors & Transducers

ISSN 1726-5479

http://www.sensorsportal.com

Noise Feature Analysis in Pulse Temperature Modulated MOS Gas Sensors

[1]Nimisha Dutta and [1,2]Manabendra Bhuyan
[1]Dept. of Electronics and Communication Engineering
Tezpur University, Napaam, Dist-Sonitpur, Assam, Pin-784028
E-mail: [1]nimisha.dutta0@gmail.com, [2]manab@tezu.ernet.in

Received: 26 June 2010 /Accepted: 14 September 2010 /Published: 27 September 2010

Abstract: MOS gas sensors are always affected by noise mostly due to thermoelectric and environmental reasons. Operating the sensor using modulating type of temperature profile becomes attractive due to its higher discriminating power, however the immunity of the sensor to noise under such conditions has not been attended so far. Experimental validation of noise immunity of three MOS gas sensor under pulse modulated heater voltage has been performed. Dependency of noise of MOS gas sensor on the pulse modulated heater voltage has been verified by FFT, probability distribution function (PDF) and noise histogram analysis. *Copyright © 2010 IFSA.*

Keywords: Electronic Nose, Gas-sensors, Noise analysis.

---

1. Introduction

Electronic nose (E-nose) is an Intelligent Sensor based device, which mimic the sense of smell of human nose (olfaction).It uses an array of gas sensors with different selectivities towards the various classes of compounds, and the composite signal of the array is used in conjunction with chemometrics for the classification and identification of classes of the samples. Electronic noses are more widely used in environmental monitoring, food production and medicine such as odour evaluation. The response of all the sensors in the e-nose together constitutes a unique profile that gives the “fingerprint” of odor.

The noise generated in the gas sensor array may result in inaccurate cluster analysis of the tested odour [1]. Two basic types of noise such as thermoelectric noise and environmental noise mostly exist in gas sensors. Another form of noise is interference from other signals due to inadequate shielding and/ or ground loops. A major problem of gas sensors is that the sensors are sensitive to variation of temperature [2] and humidity which changes the baseline of the sensor signal shifts with time and large noise exists in sensor output [3].

1.1. Temperature Modulation

Classification and discrimination capacity of gas sensor array can be enhanced by using modulating temperature of various functions, frequencies and duty cycle.

Several approaches has been tried for deriving higher numbers of features by applying modulated temperature to the sensor instead of applying a fixed temperature [4-7].

Application of periodic heating voltage to MOS sensors has several advantages:

1) Because of different rates of reaction of various gases at different temperatures, a cyclic variation of temperature gives a unique signature for each gas.
2) Operation at low temperatures may lead to accumulation of incompletely oxidized contaminants. So by raising the temperature (by raising heater voltage to 5 V) the sensor surface may be cleaned.
3) Sensitivity and selectivity may be enhanced.

Intensive research has been carried out recently on the noise in sensors [8-10] and different techniques have been developed for selectivity detection of gases [11]. Determination of noise features such as PDF and power density spectrum estimation has been performed for several typical gas sensors [12]. Fengchun Tian et al [3] determined the noise features of gas sensors due to fixed sensor temperature; however noise analysis under modulated temperature has not yet been performed. In this work, pulse modulated heater voltage with different frequencies and duty cycles were applied to the MOS sensor heater to achieve the modulation in the sensor temperature for studying the type of noise. The frequency spectrum of noise determined by FFT analysis and noise dependency was verified by PDF, histogram and Signal-to-Noise Ratio (SNR) under different frequencies and duty cycles of pulse heater voltage.

1.2. Probability Distribution Function (PDF)

PDF is an important statistical tool to analyze the noise characteristics of a sensor signal. The probability distribution of a random variable x is a spectrum of the values of probabilities for $x \geq X$ which can be written as,

$$P_x(x) = P(X \leq x) \tag{1}$$

For the data range $-\infty \leq x \leq 1$, the probability lies between 0 to 1 is given by

$$0 \leq P_x(x) \leq 1 \tag{2}$$

The PDF of a signal always satisfies the condition that

$$\int_{-\infty}^{+\infty} P_x(x)dx = 1 \tag{3}$$

If the PDF of a signal is known, the probability of the signal falling within a range can be determined by

$$P(x_1 < x < x_2) = \int_{x_1}^{x_2} p_x(x)dx \tag{4}$$

For a sensor system which can develop a large number of noise data, its PDF can be assumed to be Gaussian, however such statistics may not be obtained for less number of data.

1.3. Statistical Features of Noise

The histogram method, which has been proved to be an unbiased estimation for a random variable, is used to estimate the PDF of noise [3]. Let us represent the histogram by H_i , where i is an index that runs from *0* to *M-1*, and M is the number of possible values that each sample can take on. The histogram results a Gaussian distribution when the number of samples is large. Hence from definition of histogram, the sum of all the values in the histogram must be equal to the number of points N, in the signal:

$$N = \sum_{i=0}^{M-1} H_i \tag{5}$$

The histogram can be used to calculate the mean and standard deviation of very large data sets. The histogram groups samples together that have the same value. The mean (μ) and standard deviation (σ) are calculated from the histogram by the equations:

$$\mu = \frac{1}{N}\sum_{i=0}^{M-1} iH_i \tag{6}$$

$$\sigma^2 = \frac{1}{N-1}\sum_{i=0}^{M-1} (i-\mu)^2 \tag{7}$$

Mathematically, a histogram is a mapping mi that counts the number of observations that fall into various disjoint categories (known as bins), whereas the graph of a histogram is merely one way to represent a histogram. Thus, if n is the total number of observations and k being the total number of bins, the histogram m_i meets the following conditions:

$$n = \sum_{i=1}^{k} m_i \tag{8}$$

1.4. Signal-to-Noise Ratio

In this application, the ratio of the sensor response signal for pulsed heater voltage to the noise in the average power level is termed as the Signal-to-Noise ratio (SNR) of the sensor given by

$$SNR = \frac{P_S}{P_N}, \tag{9}$$

where P_S is the power of the sensor response signal and P_N is the noise present in the signal. Measuring the SNR usually requires that the noise be measured separately, in the absence of signal. Depending on the type of experiment, it may be possible to acquire readings of the noise alone, for example on a segment of the baseline before or after the occurrence of the signal. However, if the magnitude of the noise depends on the level of the signal, then the experimenter must try to produce a constant signal level so as to measure the noise on the signal. In a few cases, where it is possible to model the shape of the signal exactly by means of a mathematical function, the noise may be estimated by subtracting the model signal from the experimental signal.

1.5. Noise Spread and Population Behaviour

To study the noise characteristics of the sensor, the following histogram components of the signal and their ratios are defined with the help of Fig. 1.

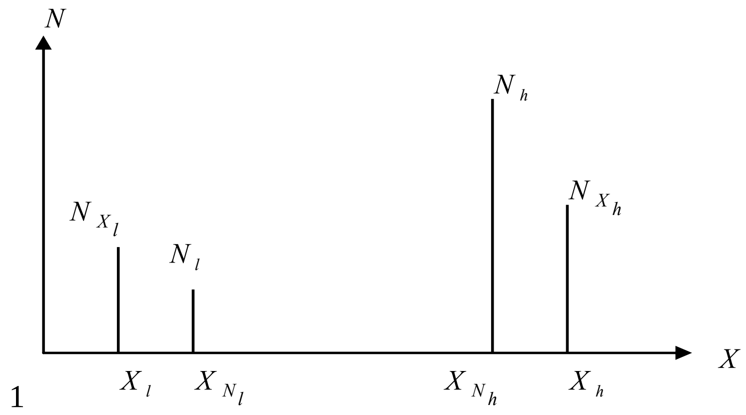


Fig. 1. Histogram showing noise spreads and population.

X_h = Highest value of noise component in histogram
X_l = Lowest value of noise component in histogram
X_{Nh} = Noise value corresponding to the highest number
X_{Nl} = Noise value corresponding to the lowest number
N_h = Highest number of noise samples in histogram
N_l = Lowest number of noise samples in histogram

The following ratios are also defined as follows:

Ratio of the highest to lowest components of noise value level in the histogram:

$$\frac{X_h}{X_l} \quad (10)$$

Ratio of the noise levels corresponding to the highest to lowest numbers:

$$\frac{X_{Nh}}{X_{Nl}} \quad (11)$$

Ratio of the highest to lowest number:

$$\frac{N_h}{N_l} \quad (12)$$

To analyze the noise spread and population behaviour, the following two terms are defined as:

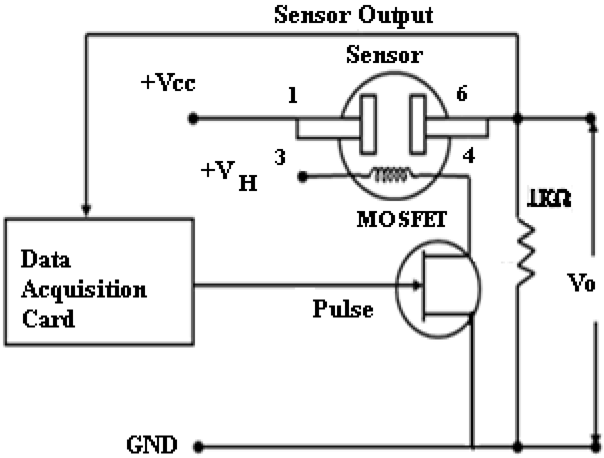
$$\text{Noise Spread Figure (NSF)} = \frac{X_h / X_l}{X_{Nh} / X_{Nl}} \tag{13}$$

$$\text{Noise Population Figure (NPF)} = \frac{X_h / X_l}{N_h / N_l} \tag{14}$$

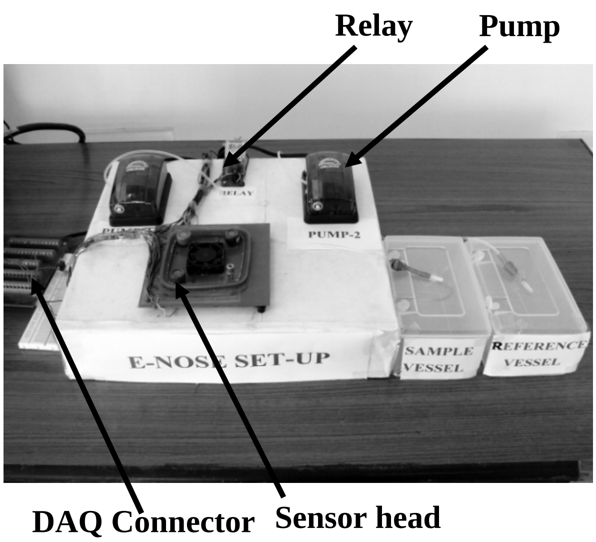
For a particular noise or noisy signal, as the noise level increases, the spread ratios shown in (10), (11) and (12) increases and as a result the NSF of (13) and NPF of (14) increases. Hence these two noise figure terms can be used to indicate the noise level of a signal.

2. Experiment

The noise feature analysis on MOS gas sensors (TGS-822, TGS-842, TGS-2611 of Figaro, Japan) was conducted for different pulse modulating temperatures. Fig.2 (a) shows the pulse modulating and data acquisition (DAQ) system. A DAQ card (PCI 6024E) was interfaced to a computer and controlled by LabVIEW to apply pulse modulated signals to the gate of the MOSFET. Therefore, the heater voltage $+V_H$ accordingly followed the pulse signal to excite the sensor. The sensor output was interfaced to a PC through the DAQ card. Fig. 2(b) shows the photograph of the sensor set- up.



(a)



(b)

Fig. 2. (a) Layout of the sensor heater voltage modulation; (b) The photograph of the sensor set-up.

2.1. Heater Voltage Modulation

The experiment was conducted on the MOS sensor without the application of any input odour and the sensors were kept inside a chamber away from interfering gas so that the baseline is established with clean air. Before each run of data acquisition, the baseline was verified and when found deviated, it was corrected by applying clean air. It was found in each run of experiment that on application of clean air the sensor baseline settles to a fixed level ensuring absence of any interfering gas.

When the pulse switches on the MOSFET, the heater voltage is switched on to +5 V with the same frequency as that of the pulse applied. As a result the sensor temperature becomes pulsating with different frequencies.

The sensor output signal, without applying any gas, captures noise developed inside the sensor which is mostly thermal related. The sensor was tested for noise with the heater ‘off’ but Vcc ‘on’, and then the pulsed heater voltage was applied. The frequency and the duty cycle of the heater ‘on’/ ‘off’ sequence were varied to analyze the noise behavior. The reason for analyzing the sensor noise behavior at different frequencies and duty cycles is that we need to know an optimum pulse frequency and duty cycle at which the sensor can be used with the best signal to noise ratio (SNR). This is important in circumstances where a sensor has to discriminate or classify odors in a noisy environment.

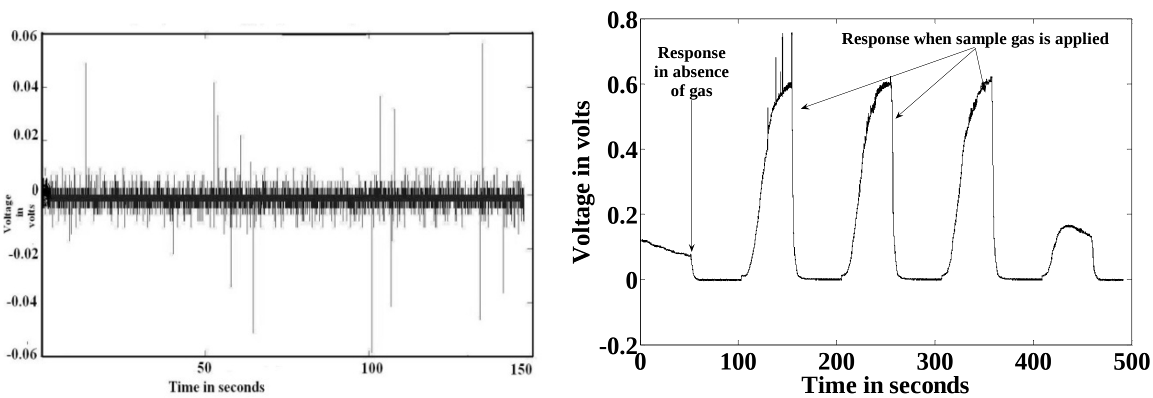
The sensor temperature was pulsed at the selected frequencies of 10 mHz, 40 mHz, 80 mHz and 120 mHz to generate noise. Further the noise pattern was changed with different ‘on’ / ‘off’ time ratio i.e. duty cycle of the pulse signal also. Therefore noise generated at 50 % and 75 % duty cycle of the pulsed temperature was also acquired. The sensor noise signals were acquired at a sampling frequency of 1 kHz over duration of about 15 min, so that sufficient data is available for analysis.

The pulse frequency and duty cycle were varied for each experiment after correcting the baseline. In order to avoid non-uniformity, data for a single pulse cycle was extracted and analyzed in MATLAB. Normalization of data was performed to highlight the noise spectrum over a positive scale.

FFT, PDF, histogram and the statistical parameters (mean, standard deviation and variance) and SNR were calculated for the data for a single pulse cycle. The total data points for frequency of 10 mHz, 40 mHz, 80 mHz and 120 mHz were 100×10^3, 25×10^3, 12.5×10^3, 8×10^3 respectively at the sampling frequency used in the experiments.

3. Results

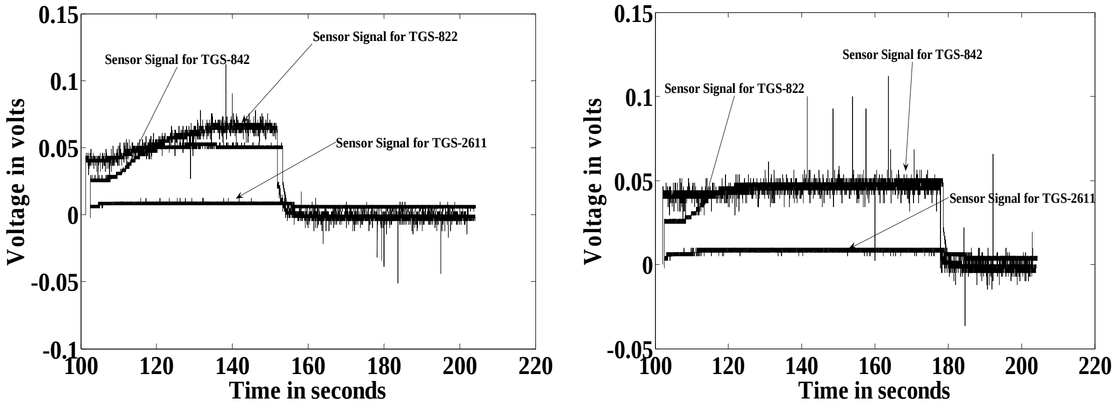
This experiment was performed for analysis of noise under pulse modulated heater voltage and Fig. 3 (a) shows the noise floor when the heater voltage was not applied. Fig. 3 (b) shows the sensor response when the sample gas ethyl acetate was applied.



(a) (b)

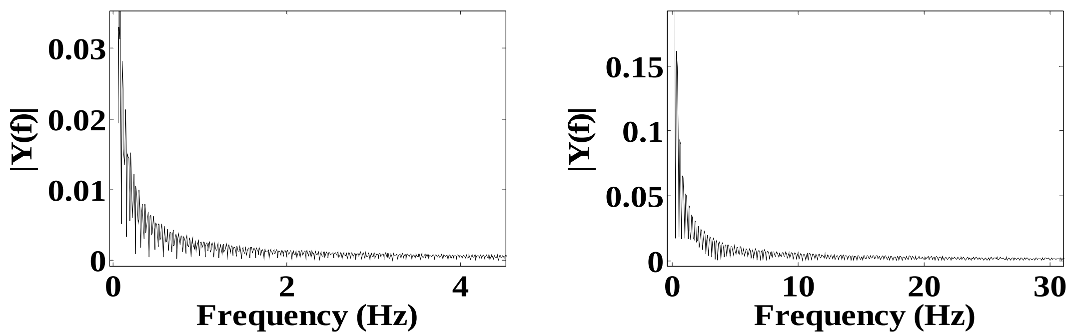
Fig. 3. (a) The noisy sensor output when heater voltage is not applied; (b) The sensor response in the presence of sample gas ethyl acetate.

The noisy sensor output signals at a frequency of 10 mHz for 50 % and 75 % duty cycle for the MOS sensors are shown in Fig. 4 (a) and Fig. 4 (b). To determine the noise bandwidth of the sensor for different frequencies and duty cycles of the pulsed heater voltage, FFT was performed using MATLAB. Fig. 5 (a)-(d) shows the FFT of the corresponding sensor noise at 10 mHz and 120 mHz each at pulsed duty cycles of 50 % and 75 %.

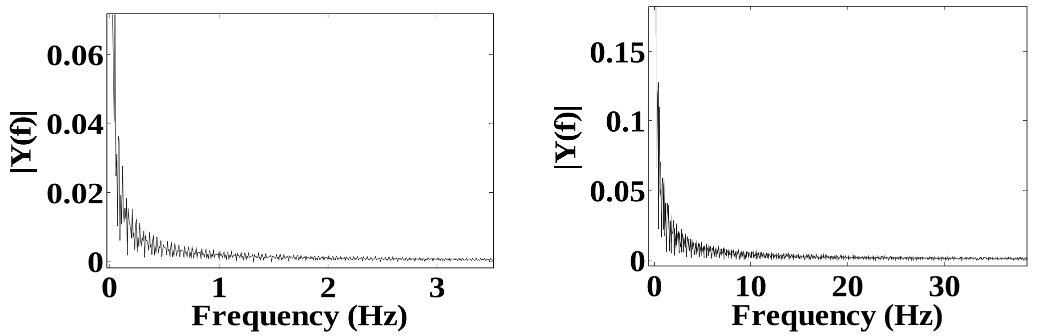


(a) (b)

Fig. 4. Noisy Sensor Signal for MOS Sensors (a) at 10 mHz and 50 % duty cycle; (b) at 10 mHz and 75 % duty cycle.



(a) (b)



(c) (d)

Fig. 5. The FFT of sensor noise signals (a) at 10 mHz and 50 % duty cycle; (b) at 120 mHz and 50 % duty cycle; (c) at 10 mHz and 7 5% duty cycle; (d) at 120 mHz at 75 % duty cycle.

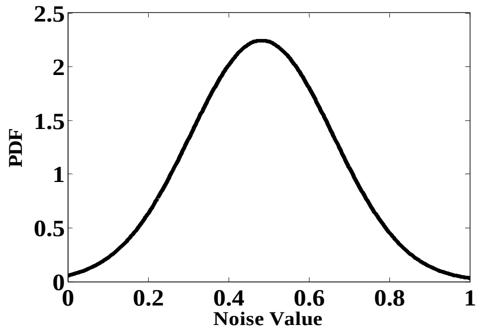
The FFT shows that the *1/f* noise spectrum of higher magnitude components at DC to a frequency of 5-10 Hz gradually decreases and smaller components are available over a wide range of higher frequencies. From FFT of Fig. 5 (a) and (c) and Fig. 5 (b) and (d) higher noise bandwidth was observed when pulse frequency was increased. Similarly it is seen from FFT of Fig. 5 (a) and (b) and Fig 5. (c) and (d) that the duty cycle of pulse also contributes to the noise bandwidth with reverse dependency i.e. noise bandwidth decreases as duty cycle increases.

Table 1 shows the bandwidth, mean, standard deviation and variance calculated for noise with different pulse frequency and duty cycle. The frequency component of noise in case of the sensors TGS-842 and TGS-2611 is very small at higher frequencies and the noise bandwidth is close to dc as seen from the table. For example, it can also be seen, that at a particular frequency of 10 mHz and 50 % duty cycle, the SNR of the three sensors ranges from about 45.63 dB to 56.88 dB. Within this particular range for the said frequency and duty cycle, the three sensors produces noise differently which is same as in the case for a different set of frequencies and duty cycle. Therefore, this analysis can be used for comparing the noise immunity of the three sensors. From Table I it can be seen that at a particular frequency of 10 mHz and 50 % duty cycle, TGS-842 shows the highest SNR as compared to TGS-822 and TGS-2611.

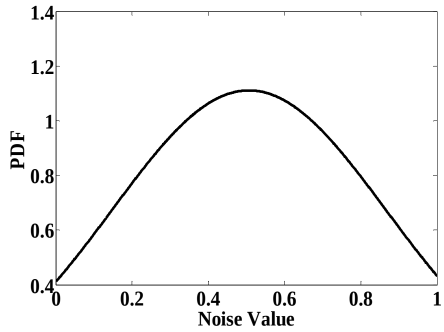
Table 1. Bandwidth, mean, variance, standard deviation and SNR of sensor data for different frequencies and duty cycles.

Sensor	Duty cycle	Pulse Frequency (mHz)	Bandwidth (mHz)	Mean	Variance	Standard deviation	Signal-to-Noise Ratio(dB)
TGS-822	50 %	10	7	0.4830	0.0316	0.1777	45.63
		40	19	0.4542	0.0735	0.2711	41.90
		80	38.3	0.5189	0.0989	0.3145	34.29
		120	70	0.5067	0.1290	0.3592	27.32
	75 %	10	3.63	0.6057	0.0230	0.1515	52.04
		40	16.3	0.6270	0.0606	0.2461	45.84
		80	32.7	0.6683	0.0743	0.2726	44.88
		120	64	0.6632	0.0911	0.3018	29.18
TGS-842	50 %	10	dc	0.4603	0.0776	0.3214	56.88
		40		0.4275	0.1241	0.3523	48.05
		80		0.4893	0.1403	0.3746	44.03
		120		0.4700	0.1540	0.3924	27.82
	75 %	10	dc	0.6846	0.0605	0.3149	57.50
		40		0.6454	0.1058	0.3252	55.49
		80		0.6699	0.1201	0.3465	49.76
		120		0.7028	0.1287	0.3545	46.61
TGS-2611	50%	10	dc	0.5267	0.0492	0.2218	48.30
		40		0.5398	0.0543	0.2330	41.03
		80		0.5221	0.0582	0.2374	33.52
		120		0.5188	0.0605	0.2413	30.79
	75%	10	dc	0.8270	0.0458	0.2110	59.22
		40		0.8239	0.0489	0.2139	49.53
		80		0.8312	0.0566	0.2279	39.99
		120		0.8463	0.0576	0.2336	33.75

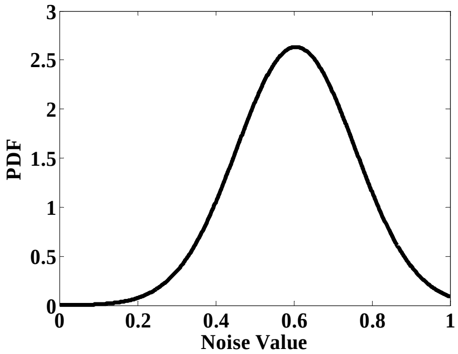
To study the statistical feature of noise at different pulsed heater voltage frequencies and duty cycles, the data from the sensors was used to compute the PDF estimation and histogram. Fig. 6 (a)-(d) shows the PDF of sensor noise at 10 mHz and 120 mHz each at 50 % and 75 % duty cycles.



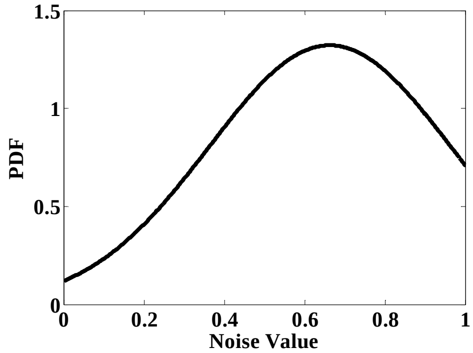
(a)



(b)



(a)



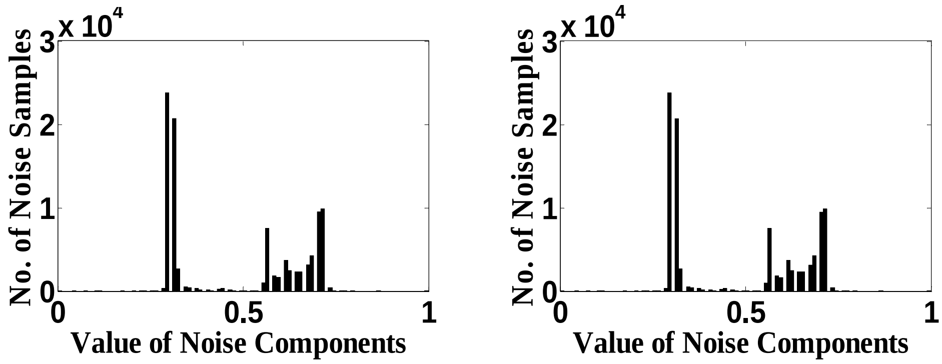
(b)

Fig. 6. The PDF of the sensor noise signals (a) at 10 mHz and 50 % duty cycle; (b) at 120 mHz and 50 % duty cycle; (c) at 10 mHz and 75 % duty cycle; (d) at 120 mHz at 75 % duty cycle.

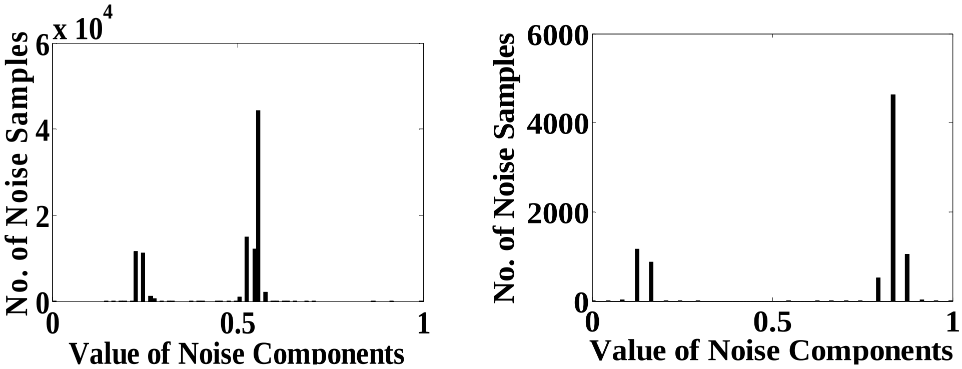
Similarly Fig. 7(a)-(d) shows the histograms of the sensor data for the same respective frequencies and duty cycles. The PDF shows that for all cases of pulses, the distribution is Gaussian noise however with different mean, variance and standard deviation. The histogram of the sensor data was used to compute the mean, standard deviation and variance of the sensor noise for the respective frequencies and duty cycles of the pulsed heater voltage. The mean value of the noise data showed that it is non-zero, depicting that the noise is colored and *1/f* type which can be seen in the noise spectrum diagram also. The FFT shows that the noise power decreases at higher frequencies with the highest component at dc, i.e. the power spectral density is inversely proportional to the frequency which indicates that the noise is pink.

Higher standard deviation and variance was observed when the pulse frequency was increased which showed that the signal becomes noisier for the three sensors when pulsed heater voltage frequency is increased. The duty cycle of the pulse also contributed to the noise level with reverse dependency i.e. noise level increases with reverse dependency i.e. noise level increases when smaller duty cycle is used.

Once the histograms are obtained for all cases of frequencies and duty cycles of the heater pulse voltage, the NSF and NPF described in (13) and (14) were calculated. The results are shown in Table 2. From Table 2 it is observed that the NSF and NPF ratios increases as the pulsed heater voltage frequency is increased which indicates that the noise level of the signal increases as the frequency is increased. It is also observed that as the duty cycle increases, the NSF and NPF ratios decreases. This confirms to the results obtained from Table 1.



(a) (b)



(a) (b)

Fig. 7. The histogram of the sensor noise signals (a) at 10 mHz and 50 % duty cycle; (b) at 120 mHz and 50 % duty cycle; (c) at 10 mHz and 75 % duty cycle; (d) at 120 mHz at 75 % duty cycle.

4. Conclusion

In this paper, noise features – both statistical and frequency spectrum of MOS gas sensor applying pulse modulated temperature with different frequencies and duty cycles are analyzed to study the type of noise. Under statistical analysis PDF, SNR and histogram while under frequency analysis the FFT analysis of the MOS sensor noise was performed to verify the noise dependency on the frequency and duty cycle of the modulated heater voltage.

The sensor noise was found to be *1/f* or pink from the statistical and frequency spectrum .It is observed that with the increase in pulsed heater voltage frequency, the noise level increases and vice-versa. Similarly the noise level decreases as the duty cycle of the pulsed modulated heater voltage is increased.

The FFT for the various heater voltage frequencies and duty cycles reveals that the sensor produces noise with higher bandwidth at higher frequency however at lower duty cycle.

The PDF for the noise signals were also determined and it was found that the noise developed were with non-zero mean confirming that the noise is colored. The change in the standard deviation and variance of the noise was analyzed and the noise dependency on frequency and duty cycle was verified. This paper deals with the study of noise in the MOS sensors without application of gas but under application of pulsed heater temperature. It was observed that the noise floor rises from the zero mean to a level determined by the sensor sensitivity. On the application of gas, the noise floor will certainly rise to a level determined by the gas strength, however, the statistical and frequency characteristics of the noise will remain the same.

Table 2. Noise Spread Figure and Noise Population Figure variation with pulse frequency an duty cycle.

Sensor	Duty cycle	Pulse Frequency (mHz)	NSF	NPF
TGS-822	50 %	10	2.80	0.05
		40	4.49	0.61
		80	5.74	0.70
		120	6.46	2.17
	75 %	10	1.17	0.03
		40	1.65	0.53
		80	1.85	0.70
		120	6.43	0.76
TGS-842	50 %	10	2.67	0.298
		40	3.12	1.039
		80	3.66	1.15
		120	4.52	2.35
	75 %	10	1.32	0.143
		40	2.59	0.871
		80	2.89	1.07
		120	3.56	1.88
TGS-2611	50 %	10	1.315	0.075
		40	1.492	0.173
		80	1.97	0.349
		120	2.04	0.375
	75 %	10	1.08	0.029
		40	1.12	0.109
		80	1.4	0.26
		120	1.98	0.313

The analysis was further extended to determine the NSF and NPF ratios shown in Table II which also confirms the noise dependency on the frequency and the duty cycle of the pulse modulated heater voltage.

It was observed in this experiment that the characteristics show different behaviour for different patterns of pulsed heater voltage (i.e. heater temperature) with variable frequency and duty cycle.

The study confirms that the noise immunity of the sensors increases with higher pulse frequency but decreases with increase in duty cycle.

Recently, researchers are trying to extract higher degree of features by applying pulsed heater temperature, there must be a compromise between the highest heater pulse frequency and lowest duty cycle to get the best SNR for a particular sensitivity of the sensor.

This study will be helpful to determine the optimum heater pulse frequency and duty cycle for a particular sensor.

Acknowledgements

This work is supported by Tezpur University Institutional Scholarship. The authors gratefully acknowledge the financial support received from Tezpur University, India.

References

[1]. K. L. Goodner, J. G. Dreher, and R. L. Rouseff, The dangers of creating false classifications due to noise in e-nose and similar multivariate analyses, *Sens. Actuators B*, 2001, 80, p. 261.

[2]. R. B. Ugryumov, Noise of semiconductor gas sensors in response to a sharp change in the composition of the gaseous phase, *Springer, Radiophysics and Quantum Electronics*, 2006, Vol. 49.

[3]. Fengchun Tian, Simon X. Yang and Kevin Dong, Circuit and Noise Analysis of Odourant Gas Sensors in an E-Nose, *Sensors*, 2005, 5, pp. 85-96.

[4]. Andrew P. Lee, and Brian J. Reedy, Temperature modulation in semiconductor gas sensing, *Sensors and Actuators B,* 60, 1999, pp. 35-42.

[5]. A. Heiling, N. Barsan, U. Weimar, M. Schweizer-Berberich, J. W. Gardner, W. Göpel, Gas Identification by Modulating Temperatures of SnO2-Based Thick Film Sensors, *Sensors and Actuators B,* 43, 1997, pp. 45-51.

[6]. Xingjiu Huang, Fanli Meng, Zongxin Pi, Weihong Xu, and Jinhuai Liu, Gas sensing behaviour of a single tin dioxide sensor under dynamic temperature modulation, *Sensors and Actuators B,* 99, 2004, pp. 444–450.

[7]. A. Vergara, E. Llobet, J. Brezmes, X. Vilanova, M. Stankova, I. Gràcia, C. Cané, X. Correig, Optimized multi-frequency temperature modulation of micro-hotplate gas sensors, *IEEE Sensors Journal*, 2004.

[8]. G. Horak, V. Bilas and D. Vasic, Noise Analysis of the Pulse-Width Modulator for Quasi-Digital Sensors, in *Proc. of the IEEE International Instrumentation and Measurement Technology Conference*, 12-15 May, 2008.

[9]. R. B. Ugryumov, A. V. Shaposhnik, and V. S. Voishchev, Spectral and Static Noise Characteristics of Semiconductor Gas Sensors in Equiresistance Conditions, *Technical Physics*, Vol. 49, No. 7, 2004, pp. 941–943.

[10]. P. Mielle and F. Marquis, Gas Sensors Arrays (‘Electronic Noses’): a study about the speed/accuracy ratio, *Sens. Actuators B*, Vol. 68, 2000, pp. 9-16.

[11]. S. Gomri, J. L. Seguin and K. Aguir, Gas Sensor Selectivity Enhancement by Noise Spectroscopy: A Model of Adsorption-Desorption Noise, *IEEE, Research in Microelectronics and Electronics*, Vol. 2, 2005.

[12]. T. Contaret, S. Gomri, J.-L. *Seguin and K. Aguir, Noise Spectroscopy Measurements in Metallic Oxide Gas Microsensors, in Proc*. of the *IEEE Sensors Conference,* 2008.

[13]. David C. Swanson, Signal Processing for Intelligent Sensor Systems, *Technology & Engineering*, 2000.

Guide for Contributors

Aims and Scope

Sensors & Transducers Journal (ISSN 1726-5479) provides an advanced forum for the science and technology of physical, chemical sensors and biosensors. It publishes state-of-the-art reviews, regular research and application specific papers, short notes, letters to Editor and sensors related books reviews as well as academic, practical and commercial information of interest to its readership. Because it is an open access, peer review international journal, papers rapidly published in *Sensors & Transducers Journal* will receive a very high publicity. The journal is published monthly as twelve issues per annual by International Frequency Association (IFSA). In additional, some special sponsored and conference issues published annually. *Sensors & Transducers Journal* is indexed and abstracted very quickly by Chemical Abstracts, IndexCopernicus Journals Master List, Open J-Gate, Google Scholar, etc.

Topics Covered

Contributions are invited on all aspects of research, development and application of the science and technology of sensors, transducers and sensor instrumentations. Topics include, but are not restricted to:

- Physical, chemical and biosensors;
- Digital, frequency, period, duty-cycle, time interval, PWM, pulse number output sensors and transducers;
- Theory, principles, effects, design, standardization and modeling;
- Smart sensors and systems;
- Sensor instrumentation;
- Virtual instruments;
- Sensors interfaces, buses and networks;
- Signal processing;
- Frequency (period, duty-cycle)-to-digital converters, ADC;
- Technologies and materials;
- Nanosensors;
- Microsystems;
- Applications.

Submission of papers

Articles should be written in English. Authors are invited to submit by e-mail editor@sensorsportal.com 8-14 pages article (including abstract, illustrations (color or grayscale), photos and references) in both: MS Word (doc) and Acrobat (pdf) formats. Detailed preparation instructions, paper example and template of manuscript are available from the journal's webpage: http://www.sensorsportal.com/HTML/DIGEST/Submition.htm Authors must follow the instructions strictly when submitting their manuscripts.

Advertising Information

Advertising orders and enquires may be sent to sales@sensorsportal.com Please download also our media kit: http://www.sensorsportal.com/DOWNLOADS/Media_Kit_2009.pdf