

WORCESTER POLYTECHNIC INSTITUTE MECHANICAL ENGINEERING DEPARTMENT

Engineering Experimentation
ME-3901, D'2012

Lecture 02

14 March 2012



General information

Office hours

Instructors: **Cosme Furlong**

Office: HL-151

Everyday:

9:00 to 9:50 am

Christopher Scarpino

Office: HL-153

TBD

Teaching Assistants: **During laboratory sessions**



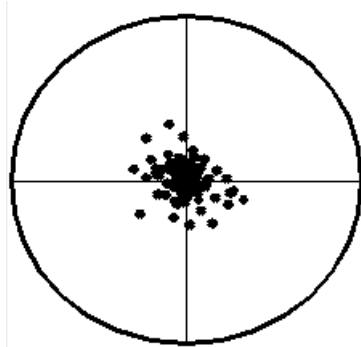
Accuracy, precision... and resolution...



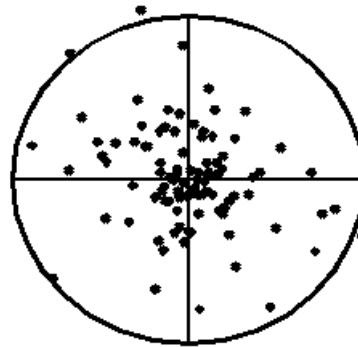
Target



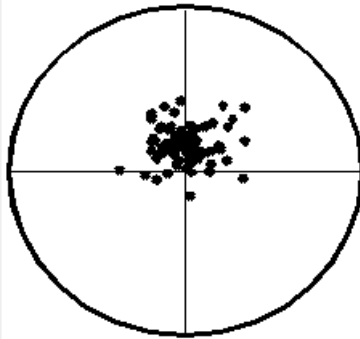
Accuracy, precision... and resolution...



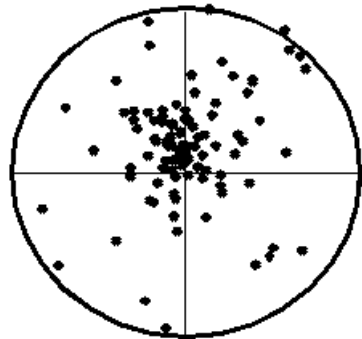
In control, capable



In control, not capable



Capable but out of control



Not capable, and out of control

Capable -> precise

In control -> accurate

Accuracy: deviation (or error) of reading from a true value;

Precision: ability to reproduce a reading (not necessarily correct);



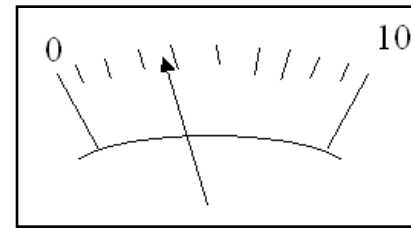
Resolution: analog systems

Resolution (R): smallest increment of change in the measured value that can be determined from an instrument's readout scale

Analog VM
(Voltmeter)



Resolution:



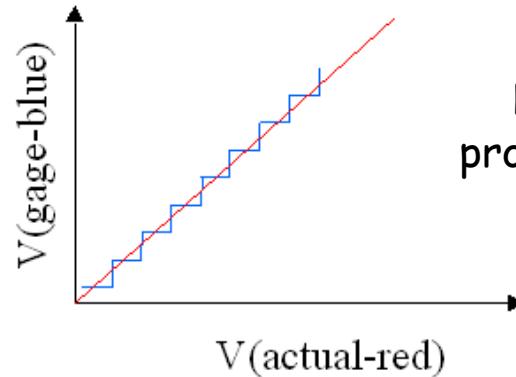
In this case, resolution of the VM based on the dial shown is:

$$R = \frac{\text{smallest graduation}}{2} = 0.5 \text{ V}$$



Resolution: digital systems

Digital VM



Digital instruments do not provide continuous output data, but rather discrete data.

How to determine measurement resolution in digital systems ?



$$R = \frac{\text{instrument's measuring range}}{2^n};$$

$n = \text{bits of digital resolution}$

For example: 8-bit DVM operating at the [0-10] V range has the resolution of

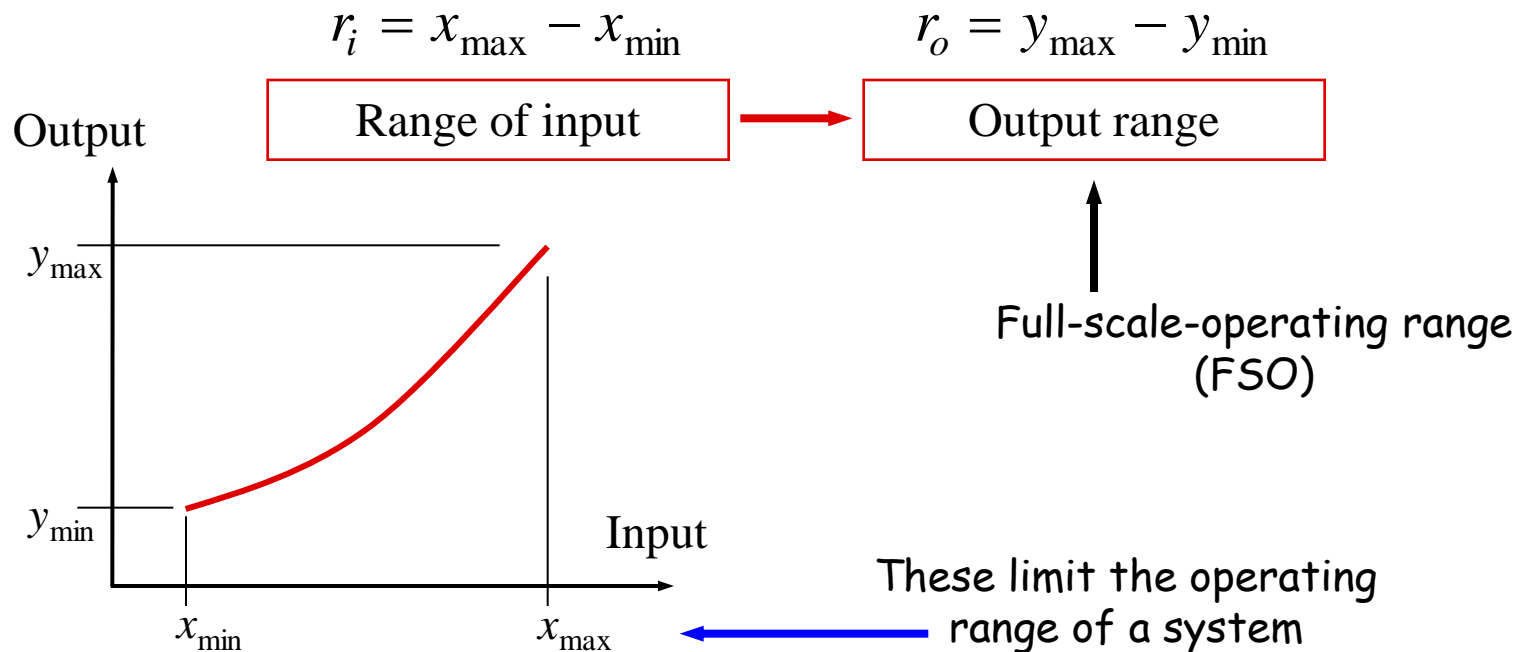
$$R = \frac{(10-0)}{2^8} \approx 0.04 \text{ V};$$

What about for a DVM with 16-bit digital resolution and the same measuring range?



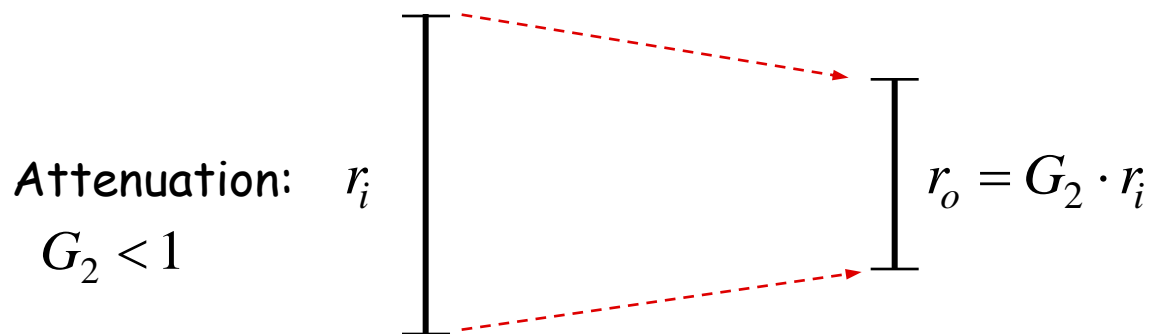
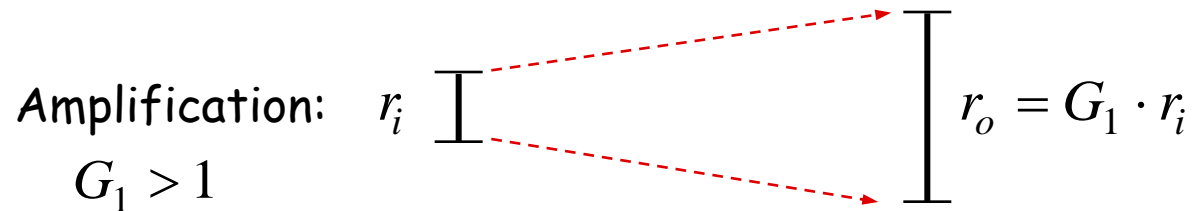
Range... gain...

- **Range:** related to the minimum and maximum values for which the measurement system is to be used
 - ◆ Smaller range → more precise representation of signals (when using same digital resolution)



Range... gain...

- **Gain:** amplification or attenuation of a signal for best fit into a range



Digital representation of... numbers...

A **1-bit** number can take values of 0 and 1 and used in

Conditionals: No and Yes;

Booleans: False and True

An **8-bit** byte number can take 2^8 values; "read" the following, 8-bit, byte number:

$Num = 10010101$

Most
significant digitLeast
significant digit



Digital representation of... numbers...

$Num = 10010101$ (8-bit byte number)

Start from the least significant digit:

2^0	\times	<i>binary value in Num</i>	$= 1 \times 1 = 1$
2^1	\times	<i>binary value in Num</i>	$= 2 \times 0 = 0$
2^2	\times	<i>binary value in Num</i>	$= 4 \times 1 = 4$
2^3	\times	<i>binary value in Num</i>	$= 8 \times 0 = 0$
2^4	\times	<i>binary value in Num</i>	$= 16 \times 1 = 16$
2^5	\times	<i>binary value in Num</i>	$= 32 \times 0 = 0$
2^6	\times	<i>binary value in Num</i>	$= 64 \times 0 = 0$
2^7	\times	<i>binary value in Num</i>	$= 128 \times 1 = 128$

Number is the sum of the results: 149

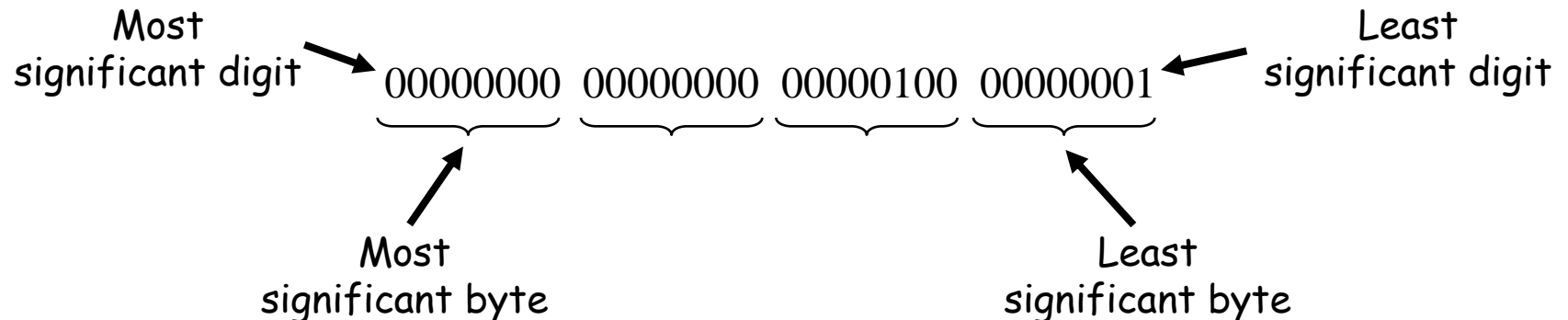
Can 8-bit byte numbers really take 2^8 values?



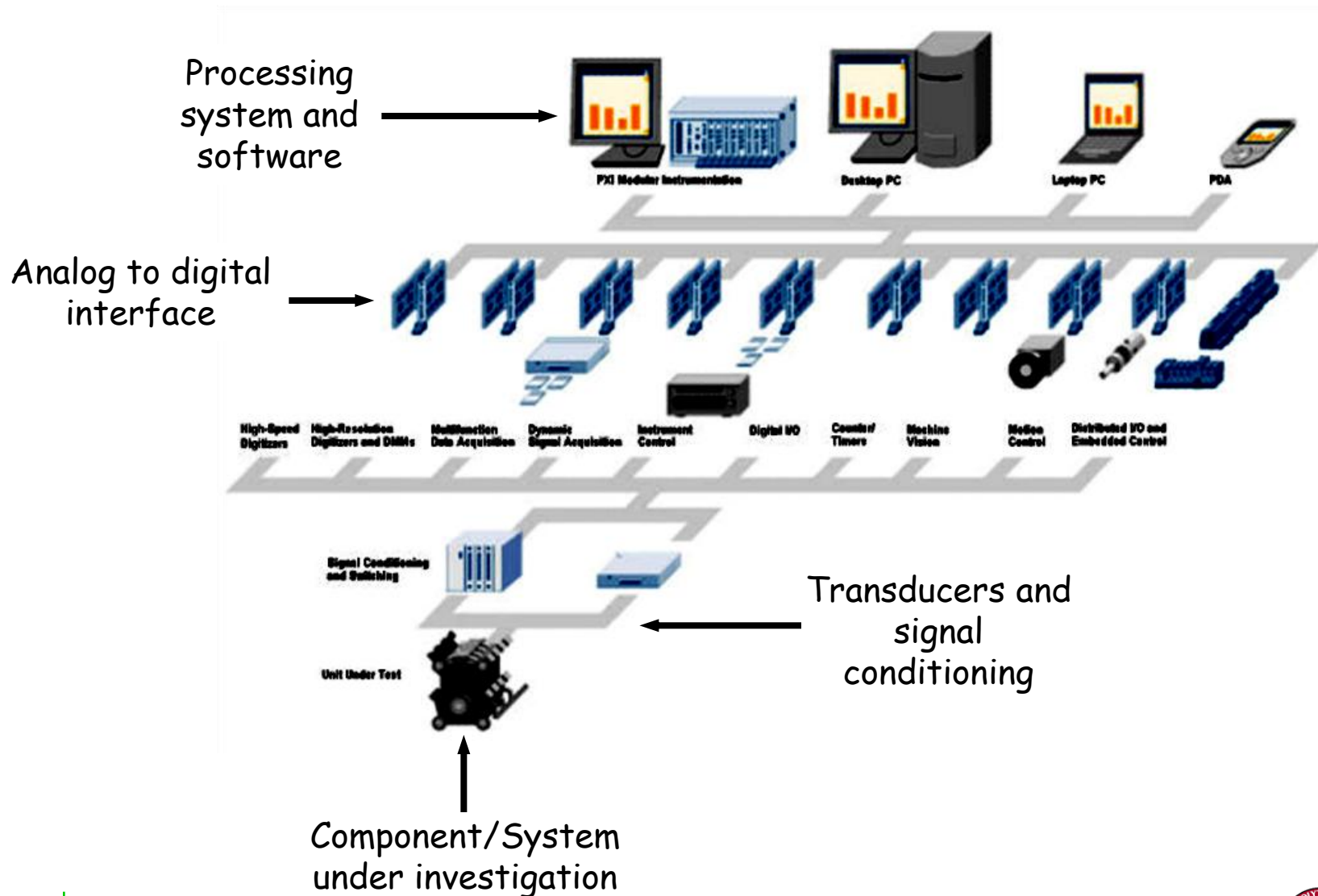
Digital representation of... numbers...

- One byte (8-bit) number is used to represent "Integers": (low resolution results, why?)
- Two and four byte numbers are used to represent "Integers"
- 4, 8, and higher byte numbers are used to represent "float" and "double precision" numbers

Here is an example on how to represent the number 1025 with 4 (8-bit) byte integer:



Recall: modern measurement systems



Modern measurement systems

DAQ systems in HL-031 have:

- Transducers,
- Signal conditioning modules,
- Analog to digital interfaces,
- Processing system and software

Each component
has its own:
accuracy,
precision,
resolution

Minimization of errors in these sub-systems will produce accurate and precise measurements within a specific resolution.

This requires "uncertainty" and error analysis.



Modern measurement systems

Transducers

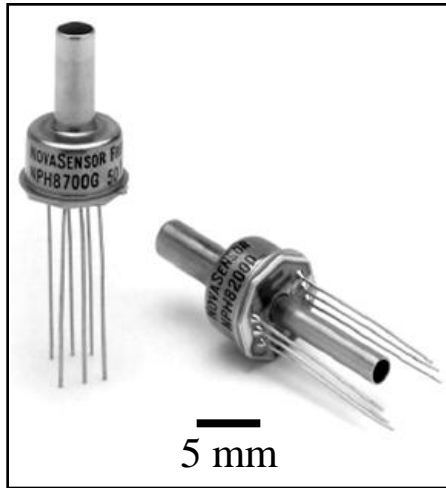
A **transducer** is a device that converts one type of energy to another for purposes of measurement or information transfer. Examples are sensors for measurement, via electrical output, of:

- Pressure
- Temperature
- Strain
- Position
- Inertial effects
- Etc...



Modern measurement systems

Example: specifications of a transducer (MEMS pressure sensor)



GE Novasensor.
NPH Series

Features

- Solid State, High Reliability
- Standard TO-8 Package Suitable for PC Board Mount
- Low Cost, Small Size
- Available in Gage, Absolute, and Differential Pressure Versions
- Media Compatible with Noncorrosive Gases and Dry air
- Output Signal of 100mV @ 1.5mA
- Thermal Accuracy FSO 0.5% Typical
- Overpressure Capability to 5 Times Maximum Rated Pressure
- Three Standard Ranges: 0–10" H₂O, 0–1 psi, and 0–5psi
- Nonlinearity 0.05% FSO Typical
- Standard 3/16" OD Pressure Port
- Ceramic Substrate with Temperature Compensation Resistors

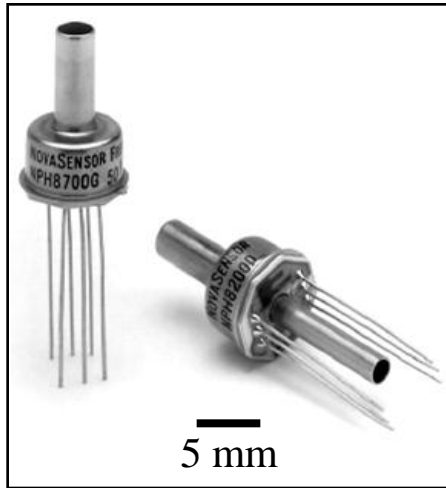
Applications

- Process Control, P-to-I Converters
- Pneumatic Control Systems
- HVAC Controls
- Biomedical: Infusion Pumps, Sphygmomanometers, Respirators
- Aerospace: Altimeters, Barometers, Cabin Pressure Sensors
- Computer Peripherals



Modern measurement systems

Example: specifications of a transducer
(MEMS pressure sensor)



GE Novasensor.
NPH Series

Parameter	Min.	Typ.	Max.	Min.	Typ.	Max.	Units	Notes
	2.5 kPa			7 & 30 kPa				
Performance Parameters (7), Compensated (1)								
Offset	-8	±2	8	-4	±2	4	mV	
Full Scale Output								
2.5 kPa	25	50	90				mV	2
7 kPa				50	75	150	mV	2
30 kPa				75	100	125	mV	2
Linearity	-1.0	0.1	1.0	-0.25	0.05	0.25	%FSO	3
Hysteresis and Repeatability	-0.2	0.05	0.2	-0.2	0.05	0.2	%FSO	
Thermal Accuracy of Offset	-3	0.5	3	-2	0.5	2	%FSO	4
Thermal Accuracy of FSO	-3	-1	3	-1.5	-0.5	1.5	%FSO	4
Thermal Hysteresis	-0.75	±0.5	0.75	-0.5	±0.2	0.5	%FSO	5
Short-Term Stability of Offset		5			5		µV/V	6, 11
Short-Term Stability of FSO		5			5		µV/V	6, 11

Notes: 1. Performance with offset, thermal accuracy of offset, and thermal accuracy of FSO compensation resistors. 2. FSO with 1.5mA input excitation. 3. Best fit straight line. 4. 0 to +70°C with reference to 25°C 5. 0 to +70°C, by design 6. Normalized offset/bridge voltage —100 hrs, typical value, not tested in production. 7. All values measured at 25°C and at 1.5mA, unless otherwise noted. 8. Reduced performance outside compensation range. 9. Backside differential tube is nickel or Kovar. 10. Top side pressure. 11. Typical specifications are for reference only; absolute values may vary.



Modern measurement systems

Signal conditioning

Measurement accuracy, precision, resolution also depend on:

- Amplification and filtering of sensor measurement electronics and algorithms
- Cable impedances and shielding
- Screw terminals

SCXI High-Performance Signal Conditioning



Modern measurement systems

Analog to Digital DAQ systems in HL-031

- NI 6229 BNC,
- 16-Bit AO/AI,
- 250 kS/s,
- 16-Analog-Inputs,
- 4-Analog-Output,
- Multifunction DAQ, including counters

If voltages in the $[-10,10]$ V range are to be measured, what is the theoretical measurement resolution of the DAQ systems in HL-031?

Why theoretical measurement resolution? Can it be better/worse? Why?



Modern measurement systems

Processing system and software

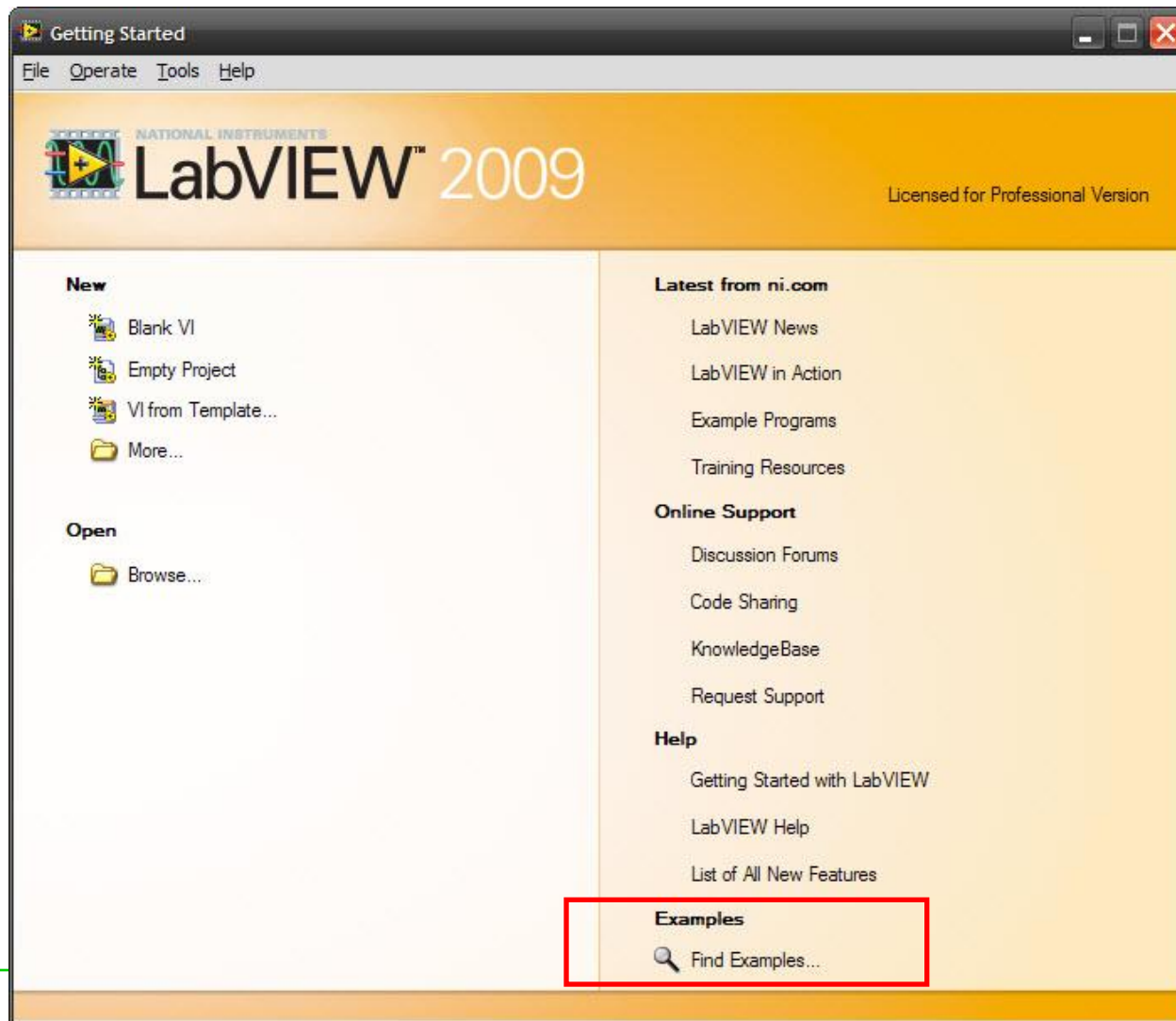
- Compatibility with hardware use (electronics)
- Use of right arithmetic (e.g., use of adequate numerical precision in all computations)
- Adequate data acquisition and analysis algorithms
- Adequate numerical methods for data processing



Modern measurement systems: software

LabVIEW 2009

Use "PrntScrn" or the "SnagIT" program to capture/save figures shown on the screen



Modern measurement systems: LabView

Virtual instrumentation

Digital spectrum analyzer (enables *frequency domain* measurements)

The image displays the LabView software interface for a Dynamic Signal Analyzer (sim).vi. On the left, the 'NI Example Finder' shows search results for 'spectrum analyzer', with 'Dynamic Signal Analyzer (sim).vi' selected. Below it is the 'Dynamic Signal Analyzer (sim).vi Front Panel', which features two main plots: a 'Time domain' plot showing a sine wave stimulus and its response, and a 'Processed signals' plot showing the frequency response function (FRF) spectrum. The FRF plot has a peak at approximately 2.0 kHz. The front panel includes control knobs for 'Signal generator' (Sine, 2.00k frequency, 750.00n amplitude), 'Settings' (FFT, Exact window, 8000.00 span, 200 resolution), and 'Display' (Channel A, Magnitude). A 'STOP' button is also present.

On the right, the 'Dynamic Signal Analyzer (sim).vi Block Diagram' shows the underlying logic. It starts with a 'Signal generator' block connected to a 'DUT' (Device Under Test) block. The output of the DUT goes to a 'DSA' (Digital Signal Analyzer) block, which then feeds into a 'DISPL' (Display) block. The DSA block is annotated with 'Computations are done here!' and 'Device Under Test In this case, we use a filter... that will allow us to look at frequency response'. The DISPL block is annotated with 'A few additional operation in order to display information'. The block diagram also includes a 'Time domain' graph, a 'Graph' for the FRF, and a 'stop' button. A 'Tools' palette is visible at the bottom left of the block diagram window.

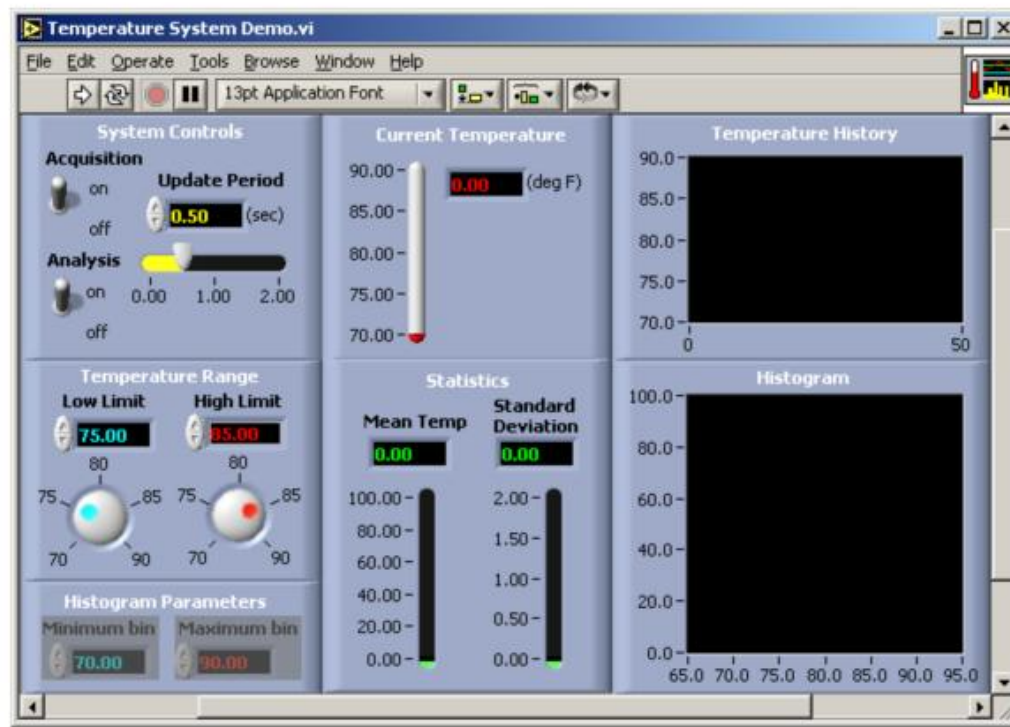


Modern measurement systems: LabView

Virtual instrumentation

It is possible to do data acquisition through the WEB!

Digital thermometer



Available resources: LabView

NI Developer Zone: <http://zone.ni.com>

The screenshot shows the NI Developer Zone website in a Windows Internet Explorer browser window. The browser's address bar displays <http://zone.ni.com/dzhp/app/main>. The website header includes the National Instruments logo, a search bar, and navigation links for MyNI, Contact NI, Products & Services, Solutions, Support, NI Developer Zone (highlighted), Academic, Events, and Company. A secondary navigation bar includes NI Home > NI Developer Zone and United States. The main content area is divided into two columns: 'Learn' and 'Collaborate'. The 'Learn' section features a 'What's New?' section with tabs for Highlights, Tutorials, Example Code, Webcasts & Videos, and Publications. Below this is a 'Browse' section with a search bar and three columns of links categorized by Content Type, Development Topic, and Product. The 'Collaborate' section features an 'NI Community' spotlight for 'Check out the NIWeek 2012 Community!', which includes a paragraph of text and a 'More »' link. At the bottom right, there is a 'Create Your Own' section with links for Example Code and Tutorials. The browser's taskbar shows various icons and the system tray displays the date and time.

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What's New?

Highlights | Tutorials | Example Code | Webcasts & Videos | **Publications**

There were no new documents in the past two weeks.

Browse

Content Type	Development Topic	Product
Examples (9924)	Programming Fundamentals (4404)	Software (7167)
Tutorials (5194)	Signal Processing & Analysis (1226)	Data Acquisition (2624)
Publications (2591)	Measurement & Instrumentation (2449)	Modular Instruments (1293)
Webcasts and Videos (1210)	Control (699)	Real-Time (479)
Instrument Drivers (5183)	Simulation & Design (373)	Signal Conditioning (252)
		Switches (194)
		Distributed I/O (686)
		Machine Vision (344)
		Motion Control (348)
		PXI/CompactPCI (997)
		Instrument Connectivity (442)
		Industrial Communications (213)
		Sound and Vibration (286)

Collaborate

NI Community

Spotlight

Check out the NIWeek 2012 Community!

NI has launched the NIWeek 2012 Community. This is the place to go to get the most up-to-date news leading up to, during, and after the 18th annual graphical system design conference and exhibition, held August 6-9 in Austin, TX.

Network with other conference attendees, share your conference schedule, and get the most out of NIWeek 2012. The NIWeek community provides regular conference updates and features on NIWeek summits and special events. During NIWeek, it will be your source for exclusive v...

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Create Your Own

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