Ciclo de Conferencias sobre Automatización e Ingenieria
CCAI 2006/07

El rol de la adquisición de datos en la automatización industrial

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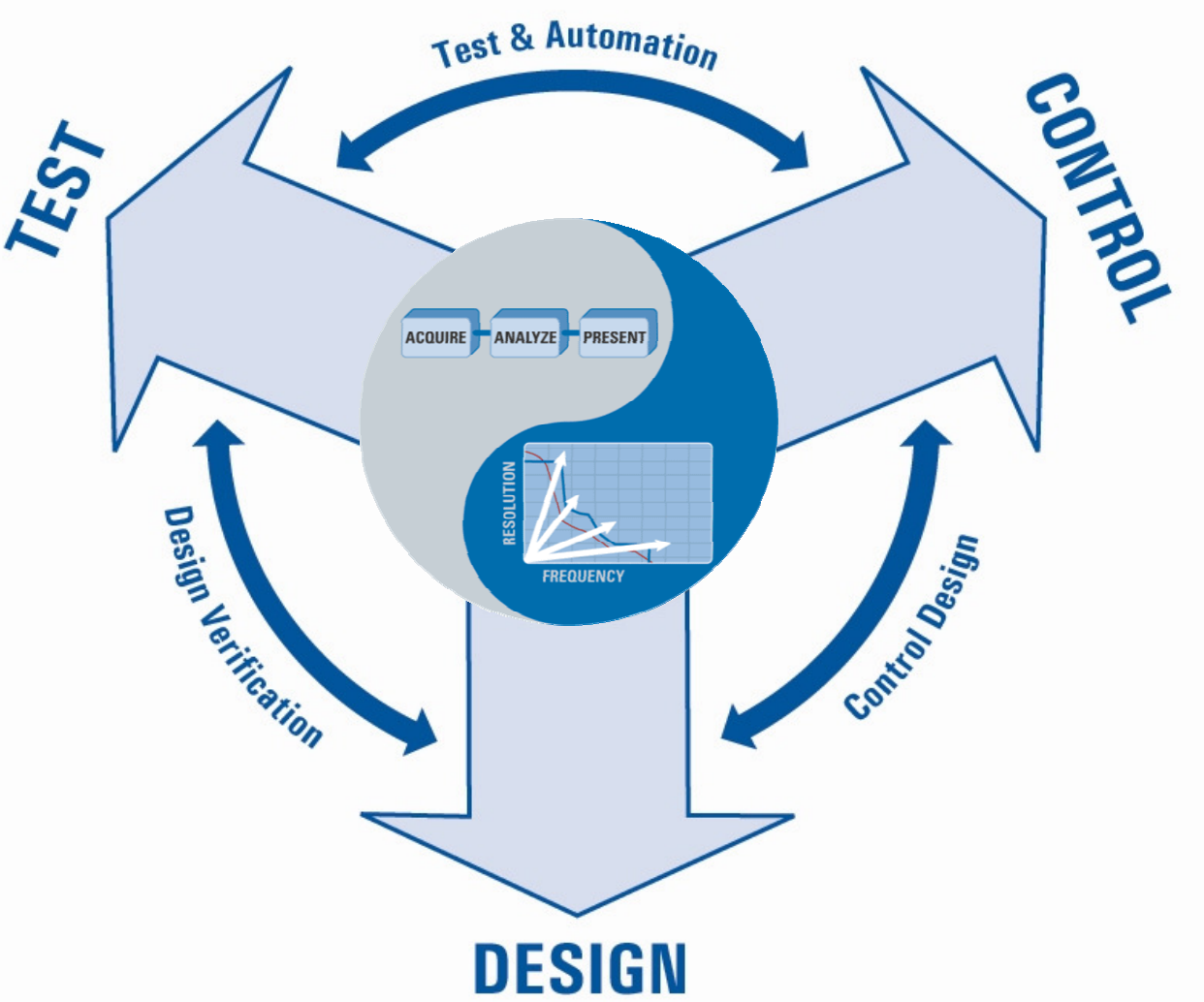
National Instruments

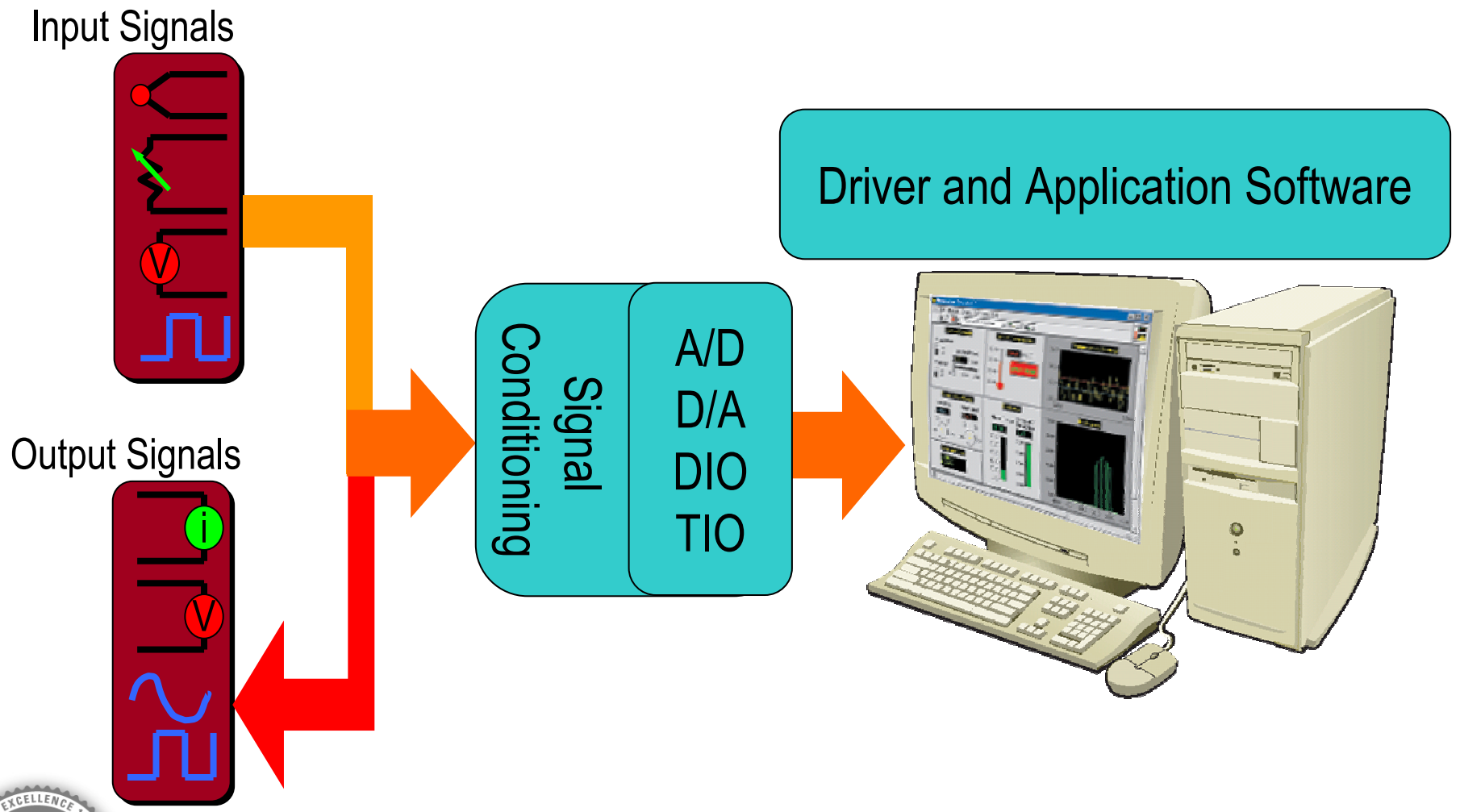


Adquisición de datos

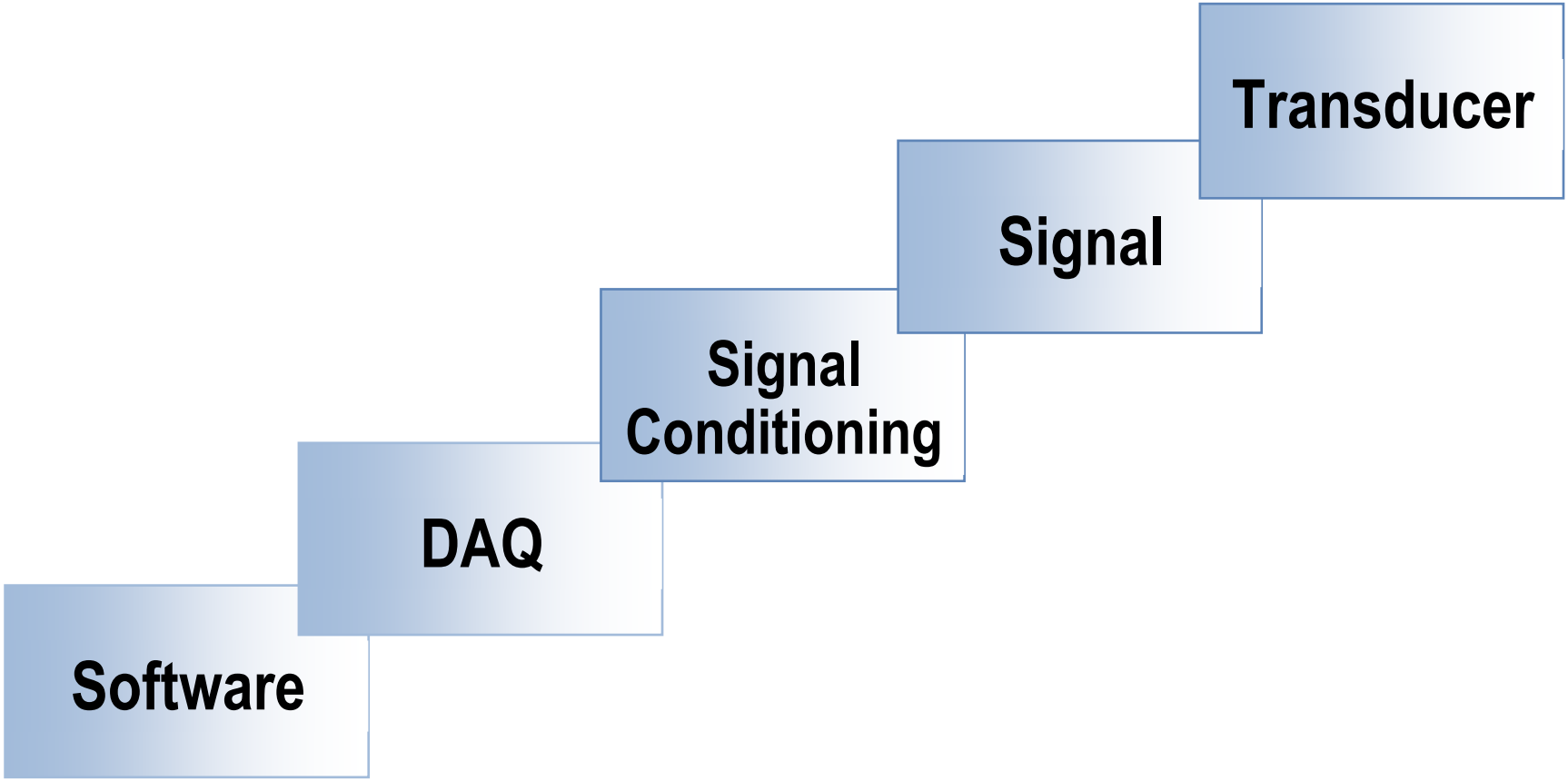
La adquisición de datos es el proceso que involucra la recopilación de información de una forma automatizada a partir de fuentes de medición análogas y digitales como sensores y dispositivos bajo prueba.

La adquisición de datos utiliza una combinación de medición de hardware y software basado en PC para proporcionar un sistema de medición flexible y definido por el usuario.

Computer-Based Data Acquisition Systems

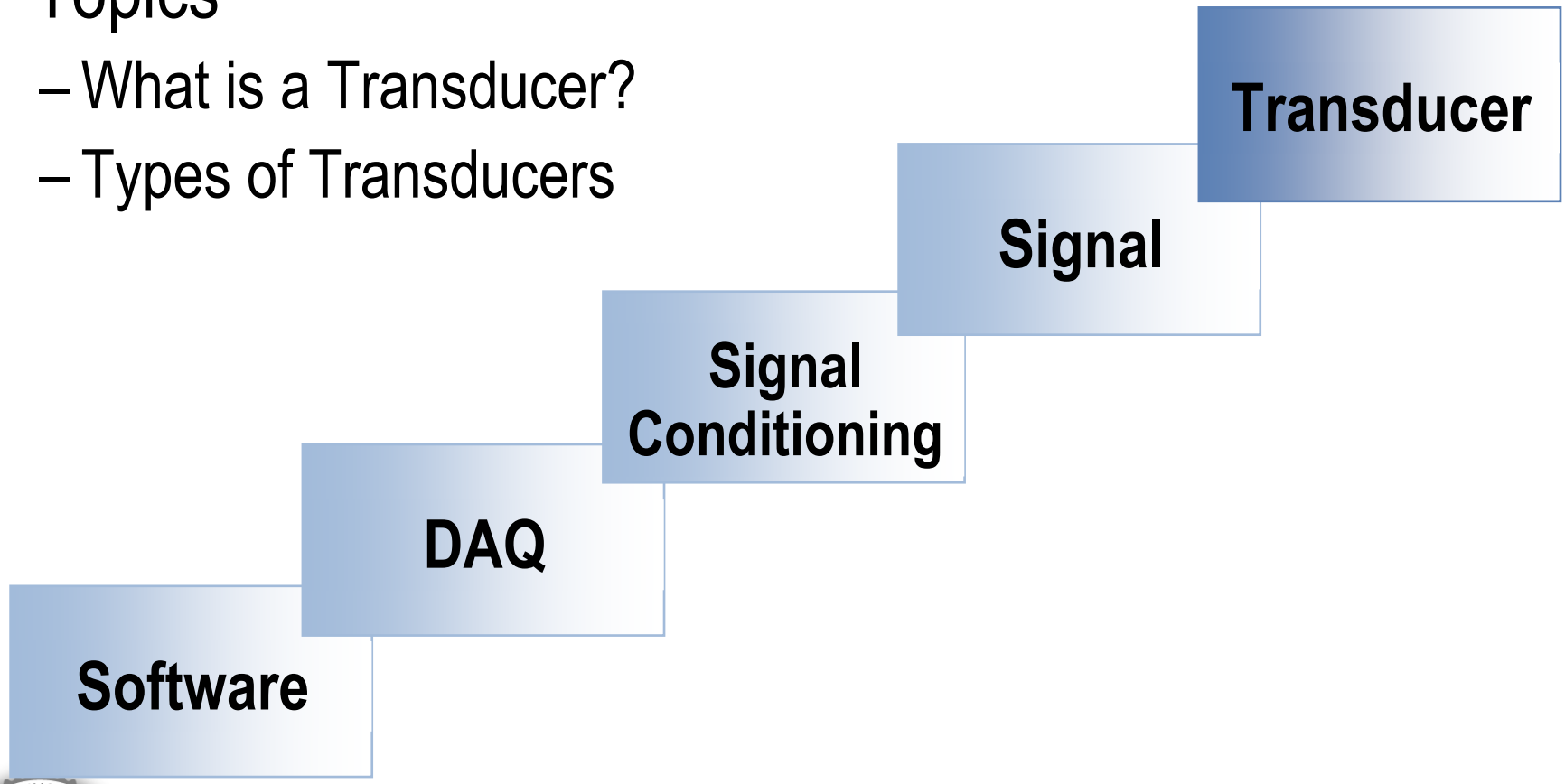


DAQ System Overview

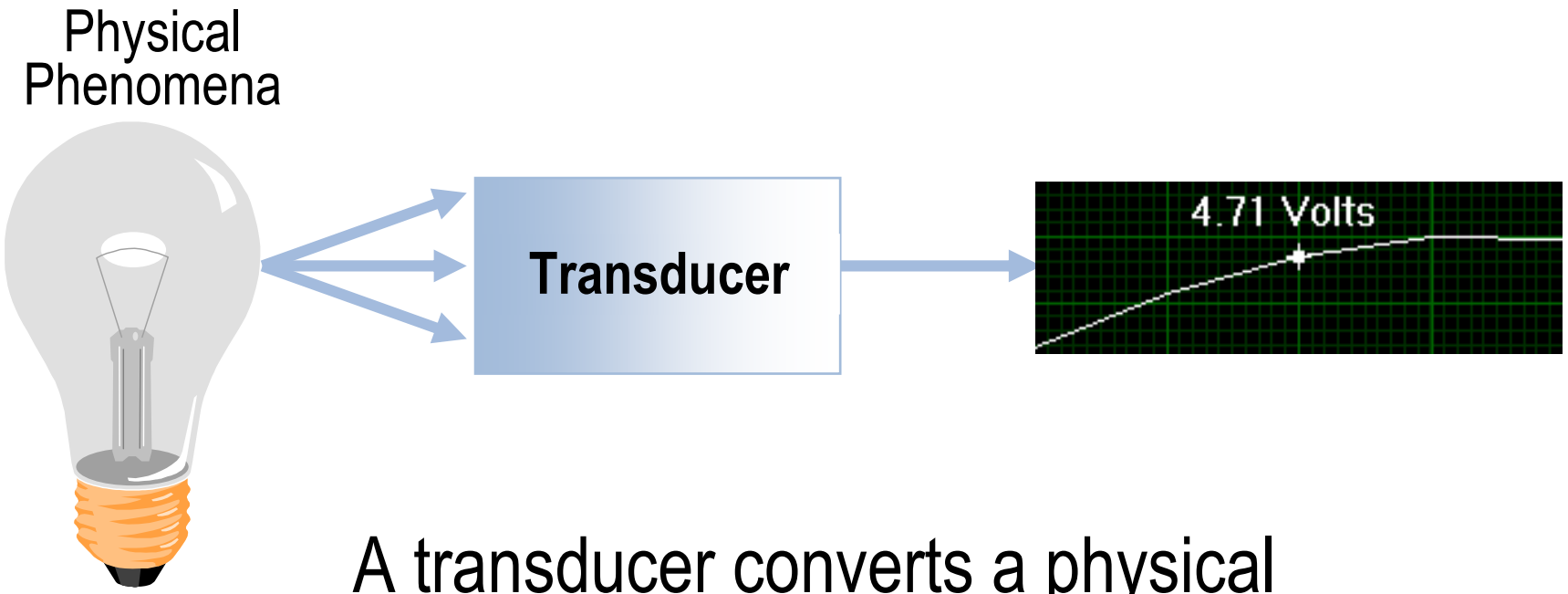


Transducer Overview

- Topics
  - What is a Transducer?
  - Types of Transducers



What is a Transducer?



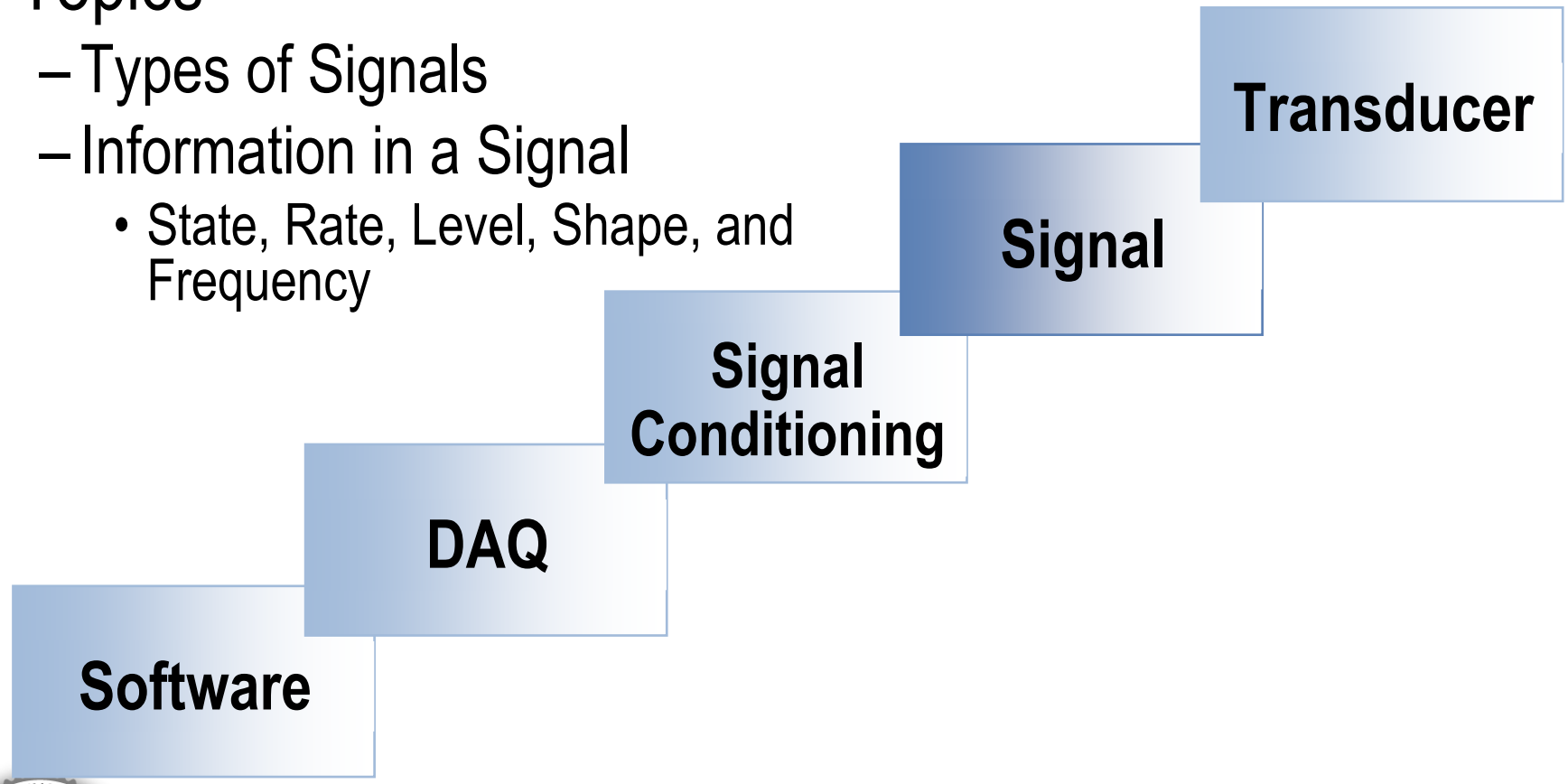
A transducer converts a physical phenomena into a measurable electrical signal that a DAQ system measures.

Types of Transducers

Phenomena	Transducer
Temperature	Thermocouples Resistive Temperature Devices (RTDs) Thermistors
Light	Vacuum tube Photo sensors
Sound	Microphone
Force and Pressure	Strain gages Piezoelectric transducers
Position and Displacement	Potentiometers Linear voltage differential transformer Optical encoder
Fluid	Head meters Rotational flowmeters
pH	pH electrodes

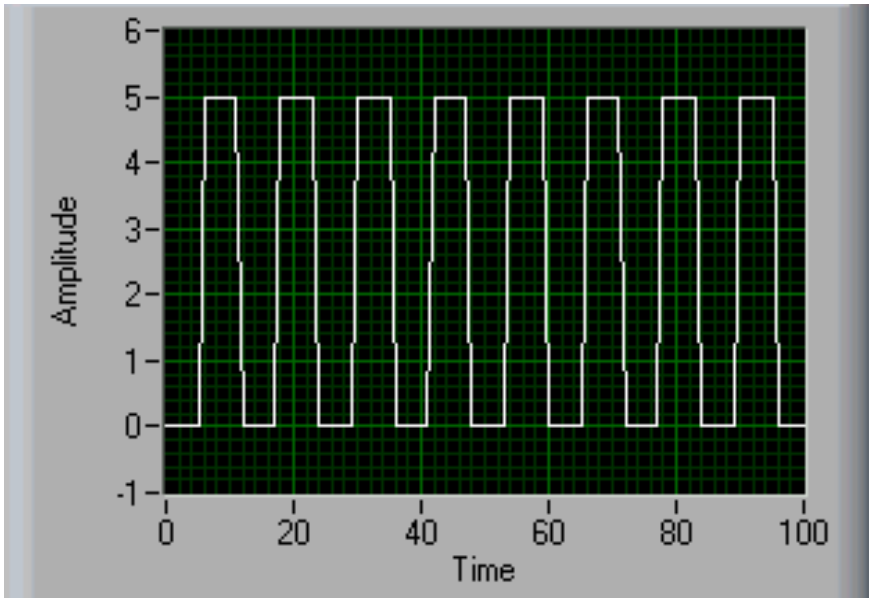
Signal Overview

- Topics
  - Types of Signals
  - Information in a Signal
    - State, Rate, Level, Shape, and Frequency

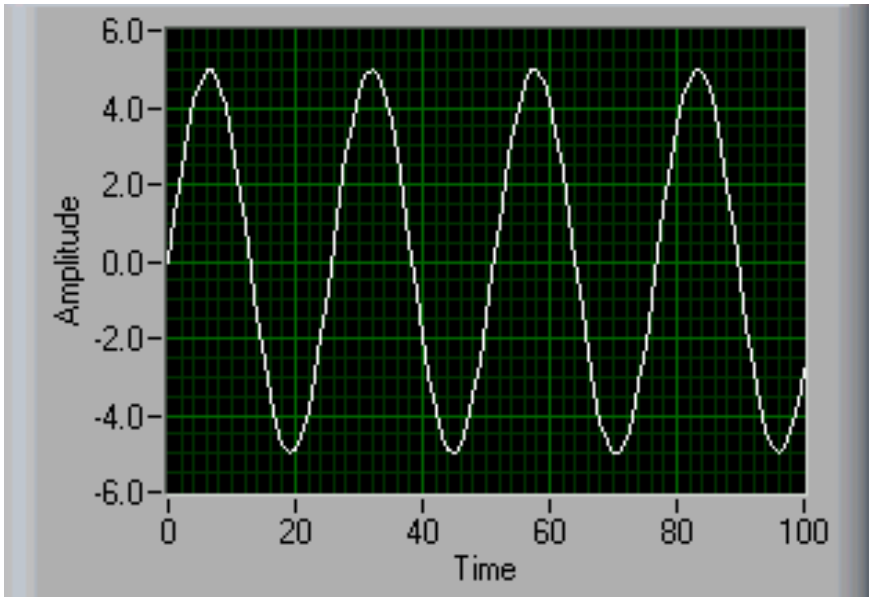


Signal Classification

Digital

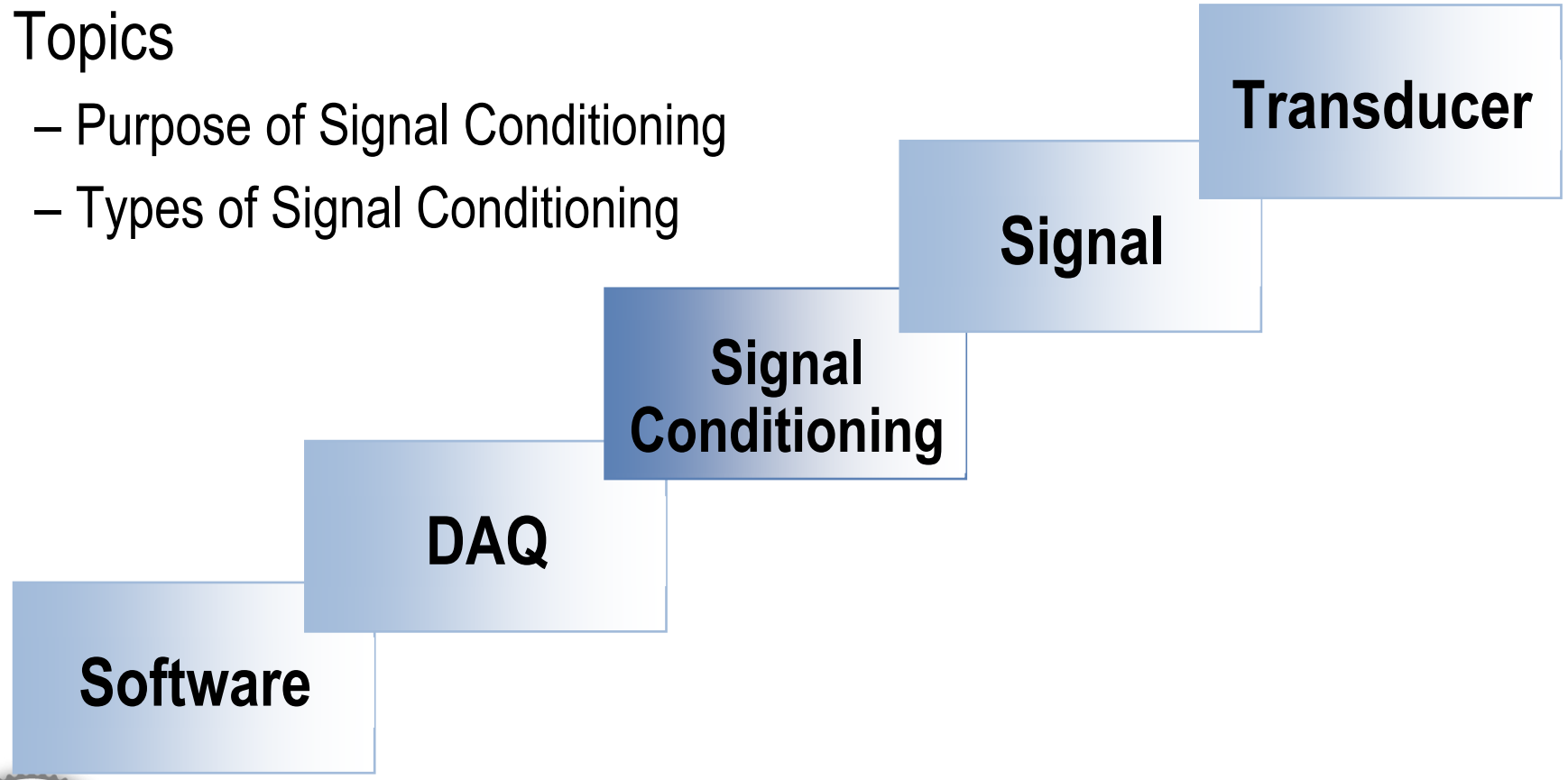


Analog

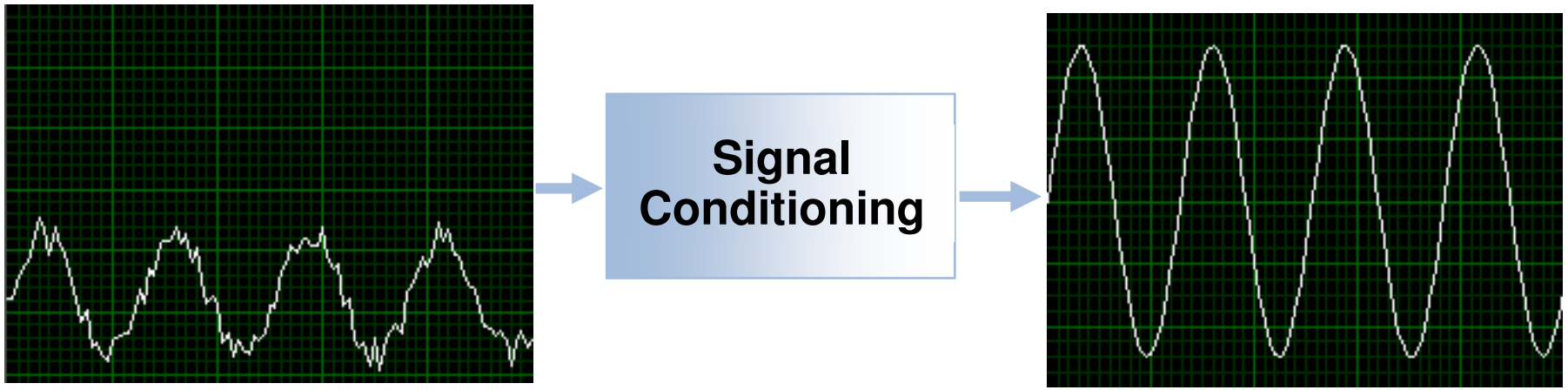


Signal Conditioning Overview

- Topics
  - Purpose of Signal Conditioning
  - Types of Signal Conditioning



Why Use Signal Conditioning?



Noisy, Low-Level Signal

Filtered, Amplified Signal

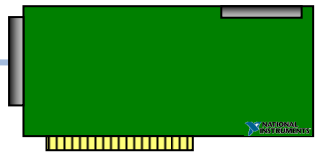
- Signal Conditioning takes a signal that is difficult for your DAQ device to measure and makes it easier to measure
- Signal Conditioning is not always required
  - Depends on the signal being measured

Other Types of Signal Conditioning

- Transducer Excitation
  - External voltage or current is applied to a transducer
  - Provided by signal conditioning hardware
- Linearization
  - Most transducers are not linear
  - Can be done in hardware or software
- Isolation
  - Protects hardware from high voltages
  - Used in systems with high common-mode voltages
- Filtering
  - Removes noise or unwanted signals
  - 4 Hz filter is low-pass making it optimum for removing 60 Hz AC noise from slowly sampled signals
  - Can be done in hardware or software

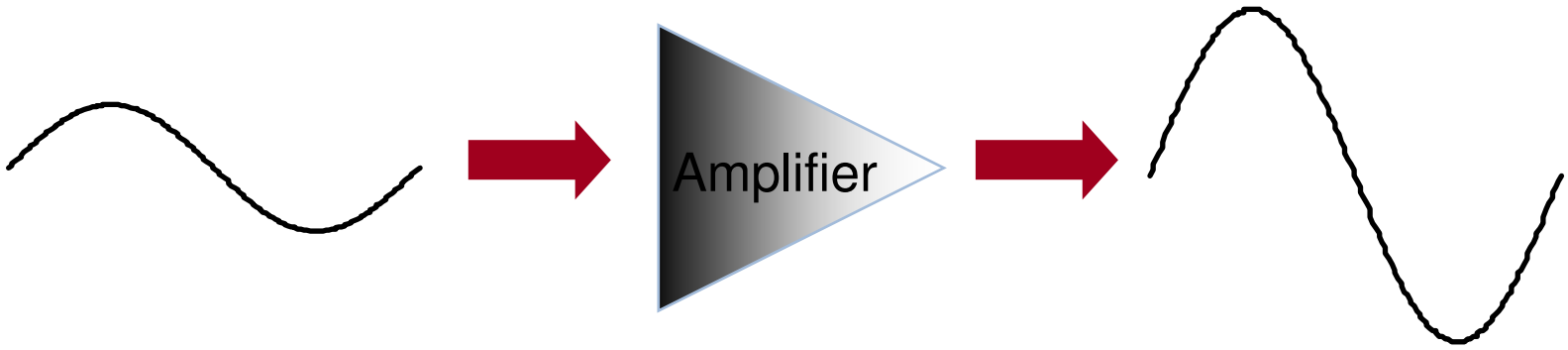
Common Types of Signal Conditioning

Transducers/Signals	Signal Conditioning
Thermocouples	Amplification, Linearization, and Cold-Junction Compensation
RTDs	Current Excitation, and Linearization
Strain Gages	Voltage Excitation, Bridge Configuration, and Linearization
Common Mode or High Voltages	Isolation Amplifiers (Optical Isolation)
Loads Requiring AC Switching or Large Current Flow	Electromechanical Relays or Solid-State Relays
Signals with High Frequency Noise	Low-Pass Filters



DAQ Device

Signal Amplification

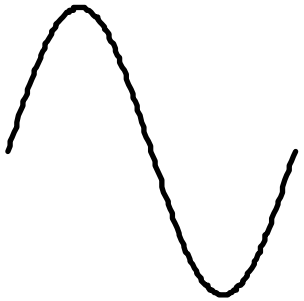


- Increases measurement resolution

12-bit Digitizer

10 mV signal

4 levels of resolution (2-bits)

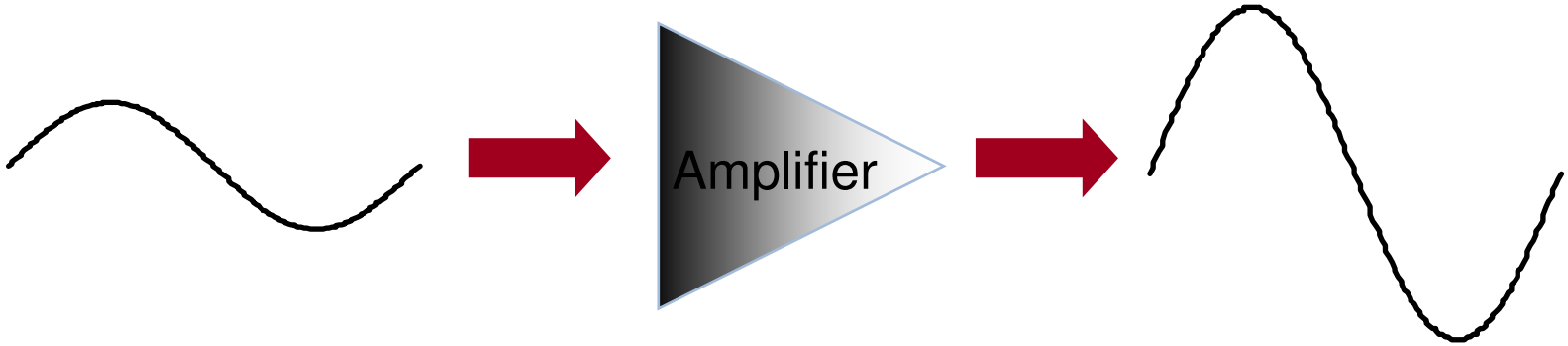


12-bit Digitizer

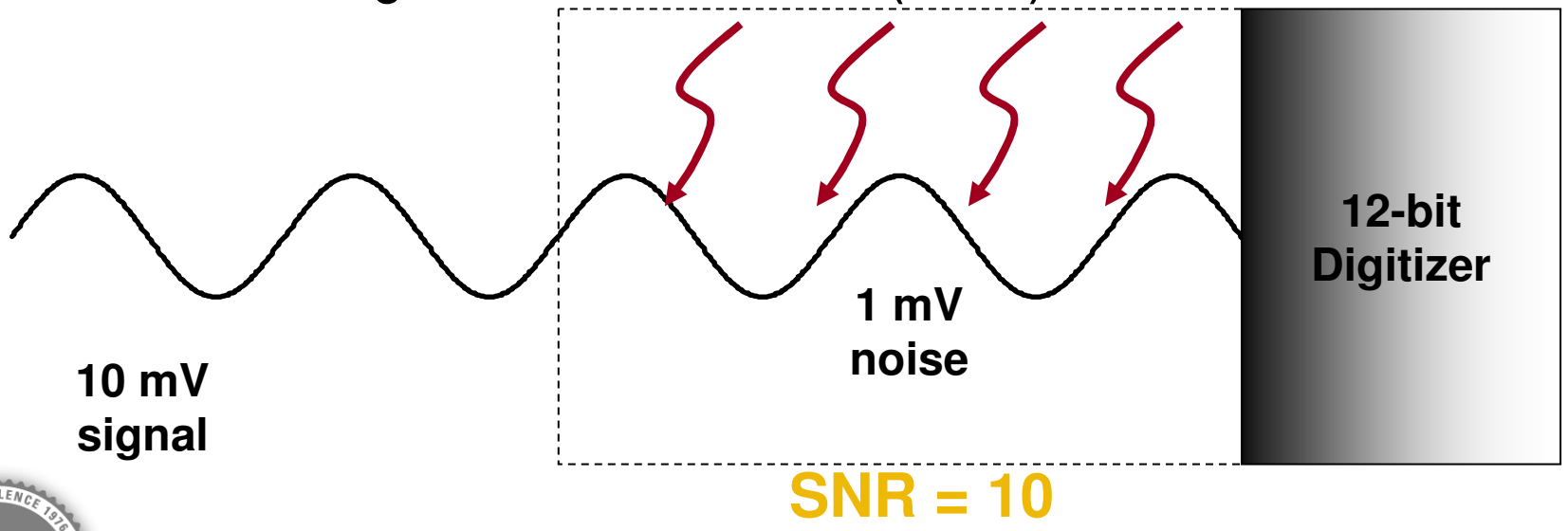
10 V signal

4096 levels of resolution (12-bits)

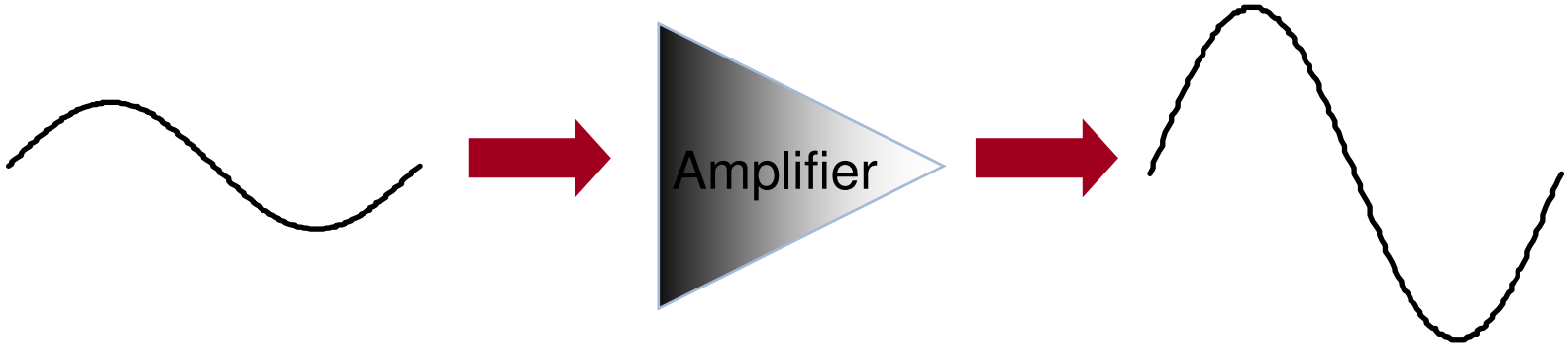
Signal Amplification



- Increases Signal-to-Noise Ratio (SNR)



Signal Amplification



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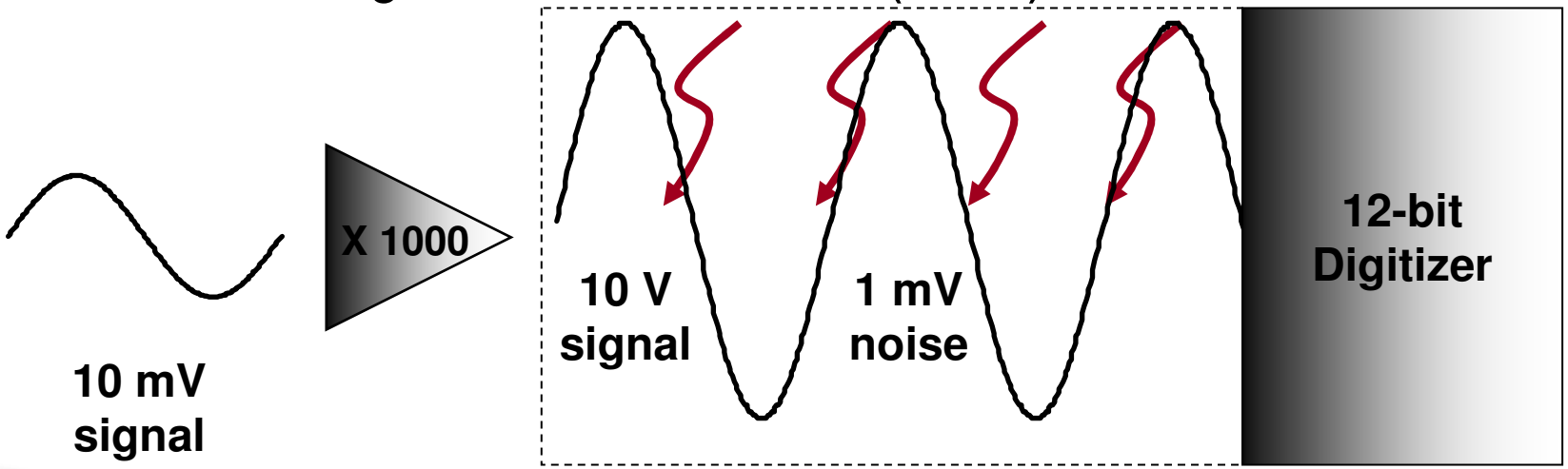
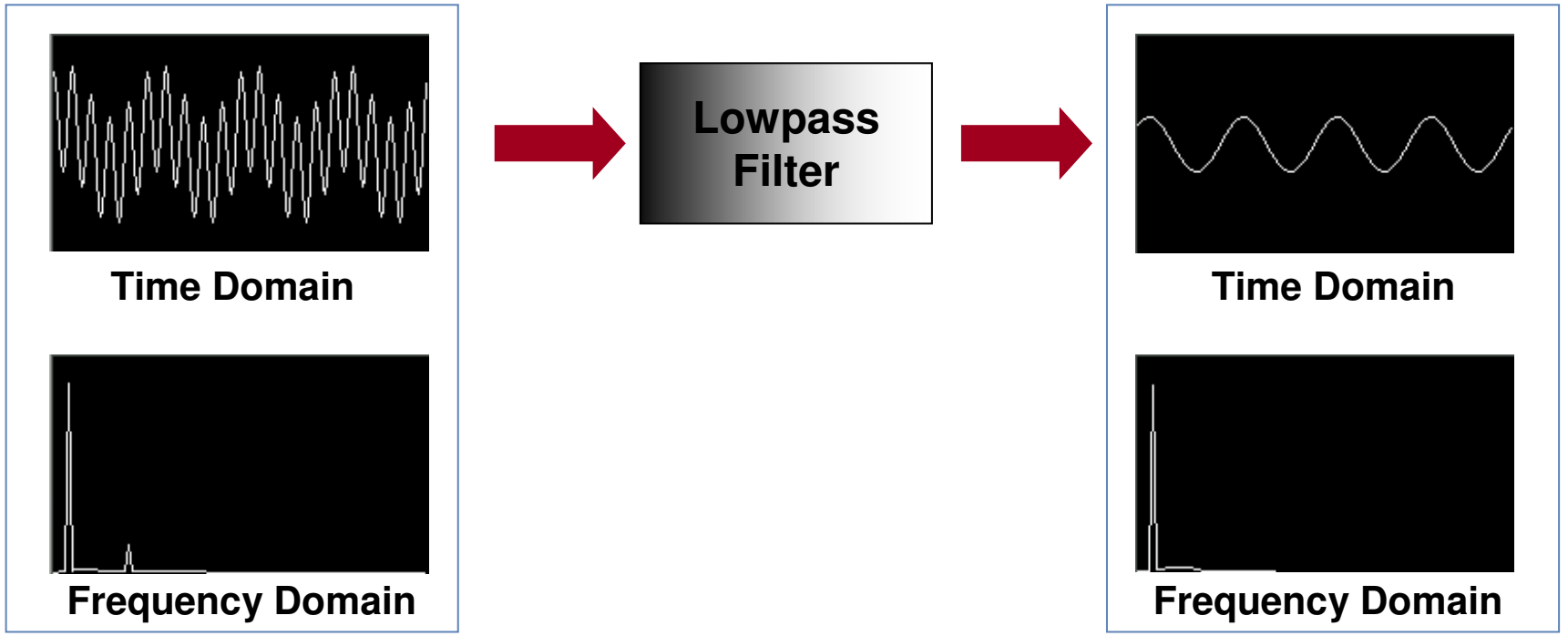
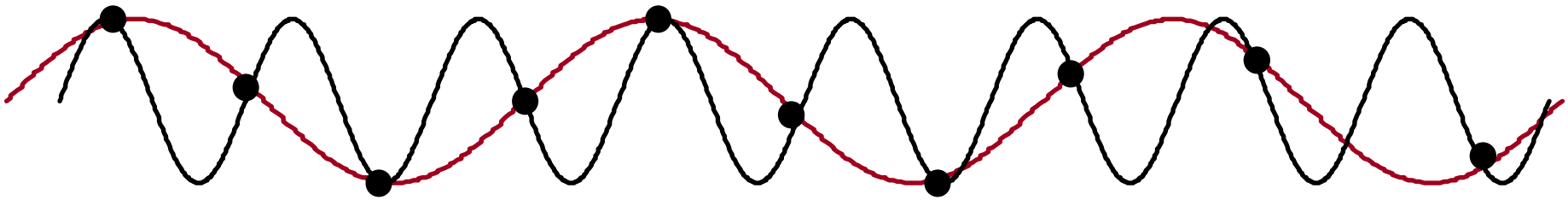


Filtering



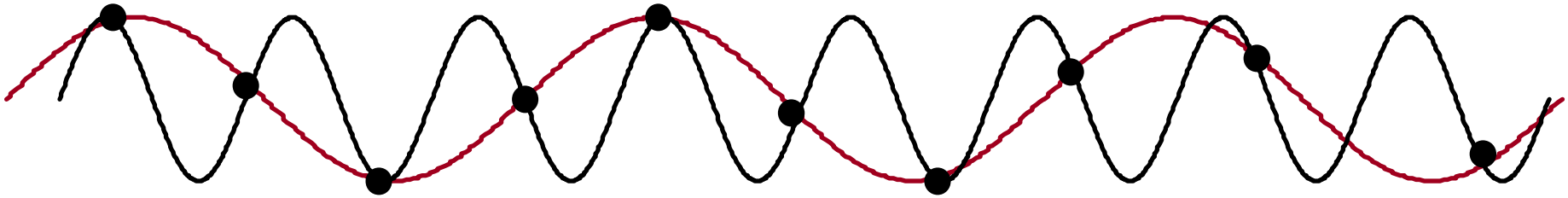
- Removes noise
- Blocks unwanted frequencies

Aliasing



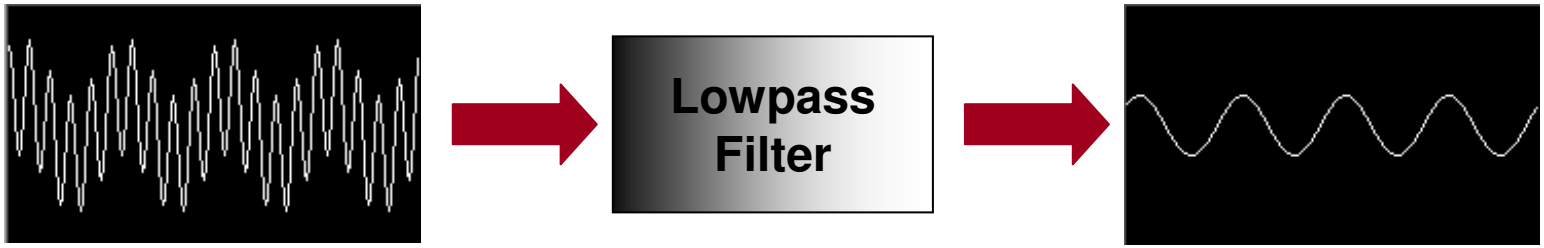
- Undersampling may result in higher frequency signals appearing as lower frequency signals
- Once a signal is aliased, it is impossible to reconstruct original signal
- Typical culprits – NOISE, harmonics

Preventing Aliasing

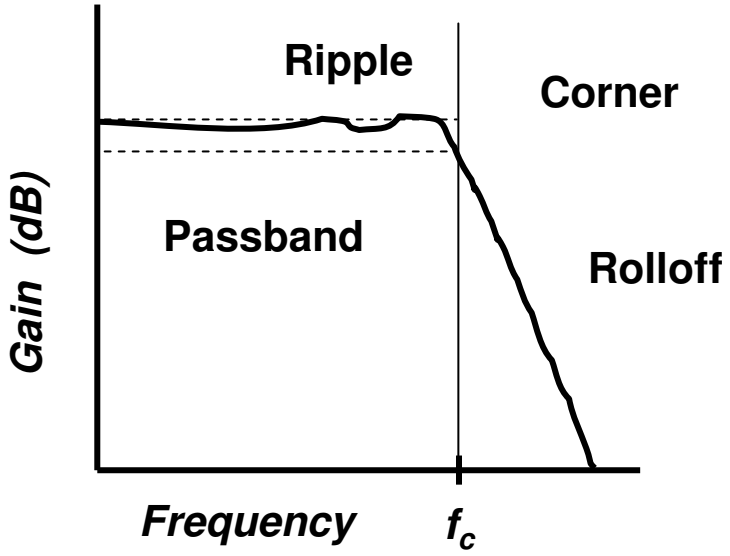


- Increase sampling rate
  - **Nyquist Theorem** – sample at twice the rate of your highest frequency signal
- Anti-alias (lowpass) filtering
  - Set a lowpass filter at less than ½ the sampling rate

Filtering



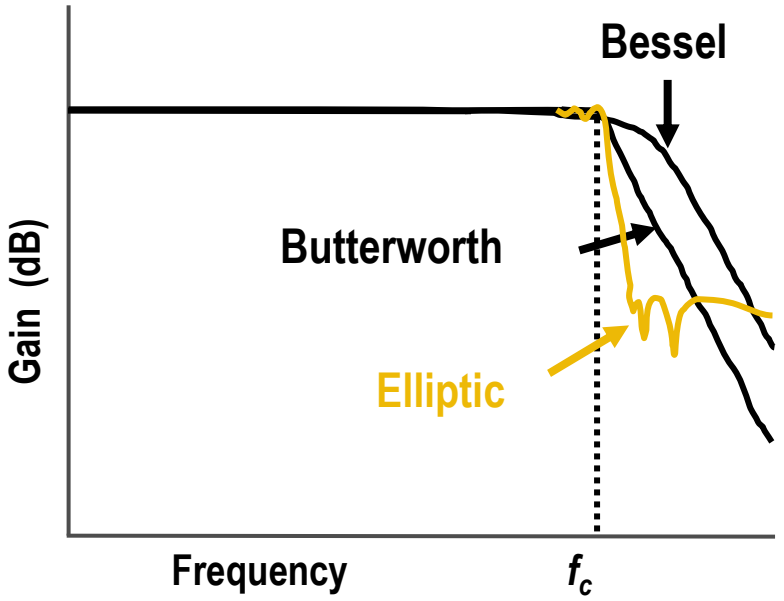
Bode Plot

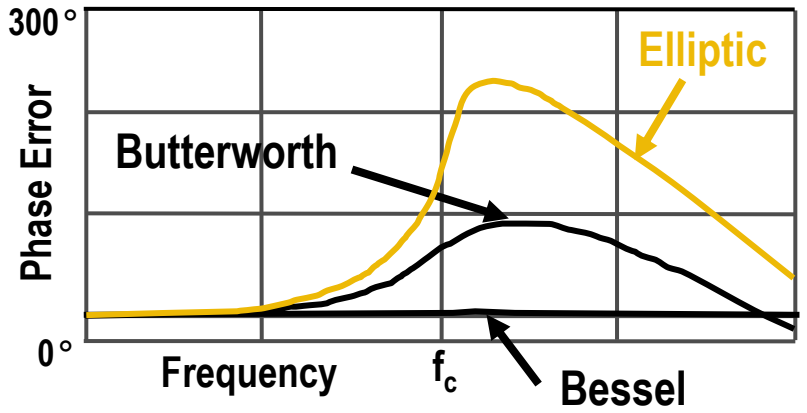


- Passband – frequencies the filter lets pass
- Ripple - filter's affect on the signal's amplitude
- Corner – frequency where the filter begins blocking the signal
- Rolloff – how sharply the filter cuts off unwanted frequencies

Filter Types

- Elliptic Filter Response
  - + Sharp rolloff
  - – Passband ringing
  - – Phase shift
- Butterworth Filter Response
  - + Maximum passband flatness
  - – Phase shift
- Bessel Filter Response
  - + Minimal phase error
  - – Gradual rolloff





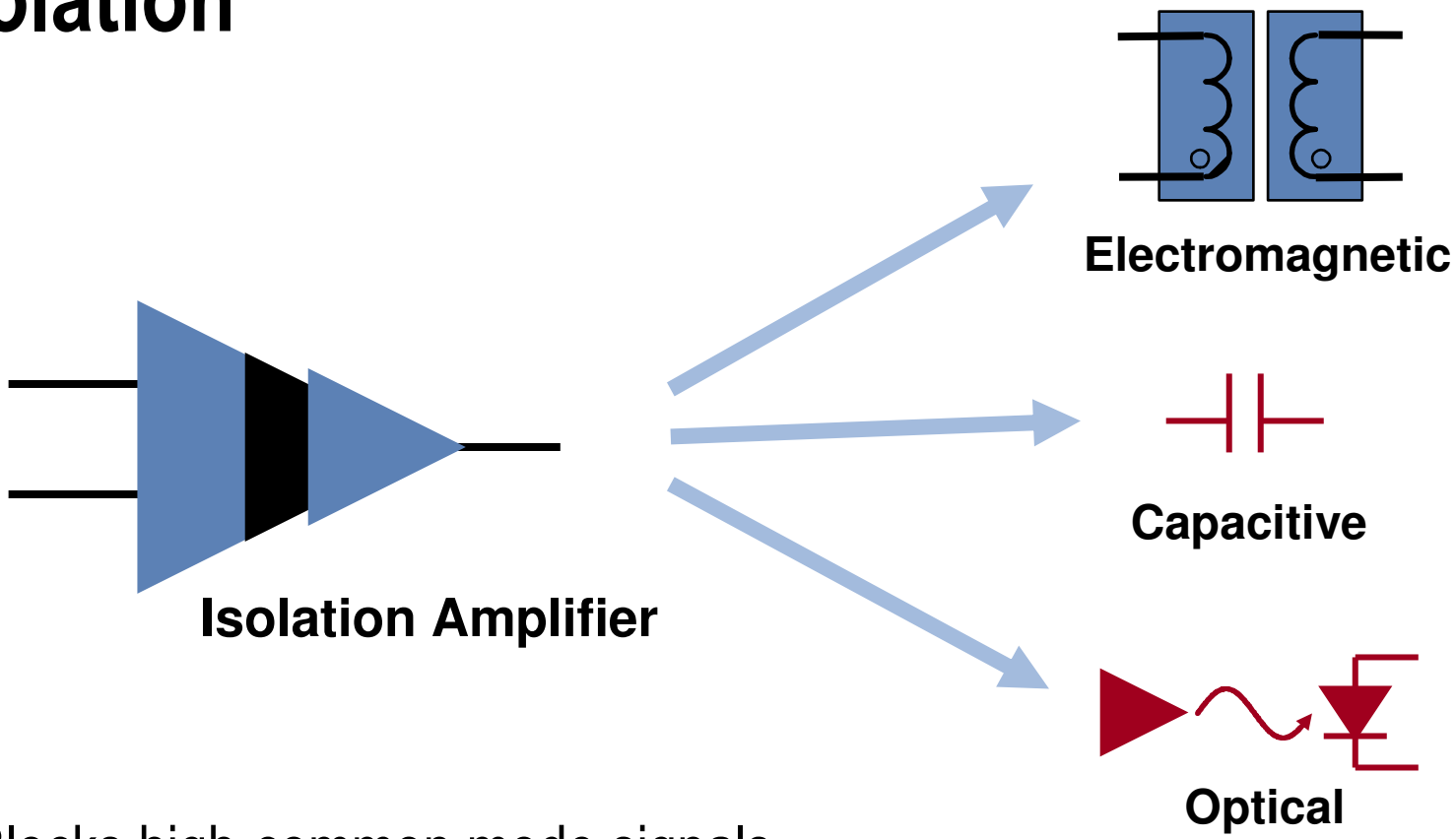
Filtering

- Remove/reject unwanted noise within certain frequency range
  - 50/60 Hz noise rejected by lowpass 4Hz filter

- Prevent aliasing
  - Remove frequency components greater than one half the sampling frequency (Nyquist Theorem)

DEMO DAQ Filtering

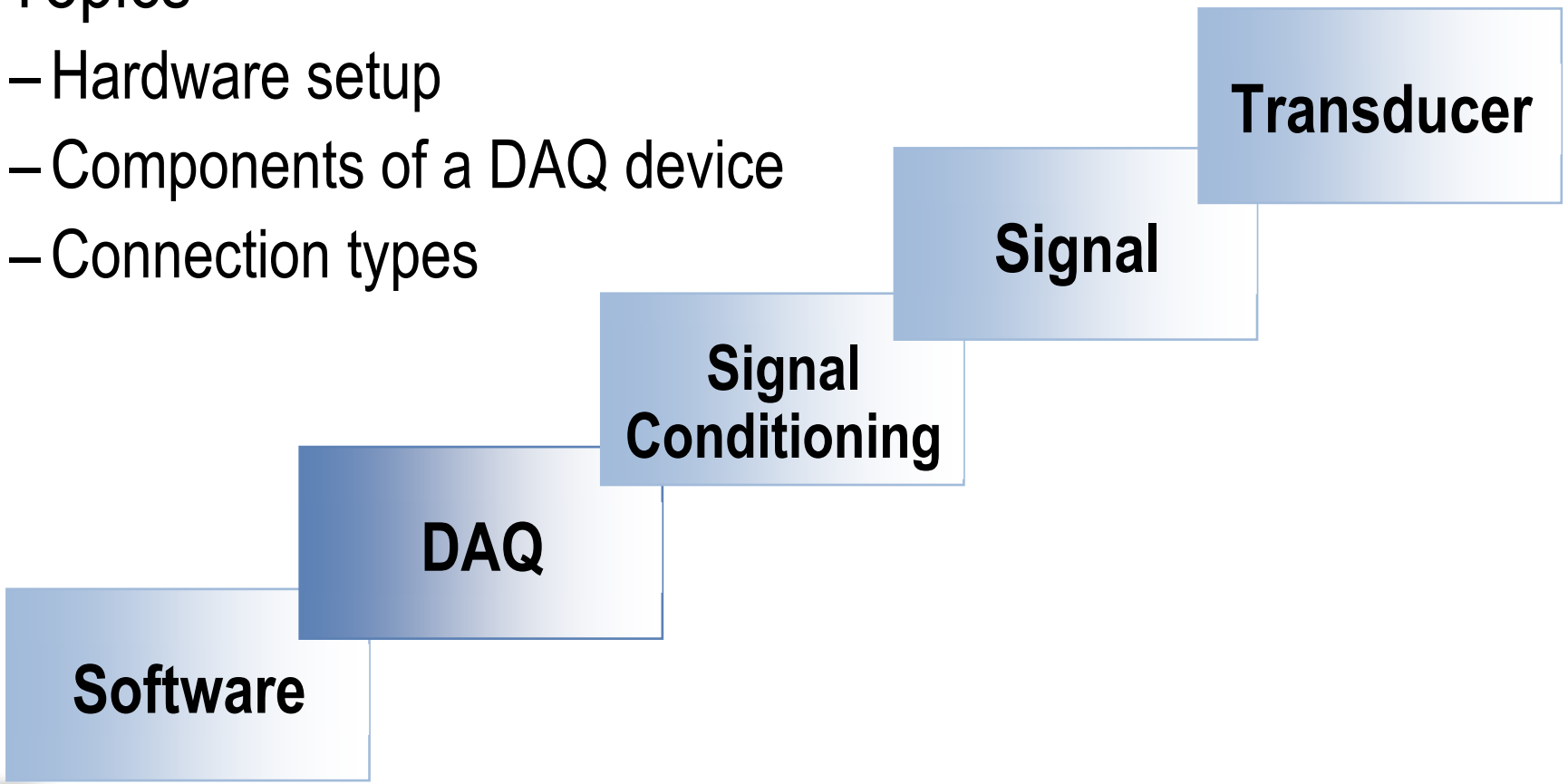
Isolation



- Blocks high-common mode signals
- Breaks ground loops
- Protects your instrumentation

DAQ Hardware Overview

- Topics
  - Hardware setup
  - Components of a DAQ device
  - Connection types



Resolution

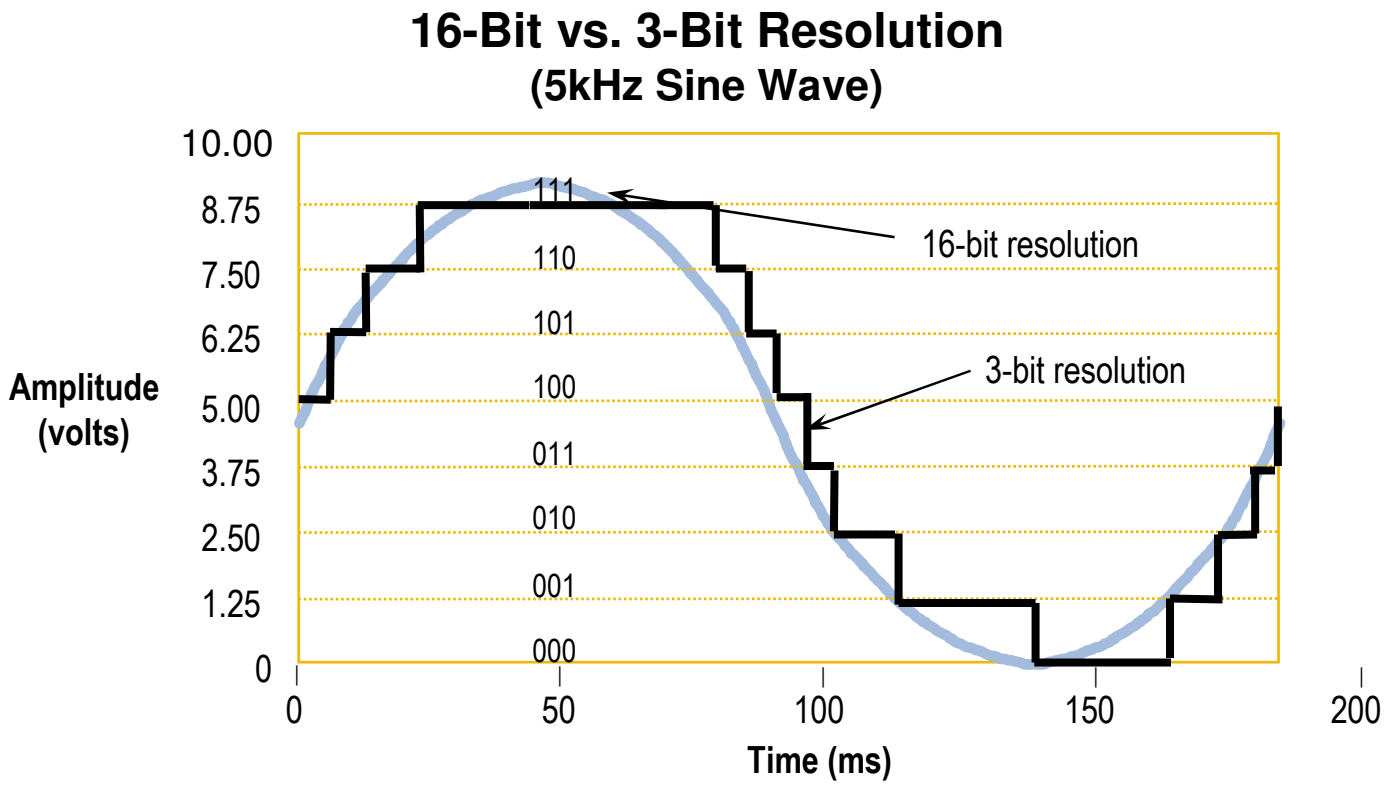
- Number of bits the ADC uses to represent a signal
- Resolution determines how many different voltage changes can be measured
- Example: 12-bit resolution

  # of levels = $2^{resolution} = 2^{12} = 4{,}096$ levels

- Larger resolution = more precise representation of your signal

Resolution Example

- 3-bit resolution can represent 8 voltage levels
- 16-bit resolution can represent 65,536 voltage levels

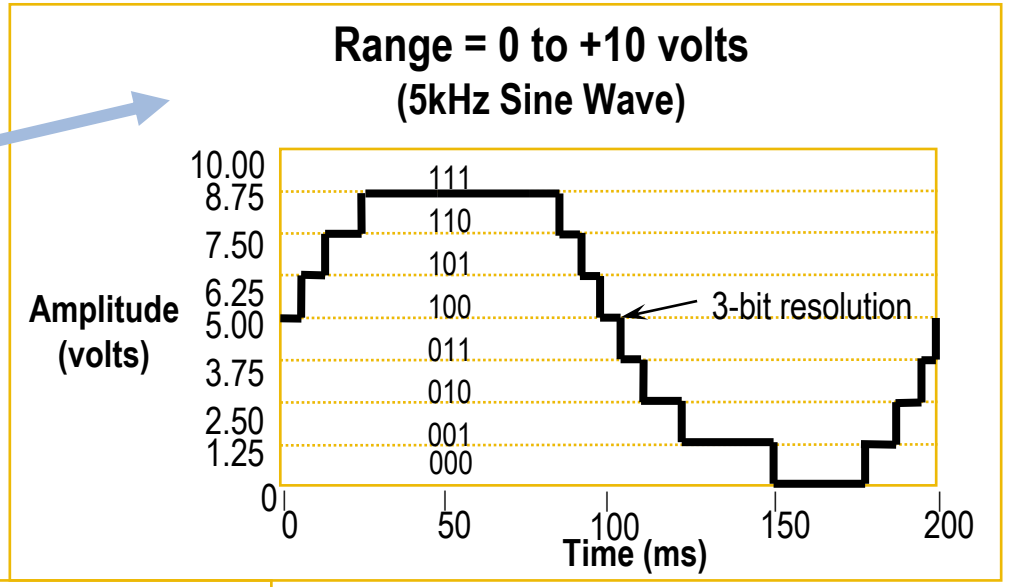


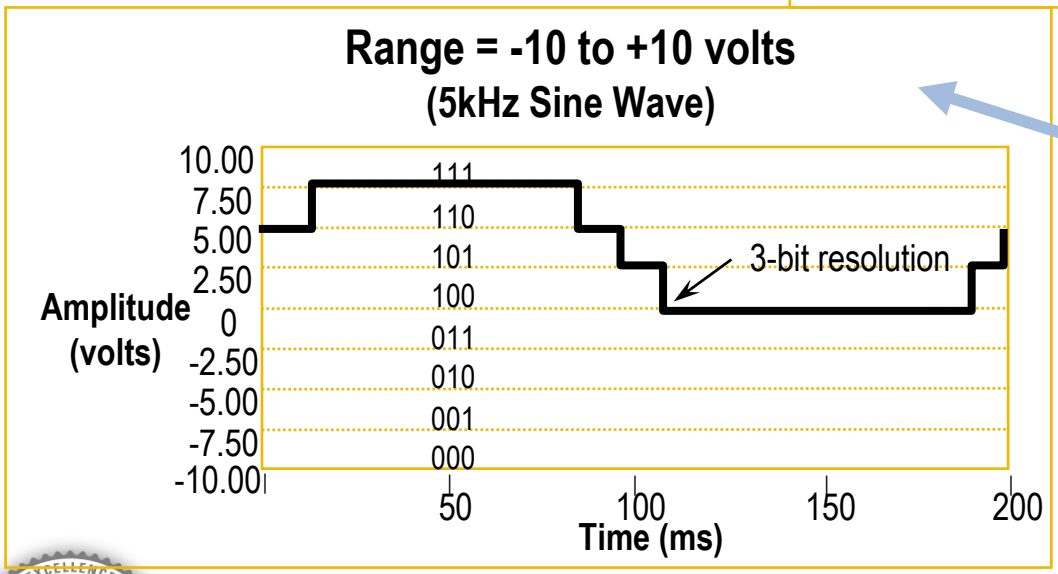
Range

- Minimum and maximum voltages the ADC can digitize
- DAQ devices often have different available ranges
  - 0 to +10 volts
  - -10 to +10 volts
- Pick a range that your signal fits in
- Smaller range = more precise representation of your signal
  - Allows you to use all of your available resolution

Range Example

- Proper Range
  - Using all 8 levels to represent your signal

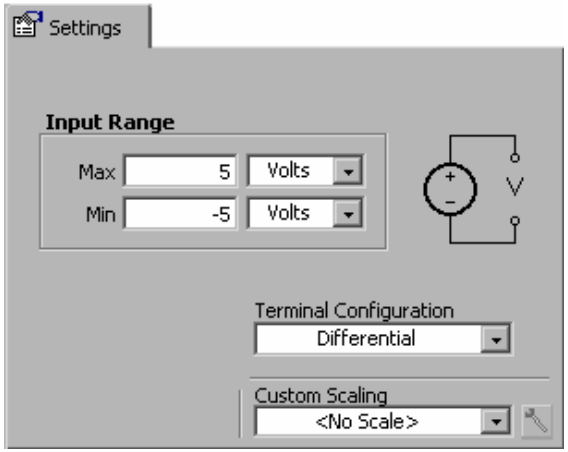


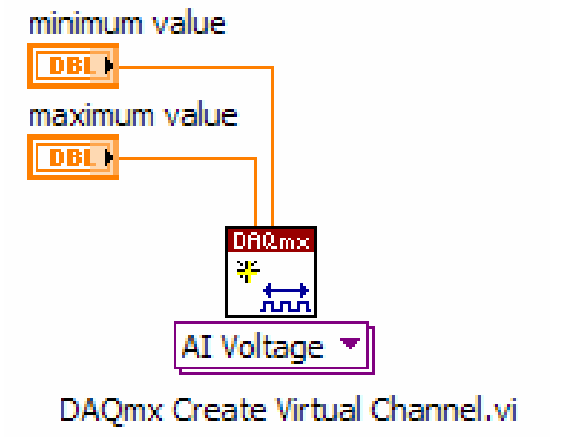


- Improper Range
  - Only using 4 levels to represent your signal

Amplification

- Max and min settings amplify or attenuate the signal for best fit in ADC range
- Settings are 0.5, 1, 2, 5, 10, 20, 50, or 100 for most devices
- You don't choose the amplification directly
  - Choose the input limits of your signal in LabVIEW or the DAQ Assistant
  - Proper amplification chosen by NI-DAQmx
- Proper amplification = more precise representation of your signal

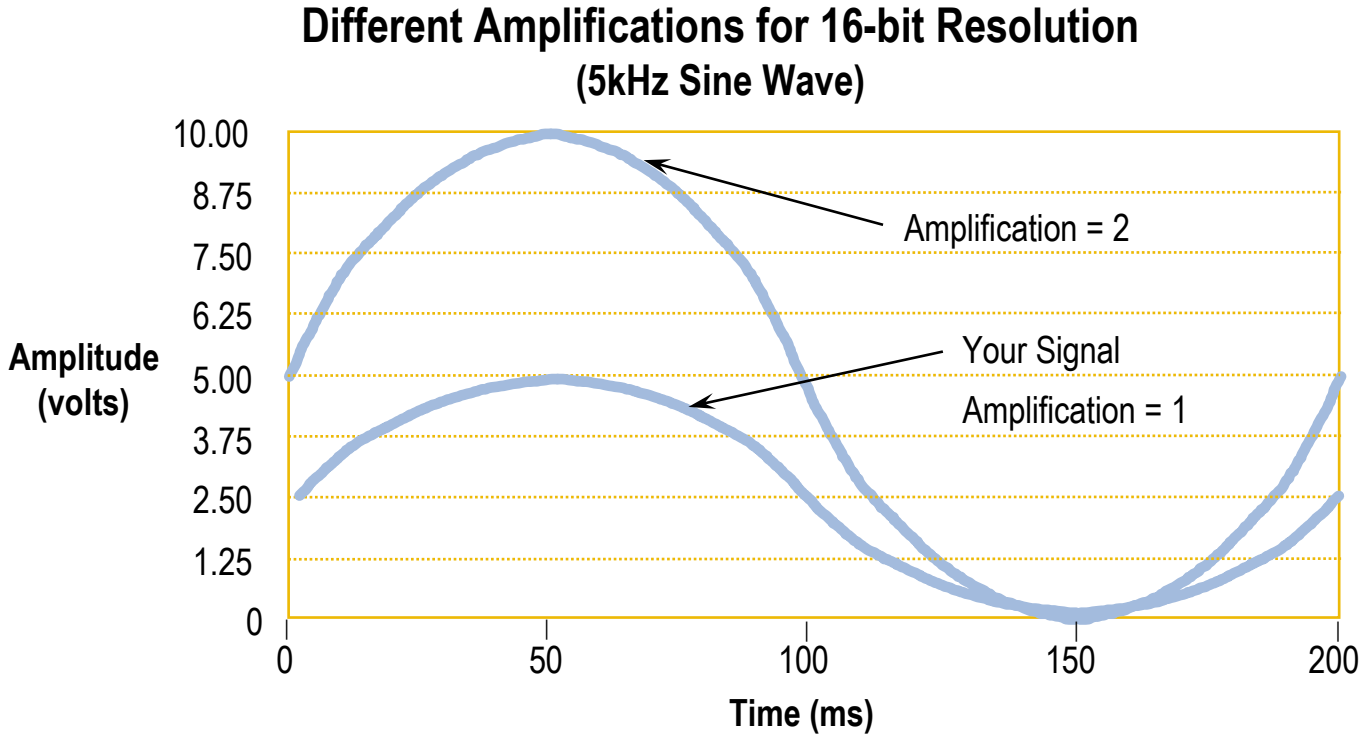




DAQmx Create Virtual Channel.vi

Amplification Example

- Input limits of the signal = 0 to 5 Volts
- Range Setting for the ADC = 0 to 10 Volts
- Amplification applied by Instrumentation Amplifier = 2



Code Width

- Code Width is the smallest change in the signal, which your system can detect (determined by resolution, range, and amplification)

$$\text{code width} = \frac{\text{range}}{\text{amplification} * 2^{\text{resolution}}}$$

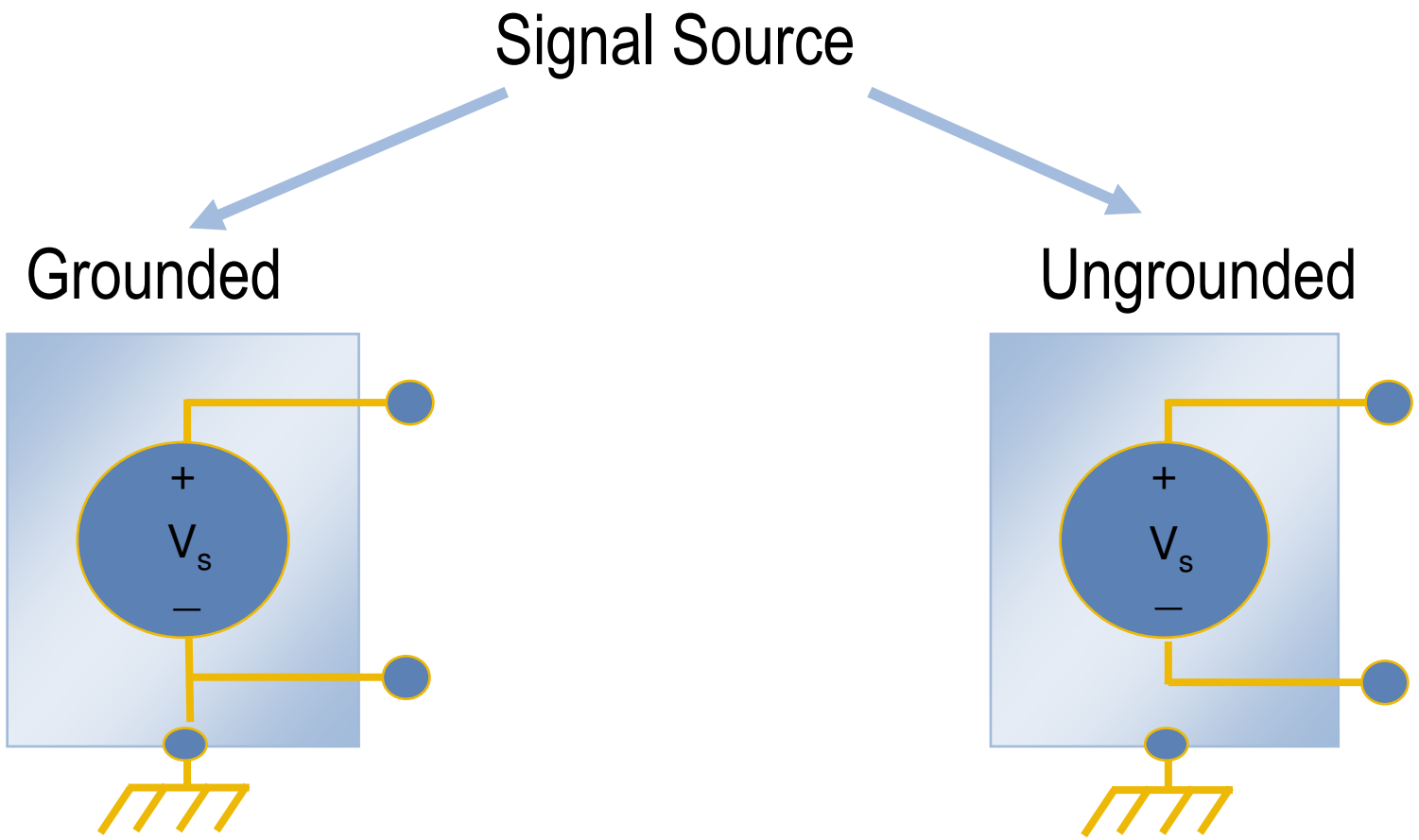
- Smaller Code Width = more precise representation of your signal
- Example: 12-bit device, range = 0 to 10V, amplification = 1

$$\frac{\text{range}}{\text{amplification} * 2^{\text{resolution}}} = \frac{10}{1 * 2^{12}} = 2.4 \text{ mV}$$

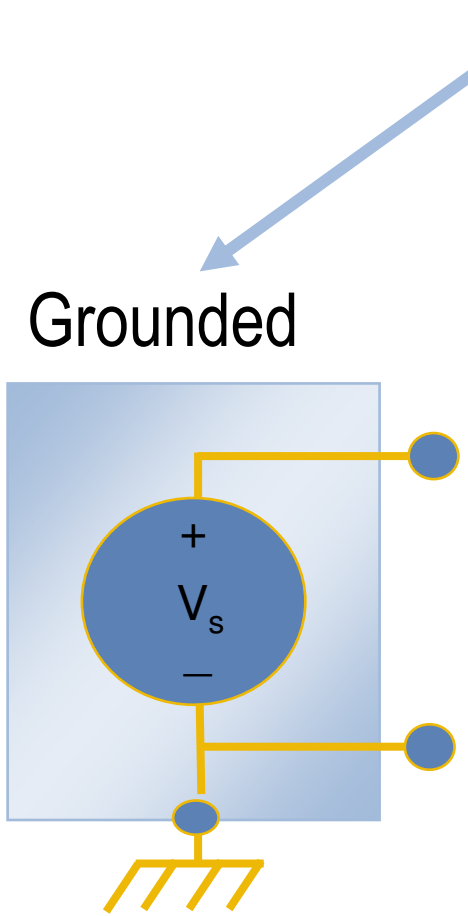
$$\text{Increase range: } \frac{20}{1 * 2^{12}} = 4.8 \text{ mV}$$

$$\text{Increase amplification: } \frac{10}{100 * 2^{12}} = 24 \text{ µV}$$

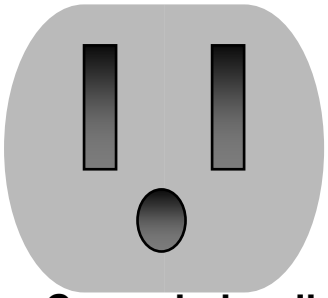
Signal Source Categories



Grounded Signal Source



- Signal is referenced to a system ground
  - Earth ground
  - Building ground
- Examples:
  - Power supplies
  - Signal Generators
  - Anything that plugs into a grounded electrical wall socket

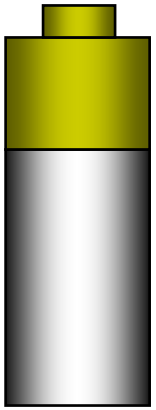


Grounded wall socket

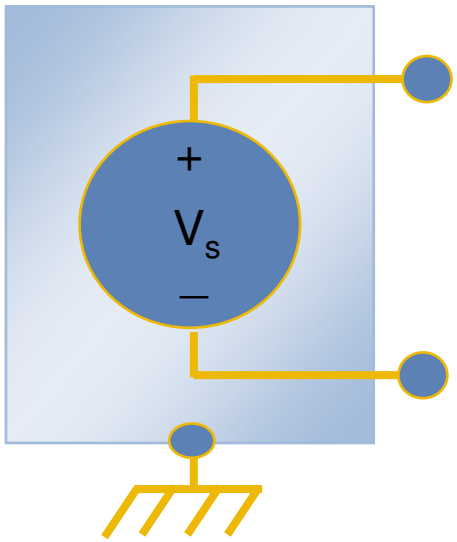
Floating Signal Source

Signal Source

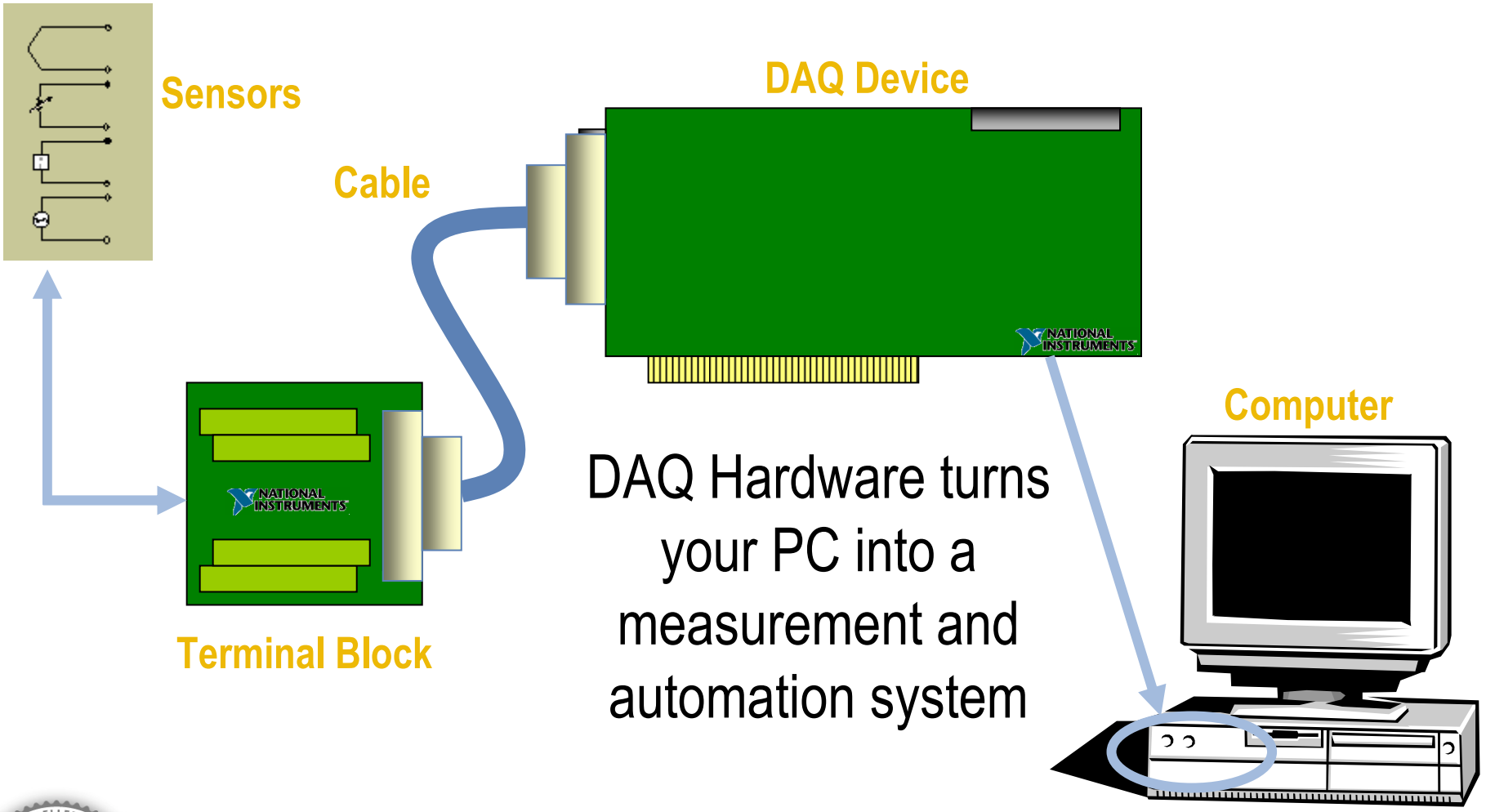
- Signal is NOT referenced to a system ground
  - Earth ground
  - Building ground
- Examples:
  - Batteries
  - Thermocouples
  - Transformers
  - Isolation Amplifiers



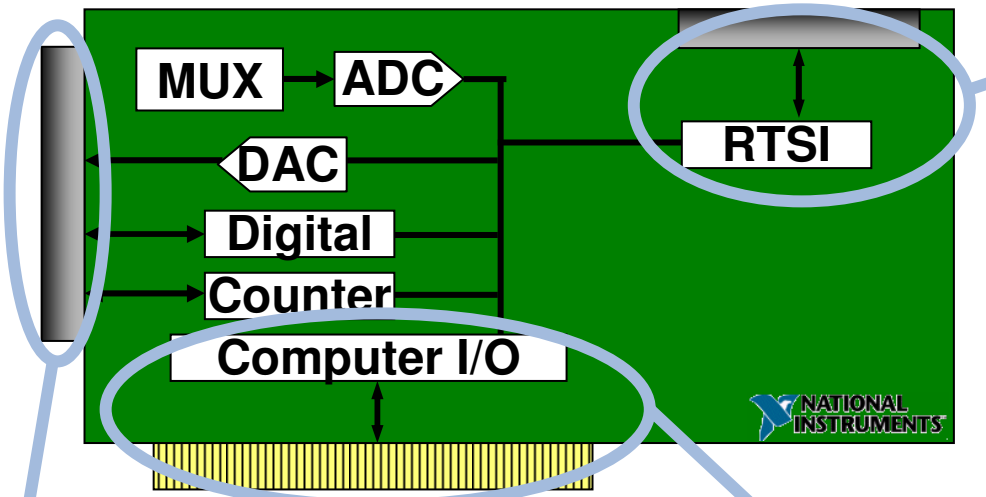
Floating



Data Acquisition Hardware



Components of a DAQ device

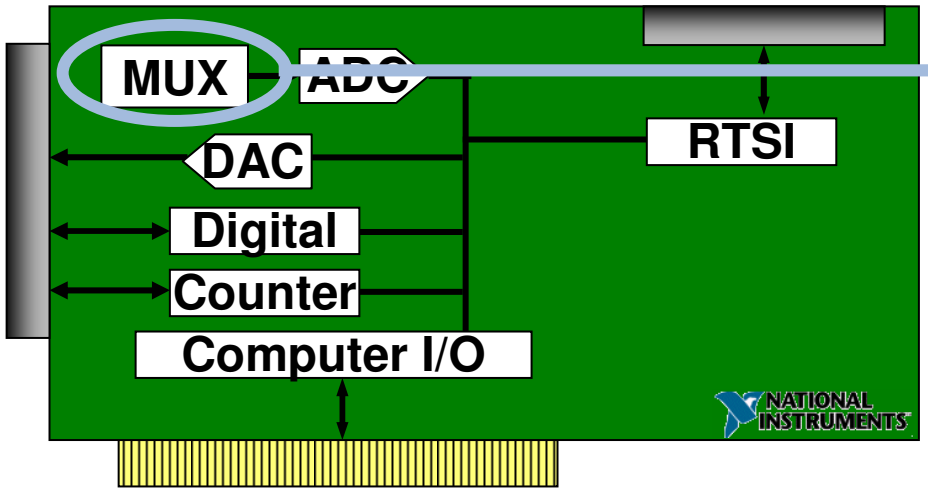


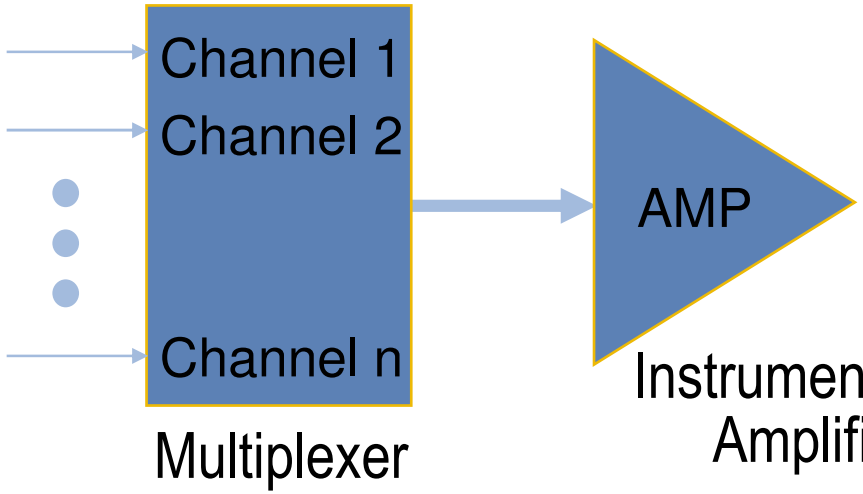
- Real-Time System Integration (RTSI) Bus
  - Used to synchronize multiple DAQ devices
  - Allows sharing of timing and trigger signals between devices

- Computer I/O Interface Circuitry
  - Connects the DAQ device to the computer
  - Can be a variety of bus structures
    - PCI, PCI Express, PXI/Compact PCI, ISA/AT,
    - PCMCIA, USB, IEEE 1394 (Firewire)

- I/O Connector
  - Connects your signal (through terminal block and cable) to the DAQ device

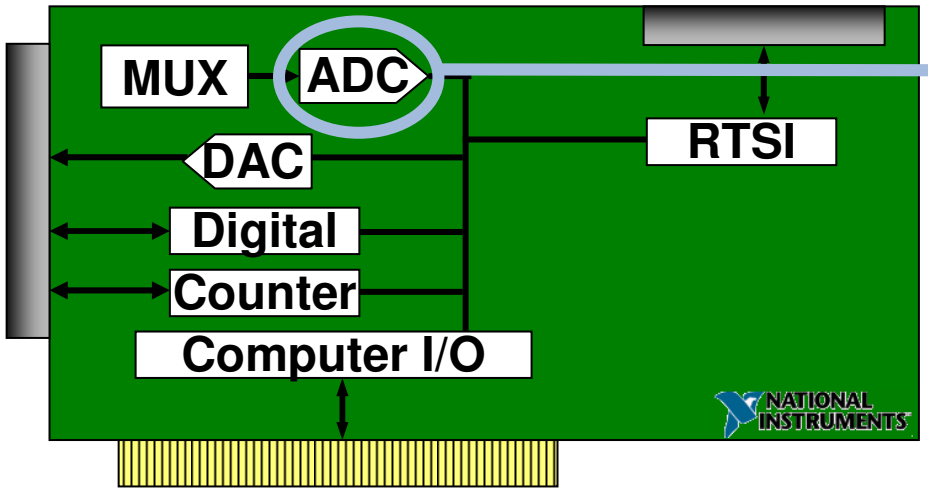
Components of a DAQ device



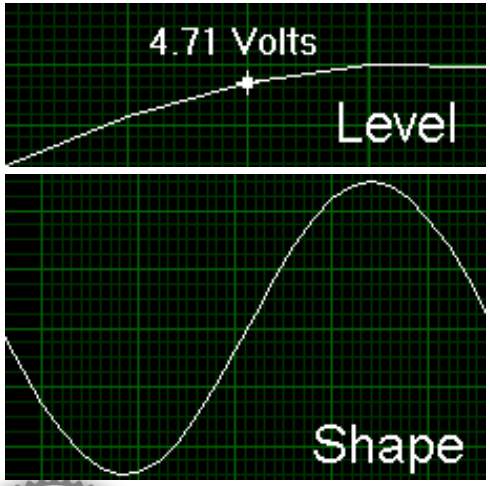


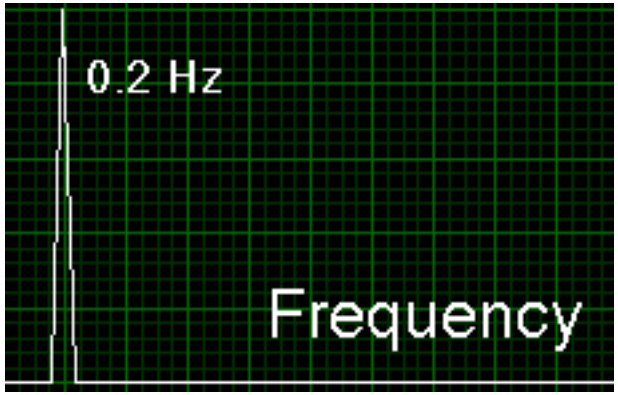
- Analog Input Circuitry
  - Multiplexer (mux)
    - Switch that has multiple input channels but only lets one channel at a time through to the instrumentation amplifier
  - Instrumentation Amplifier
    - Either amplifies or attenuates your signal

Components of a DAQ device



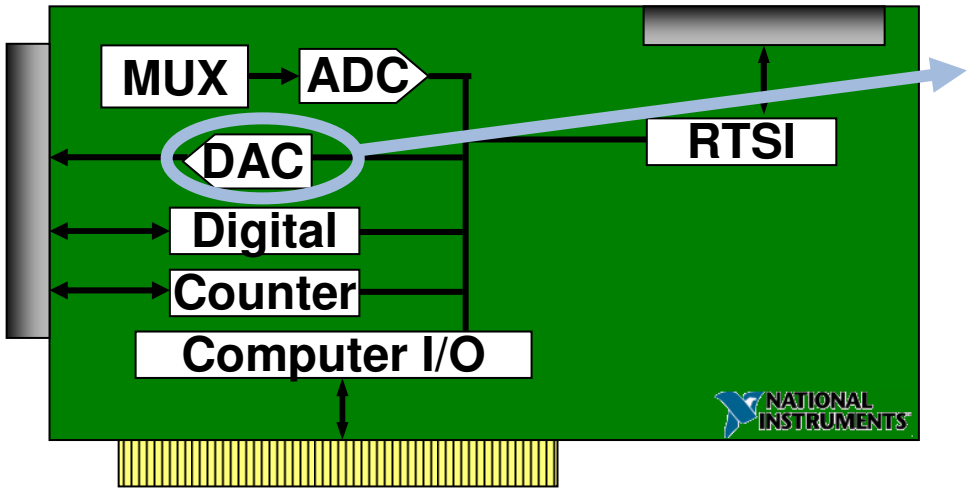
- Analog-to-Digital Converter (ADC)
  - Converts analog signal to digital number
  - Used for analog input



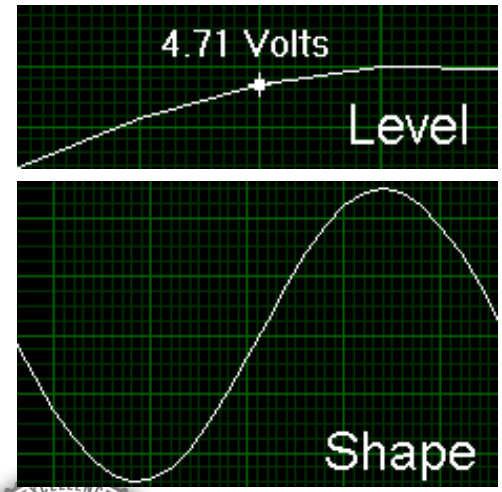


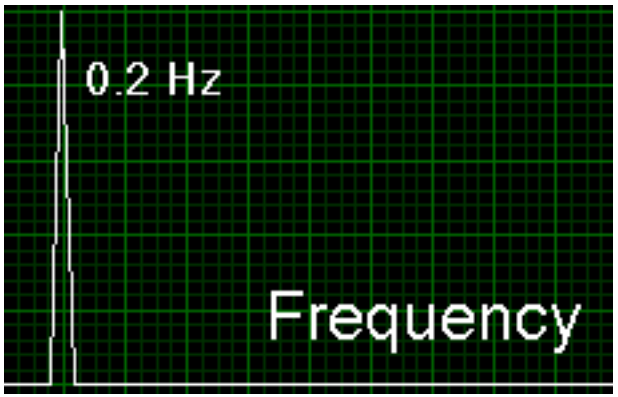
Analysis Required

Components of a DAQ device

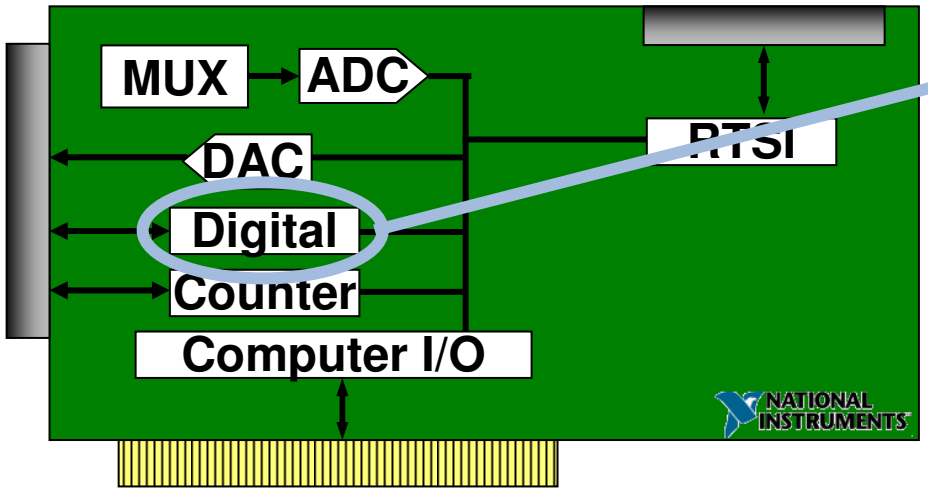


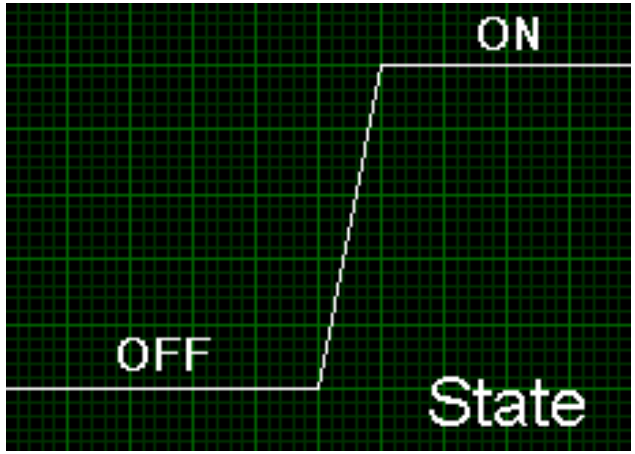
- Digital-to-Analog Converter (DAC)
  - Converts digital number to analog signal
  - Used for analog output





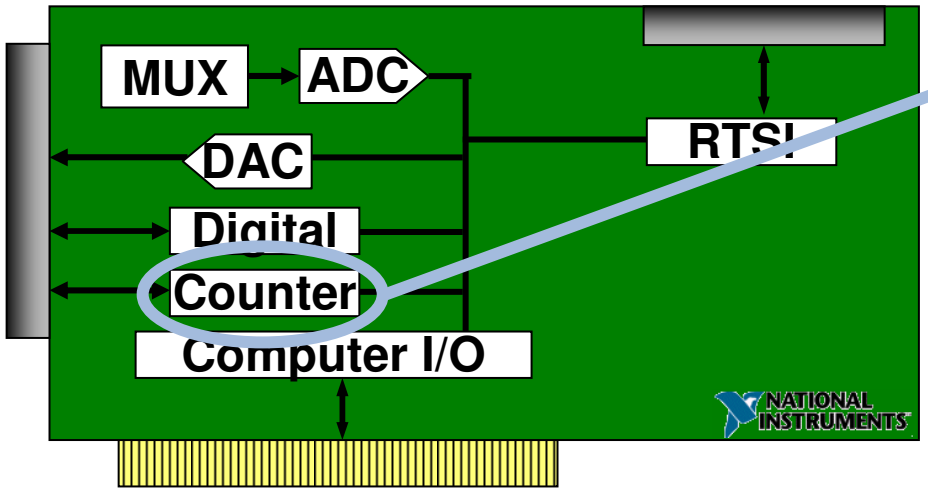
Components of a DAQ device

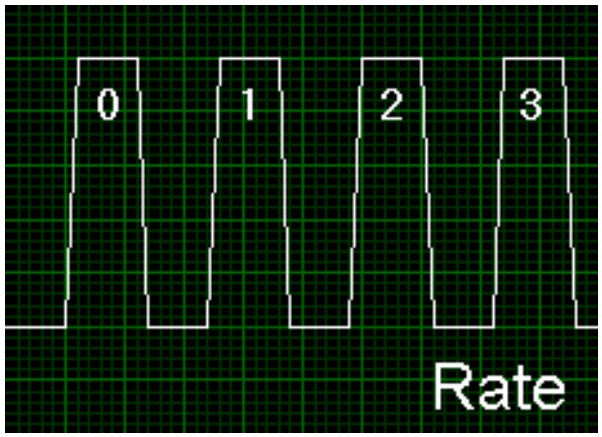




- Digital I/O Circuitry
  - Can input or output digital signals
  - Not suitable for measuring rate
    - No handshaking or timing circuitry

Components of a DAQ device





- Counter Circuitry
  - Can input or output digital signals
  - Suitable for measuring rate
    - Built in timing signals

Resolution

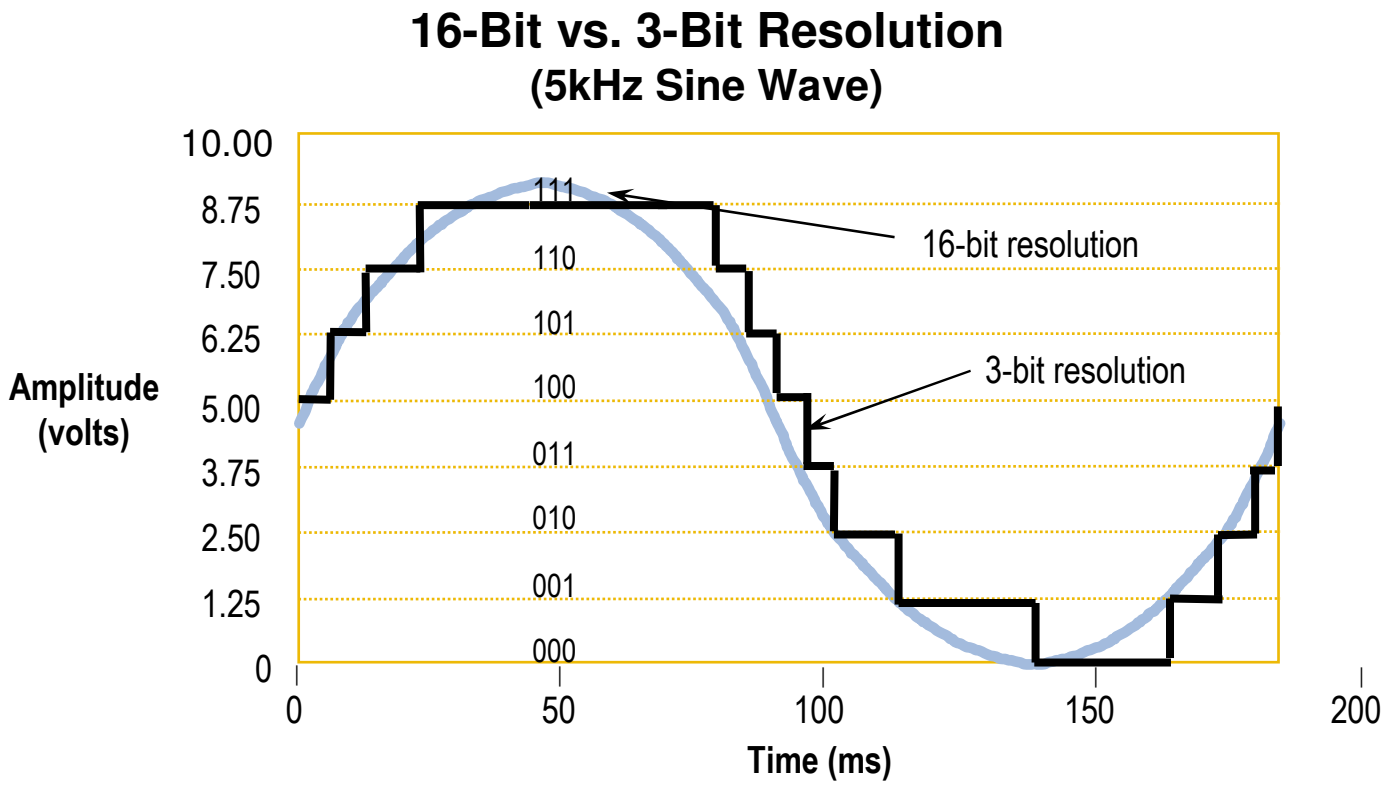
- Number of bits the ADC uses to represent a signal
- Resolution determines how many different voltage changes can be measured
- Example: 12-bit resolution

  # of levels = $2^{resolution} = 2^{12} = 4{,}096$ levels

- Larger resolution = more precise representation of your signal

Resolution Example

- 3-bit resolution can represent 8 voltage levels
- 16-bit resolution can represent 65,536 voltage levels

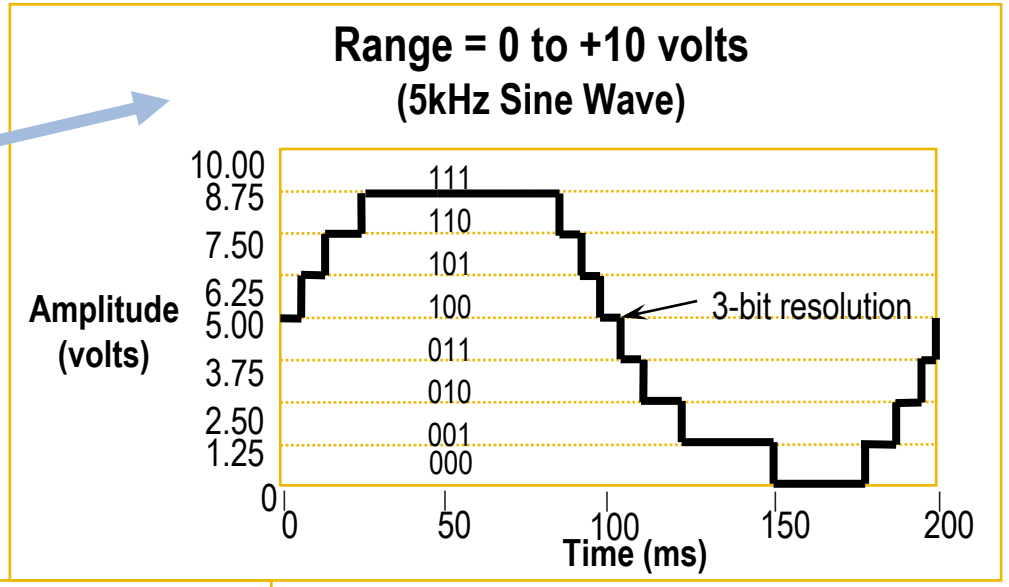


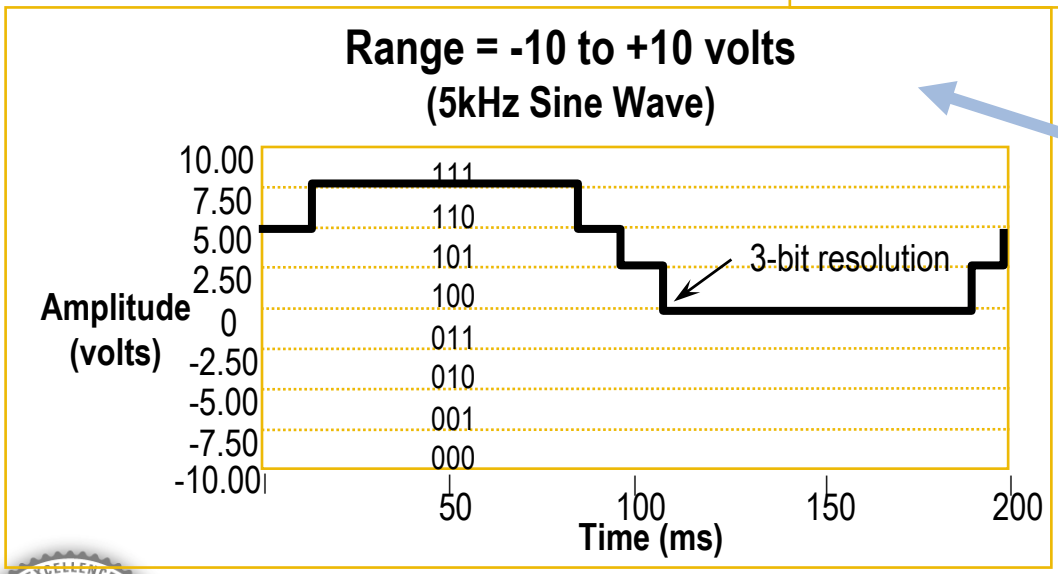
Range

- Minimum and maximum voltages the ADC can digitize
- DAQ devices often have different available ranges
  - 0 to +10 volts
  - -10 to +10 volts
- Pick a range that your signal fits in
- Smaller range = more precise representation of your signal
  - Allows you to use all of your available resolution

Range Example

- Proper Range
  - Using all 8 levels to represent your signal

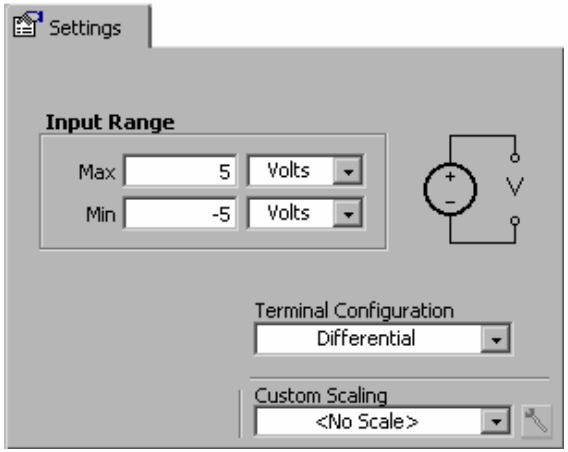


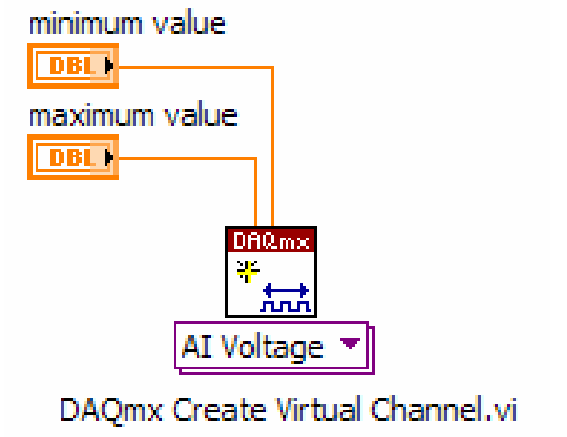


- Improper Range
  - Only using 4 levels to represent your signal

Amplification

- Max and min settings amplify or attenuate the signal for best fit in ADC range
- Settings are 0.5, 1, 2, 5, 10, 20, 50, or 100 for most devices
- You don't choose the amplification directly
  - Choose the input limits of your signal in LabVIEW or the DAQ Assistant
  - Proper amplification chosen by NI-DAQmx
- Proper amplification = more precise representation of your signal

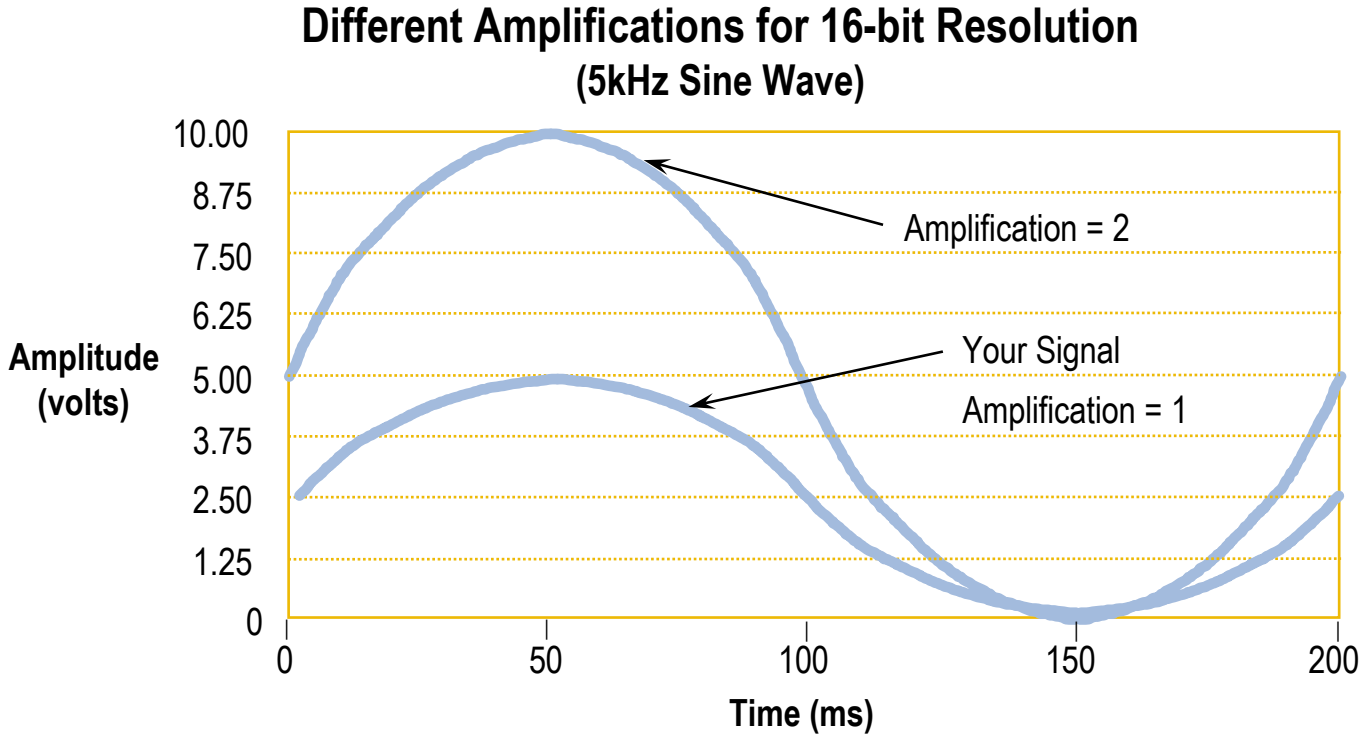




DAQmx Create Virtual Channel.vi

Amplification Example

- Input limits of the signal = 0 to 5 Volts
- Range Setting for the ADC = 0 to 10 Volts
- Amplification applied by Instrumentation Amplifier = 2



Code Width

- Code Width is the smallest change in the signal, which your system can detect (determined by resolution, range, and amplification)

$$\text{code width} = \frac{\text{range}}{\text{amplification} * 2^{\text{resolution}}}$$

- Smaller Code Width = more precise representation of your signal
- Example: 12-bit device, range = 0 to 10V, amplification = 1

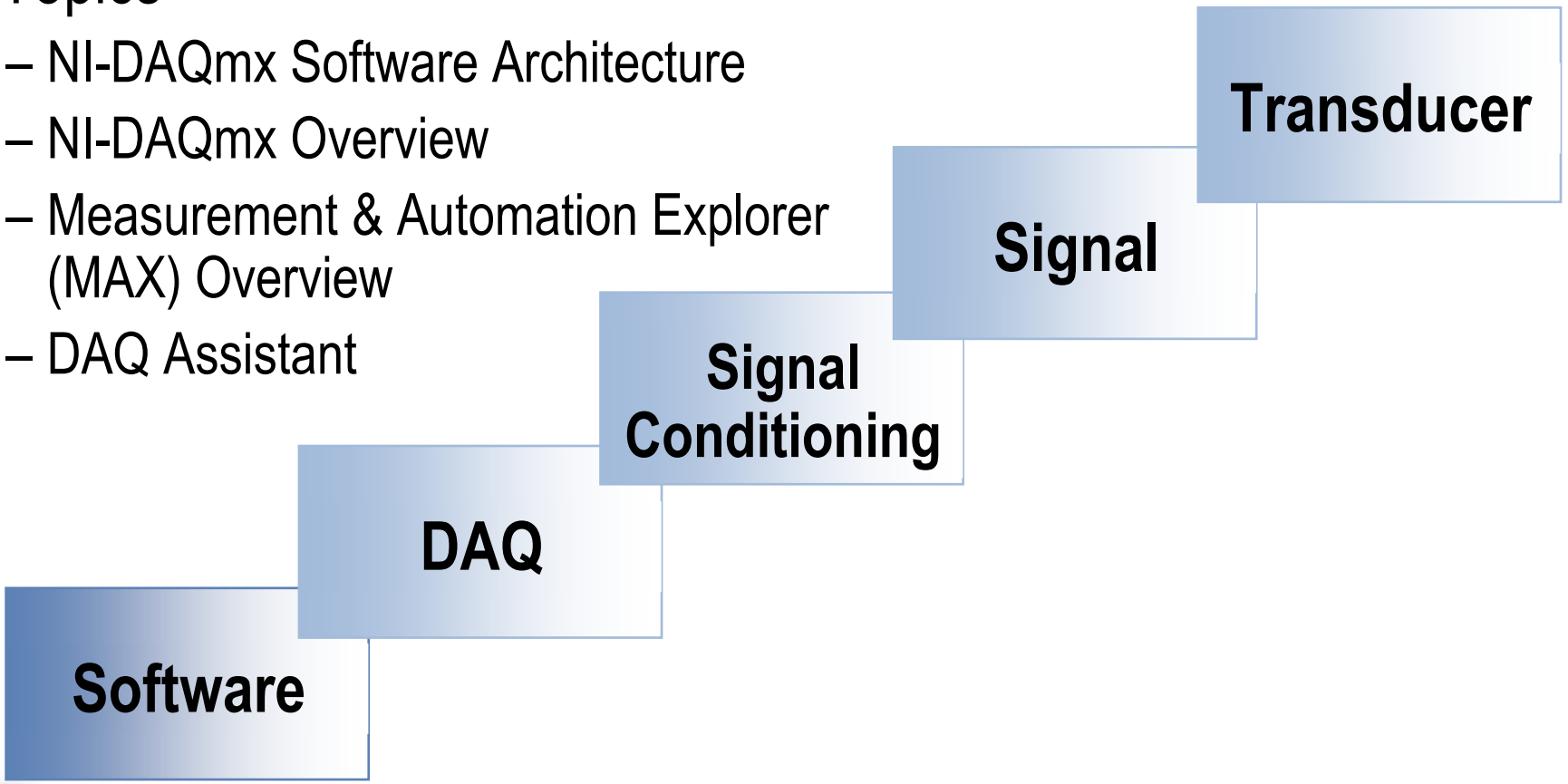
$$\frac{\text{range}}{\text{amplification} * 2^{\text{resolution}}} = \frac{10}{1 * 2^{12}} = 2.4 \text{ mV}$$

$$\text{Increase range: } \frac{20}{1 * 2^{12}} = 4.8 \text{ mV}$$

$$\text{Increase amplification: } \frac{10}{100 * 2^{12}} = 24 \text{ µV}$$

DAQ Software Overview

- Topics
  - NI-DAQmx Software Architecture
  - NI-DAQmx Overview
  - Measurement & Automation Explorer (MAX) Overview
  - DAQ Assistant



NI-DAQmx Software Architecture

DAQ Device

NI-DAQmx Driver Software (*.DLL)

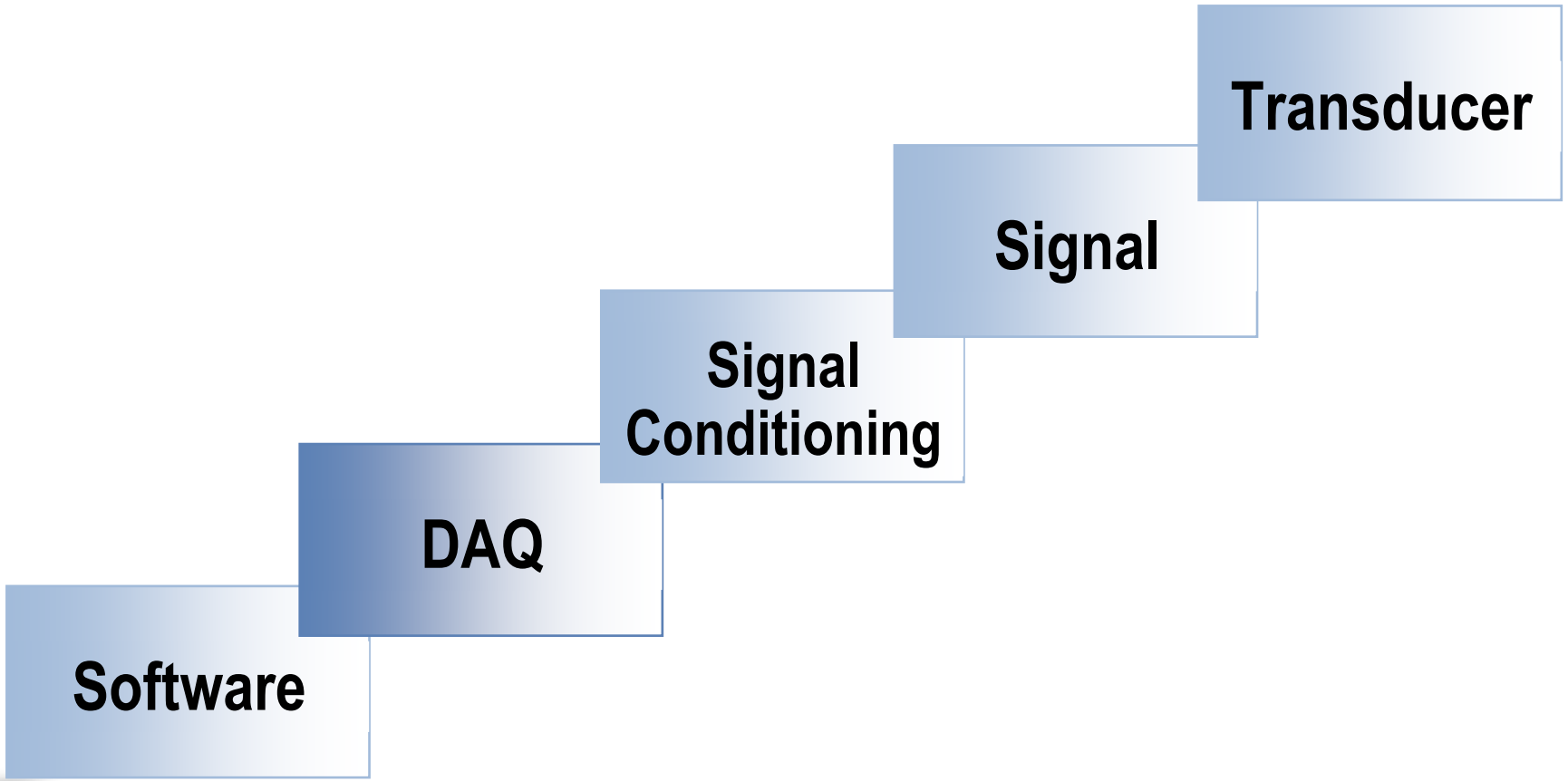
NI-DAQmx VIs

LabVIEW

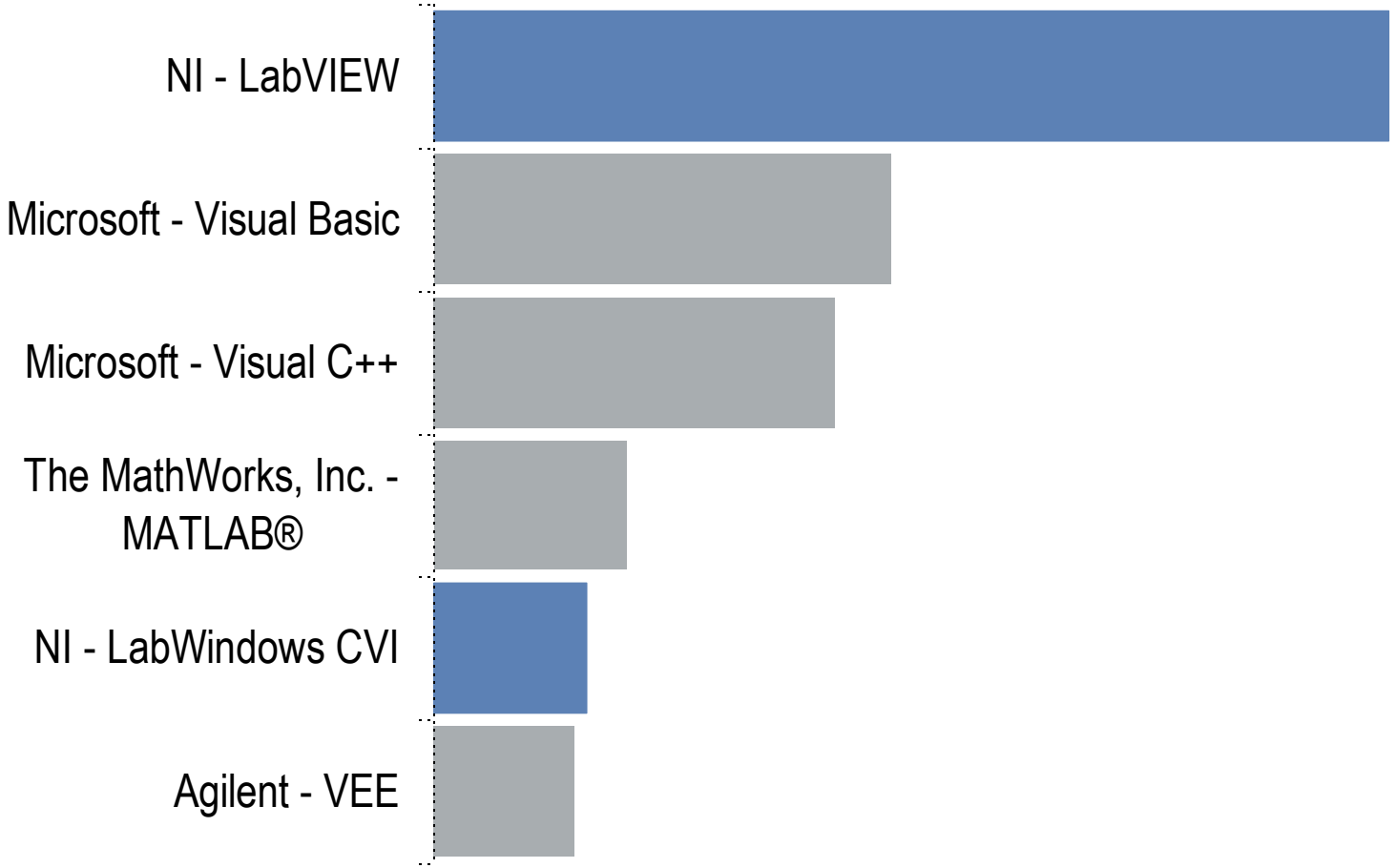
Diagnostic Tool: Measurement & Automation Explorer

Configuration Tool: Measurement & Automation Explorer

Software

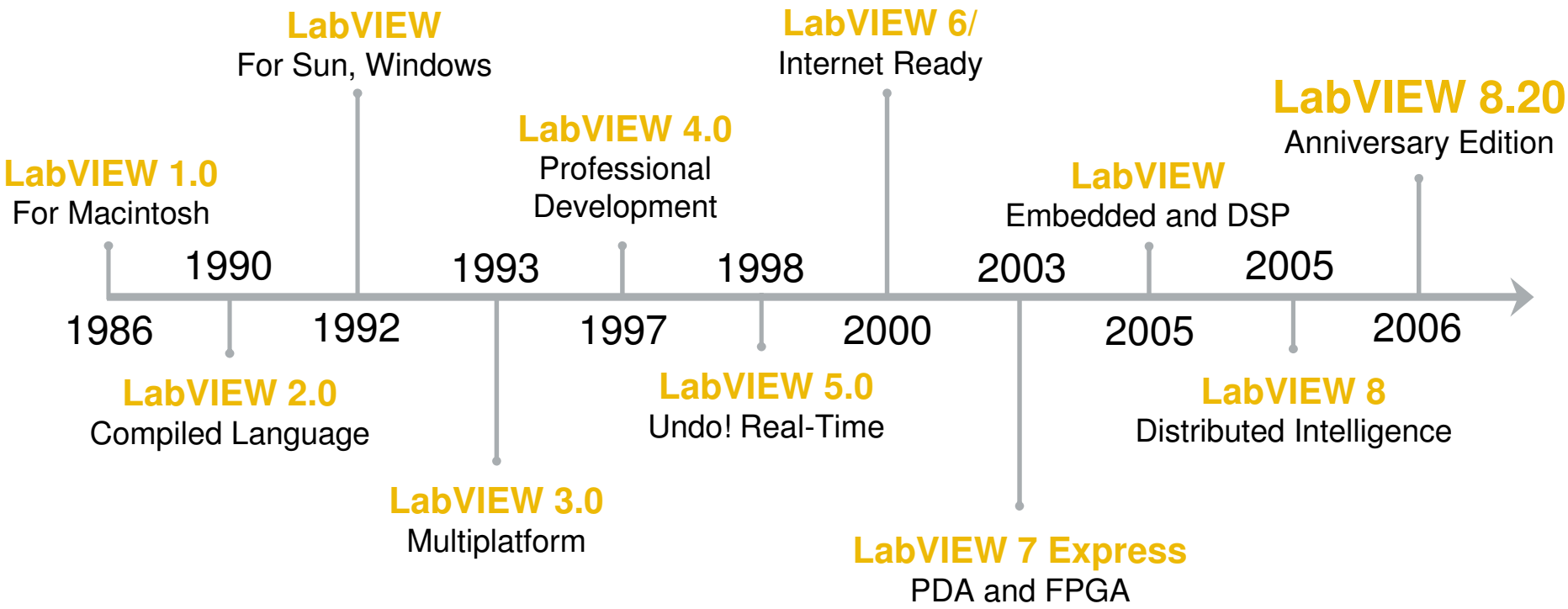


Software Used Most for DAQ and Instrument Control

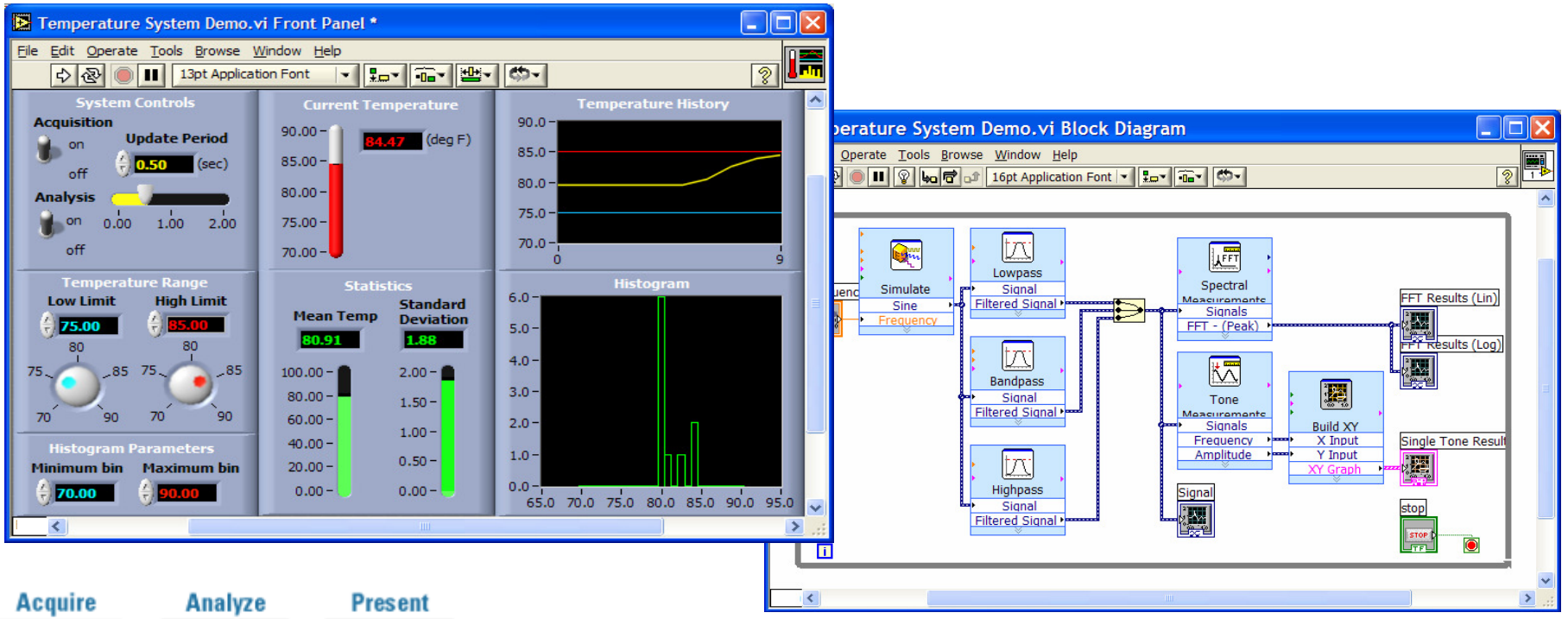


Survey: 2005 Global Product Awareness Tracking Study. Thinking of data acquisition and instrument control software, which of the following software packages do you use the most? Responses receiving less than 4% of mentions are not reported in the chart above. Other and none are not reported in the chart above. Total respondents=1006, Margin of error +/- 2.59%.

20 Years of Innovation

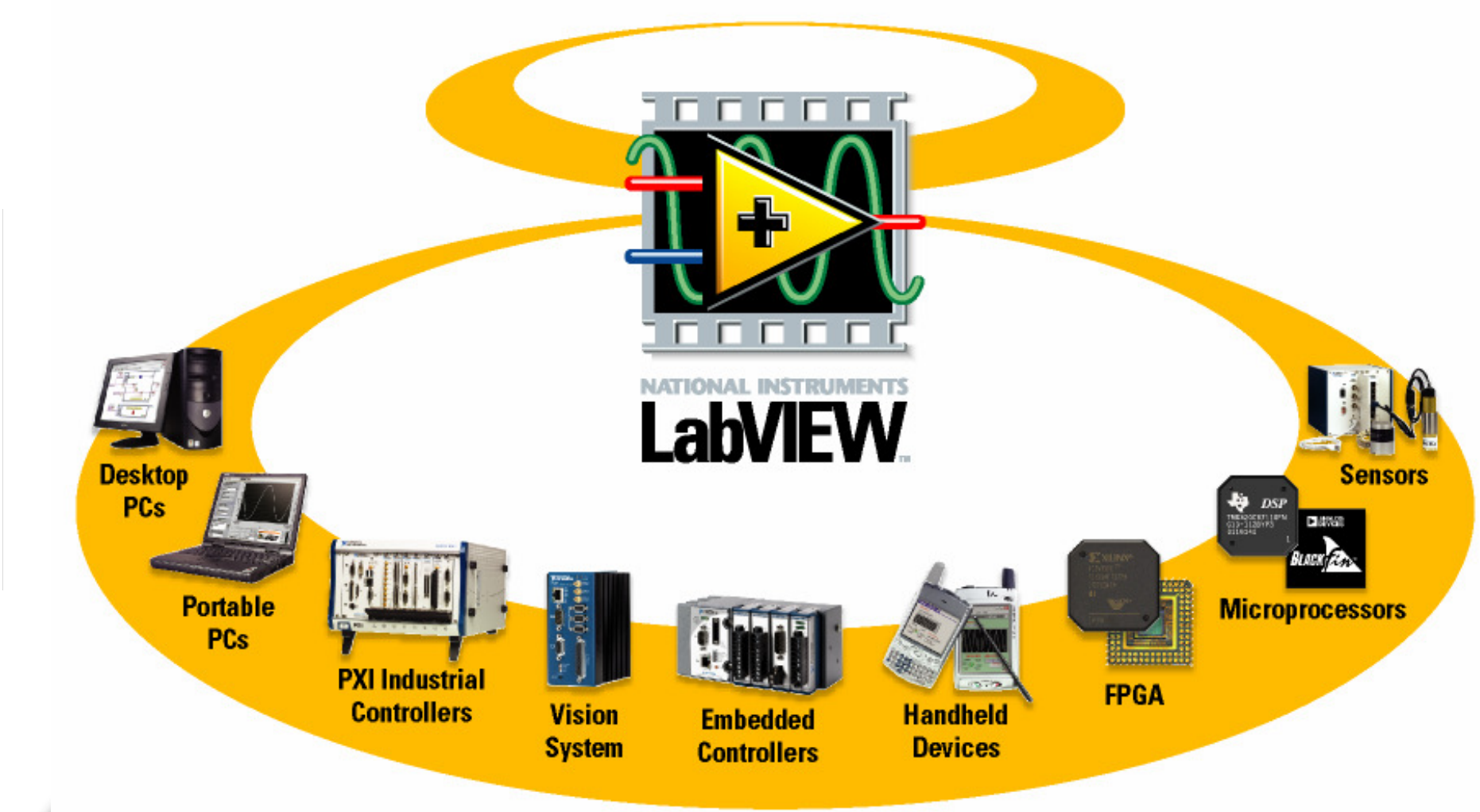


LabVIEW Graphical Programming



- Compiled graphical development environment
- Development time reduction of four to ten times
- Tools to acquire, analyze, and present your data

LabVIEW Computing Targets



What is Virtual Instrumentation?

Traditional Vendor-Defined Instruments

Customer-Defined PC-Based Measurement and Automation Solutions

- Vendor-defined functionality
- Not easily expandable
- Not upgradable

Processor | **Display**

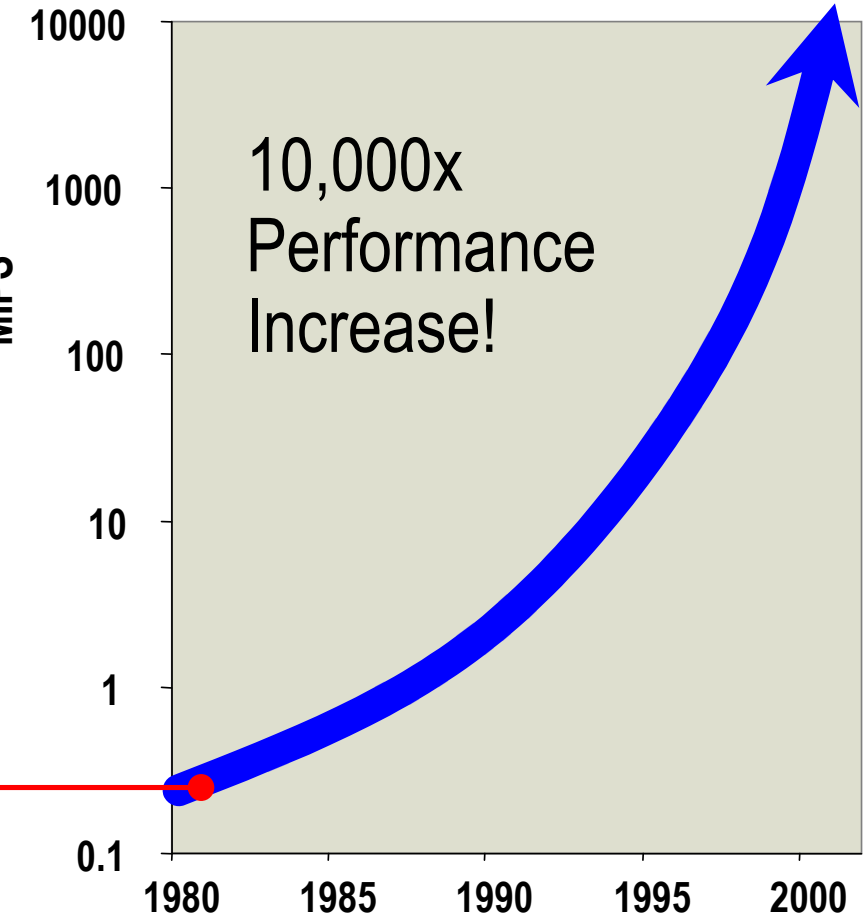
RAM | **Power Supply**

Comm Interface | **Hard Disk**

- User-defined functionality
- Processor & memory upgradable
- Expand by adding modules

Virtual Instrumentation Leverages the Evolution of PC Technology

1981
4.77 MHz
64 kB RAM
5.25" FD, 160 kB
Monochrome
$3,000



2004
2.8 GHz
512 MB RAM
80 GB HD
DVD-ROM
100 MB Ethernet
17” CRT
$1,250

NI CompactDAQ USB Data Acquisition System

USB 2.0

- Easy PC Connectivity
- High-speed (480 Mbits/sec)

ADCs and Isolators

- ADC per module
- Multiple ADCs some modules
- Low-cost converters
- MEMS Isolators (2300 V)

Modularity

- 11 modules at release
- Built-in signal conditioning and connectivity

NI LabVIEW and NI-DAQmx

PXI Common Applications

Benchtop

- Manufacturing Test
- Design Validation
- Data Acquisition Systems
- Hardware-In-the-Loop

Rack-Mount

- Manufacturing Test
- Data Acquisition Systems
- Machine Monitoring and Control

Portable / Embedded

- In-Vehicle Systems
- Design Validation
- Rapid Control Prototyping

Example PXI System

Embedded Controller (ie Windows 2000 Pentium III 1.26 GHz)

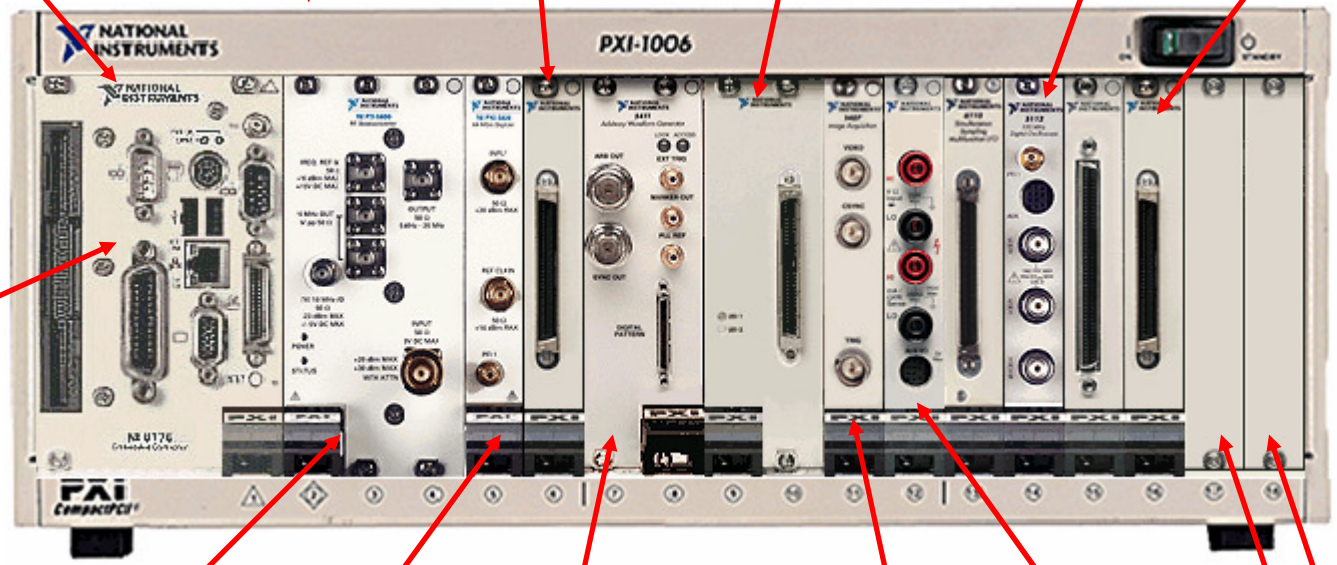
18-Slot Chassis

Multifunction Data Acquisition

Real-Time I/O Module With Processor

High-Speed Digitizer/Scope

Matrix Switch



Integrated Peripherals
GPIB
Serial
Parallel
Ethernet
USB

RF Downconverter

IF Digitizer

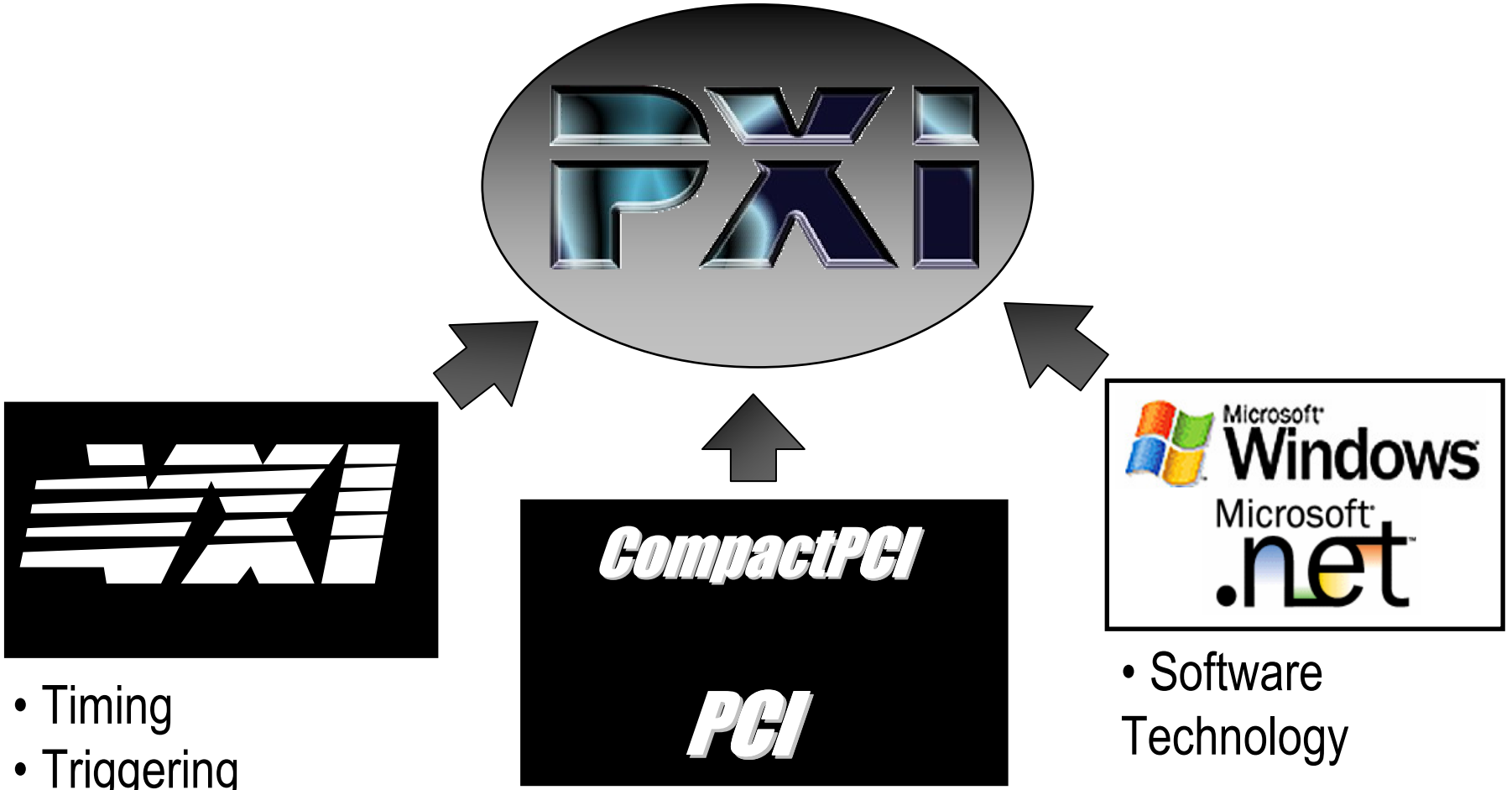
Arbitrary Waveform Generator

Image Acquisition

DMM

Empty Slots for future expansion

PXI Combines Standard Technologies

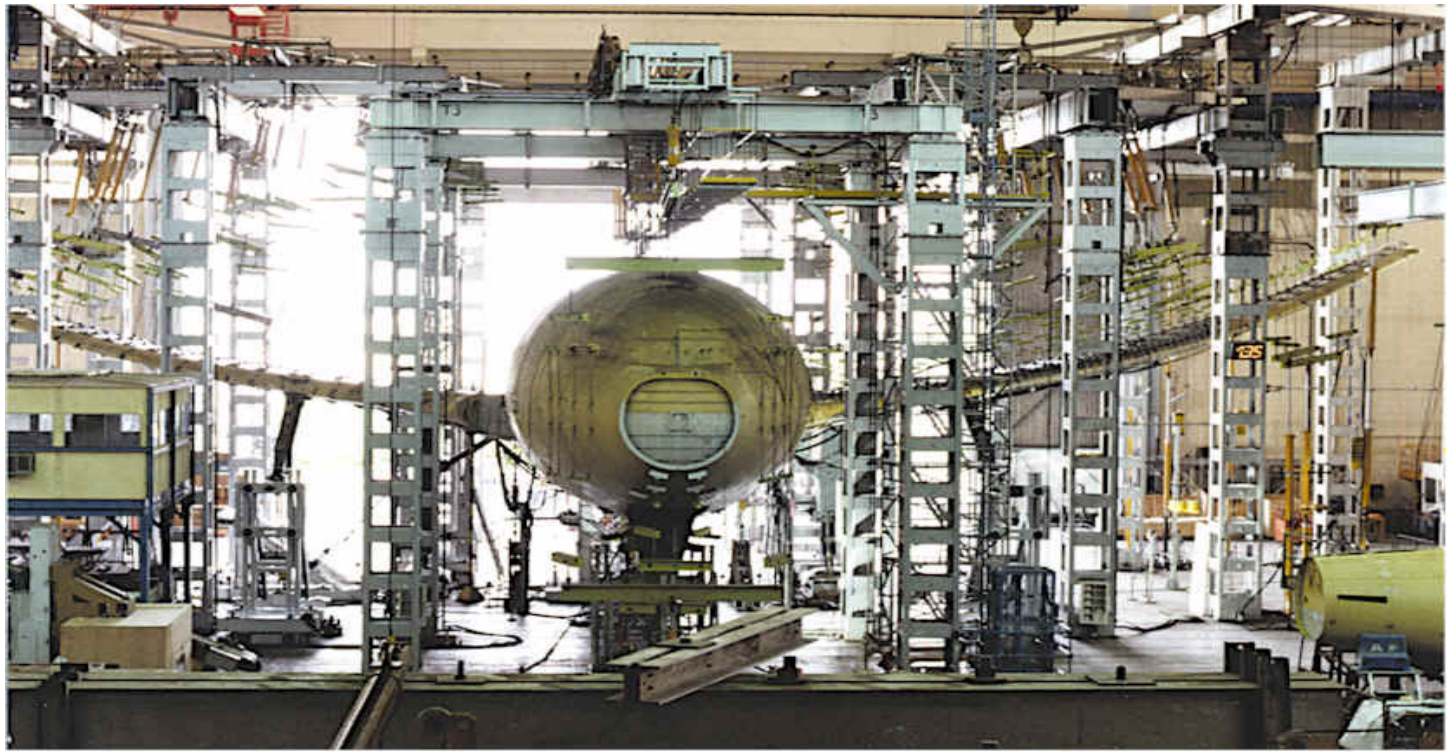


- Timing
- Triggering

- Bus technology

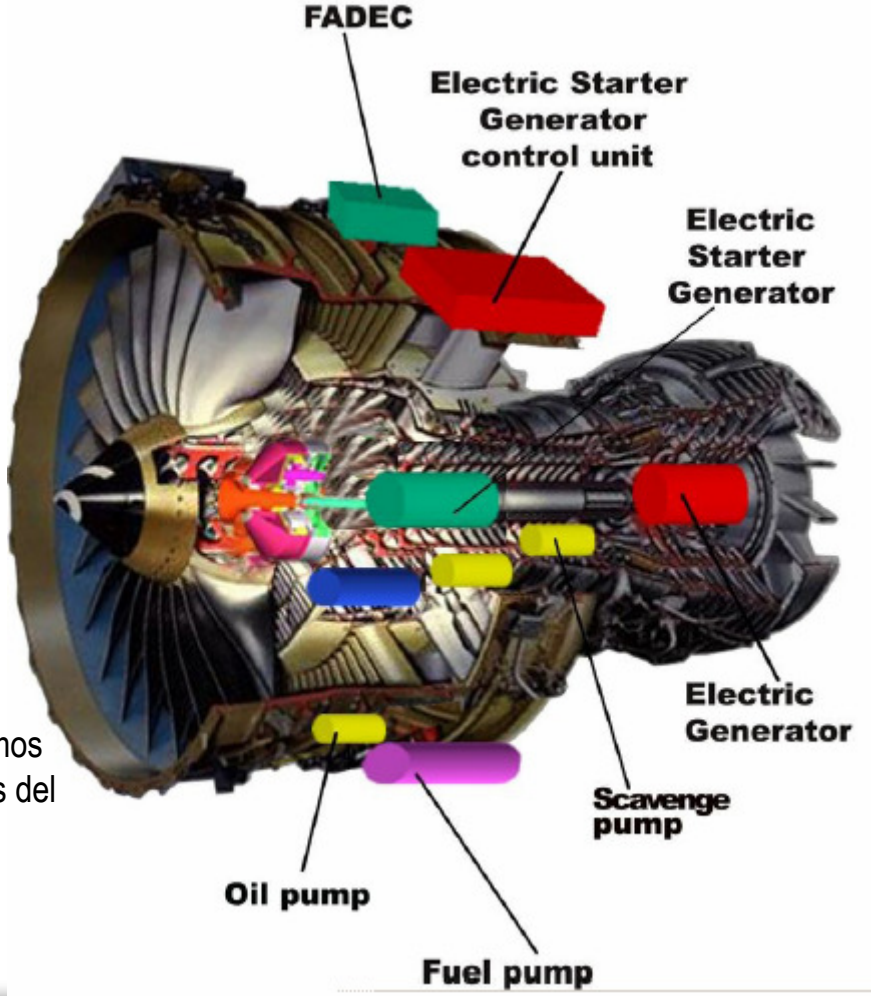
- Software Technology

Fatigue Testing



Turbine/Engine Testing

RIG for Electrical Power Generation Unit EFA and A400M Transportation Aircraft



•Planta de potencia eléctrica del avión: generadores acoplados con el motor principal a través de una desmultiplicación mecánica (gear box).

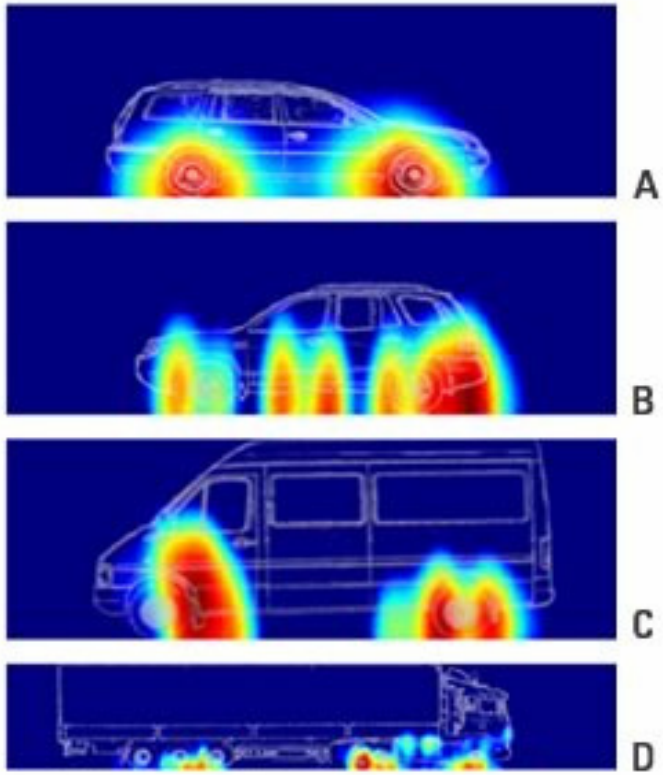
•Unidades de gestión de los generadores, lógica de control, los mecanismos de maniobra y unidades rectificadoras. Alimentación eléctrica a las barras del avión, de donde cuelgan todas las cargas.

Developing an Acoustic Camera

Application: Creating a data acquisition solution to measure noise control among multiple microphone channels.

Reasons for Choosing NI Products:

- Used NI PXI to develop a low-cost, high-channel-count data acquisition system
- Simple and inexpensive signal conditioning
- Easy to expand the system by synchronizing two PXI chassis



Using PXI to Develop an Acoustic Camera

Electric Door Control System

Application: Testing Train Doors

NI Products Used: PXI, Digital I/O boards, CAN, RS232 and LabVIEW

Reasons for Choosing NI Products:

- Execution speed (5,000+ measurements per UUT)
- Time to test reduced by 67 percent!
- Customer satisfaction and potential for replication

http://www.averna.com/

Averna Technologies
The Production Intelligence Company

NATIONAL INSTRUMENTS

End-of-Line Functional Test for XBOX Controllers

- "With PXI, we achieved a reliable production line testing [unit]"
- "Easily upgrade and maintain system ..."
- " … amazingly low cost"

Jeff Alexander, VI Engineering

PXI

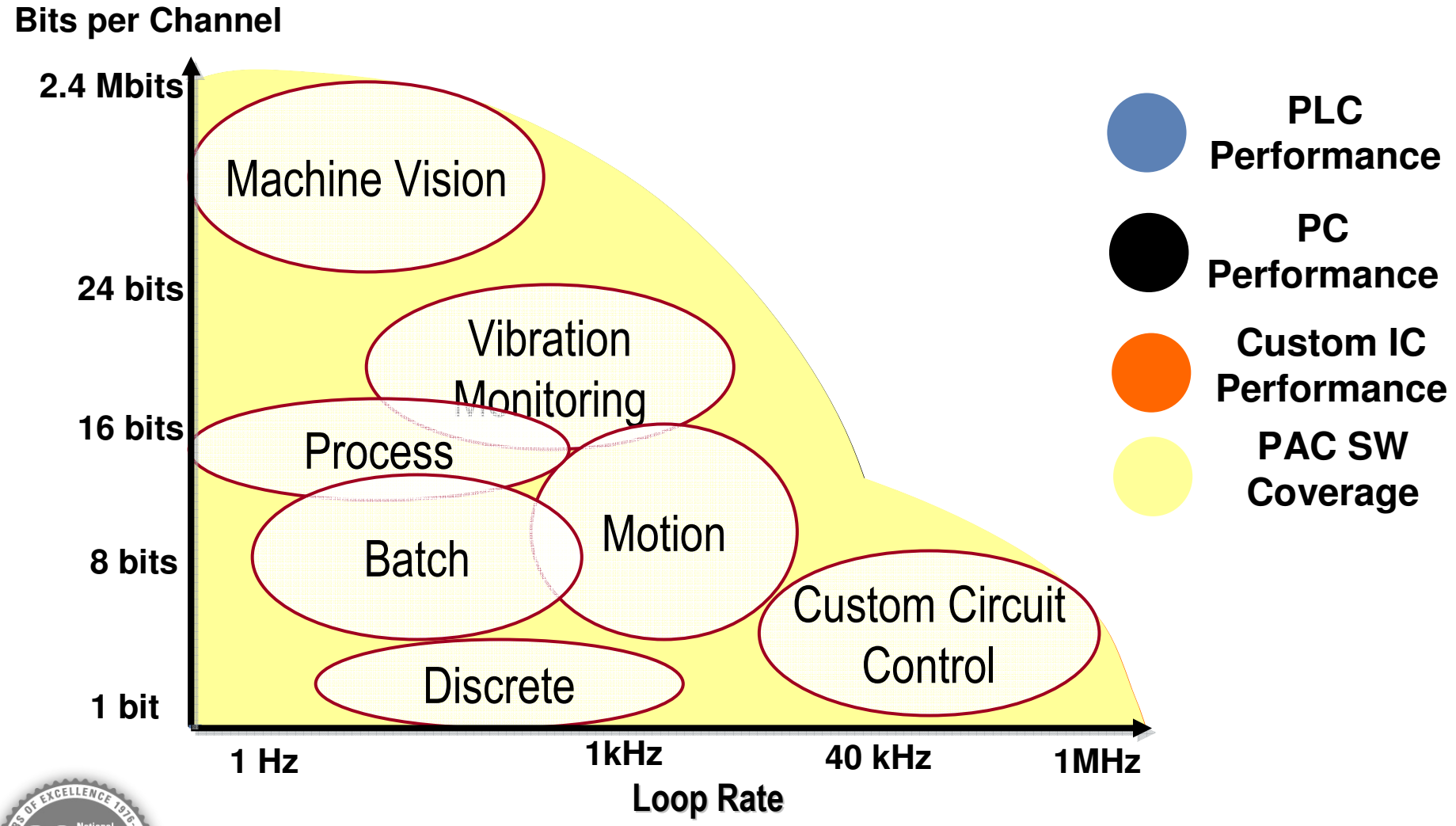
VI ENGINEERING, INC.
VALUE • INTEGRITY

XBOX

30 YEARS OF EXCELLENCE 1976-2006
National Instruments
30 20
LabVIEW
20 YEARS OF INNOVATION 1986-2006

DEMO DAQ Board Test

Multiple Control Disciplines – One Software Environment



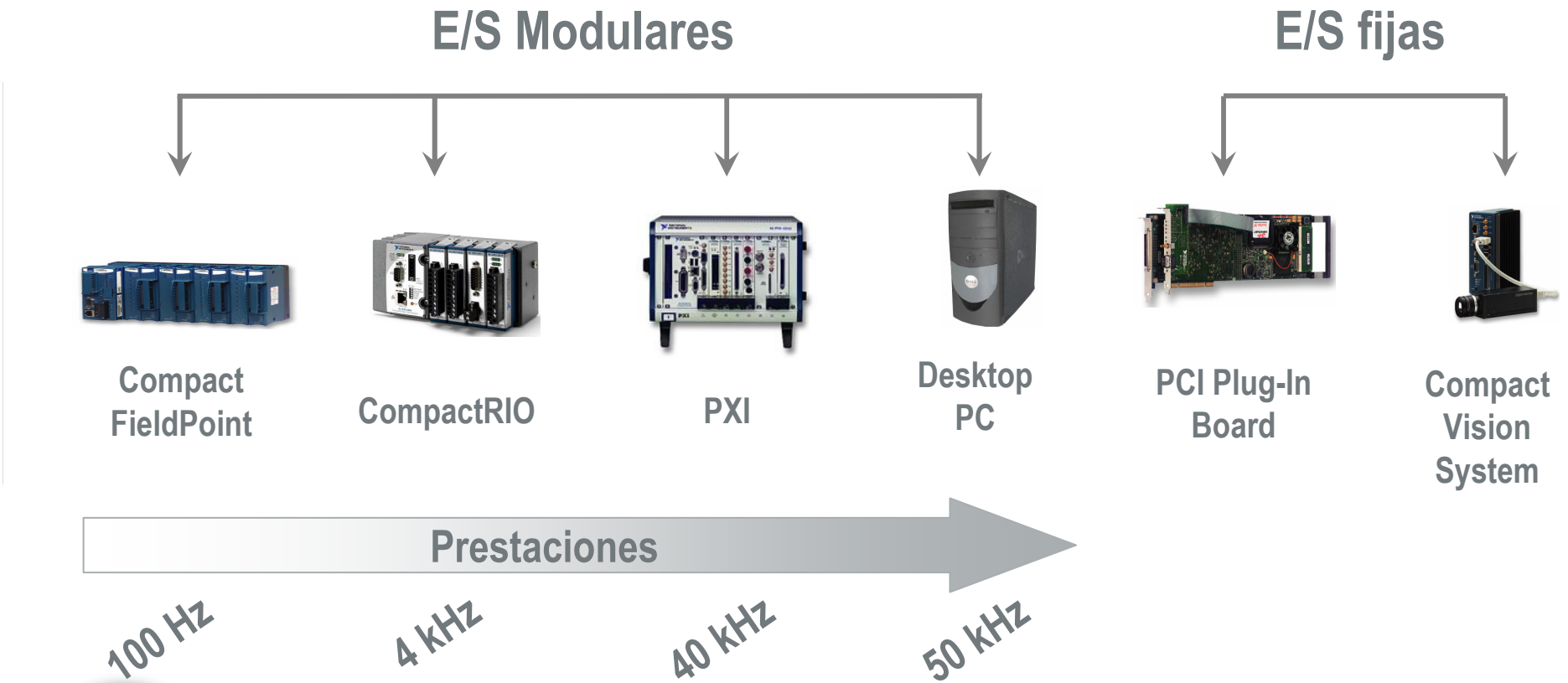
National Instruments

Programmable Automation Controllers

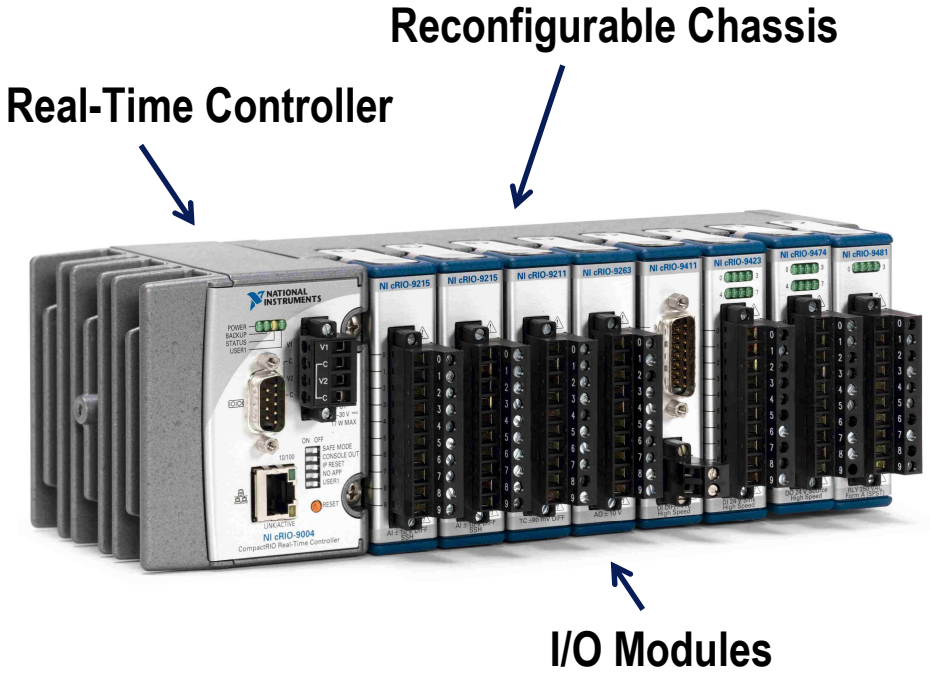
	PXI	Compact FieldPoint	Compact Vision System	CompactRIO
				
Data-Logging Capability	●	●	◑	◑
Floating-Point Processing Speed	●	◑	●	◑
High-Frequency Measurements	●	○	◑	◑
Ease of Use	◑	●	◑	○
Industrial Certifications / Rugged	◑	●	◑	●
FPGA Control	YES	NO	YES	YES

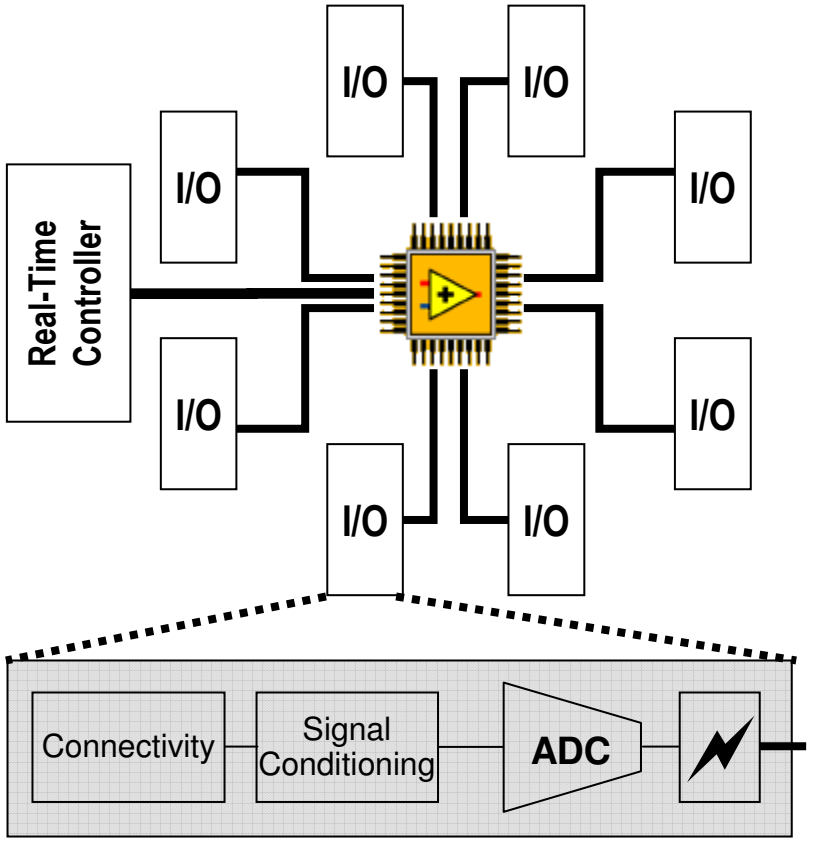
Good ○ Better ◑ Best ●

LabVIEW Real-Time Plataformas Hardware



NI CompactRIO Reconfigurable Embedded System





- DC power with redundant supply inputs
- 50 G shock
- -40 to 70 C temperature

CompactRIO Industrial Applications

Machine Control

- **Packaging/Processing**
  - High-speed motion control, batch control, discrete control
- **Heavy Machinery Control**
  - Real-time signal processing and control of power electronics, hydraulic systems
- **Semiconductor/Biomed**
  - Custom motion and vision inspection, material handling

Machine Monitoring

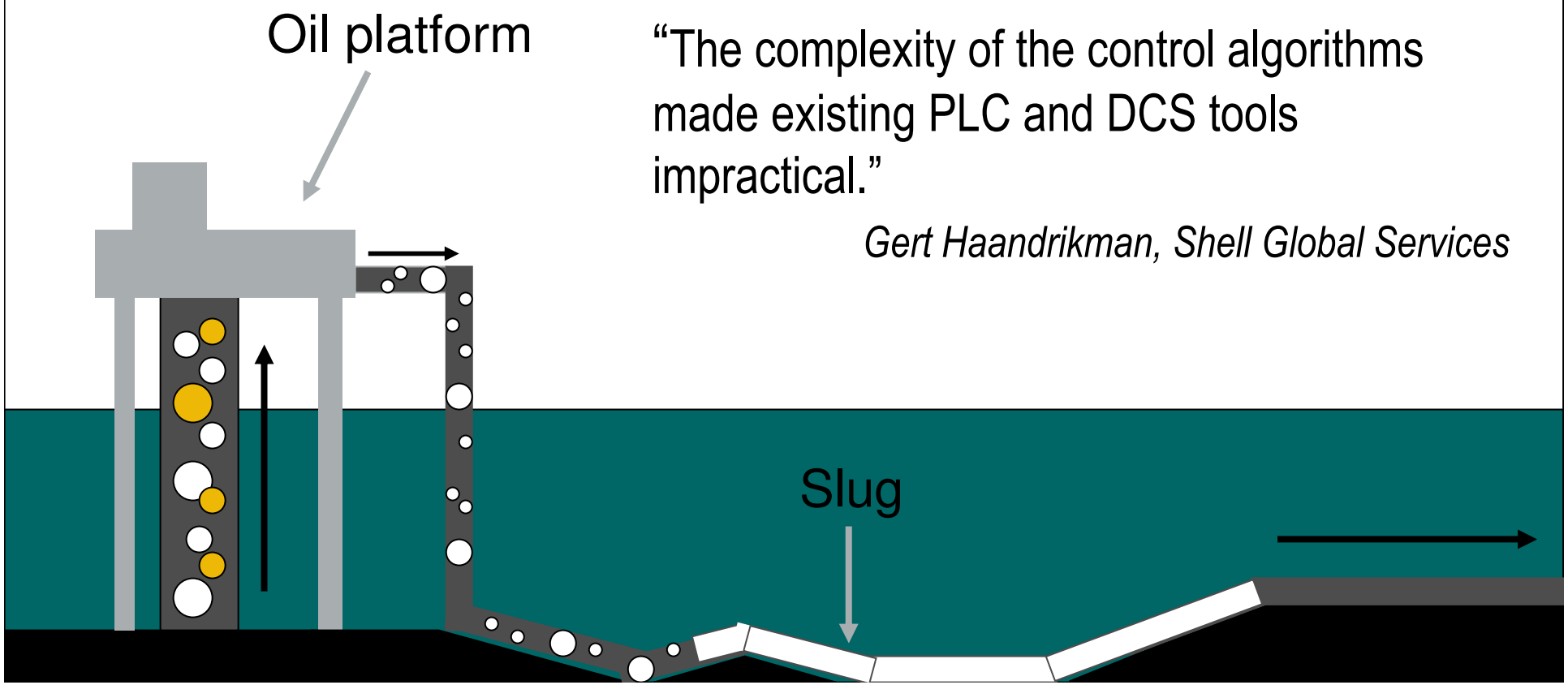
- **Machine Condition Monitoring**
  - Bearing order analysis, lubrication monitoring, cooling, combustion, …
- **Mobile/portable DSA, NVH**
  - Noise, vibration, harshness, dynamic signal analysis, acoustics
- **Distributed Acquisition**
  - Central controller with distributed I/O nodes over Ethernet/wireless

In-Vehicle Data Acquisition

- **In-Vehicle Data Acquisition**
  - Automobiles, motorcycles, recreational vehicles, research aircraft, trains
- **Engine and ECU test cells**
  - HIL testing of engines and engine controllers, sensor simulation using FPGA
- **Rapid Control Prototyping**
  - Automotive/aerospace control prototyping

Shell Oil – S3 Slug Suppression System

Reduce impact of slugs in flow lines caused by operational changes such as start-ups, and thereby reduce costs, lower maintenance and increase productivity of oil platforms.

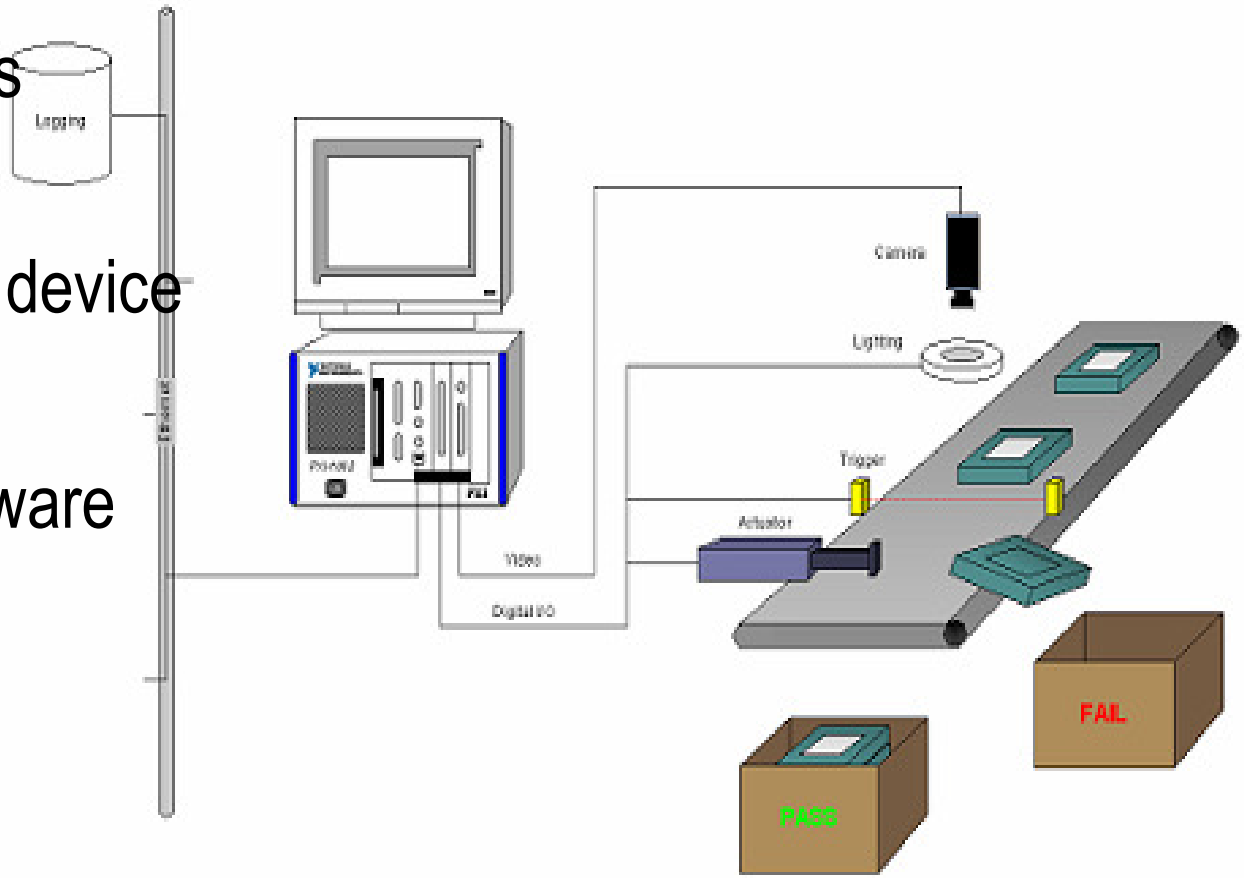


"The complexity of the control algorithms made existing PLC and DCS tools impractical."

Gert Haandrikman, Shell Global Services

Inspection System based on Vision

- Lighting and optics
- Camera
- Image acquisition device
- Image processing and analysis software



Más información en:

http:\\www.ni.com\daq

Seminario sobre Desarrollo de Aplicaciones de Adquisición de Datos

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Hotel Hesperia Vigo
Av. de la Florida, 60
Vigo, ES 36210

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Teléfono: 91 640 0085

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