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USE OF THE PARAMETERS OF THE LAW OF DISTRIBUTION OF THE MEASUREMENT ERRORS OF THE PULSE OXIMETER TO SELECT THE SENSOR SETTINGS

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ABSTRACT

Context is due to the need to develop a methodology for optimising the parameters of pulse oximeter sensor settings based on the practical determination of the accuracy of heart rate and blood oxygen saturation measurements, which, unlike existing ones, do not require analysis of the amplitude of the LED current.

A pulse oximeter is one of the sensors that monitor the patient’s vital signs, heart rate and blood oxygen saturation in particular. These indicators are determined based on the analysis of the values of the variable and constant components of the current of the red and infrared LEDs of the pulse oximeter sensor. Therefore, the accuracy of determining vital signs depends on the correct choice of the brightness and duration of the LEDs’ radiation. It is possible to select the current and duration of the LEDs’ radiation, as well as the ADC parameters of the sensor using software. In this case, the final conclusion regarding the correctness of the selected sensor settings is made based on the practical determination of the accuracy of heart rate and blood oxygen saturation measurements.

The object is to develop a methodology for assessing the correctness of the pulse oximeter sensor settings based on the analysis of the stationarity of errors in heart rate and blood oxygen saturation measurements.

Method. An experimental study of the accuracy of heart rate and blood oxygen saturation measurements by statistical analysis of measurement errors of the developed pulse oximeter model.

Results. The practical application of the proposed methodology for determining the optimal parameters of the pulse oximeter sensor settings was tested using the example of heart rate measurements.

Conclusion. A methodology has been developed to assess the correctness of the choice of sensor setting parameters based on analysing the stationarity of errors in measuring heart rate and oxygen saturation in the patient’s blood. With the help of the developed methodology, the optimal settings parameters of the MAX30102 sensor of the pulse oximeter developed based on the ESP32 board were selected, which ensures the minimum error in measuring heart rate and blood oxygen saturation.

KEYWORDS: sensor, Internet of Things, measurement errors, pulse oximeter.

ABBREVIATIONS

ADC is an analog to digital converter;
API is an application-programming interface;
CSV is a comma-separated value;
IoT is an internet of things;
HR is a heart rate;
SpO2 is an oxygen saturation in the blood.

NOMENCLATURE

$\varepsilon(t)$ is a random process of the measurement errors;

$b(t_i)$ is a random process of the estimate errors;

σ_ε^2 is a dispersion of the measurement errors;

m_ε is a mathematical expectation of measurement errors;

m_b is a mathematical expectation of the full sample of estimation errors;

m_1 is a mathematical expectation of the first part of the estimation errors sample;

m_2 is a mathematical expectation of the second part of the estimation errors sample;

S_b^2 is a dispersion of the full sample of estimation errors;

S_1^2 is a dispersion of the first part of the estimation errors sample;

S_2^2 is a dispersion of the second part of the estimation errors sample;

t_b is a Student’s *t*-distribution statistic;

F is a *F*-distribution statistic;

k_1 is a freedom’s degree of the first part of the estimation errors sample;

k_2 is a freedom’s degree of the second part of the estimation errors sample;

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$t(\alpha, n-1)$ is a quantile of the Student's *t*-distribution;
$F(\alpha, k_1, k_2)$ is a quantile of the *F*-distribution
n is a measurements number;
l is a subsample size;
$y^*(t_i)$ is a discrete measurements;
H_0 is a statistical hypothesis;
Δ is a confidence interval;
α is a level of significance.

INTRODUCTION

Maintaining sufficient oxygen levels in the blood is vital for human health. Hypoxia is a condition where the oxygen concentration in the blood falls below the normal level, and it can be a direct threat to life. Low blood oxygen concentration primarily affects the brain, heart, and kidneys. Blood oxygen saturation (SpO2) is measured by determining arterial blood's gas structure and acid-base state. However, these studies require blood sampling from an artery, qualified personnel, and specialised equipment and are typically conducted in a medical facility. Instead, using a non-invasive method, a pulse oximeter determines the heart rate and the amount of oxygen in the blood through the skin of the finger or ear. The pulse oximeter functions by emitting light and two distinct wavelengths, generally in the red and infrared spectrums, to the skin capillaries and measures how much light is reflected, which, in turn, depends on the structure of arterial blood and the amount of oxidised haemoglobin [1]. The results of the pulse oximeter measurement show the oxygen saturation in the blood, or SpO2 level, as a percentage. The standard value for blood saturation in a healthy person is over 96%. A 3–4% decrease indicates a serious illness [2].

Pulse oximeters are common devices in healthcare settings, and with the advancement of IoT technologies, they have become essential tools for remote patient monitoring. The accuracy of these devices is crucial for correct diagnosis and treatment decisions, especially in critical care scenarios. This accuracy depends primarily on the correct calibration and settings of the sensor parameters.

The object of research is to remotely monitor the results of blood saturation and heart rate measurements of patients.

The subject of research is the impact of software-defined parameters of the pulse oximeter sensor on the accuracy of measuring both heart rate and blood oxygen saturation.

The purpose of the work is the development of a methodology for assessing the correctness of the selection of the settings parameters of the MAX30102 sensor based on the analysis of the stationarity of measurement errors of heart rate and oxygen saturation in the patient's blood.

1 PROBLEM STATEMENT

Various pulse oximeters are now available, including those using IoT technologies to monitor patients' heart rate and blood oxygen saturation remotely. The microcontroller uses built-in libraries to read and process digital readings from the sensor's ADC output and to improve measurement accuracy; it is possible to programmatically change the current and duration of LED emission, as well as control the ADC parameters. The sensor settings are optimised to improve measurement accuracy by selecting the amplitude of the LED currents. The conclusion about the correctness of the selected settings parameters is made based on the practical determination of the accuracy of heart rate measurements and blood oxygen saturation. Therefore, it is advisable to develop a methodology for assessing the correctness of the choice of sensor setting parameters based on analysing the stationarity of errors in measuring heart rate and oxygen saturation in the patient's blood.

In the practical use of pulse oximeter sensors, it is necessary to determine the current amplitude of each LED, which will correspond to the optimal setting. The user can then analyse the correctness of the selected settings by determining the accuracy of HR and SpO2 (%) measurements using the SpO2 algorithm [3].

Suppose that the measurement of the parameter $x(t)$ is described by a random process

$$y(t) = x(t) + \varepsilon(t).$$

In this case, the random process $\varepsilon(t)$ satisfies the conditions of stationarity with $m_\varepsilon = 0$ and dispersion σ_ε^2, which is a priory unknown.

At the same time, the dispersion σ_ε^2 of HR and SpO2 (%) measurements depends on the brightness and duration of the LEDs, as well as the ADC parameters of the pulse oximeter sensor. Let us assume that at discrete points in time $t_i, i = 1,...,n$ a sample of measurements is obtained $y^*(t_i)$ for different values of the sensor settings parameters. It is necessary to develop a method for optimizing the sensor settings parameters based on the obtained sample of measurements $y^*(t_i)$, which is based on the stationarity of HR and SpO2 (%) measurement errors and does not require analysis of the current amplitude of the sensor LEDs.

2 REVIEW OF THE LITERATURE

The pulse oximeter is one of the sensors that monitor vital health indicators; it occupies a place at the level of 'things' in the overall architecture of the healthcare system based on the use of cloud IoT technologies [4,5,6]. Most pulse oximeter models use MAX30100, MAX30101 and MAX30102 (MAX3010x) sensors [7, 8]. The development of a portable pulse oximeter that uses the MAX30102 sensor, connected to the Arduino platform via the I2C interface, where measurements are processed and the results are displayed on an external TFT screen, was considered in [9]. Modern mobile technologies and the Internet of Things (IoT) allow for remote monitoring

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of patients' blood saturation measurements and displaying the results on remote services. This makes it possible to monitor the blood saturation of patients with mild and average disease severity at home, significantly reducing the demand for hospital beds. Secondly, doctors will not have direct contact with patients [10]. For example, in [10,11], it is proposed to create an IoT pulse oximeter based on the ESP32 platform. This platform includes a built-in WiFi module, enabling the transmission of measurement data from the MAX30100 sensor via the Internet to the ThingSpeak cloud service and displaying them in the graphical form dependencies for a sufficiently long time interval. A personal doctor periodically monitors these data by accessing the ThingSpeak server using an API key and channel number identifier with visualisation on a smartphone, tablet or personal computer. A similar approach is described in [12] but is based on the ESP8266 microcontroller. The construction and development of an IoT-based pulse oximeter capable of wirelessly transmitting the obtained readings to the Blynk mobile application is discussed in [13]. It is recommended that an Arduino-based microcontroller be used for signal processing and that the ESP-01 WiFi module be used to ensure remote data transmission.

IoT devices remotely monitoring patients' blood saturation can be used at home. However, the works do not indicate how the patient will be informed about the need for measurements in conditions when the monitoring device is not constantly on the patient's finger. Therefore, in [14], a variant of building an IoT oximeter with feedback control using the Telegram messenger based on the ESP32 DEVKIT V1 board and the MAX30102 sensor was proposed. This board has a built-in WiFi module and an LED that can be switched on at the command of a pre-created Telegram bot when measurements are required. Much attention in the literature is paid to developing various variants of pulse oximeters, including those using IoT technologies, for remote monitoring of patients' heart rate and blood oxygen saturation. However, the impact of sensor parameters configured by software on the accuracy of measuring both heart rate and blood oxygen saturation remains a significant gap in the literature.

3 MATERIALS AND METHODS

Pulse oximeter sensors typically contain two LEDs that work in the red and infrared spectrums, a photodetector, an analog amplifier, and an analog-to-digital converter. The fundamental operation of these sensors relies on the differential absorption of light by oxygenated and deoxygenated hemoglobin at the two wavelengths.

To improve measurement accuracy, several parameters can be programmatically adjusted:

1. LED brightness (current amplitude).
2. LED pulse duration.
3. Sampling rate (ADC parameters).
4. Signal filtering and processing algorithms.

The optimization of these parameters involves finding a balance between measurement accuracy, power consumption, and signal-to-noise ratio. Higher LED brightness generally provides better signal quality but increases power consumption [15]. Similarly, longer pulse durations and higher sampling rates improve signal quality at the cost of increased power consumption.

We propose a methodology based on statistical analysis of the stationarity of measurement errors to assess the correctness of the selected sensor settings. This approach provides an objective criterion for parameter optimization without requiring direct analysis of LED current amplitudes.

The MAX30102 sensor is also an integrated heart rate and blood oxygen saturation sensor. The acceptable values of the MAX3010x sensor parameters and general recommendations for their selection are listed in [3]. In particular, to improve the accuracy of blood saturation and heart rate measurements with the MAX3010x sensor, users should optimise the LED signal power, pulse duration, and sampling rate. It is noted that when measuring heart rate (HR), it is desirable to have the highest possible LED current, increasing the LEDs' brightness. However, to minimise the power supply consumption of the power supply, the current of the LEDs should be reduced. Regarding power consumption, the longer the pulse duration of the LEDs, the more power it consumes. Increasing the sampling rate also increases the power consumption of the power supply. The signal-to-noise ratio is also reduced by reducing the pulse duration and sampling rate. It is recommended that the user determines the amplitude of the current of each LED that will correspond to the optimal setting using the graphical interface of the MAX3010x set with data logging in CSV format. The user can then analyse the correctness of the selected settings. This analysis can be made based on the practical determination of the accuracy of HR and SpO2 (%) measurements using the SpO2 algorithm [3].

Therefore, to simplify the assessment of the correctness of the selected settings of the MAX30102 sensor, the following methodology is proposed based on the statistical analysis of the stationarity of HR and SpO2 measurement errors.

Suppose that at discrete points in time $t_i, i = 1,...,n$ sample of measurements $y^*(t_i)$ is obtained. If measurements $y^*(t_i)$ with a certain accuracy describe the real behavior of the parameter $x(t)$, so the statistical properties $\varepsilon(t)$ and $b(t_i) = b_i = y^*(t_i) - x(t_i)$ with increasing sample size will become increasingly. Then, the conclusion about the stationarity of the random process $\varepsilon(t)$, can be made on the basis of the analysis of the statistical properties of the process $b(t_i)$. If the dispersion of measurement errors σ_ε^2 is not known a priori, the simplest criteria for checking stationarity consists in sequentially testing the hypotheses $H_0 : E\{b(t_i)\} = m_\varepsilon$ and $H_0 : E\{b^2(t_i)\} = const$ [16]. For the normal law of distribution of measurement errors, under the actual hypothesis

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$H_0 : E\{b(t_i)\} = m_b = m_\varepsilon$, statictic $t_b = \frac{m_b}{s_b}\sqrt{n-1}$ obeys distribution of St`yudent with $n-1$ degrees of freedom. If $t_b > t(\alpha, n-1)$, the hypothesis H_0 must be declined. The quantiles of $t(\alpha, n-1)$ for different values of n and significance level α are tabulated, and the values of m_b and S_b are calculated using the formulas:

$$m_1 = \frac{1}{n}\sum_{i=1}^{n} b_i ; S_b^2 = \frac{1}{n-1}\sum_{i=1}^{n}(b_i - m_b)^2 .$$

Testing the hypothesis $H_0 : E\{b(t_i)\} = m_\varepsilon$ can be achieved in the following sequence. The sample $b_i, i = 1,...,n$ is divided into two approximately equal, non-overlapping groups, $b_1,...,b_l ; b_{l+1},...,b_n$. For each group, the following values are calculated

$$m_1 = \frac{1}{l}\sum_{i=1}^{l} b_i ; m_2 = \frac{1}{n-l}\sum_{i=l+1}^{n} b_i ;$$

$$S_1^2 = \frac{1}{l-1}\sum_{i=1}^{l}(b_i - m_1)^2 ;$$

$$S_2^2 = \frac{1}{n-l-1}\sum_{i=l+1}^{n}(b_i - m_2)^2 .$$

Estimates the value of Fisher's statistic:

$$F = \max\left[\frac{S_1^2}{S_2^2}; \frac{S_2^2}{S_1^2}\right].$$

The degrees of freedom are determined:

$$k_1 = l-1, k_2 = n-l-1 \text{ with } S_1^2 > S_2^2 ;$$
$$k_1 = n-l-1, k_2 = l-1 \text{ with } S_1^2 < S_2^2 .$$

For a defined k_1, k_2 and a fixed significance level α the critical value $F(\alpha, k_1, k_2)$ is determined. If $F < F(\alpha, k_1, k_2)$, the hypothesis $H_0 : E\{b^2(t_i)\} = \text{const}$ must be considered valid with confidence $1-\alpha$. Thus, a random process $\varepsilon(t)$ satisfies the conditions of stationarity with $m_\varepsilon = 0$ and dispersion σ_ε^2, if both hypothesis $H_0 : E\{b(t_i)\} = m_\varepsilon$ and $H_0 : E\{b^2(t_i)\} = \text{const}$ are true.

The optimal settings parameters of the pulse oximeter sensor match the maximum accuracy of measurements of heart rate HR and blood oxygen saturation SpO2 [3]. Therefore, for a stationary random process of measurement errors, the optimal setting parameters can be considered those at which $m_b \to m_\varepsilon = 0$, a $S_b \to \min$. In this case, the optimal setting corresponds to the minimum value of the confidence interval

$$\Delta = m_b \pm t(\alpha, n-1)\frac{S_b}{\sqrt{n}} .$$

4 EXPERIMENTS

To make the research, we will use a previously developed layout of a pulse oximeter based on the ESP32 DEVKIT V1 board and the MAX30102 sensor, shown in Fig. 1 [14].

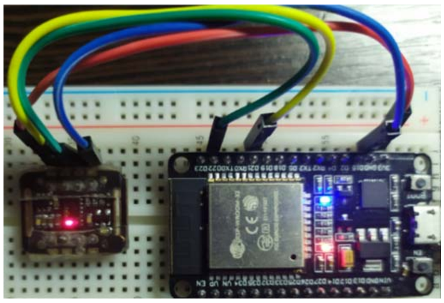

Figure 1 – Layout of IoT pulse oximeter on ESP32

The results of HR and SpO2 measurements were output to the serial port, and further statistical processing of the measurements and the construction of graphical dependencies were carried out in the Excel software environment.

In practice, the programming of pulse oximeter controllers, the typical examples of programme codes are used, which are embedded in the libraries of software systems. For instance, the Arduino IDE software environment offers the use of the program code "SparkFun MAX3010x Pulse and Proximity Sensor Library_Example_SPO2.ino", which uses the library "spo2_algorithm.h" to determine HR and SpO2. The program code has the following options, which can be modified by the user:

```
ledBrightness = 60; //Options: 0=off to 255=50mA;
sampleAverage = 4; //Options: 1, 2, 4, 8, 16, 32;
ledMode = 2; //Options: 1-Red only, 2- (Red + IR);
sampleRate = 200; //Options: 50, 100, 200, 400, 800, 1000, 1600, 3200;
pulseWidth = 411; //Options: 69, 118, 215, 411;
adcRange = 4096; //Options: 2048, 4096, 8192.
```

The acceptable values of the pulse duration and frequency of the sensor sampling when measuring SpO2 and HR are shown in Fig. 2 [3]. As shown in Fig. 1, when simultaneously measuring HR and SpO2, the pulse duration emitted by the LEDs can vary from 69 to 411 μs, and the frequency of sampling from 50 to 400 Hz.

Allowed setting for SpO2 configuration

SAMPLES PER SECOND	PULSE WIDTH (μs)			
	69	118	215	411
50	O	O	O	O
100	O	O	O	O
200	O	O	O	O
400	O	O	O	O
800	O	O	O	
1000	O	O		
1600	O			
3200				

Allowed setting for HR configuration

SAMPLES PER SECOND	PULSE WIDTH (μs)			
	69	118	215	411
50	O	O	O	O
100	O	O	O	O
200	O	O	O	O
400	O	O	O	O
800	O	O	O	O
1000	O	O	O	O
1600	O	O	O	
3200	O			

Figure 2 – Valid settings for the MAX3010x

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For instance, Figures 3 and 4 illustrate HR measurements for varying pulse durations at an LED brightness level of 60 and the amount of ADC quantisation levels of 8192 and 4096, respectively.

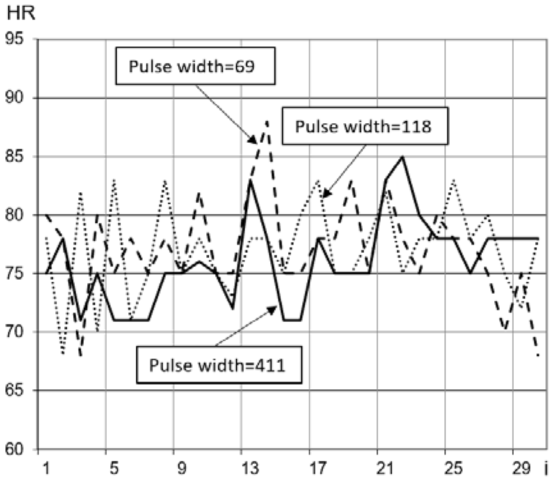

Figure 3 – Measurements HR for ledBrightness = 60, adcRange = 8192

As demonstrated in Figures 5 and 6, measurements of heart rate (HR) were taken at the same sensor settings, but for a level of LED brightness of 30.

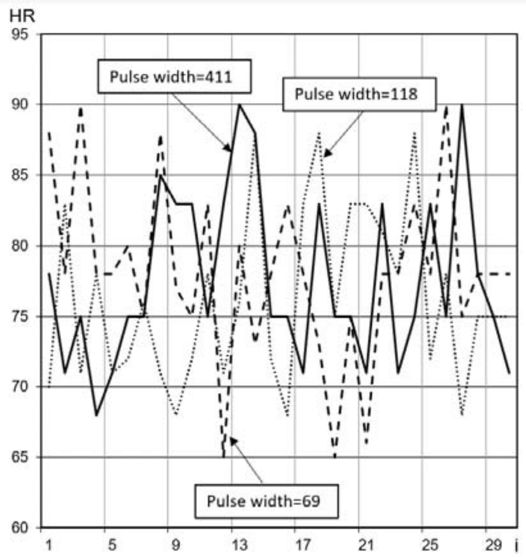

Figure 4 – Measurements HR for ledBrightness = 60, adcRange = 4096

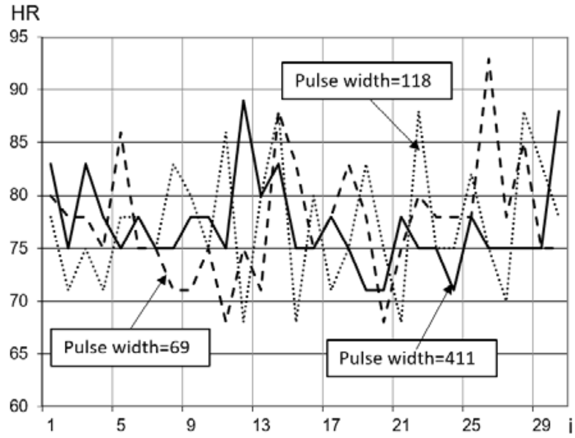

Figure 5 – Measurements HR for ledBrightness = 30, adcRange = 8192

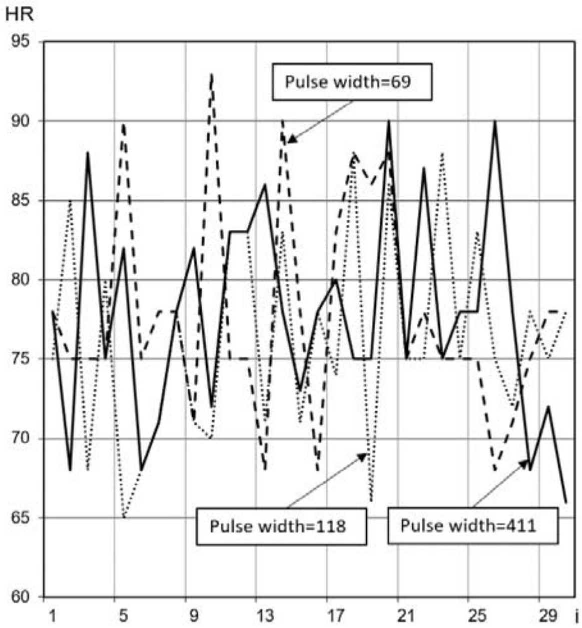

Figure 6 – Measurements HR for ledBrightness = 30, adcRange = 4096

Upon analysis of the presented data, it is challenging to draw any visual conclusions regarding which settings of the MAX30102 sensor ensure the minimum error in heart rate measurement.

5 RESULTS

The feasibility of the proposed methodology for determining the optimal parameters of the pulse oximeter sensor settings was tested using heart rate measurements. The stationarity of the random process of measurement errors was analysed using a sample of n=30 counts, which were obtained with a frequency of sampling of 200 Hz. The actual value of the heart rate during the measurements was 76 beats per minute.

As illustrated in Table 1, the values employed in the methodology for analysing the stationarity of a random process of measurement errors have been calculated for different parameters of the sensor settings when using an ADC with 8192 quantisation levels.

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Table 1 – Checking the correctness of the sensor settings (adcRange = 8192)

Value	Pulse width (ledBrightness =60)			Pulse width (ledBrightness = 30)		
	69	118	411	69	118	411
m_b	1.13	1.07	0.07	1.53	1.33	1.17
S_b	4.33	3.98	3.74	5.62	5.98	4.36
t_b	1.41	1.44	0.1	1.47	1.2	1.44
S_1^2	21.52	20.55	11.98	32.54	36.07	17.67
S_2^2	16.69	10.43	11.52	31.12	37.64	16.95
F	1.29	1.97	1.04	1.05	1.04	1.04
Δ	3.24	2.98	2.8	4.2	4.48	3.27

The quantile of the St`yudent distribution with $(n-1)$ degrees of freedom and significance level of $\alpha = 0.05$ is $t(\alpha, n-1) = 2.05$. The critical value of Fisher`s statictic $F(\alpha, k_1, k_2)$ for $k_1 = k_2 = 14$ and the significance level $\alpha = 0.05$ is 2.48 [17]. As illustrated in Table 1, the calculated values of the St`yudent`s distribution statistic $t_b < 2.05$ and the Fisher`s statistic $F < 2.48$ were obtained for all sensor settings. Thus, the random process of measurement errors meets the conditions of stationarity. The minimum value of m_b and S_b for the LED brightness level of 60, is achieved at a pulse duration of 411 µs. When the brightness level of the LEDs is reduced by two times, the minimum values of m_b and S_b correspond to a pulse duration of 411 µs. The confidence interval Δ also also reaches its minimum value at a pulse duration of 411 µs for both LED brightness levels. Therefore, the value of the LED pulse duration of 411 µs can be considered optimal for two levels of LED brightness.

As illustrated in Table 2, the analysis of the stationarity of the random process of measurement errors for different sensor settings when using an ADC with 4096 quantisation levels.

Table 2 – Checking the correctness of the sensor settings (adcRange = 4096)

Value	Pulse width (ledBrightness =60)			Pulse width (ledBrightness = 30)		
	69	118	411	69	118	411
m_b	2.07	0.23	1.53	1.83	0.27	1.67
S_b	6.27	6.06	6.08	6.69	6.45	6.57
t_b	1.78	0.21	1.36	1.48	0.22	1.37
S_1^2	40.92	29.55	43.52	51.07	43.74	40.24
S_2^2	38.35	39.71	31.78	41.26	37.78	49.09
F	1.07	1.34	1.37	1.24	1.16	1.22
Δ	4.69	4.53	4.55	5.01	4.83	4.92

As illustrated in Table 2, the calculated values of distributions statistics of the St`yudent and the Fisher satisfy the conditions of stationarity of measurement errors of all sensor settings. The minimum values of m_b, S_b, та Δ are achieved at a LED pulse duration of 118 µs for both LED brightness levels. Consequently, the value of the LED pulse width of 118 µs can be regarded as optimal for two levels of LED brightness. At the same time, the values of the standard deviations and confidence intervals of the measurement errors for pulse durations of 118 and 411 µs are insignificantly different.

6 DISCUSSION

As a result, the developed methodology simplifies the verification of the correctness of the selected sensor settings and, unlike the existing ones, does not require the analysis of the LED current amplitude. Based on the statistical analysis of the stationarity of the HR measurement errors, the following conclusions can be made. When utilising an ADC with 8192 quantisation levels, the LED pulse duration value of 411 µs can be considered optimal for two LED brightness levels. When the number of quantisation levels of the ADC is reduced by two times, the optimum value for two LED brightness levels was found to be 118 µs. However, the calculations demonstrated that for a pulse duration of 411 µs, the accuracy of HR measurements decreases slightly. Reducing the quantisation levels of the ADC and the brightness of the LEDs leads to an increase in the standard deviation and confidence intervals of measurement errors. At a pulse duration of 69 µs, the maximum displacement of the average value of m_b is marked. The optimum sampling rate is 200 Hz. Reducing or increasing the sampling rate led to the appearance of incorrect heart rate measurements in the sample.

Meanwhile, the value of the sampling rate has almost no effect on the results of SpO2 measurements. Fig. 7 shows SpO2 measurements for different sampling rates with the number of ADC quantisation levels 4096.

As demonstrated in Figure 7, even for a minimum pulse duration of 69 µs and a brightness level of 30 LEDs, all the achieved SpO2 measurements have a value of at least 96%, representing the normal blood saturation of a healthy person. It is noteworthy that the minimum range of SpO2 measurements corresponds to the sampling frequency of 200 Hz.

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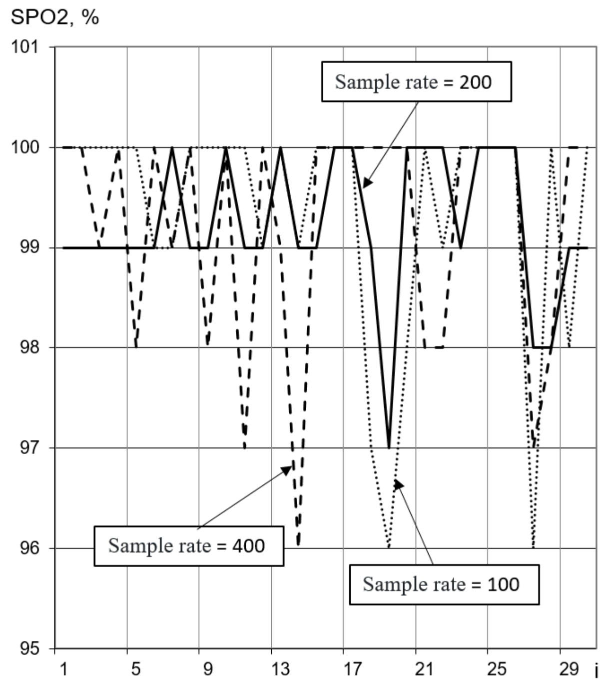

Figure 7 – SpO2 measurements for ledBrightness =30, pulseWidth =69 мкс, adcRange =4096

CONCLUSION

The scientific problem concerning the methodology for optimising the parameters of the pulse oximeter sensor settings, which has been further developed based on the practical determination of the accuracy of measurements of heart rate and blood oxygen saturation. Unlike the existing ones, this methodology does not require analysis of the current amplitude of the sensor LEDs.

Practical significance. The developed methodology has significantly simplified the selection of optimal settings for the pulse oximeter sensor, ensuring minimal error in heart rate measurement. Research has demonstrated that higher accuracy is provided at more enormous LED brightness when measuring heart rate. Conversely, reducing the quantisation levels of the ADC and the brightness of the LEDs has been demonstrated to increase measurement error.

The value of the ADC sampling rate has minimal effect on the results of blood oxygen saturation measurements, and it is advisable to select a sampling rate of 200 Hz for measuring heart rate.

Directions for further research. It should be noted that the duration of the pulse and the LED brightness affect the amount of energy consumed by the power supply, so it is worthwhile to do some additional research on the selected sensor settings when designing pulse oximeters with an autonomous power supply.

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ВИКОРИСТАННЯ ПАРАМЕТРІВ ЗАКОНУ РОЗПОДІЛУ ПОХИБОК ВИМІРІВ ПУЛЬСОКСИМЕТРУ ДЛЯ ВИБОРУ НАЛАШТУВАНЬ ДАТЧИКА

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АНОТАЦІЯ

Актуальність обумовлена необхідністю розробки методики оптимізації параметрів налаштувань датчика пульсоксиметру на основі практичного визначення точності вимірів частоти серцевих скорочень і сатурації кисню в крові, яка на відміну від існуючих, не вимагає аналізу амплітуди струму світлодіодів.

Пульсоксиметр, як один із сенсорів, що здійснюють моніторинг життєве важливих показників здоров'я пацієнта, вимірює частоту серцевих скорочень і сатурацію кисню в крові. Ці показники визначаються на основі аналізу значень змінної та сталої складової струму червоного та інфрачервоного світлодіодів датчика пульсоксиметру. Тому від правильного вибору яскравості і тривалості випромінення світлодіодів залежить точність визначення життєве важливих показників здоров'я. Існує можливість програмного вибору струму і тривалості випромінення світлодіодів, а також параметрів АЦП. При цьому, остаточний висновок щодо правильності обраних параметрів налаштувань датчика робиться на основі практичного визначення точності вимірів частоти серцевих скорочень і сатурації кисню в крові.

Метою роботи є розробка методики оцінки правильності вибору параметрів налаштувань датчика пульсоксиметру, що базується на аналізі стаціонарності похибок вимірів частоти серцевих скорочень та сатурації кисню в крові.

Метод. Експериментальне дослідження точності вимірів частоти серцевих скорочень і сатурації кисню в крові шляхом статистичного аналізу похибок вимірювань створеного макету пальсоксиметра.

Результати. Проведена перевірка практичного застосування запропонованої методики для визначення оптимальних параметрів налаштувань датчика пульсоксиметру на прикладі вимірювань частоти серцевих скорочень.

Висновки. Розроблена методика оцінки правильності вибору параметрів налаштувань датчика, що базується на аналізі стаціонарності похибок вимірів частоти серцевих скорочень та сатурації кисню в крові пацієнта. За допомогою розробленої методики обрані оптимальні параметри налаштувань макету пульсоксиметру на базі плати ESP32 та датчика MAX30102, які забезпечують мінімальну похибку виміру частоти серцевих скорочень та сатурації кисню в крові.

КЛЮЧОВІ СЛОВА: датчик, інтернет речей, похибки вимірів, пульсоксиметр.

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