VIRTUAL INSTRUMENTATION

Virtual instrument – an equiment that allows accomplishment of measurements using the computer. It looks like a real instrument, but its operation and functionality is essentially different.

VI has 2 components:
- hardware interface
- software for signal acquisition and processing

Functions:
- signal acquisition
- signal processing and information recovery
- information storing
- remote data transmission
- additional: implementation of algorithms for process monitoring and control
VIRTUAL INSTRUMENTATION

Real instruments

Virtual instrument
Basics of Virtual Instrumentation

STRUCTURE OF A VI

Process → Transducer → Hardware interface → Digital acquisition board → Computer (software)

Physical quantity → Electrical signal

Communication bus (PCI, USB, GPIB, CAN)
STRUCTURE OF A VI

- Real-time monitoring
- Data analysis
- Data logging
- Control algorithms
- Human machine interface

NI-DAQmx or NI-DAQmx Base Driver Software
ADVANTAGES OF A VI

- Possibility of measuring on a large number of points and places
- Complex processing of data and of measurement information
- Local or remote data storing
- Remote transmission of data through wired or wireless communication
- Statistics and forecasts accomplishment
- Flexibility: possibility of extension or adding of new functions to the instrument by simple modifications of software
- Improving measurement accuracy by statistical processing and compensation of influence factors
- Possibility of adding of new functions for process testing, monitoring and control
MEASUREMENT SIGNALS

**Signal** = a variable on an energetic support containing information characteristic to a quantity or a phenomenon.
Examples: audio, video or biomedical signals, sounds, music, radar, measurement signals.

**Measurement signal**
- has a voltage or current support
- contains information regarding the measurement quantity (measurand).
- Is provided by the transducer (sensor)
- Depends on time
- Information is contained in: level, shape, frequency, phase, duty cycle.

In terms of continuity, signals can be:
- **analog** (they are continuous functions in time) – almost all natural signals
- **discrete or digital** - strings of numbers representing instances of the analog signal taken at equally spaced time intervals
ANALOG AND DISCRETE SIGNALS
examples

Analog signal
Voltage variation at a thermocouple terminals

Discrete signal
Evolution of the solar spots number over time
ANALOG AND DISCRETE SIGNALS

examples

Analog signal

Discrete signal

0 2T₀ 4T₀
T₀ T₀ T₀

x(t)

x(n)

T

n

(N-1)T₀
DIGITAL SIGNAL PROCESSING

Basic steps:
1. Process
2. Digitization (Sampling + A/D conversion)
3. Digital processing
4. Recovery (D/A conversion)
5. Process
SIGNAL ACQUISITION USING THE COMPUTER

- Physical quantity
- Analog signal
- Digital signal

Process → Transducer → Signal conditioning → A/D conversion → Computer

Actuator → Signal conditioning → D/A conversion → Computer

Action → Analog signal → Digital signal
DIGITAL ACQUISITION HARDWARE OPTIONS

- Desktop
- USB
- Remote
- PXI
DIGITAL ACQUISITION BOARD ON PCI BUS
DIGITAL ACQUISITION BOARD ON USB
DIGITAL ACQUISITION BOARD ON USB
DATA ACQUISITION USING COMPACT DAQ

Inputs
- Thermocouple
- RTD
- Resistor
- Voltage
- Current
- Digital (TTL)
- Accelerometer
- Microphone
- Strain gauge

Communication
- USB
Basics of Virtual Instrumentation

PXI SYSTEM
Industrial platform for measurement and control based on process computer
DIGITAL ACQUISITION BOARD ON PCMCIA
DIGITAL ACQUISITION BOARD FOR PDA
SIGNAL CONDITIONING

High-voltage signals and many sensors require signal conditioning to properly read the signal.

**Sensors/Signals**
- Thermocouples
- RTDs
- Strain Gages
- Common Mode or High Voltages

**Signal Conditioning**
- Amplification, Cold-Junction Compensation, Filtering
- Current Excitation, Linearization, Filtering
- Voltage Excitation, Bridge Configuration, Linearization, Filtering
- Isolation

**ADC**
DATA ACQUISITION BOARD STRUCTURE

Basics of Virtual Instrumentation
DATA ACQUISITION BOARD FUNCTIONS

**Analog inputs module**
- Analog signal multiplexing
- Analog signal amplification
- Sampling
- Quantization (analog-to-digital conversion)
- Data transmission to the computer

**Analog outputs module**
- Digital-to-analog conversion
- Information updating to analog outputs

**Digital I/O module**
- Acquisition / generation of digital signals

**Counter module**
- Event counting, frequency/period measurement, pulse train generation
### TECHNICAL CHARACTERISTICS OF DAQ BOARDS

<table>
<thead>
<tr>
<th>Bus</th>
<th>Model</th>
<th>Analog inputs (AI)</th>
<th>Sampling freq. input</th>
<th>Analog outputs (AO)</th>
<th>Sampling freq. output</th>
<th>Digital I/O lines</th>
<th>Triggering</th>
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<td>6320</td>
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<tr>
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<td>8 simultan</td>
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</tr>
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</table>
Digitization supposes 3 operations:

- **Sampling** – taking at equally spaced time intervals of instantaneous values from an analog signal (samples)

- **Truncation** – cutting from an infinite time signal of a piece finite in time (window)

- **Quantization (A/D conversion)** – conversion of the samples voltage levels into digital codes (bits succession)
MULTIPLEXING

Analog signals

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<th>Command</th>
<th>OUT</th>
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<tr>
<td>0 0 0</td>
<td>AI0</td>
</tr>
<tr>
<td>0 0 1</td>
<td>AI1</td>
</tr>
<tr>
<td>0 1 0</td>
<td>AI2</td>
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Digital code (command)
PROGRAMMABLE GAIN AMPLIFIER

**Analog signal**

**Command**

<table>
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<th>Command</th>
<th>Gain</th>
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<tbody>
<tr>
<td>0 0 0</td>
<td>1</td>
</tr>
<tr>
<td>0 0 1</td>
<td>2</td>
</tr>
<tr>
<td>0 1 0</td>
<td>5</td>
</tr>
</tbody>
</table>

**PGA** = Programmable Gain Amplifier
Basics of Virtual Instrumentation

SAMPLE & HOLD

From PGA

Command

Continuous signal

T₀ – Sampling period

f₀ = \frac{1}{T₀}

To ADC

K

C

Sampled signal
Basics of Virtual Instrumentation

SAMPLE & HOLD

Analog signal

Window

Discrete signal
ANALOG-TO-DIGITAL CONVERSION (ADC)

\[
U = \frac{U_{\text{ref}}}{2^n} N
\]

- **Voltage level**: \(U\)
- **Reference voltage**: \(U_{\text{ref}}\)
- **Digital code**: \(N\)
ANALOG-TO-DIGITAL CONVERSION (ADC)

\( n = 3; \ U_{\text{ref}} = 10 \ V \)

\[
x(n) = \{0, 2, 3, 5, 7, 7, 4, 3, 4, 2, 1, 1, 0, 3\}
\]
ANALOG-TO-DIGITAL CONVERSION (ADC)
- example -

\[ n = 3; \ U_{\text{ref}} = 10 \text{ V}; \ U = 1,95 \text{ V} \]

Without amplification

\[ U = \frac{U_{\text{ref}} \cdot N}{2^n} \]
\[ U_0 = \frac{U_{\text{ref}}}{2^n} \]
\[ \varepsilon = \frac{1,95 - 1,25}{1,95} \times 100 = 35,9\% \]

With amplification (A = 5)

\[ U = \frac{U_{\text{ref}} \cdot N}{A \cdot 2^n} \]
\[ U_0 = \frac{U_{\text{ref}}}{A \cdot 2^n} \]
\[ \varepsilon = \frac{9,75 - 8,75}{8,75} \times 100 = 10,25\% \]