Diagnostic Service by Means of a Real-Time Operating System for Environmental Shielded TEM-chamber

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Abstract — The design of new device for electromagnetic compatibility testing – environmental shielded TEM-chamber – is considered. Diagnostic algorithms and functional structure decomposition of the chamber are presented. Tasks for a monitoring service of the chamber are indicated. The possibility of the diagnostic service implementation within a real-time operating system is considered for the chamber status check in the background. The specialized algorithms for the chamber hardware and software testing are developed. Recommendations for the development of software for the automated workplace of the chamber operator are proposed. Algorithms for diagnostics and testing of hardware and software for use with measuring instruments are developed.

Keywords— Diagnostics of equipment; unit testing; real-time operating system; automated workplace; measuring instruments.

I. INTRODUCTION

The creation of any hardware and software complex (HSC) consists of three main stages: design, development and testing. At each stage, there is a possibility of constructive, hardware, logical or program errors that could lead the HSC to failures or critical failure. In this case, each stage of work should be accompanied by monitoring the state of the HSC, aimed at the detection and localization of malfunctions. The effectiveness of the system diagnostics of the HSC depends to a large extent on the response of the system as a whole and the time of decision-making at the time of the failure. Providing the high speed of tasks is possible using the real-time operating system (RTOS). At present, in the development of hardware-based microcontrollers (μC), the RTOS is actively used. The software applications, system services, hardware libraries and device drivers included in the RTOS allow to optimize the operation of the μC and flexibly distribute the computing resources between the active tasks, taking into account external events and interruptions of the μC.

A new device is being developed: an environmental shielded TEM-chamber (ESC) designed for joint climatic and electromagnetic tests of integrated circuits and components of radio electronic equipment [1−3]. The environmental shielded TEM-chamber is a HSC, which needs a set of measures to ensure its correct operation, in particular, the diagnostic service. In the event of errors or failures, this service should locate the fault location and respond in a timely manner accordingly, preventing a critical failure. Thus, it is necessary to develop specialized algorithms for testing the HSC of the climatic chamber and to conduct an analysis of the possibility of introducing a centralized diagnostic service in the RTOS for monitoring peripheral devices, checking the serviceability of the system, receiving service messages from the μC, which will combine the tests of individual climatic chamber units in a centralized monitoring system and diagnostics of the functioning of the environmental shielded TEM-chamber.

The aim of this paper is to develop algorithms and software for a modular diagnostics service based on RTOS for monitoring and diagnostics the ESC.

II. GENERAL CONCEPT OF TESTING THE ENVIRONMENTAL SHIELDED TEM-CHAMBER

The decomposition of the ESC structure has been carried out, which allowed to refactor the software and to develop the concept of the functioning of the environmental shielded TEM-chamber. This allowed us to optimally use the RTOS diagnostics service and the testing of the environmental shielded TEM-chamber modules. The refactoring of the ESC software gave us structured algorithms and a minimized probability of errors.

From Fig. 1 it can be seen that as a result of decomposition software structure of the , global tasks were divided into separate modules: automatized working place; control board (μC_1–μC_N); control panel (LCD, Keys); diagnostics and testing subsystem. Each module is presented as a set of functionally completed blocks that perform a specific task. The development of a group of tests for various purposes with the possibility of testing with different "depths" was carried out. Initial testing involves testing the main elements and devices of the environmental shielded TEM-chamber (temperature, humidity, electromagnetic field, communication with peripheral devices). It is performed before each activation of the environmental shielded TEM-chamber. Selective testing allows the operator to form and execute an arbitrary set of tests using the operator's automated workstation (AWS). Full testing involves the implementation of a comprehensive test of all ESC units, including calibration of temperature sensors, electromagnetic field, etc. In this case, all the functions of the

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operating mode are performed for a specified period of time and the humidity and temperature parameters within the specified limits change. The decision to run a test is accepted by the operator through AWS software on the PC (Fig. 2).

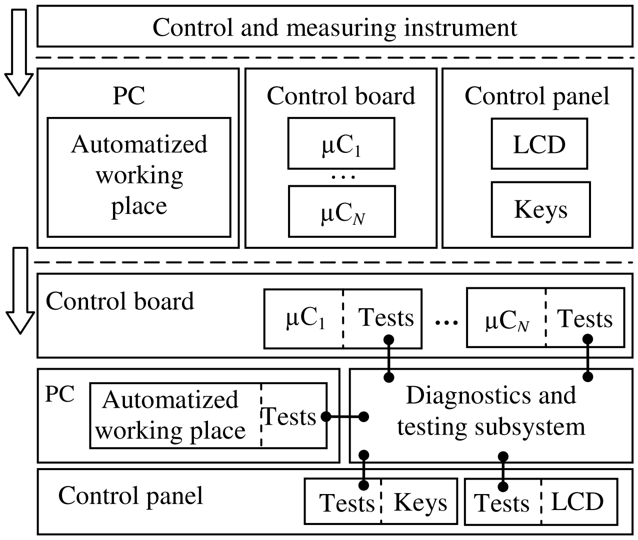

Fig. 1. Decomposition of the functional structure of the environmental shielded TEM-chamber software

This solution will allow checking the correctness of the interaction of a group of modules. The test control procedure can take place by various methods, such as conducting experiments with a "black", "white" or "gray box" [4−8]. As a "black box" with a lot of inputs and outputs, the whole system of the ESC or a separate module included in its composition can be considered. The correctness of the "black box" operation should be established by submitting test commands and observing the signals at the output. Those cases when signals from the "black box" are different from the expected result say about the inaccuracy of the work or the presence of an error. The error can be caused by a malfunction in the hardware, which is an incorrect state inside the "black box", and in the software parts of the environmental shielded TEM-chamber.

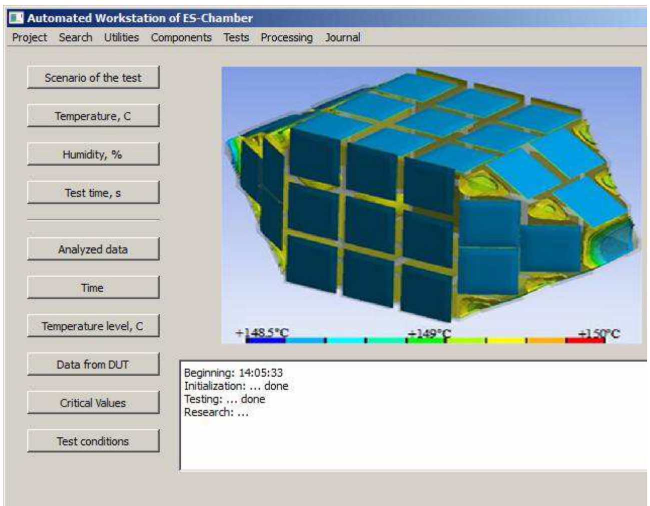

Fig. 2. The AWS program interface of the ESC

III. Primary Testing

For correctness of the received data during the operation of the ESC , an algorithm for primary testing has been developed (Fig. 3). The algorithm performs a survey of all sensors at their addresses and reads the readings of each. The result of the algorithm operation is the initialization of all the units and devices of the ESC, after polling each node and device, a message is sent to the operator's AWS and in the "Control panel". Also, the primary testing task includes checking the initial data (ESC operation parameters) entered by the user i.e. check the filling of all fields with correct values, for example, check the input of the temperature value in the test area, within the temperature range from −50°C to +150°C. Entering a value that is greater than this range will generate an error. Thus, the validity of the initial data is checked to ensure the normal operation of the ESC.

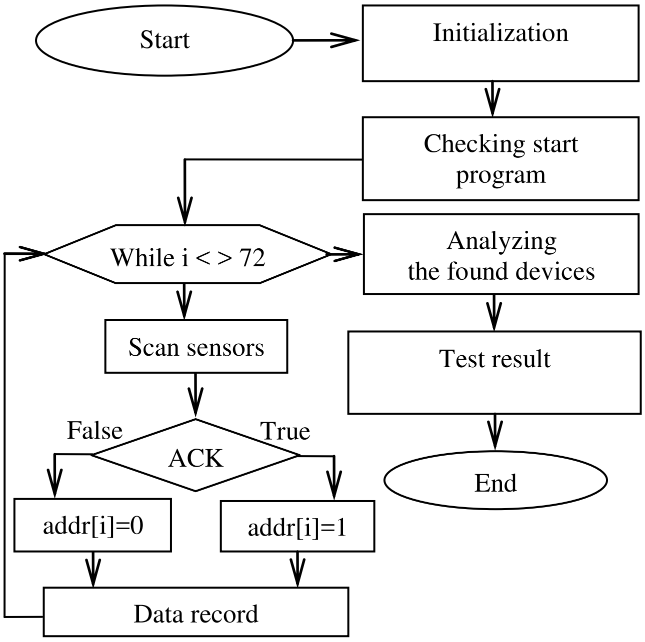

Fig. 3. Algorithm of primary system testing

IV. Testing of the Climate Subsystem

One of the main tasks of the ESC is the control and retention of the specified temperature and humidity of air inside the test container (TEM cell). In this work, each μC is involved in the management board. Testing consists in checking the values from the temperature and humidity sensors. Heating and cooling of the surface of the ESC test container is carried out by two subsystems: thermo-contact and thermo-air. In the thermo-contact subsystem there are many Peltier thermoelectric elements, near each of which there is a group of precision digital temperature sensors (PDTS). The case of a strong difference in the readings of one PDTS from the others is perceived as a malfunction in the operation of the environmental chamber. To identify such failures, an algorithm for functional testing of the climate subsystem of the ESC has been developed (Fig. 4). In the "monitoring" block, the main parameters of the environmental chamber are deflected and if the specified deviation limit is exceeded, the event is recorded (entry in the log. file). With a long operation of the PDTS, single faults in the readings are possible; these are erroneous data, which can be caused by high temperature, electromagnetic interference, high data reading speed, or sensor failure. The algorithm perceives them as erroneous and repeats the request to read the data. In this case, all erroneous data from the sensors are recorded. However, if erroneous data is repeated in a short period of time, the diagnostic system will alert the environmental chamber operator of the problem and stop the operation of the environmental chamber. The operator's AWS software gives a report file which will contain information about the failure: the address of the "problem" sensor; the last data received from it; the time of the failure and the rest of the service information.

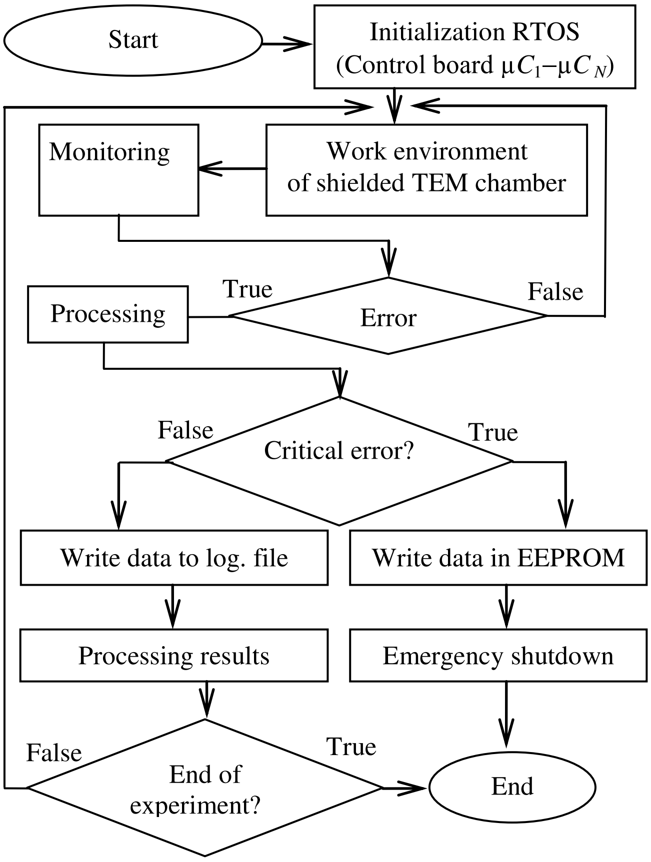

Fig. 4. Algorithm of functional testing of the climatic subsystem

V. Development of Testing Service for RTOS

As the control platform in the control board (μC_1–μC_N), mRTOS [3] is used. However, it does not provide a service for testing and monitoring devices. A monitoring service has been developed as a system service being a part of mRTOS (Fig. 5). In contrast to the task ($Task_1$–$Task_N$), the mRTOS service can directly access the kernel and other RTOS services. It can work in the background with the highest priority, while tasks are controlled by the Task Manager. The mRTOS monitoring service provides a programming interface to the operator's AWS applications and test functions for prompt intervention on the events that occurred: a critical failure; error during the work of the ESC; the ESC power off , etc. Response speed is important for saving a memory dump; registration of a failure; timely implementation of a set of measures for the emergency completion of the ESC. The emergency completion includes such events as opening a door with a test object, switching off the supply voltage of H-bridges, etc. Thus, the monitoring service is the main tool for monitoring the ESC state , which receives and processes information on the internal RTOS protocol from various devices implemented as tasks ($Task_1$–$Task_N$) (Fig. 5). The main functions of the RTOS monitoring service are: interrogation of the status of devices; decision making in case of a failure, storage of the log. file, sending messages to the application program on the PC; change the configurations for tests and peripheral settings.

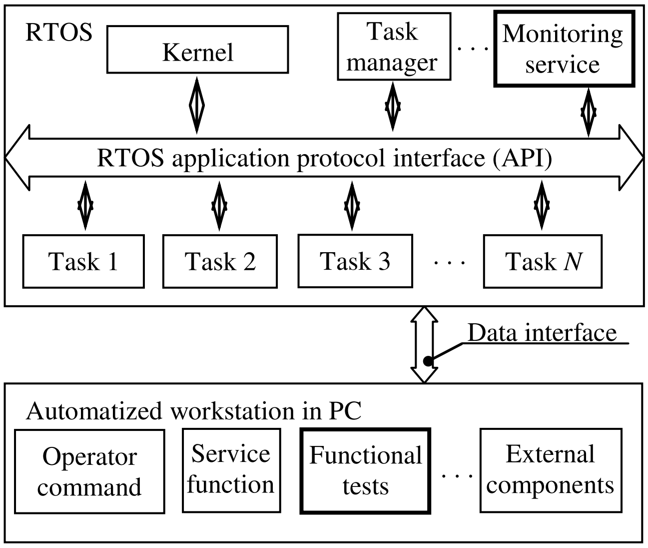

Fig. 5. Environmental chamber monitoring service in the RTOS

The monitoring service runs in the background, which allows you to operate independently of other tasks of the RTOS and work with a high priority. The monitoring service is called by an internal interrupt, which in the event of a failure allows the RTOS to respond quickly in a minimal time.

The monitoring service monitors the range of parameters of elements, nodes and devices. In the event of a malfunction in the work of the environmental shielded TEM-chamber performs a strictly defined procedure. The diagnostic service tasks include: checking user input; checking the efficiency of the ESC power part (analysis of information from current and voltage sensors); check of ESC subsystems (the analysis of the information from ESC temperature and humidity sensors); checking the functioning of the buttons and the touch screen of the control panel; verification of the communication interface between computing devices (μC, microcomputer, PC); generation of reports on the conducted testing of ESC.

Thus, RTOS monitoring service allows to determine when a specific task failed and determine what caused the failure. If the "Primary testing" is aimed at testing the hardware, then the diagnostic service recognizes software failure, errors in data and control signals, which ensures a high level of coverage of tests and the possibility of a comprehensive analysis of the ESC state .

VI. Conclusion

The ESC software code was refactored, which allowed to structure the testing algorithms and reduce the probability of errors, thereby ensuring a high level of coverage of tests and the possibility of a comprehensive analysis of the state of the ESC. The ESC testing algorithms and the RTOS monitoring service have been developed, which ensures the work control and notifies the status of the ESC AWS. Developed AWS software allows you to analyze the records of diagnostic services and test results to determine the cause of the failure in the ESC. The developed algorithms of automatic tests will warn the ESC operator when errors are detected as a result of the test, and automatically stop the operation of the ESC in case of a critical failure. Thus, in the event of an error, the developed means are able to localize the fault location to within a component level.

The diagnostic service described can also be used in other critical systems, for example, when designing a system for monitoring and controlling power supply units of a spacecraft. This application was also considered by authors.

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