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Electronic Instrumentation

Chapter 7

Data Acquisition and Conversion.

Integration of Data Acquisition Systems.

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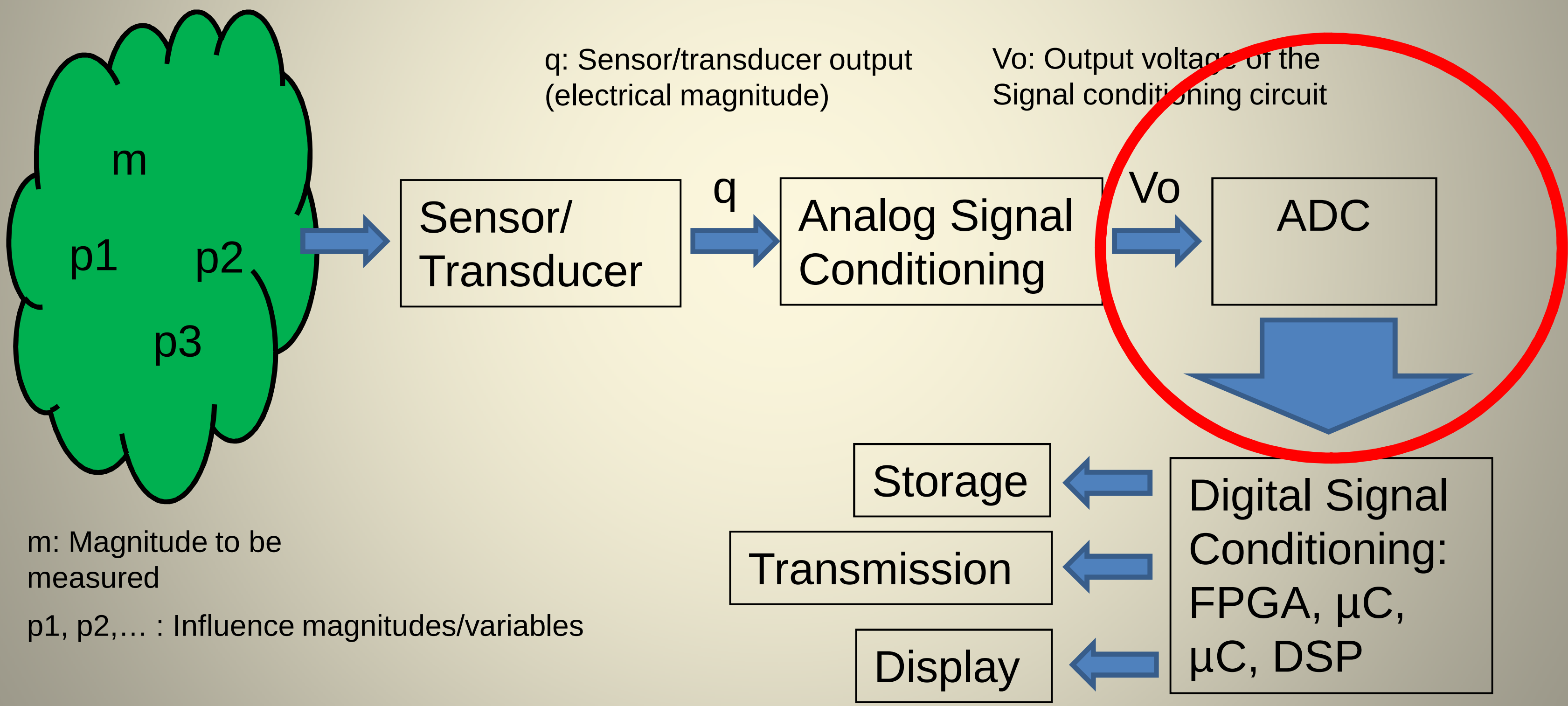
Chapter 8. Introduction

- Introduction to Data Acquisition and Conversion.
- Analog to Digital Converters (ADC).
- Digital to Analog Converters (DAC).
- Data Acquisition Systems.
    - Data Acquisition Boards
    - Instrumentation Buses.
    - Instrumentation System Integration.
- Summary

Basic Architecture for an Electronic Instrumentation Measurement System



m: Magnitude to be measured

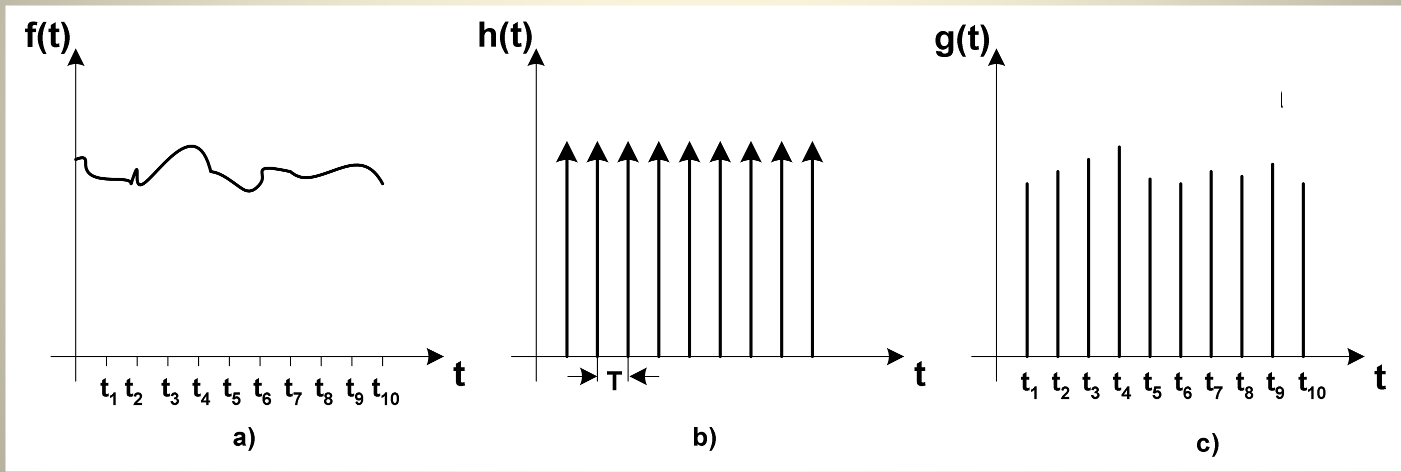
p1, p2,… : Influence magnitudes/variables

Introduction to Data Acquisition and Conversion

- In our days almost all instrumentation systems relay on digital techniques for signal processing, transmission and data storage.
- Analog outputs from sensors and analog front-ends (analog signal conditioning) have to be converted into digital signals.
- This process has two steps:
    - Analog signal sampling (Continuous time to discrete time)
    - Analog to digital conversion (Continuous Voltage to discrete amplitude values)

Introduction to Data Acquisition and Conversion

- Analog Signal Sampling:



- Nyquist Theorem: If a function x(t) contains no frequencies higher than B Hz, it is completely determined by giving its ordinates at a series of points spaced 1/(2B) seconds apart.

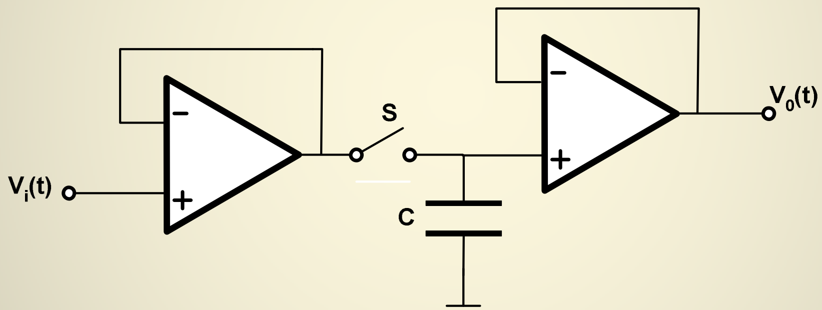
Introduction to Data Acquisition and Conversion

• Analog Signal Sampling:

- Aliasing: If Nyquist condition is not observed, high frequencies components above the Nyquist frequency introduce errors in the pass band that can lead to serious errors in digital signal processing.
- Antialiasing Filters: Analog filters introduced before the data acquisition to avoid spurious signals ("alias") in the acquired data.
- Undersampling: Band-pass signals can be undersampled. In this case the "alias" mimics the actual information and the digital processing can be done without problems.
- Analog Multiplexers: Typically one ADC is used for multiple input signals. In this case analog multiplexers are used to redirects each signal to the ADC inputs at the right time instant.

Introduction to Data Acquisition and Conversion

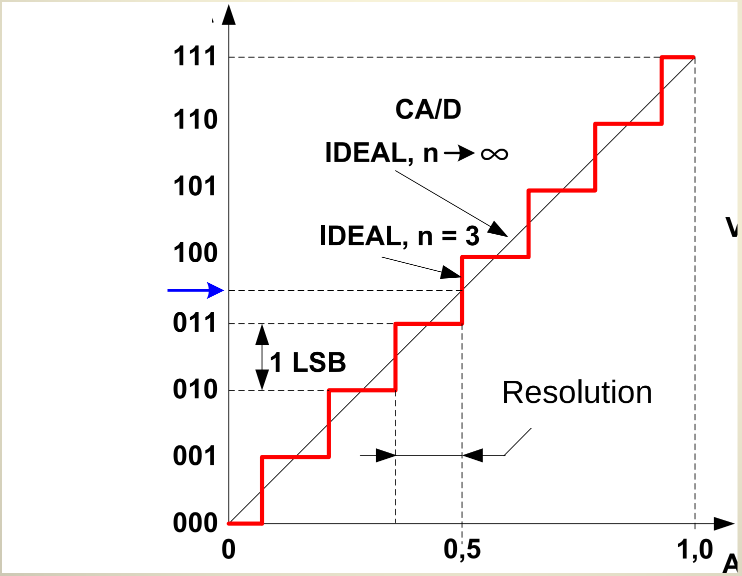
- Sampling & Hold:



- Sampling and hold circuits are used to store the analog value of the signal at the sampling instant during the analog to digital conversion time.

Analog to Digital Conversion

- Discretization of analog signals:



- The transfer function of the ADC maps voltages intervals to numbers, and it is responsible for the second discretization in the Data Acquisition Process.

Analog to Digital Conversion

- Characterization:
  - Resolution: Minimum variation in the input that produces a change between adjacent codes at the output.

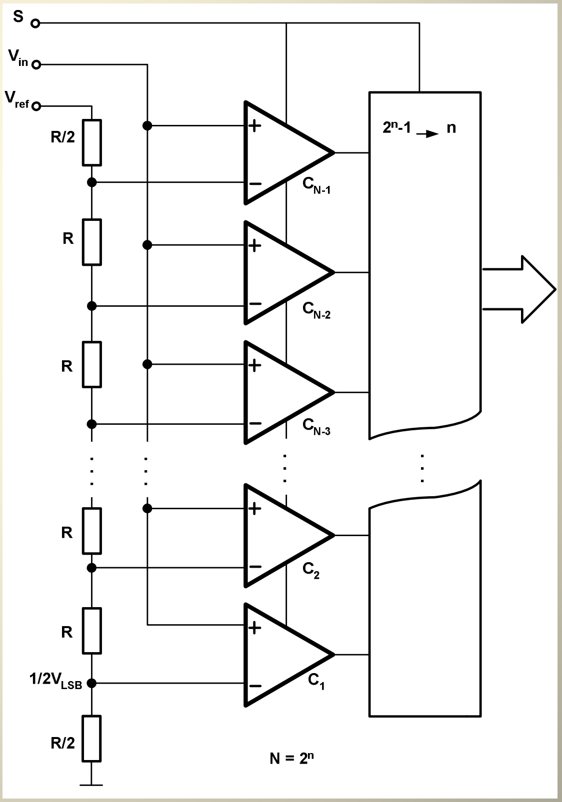
$$Resolution = \frac{Full\ Scale}{2^N - 1}$$

  - Input Range
  - Accuracy: Difference between the expected value at the output and the actual output. Expressed in LSB. Includes influences from all errors
  - Conversion time: Time needed to perform the conversion. In may included also the delay due to the sample&hold circuit if it is part of the ADC (example AD0804)
  - Errors:
    - Non linearity
    - Gain
    - Zero

Analog to Digital Conversion

- Types of ADCs: Flash (Parallel) ADCs

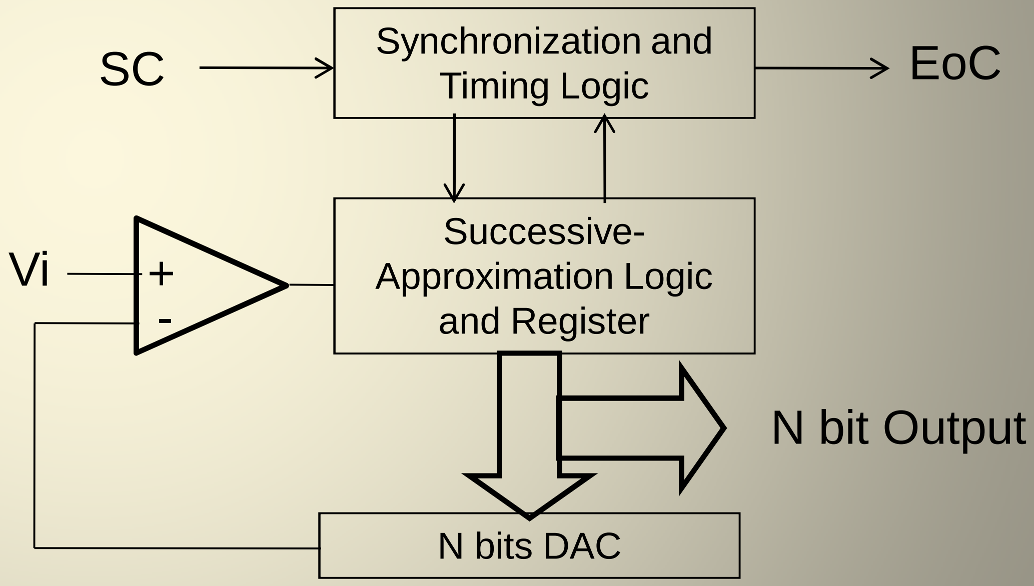
  - Very Fast: All bits are obtained at the same time
  - Use 2^N-1 high-speed comparators and small resistances: high cost and high power consumption. The comparators must have also low input offset voltages.
  - The input capacitance of all comparators appear in parallel: High input capacitance may rise problems at high sampling frequencies.



Analog to Digital Conversion

- Types of ADC: Successive-Approximation(SA) ADCs

  - The most widely use class of ADCs.
  - Low cost and moderate conversion speeds.
  - Nevertheless they are difficult to auto-zero and require the presence of a DAC
  - Example: AD0804

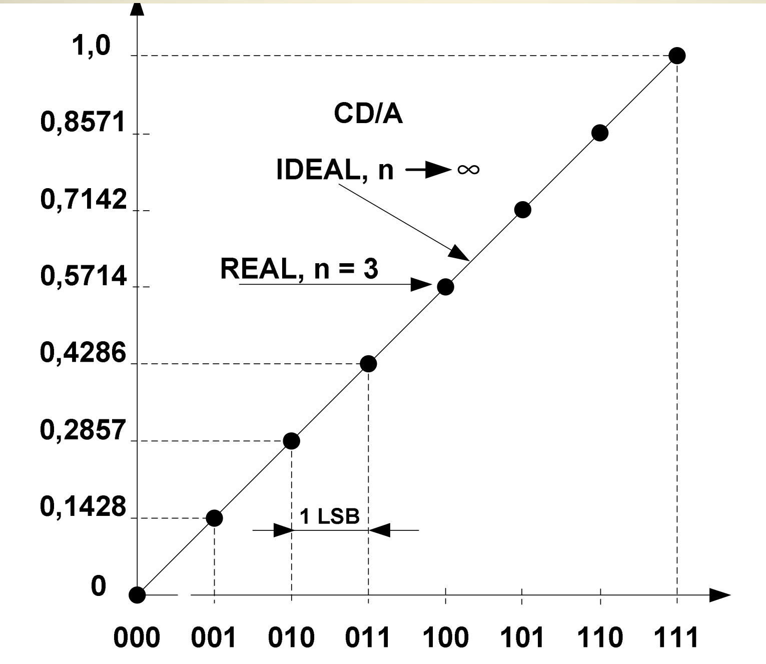


Analog to Digital Conversion

- Other Types of ADCs:
  - Dual-Slope Integrating ADCs
  - Half-flash ADCs
  - Pipelined ADCs
  - Tracking or Servo ADCs
  - Delta-Sigma ADCs

Digital to Analog Conversion

- Transfer Function:



- The transfer function of the DAC maps numbers to output voltages/currents. They are used to recover the original or processed analog signal from its digital counterpart.

Digital to Analog Conversion

- Types of DACs:
  - Binary weighted resistor DAC
  - Binary weighted current sources DAC
  - R-2R Ladder
  - Inverted R-2R Ladder
  - Switched Capacitor DAC

Data Acquisition Systems

- As shown in the first session, modern instrumentation systems generally include digital systems for further signal processing, supervision and control: Those complete systems are usually designed as Data Acquisition Systems (DAS).
- DAS can be very small (a PC with a Data acquisition Board), big (Airplane Subsystem Test-bench) or huge (ITER).
- Different and specific architectures, components and software are used depending of the application and size of the system, amongst those are:
    - Data acquisition Boards
    - Instrumentation buses
    - Modular Instruments
    - Specific Software for Instrumentation Systems (LabVIEW).

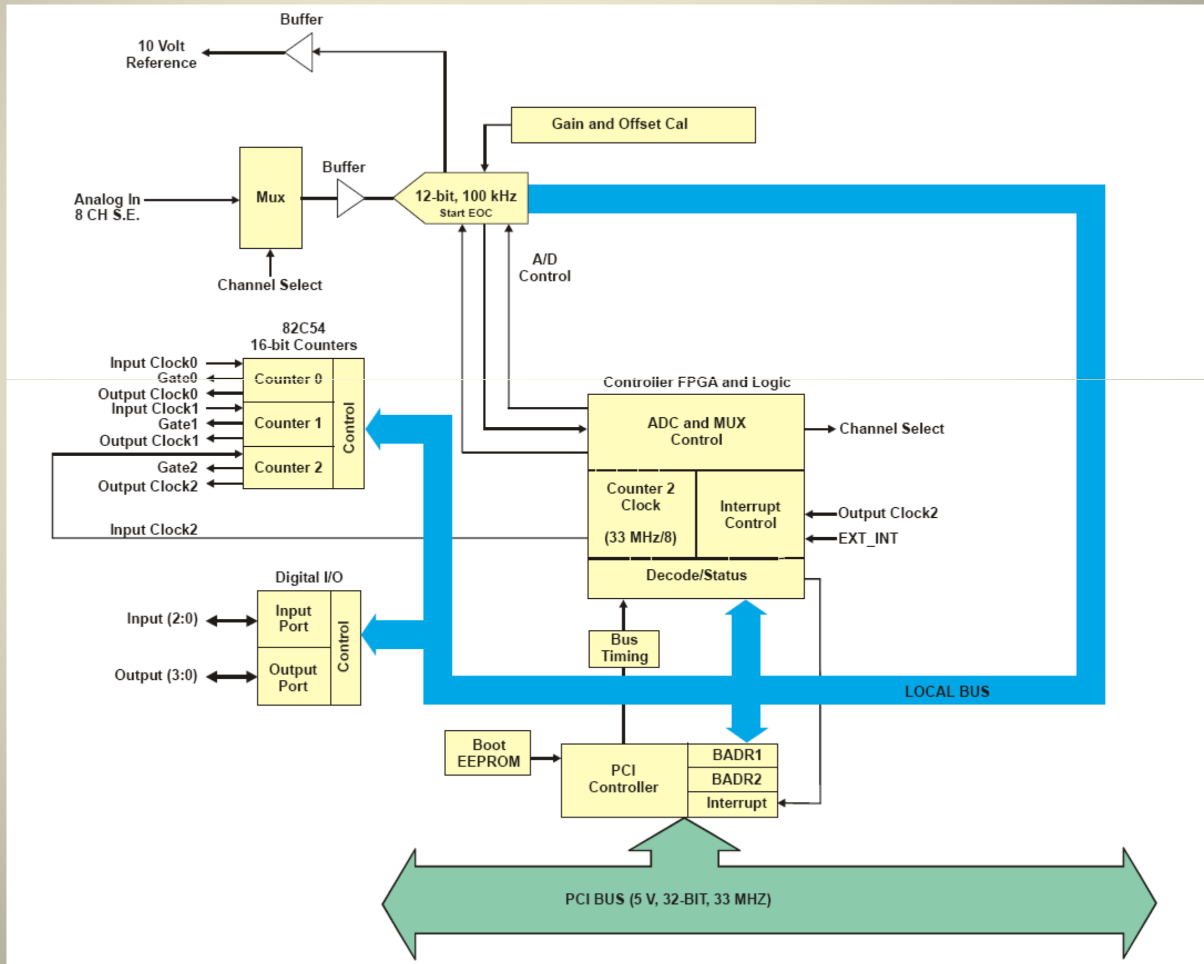
Data Acquisition Systems

- Different Configurations:

1. Personal Computer Based Systems: They use a Data acquisition board after the analog signal conditioning for Data Acquisition. The processing is usually done offline after acquisition is completed by the computer. Low cost solution.
2. Connection of Several Instruments through Instrumentation Buses and a Controller: A computer/mainframe is used to control different specific instrumentation & Measurement Equipment (Network Analyzers, Oscilloscopes,..) and Actuators. High-speed specific signal buses are typically used.
3. Modular equipment: Several Data acquisition and processing boards are hosted in the same crate along with a controller/mainframe. Additionally, multiple crates can be connected using instrumentations buses in a local area network. Many configurations are possible, including offline and on-line signal processing.

Data Acquisition Boards for PCs

PCI-DAS08
Measurement
Computing
Block Diagram



Data Acquisition Boards for PCs

- Characteristics:

- Number of analog inputs. Note that they can be multiplexed (as in the PCI-DAS08)
- Triggering strategies.
- Differential/Single ended inputs
- Maximum Sampling Frequency
- MEMORY!!!!
- DMA and Data transfer strategies
- Multifunction Data Acquisition Boards:
    - Analog Outputs
    - Digital Inputs/Outputs
    - Counters
    - Timers

Instrumentation Buses

- Data acquisition Systems based on multiple instruments can be connected together and controlled by means of a Instrumentation bus
- Such buses can be either specific (eg. IEEE-488) or general purpose (USB); parallel or serial.
- Once all the instruments are connected a computer or mainframe that controls the acquisition process and signal transmission.

Instrumentation Buses

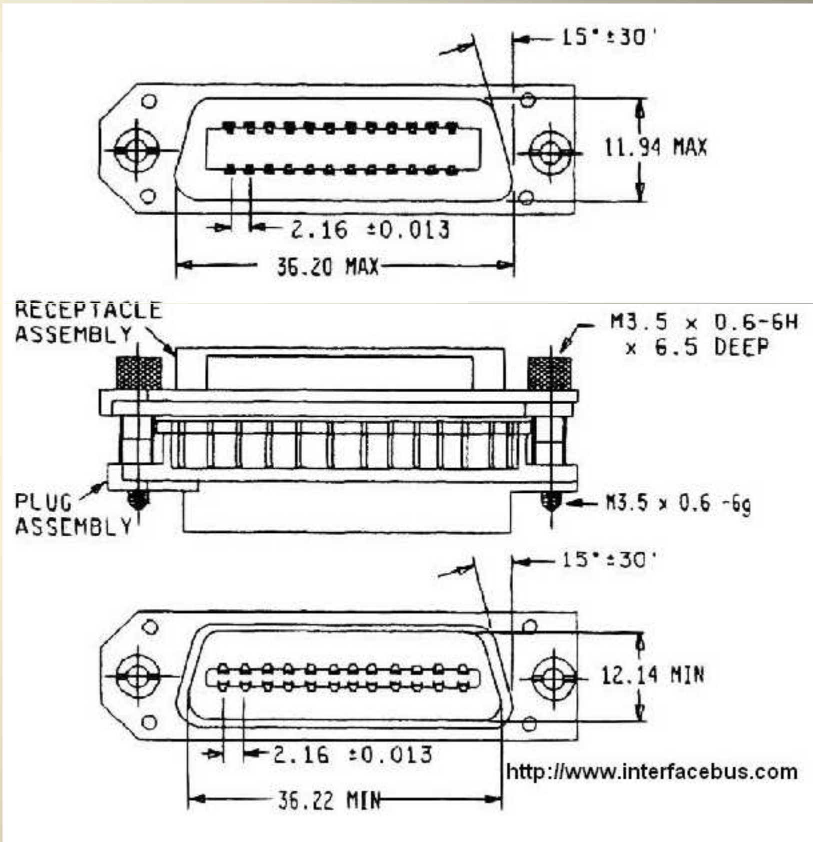
- GPIB (IEEE-488):

- 8 bit parallel bus originally designed by Hewlett Packard (HP-IB) in the sixties. In the seventies it became a standard (IEEE-488) and is widely found in all measurement and tests equipments.
- Up to 15 devices can be connected in a range of approximately 3 meters. Data transmission rate can reach 2 Mb/s.
- Many manufactures of interface cards for PCs an MACs offer IEEE-488.2 compatible cards and controlling software (eg. LabVIEW). A simple PC with one of these cards can control the instruments.

Instrumentation Buses

- GPIB (II):

Pin #	Signal Names	Signal Description	Pin #	Signal Names	Signal Description
1	DIO1	Data Input/Output Bit 1	13	DIO5	Data Input/Output Bit 5
2	DIO2	Data Input/Output Bit 2	14	DIO6	Data Input/Output Bit 6
3	DIO3	Data Input/Output Bit 3	15	DIO7	Data Input/Output Bit 7
4	DIO4	Data Input/Output Bit 4	16	DIO8	Data Input/Output Bit 8
5	EIO	End-Or-Identify	17	REN	Remote Enable
6	DAV	Data Valid	18	Shield	Ground (DAV)
7	NRFD	Not Ready For Data	19	Shield	Ground (NRFD)
8	NDAC	Not Data Accepted	20	Shield	Ground (NDAC)
9	IFC	Interface Clear	21	Shield	Ground (IFC)
10	SRQ	Service Request	22	Shield	Ground (SRQ)
11	ATN	Attention	23	Shield	Ground (ATN)
12	Shield	Chassis Ground	24	Single GND	Single Ground



Instrumentation Buses

- Serial Buses (I)

- RS232C and D: Oldest serial bus but still in use. Uses 8-bit ASCII words around 100 kb/s. Distances have to be kept under 15 m. They use a DB25 connector.
- RS-422, RS423 and RS-485: Serial buses that multiplied by 5 (roughly) the RS232 speed. Maximum cable length can be up to 400'm.
- USB (Universal Serial Bus): This bus is rapidly replacing (if it hasn't done it yet) the RS-232C &D serial interfaces as a means for a computer to communicate with medium speed peripheral devices. First released in 1996, we can connect up to 127 peripheral devices to one host computer's USB port. Speeds up to 12Mb/s can be achieved using USB 2.0.

Instrumentation Buses

- Serial Buses (II)

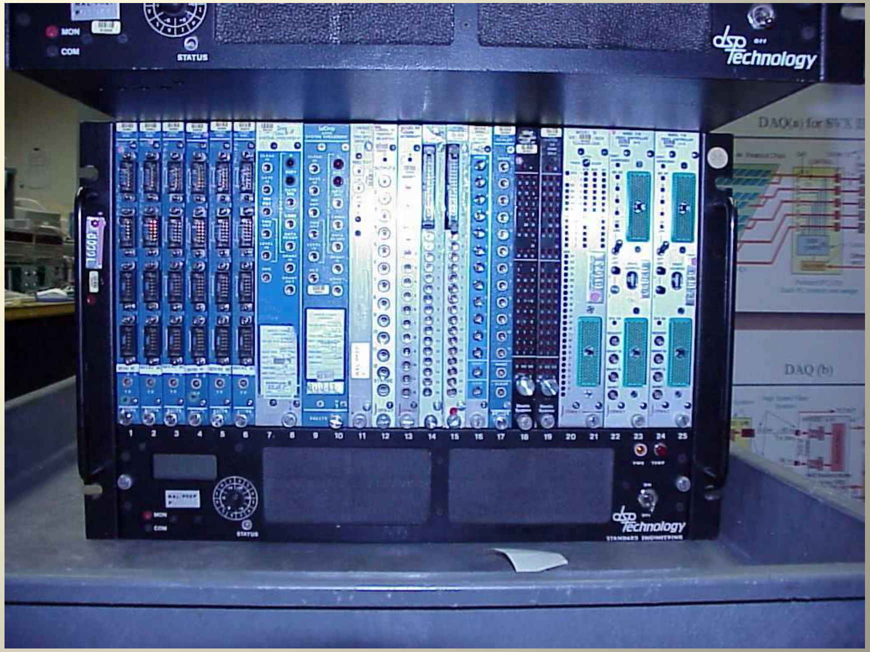
- EtherCAT (Ethernet Control Automation Technology): High performance, industrial communication protocol for deterministic Ethernet. It extends the IEEE 802.3 Ethernet standard to transfer data with predictable timing and precise synchronization.
- Implements a master/slave architecture over standard Ethernet cabling
- This very new standard will probable have a high impact in the configuration of future massive data acquisition system due to its compatibility with Ethernet cabling.

Instrumentation Buses

- Buses for Modular Instrumentation

- CAMAC (IEEE-583): This standard define a hardware and data transmission system which is used to house, support and communicate with various compatible instrumentation ***modules.***

A Typical CAMAC crate has 25 slots for compatible, plug-in instruments. Two of them are usually used for the controller. Several crates can be connected.



Instrumentation Buses

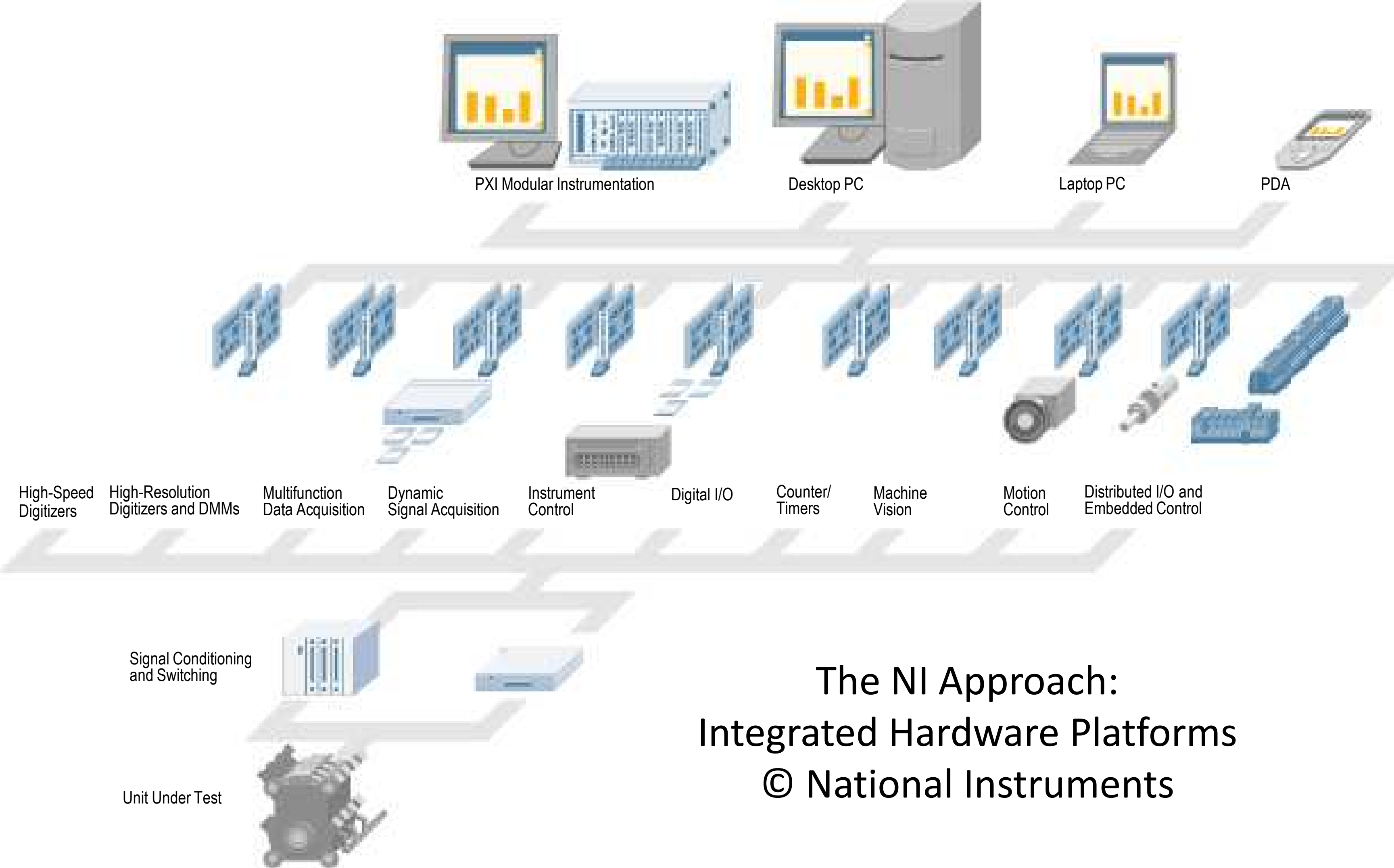
- Buses for Modular Instrumentation

- VXI (VMEbus eXtension for Instrumentation): Non-propietary, open architecture bus for modular instrumentation systems that incorporates de VMEbus standard (PCs). It includes not only mechanical and electrical interfacing, but also communications protocols. Modules are plug to a backplane.
- Based on a 32 bit bus, it can handle up to 10 Mb/s signals (100 Mb/s in some configurations with local bus)
- Easy integration (open system)

Instrumentation Systems Integration

- As seen before, Data acquisition Systems can be very sophisticated, including different modular instruments on several VXI/CAMAC crates.
- Design, Integration and control of such a big systems can't be done directly and specific strategies and auxiliary software must be used.
- Between the different software available, LabVIEW, developed by NI, has become the industrial standard for big (and not that big) system integration.

Hardware Architecture



The NI Approach:
Integrated Hardware Platforms
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Summary

- In our days almost all instrumentation systems relay on digital techniques for signal processing, transmission and data storage so analog outputs from sensors and analog front-ends (analog signal conditioning) have to be converted into digital signals.
- DAS (Data Acquisition Systems) range from very small systems (a PC with a Data acquisition Board), to huge architectures (ITER)
- Different and specific architectures, components and software are used depending of the application and size of the system