MULTIPLATFORMNA SINHRONIZACISKA TEHNIKA ZA AKVIZICIJU NA BIAKSIJALNOJ VIBRO-PLATFORMI
MULTIPLATFORM DAQ SYNCHRONIZATION TECHNIQUE OF A BIAXIAL SHAKING TABLE FOR STRUCTURAL TESTING

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Sadržaj: *Instrumentacijski problemi iz prakse su puni predizika jer po pravilu obuhvataju hibridne akvizicijske (DAQ) sisteme, sastavljene od razlicitih hardverskih platformi. Sustinski problem u takvim hibridnim sistemima je sinhronizacija akvizicije na svim platformama i kombinovanje podataka. Ovaj clanak ilustrira resenje za 152-kanalnu akviziiju na 40-tonskoj vibro-platformi za strukturna testiranja.*

Abstract: *Practical instrumentation setups are more or less always challenging due to the different platforms of Data Acquisition (DAQ) they usually embrace. The essential problem with the use of such hybrid setups is the synchronization of the DAQ on all the platforms used, as well as combining their data. This article depicts a solution for a 152-channel DAQ on a 40-ton biaxial shaking table for structural testing.*

1. THE BIAXIAL SHAKING TABLE

The shaking table on which structural models are installed in order to be subjected to a biaxial earthquake motion, is a prestressed reinforced concrete plate, 5.0 x 5.0 m in plan (figure 1).

Figure 1. The biaxial shaking table

The table is supported by four vertical hydraulic actuators located at four corners at a distance of 3.5m in both orthogonal directions. The table is controlled in horizontal direction by two hydraulic actuators at a distance of 3.5m with a total force capacity of 850kN. The four vertical actuators have a total force capacity of 888kN.

The shaking system controls five degrees of freedom - two translations and three rotations (figure 2). The digital (embedded PowerPC) control system controls displacement, velocity, differential pressure and acceleration of the six actuators.

Reverse control is provided by three variable servo control system which is capable of controlling displacement, velocity and acceleration simultaneously - in the low frequencies the system provides control by displacement, while for higher frequencies in respect to acceleration.

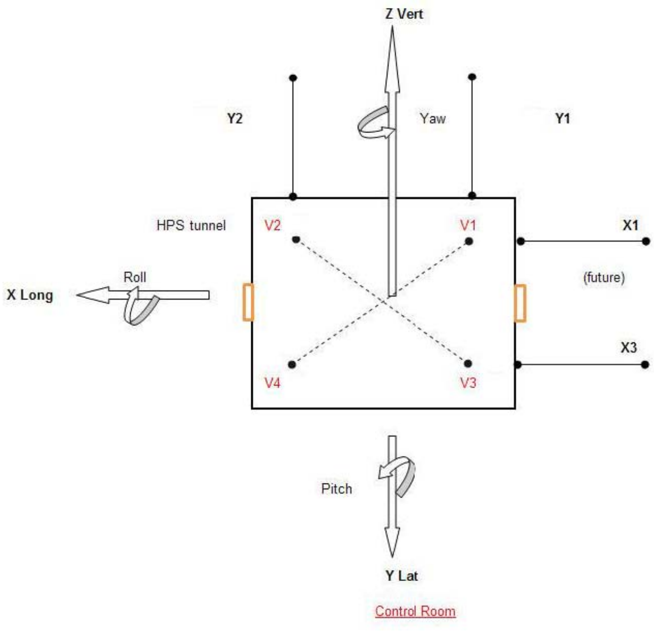

Figure 2. Degrees of Freedom (DOFs)

Maximum model mass is 40t with height over 7m, and dynamic range up to 80Hz.

Typical models include buildings or structural assemblages in given scale (figure 3), bridges and dams, power equipment and industrial objects, special structures like water and cooling towers, nuclear power plants, etc.

Typical services are related to seismic qualification according to certain standards (like IEEE 693), as well as proof testing of different products subjected to dynamic or earthquake effects, as required by standards.

Figure 3. Model of a church

2. THE CHALLENGE

Instrumentation of structures subjected to dynamic testing (scaled earthquake simulation, random & sweep resonant searches as well as synthetic spectrum excitation) requires lot of sensors to be appropriately positioned.

Four types of sensors (channels) are used:

LVDT - linear variable differential transformer
LP - linear potentiometer
ACC - accelerometer
SG - strain gauge

LPs and LVDTs are used to calculate the relative movements of segments of the structure (storeys) with respect to the rest of it (showing the elasticity of the object). ACCs and SGs measure the acceleration of and the strain on the critical points of the structure, providing important information on the tensions it suffers as well as on the cracking conditions.

Figure 4 shows a typical model of a structure instrumented with LPs (yellow strains), LVDTs (green stiff joints) and ACCs & SGs (red marked locations).

Amazingly, values of relative displacements (DIS) are measured in the range of 10mm along with accelerations (ACC) of sometimes 2g - implicating high tensions in stiff structures. This requires high resolution of the data acquisition (DAQ) system in both the time and frequency domains.

DAQ standard is 24-bit A/D conversion and up to 102.4kHz acquired spectrum for DSA (dynamic signal acquisition). The latter is usually required for an optimal anti-aliasing filtering, so signals are commonly down sampled afterwards according to the specific requirements.

So the DAQ challenge presents itself explicitly as a need to detect [mm] of movements as well as propagations (velocities - VEL) in stiff materials that range well over 10km/s implicating time determinism of [μs].

Figure 4. Typical test model of building

Given the spectral requirements a single DAQ channel would require 102.4kS/s (minimal sampling rate for the 51.2kHz spectrum), 4 bytes per sample (24bit acquisition normally packed with 4B), therefore 409.6kB/s (0.5MB/s).

DAQ equipment is multiplatform, reflecting different technological periods of purchase as well as implying the financial capacity which allows for gradual procurement in time.

The "core" of the DAQ is a PXI chassis with 9x 8-channels DSA modules and a signal generation module all of them providing 72 simultaneous DSA channels IEPE current sourcing capable (figure 5). Added are 3x cDAQ Ethernet chassis providing DSA modules for SG acquisition of 80 bridge-based channels (figure 6). System excitation is generated and coordinated with the table's three variable (AVD) and 5x DoF control by the embedded PowerPC controller.

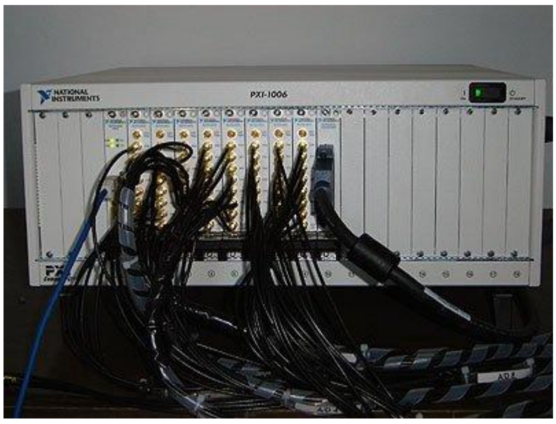

Figure 5. The PXI chassis

Figure 6. The cDAQ chassis

3. THE SOLUTION

The PXI chassis streams to the desktop PC via a serial optical link. The cDAQ chassis stream over Ethernet. Although signals are post-processed, yet the Real-Time acquisition has to be achieved and the following problems are therefore addressed:

- bandwidth limitations and data throughput
- simultaneous START & CLK of DAQ triggering
- CLOCK synchronization
- synchronized file streaming
- data streaming to Internet (optional tele-presence)

The required bandwidth for the typical sampling rate of 102.4kS/s is about 36MB/s for the PXI chassis via its serial link, and about 40MB/s for the three cDAQ chassis via their Ethernet LAN. The cDAQ LAN is dedicated for the three cDAQ chassis and a dedicated NIC of the DAQ PC. The PC under WindowsXP can successfully stream these 76MB/s to its SCSI disk system, while performing all of its other OS and application tasks.

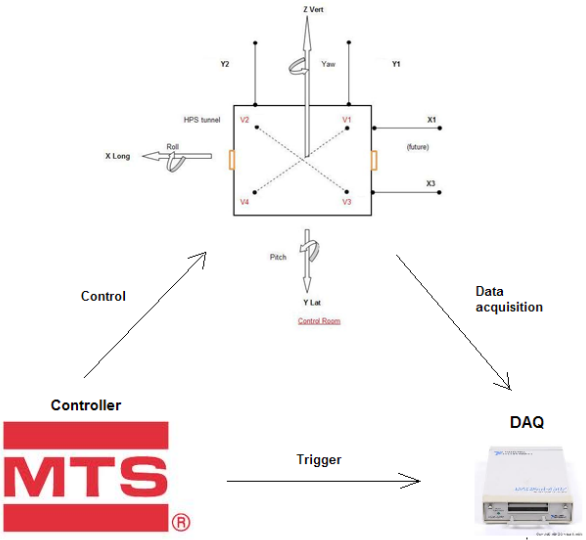

Figure 7. Table-Controller-DAQ scheme

The synchronization has two issues - synchronous START of DAQ on all four chassis, and a single CLOCK signal triggering the 152 simultaneous A/D converters on the four chassis (all driven by local time bases). Additionally, safe parallel streaming to disk into four files.

Figure 7 show the connection concept. The START (DAQ) signal being associated with the event of beginning the signal generation, is taken from the controller's marshalling panel and distributed to all four chassis via equally long cables.

The CLOCK is shared from the PXI chassis' time base and appropriately divided for the cDAQ platform to avoid the jitter among the 152 ADCs.

On the software level, the problem of storing those 76MB/s in real-time, as well as performing some digital conditions for the end-of-DAQ is solved.

The application implements a manageable set of FIFO buffers for the incoming chunks of the four DAQ tasks as well as a producer-consumer loops methodology (in LabVIEW) for prioritizing DAQ and disk-streaming (figure 9).

The producer loop performs the DAQ on all four tasks in an asynchronous manner yet in real-time stamping. It also monitors the digital START trigger as to sense the end of DAQ by the controller. It also stores the chunks of incoming data into four FIFO buffers to pile up for disk streaming.

The consumer (low priority) loop takes data off the FIFO buffers effectively and streams it into four binary files for post processing.

Both the producer and the consumer loops allow time slots for some data indexing and on-the-fly processing for some alarming purposes.

This kind of synchronization techniques allows also for UDP/TCP streaming in parallel to the disk streaming (figure 9).

Figure 8. Live video & data streaming ethernet

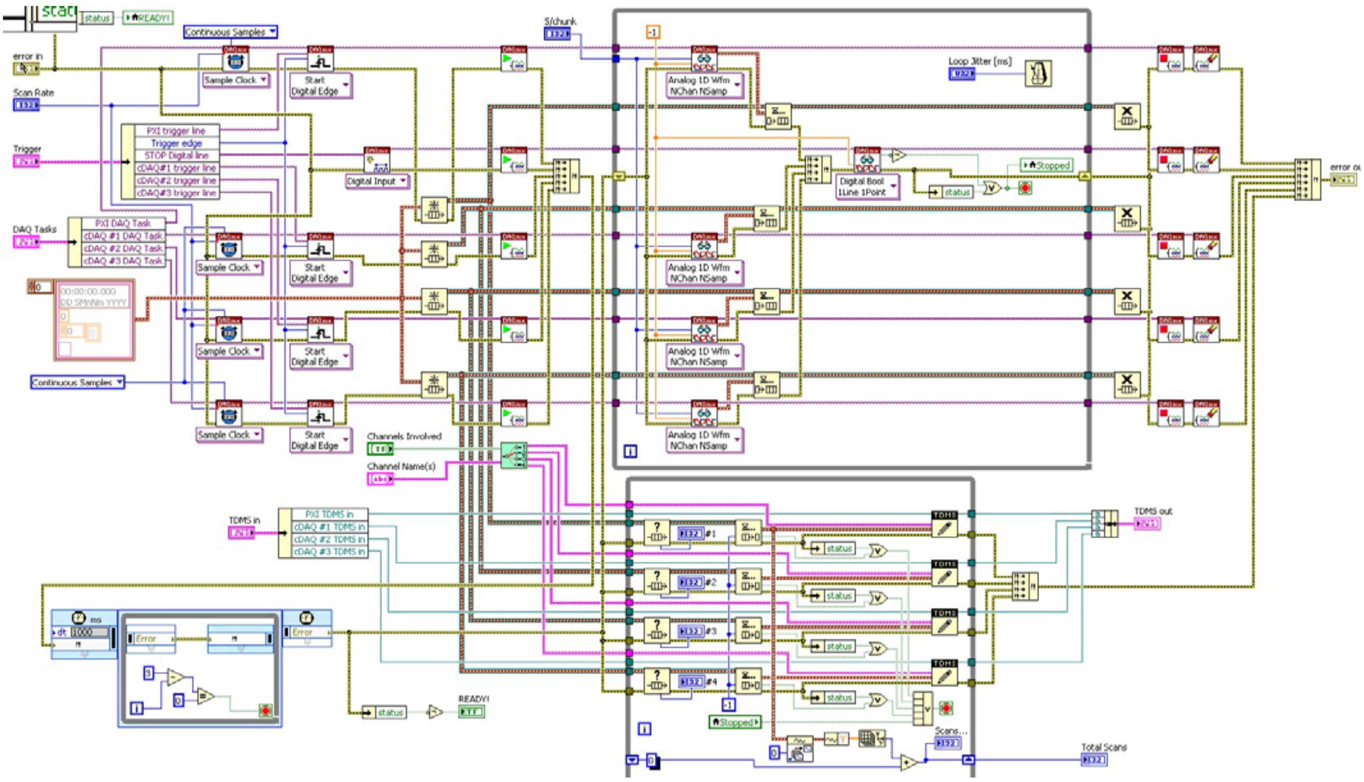

Figure 9. FIFO based streaming system (in LabVIEW)

The source code on figure 9 is in LabVIEW. It depicts the core subroutine for the DAQ and disk streaming. It dynamically allocates RAM for the four FIFO buffers with their elements being clusters of waveform type of data (structures of a time-stamp, sampling period and acquired array of data).

This routine also configures the timing and synchronization of all four chassis and distributes START and CLOCK for the DAQ.

The producer (upper) loop reads packed chunks of the corresponding channels of the four chassis and stores them in their respective FIFOs. Data from the cDAQ chassis come via Ethernet LAN, and from the PXI chassis via the optical serial link. The producer loop also checks the START signal on an additional digital (DI) TTL line for the STOP of DAQ. This loop is of highest priority and is therefore "relieved" from processing activities other than filling the FIFOs.

The consumer (lower) loop deals with the data streaming to disk. It uses structured (data-base like) file packing of the parallel chunks taken off the FIFOs. It uses custom channels naming in the TDMS file format. TCP streaming is also applicable inside this consumer loop

4. CONCLUSION

The described multiplatform synchronization acquisition methodology has proved itself to be a successful one. It allows for effective DAQ setups to be organized around average cheap desktop computers with non-deterministic OS like Windows. Powerful programming APIs like LabVIEW allows for appropriate applications of deterministic data handling to be deployed.

REFERENCES

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[4] Routing PXI Trigger Lines Across the Buses of Multisegment PXI Chassis, National Instruments