UDC 629.78.054:621.396.018
Doi: 10.31772/2712-8970-2021-22-3-425-431

Для цитирования: Красненко С. С., Хайдукова В. Н., Недорезов Д. А. Автоматизированная система обнаружения аномалий периодических электрических сигналов // Сибирский аэрокосмический журнал. 2021. Т. 22, № 3. С. 425–431. Doi: 10.31772/2712-8970-2021-22-3-425-431.

For citation: Krasnenko S. S., Khaidukova V. N., Nedorezov D. A. Automated system for detecting anomalies of periodic electrical signals. *Siberian Aerospace Journal.* 2021, Vol. 22, No. 3, P. 425–431. Doi: 10.31772/2712-8970-2021-22-3-425-431.

Автоматизированная система обнаружения аномалий периодических электрических сигналов

С. С. Красненко[1], В. Н. Хайдукова[2], Д. А. Недорезов[2*]

[1]АО «Информационные спутниковые системы» имени академика М. Ф. Решетнева»
Российская Федерация, 662972, г. Железногорск Красноярского края, ул. Ленина, 52
[2]Сибирский федеральный университет
Российская Федерация, 660041, г. Красноярск, просп. Свободный, 79
[*]E-mail: Nedorezovd@mail.ru

Целью работы является разработка автоматизированной системы обнаружения аномалий периодических электрических сигналов с улучшенными характеристиками скорости и эффективности поиска. Для решения поставленной цели проведен анализ проблемы обнаружения аномалий периодических электрических сигналов, измеренных от электронной аппаратуры, и обоснована ее актуальность. Разработана аппаратно-программная система обнаружения аномалий периодических электрических сигналов, которая позволяет автоматизировать процесс испытаний и повысить эффективность обнаружения неисправностей электронной аппаратуры различного назначения. Улучшение означенных характеристик достигнуто за счет нового метода испытаний, лежащего в основе реализации предложенной системы и защищенного патентом Российской Федерации на изобретение, а также за счет качественной реализации программного и аппаратного обеспечения. При решении поставленных задач применены методы алгебры-логики, математической статистики и объектно-ориентированного программирования. Изложены результаты разработки аппаратуры и программного обеспечения, а также алгоритмов испытаний. Описана программа для электронной вычислительной машины, реализующая управление предложенной аппаратно-программной системой.

Ключевые слова: аномалии периодических электрических сигналов, аппаратно-программный комплекс, отработка, испытания, артефакты, электронная аппаратура, автоматизация.

Automated system for detecting anomalies of periodic electrical signals

S. S. Krasnenko[1], V. N. Khaidukova[2], D. A. Nedorezov[2*]

[1]JSC Academician M. F. Reshetnev Information Satellite Systems
52, Lenin St., Zheleznogorsk, Krasnoyarsk region, 662972, Russian Federation
[2]Siberian Federal University
79, Svobodny Pr., Krasnoyarsk, 660041, Russian Federation
[*]E-mail: Nedorezovd@mail.ru

The aim of the work is to develop an automated system for detecting anomalies of periodic electrical signals with improved characteristics of the speed and efficiency of search. To solve this goal, the analysis of the problem of detecting anomalies of periodic electrical signals measured from electronic equipment was carried out and its relevance was substantiated. A hardware and software system for detecting anomalies of periodic electrical signals has been developed, which makes it possible to automate the testing process and increase the efficiency of detecting malfunctions of electronic equipment for various purposes. The improvement of the aforementioned characteristics was achieved due to a new test method underlying the implementation of the proposed system and protected by the patent of the Russian Federation for an invention, as well as due to the high-quality implementation of software and hardware. When solving the set tasks, the methods of algebra-logic, mathematical statistics and object-oriented programming were used. The results of developing hardware, software and test algorithms are presented. A program for an electronic computer that implements control of the proposed hardware-software system is described.

Keywords: anomalies of periodic electrical signals, hardware and software complex, debug, testing, artifacts, electronic equipment, automation.

Introduction

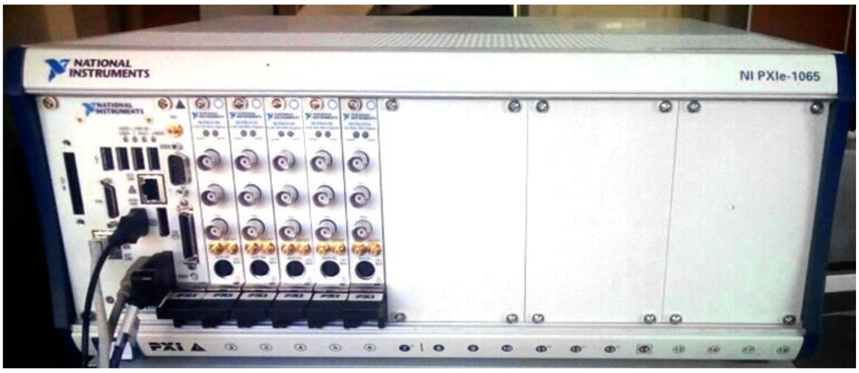
At present, the issue of developing testing systems with improved characteristics is becoming more and more urgent. This is due to the increased requirements for target engineering systems being used in the national economy. For example, there is a tendency towards miniaturization of the units being used in military and civil aviation equipment, land vehicles, water transport, etc. In this case, the functionality assigned to the above systems increases. The described processes necessarily influence the reliability of the equipment being manufactured, since any complication of the system threatens this characteristic. This article discusses a particular problem, determined by general trends in production, namely, test hardware and software systems that perform the function of oscillography of periodic electrical signals, which makes it possible to increase the level of reliability of technical systems. An oscilloscope is one of the main tools for controlling and testing complex equipment. With the help of an oscilloscope, it is possible to examine the shape of periodic electrical signals and detect its anomalies. Nevertheless, period anomalies can rarely appear. It made it necessary to conduct long-term recording of signals being received from monitor objects on information storage devices for their subsequent in-depth analysis. Conducting such experiments is essential for: registering bioparameters of a human body [1; 2], controlling and ensuring safety of the operation of nuclear reactors [3], testing electronic equipment [4; 5], for example, monitoring the periods of reference frequency generators, the distortion of which can lead to critical malfunctions of devices.

During the long-term measurements, with recording on information storage devices, huge volumes of digitized data accumulate, especially if synchronous recording is performed on multiple channels. An operator is not able to analyze received data manually. The presented arguments make the development of multichannel hardware-software oscillographic systems with functions of recording and automated analysis of oscillograms very urgent. In the course of the analysis of the level of technical solutions, it was determined that at present on the market there are few technical solutions that meet the requirements, and their characteristics can be improved [6–11].

The hardware of the proposed system

The technology of construction on the basis of main-modular systems for industrial use in the PXI, PXIe and cPCI standards has been chosen as the most suitable from the currently available technologies for organizing the equipment of test complexes [12]. This determined high reliability of the electronic component database, relatively low cost of the equipment, and most importantly, manifold possibilities for configuring oscilloscope systems, which is undoubtedly important for the creation of multichannel systems [13]. This approach makes it possible to increase the number of channels of the oscilloscope system up to 200 by installing new modules and racks, as well as to develop complex hardware and software systems, which, in addition to oscilloscopes, can include devices of various functionalities. For example, digital input – output devices, various generators and analyzers, controllers of industrial and civil interfaces, etc. This approach allows to conduct complex multifunctional tests [14]. Furthermore, the use of the above-mentioned test equipment standards allows specialists to provide high-quality synchronization of oscillography channels with each other, which is certainly important for comparing data obtained through different channels during the analysis.

The image of the developed laboratory layout of the oscillographic complex for detecting anomalies of periodic electrical signals is shown in the figure.



Лабораторный макет осциллографического комплекса

Laboratory layout of an oscillographic complex

The software of the proposed system

The software for the electrical signal anomaly detection system includes three main modules: oscilloscope module, oscillogram analysis module, technological process module [15].

The oscilloscope module performs the following functions:

1) configuring parameters for displaying and recording electrical signals from units under test, such as the number of channels, terminal impedance, sampling frequency, length of the sample presented on a display, etc.;

2) displaying signals measured from units under test;

3) recording signals measured from units under test to data storage devices.

The oscillogram analysis module performs the following functions:

1) setting a graphical sample of the periods of oscillograms, which the automated analytical system (AAS) (which is part of the system for detecting anomalies of periodic electrical signals), will take as a normal period that does not have anomalies;

2) configuring the deviation rates that are used by the AAS as an input parameter for searching for anomalous periods of the oscillogram being analyzed that differ from the one specified as a sample;

3) searching and detecting anomalous periods of the oscillogram being analyzed;

4) creating the images of detected anomalous periods;

5) creating a text file containing statistical data obtained as a result of the analysis: the number of

analyzed periods, the number of detected anomalous periods, coordinates of points of the detected anomalous periods in the oscillogram, etc.

The module of engineering processes performs the following functions:

1) viewing oscillograms in manual mode;

2) converting waveform data, for example, from a numeric type to text or graphics.

Test Algorithm

The test algorithm with the use of the proposed system for detecting anomalies of periodic electrical signals, in a general way, consists in the following: the input channels of an oscilloscope are connected to the sections of the electrical circuits of the units under test; put the units under test into operating modes; perform measurements continuously for a long time, recording data on data storage devices; on the display of the system for detecting anomalies they reproduce an oscillogram as a static image; an experiment operator graphically indicates a part of the oscillogram, from which the AAS should automatically calculate a sample of the normal period of the oscillogram, which will be taken as a sample, during the analysis for the presence of abnormal periods in the oscillogram under study, different from the calculated sample; the operator of the experiment configures the coefficients of deflection of the periods, thereby determining how much the analyzed period of the oscillogram should differ from the specified normal sample in order for the AAS to classify it as anomalous; the AAS automatically enumerates all periods of the oscillogram being analyzed and classifies each period according to the "normal / abnormal" attribute; the AAS generates a text file containing statistical data on the test results; the AAS creates the images of detected anomalies and saves them to data storage devices[16].

In appropriate cases, it is possible to adjust the system for the simultaneous continuous accumulation of data on the server with their automatic analysis and search for anomalies of a specialized high-performance computer. The digitized data saved on the server is stored in files as an array. Depending on the requirements for an oscilloscope and analysis system, these files can contain digitized data for a certain (specified) time. The minimum data recording time for one file must not be less than the full signal period, the maximum is limited only by the volume of server information space. Thus, if such a need arises, it is possible to adjust the system so that the first signal anomalies can be detected after receiving the first file with digitized data, i.e. within a few seconds.

Conclusion

The system developed for detecting anomalies of periodic electrical signals is protected by the patent of the Russian Federation for an invention and it allows:

– to record electrical signals received from the units under test on data storage devices for a long period of time (up to a year) , without data loss;

– to reproduce on the display and record electrical signals received from the units under test over a multitude of channels (up to 200) synchronized with each other;

– to perform automatic analysis of large volumes of oscillograms received from the units under test for the presence of anomalous periods in them.

The algorithms for detecting anomalies, on the basis of which the software modules of the proposed hardware-software system have been developed, are protected by the Russian Federation patent for an invention and have advantages in the detection efficiency.

The proposed oscilloscope method makes it possible to increase the probability of automatic detection of anomalies of periodic electrical signals contained in the analyzed oscillogram, while reducing time spent on the endurance run. This improves test efficiency.

The laboratory layout of an oscilloscope and the algorithms for measuring and searching for anomalies have been successfully tested at the JSC ACADEMICIAN M. F. RESHETNEV Information Satellite Systems while testing the control equipment for three-phase electromagnetic motors of the thermal control system.

Библиографические ссылки

1. Нгуен Ч. Т., Юлдашев З. М., Садыкова Е. В. Система удаленного мониторинга сердечного ритма для выявления эпизодов фибрилляции предсердий // Медицинская техника. 2017. № 3(303). С. 28–31.

2. Gant K., Bohorquez J., Thomas C. K. Long-term recording of electromyographic activity from multiple muscles to monitor physical activity of participants with or without a neurological disorder // Biomedizinische Technik. 2019. No. 64(1). P. 81–91.

3. Development of Custom Oscilloscope Based on CSNS Wall Current Monitor Data Acquisition / F. Li, J. Sun, T. Xu et al. // Yuanzineng Kexue Jishu. Atomic Energy Science and Technology. 2019. No. 53(9). P. 1715–1718.

4. Isaeva O., Nozhenkova L. Spacecraft onboard equipment testing automation technology on the basis of simulation model // IOP Conference Series: Materials Science and Engineering. 2019. No. 537(3). P. 032067.

5. Модули твердотельной памяти для бортовой аппаратуры малых космических аппаратов / О. В. Непомнящий, А. С. Правитель, Н. А. Мамбеталиев и др. // Наукоемкие технологии. 2015. Т. 16, № 3. С. 71–76.

6. Сайт компании Tektronix. Система Wave Inspector [Электронный ресурс]. URL: https://ru.tek.com/product-features/wave-inspector-navigation-and-automated-search (дата обращения: 17.05.2021).

7. Сайт компании Teledyne Lecroy. Система Wave Scan [Электронный ресурс]. URL: https://teledynelecroy.com/doc/wavescan-in-wavesurfer-3000z-oscilloscopes (дата обращения: 17.05.2021).

8. Сайт компании Teledyne Lecroy. Обзорный каталог. Осциллографы и анализаторы протоколов [Электронный ресурс]. URL: http://cdn.teledynelecroy.com/files/pdf/labmaster-10zi-a-datasheet.pdf (дата обращения: 17.05.2021).

9. Сайт компании Teledyne Lecroy. Система Trigger Scan [Электронный ресурс]. URL: https://teledynelecroy.com/doc/triggerscan-technical-brief (дата обращения: 17.05.2021).

10. Сайт компании Rohde & Schwarz [Электронный ресурс]. URL: https://www.rohde-schwarz.com/ru/product/rtc1000-productstartpage_63493-515585.html (дата обращения: 17.05.2021).

11. Сайт компании Tektronix [Электронный ресурс]. URL: https://www.tek.com/oscilloscope/tds2000-digital-storage-oscilloscope (дата обращения: 17.05.2021).

12. Li, Z., Hu, X., Zhang, G. Design and realization of HA hot-swap application for CPCI/PXI system // Proceedings of the 2014 9th IEEE Conference on Industrial Electronics and Applications, ICIEA 2014 6931478. 2014. P. 1898–1902.

13. Li D., Hu X. Hot-swap and redundancy technology for CPCI measurement and control systems // Proceedings of the 2016 IEEE 11th Conference on Industrial Electronics and Applications, ICIEA 2016 7603795. 2016. P. 1355–1358.

14. Пичкалев А. В. Аппаратура долговременного прогона для отработки узлов бортовой аппаратуры // Решетневские чтения : материалы XVIII Международной научной конференции, г. Красноярск. 2014. С. 240–241.

15. Свидетельство о регистрации программы для ЭВМ № 2017663519. Многоканальный самописец / Д. А Недорезов, регистр. 07.12.2017.

16. Пат. 2684203 Российская Федерация, МПК G06K 11/00. Способ интеллектуального анализа осциллограмм / Д. А Недорезов. № 2017140553 ; заявл. 21.11.2017 ; опубл. от 04.04.2019.

References

1. Nguen Sh. T., Uldashev Z. M., Sadukova E. V. [Remote heart rate monitoring system for detecting episodes of atrial fibrillation]. *Medicinskaia tehnika*. 2017, No. 3(303), P. 28–31 (In Russ.).

2. Gant K., Bohorquez J., Thomas C. K. Long-term recording of electromyographic activity from multiple muscles to monitor physical activity of participants with or without a neurological disorder. *Biomedizinische Technik.* 2019, No. 64(1), P. 81–91.

3. Li F., Sun J., Xu T. et. al. Development of Custom Oscilloscope Based on CSNS Wall Current Monitor Data Acquisition. Yuanzineng Kexue Jishu. *Atomic Energy Science and Technology*. 2019, No. 53(9), P. 1715–1718.

4. Isaeva O., Nozhenkova L. Spacecraft onboard equipment testing automation technology on the basis of simulation model. *IOP Conference Series: Materials Science and Engineering.* 2019, No. 537(3), P. 032067.

5. Nepomnyashchiy O. V., Pravitel A. S., Mambetaliev N. A. et. al. [Solid-state memory modules for onboard equipment of small spacecraft]. *Naykoemkie tehnologii.* 2015, Vol. 16, No 3, P. 71–76 (In Russ.).

6. *Tektronix* [System Wave Inspector]. Available at: https://ru.tek.com/product-features/wave-inspector-navigation-and-automated-search (accessed: 17.05.2021).

7. *Teledyne Lecroy* [System Wave Scan]. Available at: https://teledynelecroy.com/doc/wavescan-in-wavesurfer-3000z-oscilloscopes (accessed 17.05.2021).

8. *Teledyne Lecroy* [Oscilloscopes & Protocol Analyzers]. Available at: http://cdn.teledynelecroy.com/files/ pdf/labmaster-10zi-a-datasheet.pdf (accessed: 17.05.2021).

9. *Teledyne Lecroy* [System Trigger Scan]. Available at: https://teledynelecroy.com/doc/ triggerscan-technical-brief (accessed 17.05.2021).

10. *Rohde & Schwarz* [Oscilloscopes]. Available at: https://www.rohde-schwarz.com/ru/product/rtc1000-productstartpage_63493-515585.html (accessed: 17.05.2021).

11. *Tektronix* [Oscilloscopes]. Available at: https://www.tek.com/oscilloscope/tds2000-digital-storage-oscilloscope (accessed: 17.05.2021).

12. Li Z., Hu X., Zhang G. Design and realization of HA hot-swap application for CPCI/PXI system. Proceedings of the 2014 9th IEEE Conference on Industrial Electronics and Applications, ICIEA 2014 6931478, 2014, P. 1898–1902.

13. Li D., Hu X. Hot-swap and redundancy technology for CPCI measurement and control systems. Proceedings of the 2016 IEEE 11th Conference on Industrial Electronics and Applications, ICIEA 2016 7603795, 2016, P. 1355–1358.

14. Pichkalev A. V. [The equipment of long-term run for onboard equipment knot debugging]. *Materialy XVIII Mezhdunarodnoy nauchnoy konferentsii “Reshetnevskie chteniya.* [Reshetnev Readings: Materials of the XVIII International Scientific Conference]. Krasnoyrsk, 2014. P. 240–241 (In Russ).

15. Nedorezov D. A. *Mnogokanalnii samopisec* [Multichannel recorder]. Computer programs, No. 2017663519, 07.12.2017.

16. Nedorezov D. A. Sposob intelektyalnogo analiza oscilogram [Waveform Intelligent Analysis Method]. Patent RF, No. 2017140553.

Красненко Сергей Сергеевич – инженер-конструктор 2 категории; Акционерное общество «Информационные спутниковые системы» имени академика М. Ф. Решетнева». E-mail: t_150@list.ru.

Хайдукова Валерия Николаевна – магистрант; Сибирский федеральный университет. E-mail: Valeriya_iks@mail.ru.

Недорезов Дмитрий Александрович – магистрант; Сибирский федеральный университет. E-mail: Nedorezovd@mail.ru.

Krasnenko Sergey Sergeevich – second rank design engineer, JSC Academician M. F. Reshetnev Information Satellite Systems. E-mail: t_150@list.ru.

Khaidukova Valeria Nikolaevna – Master student; Siberian Federal University. E-mail: Valeriya_iks@mail.ru.

Nedorezov Dmitrii Aleksandrovich – Master student; Siberian Federal University. E-mail: Nedorezovd@mail.ru.