INSTRUMENTATION DEVELOPMENT BASED ON REDUCE AND REUSE PRINCIPLES

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In the implementation of different types of instrumentation, one of the measurement and control components is often represented by a computer with a significant role in the system. The paper will show that instrumentation goals can often be achieved with computers of older generations without loss of reliability and performance, while additional benefits are realized in the form of reduction of electronic waste and reduction of the price of implementation of the given instrumentation.

Keywords: instrumentation, Linux, open source, reduce, reuse, software, e-waste management.

Instrumentation is most often used as a term to denote a group of measuring devices, and in most cases this definition of the term instrumentation would not be wrong. However, today the concept of instrumentation goes beyond the scope of the mentioned definition, especially in the industrial segment of application where instrumentation acquires not only measuring, but also control and monitoring properties. Taking into account modern trends and progress in the technical-technological sense, it must be emphasized that today the concept of instrumentation cannot be limited exclusively to measuring instruments. A broader meaning must also be included, since within modern instrumentation today we encounter not only measuring devices in the classical sense, but also different types of IT devices, computer and telecommunication networks, intelligent and smart sensors, software solutions and the like which leads to the fact that the instrumentation itself is becoming more and more complex [1].

When considering the basic application of computers in instrumentation today, that application is often identified with some control functions that enable an open or closed coupling effect on the system in which the instrumentation accomplishes its intended tasks. However, it should be noted here that in many cases, in addition to the above, the use of computers is also reflected in monitoring the condition of the measuring equipment [2], reading and storing the appropriate measured values and the environmental conditions found during the implementation of the measurement process itself, as well as achieving certain adaptability during the implementation of various measurement and control processes [3]. Accordingly, it can be said that the computer in modern instrumentation can be assigned various roles when achieving defined tasks and anticipated goals of varying complexity [4 – 6]. The modernization of the instrumentation was accompanied by the modernization of the computers used as part of the instrumentation. It has become common practice to use the last generation of computers as part of the instrumentation, while the older generations of computers previously used in the instrumentation became electronic waste, which in a small number of cases was adequately disposed of.

Often, with the appearance of newer generations of computers, the replacement of computers of older generations with newer ones in the instrumentation was carried out spontaneously without adequate analyzes and the real needs of the instrumentation. Such moves have led to constant increases in instrumentation implementation costs caused by the prices of new computer hardware and software, as well as to an increase in the amount of electronic waste. The question arises, whether this tendency can be avoided, that is, whether a part of computers of older generations can still be reused in accordance with the appropriate principles of electronic waste (e-waste) management [7] and adequately integrated into modern instrumentation.

In the following, it will be shown that this principle is achievable and that it can give concrete results by using the reduce and reuse principles used in the electronic waste management [8]. At the same time, all considerations of the reduce and reuse principles will be analyzed from the side of the instrumentation user, while some other possible compatible procedures from the manufacturer in the form of refurbished and remanufacturing [9] methods will not be considered here.

Description of the testing system

In order to test the feasibility of the above-mentioned principles, an appropriate test scenario was prepared. The test consisted in measuring the impedance of the defined reference model for given frequencies at the corresponding given temperature using instrumentation shown in Figure 1.

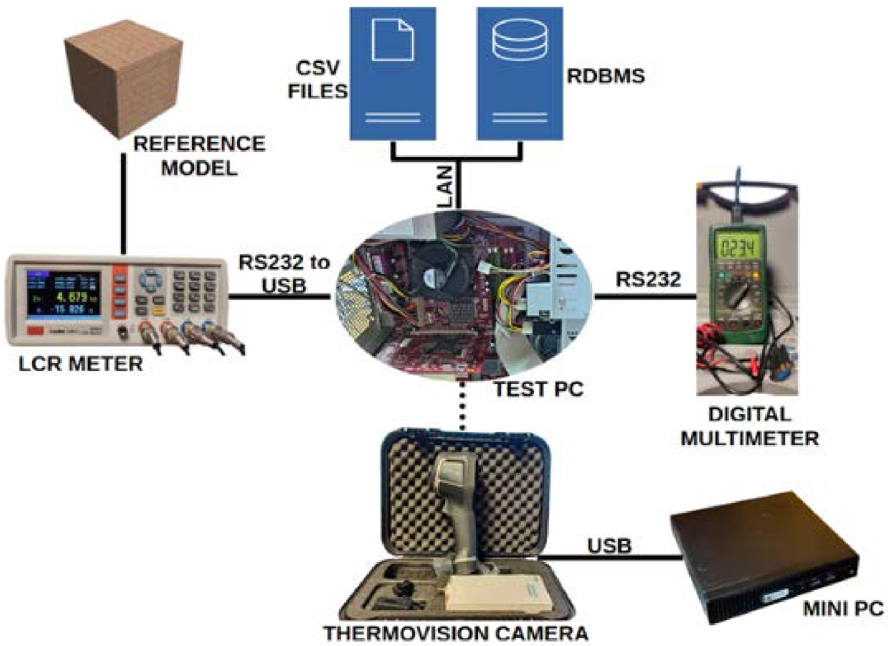

Fig. 1. Simplified schematic representation of the testing system

As can be seen from Fig. 1, the central place is occupied by an older generation computer, for which we want to prove the possibility of its reuse in instrumentation. In this case, it is a computer about 15 years old based on Intel 945PL chipset and Intel Pentium E2140 processor at 1.6 GHz, with 2 GB 533 MHz DDR2 SDRAM, 80 GB ATA HDD, GeForce 7300GT PCIe graphics card and standard 350 W ATX power supply. which has several USB 2.0 ports and one RS232 port. The computer is connected to a RuoShui 4091C 100 KHz LCR meter (connection on the instrument is achieved using the RS232 port, while on the computer the USB port is used via a suitable converter), which for the parameters sent by the computer (set frequency, internal resistance of the instrument, sampling rate, etc.) performs the measurement of the corresponding impedance of the reference model. The measurement results are then forwarded to the computer that performs double recording, to the appropriate database on the RDBMS (Relational DataBase Management System, as well as within the appropriate CSV (Comma Separated Values) file. In order to ensure the recording of values at the moment of reaching the target temperature, the computer is connected via RS232 connection to the Mastech MS8226 DMM (Digital MultiMeter) which sends the current values of the ambient temperature to the computer. When the appropriate set temperature value is reached, the computer starts the corresponding set of measurements on the LCR meter, so the DMM performs a specific triggering function in addition to the temperature measurement. For each of the specified 38 frequencies, 100 impedance measurements are performed, and then the mean measurement value for each specified frequency is calculated and entered as such as the result of the measurement. Each set of measurements lasts about 10 minutes on average, so over 100 measurement cycles were performed in the 24-hour measurement period. The entire system includes a thermal imaging camera that is connected to a mini PC in order to perform permanent thermal imaging monitoring of the state of the computer's hardware.

The Linux Fedora 39 [10] operating system (released at the end of 2023) is installed on the computer, in the version Linux Fedora 39 LXDE (desktop spin version), which ensures that the computer meets all modern software requirements and is competitive. The entire software for working with instrumentation was developed using the Python programming language using the pySerial module [11], which enables adequate communication, sending and receiving data from measuring instruments. It should be noted that when working with the LCR meter, SCPI (Standard Commands for Programmable Instruments) [12] is used, since this standard is supported by the instrument itself.

Results of the 24-hour test

During the 24-hour testing, 120 measurement cycles were performed, during which 120 CSV files were generated and a total of 4560 lines were written, both in the corresponding files and in the corresponding database. The analysis of the measurement results found that there are no missing values, and that there are no corrupted records, and that the obtained values are in accordance with the expected values provided by the reference model. This proves the validity of the data obtained from the measurements.

The time required for the computer from the moment of switching on to reach complete readiness for starting the planned tasks within the instrumentation was 39.838 s, which is an extremely good time, bearing in mind that it is 15 years old hardware on which the operating system is only a few months old. It should be noted here that this time was measured with the default values of the operating system, so this time can be significantly reduced with further system adjustments (fine tuning of the OS).

As for memory consumption, on installed OS with updated kernel to version 6.7.5-200, in idle mode, an average memory consumption of only 448 MB was recorded. During the operation of the instrumentation at the highest load, an average value of 1001 MB was recorded using the same kernel. To compare the values, a computer based on i5-6400, 8 GB DDR4 and SATA SSD using Windows 10 Enterprise 22H2 build 19045.4046 for the same tasks has an average memory consumption of 2.1 GB in idle mode and 3.1 GB in the highest load mode during instrumentation operation. Comparing the values, it can be seen that there is a significant reduction in memory consumption (on average 3–5 times less consumption can be achieved).

As already mentioned, during the test, permanent thermography monitoring of the computer hardware was carried out, with the aim of detecting potential anomalies of the computer hardware based on the extracted thermograms during recording. One such thermogram recorded during the maximum load of the observed computer is shown in Fig. 2.

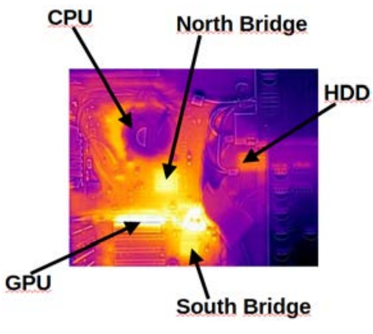

Fig. 2. Thermogram of the observed computer at the maximum load of the test system

As you can see from the picture, CPU and HDD recorded certain temperature increases due to increased load, but these increases remained within the permissible limits. On the thermogram, certain hotspots on the graphics card, north bridge and south bridge are spotted. Further analyzes are shown that they do not represent anomalies of the computer hardware, but that it is a normal transfer of heat to the surrounding hardware elements from the graphics card due to the passive cooling of the graphics card itself. It must be noted here that the computer was running in a basic configuration. If the appropriate fans were added to the case, as well as on the graphics card in terms of obtaining active cooling, better air flow would be enabled, which would lead to a more significant drop in operating temperatures in the load regime.

Conclusion

Based on the above, it can be seen that there is significant scope for the possibility of realizing instrumentation using computers of older generations marked as electronic waste through the appropriate reduce and reuse principles. It has been shown that using this approach does not necessarily mean performance degradation and loss of certain functionalities, as is often thought. On the contrary, if good planning and appropriate integration into the instrumentation is carried out, this approach can fully achieve the goals set within the instrumentation itself and the measurement process. Of course, such a rule should not be generalized, but it should not be completely rejected either, but should be given the chance to be applied where such application is feasible. This feasibility can be seen based on experience, analysis of the environment, analysis of the instrumentation itself, measurement process and other relevant factors.

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This research was funded supported by the Science Fund of the Republic of Serbia, grant No. 6706, Low-dimensional nanomaterials for energy storage and sensing applications: Innovation through synergy of action – ASPIRE and by the Ministry of Science, Technological Development and Innovation of the Republic of Serbia (contracts No. 451-03-65/2024-03/200131 and 451-03-66/2024-03/200017).

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Розробка контрольно-вимірювальних приладів на основі принципів економії та повторного використання

При реалізації різних типів контрольно-вимірювальних приладів одним із компонентів вимірювання та керування частотою є комп'ютер, який відіграє значну роль в системі. У роботі показано, що цілі вимірювання часто можуть бути досягнуті за допомогою комп'ютерів старих поколінь без втрати надійності та продуктивності, при цьому додаткові переваги реалізуються у формі зменшення відходів електронної промисловості та зниження ціни впровадження цих контрольно-вимірювальних приладів.

Ключові слова: контрольно-вимірювальні прилади, Linux, відкритий код, економія, повторне використання, програмне забезпечення, перероблення відходів електронної промисловості.