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AUTOMATION IN INDUSTRY

New Generation of Mixed and Dynamic Module-type Information-measuring Telemetering Systems Based on XXI and LXI Standards

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Abstract—The architecture of information-measuring and telemetering systems based on VXI-LXI standard and ACTest software package is considered; the architecture appears to be the most promising and optimal for testing, investigations, control and diagnostics of complex technical objects, as well as for industrial and power objects monitoring. VXI standard is intended to design the accurate and safe control-diagnostic systems and measuring-controlling systems. The paper is dedicated to detailed discussion of the issues regarding design of such systems on the basis of hardware manufactured by Informtest and software package ACTest-VXI, developed by Automation and Control Laboratory (AC) Ltd. [1].

1. ARCHITECTURAL FEATURES OF MODERN INFORMATION-MEASURING SYSTEMS

Bench tests for complex control objects, e.g., the products of space-rocket industry, aircrafts and their engines, etc., require information-measuring systems (IMS's) and telemetering systems ensuring efficient data collection and registration from various sensors [1]. The existing benches include numerous systems of this kind; they were designed and produced by different companies at different time. A certain architecture and design principles have been adopted for the IMS's in recent 15–20 years, see [2].

1. IMS's may be divided into static (slow) parameter registration systems (IMS-SPR, having channel inquiry speed within the range of 1 Hz–2 kHz), static-dynamic parameter registration systems (the corresponding speed is 2–10 kHz for the channel) and dynamic parameter registration systems (IMS-DPR, with the speed between 10 kHz and 2.5 MHz for the channel).

2. As a rule, the electrical circuit includes a certain normalizing module between the sensor and measurer; this module ensures disturbance amplification and filtration, as well as useful signal conversion to the form being comfortable for digitization through the measurer. Let us not focus on outdated systems with analog measurers. The type range of signal normalizers is huge, they involve various control principles and (in many cases) have unique design. We emphasize that there exist no standards regarding the structure of the normalizers; therefore, these devices are diverse and expensive. However, new models of the measurers generally have broad bands, utilize high-accuracy ADCs and DACs of next generation (with built-in calibration systems) and require no normalizers in the measuring channel. Another major aspect of the normalizer-free IMS consists in possibility to place the measurers closer to the controlled object, thus minimizing the cable network and improving the quality of measurements. These aims are ideally ensured by modern LXI crates with special-type power supply (12–36 V), adapted for operation in highly explosive areas and provided with remote control and data transmission via Ethernet. The aforesaid explains the tendency to reduce the number of signal normalizers in modern systems; this fact makes the work of testing engineers easier and increases the measurement accuracy. When evaluating the

cost of IMS development and comparing various measurers, the tendency in question leads to necessity to take into account the cost of the normalizers and their maintenance. In addition, combining the normalizing and measuring functions within a single module, as well as wide Ethernet application allow for significant reduction of disturbances and accuracy improvement (making the latter unattainable for IMS's of the previous generation).

3. As a rule, IMS hardware is installed in isolated room supplied with cable network connected to the sensors; the sensors are located on the controlled object. The normalizers and measurers are often placed on the same post; they are implemented using various crate systems, both standard (VXI [3], PXI designed by VXI Technology, Kinetic, Bustec, National Instruments, Informtest) and nonstandard ones (engineering solutions provided by the following companies: LMS, Bruel & Kjaer, Lcard, NPP Mera and others).

4. The existing IMS's have software that may be classified, first, as closed-type one being strictly dependent on the specific hardware (solutions proposed by LMS, Bruel & Kjaer, NPP Mera) and, second, opened-type one operating with hardware supllied by different manufacturers (solutions suggested by MTS, MDSAero – Prodas, M+P International—Coda, Informtest—Registrator, Automation and Control Laboratory (AC) Ltd.—ACTest [4], etc).

Since dynamic systems have always been extremely expensive and complicated, technological progress and new advances in hardware are the spheres exerting the most significant influence on them. Moreover, network technology has made it possible to design mixed systems composed of dynamic and static elements (ensuring their synchronization and operation within the integrated complex).

1.1. The Key Distinguishing Features of Dynamic System

1. Every channel has individual ADC. Inquiries to the channels are performed in parallel. The best measurers possess galvanic isolation of the channels and minimum channel interference.

2. The sampling speed (i.e., the number of measurements within 1 s) constitutes 10 kHz–5 MHz for each channel.

3. Dynamic systems of new generation employ wide range of measurers being united in the entire system; they are pressure meters, tachometers, strain measurers.

4. The number of the channels makes 2–256. As a rule, for additional channels several dynamic systems are installed, with synchronization using master-slave technology.

1.2. The Key Distinguishing Features of Static System

1. A group of channels have a commutator and ADC. The channels are inquired in series.

2. The sampling speed of the majority of slow IMS's lies within the range 1 Hz–2 kHz.

3. The number of channels is between 16 and 15 000.

4. Slow systems often include numerous types of the measurers.

5. Both for slow and dynamic systems, of principal importance is high quality synchronization and the presence of special control modules generating the commands (start, transport, etc) via the TTL/TRJ communication lines. It should be underlined that for VXI- and PXI-based standard systems these are TTL signals; on the other hand, LXI standard utilizes LVDS signals.

Software for static and dynamic systems should bind each information frame to absolute time of the system. This requirement is crucial for subsequent reliable processing of experimental results.

In mixed (static-dynamic) IMS's one may find static, static-dynamic and dynamic parameters; they are simultaneously and synchronously logged. Studying the testing process in the whole makes it possible to underline the following. In many cases the separation of information logging process into slow and fast channels is artificial and caused by hardware difficulties to implement information acquisition. It makes no difference since at postprocessing stage the results should be combined. The existing crate systems based on bus-modular principle always possess a certain physical boundary on transmission capacity (defined by bus capabilities and the speed of united dataflow). Bus controller will always serve the bottleneck determining the transmission capacity of the system regardless of the standard being used. Increasing the transmission capacity of the controllers significantly improves the speed of dataflow being transmitted; still, there is no radical change in the approach being involved. It was exactly the principle that set bounds on the number of dynamic channels within a single crate of any standard (based on utilization of a single bus). With numerous dynamic channels required, the number of crates and built-in computers managing them was increased. The large number of computers extremely complicated the system software (the complexity growth could be described by a certain geometric progression). As the result, "vicious circle" was formed. To minimize the costs, the customers strived to increase the number of channels within a single crate; however, for dynamic systems the procedure under consideration led to rapid attaining the limit transmission capacity for the dataflow. Hence, one had to split up the system into several crates, thus increasing the costs and complexity to log and process the information. Following the sampling speed growth and increase in capacity of the measurer, the dataflow speed was improved accordingly; again, it resulted in reaching the limit transmission capacity and the reduced number of channels in dynamic system. The above-stated problems predetermined slow growth of the number of channels within dynamic systems (under conditions of continuous development in capacity of the measurers) and exponent-like increase in the cost of the channel in high-accuracy dynamic systems.

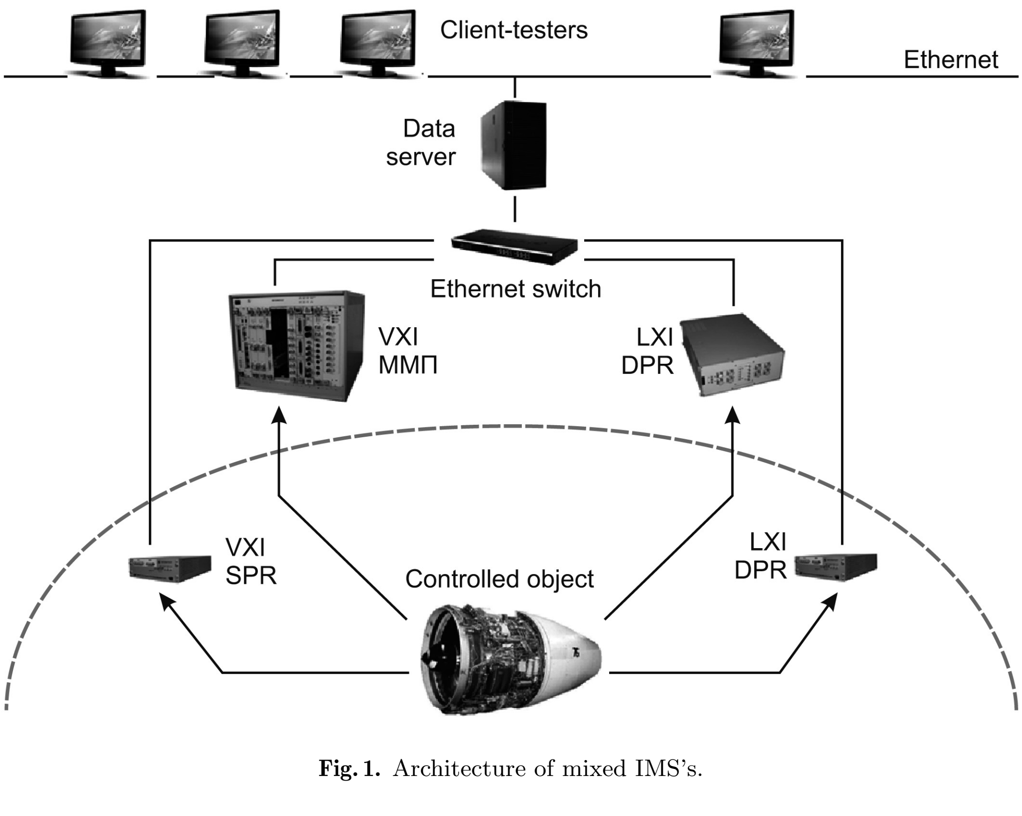

Fig. 1. Architecture of mixed IMS's.

The way out of this impasse situation for bus-modular systems has been found recently. It is provided by new version of VXI 4.0 standard assuming availability of two buses and two controllers. The first standard parallel bus is used for data control and transmission, while the second (serial) one goes from each module to network controller based on “star” principle. Such configuration allows for separating the control and data transmission buses, as well as to ensure high speed (up to 80 MB/s) of data collection from each slot using 1GB LAN or PCI Express. Nevertheless, VXI 4.0 has just appeared and there exist no implementation examples for such systems in the world; though, some companies are working hard on the matter and planning to demonstrate the first design results by the end of 2009.

2. DESIGN PRINCIPLES FOR INFORMATION-MEASURING SYSTEMS ACCORDING TO VXI AND LXI STANDARDS

Let us in detail study design principles for systems based on VXI 4.0 standard. This standard ensures data exchange using 2eSST protocol with the speed of 320 MB/s. Additional serial bus is installed on the VXI 4.0 cross panel, serving for dataflow exchange with every module using 1 GB LAN, VXS and PCI Express protocols. Any interface may be involved by the customer, depending on the type of switching slot that implements the exchange. In the judgment of VXI 4.0 developers, 1 GB LAN will be the most widely adopted serial interface; in the future it will be substituted by 10 GB LAN. PCI Express is embedded in the group of serial buses to link-up with PCI Express; this was done even ignoring the objections expressed by some members of the consortium.

The principal difference between VXI 4.0 and PCI Express architecture lies in that all modules of the latter are united within the controller using the “star” concept; the controller has an output PCI Express channel going to the control computer. This output channel nullifies all the advantages of the star-shaped coupling between the modules and controller; it represents a natural delimiter for such architecture making the group speed of the flow (according to “star” concept) close to the speed provided by cable version of a single PCI Express port at the output of the controller. In VXI 4.0 standard, the control is implemented through slot-0 VXI 4.0, ensuring data exchange over parallel bus VXI with 2eSST protocol (320 MB/s). Note that dataflow is transferred to the computer via multiport switch of 1 GB LAN or PCI Express (9 ports). The given module represents a separate slot in VXI 4.0 crate and has the identical number of outputs/inputs. Thus, the feasibility of data loading into the computer (from each slot VXI 4.0 at maximum possible speed of serial bus) is provided.

The developers believe that VXI 4.0 will be an ideal standard for mixed systems, making it possible to couple hundreds of fast and slow channels within the framework of a single system.

Further development of bus-modular systems represents just one of the ways to design modern mixed and dynamic systems.

The second approach is based on involving network technology and platform-independent measurers from the class of “synthetic tools” installed on VXI and LXI crates. Note that fast measurers are installed on VXI crates, while LXI crates carry the fast ones. In general, IMS is the set of measuring clusters; each of them solve a specific task, and dataflows within every cluster have no intersection. Such concept allows for combining the advantages of VXI (i.e., the maximum number of slow channels per crate) with the ones of LXI carriers (notably, no constraints imposed on the speed of data transmission), since each carrier possesses a separate LAN port and dataflows are united via Ethernet switch to reach data processing server. For instance, engineering solutions supplied by Informtest ensure up to 1408 measuring channels per crate with 128 channels for the module; Bustec suggests up to 2112 channels. Therefore, such approach provides opportunity for parallel operation of numerous dynamic channels in LXI carriers and numerous slow channels in VXI crates within a certain mixed IMS.

Another significant peculiarity of the intermediate measurers belonging to the class of “synthetic tools” consists in extension of possible range of systems (according to a certain geometric progression). For instance, presently Informtest Holding manufactures 27 types of intermediate modules answering various purposes, as well as 4 types of carrying modules for VXI- and LXI-based designs. They may be used to develop hundreds of diverse control-measuring systems according to VXI and LXI standards. Over 20 types of intermediate modules are produced by VXI Technology, while Bustec offers about 30 types; in addition, many intermediate module-based devices are provided by C&H Technologies, Kinetic EADS NA Defence and other companies. Being typical for VXI standard, the above-described approach appears feasible for LXI standard only through combining intermediate measurers and LXI carriers. The examples of LXI carriers could be found in MezaBOX 1 (the carrier of two intermediate modules) and MezaBOX 2 (the carrier of eight intermediate modules) [5].

Fig. 2. Dynamic parameter logging device Test-BMP1.

Fig. 3. Dynamic parameter logging device Test-BMP2.

Based on the above-stated approach, in 2008 the first couple of systems for logging and analyzing dynamic processes with rapid-changing parameters (RCP) were presented at Russian market, namely, Test-BMP1 (Fig. 2) and Test-BMP2 (Fig. 3). These systems are designed according to LXI standard and may be employed as a basis to develop distributed systems for logging and analyzing dynamic parameters, with access to local networks and Internet. Each system has individual URL and control-testing unit operating via Internet. The systems are constructed based on two types of carriers for intermediate modules (LXI standard), MezaBOX 1 and MezaBOX 2, respectively. Both systems are equipped with special adapters for 220V power supply.

Test-BMP1 is a portative system enabling installation of two intermediate standard-sized modules. It has USB 2.0 TMC and Ethernet 10/100 interfaces, field design with battery-based power supply (ensuring 9–11 h of continuous operation, depending on the measurers' type) and fully complies with requirements of LXI standard. The system is transported in a special case.

Test-BMP2 system (based on MezaBOX 2) makes it possible to install up to eight (any-type) intermediate measurers of standard width manufactured by Informtest Holding. Test-BMP2 is equipped with a special detachable switchboard panel intended to connect the cables coming from the controlled object, as well as synchronization cables; in addition, this system includes Ethernet 10/100/1000 and USB 2.0 TMC interfaces. The speed of the general dataflow reaches 26 MB/s. Depending on the type of intermediate measuring modules being used, the given speed corresponds to the logging speed of up to 5–5.5 million measurements per second. The power supply of 16–36 V, accompanied by spark-protecting covers on the switchboard, allow for using the system in highly explosive rooms. Moreover, Test-BMP2 possesses two built-in (connected) batteries that guarantee nonstop operation of the system in the case of power cut; depending on the module type, capacity of the batteries provides 5–7 h of system operation. The system is fitted out with special adapters to use standard power supply of 220 V. The architecture of Test-BMP2 enables designing the dual and triple measuring channels. The availability of special power supply and remote control make it possible to place the system at the shortest distance to the controlled object; thus, the size of the cable network and testing disturbances are reduced.

Test-BMP 1, 2 systems have synchronization over TTL/TRJ and CLK 10, ensuring the runaway of data binding (in time) subject to different channels within the limits of 2–5 ms for nonstop operation of 10–20 h. If necessary, the systems are configured within integrated measuring complex that includes any other measuring and telemetering systems, designed according to VXI, PXI and LXI standards. All the intermediate measuring modules (used in Test-BMP) have VXI Plug&play drivers and may be embedded in various VXI systems with VXI-HM and VXI-HMC carriers.

Software supporting Test-BMP systems includes channel configuration, as well as logging, recording, network translation and displaying of the data. Numerous clients (up to 20) may be connected to the server to display the data; note that every client is able to display over 20 parameters during the experiment. Before starting the operation, system software allows for making automatic adjustment of the channels and measuring noise level in the channel.

To perform postprocessing of the experimental results, the customers are offered to use back-end processors for packages of processing experimental results, e.g., postsession processing module within ACTest (manufactured by Automation and Control Laboratory (AC) Ltd.) or WinPOS (supplied by NPP Mera). ACTest is remarkable for the fact of involving open system technology to construct it; therefore, following the requirements of the customer, ACTest may be enlarged by auxiliary postprocessing procedures. If the customer has specific systems of postprocessing, the corresponding back-end processor could be easily embedded in ACTest-based system.

The following intermediate measuring modules (that formally may be viewed as the dynamic ones) are used in Test-BMP systems.

–MN4V—4 channels, 24 bit, 8 ranges (25 mV–10 V), group-type galvanic isolation, sampling speed of 102.4 kilosamples/s;

–MN8I—8 channels, 18 bit, 1 range (optional), individual galvanic isolation, sampling speed of 200 kilosamples/s;

–MN32SM—32 channels, 18 bit, 3 ranges, group-type galvanic isolation, sampling speed of 20 kilosamples/s (with 16 channels employed) and 12 kilosamples/s (with 32 channels employed);

–MN3I—3 channels, 16 bit, sampling speed up to 2.5 ms/s, individual galvanic isolation, 3 ranges;

–MTM-6—6 channels for strain measuring, 1/4, 1/2, full bridge, 8-cable coupling, sampling speed up to 130 kilosamples/s for the channel, built-in power supply 0–8 V for strain measurers (discrete step of 2.5 mV). Maximum sensor supply current up to 50 mA, sensor resistance of 120, 350, 1000 Ω, custom-made, electric calibration of the channel (calibration resistor 49,9 kΩ). Different connection diagrams for the sensor to measure longitudinal and lateral deformation, measurement range of 1000–20 000;

–MS ensures synchronization of VXI and LXI standards, as well as command reception (start, transport, etc).

On the request of the customer, Test-BMP may include any other intermediate measurers and formers manufactured by Informtest Holding.

In April 2009 the systems Test-BMP1, 2 were successfully verified through testing the foreign aircraft engine at Testing Center, Central Institute for Aeronautical Engine-Making. The experiment involved Test-BMP1 with the following configuration: 4 dynamic channels on the module MN4V (4 channels, 102.4 ks/s, 24 bit) and 32 static channels for measuring the voltage on the module MN32S (32 channels, 24 bit, 200 Hz).

Test-BMP2 is assembled on the basis of MezaBOX 2 with switchboard panel for BNC sockets. In total the system includes 92 dynamic channels: 64 channels at 12.5 kHz or 40 channels at 20 kHz are implemented through two MN32SM modules with group-type galvanic isolation; 16 channels at 100 kHz on two MN8I modules with channel-wise galvanic isolation; 8 channels on MN4V modules; 4 channels measuring the number of revolutions on the MNCH-4 module (4 channels, 10 mV–25V, 0.1 Hz–500 kHz); MS synchronization module (supports the signals such as start, transport, etc).

Both systems are coupled via Ethernet switch (1GB LAN, 1GB port of special server); the server ensures data acquisition, logging, archiving and network translation. The second 1GB port of the server is to connect computers to display information to the users. As far as Test-BMP1, 2 are designed within the framework of LXI standard, every system has personal IP address; this feature allows controlling the system through Internet. It appears comfortable for system maintenance, functionality control, etc. Test-BMP1, 2 may have different configurations depending on the number and types of the channels (www.inftest.ru).

Let us compare Test-BMP with analogous systems being offered at Russian market. Within the framework of LXI standard, real analogues could not be found. There exist foreign analogues among the systems operating through Ethernet and using the same modules in various configurations. Nevertheless, from hardware point of view, Test-BMP 1, 2 possess much wider range of measuring modules for dynamic and static measurements (in particular, 27 types at the beginning of 2009). Moreover, all the modules for Test-BMP1, 2 may be installed on the carriers within VXI standard; the corresponding analogues miss this feature. The product range of measuring modules for Test-BMP1, 2 fully covers the applications of slow systems (in contrast to analogues). This aspect makes it possible to design mixed systems using the same software, thus simplifying the work of the customer and reducing the costs.

Test-BMP 1, 2 software ensures parameter logging, archiving, network transferring, displaying and rapid processing of the data. Registrator software is supplied to the customers with Russian language. System support and postprocessing for Test-BMP1, 2 are provided by software package of automated measurements, testing and monitoring, ACTest-VXI, designed in Russian language, either.

We should emphasize that the average channel price within Test-BMP 1, 2 systems is 2.5–3 times less in comparison to foreign analogues. The price serves one of crucial factors, especially during economic recession. Test-BMP 1, 2 systems are manufactured in Russia (Zelenograd, Moscow) based on imported components, with full documentation in Russian language; every configuration of the system has certificate of pattern approval. Note that if required the quality of products may be verified directly by the customer. Each measuring module is supplied with full set of technical documents and properly tested.

Let Test-BMP 1, 2 be compared with RCP systems based on PC boards (in Russia there exist numerous systems of this type) mounted inside computer; such comparison would be not for the benefit of the latter. One may mount 2–3 boards inside computer thus posing constraints on the number of the channels (as a rule, 16 or 24 channels per system). Supplied by any manufacturer, computer mainboards have huge nonnormalized interferences significantly worsening the quality of measurements. PCI bus is not synchronized; this fact leads to considerable data runaways when using several PC-based systems within a certain complex. Moreover, electrical power units of computers are not normalized subject to noise level. Mounted on PCI bus, measuring modules generally have no guard shields. All the above-discussed aspects imply extremely low quality of measurements, as well as lead to small number of channels within a single system. These are exact motives not to utilize PC-based measuring boards in important multichannel testing systems for air- and spacecrafts, both in Russia and overseas. Note that in some cases the boards may be involved due to certain forcing circumstances; still, they are preferably changed when the corresponding opportunity appears.

The major advantage of systems based on PC boards consists in relatively low price. However, if one compares Test-BMP2 with 92 channels with analogous PC-based systems, at least six 16-channel systems with complicated synchronization would be required; probably, their price exceeds the one of Test-BMP2.

The next stage to develop the complex IMS is to integrate isolated modules and devices within a certain automation system, satisfying the requirements of controlling the complex objects (as much as possible).

3. INTEGRATED ENVIRONMENT FOR DATA ACQUISITION, PROCESSING AND DISPLAYING IN MODULAR INFORMATION-MEASURING AND TELEMETERING SYSTEMS

Every IMS is designed as a special integrated environment uniting software control shells via individual modules [6]. The kernel of such integrated environment is composed of multiwindow visualization tools for primary and processed data, adjustment and control tools for the complex, as well as tools to select operation modes allowing to perform general actions.

Data acquisition. For each type of interface facility, a certain dynamic library is developed to support specific operation of bridging devices. Integrated environment makes it possible to activate dynamic library being responsible for interaction with external devices; this allows for adjusting and performing data acquisition session. The environment "has no idea" regarding algorithms of the acquisition, being merely informed on the location of the collected data (i.e., memory descriptor). Acquisition specifics (notably, interaction modes, base addresses, interrupt vectors, etc) is considered by the activated dynamic library. The latter is responsible for operative configuration; if necessary, it displays the corresponding dialog boxes.

Typical adjustment parameters are the following.

- device parameters—base address, the number of interrupt vector;
- interaction mode—method to interact with of PC (availability, interrupt, direct memory access);
- synchronization mode—technique to initialize acquisition process;
- history definition—method to divide the data into "preliminary" and "basic" information;

• coordination levels—the levels of input/output channels used to communicate with the external device;

• discretization mode—the type (internal or external) and parameters of the generator employed to produce sampling frequency for data acquisition;

• acquisition mode—continuous or single-time data recording subject to selected channels.

Data visualization. Visualization supporting element (i.e., the one displaying the data) is built-in, as far as it is required in any operation mode including data acquisition, operations with files or tables, mathematical treatment of the results.

Graphic windows are involved for visualization purposes; note that the number of simultaneously opened windows is arbitrary. Each standard window serves for demonstrating the signals provided by all the "handled" devices, both digital (logic-type) and analog ones. The number of visible or active signals (at specific time) may be adjusted according to the circumstances. To scan the values of the signals, movable markers and representation fields are employed. It is possible to perform scanning and other operations for the groups of analog and logical signals, separately or together. It stands to reason that the windows may be duplicated, saved as files, etc.

Examination of data segments using zooming tool. For detailed examination of data, the system provides a certain tool for scaled-up viewing the selected data segment. Bounds of the segment (to-be-studied in detail) are marked in the signal displaying window; using the corresponding command, the selected segment is displayed in a new zoom-window. Moves of the marker in this window are synchronized with the position of the active marker within the initial window. The number of zoom-windows is limited by the computer performance.

Data processing. Data processing tools are the element providing the most visual illustration for design principles of the system. On the one hand, these tools have to ensure sufficient level of basic operations; on the other hand, they should guarantee flexibility and expandability of specific realizations.

Processing tools are implemented in two forms, namely,

• *rapid processing*, being the most general kind of processing subject to the formulas typed in real-time;

• *algorithm processing*, i.e., the special one (for the application under consideration) subject to prewritten algorithms.

Rapid processing makes it possible to perform different computations according to the formulas typed by the user. These could be separate calculations and group-related operations (e.g., for arrays). The list of feasible arguments includes primary (not processed) data, parameters describing conditions of acquisition, constants (numbers and their identifiers), both being computed subject to formulas used earlier or standard mathematical functions. The typed formulas may be temporal or stored in memory for future use, thus enlarging the library (base) of rapid functions.

Algorithm processing. To calculate parameters based on complicated functions (algorithms), special libraries are developed; the number of them is constantly growing. In addition, there exist regulations (protocols) to be observed by the users in order to design such libraries themselves; when designed, the user library may be connected to the device complex.

Tables support. Improving the concept of integrated environment design, much attention should be paid to data storage methods. An explanation is in special structure of the data produced in device-based systems; the structure in question do not coincide with data formats involved in common databases intended for management control automation. The authors take into account the following aspects of the problem:

• static aspect, related to the structure used to store the data on the disk;

• dynamic aspect, concerning the method of interaction with data tables.

Structure of storage. There are several types of the tables, i.e.,

• *root tables*, containing information on available data tables and conditions used to obtain the data. A certain folder within the basic one of integrated environment is employed to store these tables. The number of root tables could be large.

• *testing tables*, containing data generated during testing procedure.

• *reference tables*, containing data to be used in some cases as a reference (e.g., when involving the complex to perform malfunction diagnosis). Note that the data in reference tables is similar to the one of testing tables.

• *format tables*, containing information describing the structure of tables being used.

The suggested principle of table storage serves only as a recommendation; users may utilize personal principles of storage, as well. The most important thing is to build a certain storage structure, so as no to "get confused" with the data. Therefore, we suggest a special tool to support the structure.

Modes of calling the tables. Two ways to activate data tables are provided, namely, calling via root table and direct call. Each entry in the root table is related to the data table corresponding to the data acquisition session. The following basic operations are defined for the root table.

• entry actuation, when graphic window appears demonstrating the data from the table under consideration.

• entry elimination, note that the corresponding data table is not physically deleted.

• entry editing.

Direct call of the table is performed through standard dialog boxes of the file-opening panel.

4. ACTEST: INTEGRATED ENVIRONMENT FOR DATA ACQUISITION, PROCESSING AND DISPLAYING

The stated ideas are implemented in ACTest [4], software package for experimental and industrial assemblies; this product is designed in Automation and Control Laboratory (AC) Ltd. (www.actech.ru) and has received Rospatent certificates. Nowadays, the package is on the market as finished "shrink-wrapped" application and as a basic tool to design systems according to requirements of the customer. ACTest possesses well-developed tools of data visualization in real-time. In addition to common visualization tools, i.e., symbolic circuits with digital elements, graphers, table elements (supplied by most automation systems), there exist visualization tools being implemented as "virtual devices" (oscillograph, spectrum analyzer) intended for displaying extremely dynamic data. Using functionality of ACTest package and based on standard data-acquisition units, one may implement various device complexes.

Moreover, ACTest provides visualization and user-interaction tools that allow to adjust scenarios for selected mode of automated device complex, as well as to store and search for required scenario in the database; these tools make it also possible to perform measurements in real-time (with simultaneous data archiving and visualization), to view and analyze the results.

The primary mathematical treatment and control of critical values for measured parameters are carried out in real-time. All information is stored in the corresponding database and appears available for subsequent processing and analysis. The package includes certain software for secondary processing and visualization of the measurement results.

It is possible to operate the package via a single computer or within a certain distributed system (involving client-server technology), see Fig. 4.

Bench-test automation system based on ACTest package is demonstrated by Fig. 5.

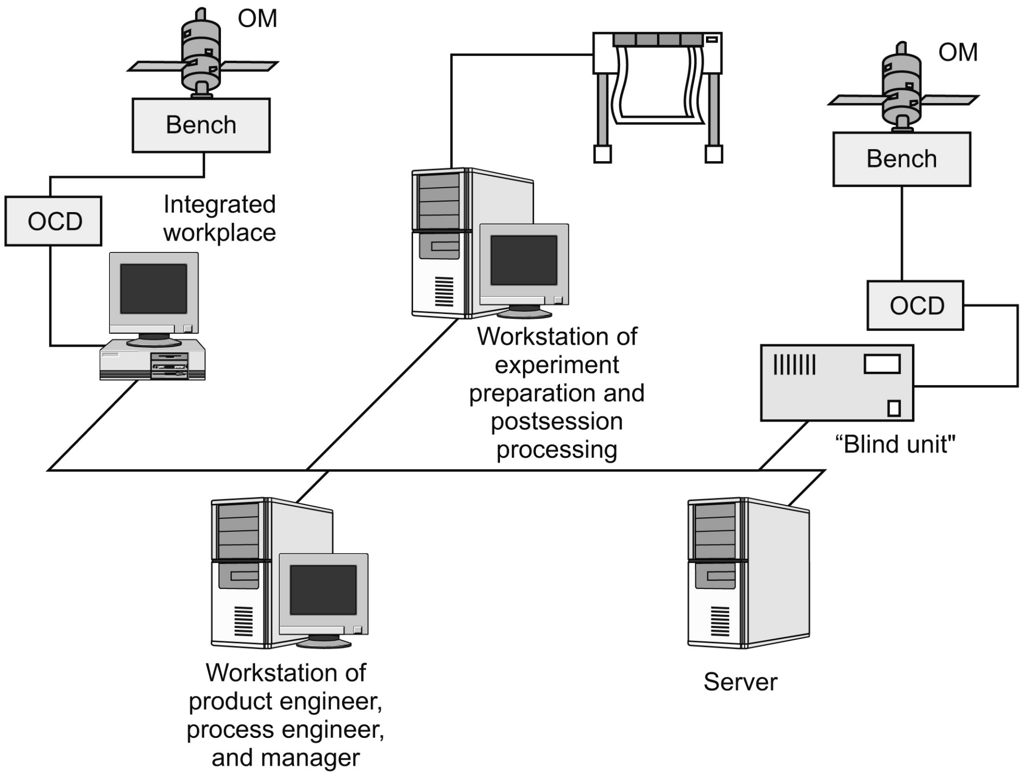

Fig. 4. Local network of laboratory bench complex.

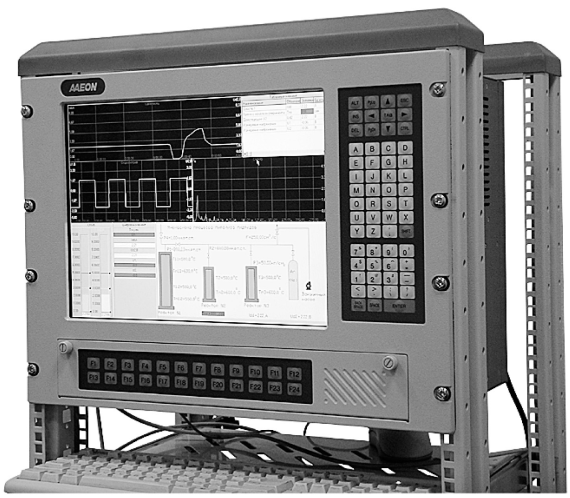

Fig. 5. Bench-test automation system based on ACTest package.

5. CONCLUSION

Today, Informtest Holding is the unique Russian company that has developed the manufacture of IMS's for analyzing static, static-dynamic and dynamic parameters according to VXI and LXI standards. Wide range of intermediate measuring devices (27 types) are serial products made following the technology of "synthetic tools." In practice, this means that it is possible to use the same measurers (without any hardware of software modifications) to develop IMS's within different open-type standards.

Automation and Control Laboratory (AC) Ltd. is engaged in designing control systems, connecting specific modules and devices to experimental testing systems; the company provides end-to-end solutions for integrating VXI- and LXI-based devices within fully functional automatic systems, as well as designs and supplies measuring and testing systems at all stages of their life cycle.

VXI- and LXI-based modules are integrated within the common system using special version of ACTest, software package developed in Automation and Control Laboratory (AC) Ltd.. This version is known as **Programmnyi kompleks avtomatizatsii izmerenii, ispytanii i monitoringa**—ACTest-VXI© (Software package for Automated Measurements, Testing and Monitoring); it has received certificated No. 2007613393 issued by Rospatent. VXI and LXI modules produced by Informtest Holding have successfully passed the testing procedure and assigned the status "ACTest-Compatible" in Automation and Control Laboratory (AC) Ltd.

Presently, the package ACTest and its components (with digital and analog data acquisition units) are utilized by, at least, 260 companies and institutions; many organizations de facto use the package as the standard. ACTest is developed on the basis of integrated software shells that include measurement devices. It represents open-type system allowing for

• adapting the existing program units to certain (possibly, very specific) requirements.

• increasing the number of dynamic libraries (due to flexible embedding procedure for new components); this could be done with the aim of extending opportunities for data acquisition, processing, displaying, storing, etc.

• continuous improving the system following state-of-the-art technology (e.g., expanding the system scope to global networks via Internet-related component).

The authors have a clear understanding that the stated approach could be considered as a revolution in the field; this is the case against the background of bad situation in aircraft and spacecraft industry (especially, in the area of module engineering). Nevertheless, this approach would determine the future state of the subject. This approach has been selected by the foreign companies; probably, we should follow the same path.

The discussed approach is of particular relevance for new types of scientific equipment in the field of nuclear physics, nanotechnology, etc. This is the only approach to prevent unlimited cost growth for new measuring systems; without the latter, it seems impossible to keep abreast of science and technology race, forming the basis of innovation economics of the future.

REFERENCES

1. Pertsovsky, M.I., Development and Modernization Strategy for Enterprise Testing-Experimental Facilities, *Avtomatizatsiya v Promyshlennosti*, 2009, no. 6.
2. Zaichenko, S.N., Komarov, M.V., Strakhov, A.F., and Filimonov, S.N., VXI and LXI Standard Tools for Next-Generation Automatic Control and Diagnostic Systems, *Voprosy Elektroniki. Seriya Obshchetekhnicheskaya*, 2009, vol. 1.
3. Bloennigen, F., *What Is the Ideal Bus?*, Shannon: Bustec, 2001, EE-Evaluation Engineering, http://www.bustec.com. Translated under the title *Ideal'naya magistral'*, Moscow: Informtest, 2006.
4. Pertsovsky, M.I., Rtishchev, A.V., Shulik, A.S., and Yakovlev, A.V., ACTest Software Package as Complex Approach to Testing and Experiment Automation, *RMMagazine*, 2006, no. 5.
5. Zaichenko, S.N., Filimonov, S.N., and Khartov, V.V., VXI: A Standard to Design Bus-Modular Data Acquisition Systems, in *Tsifrovye izmereniya. Medody i skhemotekhnika* (Digital Measurements. Methods and Circuit Technology), Moscow: Tekhnosfera, 2004.
6. Pertsovsky, M., Vorob'ev, E., Kiryukhin, S., and Kutsevich, N., Integrated Environment for Acquisition, Processing and Control by Digital Data, *Int. Symp. on Problems of Modular Information Computer Systems and NetWorks*, ESONE Committee, 1996.