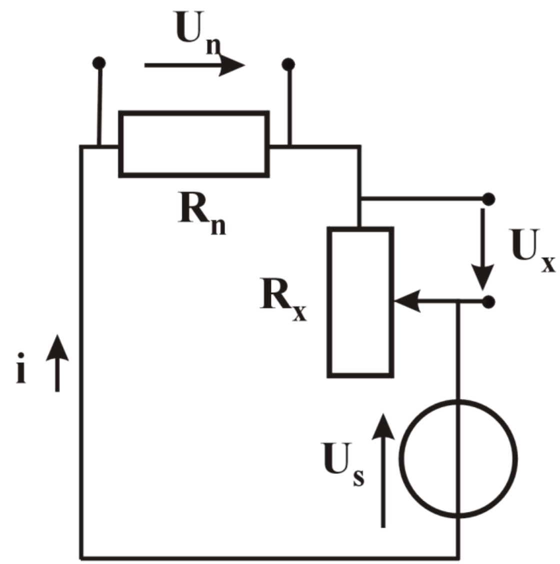
SIGNAL ACQUSITION OF ELECTRICAL SIGNALS

(RESISTANCE MEASUREMENT) COMPUTER BASED DAQ SYSTEMS

ADAM SCHIFFER, PHD

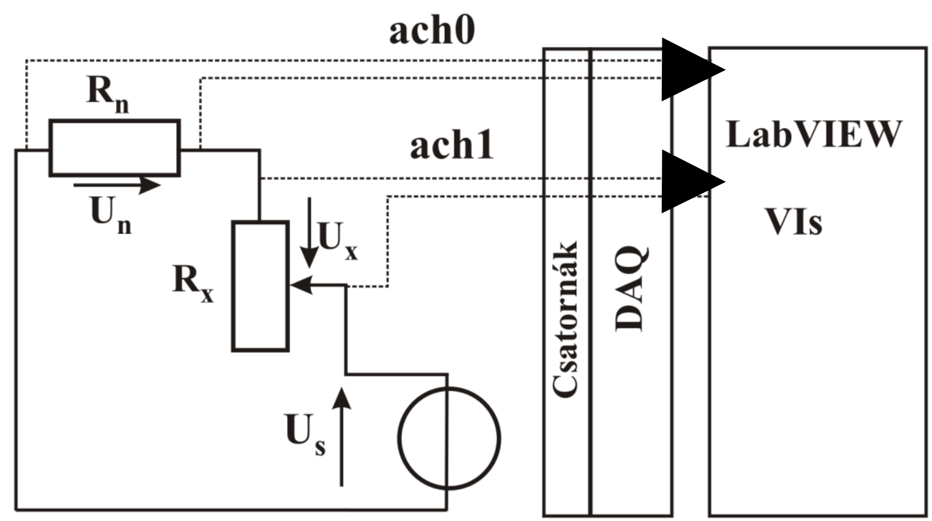
Resistance measurement



R_n – defined resistance

U_n, U_x -measured signals

$$i = \frac{U_n}{R_n}, \quad R_x = \frac{U_x}{i}$$



gerjesztés U_s – külső forrás

válaszjelek $\begin{cases} U_n \square\ ach0 \\ U_x \square\ ach1 \end{cases}$

DAQ Card (Built in)

Low-Cost E Series Multifunction DAQ
12-Bit, 200 kS/s, 16 Analog Inputs

NI 6023E, NI 6024E, NI 6025E

- 16 analog inputs at 200 kS/s, 12-bit resolution
- Up to 2 analog outputs, 12-bit resolution
- 8 digital I/O lines (5 V/TTL/CMOS); two 24-bit counter/timers
- Digital triggering
- 4 analog input signal ranges
- NI-DAQ driver simplifies configuration and measurements

Models
- NI PCI-6023E
- NI PCI-6024E
- ~~NI DAQCard-6024E~~ for PCMCIA
- NI PCI-6025E
- NI PXI-6025E

*See ordering information

Operating Systems
- Windows 2000/NT/XP/Me/9x
- Mac OS 9*
- Real-time performance with LabVIEW (page 134)
- Others such as Linux (page 187)

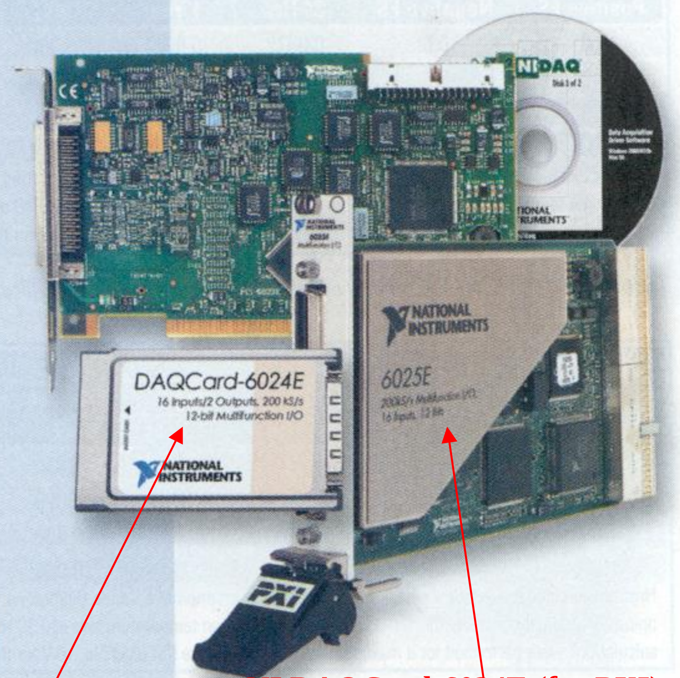
Recommended Software
- LabVIEW
- LabWindows/CVI
- Measurement Studio for Visual Basic
- VI Logger

Other Compatible Software
- Visual Basic
- C/C++

Driver Software (included)
- NI-DAQ

Calibration Certificate Included

See page 21



NI DAQCard-6024E (for PXI)

NI DAQCard-6024E (for PCMCIA)

f_s=200 kHz

NI PCI-6120

16-Bit, 1 MS/s/ch, Simultaneous Sampling Multifunction DAQ

S Series Multifunction DAQ 12 or 16-Bit, 1 to 10 MS/s, 4 Analog Inputs

NI 6120, NI 6115, NI 6110, NI 6111

- 2 or 4 analog inputs; dedicated A/D converter per channel
- 1 to 10 MS/s per channel maximum sample rate
- Analog and digital triggering
- AC or DC coupling
- 8 input ranges from ±200 mV to ±42 V
- 2 analog outputs at 4 MS/s single channel or 2.5 MS/s dual channel
- 8 digital I/O lines (5 V TTL/CMOS)
- Two 24-bit counter/timers
- Measurement services that simplify configuration and measurements

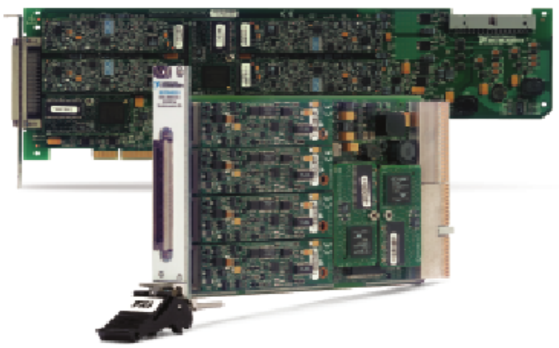
Operating Systems
- Windows 2000/NT/XP
- Mac OS X
- Linux

Recommended Software
- LabVIEW 7.x or higher
- LabWindows/CVI 7.x or higher
- Measurement Studio 7.x or higher
- Digital Waveform Editor
- SignalExpress 1.x or higher

Other Compatible Software
- VI Logger 2.x or higher
- Visual Studio .NET
- Visual Basic, C/C++, and C#

Measurement Services Software (included)[1]
- NI-DAQmx driver software
- Measurement & Automation Explorer configuration utility
- VI Logger Lite data-logging software

[1]Mac OS X and Linux applications must use NI-DAQmx Base driver software.



Calibration Certificate Available

Family	Bus	Analog Inputs	Input Resolution (bits)	Sampling Rate (MS/s)	Input Range (V)	Analog Outputs	Max Output Rate (MS/s)	Output Range (V)	Digital I/O	Counter/ Timers	Triggers
NI 6120	PCI, PXI	4	16	1[3]	±0.2 to ±42	2	4[1]	±10	8[2]	2, 24-bit	Analog, digital
NI 6115	PCI, PXI	4	12	10	±0.2 to ±42	2	4[1]	±10	8[2]	2, 24-bit	Analog, digital
NI 6110	PCI	4	12	5	±0.2 to ±42	2	4[1]	±10	8	2, 24-bit	Analog, digital
NI 6111	PCI	2	12	5	±0.2 to ±42	2	4[1]	±10	8	2, 24-bit	Analog, digital

[1]4 MS/s single channel; 2.5 MS/s on two channels [2]Hardware-timed up to 10 MB/s [3]800 kS/s with NI-DAQmx, 1 MS/s with additional download. Special conditions apply.

NI PCIe-6363

X Series Data Acquisition

32 analog inputs, 2 MS/s 1-channel, 1 MS/s multichannel; 16-bit resolution, ±10 V

Four analog outputs, 2.86 MS/s, 16-bit resolution, ±10 V

48 digital I/O lines (32 hardware-timed up to 10 MHz)

Four 32-bit counter/timers for PWM, encoder, frequency, event counting, and more

Analog and digital triggering and advanced timing with NI-STC3 technology

Support for Windows 7/Vista/XP/2000

Specifications (NI PCIe-6363)

General

Product Name	NI PCIe-6363
Product Family	Multifunction Data Acquisition
Form Factor	PCI Express
Part Number	781051-01
Operating System/Target	Real-Time , Windows
LabVIEW RT Support	Yes
DAQ Product Family	X Series
Measurement Type	Digital , Frequency , Voltage , Quadrature encoder
RoHS Compliant	Yes

Specifications (NI PCIe-6363)

Analog Input

Channels 16 , 32

Single-Ended Channels 32

Differential Channels 16

Resolution 16 bits

Sample Rate 2 MS/s

Throughput (All Channels) 1 MS/s

Max Voltage 10 V

Maximum Voltage Range -10 V , 10 V

Maximum Voltage Range Accuracy 1.74 mV

Minimum Voltage Range -0.1 V , 0.1 V

Minimum Voltage Range Accuracy 38 µV

Number of Ranges 7

Simultaneous Sampling No

Specifications (NI PCIe-6363)

Analog Output	
Channels	4
Resolution	16 bits
Max Voltage	10 V
Maximum Voltage Range	-10 V , 10 V
Maximum Voltage Range Accuracy	1.89 mV
Minimum Voltage Range	-5 V , 5 V
Minimum Voltage Range Accuracy	935 µV
Update Rate	2.86 MS/s

Specifications (NI PCIe-6363)

Digital I/O

Bidirectional Channels	48
Input-Only Channels	0
Output-Only Channels	0
Number of Channels	0 , 48
Timing	Software , Hardware
Clocked Lines	32
Max Clock Rate	10 MHz
Logic Levels	TTL
Input Current Flow	Sinking , Sourcing
Output Current Flow	Sinking , Sourcing
Programmable Input Filters	Yes
Supports Programmable Power-Up States?	Yes
Current Drive Single	24 mA
Current Drive All	1 A
Watchdog Timer	Yes
Supports Handshaking I/O?	No
Supports Pattern I/O?	Yes
Maximum Input Range	0 V , 5 V
Maximum Output Range	0 V , 5 V

Specifications (NI PCIe-6363)

Counter/Timers

Counters 4

Number of DMA Channels 8

Buffered Operations Yes

Debouncing/Glitch Removal Yes

GPS Synchronization No

Maximum Range 0 V , 5 V

Max Source Frequency 100 MHz

Pulse Generation Yes

Resolution 32 bits

Timebase Stability 50 ppm

Logic Levels TTL

Specifications (NI PCIe-6363)

Physical Specifications

Length 16.8 cm

Width 50 mm

Height 9.9 cm

I/O Connector 68-pin VHDCI female

Timing/Triggering/Synchronization

Triggering Digital , Analog

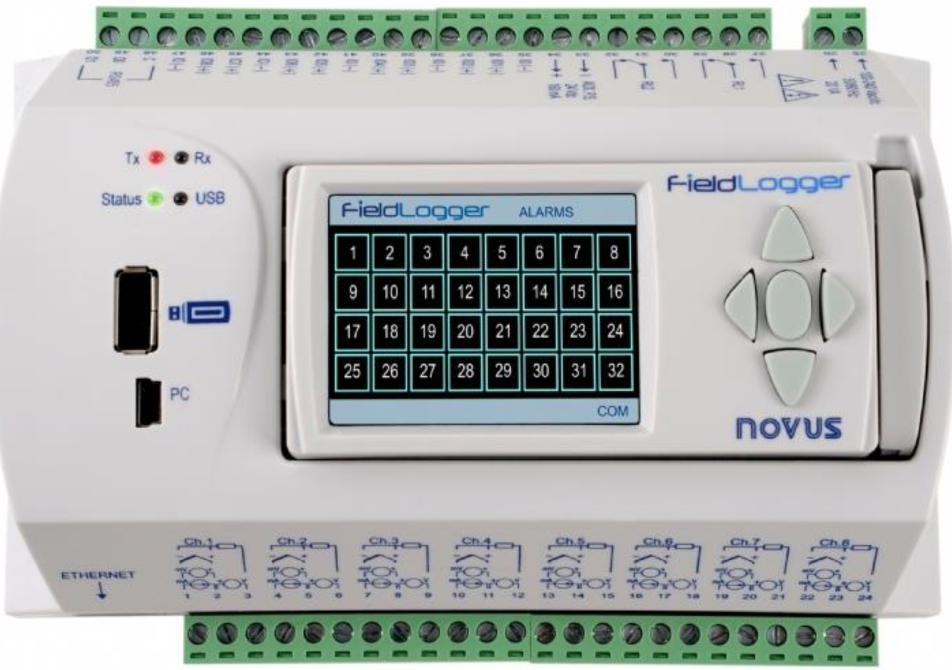
Synchronization Bus (RTSI) Yes

NI PXIe-5665
High-Performance Vector Signal Analyzer up to 14 GHz

20 Hz to 3.6 GHz / 14 GHz frequency range
25/50 MHz instantaneous bandwidth
129 dBc/Hz typical phase noise at 10 kHz offset at 800 MHz
±0.35 dB typical flatness within 20 MHz bandwidth
±0.1 dB typical amplitude accuracy

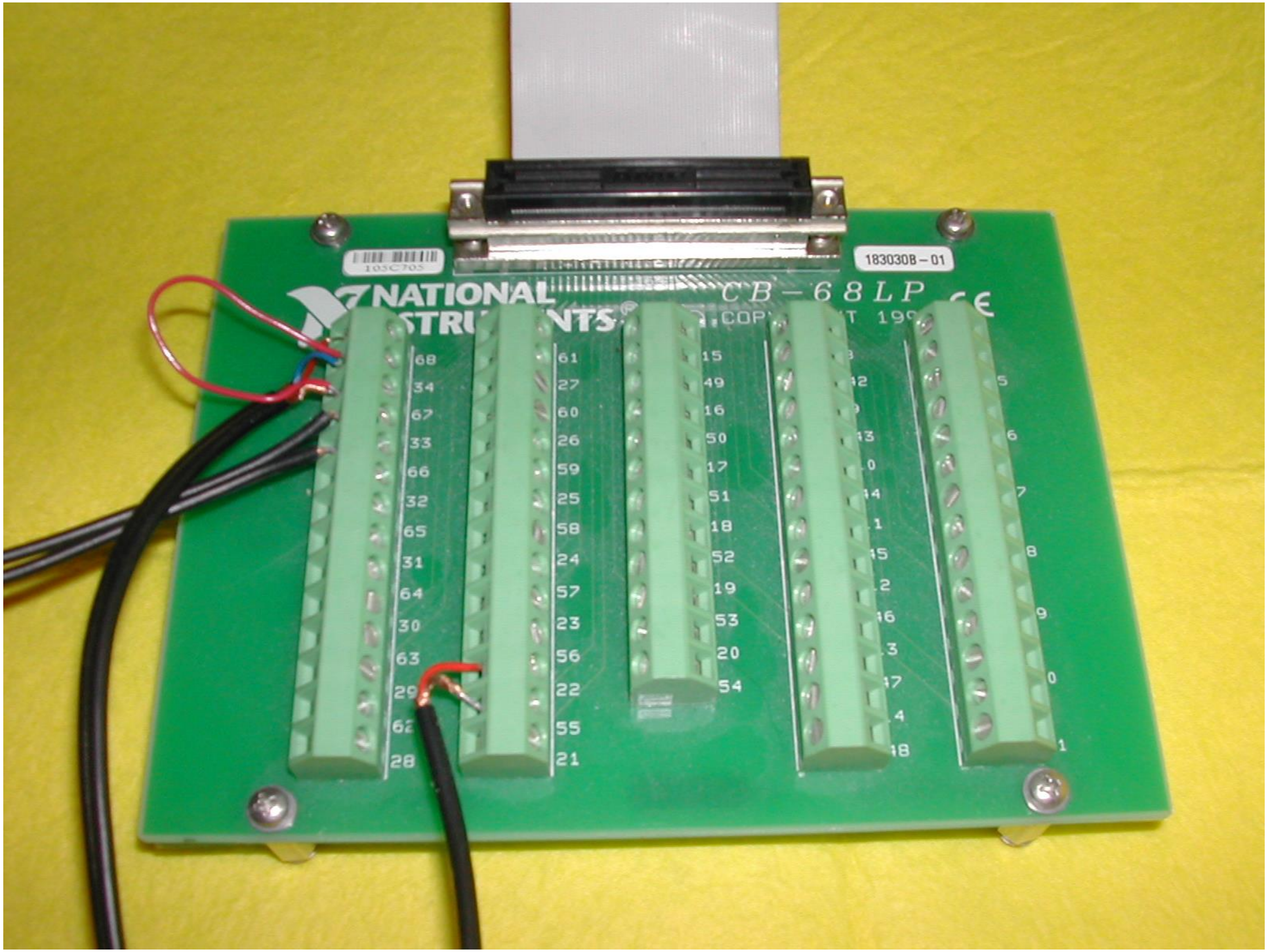
750 MB/s sustained read and write speeds for 80 percent of the storage capacity
Three storage capacities available: 6TB (12 x 500GB), 12TB (12 x 1TB) and 24TB (12 x 2TB)
Supports various RAID modes (RAID-0/1/10/5/6)
Programmatic control and monitoring of hard drives and RAID partitions
Supports hot swap of hard drives
Offers Endless record mode

FieldLogger



- 8 universal analog channels per module
- Accepts t/c J, K, T, E, N, R, S, B; 4-20 mA, Pt100, 0-50 mV without hardware change
- Internal memory (optional) for 32,000 to 128,000 recordings and real time clock
- Input resolution: 12,000 levels
- Accuracy: 0.1 % of full scale (FS)
- Scanning: 8 channels in 0.5 seconds
- Reading rate: from 0.2s to 1 day
- Power: 100-240 Vac, optional 24 Vdc/ac
- Alarms: 2 relays 3 A for the 8 channels
- Digital input for remote START/STOP
- RS-485, MODBUS - RTU, 19200 bps
- 35 mm DIN rail mounting

Connector Panel(68LP)



The 'Built in' NI PCI 6023 DAQ CARD CONNECTION DIAGRAM

ACH8	34	68	ACH0
ACH1	33	67	AIGND
AIGND	32	66	ACH9
ACH10	31	65	ACH2
ACH3	30	64	AIGND
AIGND	29	63	ACH11
ACH4	28	62	AISENSE
AIGND	27	61	ACH12
ACH13	26	60	ACH5
ACH6	25	59	AIGND
AIGND	24	58	ACH14
ACH15	23	57	ACH7
DAC0OUT[1]	22	56	AIGND
DAC1OUT[1]	21	55	AOGND
RESERVED	20	54	AOGND
DIO4	19	53	DGND
DGND	18	52	DIO0
DIO1	17	51	DIO5
DIO6	16	50	DGND
DGND	15	49	DIO2
+5 V	14	48	DIO7
DGND	13	47	DIO3
DGND	12	46	SCANCLK
PFI0/TRIG1	11	45	EXTSTROBE*
PFI1/TRIG2	10	44	DGND
DGND	9	43	PFI2/CONVERT*
+5 V	8	42	PFI3/GPCTR1_SOURCE
DGND	7	41	PFI4/GPCTR1_GATE
PFI5/UPDATE*	6	40	GPCTR1_OUT
PFI6/WFTRIG	5	39	DGND
DGND	4	38	PFI7/STARTSCAN
PFI9/GPCTR0_GATE	3	37	PFI8/GPCTR0_SOURCE
GPCTR0_OUT	2	36	DGND
FREQ_OUT	1	35	DGND

[1] Not available on the 6023E

Figure 4-1. I/O Connector Pin Assignment for the 6023E/6024E

page 32

Other connector panels (BNC, examples)

NI BNC-2090A

NI BNC-2110

(standard, differencial)

NI BNC-2111

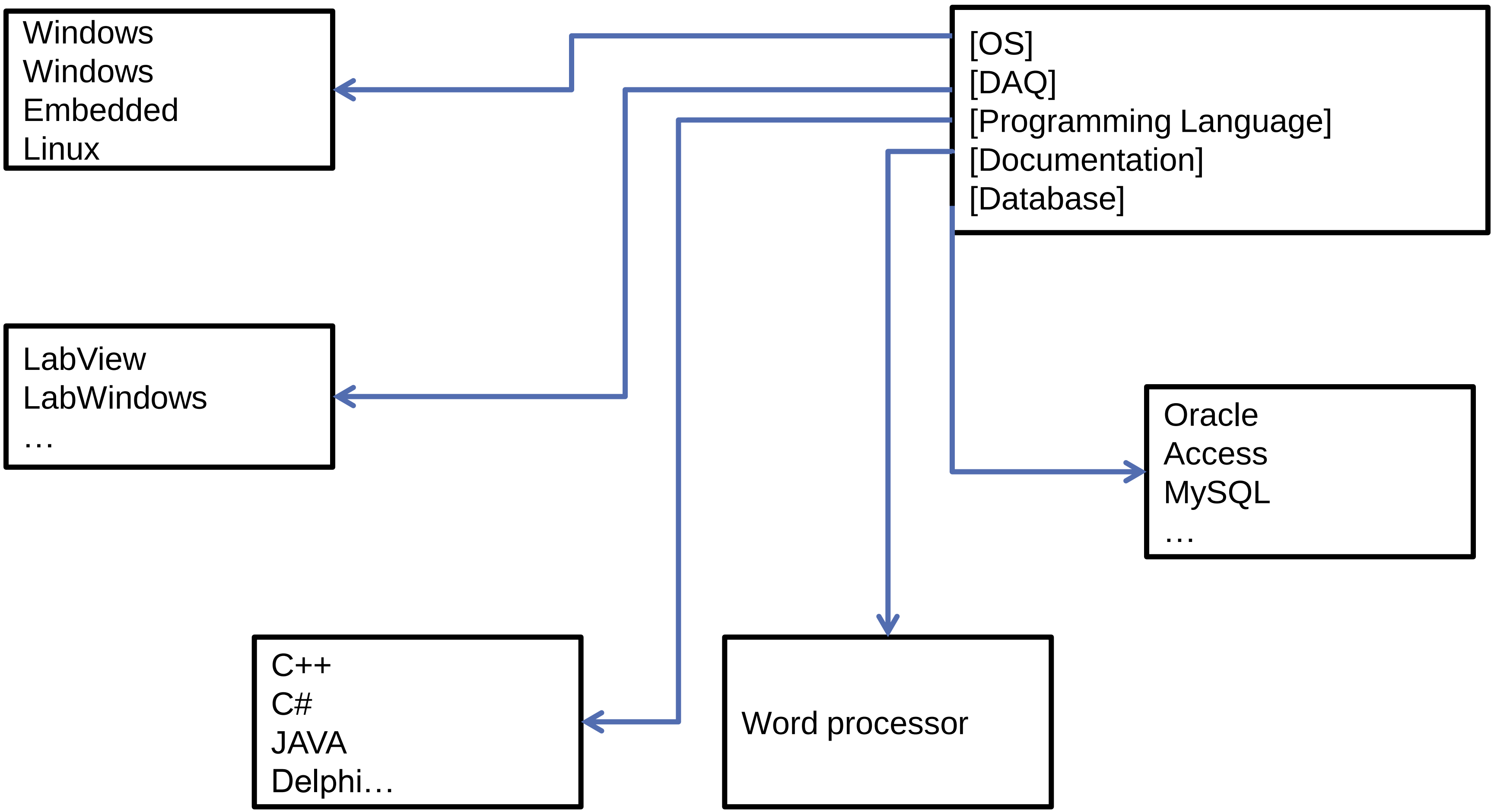
(standard, single ended)

DIN-Rail Mount Terminal Block for 37-Pin D-SUB Modules

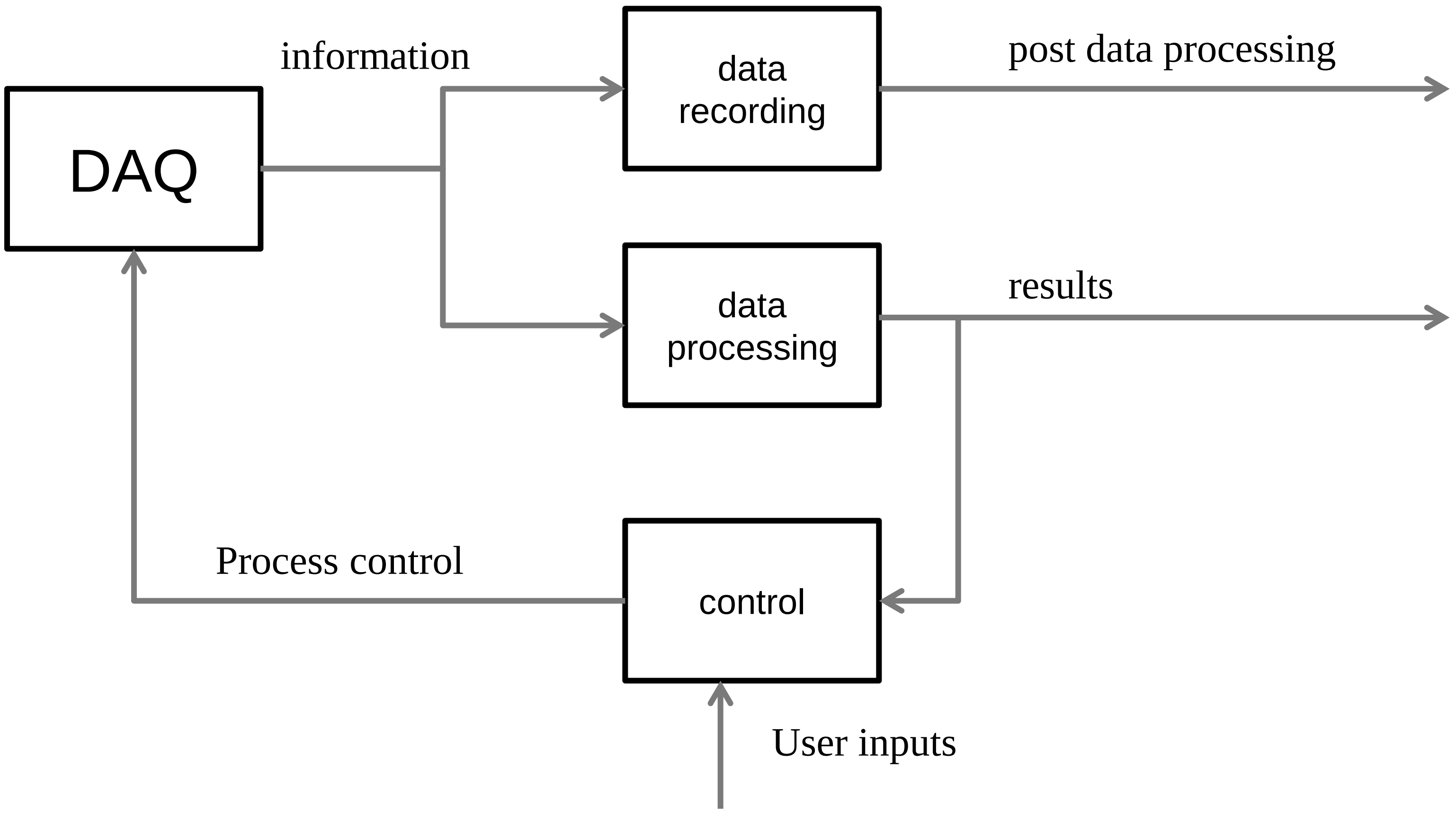
Tasks of the computer based measurement

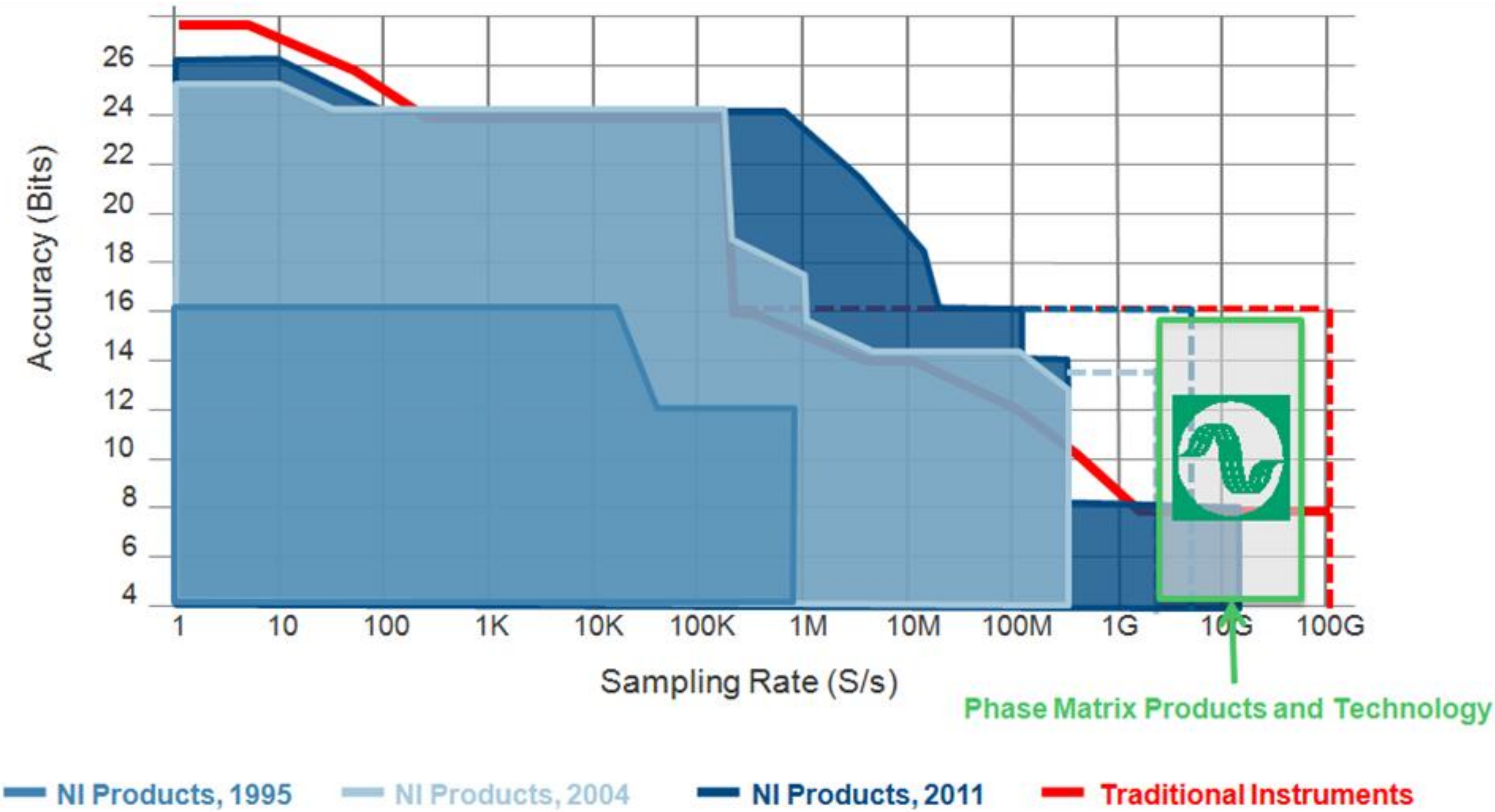
- Data acquisition: collection, archiving, simplifying, data processing, data storage,
- Devices, other peripherals, process control,
- Measurement process development,
- Documentation.

Computer (PC) based measurement system's software background



Data processing in the PC based measurement systems



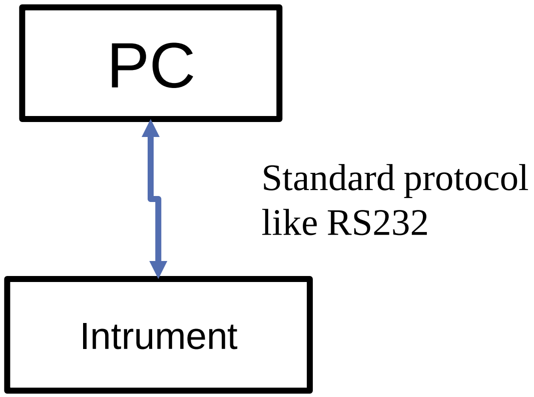

Accuracy (Bits)
26
24
22
20
18
16
14
12
10
8
6
4
1
10
100
1K
10K
100K
1M
10M
100M
1G
10G
100G
Sampling Rate (S/s)
Phase Matrix Products and Technology
NI Products, 1995
NI Products, 2004
NI Products, 2011
Traditional Instruments

Structure of the PC based measurement systems

The functional organization of the measuring devices and the PC, the measurement system’s layout is determined by the measurement task.

The simplest measurement structure is one PC and one instrument in a system. According to a standard protocol, for example RS232 is made of the transfer.

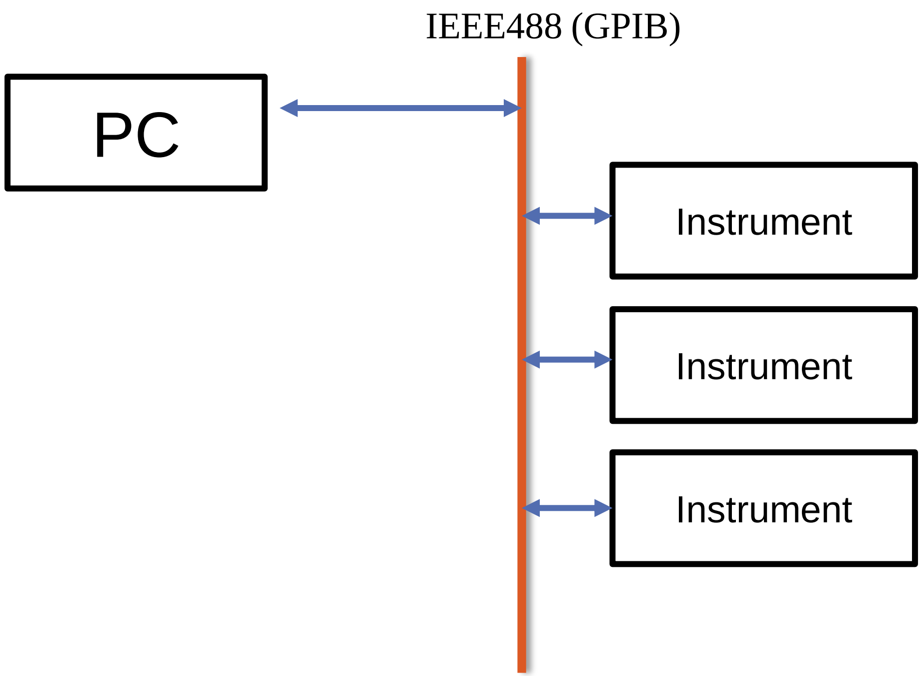
Such an arrangement meter park, especially for serial communication is very limited form suitable for real-time tasks. (Communication between the PC and the instrument has a low bandwidth)



1 PC more instruments

•The communication between the PC and the instruments is based on a strandard protocoll as IEEE488 (GPIB)

•This type of arrangement is felxible, new instruments can be connected a defined easily.



Huge number of instruments

•Huge numbers of instruments slow down the system's operating speed. There is a demand level that is no longer able to fulfill your PC. In this case more PCs are required.

•With this the instrument number per PC is reduced, the controller has more time.

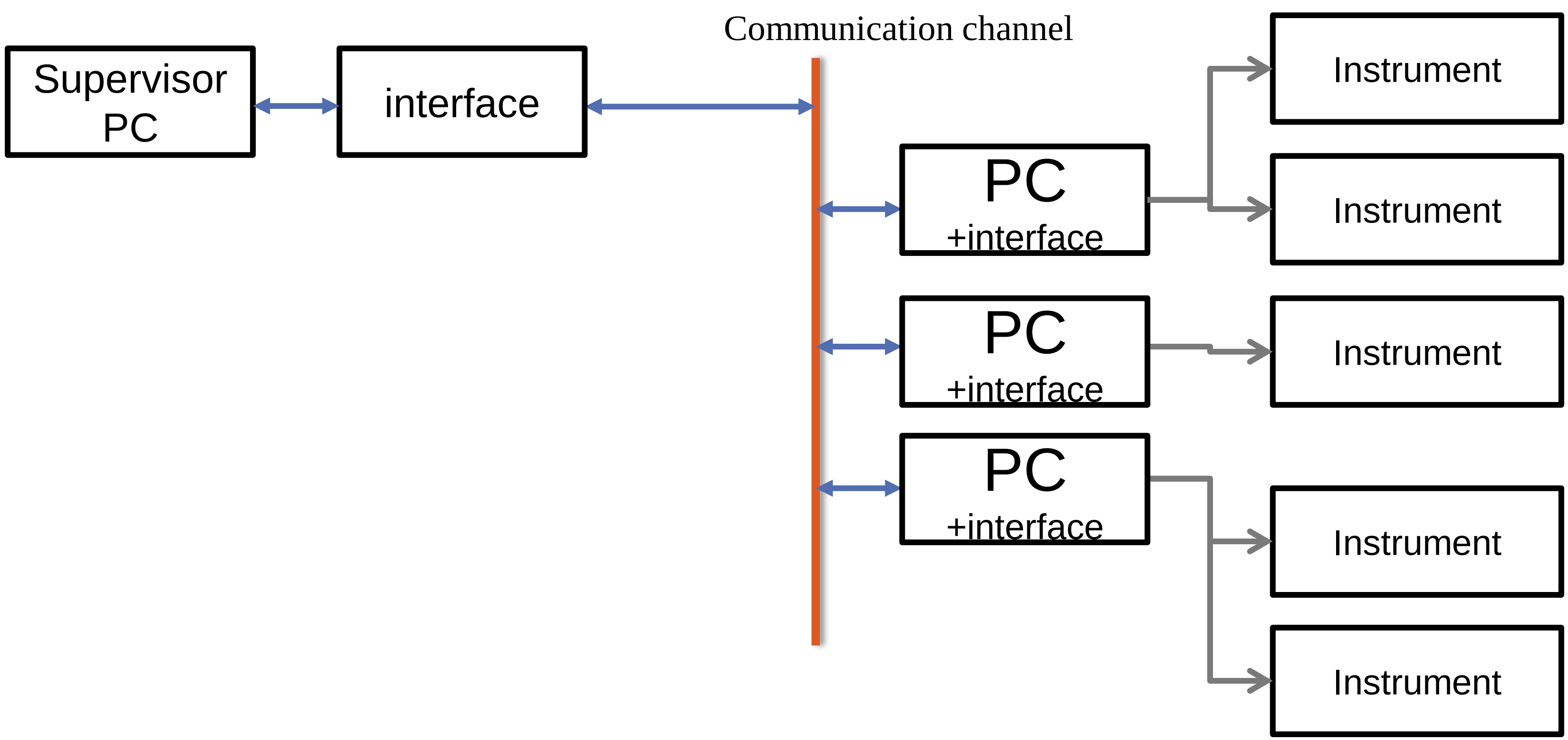
•The PC-based communication is made by a channel (shared communication channel)

•done The communication channel can be another form of this arrangement, the so-called. LAN (Local Area Network).

•Through the LAN the communication between the processors are generally slower because the system needs to fit into a standard LAN to communicate well,

Supervisor PC

- For the coordination tasks between the PCs.
- Instruments are not connected to the Supervisor PC. The task of the work of the management of PCs
- This is called as „master-slave” hierarchy



Supervisor PC

- The PC supervisor constantly monitors the system activity
- The flexibility of the system grows, easily reconfigurable measuring equipments, development and installation of new measurement processes can be performed
- In case of failure of the supervisor PC you can take over the task of faulty PC
- Multi-user system can be developed, which means that each slave has spare capacity PCs from the process of independent "outside" may perform tasks (time-sharing)

Data transfer methods in measurement systems

The PC-based measurement system can be done in three different ways to move data:

- program-controlled
- Interrupt controlled
-DMA controlled (Direct Memory Access)

Method	**relative speed**	**control**
program-controlled	slow	high
Interrupt controlled	middle	middle
DMA controlled	fast	low

The „relative speed” is related to the system’s data transfer speed.

The „control” is related to the CPU’s utilization

Data transfer methods in measurement systems

- The high level of controllability shows that the process of the CPU control over each step has the sequence of control commands executed strictly defined.
- The low controllability means that the CPU gives the control for other units, such as less or not at all involved in the transmission of data management.
- The table shows that the speed is increased, the system controllability decreases, and vice versa. Therefore it is always decided by the respective measurement task to use in each case which method provides a more efficient operation.

Program controlled data transfer

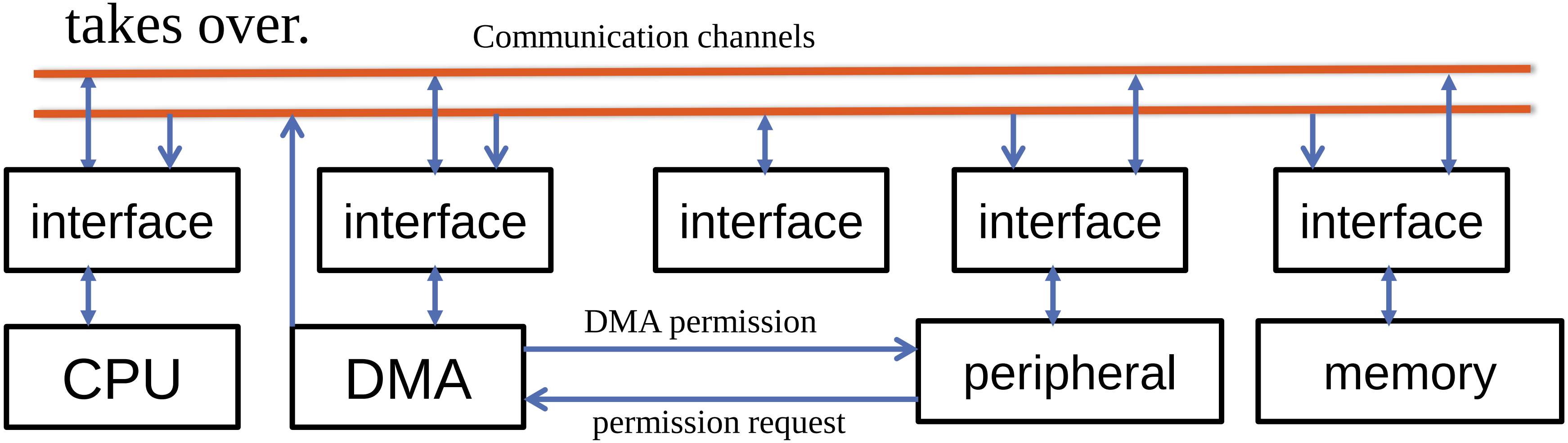
- The processor in this case, is always keep the process control.
- Following the instructions it handles the peripherals, it controls the data collection, data movement, storage, and processing.
- For example, the program is controlled to wait for the processor until the sampling is in progress

Interrupt controlled data transfer

•Each peripheral has a user-defined level interrupt (interrupt -IRQ -level).
•When a peripheral wants to „speak”, an interrupt request is forwarded to the encoding priority. The processor then suspends the currently running process and enables the respective periphery of the disclosure of information.
•When the transmission is complete, the CPU continues the work where it left off before the break.
•If there are multiple interrupt the periphery of the first to get the opportunity to present information in which the IRQ level is higher. Thus, the higher priority peripheral interrupt a lower priority peripheral operation of which is running well.

DMA controlled data transfer

This is the fastest data transfer method, but this method of control is almost entirely out of the CPU's control.
The control (management of I / O operations) in this case the processor is a separate circuit board, called a direct memory access controller (DMA - Direct Memory Access - controller) takes over.



RS-232, RS-422, RS-485 Serial Communication General Concepts

Serial Communication

- The concept of serial communication is simple. The serial port sends and receives bytes of information one bit at a time.
- Typically, serial is used to transmit ASCII data. Communication is completed using 3 transmission lines: (1) Ground, (2) Transmit, and (3) Receive.
- Since serial is asynchronous, the port is able to transmit data on one line while receiving data on another. This is referred to as Full-Duplex transmission
- The important serial characteristics are baud rate, data bits, stop bits, and parity.

Serial Communication

Baud rate is a speed measurement for communication. It indicates the number of bit transfers per second

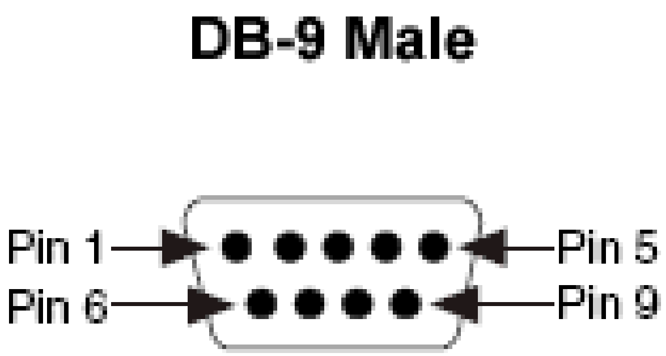
Data bits are a measurement of the actual data bits in a transmission

Stop bits are used to signal the end of communication for a single packet. Typical values are 1, 1.5, and 2 bits

Parity is a simple form of error checking that is used in serial communication. There are four types of parity: even, odd, marked, and spaced.

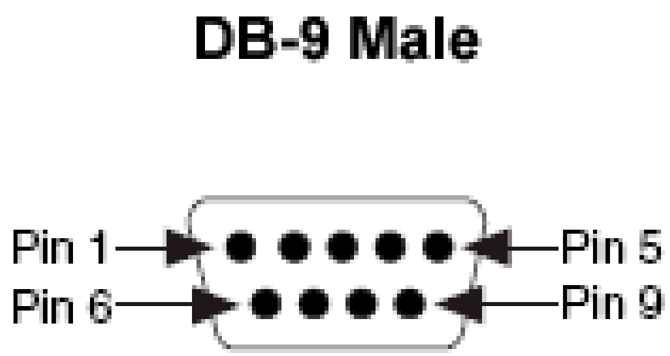
RS232

- RS-232 (ANSI/EIA-232 Standard) is the serial connection historically found on IBM-compatible PCs.
- RS-232 is limited to point-to-point connections between PC serial ports and devices.
- RS-232 hardware can be used for serial communication up to distances of 50 feet.



RS422

- RS-422 (EIA RS-422-A Standard) is the serial connection historically used on Apple Macintosh computers
- Differential transmission uses two lines each for transmit and receive signals which results in greater noise immunity and longer distances as compared to the RS-232



RS485

- RS-485 (EIA-485 Standard) is an improvement over RS-422, because it increases the number of devices from 10 to 32
- can create networks of devices connected to a single RS-485 serial port
- The noise immunity and multi-drop capability make RS-485 the serial connection of choice in industrial applications requiring many distributed devices networked to a PC or other controller for data collection, HMI, or other operations.
- all RS-422 devices may be controlled by RS-485. RS-485 hardware may be used for serial communication with up to 4000 feet of cable.

GPIB (IEEE 488)

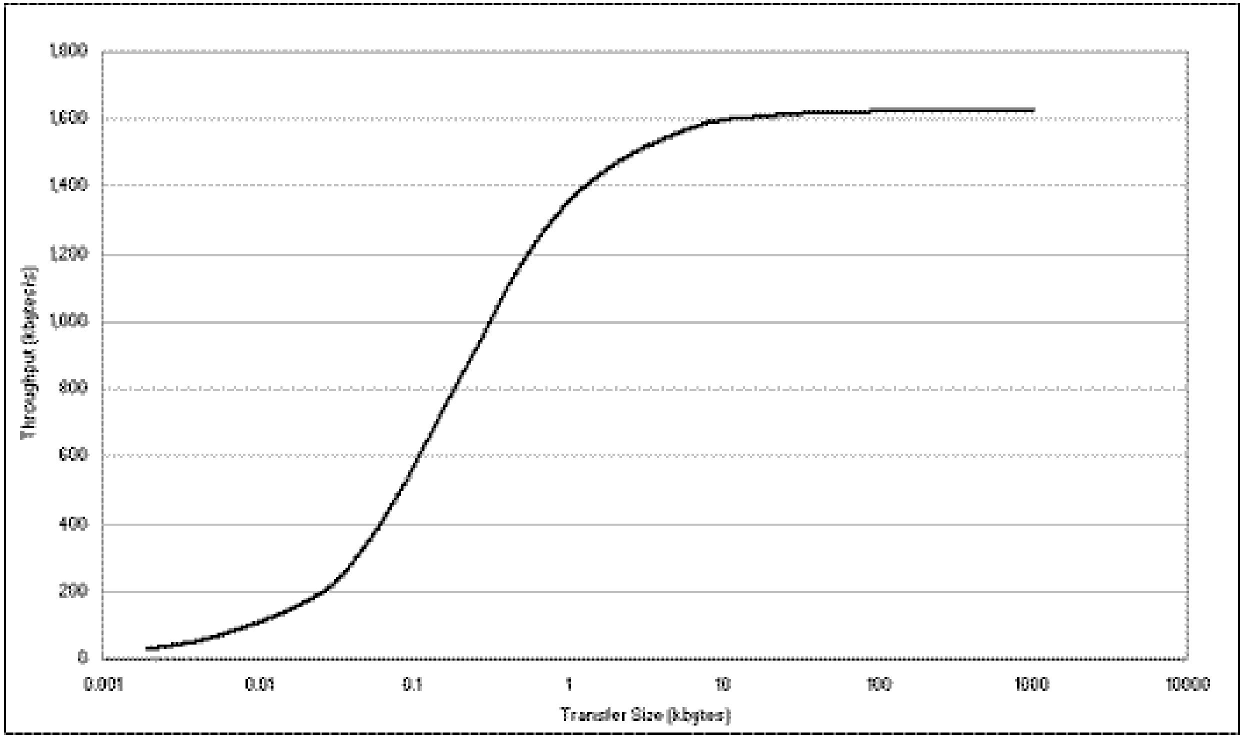
Origin of GPIB

- The original GPIB was developed in the late 1960s by Hewlett-Packard (where it is called the HP-IB) to connect and control programmable instruments that Hewlett-Packard manufactured.
- With the introduction of digital controllers and programmable test equipment, the need arose for a standard, high-speed interface for communication between instruments and controllers from **various vendors**.
- In 1990, the IEEE 488.2 specification included the Standard Commands for Programmable Instrumentation (SCPI) document. SCPI defines specific commands that each instrument class (which usually includes instruments from various vendors) must obey. Thus, SCPI guarantees complete system compatibility and configurability among these instruments

GPIB controllers (PXI and External)

GPIB connector

Performance of a PCI-GPIB Board



It can be seen how fast a GPIB board can transfer data under differing transfer sizes. For example, does the board perform as well using small data blocks and large data blocks? How consistent is the throughput response of the board over a range of data transfer block sizes? Figure shows the performance of the NI PCI-GPIB for various data block sizes.