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**

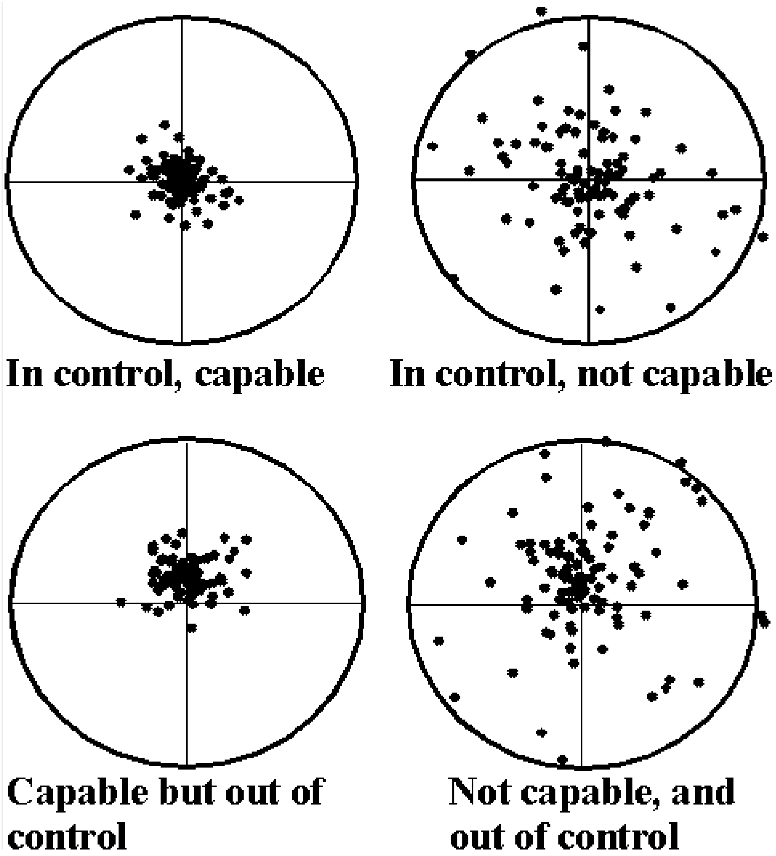
Christopher Scarpino — Office: HL-153 — **TBD**

Teaching Assistants: **During laboratory sessions**

Accuracy, precision… and resolution…

Target

Accuracy, precision… and resolution…



Capable -> precise

In control -> accurate

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

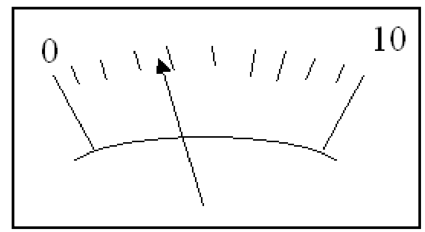
Precision: ability to reproduce a reading (not necessarily correct);

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:

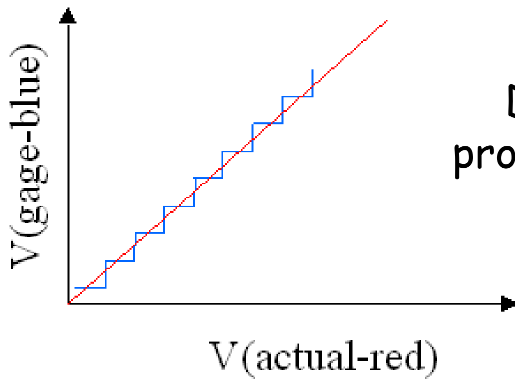


In this case, resolution of the VM based on the dial shown is:

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

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 ? →

$$R = \frac{instrument's\ measuring\ range}{2^n};$$
$$n = bits\ of\ digital\ resolution$$

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

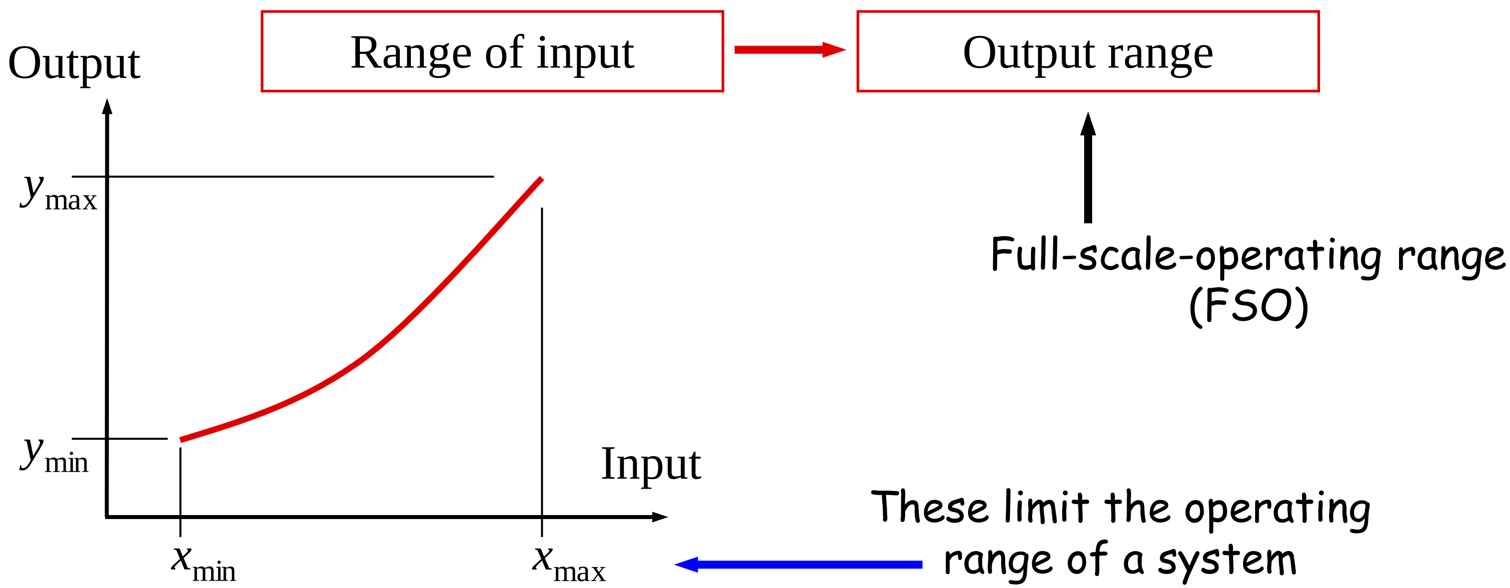
$$R = \frac{(10-0)}{2^8} \approx 0.04\,V;$$

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)

$$r_i = x_{\max} - x_{\min} \qquad r_o = y_{\max} - y_{\min}$$

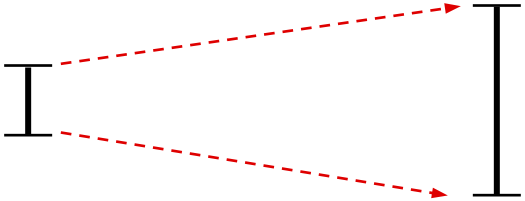


Range… gain…

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

Amplification: r_i

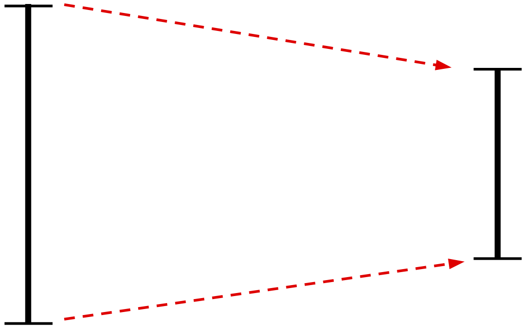
$G_1 > 1$



$$r_o = G_1 \cdot r_i$$

Attenuation: r_i

$G_2 < 1$



$$r_o = G_2 \cdot r_i$$

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 digit

Least significant digit

Digital representation of… numbers…

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

Start from the least significant digit: $2^0 \times$ binary value in $Num = 1 \times 1 = 1$

$2^1 \times$ binary value in $Num = 2 \times 0 = 0$

$2^2 \times$ binary value in $Num = 4 \times 1 = 4$

$2^3 \times$ binary value in $Num = 8 \times 0 = 0$

$2^4 \times$ binary value in $Num = 16 \times 1 = 16$

$2^5 \times$ binary value in $Num = 32 \times 0 = 0$

$2^6 \times$ binary value in $Num = 64 \times 0 = 0$

$2^7 \times$ binary value in $Num = 128 \times 1 = 128$

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

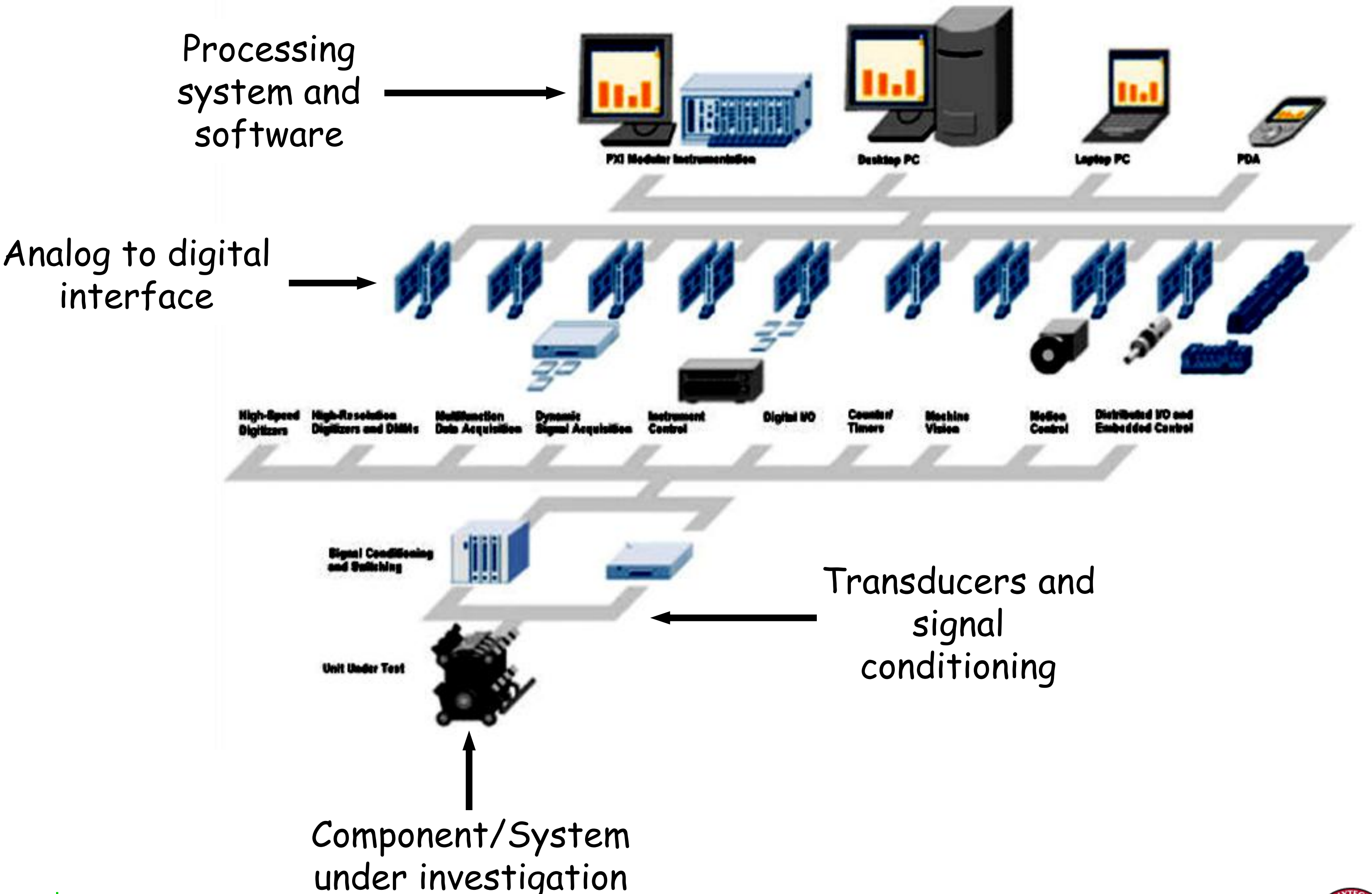
Here is an example on how to represent the number 1025 with 4 (8-bit) byte integer:

Most significant digit → 00000000 00000000 00000100 00000001 ← Least significant digit

Most significant byte (first byte: 00000000)

Least significant byte (last byte: 00000001)

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

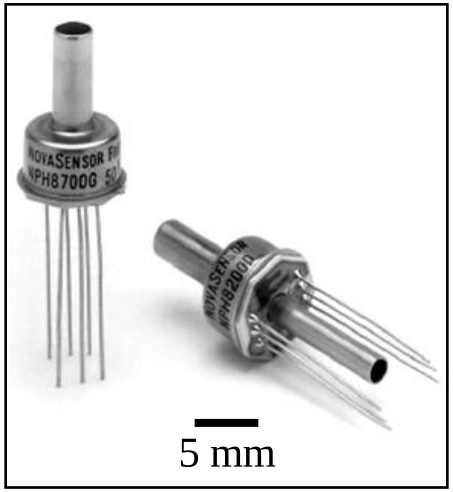
Transducers

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

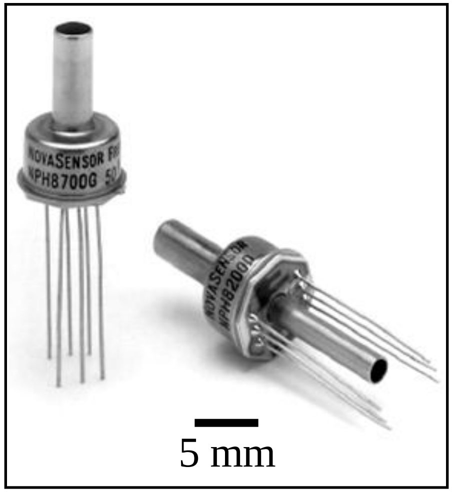
- Solid State, High Reliability
- Standard TO-8 Package Suitable for PC Board Mount
- Low Cost, Small Size
- Available in Gage, Absolute, and Differential Pressure Versions
- Media Compatible with Noncorrosive Gases and Dry air
- Output Signal of 100mV @ 1.5mA
- Thermal Accuracy FSO 0.5% Typical
- Overpressure 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?

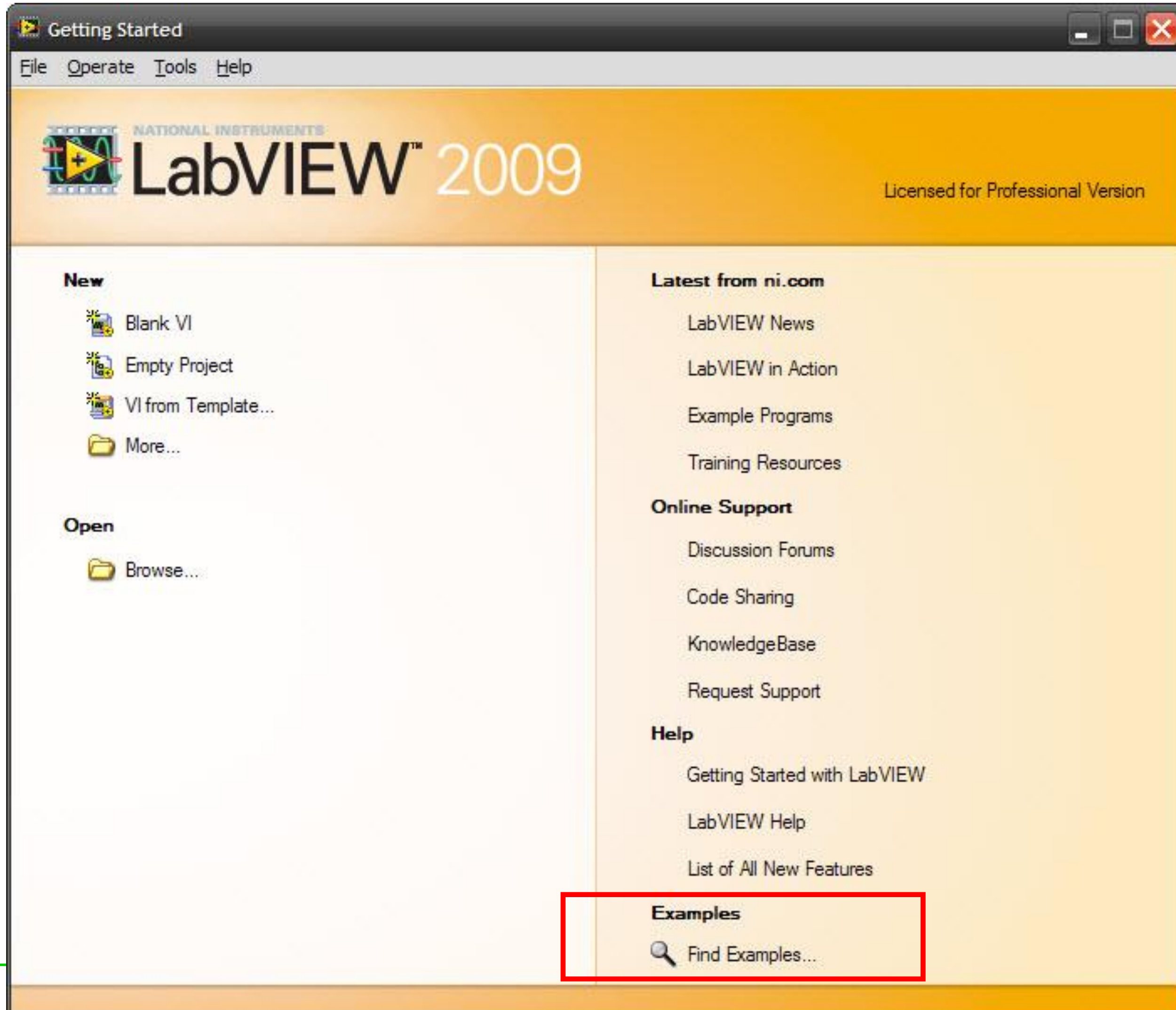
Modern measurement systems

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

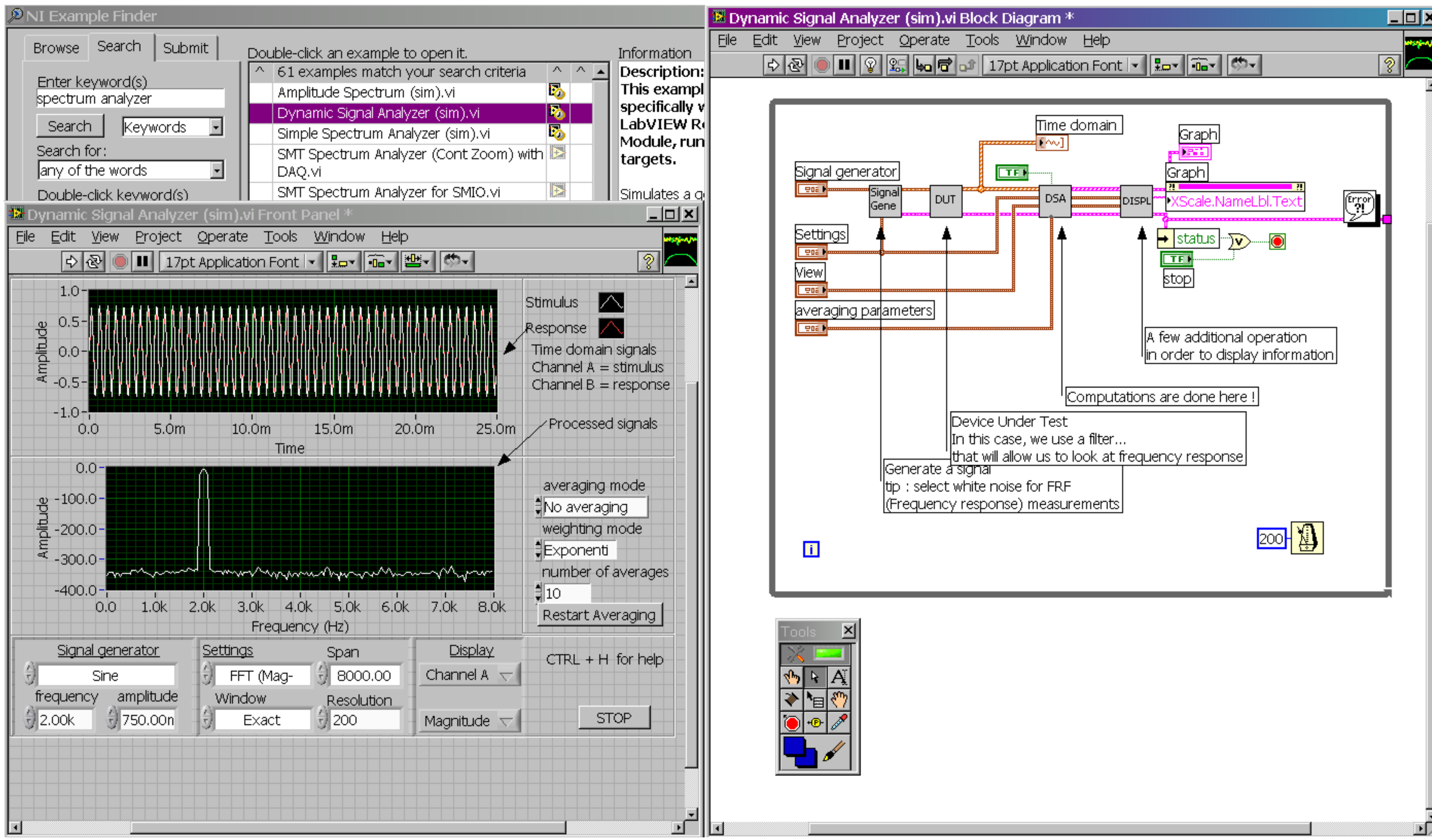
Modern measurement systems: software
LabView 2009

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



Modern measurement systems: LabView
Virtual instrumentation

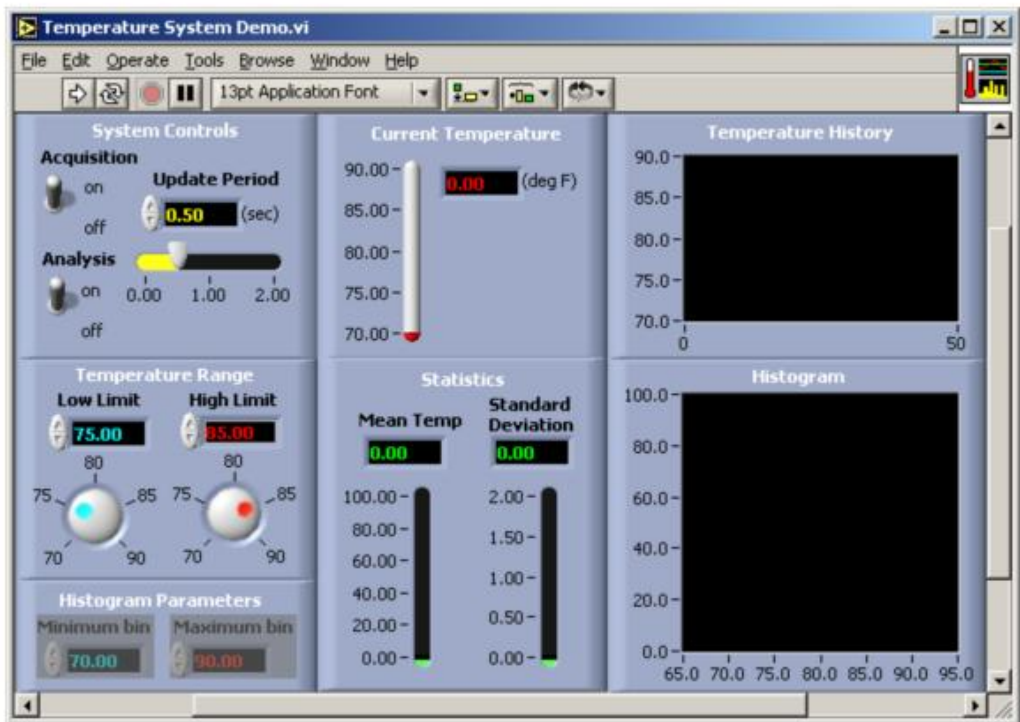
Digital spectrum analyzer (enables ***frequency domain*** measurements)



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